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WIND PRODUCTS DEVELOPMENT PLAN OF THE EUMETSAT MPEF

This paper summarises the plans for development of the EUMETSAT MPEF wind products from Meteosat-5 and Meteosat-7.

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1 USER REQUIREMENTS

The key driving forces for the development of the Meteosat products have been the support to the global NWP operators, the support to the synoptic forecasters and the support to the WMO climate programs. By and large this will remain so in the coming years. The following key developments in the user community are foreseen in the coming years and should be supported by the MPEF.

1.1 Variational data assimilation

The migration of the optimum interpolation analysis schemes to variational methods has already started. ECMWF has for several years employed variational schemes for assimilation of TOVS radiances and is planning the operational assimilation of METEOSAT clear-sky radiances. The variational methods make possible the assimilation of data containing non-model variables by the use of so-called observation operators, which define a relation between model variables and observed data. An example of an observation operator is a forward radiative transfer model, defining a relationship between a profile of temperature and humidity and observed radiances in specific channels. The variational methods then makes it possible to assimilate satellite radiances, even if they cannot be directly converted into a real profile.

The variational technique can also be used to assimilate bulk data like deep-layer mean winds. Such a procedure could be employed for clear-sky WV winds, but no significant development work in this area has yet been done in the user community.

1.2 4-D data assimilation

The analysis schemes of at least the major NWP centres will over the next decade be migrated to the next generation 4-D variational methods and this will considerably change the data requirements. Whereas the NWP analysis schemes now depend almost solely on synoptic data, they will evolve into continuous data-assimilation systems with no special dependency on synoptic hours. As the geostationary satellites are the main continuous source of asynoptic data this will become a very important driving force for the METEOSAT products.

An ongoing debate in the NWP community addresses the issue of 4-D assimilation of satellite geophysical products, e.g. winds, vs. direct assimilation of satellite radiances. Theoretical arguments would suggest that 4-D assimilation of cloud-cleared radiances would generate a wind field consistent with the wind field derived directly from the images. This would indicate no need to assimilate clear-sky winds directly. This is however a theoretical argument, as direct assimilation of the radiances at instrument resolution in space and time is quite out of reach with current assimilation systems. Therefore a more pragmatic approach seems to prevail, namely the concurrent assimilation of radiances and winds at an appropriate resolution in space and time.

The major technical challenge in the 4-DVAR scheme is the correct handling of physics, especially in the tropics, but these issues have been satisfactorily resolved for the ECMWF model. ECMWF introduced 4-DVAR operationally in November 1997.

Other major NWP operators are monitoring the ECMWF progress with 4-D Var, but are currently not committed to operational implementation schedules.

2 DEVELOPMENT PLANS

2.1 Pre-processing

2.1.1 Calibration

Based on data collected on the performance of the METEOSAT-7 black-body calibration a new calibration scheme is under development to be based on black-body measurements performed at least twice a day, as well as a simplified front-optics model. This scheme gives promising results, and tests on its performance in the eclipse season are under way.

A scheme for routine calibration monitoring, using level 1b data from HIRS and the MPEF Radiative Transfer Model, is under development. It is expected to be particularly useful for METEOSAT-5, which does not have a functioning black-body mechanism.

2.1.2 Improved spatial resolution of forecast data

On March 1 1999, the migration of ECMWF forecast data used in MPEF from GRID fields with very coarse horizontal and vertical resolution (3x3 deg, 10 pressure levels), to high-resolution GRIB data (1.5x1.5 deg, model hybrid-sigma levels (currently 50) was completed. The high-resolution forecast data provides very significant improvements in the description of deep low-level trade inversions and together with the new inversion height assignment scheme, this has significantly improved the quality of the low-level wind products in the subtropics.

2.1.3 Improved resolution of diurnal cycle

Improving the resolution of the diurnal cycle in surface temperature is important for the prediction of IR radiances for surface scenes. Because of the 6-hour resolution in time, the diurnal cycle variation has to be simulated in a separate step. The present scheme will be improved by the use of 3 hourly forecast fields, to provide a better resolution of the diurnal cycle.

2.1.4 Improved Semi-Transparency correction

Studies indicate that the height assignment of IR and WV winds in many cases fail because of failure to apply a correct semi-transparency correction to the cloud clusters. Several factors can contribute to an improvement in this area:

The Semi-Transparency correction can be calculated by using a linear regression on the individual pixels. This eliminates the requirement for background scene identification.
The quality of the humidity forecast is crucial in determining the radiance curve, and with the rapidly improving humidity fields supplied from the NWP centres an improvement will be expected.

A posteriori adjustment of the radiance curve to fit the observed background clusters could be investigated.

The Semi-Transparency model could be refined to more truly represent semi-transparent clouds. Improvements of the stability of the WV vicarious calibration will have a significant effect on the semi-transparency correction.

An improved semi-transparency correction scheme, primarily based on the linear regression technique, is being development as part of MSG MPEF prototyping, and will, after completion of an extensive validation, be tested for at least partial integration into MTP MPEF.

2.1.5 Improved radiosonde quality control

The quality control procedures for radiosondes used for calibration and verification will be improved. The need for this has especially become apparent after the start of the METEOSAT-5 mission at 63°E and the associated different area of radiosondes received.

3 WIND PRODUCTS

3.1 General

The wind products are computed by identifying and localising the same pattern ("tracer") in consecutive METEOSAT images (Buhler and Holmlund, 1993). This tracking is done in all 3 spectral channels independently. Using the knowledge of the tracer displacement, combined with the measurement of its temperature, the following values are extracted which constitute the wind product : wind location, wind speed, wind direction, temperature and pressure level.

The first operation performed is the selection of the structures that will be used as the tracers, based on the information provided by the Histogram Analysis. This tracer selection is done in a channel-specific way, including cluster merging or rejection when necessary. When a useful tracer has been identified, height assignment is performed and the corresponding wind component can be extracted. The wind-component extraction process comprises the definition of the Target and Search areas taken from the current and previous image, their enhancement, followed by their cross-correlation.

For CMW and ELW the tracers are clouds identified from 5 km imagery from all channels, for HRV clouds clouds identified from 2.5 km visible imagery and for WVW the tracers are cloud-free tracers identified from 5km WV imagery.

The extracted wind components are thereafter subject to automatic quality control (AQC) (Holmlund, 1996). The AQC process calculates a number (currently 5) of consistency indicators for the extracted wind, and combines these as a weighted mean into an overall reliability indicator. The intermediate wind products contain all extracted winds and associated reliability indicators. No manual quality control is applied.

The intermediate wind products are encoded into GTS formats. For the CMW product the best wind per geographical location, as determined by the value of the overall reliability indicator, is selected from this intermediate product, and encoded into SATOB, if the reliability indicator exceeds a certain threshold value (currently 80%). For the ELW, HRV and WVW products, the winds are encoded in BUFR, together with the reliability indicators themselves. All winds down to a low reliability (30%) are included, but for each product, a suggested reliability indicator threshold is provided in the BUFR format. The BUFR and SATOB products are distributed on the GTS. The original intermediate products are archived in the Meteosat archive facility (MARF) and are thus available for historical retrievals.

Further details about the wind extraction process are provided in (Rattenborg and Holmlund 1996) and (Schmetz et.al.).

The following areas can be identified, where further improvement of the current MPEF wind products are desired:

Low level coverage around developing tropical systems. The deficient cloud motion-wind coverage in the vicinity of developing and developed tropical disturbances is an important issue for hurricane forecasting.
Low-level height assignment in trade wind inversion areas. In the inversion areas, the Temperature-to-Pressure transformation is multi-valued. This results in low-level IR height assignment problems.
Medium-level coverage. Although this area presents fundamental meteorological problems, the MPEF wind coverage at medium levels seems to be too low.
High-level height assignment for cloud tracked winds. Significant scope for improvements to the semi-transparency correction.
Provision of reliability indicators for speed, direction, pressure and temperature

The needs of the user community will be addressed partly through improvements to the existing operational wind products (CMW and HRV) and partly through the introduction of new wind products.

3.2 HRV tracer selection improvements

The tracer selection and height assignment for HRV will be based on averaging pixel counts over the target area in the pixel-classified image instead of using the segment-based cluster information. This will provide more HRV winds in mixed cloud segments and better coverage in areas with developing systems.

3.3 Medium-level IR winds

The quality and coverage of the medium level IR winds is relatively poor. This is mainly a reflection of the complex physics and dynamics of the mid-level atmosphere, especially over the continents, and no single internal problems causing this have been identified, but the medium-level winds issue will continue to be investigated.

3.4 WV winds from cloud-free areas

The tracking of water vapour in cloud-free areas provides a wind product with extensive coverage. This product (WVW) at a resolution of 160 km is now available as an operational product, using the single-level height assignment based on the cluster EBBT. With the new unified BUFR template, is it possible to provide the user with alternative height assignments, and it is planned to include height assignment information based on the WV contribution function calculated in the Radiative Transfer Model.

3.5 Low-level tracking over land

The tracking of low-level clouds over land presents significant problems because of the short lifetime of low-level clouds over land, the impact of surface features on the tracking and of flow deformation/curvature effects. The feasibility of advanced techniques to address these issues using the MSG spacecraft is being addressed in a EUMETSAT study, and if the results of this study are promising and applicable an implementation in the MTP system will be considered.

3.6 High Resolution WV winds

The Meteosat Second Generation prototyping activities for the Atmospheric Motion Vector (AMV) product have suggested that the production of 80km resolution, cloud tracked vapour motion winds from Meteosat images would be feasible. The present processing segment used for CMW is split into 4 quadrants each of 16×16 pixels, and each of these in turn is used as a target area in the extraction of a wind vector. The search area is then a 56×56 pixel region centred on the target area, and extending 20 pixels beyond it on each side. This ensures that tracers moving at up to ~78 ms^{-1} (28 pixels per slot) at the sub satellite point can be successfully tracked. The height assignment method for HWW makes use of the classification of each pixel within a quadrant to determine the coldest cluster of self-similar pixels that fall, to a configurable minimum extent, within the quadrant. The water vapour count of this cluster is then used to derive the height. This method allows height assignment and classification of cloud winds on a per quadrant basis.

The HWW product has been distributed to ECMWF and the UK Met Office for testing since July 1 1999 and it is planned to introduce the product as fully operational in 4^{th} quarter of 1999.

Investigations have shown, that tracking with 16x16 targets is not feasible in cloud-free areas with the current tracking algorithm. Further investigations will assess whether improvements can be expected from other methods.

3.7 Better geographical positioning

Presently the extracted winds are positioned at the segment centres, introducing an inaccuracy of up to half a segment size. A better positioning can be obtained by explicit tracer location in the image. Initial results are encouraging and this change will be introduced operationally in 4th quarter of 1999.

3.8 Increased time-frequency of winds distribution

The MPEF distributes winds in BUFR format every 1.5 hours. A further reduction of the wind extraction cycle to 1 hour, made possible by more powerful workstations, will bring the schedule inline with the MSG baseline and is planned for early 2000.

3.9 Move winds derivation to synoptic times

To leave enough time for manual quality control, the derivation of the wind products has historically been performed 1 hour before the main synoptic hours, e.g. 12Z products were derived from the three images ending at 10:30Z, 11:00Z and 11:30Z. As all procedures are now fully automated, this is no longer required, and the wind extraction times will be moved to match the synoptic hours. Planned for 1st quarter of 2000.

3.10 Automatic Quality Control

A core issue to be addressed for the MPEF CMW product is the definition of the AQC processes and parameters. The process is essential to ensure a maximum yield of high-quality winds for all channels and all levels and to ensure the availability of stable reliability indicators for the user community. A very important aim is also to provide quality indicators which are independent of the forecast wind fields. The AQC tuning is based on the continuously growing data set of collocated radiosondes and MPEF satellite winds, as well as on comparisons with ECMWF first-guess fields. The AQC definition process is ongoing with continuous improvements over the next year.

With an optimal AQC the size and coverage of the SATOB encoded product can be increased and meaningful reliability indicators for the BUFR product, including individual reliability indicators for speed, direction and height, can be provided, as well as quality indicators with and without forecast information. It could also be investigated whether estimates for the error distribution functions can be produced, which could be used in the NWP data assimilation schemes.

The optimised AQC system will be used as a basis for tuning the MSG MPEF, as the MSG system will employ the same AQC system as MTP.

3.11 Verification improvements

The verification of the CMW product is currently based exclusively on radiosondes and forecast fields. Use of other data (e.g. AIREP/ASDAR/ACARS) for verification is foreseen.