WIND EXTRACTION AND VALIDATION FROM THE WATER VAPOR CHANNEL OF METEOSAT DURING THE INTERNATIONAL CIRRUS EXPERIMENT

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ABSTRACT

The water vapor channel of consecutive Meteosat pictures is used to calculate winds with a norm 2 (euclidian distance) method. Selection tests and the comparison of 2 consecutive wind fields eliminate incoherent wind vectors. In order to attribute a level to the vectors, the average temperature of the coldest pixels are calculated. Meteosat wind fields are then compared with ECMWF analyzed winds at different pressure levels, comparisons are also done with radiosonde measurements.
Conclusions are drawn from a few situations obtained during the International Cirrus Experiment (ICE) in september-october 1989.

1) INTRODUCTION

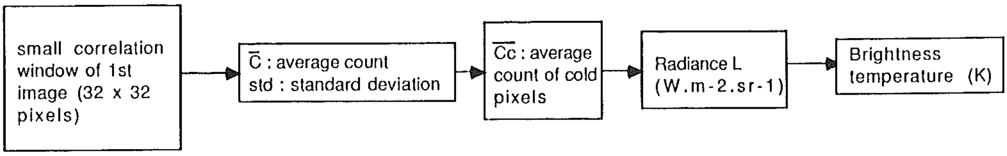
The infrared channel of Meteosat is currently used to calculate cloud motion vectors. The use of the water vapor channel seems to provide complementary informations especially at high levels (Laurent, 1990). This study tries to validate parts of these vector fields as high level winds for a few situations by comparing them with winds analyzed by the European Center for Medium Range Weather Forecast (ECMWF, subscript EC) and radiosonde measurements.

2) CALCULATION OF METEOSAT CLOUD MOTION WINDS

The Norm 2 (or euclidian distance) method is used (Sitbon et al., 1974) with segments of 32 X 32 pixels. Images are taken 1/2 or 1 hour apart. Cloud motion vectors are calculated every 2.5° in longitude and latitude between 35° and 62.5° N from images of Meteosat covering Europe, north Africa and the north-eastern Atlantic.

Tests on correlation, on the maximal possible displacement, on coherence between 2 consecutive vectors (symetry test) eliminate vectors which seem inconsistent.

For every segment, the average count of "cold pixels" (pixels below the average of all pixels within the 32 X 32 segment minus the standard deviation) is used to evaluate the brightness temperature of the coldest clouds.



Vectors associated to cold clouds are kept for comparisons if their associated brightness temperature is below -30° C (243 K).

3) COMPARISONS OF INFRARED AND WATER VAPOR FIELDS :

The selected case, oct. 13th 1989 between 12 and 13 h, is shown on figure 1. Cloud motion vectors from the water vapor (in blue-green) and infrared channel (in red) are superimposed on the water vapor image. The coldest regions are white. 33 "cold winds" are common to both channels.

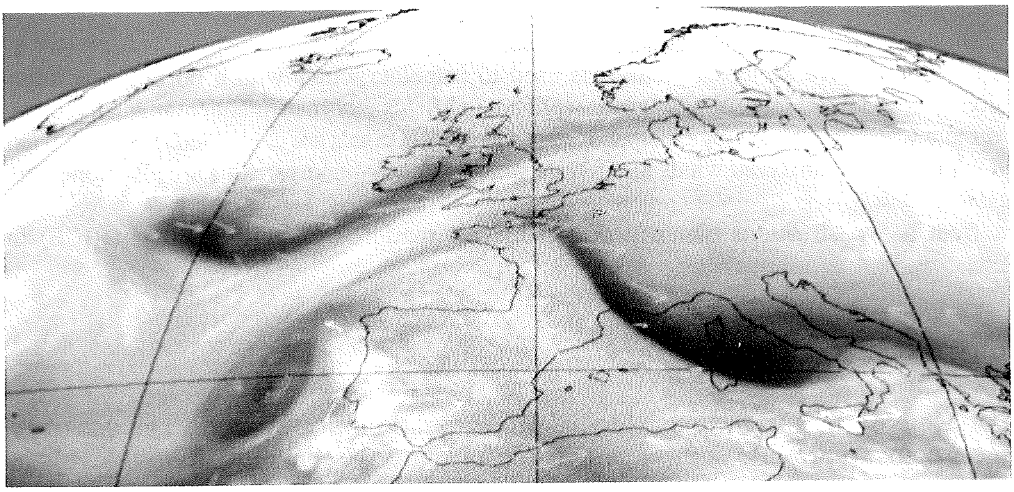


Fig. 1 : Infrared and water vapor vectors

It appears that much more W.V. vectors are left due to same temperature threshold for both channels and to better tracking of high level structures .The histogram of the vector difference $|\vec{V}_{ir} - \vec{V}_{wv}|$ gives an average value of 4.3 m/s and a standard deviation of 3.4 m/s. The histogram of the difference of vector intensities $|\vec{V}_{ir}| - |\vec{V}_{wv}|$, shown of fig. 2, gives an average value of -1.3 m/s ; this indicates that water vapor vectors are generally stronger than the corresponding infrared vectors. The standard deviation is 4.3 m/s.

Fig. 3 compares the brightness temperatures of common "cold" vectors. Infrared vectors are ditributed on a larger scale than their water vapor counterparts. Some of the coldest W.V. vectors appear to be warmer than the corresponding IR vectors, due possibly to calibration problems .

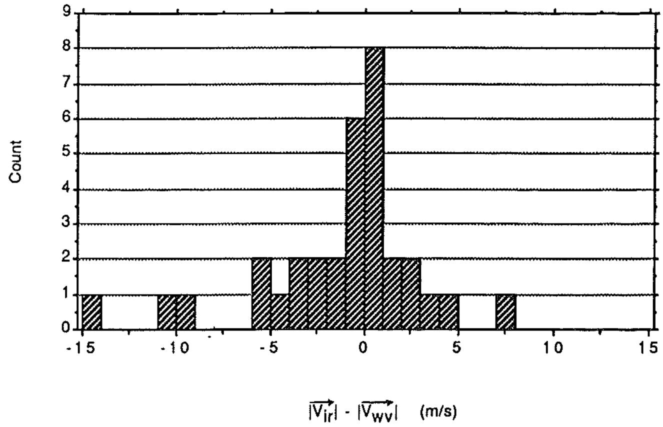


Fig. 2 : histogram of $|\vec{Vir}| - |\vec{Vwv}|$ (in m/s)

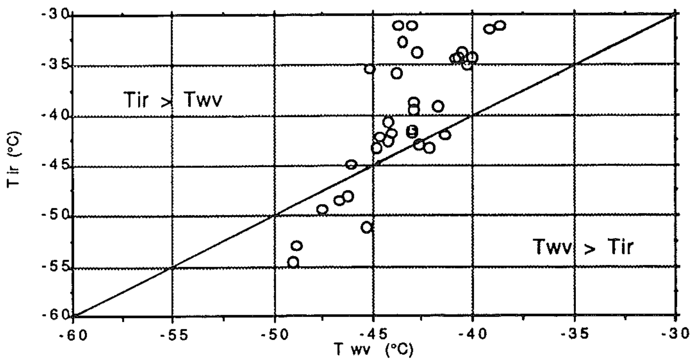


Fig. 3 : Comparison of temperatures of common "cold" vectors :

4) COMPARISONS OF METEOSAT VS. ECMWF VECTORS

The studied case is on september 28th 1989 between 12 and 13 h.

4.1) Comparison Meteosat water vapor winds / E.C. winds with minimal temperature difference :

Comparisons are made between Meteosat water vapor vectors and the E.C. winds at the corresponding pressure level (i.e. the level where the E.C. temperature and the W.V. brightness temperature associated to the vector are the closest). On fig. 4, W.V. vectors are in black while E.C. winds are coloured from dark blue (100 hPa level) to red (P = 400 hPa). The same comparison has been made with the infrared vector field (less vectors are compared). Fig. 5 shows the histogram of the difference of wind vector intensities $dV_{mod} = |\vec{V}_{ec}| - |\vec{V}_{wv}|$ for the water vapor channel (170 vectors are compared).

In this example, the bias (average of $|\vec{V}_{wv}| - |\vec{V}_{ec}|$) is -3 m/s for an average value of 14.7 m/s for W.V. cloud motion vectors. E.C. winds are larger than W.V. vectors in a majority of cases. Temperatures deduced from cold regions correspond preferencially to the 300 hPa pressure level, with no wind below the 400 hPa level.

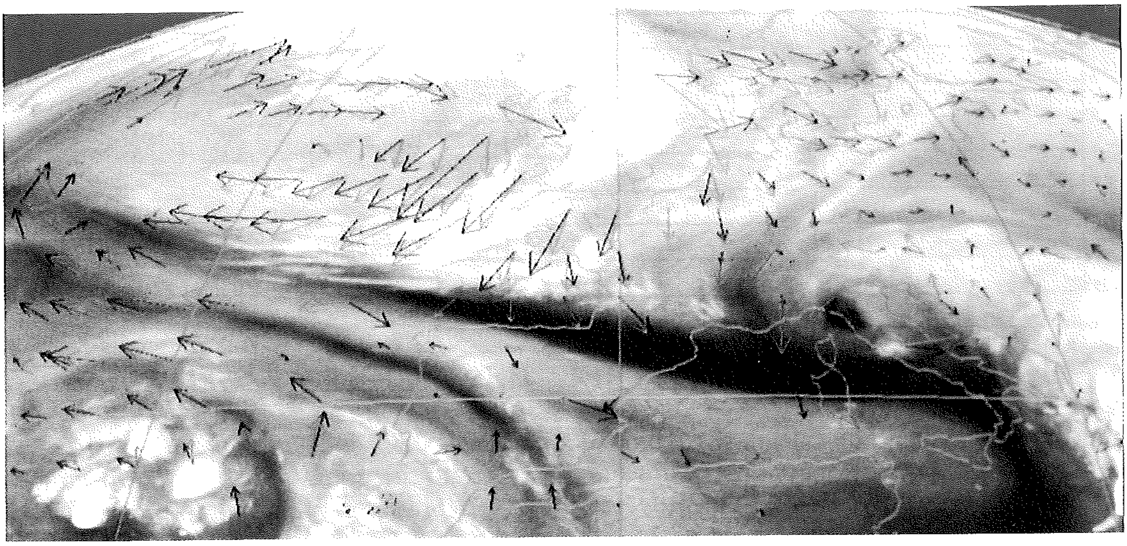


Fig. 4 : W.V. and E.C. "cold" vectors (for the closest temperature)
(P=100 hPa : dark blue, 200 hPa : blue, 300 hPa : green, 400 hPa : red)

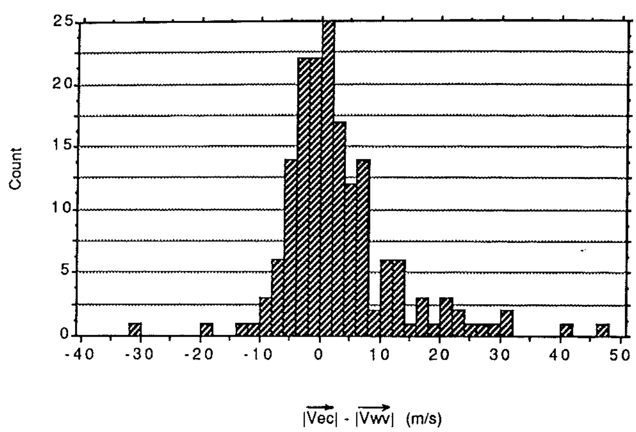


Fig. 5 : histogram of $|\vec{Vec}| - |\vec{Vwv}|$

4.2) Best fit level :

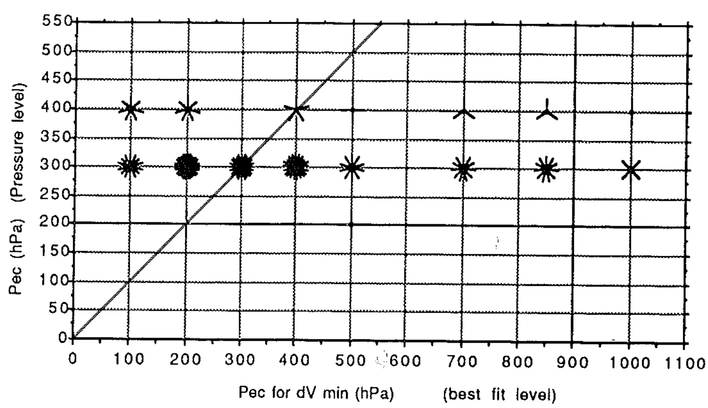
For each pressure level of the E.C. data, the vector difference $\vec{dV} = \vec{V_{ec}} - \vec{V_{msat}}$ is calculated. When dV is minimal, the corresponding E.C. wind is kept for comparisons (fig. 6). The same comparison has been made with infrared vectors.

It appears that no really dominant pressure level can be found. The best fit can even be at low levels. The most important class for best fit is the 200 hPa level (26.5 % of all W.V. vectors, 14.1 % for the 300 hPa level ,15.3 % for the 400 hPa level). The infrared channel has fewer vectors than the W.V. channel , without any dominant class (each class has between 8 and 20 % of all vectors).

Fig. 6 : W.V. and E.C. "cold" vectors (best fit level)
(P=100 hPa : dark blue, 200 hPa : blue, 300 hPa : green, 400 hPa : red, > 400 hPa : yellow)

4.3) Comparison of best fit level and pressure level deduced from temperature:

Both levels are shown on the bidimensional histogram (fig. 7). The most common case corresponds to a (temperature associated) pressure level of 300 hPa and a best fit level of 200 hPa. No relation between pressure level and best fit level appears clearly on this histogram.



(One star branch corresponds to one wind vector)

Fig. 7 : comparison of E.C. pressures for Meteosat W.V. winds

5) COMPARISONS WITH RADIOSONDE MEASUREMENTS :

Comparisons have been made between 3 radiosonde measurements on october 13th, over the North Sea and the corresponding wind vectors calculated for both channels (IR and WV) and for 2 sizes of correlation windows (32-80 and 16-40 pixels). One case is shown on fig. 8.

No selection on temperature and no symetry test have been made. Winds are calculated from images 1/2 hour apart (before and after the radiosonde measurement).

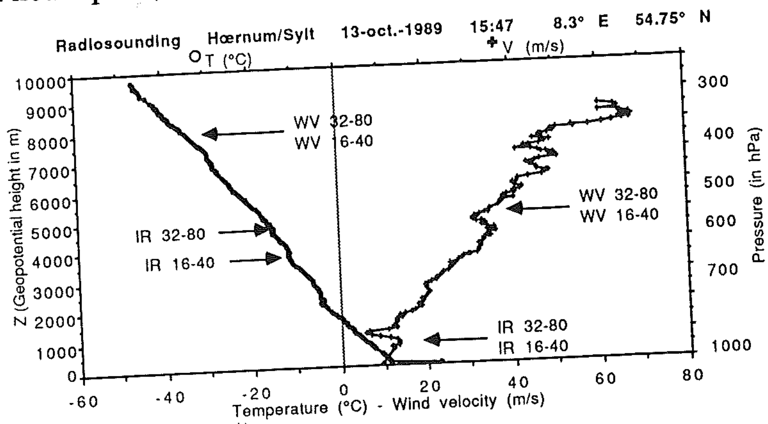


Fig. 8 : comparison of a radiosonde measurement with Meteosat cloud motion vectors and brightness temperatures

The pressure level is above the best fit level in all but one comparison. Results are very close results for small (16-40) and large (32-80) correlation windows (except for one estimation of best fit level). Pressures for the I.R. comparisons are larger than corresponding pressures for the W.V. comparisons (for both best fit and pressure levels). Infrared temperatures are also larger (except in one case not shown).

6) CONCLUSIONS AND PROSPECTS:

- For cold cloud regions, temperatures associated to the water vapor channel are lower than their infrared counterparts in most cases when both cloud motion vectors are calculated and selected.
- The winds from ECMWF analyses are larger than the cloud motion vectors calculated from Meteosat images at the corresponding temperature ; the difference is more important for the infrared than for the water vapor vectors.
- Temperatures calculated from the Meteosat water vapor channels correspond to pressure levels between 200 and 400 hPa, as shown by the comparisons with E.C. analyses and radiosonde data.
- The best fit level can be at any pressure level, but a small majority of cases is found for the lowest pressures.

Water vapor winds appear to be useful to complete and improve wind fields from the infrared channel for high levels.

This study should be extended :
- with studies of other cases (in this study, the radiosoundings were limited in number and height);
- the selection of cirrus zones should be improved. This can be done with a classification algorithm.
- More continuous measurements of high level winds in time and space, together with a determination of the true cloud top height over sufficiently large areas, would be useful for better validation.
- the question of the size of the correlation window has still to be investigated.

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- Sitbon P., Berroir A. and Chaume D., 1974 : Determination des champs de vents à partir de photographies de satellites géostationnaires . 2e partie : examen de procédés numériques autres que la corrélation. Internal report, Laboratoire de Météorologie Dynamique, Palaiseau, France.