Assimilation of IASI all-sky radiances for Numerical Weather Prediction (PhD).

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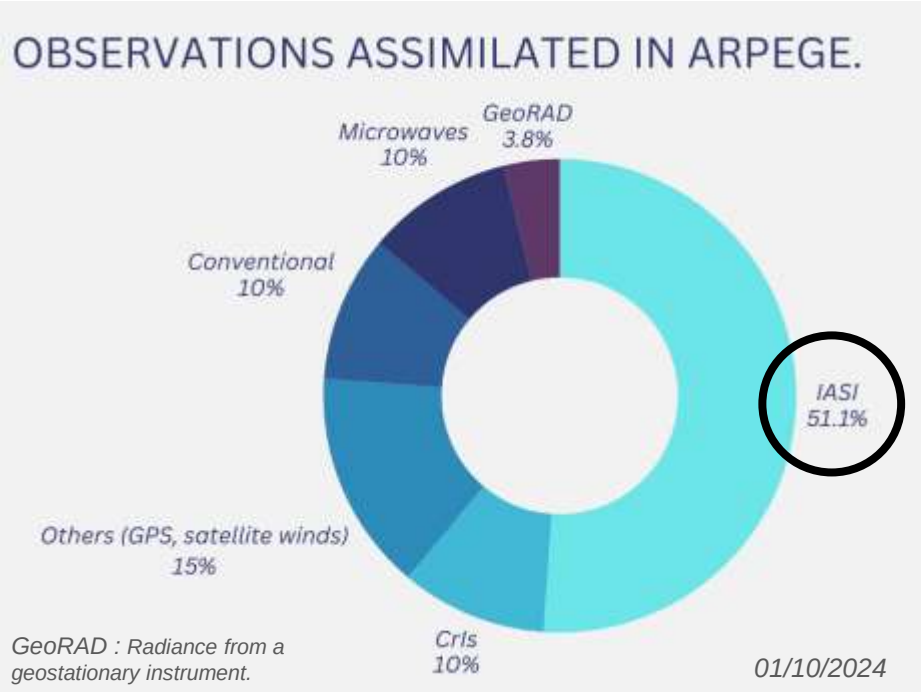
1.A Observations in ARPEGE

- At Météo-France **90%** of assimilated observations come from satellites.
- **65% of observations come from IR** (infrared) **instruments.** Including 4% from imagers onboard geostationary satellites, 10% from CrIS and over 50% from IASI.



1.B Towards all-sky assimilation

For the moment :

- We only assimilate data identified as clear.
- **80%** of IASI BT (brightness temperature) are impacted by clouds.

The benefits of all-sky assimilation :

- Retrieving information on hydrometeors in cloud tops.
- Unify processing of IASI observations.

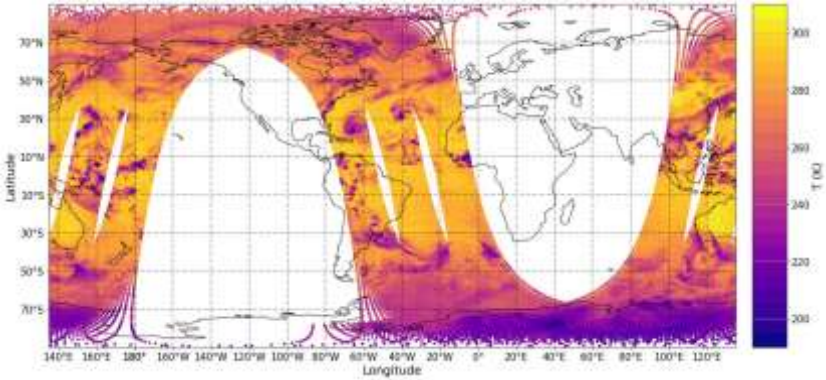
Necessary conditions of all-sky assimilation :

- Cloud representation in the forecast model.
- Simulation of observations (RTM).
- Need to take into account new observations errors in cloud conditions.

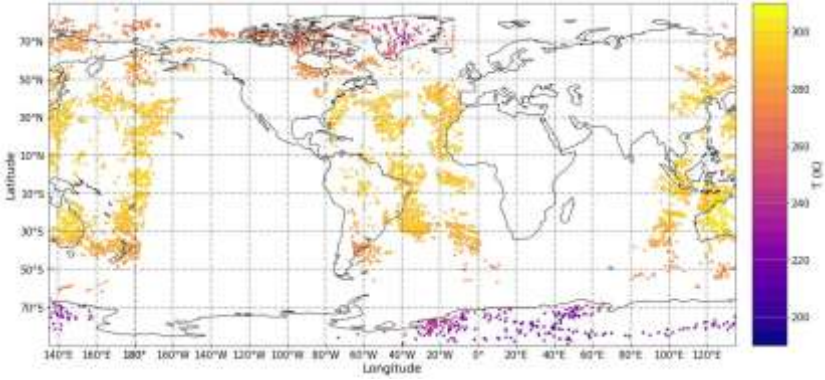
Microwave all-sky assimilation is already **in operations** at ECMWF and Météo-France in ARPEGE (Duruisseau et al., 2019) and (Barreyat et al., 2023).

→ **The objective is to extend to IR all-sky assimilation.**

All measurements (BT) made by a surface channel 1191 [942.25 cm^{-1}] on 15/08/2023 at 00 UTC.



Assimilated observations (BT) of a surface channel 1191 [942 .25 cm^{-1}] on 15/08/2023 at 00 UTC.



1.C Previous studies on all-sky assimilation for IR

All-sky assimilation of 3 AHI water vapor channels in the JMA global model.

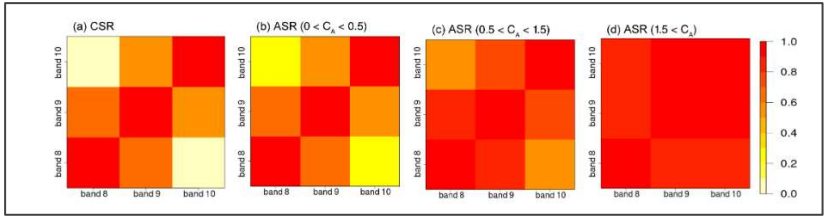
(Okamoto et al., 2023)

→ Develops a cloud diagnostic to pre-identify the radiative influence of clouds (C_A) :

$$C_A = \frac{|B_{cloud} - B_{clear}| + |OBS - B_{clear}|}{2}$$

→ **Observation error variances model** (Geer et Bauer, 2011).

→ **Estimation of error correlation matrices** for AHI in the global JMA model (more or less cloudy).



→ **Forecast improvements** for up to 3 days with AHI all-sky.

→Presented **encouraging results for IASI's all-sky assimilation at a WMO conference**

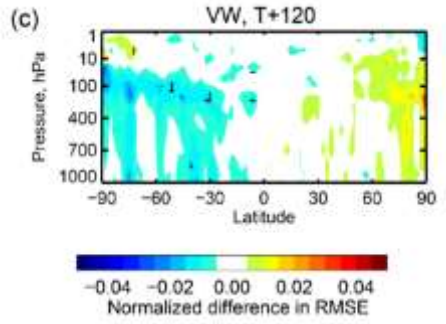
All-sky assimilation of 7 IASI water vapor channels in the IFS global model.

(Geer et al., 2019)

→ **Observation error variances model** (Geer et Bauer, 2011).

→ **Error correlation matrix** adapted to each cloud situation for IASI.

→IASI's all-sky assimilation in IFS **improves** long-range forecasts (+2%) in the southern hemisphere.



1.D Steps of my thesis

Problematic

What is the impact of IASI's all-sky assimilation for numerical weather prediction in the ARPEGE model ?

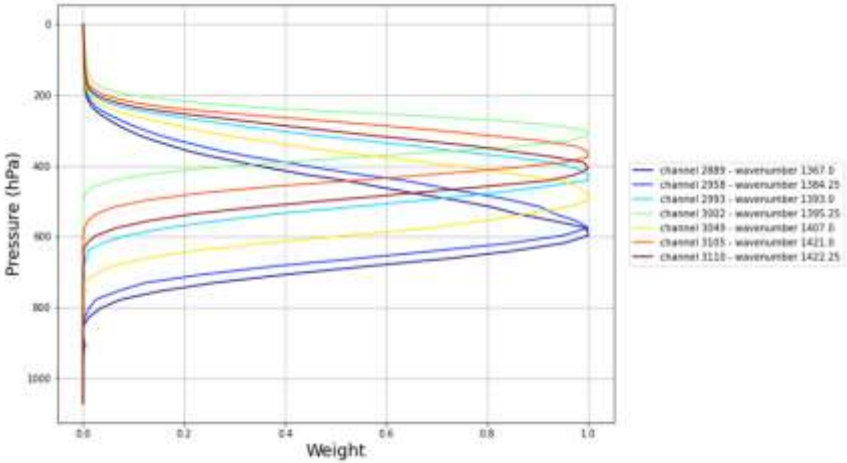
Different stages :

- Setting up IASI cloud simulation.
- Setting up IASI cloud assimilation :
  - Setting up QC (Quality Control).
  - Setting up an observation error model.
- Study of the impact of all sky assimilation in ARPEGE model.

2. Experimental framework

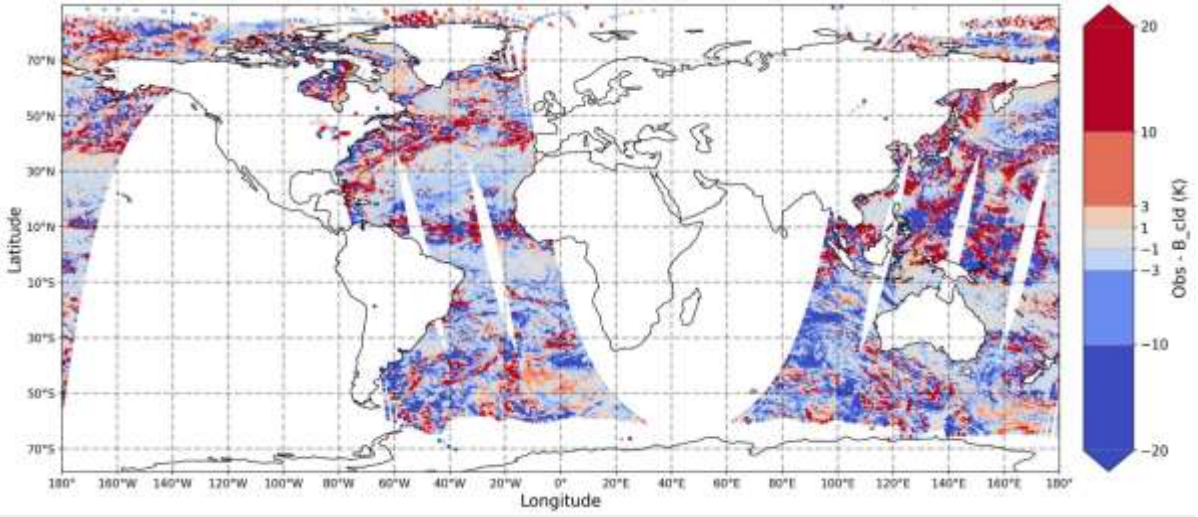
- **Global model :** ARPEGE (Bouyssel et al., 2022).
- **Radiative Transfer Model** : RTTOV 12.
  - **Micro-physical parameterization** : Baran parameterization *(Baran et al., 2014).*

Channel number	Wavenumber [cm^{-1}]	Peak of weighting function [hPa]
1191 (surface channel)	942.50	1000
2889 (Water Vapor)	1367.00	684
2958 (WV)	1384.25	662
2993 (WV)	1393.00	538
3002 (WV)	1395.25	405
3049 (WV)	1407.00	604
3105 (WV)	1421.00	468
3110 (WV)	1422.25	520

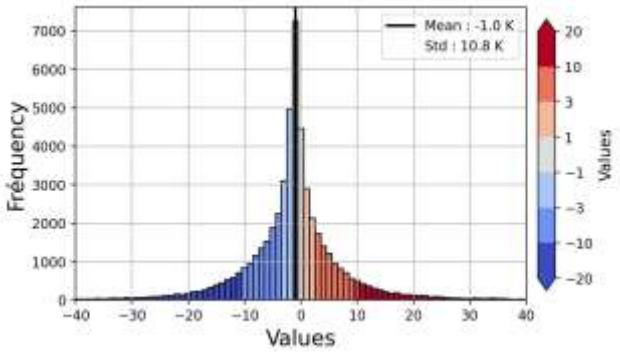


3. All-sky simulation configuration

Innovation (Obs-B) for surface **channel 1191** [942.5 cm^{-1}] on 15/08/2023 at 00 UTC.



Histogram of innovation for surface **channel 1191** [942.5 cm^{-1}] on 15/08/2023 at 00 UTC.



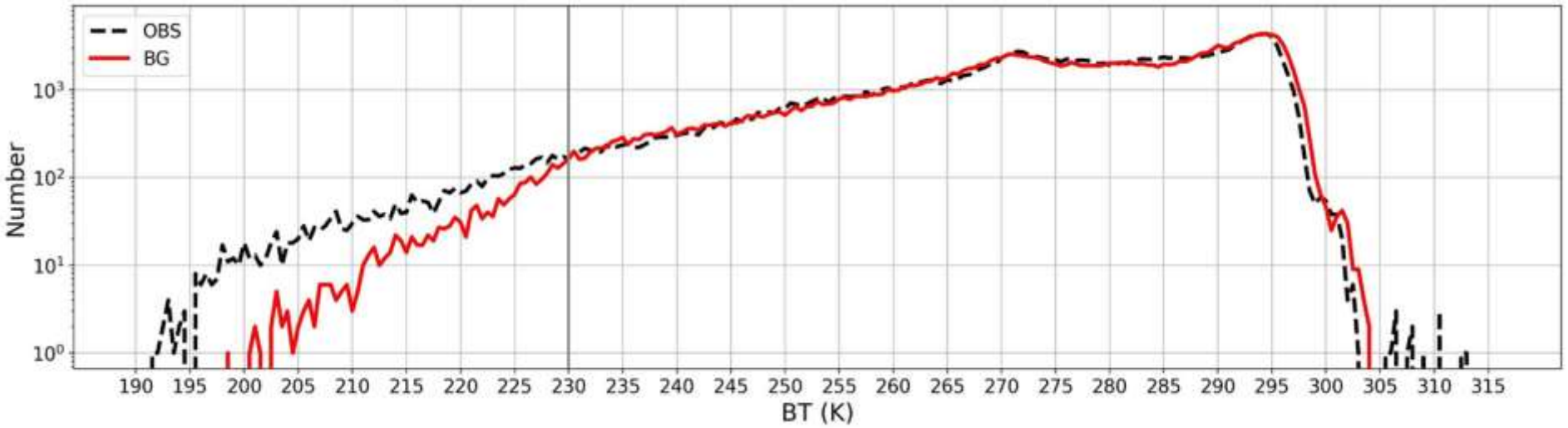
→ Map includes only ocean point without seaice. **Some offset of cloud structure** can be seen.

→ **Histogram are centered around zero** ⇒ A positive point for progressing towards all-sky assimilation.

→ **But, Bias is generally negative** ⇒ This indicates a lack of clouds in the model or clouds not high enough in the model.

3.A Representation of ice clouds

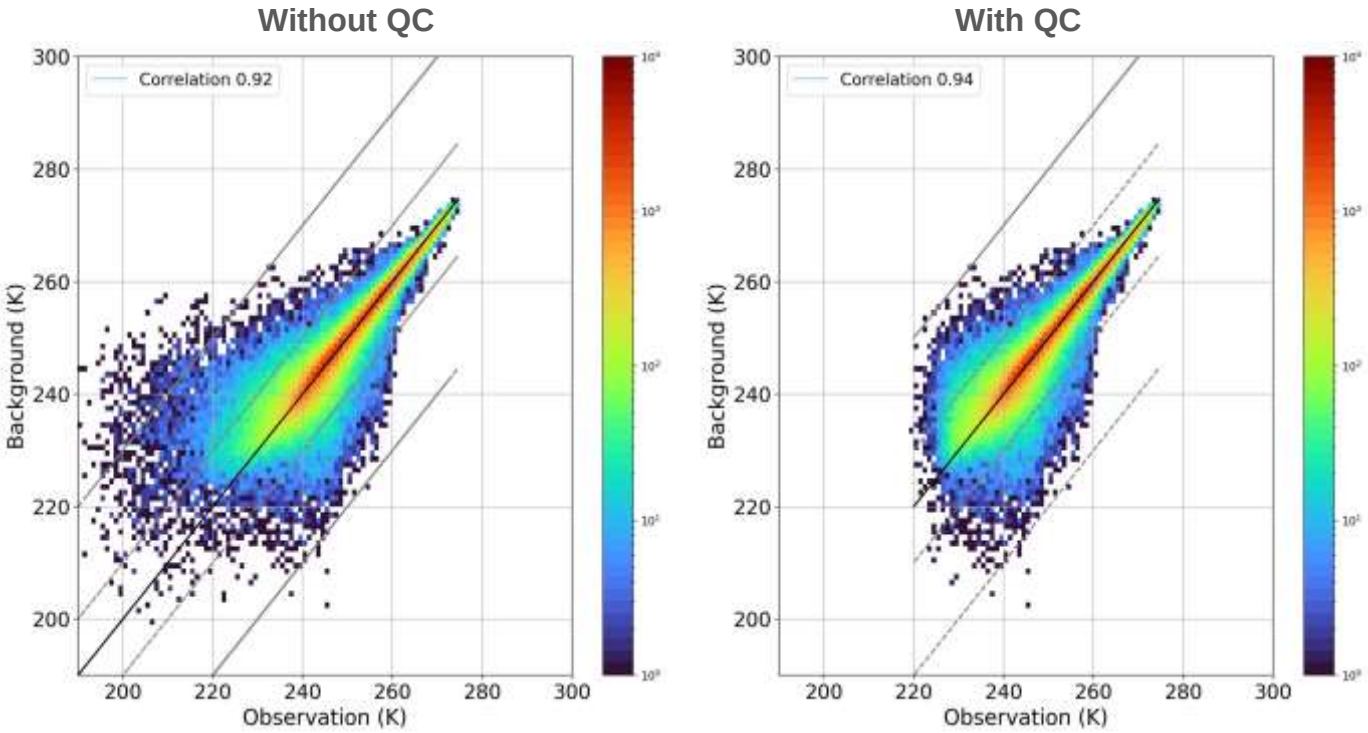
BT distributions for a surface **channel 1191** [942.25 cm^{-1}] between observation (black line) and cloud simulation (red line) on 15/08/2023.



→ The cloud simulation is **correct with respect to observation** except for values below 230 K.
Similar to Okamoto et al., 2023 results, we will impose a threshold to only **take into account observations above 230 K (QC)**.
⇒ As Okamoto shows, the problem is the lack of a thick ice cloud in the model (Okamoto et al., 2023)**.**

3.B Effect of QC

Water vapor
Channel **3105**
[468 hPa]

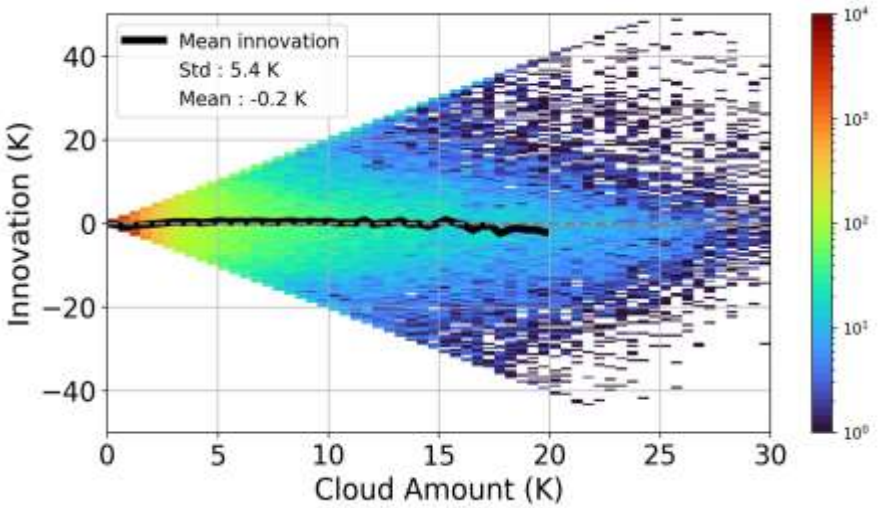


The black line represents x=y and the dotted lines represent a difference of 10 and 30 K.

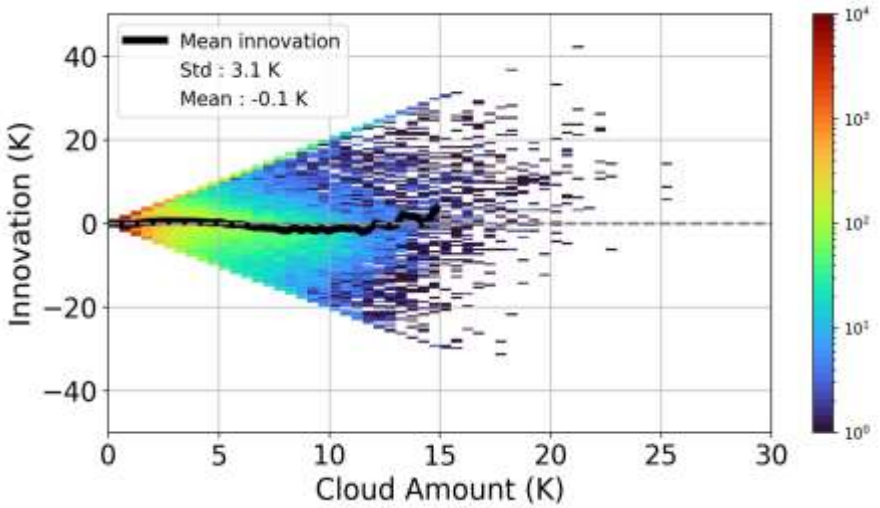
Applying QC reduces point dispersion and slightly increases correlation.

3.C Result of all-sky simulation

Water vapor channel **2889** [684 hPa]



Water vapor channel **3105** [468 hPa]



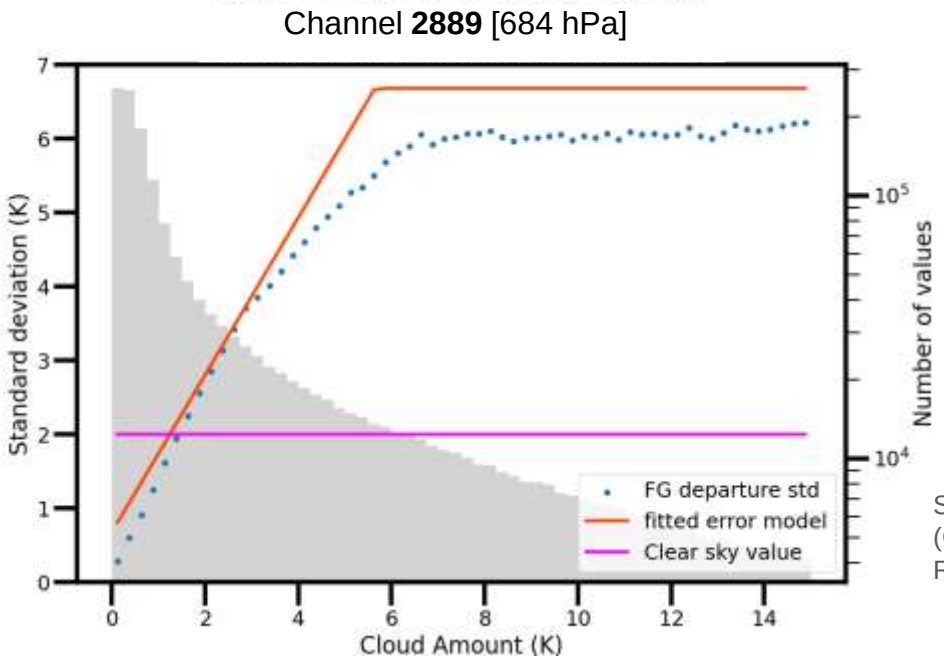
After applying QC, Innovation is close to zero, even for strong C_A.

Very positive results for moving towards all-sky assimilation → **Next step is observation error model**.

4. Variance error model

The **observation errors are determined based on the standard deviations of the innovations**.
The greater the cloud amount the larger the error.

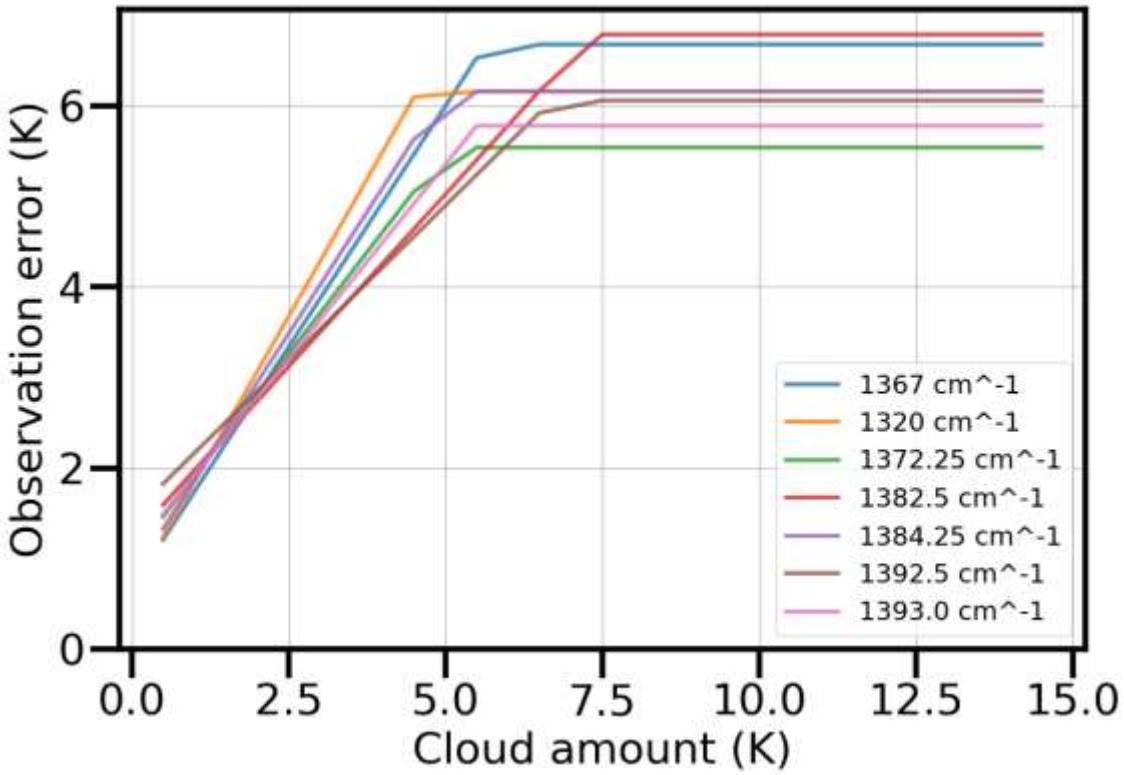
Geer et Bauer, 2011



Statistics over 1 month, based on (Geer et Bauer, 2011) adapted by Rivoire et al., 2024.

4. Variance error model

Observation error model for the 7 water vapor channels



- The plateau value of error models varies from channel to channel (between 5.4 and 6.5 K).

5. Next steps

IASI's cloud simulation is working fine.

Determination of observation error models.

Conclusion

Implement error models in ARPEGE.

In progress

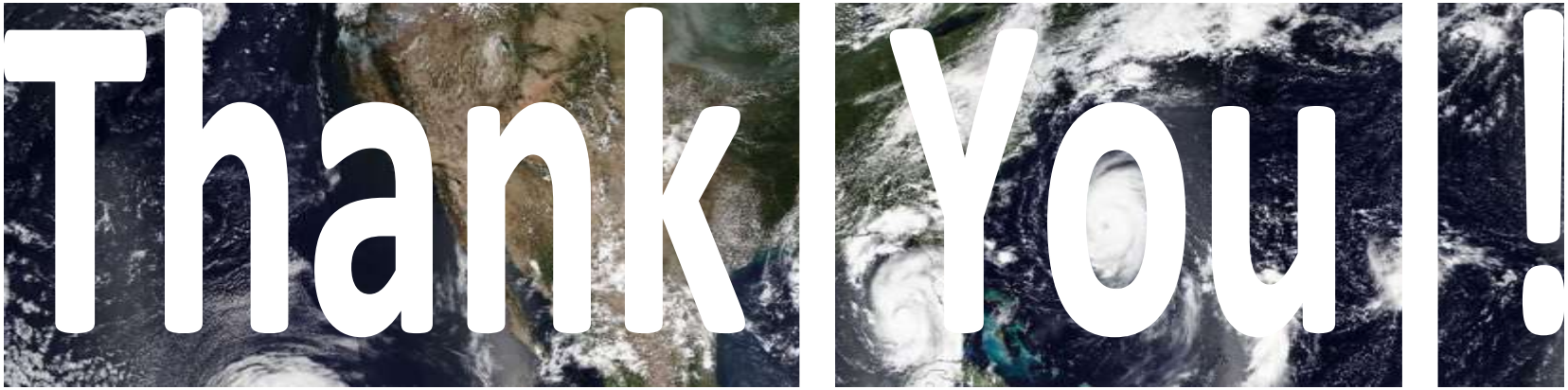
Test the error variance model. (Geer and Bauer, 2011). → Assimilation of **1 water vapor channel**.

Test the channel correlation model as a function of cloud amount (Okamoto et al., 2023). → Assimilation of the **7 water vapor channels**.

Evaluate the impact of this assimilation in the ARPEGE model. → Assimilation of the **129 IASI channels** with the 7 all-sky and the others clear-sky.

In the longer term, we can change the channel selection for all-sky.

Perspectives



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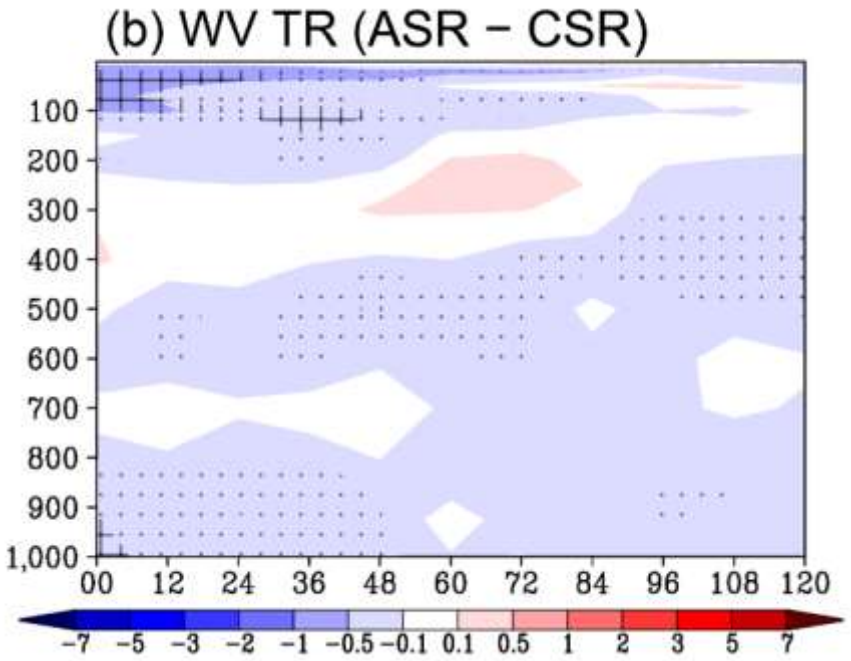
Annexe 1 : **Forecast score** - all-sky vs. clear sky

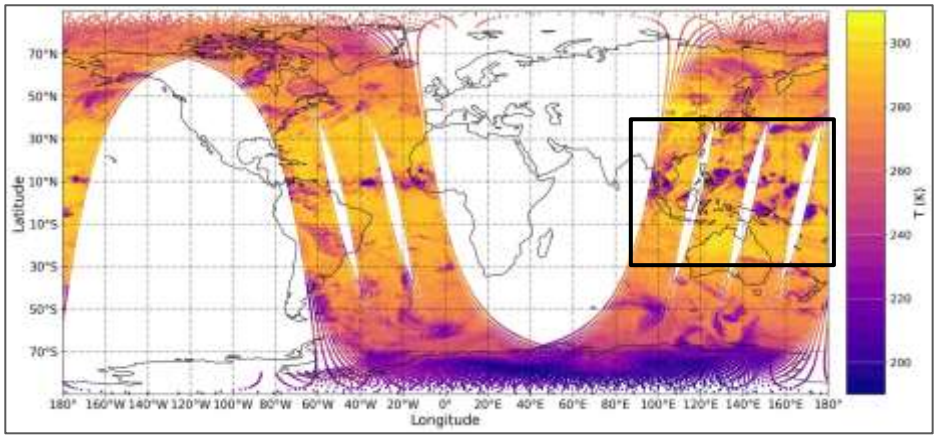
AHI 3 water vapor channel



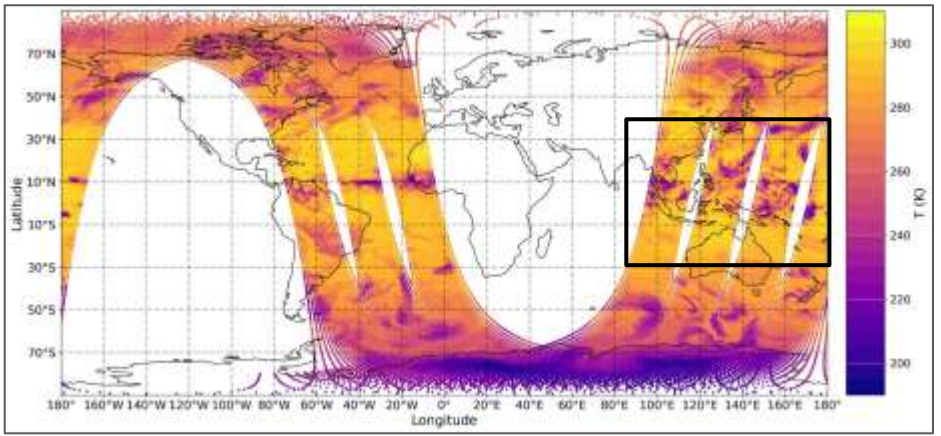
Okamoto et al., 2023

Annexe 2 : Observation and cloudy simulation

Observation *[channel1191]*



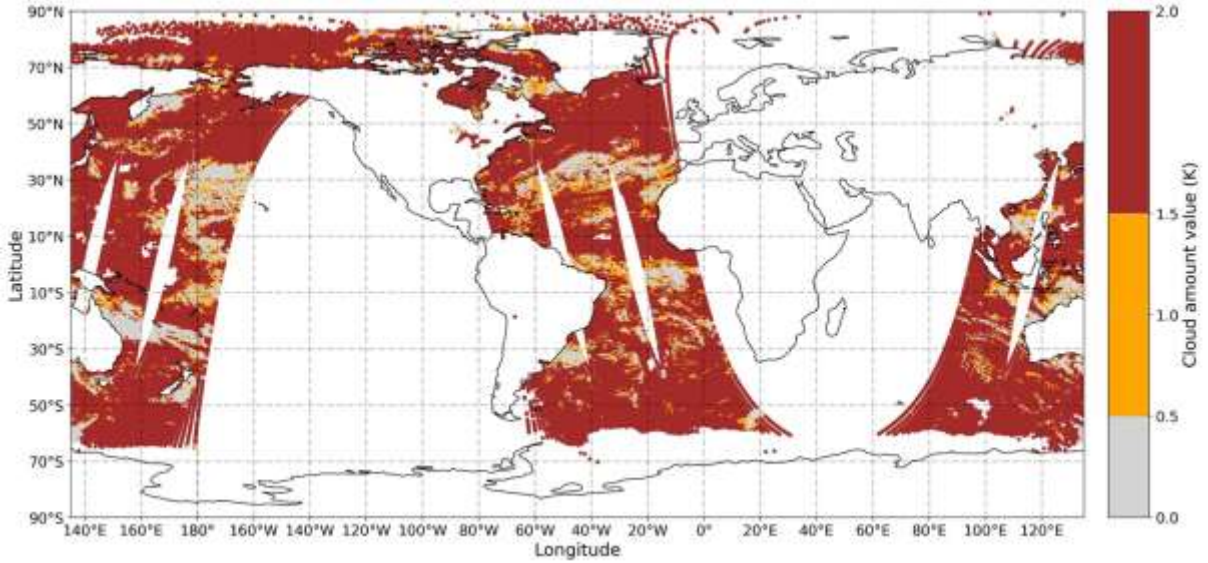
Cloudy simulation *[channel1191]*



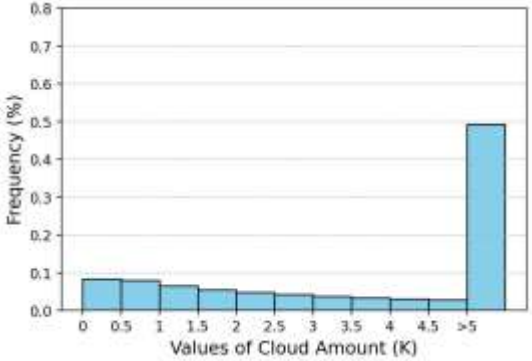
Annexe 3 : The Cloud Amount

$$C_A = \frac{|B_{cloud} - B_{clear}| + |OBS - B_{clear}|}{2}$$

Cloud Amount ***[channel1191]***

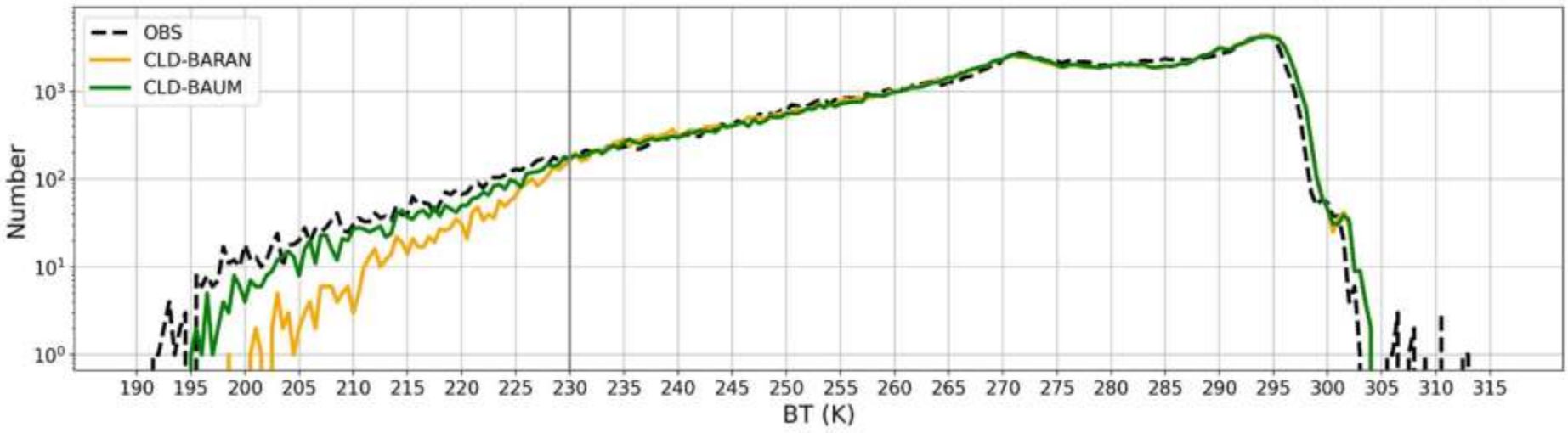


Cloud Amount ***[channel1191]***



→ Calculating the radiative influence of clouds in observation and model space.

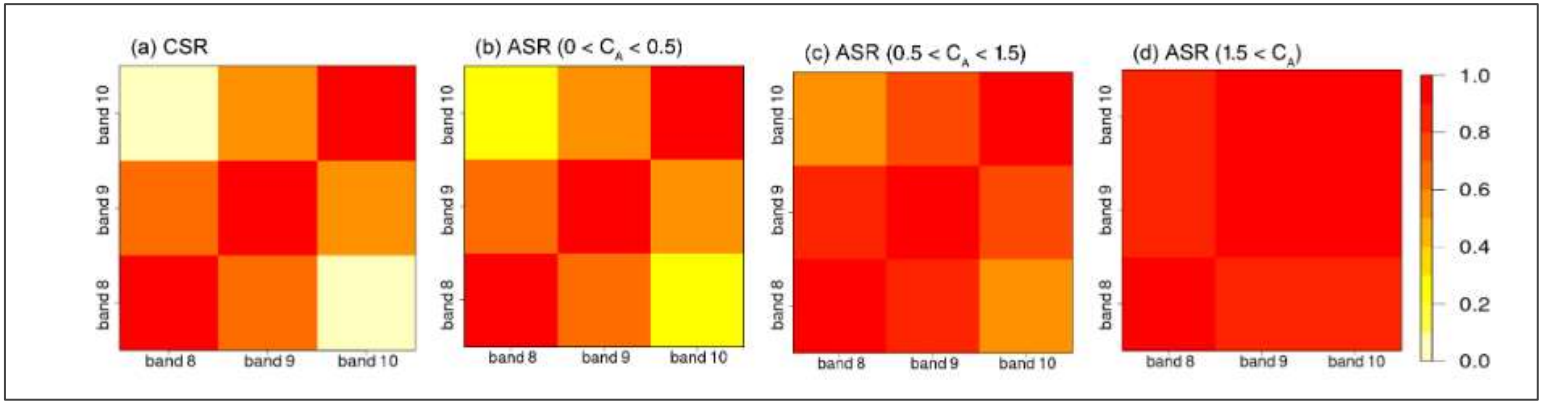
Annexe 4 : Configuration for the cloudy simulation



Same signal between Baran and Baum parameterization.

Annexe 5 : Error correlation model Okamoto et al., 2023

$$C_A = \frac{|B_{cloud} - B_{clear}| + |OBS - B_{clear}|}{2}$$



Clear | little cloudy | Cloudy | Very cloudy

Annexe 6 : Values of observation error in OPER at Météo-France

Channel	Observation error in clear sky
1191	0.8
2889	2
2958	2.5
2993	2.5
3002	2.5
3049	2.5
3105	2.5
3110	2

Annexe 7 : Effect of QC on observations

Innovation 4R	**Condition d'évaluation de la simulation nuageuse.**		**1 QC (OBS>230K).**	
Channel	Mean	Std	Mean	Std
2889	-0.55	6.35	-0.16	5.40
3105	-0.29	3.95	-0.01	3.14

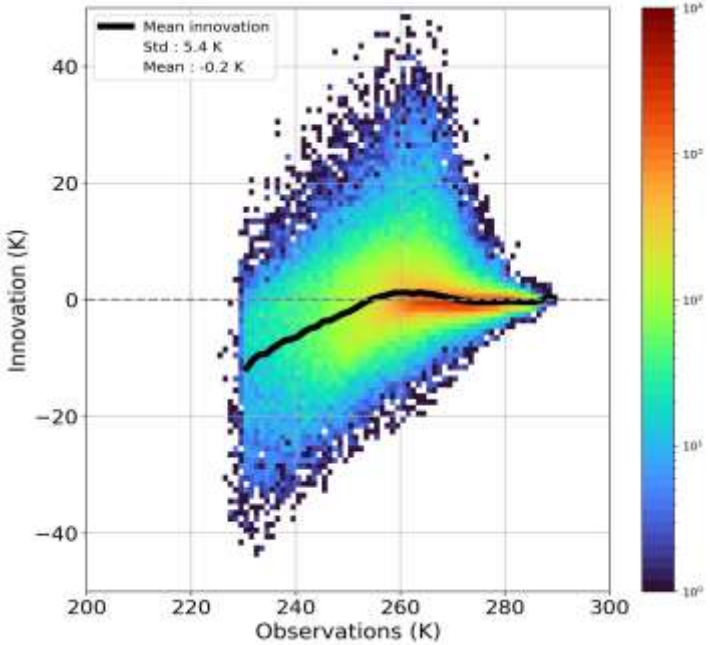
MEAN and STD  **with the QC.**

Annexe 7b : Effect of QC on observations

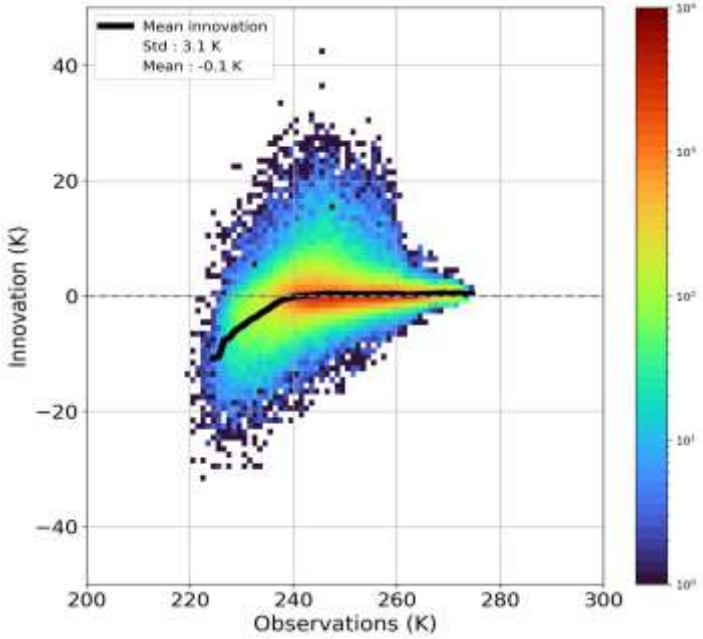
Innovation - 4R	**Cloud simulation evaluation condition.**			**1 QC (OBS>230K).** *(obs<230 ~~ 1364 points)*		
Channel	Mean	Std	% obs	Mean	Std	% obs
1191	-1.10	10.30	62.8 %	-0.62	9.40	61.1 %
2889	-0.55	6.35	52229	-0.16	5.40	50865
2958	-0.10	6.13	“	0.29	5.18	“
2993	-0.19	4.74	“	0.14	3.85	“
3002	-0.43	3.20	“	-0.20	2.52	“
3049	0.16	5.48	“	0.53	4.53	“
3105	-0.29	3.95	“	-0.01	3.14	“
3110	-0.08	4.49	“	0.23	3.62	“

Annexe : Other diagnostics

Channel 2889 [684 hPa]



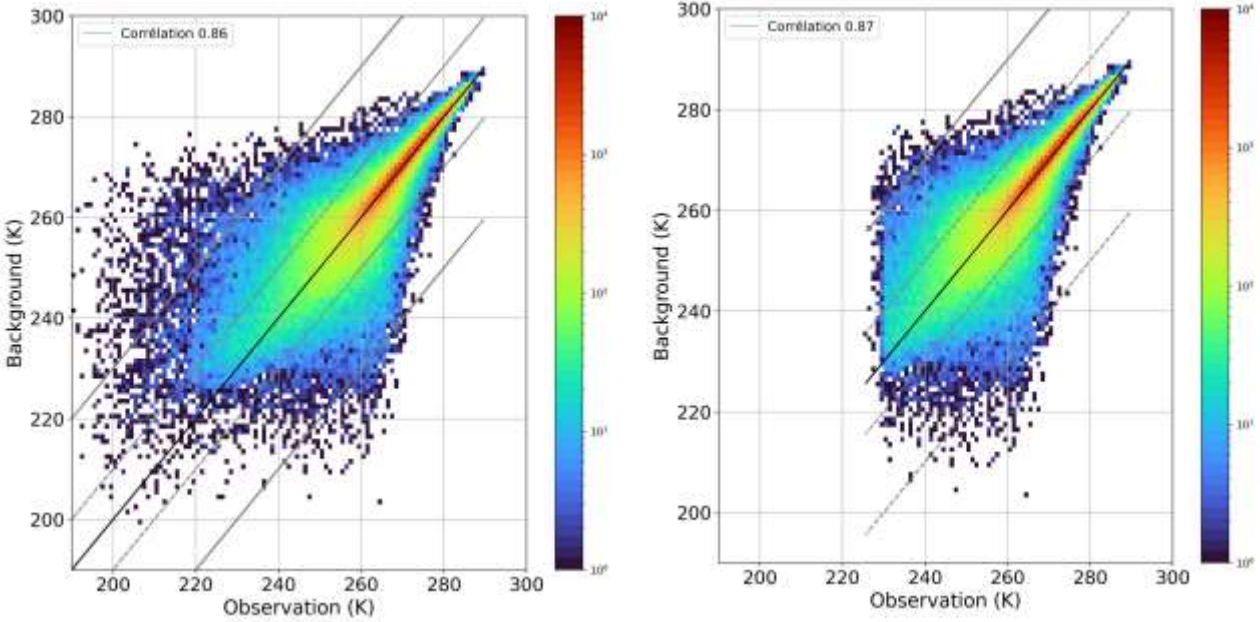
Channel 3105 [468 hPa]



After applying QC, the innovation average is close to zero, a good point for moving towards data assimilation.

Diagnosis based on observation

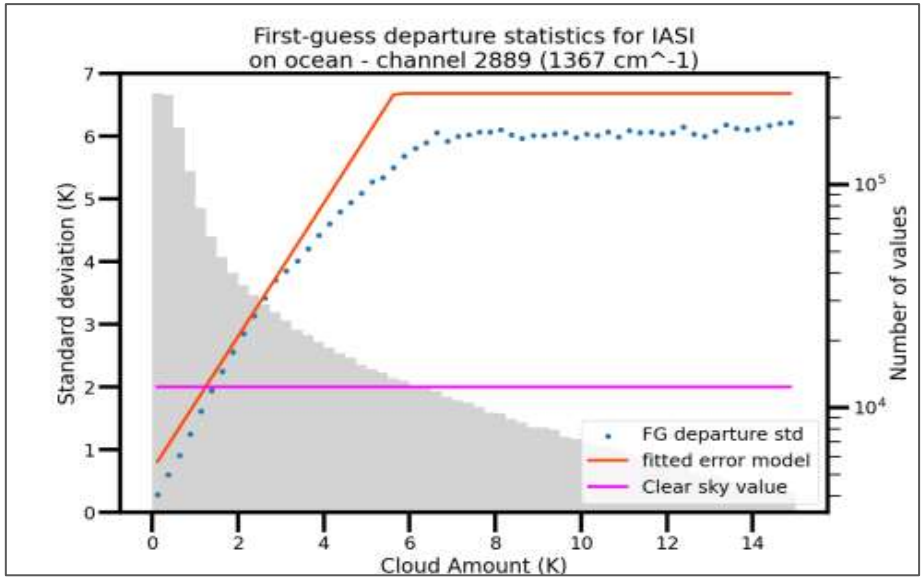
Channel 2889
[684 hPa]



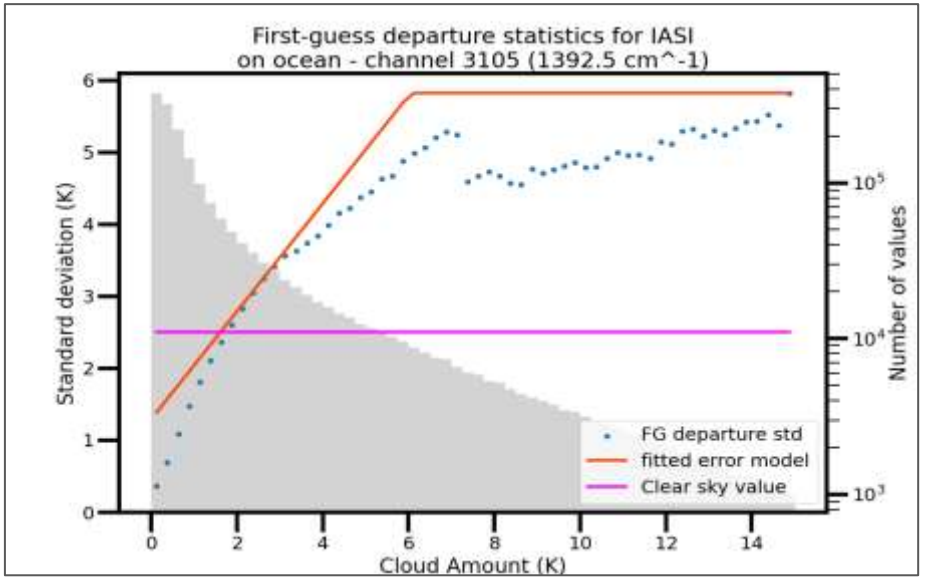
Applying QC reduces point dispersion and slightly increases correlation.

Variance error model

Channel 2889 (684 hPa)



Channel 3105 (468 hPa)



The error model of channel 2889 goes higher than channel 3105 because it is sensitive to more clouds.