DEVELOPMENTS FOR A HIGH-RESOLUTION WIND PRODUCT FROM THE HRV VISIBLE CHANNEL OF THE METEOSAT SECOND GENERATION

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ABSTRACT

The Satellite Application Facility -SAF- for Eumetsat in support to nowcasting (and very short-range forecasting) develops algorithms and software to provide cloud, precipitation, air mass and synoptic analysis products, from data of the future MSG satellite system. A wind product -HRW- was also included to add some dynamical information. It is centred in the exploitation of the HRV channel at 1km horizontal resolution (s.s.p.) as closer in possibilities to the meso-scale than other channels at only 3km, more indicated for synoptic scale winds to be produced at Eumetsat Central Facilities -MPEF.

Existing techniques allow appreciable results in tracer scales around 25 to 35 pixels (km), but the HRW product should offer improved resolution (around 10 pixels) for at least some zones or tracers, whilst preserving a good level of accuracy and efficiency. It is in consequence aimed in the development to work at 2 or more different scales but with reasonable link among these, and to work on tracer features for selection and tracking.

The current approach considers mainly 3 development parts, enhancement on existing, alternative objects method, additional quality control and other aspects. The first one already boarded, on gradual enhancement of starting existing methods (the INM-VDI satellite wind procedures developed from a McIDAS core, and the use of some adapted specific elements from current or proposed Eumetsat methods): to the basic tracer selection based on the laplacian operator, have been added some optimising criteria considering tracer features (a well determined brightness frontier used as threshold to determine if enough variability in the tracer); the next step is the use of these same criteria in the tracking step (it seems in fact convenient, to avoid some errors when tracking with the usual correlation on some tracers so selected), and to determine lower scale tracers. Results from the work already done are the subject of the presentation.

1. Improvement of the tracer selection - TRAZ method.

An overview of the intended HRW product for the SAF for Nowcasting can be found at (Fernández, 1998). It is assumed that the VIS channel present distinct cloudy targets but the clouds could present less sharp edges than IR window channels (due to characteristics of the top of the cloud and illumination), so an approach including histogram classification and tracer determination of features at an intermediate resolution could be adequate, lying in-between merging between target determination based on gradients (introduced for IR channels, e.g. Hayden, 1989) or prior segment classification, and direct image matching or correlation (rather used for WV channels, e.g. Jedlovec, 1998).
The operational INM-VDI for Meteosat winds (Fernández, 1996) uses the McIDAS WINDCO gradient method -TARGET. The image is explored by segments LSIZExESIZE. Wherever a MIN threshold and a DVAL contrast area reached (cosZ-corrected brightness values in the scale 0-255), the laplacian ($\Delta R/\Delta x+\Delta R/\Delta y$)is evaluated, and the location of its maximum (unless at boundary of the segment) provides the tracer centre. Rather standard values (LSIZE, ESIZE=20, 24 pixels, MIN=75, DVAL=25 and $\Delta x=\Delta y=5$, are retained for the as starting point for the 'coarse' approach.

TARGET is generally providing good results at this resolution, but often tracers do not suggest well marked structure for eased recognition, are too linear, or too simple, and more tracer are wanted. An additional search algorithm has thus been implemented. It basically searches for a defined frontier in the brightness histogram of the pixels of the segment, serving to classify it in a 4x4 array of 'big pixels' then explored for enough 'variability', with conditions to be met. Optimisation search around initial centre is performed. The chosen TRAZ method onsiders 1 step or 2 steps around any candidate centre in the basic grid, in the first TARGET tracers are determined and then fine-adjusted in location (or rejected) with the new algorithm parts, if no result a second step only with these re-starts from the basic initial centre trying to fill holes in coverage.

The algorithm mainly includes the 2 routines dealing with histogram -HISTFRON- and 'big-pixels' creation and evaluation -SUBSEC-. HISTFRON performs again basic checks (MIN and contrast now on percent values 90%, and 97%-3% which contrast must be CONTR=30 or reduced value for 'generally bright' segments for cloud-over-cloud cases). The histogram (smoothed with a x3 passing filter), is explored -bottom to top- to get frontiers (brightness minima), evaluation of 3 terms -6 contiguous classes summed by pairs-, (1^{st} -2^{nd}) + (3^{rd} - 2^{nd}), any frontier has to be deeper than UMB_PROF=14.

The SUBSEC routine assigns 0, 1, 2 class-value to each big-pixel (in an 4x4 array) depending on the position of the frontier relative to the percentiles 30% and 70% in the big-pixel, values 0 and 2 should appear at least once. The 4x4 array is checked for each frontier (brightest to dimmest) until a good 'variability' is found in 4 directions (row, column, 2 diagonals); are checked the absolute sum of contiguous differences in class value along each linear array (of at least 3 elements) of each direction, at least equal to UMB_DIR=6 (also 4 used in the tests) , see fig.1. A second test and condition CRI_ARR, at least one 'complete' transition 2-0-2 or 0-2-0 in any linear array of at least 2 out of the 4 directions, is also used in addition (also tested alone but poorer results).

0 0 0 0	2 2 2 2	0 0 0 0	2 2 2 2	0 0 1 0	0 1 1 0
0 0 0 0	2 2 2 2	0 1 0 0	2 1 2 2	0 1 2 1	0 2 1 0
0 2 0 0	2 0 2 2	0 2 1 0	2 0 1 2	0 1 2 2	1 2 1 0
0 0 0 0	2 2 2 2	0 0 0 0	2 2 2 2	0 2 1 1	1 2 0 0
UMB_DIR=4		UMB_DIR=6			

Figure 1. 4 examples of 'extreme acceptable configurations' for target as a 4x4 array of 'big pixels', also meeting CRI_ARR condition. Target 5 meets UMB_DIR conditions (4 or 6) but not the CRI_ARR ('complete transition' only in SW-NE direction) . Last target meets CRI_ARR, but none UMB_DIR (low 'variability' N-S) . 0 if 70% of values below frontier, 2 if 70% above, 1 for the other less defined cases.

Comparative results (TARGET; and TRAZ tracers, with UMB_DIR=4 -plus CRI_ARR- and =6 -alone and plus CRI_ARR- for Meteosat -2.5km- and GOES -1km, only TARGET and last TRAZ case-) are shown in fig.2 and fig.3; TRAZ is expected to provide more determined tracers to be tracked. The TRAZ method is by now quite slow (even 2.5min for the intented regions of 1500x1500, to be compared to a few seconds for the TARGET method), but it will be ran as a pre-processing for next time-slot, at the end of the wind computation, and will provide data useful for the wind computation and quality control (tracer characteristics from the HISFRON and SUBSEC), intended to speed-up this next step which could be the critical one.

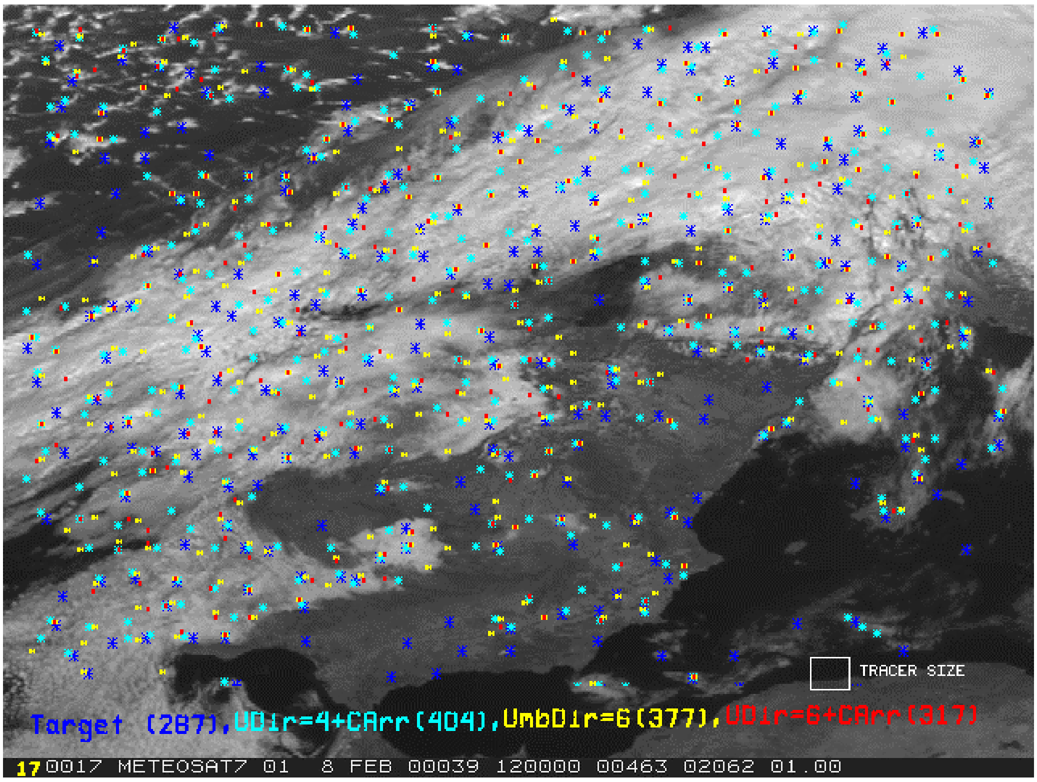

Figure 2. Meteosat example of targets, and tracers determined using 3 criteria.

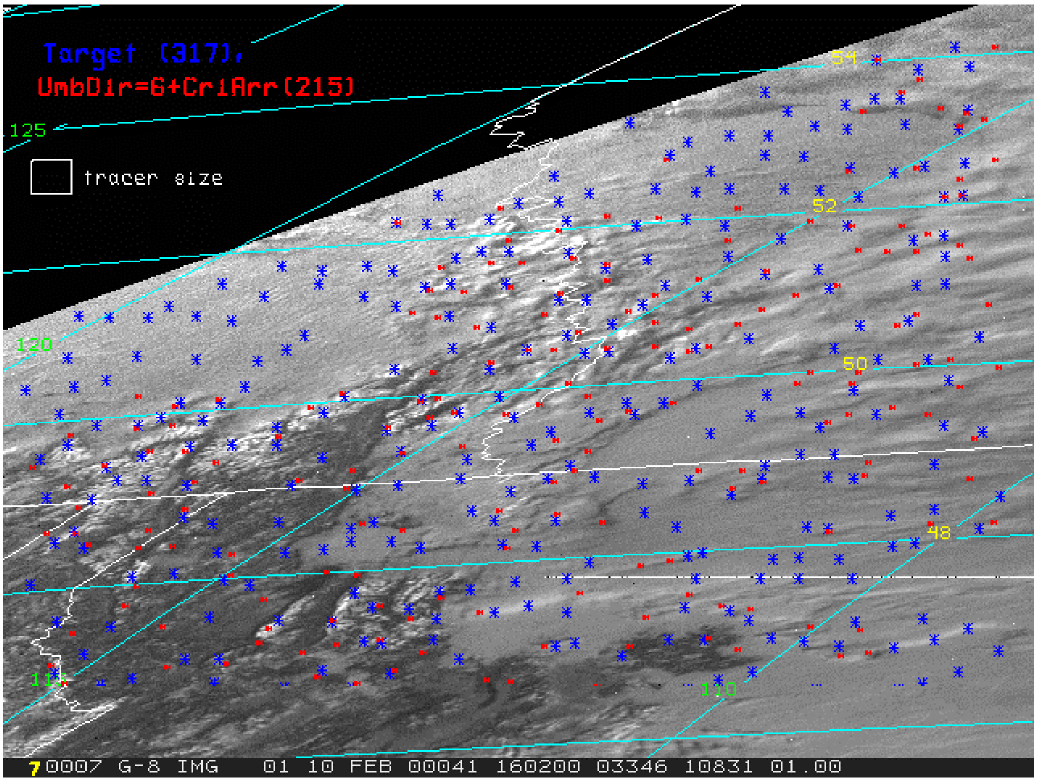

Figure 3. GOES example of targets and tracers.

2. Use of 'medium resolution' features of the tracers for approximate tracking then refined with limited cross correlation analysis -MATCH method.

The TRAZ method provides a basic set of tracers, also expected to be improved when coupling the 'coarse' tracers at around 20x24 with 'detailed' providing up to 4 tracers at around 10x12 (same initial centre) where some conditions are met for its computation. All these would be input to a tracking based in cross-correlation with a guess to reasonably shorten computations meeting some '5min' figure for the mentioned 1500x1500 region; guess winds from NWP and MPEF are considered for the HRW product.

It is also being considered to get rather independent of external guess, introducing internal considerations to reduce search zone for cross-correlation -final step, a sort of internal guess or rough step. Apart from the fact that combination of quality control with the continuous HRW could perhaps limit search area (e.g. limit search to 50% level of confidence for a previous wind), current developments explore the possibility of performing a rough step which is a pattern matching, based on TRAZ characteristics with some quality control, in the large search zone: classification in 'big boxes' (similar to that in TRAZ for the given tracer) in the final image throughout a grid of centre locations (size LLAGxELAG, =50 -Meteosat- and 60 -GOES- are chosen) centred in the tracer position in the initial image, 'candidate tracers' are compared to the initial tracer.

MATCH includes in fact 3 principal functions. The comparison of tracer -initial image- to any 'candidate' -final image- is done by absolute sum of classes differences at the same relative locations. The evaluation of the best candidate (and its centre) considers the 2 minimal difference-values (this introduces some smoothing, search of candidates is in fact computed each 3 or 2 lines and elements, only so the computation is fast enough, a factor x5 or x3, with respect to full correlation; as no great difference was found x3 was used). If more than one 'best candidate', an average centre is determined, and the final-step search zone increased accordingly, for the final cross-correlation, limited to a 9x9 or 6x6 search grid of centres. The quality acceptance includes -by now: the 'best candidate centres' should 'not be too distant', and a correlation maximum to be found which is close, with correlation value at least .55 for these coarse tracers.

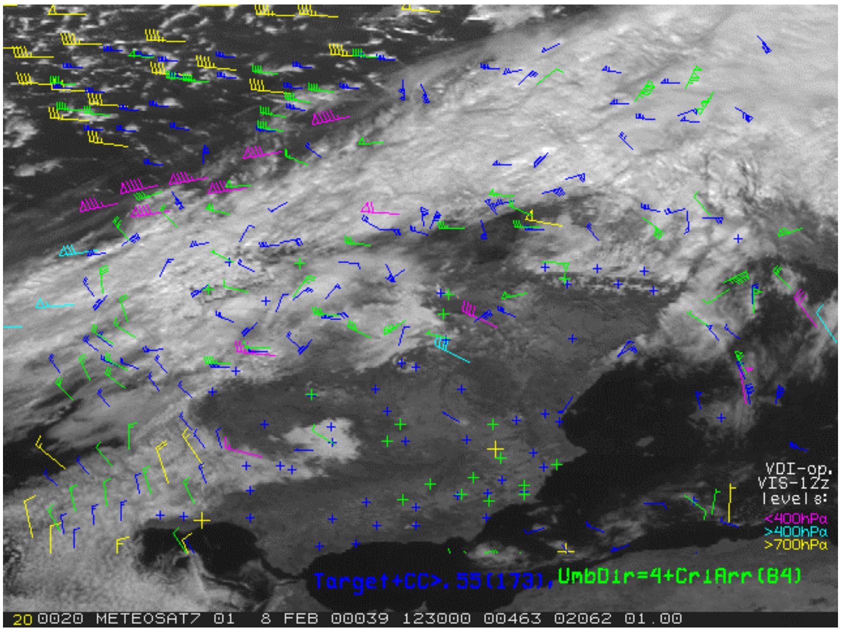

Figure 4. Meteosat VDI-INM VIS winds (computed using TARGET tracers, NWP guess wind, quality selected using sequence of 2 winds and spatial coherence including IR and WV winds). Full cross-correlation winds (CC>0.55), from TARGET tracers. TRAZ+MATCH winds (frontier as invariant), at a x3 step search, for the option providing the best apparent results (UMB_DIR=4 + CRI_ARR).

Basically, TRAZ selected frontier is the 'invariant' for MATCH. Also was checked to rather its percent (and re-compute frontiers at the final image at any candidate centre for a given tracer), based in the expectation that the percent distribution (if cloud time-changes are small) of an image should be few dependent on the illumination changes (hypothesis used for normalisation of VIS images, e.g. Binder, 1989). But this could also selects spurious candidates and slows down (not critically but sensibly) the procedure; this will be rather serve in any case to determine in the development expected changes in frontier value for changing sun elevation (a combination of both methods could be tested including application to non-normalised brightness as the normalisation method introduces noise).

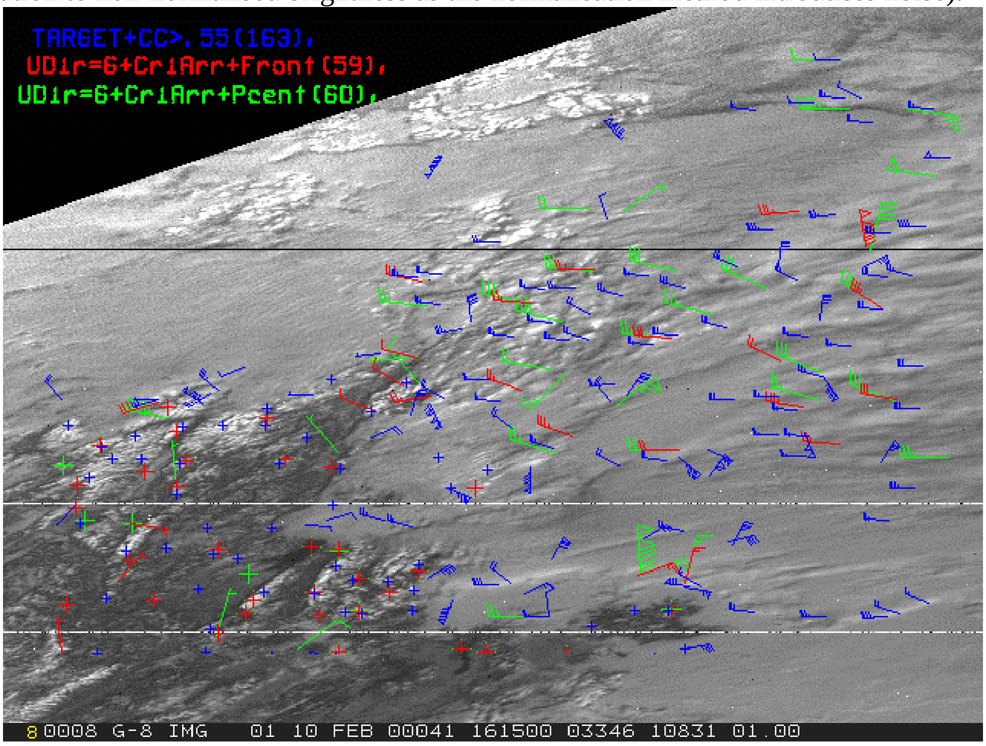

Figure 5. GOES winds: full cross- correlation (CC>0.55) from TARGET tracers. TRAZ(UMB_DIR=6 + CRI_ARR) +MATCH (frontier and frontier percent, as invariants), at a x3 step search.

Comparative examples of MATCH results are shown for Meteosat (fig.4 and fig.5, image presenting wide diversity in cloud patterns) , and GOES (fig.6, image with low view and illumination angles).

MATCH (or TRAZ+MATCH) as now needs certainly improvement. The tools implemented to check at any location tracers features and matching matrices allow to identify particular causes of errors or deletion. Among these, cloud level confusion (inside the tracer or in its tracking), a too simple determination of candidates (when different 'best candidates' could appear selection should consider additional criteria). Orography effects, and the selected frontier being too high or too low (depending on case) given a tracer few defined for tracking, are, in close connection with the former, cause of difficult tracking and errors.

Finally the whole method was tested at detailed resolution (LSIZE=10, ESIZE=12), with options quite the same of the coarse ('best' results nevertheless with UMB_DIR=4 only) and independently, with rather poor results (but some promising results in zones considered a priori of interest, as in zones of continuous Sc with few details).

3. Conclusions, further developments.

The described methods provide a basis for selection of a wide set of targets, and winds. The basic methods are desired to change little, but actions on options and thresholds should improve them. Despite this tuning can seem complex, the availability of checking tools and determination of priorities in the method improvement and tuning should partly ease this task.

TRAZ will include level assignment (and derived tracer acceptance), and the linked selection of detailed tracers. MATCH will have to improve selection of tracer matching candidates, and include quality tests.

The quality acceptance and flagging in the method is a very important issue for development. Given that in this case the fast availability (and a dense wind pattern) is a major requirement, among the tests on time and space consistency, it is assumed that some of the first (which include wind -Holmlund, 1998, and tracer and level continuity which could perhaps use related techniques) could rather serve to reduce computations, and that the second should be in this case very important for the final flagging.
In particular of importance is the final quality control with relation to orography. The combined use of external winds, orography patterns in relation to HRW winds, and other SAF products (e.g. on stability) is considered for this task.

Finally, it was considered for the HRW development on alternative methods, the tracking of objects at combined different scales; in a first study it was determined that statistical entropy (for object selection), and a pyramidal method (to go through scales) could be candidate methods. The studies could not be continued until now. Continuation on this issue is subject to evolution in described in this presentation as it could in fact provide a good part of requested from these alternative methods, and these could otherwise represent a major development or research.

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