ESA WACMOS IASI-SEVIRI merged water vapour product

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Introduction

Water vapour is a key variable in the earth's water and energy cycles. The latent heat flux from the surface to the atmosphere that is associated with evaporation or condensation of water vapour plays a major role in the energy cycle. In addition, water vapour is the most effective greenhouse gas and due to a strongly positive climate feedback, it plays an amplifying role in global warming.

Water vapour strongly varies in space and time leading to the necessity of its global monitoring from satellites. Today, a large number of scientific and operational satellites are capable of providing information on atmospheric water vapour.

Various spectral ranges and retrieval techniques are utilized, each having its own particular advantages and disadvantages. Hence, the combination of measurements from different sensors is expected to result in products with improved quality, coverage and resolution.

In the framework of ESA's Water Cycle Multi-Mission Observation Strategy (WACMOS) a merged water vapour product based on the MetOp IASI and MSG SEVIRI is currently developed. It combines the high vertical sampling and expected high quality of IASI measurements with the high temporal sampling of SEVIRI using a Kriging approach.

WACMOS

ESA's Water Cycle Multi-Mission Observation Strategy (WACMOS) is a Support to Science Element (STSE) and an ESA contribution to GEWEX. WACMOS is motivated by the increasing potential of synergic capabilities and the growing needs for coherent long-term geo-information datasets.

The project goal is the development and the validation of a Product Portfolio of water multi-mission based enhanced datasets maximising the use of ESA data. The four WACMOS priorities comprise evapotranspiration, soil moisture, clouds and water vapour. The project members are the International Institute for GeoInformation Sciences and Earth Observations (ITC), Vrije University Amsterdam (VUA), The Technical Unitversity of Vienna (TUW) and Germany's National Meteorological Service (DWD).

Methodology

Product Description

WACMOS aims at developing an improved water vapour product by combining the high temporal resolution of SEVIRI with the high vertical resolution of IASI (Fig. 1). The merged SEVIRI + IASI product will provide tropospheric water vapour profiles in three vertical layers for a region covering the full MSG disc with a spatial resolution of (0.25°)². The time period between June 2008 and May 2009 is processed with a three-hourly temporal resolution. Regarding accuracy, the bias and the RMSE are expected to be smaller than the values given in Tab. 1.

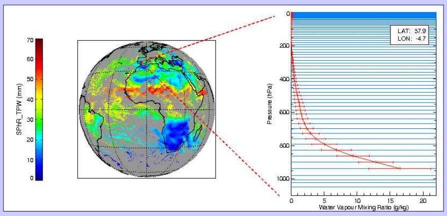


Fig.1: SEVIRI total precipitable water (TPW) on August 01 2008, obtained with the new NWC/SAF SEVIRI Physical Retrieval (left). Water vapour mixing ratio from the EUMETSAT IASI Level 2 product at one pixel in Spain on August 01 2008 (right).

Parameter	Layer 1 (200-500 hPa)	Layer 2 (500-850 hPa)	Layer 3 (850 - surface)
Bias (kg m^{-2})	0.2	0.6	0.8
RMSE (kg m^{-2})	0.8	2.0	3.0

Tab.1: Expected upper limits of bias and root mean square error (RMSE) of the merged layered water vapour for the three vertical layers.

Processing Steps

The data and processing steps involved in the generation of the merged SEVIRI + IASI water vapour product are illustrated in Fig. 2. IASI Level 2 data (native files) were delivered by EUMETSAT's Unified Meteorological Archive and Retrieval Facility (U-MARF). SEVIRI level 1.5 and the SEVIRI CM-SAF cloud mask are available from the DWD data archive.

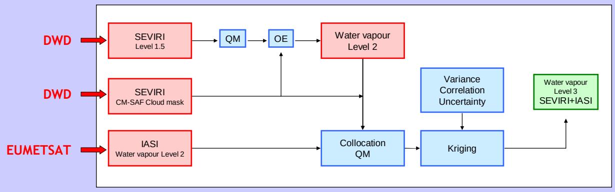


Fig. 2: Flow chart of the merged SEVIRI+IASI water vapour product (QM:quality monitoring, OE: optimal estimation). Blue boxes: processing steps with software developed and applied during WACMOS. Red boxes: input fields from external source. Green box: Envisaged end product.

SEVIRI Level 2 Processing

A new SEVIRI Physical Retrieval (SPhR) of temperature and moisture profiles, developed by the Satellite Application Facility on support to Nowcasting and Very Short-Range Forecasting (NWC-SAF), is applied to the SEVIRI level 1.5 data (NWC-SAF ATBD for PGE13). The new physical algorithm is based on optimum estimation theory and iteratively finds the atmospheric temperature and moisture profile that best reproduces the observations. A non-linear regression is used to build a first-guess. Since only clear-sky pixels are processed, the SEVIRI cloud mask, available e.g. from the Satellite Application Facility on Climate Monitoring (CM-SAF), is a mandatory input. As output the temperature and specific humidity profiles at the 43 RTTOV pressure levels are stored.

References:
- EUMETSAT Satellite Application Facility on Nowcasting and Very Short Range Forecasting: Algorithm Theoretical Basis Document for PGE13 "SEVIRI Physical Retrieval Product" (SPhR) v0.1.
- Lindau, R.: Algorithm Theoretical Basis Document for the Kriging Routines used at CM-SAF, 2009.
- Lindenbergh, R., M. Keshin, H. van der Marel, R. Hanssen. High resolution spatio-temporal water vapour mapping using GPS and MERIS observations. International Journal of Remote Sensing, 29(8),2393-2409, 2008.

Collocation and Quality Management

Before the merging can be applied, the swath-based satellite data are remapped to a common grid and quality flags are analysed. Both, SEVIRI and IASI Level 2 data are re-sampled to a regular longitude-latitude grid, which covers the whole MSG disc. The borders were chosen at 65°E, 65°W, 65°N and 65°S. The spatial resolution is set to 0.25°.

The clear-sky SEVIRI specific humidity profiles at the 43 RTTOV pressure levels, are read and converted to mixing ratios. IASI Level 2 data contain the water vapour mixing ratio and it's error variance at 90 vertical levels. The flags *FLG_IASIBAD, FLG_IASICLD, FLG_RESID* and *FLG_SATMAN* are evaluated in order to select only good quality, clear sky IASI vertical profiles. The other flags are ignored. The IASI profiles are vertically interpolated to the RTTOV pressure levels used for SEVIRI. Since the water vapour amount is normally negligible for pressure levels above 200 hPa, the levels above 200 hPa are neglected, resulting in 23 vertical levels between 1013 and 194 hPa for the merged SEVIRI+IASI product.

Kriging

For both WACMOS water vapour products a kriging method is applied to obtain the optimum water vapour field together with an error map. Within WACMOS, the method of Lindenbergh et al. (2008) is combined with the CM-SAF operational kriging approach (Lindau, 2009). The water vapour mixing ratio $x(p_0,t_S)$ at location p_0 and time t_S is estimated as a linear combination of SEVIRI observations, $x_S(p_i,t_S)$, made at n different locations (p_i) at time t_S and one IASI observation $x_M(p_0,t_M)$ at location p_0, obtained at time t_M. Δx_S and Δx_M denote the SEVIRI and IASI retrieval error obtained from the optimal estimation, respectively.

$$x(p_0,t_S) = \sum_{i=1}^{n} \lambda_i \left[x_S(p_i,t_S) + \Delta x_S(p_i,t_S)\right] + \nu \left[x_M(p_0,t_M) + \Delta x_M(p_0,t_M)\right]$$

The kriging error can be written as:

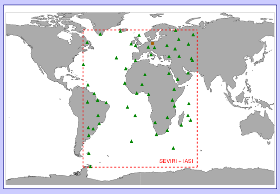
$$\begin{aligned}\sigma_{krig} \;=\; & [x_{0S}\, x_{0S}] - 2\sum_{i=1}^{n}\lambda_i\,[x_{S,iS}\, x_{0S}] + \sum_{i=1}^{n}\sum_{j=1}^{n}\lambda_i\lambda_j\,[x_{S,iS}\, x_{S,jS}] \\ & - 2\nu\,[x_{0S}\, x_{M,0M}] + \nu^2\,[x_{M,0M}\, x_{M,0M}] + 2\nu\sum_{i=1}^{n}\lambda_i[x_{S,iS}\, x_{M,0M}] \\ & + \nu^2\,[\Delta x_{M,0M}\, \Delta x_{M,0M}] + \sum_{i=1}^{n}\sum_{j=1}^{n}\lambda_i\lambda_j\,[\Delta x_{S,iS}\, \Delta x_{S,jS}]\end{aligned}$$

The kriging will be performed separately on 23 vertical layers in order to obtain a merged water vapour profile. The layered water vapour estimates will then be obtained by a vertical integration considering error propagation.

Systematic differences between the two datasets to be merged need to be eliminated before entering the kriging approach. It is planned to calculate the monthly mean of the individual data sets and subtract the IASI bias from the SEVIRI measurements, i.e., IASI is used as reference estimate due to it's expected better quality.

Product Validation

Quality checked, temporal and spatial collocated radiosonde observations of the GCOS Upper Air Network (GUAN) are used for the validation of the merged WACMOS SEVIRI + IASI water vapour product (Fig. 3). Ground-based observations with a microwave profiler and a Raman lidar at the Meteorological Observatory Lindenberg, Germany, will also be used. So far, the validation software was applied to the SEVIRI layered water vapour obtained from the new NWC-SAF physical retrieval.



For most of the cases the bias and RMS is smaller than the values given in Tab. 1. This is promising result because it can be assumed that the quality of the SEVIRI product is the lower limit of the final WACMOS product quality.

Fig. 3: Location of GUAN radiosonde stations (green triangles) within the domain of the SEVIRI + IASI (dashed red square) product. The Meteorological Observatory Lindenberg is marked with a brown circle.

- For more information – www.wacmos.org – E-Mail: katja.hungershoefer@dwd.de –