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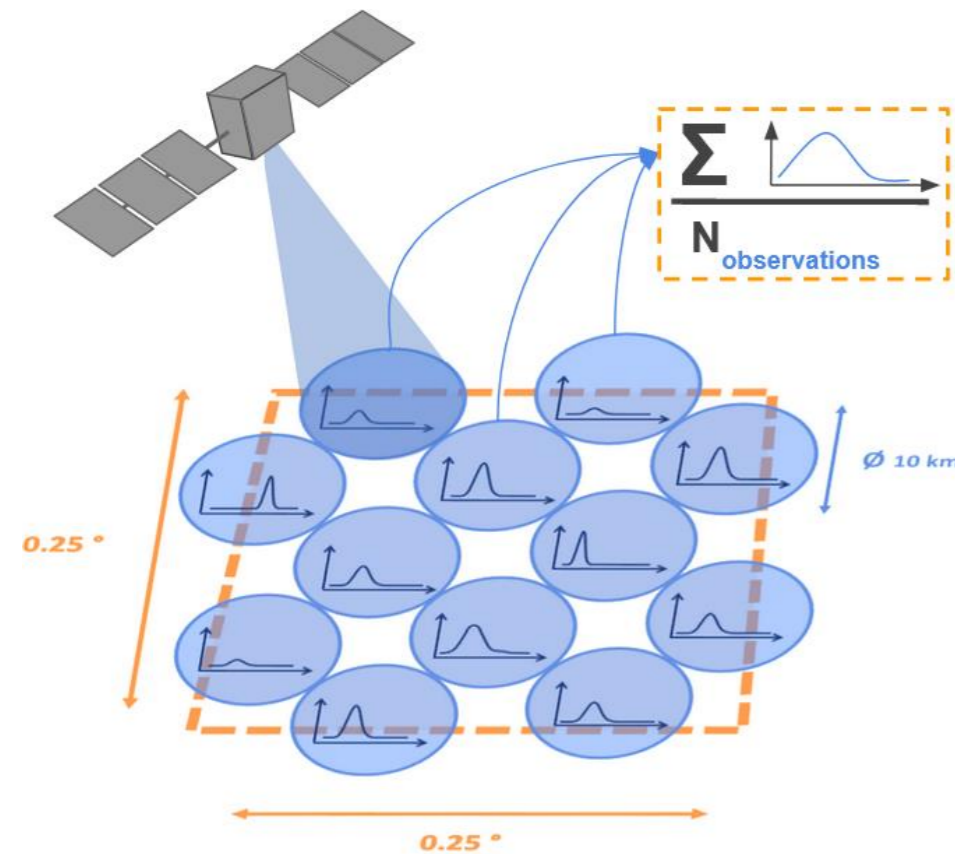
Using satellite probabilistic estimates to assess modeled relative humidity : application to a NWP model

C. Radice (chloe.radice@latmos.ipsl.fr), H. Brogniez, P.-E. Kirstetter, P. Chambon

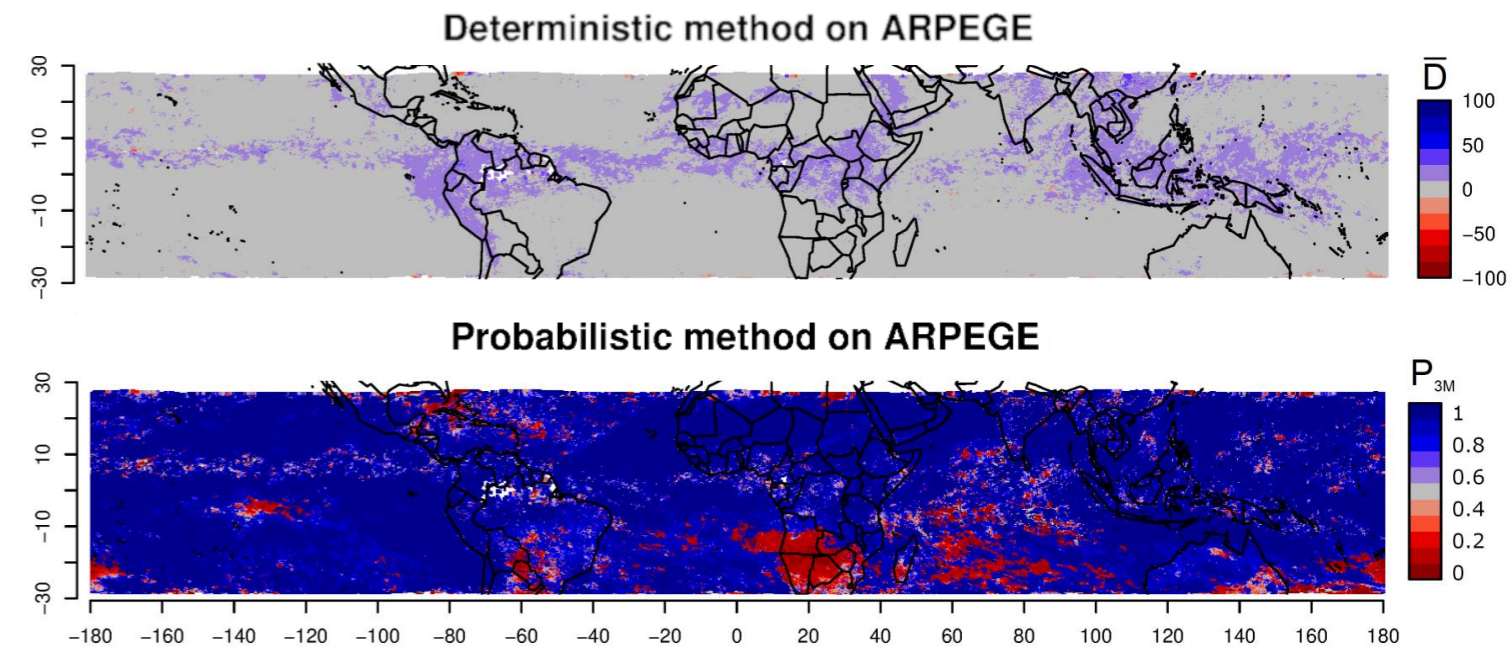
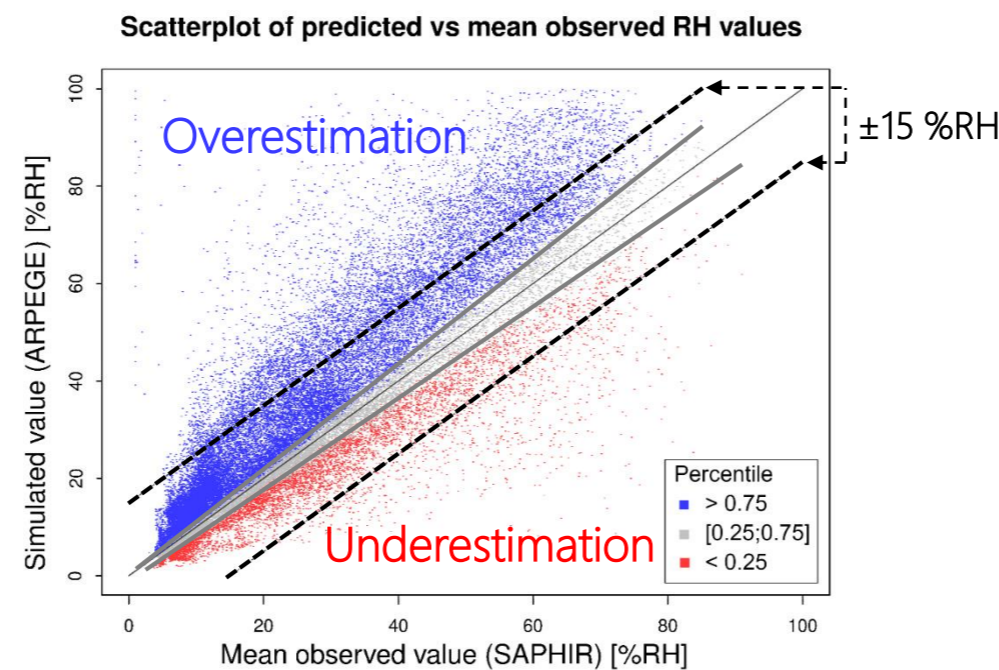


Deterministic method : is the simulated value within a fixed interval around the mean observed value ?

Probabilistic method : uses the full estimated distribution to determine the probability of the simulated value being an over- or underestimation



Both methods were applied to 3 months worth of the ARPEGE-SAPHIR colocated dataset (April-May-June 2018)



Probabilistic RH estimates from microwave sounder **SAPHIR** aboard satellite Megha-Tropiques

Simulated RH by the Numerical Weather Prediction model **ARPEGE** developed by Météo France

Deterministic assessment: slight humid bias over the ITCZ

Probabilistic assessment: overall overestimation with local patches of underestimation

Even when the simulated values are close to the mean estimation, they actually correspond to the extreme ends of the entire subgrid distribution.

→ **Complementary to a deterministic approach + adds contrast within the deterministic interval**



Using satellite probabilistic estimates to assess modeled relative humidity : application to a NWP model

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Context

Datasets

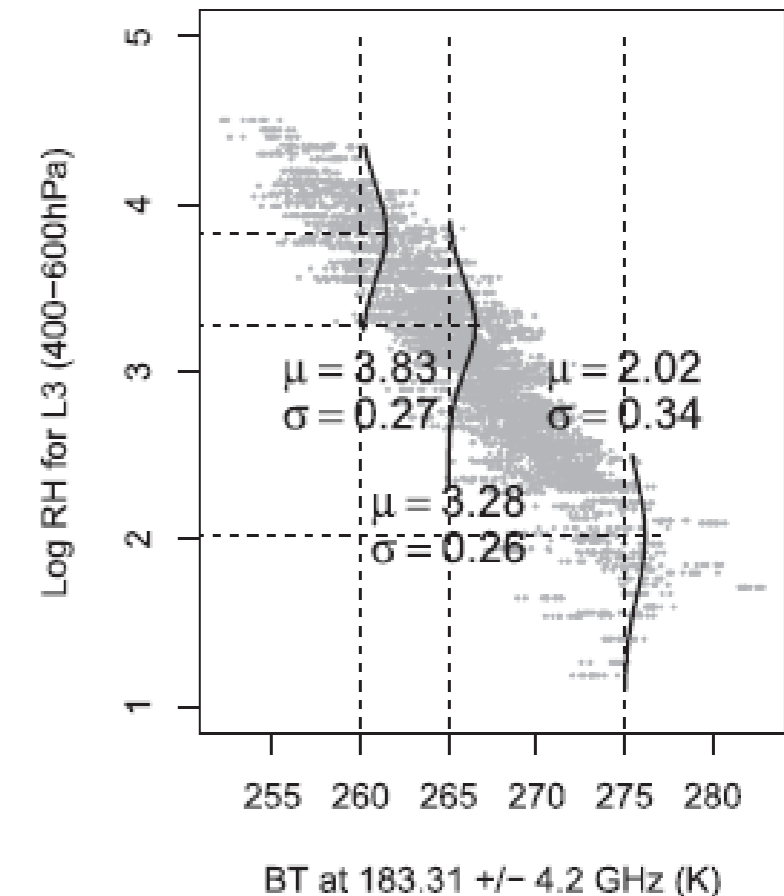


ARPEGE at Météo-France

- Numerical weather forecasting model operated by Météo-France
- Forecasts initialized with a four dimensional variational system with 6h windows (00:00, 06:00, 12:00 and 18:00 UTC)
- For this study : 6-hourly instantaneous simulated RH fields at 6 hour lead time for the months April, May and June 2018.
- The resolution of the model grid used is $0.25^\circ \times 0.25^\circ$

SAPHIR microwave sounder

- 6 channels sampling the 183 GHz water vapour absorption line
- Onboard Indo-French (ISRO x CNES) satellite Megha-Tropiques
- Scans the tropical belt (between 30°N and 30°S)
- Retrieval scheme for a profile of RH over 6 layers (100 to 950 hPa)
- For each layer : expected $\overline{\text{RH}}$ as well as its PDF to account for uncertainty in the retrieval ([Sivira et al 2015](#), [Brogniez et al 2016](#)).



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Methodology

Assessing forecasts with satellite observations

Colocation

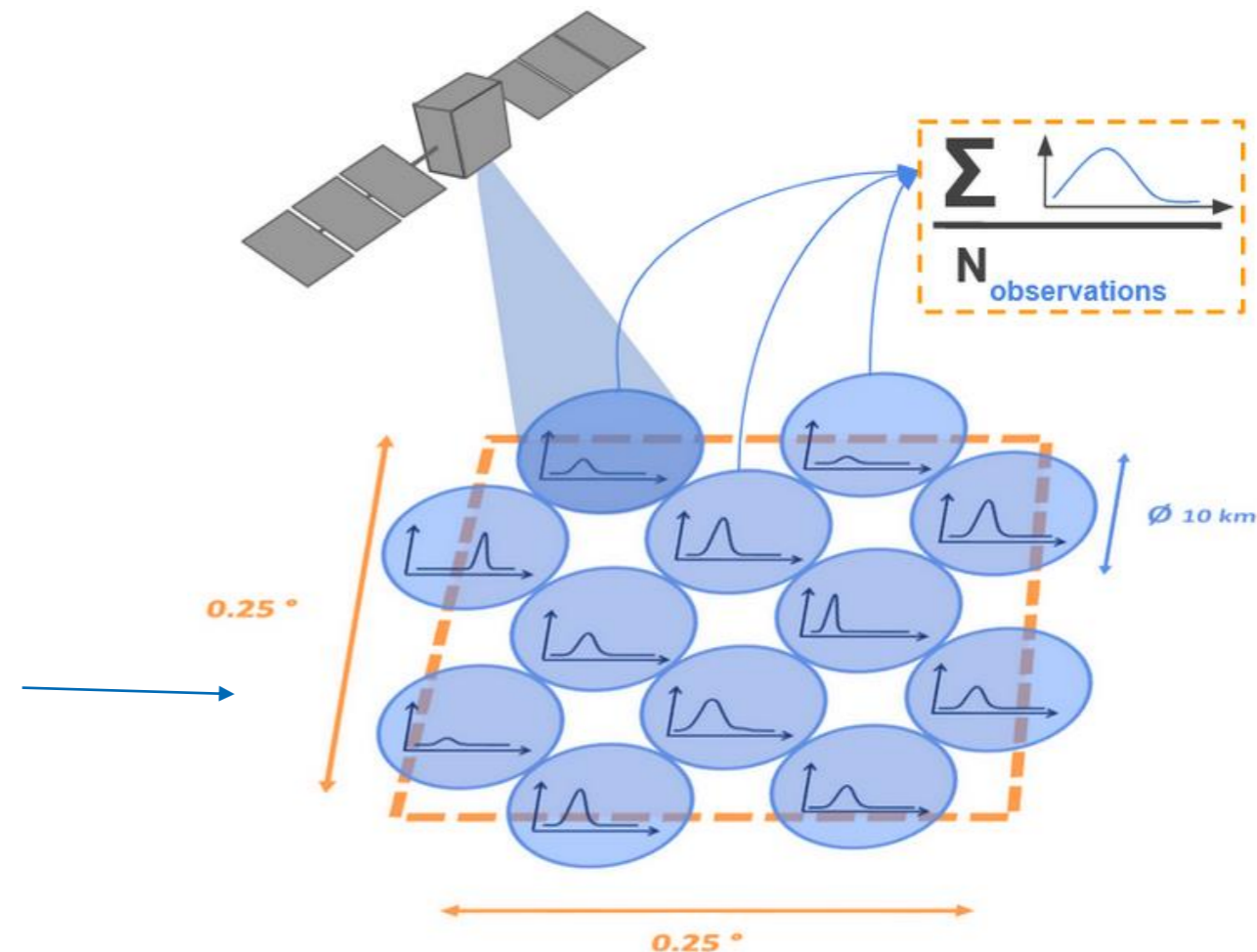
- ± 30 min time frame around the ARPEGE simulation
- Atmospheric levels of the simulations are aggregated together to mimic the vertical resolution of the SAPHIR RH profiles (6 pressure layers)

Our probabilistic method

- Convoluting the PDF of every footprints within each gridbox of ARPEGE
- Projecting the simulated value (SV) onto the distribution

Deterministic comparison

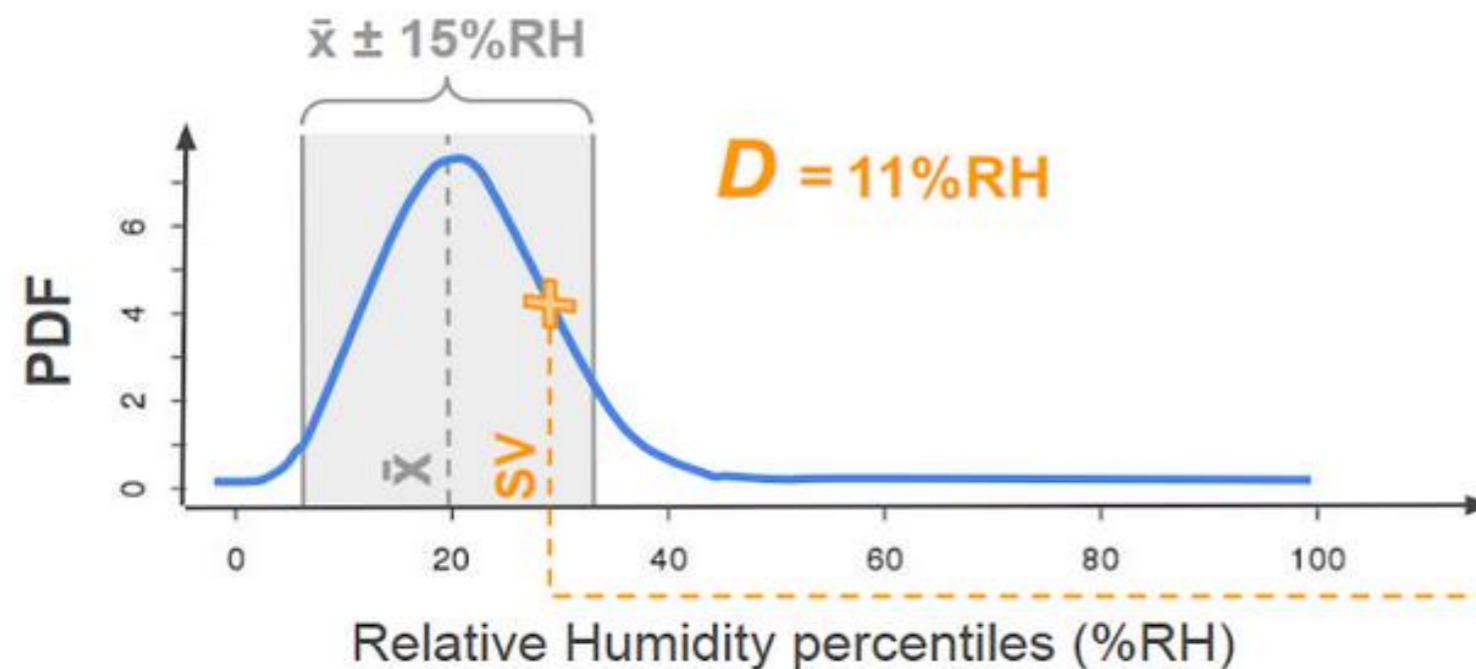
- For every gridbox of ARPEGE, spatial average of SAPHIR \overline{RH}
- Confronting the simulated value (SV) to this averaged value



Methodology Application

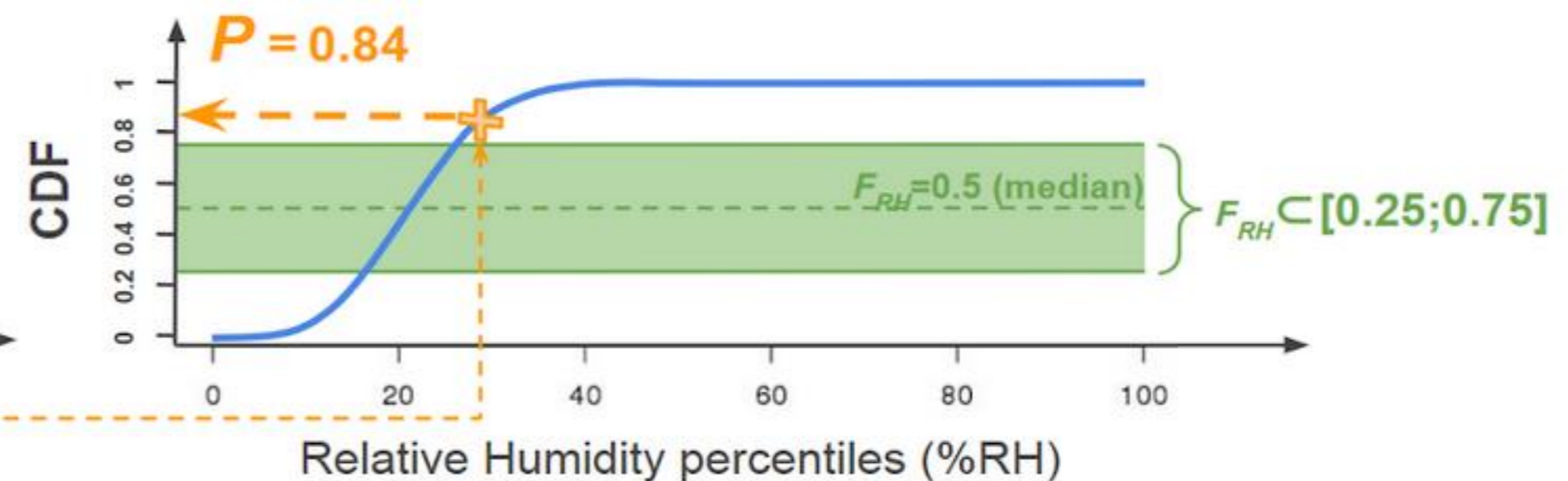
Deterministic comparison

- \overline{RH} computed from the PDF
 - + Confidence interval arbitrarily set to $\pm 15\%RH$ (defined from a global evaluation of the retrieval using radiosoundings)
- Difference : $D = SV - \overline{RH}$
- Example : ARPEGE SV = 30 %RH $\rightarrow D = 11\%RH$



Our probabilistic method

- PDF \rightarrow Cumulative Density Function (CDF)
- $CDF(SV) = \mathcal{P}(RH \leq SV) = P$
- Situates SV in the estimated CDF within or outside the inter-quartile 0.25-0.75
- Example : $P=0.84$
 - \rightarrow probability of 84% that the true RH estimate is lower than SV
 - \rightarrow SV falls within the upper quarter of the distribution ($P > 0.75$)
 - \Rightarrow High probability that the model overestimates the RH



Motivations

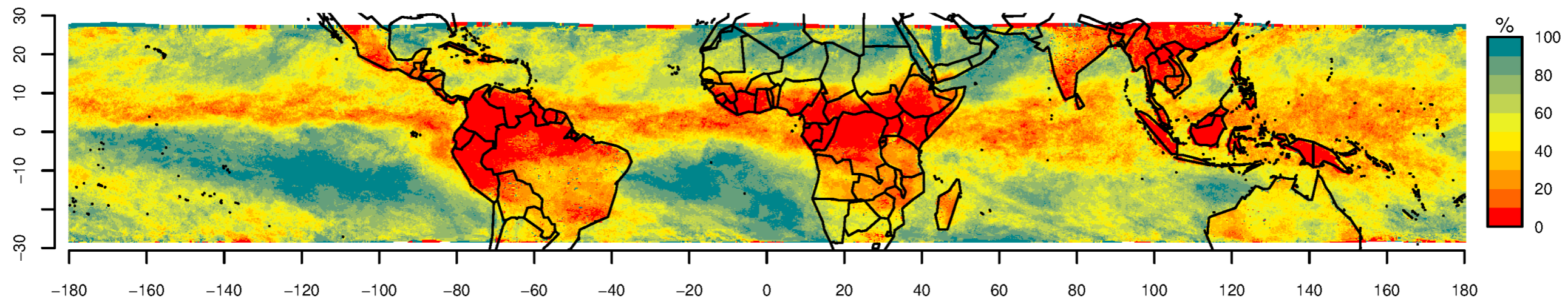
Comparing to the same deterministic interval does not account for the shape of the whole distribution.

IQR = Interquartile Range ($Q3-Q1$ or $X_{P(X)=0.75} - X_{P(X)=0.25}$) of the subgrid distributions

IQR < 15%RH → the subgrid distribution has a smaller uncertainty than the $\pm 15\%RH$ deterministic interval
→ the $\pm 15\%RH$ error works

IQR > 15%RH → the subgrid distribution is too wide to fit the $\pm 15\%RH$ deterministic interval
→ need to have a wider error than $\pm 15\%RH$

(c) Frequencies of IQR within the 15%RH confidence interval
Spring 2018 Layer 650–700 hPa



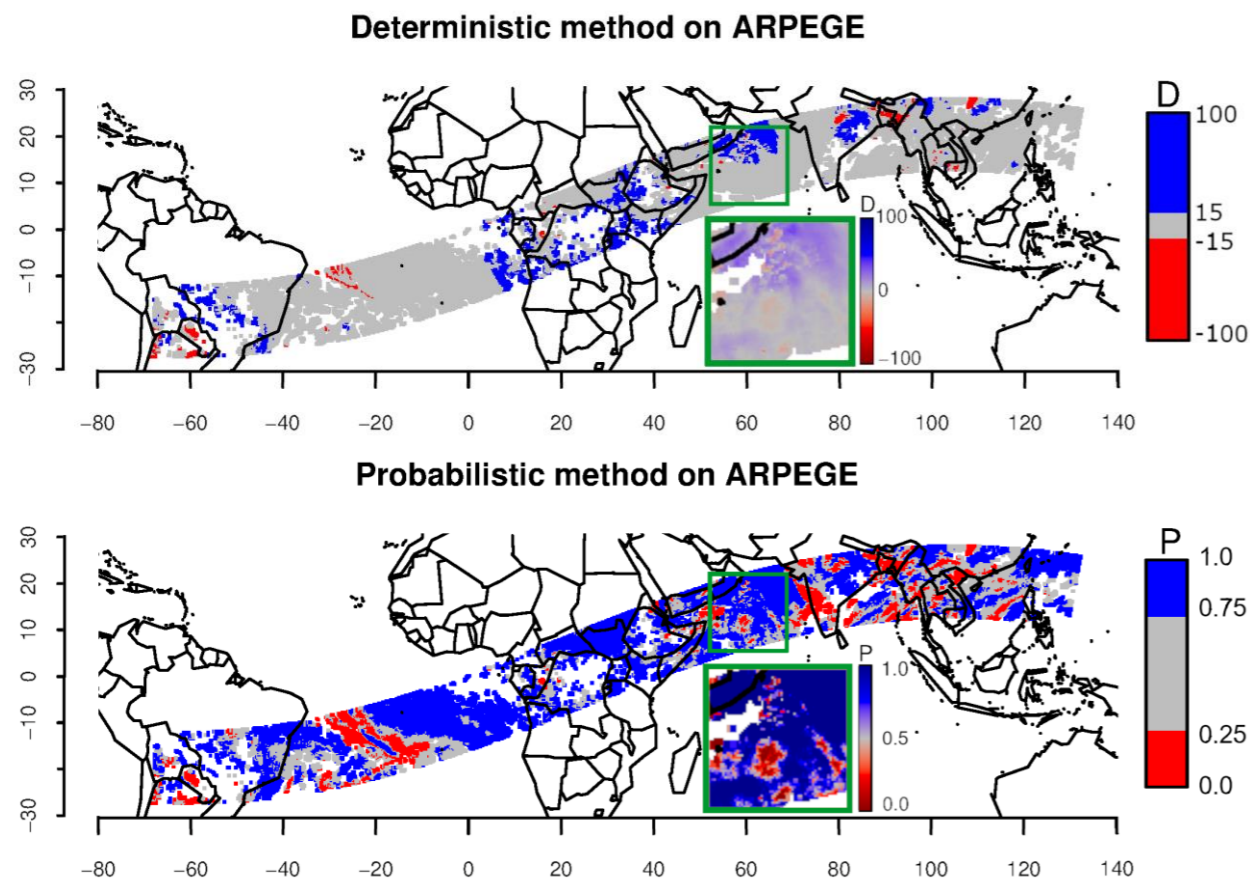
Results

Maps



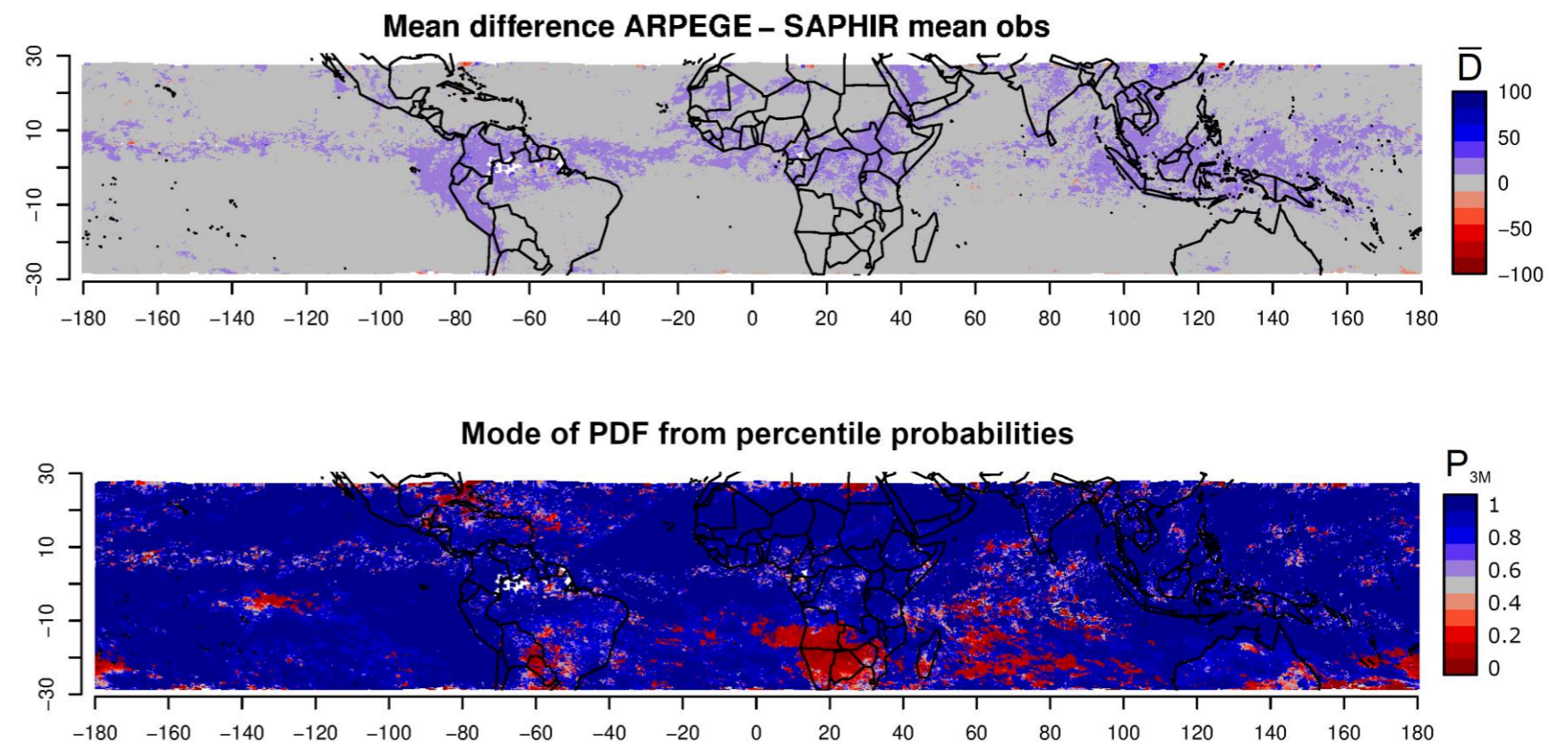
One time step, one atmospheric layer

01/04/2018 – 00UTC – 400 to 600 hPa



3-month period, one layer

April to June 2018 – 400 to 600 hPa



- Same structures of biases highlighted by the two methods (see zoomed areas)
- Overall, with the deterministic method, ARPEGE SV close to the mean estimate (within the $\pm 15\%$ RH interval)
- The probabilistic method shows very contrasting patterns (< 0.25 or > 0.75)
- The deterministic method only highlights a slight moist bias (\bar{D} between 15 and 30 %RH) in the Intertropical Convergence Zone (ITCZ)
- The probabilistic method shows a very high probability (> 0.8) that the model overestimates the atmospheric RH for this pressure layer
- Some patches of probable underestimation of RH (< 0.2) appear only with this method (above the south of Africa, the Indian Ocean, equatorial Pacific Ocean, etc.)



Results

Distributions for the whole tropical belt (30°N-30°S)

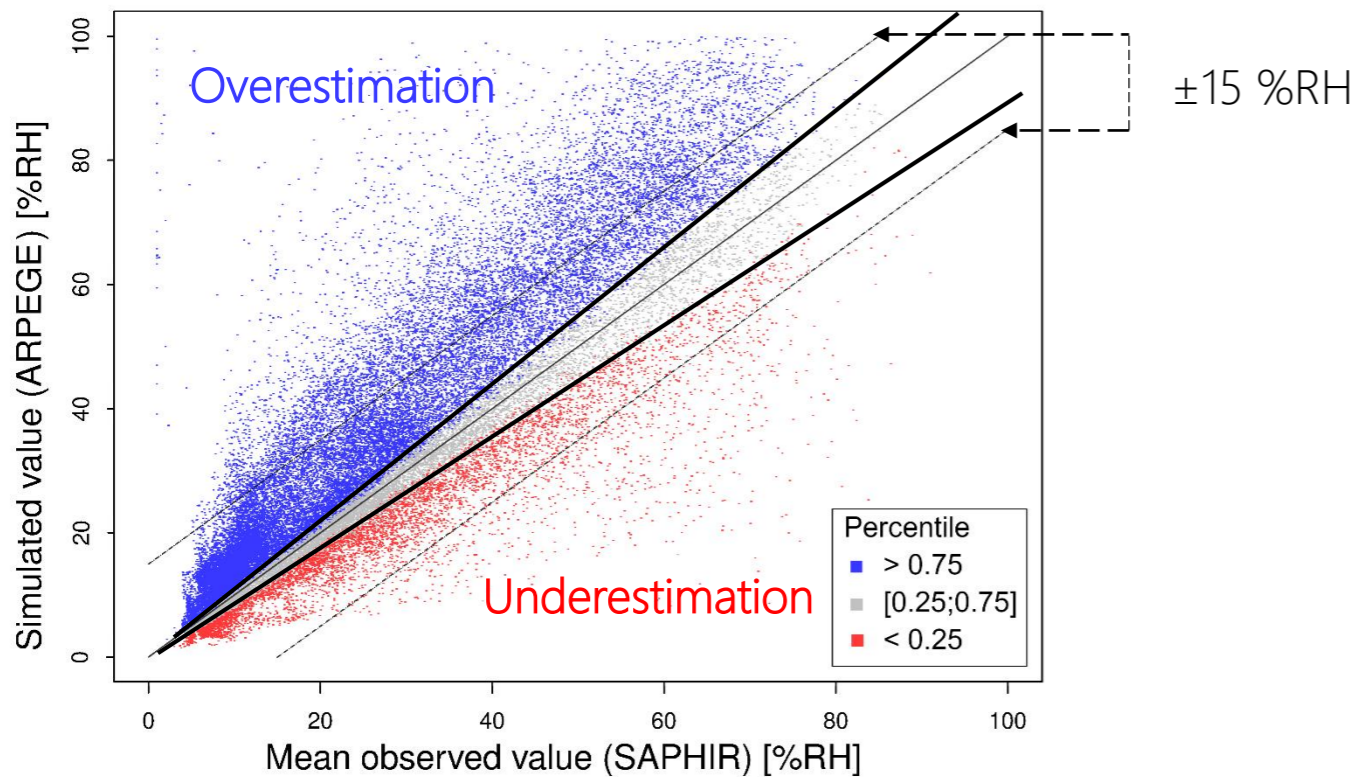
1 time step, 1 atmospheric layer

01/04/2018 – 00UTC – 400 to 600 hPa

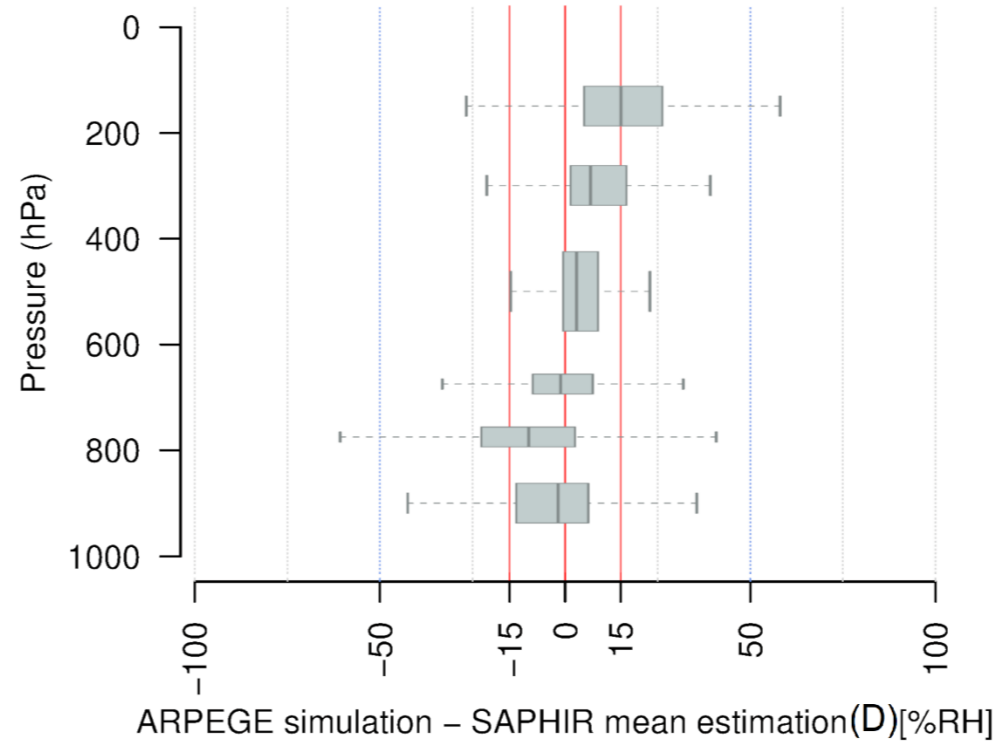
3-month period, all layers

April to June 2018 – 100 to 950 hPa

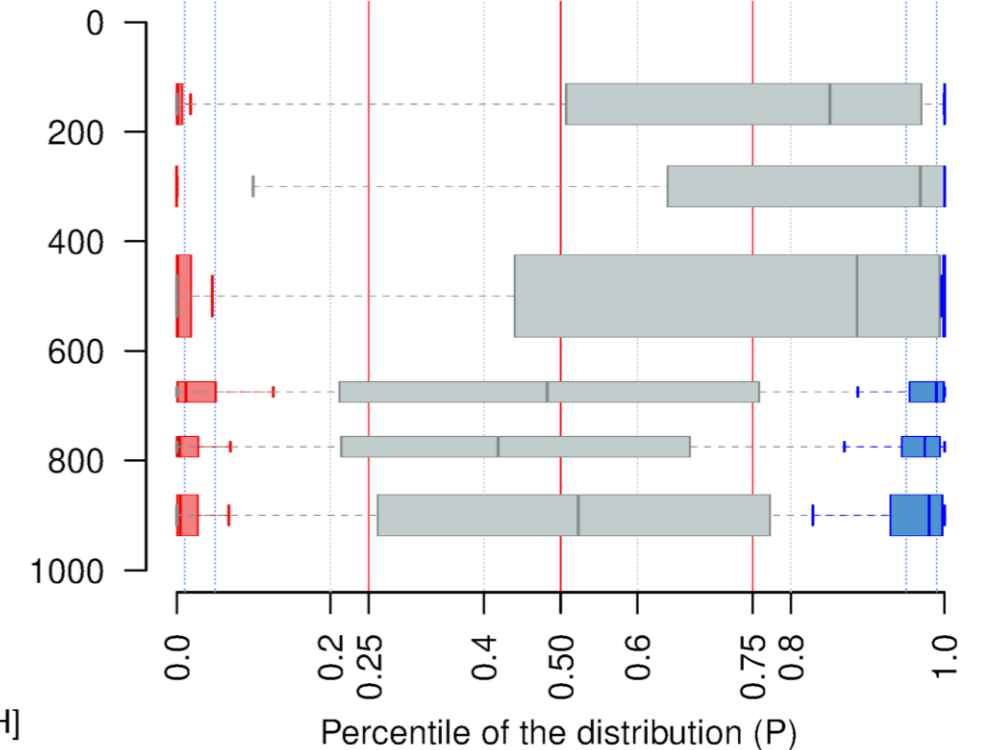
Scatterplot of predicted vs mean observed RH values



Distribution of the deviations from mean (D)
ARPEGE Spring 2018



Distribution of the associated percentiles (P)
ARPEGE Spring 2018



- Grey area not symmetrical around the $y=x$ line
→ $[0.25;0.75]$ interval not centred around the mean
- A fixed confidence interval (ex. $\pm 15\%$ RH) is not suitable and the knowledge of the spread of the retrieval (PDF/CDF) better quantifies the assessment of the model

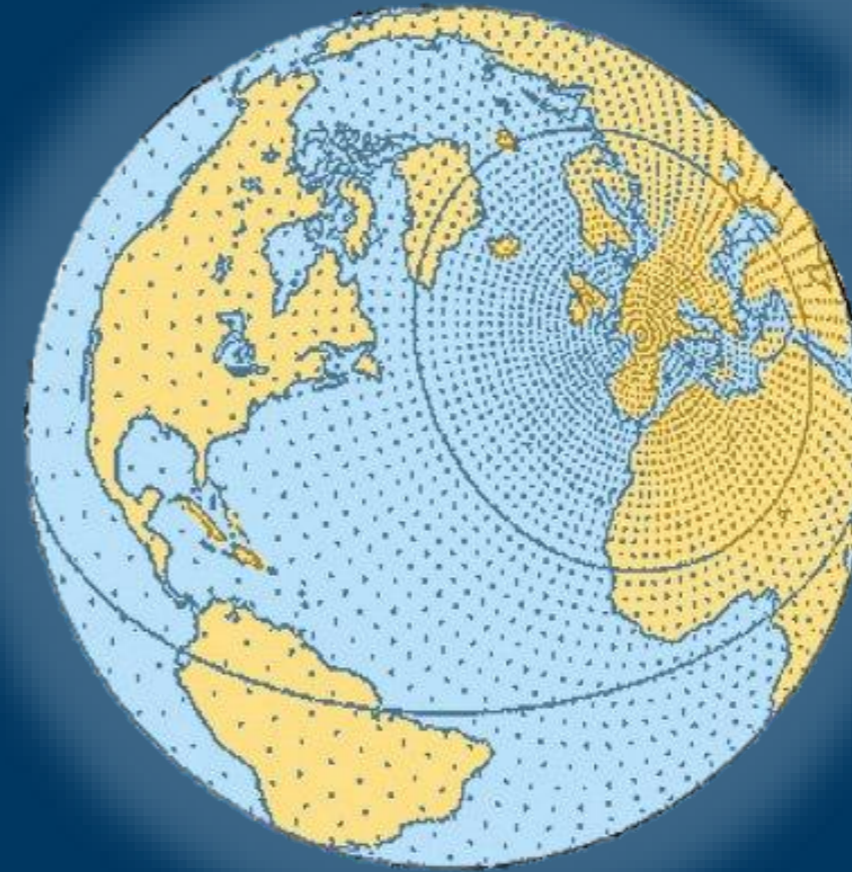
- Grey : distribution of P when D ($SV - \overline{RH}$) within the $\pm 15\%$ RH interval
- Red : distribution of P when $D < -15\%$ RH
- Blue : distribution of P when $D > +15\%$ RH

- When SV outside $\pm 15\%$ RH, P in majority in the extreme 5% of the distributions (< 0.5 or > 0.95)
- Added information content in the probabilistic results (wide distributions) wrt the deterministic method (narrower distributions with few extreme values)

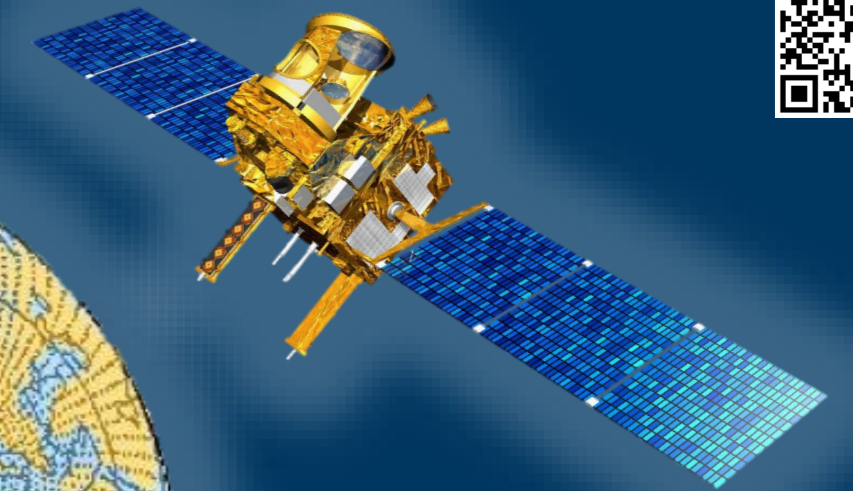


Conclusion

- The probabilistic method adds significant information to the comparisons, adapts to each situation and allows a both robust and precise diagnosis.
- This probabilistic method shows promising results on this data set but is perfectly adaptable to any other variable, model and reference PDF
- Check out [radice et al., 2022](#) for more details !



Grid of the numerical weather forecasting model ARPEGE
© Météo-France



Atmospheric water cycle studying satellite Megha-Tropiques
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