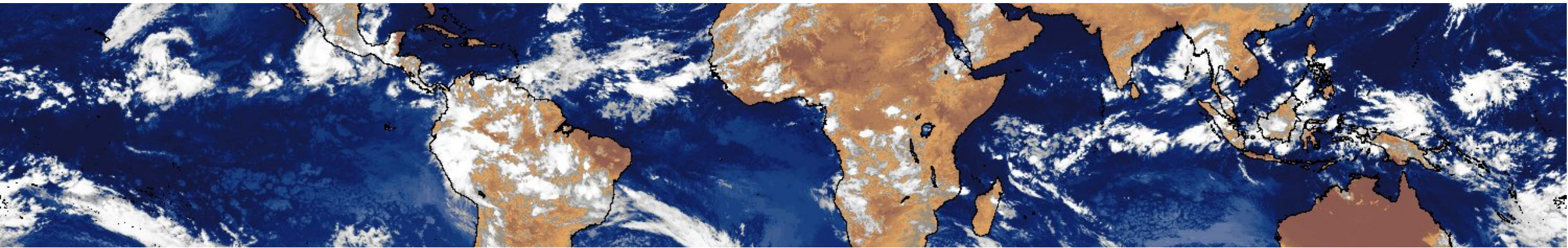




Assimilating cloudy and rainy microwave observations within the ARPEGE global model



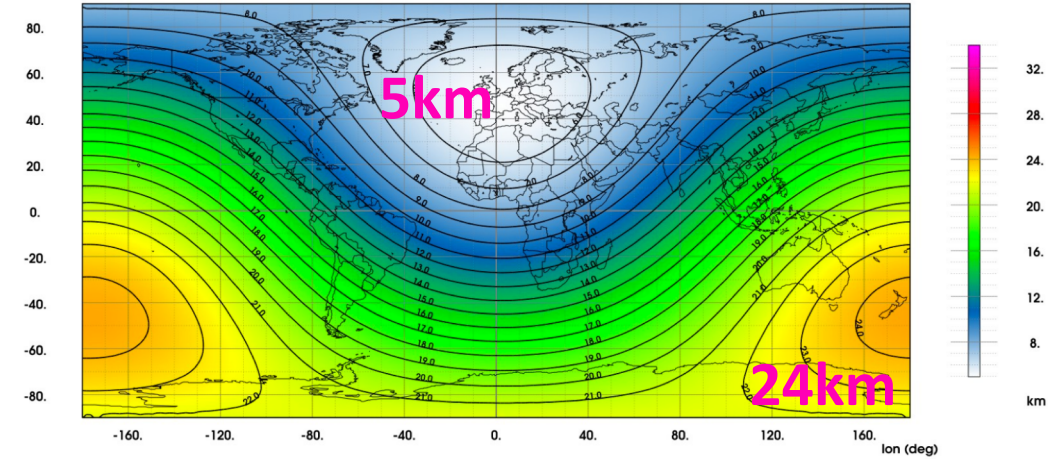
(<https://satmos.aeris-data.fr>)

Philippe Chambon, Fabrice Duruisseau, Marylis Barreyat and Jean-François Mahfouf

CNRM UMR-3589, Météo-France & CNRS

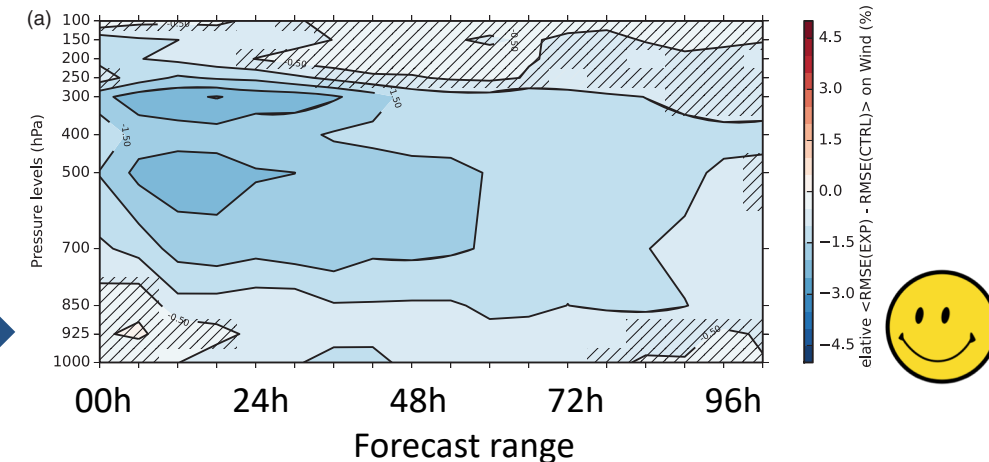
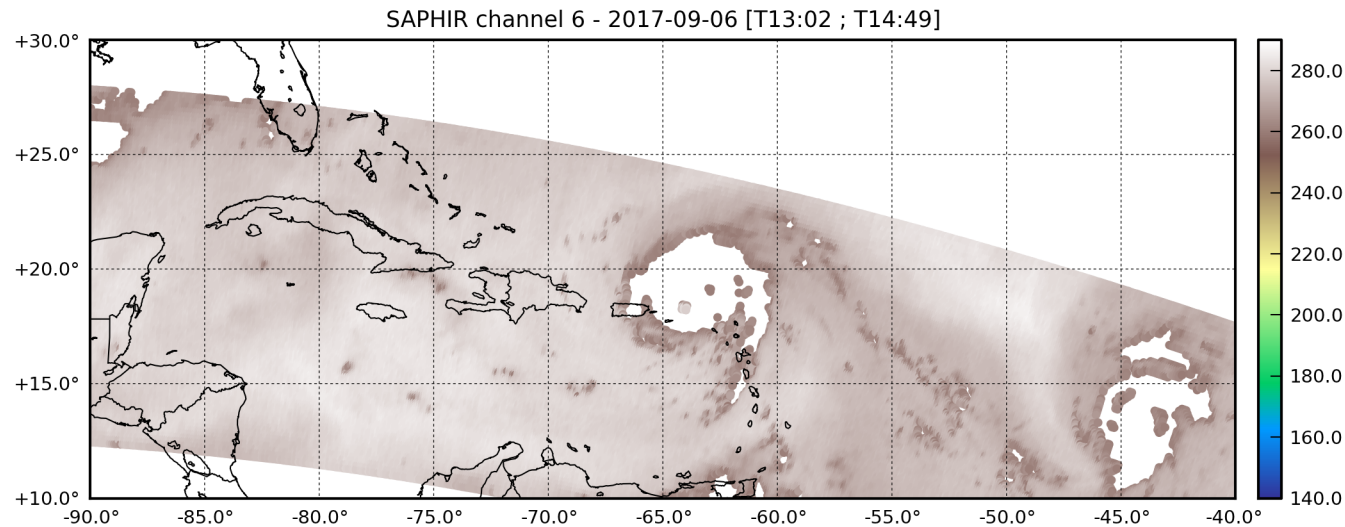
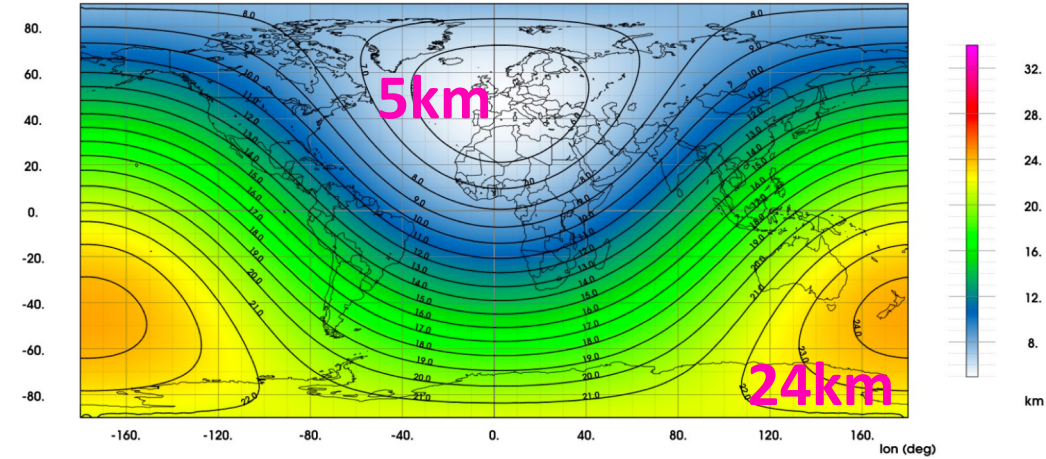
Introduction

- **Météo-France operates both a global model (ARPEGE) and regional models over Europe and in the Tropics (AROME)**
- **In ARPEGE, Observations from the fleet of microwave sounders, including SAPHIR onboard Megha-Tropiques, are assimilated in clear-sky only**



Introduction

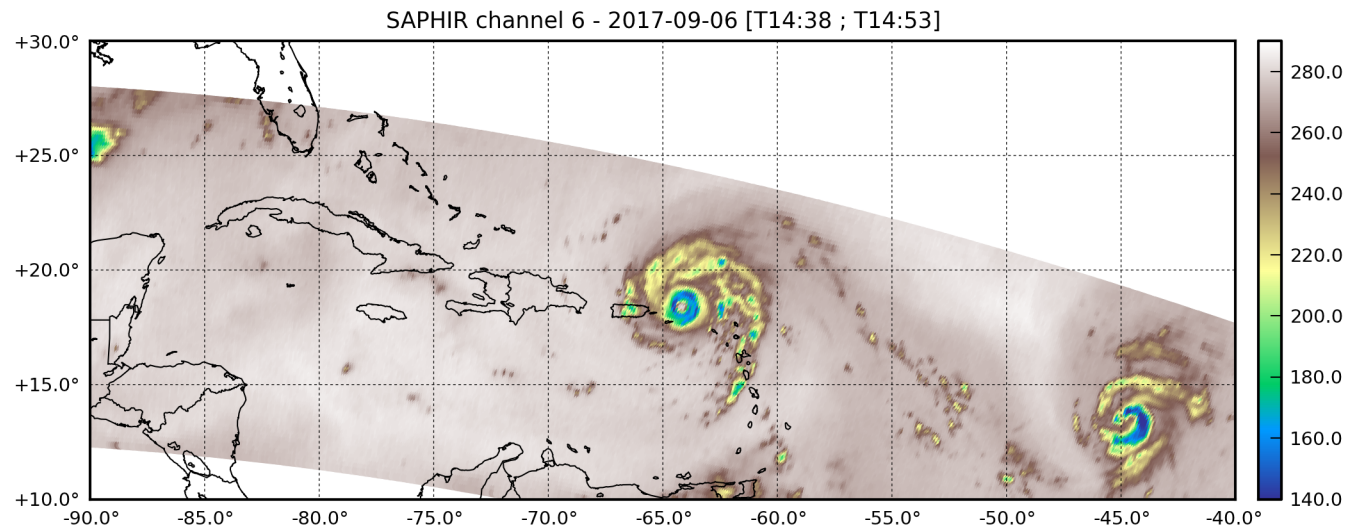
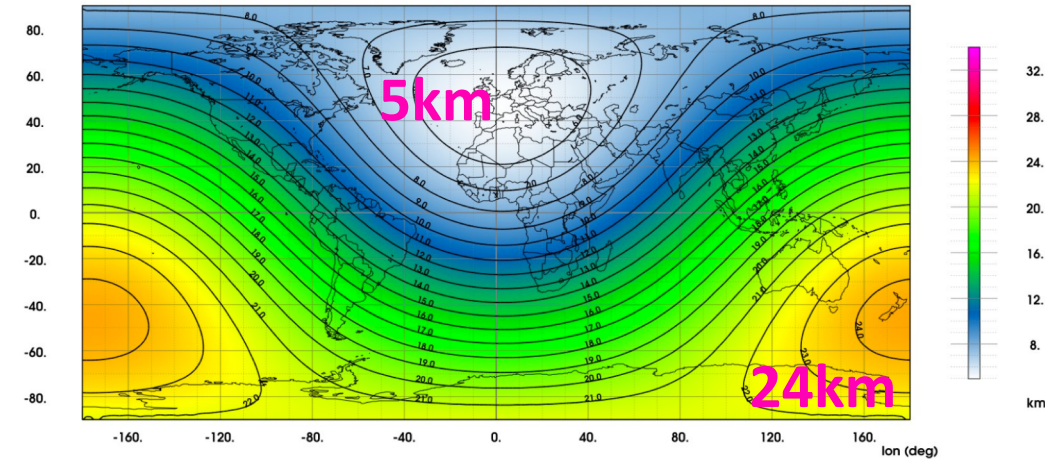
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- In ARPEGE, Observations from the fleet of microwave sounders, including SAPHIR onboard Megha-Tropiques, are assimilated in clear-sky only



Positive impact of SAPHIR on Tropical wind forecasts
(Chambon et al., 2014)

Introduction

- **Météo-France operates both a global model (ARPEGE) and regional models over Europe and in the Tropics (AROME)**
- **In ARPEGE, Observations from the fleet of microwave sounders, including SAPHIR onboard Megha-Tropiques, are assimilated in clear-sky only**



**Cloud assimilation
framework to complement
the clear sky assimilation**

Outline of the presentation

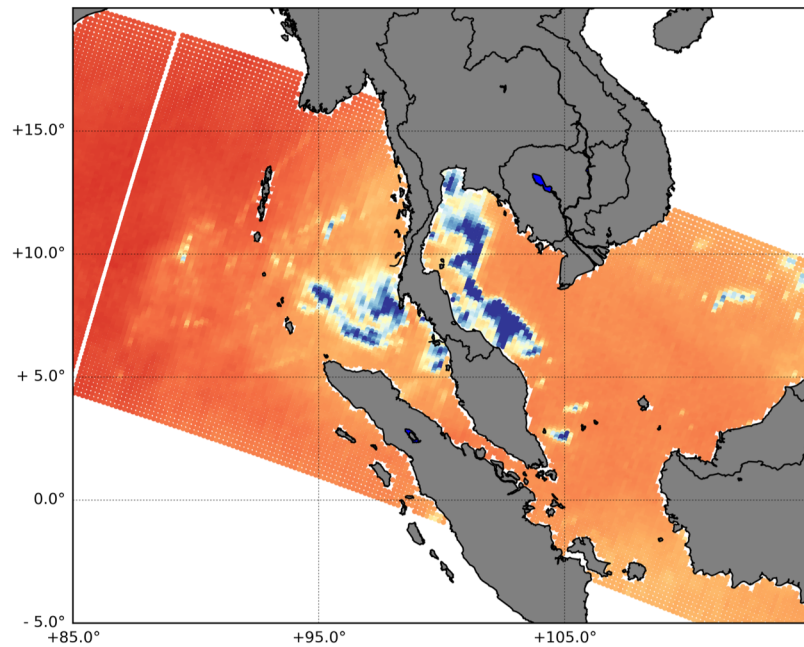
- 1. Cloud assimilation framework**
- 2. Impacts on global forecasts**
- 3. Conclusions and perspectives**

Outline of the presentation

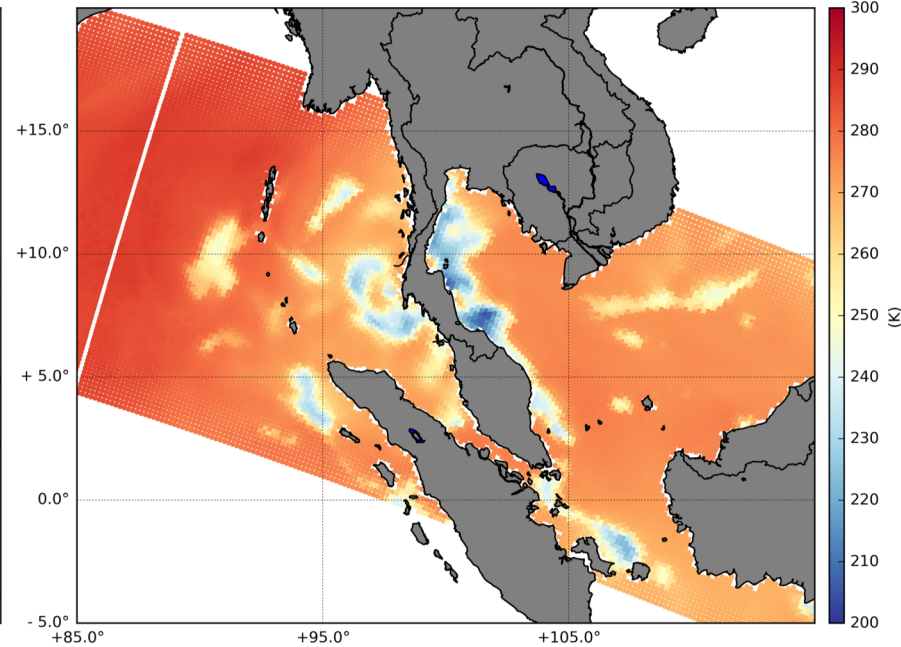
- 1. Cloud assimilation framework**
2. Impacts on global forecasts
3. Conclusions and perspectives

1. Cloud assimilation framework: 1D-Bayesian + 4D-Var

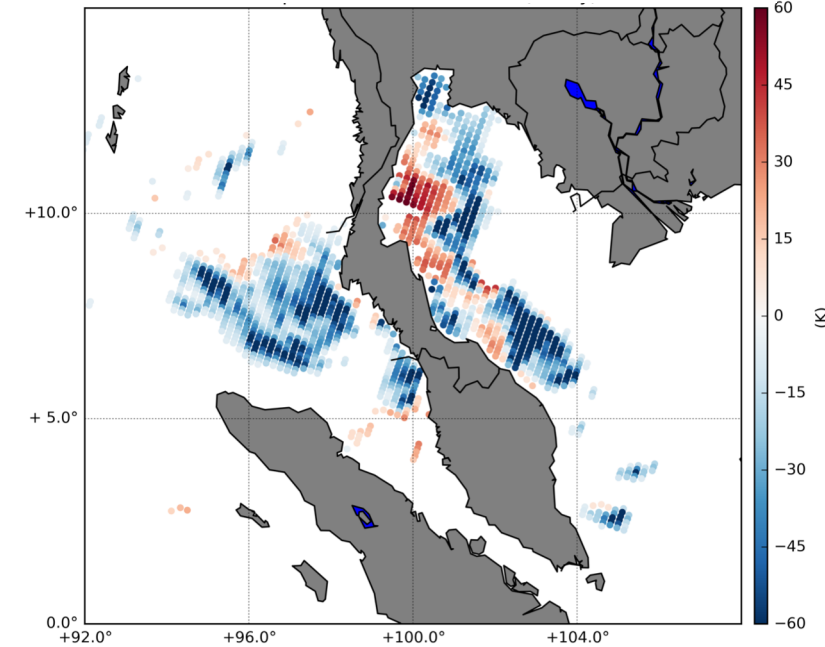
SAPHIR Observation (183+/-11 GHz)



ARPEGE simulation (183+/-11 GHz)
RTTOV-SCATT V11.2



SAPHIR - ARPEGE (183+/-11 GHz)



Compute $H(x)$ and $y-H(x)$

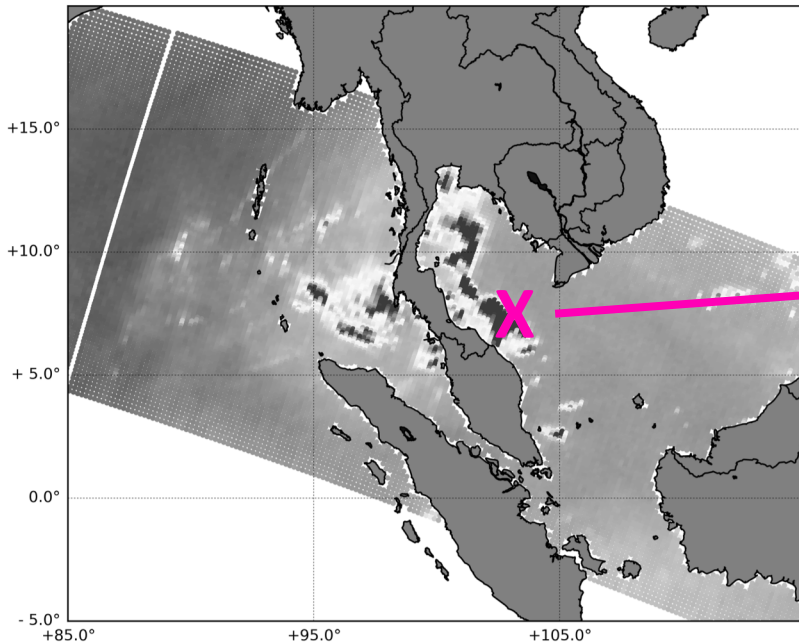
1D Bayesian inversion

Extracting humidity
information from retrieval

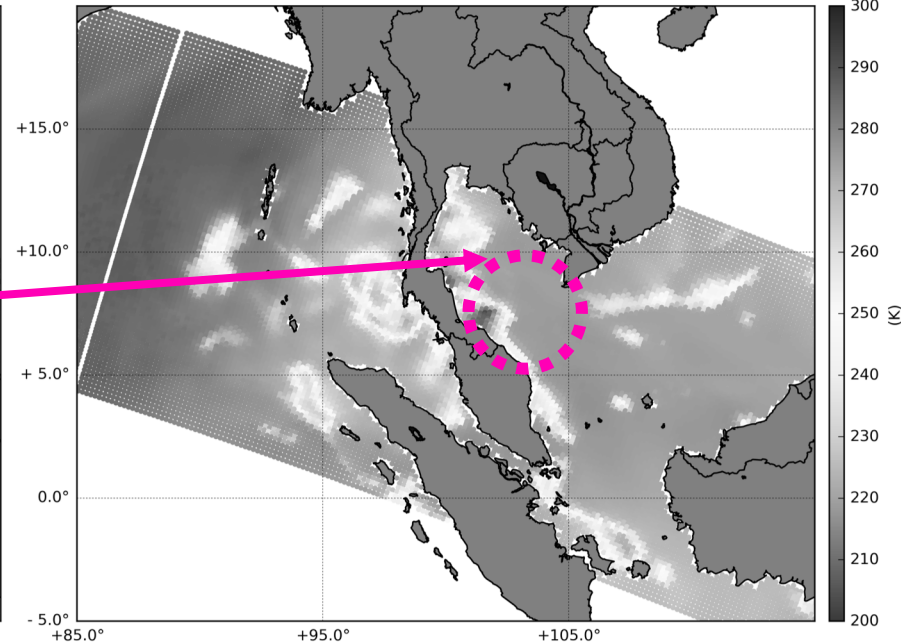
Assimilation of retrievals
within 4D-Var

1. Cloud assimilation framework: 1D-Bayesian + 4D-Var

SAPHIR Observation (183+/-11 GHz)



ARPEGE simulation (183+/-11 GHz)
RTTOV-SCATT V11.2



Bayesian inversion of SAPHIR TBs:
GPROF-like inversion using
a dynamically evolving database

$$\text{Weight of } x_j = e^{-\frac{1}{2} \sum_{i=1}^6 \frac{(T^i - H^i(x_j))^2}{\sigma_o}}$$

$$x_{\text{retrieved}} = \sum_{\text{pink dashed circle}} \frac{W_j \cdot x_j}{\sum_{\text{pink dashed circle}} W_j}$$

Compute $H(x)$ and $y-H(x)$

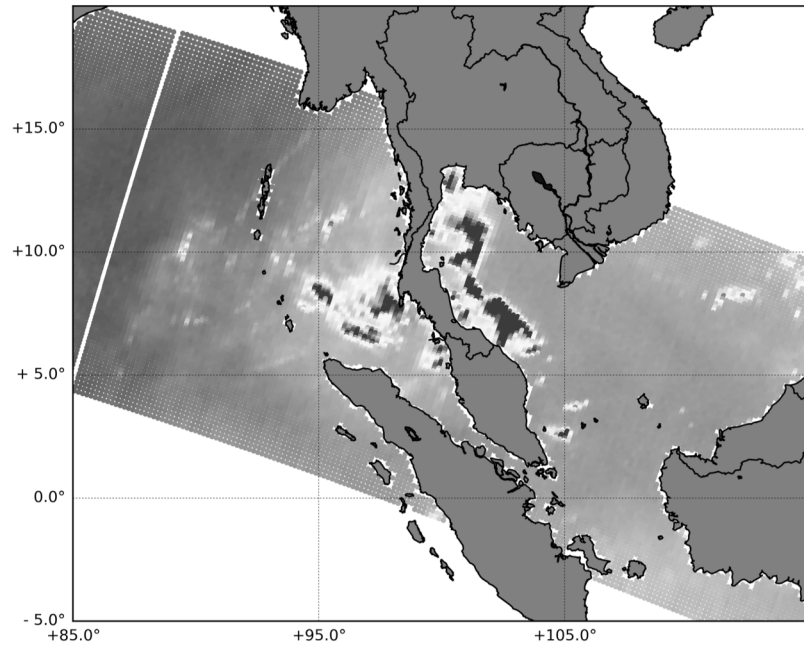
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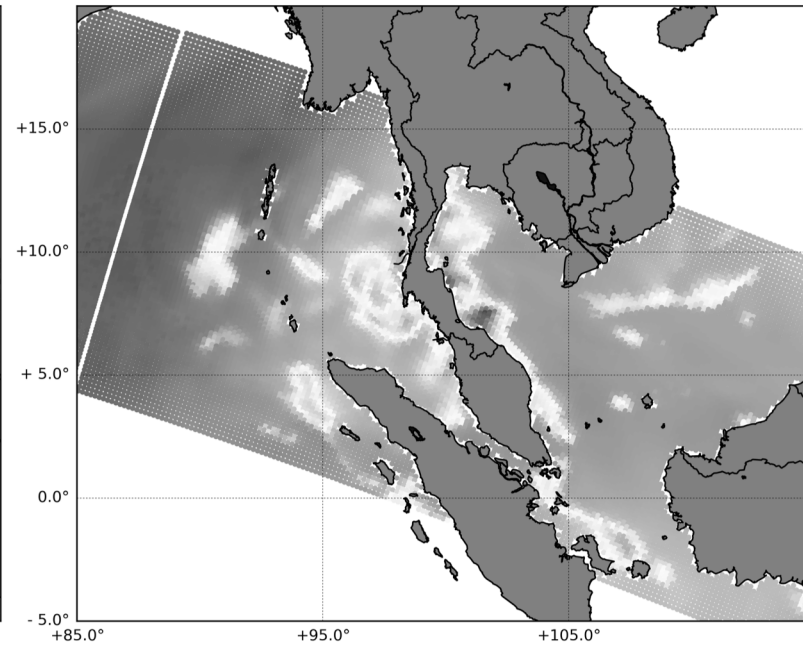
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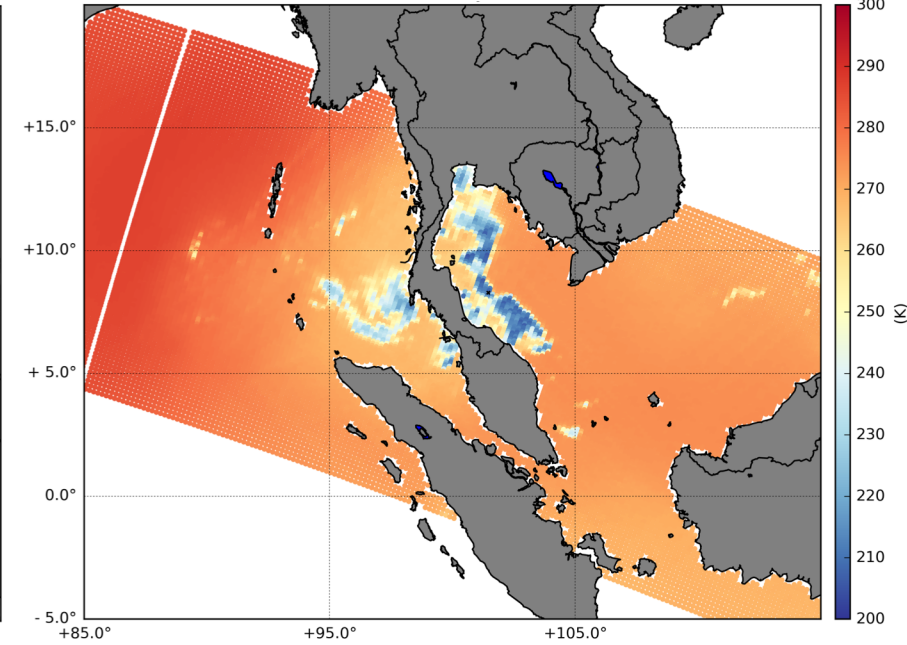
SAPHIR Observation (183+/-11 GHz)



ARPEGE simulation (183+/-11 GHz)
RTTOV-SCATT V11.2



$H(x_{retrieved})$



Compute $H(x)$ and $y-H(x)$

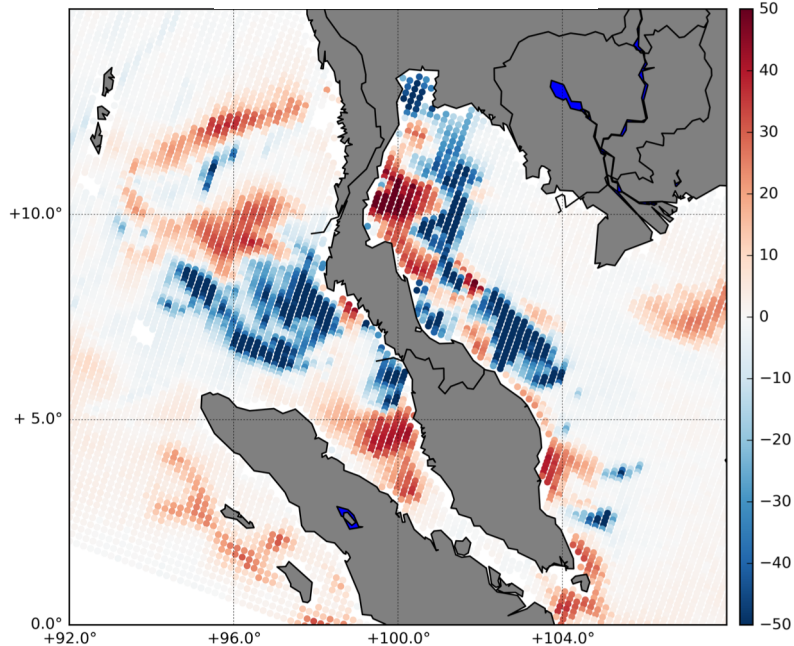
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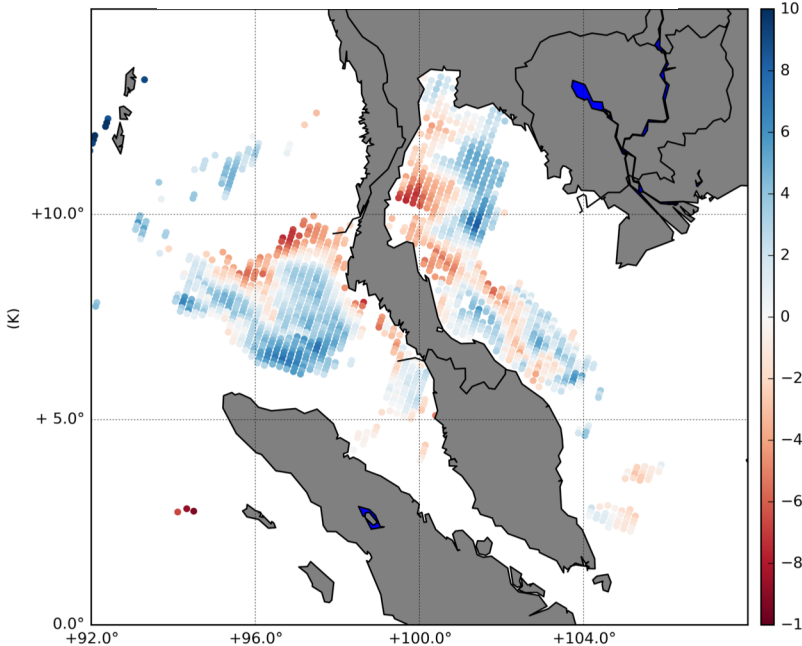
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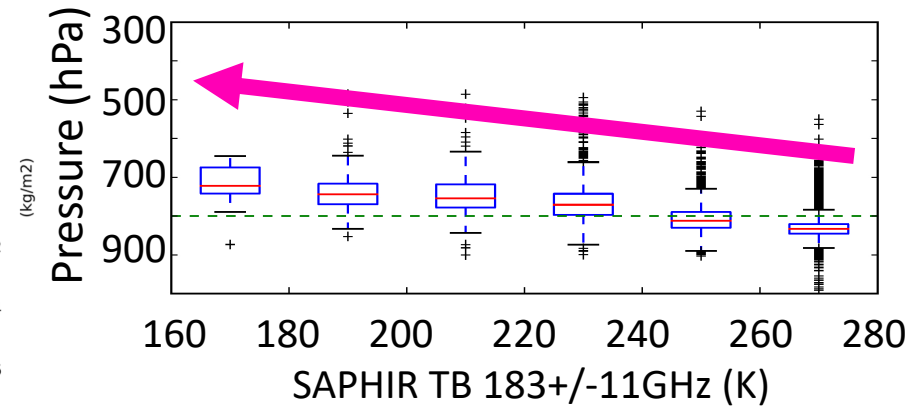
$TB_{SAPHIR} - TB_{ARPEGE}$



$TCWV_{SAPHIR} - TCWV_{ARPEGE}$



Distribution of SAPHIR information content lower bound for humidity



Compute $H(x)$ and $y-H(x)$

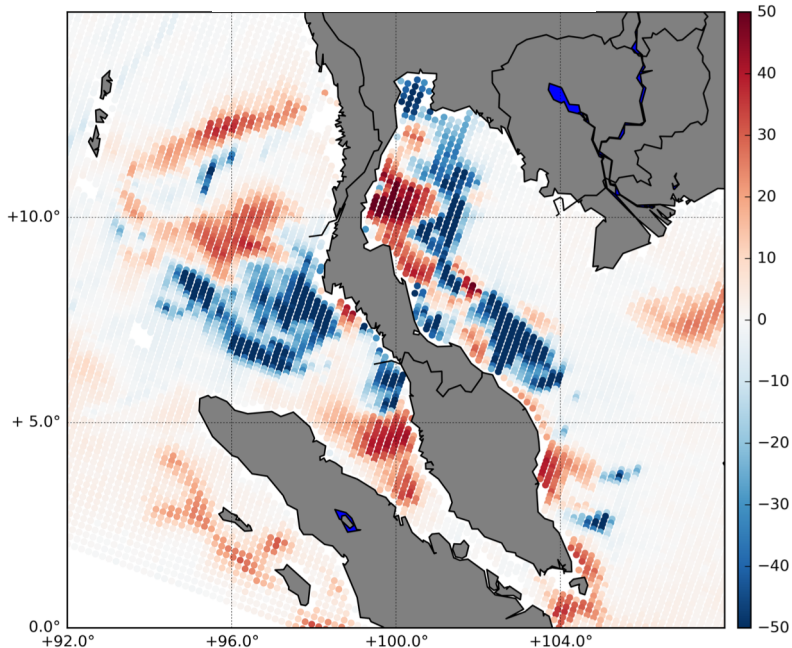
1D Bayesian inversion

Extracting humidity information from retrieval

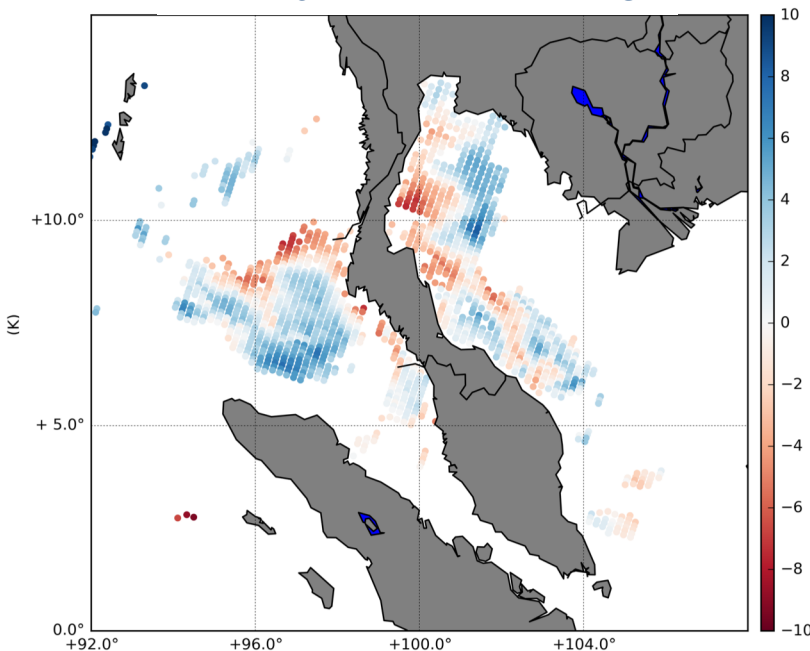
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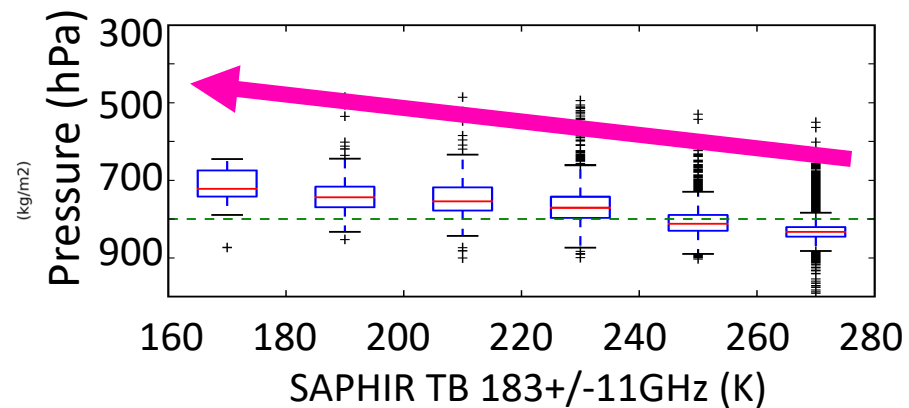
$TB_{SAPHIR} - TB_{ARPEGE}$



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Distribution of SAPHIR information content lower bound for humidity



Compute $H(x)$ and $y-H(x)$

1D Bayesian inversion

Extracting humidity information from retrieval

Assimilation of retrievals within 4D-Var

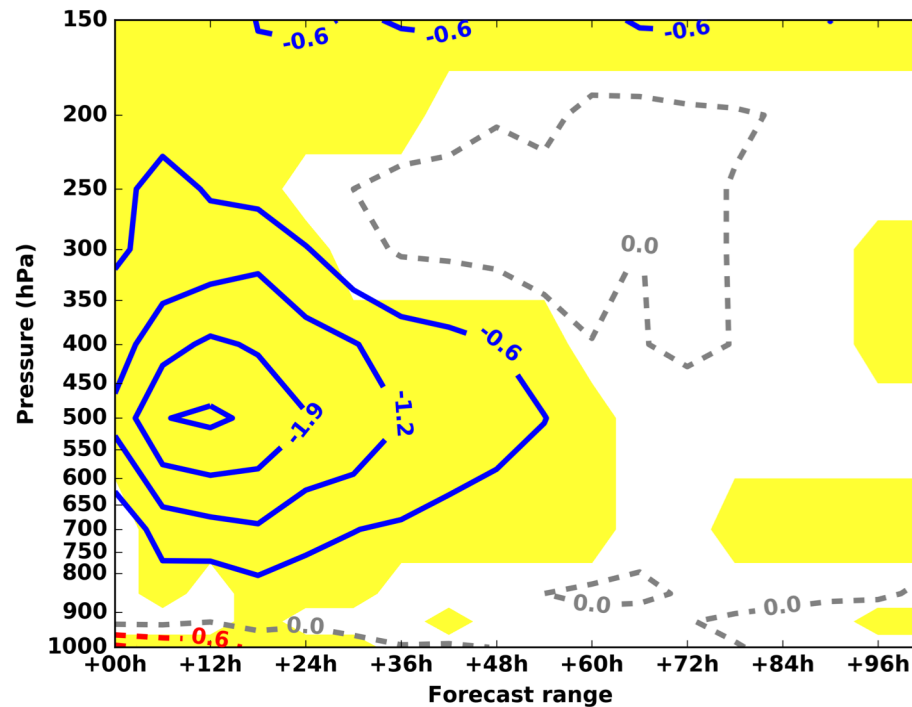
Outline of the presentation

1. Cloud assimilation framework
- 2. Impacts on global forecasts**
3. Conclusions and perspectives

2. Impacts on global forecasts

Impacts of assimilating SAPHIR in cloudy and rainy areas with the 1D-Bayesian + 4D-Var technique within ARPEGE over a 4-month period (July to October 2018)

Relative difference of RMSE on Temperature forecasts errors



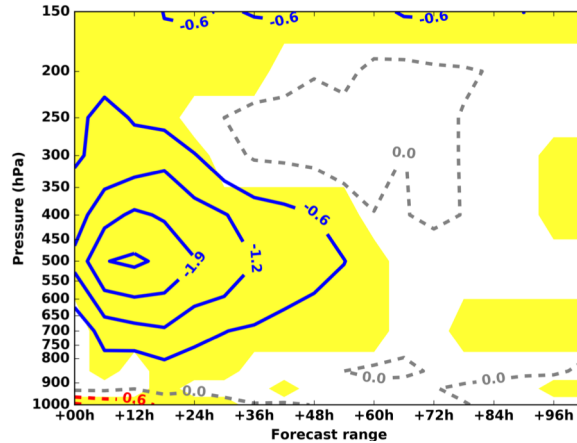
Domain: Tropics
Reference:
ECMWF analysis

 
 significant at 99%

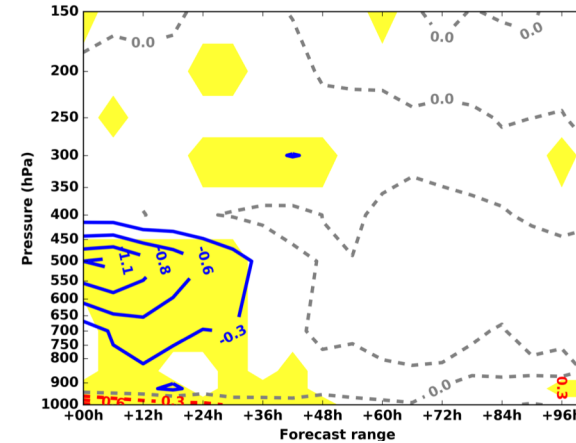
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Impacts of assimilating SAPHIR in cloudy and rainy areas with the 1D-Bayesian + 4D-Var technique within ARPEGE over a 4-month period (July to October 2018)

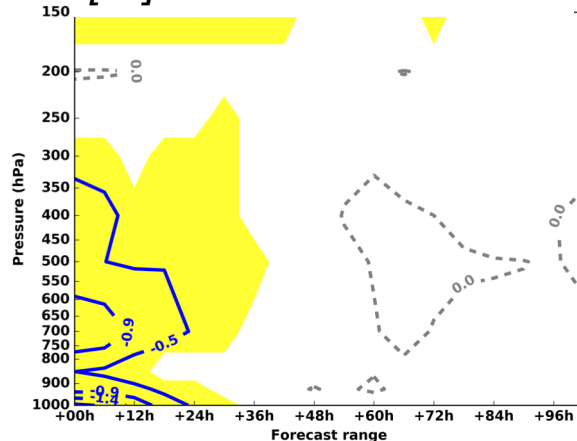
Relative impact on RMSE of Temperature forecasts



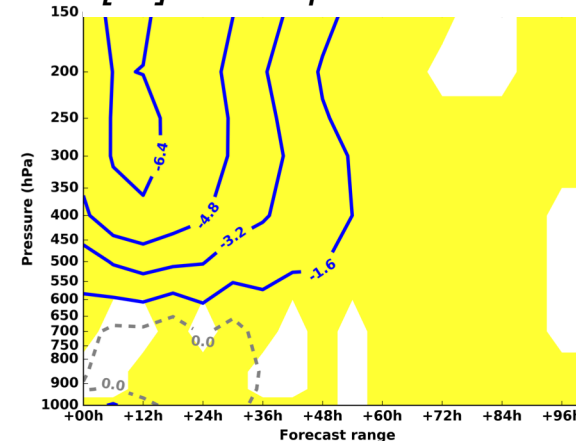
[...] of Humidity forecasts





[...] of Wind forecasts



[...] of Geopotential forecasts



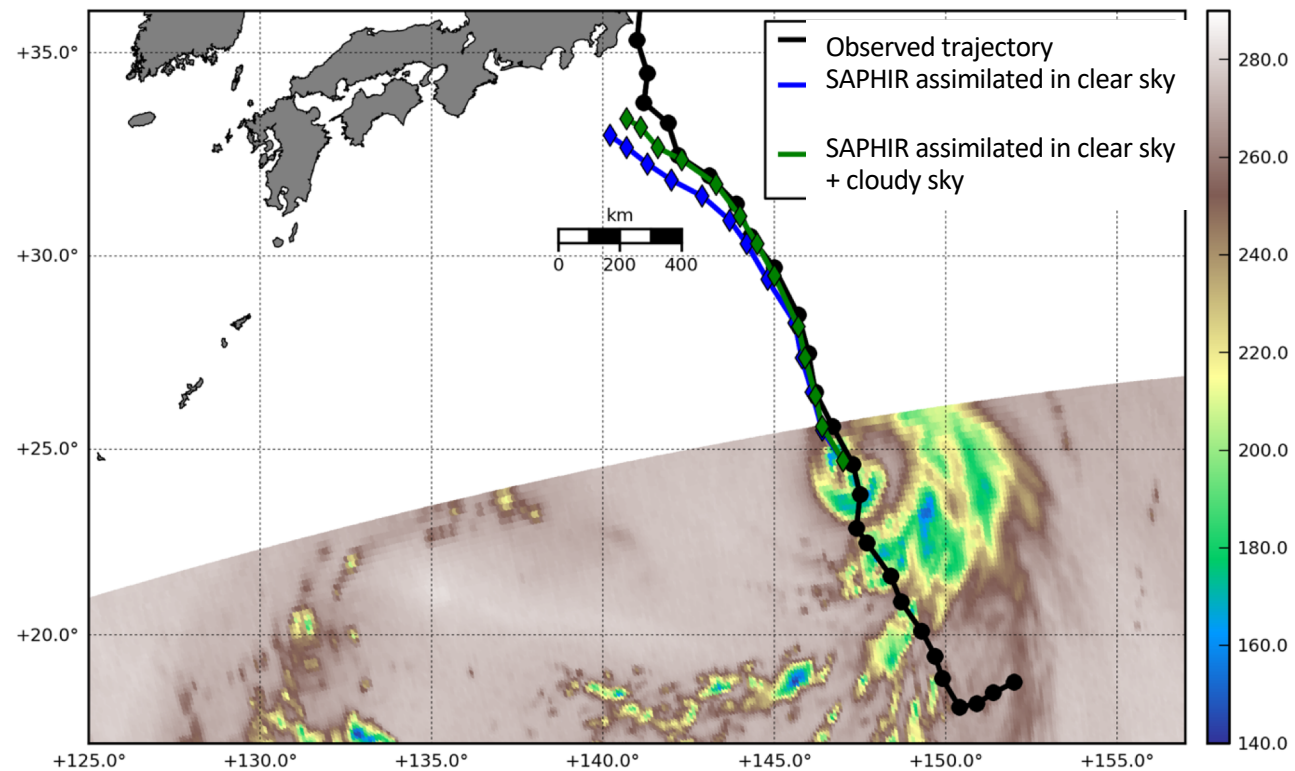
Domain: Tropics
Reference:
ECMWF analysis

 significant at 99% 

2. Impacts on global forecasts

Impact of SAPHIR cloudy radiances on hurricane forecasts: Example of Typhoon Shanshan

North West Pacific basin, +72h forecasts initialized on August 5th, 2018

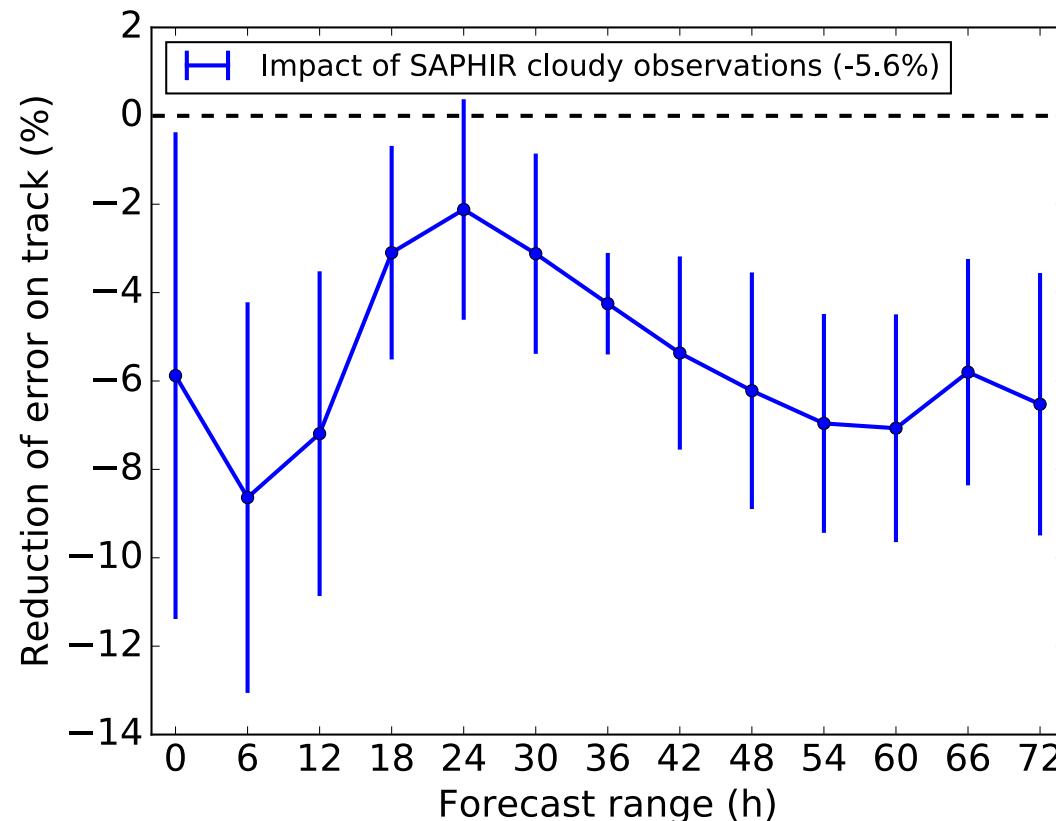


2. Impacts on global forecasts

Impact of SAPHIR cloudy radiances on hurricane forecasts:

Impact for 16 hurricanes over several basins for a sample of 432 hurricane forecasts

(c) Reduction of error on track for hurricanes: Beryl (ATL), Chris (ATL), Maria (NWP), Fabio (NEP), Ampil (NWP), Wukong (NWP), Shanshan (NWP), Jongdari (NWP), Hector (NEP), John (NEP), Florence (ATL), Helene (ATL), Isaac (ATL), Kirk (ATL), Michael (ATL), Jebi (NWP)
(16 hurricanes - 432 forecasts)



Reduction of error of ~6% in average over the life cycle of the 16 hurricanes.

Impact statistically significant at 95% level of confidence

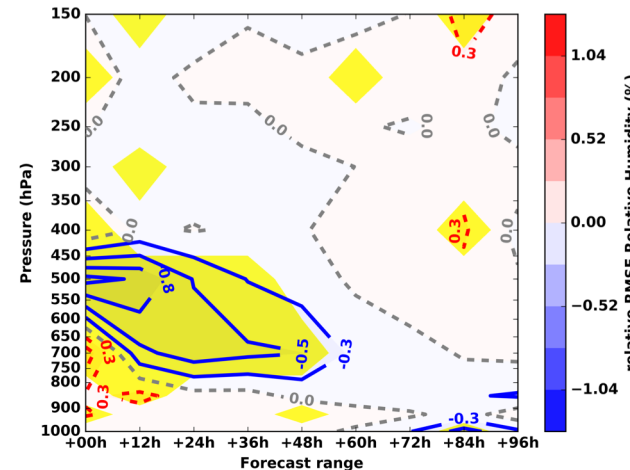
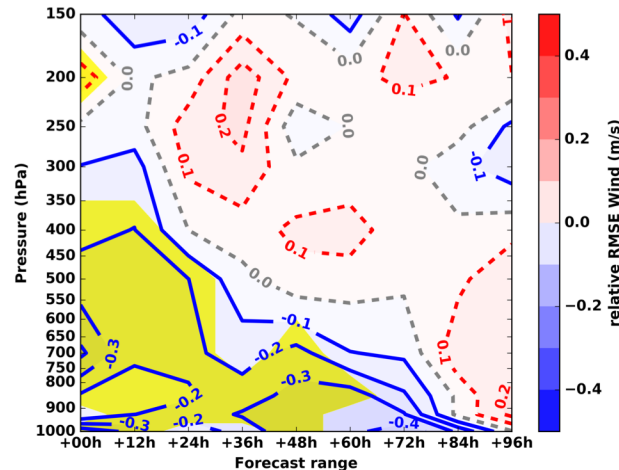
Outline of the presentation

1. Cloud assimilation framework
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3. Conclusions and perspectives

- ✓ The cloud assimilation framework developed for MT data does improve ARPEGE global forecasts
=> *Duruiseau et al., 2018. (QJRMS)*
- ✓ This framework has been adapted to MHS and ATMS sounders and can now include cloudy observations in the mid-latitudes as well
=> Experiments are ongoing with ARPEGE cy46t1 assimilating the 4 MHS cloudy observations, up to 60°N/S

Relative impact on RMSE of Wind forecast for Latitudes >20° for a 3-month period June to September 2019 period



Relative impact on RMSE of Relative Humidity forecast for Latitudes >20° for a 3-month period June to September 2019 period

3. Conclusions and perspectives

- ✓ **The framework offers opportunities to develop and test new ideas**
*=> two new error models have been developed (not shown) including one for describing **radiative transfer uncertainties in scattering conditions** (based on an **ensemble** of multi-microphysics simulations)*
- ✓ **Next steps: (i) transfer this work for the 2020 Météo-France parallel suite ; (ii) generalize the framework to imagers (ongoing work with GMI)**

Thank you !

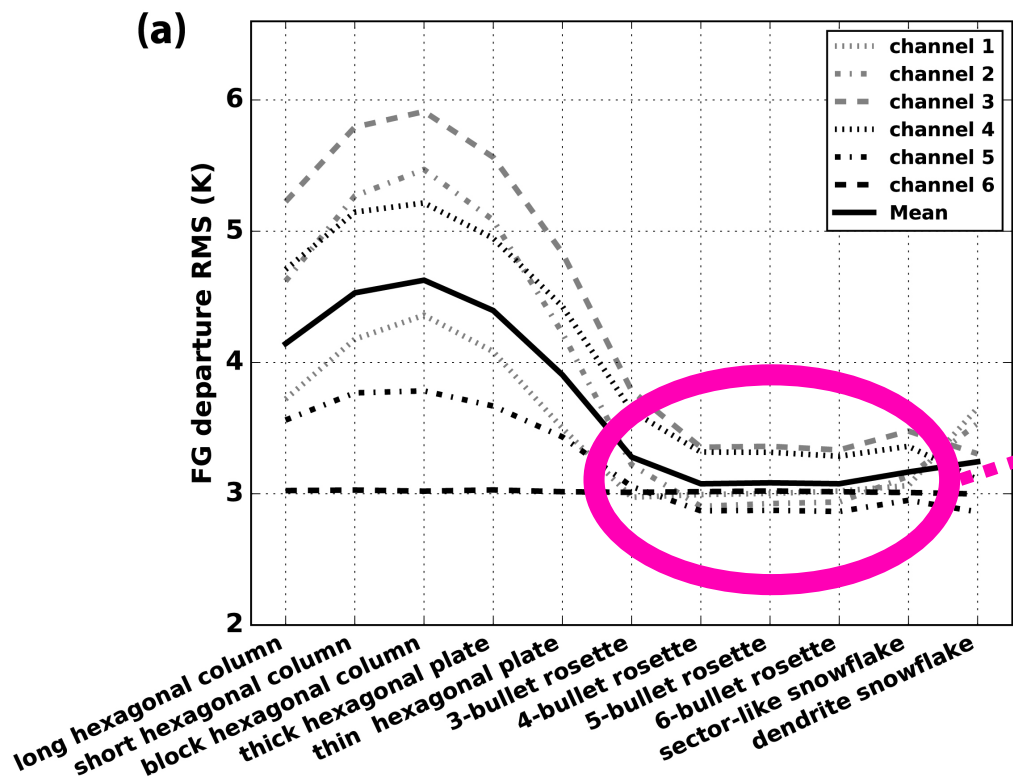


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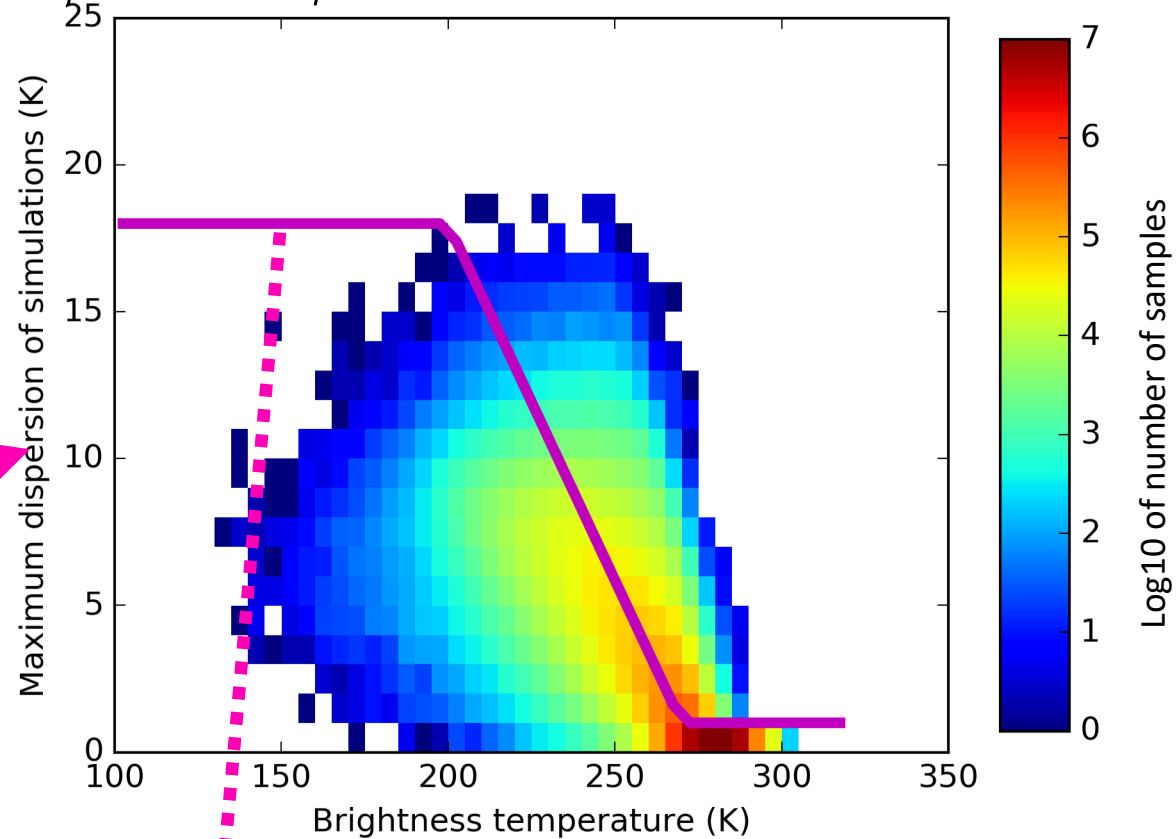
(Source: CNES)

Backup slides

Inversion error model



Simple modelling of the spread of the 5 best particle shapes



$$J_o^j = \frac{1}{2} \cdot \sum_{channels=1}^6 \left(\frac{H(x_j) - TB_{OBS}}{\sigma_o} \right)^2$$

First guess departure histogram of Relative Humidity at 800hPa

Observations:



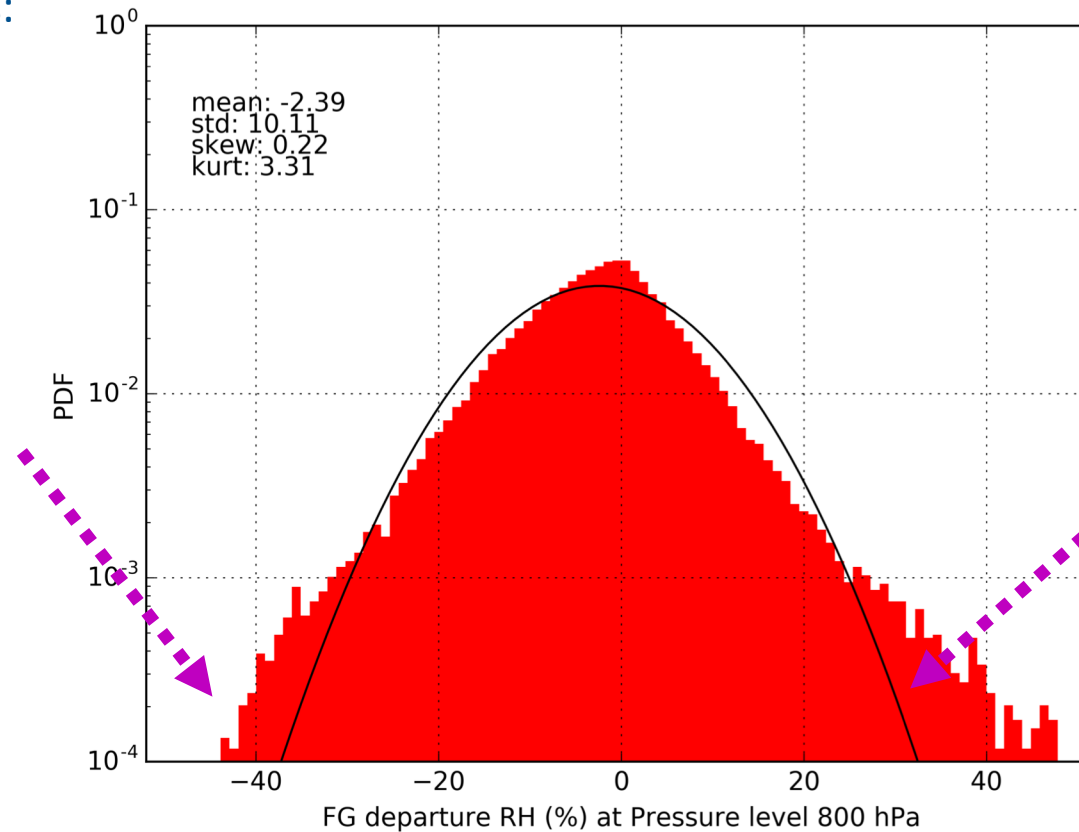
First Guess:



Observations:

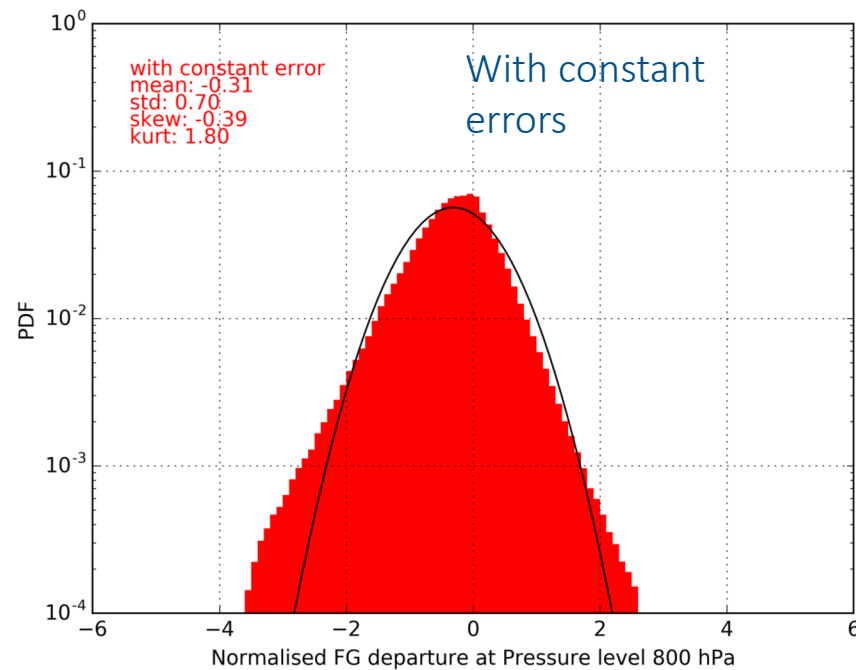


First guess:

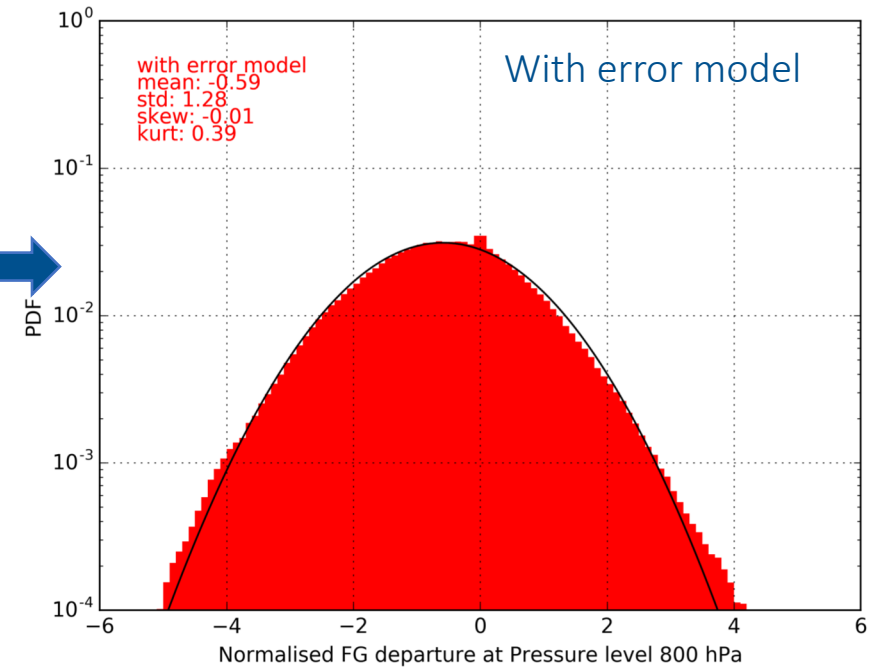


First guess departure histogram of Relative Humidity at 800hPa

Normalized innovations



$(Obs - First\ Guess) / Observation\ error$



$(Obs - First\ Guess) / Observation\ error$