CAMAERA

ASSIMILATION OF IASI RADIANCES TO IMPROVE THE REPRESENTATION OF DUST IN THE ARPEGE-COMPO GLOBAL MODEL

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CONTEXT OF THE STUDY

- **Dust aerosols in global Compo models**

  → A large effort is made to improve dust representation and dust forecasts, to be used for public health (WMO SDS WAS) and civil aviation for instance. Recent work in CAMS has revisited the dust representation (cf. Sam's presentation at CAMS GA 2025). And dust source inversion in CAMAERA!

- **Why is it important to accurately represent dust in NWP models?**

→ Aerosols, including desert dust, can have a significant impact on NWP models. Currently, these aerosols are not taken into account in the **ARPEGE/IFS** global model, which can have a non-realistic representation of radiation (**ecRAD**), cloud cover forecasts, and surface temperature forecasts.

→ Representing the dust particles interactively in the model would improve the radiation representation and forecasts.

- **What is currently being assimilated in global Compo models?**

→ IFS-compo assimilates total AOD (L2 and without speciation) into its operational model, just like the global MOCAGE model and other global models --> information on aerosol type is required.

→ Initial tests on the assimilation of AOD dust at 10 µm into IFS-compo from IASI (cf. Melanie Ades' seminar in April)

MOTIVATIONS FOR THIS STUDY

- **Two models, one shared code base**

→ IFS and ARPEGE share the same code base, particularly in the assimilation module.

→ ARPEGE uses a stretched grid with a resolution of 5 km over France and 24 km at the antipodes, and 105 vertical levels.

→ IFS uses a octahedral reduced Gaussian grid with a resolution of 9 km and 137 vertical levels.

→ In global NWP models such as IFS and ARPEGE, raw radiances (L1) are assimilated for temperature, humidity, and surface, particularly in the infrared.

→ This is why we are working on the assimilation of IASI radiance data for dust, in ARPEGE-Compo in order to ensure consistency with the assimilation used for NWP.

→ In CAMEO, this approach has already been used for visible data in IFS-Compo (D1.2 Report on operational AVRAS experiment, Samuel Quesada-Ruiz, Angela Benedetti, Cristina Lupu, Tobias Necker)

ARPEGE

IFS

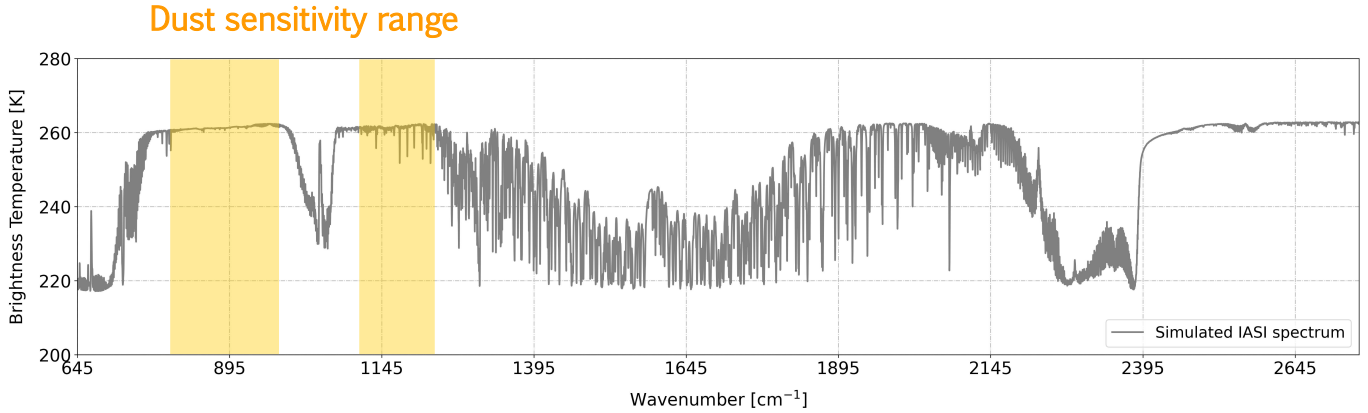
MOTIVATIONS FOR THIS STUDY

- **Current developments at Météo-France/CNRM**

→ As part of a project at Météo-France, a new library (**ACLIB**) enables the representation of aerosols and gases to be activated online in any model, including ARPEGE → **ARPEGE-Compo**

→ To improve the representation of these aerosols in ARPEGE-Compo, the **IASI** infrared sounder appears to be a good candidate, with its channels being highly sensitive to desert dust.

→ As part of his PhD thesis, Étienne Gruet is currently working to assimilate IASI and IASI-NG data into the MOCAGE global atmospheric composition model in order to improve the accuracy of dust forecasts.

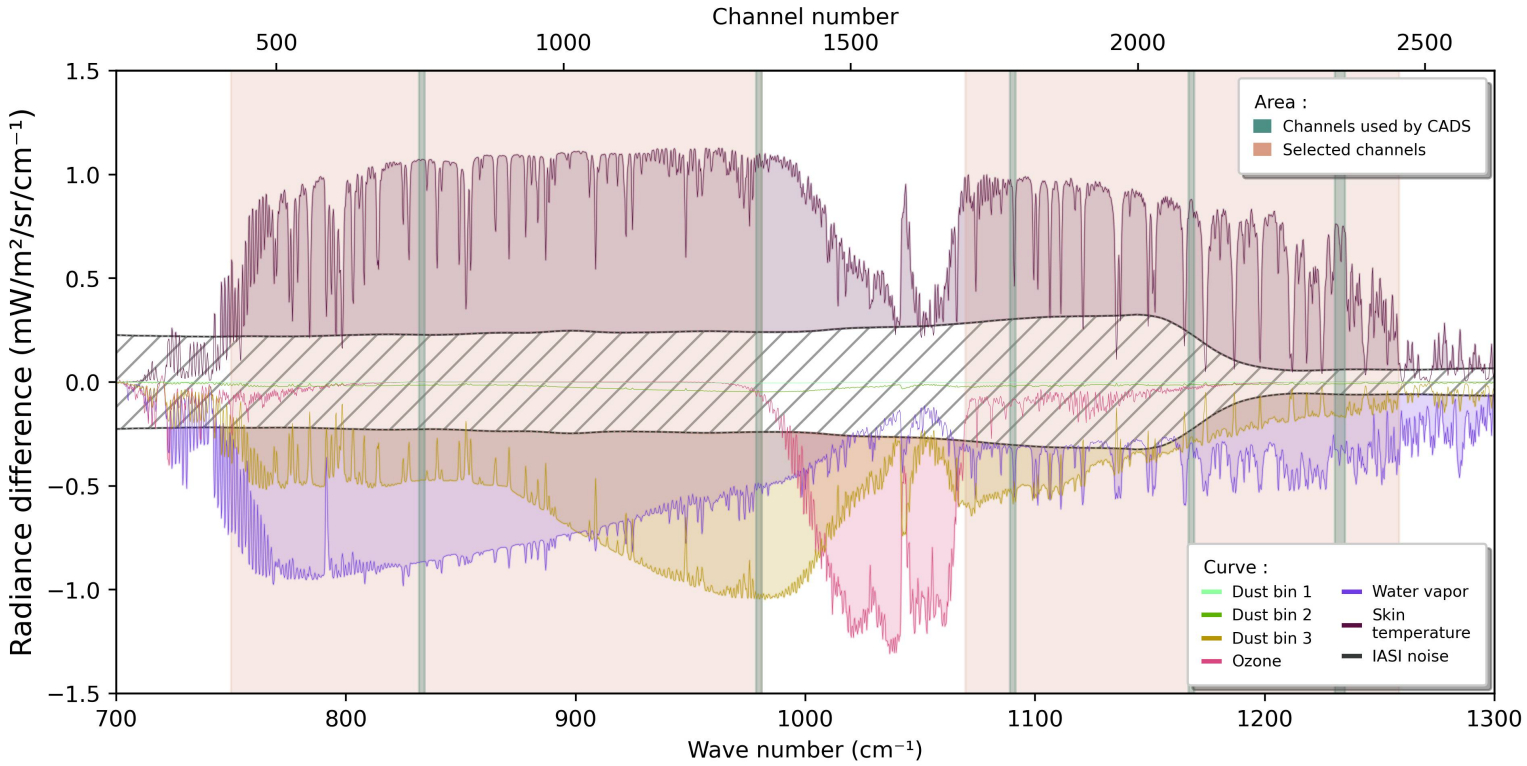


Typical IASI spectrum

MOTIVATIONS FOR THIS STUDY

- Sensitivity Analysis of IASI to Dust Particles (Étienne Gruet)

→ Statistics on the difference between IASI RTTOV simulations under clear and dusty sky conditions, based on 5,000 typical profiles from CAMS. The figure shows IASI's sensitivity to dust (bins 1, 2, and 3), temperature, water vapor, and ozone, taking instrumental noise into account.



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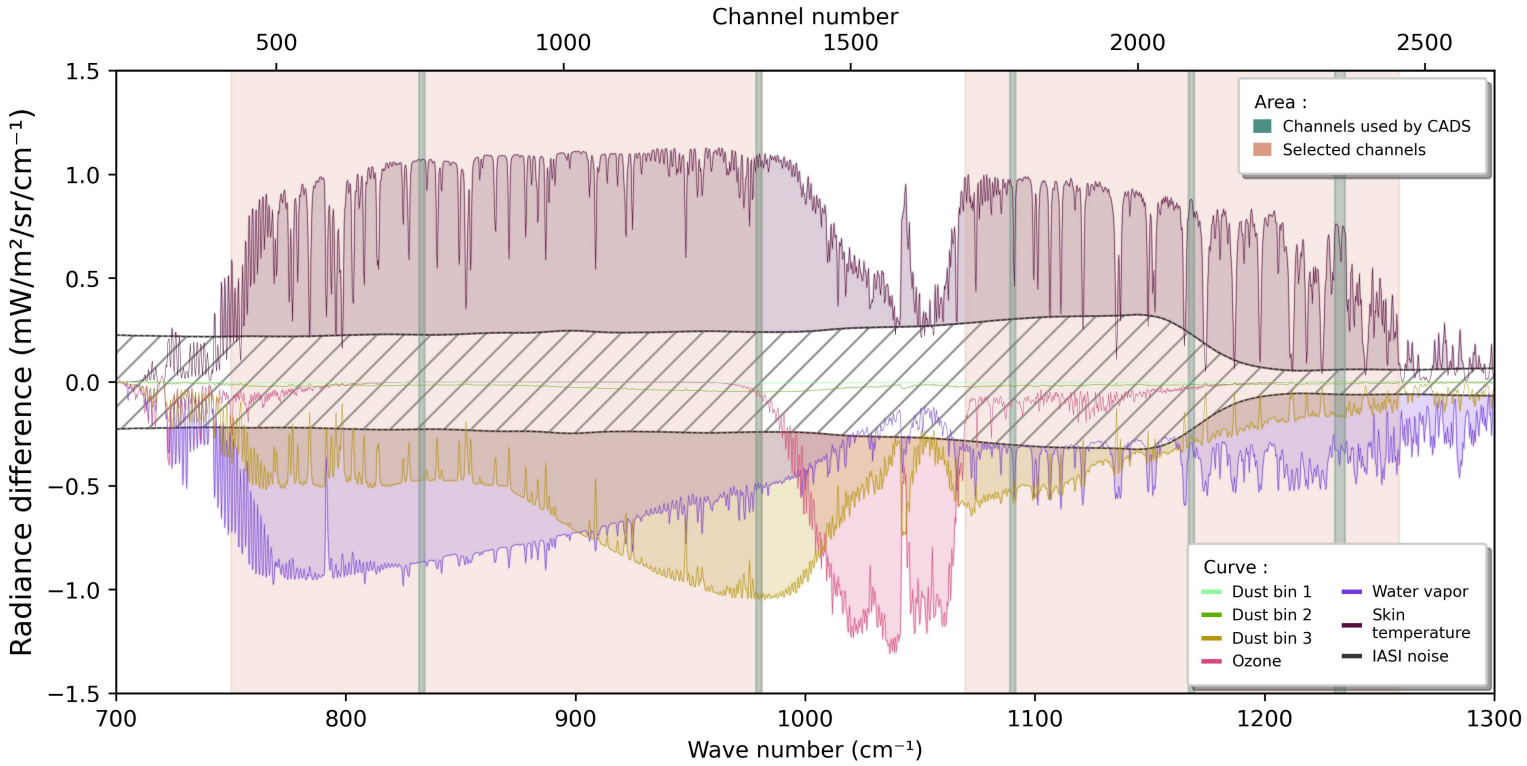


IASI is particularly sensitive to dust particles ranging in size from 0.9 to 20 µm (bin 3)

STUDY PLAN

- Objective: To prepare and evaluate the assimilation of IASI radiances to improve the representation of dust in the ARPEGE-Compo global model

→ Initial tests to identify dusty pixels

→ Setting up a configuration with interactive dust

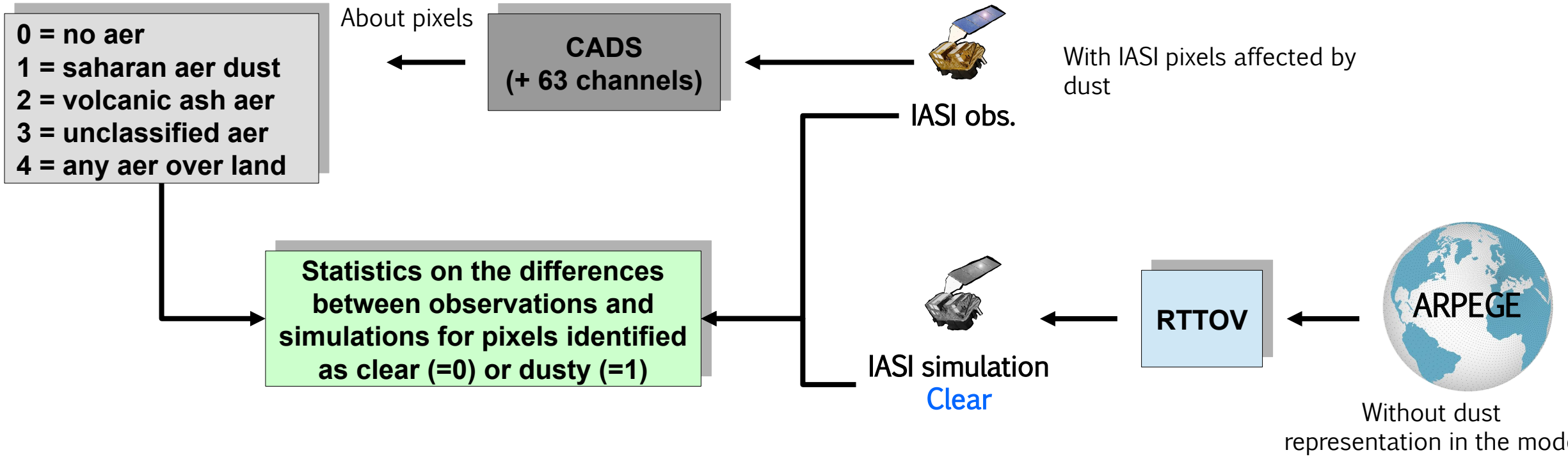
→ The next steps

INITIAL TESTS – IDENTIFY DUSTY PIXELS

- Construction of an experiment with activation of the CADS algorithm to identify IASI pixels affected by dust.

→ ARPEGE NWP experiment on a 49t1 operational configuration

→ Study period between December 18 and 29, 2024, with a strong dust episode coming from West Africa.



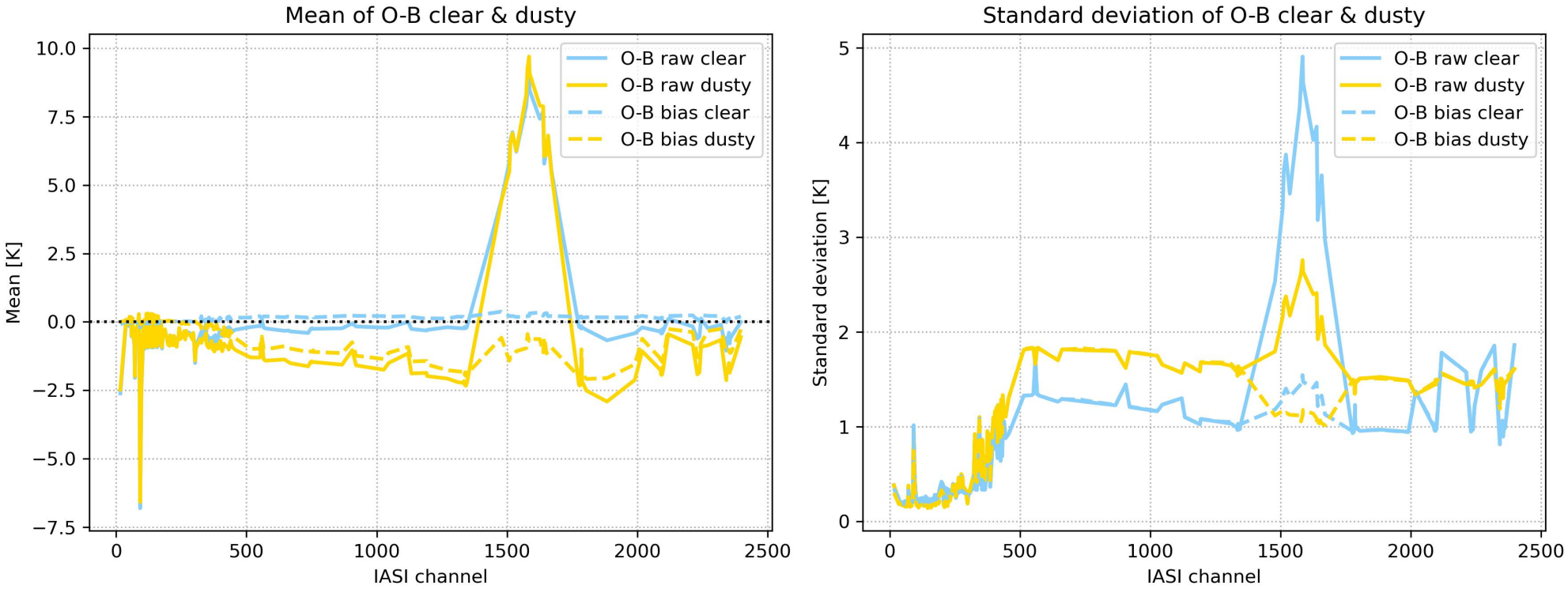
INITIAL TESTS – IDENTIFY DUSTY PIXELS

- Calculation of first guess departure statistics

→ Over the full period

→ Statistics for identified clear & dusty pixels over ocean, for obs minus guess, with and without bias-correction

Statistics from 20241218 to 20241229



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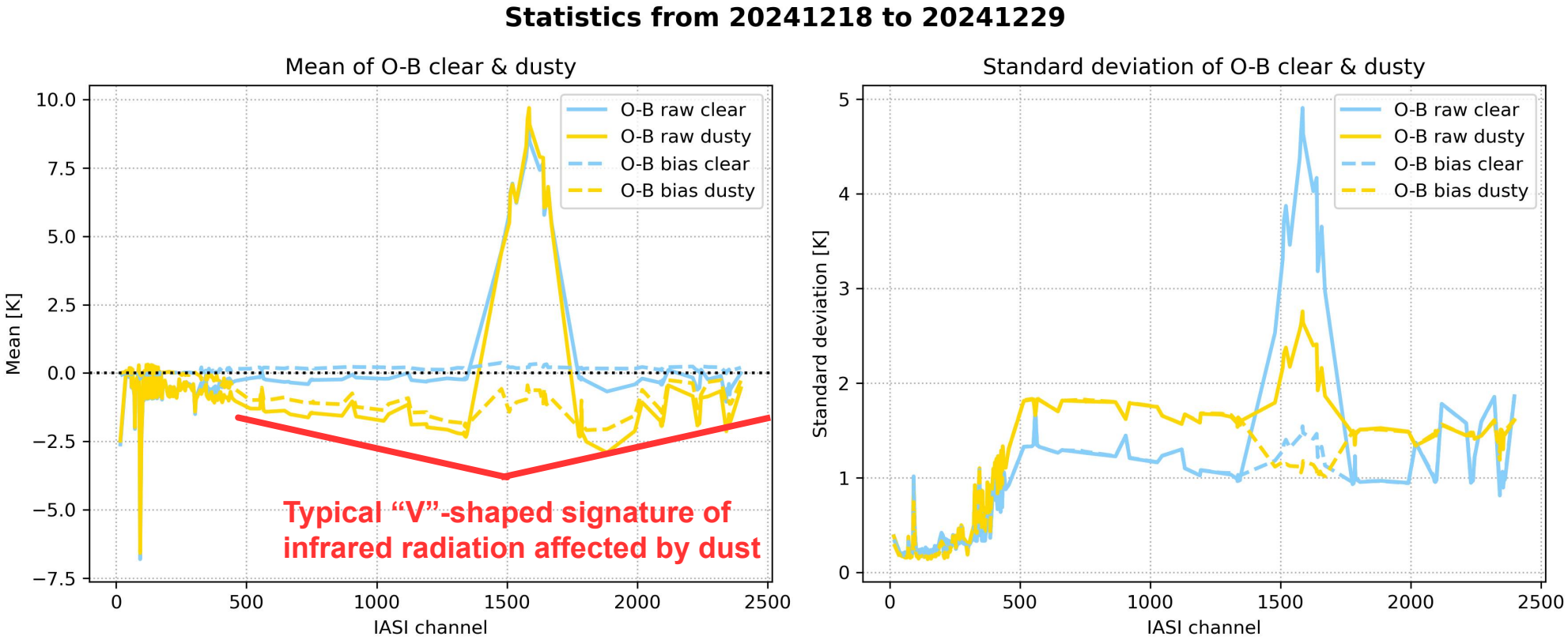
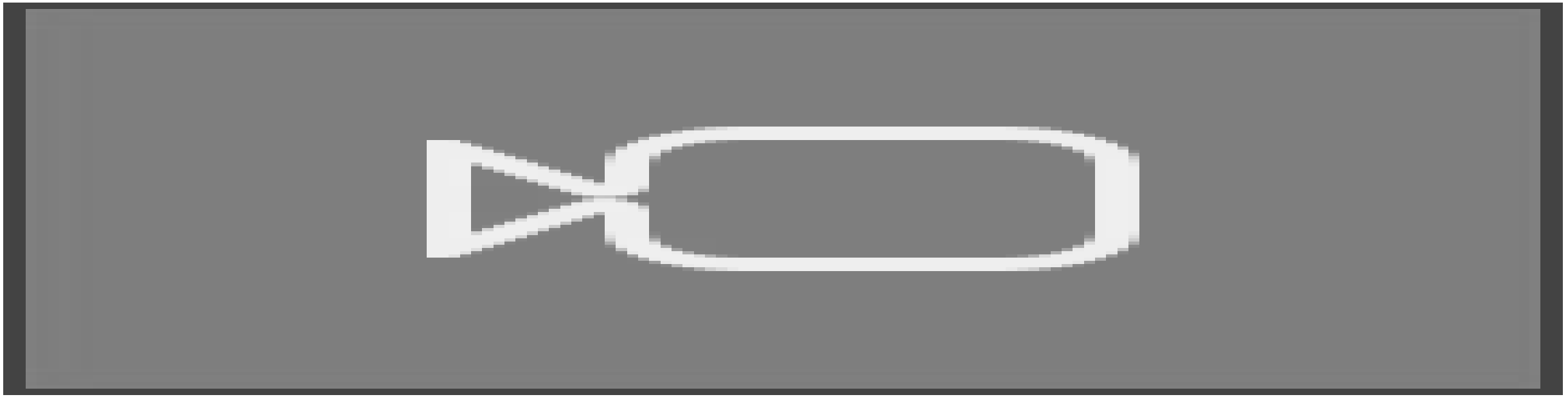


INITIAL TESTS – IDENTIFY DUSTY PIXELS

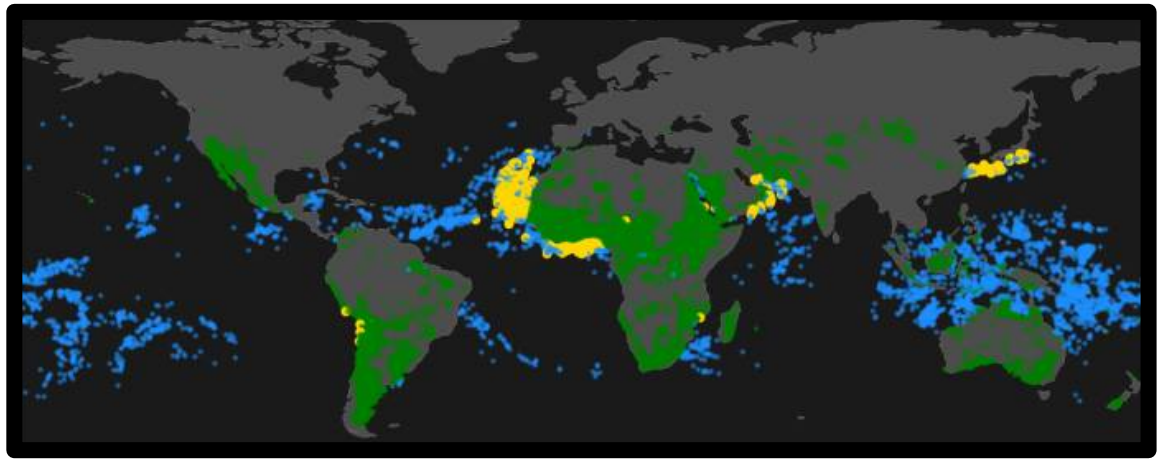
- Monitoring of IASI pixels identified as “dusty”

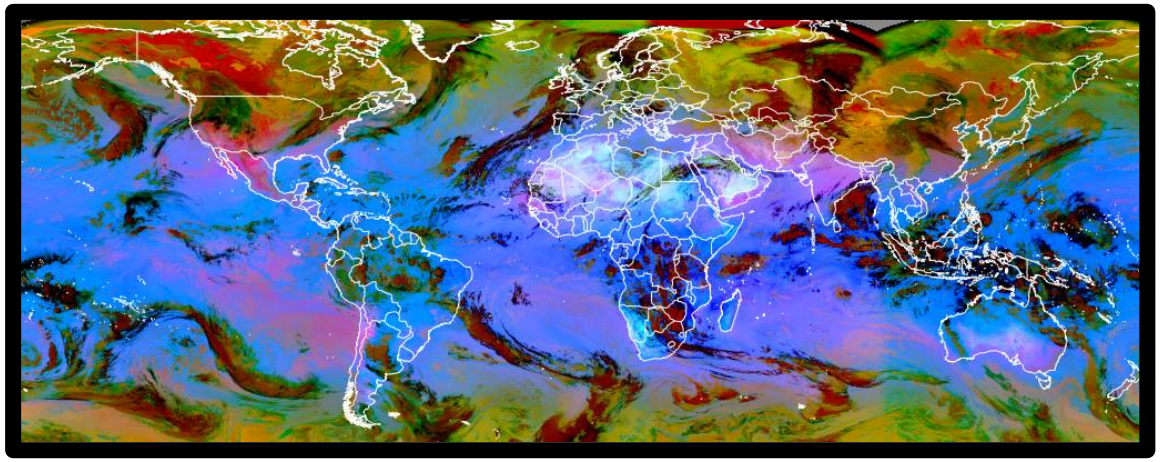


INITIAL TESTS – IDENTIFY DUSTY PIXELS

- Comparison with EUMETSAT products

→ The case from December 18 compared to the product: Geostationary Ring Dust RGB





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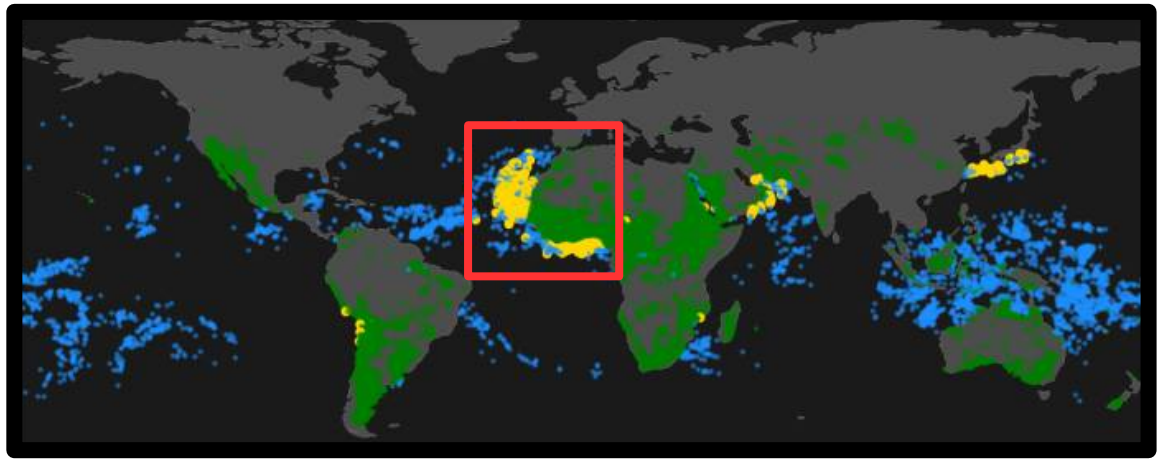

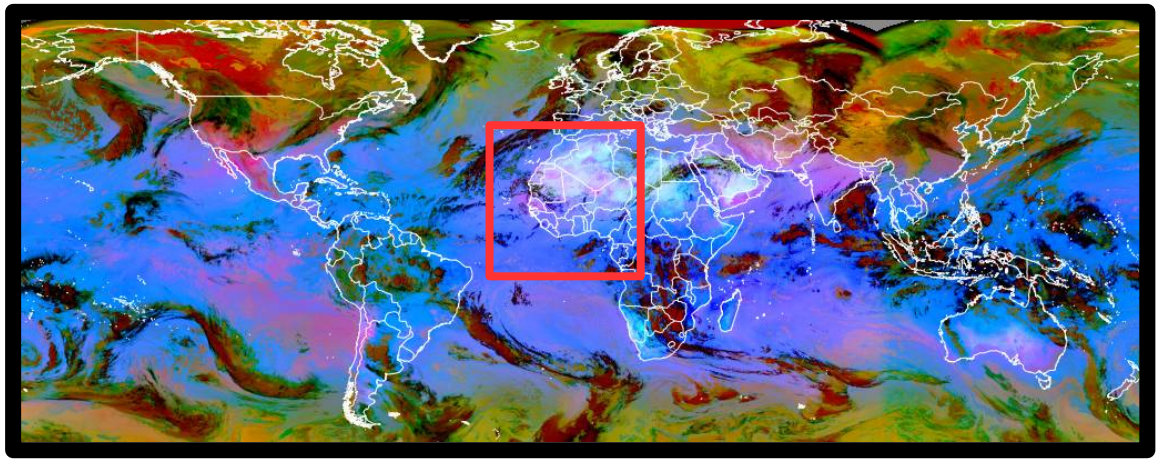

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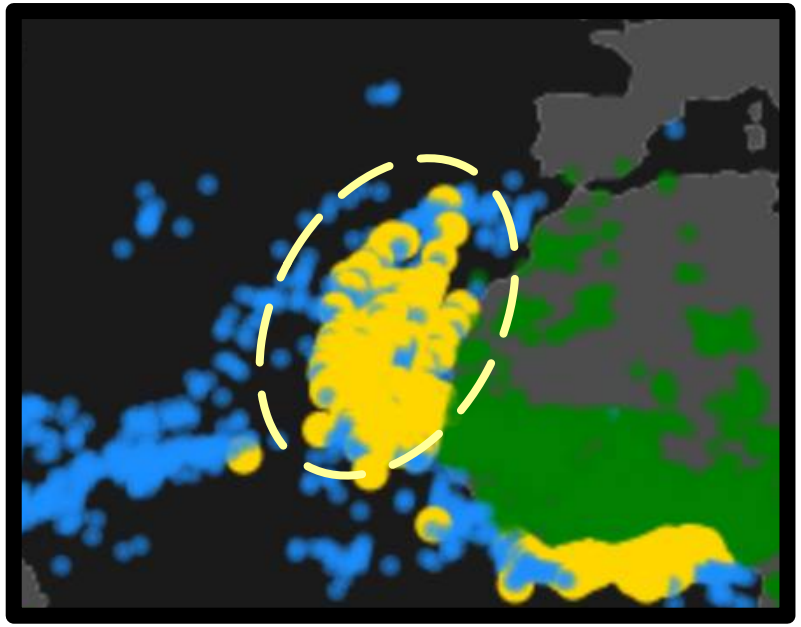
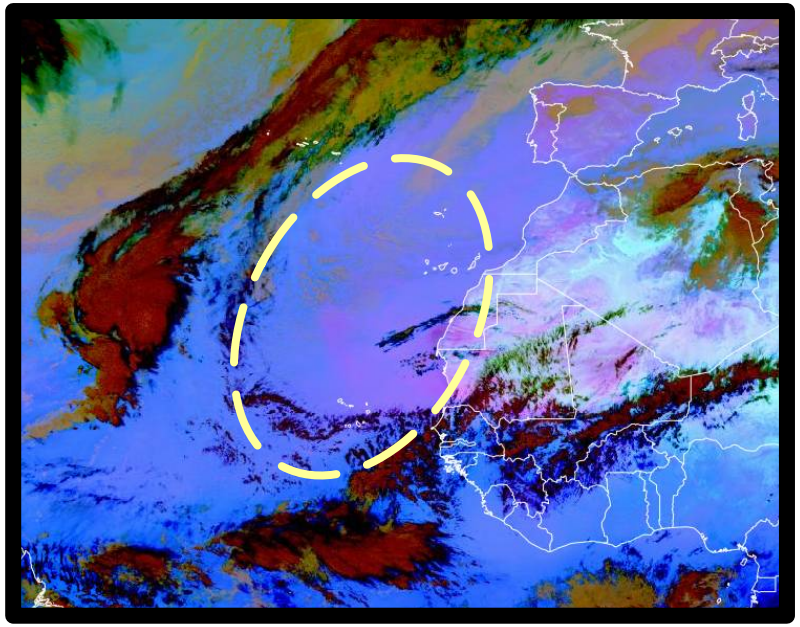
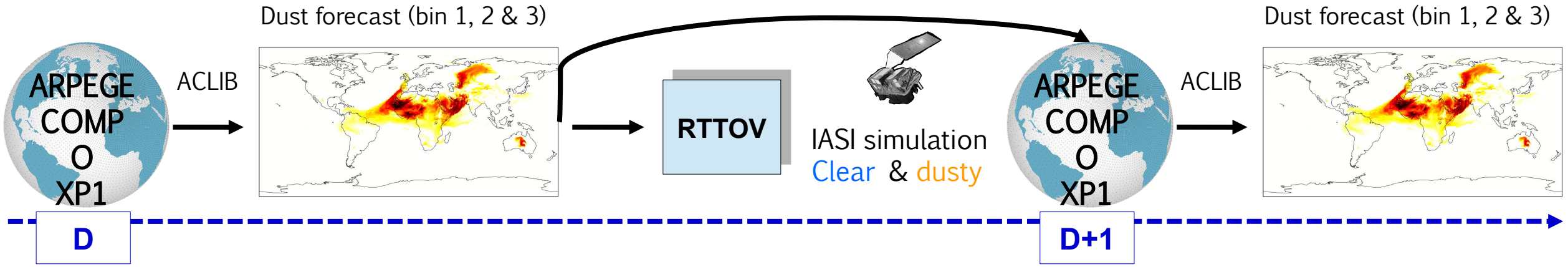




ARPEGE-COMPO WITH DUST

- **Setting up an ARPEGE-compo configuration with interactive dust**

→ Testing of two experiments with implementation of the ACLIB library for activation and forecast of dusts in ARPEGE-compo : **XP 1** : forecast cycle & **XP 2** : initialization using MOCAGE dust at the start of each forecast



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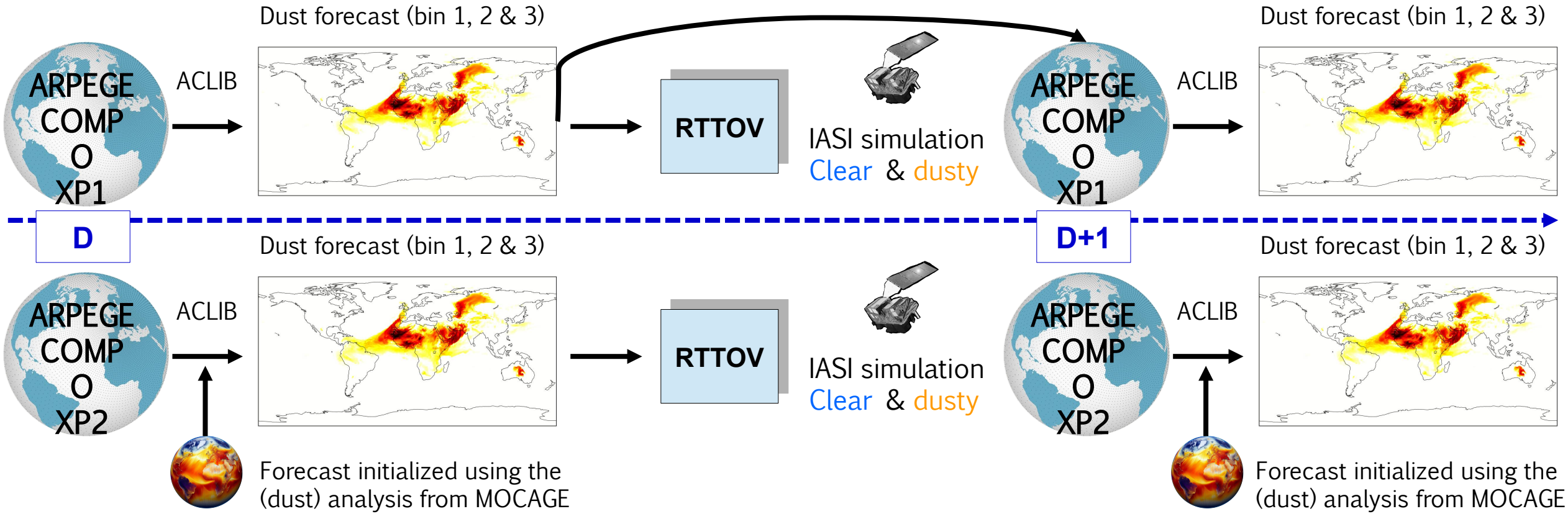
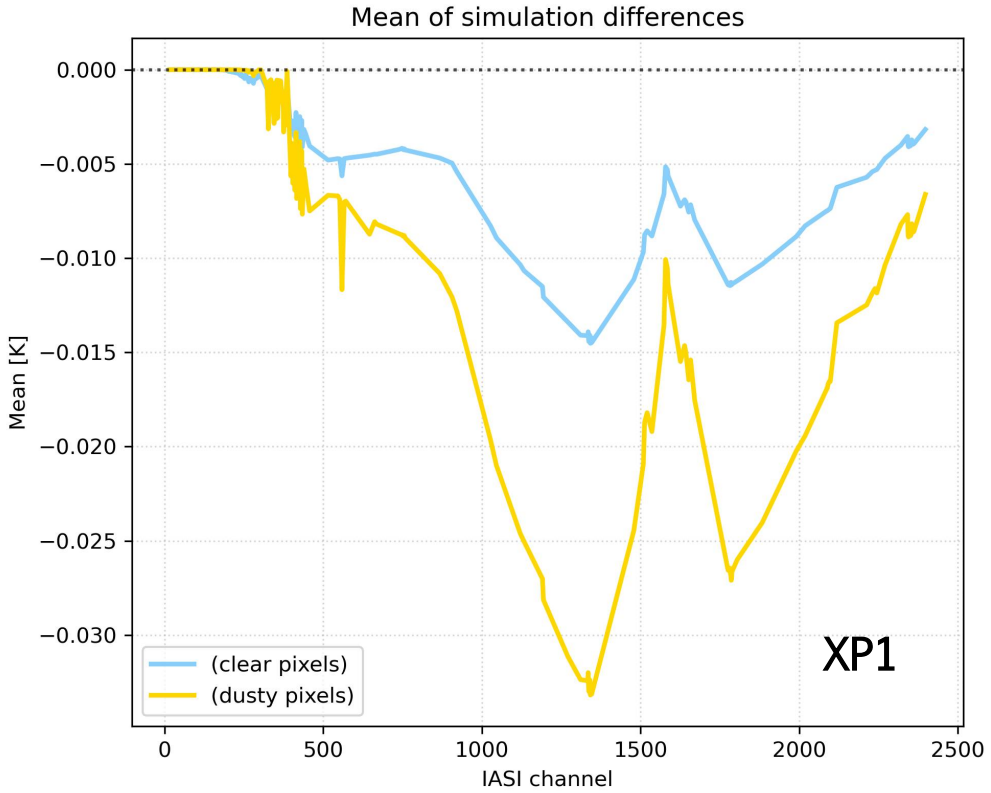
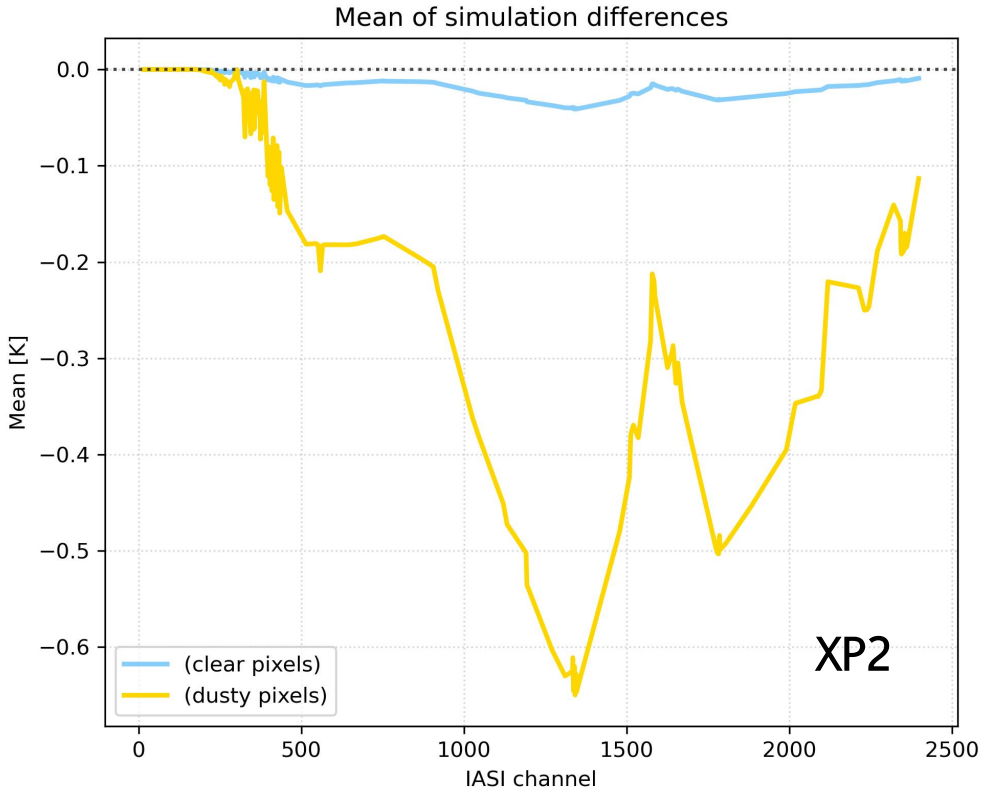


ARPEGE-COMPO WITH DUST

- Impact on simulations (clear and dusty)

→ Statistics on the differences between the clear and dusty simulations over the entire period for pixels identified as clear (blue) and dusty (orange) for **XP1** (left) and **XP2** (right)

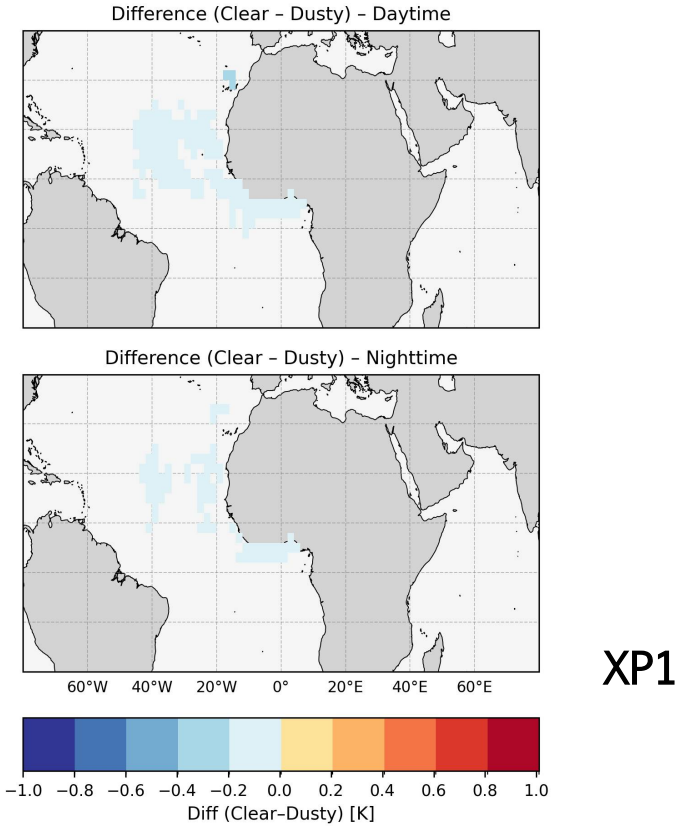




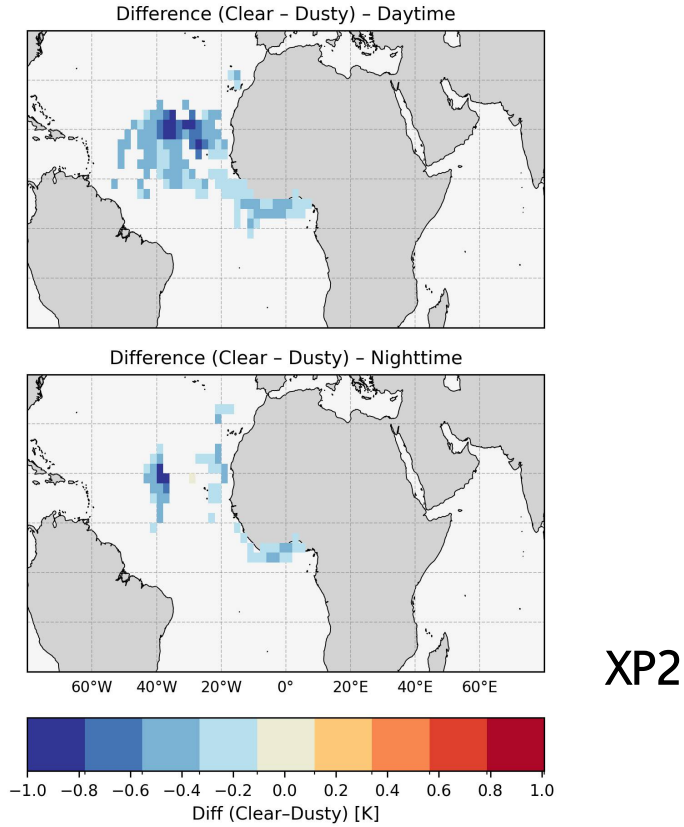
ARPEGE-COMPO WITH DUST

- Impact on simulations (clear and dusty)

→ Statistics on the differences between the clear and dusty simulations over the entire period for pixels identified as clear (blue) and dusty (orange) for XP1 (left) and XP2 (right) for channel 1027



XP1



XP2

ARPEGE-COMPO WITH DUST

- Conclusions

→ The aerosol detection algorithm works correctly in ARPEGE and allows for the identification of IASI pixels contaminated by dust.

→ Enabling aerosol scattering in RTTOV works and allows for the simulation of IASI observations while accounting for dust fields.

→ Initial experiments using an ARPEGE-compo configuration with ACLIB enabled for dust also work. Similar effects are observed in the IASI observation simulations (V-band signature), although there are significant differences in magnitude (more than a factor of 10) between XP1 and XP2.

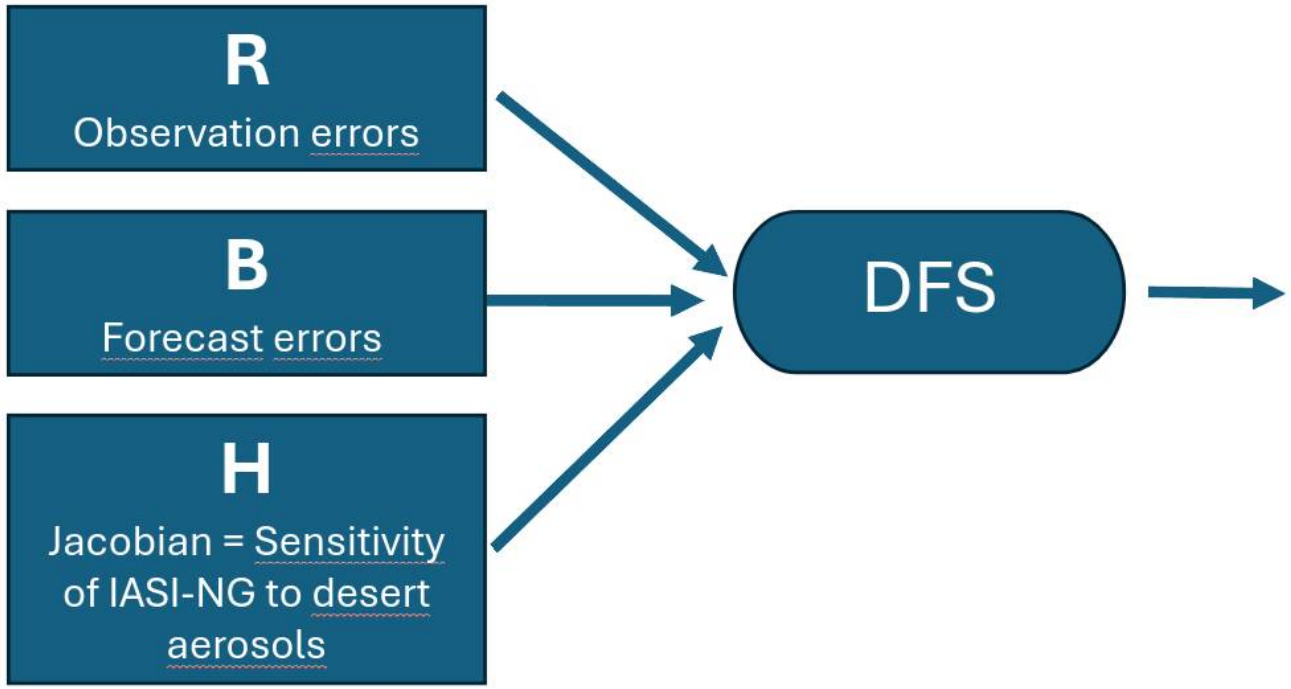
→ Additional adjustments to ACLIB are therefore needed to obtain a dust field equivalent to that which could be achieved in MOCAGE. This work is currently being investigated by our experts.

IASI CHANNEL SELECTION

Courtesy E. Gruet

DFS = Degree of Freedom for Signal = maximising information using the fewest possible channels

$$= \mathrm{Tr}(\mathbf{I} - (\mathbf{B}^{-1} + \mathbf{H}^{T}\,\mathbf{R}^{-1}\,\mathbf{H})^{-1}\,\mathbf{B}^{-1})$$



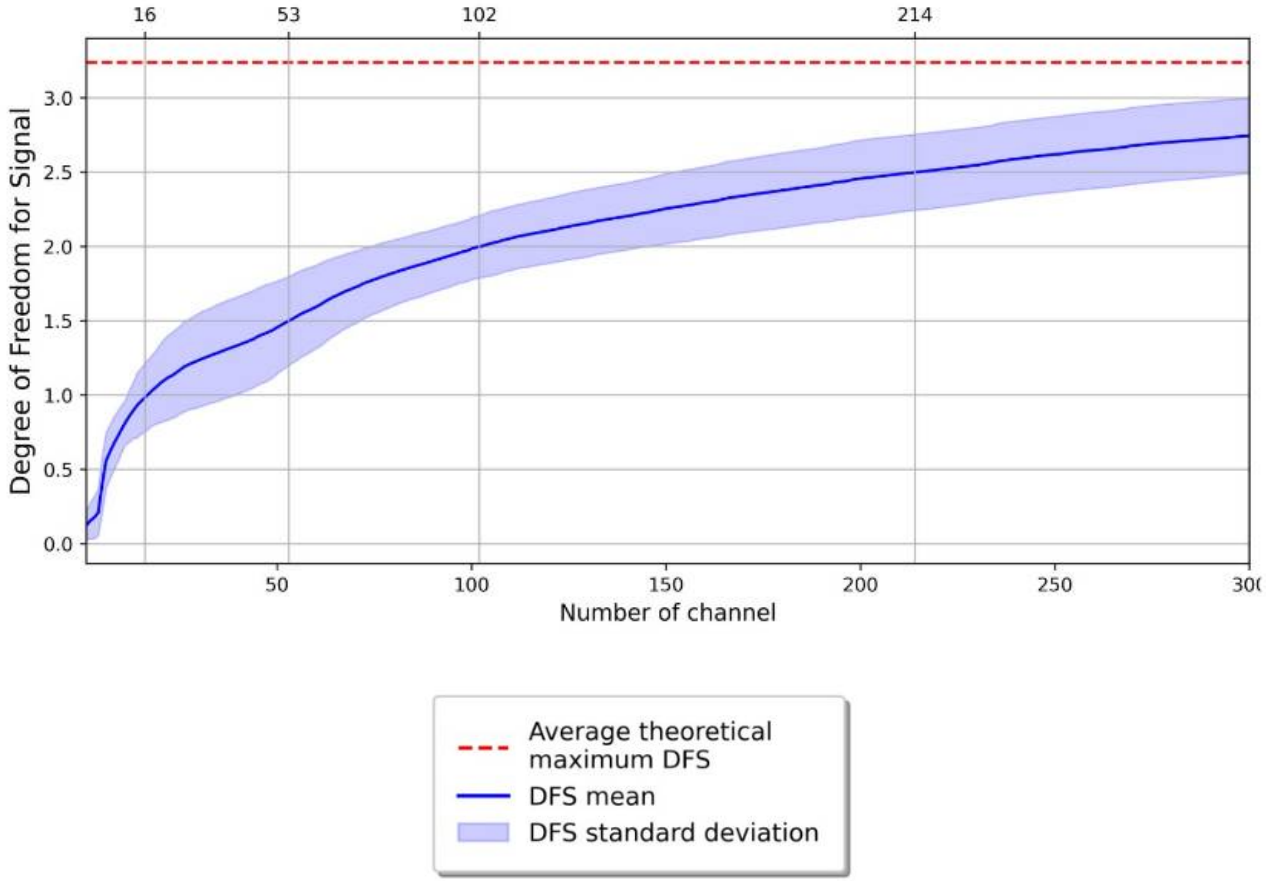
DFS result:

- If DFS = 1 → Concentration of the entire column (e.g. Total column or AOD)
- If DFS = 2 → Concentration on 2 distinct levels (e.g. two partial columns)
- If DFS = 60 → Concentration for each MOCAGE level

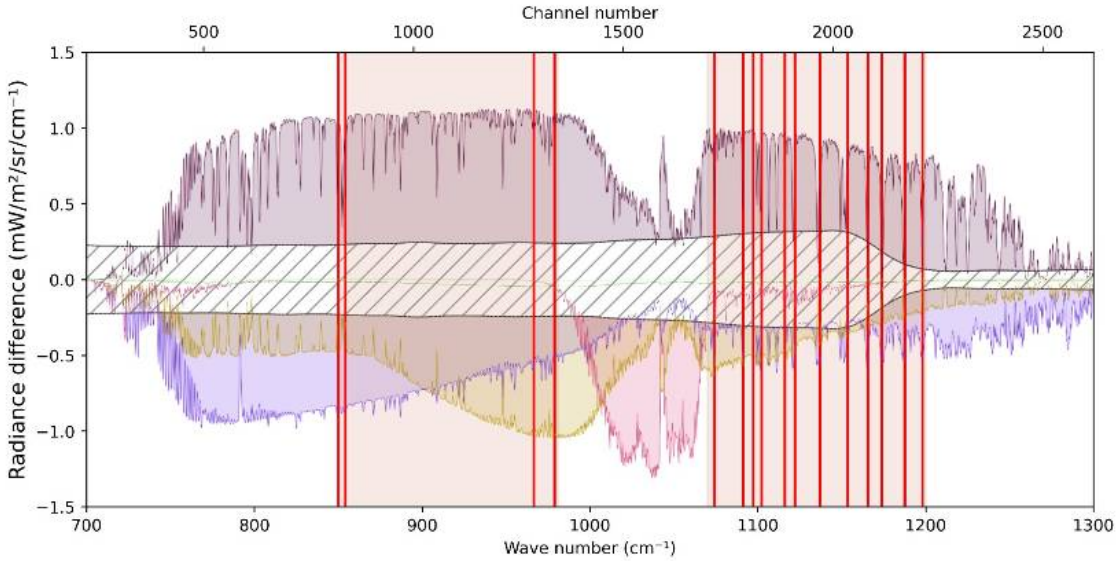
1

IASI CHANNEL SELECTION

Courtesy E. Gruet



(16 channels)



NEXT STEPS

- Accurate analysis of the impact of interactive dust on the simulation of IASI observations during periods of intense episodes
- Comparison of dust fields in ARPEGE-Compo with MOCAGE and IFS-COMPO
- Evaluate one or two channel selections of IASI channels sensitive to dust
- Implement the 4D-Var data assimilation system to assimilate IASI channels sensitive to dust :

→ Initial assimilation tests and diagnostics of observation errors

→ Addition of dust to the ARPEGE ensemble data assimilation for the calculation of background errors

→ Addition of dust to ARPEGE control variables

→ Initial assimilation tests and impact on NWP forecasts