Evaluation of data impact in the mesoscale AROME 3D-Var system at Météo-France

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Outline

- Main features of the AROME forecasting system
- Observation usage for data assimilation
- Diagnostics :
  - Degrees of Freedom for Signal (Desroziers and Ivanov, 2001)
  - Reduction of error variance of estimation (Desroziers et al., 2005)
- Conclusions

Regional model AROME

- Spectral limited area non-hydrostatic model with explicit moist convection
- Heritage : ARPEGE and ALADIN NWP models – MESO-NH research model
- Operational at Météo-France since December 2008
- Horizontal resolution : 2.5 km
- 60 vertical levels (up to 1 hPa)
- 3D-Var assimilation (3h window)
- Coupling files : hourly forecasts from global model ARPEGE
- Forecast range : 30 hours

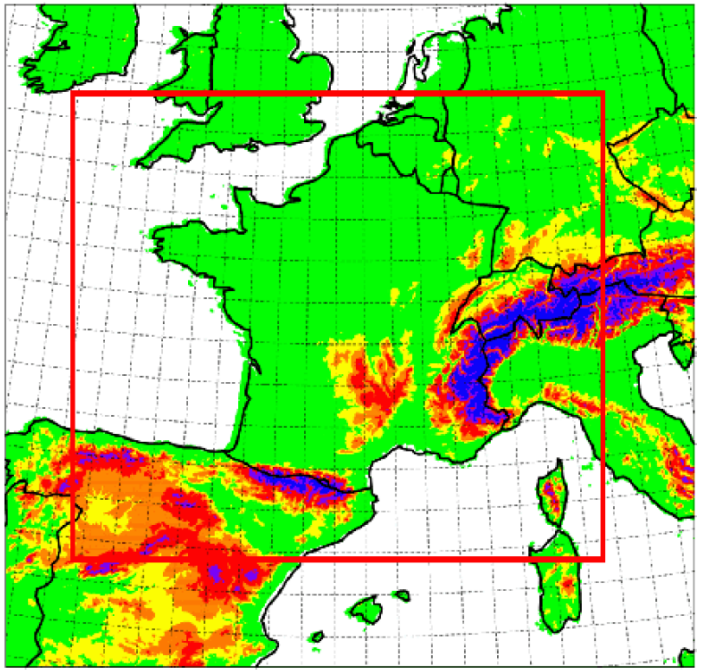

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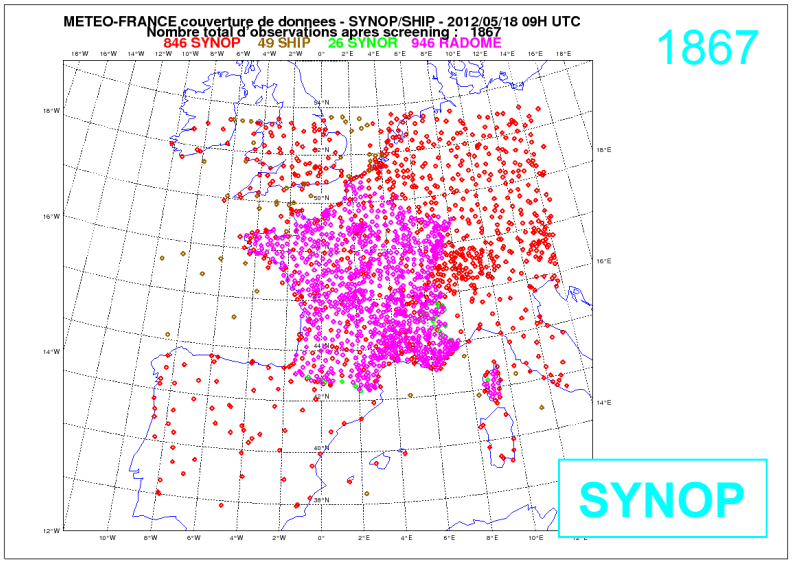
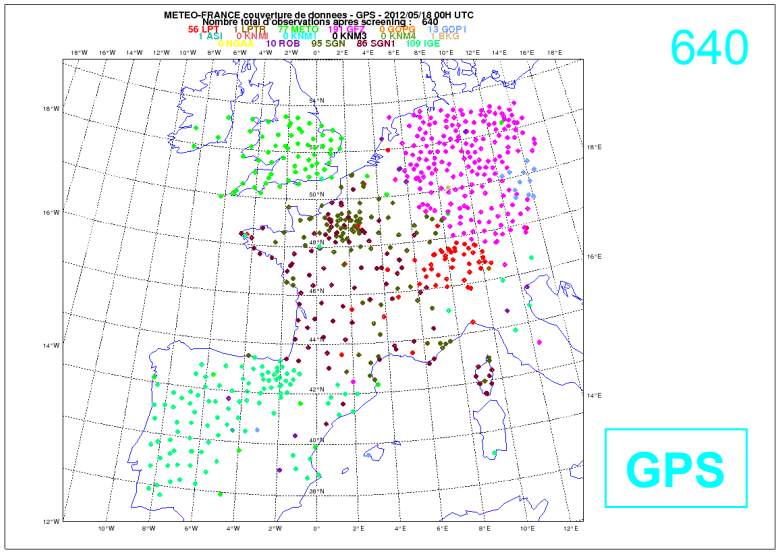
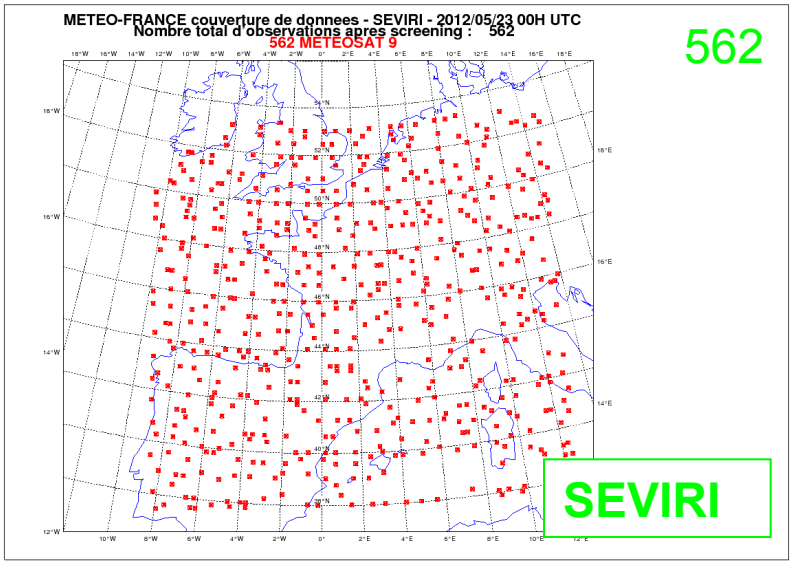
Illustration of data usage in 3D-Var (type 1)







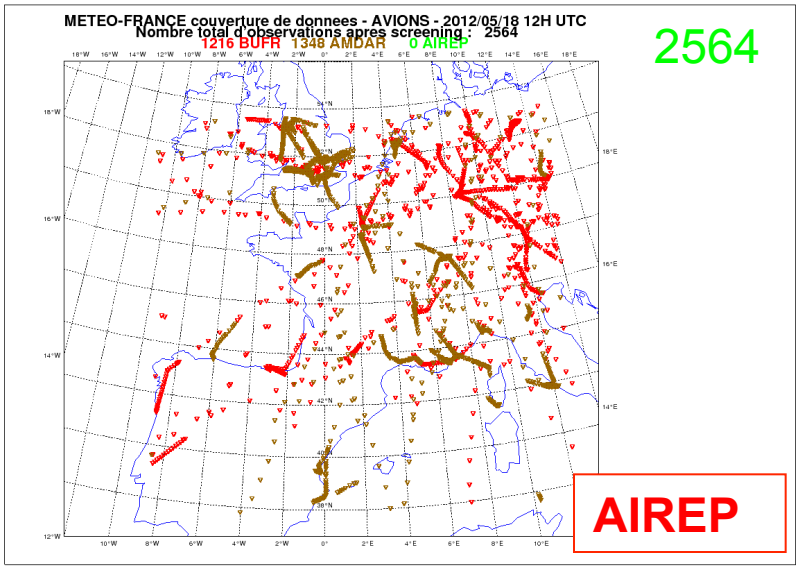
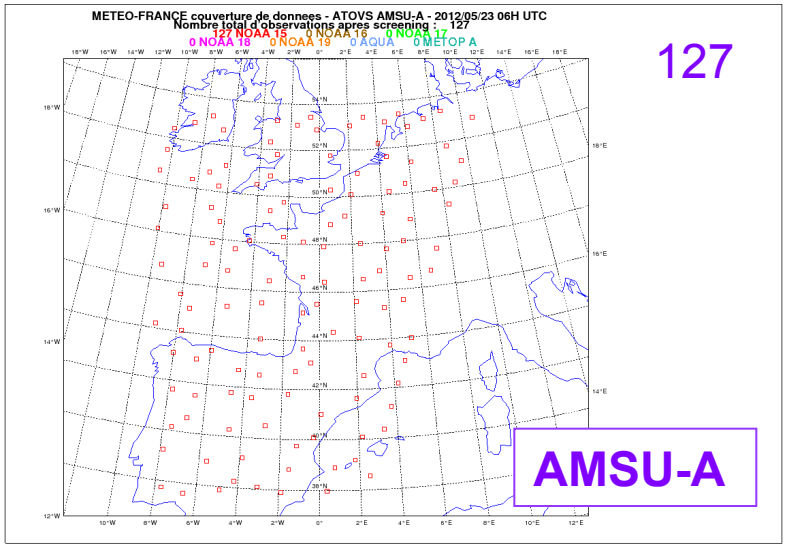


Illustration of data usage in 3D-Var (type 2)



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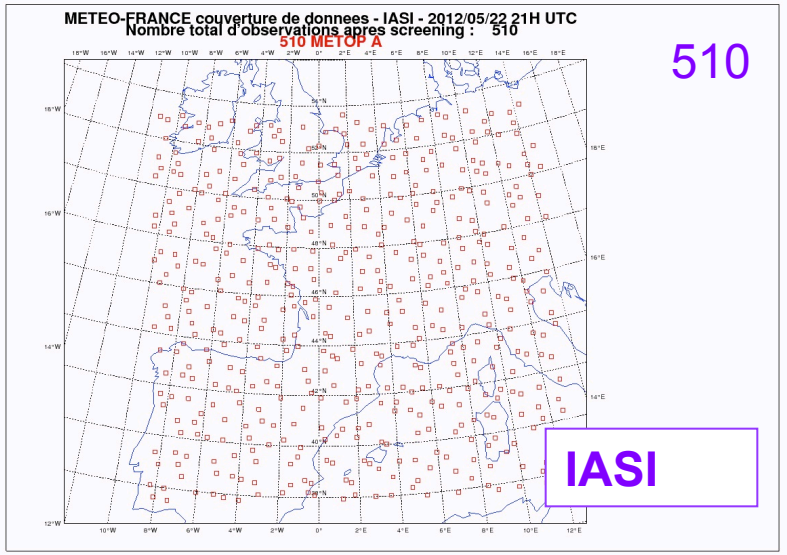
AMSU-A



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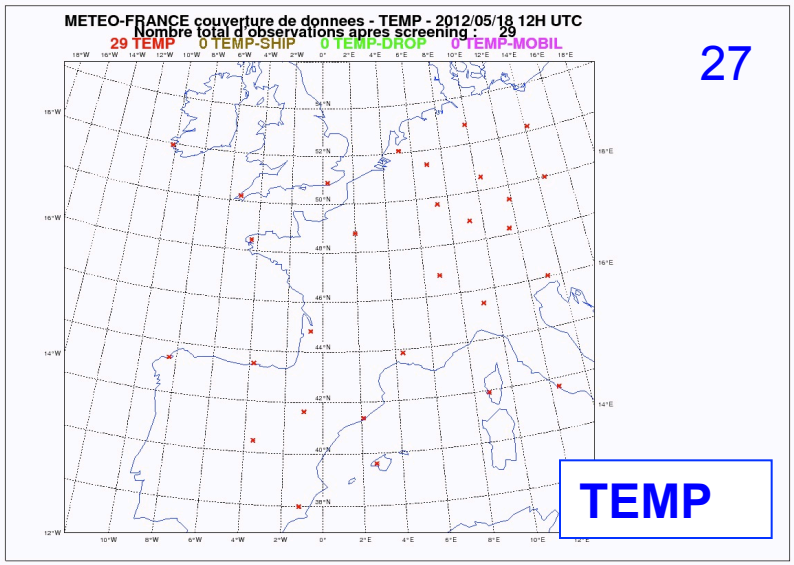
IASI



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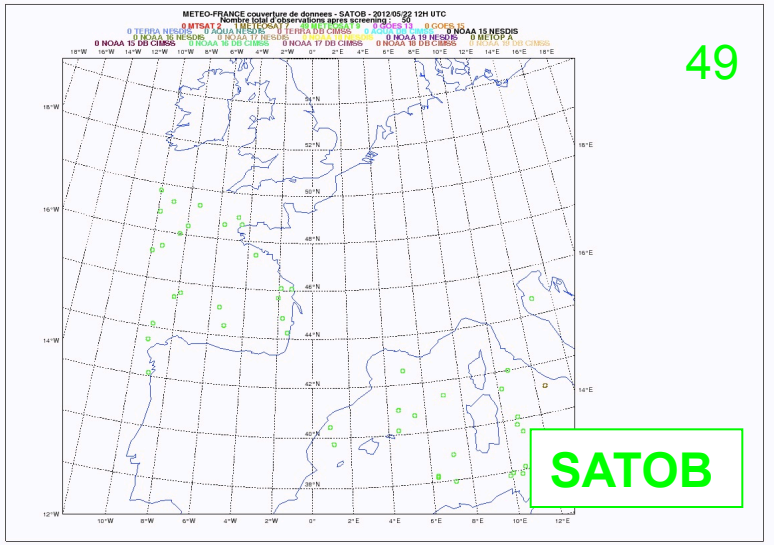
TEMP



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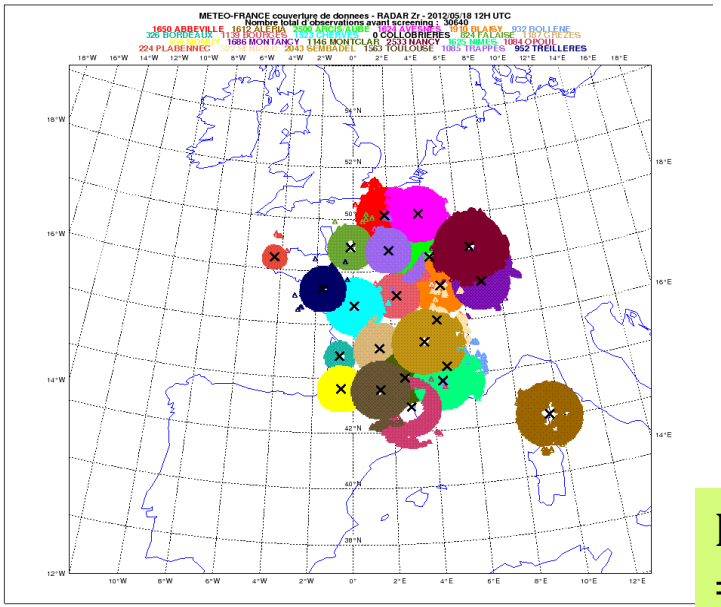
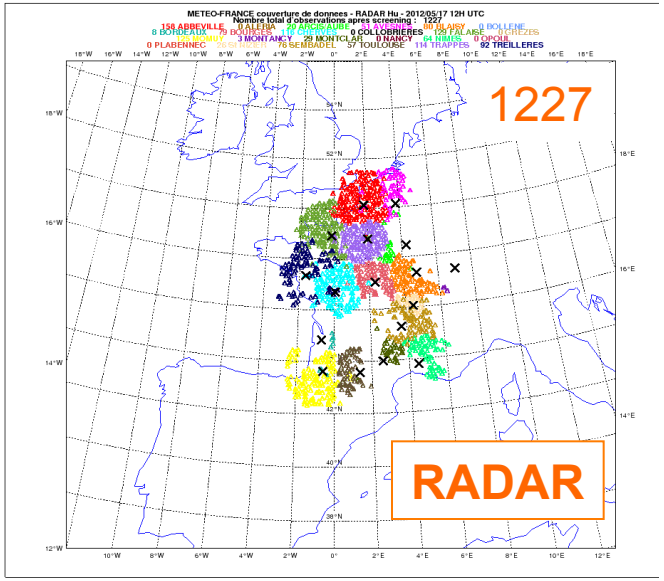
SATOB

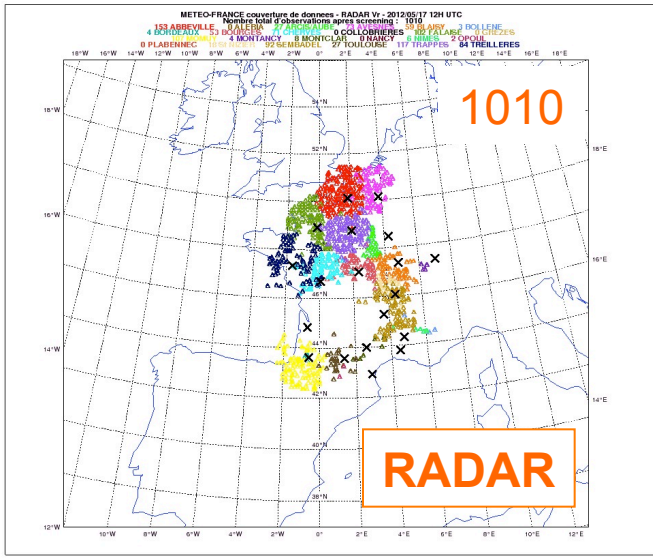
ARAMIS : French network of 24 Doppler radars



Radial wind



Relative humidity = F(reflectivity)



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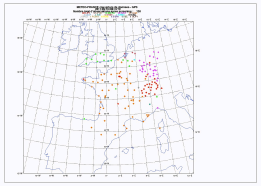
DFS in AROME

- Mean over 8 analyses per day
- Mean over 10 days in May 2010 (*fewer GPS*)

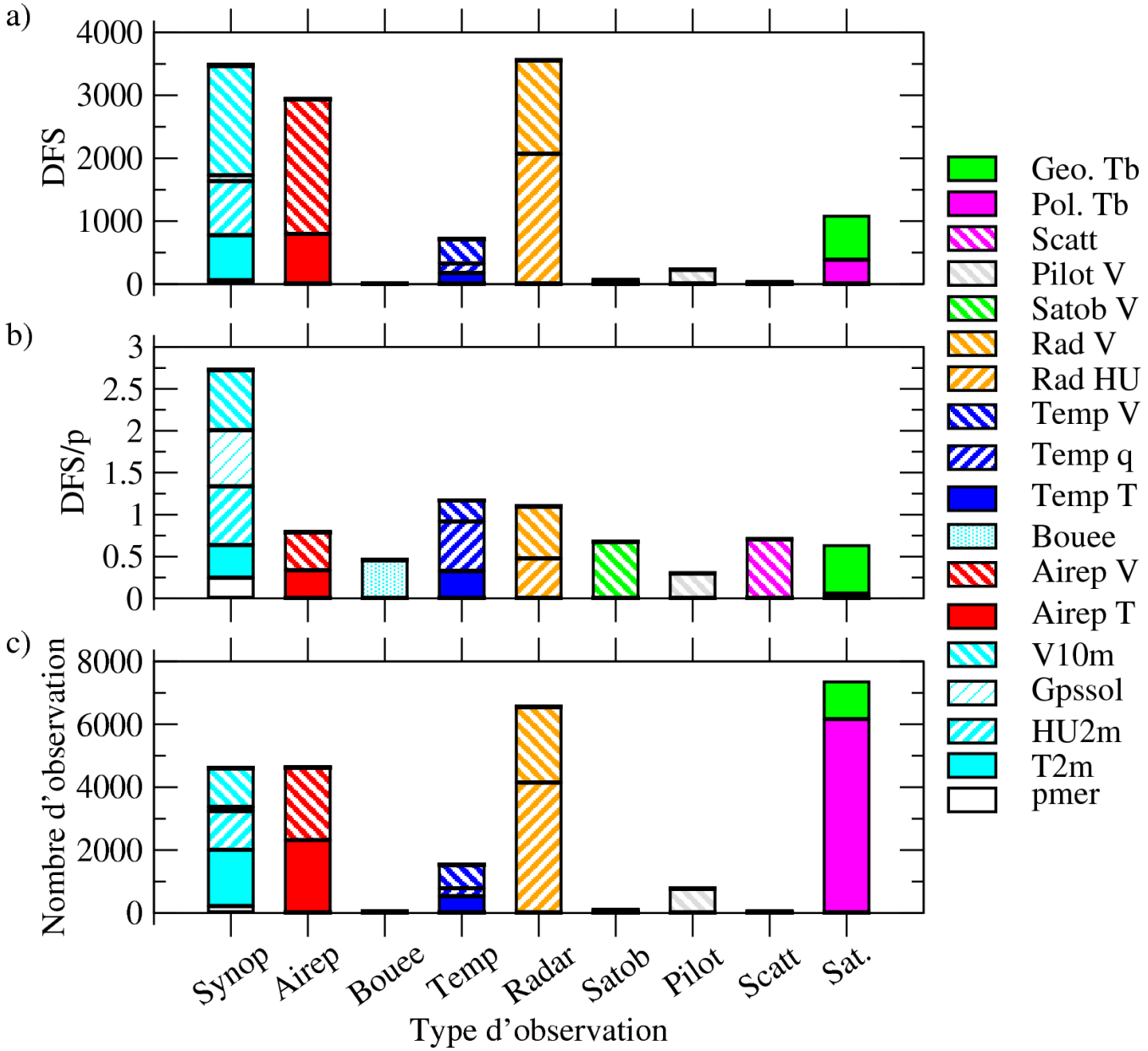


wind

humidity

temperature

pressure



Reduction of error variance of estimation

- Analysis error covariance matrix (from linear estimation theory) :

$$\mathbf{A} = \mathbf{B} - \mathbf{KHB}$$

- Reduction of error variance of estimation: $r = Tr(\mathbf{B}) - Tr(\mathbf{A}) = Tr(\mathbf{KHB})$

- When **R** is block-diagonal, *r* can be split between observational subsets i :

$$r_i = Tr(\mathbf{K}_i\mathbf{HB}) \qquad \mathbf{K}_i = \mathbf{K}\Pi_i^T\Pi_i$$

- A transformation **L** can also be applied : projection over a geographical domain, specific field or model level, specific norm, forecast model, …

$$r = Tr(\mathbf{LKHBL}^T)$$

- Estimation from a randomization technique proposed by Desroziers et al. (2005) : differences between a reference analysis and analyses with perturbed observations

Some properties

- DFS has no dimension : global and synthetic measure of the informativity of observations on an analysis
- *r* has the dimension of the variance of a model field : comparison only for fields having the same dimension
- When $\frac{\sigma_o}{\sigma_b}$ increases (observation weight decreases), DFS et *r* are reduced.
- When background correlation lengths are increased :
  - DFS is reduced : each observation has less freedom to modify the background independently from the others
  - *r* is increased : each observation modifies the background and reduces the variance over a wider domain

Validation of the computation

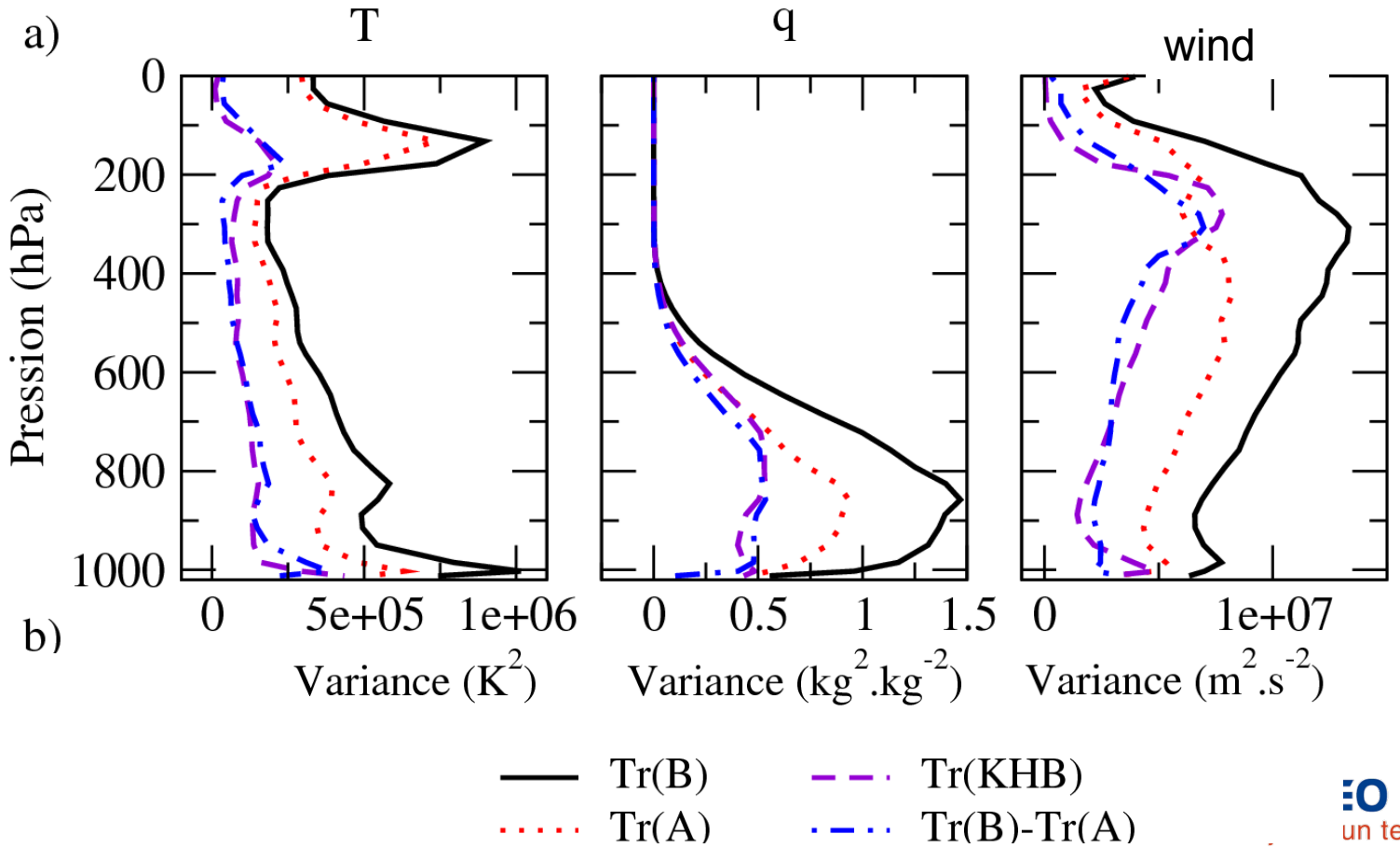
- In the optimal case :

$$r = Tr(\mathbf{B}) - Tr(\mathbf{A}) = Tr(\mathbf{KHB})$$

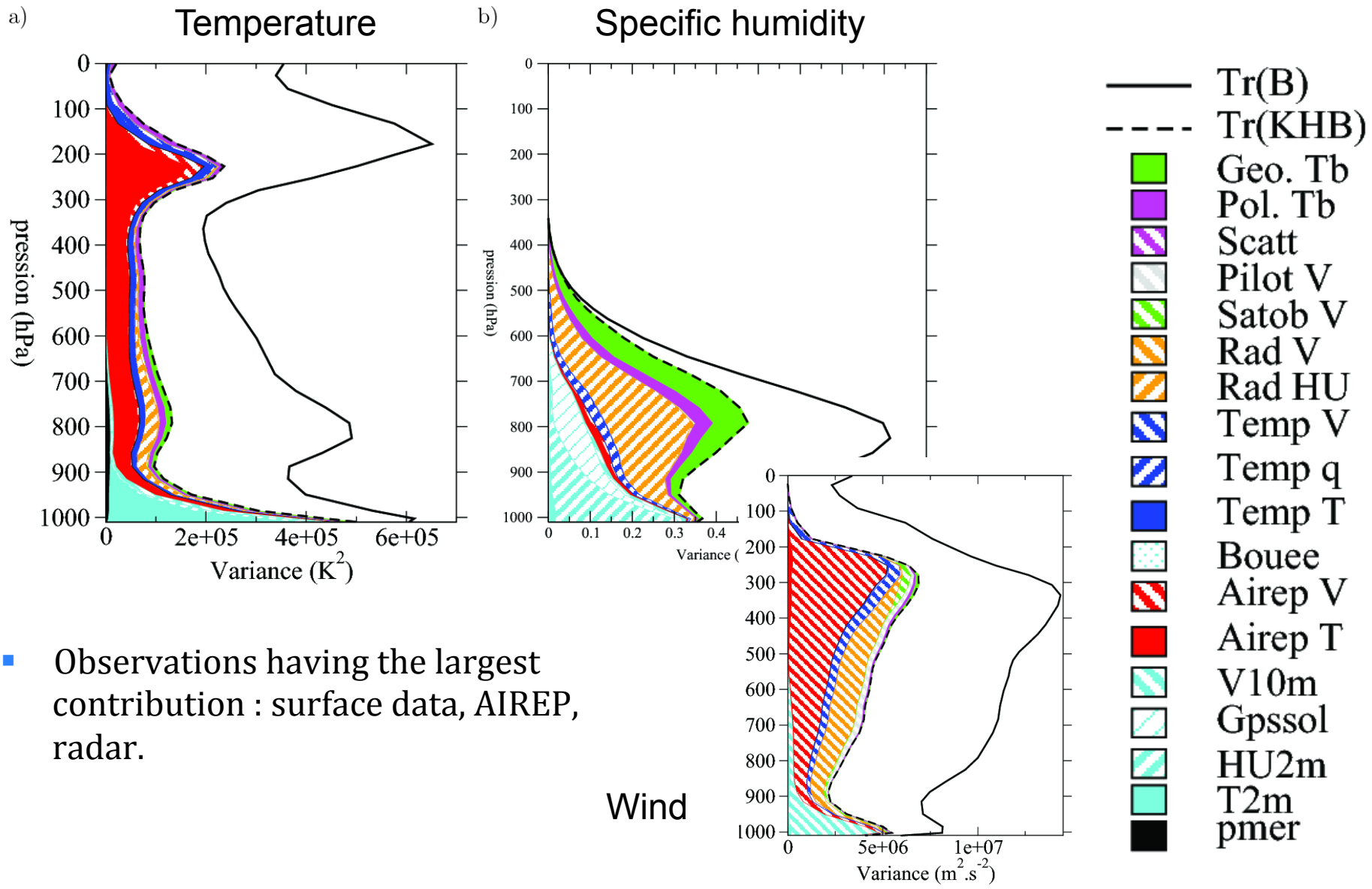
Prescribed

Estimated from an ensemble of analyses

Estimated from the proposed method

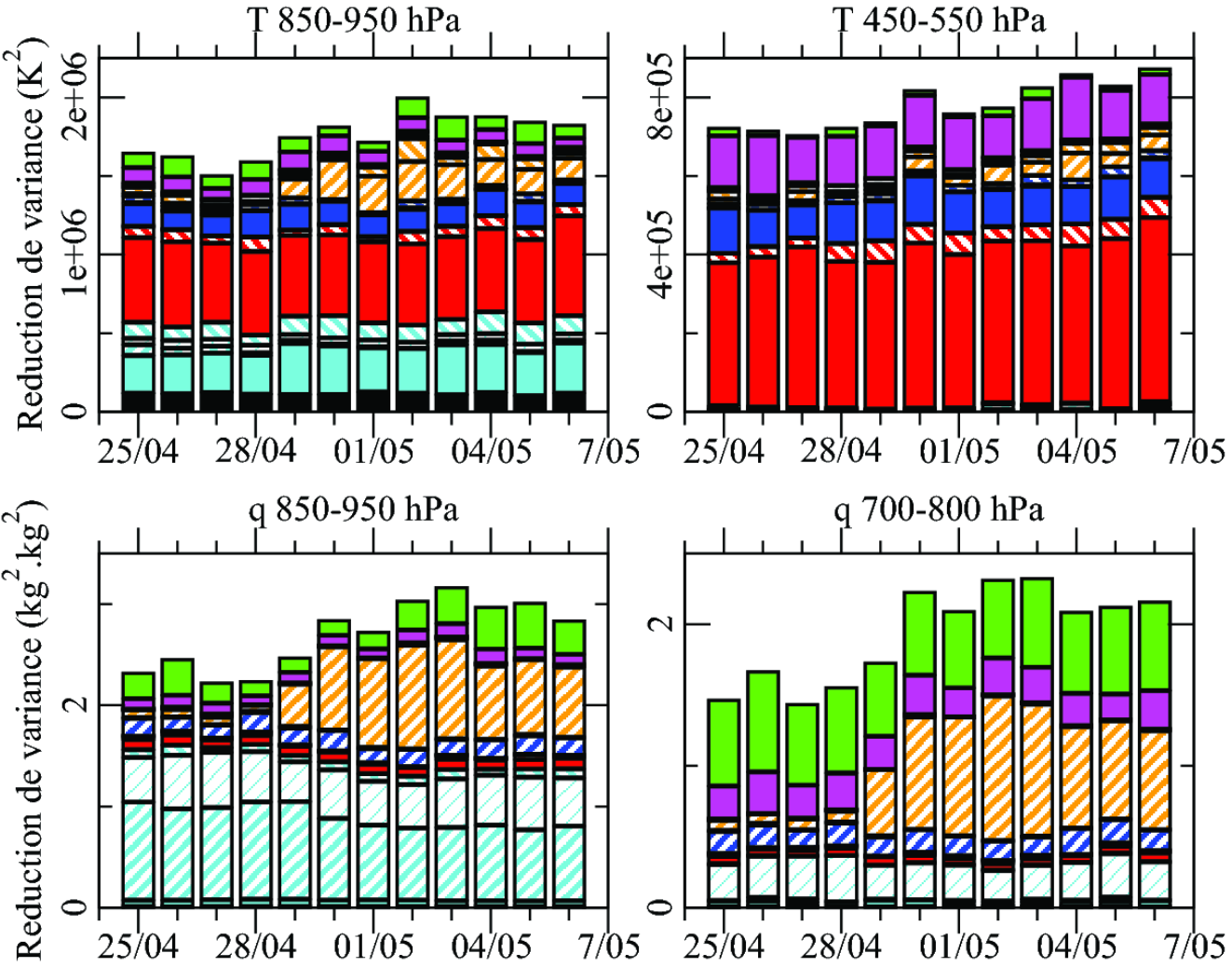


Daily mean variances



- Observations having the largest contribution : surface data, AIREP, radar.

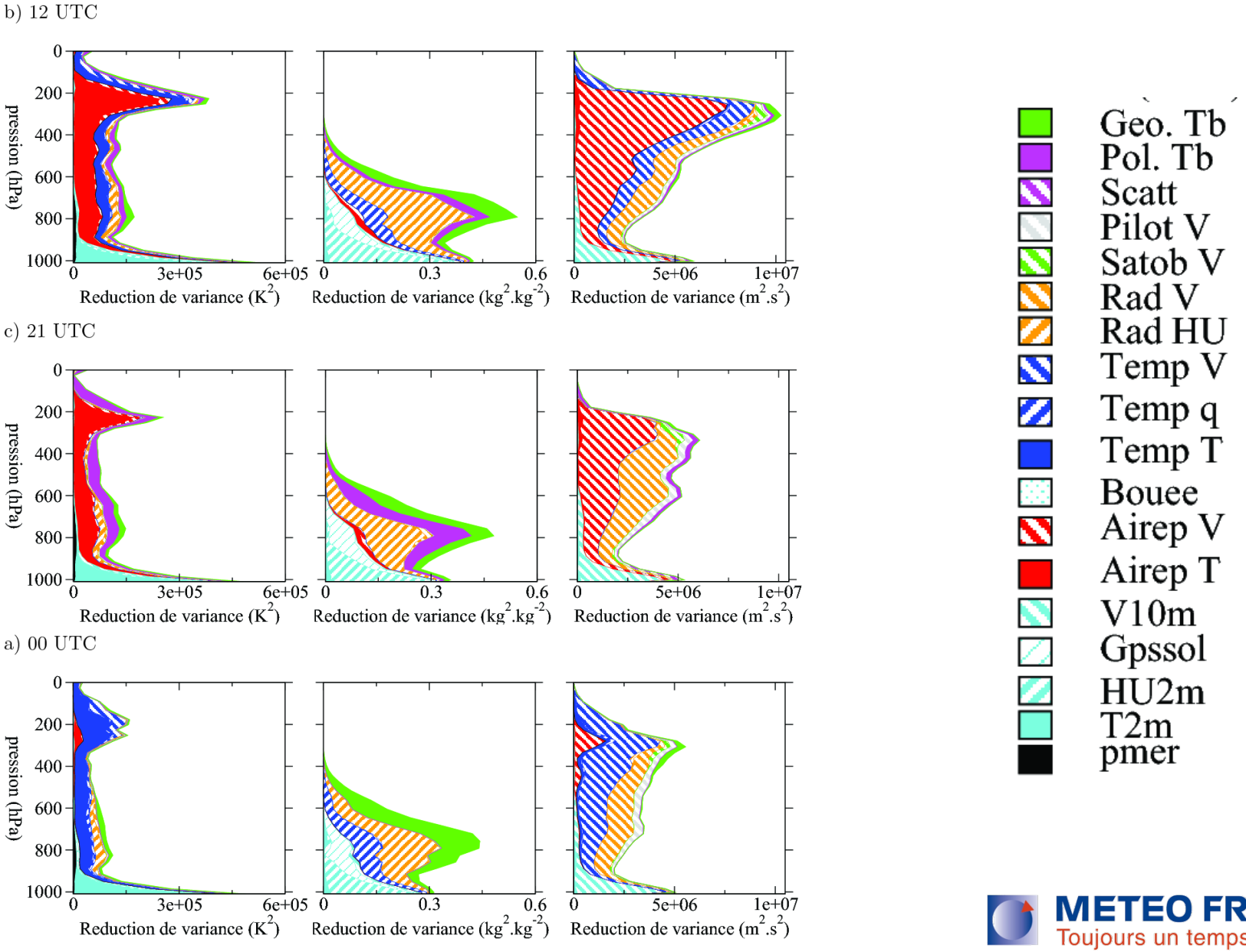
Day to day variability



Larger reduction during rainy periods coming from radar radial winds

- Geo. Tb
- Pol. Tb
- Scatt
- Pilot V
- Satob V
- Rad V
- Rad HU
- Temp V
- Temp q
- Temp T
- Bouee
- Airep V
- Airep T
- V10m
- Gpssol
- HU2m
- T2m
- pmer

Dependency with analysis time



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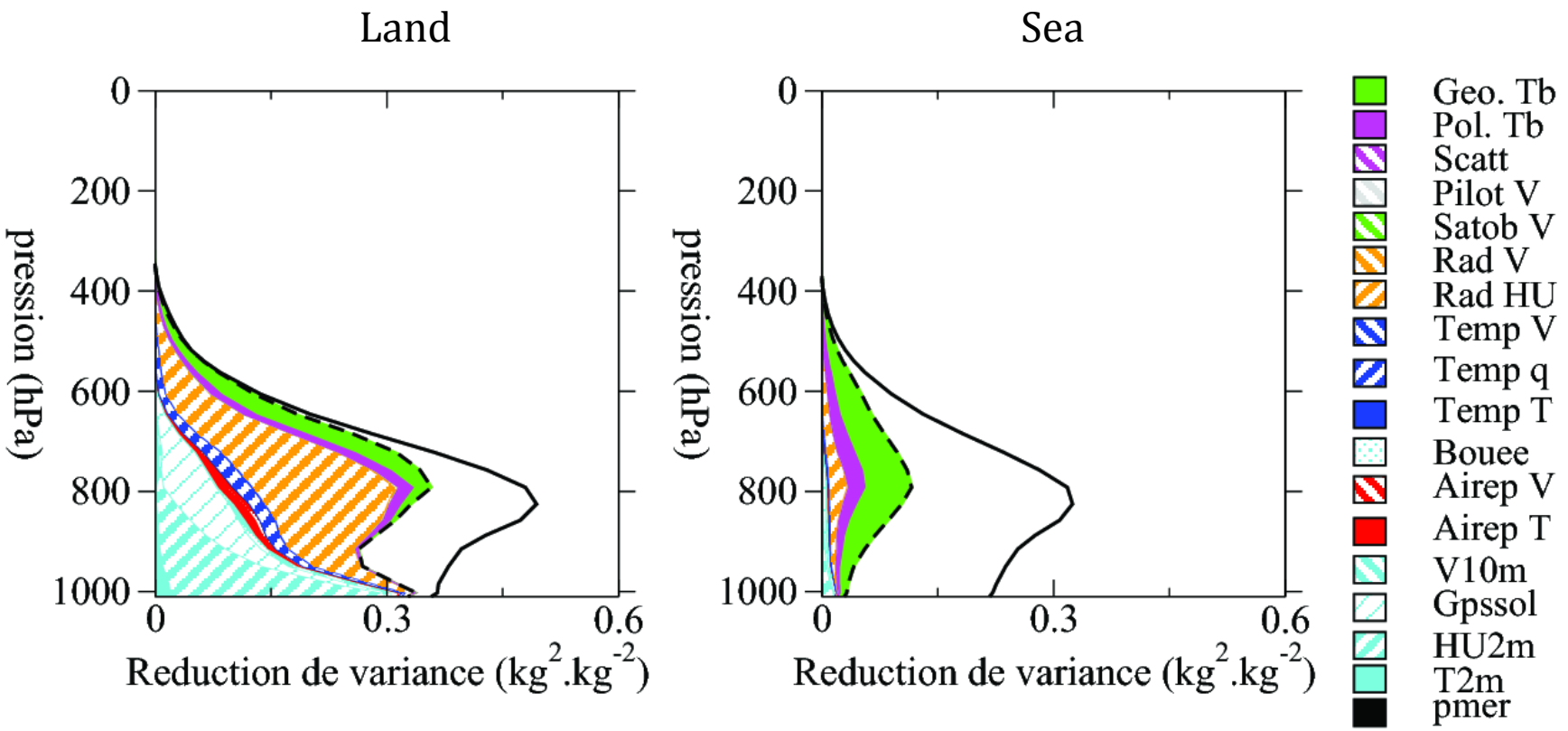
Dependency with surface type

Specific humidity



- Over sea, the variance reduction reaches only 25-30% of the total variance

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Summary

- Presentation of the convection-permitting model AROME with a RUC 3D-Var system (opérational at Météo-France since end 2008)
- Presentation of a posteriori diagnostics : DFS and reduction of error variance
- Observations having the most important impact at mesoscale : **surface data (SYNOP + GPS), radar (wind and humidity), aircrafts**
- Variability of reduction of error variance :
  - From day to day : stable except for radar observations
  - Contributing observations depend upon analysis time (AIREP vs. TEMP)
  - Dependency with surface type (land/sea)
- Spectral decomposition:
  - Reduction of error variance is maximum near the max of spectral variance (observations correct the most relevant scales)
  - For scales below 200 km only GPS and radar data contribute to the reduction of error variance

Conclusions : data usage at mesoscale

- Mesoscale data assimilation : need for observations with high spatial and temporal resolutions (AROME : 2.5 km / 3 hours => near future 1.25 km / 1 hour)
- Over Europe : largest data impact come from non-satellite observations including networks coordinated and supported by EUCOS and EUMETNET *optional* programmes :
  - Ground based GPS : E-GVAP
  - Aircraft reports : E-AMDAR
  - Radar winds and reflectivity : OPERA
- Needs : improved exchange of radar data (current OPERA status not sufficient) – Exchange of more SYNOP type surface observations. Diagnostics on observation error correlations : to increase spatial and temporal densities of observations (e.g. current radar thinning at 15 km)