	<p>Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)</p>	<p><b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10  <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012  <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1  <b>Page:</b> 1/95</p>
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# Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)

SAF/NWC/CDOP/ZAMG/SCI/PUM/10, Issue 2, Rev. 4.1

*15 February 2012*



*Applicable to SAFNWC/MSG version 2012*

The EUMETSAT  
Network of  
Satellite Application  
Facilities





**NWC SAF**

Support to Nowcasting and  
Very Short Range Forecasting

		Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 2/95
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### REPORT SIGNATURE TABLE

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		Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 3/95
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### DOCUMENT CHANGE RECORD

Version	Date	Pages	CHANGE(S)
2.2	23 February 2009	93	Initial version (content derived from various precursor documents on PGE10, most notably “Software User Manual for the SAFNWC/MSG: Scientific part for the PGE10”)
2.3	22 September 2009	94	Update for release SAFNWC/MSG v2010
2.4	2 February 2011	96	Update for release SAFNWC/MSG v2011
2.4.1	15 February 2012	95	No scientific updates. Date issue and rev. adapted to v2012



		Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 4/95
--	--	---	---

## Table of contents

<b>1. INTRODUCTION .....</b>	<b>8</b>
1.1 SCOPE OF THE DOCUMENT .....	8
1.2 SCOPE OF OTHER DOCUMENTS .....	8
1.3 SOFTWARE VERSION IDENTIFICATION .....	8
1.4 IMPROVEMENT FROM PREVIOUS VERSION .....	8
1.5 DEFINITIONS, ACRONYMS AND ABBREVIATIONS .....	9
1.6 REFERENCES .....	10
1.6.1 <i>Applicable Documents</i> .....	10
1.6.2 <i>Reference Documents</i> .....	10
<b>2. DESCRIPTION OF THE AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII) PRODUCT .....</b>	<b>12</b>
2.1 GOAL OF THE AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII) PRODUCT .....	12
2.2 OUTLINE OF AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII) ALGORITHMS .....	12
2.2.1 <i>Satellite data pre-processing</i> .....	12
2.2.2 <i>Development images</i> .....	13
2.2.3 <i>NWP data input</i> .....	13
2.2.4 <i>Ingestion of analysis information from the preceding slot ("memory")</i> .....	13
2.2.5 <i>Detection of contiguous areas with similar cloud structure</i> .....	13
2.2.6 <i>Pattern recognition methods and topographic functions</i> .....	14
2.3 DESCRIPTION OF THE OUTPUT .....	14
2.3.1 <i>Detailed description of conceptual models</i> .....	16
2.3.1.1 Cold Front (CF) .....	16
2.3.1.2 Warm front (WF) .....	23
2.3.1.3 Occlusion .....	26
2.3.1.4 Wave .....	32
2.3.1.5 Upper Wave .....	36
2.3.1.6 Front Intensification (FI) by Jet .....	39
2.3.1.7 Dry Intrusion (DI) .....	41
2.3.1.8 Upper Level Low .....	45
2.3.1.9 Comma Cloudiness .....	49
2.3.1.10 Enhanced Cumulus (EC) .....	52
2.3.1.11 Cumulonimbus Cluster (Cb) .....	55
2.3.1.12 Mesoscale Convective Systems (MCS) .....	59
2.3.1.13 Cold air cloudiness .....	64
2.3.1.14 Fibres .....	66
2.3.1.15 Lee cloudiness .....	70
2.3.2 <i>Summary of rules for identification of conceptual models</i> .....	74
2.3.3 <i>Synoptic explanations for corresponding and controversial classifications of conceptual models in Automatic satellite image interpretation with NWP (ASIIINWP) and without NWP inclusion (ASII)</i> .....	75
<b>3. IMPLEMENTATION OF AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII) .....</b>	<b>78</b>
3.1 HOW TO IMPLEMENT THE TEMPORAL INTERPOLATION OF NWP VIA CEOF .....	79
<b>4. INPUTS AND CONFIGURABLE PARAMETERS FOR AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII) .....</b>	<b>81</b>
4.1 LIST OF INPUTS .....	81
4.2 CONFIGURABLE PARAMETERS FOR AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII) .....	81



		Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 5/95
--	--	---	---

<b>5. SUMMARY OF AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII) VALIDATION RESULTS.....</b>	<b>82</b>
<b>6. TYPICAL KNOWN PROBLEMS AND RECOMMENDATION FOR USE .....</b>	<b>84</b>
<b>7. EXAMPLES OF AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII) VISUALISATION .....</b>	<b>85</b>
7.1 CONCEPTUAL MODELS .....	85
7.2 ATMOSPHERIC MOTION VECTORS.....	89
<b>8. REFERENCES .....</b>	<b>93</b>
<b>APPENDIX 1: RANKING AMONG SIMULTANEOUSLY DIAGNOSED CONCEPTUAL MODELS.....</b>	<b>94</b>

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 6/95
---	---	---	---

## List of Tables and Figures

<b>Table 1:</b> List of Applicable Documents.....	10
<b>Table 2:</b> List of Referenced Documents.....	11
<b>Table 3:</b> Description of classes. The column “number” gives code numbers which are occasionally referred to in later sections. ....	13
<b>Table 4:</b> Symbols used for the different conceptual models in the ASII (SAT) output .....	15
<b>Table 5:</b> Symbols used for the different conceptual models in the ASIINWP (SAT+NWP) output .....	16
<b>Table 6:</b> "Firm meteorological content" for each conceptual model, depending on the output branch (ASII or ASIINWP). In some cases it is sufficient if at least one criterion is fulfilled. Then 'OR' indicates the possible choice. ....	74
<b>Table 7:</b> Explanation for controversial classifications in ASII and ASIINWP .....	77
<b>Figure 1:</b> Conditions for the detection of a CF in ASII (black) and ASIINWP (blue);in ASIINWP the two branches are symbolising the classical cold front and the low cold front .....	19
<b>Figure 2:</b> Conditions for the detection of a CF in WA in ASIINWP .....	20
<b>Figure 3:</b> Upper panel: 3 <sup>rd</sup> December 2001, 06 UTC; ASII; WV AMVs superimposed (which suggests WF conditions, hence the labelling by red 'w'). Lower panel: 3 <sup>rd</sup> December 2001, 06 UTC; ASIINWP; CA changes the ASII analysis of WF into a CF .....	22
<b>Figure 4:</b> Conditions for the detection of a WF in ASII (black) and ASIINWP (blue) .....	24
<b>Figure 5:</b> Conditions for the detection of an occlusion in ASII (black) and ASIINWP (blue) .....	29
<b>Figure 6:</b> Upper panel: ASII analysis of the 06 UTC IR satellite image from 22 <sup>nd</sup> May 2001. The spiralled cloud band has been analysed as occlusion (green "o" tags), however with some undesired inclusions of cold front (blue *c*). Lower panel: ASIINWP analysis of the same satellite image.....	31
<b>Figure 7:</b> Conditions for the detection of a wave in ASII (black) and ASIINWP (blue) .....	35
<b>Figure 8:</b> Conditions for the detection of an upper wave in ASII (black) and ASIINWP (blue)...	38
<b>Figure 9:</b> Conditions for the detection of a front intensification in ASIINWP (blue).....	40
<b>Figure 10:</b> Conditions for the detection of a dry intrusion in ASII (black) and in ASIINWP (blue) .....	43
<b>Figure 11:</b> Conditions for the detection of an upper level low in ASIINWP.....	47
<b>Figure 12:</b> Conditions for the detection of a comma in ASII (black) and in ASIINWP (blue).....	51
<b>Figure 13:</b> Conditions for the detection of EC in ASII (black) and in ASIINWP (blue) .....	54
<b>Figure 14:</b> Conditions for the detection of a Cb in ASII (black) and in ASIINWP (blue).....	57
<b>Figure 15:</b> Conditions for the detection of an MCS in ASII (black) and in ASIINWP (blue).....	62

		Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 7/95
--	--	---	---

**Figure 16:** Conditions for the detection of a cellular cold air cloudiness in ASII (black) and in ASIINWP (blue).....65

**Figure 17:** IR-satellite image from 19 February 1997, 06 UTC; the fibre extends from about 40N/35W across the Atlantic to about 50N/20W; it accompanies the jet axis (black line is zero line of shear vorticity at 300 hPa).....66

**Figure 18:** Conditions for the detection of a fibre in ASII (black) and in ASIINWP (blue).....68



**Figure 19:** Conditions for the detection of lee clouds in ASII (black) and in ASIINWP (blue)....72

**Figure 20:** PGE10 analysis for 25 January 2008, 0000 UTC (ASII).....85

**Figure 21:** Infra-red (red) and water-vapour (blue) AMV fields as derived for input into the PGE10 analysis for 14 October 2002, 0600 UTC. ....90

**Figure 22:** Ranking diagram for ASII: the arrows are drawn from the conceptual model which is overwriting to that one which is overwritten. The left column comprises the frontal CMs, the right column the small and mesoscale CMs .....94

**Figure 23:** Ranking diagram for ASIINWP: the arrows are drawn from the conceptual model which is overwriting to that one which is overwritten. The left column comprises the frontal CMs, the right column the small and mesoscale CMs. ....95

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 8/95
---	--	---	---

## 1. INTRODUCTION

The Eumetsat “Satellite Application Facilities” (SAF) are dedicated centres of excellence for processing satellite data, and form an integral part of the distributed EUMETSAT Application Ground Segment (<http://www.eumetsat.int>). This documentation is provided by the SAF on Support to Nowcasting and Very Short Range Forecasting, SAFNWC. The main objective of SAFNWC is to provide, further develop and maintain software packages to be used for Nowcasting applications of operational meteorological satellite data by National Meteorological Services. More information can be found at the SAFNWC webpage, <http://www.nwcsaf.org>. This document is applicable to the SAFNWC processing package for Meteosat Second Generation satellites, SAFNWC/MSG.

### 1.1 SCOPE OF THE DOCUMENT

This document is the Product User Manual for the MSG Automatic Satellite Image Interpretation Product (PGE10 of the SAFNWC/MSG software).

This document contains practical information for the daily use of the product. This document is intended for the meteorologist giving some principal information on the abilities and limitation of the product output.

### 1.2 SCOPE OF OTHER DOCUMENTS

The algorithms used in this software are described in the Algorithm Theoretical Basis Document (AD. 6).

Details of input and output data format of the products are also described in the Interface Control Documents (AD. 1) for the External and Internal Interfaces of the SAFNWC/MSG and in the MSG Output Product Format Definition (AD. 2).

The general architecture of the software (interface with the SAFNWC software, architecture of the PGE) is described in the Architectural Design Document (AD. 3).

The product generator elements are described in the Software Version Description (AD. 4).

Instructions how to install, configure and execute the SAFNWC/MSG software in order to extract the MSG Automatic Satellite Image Interpretation Product (PGE10) are detailed in the SAFNWC/MSG Software User Manual (AD. 5).

The latest validation of the algorithms used to extract the MSG Automatic Satellite Image Interpretation (PGE10) is reported in a validation report (RD. 3)



### 1.3 SOFTWARE VERSION IDENTIFICATION

This document is compliant with the PGE10 version of the 2012 SAFNWC software package delivery.

### 1.4 IMPROVEMENT FROM PREVIOUS VERSION



Minor algorithmic changes in order to take into account certain opposite signs on the Southern Hemisphere.



		Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 9/95
--	--	---	---

## 1.5 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

AD	Applicable Document
AMV	Atmospheric Motion Vectors
ASII	Automatic Satellite Image Interpretation
ASIIINWP	Automatic Satellite Image Interpretation including NWP fields
BUFR	Binary Universal Form from the Representation of meteorological data
CA	Cold air Advection
CAC	Cold Air Cloudiness
Cb	Cumulonimbus
CC	Convective Cells
CEOF	Complex Empirical Orthogonal Function
CF	Cold Front
CM	Conceptual Model
COST	European Cooperation on Scientific and Technical Research
DI	Dry Intrusion
EC	Enhanced Cumulus
ECMWF	European Center for Medium-range Weather Forecast
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
IR	Infrared
JI	Front Intensification by Jet Streak
MSG	Meteosat Second Generation
NWP	Numerical Weather Prediction
OCCL	Occlusion
PGE	Product Generation Element
PV	Potential Vorticity
PVA	Positive Vorticity Advection
PVU	Potential Vorticity Unit
RC	Rapid Cyclogenesis
RSV	Relative Shear Vorticity
RV	Relative Vorticity
SAF	Satellite Application Facility
SAFNWC	SAF to support NoWCasting and Very-Short-Range Forecasting
SAI	Stability Analysis Imagery
SEVIRI	Spinning Enhanced Visible and Infrared Imager

 	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 10/95
---	---	--

SH	Showalter Index
SUM	Software User Manual
TA	Temperature Advection
TFP	Thermal Front Parameter
ULL	Upper Level Low
UTC	Universal Time Coordinated
WA	Warm air Advection
WF	Warm Front
WV	Water Vapour
ZAMG	Zentralanstalt für Meteorologie und Geodynamik (= Central Institute for Meteorology and Geodynamics, Vienna)

## 1.6 REFERENCES

### 1.6.1 Applicable Documents

For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the document referred to applies.

Latest documentation can be found at the SAFNWC Help Desk at <http://www.nwcsaf.org>



Reference	Title	Code	Vers	Date
[AD. 1]	Interface Control Document for the External and Internal Interfaces of the SAFNWC/MSG	SAF/NWC/CDOP/INM/SW/ICD/1		
[AD. 2]	SAFNWC/MSG Output Products Format Definition	SAF/NWC/CDOP/INM/SW/ICD/3		
[AD. 3]	Architectural Design Document for “Automatic Satellite Image Interpretation”	SAF/NWC/CDOP/ZAMG/SW/AD/1		
[AD. 4]	Software Version Description Document for PGE10 and PGE12 of the SAFNWC/MSG	SAF/NWC/CDOP/ZAMG/SW/SV D/1		
[AD. 5]	Software User Manual for the SAFNWC/MSG application	SAF/NWC/CDOP/INM/SW/SUM/2		
[AD. 6]	Algorithm Theoretical Basis Document for the "Automatic Satellite Image Interpretation" product (ASII, PGE10)	SAF/NWC/CDOP/ZAMG/SCI/AT BD/2		

*Table 1: List of Applicable Documents*

### 1.6.2 Reference Documents



The reference documents contain useful information related to the subject of the project. This reference document complements the applicable documents. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the document referred to applies.

Latest documentation can be found at the SAFNWC Help Desk at <http://www.nwcsaf.org>

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 11/95
---	---	---	--

Reference	Title	Code	Vers	Date
[RD.1]	Validation Report for the “Automatic Satellite Image Interpretation” (ASII-PGE10, v2.0)	SAF/NWC/CDOP/ZAMG/SCI/VR/01	1.1	16/11/07
[RD.2]	Scientific Report on changes implemented in “Automatic Satellite Image Interpretation” (ASII- PGE10 v2.1)	SAF/NWC/CDOP/ZAMG/SCI/RP/01	1.0	16/11/07
[RD.3]	Validation Report for “Automatic Satellite Image Interpretation” (ASII-PGE10, v2010)	SAF/NWC/CDOP/ZAMG/SCI/VR/4	1.0	20 April 2010

**Table 2: List of Referenced Documents**

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 12/95
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## **2. DESCRIPTION OF THE AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII) PRODUCT**

### **2.1 GOAL OF THE AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII) PRODUCT**

PGE10 of the SAFNWC/MSG provides an automatic satellite image interpretation in terms of conceptual models (CMs). Conceptual models are important tools for forecasters in diagnosis, nowcasting and very short range forecasting; they describe a synthesis of typical features in satellite images as well as in other synoptic material (for instance numerical model output parameters) and the physical processes causing them. A CM diagnosis cannot only be used for detection of an ongoing process but also for the determination of the stage of development within this process.

An inventory of the usage of CMs in weather services was produced within the COST78 project, providing a collection of more than 80 CMs used in European weather services as well as a collection of the existing experiences with them (COST78, 1996). Other literature providing summaries of CMs include Bader et al. (1995) and ZAMG (1999, 2005).

Typical features/configurations in satellite images are fundamental input to conceptual models and often show the very first stages of a new development. To be able to recognise all necessary satellite features and feature changes in a time scale appropriate for nowcasting, the only way to manage the huge amount of satellite data (images) is an automatic detection of CMs.

PGE10 carries out the recognition of CMs along two lines:

ASII: Automatic Satellite Image Interpretation from MSG SEVIRI satellite data alone

ASIIINWP: Automatic Satellite Image Interpretation from MSG SEVIRI satellite data supplemented by typical key parameters from the numerical model output (Numerical model used: ECMWF)

### **2.2 OUTLINE OF AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII) ALGORITHMS<sup>1</sup>**



#### **2.2.1 Satellite data pre-processing**

Satellite images from MSG are preprocessed before being further analysed by ASII. This preprocessing consists in converting the radiation values to temperature values, reprojection and image filtering methods to increase the performance of the search methods. Image information is transferred to a lower resolution grid to reduce computation time.

Atmospheric motion vectors (AMV) are calculated from pairs of WV- and IR-images. While in IR-images AMVs cannot be extracted from cloud free regions, in WV-imagery, they show a smooth flow pattern all over the image. AMVs are used to detect the evolution of convective cells and the large scale displacement of frontal systems. They also serve for the computation of flow

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<sup>1</sup> Several of the algorithms described in the manual have been developed in the frame of scientific projects supported by the Austrian Ministry for Education, Science and Culture (BM:BWK) in cooperation with the company GEPARD (J. Scheiber).

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 13/95
---	---	---	--

parameters like the vorticity and neighbourhood-related functions (e.g. lee near the mountain crest).

### 2.2.2 Development images

Development images are calculated from 2 consecutive satellite images. The later image is temporally extrapolated towards the first image with help of the AMVs. The content of the development image, which is the difference image between the extrapolated and the actual image, can therefore be interpreted as the non-advective changes in the cloud field.

The development images are used for CMs which potentially show some stronger developments in particular phases of their life cycle. Depending on the values of the development image at a grid mesh, the conceptual model analysed there is flagged as developing or decaying.

### 2.2.3 NWP data input

At the forecast times 00, 06, 12, and 18 UTC (and - if available - 03, 09, 15 and 21 UTC), derived quantities are computed from the NWP data. In a further step they are interpolated to the analysis grid. The basic inputs to the software are ECMWF forecast fields on a regular longitude-latitude grid. It is required that the provided ECMWF NWP data cover the entire area chosen by the user, otherwise the NWP branch of PGE10 cannot be carried out.

For slots without corresponding NWP forecast, the NWP data are either extrapolated by means of the AMVs from the WV channel or interpolated in time using a Complex Empirical Orthogonal Functions analysis approach.

### 2.2.4 Ingestion of analysis information from the preceding slot ("memory")



To achieve a more continuous analysis of the satellite images, the algorithm takes into account the results from previous analyses. The software dumps the determined information on conceptual models which is then read during the analysis of the following image. The position of the memorized conceptual model is modified with help of the AMVs.

### 2.2.5 Detection of contiguous areas with similar cloud structure

Using statistical methods, the IR image is classified in coherent areas. The classification is based on image brightness and texture. The idea behind is to extract regions of similar cloud structure and hence to find the extension of conceptual models. A number is assigned to each cloud classification (cf. Table 3).

Class	Number
Cloudless area;	1
Bright (cold) smooth cloudiness, as characteristic for warm fronts;	11
Dark grey to grey cloudiness with smooth to medium rough texture, as it is typically observed in low cold fronts;	21
Bright to medium bright cloudiness with rough texture ; as it is typical for multi-layered frontal systems	32
Bright (cold) and small cellular cloudiness as it is typical for enhanced Cumuli;	61
Very bright (cold) and bigger cloud cells as they are typical for Cumulonimbus cloudiness;	80
Low-level cellular cloudiness as it is typical for the cold-air cellular cloudiness.	91

**Table 3:** Description of classes. The column “number” gives code numbers which are occasionally referred to in later sections.

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 14/95
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Another method is employed to extract the information “frontal” and “non-frontal” from the satellite images. While the classification method analyses substructures in cloud features, this method analyses the cloud system as a whole and plots the so called “contour line” which is re-analysed with pattern recognition methods (e.g. S-shaped lines).

## 2.2.6 Pattern recognition methods and topographic functions

Topographic functions describe the position of an attribute field (e.g. maximum, minimum, ridge lines ...) either in satellite images or in NWP-fields in respect to the position of other attribute fields. Such a topographic function is used for the detection of left exit regions of jet streaks (applied to numerical model fields) or for the detection of lee cloudiness (applied to the IR-imagery).

Pattern recognition methods are widely used to detect characteristic structures in the IR- or WV-image. As an example the S-shaped rear side of a frontal wave can be seen as a characteristic feature for this conceptual model. This pattern is automatically detected and taken into consideration for the automatic detection of wave features embedded in cold fronts. As another example the automatic detection of small convective cells (EC and Cb) is performed by a module which recognises bright, circular shaped cloud features.

Pattern recognition methods are widely used for the detection of cloud fibres, spiralstructures, curved frontal cloud bands or black stripes in the WV-imagery. These methods are implemented in the detection algorithm of several conceptual models like occlusions, comma clouds, cloud fibres and many other more.

## 2.3 DESCRIPTION OF THE OUTPUT



The following two tables give an overview over the symbols used for the different conceptual models in figures below.

<b>SAT:</b>		
<b>Symbol</b>	<b>Colour</b>	<b>Conceptual Model</b>
w	red	warm front
c	blue	cold front
~	magenta	frontal wave
~	red	developing frontal wave
O	green	occlusion
DI	cyan	dry intrusion
ec	cyan	enhanced cumulus
cb	blue	Cumulonimbus (decaying stage)
cb	yellow	Cumulonimbus (mature stage)
cb	magenta	Cumulonimbus (developing stage)
M	yellow	Meso scale Convective System
•	yellow	embedded convective cell

F	yellow	jet cloud fibres
z	yellow	cold air cloudiness
co	yellow	comma
L	yellow	lee cloud

**Table 4:** Symbols used for the different conceptual models in the ASII (SAT) output

<b>NWP+SAT:</b>		
<b>Symbol</b>	<b>Colour</b>	<b>Conceptual Model</b>
w	red	warm front
c	blue	cold front
c	red	cold front in warm air advection
~	magenta	frontal wave
~	red	developing frontal wave
~	green	upper wave
O	green	occlusion
DI	cyan	dry intrusion
ec	cyan	enhanced cumulus
cb	blue	Cumulonimbus (decaying stage)
cb	yellow	Cumulonimbus (mature stage)
cb	magenta	Cumulonimbus (developing stage)
M	yellow	Meso scale Convective System
•	yellow	embedded convective cell
F	yellow	jet cloud fibres
z	yellow	cold air cloudiness
co	yellow	comma
L	yellow	lee cloud
ji	yellow	front intensification in left exit region of a jet streak
ul	yellow	upper level low

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 16/95
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*Table 5: Symbols used for the different conceptual models in the ASIINWP (SAT+NWP) output*

## 2.3.1 Detailed description of conceptual models

### 2.3.1.1 Cold Front (CF)

The main physical process for the development of cold fronts is the movement of cold dry against warm moist air. As a consequence of this movement and relative to it, the warm air tends to glide up on this air mass boundary while the cold air tends to sink below it. This upward motion may lead to condensation and subsequently to the development of clouds and precipitation.

For more details see ZAMG (2005).

## Key parameters used in the ASII product

### Frontal area:

The frontal area defines large cloud fields with a high probability of being a frontal system. CF tags are analysed within such a frontal area.

This is the only criterion which is checked in ASII for CF. Since a CF is overwritten by each of the other frontal Conceptual Models if their criteria are fulfilled as well, a CF tag only remains if NOTHING else is analysed at this place. Therefore CF tags are necessarily connected to a frontal rear side and are limited to a width less than 12 grid meshes (cf. WF, section 2.4.1.2).



## Key parameters used in the ASIINWP product

Three types of cold fronts are diagnosed by the ASIINWP product by different procedures and key parameters:

- The classical cold front
- A cold front in WA
- Low cold front bands

### The classical cold front



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**The detection mechanism is the same as in ASII:**

### **Frontal area**

No NWP fields are used actively for classical cold fronts although TA is used indirectly. The CF tags assigned to a classical front are thought to be under CA and are tested only later in connection with the CF in WA (see below).

The CF analysis is replaced in the further analysis by other conceptual models if they are superimposed on the frontal cloud band. For instance: Cbs, MCSs, JI, fibres.

### **A cold front in WA**

The CF in WA is analysed only in the ASIINWP product since TA is necessary for its analysis. But it is not the complete CM “CF in WA”: only the existence of WA within the cloud band is judged but not the existence of WA in the cold air behind the cold front cloud band (which would be a necessary condition for the CM "CF in WA").

Input from ASII:

### **Frontal area**

#### **Frontal rear side**

For a CF in WA a frontal rear side must be detected; this is the main difference to a WF where no frontal rear side exists.



Additional parameters from NWP:

#### **Temperature advection at 700 hPa (TA):**

The CF in WA has to be located in  $TA > 0$  K/12 hours.

### **Low cold front bands**

This conceptual model has been introduced for those cases where clouds do not exceed the temperature threshold necessary for the detection of a frontal area (approximately  $-15^{\circ}$  cloud top

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temperature). With the thermal front parameter and a selection of typical low cloud classifications this module analyses low cold front cloud bands in addition to the cold fronts defined by a frontal area.

**Classification:**

All classifications correspond to low brightness in the IR satellite image.

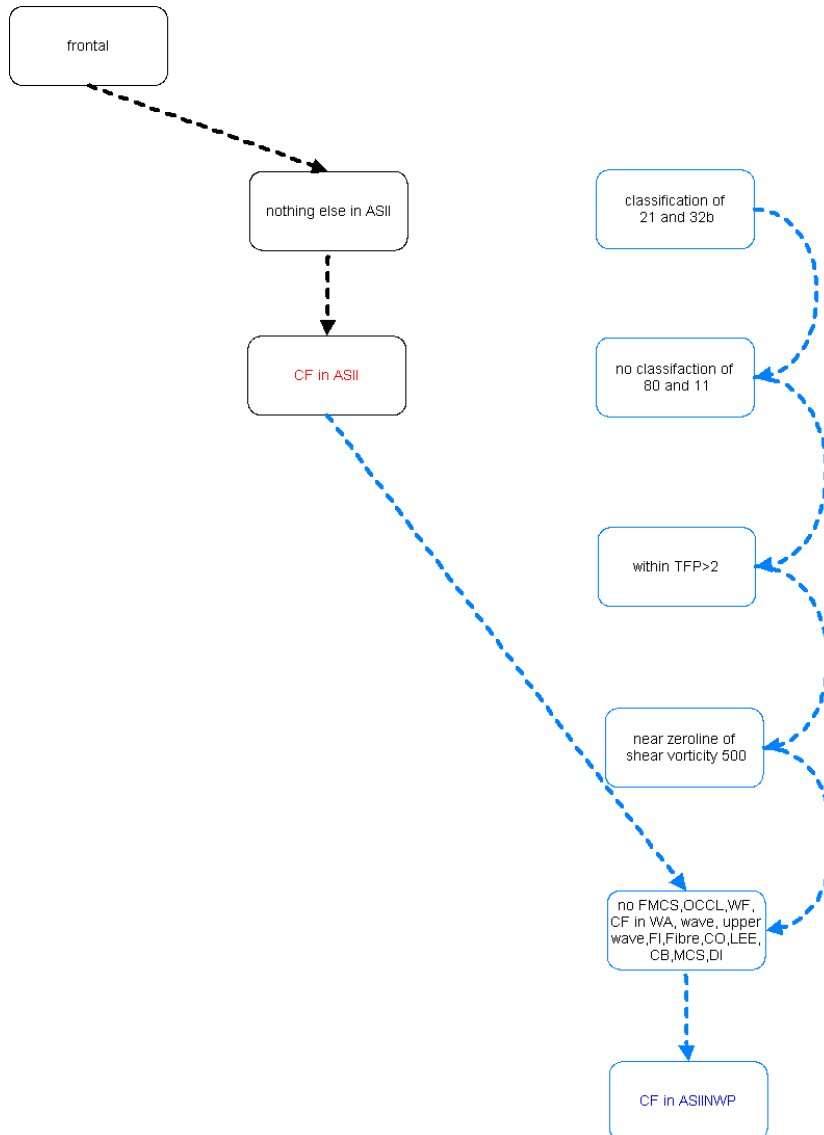
**Thermal front parameter (TFP):**

Positive values of the TFP are required.

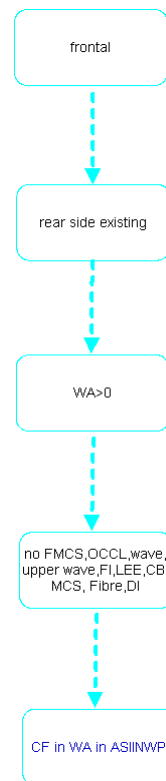
**Relative vorticity at 500 hPa (RV500):**

A probability region of 8 grid-meshes width (4 grid-meshes on each side of the zero line) along the zero line of the RV500 field is applied.

**Schematics of the diagnosis processes**



**Figure 1:** Conditions for the detection of a CF in ASII (black) and ASINWP (blue); in ASINWP the two branches are symbolising the classical cold front and the low cold front



*Figure 2: Conditions for the detection of a CF in WA in ASIINWP*

For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.



## Practical application rules and inherent problems

### General application rules:

- If a CF is analysed by ASII, forecasters can be sure that there is a frontal area with a frontal rear side;
- If a classical CF is analysed in ASIINWP, forecasters can be sure that there is CA at 700 hPa within the frontal cloud band;
- If a CF in WA is analysed in ASIINWP, forecasters can be sure that there is a frontal area with a frontal rear side and  $WA > 0$  K/12 h
- If a low level CF is analysed in ASIINWP, forecasters can be sure that the cloud fields are accompanied by a frontal parameter in NWP (TFP and zero-line of vorticity at 500 hPa).

### Comparison ASII vs. ASIINWP:

- Typical differences in ASII and ASIINWP can be used to reveal details of the CF; the following examples happen frequently:
  - ASII: CF; ASIINWP: CF in WA;

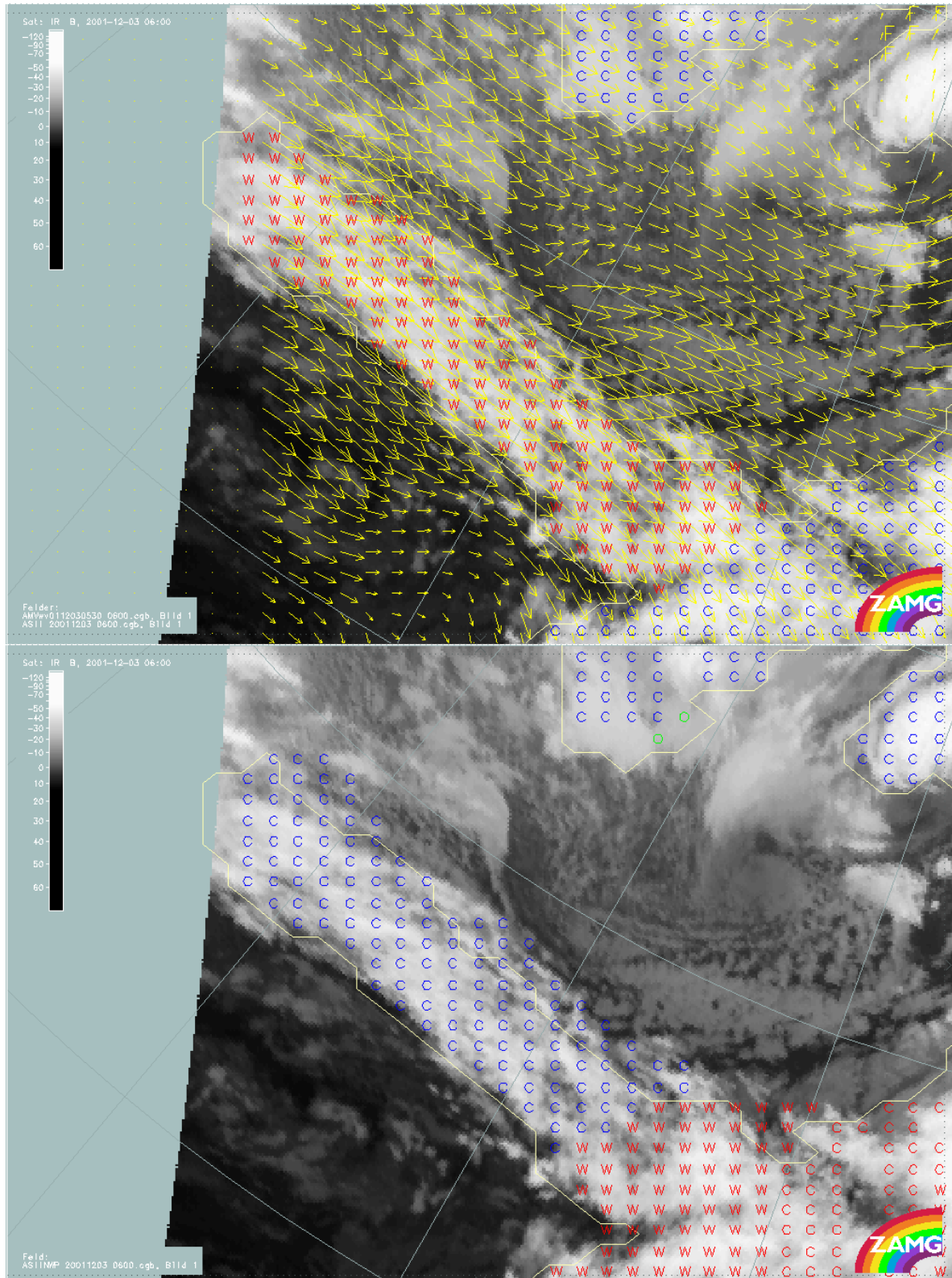
 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 21/95
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this means the typical movement of a CF but the existence of WA in the area of the cloudiness; this needs not be a model error as for instance in case of Katafronts the zeroline of TA is close to the frontal rear side;



- ASII: no CF diagnosis but for instance comma; ASIINWP: CF  
 this means that no frontal area is diagnosed either because the thresholds of extension is not reached or (mostly) because of the temperature threshold is not reached; this happens in case of a low CF cloud band which has some additional characteristics of a comma (see 2.3.1.9).

### **Inherent problems**

- There are CFs which are stationary as a whole and therefore accompanied by cloud-band parallel WV AMVs; consequently these cloud bands, which are apparently CFs, are analysed as WFs in ASII. Those cases are diagnosed as CF in ASIINWP if CA is prevailing. See Figure 3.



**Figure 3:** Upper panel: 3<sup>rd</sup> December 2001, 06 UTC; ASII; WV AMVs superimposed (which suggests WF conditions, hence the labelling by red 'w'). Lower panel: 3<sup>rd</sup> December 2001, 06 UTC; ASIINWP; CA changes the ASII analysis of WF into a CF

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### **2.3.1.2 Warm front (WF)**

In the case of a warm front, warm moist air moves against colder dry air. At the boundary of these two air masses the warm air tends to glide up over the wedge of colder air. This process causes the development of a frontal cloud band, and therefore also the precipitation, to be found in front of the surface front (or a front parameter like the Thermal Front Parameter TFP).

For more details see ZAMG (2005).

## **Key parameters used in the ASII product**

### **Frontal area:**

The parameter “frontal area“ (see chapter 3.1.8 in AD. 6) is used to separate frontal systems from others using the size and pixel brightness (temperature) of the comprised cloud area as main criteria. Warm fronts must be located within such a “frontal area”.

### **Frontal rear side:**

The algorithm used for the detection of “frontal rear sides” is described chapter 3.1.8 in AD. 6. For WFs, they are tightly connected to the “rear side detection” of Cold Fronts (CFs). Warm front tags are analysed in a frontal area if no frontal rear side is detected.

Another possibility for a warm front analysis is the diagnosis in case of an extended shield-like cloud field. Such cloud shields are detected if the distance between frontal rear side and the corresponding leading edge of the cloud shield exceeds an empirically gained threshold of 12 grid meshes.

### **Memory**

As experience has shown, warm fronts undergo rather frequent fluctuations in a small scale. To overcome this problem, the warm front analysis from the preceding satellite image is displaced with help of the AMVs and included in the present analysis.

## **Key parameters used in the ASIINWP product**

**The ASIINWP product uses the following criteria from ASII:**

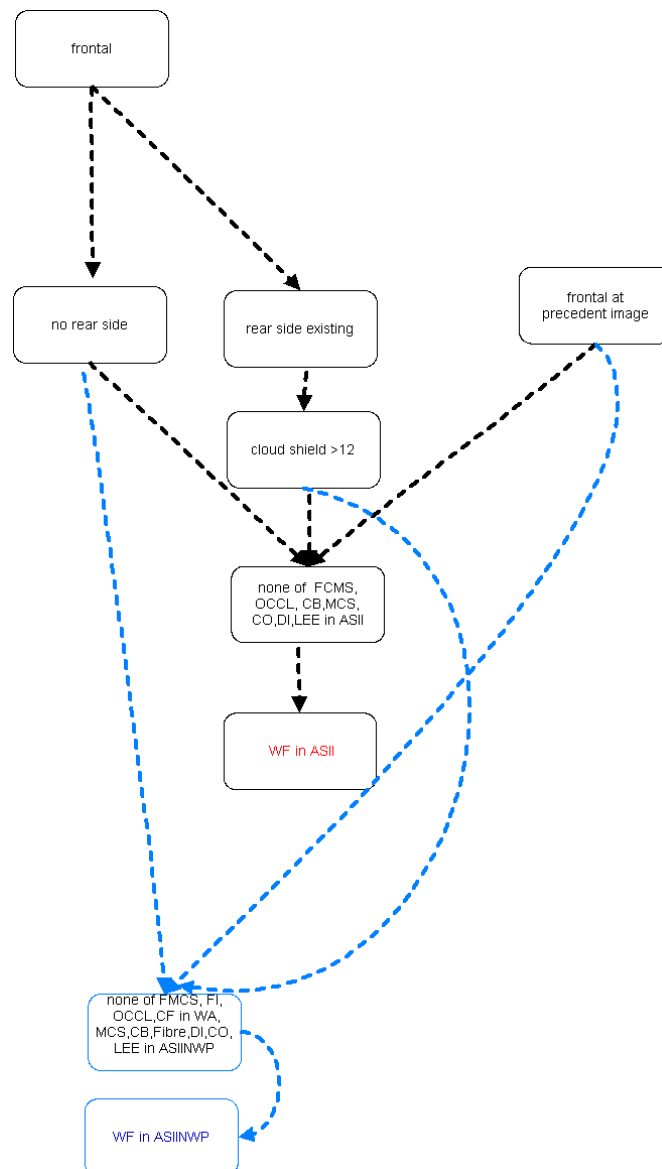
**Frontal area**

**Rear side detection**

**Memory**

There are no NWP fields used for the detection of warm fronts in ASIINWP. Although synoptic experiences often show warm advection within the warm front shield, the use of TA 700 hPa has led to a significantly lower rate of detection than in ASII. Therefore the former NWP part was skipped.



## Schematics of the diagnosis process



**Figure 4:** Conditions for the detection of a WF in ASII (black) and ASIINWP (blue)

For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.



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## Practical application rules and inherent problems

### General application rules:



- If in ASII a WF is diagnosed forecasters can be sure:
  - either: that there is a frontal area without any frontal rear side;
  - or: that the frontal area has the form of a broad cloud shield.

### Comparison ASII vs. ASIINWP:

- The analyses in ASII and ASIINWP are based on the same criteria, therefore all WF in ASII are also analysed as WF in ASIINWP. There might be slight differences in cases where other conceptual models overwrite the warm front tags like the front intensification, which is only defined in ASIINWP. The differences are concerning only small (embedded) parts of the cloud shield and not the whole system.

### Inherent problems:

- For ASIINWP no numerical fields could be found to ameliorate the discrimination between cold fronts and warm fronts. A meteorologist can easily see the difference by using vertical cross sections, but a single level (or layer) was not found to be representative.
- There are CFs which are stationary as a whole and therefore accompanied by cloud-band parallel WV AMVs; consequently these cloud bands which are apparently CFs are analysed as WFs in ASII.

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 26/95
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### 2.3.1.3 Occlusion

The cloud band of an occlusion described in this chapter is the result of a classical development process starting from a wave stage represented by a cloud bulge at the rear side of a cold front cloud band growing to a multi-layered, cyclonically curved synoptic-scale cloud spiral.

For more details see ZAMG (2005).

## Key parameters used in the ASII product

### Frontal area:

An occlusion cloud band must be located within a frontal area, since it is always part of a larger frontal system. Concerning the detailed algorithm for detection of frontal areas see (AD. 6).

### WV-AMV-Vorticity:

Vorticity is calculated from the WV-AMV field. After the detection of the maximum of relative vorticity from a smoothed vorticity field, a probability region, whose extension depends upon the strength of the detected vorticity maximum, is calculated. For weaker vorticity maxima (6 – 10 units), a probability region with a radius of 9 grid meshes is assigned, for stronger vorticity maxima (> 10 units), a probability region with a radius of 12 grid meshes is assigned to take into account, that occlusion cloud spirals within deeper low pressure systems can be more extended.

### Hough knot:

This method recognises curved cloud bands by analysing the orientation of small frontal segments (for a detailed description of the algorithm see chapter 3.1.15 in AD. 6). Around a detected Hough knot a probability region with a radius of 11 grid meshes is applied. Such a Hough knot must be situated outside the frontal area. If the criterion of the Hough knot is fulfilled, the WV AMV vorticity is not checked any more. This enables ASII to find more occlusions.

### IR-AMV direction:



Atmospheric motion vectors, computed from the IR images, are supposed to have at least a small easterly component (i.e.  $U < 0$ ). Also, they should have either

- a northward direction or
- if southward, only a weak meridional component not exceeding 10 m/s (i.e.  $V > -10$ ).

If a combination of a

- northerly wind component exceeding 15 m/s ( $V > 15$  m/s) and
- a weak easterly wind component not exceeding 5 m/s ( $U > -5$  m/s)

is found, an occlusion analysis is excluded.

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The reason for the restriction in IR-AMV wind direction is to cover the typical conditions for occlusion cloud bands and therefore exclude other CM like CF and WF.

These conditions take into account the typical streaming situation in connection with occlusion cloud bands.

**“Frontal rear side”:**

Occlusion cloud bands are at least in some parts of the cloud band subject to the criterion of the frontal rear side. Although this key parameter is not strictly necessary to identify occlusion cloud bands, it has shown useful in eliminating wrong analyses of that conceptual model.

**Memory**

As experience has shown, occlusions undergo rather frequent fluctuations in a small scale. To overcome this problem, the occlusion analysis from the preceding satellite image is displaced with help of the AMVs and included in the present analysis.

**Additional:**

In the detection mechanism two probability areas are involved. Occlusion tags are diagnosed across the union of the probability areas. A mechanism has been included to extend the occlusion tags (once analysed) to the limits of the cloud band. In the same way, occlusion tags are extended over a small area filled with CF tags if they are located next to or within the occlusion.

**Key parameters used in the ASIINWP product**

The occlusion analysis in ASIINWP adopts the ASII analysis, this means, that the occlusion analysis from the satellite image cannot be overruled by the ASIINWP analysis. Instead, ASIINWP searches for occlusion which could not be detected from the imagery alone.

Analysis from ASII:

**Frontal area**

**WV-AMV voriticity**



**Hough knot**

**IR AMV direction**

**“Frontal rear side”**

**Memory**

Additionally to the ASII criteria, the following NWP criteria are used:

		Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 28/95
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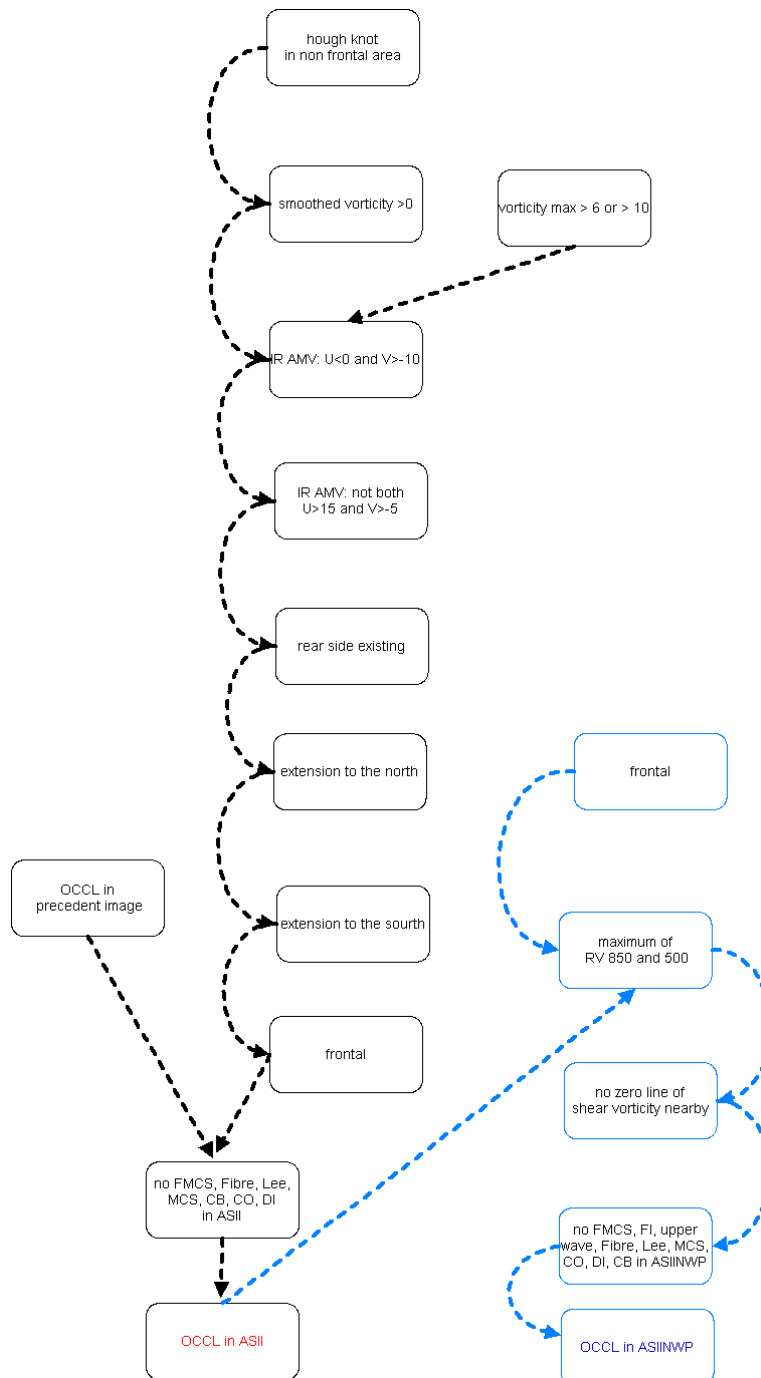
### **Relative vorticity at 500 and at 850 hPa:**

Occlusion cloud bands are connected to the big low pressure centres which extend throughout the whole troposphere. The field of the relative vorticity reflects the pressure field at a certain level. Therefore thresholds have been assigned to the different levels:  $4 * 10^{-6} [s^{-1}]$  for the vorticity at 850 hPa and  $6 * 10^{-6} [s^{-1}]$  for the vorticity at 500 hPa. Both thresholds have been chosen empirically. The radius of the probability fields is 10 grid meshes for both.

### **Additional:**

Occlusion tags are not allowed in a probability region along the zero line of the relative vorticity at 500 hPa. This criterion is necessary to avoid that occlusion tags are embedded in cold fronts

## **Schematics of the diagnosis process**



**Figure 5:** Conditions for the detection of an occlusion in ASII (black) and ASIINWP (blue)

## Practical application rules and inherent problems

### General application rules:

- If an occlusion is analysed in ASII, forecasters can be sure that there is an eastward component in the IR AMVs within a cloud spiral;

- If an occlusion is analysed in ASIINWP, forecasters can be sure about the spiral character as well as about an existing low pressure centre throughout the whole troposphere.

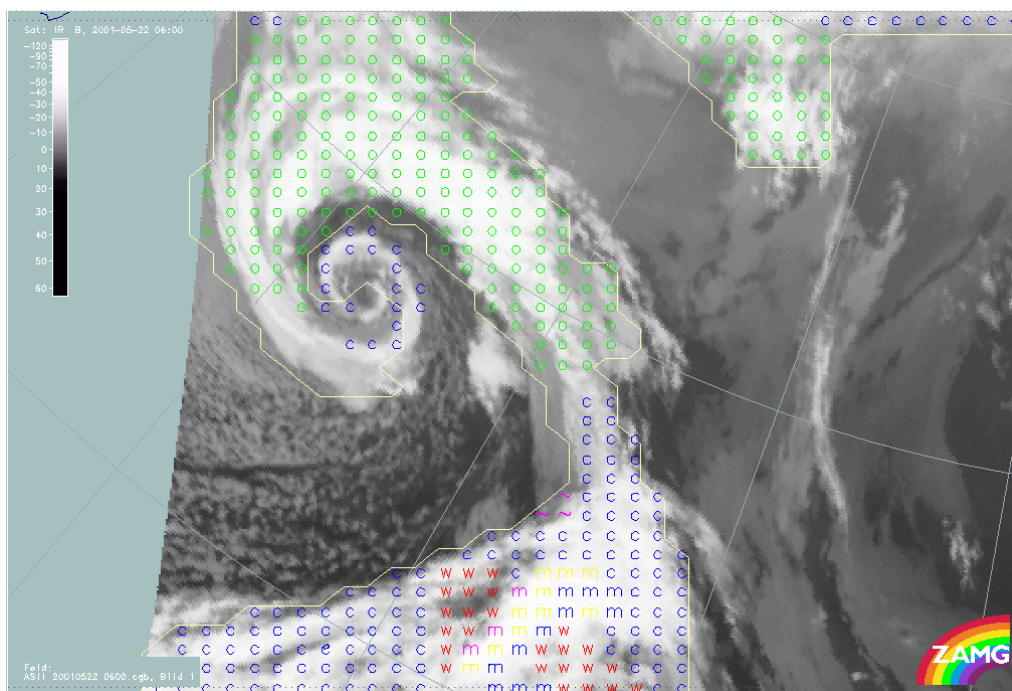
### Comparison ASII vs. ASIINWP:

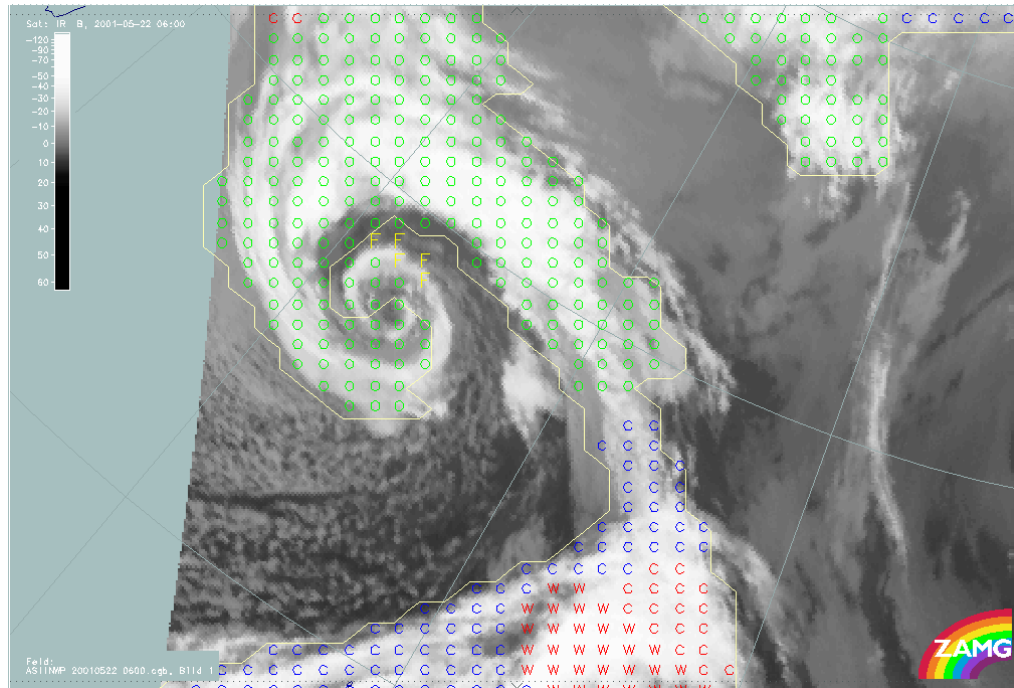
- The innermost parts of occlusions often are diagnosed as CF in ASII due to the fact that the IR AMVs are western again (see inherent problems below).
- Those areas are correctly diagnosed as occlusion with help of the criteria used in ASIINWP.
- Consequently a comparison of ASII and ASIINWP helps to correct the apparently wrong ASII diagnosis.
- Sometimes old occlusion cloud bands in dissolution are diagnosed as comma in ASII and in ASIINWP; this is an indication that the cloud area is discontinuous.

### Inherent problems



As in ASII, an eastward component of the IR AMVs is a necessary condition, the innermost parts of the occlusion spirals very often are analysed as CFs; this wrong diagnosis cannot be avoided at the time being but should easily be handled by forecasters for instance by comparison with ASIINWP (see comparison ASII vs. ASIINWP in Figure 6)

- Small areas within CFs which are analysed as “occlusion” in ASII are areas within the probability regions of the WV AMV vorticity and the Hough knot and do have an eastward component in the IR AMVs; although those analyses seem to be wrong from a general synoptic view, the conditions just mentioned are fulfilled; sometimes it might indicate an early stage of a wave.





**Figure 6:** Upper panel: ASII analysis of the 06 UTC IR satellite image from 22<sup>nd</sup> May 2001. The spiralled cloud band has been analysed as occlusion (green "o" tags), however with some undesired inclusions of cold front (blue \*c\*). Lower panel: ASIINWP analysis of the same satellite image.

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 32/95
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### 2.3.1.4 Wave

Waves are areas within cold front cloud bands where secondary cyclogenesis takes place. Such a process is indicated by a convex bulge of enhanced cloudiness at the rear side of the frontal cloud band; in case of a further development a more and more intensive spiral structure forms, leading to an occlusion cloud spiral.

For more details see ZAMG (2005).

## Key parameters used in the ASII product

### Frontal rear side:

Waves can only appear at the rear side of CF cloud bands. For the detailed algorithm of the rear side detection see chapter 3.1.9 in [AD. 6].

### WV-AMV curvature vorticity:

The WV AMV curvature vorticity is calculated from the water vapour (WV)-AMV field. Vorticity maxima ( $> 4$  units) near the frontal rear side are selected and a probability region with a radius of 4 grid meshes size is chosen around the relative maximum. The relative vorticity maximum must be in the cold air behind the frontal area and consequently the probability region around the maximum overlaps the frontal cloud band.

### S-line detection:

The frontal rear side at the place where a frontal wave emerges usually exhibits an S-shaped pattern. This pattern is automatically recognised.

Three types of S-lines are distinguished:



- Two kinds of short S-lines: they are based based on contour lines with two different enhancements.
- A type of large S-line: The same algorithm is used with some modifications in order to analyse large-scale wave structures which are accompanied by rather weak S-lines.

### Convex frontal rear sides:

For a detailed description of the algorithm see (AD. 6). This algorithm is used in addition to the S-line because a large number of frontal waves do not show a complete S-structure; either cold fronts do not show a clear cyclonic curvature or the cold front part of the wave is dissolving and hence not correctly analysed by the contour line.

For a positive diagnosis of frontal waves, only one of the two algorithms needs to give a positive result. For the localisation of the wave tags see “inherent problems”.



 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 33/95
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## Memory

Waves detected with help of the S-line detection in the preceding satellite image are displaced with help of the AMVs. If they fail to fulfil the above mentioned key parameter criteria, they are once again examined with a lower curvature vorticity threshold (3 instead of 4 units).

## Additional:

Once the above-mentioned criteria are fulfilled for an s-line segment (or a convex area), the wave tags are finally extended over the whole wave pattern. This facilitates the visual assignment to the affected wave pattern.

A motion-corrected image field, also called development image (see chapter 2.2.2) is used to give some hints about the development of cloudiness. A developing wave is characterised by increasing cloudiness which is reflected in positive values of deviation computed from the motion-corrected difference image. In the time period of half an hour, the pixel values in the wave region must have increased by at least 5 units. For large S-lines, no representative development value can be found for the whole wave area due to a high small-scale fluctuation of the development field; hence, no information about the stage of development can be given.

To avoid that MCS embedded at the rear of frontal cloud bands are analysed as large waves, wave tags are suppressed in the neighbourhood of MCSs.

Occlusion cloud bands often exhibit structures which are interpreted by the S-line detection module as well as by high curvature vorticity as frontal waves, although from a synoptic point of view, they have nothing in common with the latter. To avoid this kind of wave analysis, occlusion diagnosis is dominant over waves.

## Key parameters used in the ASIINWP product

The wave detection from ASII is also used for ASIINWP:

### Frontal rear side

### WV-AMV curvature vorticity



### S-line detection

### Convex frontal rear side

## Memory

Additionally the following NWP input data are required:

### PVA at 500 hPa (PVA500):

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 34/95
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The PVA at 500 hPa is very indicative for a wave representing its deepening. The maximum of positive vorticity advection at 500 hPa must exceed  $4 \cdot 10^{-9} \text{ [s}^{-2}\text{]}$  an empirically determined threshold. The radius of the probability field is 3 grid meshes.

#### **Relative vorticity at 850 hPa (RV850):**

The development of frontal waves goes hand in hand with the deepening of the surface trough and the formation of a surface pressure minimum. Hence, the maximum of the relative vorticity at 850 hPa must exceed  $6 \cdot 10^{-6} \text{ [s}^{-1}\text{]}$ , a threshold which has been chosen empirically. The radius of the probability field is the same as for PVA500.

For the wave detection, only one of those two criteria (either PVA500 or RV850) needs to be fulfilled.

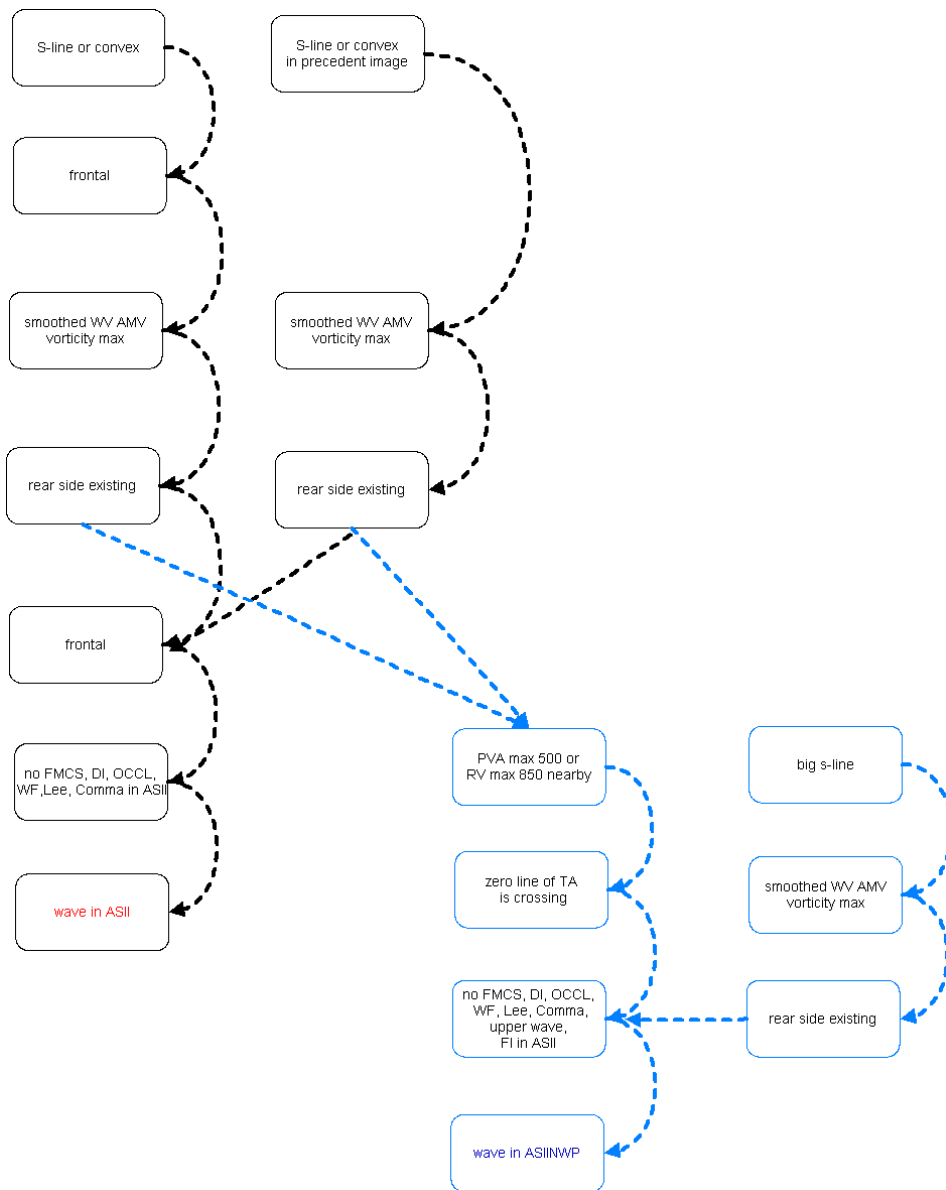
#### **Temperature advection at 700 hPa (TA700):**

The zero line of the temperature advection crosses the centre of the wave region. This criterion indicates a change of the temperature advection from CA to WA. A probability region extending 4 grid meshes to each side of the zero line is chosen.

#### **Additional:**

Same as for ASII.

## **Schematics of the diagnosis process**





**Figure 7:** Conditions for the detection of a wave in ASII (black) and ASIINWP (blue)

## Practical application rules and inherent problems

### General application rules:

- If in ASII a wave is analysed forecasters can be sure that there is a convex cloud bulge at the rear side of a frontal cloud band exceeding the implicit thresholds;
- If in ASIINWP a wave is analysed forecasters can be sure that additionally to the existence of the cloud bulge in the cloud satellite image all other physical-meteorological conditions like WA-CA maximum, a surface pressure minimum and/or a PVA maximum at high levels are fulfilled.

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### Comparison ASII vs. ASIINWP:

- If a wave is analysed in ASII, but not in ASIINWP, this means that at least one of the necessary NWP parameters is not fulfilled. There are some possible interpretations:
  - The wave bulge does not represent a classical front at the time being
  - The NWP model does not yet recognise the wave and therefore the ASII diagnosis has to be observed carefully for possible further development
  - There might be an NWP error.



### Inherent problems:

- The localisation of the wave tags is done according to fixed rules and does not always correspond to the physically related wave centre. The following rules are applied:
  - For a wave detection based on the S-line algorithm that part of the S is diagnosed as wave that corresponds to a frontal rear side;
  - For a wave detection based on the “convex” algorithm that part of the convex line that corresponds to a rear side is diagnosed as wave which should be rather downstream of the physical-meteorological wave position;
  - If both detection criteria are existent, the wave assignment according to the S-line is used.
- In the wave detection algorithm, rather sensitive thresholds are involved; consequently if parameters are close to these thresholds an unstable wave diagnosis might result: the wave diagnosis is interrupted for small time intervals within a longer time period where wave tag are analysed.
- Such a situation can be taken as a sign for a rather stationary wave bulge.
- Large S-lines do not contain a development value.
- The assignment of wave tags is driven by optical criteria (S-line, convex cloud bulge) and might therefore be in a wider area compared to the small scale of the position of the corresponding surface low.

#### **2.3.1.5 Upper Wave**

An upper wave is accompanied in the initial stages by a convex bulge of enhanced cloudiness on the rearward side of frontal cloud bands (mainly CF), very similar to a classical wave. A detailed inspection of the images shows hardly any differences to classical wave developments. There might be a tendency that cloud edges of jet waves are sharper with very bright grey shades. The differentiation can be accomplished with help of relevant numerical parameters which show the connection to the right entrance region of a jet streak; as upper waves appear in the area of CA usually there is not much potential for a development.

For more details see ZAMG (2005).

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## Key parameters used in the ASII product

An upper wave cannot be analysed as such from the satellite imagery alone since there is no remarkable difference to the appearance of classical frontal waves. Consequently in ASII a wave will be detected in the area of an upper wave if the criteria for waves are fulfilled, i.e. if the cloud bulge is distinct enough.

The following satellite criteria are used and shortly summarised (for more details see chapter "wave", 2.4.1.4):

**Frontal area**

**Frontal rear side**

**S-line detection**

**Convex frontal rear sides**

## Key parameters used in the ASIINWP product

Whether a wave, which is detected in ASII, is a classical wave or an upper wave feature can be detected primarily with the help of the NWP fields since the satellite image gives neither reliable information about the location of a jet streak nor about the reached wind speeds. Consequently the detection of a wave bulge from ASII is used by ASIINWP, but in addition the following parameters from NWP are inspected:

### **Wind speed at 300 hPa (V300):**

By definition, the wind speed within a jet streak has to exceed 30 m/s. The threshold chosen here is fixed at 20 m/s so that model errors like underestimation of the real wind speed or displacement of the jet axis or simply the fact that the jet level is not at 300 hPa, are taken into consideration.

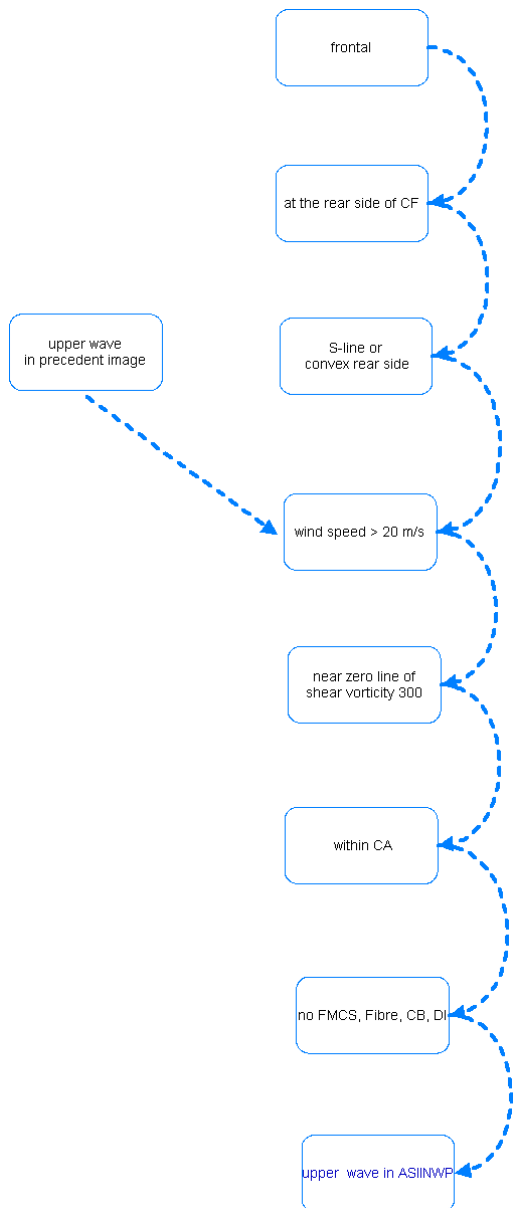
### **Temperature advection at 700 hPa (TA700):**

As mentioned above an upper wave is located in CA. Therefore a large part of the corresponding cloud band has to be under the influence of CA.

### **Zero line of the shear vorticity at 300 hPa (RSV300):**

As the zeroline of shear vorticity indicates the jet axis a region is defined along the zero line of the shear vorticity at 300 hPa indicating the area where an upper wave is expected. The upper wave should be located within such a region.

## Schematics of the diagnosis process



**Figure 8:** Conditions for the detection of an upper wave in ASII (black) and ASIIINWP (blue)



For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

## Practical application rules and inherent problems

### General application rules

- If in ASII a wave and in NWP an “upper wave” is analysed a forecaster can be sure that the wave bulge is under the influence of CA and within a jet maximum.

### Inherent problems

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- Problems concerning the stability of the wave detection are the same as for waves (see above).
- Upper waves appear at the rear side of cold fronts which are widely under CA (for instance at Anafronts) in heights around 300 hPa (jet level). Nevertheless the 700 hPa level is used for the evaluation of the temperature advection. Some misclassifications may arise from this level inconsistency.

### **2.3.1.6 Front Intensification (FI) by Jet**

If a jet streak approaches and crosses a frontal zone at a large acute angle, horizontal and vertical increase of frontal cloudiness in the left exit region of this crossing jet streak can be observed. These cloud phenomena are produced by the interaction between the circulation within the front and within the exit region of the jet streak.

For more details see ZAMG (2005).

## **Key parameters used in the ASII product**

The CM “Front Intensification by jet streak crossing” cannot be found automatically from satellite information alone. The main reason is that intensification within a frontal cloud band is very similar to other CMs like for instance waves, embedded MCSs and Cbs. Nevertheless some basic frontal satellite information is necessary also for the NWP data. This is described in the chapter below.

## **Key parameters used in the ASIINWP product**

### **Frontal areas:**



The CM “FI by Jet Crossing” is a substructure of a cold front. It must therefore be located within the Frontal Area.

### **Classification:**

Frontal regions within the left exit region of a jet streak show enhanced cloudiness, sometimes with pronounced convection. Therefore the classification is characterised by categories with high pixel values and a smooth texture showing high pixel gradients at the marging of the enhanced area. The resulting classifications are indicative for bright (cold) cloudiness.

### **Determination of the left exit region of a jet streak**

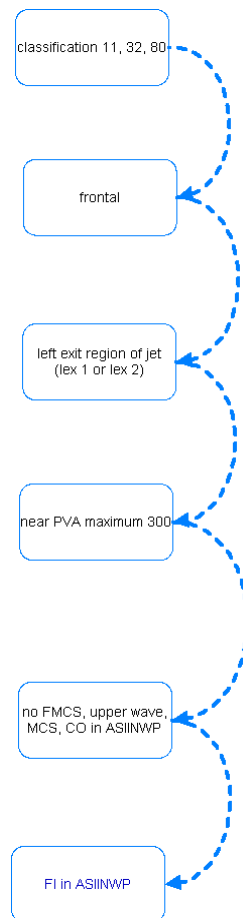
This function locates a left exit region with help of the location of the jet axis and the wind speeds. The function determines those points where the zero line of the relative shear vorticity at 300 hPa leaves the area determined by a given wind threshold. The function is applied twice, first with a wind speed threshold of 40 m/s and then with a threshold of 50 m/s. The determination of the left/cyclonic part of the exit region is given by the wind direction at the exit point and is located to the left of the jet axis.

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### Positive vorticity advection at 300 hPa (PVA300):

A positive vorticity maximum is required in the left exit region of the jet streak. Every PVA maximum at 300 hPa exceeding  $3 * 10^{-9} [s^{-2}]$  is considered. The region with possible cloud enhancement has to be located within the PVA300 = 3 units isoline.

### Schematics of input parameters



**Figure 9:** Conditions for the detection of a front intensification in ASIINWP (blue)



For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

## Practical application rules and inherent problems

### General application rules

- If the CM “JI” (“Front Intensification by Jet crossing”) is analysed in ASIINWP, a forecaster can be sure that a PVA maximum in connection with the left exit region of a jet streak (on its cyclonic side) is superimposed on a frontal cloud band.



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### **Inherent problems**

- As there is no algorithm to distinguish between a PVA maximum caused predominantly by shear (as it is the case in the left exit region of a straight jet streak) and one caused predominantly by curvature (as is the case at the rear side of a frontal cloud band) a mixing of these two situations sometimes might happen

### **2.3.1.7 Dry Intrusion (DI)**

A dry intrusion (DI) is characterised by a black stripe in the WV imagery, located at the rear side of a CF (indication for a Split Front), or more frequent, near the occlusion point of a well developed frontal system. In some cases, DI-tags are located in the vicinity of the cloud head of a developing Rapid Cyclogenesis. If the latter is the case, the drying air from above indicates the progression of the cyclogenetic process.

For more details see ZAMG (2005).

## **Key parameters used in the ASII product**

### **Areas in the vicinity of fronts:**

A dry intrusion can be analysed outside the frontal area. But because of its strong connection to CF it has to be situated very near to a frontal area.

### **Frontal rear side:**

A dry intrusion can only develop near a frontal rear side.

### **Detection of black stripes in the WV image:**



With the pattern recognition method for the automatic detection of black stripes in WV images, elongated areas of low WV content (so called "black stripes") are sought.

### **Intersection of WV black stripes with the frontal rear side:**

A main characteristic of the dry intrusion is the sinking dry air at the rear side of a cold front accompanied with a cloud dissolution process. The intersection of the black WV stripe with the frontal cloud band is determined automatically. In this special case the determination of the frontal cloud band is done with the algorithm to identify contiguous areas (cf 2.2.5) alone, whereas in all other cases, the frontal area is reduced by the intersection area with a black stripe.

### **AMV vorticity:**

The cold front and the drying region typically lie in areas with cyclonic vorticity. Therefore a key parameter for the location of a dry intrusion is the positive (large-scale) AMV vorticity.

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### **Memory:**

The outcome of the DI analysis from the preceding satellite image is displaced with help of the AMVs and implemented in the present analysis.

### **Additional:**

The area where the DI tags are assigned to is dependent on the length of the intersection area with the black stripe and does not reflect the intensity of the process.

## **Key parameters from the ASIINWP product**

The satellite part of ASIINWP is identical with the one from ASII.

### **Areas in the vicinity of fronts**

#### **Frontal rear side**

#### **Detection of black stripes in the WV image**

#### **Intersection of WV black stripes with the frontal rear side**

### **Memory**

The following NWP fields are required in addition:

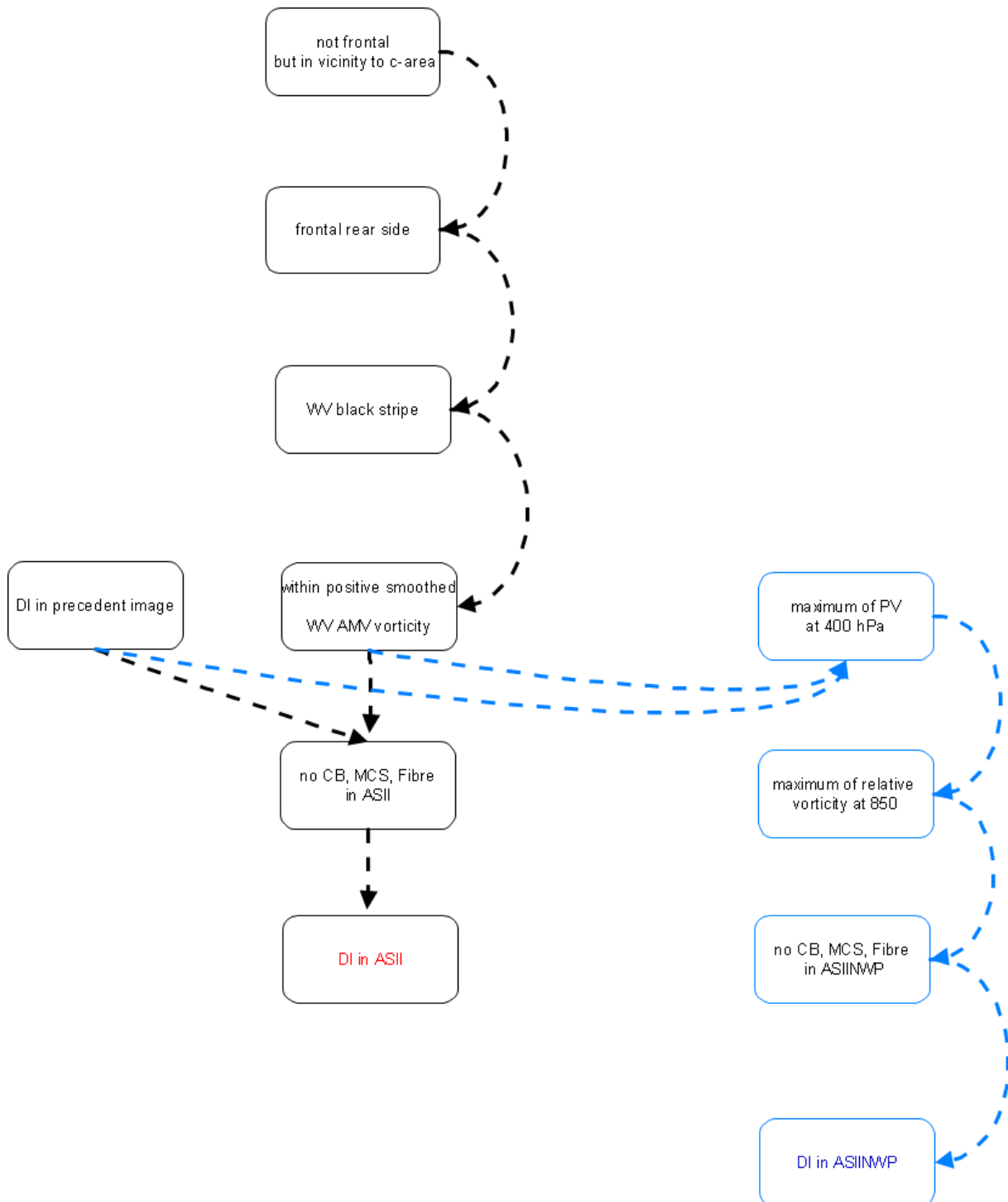
### **Potential vorticity (PV):**

A main feature from the numerical fields is the presence of a PV maximum in the troposphere. Relative maxima on the 400 hPa level with a value  $>1.25$  PVU are sought. A probability region with a radius of 5 grid meshes around the maximum has been chosen empirically.

### **The relative vorticity at 850 hPa**

The relative vorticity maximum at 850 hPa ( $> 6 \cdot 10^{-6} [s^{-1}]$ ) gives an indication for the deepening of the surface trough or the formation of a surface low. The threshold has been chosen empirically. A probability region with a radius of 5 grid meshes around the relative maximum is investigated.



## **Schematics of the diagnosis process**



**Figure 10:** Conditions for the detection of a dry intrusion in ASII (black) and in ASIINWP (blue)

For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

## Practical application rules and inherent problems



		Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 44/95
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## General application rules

- If a dry intrusion is analysed by ASII, forecasters can be sure that a black stripe in the WV image intersects the frontal cloud band at its rear side;
- These areas can be regarded either as a split front region (when located at the rear side of a CF) or as ongoing cyclogenetic process. In some cases (presence of a cloud head), the DI-tags are a good indicator for a developing Rapid Cyclogenesis.

## Inherent problems

The dry intrusion, i.e. the intersection of the frontal area with the black stripe, is a powerful tool but it is not only the sign for a rapid cyclogenesis; it can also represent a developing Kata- or Split front mostly in the area of the occlusion point; in any case the process indicates that drying from above is going on in this area but this does not necessarily mean that a RC will develop.

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### 2.3.1.8 Upper Level Low

Upper Level Lows are the result of a cut-off process at high levels like for instance 500 hPa without any correspondence in low levels (for instance 1000 – 850 hPa) . An upper level trough (“Trough stage”) becomes deeper and sharper and starts to be teared off from the main westerly flow (“Tear-off stage”). In the end phase the trough is cut off from the main flow to the north (“Cut-off stage”). Cloudiness connected to this process consists of remnants of a frontal cloud band at the leading side as well as convective cloud types in the centre of the trough/low.

For more details see ZAMG (2005).

### Key parameter used in the ASII product

There is no special module to analyse upper level lows in the ASII product since there is no cloudiness which typically appears only with ULL cloudiness. But cloud configurations like frontal cloud bands can be observed at the leading edge, convective cold air features in the centre and sometimes fibrous cloud elements at the rear side. Those cloud systems are diagnosed separately (for instance as comma, Cb, cold front, occlusion, etc) but their co-existence and relation to the ULL cannot be diagnosed from satellite features alone.

### Key parameters used in the ASIINWP product

The CM upper level low (ULL) is analysed only with help of NWP data. The absolute topography at 500 hPa is investigated for a local minimum and then compared with the vorticity field at 850 hPa.



#### **Absolute topography at 500 hPa:**

The upper level low is characterised by a local minimum in the absolute topography at 500 hPa. A probability region is calculated around every local minimum of the geopotential height field.

#### **Relative vorticity at 850 hPa:**

Surface lows are reflected by a maximum of the relative vorticity in lower levels of the atmosphere (e.g. 850 hPa). In case of ULLs there is no or only a very weak corresponding low in lower levels. ASIINWP uses the vorticity at 850hPa instead of the surface field because the latter is too much influenced by planetary boundary layer effects; for a positive ULL diagnosis, the vorticity field has to remain below an empirically chosen threshold of  $6 \cdot 10^{-6} \text{ s}^{-1}$ . The area where no local minimum of the relative vorticity at 850 hPa should be present has a radius of 8 grid meshes (around the prospective ULL centre).

#### **Potential vorticity:**

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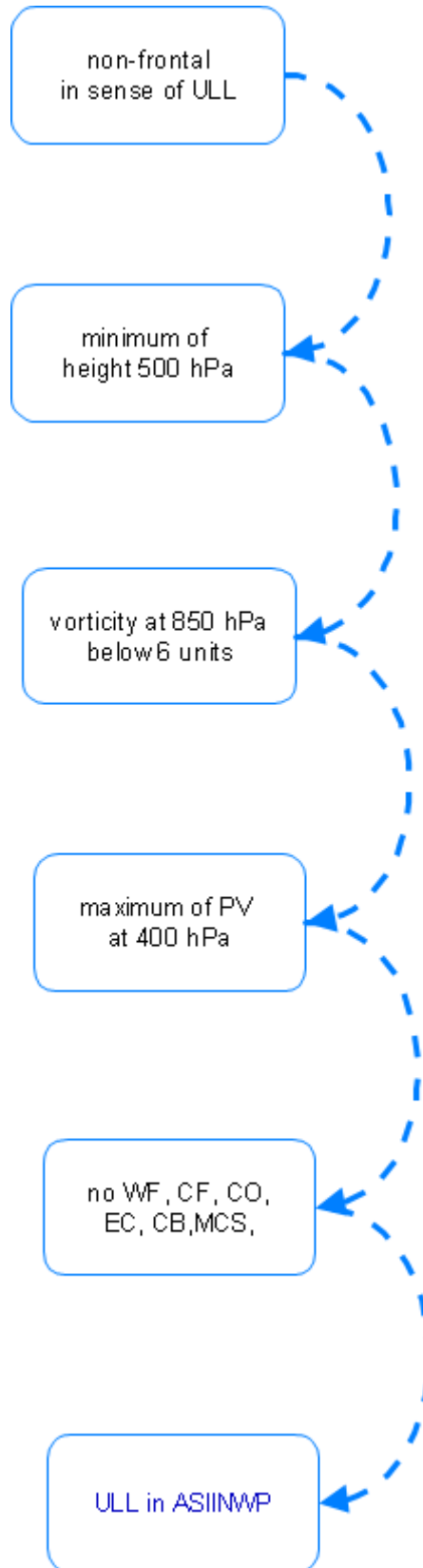
ULLs are areas where high values of PV have protruded far down into the troposphere. Relative maxima on the 400 hPa level with a value  $>1.25$  PVU are sought.

**Additional:**



The upper level low tags are placed in the centre of the low pressure area at 500 hPa. If frontal systems are located at the same place as the ULL, the latter are suppressed.

For similar reasons ULLs are rejected in regions where the satellite data indicate a high probability for occlusions.

**Schematics of the diagnosis process**



*Figure 11: Conditions for the detection of an upper level low in ASIINWP.*

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For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

## Practical application rules and inherent problems

### General application rules

- If an ULL is analysed in ASIINWP, forecasters can be sure that there is a depression at 500 hPa without a corresponding depression at 850 hPa; this upper level depression might also be connected to a small scale trough.



 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 49/95
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### **2.3.1.9 Comma Cloudiness**

A comma is a very prominent feature developing and existing in cold air. The comma cloudiness consists of a small cloud spiral consisting of white (i.e. cold) cloud cells partly overlaid by cirrus shields. Sometimes a comma head, which is the enhanced part, and a comma tail, which consists of much smoother and warmer cloud tops, can be discriminated. The scale is between 200 and 1000 km which is much smaller than for a frontal cloud spiral.

For more details see ZAMG (2005).

## **Key parameters used in the ASII product**

### **Sub-frontal area:**

The algorithm for determining frontal areas has been adapted to identify cloud structures of comma size, using the size of the comprised cloud area as main criterion.

### **WV-AMV vorticity:**

Since comma clouds usually form in the trough region behind a frontal system, the comma detection module searches for an area of the (smoothed) WV AMV vorticity field which exceeds 2 units.

### **Cloud curvature:**

Starting from the analysis of the cloud texture which represents the main direction of the cloud elements, the curvature radius of the detected comma cloud features is computed. The curvature has to exceed a prescribed threshold in order to fulfil the comma criterion.



### **Memory:**

Comma clouds from the preceding image are displaced with help of the WV-AMVs to the relevant position in the present analysis.

### **Additional:**

If the probability regions (WV-AMV vorticity and radius of cloud curvature) cover only parts of the comma, the diagnosis is extended to the whole sub-frontal area.

## **Key parameters used in the ASIINWP product**

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 50/95
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The NWP branch of the comma detection module uses the same information from the satellite images as ASII:

**Automatic detection of comma size cloud structures**

**WV-AMV vorticity**

**Cloud curvature**

**Memory**

The following NWP criteria are added to the analysis, of which at least one must be fulfilled:

**Positive vorticity advection at 500 hPa (PVA500):**

A maximum of the PVA500 field is required for the comma analysis. The threshold for the PVA maximum at 500 hPa is  $4 \cdot 10^{-9} [s^{-2}]$  which is an empirically chosen value. A probability area with a radius of 2 grid meshes around the relative maximum is evaluated.

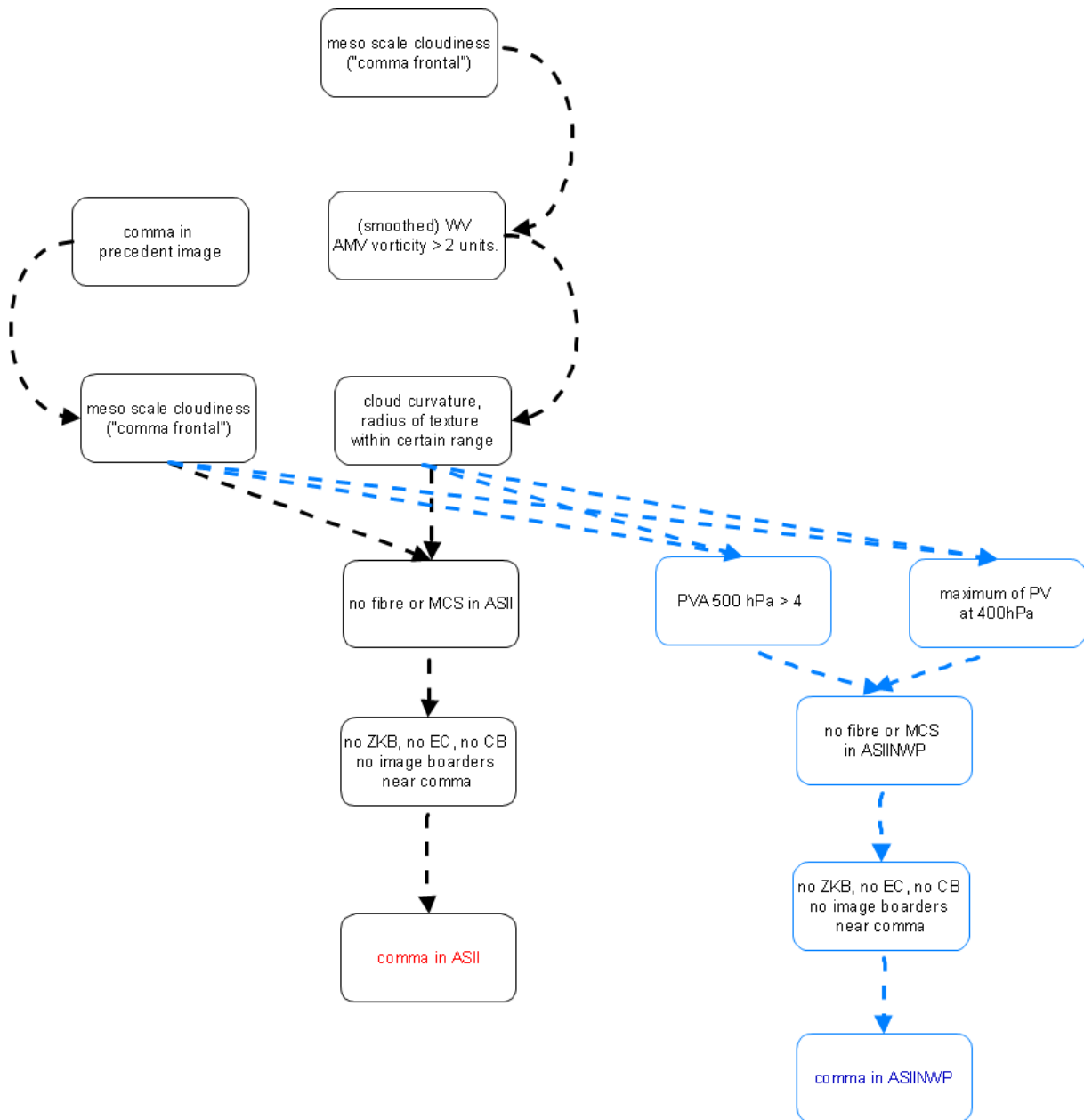
**Potential vorticity (PV):**

A main feature from the numerical fields is the presence of a PV maximum in upper layers of the troposphere. Relative maxima on the 400 hPa level with a value  $>1.25$  PVU are sought.

**Additional**

The two NWP criteria are supplemental; only one of the two criteria must be fulfilled.

**Schematics of the diagnosis process**





**Figure 12:** Conditions for the detection of a comma in ASII (black) and in ASIINWP (blue)

For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

## Practical application rules and inherent problems

### General application rules:

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 52/95
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- If a comma is analysed in ASII, forecasters can be sure that there exists a meso-scale/sub-frontal cloud spiral embedded in a cyclonic wind field;
- If a comma is analysed in ASIINWP, forecasters can be sure that there exists a meso-scale/sub-frontal cloud spiral which is influenced by an upper level vorticity feature.
- Commas might have Cbs and MCSs embedded.

### **Comparison ASII vs. ASIINWP:**

- If a comma is diagnosed in ASII but not in ASIINWP, the model fields do not confirm the satellite analysis (e.g. the upper level triggering is not existing or too weak)

### **Inherent problems:**

- The most important problem arises when the comma cloud is close to a cold front or occlusion cloud band. The contour line merges in this case the frontal system with the comma cloud and flags both as "frontal". This is caused by the fact that the contour line is derived from a smoothed image. The advantage of this method to determine continuous frontal cloud bands turns into a disadvantage when different cloud systems are close together.

### **2.3.1.10 Enhanced Cumulus (EC)**

Enhanced Cumulus cloudiness is an area with cloud cells of increased convective activity, embedded within the cold air cloudiness at the rear of cold fronts. It is active in respect to shower and thunderstorm activity.

For more details see ZAMG (2005).



## **Key parameters used in the ASII product**

The EC detection module uses a convective cell detection module (cf. 2.2.6) based on IR satellite pattern. The same detection algorithms are used for the detection of CBs. The output is refined by a difference image (MSG channel 5 – 9) to sort out inactive, convective cell like cloud pattern from active ECs.

### **Frontal area:**

This is an indirect usage: Small scale cloud systems (like ECs) are not allowed within a frontal area.

### **WV-AMV vorticity:**

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 53/95
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ECs usually develop in the upper level trough area behind cold fronts, in a region characterised by cyclonic vorticity. Therefore the vorticity computed from WV AMVs must be  $> 2$ .

### **CC-Algorithm (Convective Cell detection – Algorithm):**

The convective cell detection algorithm has been adapted to the typical EC pattern. Two kinds of ECs are analysed to take seasonal variations into account (for details see chapter 3.1.12 in AD. 6). For the summer season, ECs show a lower mean brightness and a smaller extension while in the winter season also more extended ECs with a higher mean brightness do exist. This algorithm has been extended by the pattern matching algorithm for CBs.

### **Memory**

The outcome of the CC-Algorithm from the preceding satellite image is displaced with help of the AMVs and assigned to the present analysis if the other two criteria (WV AMV-vorticity and frontal area) are fulfilled.

### **Additional:**

CB and EC are very similar phenomena seen from the involved physical processes. Nevertheless we differentiate these 2 conceptual models. A main criterion for separation is their respective location to frontal systems. EC can be found at the rear side of cold fronts, i.e. in an upper level trough. CBs are located in the unstable air of a thickness ridge, e.g. in front of a frontal system or in areas with weak pressure gradients.

## **Key parameters used in the ASIINWP product**

All satellite input parameters from ASII are used in the ASIINWP product.

### **Frontal area (indirect)**

#### **CC-Algorithm**

#### **WV-AMV vorticity**

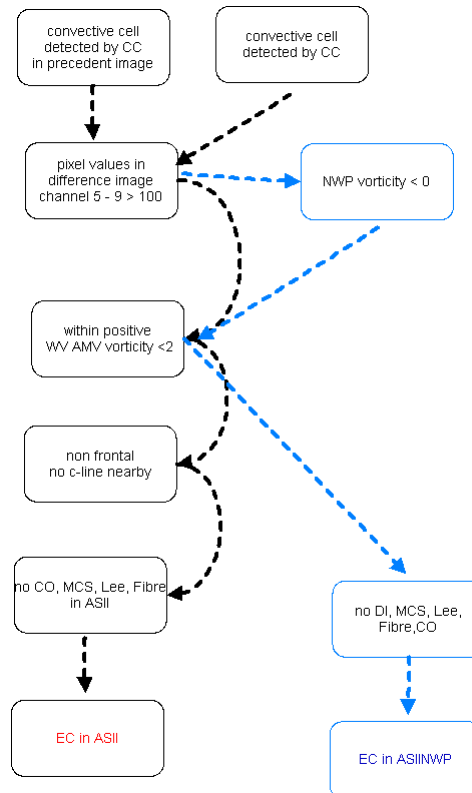
#### **Memory**

The following NWP input is required:

### **Vorticity at 500 hPa:**

EC must be situated in an area with vorticity at 500 hPa above 2 units.

## **Schematics of the diagnosis process**



**Figure 13:** Conditions for the detection of EC in ASII (black) and in ASIINWP (blue)

For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.



## Practical application rules and inherent problems

### General application rules:

- If “EC” is diagnosed in ASII or ASIINWP forecasters can be sure that there is a cluster of bright (cold) small convective cells in a large scale area with cyclonically curved WV AMV streamlines.
- There are five different CMs in ASII/ASIINWP dealing with convective cloud features: Cbs and Cb cluster, MCS (Mesoscale Convective Systems), EC (Enhanced Cumuli), commas and cold air cloudiness.
- If “EC” are diagnosed, forecasters can be sure that:
  - smaller convective cells than those diagnosed for MCS are forming a cluster;
  - it does not form a mesoscale curved cloud feature (as a comma).

### Comparison ASII vs. ASIINWP:

- If “EC” is only diagnosed in ASII but not in ASIINWP the PVA condition used in ASIINWP is not fulfilled

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### **2.3.1.11 Cumulonimbus Cluster (Cb)**

Cumulonimbus clusters are an aggregation of single Cbs. While the latter are small scale phenomena, the Cb clusters are mesoscale cloud phenomena with an average diameter of approximately 200 km. Cumulonimbus clusters (Cbs) are not restricted to frontal zones, but can develop in the unstable air of the warm sector or in the cold air behind a cold front. Cb clusters in warm air do not develop at the boundary of two air masses like cold- or warm fronts, but ahead of the cold front in the area of a thermal ridge. Cb clusters often are also embedded in cellular cold air cloudiness with tops reaching only to the lower levels of the troposphere.

For more details see ZAMG (2005).

## **Key parameters used in ASII**

### **CC-Algorithm (Convective Cell detection – Algorithm):**

As for the detection of enhanced cumuli, the results from the automatic detection of convective cells (4 cell types) are used for the recognition of CBs.

### **Motion corrected difference image (see chapter 2.2.2):**



Three stages of the life cycle of convective cells are classified with help of the motion-corrected difference image: developing, mature and decaying:

- Developing Cb: the mean value of all pixels within the grid mesh has increased by more than 10 units in the last half an hour.
- Mature Cb: the mean value of all pixels within the grid mesh has increased by 0 to 10 units in the last half an hour.
- Decaying Cb: the mean value of all pixels within the grid mesh has decreased in the last half an hour.

The detection of Cbs is excluded in trough regions (e.g. behind cold fronts). There, convective cells are analysed as ECs.

Fibre-like cloud bands are often analysed as a chain of small Cbs. To reduce this kind of false detection, the fibre detection module is used.

Cb cluster located within a frontal system are flagged as embedded convective systems (cf. Table 4 and Table 5).

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## Key parameters used in ASIINWP

The NWP branch of the Cb detection module is based on the same satellite criteria as the ASII branch:

### CC-detection

#### Motion corrected difference images

The Showalter index is taken as further information from NWP data.

#### Showalter index:

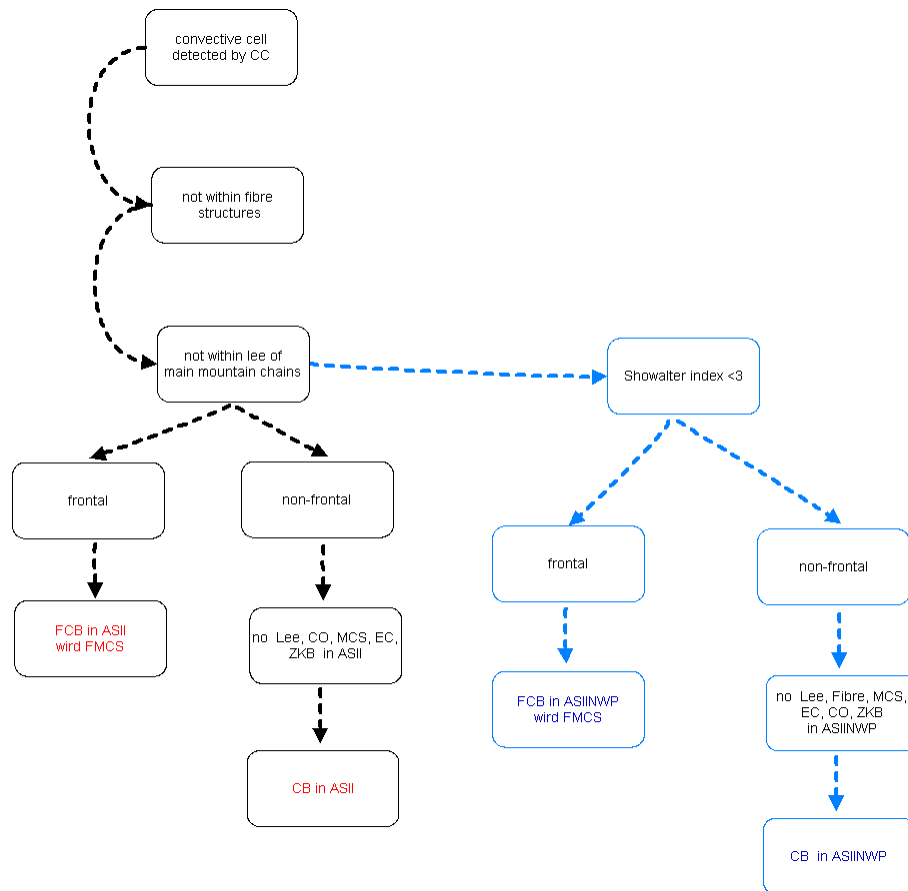
The threshold of the Showalter index is chosen with +3. Above that value, air masses are considered as stable and Cb development should not take place, below 3 the stratification is considered as unstable. Therefore areas with Cbs which are detected in ASII and not in ASIINWP give hints for a stable stratification of the troposphere.

#### Additional:

Cb cluster located within a frontal system are flagged as embedded convective cells (cf. Table 4 and Table 5).

## Schematics of the diagnosis process







**Figure 14:** Conditions for the detection of a Cb in ASII (black) and in ASIINWP (blue)

For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

## Practical application rules and inherent problems



### General application rules:

- If Cbs are diagnosed in ASII forecasters can be sure that there are bright convective cells with some stages of development assigned.
- If Cbs are diagnosed in ASIINWP forecasters can be sure that there are bright convective cells in an unstable environment with some stages of development assigned.
- There are five different CMs in ASII/ASIINWP dealing with convective cloud features: Cbs and Cb cluster, MCSs (Mesoscale Convective Systems), ec (Enhanced Cumuli), commas and cold air cloudiness.
- If Cbs are diagnosed forecasters can be sure that:
  - the size is smaller than it is necessary for an MCS
  - it does not form a mesoscale curved cloud feature (as a comma)

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### Inherent problems

- The deviation value is computed as mean value for a whole grid mesh. Consequently the deviation value for individual cells within one grid mesh is falsified.
- A major problem arises when Cbs develop in mountainous regions. The ASII Cb detection module cannot differentiate between lee cloudiness and large Cbs from classification alone. One possibility for discrimination is the usage of a stability parameter in ASIINWP. In a stable atmosphere, Cb classifications are eliminated and replaced by lee cloudiness classification.

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### **2.3.1.12 Mesoscale Convective Systems (MCS)**

Thunderstorms in satellite imagery exist in different scales:

- Single-cell storms: which mostly are too small to be detected in Meteosat images
- Multi-cell storms: which consist of several single cells in different stages of development
- Super-cell storms: which are huge single cell storms

Another term commonly used in satellite meteorology is the Mesoscale Convective System (MCS) which forms on a bigger scale. MCSs usually describe multi cell storms, but sometimes also are formed by super cell storms.

There exist many definitions for MCS in literature. One frequently used is: Deep convective system which is considerably larger than an individual thunderstorm; it is often marked by an extensive middle-to-upper tropospheric stratiform anvil cloud of several hundred kilometres in breadth.

For more details see ZAMG (2005).

## **Key parameters used in the ASII product**

The MCS module is based on two different methods to extract MCSs from the satellite image: The first method uses the image classification output, which is based on the analysis of image texture, while the second method uses the Convective Cell-algorithm (CC-algorithm) which is an extraction method on pixel basis.



### **A) Classification method**

With this method only extended MCSs are diagnosed. In the ideal case an MCS consists of classification 11 (smooth and bright pixels) in the centre and is encircled by classification 80 (high brightness gradient between pixels). A neighbourhood function is used to detect this juxtaposition

### **B) CC-algorithm**

The following criteria are used:

- Temperature threshold
- Relative temperature minimum
- Temperature difference between centre and surroundings.

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Both extraction methods have to be fulfilled and the motion corrected difference image is applied for the analysis of the life cycle (see chapter 2.2.2).

### **Difference image (MSG channel 5 – 9)**

The difference image (channel 5-9) is used to detect high reaching MCS. The temperature difference is useful for determining the cloud top height relative to the tropopause. Positive values of the temperature difference correspond with convective cloud tops that are at or above the tropopause.

### **Difference image (MSG channel 10 – 9)**

The difference image (channel 10 – 9) is used to detect cirrus clouds. From the satellite viewing angle, the active part of MCS cloud often cannot be determined. This IR temperature difference recognises shallow cirrus clouds (anvil cloud) and helps restricting the MCS analysis to the active part of the system.

### **AMV vorticity**

The vorticity derived from AMV has to be smaller than 2 units.

### **Memory**

The outcome of the CC-Algorithm from the preceding satellite image is displaced with help of the AMVs and assigned to the present analysis.

### **Additional**

If the analysed cloud feature with classification 11 and 80 nearby is too large (> 60 grid meshes), which sometimes happens in warm front shields, then it is not analysed as MCS anymore.

MCS located within a frontal system are flagged as embedded convective system (cf. Table 4 and Table 5).

## **Key parameters used in the ASIINWP product**

All detection methods from ASII except the AMV vorticity are used for ASIINWP:



### **Classification**

### **CC-algorithm**

### **Difference image (MSG channel 5 – 9)**

### **Difference image (MSG channel 10 – 9)**

### **Memory**

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In addition to this a stability index and vorticity is used from the NWP data.

**Stability index:**

The MCSs analysed from the satellite data are considered reliable when they are located within unstable air masses (i.e. Showalter index below 3). The MCS analysis is rejected, if the Showalter index is above 3 units. Therefore differences in ASII and ASIINWP can be explained by a stability parameter revealing an unstable or stable troposphere.

**Vorticity:**

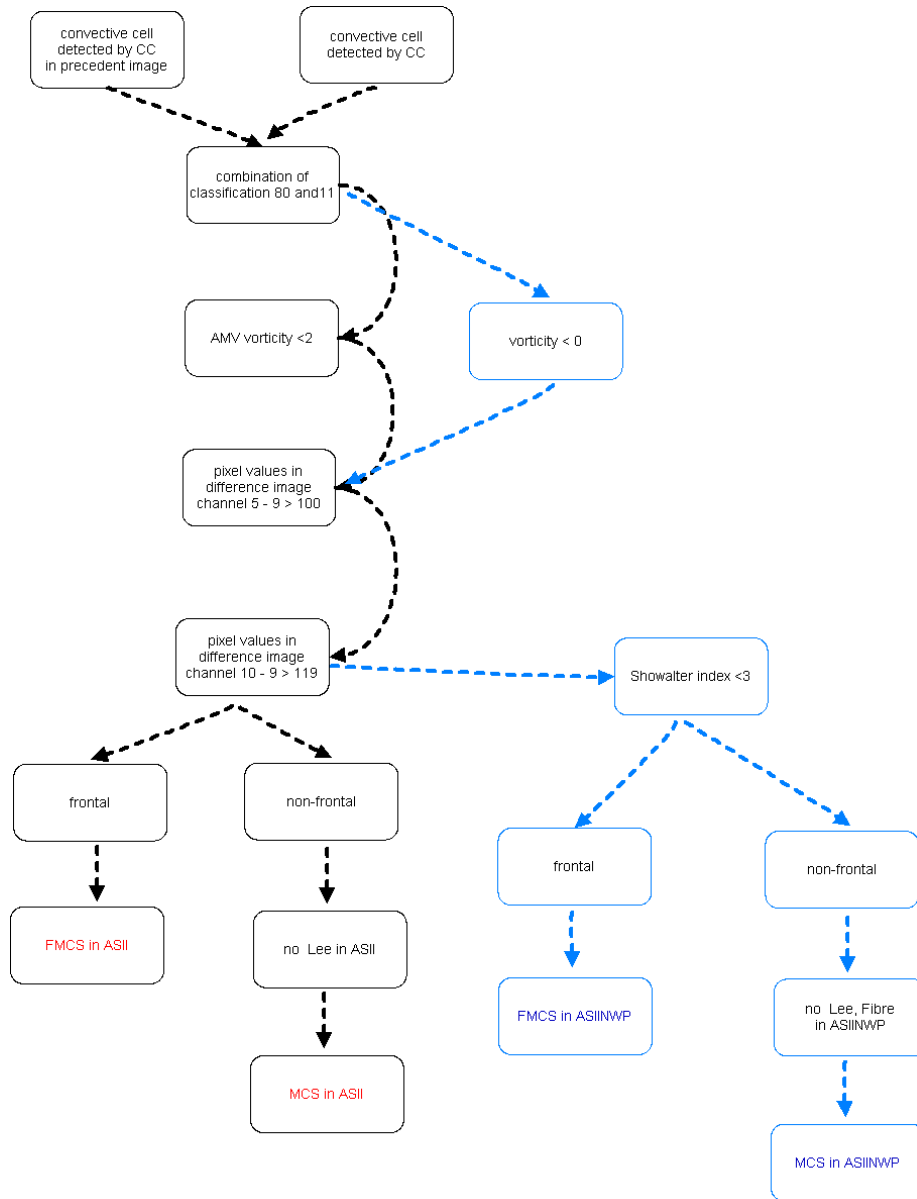
The MCSs must be situated within negative vorticity.

**Additional:**

An MCS is also considered to lie in unstable air if only a small part of the cloud cell lies in a region with a Showalter index < 3. The idea behind is to correct for possible uncertainties in the numerical model fields.

MCS located within a frontal system are flagged as embedded convective system (cf. Table 4 and Table 5).

**Schematics of the diagnosis process**





**Figure 15:** Conditions for the detection of an MCS in ASII (black) and in ASIINWP (blue)

For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

## Practical application rules and inherent problems

### General application rules:

- If MCSs are diagnosed in ASII forecasters can be sure that there are extended bright convective cells with some stages of development assigned.

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- If MCSs are diagnosed in ASIINWP forecasters can be sure that there are extended bright (cold) convective cells in an unstable environment with some stages of development assigned.
- There are five different CMs in ASII/ASIINWP dealing with convective cloud features: Cbs and Cb cluster, MCSs (Mesoscale Convective Systems), ec (Enhanced Cumuli), comma clouds and cold air cloudiness.
- If MCSs are diagnosed forecasters can be sure that:
  - the size is bigger than it is necessary for a Cb;
  - the brightness is higher than for the single cells forming an “ec”;
  - it does not form a mesoscale curved cloud feature (as a comma);

### **Comparison ASII vs. ASIINWP:**

- If MCSs are diagnosed in ASII but not in ASIINWP this means that the configuration of an extended convective cell is fulfilled but it appears in a stable area and consequently the MCS diagnosis is cancelled.
- Differences can also occur due to different vorticity fields: AMV vorticity used in ASII can be different from NWP vorticity used in ASIINWP.

### **Inherent problems**

- A major problem arises when MCSs develop in mountainous regions. The ASII MCS detection module cannot differentiate between lee cloudiness and MCSs from classification alone. One possibility for discrimination is the usage of a stability parameter.
- When MCSs are analysed from image features alone (ASII branch), they are quite often analysed as embedded MCSs in frontal cloud bands (even within warm fronts). In this case a comparison between ASII and ASIINWP gives hints about stability.

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### **2.3.1.13 Cold air cloudiness**

Cold air cloudiness (open cell convection) develops at the rear side of cold fronts, during a cold air outbreak at locations where air-sea temperature difference is greatest. The convection is often only 2-3 km deep, the deepest convection occurs ahead of upper troughs. The diameter of the open cells usually increases downstream with a typical aspect ratio of up to 30:1 (diameter:height).

## **Key parameters used in the ASII product**

### **Classification**

The detection of cold air cloudiness (open cells) is primarily based on the cloud classification. The cellular cloud pattern is represented in classifications with high pixel brightness variations.

### **WV-AMV vorticity**

For the identification of the location of the open cloud cells at the position of an upper level trough, the same criterion as for the location of ECs is used, i.e. the vorticity computed from WV AMVs must be positive ( $> 2$ ).

### **Memory**

The position of the previously detected cold air cloudiness is memorised and tracked with help of the AMV.

### **Additional:**

Cold air cloudiness is never embedded in frontal areas (“frontal” as defined in ASII).

The cold air cloudiness analysis is suppressed at grid-meshes located directly in the vicinity of frontal areas.

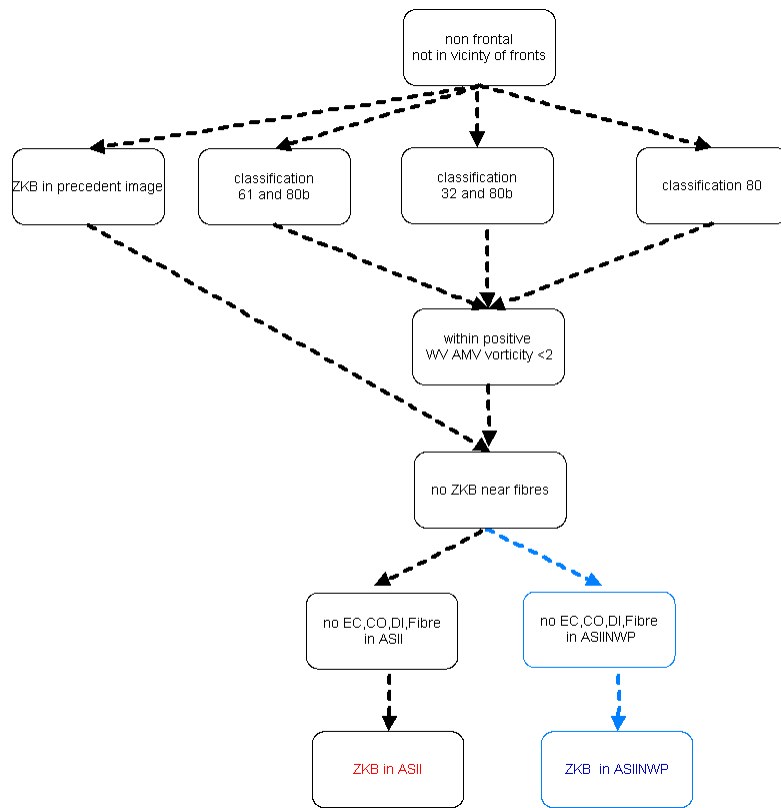
The cold air cloudiness analysis is also suppressed if it is situated near fibres.

## **Key parameters used in the ASIINWP product**

At the time being, no input parameters are required from the model fields. The open convective cells detection is purely based on parameters derived from the IR and WV satellite images.

## **Schematics of input parameters**





**Figure 16:** Conditions for the detection of a cellular cold air cloudiness in ASII (black) and in ASIINWP (blue)

For ranking rules used to decide between two conceptual models appearing feasible at the same location consult Appendix 1.



## Practical application rules and inherent problems

### General application rules:

- When “Cold Air Cloudiness” is analysed in ASII or ASIINWP, the forecaster can be sure, that the system detects cloud cells located in a trough region.

### Inherent problems

- Since the open convective cells are detected with help of the image classification, it may happen that fewer regions with cold air cloudiness are analysed than the human observer can detect. To avoid an over-analysis of open cells, only those image classifications are used which show in any case widespread convective cells.

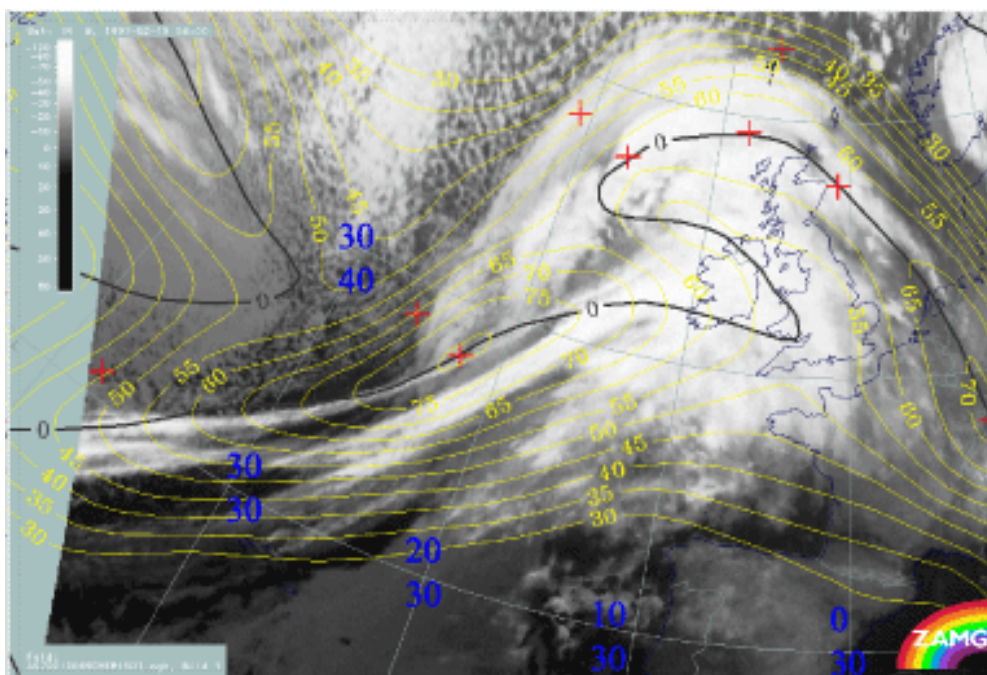
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- In winter time, open convective cells are often extended over wide areas and exhibiting a very compact structure. These areas are often misinterpreted as frontal areas.

### 2.3.1.14 Fibres

Cloud fibres are narrow cloud lines with a width in the order of magnitude of several tens of kilometres which can extend in length to several thousands of kilometres. They are very bright (cold) in the IR and WV image but only grey, translucent in the VIS image. This is because they develop and exist in high levels close to or directly at the jet axis but on the anticyclonic side. Their synoptic importance is not only the indication of a jet axis but also the indication for an interaction of fronts with the jet streak.



For more details see ZAMG (2005).



**Figure 17:** IR-satellite image from 19 February 1997, 06 UTC; the fibre extends from about 40N/35W across the Atlantic to about 50N/20W; it accompanies the jet axis (black line is zero line of shear vorticity at 300 hPa)

## Key parameters used in the ASII product

With the automatic fibre detection algorithm all fibre-like cloud structures are detected independent from their physical environment. In ASII the aim is to identify only those cloud

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fibres which give a hint for the presence of a jet streak at higher levels. Therefore, the WV imagery is also used, especially the automatic recognition of black stripes, to find out the possible location of the jet axis. The following criteria are used:

### **Automatic fibre detection**

ASII uses a pattern recognition method to detect fibre-like cloud structures.

Four types of fibres are detected. Two of them are short fibres, one is a medium fibre and the last one is a long fibre. Fibres are arranged according to length and thickness.

- short and thick
- short and thin
- medium and thin
- long and thin

### **Detection of black stripes in the WV image**

For details of the WV stripe algorithms see chapter 3.1.13 in [AD. 6]. As mentioned above, only the combination of fibre structures and black stripes is diagnosed.

### **Memory**

The outcome of the automatic fibre detection from the preceding satellite image is displaced with help of the AMVs and assigned to the present analysis.

### **Additional**

Due to a high similarity of the typical fibre classification to the Cbs the latter are eliminated when they are located within the grid mesh or within one grid mesh distance to the fibre.

## **Key parameters used in the ASIINWP product**

The satellite part is identical with the ASII analysis:

### **Automatic fibre detection**

### **Detection of black stripes in the WV image**

### **Memory**

In addition the following NWP criteria have been implemented:

### **Wind speed at 300 hPa (FF300):**

The cloud fibre has to be located within the 20 m/s isoline of the 300 hPa wind field.

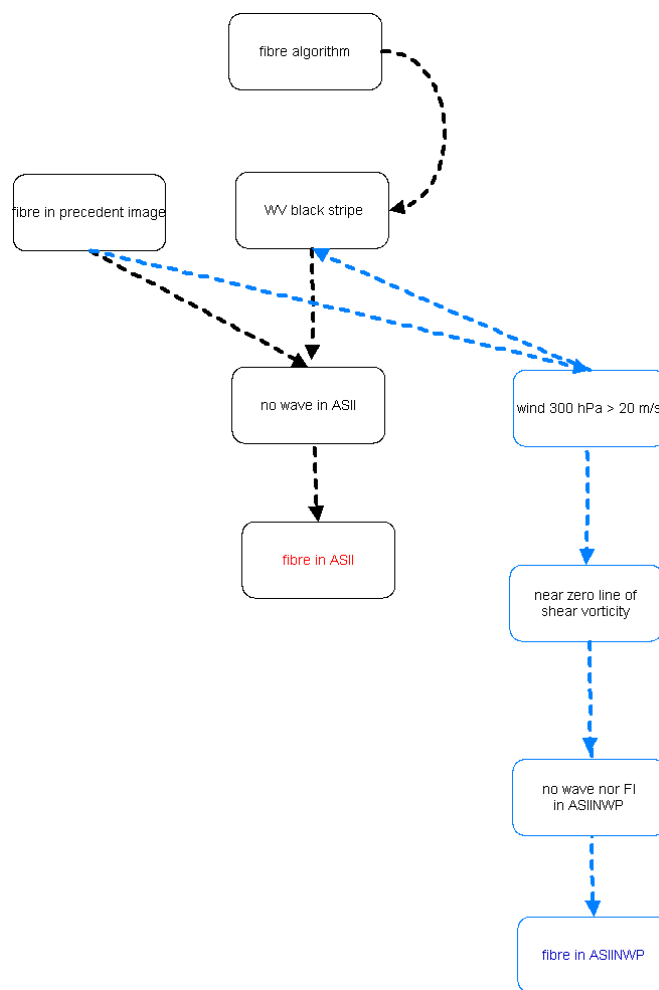
**Zero line of the shear vorticity at 300 hPa (RSV300):**

The detected cloud fibre also has to be located in a probability region along the zero line of the shear vorticity at 300 hPa which marks the axis of a jet streak. The probability region extends 4 grid meshes in each direction of the zeroline.

**Additional**



Same restrictions as mentioned for ASII.

**Schematics of the diagnosis process**



**Figure 18:** Conditions for the detection of a fibre in ASII (black) and in ASIINWP (blue)

For ranking rules used to decide between two conceptual models appearing feasible at the same location consult Appendix 1.

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## Practical application rules and inherent problems

### General application rules:



- If a fibre is detected in ASII forecasters can be sure that a fibre feature is next to a black stripe in the WV image; a situation which is very indicative for a jet axis.
- If a fibre is detected in ASIINWP forecasters can be sure that a fibre feature is next to a black stripe in the WV image and accompanied by a jet streak (wind speed and jet axis) at 300 hPa.

### Comparison ASII vs. ASIINWP:

- If a fibre is detected in ASII but not in ASIINWP, the model fields do not confirm the satellite analysis (e.g. no jet streak is superimposed).

### Inherent problems

- There are rather sensitive thresholds, for instance concerning width in the automatic fibre detection algorithm. Consequently, some typical fibre configurations have to be fixed. This can lead to the fact that some fibres which fail the threshold even only marginally are not detected.
- If smaller Cbs are configured in form of lines with small distances between the single cells they might be wrongly diagnosed as fibre.

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### **2.3.1.15 Lee cloudiness**

Lee cloudiness is the result of an orographically influenced air flow on the lee side of the mountain crest. Depending on the atmospheric conditions two kinds of cloudiness can be observed:

- Lee waves, which are characterised by narrow cloud bands quite perpendicular to the wind direction. The wave length can range from few kilometres to some 10s of kilometres. They can be observed most easily in high resolution images (like from polar orbiting satellites). Their crests are always white in the visible picture but in the IR image they can vary from white to dark grey.
- High lee cloudiness which consists of Cirrus cloudiness reaching from the mountain chain into the leeward side, in some cases up to the extent of 1000 kilometres and more. They are lee waves with a much longer wave length. They are very bright (cold) in the IR images. Sometimes they can be detached from the mountain by strong winds and then seem to start far away from the obstacle.

For more details see ZAMG (2005).



The lee cloudiness detection in ASII and ASIINWP deals only with the type of high lee cloudiness.

## **Key parameters used in the ASII product**

### **Mountain mask:**

At present the following mountain ranges are taken into account:

- Alps
- Apennine
- Carpathian mountains
- Central and South Italy
- Corsica
- England
- Greenland
- Iceland
- Pyrenees
- Peloponnes
- Sardinia
- Scotland

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The mentioned mountain masks are introduced into the algorithm as one straight barrier; they are not differentiated into sub-parts with different orientation or valleys.

### **Wind field (WV-AMVs):**

Lee cloudiness is a phenomenon which can best be seen in the IR image loop. Cloudiness remains stationary for many hours at the upwind edge close to the mountain chain. The strong winds, necessary for the development of lee waves, are reflected in the WV motion vectors. An empirical threshold of 10m/s is chosen, to differentiate lee cloudiness from orographically induced convection.

### **Pixel brightness difference:**

Typical lee cloudiness forms at the lee side of an orographic barrier, consequently high pixel values are located at one side of the mountain range and lower pixel values (land surface or lower cloud) on the other side. It has shown useful to set a minimum threshold for the brightness (temperature) of the lee cloudiness at  $-44^{\circ}\text{C}$ . If this condition is fulfilled, the detection module checks the other side of the mountain range (windward side). There, cloudiness should have pixel values below  $-44^{\circ}\text{C}$ . The rather cold threshold of  $-44^{\circ}\text{C}$  is motivated by barrage cloudiness which often appears in combination with Lee cloudiness.

### **Memory**

The lee cloud analysis from the preceding satellite image is displaced with help of the AMVs and assigned to the present analysis.

### **Additional:**

If MCSs with a classification 11 and 80 are detected, lee cloudiness tags (if analysed) are suppressed. Classification 11 and 80 represents an extended area of very bright mean pixel values and are therefore very close to the pixel threshold of 175 chosen for the lee cloudiness.

## **Key parameters used in the ASIINWP product**

The satellite part of the lee cloud detection module in the NWP branch is the same as in ASII.

### **Mountain mask**

### **Wind field (WV AMVs)**

### **Pixel brightness difference**

### **Memory**

Additionally the following NWP parameter is used:

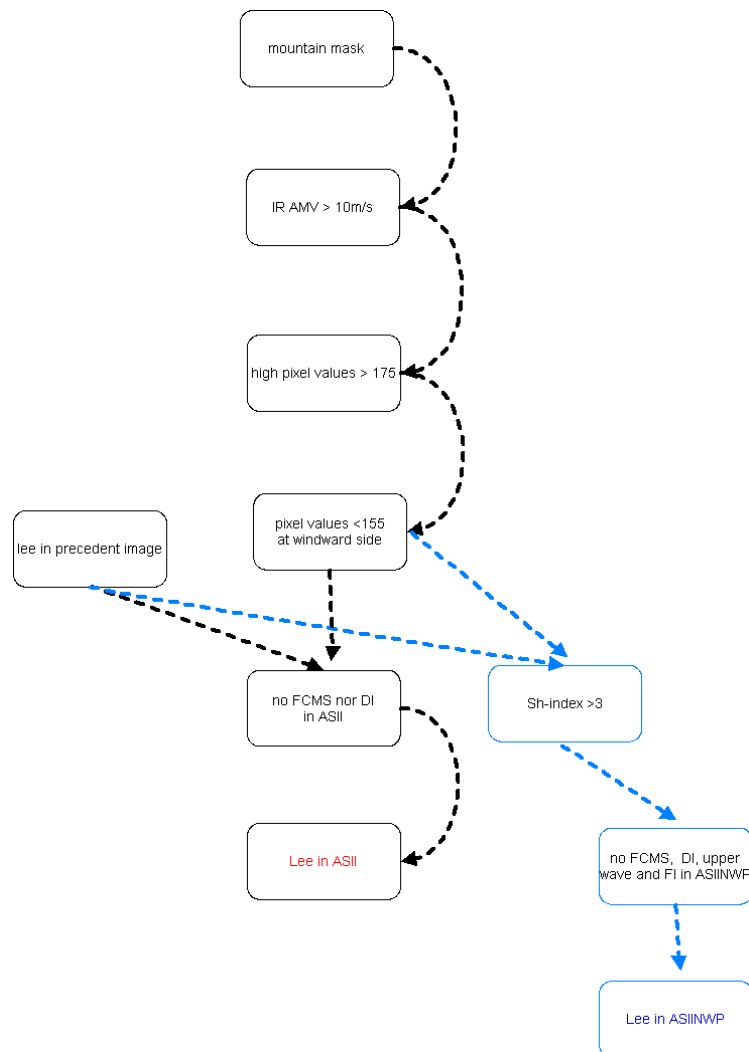
### **Stability:**

As discussed below, lee cloudiness is often confused with MCS or Cbs in the mere satellite analysis. One attempt to eliminate MCS or Cb analysis in favour of lee cloudiness is to introduce a stability index (Showalter index, SAI (NWCSAF PGE08)). Stable stratification with a Showalter index above 3 is required for lee cloudiness.

**Additional:**



If MCSs (combination of classification 11 and 80) are detected, lee cloudiness tags (if analysed) are suppressed. A subsequent check according to instability is discussed above.

**Schematics of the diagnosis process**



**Figure 19:** Conditions for the detection of lee clouds in ASII (black) and in ASINWP (blue)



 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 73/95
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For ranking rules used to decide between two conceptual models, when both appear feasible at the same location, consult Appendix 1.

## Practical application rules and inherent problems

### General application rules:

- If lee cloud is diagnosed in ASII forecasters can be sure that there is some orographically induced cloudiness at the mountain range, showing higher and colder tops at the lee side of the mountains with WV motion vectors > 10m/s.
- If lee cloudiness is confirmed by ASIINWP, forecasters can also be sure, that the model fields exhibit a stable stratification.

### Comparison ASII vs. ASIINWP:

If there is lee cloud analysed in ASII but not in ASIINWP this means that there is an unstable troposphere and the existing cloud might be Cbs or MCSs.



### Inherent problems:

- Cbs, MCSs and lee cloudiness are three types of cloudiness which often show similar patterns in the IR image. Especially convective cells formed in mountainous areas are hard to discern from lee cloudiness. More often, lee cloudiness is analysed as MCS or Cb cluster due to its classification (80 or/and 11) and the high contrast between overcast and cloud free areas.
- Detached lee cloudiness which is already far from its originating mountain (and hence the mountain mask) cannot be detected.
- Problems also arise when lee cloudiness is embedded in a frontal cloud band, because the pixel difference between windward and lee side often is not fulfilled.

### 2.3.2 Summary of rules for identification of conceptual models



CM	Firm meteorological content	
	ASII	ASIINWP
<b>WF</b>	frontal area without frontal rear side frontal area in broad shield form	frontal area without frontal rear side frontal area in broad shield form
<b>CF (classical)</b>	frontal area	frontal area frontal area under CA (or WA < 0 K/12h))
<b>CF in WA</b>	-----	frontal area with frontal rear side frontal area under WA > 0
<b>low CF</b>	-----	low cloud system (classification) thermal front parameter zeroline of vorticity at 500 hPa
<b>occlusion</b>	frontal area with spiral form IR-AMVs have E-component	frontal area with spiral form low in deep layer of troposphere
<b>wave</b>	s-line OR convex bulge at rear side of frontal area	s-line OR convex bulge at rear side of frontal area WA-CA, PVA max at 500 OR low-level low
<b>upper wave</b>	convex bulge at rear side of frontal area	convex bulge at rear side of frontal area CA and within jet streak
<b>FI by Jet</b>	-----	convective/multilevel part of frontal area PVA max in left exit region of a jet streak
<b>Dry intrusion</b>	frontal area black stripe in WV intersects frontal area	frontal area black stripe in WV intersects frontal area  PV low down in troposphere depression at low levels (850 hPa)
<b>ULL</b>	-----	Upper level depression no depression at low levels
<b>comma</b>	sub-frontal cloud spiral WV-AMV vorticity > 2 units	sub-frontal cloud spiral upper level triggering (PV OR PVA at 500 hPa) WV-AMV vorticity > 2 units
<b>EC</b>	cluster of bright small cells cyclonic area (WV AMVs)	cluster of bright small cells cyclonic area (WV AMVs)  relative vorticity in 500 hPa >= 2
<b>Cb</b>	bright convective cells three stages of development	bright convective cells three stages of development unstable troposphere
<b>MCS</b>	extended bright convective cells  WV-AMV vorticity < 2 units	extended bright convective cells  unstable troposphere relative vorticity in 500 hPa < 2 units
<b>fibre</b>	fibre feature next to a black stripe in WV	fibre feature next to a black stripe in WV jet streak: (wind speed + zeroline of shear vorticity at 300 hPa)
<b>Lee cloudiness</b>	bright cloud in the lee of mountains IR AMVs stationary at mountain ridge	bright cloud in the lee of mountains IR AMVs stationary at mountain ridge stable troposphere
<b>Cold air cloudiness</b>	Cellular cloudiness located in a trough region	Cellular cloudiness located in a trough region

*Table 6: "Firm meteorological content" for each conceptual model, depending on the output branch (ASII or ASIINWP). In some cases it is sufficient if at least one criterion is fulfilled. Then 'OR' indicates the possible choice.*



		Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 75/95
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### 2.3.3 Synoptic explanations for corresponding and controversial classifications of conceptual models in Automatic satellite image interpretation with NWP (ASIINWP) and without NWP inclusion (ASII)

ASII	ASIINWP	EXPLANATION
(nothing)	CF (classical)	Only low CF cloud band
CF (classical)	CF (classical)	Classical CF cloud band or CF cloud band in CA
CF (classical)	CF in WA	CF cloud band under WA
CF (classical)	occlusion	Some occl. parameters for satellite features not fulfilled but model parameters indicate occl. Often observed at innermost part of cloud spiral where AMVs have western component
CF (classical)	FI by Jet	Cold front with cloud intensification by a crossing jet streak (FI by Jet)
WF	WF	Classical WF band or WF shield
WF	CF (classical)	Stationary CF WF in ASII indicates cloud parallel AMVs
WF	CF in WA	Occurs very seldom: in case of small areas (sometimes only small stripes) within a WF shield where a rear side is detected; usually the WF diagnosis is the correct one
WF	upper wave	Occurs very seldom and only in cases of WF shields: CA in model fields support a CF instead of the recognised WF and consequent allows an upper wave to be detected;
WF	occlusion	Some satellite features for an occlusion are not fulfilled but model parameters support an occlusion
WF	Lee cloudiness (within WF)	Occurs very seldom: One parameter (information on cloud development) for Lee detection in ASII not fulfilled
WF	FI by Jet (within WF)	Occurs very seldom: Model fields indicated left exit region and PVA max. in the WF area
occlusion	occlusion	Classical occlusion cloud band
occlusion	Lee cloudiness (within occlusion)	Occurs very seldom: One parameter (information on cloud development) for Lee detection in ASII not fulfilled
occlusion	FI by Jet	Occlusion cloud band with an area of cloud intensification by jet crossing (FibyJet) superimposed
wave	CF (classical)	NWP fields do not support the wave analysis from satellite imagery



		Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 76/95
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wave	occlusion	Only in cases where CF in ASII and O in ASIINWP: cloud bulges at the rear side of occlusion bands are not allowed to be identified as waves
wave	wave	Classical wave with potential for further development
wave	upper wave	Cloud bulge in satellite images exists but model fields diagnose only Upper wave; no potential for further development
wave	Cb, MCS (embedded)	Cloud bulge detected in the satellite image is not diagnosed by model data as wave but is the result of Cbs and MCSs
wave	Fibre	Cloud bulge detected in the satellite image is not diagnosed by model data as wave but fibre indicates a distinct jet axis in this area
wave	FI by Jet	Cloud bulge at the rear side of a frontal cloud band is the result of an intensification by a crossing jet (FibyJet)
Dry intrusion	CF (classical), CF in WA, occlusion, WF, upper wave, wave, fibre, MCS, Cb, FI by Jet, lee cloudiness	Satellite images show dry air overrunning a frontal cloud band but model parameters do not support a jet axis there
Dry intrusion	Dry intrusion	Black stripe crosses frontal cloud band at the rear side and model parameters support a jet axis there
Lee cloudiness	Lee cloudiness	Classical lee cloud
Lee cloudiness	Cb, MCS	Lee cloud analysis from the satellite imagery but unstable stratification (Showalter index)
Lee cloudiness (embedded)	CF (classical), CF in WA, occlusion, WF	Lee cloud detected in satellite images within frontal areas is not supported by model parameters
Lee cloudiness	FI by Jet	Cloud features detect Lee but model parameters support intensification by a crossing jet; lee detection might be neglected
Lee cloudiness	(nothing)	Occurs very seldom: Lee cloud detected from satellite features occur in unstable troposphere but cloud tops are too warm for convective cells
fibre	fibre	Indication for a fibre at a jet axis
fibre	(nothing)	fibre can be seen in satellite image but model does not indicate a jet axis
fibre	CF (classical), occlusion, WF, MCS, Cb, EC, comma, upper wave, wave, lee cloudiness	Fibre can be seen in satellite image but model does not indicate a jet axis
fibre	FI by Jet	Occurs very seldom: Fibre indicates the jet axis which leads to an intensification within the frontal band
Cb	Cb	Typical Cb in image and model parameters
Cb	(nothing)	Cb-like feature but stable troposphere
Cb	CF (classical), CF in WA, occlusion, WF	Model parameters indicate a stable troposphere within the frontal cloud systems

		Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 77/95
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Cb	FI by Jet	FI by jet area contains embedded Cbs
MCS	MCS	Typical MCS in image and model data
MCS	Lee cloudiness, (nothing), comma	MCSs detected within mesoscale features are under stable conditions;
MCS (embedded)	CF (classical), CF in WA, occlusion, WF	Cloud features for MCS do exit, but Showalter index indicates a stable troposphere
EC	EC	Typical EC cloud in images and model fields
EC	(nothing)	EC cloud detected in satellite image but no PVA max at 500 hPa
EC	Lee cloudiness	Occurs very seldom: Convective appearance of cloud but stable troposphere
comma	comma	Typical comma cloud in satellite image and model fields
comma	Lee cloudiness	Occurs very seldom: Comma not supported model fields; lee remains if detected before
comma	Upper-level low	Comma feature appears within an ULL area
comma	(nothing)	Typical comma in satellite features but model parameters do not confirm comma (PV, PVA)
Cold air cloudiness	Cold air cloudiness	Cold air cloudiness
Cold air cloudiness	Upper-level low	Upper level low cannot be detected in ASII

**Table 7:** *Explanation for controversial classifications in ASII and ASIINWP*

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 78/95
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### 3. IMPLEMENTATION OF AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII)

The implementation of the PGE10 software follows the general implementation of components of the SAFNWC/MSG software (see the software part of the Software Users Manual of the SAFNWC/MSG software for more details).

Basically, the following steps are needed to run the PGE10 software:



1. Create or update configuration files (system, region and run configuration files) according to their format (see the Interface Control Document ICD/1 for the External and Internal Interfaces of the SAFNWC/MSG). Files are situated in \$SAFNWC/config. The region configuration file has to be present in that directory, too. Several components of the PGE benefit from a larger vicinity; therefore, a fixed and comparative large analysis region was prescribed until v2009 of SAFNWC/MSG. For continuity reasons and in order to provide an example region configuration file that proved adequate, the formerly imposed file “region\_conf\_fileZA” is provided with later software packages, but users are free to use any other region definition.
2. Algorithm configuration files are situated in directory “\$SAFNWC/import/Aux\_data/PGE10”. These PGE10 input files are provided with the software package, installed together with it, and are not foreseen for modification by users.
3. For producing the subproduct including NWP data, the original NWP data has to be available in the directory \$SAFNWC/import/NWP\_data/ for runs at 00, 06, 12, and 18 UTC. For other slots, the NWP data are extrapolated by means of the AMV from the WV channel. This requires dumps of the processed NWP data in the DATABUF directory “\$SAFNWC/tmp”. The precursor run of PGE10 automatically creates the required data.
4. Ensure that the SEVIRI image file in HRIT format (mandatory input) is available in the directory \$SAFNWC/import/SEVIRI\_data/ (current and previous slot required).
5. Make sure that the environment variable \$SAFNWC is set. The environment variable \$BUFR\_TABLES needs also be set (as \$SAFNWC/src/bufr\_000360/bufrtables/).
6. Make sure that the following supplementary files are available:
  - a) \$SAFNWC/src/bufr\_000360/bufrtables/B0000000000098002001.TXT,
  - b) \$SAFNWC/src/bufr\_000360/bufrtables/D0000000000098002001.TXT,

These files are not included in the PGE10 distribution because they are packed into other libraries also delivered with SAFNWC/MSG. The listed files should be available after unpacking the full SAFNWC/MSG SW package, as described in the relevant documentation.

Then, the processing of PGE10 is automatically monitored by the task manager (see the Software Users Manual for the Task Manager of the SAFNWC/MSG software).

#### Submitting PGE10 in stand-alone mode, not using the task manager:

Ensure that all required input data is available in their respective directories, and that pre-requirements listed under items 1-6 are fulfilled. Note that the processed NWP data in

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 79/95
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“\$SAFNWC/tmp” (item 3. in above list) is only available if through runs for precursor slots, the opportunity has been given to extrapolate the NWP data in time from the model input runs at 00, 06, 12, or 18 UTC.

PGE10 can be called as follows (from the directory where it is situated):

```
./PGE10 yyyyymmddhhmm <region configuration file> <model configuration file>
```

example:

```
./PGE10 200503281145 myregion.cfg safnwc_pge10.cfm
```

### 3.1 HOW TO IMPLEMENT THE TEMPORAL INTERPOLATION OF NWP VIA CEOF

For slots without corresponding NWP forecast, two alternative ways of obtaining the required NWP data exist:

- 1) The “classical” method - used in PGE10 since 1996 - works via extrapolation by means of the AMV from the WV channel.
- 2) An interpolation technique based on Complex Empirical Orthogonal Function analysis (e.g. Wirth et al., 2008) can optionally be exploited. Thereby, one can ensure a continuous analysis from the Satellite+NWP branch (the approach pursued so far led to outages until the next forecast date in case of gaps in WV image provision).

Method 2) is available for the first time in v2011 and deemed superior to the NWP handling used earlier. However, as the newly implemented algorithm makes use of third-party algebraic modules, for which (legal) reservations on the direct distribution together with the SAFNWC/MSG package exist, the default method installed during SAFNWC/MSG installation is still the extrapolative one. With a few simple steps, however, users may activate the modules performing the new interpolation technique:



- 1) Download and unpack Numeric.24.2.tar.gz from <http://sourceforge.net/projects/numpy/files/Old%20Numeric/24.2/>. This package contains the necessary LAPACK and FFTPACK source code files
  - fftpack.c, in subdirectory Numeric-24.2/Packages/FFT/Src;
  - f2c\_lite.c, blas\_lite.c, dlapack\_lite.c, dlamch.c and zlapack\_lite.c, in the subfolder Numeric-24.2/Src;
  - f2c.h, in subdirectory Numeric-24.2/include/Numeric/.

The mentioned C files \*.c should be transferred to the directory \$SAFNWC/src/PGE10, the include file f2c.h should be placed in the directory \$SAFNWC/include/PGE10/Numeric.

- 2) Once the files are in the right place, go to \$SAFNWC/src/PGE10 and type



```
make -f makefile.ceof
```

As PGE10 uses common NWCSAF libraries, the prerequisite is that the NWCSAF package as a whole has been properly installed beforehand, as described in the NWCSAF top-level documentation. The last-mentioned command then simply results in an overwriting of the previously generated executable \$SAFNWC/bin/PGE10. One may at

 NWC SAF	 ZAMG	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 80/95
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any time go back to the version with the extrapolative NWP handling by typing `make a11` while being in the `$SAFNWC/src/PGE10` directory.



 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 81/95
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## 4. INPUTS AND CONFIGURABLE PARAMETERS FOR AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII)



### 4.1 LIST OF INPUTS

- SEVIRI IR imagery, channel 10.8, current and previous slot (time difference  $\leq 30$  minutes)
- SEVIRI IR imagery, channel 12.0, current time slot.
- SEVIRI WV image, channel 6.2, current and previous slot (time difference  $\leq 30$  minutes)
- ECMWF NWP data
- Supplementary invariable input files:
  - BUFR templates
  - Description of centres of gravity for classification process (cf. chapter 3.1.3.2 in AD. 6)
  - Rules and empirical numerical parameters for devising conceptual model classifications from raw input quantities

### 4.2 CONFIGURABLE PARAMETERS FOR AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII)

The configurable parameters can be found in the model configuration file for the PGE10, which is separated into two parts. The first section contains three parameters that can be set by the user (Then, starting with the entry PGE\_ID, the rest of the model configuration file is constituted by a section that should be touched only by the institute responsible for development/maintenance of PGE10, which at present is ZAMG.) The user has the options to suppress the PGE10 core product if only the computation of atmospheric motion vectors is desired. The dump of BUFR files with infrared and water vapour AMVs is handled by the other two configurable parameters. The three parameters work independently, so any combination of ASII and AMV output can be achieved:

Keyword	Description	Type	Possible Value(s)
NO_ASII__AMV_ONLY	Decide whether the ASII computations should be suppressed (choice of “YES” is appropriate if AMVs are the only desired output)	chain of characters	YES or NO
OUTPUT_IR_AMV	Decides whether there should be an explicit IR AMV output	chain of characters	YES or NO
OUTPUT_WV_AMV	Decides whether there should be an explicit WV AMV output	chain of characters	YES or NO

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 82/95
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## **5. SUMMARY OF AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII) VALIDATION RESULTS**

The automatic image analysis product has been validated against the manually generated SatRep for 06 and 12 UTC (cf. the PGE10 validation report [RD.1]). The validation period for ASII comprised 8.5 months, starting on 4<sup>th</sup> April 2006 and ending on 12<sup>th</sup> December 2006.

The SatRep is a manually generated analysis of the IR and WV image in terms of conceptual models. This analysis has been taken as a reference against which to validate the automatic analysis of ASII. Please consult the full ASII validation report [RD.1] for details, particularly about the definitions of "right" and "wrong" ASII diagnoses.

Amongst the frontal categories in the ASII validation (without model fields), the CF category gives satisfying results with a detection rate of 60% followed by the WF category with 48% and the occlusions with only 35%. In ASIINWP (including model fields), the overall CF and WF detection performs similar with a 60% detection rate for CFs, 48% for WFs. The detection of occlusions works better when including of model parameters (42%).

Concerning the non frontal categories, lee cloudiness (26%) and jet fibres (12%) are poorly detected. Convective systems show a seasonal variation, being better detected in summer time. Cb clusters (62%) are better detected than MCS (48%), but both are less performing in ASIINWP probably because of inaccurately predicted stability parameters. Convection in cold air (EC and Comma) is less often detected with 22% and 27% respectively. The best detection rate is obtained for the Closed Convective Cells with almost 65%.

Some conceptual models are analysed in ASIINWP only. FI by Jet is detected in 44% of all cases, more than half of the ULL (53%) analysed in the SatRep are detected in ASIINWP. The Upper Wave is detected in almost 40% of all SatRep cases.

Summarized, one can state, that best performances are obtained for frontal categories and small scale convective patterns in the warm sector as well as in the cold air behind a cold front. Amongst the least satisfactory conceptual models, one has to mention the frontal waves in ASIINWP (detection rate 14%), the jet cloud fibres and the Open Cell Convection (13% in both ASII and ASIINWP).



Since the validation report 2007 [RD.1] was issued, the main changes in PGE10 were

- a) a different scheme of front detection based on temporal changes
- b) a new fibre detection algorithm (prompted by the poor detection found in the extensive validation campaign)

So the current PGE10 version certainly has a better detection rate w.r.t. fibres. Item a) should have little effect on the detection rates; it rather reduces the false alarms of frontal systems over cold cloudfree land, yet false alarms were not statistically considered during the validation campaign.

PGE10 version 2010 for the first time allowed a flexible selection of the analysis grid. This opened up the opportunity for a new kind of evaluation of the Automatic Satellite Image Interpretation product, namely to assess the uncertainty of the obtained classifications that are due to algorithmic (non-meteorological) factors. In the most recent validation report [RD.3], two tests have been performed in this direction



- A gradual decrease of the considered analysis region (i.e. removing the outermost grid points without changing the coordinates of the remaining ones).
- ASII analyses on equally sized grids which were, however, slightly shifted against each other.

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 83/95
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20 test cases from all seasons and with various synoptic situations went into the statistics. Results are preliminary at the time of this writing.

It was found that on the whole, the detection of conceptual models worked satisfactorily stable when the size of the analysis area grid was reduced, in particular for those conceptual models whose detection is largely based on local pixel analysis (e.g. enhanced cumuli, cumulonimbus and mesoscale convective systems). On the other hand, frontal conceptual models turned out to be more sensitive: if the reduction of the analysis area removes too much of the system, it is not accepted as a front anymore since the PGE10 decision tree explicitly checks for the areal extent as one criterion to be fulfilled. As a summary result, one can give recommendations on the minimum region size a user should allow so that the analysis for *each* conceptual model over the central region of interest is not negatively impacted by boundary effects. For example, users on the European mainland are advised to use a region extending from Iceland to the eastern part of Europe including Turkey.

The second investigation dealt with small shifts of the analysis grid vis-a-vis a reference grid. Though these shifts were just (approx.) a tenth of the size of a grid mesh, this was enough to bring the agreement between the analyses down to 50-75% for small-scale conceptual models which were the worst performers (e.g. Cumulonimbus, fibres ...). The most likely explanation for this result is that - when these systems are close to the border of a reference grid cell - they can to a large degree be assigned to adjacent grid points if the grid changes slightly. For frontal categories, such phenomena (that do NOT indicate “unstable” pattern recognition approaches) do not have the same effect (percentage-wise); as may be expected, they are among the best performers with correspondence rates above 80%.

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 84/95
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## 6. TYPICAL KNOWN PROBLEMS AND RECOMMENDATION FOR USE

Pattern recognition methods - as used in this PGE - to analyse the structure of satellite cloud fields are time-consuming. This constrained the developers to concentrate on essential patterns, reducing the number of considered and detected conceptual models. Similar conceptual models, e.g. baroclinic boundary and cold front, are not distinguished and appear in the output under the same name.

Conceptual models are idealized descriptions. In reality, the variability in the appearance of meteorological phenomena makes it frequently difficult even for the trained subjective analyst to be sure about the right designation of a certain cloud system; it cannot be expected that the empirical spread defined for a meteorological parameter in such a mechanical system as ASII will be suitable in every instance to yield the right yes/no-decisions. The human analyst in cases of doubt has some mechanisms not accessible to ASII:

- the option to give little or no weight to features not fitting to a "prejudice";
- the option to view image loops over a period "as long as necessary". Though ASII takes into account the analysis of the preceding slot, that powerful technique of looping and viewing the genesis of systems is obviously hard to be simulated fully in an objective system.

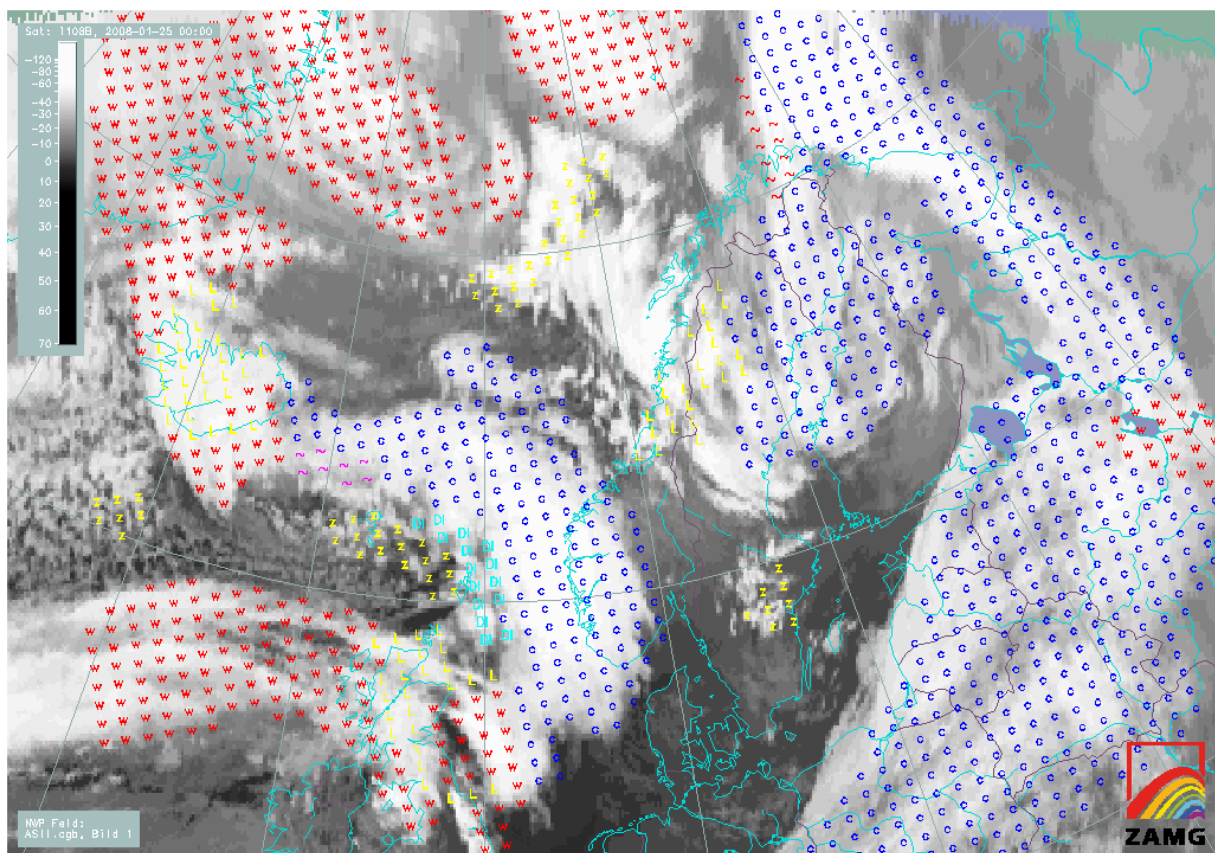
One must expect inferior performance at boundaries of the covered domain (pattern recognition techniques generally benefit from a larger vicinity) and in far-northern regions where the reduced spatial resolution blurs the image features.

For the practical application rules and inherent problems, please refer to the end of each conceptual model chapter.

## 7. EXAMPLES OF AUTOMATIC SATELLITE IMAGE INTERPRETATION (ASII) VISUALISATION

### 7.1 CONCEPTUAL MODELS

**Figure 20** shows the visualisation of an ASII product, depicting in symbolic manner the analysed conceptual models at the analysis grid points. The meaning of the symbols used in the graphics here (and at the reference product site hosted by AeMet) follows Tables 4 and 5.



**Figure 20:** PGE10 analysis for 25 January 2008, 0000 UTC (ASII).

For convenience, the FORTRAN 77 source code of the production program is included next. Users are probably interested most in the sections on BUFR decoding, hence these parts are highlighted by boldface printing. The BUFRDC software, freely available from ECMWF, is used here (subroutines PBOPEN, PBBUFR, BUFREX, PBCLOSE); note that the BUFR decoding sections are identical for the two sub-products. The other parts of the program mainly contain commands to accomplish the graphics output by the MAGICS package.

```

C      THIS IS A DEMO BUFR DECODING ROUTINE FOR CONCEPTUAL MODEL/LONGITUDE/
C      LATITUDE INFORMATION SUBMITTED BY SAFNWC ASII ROUTINES
C      AUTHOR:      ALEXANDER JANN / ZAMG / VIENNA, AUSTRIA
C      CREATION DATE: 02/08/2001
C      THIS IS INTENDED TO REPRESENT A USEFUL SUPPORT TO USERS OF THE
C      SAFNWC/MSG SOFTWARE PACKAGE, BUT COMES WITHOUT WARRANTY OF ANY KIND.

```

```
PROGRAM SAFNWC_ASII_BUFR
```



```
PARAMETER (JSEC0=3, JSEC1=40, JSEC2=64, JSEC3=4, JSEC4=2)
PARAMETER (JELEM=20000, JSUP=9, JBYTE=80000)
PARAMETER (KELEM=20000, KVALS=80000, KVALS1=80000)

DIMENSION KBUFF(20000), KSUP(JSUP)
DIMENSION KSEC0(JSEC0), KSEC1(JSEC1), KSEC2(JSEC2), KSEC3(JSEC3)
DIMENSION KSEC4(JSEC4)
#ifdef R_4
  REAL*8 VALUES(KVALS1)
#else
  REAL VALUES(KVALS1)
#endif

CHARACTER*80 CVALS(KVALS)
CHARACTER*24 CUNITS(KELEM)
CHARACTER*64 CNames(KELEM)

CHARACTER*80 EXPORT_PATH, CGBNAMEINTRO, MM



DIMENSION CONTOURX(20000), CONTOURY(20000)
CHARACTER*2 MARKSYM(20000)
CHARACTER*80 CONCMOD(20)
CHARACTER*10 COLOURS(20)
CHARACTER*2 SYMBOLS(20)

DATA CONCMOD/'warm front', 'cold front',
+ 'cold front under warm air advection',
+ 'front intensification by jet streak crossing',
+ 'enhanced cumuli','dry intrusion',
+ 'cold air cloudiness',
+ 'mature cumulonimbus','growing cumulonimbus',
+ 'decaying cumulonimbus','occlusion','comma',
+ 'non-developing wave','developing wave','upper wave',
+ 'upper level low','mesoscale convective system',
+ 'lee cloudiness','jet cloud (fibres)',
+ 'embedded convective cell'/

DATA COLOURS/'RED', 'BLUE',
+ 'RED',
+ 'YELLOW',
+ 'CYAN','CYAN',
+ 'YELLOW',
+ 'YELLOW', 'MAGENTA',
+ 'BLUE','GREEN','YELLOW',
+ 'MAGENTA','RED','GREEN',
+ 'YELLOW','YELLOW',
+ 'YELLOW', 'YELLOW',
+ 'YELLOW'/

DATA SYMBOLS/'w','c',
+ 'c',
+ 'ji',
+ 'ec','DI',
+ 'z',
+ 'cb','cb','cb',
+ 'o','co','~','~','~',
+ 'ul','m',
+ 'L','F',
+ './

CGBNAMEINTRO='SAFNWC_MSG2_ASII_200801250000_Region_ZAMG_'
N=GETENV('SAFNWC',EXPORT_PATH)
EXPORT_PATH=EXPORT_PATH(1:INDEX(EXPORT_PATH,' ')-1)//'/export/PGE10/'
INDEXPO=INDEX(EXPORT_PATH,' ')-1
```

		Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 87/95
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C OPEN MAGICS, DEFINE GRAPHICAL DEVICE AND FIX GEOGRAPHICAL AREA

```

CALL POPEN
CALL PNEW ('SUPER_PAGE')
CALL PNEW ('PAGE')
CALL PSETI ('WORKSTATION_COUNT',1)
CALL PSETC ('WORKSTATION_1','CGM_BINARY')
CALL PSETC ('PAGE_FRAME','OFF')
MM = 'MAGICS_METAFILE='//EXPORT_PATH(1:INDEXPO)//'ASII.cgb'
JI = PUTENV(MM)
CALL PSETC ('SUPER_PAGE_FRAME','ON')
CALL PSETR ('SUPER_PAGE_X_LENGTH',29.7)
CALL PSETR ('SUPER_PAGE_Y_LENGTH',24.0)
CALL PSETR ('PAGE_X_LENGTH',29.7)
CALL PSETR ('PAGE_Y_LENGTH',24.0)
CALL PSETC ('SUBPAGE_MAP_PROJECTION','POLAR_STEREOGRAPHIC')
CALL PSETC ('SUBPAGE_MAP_AREA_DEFINITION','CORNERS')
CALL PSETR ('SUBPAGE_MAP_VERTICAL_LONGITUDE',0.0)
CALL PSETR ('SUBPAGE_LOWER_LEFT_LONGITUDE',-29.5)
CALL PSETR ('SUBPAGE_LOWER_LEFT_LATITUDE',22.6)
CALL PSETR ('SUBPAGE_UPPER_RIGHT_LONGITUDE',73.1)
CALL PSETR ('SUBPAGE_UPPER_RIGHT_LATITUDE',56.3)
CALL PSETR ('SUBPAGE_X_POSITION',2.23)
CALL PSETR ('SUBPAGE_Y_POSITION',1.05)
CALL PSETR ('SUBPAGE_X_LENGTH',22.41)
CALL PSETR ('SUBPAGE_Y_LENGTH',17.85)

```

```

C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
C DECODE BUFR FILE CONTAINING THE SAFNWC/ASII-SATonly PRODUCT
C !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

```

```

IRET=0
CALL PBOPEN (IUNIT,EXPORT_PATH(1:INDEXPO)//
+ CGBNAMEINTRO(1:INDEX(CGNAMEINTRO,'.'))//'SATonly.buf','r',IRET)
IF (IRET.NE. 0) GOTO 13

```

```

IERR=0
IRET=0
KBUFL=0

```

11 CONTINUE

C EXTRACT COORDINATES OF ONE CONCEPTUAL MODEL (AND ITS DESIGNATION)

```

CALL PBBUFR (IUNIT,KBUFF,JBYTE,KBUFL,IRET)
IF (IRET.EQ. -1) GOTO 13
KBUFL=KBUFL/4+1
KEL=KELEM
CALL BUFREX (KBUFL,KBUFF,KSUP,KSEC0,KSEC1,KSEC2,KSEC3,KSEC4,
+ KEL,CNAMES,CUNITS,KVALS,VALUES,CVALS,KERR)

```

```

IF (VALUES(1).EQ. 0.) GOTO 11 ! NEXT CONCEPTUAL MODEL

```

C GET INDEX OF CURRENT CONCEPTUAL MODEL

```



DO 111 K=1,20
NAMELENGTH=MIN(INDEX(CONCMOD(K),' ')-1,32)
IF (CVALS(1)(1:NAMELENGTH).EQ.
+ CONCMOD(K)(1:NAMELENGTH)) INDEXCM=K
111 CONTINUE

```

```

DO 12 K=1,VALUES(1)
CONTOURY(K)=VALUES(2*K)
CONTOURX(K)=VALUES(2*K+1)
MARKSYM(K)=SYMBOLS(INDEXCM)

```

 	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 88/95
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**12 CONTINUE**

C PLOT THE CONCEPTUAL MODEL WITH CORRECT COLOUR AND SYMBOL

```
CALL PSET1R('SYMBOL_INPUT_X_POSITION',CONTOURX,K-1)
CALL PSET1R('SYMBOL_INPUT_Y_POSITION',CONTOURY,K-1)
CALL PSETC('SYMBOL_TABLE_MODE','OFF')
CALL PSETC('LEGEND','OFF')
CALL PSETC('LEGEND_ENTRY','OFF')
CALL PSETC('SYMBOL_TYPE','TEXT')
CALL PSET1C('SYMBOL_INPUT_TEXT_LIST',MARKSYM,K-1)
CALL PSETC('SYMBOL_COLOUR',COLOURS(INDEXCM))
CALL PSETR('SYMBOL_HEIGHT',0.09)
CALL PSYMB
```

GOTO 11 ! NEXT CONCEPTUAL MODEL

C CLOSE BUFR FILE, CLOSE MAGICS

**13 CALL PBCLOSE(IUNIT,IRET)**

CALL PCLOSE

C RE-OPEN MAGICS, DEFINE GRAPHICAL DEVICE AND FIX GEOGRAPHICAL AREA

```
CALL POPEN
CALL PSETI('WORKSTATION_COUNT',1)
CALL PSETC('WORKSTATION_1','CGM_BINARY')
CALL PSETC('PAGE_FRAME','OFF')
MM = 'MAGICS_METAFILE='//EXPORT_PATH(1:INDEXPO)//'ASIINWP.cgb'
JI = PUTENV(MM)
CALL PSETC('SUPER_PAGE_FRAME','ON')
CALL PSETR('SUPER_PAGE_X_LENGTH',29.7)
CALL PSETR('SUPER_PAGE_Y_LENGTH',24.0)
CALL PSETR('PAGE_X_LENGTH',29.7)
CALL PSETR('PAGE_Y_LENGTH',24.0)
CALL PSETC('SUBPAGE_MAP_PROJECTION','POLAR_STEREOGRAPHIC')
CALL PSETC('SUBPAGE_MAP_AREA_DEFINITION','CORNERS')
CALL PSETR('SUBPAGE_MAP_VERTICAL_LONGITUDE',0.0)
CALL PSETR('SUBPAGE_LOWER_LEFT_LONGITUDE',-29.5)
CALL PSETR('SUBPAGE_LOWER_LEFT_LATITUDE',22.6)
CALL PSETR('SUBPAGE_UPPER_RIGHT_LONGITUDE',73.1)
CALL PSETR('SUBPAGE_UPPER_RIGHT_LATITUDE',56.3)
CALL PSETR('SUBPAGE_X_POSITION',2.23)
CALL PSETR('SUBPAGE_Y_POSITION',1.05)
CALL PSETR('SUBPAGE_X_LENGTH',22.41)
CALL PSETR('SUBPAGE_Y_LENGTH',17.85)
```

C !!!  
 C DECODE BUFR FILE CONTAINING THE SAFNWC/ASII-SAT/NWP PRODUCT  
 C !!!

```
IRET=0
CALL PBOPEN(IUNIT,EXPORT_PATH(1:INDEXPO)//
+ CGBNAMEINTRO(1:INDEX(CGBNAMEINTRO,'.'))//'SAT+NWP.buf','r',IRET)
IF(IRET.NE.0)GOTO 23
```



```
IERR=0
IRET=0
KBUFL=0
```

**21 CONTINUE**

C EXTRACT COORDINATES OF ONE CONCEPTUAL MODEL (AND ITS DESIGNATION)

```
CALL PBBUFR(IUNIT,KBUFF,JBYTE,KBUFL,IRET)
IF(IRET.EQ.-1)GOTO 23
```



		Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 89/95
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```

      KBUFL=KBUFL/4+1
      KEL=KELEM
      CALL BUFREX (KBUFL,KBUFF,KSUP,KSEC0,KSEC1,KSEC2,KSEC3,KSEC4,
+    KEL,CNAMES,CUNITS,KVALS,VALUES,CVALS,KERR)

      IF (VALUES(1) .EQ. 0.) GOTO 21 ! NEXT CONCEPTUAL MODEL

C     GET INDEX OF CURRENT CONCEPTUAL MODEL

      DO 211 K=1,20
          NAMELENGTH=MIN( INDEX( CONCMOD(K), '  ' )-1,32)
          IF (CVALS(1)(1:NAMELENGTH) .EQ.
+    CONCMOD(K)(1:NAMELENGTH)) INDEXCM=K
211   CONTINUE

      DO 22 K=1,VALUES(1)
          CONTOURY(K)=VALUES(2*K)
          CONTOURX(K)=VALUES(2*K+1)
          MARKSYM(K)=SYMBOLS(INDEXCM)
22   CONTINUE

C     PLOT THE CONCEPTUAL MODEL WITH CORRECT COLOUR AND SYMBOL

      CALL PSET1R('SYMBOL_INPUT_X_POSITION',CONTOURX,K-1)
      CALL PSET1R('SYMBOL_INPUT_Y_POSITION',CONTOURY,K-1)
      CALL PSETC('SYMBOL_TABLE_MODE','OFF')
      CALL PSETC('LEGEND','OFF')
      CALL PSETC('LEGEND_ENTRY','OFF')
      CALL PSETC('SYMBOL_TYPE','TEXT')
      CALL PSET1C('SYMBOL_INPUT_TEXT_LIST',MARKSYM,K-1)
      CALL PSETC('SYMBOL_COLOUR',COLOURS(INDEXCM))
      CALL PSETR('SYMBOL_HEIGHT',0.09)
      CALL PSYMB

      GOTO 21 ! NEXT CONCEPTUAL MODEL

C     CLOSE BUFR FILE, CLOSE MAGICS



23   CALL PBCLOSE(IUNIT,IRET)
      CALL PCLOSE

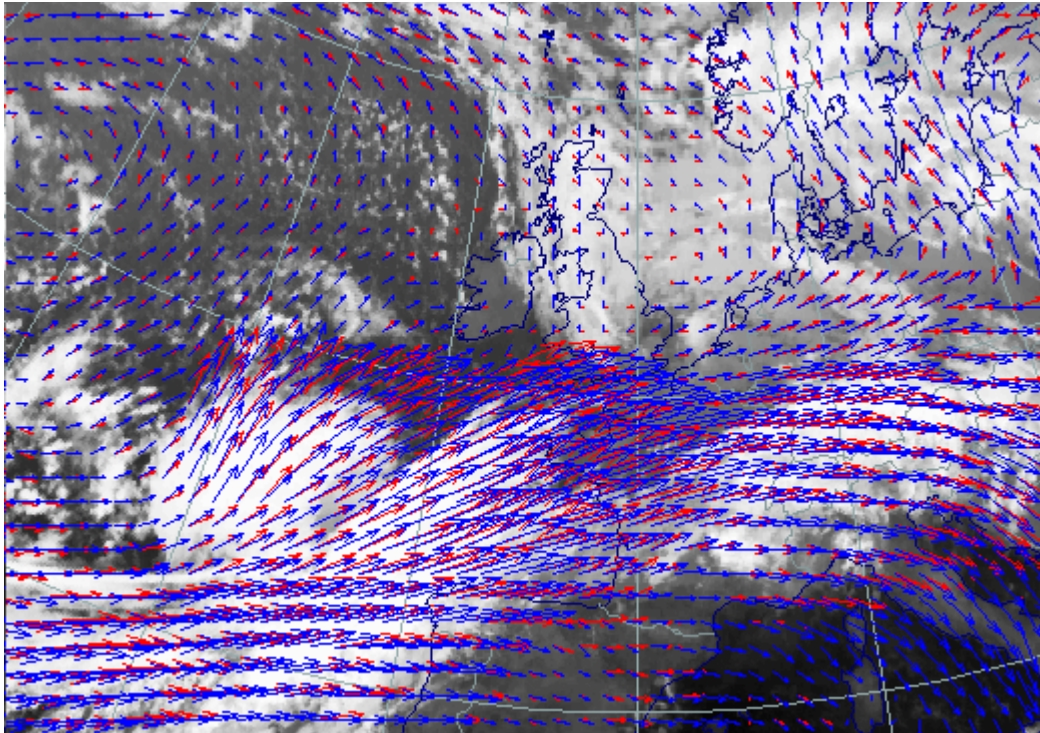
      END

```

## 7.2 ATMOSPHERIC MOTION VECTORS

**Figure 21** shows the visualisation of the optional AMV products of the SAFNWC/MSG ASII product.

 	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 90/95
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*Figure 21: Infra-red (red) and water-vapour (blue) AMV fields as derived for input into the PGE10 analysis for 14 October 2002, 0600 UTC.*

For convenience, the FORTRAN 90 source code of an example plotting program is included hereafter. Users are probably interested most in the sections on BUFR decoding; hence these parts are highlighted by boldface printing. The BUFRDC software, freely available from ECMWF, is used here (subroutines PBOPEN, PBBUFR, BUFREX, PBCLOSE); note that the BUFR decoding sections are identical for the two AMV fields. The other parts of the program mainly contain commands to accomplish the graphics output by the MAGICSS++ package (which in principle is able to digest BUFR input directly; this functionality is, however, not exploited here in order to also support users of other visualization software).

```

!      THIS IS A DEMO BUFR DECODING ROUTINE FOR AMV/LONGITUDE/
!      LATITUDE INFORMATION GENERATED BY SAFNWC ASII ROUTINES
!      AUTHOR:      ALEXANDER JANN / ZAMG / VIENNA, AUSTRIA
!      CREATION DATE: 13/05/2011
!      THIS IS INTENDED TO REPRESENT A USEFUL SUPPORT TO USERS OF THE
!      SAFNWC/MSG SOFTWARE PACKAGE, BUT COMES WITHOUT WARRANTY OF ANY KIND.



PROGRAM SAFNWC_ASII_BUFR
PARAMETER( JSUP=9, JSEC0=3, JSEC1=40, JSEC2=4096, JSEC3=4, &
JSEC4=2, JELEM=160000, JBUFL=300000, JBYTE=440000, KELEM=160000, &
JBPW=32, KVALS=4096000)

DIMENSION KSUP(JSUP), KSEC0(JSEC0), KSEC1(JSEC1)
DIMENSION KSEC2(JSEC2), KSEC3(JSEC3), KSEC4(JSEC4)
INTEGER, DIMENSION(JBUFL) :: KBUFF
REAL*8, DIMENSION(KVALS) :: VALUES

CHARACTER (LEN=64), DIMENSION(KELEM) :: CNames
CHARACTER (LEN=24), DIMENSION(KELEM) :: CUnits

```



		Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 92/95
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```

IRET=0
CALL PBOPEN (IUNIT,'SAFNWC_MSG2_ASII_201105130715_Region_ZAMG_WVAMV.buf', &
'r',IRET)
IF (IRET.NE. 0) GOTO 23

```

```
! RE-OPEN MAGICS, DEFINE GRAPHICAL DEVICE AND FIX GEOGRAPHICAL AREA
```

```

CALL POPEN
CALL PSETC ('OUTPUT_FORMAT','PS')
CALL PSETC ('OUTPUT_NAME','PGE10d')
CALL PSETC ('PAGE_ID_LINE','OFF')
CALL PSETC ('SUBPAGE_MAP_PROJECTION','POLAR_STEREOGRAPHIC')
CALL PSETC ('SUBPAGE_MAP_AREA_DEFINITION','CORNERS')
CALL PSETR ('SUBPAGE_MAP_VERTICAL_LONGITUDE',0.0 )
CALL PSETR ('SUBPAGE_LOWER_LEFT_LONGITUDE',-29.5)
CALL PSETR ('SUBPAGE_LOWER_LEFT_LATITUDE', 22.6)
CALL PSETR ('SUBPAGE_UPPER_RIGHT_LONGITUDE',73.1)
CALL PSETR ('SUBPAGE_UPPER_RIGHT_LATITUDE', 56.3)
CALL PCOAST

```

```
! EXTRACT COORDINATES AND COMPONENTS OF ATMOSPHERIC MOTION VECTORS
```

```

CALL PBBUFR (IUNIT,KBUFF,JBYTE,KBUFL,IRET)
IF (IRET.EQ. -1) GOTO 23
KBUFL=KBUFL/4+1
KEL=KELEM
CALL BUFREX (KBUFL,KBUFF,KSUP,KSEC0,KSEC1,KSEC2,KSEC3,KSEC4, &
KEL,CNAMES,CUNITS,KVALS,VALUES,CVALS,KERR)
CALL PSETC ('INPUT_FIELD_SUBPAGE_MAPPING','LOWER_LEFT')
CALL PSETR ('INPUT_FIELD_LATITUDE_STEP',0.1075) ! DUMMY
CALL PSETR ('INPUT_FIELD_LONGITUDE_STEP',0.165) ! DUMMY
CALL PSETC('WIND_ARROW_COLOUR','BLUE')
CALL PSETC('WIND_LEGEND','OFF')

```

```
! Plot the AMVs one by one (irregular field)
```

```

DO K=1,INT(VALUES(1))
  AMVLAT=VALUES(4*K-2)
  AMVLONG=VALUES(4*K-1)
  AMVUCOMP=VALUES(4*K)
  AMVVCOMP=VALUES(4*K+1)
  CALL PSETR ('INPUT_FIELD_INITIAL_LATITUDE',AMVLAT)
  CALL PSETR ('INPUT_FIELD_INITIAL_LONGITUDE',AMVLONG)
  CALL PSET2R('INPUT_WIND_U_COMPONENT',AMVUCOMP,1,1)
  CALL PSET2R('INPUT_WIND_V_COMPONENT',AMVVCOMP,1,1)
  CALL PWIND

```

```



END DO
CALL PCLOSE

```

```

23 CALL PBCLOSE(IUNIT,IRET)
END

```

 <b>NWC SAF</b>	 <b>ZAMG</b>	Product User Manual for the “Automatic Satellite Image Interpretation” product (ASII-PGE10, v2.4)	<b>Code:</b> SAF/NWC/CDOP/ZAMG/SCI/PUM/10 <b>Issue:</b> 2.4.1 <b>Date:</b> 15 February 2012 <b>File:</b> SAF-NWC-CDOP-ZAMG-SCI-PUM-10_v2.4.1 <b>Page:</b> 93/95
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## 8. REFERENCES

Bader, M.J., Forbes, G.S., Grant, J.R., Lilley, R.B.E., and Waters, A.J. (Eds.) (1995): Images in weather forecasting. Cambridge University Press, Cambridge.

COST78 (1996): Nowcasting, a survey of current knowledge, techniques, and practice. Phase 1 report. Office for Official Publications of the European Communities, Luxembourg.

Wirth, A., Jann, A. and Zeiner, B. (2008): On the use of complex empirical orthogonal functions for the temporal interpolation of NWP, radar and satellite data. Proceedings, 2008 EUMETSAT Meteorological Satellite Conference, Darmstadt, 8 - 12 September 2008, EUMETSAT P. 52, ISBN 978-92-9110-082-8, ISSN 1011-3932, 8pp.

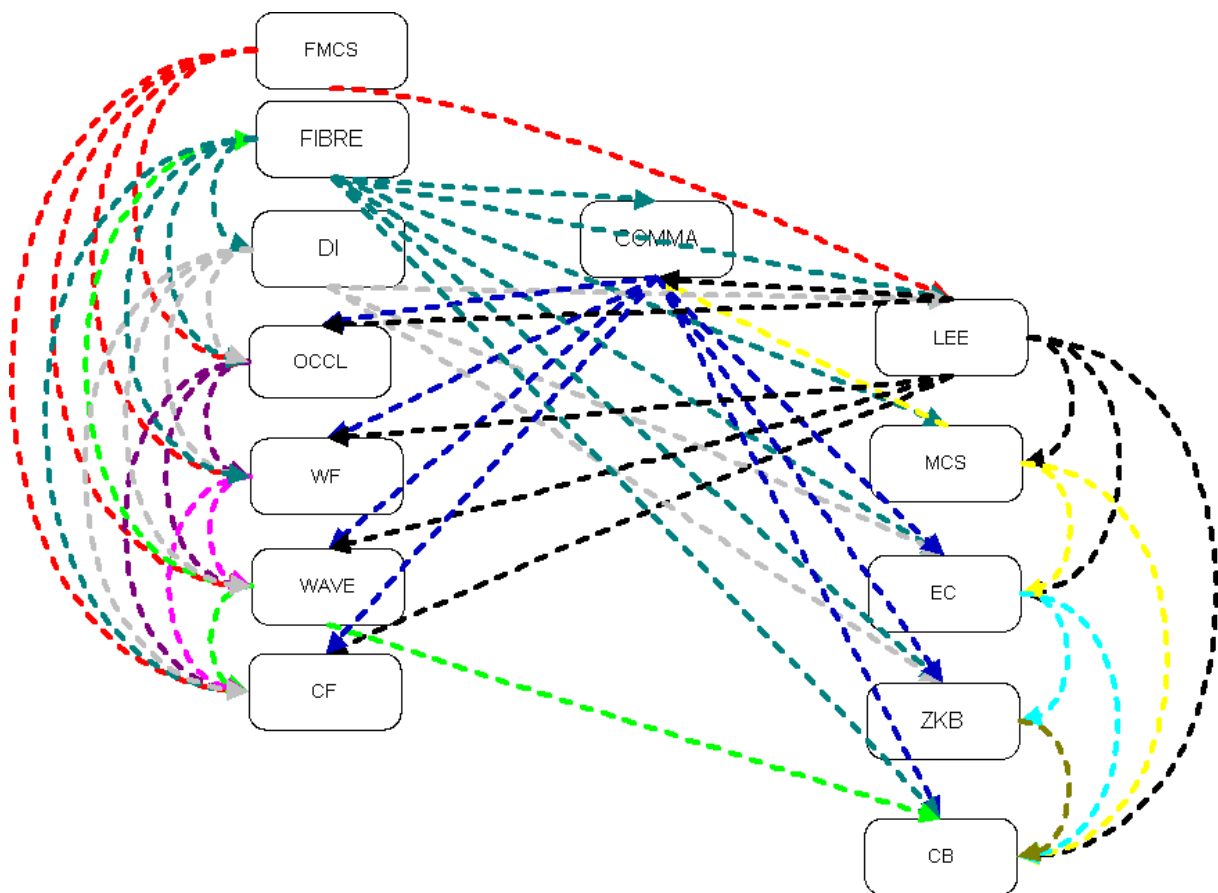
ZAMG (2005): Manual of synoptic satellite meteorology: Conceptual models. Version 6.0. CD-ROM (available from ZAMG).

ZAMG (1999): Training course: Diagnosis of satellite images with help of conceptual models. CD-ROM (available from ZAMG).

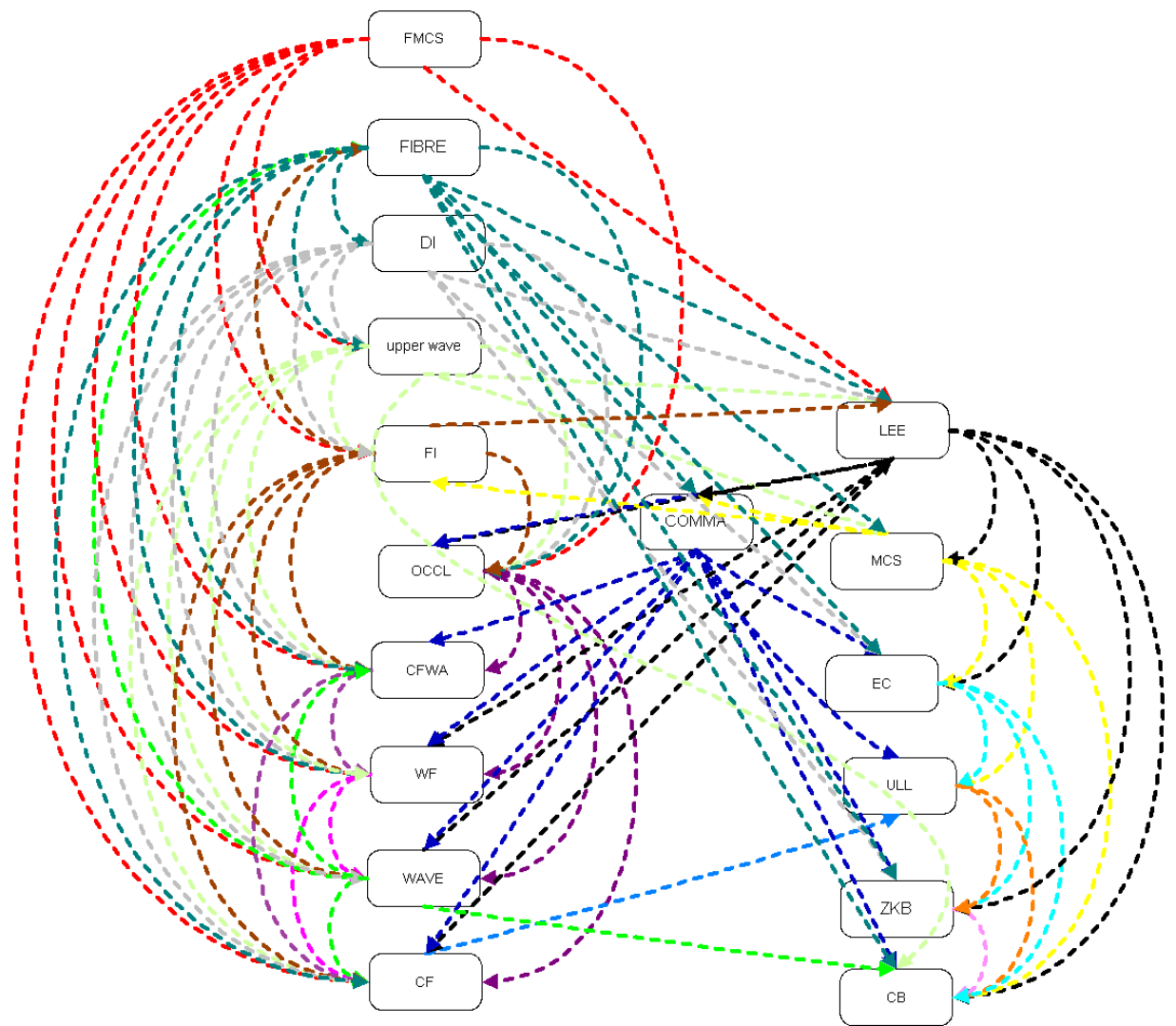
## APPENDIX 1: RANKING AMONG SIMULTANEOUSLY DIAGNOSED CONCEPTUAL MODELS

The following graphics summarise the ranking in-between the detected conceptual models, when two or more conceptual models are deemed acceptable for the same grid mesh. The following diagram table is valid for ASII, the subsequent one for ASIINWP.

Between the frontal and non-frontal conceptual models, only few ranking rules exist. This is the case as these conceptual models never happen to be on the same grid mesh because the necessary conditions for each of them are contradictory.



**Figure 22:** Ranking diagram for ASII: the arrows are drawn from the conceptual model which is overwriting to that one which is overwritten. The left column comprises the frontal CMs, the right column the small and mesoscale CMs



**Figure 23:** Ranking diagram for ASIINWP: the arrows are drawn from the conceptual model which is overwriting to that one which is overwritten. The left column comprises the frontal CMs, the right column the small and mesoscale CMs.