The EUMETSAT Network of Satellite Application Facilities

H SAF

Support to Operational Hydrology and Water Management

Italian Meteorological Service

Italian Department of Civil Defence

H-SAF Product User Manual (PUM)

PR-ASS-1 - Instantaneous and accumulated precipitation at ground computed by a NWP model

Zentralanstalt für Meteorologie und Geodynamik

Vienna University of Technology Institut für Photogrammetrie und Fernerkundung

Royal Meteorological Institute of Belgium

European Centre for Medium-Range Weather Forecasts

Finnish Meteorological Institute

Finnish Environment Institute

Helsinki University of Technology

Météo-France

CNRS Laboratoire Atmosphères, Milieux, Observations Spatiales

CNRS Centre d'Etudes Spatiales de la BIOsphere

Bundesanstalt für Gewässerkunde

Hungarian Meteorological Service

CNR - Istituto Scienze dell'Atmosfera e del Clima

Università di Ferrara

Institute of Meteorology and Water Management

Romania National Meteorological Administration

Slovak Hydro-Meteorological Institute

Turkish State Meteorological Service

Middle East Technical University

Istanbul Technical University

Anadolu University

31 August 2010

H-SAF Product User Manual PUM-06
Product PR-ASS-1
Instantaneous and accumulated precipitation at ground computed by a NWP model

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Acronyms

ATDD	Algorithms Theoretical Definition Document
AU	Anadolu University (in Turkey)
BfG	Bundesanstalt für Gewässerkunde (in Germany)
CAF	Central Application Facility (of EUMETSAT)
CC	Correlation Coefficient
CDOP	Continuous Development-Operation Phase
CESBIO	Centre d'Etudes Spatiales de la BIOsphere (of CNRS, in France)
CM-SAF	SAF on Climate Monitoring
CNMCA	Centro Nazionale di Meteorologia e Climatologia Aeronautica (in Italy)
CNR	Consiglio Nazionale delle Ricerche (of Italy)
CNRS	Centre Nationale de la Recherche Scientifique (of France)
COSMO	Consortium for Small-Scale Modelling
COSMO-ME	Consortium for Small-Scale Modelling - version for Mediterranean
CSI	Critical Success Index
DPC	Dipartimento Protezione Civile (of Italy)
EARS	EUMETSAT Advanced Retransmission Service
ECMWF	European Centre for Medium-range Weather Forecasts
EDC	EUMETSAT Data Centre, previously known as U-MARF
EUM	Short for EUMETSAT
EUMETCast	EUMETSAT's Broadcast System for Environmental Data
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAQ	Frequently Asked Questions
FAR	False Alarm Rate
FMI	Finnish Meteorological Institute
FTP	File Transfer Protocol
GEO	Geostationary Earth Orbit
GRAS-SAF	SAF on GRAS Meteorology
GRIB	Gridded Binary
GTS	Global Telecommunication System
H-SAF	SAF on Support to Operational Hydrology and Water Management
IMWM	Institute of Meteorology and Water Management (in Poland)
IPF	Institut für Photogrammetrie und Fernerkundung (of TU-Wien, in Austria)
IR	Infra Red
IRM	Institut Royal Météorologique (of Belgium) (alternative of RMI)
ISAC	Istituto di Scienze dell'Atmosfera e del Clima (of CNR, Italy)
ITU	İstanbul Technical University (in Turkey)
LATMOS	Laboratoire Atmosphères, Milieux, Observations Spatiales (of CNRS, in France)
LEO	Low Earth Orbit
LSA-SAF	SAF on Land Surface Analysis
ME	Mean Error
Météo France	National Meteorological Service of France
METU	Middle East Technical University (in Turkey)
MW	Micro Wave
NMA	National Meteorological Administration (of Romania)
NOAA	National Oceanic and Atmospheric Administration (Agency and satellite)
NWC-SAF	SAF in support to Nowcasting & Very Short Range Forecasting
NWP	Numerical Weather Prediction
NWP-SAF	SAF on Numerical Weather Prediction
O3M-SAF	SAF on Ozone and Atmospheric Chemistry Monitoring
OMSZ	Hungarian Meteorological Service

ORR	Operations Readiness Review
OSI-SAF	SAF on Ocean and Sea Ice
PNG	Portable Network Graphics
POD	Probability of Detection
PP	Project Plan
PUM	Product User Manual
PVR	Product Validation Report
RMI	Royal Meteorological Institute (of Belgium) (alternative of IRM)
RMS	Root Mean Square
RMSE	Root Mean Square Error
SAF	Satellite Application Facility
SD	Standard Deviation
SHMÚ	Slovak Hydro-Meteorological Institute
SYKE	Suomen ympäristökeskus (Finnish Environment Institute)
TKK	Teknillinen korkeakoulu (Helsinki University of Technology)
TSMS	Turkish State Meteorological Service
TU-Wien	Technische Universität Wien (in Austria)
U-MARF	Unified Meteorological Archive and Retrieval Facility
UniFe	University of Ferrara (in Italy)
URD	User Requirements Document
URL	Uniform Resource Locator
UTC	Universal Coordinated Time
VIS	Visible
ZAMG	Zentralanstalt für Meteorologie und Geodynamik (of Austria)

1. Introduction to H-SAF

1.1 The EUMETSAT Satellite Application Facilities

H-SAF is part of the distributed application ground segment of the "*European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)*". The application ground segment consists of a "*Central Application Facility (CAF)*" and a network of eight "*Satellite Application Facilities (SAFs*)" dedicated to development and operational activities to provide satellite-derived data to support specific user communities. See ***Fig. 01***.

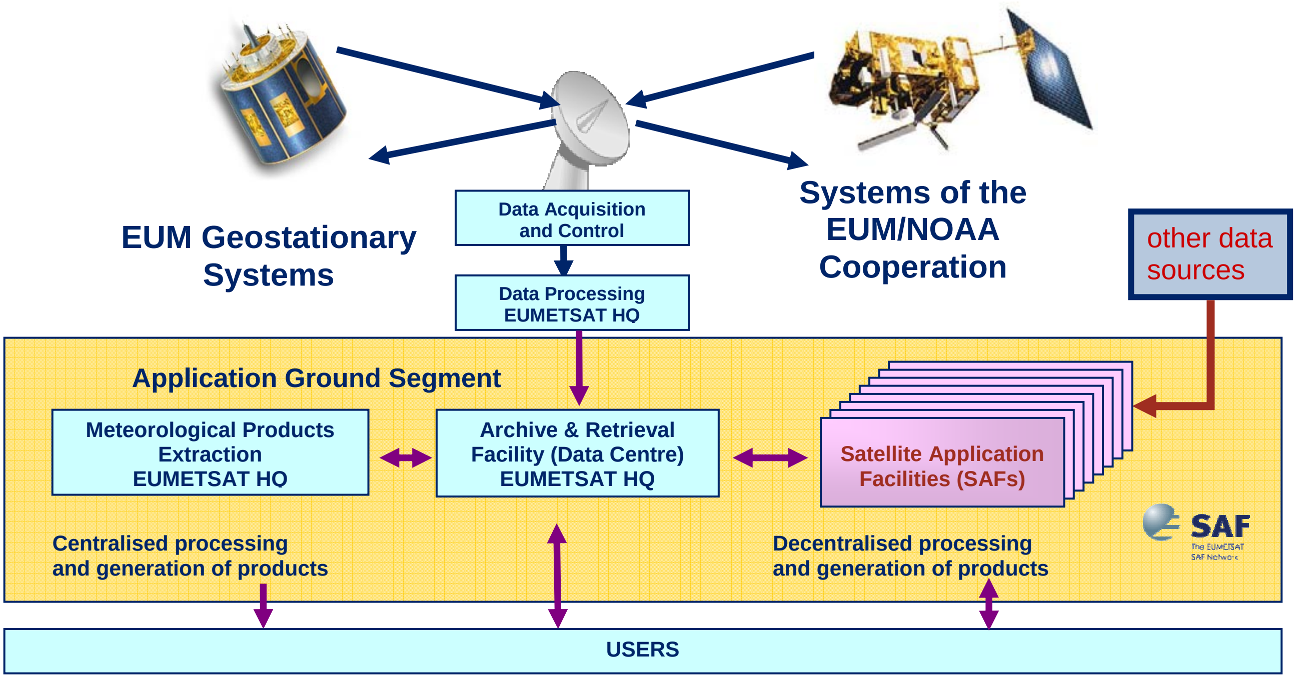

Fig. 01 - Conceptual scheme of the EUMETSAT application ground segment.

Fig. 02 reminds the current composition of the EUMETSAT SAF network (in order of establishment).

NWC SAF	OSI SAF	O3M SAF	CM SAF	NWP SAF	GRAS SAF	LSA SAF	H SAF
Nowcasting & Very Short Range Forecasting	Ocean and Sea Ice	Ozone & Atmospheric Chemistry Monitoring	Climate Monitoring	Numerical Weather Prediction	GRAS Meteorology	Land Surface Analysis	Operational Hydrology & Water Management

Fig. 02 - Current composition of the EUMETSAT SAF network (in order of establishment).

1.2 H-SAF objectives and products

The "*EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management (H-SAF)*" was established by the EUMETSAT Council on 3 July 2005. Its Development Phase started on 1st September 2005 and ends on 31 August 2010. The work programme makes distinction between two Phases:

- Phase 1: products development, prototypes generation, preliminary validation.
- Phase 2: regular production, extended validation, hydrological validation.

The H-SAF objectives are:

a. ***to provide new satellite-derived products*** from existing and future satellites with sufficient time and space resolution to satisfy the needs of operational hydrology; identified products:

- precipitation (liquid, solid, rate, accumulated);

- soil moisture (at large-scale, at local-scale, at surface, in the roots region);
- snow parameters (detection, cover, melting conditions, water equivalent);

b. to perform independent validation of the usefulness of the new products for fighting against floods, landslides, avalanches, and evaluating water resources; the activity includes:

- downscaling/upscaling modelling from observed/predicted fields to basin level;
- fusion of satellite-derived measurements with data from radar and raingauge networks;
- assimilation of satellite-derived products in hydrological models;
- assessment of the impact of the new satellite-derived products on hydrological applications.

This document (the PUM, Product User Manual) is concerned only with the satellite-derived products. The list of products to be generated by H-SAF is shown in ***Table 01.***

Table 01 - List of H-SAF products

Code	Acronym	Product name
H01	PR-OBS-1	Precipitation rate at ground by MW conical scanners (with indication of phase)
H02	PR-OBS-2	Precipitation rate at ground by MW cross-track scanners (with indication of phase)
H03	PR-OBS-3	Precipitation rate at ground by GEO/IR supported by LEO/MW
H04	PR-OBS-4	Precipitation rate at ground by LEO/MW supported by GEO/IR (with flag for phase)
H05	PR-OBS-5	Accumulated precipitation at ground by blended MW and IR
H06	PR-ASS-1	Instantaneous and accumulated precipitation at ground computed by a NWP model
H07	SM-OBS-1	Large-scale surface soil moisture by radar scatterometer
H08	SM-OBS-2	Small-scale surface soil moisture by radar scatterometer
H09	SM-ASS-1	Volumetric soil moisture (roots region) by scatterometer assimilation in NWP model
H10	SN-OBS-1	Snow detection (snow mask) by VIS/IR radiometry
H11	SN-OBS-2	Snow status (dry/wet) by MW radiometry
H12	SN-OBS-3	Effective snow cover by VIS/IR radiometry
H13	SN-OBS-4	Snow water equivalent by MW radiometry

The work of products generation is shared in the H-SAF Consortium as follows:

- Precipitation products (pre-fix: PR) are generated in Italy by the CNMCA, close to Rome.
- CNMCA also manages the Central Archive and the Data service.
- Soil moisture products (pre-fix: SM) are generated in Austria by ZAMG in Vienna, and at ECMWF; all derive from a Global surface soil moisture generated by EUMETSAT and transmitted worldwide via EUMETCast.
- ZAMG extracts SM-OBS-1 covering the H-SAF area from the EUMETSAT Global product, and generates SM-OBS-2 by disaggregating SM-OBS-1.
- ECMWF generates a Global volumetric soil moisture by assimilating the EUMETSAT Global product, and distributes its worldwide according to its data policy; then extracts SM-ASS-1 covering the H-SAF area.
- Snow products (pre-fix: SN) are generated in Finland by FMI in Helsinki, and in Turkey by TSMS in Ankara. Products from FMI and TSMS cover the full H-SAF area, but then they are merged (in FMI) in such a way that the flat and forested areas stem from the FMI product, the mountainous ones from the TSMS product. Exception: product SN-OBS-2 is only generated by FMI.

Table 02 deploys the user community addressed by H-SAF products.

Table 02 - User community addressed by H-SAF products

Entity	Application	Precipitation	Soil moisture	Snow parameters
Operational hydrological units	Fluvial basins management	Early warning of potential floods.	Landslides and flash flood forecasting.	Evaluation of flood damping or enhancing factors.
	Territory management	Extreme events statistics and hydrological risk mapping.	Soil characterisation and hydrological response units.	Dimes and exploitation of snow and glaciers for river regime regularisation.
		Public works planning.		
	Water reservoirs evaluation	Inventory of potential stored water resources.	Monitoring of available water to sustain vegetation.	Dimes and exploitation of snow and glaciers for drinkable water and irrigation.
National meteorological services	Numerical Weather Prediction	Assimilation to represent latent heat release inside the atmosphere.	Input of latent heat by evapotranspiration through the Planetary Boundary Layer.	Input of radiative heat from surface to atmosphere.
		Evaluation of NWP model's skill.		
	Nowcasting	Public information on actual weather.	Warning on the status of the territory for transport in emergencies.	Warning of avalanches.
		Warning for fishery and coastal zone activities.		Tourism information.
		Warning for agricultural works and crop protection.		Assistance to aviation during take-off and landing.
	Climate monitoring	Representation of the global water cycle in General Circulation Models.	Monitoring of desertification processes.	Monitoring glacier extension.
				Monitoring changes of planetary albedo.
Civil defence	Preparation for emergencies	Progressive level of attention function of rainfall monitoring.	Monitoring soil moisture growth.	Monitoring snow accumulation.
		Preparation of facilities and staff for a possible emergency.	Planning of in-field activities for event mitigation.	Planning of in-field activities for event mitigation.
	Emergency management	Alert to population.	Operational conditions for transport and use of staff and mitigation facilities.	Operational conditions for transport and use of staff and mitigation facilities.
	Post-emergency phase	De-ranking of alert level and monitoring of event ceasing.	Withdrawing of staff and mitigation facilities.	Withdrawing of staff and mitigation facilities.
			Assessment of vulnerability to possible event iteration.	Assessment of vulnerability to possible event iteration.
Research & development activities	Meteorology	Improved knowledge of the precipitation process.	Assessment of the role of observed soil moisture in NWP, either for verification or initialisation.	Assessment of the role of observed snow parameters in NWP, either for verification or initialisation.
		Assimilation of precipitation observation in NWP models.		
	Hydrology	Downscaling/upscaling of satellite precipitation observations.	Downscaling/upscaling of satellite soil moisture observations.	Downscaling/upscaling of satellite snow observations.
		Fusion with ground-based observations.	GIS-based fusion with ground-based observations.	GIS-based fusion with ground-based observations.
		Assimilation and impact studies.	Assimilation and impact studies.	Assimilation and impact studies.
	Civil defence	Decisional models for the alert system.	Organisational models for operating over moist soil.	Organisational models for operating over snow.

1.3 Evolution of H-SAF products

One special requirement of the H-SAF work plan was that the Hydrological validation programme, that started downstream of products availability, lasts for a sufficient time There was therefore a need to make available as soon as possible at least part of the products, accepting that their status of consolidation was still incomplete, the quality was not yet the best, and the characterisation was still poor due to limited validation. According to EUMETSAT definitions, the status of development of a product is qualified as in ***Table 03***.

Table 03 - Definition of the development status of a product according to EUMETSAT

In development	Products or software packages that are in development and not yet available to users
Demonstrational	Products or software packages that are provided to users without any commitment on the quality or availability of the service and have been considered by the relevant Steering Group to be useful to be disseminated in order to enabling users to test the product and to provide feedback
Pre-operational	Products or software packages with documented limitations that are able to satisfy the majority of applicable requirements and/or have been considered by the relevant Steering Group suitable for distribution to users
Operational	Products or software packages with documented non-relevant limitations that largely satisfy the requirements applicable and/or have been considered by the relevant Steering Group mature enough for distribution to users

The need for early release of products to activate the Hydrological validation programme as soon as possible led to define a stepwise approach for H-SAF products development. This is shown in ***Fig. 03***.

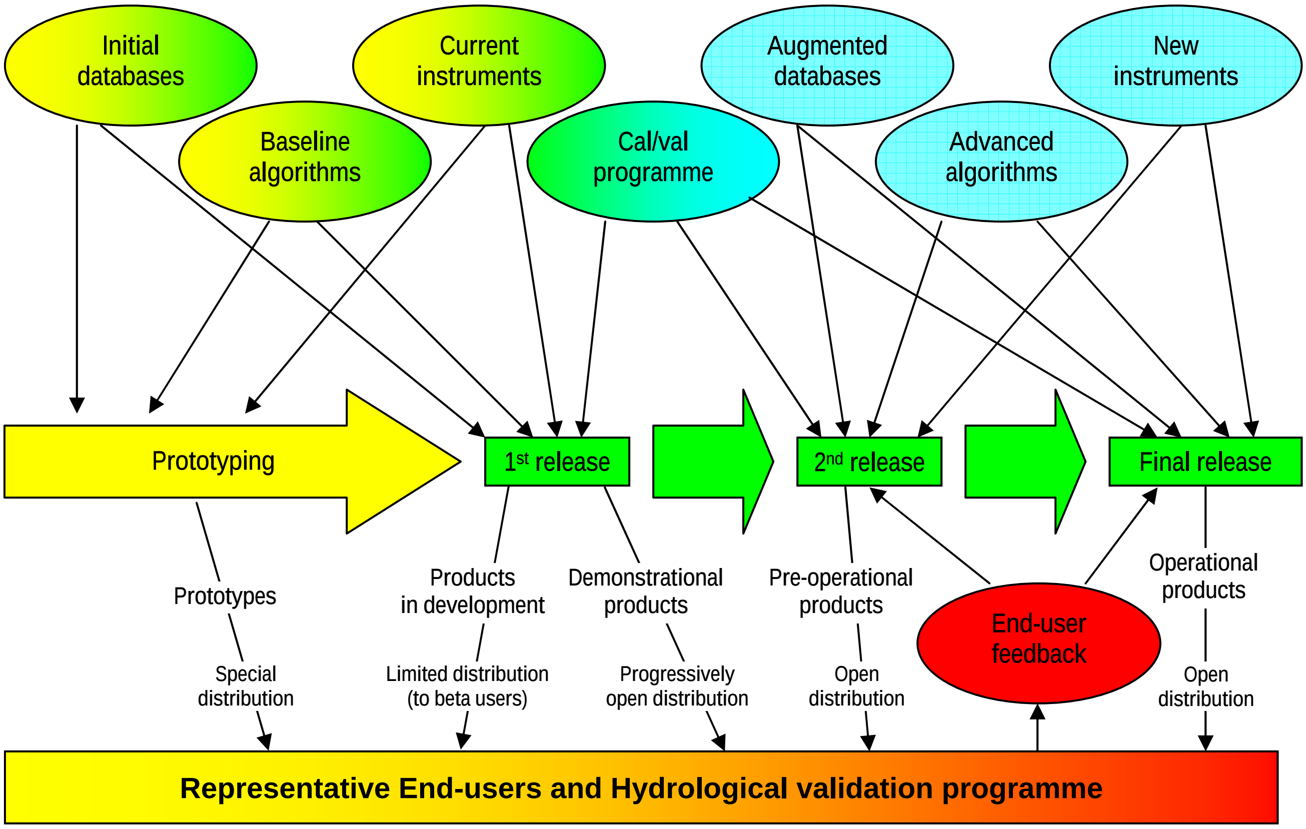

Fig. 03 - Logic of the incremental development scheme.

The time reference for this work plan is as follows:

- after approximately two years from the start of the Project (i.e. starting from the nominal date of 1st January 2008) a substantial fraction of the products listed in Table 01 are released first as "in development" and then after, as soon as some validation is performed, as "demonstrational";
- in the remaining three years the Hydrological validation programme builds up and grows. Mid-time, i.e. in mid-2009, the products of the first release are supposed to become "pre-operational", and the products missing the first release reach at least a demonstrational status. All products should become "operational" at the end of the Development Phase (31 August 2010).

Until the products are in the development status, their distribution is limited to the so-called *beta users*. Demonstrational, pre-operational and operational products have open distribution.

It is fair to record that not all products have been able to follow this schedule. Therefore, at the end of the Development Phase, the status of "in development", "demonstrational", "pre-operational" and "operational" will apply differently to the different products.

1.4 User service

In this section a short overview of the User service is provided, in terms of product geographic coverage, data circulation and management, Web site and Help desk.

1.4.1 Product coverage

Fig. 04 shows the required geographic coverage for H-SAF products. This area is fully covered by the Meteosat image (although the resolution sharply decreases at higher latitudes) each 15 min. For polar satellites, the area is covered by strips of swath approximately 1500 km (conical scanners) or 2200 km (cross-track scanners) at about 100 min intervals. Swaths intercepting the acquisition range of direct-read-out stations provide data in few minutes; for swaths outside the acquisition range the delay may be several tens of minutes if the satellite/instrument data are part of the EARS / EUMETCast broadcast, some hours otherwise (e.g., by ftp). The time resolution (*observing cycle*) is controlled by the number of satellites concurring to perform the observation, and the instrument swath.

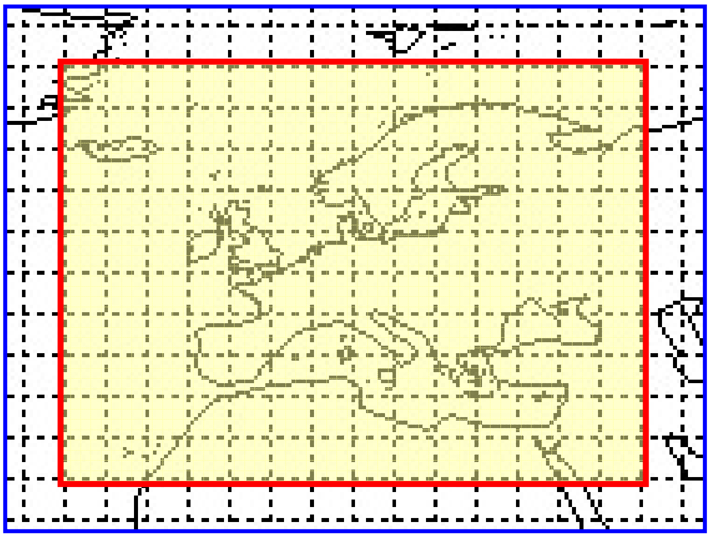

Fig. 04 - Required H-SAF coverage: 25-75°N lat, 25°W - 45°E

1.4.2 Data circulation and management

Fig. 05 shows the data circulation scheme in H-SAF. All products from the generating centres are concentrated at CNMCA (except that certain can go directly to the user by dedicated links: example, GTS, Global Telecommunication System connecting operational meteorological services). From CNMCA the data are sent to EUMETSAT to be broadcast by EUMETCast in near-real-time.

All data also go to the H-SAF Archive where they can be accessed through the EUMETSAT Data Centre via a Client. Therefore, the H-SAF products may be accessed:

- via EUMETCast in near-real-time (primary access mode);
- off-line via the EUMETSAT Data Centre (most common access mode for the scientific community);
- by dedicate links such as GTS (fastest mode, generally available to operational meteorological services).

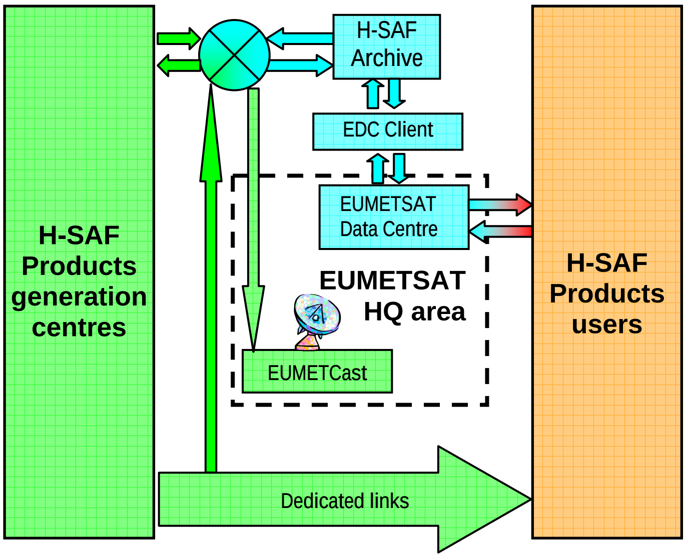

Fig. 05 - H-SAF central archive and distribution facilities.

It is noted that this scheme is valid only for pre-operational and operational products. For products in development disseminated to beta-users only, or demonstrational products, the distribution ordinarily utilises the ftp servers of the product generation centres, or the CNMCA server. CNMCA also re-disseminate the products generated in other centres, therefore <u>all</u> products can be retrieved from the CNMCA server.

The ftp dissemination stream will continue to be active even after the EUMETCast dissemination becomes effective, both for redundancy purpose, and for users not equipped for EUMETCast reception.

1.4.3 The H-SAF web site

The address of the H-SAF web site is:

- http://www.meteoam.it/modules.php?name=hsaf .

The web site provides:

- general public information on H-SAF
- H-SAF products description
- rolling information on the H-SAF implementation status
- an area for collecting/updating information on the status of satellites and instruments used in H-SAF
- an area to collect Education and Training material
- an area for "forums" (on algorithms, on validation campaigns, etc.)
- indication of useful links (specifically with other SAF's)
- an area for "Frequently Asked Questions" (FAQ) to alleviate the load on the Help desk.

The web site supports operations by providing:

- daily schedule of H-SAF product distribution
- administrative messages on changes of product version (new algorithms, etc.).

The web site contains some basic H-SAF documents (the ATDD, Algorithms Theoretical Definition Document; this Product User Manual, …). However, most working documents (REP-3: Report of the Products Validation Programme; REP-4: Report of the Hydrological Validation Programme; etc.), programmatic documents (PP: Project Plan; URD: User Requirements Documents; etc.) and engineering documents are to be found in the CNMCA ftp server (restricted access; see later for the URL).

It is noted that certain areas of the web sites are protected by an ID ("satelliti") and a password (again, "satelliti").

1.4.4 The Help desk

For any question that cannot be solved by consulting the web site, specifically the FAQ area, the following Help desk is available:

- hsaf user support <us_hsaf@meteoam.it>

When addressing the Help desk, the user should specify in the "Subject" one of the following codes:

- MAN (management)
- PRE (precipitation)
- SOM (soil moisture)
- SNO (snow)
- HYD (hydrology)
- ARC (archive)
- GEN (general).

1.5 The Products User Manual and its linkage to other documents

Product User Manuals are available for each (pre)-operational H-SAF product, for open users, and also for demonstrational products, as necessary for *beta-users*.

Each PUM repeats:

- Chapter 1, this Introduction, that includes common information on Objectives and products, Evolution of H-SAF products, User service and Guide to the Products User Manual;

followed by Chapters specific to each product:

- Chapter 2, that introduces the specific product: Principle of sensing, Satellites utilized, Instrument(s) description, Highlights of the algorithm, Architecture of the products generation chain, Product coverage and appearance;

- Chapter 3, that describes the main product operational characteristics: Horizontal resolution and sampling, Vertical resolution if applicable (only for SM-ASS-1), Observing cycle and time sampling, Timeliness;
- Chapter 4, that provides an overview of the product validation activity: Validation strategy, Global statistics, Product characterisation
- Chapter 5, that provides basic information on product availability: Access modes, Description of the code, Description of the file structure

Although reasonably self-standing, the PUM's rely on other documents for further details. Specifically:

- ATDD (*Algorithms Theoretical Definition Document*), for extensive details on the algorithms, only highlighted here;
- PVR (*Product Validation Report*), for full recount of the validation activity, both the evolution and the latest results.

These documents are structured as this PUM, i.e. one document for each product. They can be retrieved from the CNMCA site:

- ftp://ftp.meteoam.it - username: *hsaf* - password: *00Hsaf* - directory: *hsaf* - folder: *Final-Report-Development-Phase*.

On the same site, it is interesting to consult, although not closely connected to this PUM, the full reporting on hydrological validation experiments (*impact studies*):

- HVR (*Hydrological Validation Report*), spread in 10 Parts, first one on requirements, tools and models, then 8, each one for one participating country, and a last Part with overall statements on the impact of H-SAF products in Hydrology.

1.6 Relevant staff associated to the User Service and to product PR-ASS-1

Table 04 records the names of the persons associated to the development and operation of the User service and of product PR-ASS-1.

Table 04 - Relevant persons associated to the User service and to product PR-ASS-1

User service development and operation			
Adriano Raspanti (Leader)	Centro Nazionale di Meteorologia e Climatologia Aeronautica (CNMCA)	Italy	a.raspanti@meteoam.it
Leonardo Facciorusso			l.facciorusso@meteoam.it
Francesco Coppola			f.coppola@meteoam.it
Giuseppe Leonforte			g.leonforte@meteoam.it
Product Development Team			
Lucio Torrisi (Leader)	Centro Nazionale di Meteorologia e Climatologia Aeronautica (CNMCA)	Italy	l.torrisi@meteoam.it
Francesca Marcucci			marcucci@meteoam.it
David Palella			palella@meteoam.it
Product Operations Team			
Francesco Zauli (Leader)	Centro Nazionale di Meteorologia e Climatologia Aeronautica (CNMCA)	Italy	f.zauli@meteoam.it
Davide Melfi			d.melfi@meteoam.it
Daniele Biron			d.biron@meteoam.it

2. Introduction to product PR-ASS-1

2.1 Principle of the product

Product PR-ASS-1 (*Instantaneous and accumulated precipitation at ground computed by a NWP model*) is the output of the operational COSMO-ME NWP model in use at CNMCA. Its main characteristics are shown in ***Fig. 06***.

Model Equations

- Basic hydro-thermodynamical equations in advection form,
- no scale approximations (i.e. fully compressible and non-hydrostatic),
- substraction of horizontally homogeneous basic state at rest.

Prognostic Variables

- Horizontal and vertical wind components (u,v,w)
- Temperature (T)
- Pressure perturbation (p', deviation from the reference state)
- Specific humidity (qv),
- Specific cloud water content (qc)
- Specific cloud ice content (qi)
- Specific rain content (qr)
- Specific snow content (qs)
- Turbulent kinetic energy (tke)
- Optionally, specific graupel content (qg)

Coordinate System

- Rotated geographical (lat/lon) coordinate system horizontally,
- Generalized terrain-following height-coordinate vertically.

Grid Structure

- Arakawa C-grid, Lorenz vertical grid staggering

Spatial Discretization

- Second-order horizontal and vertical differencing (centred)

Time Integration

- 3 time-level (Leapfrog) split explicit using extensions proposed by Skamarock and Klemp (1992).
- Additional Options:
  - 2 time-level Runge-Kutta 3rd-order scheme (regular or TVD) with various options for high-order spatial discretization (Forstner and Doms, 2004),
  - 3 time-level semi-implicit scheme (Thomas et al., 2000),
  - 2 time-level Runge-Kutta 2nd order split-explicit scheme (Wicker and Skamarock, 1998).

Numerical Smoothing

- Rayleigh damping layer at upper boundary
- 4th order linear horizontal diffusion with option for a monotonic version including an orographic limiter,
- 3-D divergence damping and off-centering in split steps

Lateral Boundaries

- 1-way nesting using the lateral boundary formulation to Davies and Turner (1977).

Initialization

- Diabatic digital filtering initialization scheme (Lynch et al. 1997)

Grid-Scale Clouds and Precipitation

- Cloud water formation dissipation by saturation adjustment.
- Precipitation formation by a bulk-parameterization including water vapour, cloud water, cloud ice, rain and snow as hydrometeor categories (Doms 2002; Baldauf and Schultz 2004; Reinhardt and Seifert 2006).

Subgrid-Scale Clouds

- Subgrid-scale cloudiness (fractional cloud cover) is interpreted by an empirical function depending on relative humidity. A corresponding cloud water content is also diagnosed.

Moist Convection

- Mass-flux convection scheme after Tiedtke (1989) with closure based on moisture convergence.
- Option for a modified closure based on CAPE.

Radiation

- δ-two stream radiation scheme based on Ritter and Geylen (1989) for short- and longwave fluxes; full cloud-radiation feedback.

Turbulent Diffusion

- Level 2.5-scheme with a prognostic treatment of turbulent kinetic energy; effects of subgrid-scale condensation and evaporation are included.
- Optionally, diagnostic K-closure (at hierarchy level 2) for vertical diffusion.

Subgrid-scale orography

- Blocked flow and gravity wave drag (Lott and Miller, 1997).

Surface Layer

- Scheme based on turbulent kinetic energy; includes effects from subgrid-scale thermal circulations.
- Optionally, constant flux layer parameterization.

Soil Processes

- Multi-layer soil model including freezing of soil water (Schrodin and Heise, 2001).
- Optionally, two-layer soil model after Jacobsen and Heise (1984) with Penman-Monteith type transpiration. Snow and interception storage are included. Climate values changing monthly (but fixed during forecast) in third layer.

Current area coverage

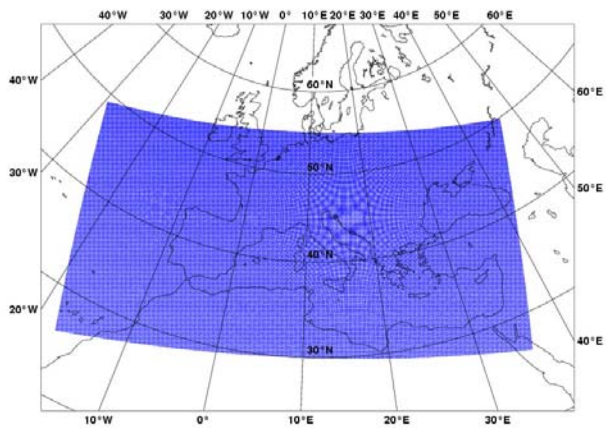

Fig. 06 - COSMO-ME model formulation and current area coverage.

The role of PR-ASS-1 is to provide a background precipitation field regular in space and time, unlike satellite-derived observations that are available at changing times and locations, depending on the specific orbit. The product has been developed, is operationally running and is being progressively improved at CNMCA. It is a "best effort" product: e.g., the covered area (as shown in Fig. 06), and the number of runs/day will not meet H-SAF requirement by the end of the Development Phase; but it is a fully operational product.

2.2 Highlights of the algorithm

The baseline algorithm for PR-ASS-1 processing is described in ATDD-06. Only essential elements are highlighted here.

Fig. 07 illustrates the module that most concerns the precipitation products, the so-called "two-category ice scheme" (Doms 2002[1]; Baldauf and Schultz 2004[2]). This parameterization considers water vapour, cloud water, cloud ice, rain and snow as prognostic variables in the hydrological cycle and allows for the simulation of precipitation formation in water, mixed-phase and ice clouds. In the near future a three category ice scheme (Reinhardt and Seifert 2006[3]) comprising graupel will be implemented.

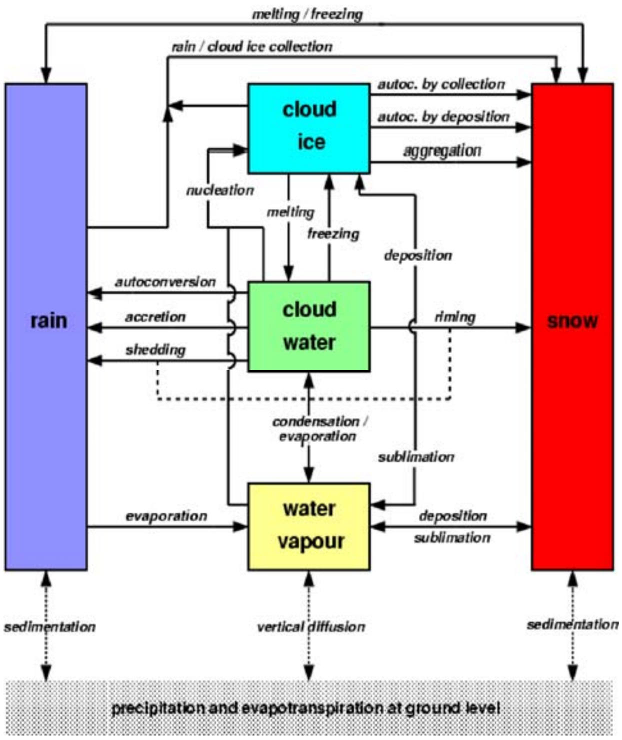

Fig. 07 - Cloud microphysical processes considered in the two-category ice scheme.

The COSMO-ME model having a 7 km grid spacing uses a cumulus parameterization; in particular the Tiedtke mass-flux scheme is switched on. In the mass-flux schemes the effects of the clouds on the resolvable-scale variables are parameterized in terms of the convective mass fluxes and the convection is assumed to influence the environment through environmental subsidence and detrainment at the top of the updraft or the bottom of the downdraft. In the Tiedke scheme a 1-dimensional cloud model is closed by making convection (triggering and intensity) dependent on the moisture supply by large-scale flow convergence and boundary layer turbulence. The vertical distribution of heating and drying is estimated using the cloud model to satisfy the constraints on intensity. Column equilibrium is supposed for precipitation formed in convective clouds where the source/sink terms include the conversion of cloud water to form rain, the evaporation of rain in the downdraft and below cloud base.

---

[1] Doms G., 2002: "The LM cloud ice scheme". *Cosmo Newsletter*, No. 2, 128-136. Available on line at www.cosmo-model.org.

[2] Baldauf M. and J.P. Schultz, 2004: "Prognostic precipitation in the Lokal Modell (LM) of DWD". *Cosmo Newsletter*, No. 4, 177-180. Available on line at www.cosmo-model.org.

[3] Reinhardt T. and A. Seifer 2006:"A three category Ice Scheme for LMK", *Cosmo Newsletter*, No. 6, 115-120. Available on line at www.cosmo-model.org .

2.3 Architecture of the products generation chain

The architecture of the PR-ASS-1 product generation chain is shown in ***Fig. 08***

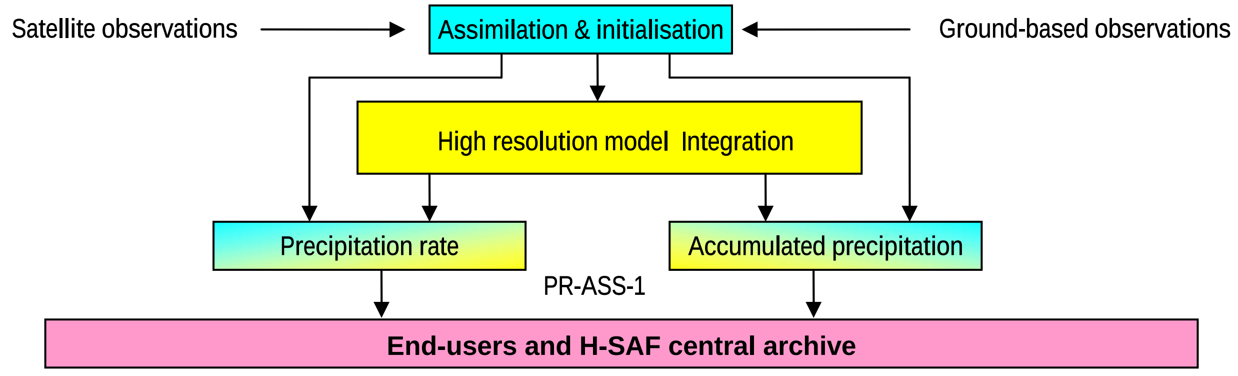

Fig. 08 - Products generation chain for PR-ASS-1.

The output consists of five figures at 3-hour intervals:

- the precipitation rate and
- the accumulated precipitation over the previous 3, 6, 12 and 24 hours.

The product is disseminated to the Users by FTP and also intended to be utilised internally in support of other H-SAF products, especially PR-OBS-5 (*Accumulated precipitation at ground by blended MW and IR*), for constraining the output in order to reduce biases [not yet implemented].

2.4 Product coverage and appearance

Fig. 09 and ***Fig. 10*** show examples of PR-ASS-1 products, a 24-hour accumulated precipitation map and a map of instantaneous precipitation, respectively. It is noted that the product does not cover the full H-SAF area. However, the area will be progressively extended in the course of CDOP. Maps are in *equal latitude/longitude projection*. The products result from the forecasting run started at a T_0 conveniently in advance so as to enable the output to be sufficiently stabilised. The accumulated precipitation in the first figure refers to the previous 24 h.

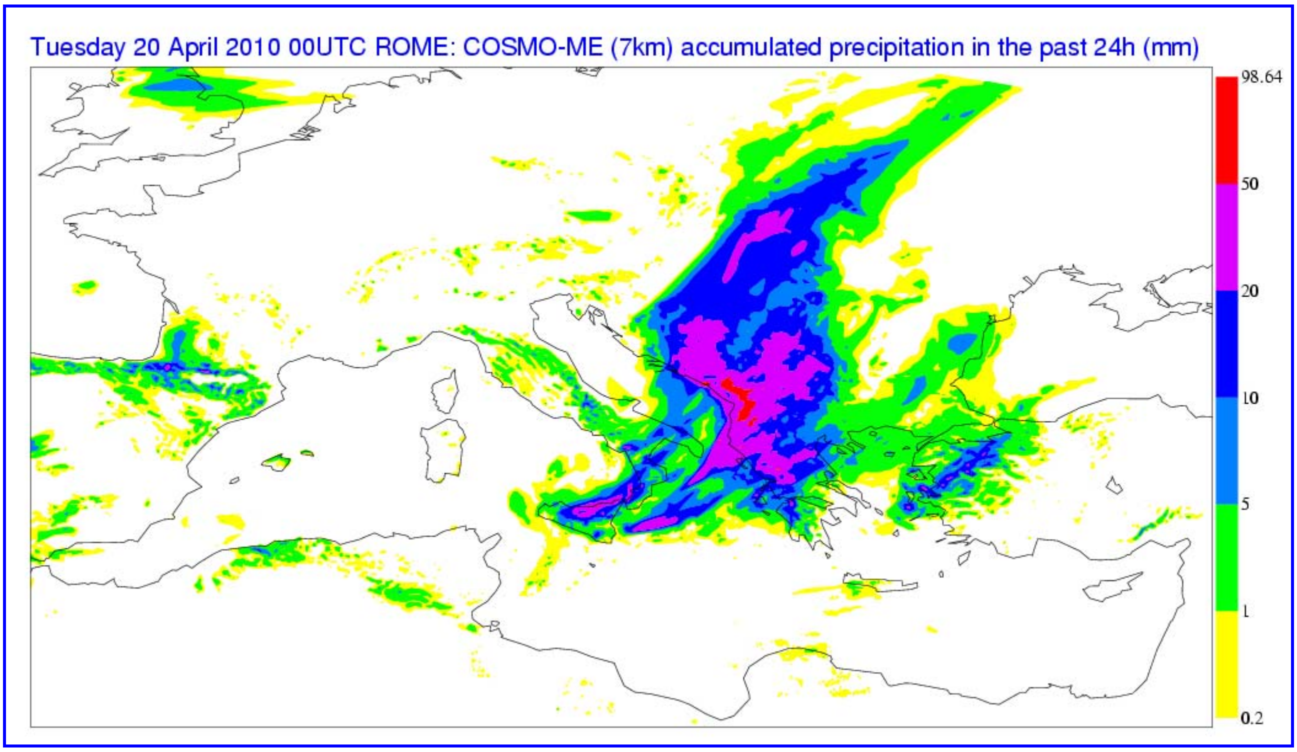

Fig. 09 - 24-hour accumulated precipitation from COSMO-ME for 20 Apr 2010, 00 UTC. Forecast run initialised at 00 UTC of 19 Apr 2010.

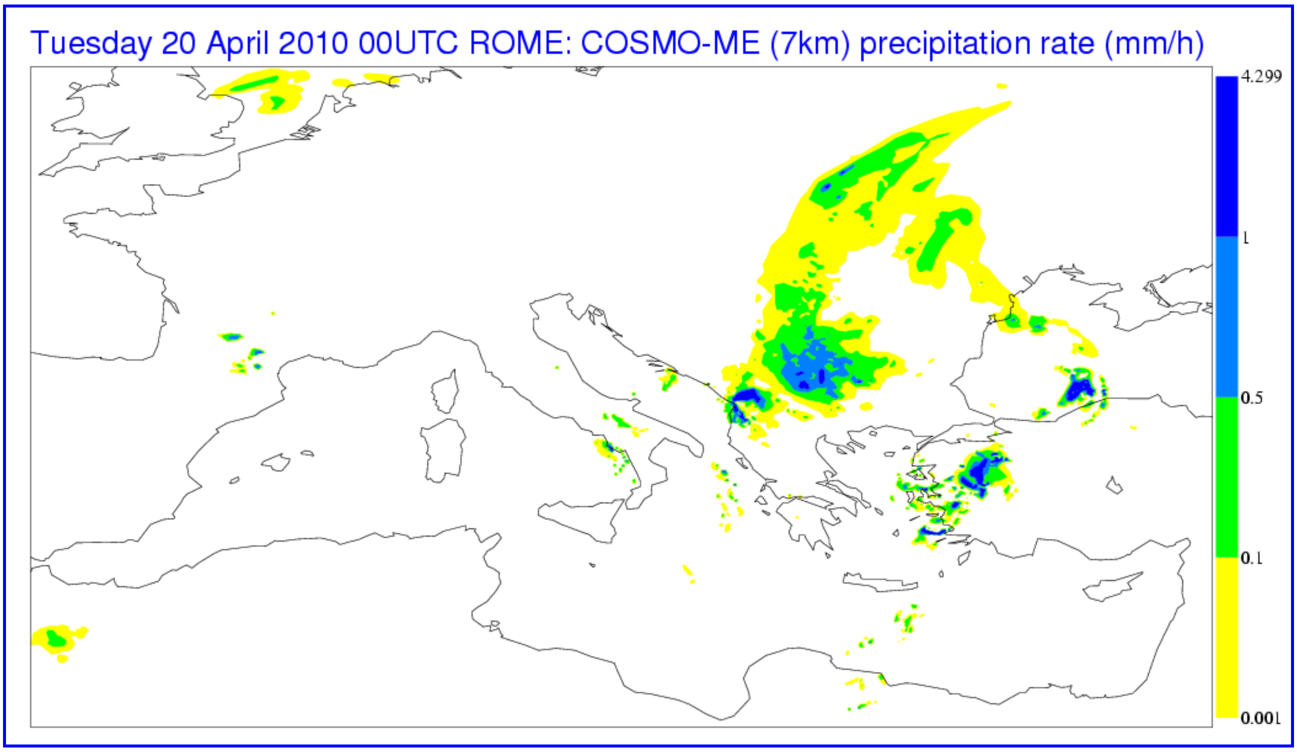

Fig. 10 - Instantaneous precipitation from COSMO-ME for 20 Apr 2010, 00 UTC. Forecast run initialised at 00 UTC of 19 Apr 2010.

3. Product operational characteristics

3.1 Horizontal resolution and sampling

The *horizontal resolution (Δx)* is the convolution of several features (sampling distance, degree of independence of the information relative to nearby samples, …). To simplify matters, it is generally agreed to refer to the sampling distance between two successive product values, assuming that they carry forward reasonably independent information. For a product generated by a NWP model, very often the resolution is quoted as the grid mesh (7 km for COSMO-ME), but this is not correct. The model describes the evolution of waves, and the accuracy of description depends on the specific parameter, For precipitation, the scale of motion correctly described by COSMO-ME is several tens of kilometres. It is estimated that the resolution in terms of motion scale correctly represented in the model is ***Δx ~ 30 km***. Sampling interval is ***~ 7 km*** (the grid mesh).

3.2 Vertical resolution if applicable

The vertical resolution (Δz) also is defined by referring to the vertical sampling distance between two successive product values, assuming that they carry forward reasonably independent information. In H-SAF, the only product with vertical structure is SM-ASS-1, Volumetric soil moisture.

3.3 Observing cycle and sampling time

The *observing cycle (Δt)* is defined as the average time interval between two measurements over the same area. In the case of PR-ASS-1, that is generated by a NWP model, the concept is not applicable because the observations utilised in the model may have been taken long before. In addition, the model output is controlled by the main predictive parameters (profiles of wind, temperature and humidity) whereas the observation of precipitation is not directly assimilated. It is therefore appropriate to adopt as observing cycle that one associated to the number of runs/day. For COSMO-ME there are currently two runs/day, at 00 and 12 UTC, therefore it is correct to quote an observing cycle ***Δt = 12 h*** (to be reduced to Δt = 6 h in the near future, when runs at 06 and 18 UTC will be added). All products are outputted at ***3-hour*** intervals, that therefore represents the sampling time.

3.4 Timeliness

The *timeliness (δ)* is defined as the time between observation taking and product available at the user site assuming a defined dissemination mean. In the case of a forecast product the usual definition of timeliness does not apply. Rather, timeliness is intended as the difference between the nominal time of the run start and the availability of forecast products, inclusive of the window cut-off for observation collection, analysis, initialisation, processing and output stabilisation. For COSMO-ME this is currently ***δ ~ 4 h***.

4. Product validation

4.1 Validation strategy

Whereas the previous operational characteristics have been evaluated on the base of the COSMO-ME model characteristics and its operational features, the evaluation of accuracy requires validation, i.e. comparison with the ground truth or with something assumed as "true". PR-ASS-1, as any other H-SAF product, has been submitted to validation entrusted to a number of institutes (see ***Fig. 11***).

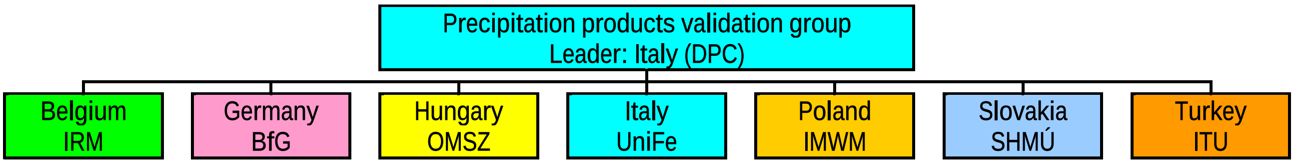

Fig. 11 - Structure of the Precipitation products validation team.

Precipitation data have been compared with rain gauges and meteorological radar. Before undertaking comparison, ground data and model-grid data have been submitted to scaling and filtering procedures. Two streams of activities were carried out:

- evaluation of general statistics (multi-categorical and continuous), to help in identifying existence of pathological behaviour
- selected case studies, useful in identifying the roots of such behaviour.

Detailed report of the product validation activity for product PR-ASS-1 is provided as document:

- PVR-06: Product Validation Report for PR-ASS-1.

In this PUM-06 only summary results are provided, mainly aiming at characterising the seasonal variability of the product quality.

4.2 Summary of results

Products PR-ASS-1 have been available for H-SAF purposes since early 2008 and since then have been regularly distributed. PR-ASS-1 actually provides five products each set extracted each three hours:

- precipitation rate, and accumulated precipitation over 3, 6, 12 and 24 h.

A selection of results are reported in ***Table 05***. The results are reported for each season and for the yearly average. The following statistical scores are reported (for more information, see PVR-06):

- ME: Mean Error
- RMSE (%): Root Mean Square Error expressed as % of the rain rate or accumulated at station
- POD: Probability Of Detection
- FAR: False Alarm Rate.

Comparisons are recorded separately for precipitation intensity and accumulated precipitation. The precipitation intensity is split in three classes:

- heavy (> 10 mm/h)
- medium (1-10 mm/h)
- light (< 1 mm/h).

The accumulated precipitation is integrated over 3, 6, 12 and 24 hours.

The most significant features of the performance is the RMSE (%), "yellow" rows in Table 05 (for rain rate, the medium intensity, 1-10 mm/h, is considered the most significant).

Table 05 - Abstract of validation results for products PR-ASS-1. Validation tools: radar and gauge

Spring: March, April and May 2009	Summer: June, July and August 2009	Autumn: Sept., Oct. and Nov. 2009	Winter: Dec. 2009, Jan. and Feb. 2010

PR-ASS-1	Version 1.0	Spring 2009	Summer 2009	Autumn 2009	Winter 2009/10	Yearly average
Instantaneous						
N. of samples	> 10 mm/h	6,784	16,248	12,288	4,816	40,136
	1-10 mm/h	419,371	453,280	463,961	497,864	1,834,476
	< 1 mm/h	785,656	502,999	780,873	1,273,711	3,343,239
ME (mm/h)	> 10 mm/h	-16.7	-16.0	-15.0	-12.4	-15.4
	1-10 mm/h	-1.44	-1.96	-1.49	-1.21	-1.52
	< 1 mm/h	-0.15	-0.12	-0.07	-0.17	-0.13
RMSE (%)	> 10 mm/h	92	96	93	82	93
	1-10 mm/h	113	119	102	88	105
	< 1 mm/h	184	302	221	149	197
POD	≥ 0.25 mm/h	0.30	0.21	0.34	0.34	0.31
FAR	≥ 0.25 mm/h	0.65	0.78	0.64	0.59	0.65
Accumulated						
3 h	N. of samples	1,798,567	1,569,510	1,908,716	2,308,136	7,584,929
	ME (mm)	-1.40	-2.12	-1.62	-1.13	-1.52
	RMSE (%)	128	151	122	109	125
	POD (≥ 1 mm)	0.43	0.30	0.46	0.46	0.42
	FAR (≥ 1 mm)	0.60	0.72	0.57	0.46	0.57
6 h	N. of samples	1,122,479	1,384,377	1,307,524	1,587,946	5,402,326
	ME (mm)	-1.19	-1.71	-1.04	-1.27	-1.31
	RMSE (%)	165	191	145	106	149
	POD (≥ 1 mm)	0.48	0.43	0.51	0.42	0.46
	FAR (≥ 1 mm)	0.50	0.58	0.45	0.34	0.46
12 h	N. of samples	1,818,273	2,130,926	2,114,676	2,674,246	8,738,121
	ME (mm)	-1.27	-1.56	-0.99	-1.58	-1.37
	RMSE (%)	202	212	152	112	165
	POD (≥ 1 mm)	0.58	0.53	0.58	0.47	0.53
	FAR (≥ 1 mm)	0.40	0.47	0.34	0.24	0.35
24 h	N. of samples	5,639,952	4,630,486	5,777,685	8,837,111	24,885,234
	ME (mm)	-1.25	-2.11	-1.68	-1.31	-1.53
	RMSE (%)	200	223	176	145	179
	POD (≥ 1 mm)	0.67	0.58	0.62	0.65	0.63
	FAR (≥ 1 mm)	0.27	0.38	0.24	0.16	0.24

5. Product availability

5.1 Site

PR-ASS-1 will be available via EUMETCast (when authorized) and via FTP (after log in).

The current access is via FTP at the following site:

- URL: ftp://ftp.meteoam.it
- username: *hsaf*
- password: *00Hsaf* .

In the FTP site there are three relevant directories:

- *products*, for near-real-time dissemination;
- *reprocess_year*, for previous months;
- *utilities*, for providing decoding tools.

5.2 Directory "*products*"

In this directory the products appear shortly after generation, consistently with the "timeliness" requirement. They are kept available for nominally 1-2 months, often more.

Quick-looks of the latest set of 5 PR-ASS-1 maps (rate and accumulated over 3, 6, 12 and 24 h) can be viewed on the H-SAF web site:

- http://www.meteoam.it/modules.php?name=hsaf
- directory: *products*, sub-directory: *precipitation*, ID: *satelliti*, password: *satelliti*.

5.3 Directory "*reprocessed_year*"

Currently "reprocessed_2010". This directory holds the data of the previous months, minimum six, processed or reprocessed by the same software release as in *products* (i.e. the latest release).

Older data are stored in the permanent H-SAF archive, and can be recovered on request.

5.4 Directory "*utilities*"

This directory provides tools to decode and manage the digital data.

5.5 Formats and codes

Two type of files are provided for PR-ASS-1:

- the digital data, coded in GRIB1
- the image-like maps, coded in PNG.

In the directory "*utilities*", the folder *grib1_decode* provides the instructions for reading the digital data. In addition, the output description of PR-ASS-1 is provided in Appendix.

5.6 Description of the files

Current data

- Directory: *products*
- Sub-directory: *h06*
- Two folders:
  - h06_cur_mon_grb
  - h06_cur_mon_png

Recent past data

- Directory: *reprocess_year*
- Sub-directory: *h06*

- Monthly folders of two sub-folders:
  - h06_yyyymm_grb
  - h06_yyyymm_png

In both directories *products* and *reprocess* the files have identical structures. ***Table 13*** summarises the situation and provides the information on the file structure, including the legenda.

Table 06 - Summary instructions for accessing PR-ASS-1 data

<table>
<tr><td colspan="2">URL: ftp://ftp.meteoam.it</td><td>username: hsaf</td><td>password: 00Hsaf</td></tr>
<tr><td colspan="2">Directory: products - Product identifier: h06</td><td colspan="2">Directory: reprocess_year - Product identifier: h06</td></tr>
<tr><td>h06_cur_mon_grb</td><td rowspan="2">data of current months</td><td>h06_yyyymm_grb</td><td rowspan="2">data of previous months</td></tr>
<tr><td>h06_cur_mon_png</td><td>h06_yyyymm_png</td></tr>
<tr><td rowspan="2">Files description
(for both directories)</td><td colspan="2">h06_yyyymmdd_hh_ii_rom.grb</td><td>digital data</td></tr>
<tr><td colspan="2">h06_yyyymmdd_hh_ii_rom.png</td><td>image data</td></tr>
<tr><td>yyyymm:</td><td colspan="3">year, month</td></tr>
<tr><td>yyyymmdd:</td><td colspan="3">year, month, day</td></tr>
<tr><td>hh:</td><td colspan="3">nominal synoptic hour to which the product refers (00, 03, 06, 09, 12, 15, 18, 21 UTC)</td></tr>
<tr><td>ii:</td><td colspan="3">integration interval (00, i.e. instantaneous precipitation, and previous 03, 06, 12 or 24 hours)</td></tr>
</table>

5.7 Condition for use

All H-SAF products are owned by EUMETSAT, and the EUMETSAT SAF Data Policy applies. They are available for all users free of charge.

Users should recognise the respective roles of EUMETSAT, the H-SAF Leading Entity and the H-SAF Consortium when publishing results that are based on H-SAF products. EUMETSAT's ownership of and intellectual property rights into the SAF data and products is best safeguarded by simply displaying the words "**© EUMETSAT**" under each of the SAF data and products shown in a publication or website.

See Appendix: *PR-ASS-1 Output description*

Appendix: PR-ASS-1 Output description

The PR-ASS1 products are the precipitation rate and the accumulated precipitation over the previous 3, 6, 12 and 24 hours obtained by COSMO-ME numerical model. They are encoded in GRIB1, as described in World.

GRIB is the name of a data representation form for general regularly-distributed information in binary, encoded in keys and as a continuous bit-stream made of a sequence of octets (1 octet = 8 bits), that could be grouped in sections:

Section Number	*Section Name*	*Section Contents*
0	Indicator	"GRIB", Discipline, GRIB Edition number, length of message
1	Product definition section	Length of section, section number, characteristics of containing data
2	Grid description section	Length of section, section number, definition of grid surface and geometry
3	Bit map section	Length of section, section number, bitmap
4	Data section	Length of section, section number, data
5	End Section	"7777"

The beginning and the end of the code shall be identified by 4 octets coded according to the International Alphabet No. 5 to represent the indicators "GRIB" and "7777" in Indicator Section 0 and End Section 5, respectively. All other octets included in the code shall represent data in binary form.

In the followings the GRIB keys that are significant for the product and their assigned values:

Section 0:
"GRIB"
"editionNumber" = 1; *GRIB edition number 1*

Section 1:
"centre" = 80; *Rome (RSMC)*, Common Code Table C-11
"table2Version" = 2; *Current operational version number 3*, Code Table 1.0
"indicatorOfParameter" =59; *Precipitation rate (for the precipitation rate)*
=61; *Total precipitation (for the accumulated precipitation)*
"indicatorOfTypeOfLevel"=1 *Surface*
"year", *Year of reference time*
"month", *Month of reference time*
"day", *Day of reference time*
"hour", *Hour of reference time*
"minute", *Minute of reference time*
"second" = 0; *Actually indication for seconds fixed at 0*
"stepUnits" = 1; *Hour*
"timeRangeIndicator" =0; *Uninitialized analysis product for reference time (for the precipitation rate)*
=4; *Accumulation (reference time + P1 to reference time + P2) product considered valid at reference time + P2 (for the accumulated precipitation)*
"P1" =0; *(for the precipitation rate)*
=P1*; (for the accumulated precipitation)*
"P2" =0; *(for the precipitation rate)*
=P2*; (for the accumulated precipitation)*

Note:
The rain rate product is valid at the reference time.
The accumulated precipitation products are valid at the reference time + P2 and they represent the precipitation accumulated over the previous P2-P1 hours (= 3, 6, 12, 24).

Section 2:
"dataRepresentationType"=10; *Rotated Latitude/Longitude grid*
"Ni"=779; *No of points along a parallel*
"Nj"=401; *No of points along a meridian*
"latitudeOfFirstGridPoint" =-13000;
"longitudeOfFirstGridPoint" =-25250;

“latitudeOfLastGridPoint” =12000;
“longitudeOfLastGridPoint” =23375;
“latitudeOfSouthernPole” =-47000;
“latitudeOfSouthernPole” =10000;

Section 3:

Bitmap is not present in this product

Section 4:

"numberOfCodedValues" = 312379;
"numberOfBitsContainingEachPackedValue" = 16; *Number of bits used for each packed value*
"missingValue" = 9999;
"values" = {…} ; *array of product values*