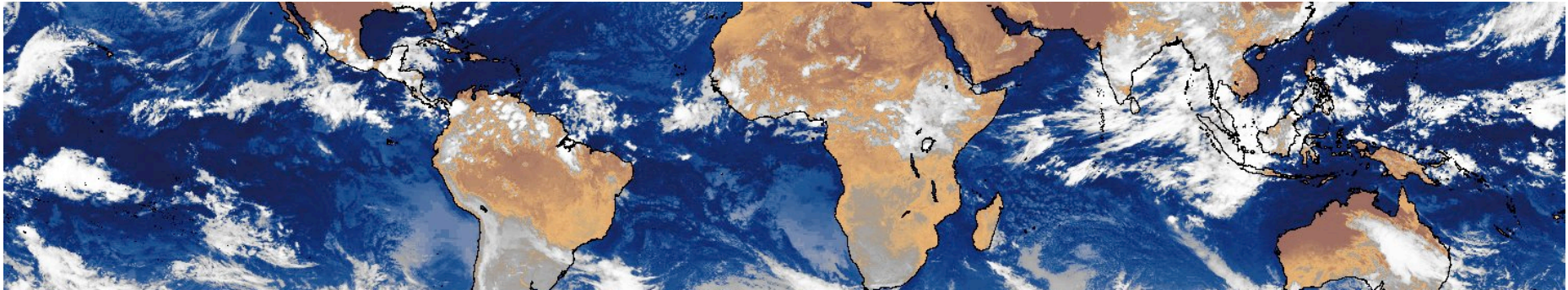




# Tropical modelling activities at Météo-France and potential applications of TROPICS data



(Source: [satmos.meteo.fr](http://satmos.meteo.fr))

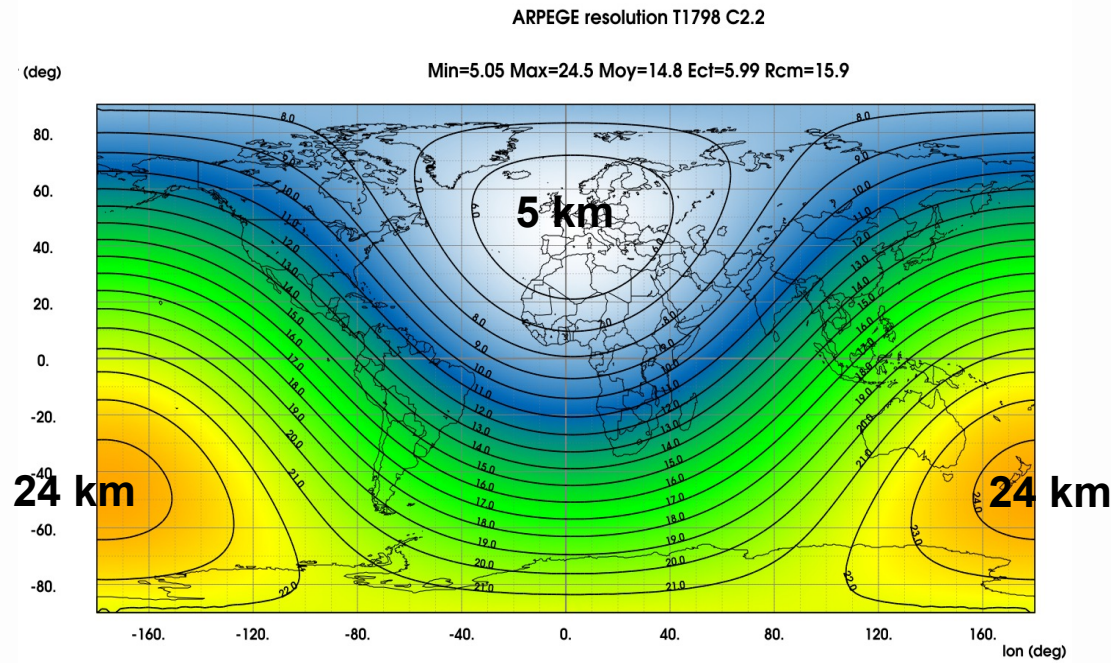
**Philippe Chambon, Ghislain Faure and Fabrice Duruisseau**

*CNRM, Météo-France & CNRS, Toulouse*

# Numerical Weather Prediction systems operational at Météo-France for tropical regions

Météo-France operates two different atmospheric models which provide forecast products in the Tropics:

- a global model called ARPEGE
- Stretched and tilted grid: 5 km over Europe and 7 to 24 km in the Tropics
- 4D-Var data assimilation system with 6h windows
- Ensemble-based background error co-variances
- Forecasts up to +102h



# Numerical Weather Prediction systems operational at Météo-France for tropical regions

Météo-France operates two different atmospheric models which provide forecast products in the Tropics:

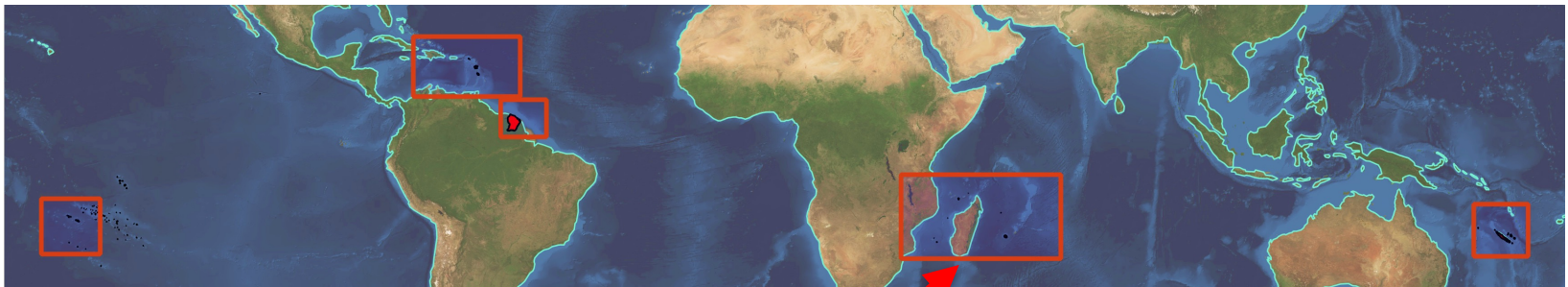
- a **non-hydrostatic** model called AROME

## Over Western Europe

- 1.3km resolution/90 vertical levels
- Lateral boundary conditions from ARPEGE
- 3D-Var including ground radar reflectivities

## Over 5 domains in the Tropics

- 2.5 km resolution / 90 vertical levels
- Lateral boundary and initial conditions from the IFS model
- Coupling with a 1D ocean model
- 3D-Var in research mode



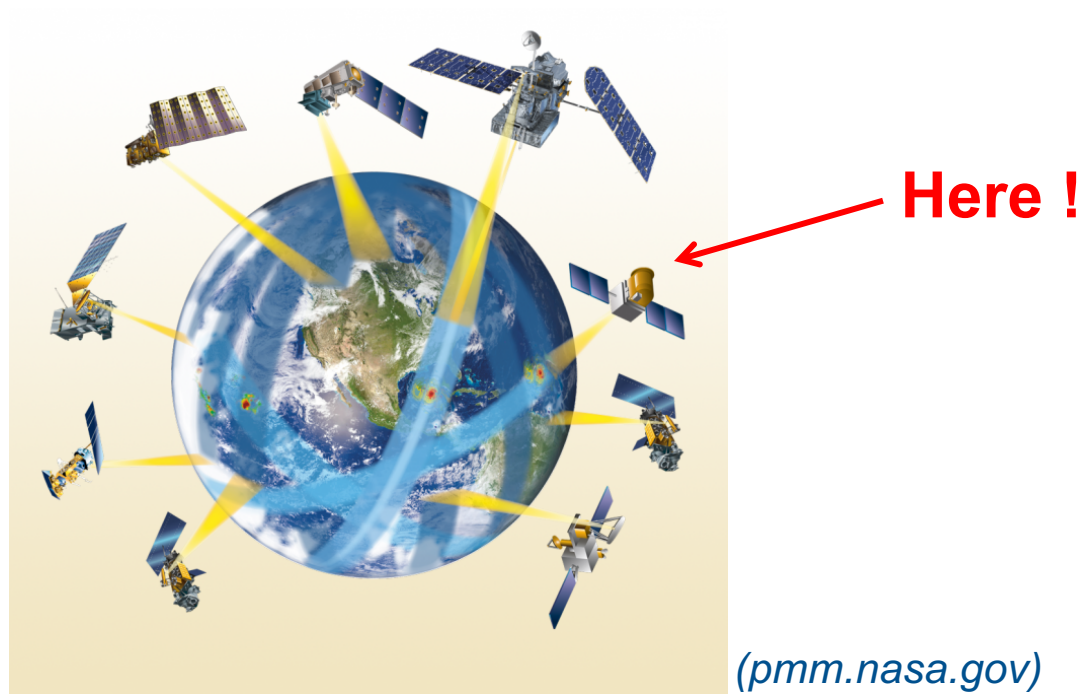
La Réunion – Météo-France  
WMO Regional Specialized Meteorological Centre  
for the South-West Indian Ocean



# Ongoing research to improve these Tropical forecasts

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Data assimilation project ongoing with the French Megha-Tropiques science team



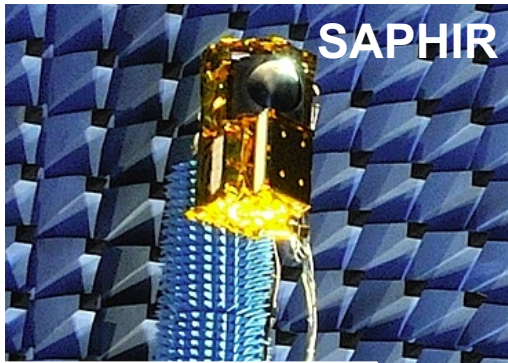
- Indo-French Mission built by ISRO and CNES launched in October 2011
  - Dedicated to the monitoring of the water and energy cycle in the tropics
  - Orbit with 20° inclination on the equator
  - Nominal life: 3 years + 2 years extension up to end 2016
- ⇒ now extended from 2017 to 2021 (but problems are ongoing on the platform and are currently under investigation)



# Ongoing research to improve these Tropical forecasts

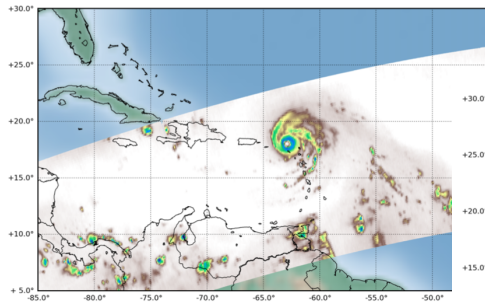
In ARPEGE and AROME, microwave observations are assimilation in clear sky only in operations.

=>Project on data assimilation of SAPHIR observations in cloudy and rainy sky

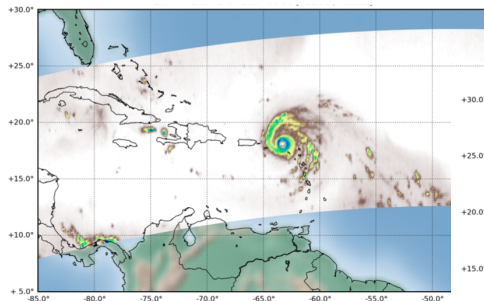


Channel	Frequency	Bandwidth	Horizontal resolution
1	183.31 +/- 0.2 GHz	200 MHz	10km at nadir
2	183.31 +/- 1.1 GHz	350 MHz	10km at nadir
3	183.31 +/- 2.8 GHz	500 MHz	10km at nadir
4	183.31 +/- 4.2 GHz	700 MHz	10km at nadir
5	183.31 +/- 6.8 GHz	1200 MHz	10km at nadir
6	183.31 +/- 11 GHz	2000 MHz	10km at nadir

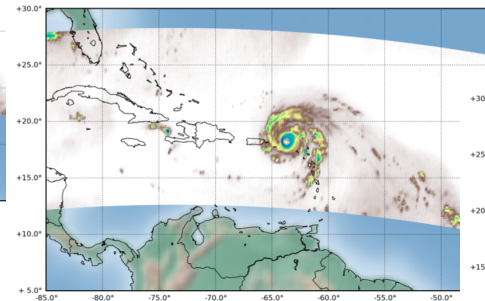
Ch6 - 9h10 to 9h23UTC



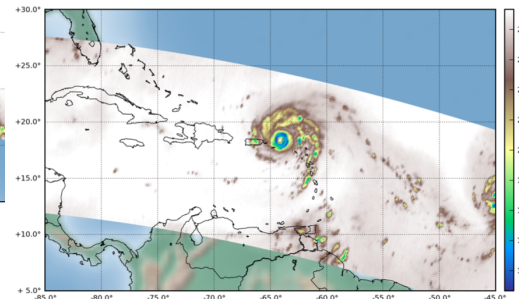
Ch6 - 11h00 to 11h12UTC



Ch6 - 12h50 to 13h02UTC



Ch6 - 14h39 to 14h52UTC



September 6<sup>th</sup>  
Hurricane Irma

# Ongoing research to improve these Tropical forecasts

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## Data assimilation of SAPHIR observations in cloudy and rainy sky

**Methodology:** original 1D-Bayesian + 4D-Var framework which allow to:

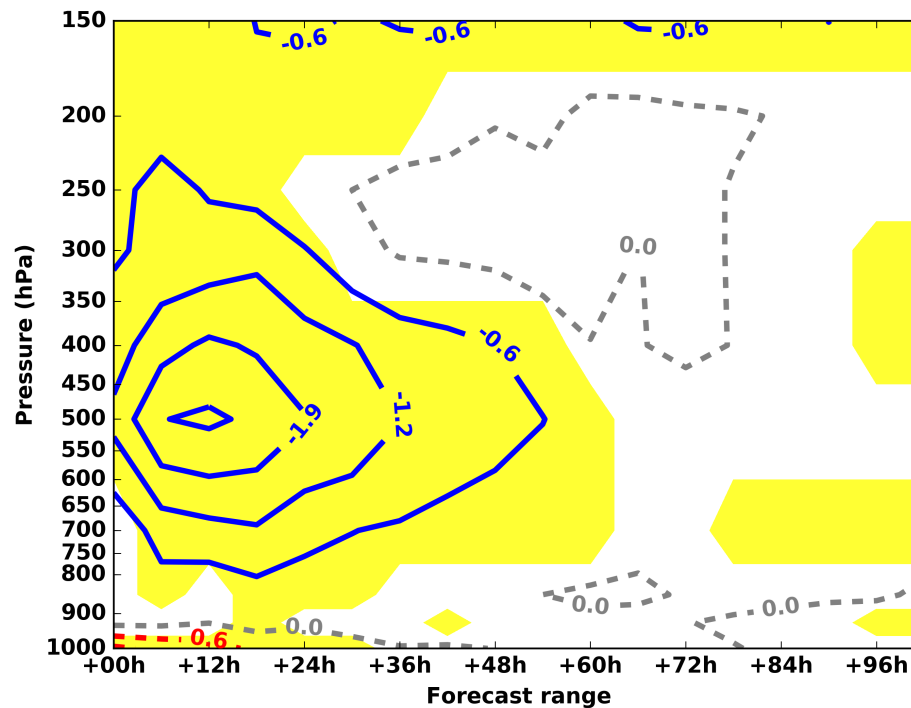
- Retrieve atmospheric profiles (RH, q, T, hydrometeors) and assimilate the retrievals (=> would benefit from 118GHz channels in addition to 183GHz)
- Can include some interesting features in the radiative transfer usage like multiple microphysical assumptions within the retrieval process
- Main idea: making use of the first guess in the neighborhood of an observations

*Duruisseau F, Chambon P, Wattrelot E, Barreyat M, Mahfouf J-F. Assimilating cloudy and rainy microwave observations from SAPHIR on board Megha Tropiques within the ARPEGE global model. Q J R Meteorol Soc 2019;1–22. <https://doi.org/10.1002/qj.3456>*

# Ongoing research to improve these Tropical 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 in the Tropics with respect to ECMWF analysis*



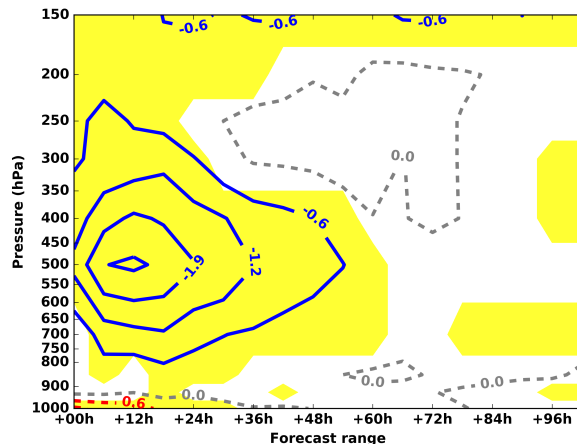
— 🤗  
significant at 99%



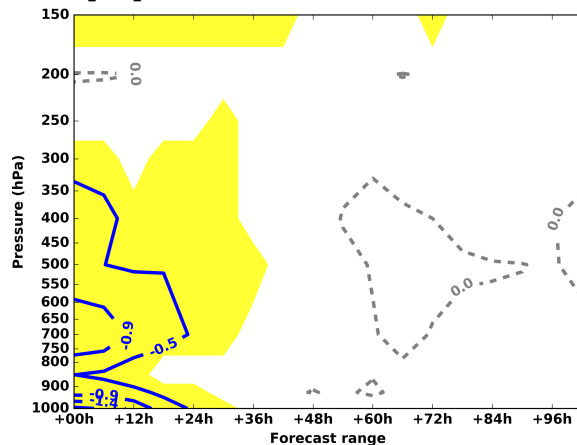
# Ongoing research to improve these Tropical forecasts

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)

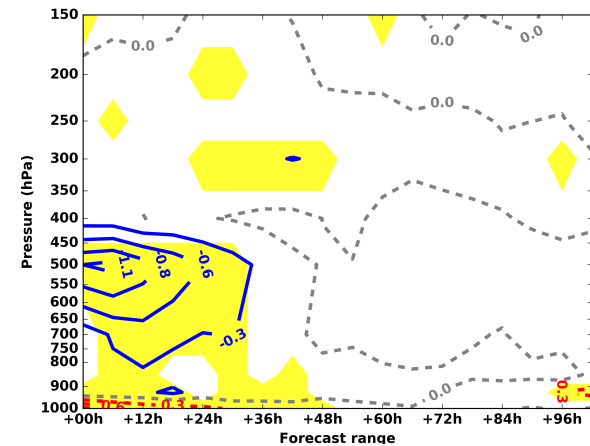
Relative impact on RMSE of Temperature forecasts



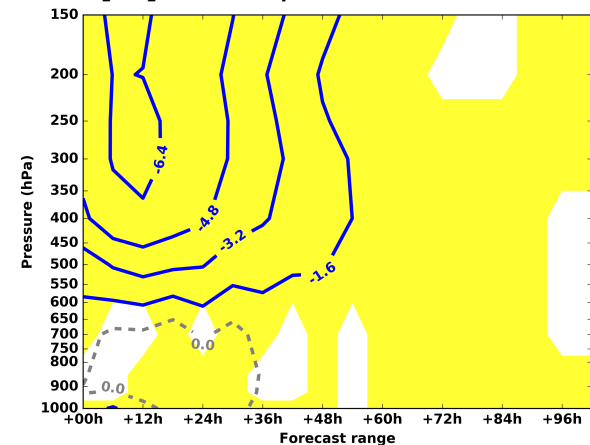
[...] of Wind forecasts





[...] of Humidity forecasts



[...] of Geopotential forecasts



 significant at 99%

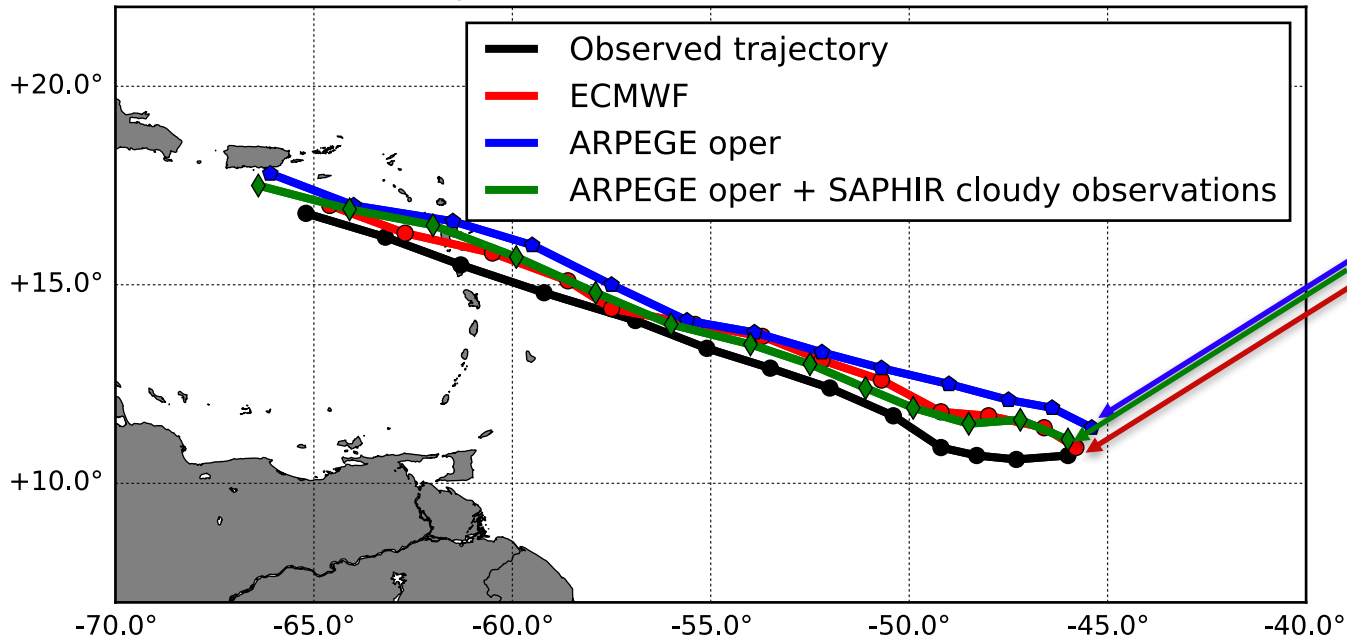


# Ongoing research to improve these Tropical forecasts

## Impact of SAPHIR cloudy radiances on hurricane forecasts:

### Example of Hurricane Beryl

(a) Hurricane Beryl - Forecasts initialized on 2018-07-06T12:00:00

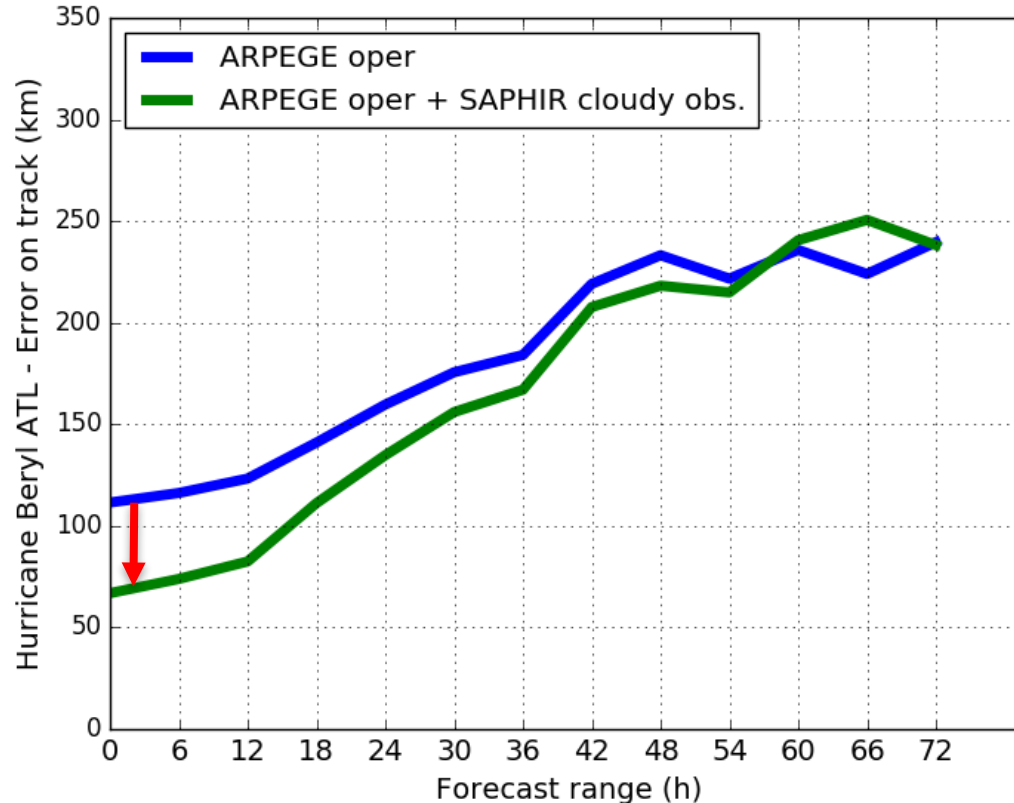


Location of Hurricane Beryl in the initial conditions of the 3 forecasts

# Ongoing research to improve these Tropical forecasts

## Impact of SAPHIR cloudy radiances on hurricane forecasts:

### Example of Hurricane Beryl (averaged impact from July 5<sup>th</sup> to July 8<sup>th</sup>, 2018)



Reduction of error  
on forecasts of  
hurricane track

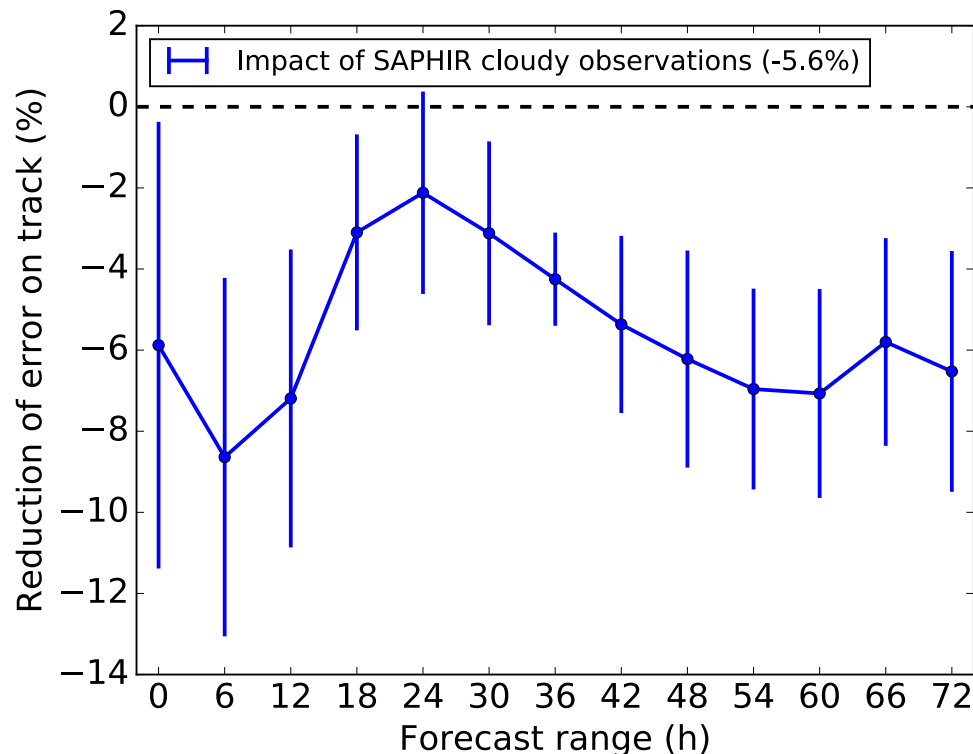


# Ongoing research to improve these Tropical forecasts

## Impact of SAPHIR cloudy radiances on hurricane forecasts:

Analysis of 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

# Ongoing research to improve these Tropical forecasts

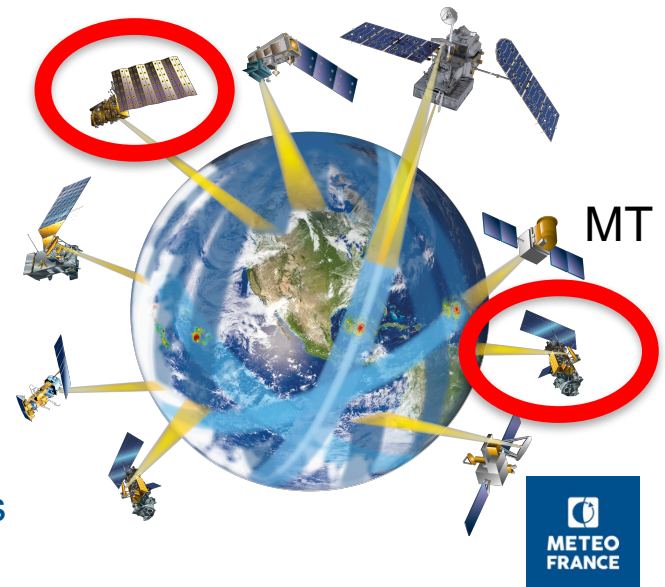
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- Our method seems mature enough to be transferred to the operational forecasting system at Météo-France => candidate for our next parallel suite
- Currently, the Megha-Tropiques platform has problems which are under investigation by ISRO and CNES => no data are available in NRT since mid November 2018.

# Ongoing research to improve these Tropical forecasts

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- Our method seems mature enough to be transferred to the operational forecasting system at Météo-France => candidate for our next parallel suite
- Currently, the Megha-Tropiques platform has problems which are under investigation by ISRO and CNES => no data are available in NRT since mid November 2018.
- The developments shown have therefore been adapted to the MHS sounders onboard MetOp-A, B, C and NOAA-19 => a constellation of 4 sounders in the Tropics provides a similar impact than Megha-Tropiques (same conclusion as in Chambon and Geer, 2017)
- Our latest results support the idea that low inclined orbits have a good impact on NWP





# Early Adopter Quad Chart



## Assimilating TROPICS data within clouds and precipitation

PHILIPPE CHAMBON/CNRM, MÉTÉO-FRANCE & CNRS



### Objective(s):

- Météo-France (MF) operates both a global model (ARPEGE) and regional models over Europe and in the Tropics (AROME). ARPEGE has a stretched and tilted grid shown on the left figure below. AROME is a non-hydrostatic model explicitly resolving convection and is run at 2.5km resolution over the 5 domains shown on the right figure. Both models need data to be better initialized and validated, in particular there is a real need for the frequent microwave observations like TROPICS will provide.
- The project consists in studying the impact of TROPICS observations on both ARPEGE and AROME analysis and forecasts, in particular within clouds and precipitation.

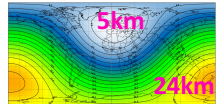


Figure 1: ARPEGE horizontal grid



Figure 2: AROME domains in the Tropics

### Key Milestones & Updates for End User

- Simulating TROPICS observations with the radiative transfer model RTTOV-SCATT
- Studying first guess departure (observation - model) distribution statistics in order to start evaluating the observations quality, both with the global and the mesoscale models
- Tuning observation errors and quality control
- Conducting assimilation experiments, in particular on hurricane case studies

### End user(s)/Co-Investigator(s):

### Approach

- The approach which will be followed for the assimilation of TROPICS observations will be similar to the one developed for Megha-Tropiques/SAPHIR observations in clouds and precipitation
- The used methodology consists in a 1D-Bayesian+4D-Var approach to first retrieve relative humidity and temperature profiles from brightness temperatures and then assimilate the retrievals with a dedicated quality control and observation errors.
- This data assimilation method was evaluated over long periods and provide in particular good impacts on tropical wind forecasts (Duruissette et al., 2018)
- More recently, an evaluation of the impact of the 1D-Bayesian+4D-Var of SAPHIR cloud observations on ARPEGE hurricane forecasts has started. The first results are encouraging as shown on the Figure on the right for hurricane Beryl.

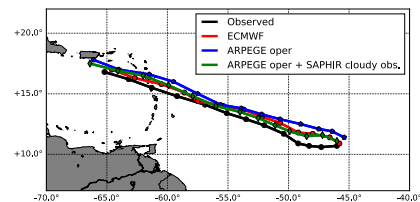


Figure 3: Hurricane Beryl - Forecasts initialized on 2018-07-06 at 12h UTC

### Schedule and Issues

- When the data of the first MicroMas-2a launched in 2018 will be made available to EA, the first comparisons will be performed both with our global and our meso-scale models
- In the mean time, data from the MWHS2 sounder onboard the FY3-C satellite will be added to our 1D-Bayesian+4D-Var framework in order to gain experience on the use of 118 GHz observations in cloudy and rainy sky.
- Some work will also be needed around the 205 GHz as this frequency is not necessarily taken into account in all databases of single scattering properties of hydrometeors.
- If the impacts found are positive and the latency of the TROPICS data dissemination compatible with Météo-France system's cut off, TROPICS data may be assimilated in MF NWP systems.

DATE: November 30<sup>th</sup>, 2018

# Thanks !

© cnrs - labo Photon/M Regy

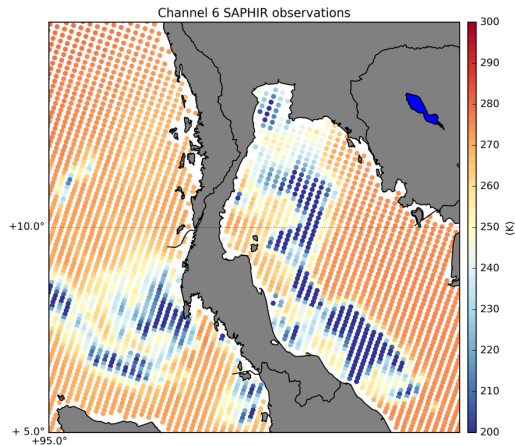


**Back up slides**

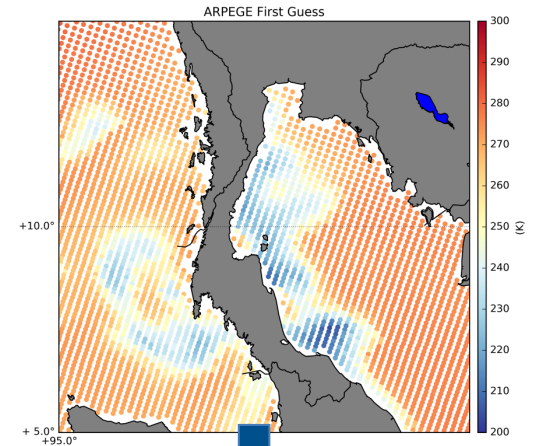
# Data assimilation methodology

20170108 r00h UTC

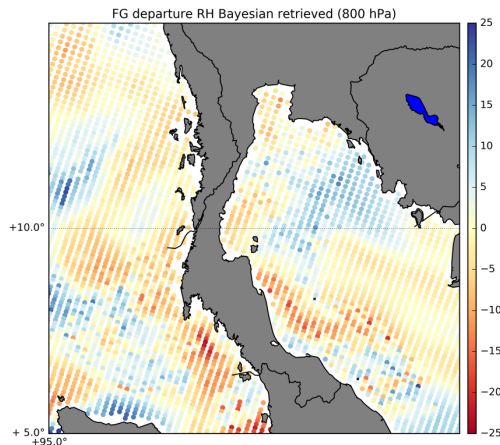
Observations SAPHIR S6



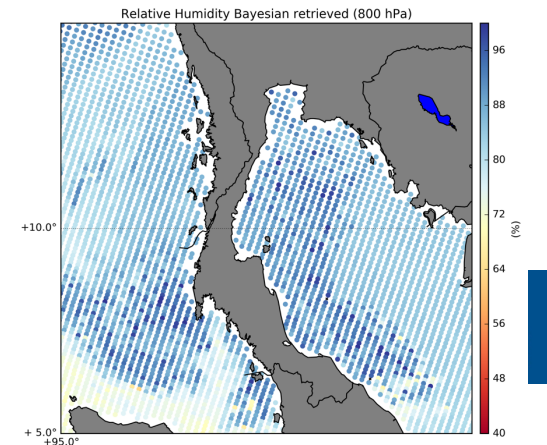
First Guess from ARPEGE simulated with RTTOV SCATT



First Guess departure of Relative Humidity at 800hPa

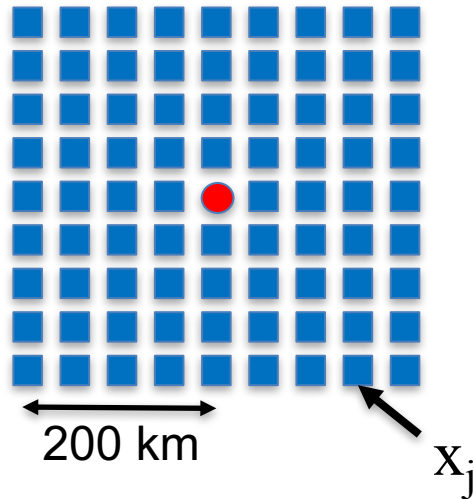


Retrieved Relative Humidity at 800hPa



Assimilation of retrievals





**Observations SAPHIR**  
 Model first guess in the surroundings of an observation

**Cost Function**

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

All SAPHIR channels?

**Weights of each Neighbors**

$$w_j = e^{-J_o^j}$$

**Computation of the retrieved profile**

$$x_{retr} = \frac{\sum_{j=1}^{80} x_j \cdot w_j}{\sum_{j=1}^{80} w_j}$$

Accuracy wanted for the retrieval