Evaluation of new IASI channel selections to improve the assimilation of cloud-affected radiances by the retrieval of cloud microphysical variables

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State of the art of the assimilation of cloud-affected infrared radiances at Météo-France

Comparison of two channel selection methodologies

- Selection based on the Degrees of Freedom of the Signal (DFS)
- Physical selection based on the sensitivity of the brightness temperature to a perturbation of the cloud variables

Sensitivity study

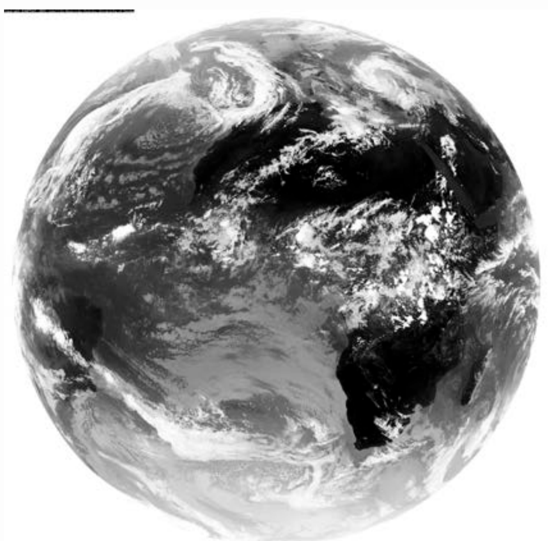
- To the ice optical parametrization in RTTOV
- Weather regime dependency

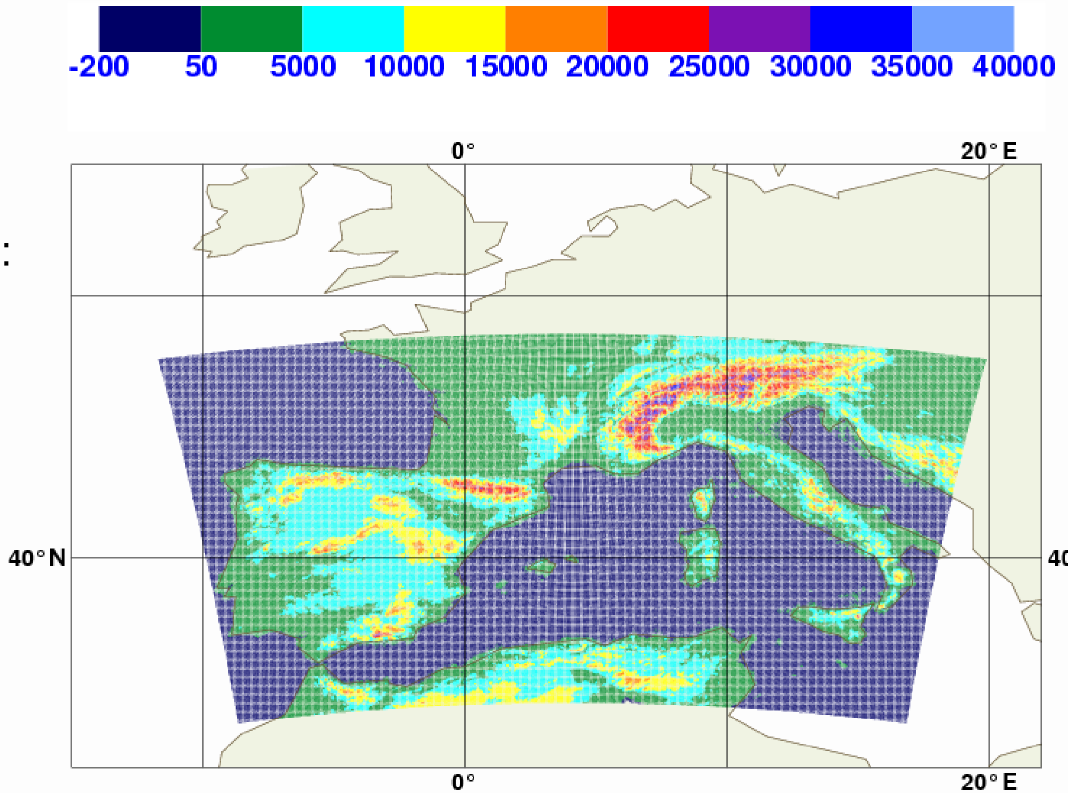
Context of the study

• Experimental campaign **HyMeX [1]**: better understanding of the hydrological cycle in the Mediterranean Sea.

• Convective scale model AROME W MED: 2.5 km grid size (Fourrié et al, 2012)

• 80 % of satellite data are covered by clouds.





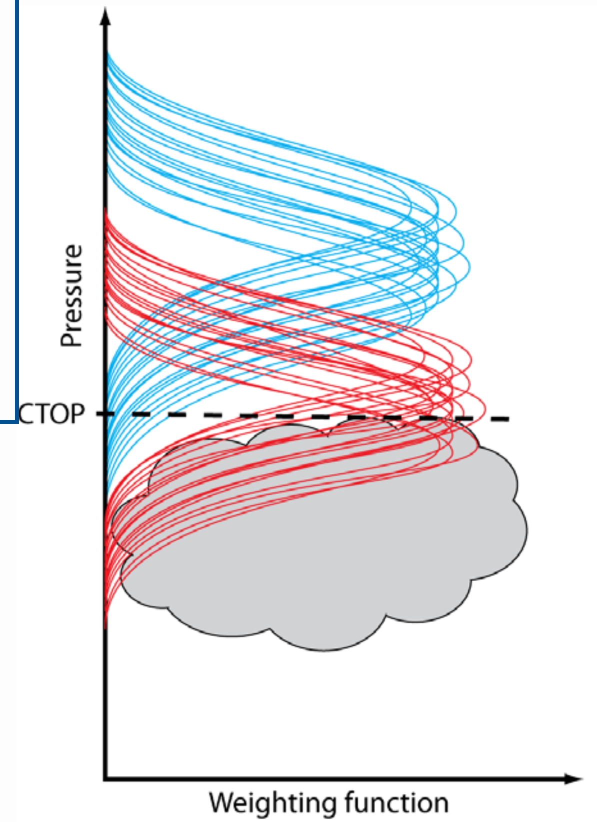
New developments to improve the assimilation of cloud-affected radiances from the hyperspectral infrared sounder IASI in the convective scale model AROME.

State of the art for the treatment of cloud-affected radiances

Operational assimilation

- Use two cloud parameters: cloud top pressure (**CTOP**) and effective cloud fraction (**Ne**) to constrain the assimilation (Guidard, Fourrié et al, 2011)

  + Use of cloud-affected channels
  - Problems for the detection of low level clouds and thin cirrus clouds, simplified modelling of clouds (single layers of opaque clouds)



CNRS dépasser les frontières

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State of the art for the treatment of cloud-affected radiances

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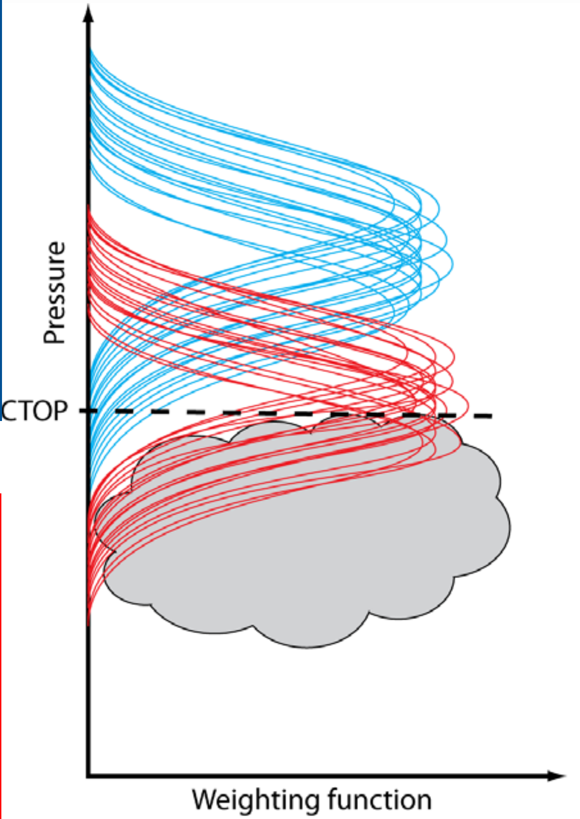


New developments

- Use of microphysical variables for the assimilation: liquid water content (lwc) and ice water content (iwc).

+ Better modelling of clouds (multi layer, mixed phase).
- Linearity

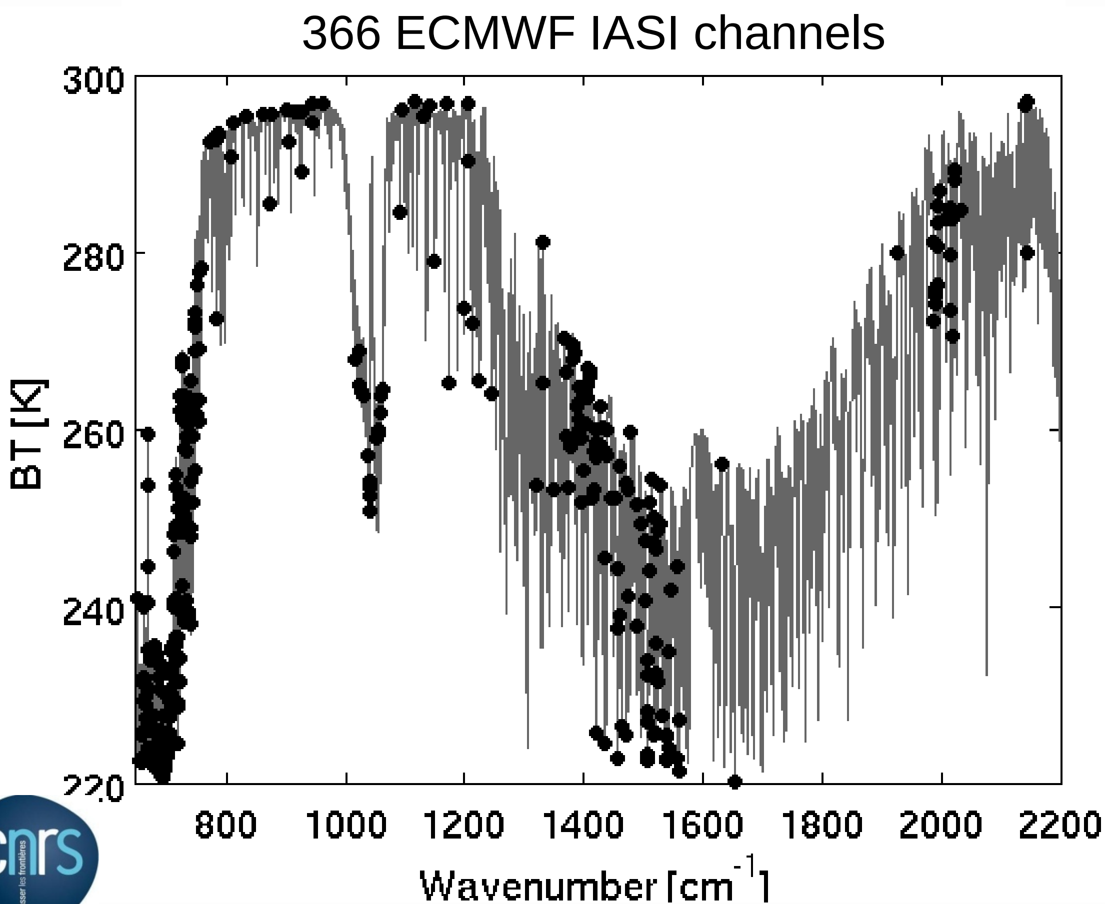
Encouraging results have been found by Martinet et al (2012)[1] with only 77 channels.

Are these channels suitable for cloudy retrievals ? Can we improve the retrieval of microphysical variables with new channels sensitive to cloud variables ?

1: Martinet et al 2012: Towards the use of microphysical variables for the assimilation of cloud-affected infrared radiances, QJRMS, DOI: 10.1002/qj.2046.

Methodology

➢ Evaluation of the selection of the **366** IASI channels used operationally at the European Centre for Medium-Range Weather Forecast (**ECMWF**). This selection was performed with the Degrees of Freedom of the signal (DFS) as the figure of merit on clear atmospheric profiles (Collard and McNally 2009).



➢ Addition of **134** channels sensitive to cloud variables. **366+134=500** channels: limit of the GTS to provide IASI observations to operational centres.

➢ Selection on 15 cloudy profiles from AROME: 5 semi-transparent ice clouds, 5 ice opaque clouds, 5 low liquid clouds.

Comparison of two channel selections

Selection based on the spectral sensitivity to the perturbation of lwc/iwc

$$\Delta BT = BT(x+\delta x) - BT(x)$$

- BT response to the perturbation of each atmospheric constituent: lwc, iwc, T,q, Tskin, O_3, CH_4, CO.
- Selection of channels with the highest sensitivity to lwc/iwc variables, the lowest sensitivity to interfering species (T,q…) and the lowest instrumental noise.

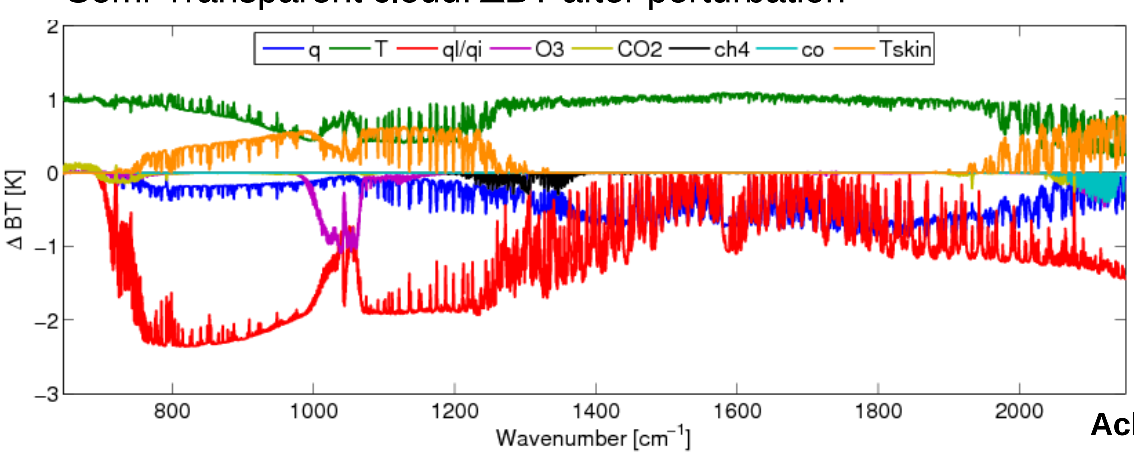
Selection based on the DFS

$$DFS = tr(I - \mathbf{A}\mathbf{B}^{-1})$$

A: analysis error covariance matrix.
B: background error covariance matrix. (cloudy matrix computed from a 6 member AROME ensemble on convective cases).

- Based on linear estimation theory
- Selection of the channels that most improve the DFS.
- Update of the **B** matrix with the **A** matrix computed after *i* channels have been chosen to take into account redundant information.

Semi-Transparent cloud: ΔBT after perturbation



lwc/iwc perturbation:+ 10%
Ozone perturbation: +10%
Q perturbation: +10%
T perturbation: +1 K
Tskin perturbation: +1 K

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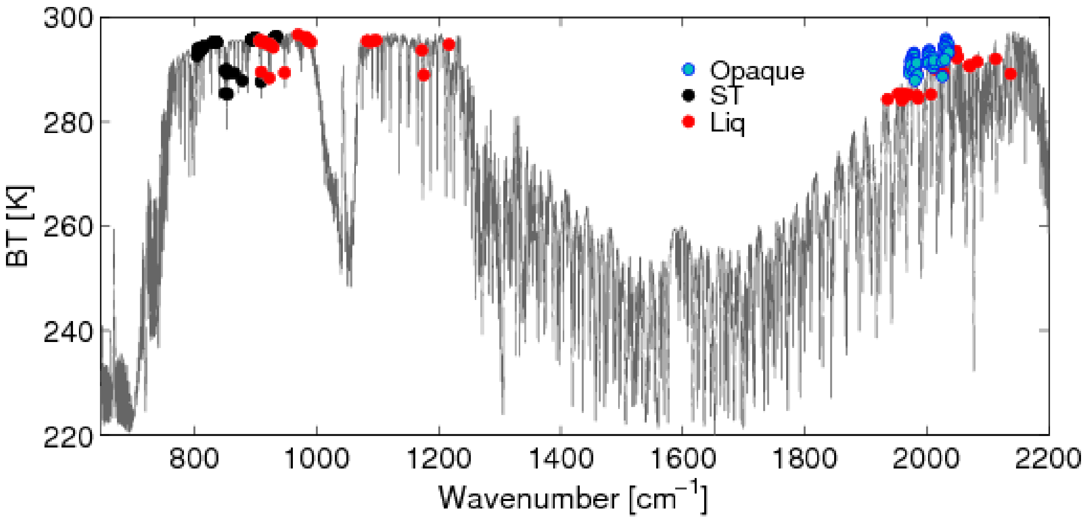
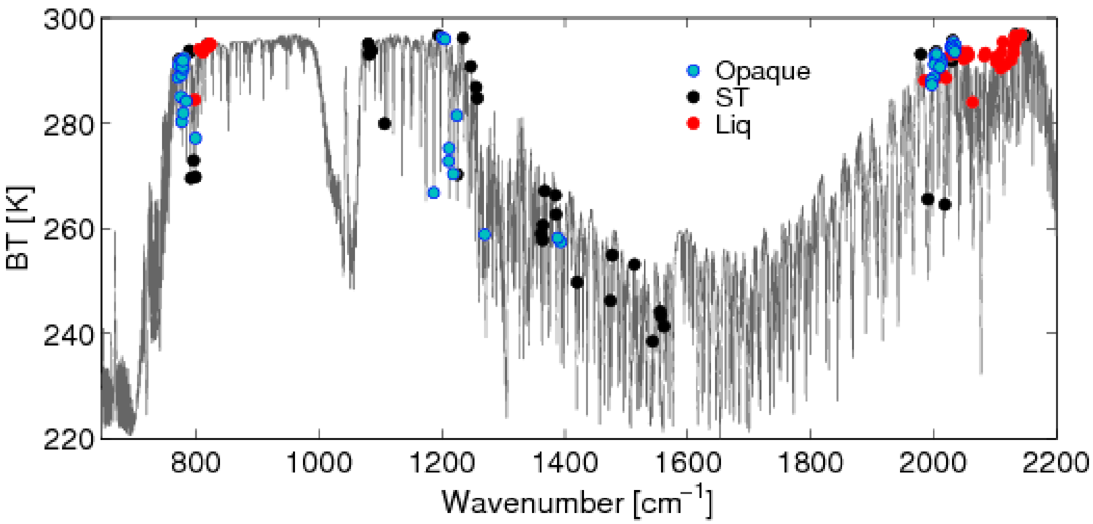
Ackn: C. Clerbaux and J. Hadji-Lazaro for CO profile

Comparison of two channel selections

Selection based on the spectral sensitivity to the perturbation of lwc/iwc



Selection based on the DFS



- Only 24 channels shared by the two methods of selection

- Selection in the 3 window regions: 800-1000 cm^{-1}, 1090-1200 cm^{-1}, 1800-2150 cm^{-1}

- Selection of water vapour channels by the DFS (contribution to cloud variables and cross-correlations between lwc/iwc and q in the **B** matrix).

- For both selections, most of the selected channels are located in the band **1800-2150 cm^{-1}** (higher wave numbers have been discarded to avoid noisy channels).

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Evaluation by mean of 1D-Var retrieval applications in the context of OSSE.

- Use of AROME profiles within homogeneous overcast observations perturbed with a Gaussian noise proportional to the **B matrix**:

$$x = x_{true} + \varepsilon_b \mathbf{B}^{1/2}$$

- Simulation of IASI radiances with RTTOV CLD. Perturbation with the IASI instrument noise provided by CNES and radiative transfer model errors.

$$y = H(x_{true}) + \varepsilon_o \mathbf{R}^{1/2}$$

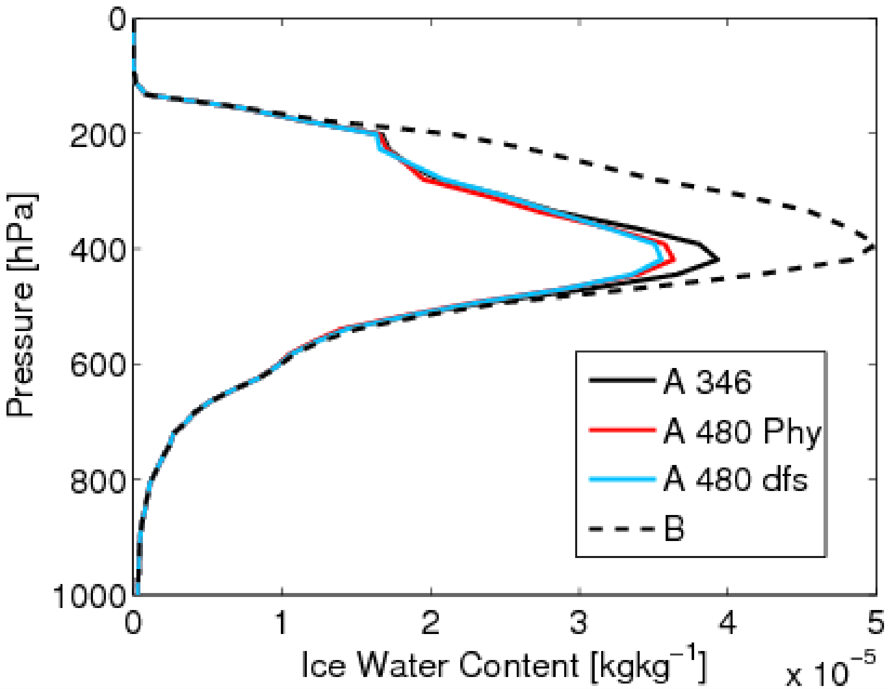
- Use of a background error **B** matrix computed from a 6 member AROME ensemble on **convective cases** **(Thibaut Montmerle [1])**.

- Comparison of RMSE of the background and the analysis with respect to the « true » profile. 346 channels monitored at ECMWF + new selection of 134 channels (480 channels total).

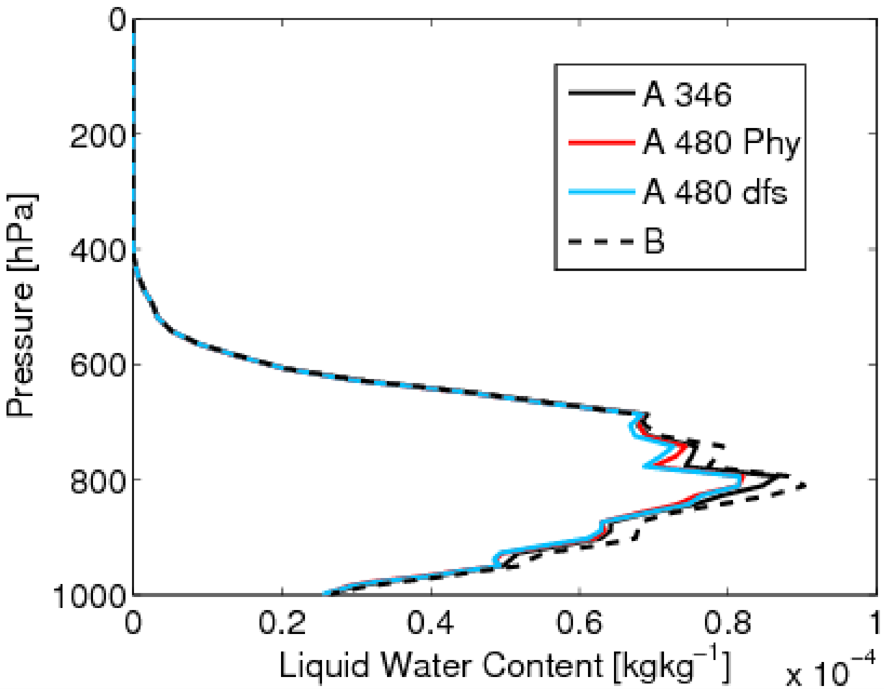
1. Michel et al 2011: Heterogeneous Convective-Scale Background Error Covariances with the inclusion of hydrometeor Variables. Montly Weather Review, 139, 2994-3015.

Evaluation by mean of 1D-Var retrieval applications in the context of OSSE.

RMSE ice water content opaque clouds



RMSE liquid water content low clouds

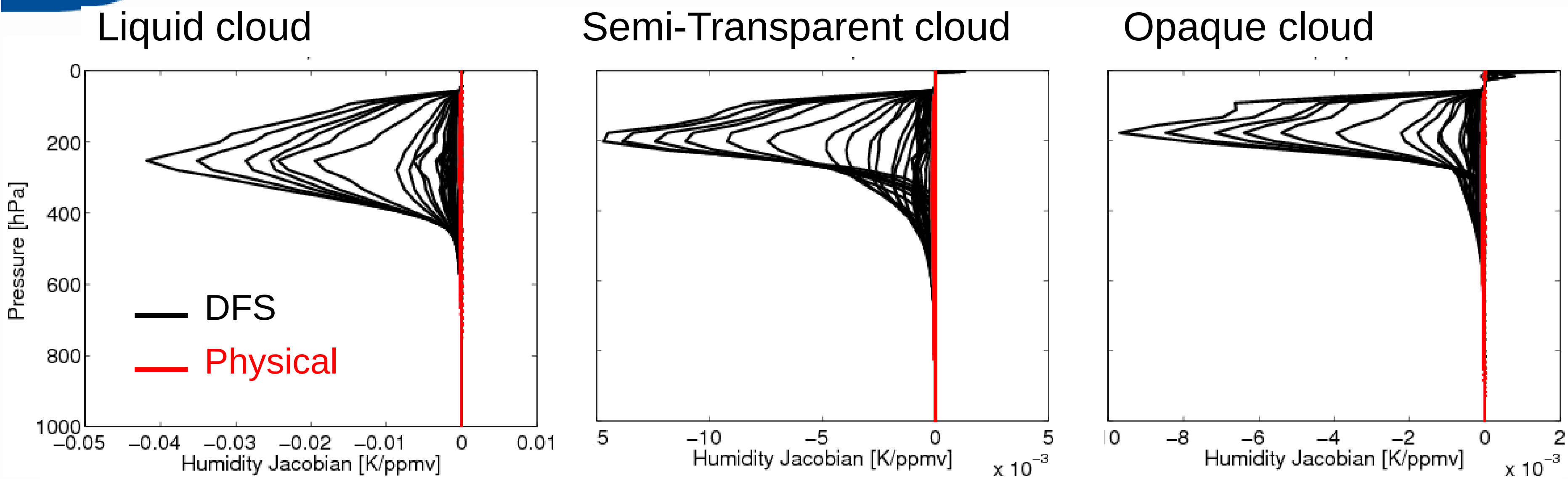


- Good quality of the 366 IASI channels for cloudy retrievals.
- BUT Improvement of the RMSE by **7%** with the new selections.

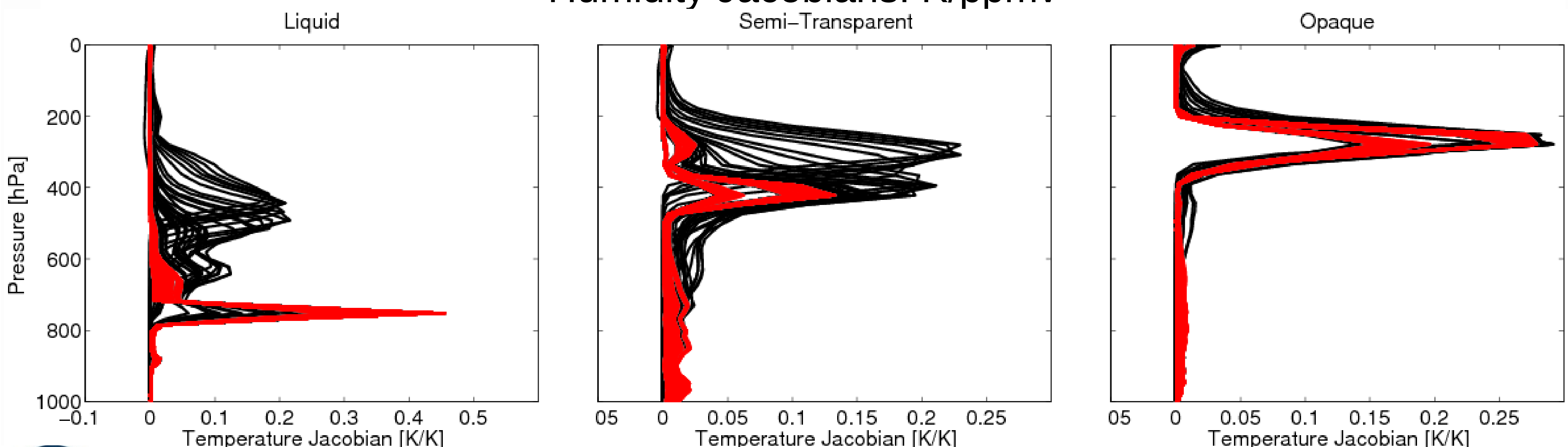
- Good quality of the 366 IASI channels for cloudy retrievals.
- BUT Improvement of the RMSE by **5%** with the new selections.

- RMSE equivalent with 366 and 500 channels in the case of semi-transparent clouds (not shown)
- Equivalence of the two selections in terms of RMSE.

Temperature and humidity Jacobians



Humidity Jacobians: K/ppmv



TemperatureJacobians: K/K

Sensitivity to the ice optical parametrizations in RTTOV-CLD. (Example of the physical selection)

- In RTTOV-CLD, the user must choose what assumption to use to parameterize the effective diameter. 4 parametrizations available: Boudala, McFarquhar, Ou and Liou, Wyser.

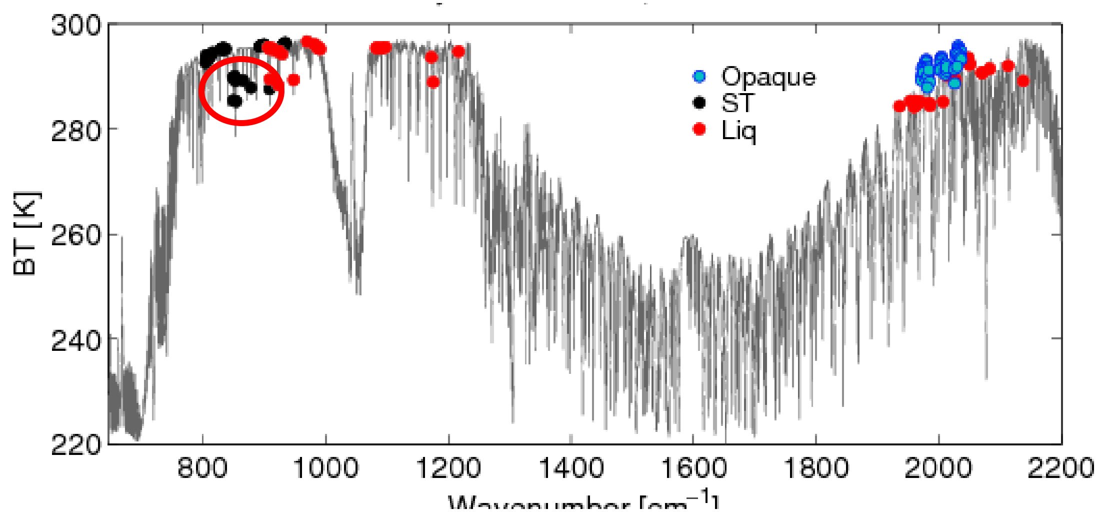
- 60% of the selected channels are shared by both parametrizations.

- Small differences are observed.

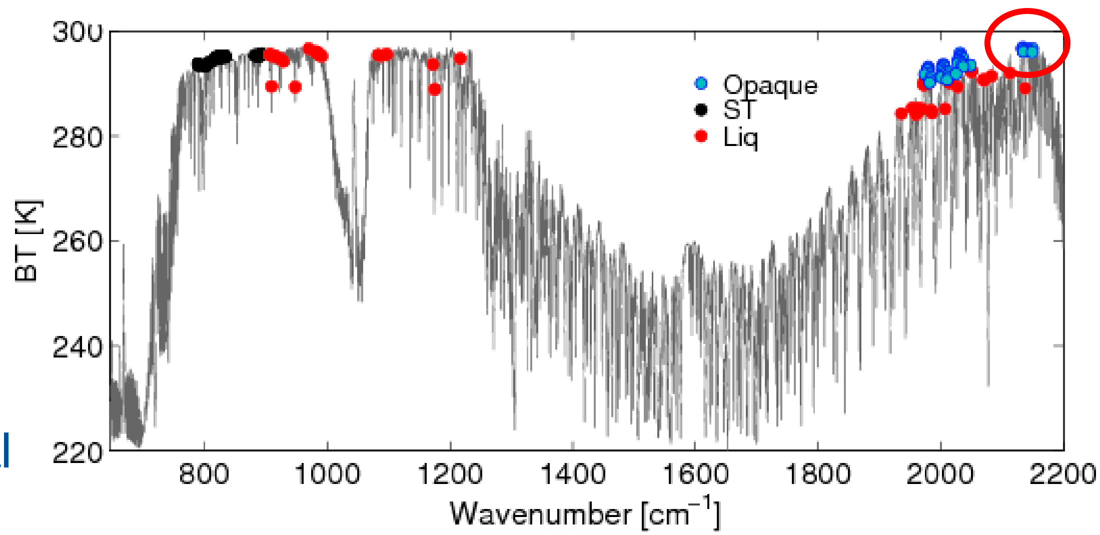
- No impact on 1D-Var retrievals.

Robustness of the physical selection to the ice optical properties.

Physical selection: **Boudala** parametrization



Physical selection: **McFarquhar** parametrization



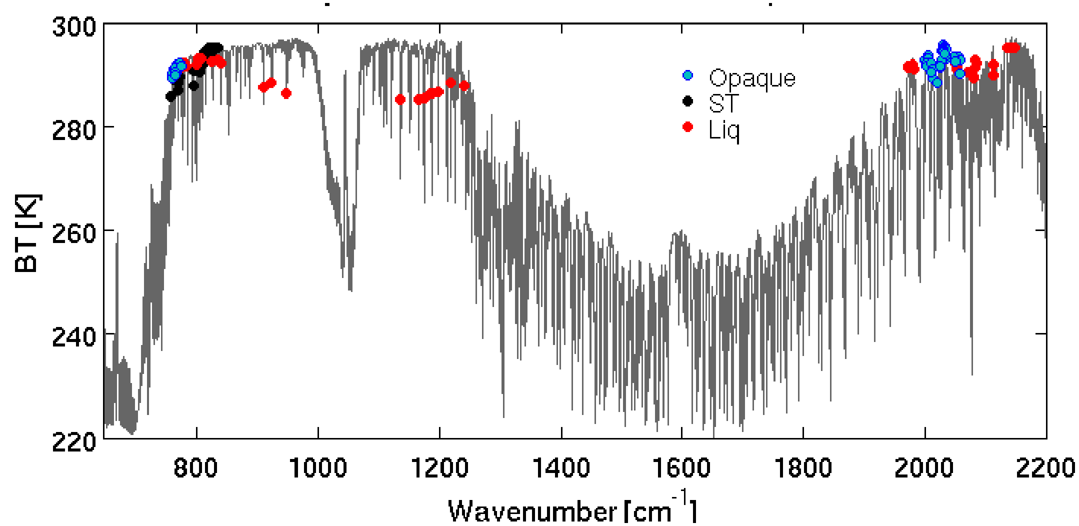
Sensitivity to the weather regime.

• Atmospheric profiles from the last **ECMWF database** are used to perform the physical selection.

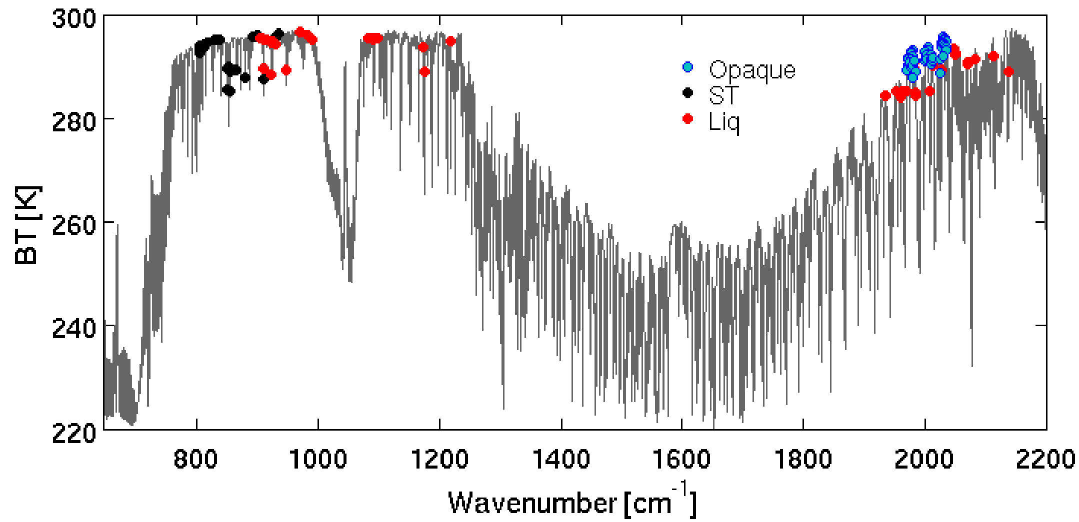
• Each cloud type (semi-transparent, opaque, liquid) is composed of four air-mass types: **Mid-Latitude South, Mid Latitude North, polar and tropical.**

Significant differences in bands 800-1000cm^{-1} 1090-1200 cm^{-1} but most of the channels are selected in band **1800-2150** cm^{-1} for both selections.

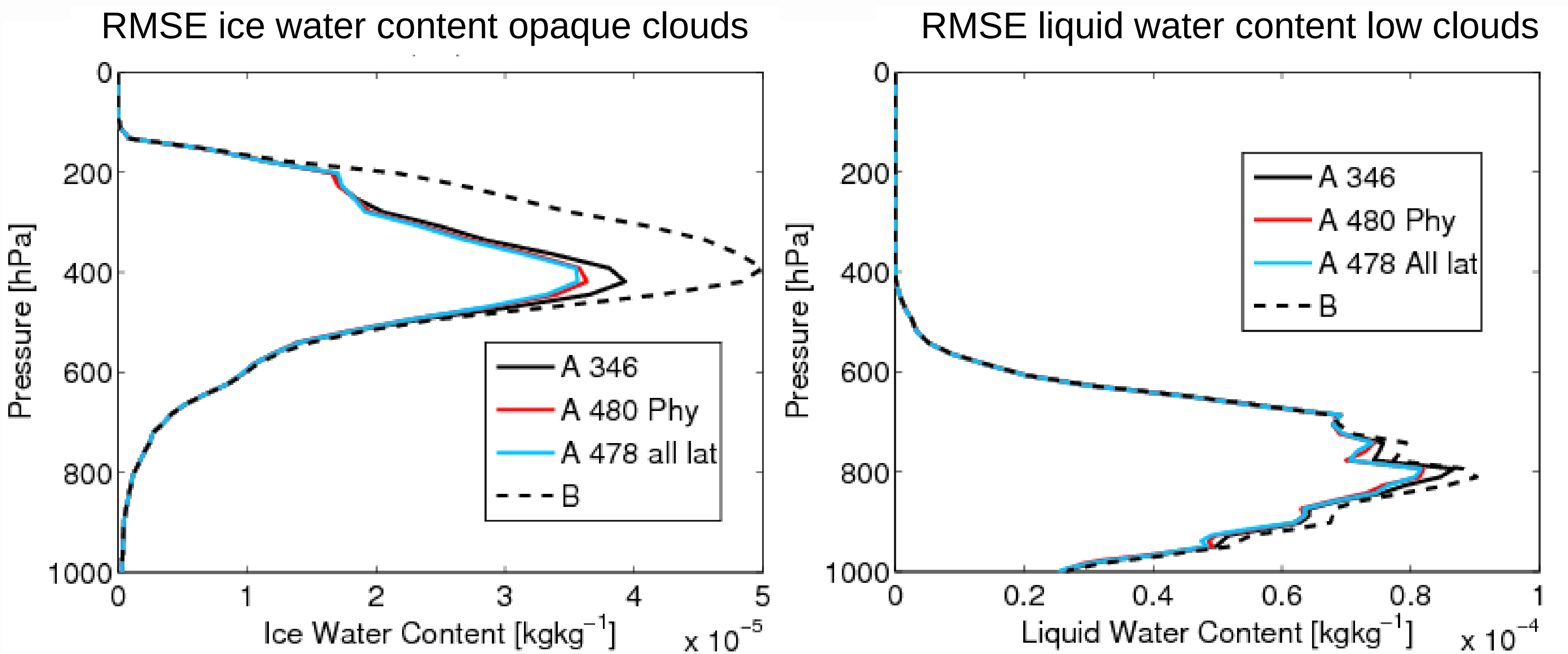
Physical selection: ECMWF profiles



Physical selection: Mediterranean profiles (AROME)



Sensitivity to the weather regime: 1D-Var performance.



- No significant difference is observed in terms of 1D-Var retrievals
- **The physical selection is quite independent of the air-mass type.**

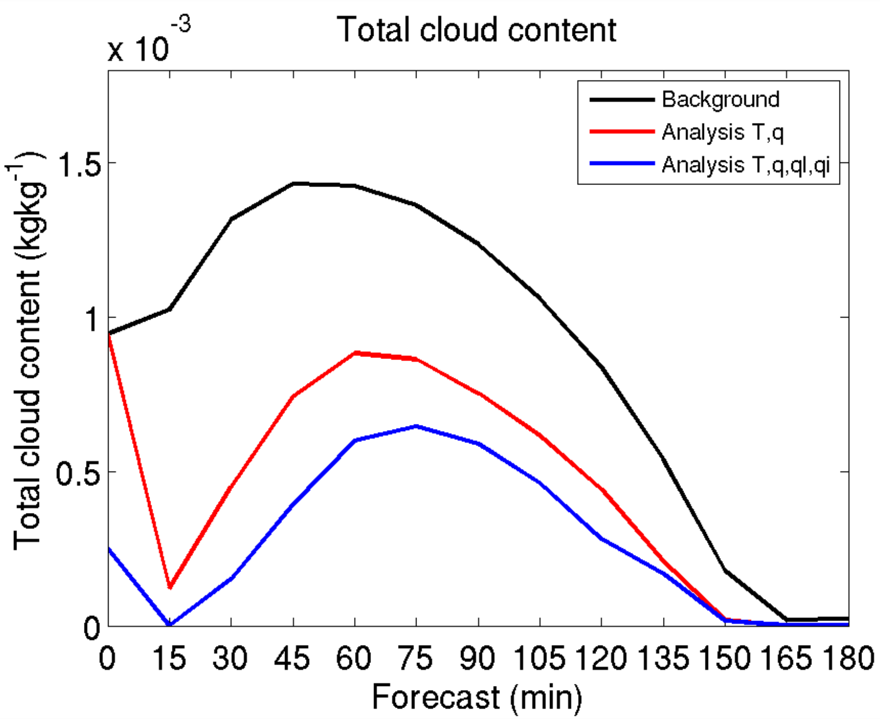
1.Martinet et al 2012:Evaluation of a revised IASI channel selection for cloudy retrievals with a focus on the Mediterranean basin, QJRMS, submitted.

Impact of the analysis of cloud variables on NWP forecast.

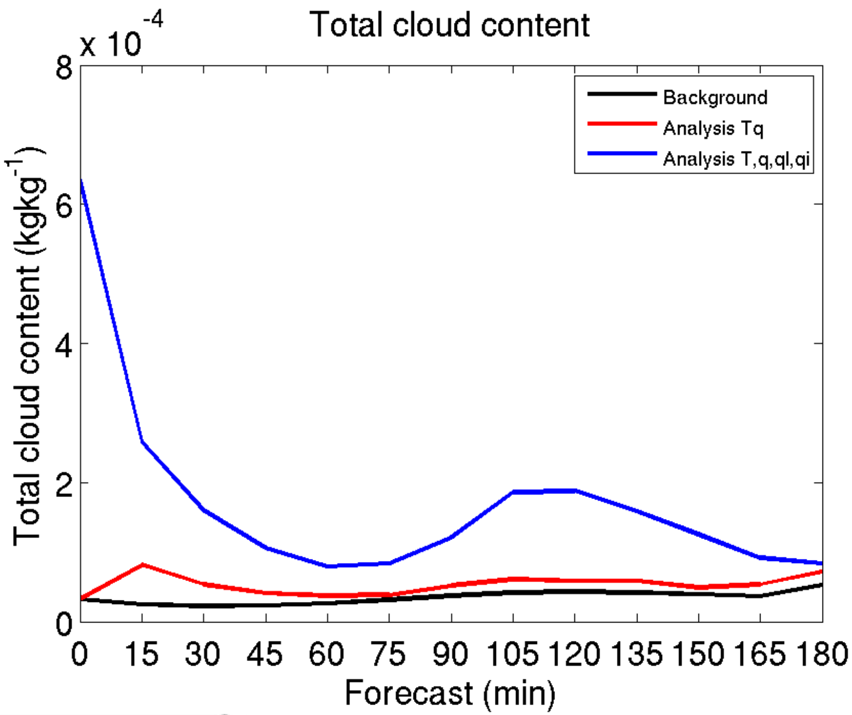
• The profiles analysed with 480 channels are used in a **1D-version** of the **AROME** model
• Evolution of the profiles during 3 hours to evaluate if the information brought by the observation is well conserved by the model.

• Three cases are tested: evolution of the **background**, the **analysis of T,q,LWC,IWC** and the **analysis of only T and q** keeping LWC and IWC to the background values.

LWC liquid cloud



IWC semi-transparent cloud



Conclusion and prospects

Past

- A set of 134 channels selected with a physical approach are proposed to improve the analysis of cloud variables

- Its robustness on the ice optical parametrization and the weather regime was demonstrated.

- Encouraging results have been found on a simplified version of AROME: the analyses of cloud variables are able to modify the forecast of cloud variables during the 3 hours of the assimilation window.

Future

- Modification of the cloud fraction during the assimilation (according to the lwc/iwc modifications).

- Global validation of the new channel selection in a quasi-operational context (if the lwc/iwc variables can be included in the 3D version of the model).

Thanks for your attention.

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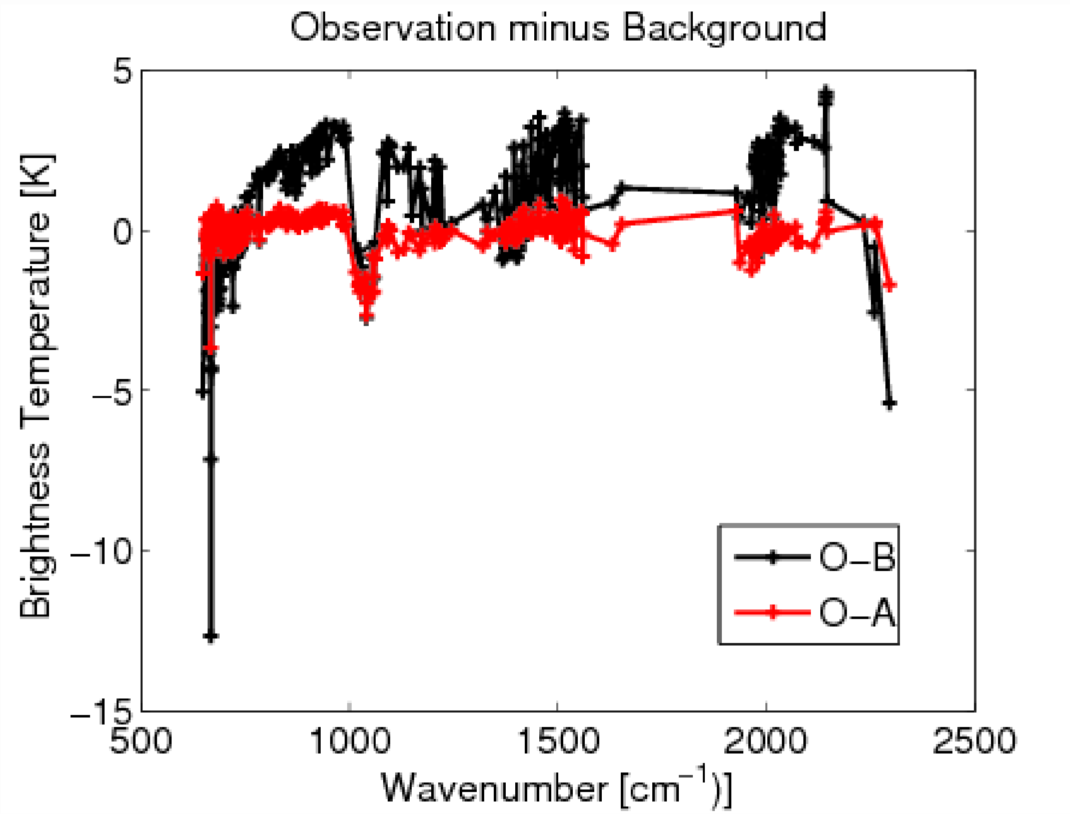
First studied case: Low Cloud (Observation minus background departures)

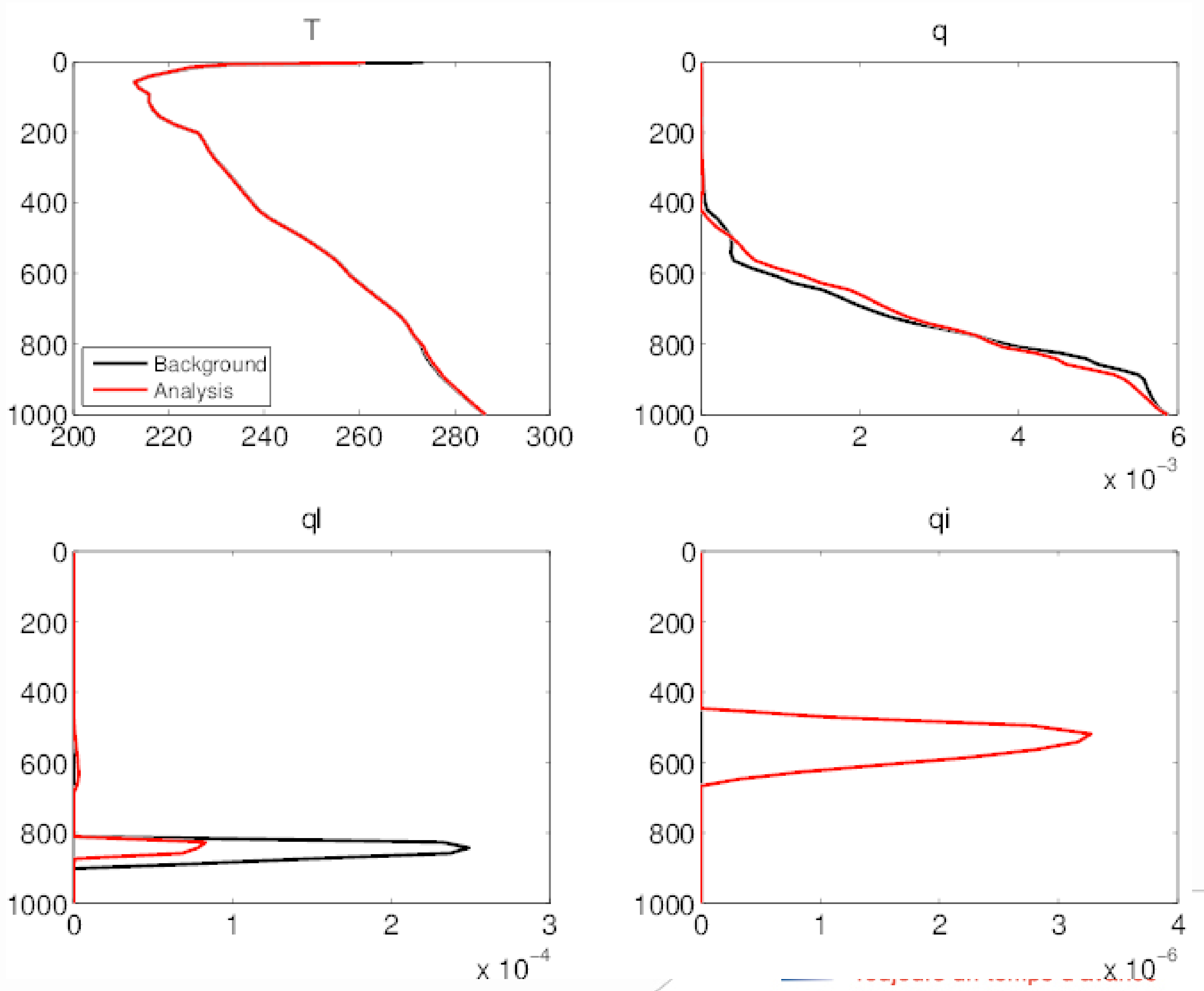


Decrease of the model cloudiness to fit the observation.

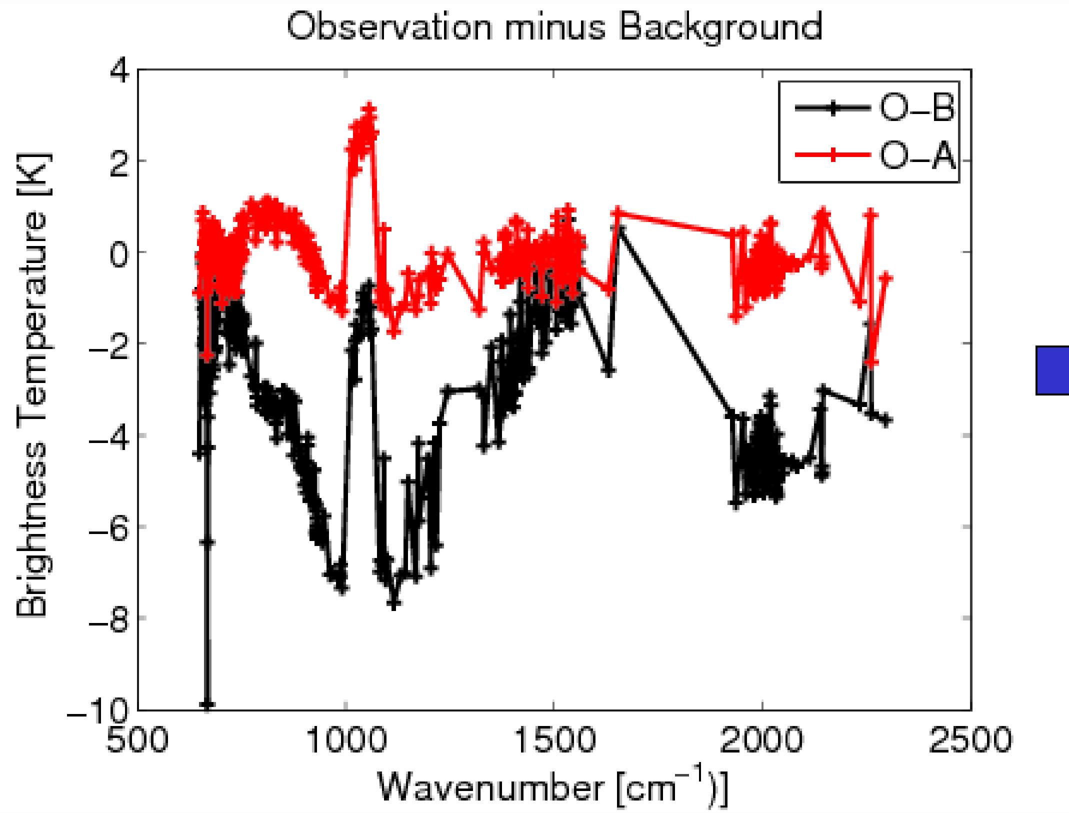
First studied case: Low Cloud

• Decrease of the liquid water content.

• A small amount of ice water content appears because of the cross-correlations between q and IWC.

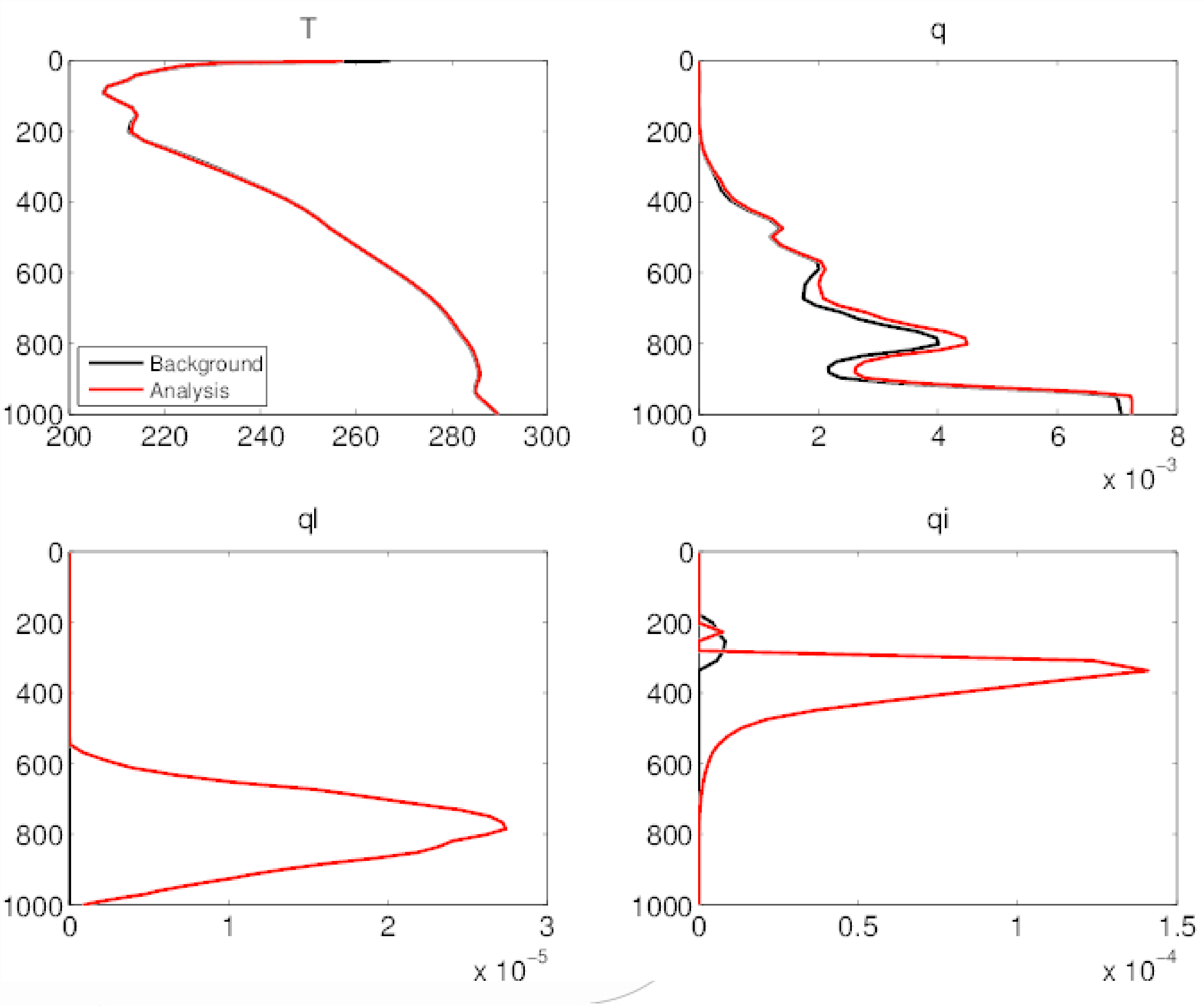


Second studied case: Semi-Transparent Cloud



Increase of the model cloudiness to fit the observation.

Second studied case: Semi-Transparent Cloud



- Increase of the ice water content.
- A small amount of liquid water content appears because of the cross-correlations between q and LWC.