CLOUD CHARACTERISTICS AND CHANNEL SELECTION FOR IASI RADIANCES IN THE METEOROLOGICALLY SENSITIVE AREAS

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Cloud characteristics in meteorologically sensitive areas

✳ **IASI**=Infrared Atmospheric Sounding Interferometer developed by CNES-EUMETSAT

✳ Sensitive areas: where small changes in the analysis can drastically change the forecast. IASI can resolve some of the small structures identified by sensitivity studies (Rabier et al, 96, Prunet et al. 1998, Collard, 1998).

✳ McNally (2002) showed with ECMWF model clouds that **sensitive areas** are widely covered by high-level and low-level clouds.

✳ Is it true for clouds seen by the imager AVHRR in the IASI pixel? MAIA (Mask AVHRR for Inversion ATOVS) method used for FASTEX cases.

Sensitive areas

Diagnostic function: forecast of the mean sea level pressure over the region of interest on 19 Feb 1997,12 UTC

12 UTC 97/2/19

Adjoint model -36 hours

0 UTC 97/2/18

Sensitive area determined with temperature fields of the gradient of the diagnostic function with respect to initial conditions (18 Feb 1997,0 UTC)

Example for IOP 17 (0UTC 18/2/97)

Cloud top pressure of the simulated IASI pixels

<200hPa 200-300hPa 300-400hPa 400-500hPa 500-600hPa 600-700hPa 700-800hPa 800-900hPa 900-1000hPa Clear sky

— Equivalent potential temperature at 850 hPa
— Sensitive area
⬤ Wind velocity at 300 hPa

40% 30% 20% 10% 0%
Sensitive area / Total

Clear sky 900-1000 hPa 800-900 hPa 700-800 hPa 600-700 hPa 500-600 hPa 400-500 hPa 300-400 hPa 200-300 hPa <200 hPa

·Large amount of cloud top level above 600 hPa observed in a wide southern part of the sensitive area
·Low-level clouds are present in the northern part.

Overview over 8 FASTEX cases.

Sensitive area / Total

20.00 10.00 0.00

Top pressure (hPa)
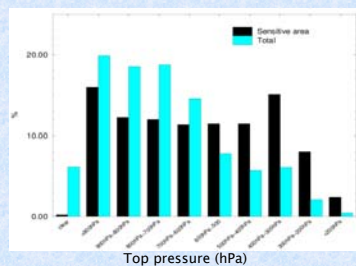
Average distribution of the cloud top height of the IASI pixels over 8 sensitive areas of the FASTEX Intensive Observing Periods and on the whole data set corresponding to a mid-latitude region.

➢For sensitive areas, 2 maxima in the distribution observed : 1000-900 hPa and 400-300hPa atmospheric layers.
➢For the whole IASI dataset, 60% of the cloud tops are situated below 600 hPa.

Conclusions

·The simulated IASI pixels located in the sensitive areas are usually covered by low-level clouds and by high-level clouds

·Channel selection of Rabier et al 2002 study compared with two method derived from targeting strategy (sensitivity to observation and Kalman filter sensitivity). Iterative method based on Entropy Reduction (ER) shares few channels with the two other ones but is quite robust even for highly sensitive profiles.
·Constant channel set computed from an independent set of atmospheric profiles leads to a significant improvement of the analysis compared with the background even if analysis error is larger than the one obtained with an optimal channel set.

Channel selections in the sensitive areas

✳ Advanced IR sounders
–large volume of data, prohibitive in operational NWP-> reduced channel set used in operational context.

✳ *Selection of individual channels*
✳ At each step, one channel is picked. It is the most informative channel among those which have not been previously selected.
✳ The analysis error covariance matrix is then updated

✳ *Iterative Method (Rodgers, 1996 and Rabier et al, 2002)* or **Entropy Reduction** (ER) method
✓This method is a step by step iterative selection scheme, based on information content wrt the background information.
  ·The selection criterion is ER
    ■ ER=-1/2 $\log_2 \det(AB^{-1})$
    ■ Where B= background and A= analysis error covariance

✓«Constant» selection obtained by averaging the ranks of the channels
  Cst selection =Ave (Selection i)

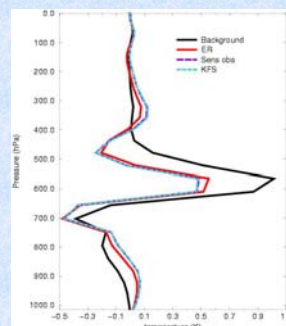✳ *Channel selections based on targeting strategy*
  ✳ **Sensitivity to observations** *(Baker and Daley, 2000;Doerenbecher and Bergot, 2001).* Channel selected wrt the maximization of the sensitivity to observations $\nabla_{yo} J$:
    ✳ $\nabla_{yo} J = r_i h'_i{}^T A_i \nabla_{xa} J$
    Where r_i is the error value, h'_i is the vector corresponding to a line of the Jacobian matrix, $\nabla_{xa} J$ is the sensitivity to initial conditions
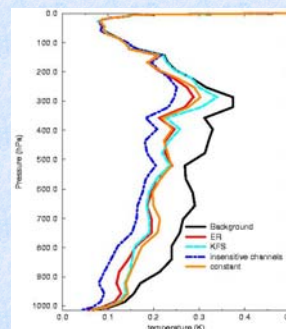
  ✳ *Kalman Filter Sensitivity (Bergot and Doerenbecher, 2002).* Channel selected wrt the maximum decrease of the variance of the error on a given scalar function of the forecast $\delta\sigma$;
    ✳ $(\delta\sigma_i)^2 = \nabla_{xa} J B_{i-1} h'_i (r_i + h'_i{}^T B_{i-1} h'_i)^{-1} h'_i{}^T B_{i-1} \nabla_{xa} J$

Deviations from the true temperature for 1 representative profile for the background and 3 different analyses. «Background» refers to the background error, «ER» to the analysis error obtained with the Entropy Reduction method, «Sens obs» to the analysis error given by the sensitivity to observations method and «KFS» to the analysis error produced by the Kalman Filter Sensitivity method.

➢Background error large in the 400-900hPa layer and maximum located at about 550hPa. Another relative maximum at 700 hPa.
➢3 methods largely decrease the analysis error compared with the background one. Slight degradation observed in the 650-750hPa layer. Both methods based on adjoint gradient give better results around the mean error peak.
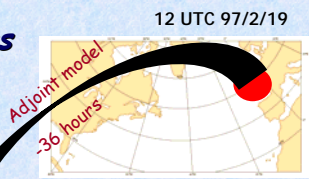
Root mean Square errors for 4 channel selection methods averaged over 142 profiles corresponding to a cloud top level of 1000hpa. «Insensitive channels» corresponds to the assimilation of all the channels not contaminated by low level cloud effects (about 2140 channels, number depending on the profile). «Constant» correponds to an analysis computed with a constant channel set for clear sky condition but channels contaminated by cloud effect have been removed (about 220 channels, depending on the profile).

➢Slight degradation observed in the troposphere with the constant channel set in comparison with an optimal channel set.
➢The assimilation of all the channels insensitive to cloud effects give an improvement of about 0.03K
➢KFS better han constant, but not better than ER

Future work
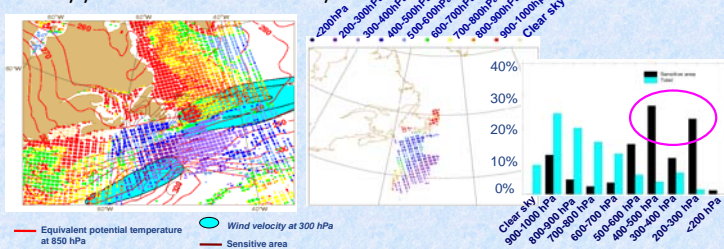·Taking into account the clouds in the radiative transfer model for the channel selection
·Assimilation of the IASI radiances in the NWP assimilation scheme → test of the actual impact of the different channel selection on the forecast score.

References:
·Baker, N. L; and Daley, R., 2000: Observation and background adjoint sensitivity in the adaptive observation targeting problem. *Q. J. R. Meteor. Soc.*, **126**, 1431-1454.
·Bergot T. and Doerenbecher A., 2002: Study on the optimization of the deploymentof the targeted observations using adjoint-based methods. *Q. J. R. Meteor. Soc.*, **128**, 1689-1712.
·Collard A. D., 1998: Notes on IASI performance, *NWP Technical Report*, No. 253, Met Office, Bracknell, UK.
·Doerenbecher A. and Bergot T., 2001: Sensitivity to observations applied to FASTEX cases. Non-linear Processes in Geophysics, **8**(6), 467-481.
·McNally, A. P., 2002: A note on the occurrence of cloud in meteorologically sensitive areas and the implications for advanced infrared sounders. *Q. J. R. Meteor. Soc.*, **128**, 2551-2556.
·Prunet P., Thépaut J.-N. and Cassé V., 1998: The information content of clear-sky IASI radiances and their potential for numerical weather prediction. *Q. J. R. Meteor. Soc.*, **124**, 211-241.
·Rodgers, C. D., 1996: Information content and optimisation of high spectral resolution measurements. *Optical Spectroscopic Techniques and Instrumentation for Atmospheric and Space Research II*, **SPIE Volume 2830**, 136-147.
·Rabier, F., Fourrié, N., Chafaï D. and P. Prunet, 2002: Channel selection methods for infrared atmospheric sounding interferometer radiances. *Q. J. R. Meteor. Soc.*, **128**, 1011-1027.