Establishing essential climate variable data records from 3 successive Metop/IASI

Cyril Crevoisier, Raymond Armante, Victor Bon, Virginie Capelle, Thibault Delahaye, Axel Guedj, Jean-Michel Hartmann, Elsa Jacquette, Nicolas Meilhac, Rémy Orset, Jérôme Pernin, Thomas Ponthieu, Claudia Stubenrauch

Essential Climate Variables from IASI

Two main objectives:

- Understanding **processes** that drive climate evolution and climate change.
- Monitoring **over the long term** and homogeneously the climate system: trends, seasonal, annual and interannual variation.

GCOS (Global Climate Observing System) international program :

Definition of 54 Essential Climate Variables (ECVs)

→ ECV = physical, chemical or biological variables that critically contributes to the characterization of Earth's climate.

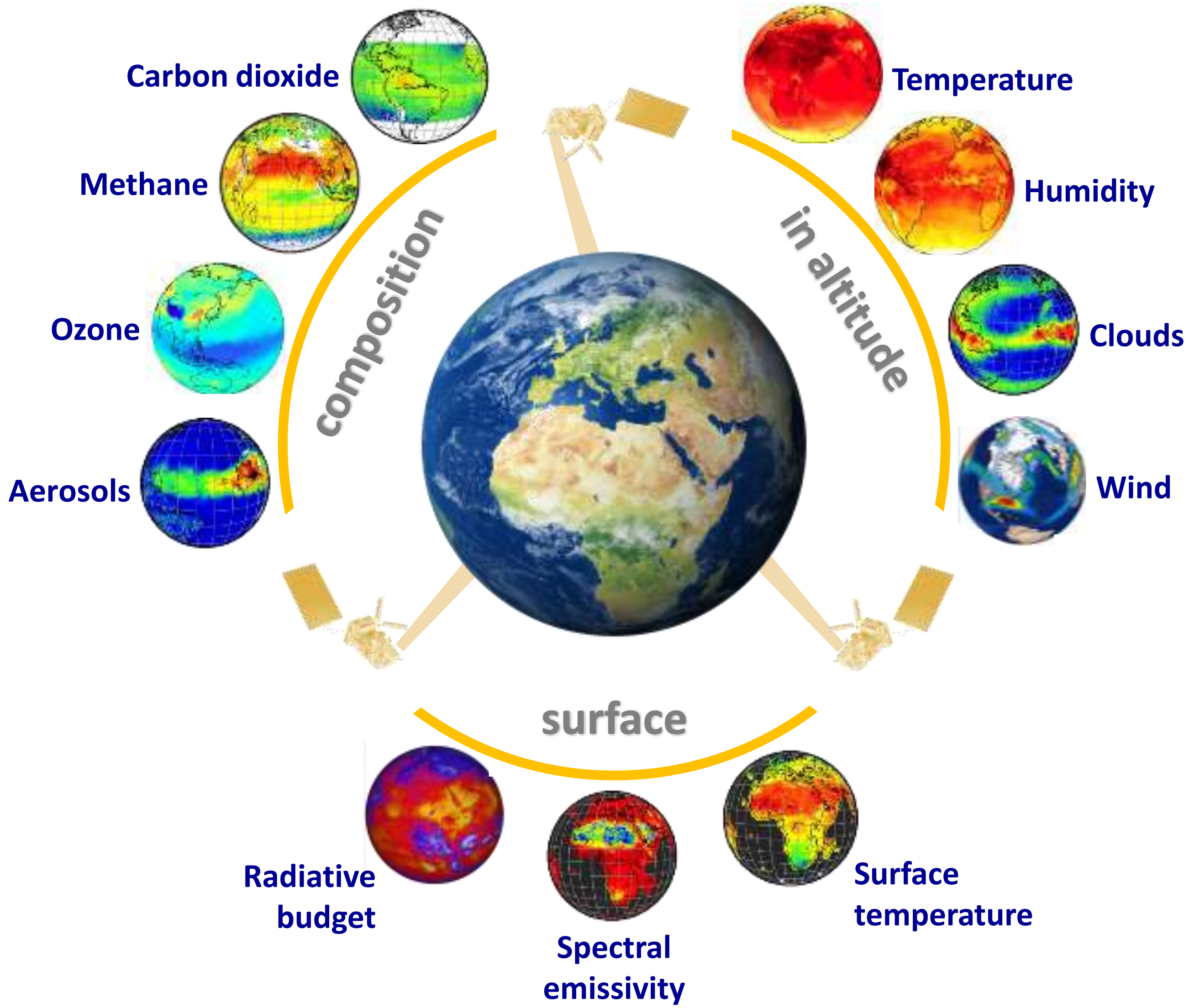
→ 16 ECVs for the **atmosphere**

The Essential Climate Variables

Domain		Essential Climate Variables
Atmospheric (over land, sea and ice)	Surface:	Air temperature, **precipitation**, air pressure, surface radiation budget, wind speed and direction, water vapour.
	Upper air:	**Earth radiation budget (including solar irradiance), upper air temperature (including MSU radiances), wind speed and direction, water vapour, cloud properties.**
	Composition:	**Carbon dioxide**, methane, **ozone**, other long-lived greenhouse gases, **aerosol properties.**

IASI contributes to the monitoring of all of them!

Essential Climate Variables for the atmosphere seen by IASI



<u>Focus of this presentation</u>

Why can we consider IASI as a real 'Climate mission'…

… what can we do with it in terms of trend detection?

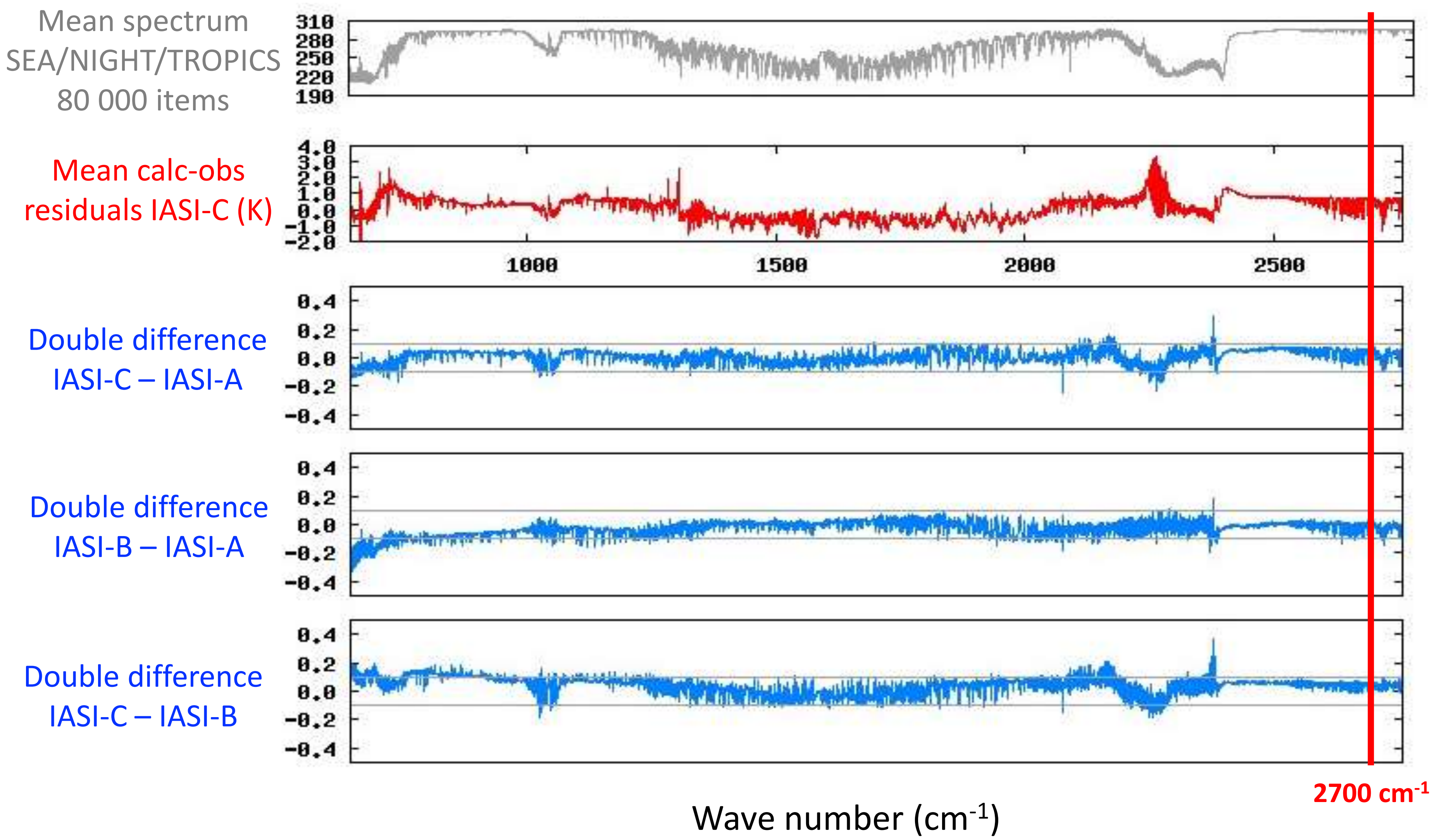
… and what are the implications in terms of instrument monitoring and creation of Climate Dara Records?

→ Study of Level1 and Level2 data

Monitoring of IASI L1 with a stand-alone approach

Comparison of BT 'calc-obs' residuals for IASI/Metop-A, B and C

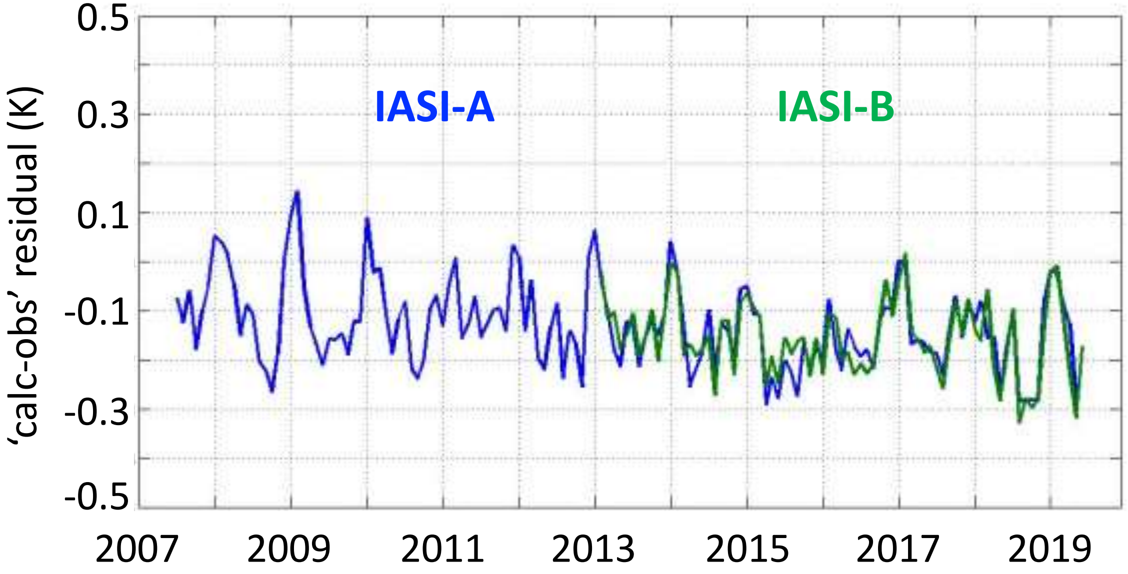
calc = 4A/OP with ECMWF analyses as inputs
obs = IASI-A/B/C



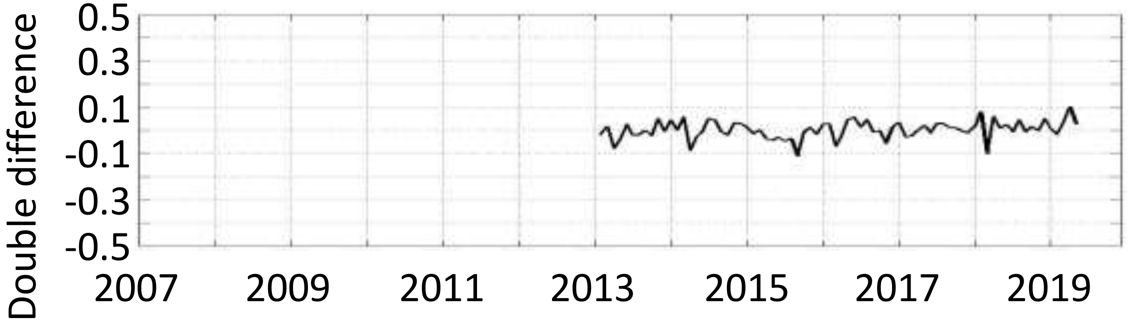
- **Objectives:**
  - identify which instrument might deviate from the other(s).
  - compare wide ranges of BT.
  - study each channel of each instrument, independently.
- **Complements satellite inter-calibration approaches.**
- **Conclusion: each couple of IASI instruments lie within ±0.1K over most of the spectrum and this bias is extremely stable.**

Monitoring of IASI: directly from L1 and indirectly from L2

'calc- obs' residuals for IASI channel @2700.00 cm^{-1}

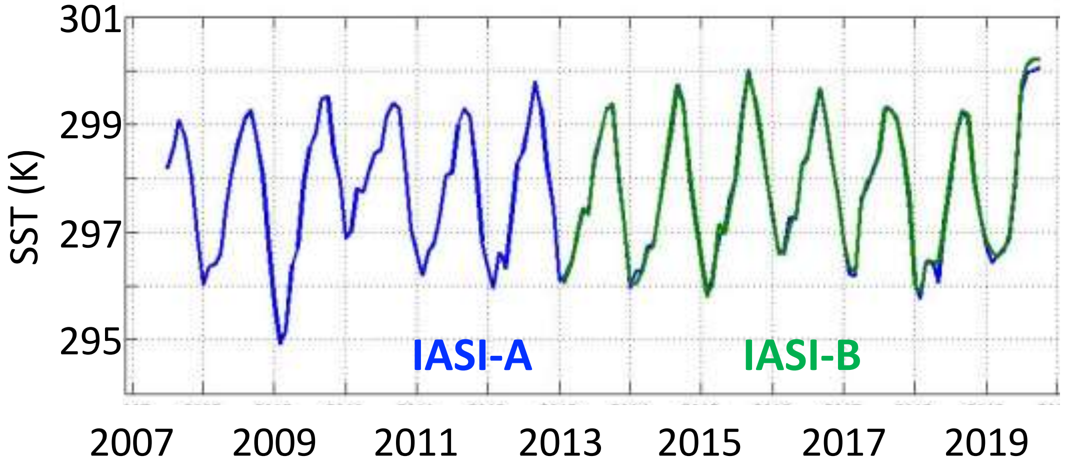


Double difference IASI-A – IASI-B



Sea surface temperature retrieved from 3.8 µm channels

Average over the tropics for nighttime observations



Methodology: Full-physics retrieval

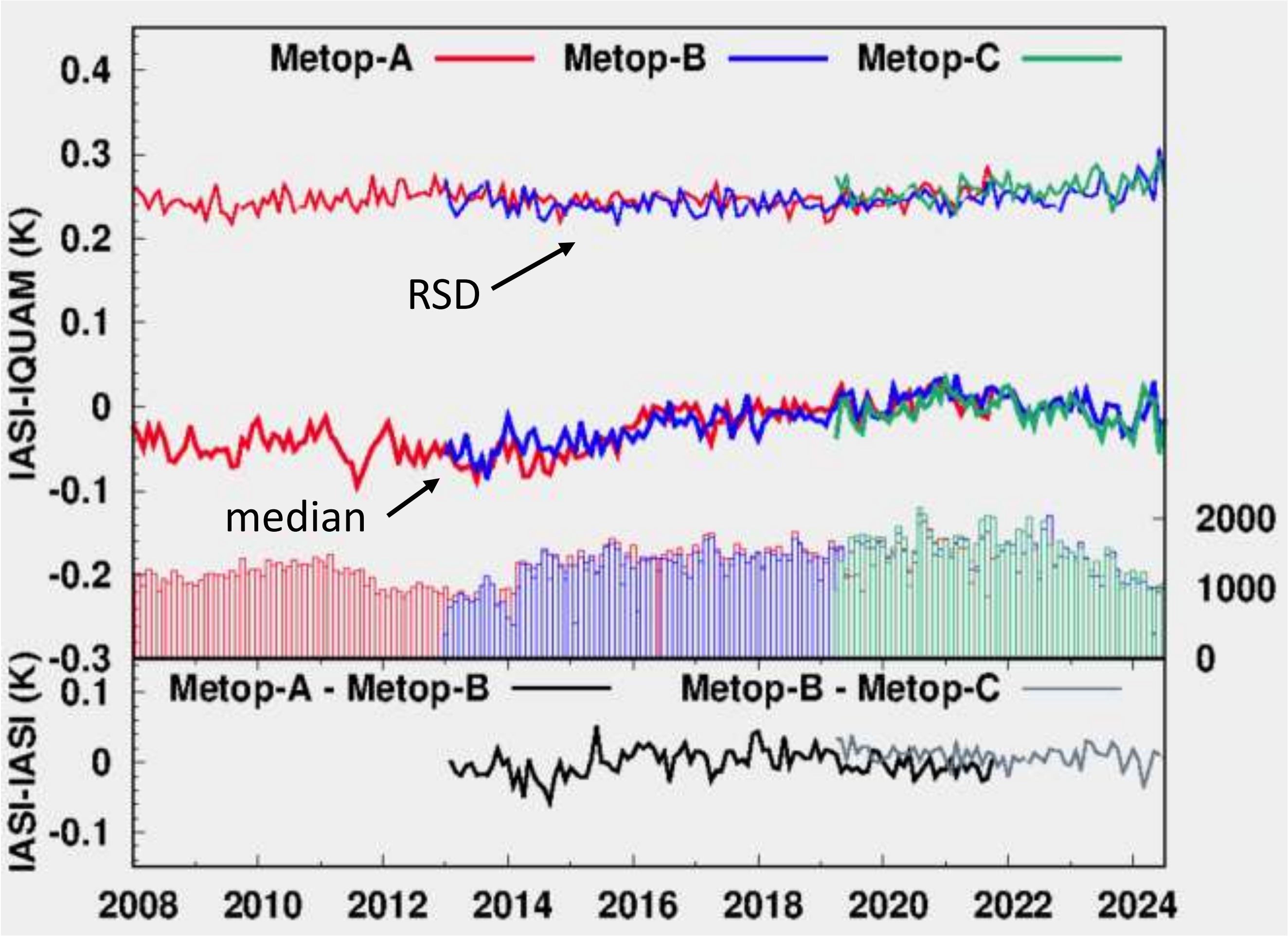
$$T_s = B^{-1}\left(\frac{I_{sat}(\lambda_0,\theta) - \int_{\tau_s(\lambda_0,\theta)}^{1} B[\lambda_0, T(\tau(\lambda_0,\theta))]\,d\tau - (1-\varepsilon_s(\lambda_0))\,\tau_s(\lambda_0,\theta) \int_{\tau_s(\lambda_0,\theta)}^{1} B[\lambda_0, T(\tau'(\lambda_0,\theta))]\,d\tau'}{\varepsilon_s(\lambda_0)\,\tau_s(\lambda_0,\theta)} \right)$$

Capelle et al. 2021

→ What about the long-term trend?

An amazing precision on SST

Comparison between IASI SST and in-situ SST (buoys)



Update from Capelle et al., 2021

- **A remarkably small and stable bias between each couple of IASI:** ~0.002K
- **Excellent statistics between IASI and buoys:**
  - ⇒ IASI-A (2008-2020): median=-0.03K; RSD=0.25K
  - ⇒ IASI-B (2013-2020): median= -0.02K; RSD=0.24K
  - ⇒ IASI-C (2018-2020): median= 0.01K; RSD=0.25K
- **Excellent stability of the bias:** <0.05K / decade
- **Precision, stability and homogeneity criteria are met for SST to be considered as a Climate Data Record**

→ **It is possible to consider IASI-A / IASI-B / IASI-C as the same instrument to study climate!**

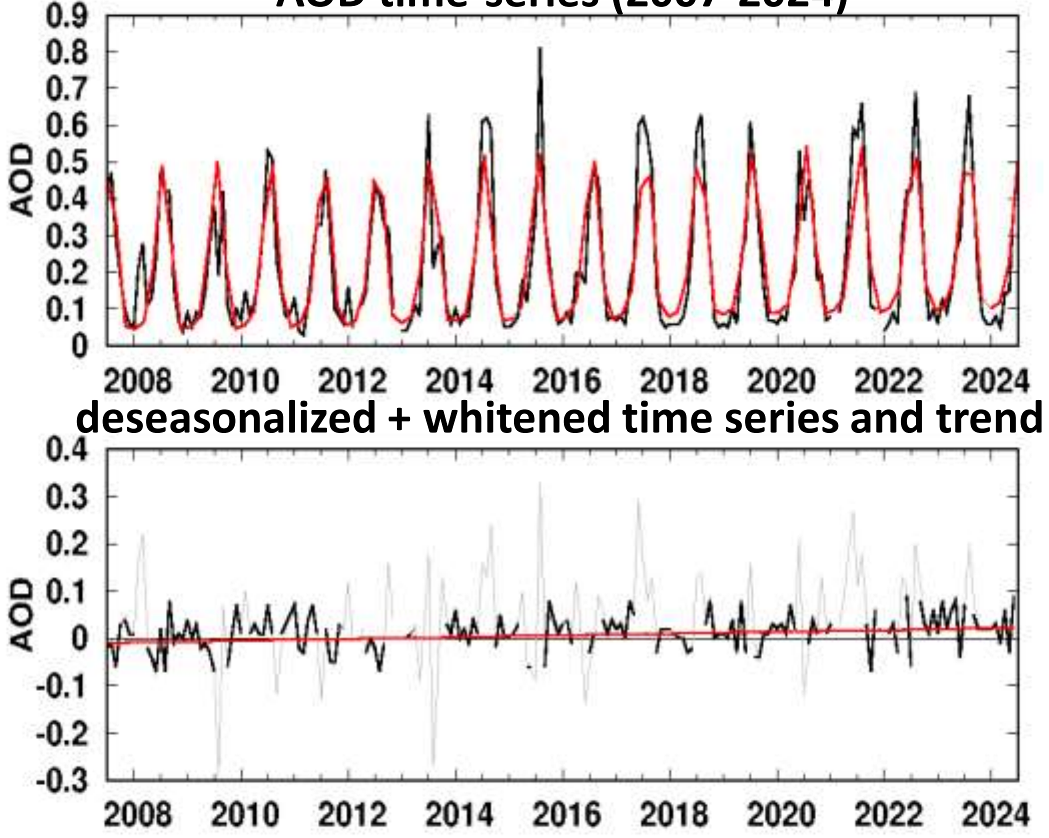
How to detect trends on ECV: a case-study with dust aerosols

- **Detecting trends in geophysical variable time series requires taking into account:**
  - Weak values of geophysical trends
  - Non-Gaussian samples
  - Presence of « holes », « outliers » or large interannual variations in the data
  - Presence of serial correlations

- **A case-study: what are the trends in dust aerosols detected by IASI in the Sahara?**

- **Data used here:**
  - **Metop-A and Metop-B series are merged**
  - **0.5° gridded monthly mean AOD** are determined (median rather than mean)
  - **Day** and **night** time series are calculated **separately**
  - For each pixel, time series are **deseasonalized** and **whitened** (low-pass filter)

Example of Bordj_Badji _Mokhtar



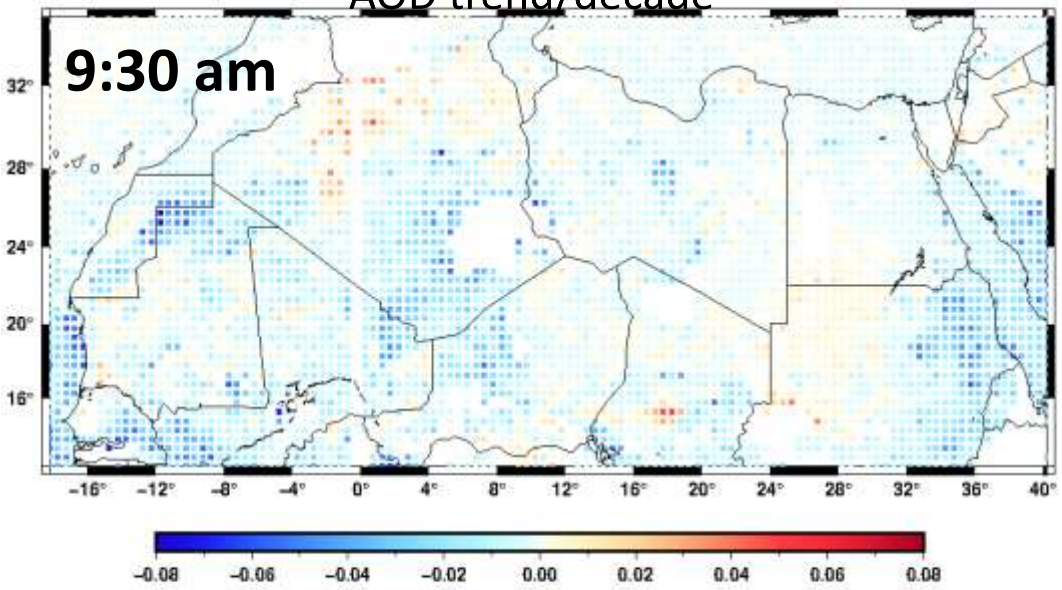
Updated from Chédin et al., 2018

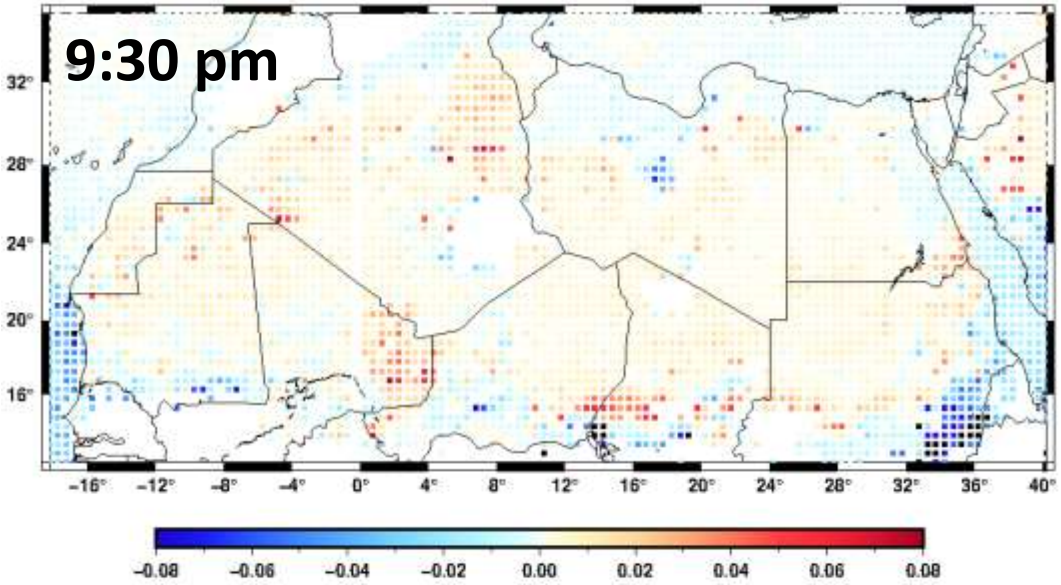
How to detect trends on ECV: a case-study with dust aerosols

Trend computation:

- Trends are determined using the **non-parametric Theil-Sen slope estimator** followed by **the Mann-Kendall statistical test**

AOD trend/decade



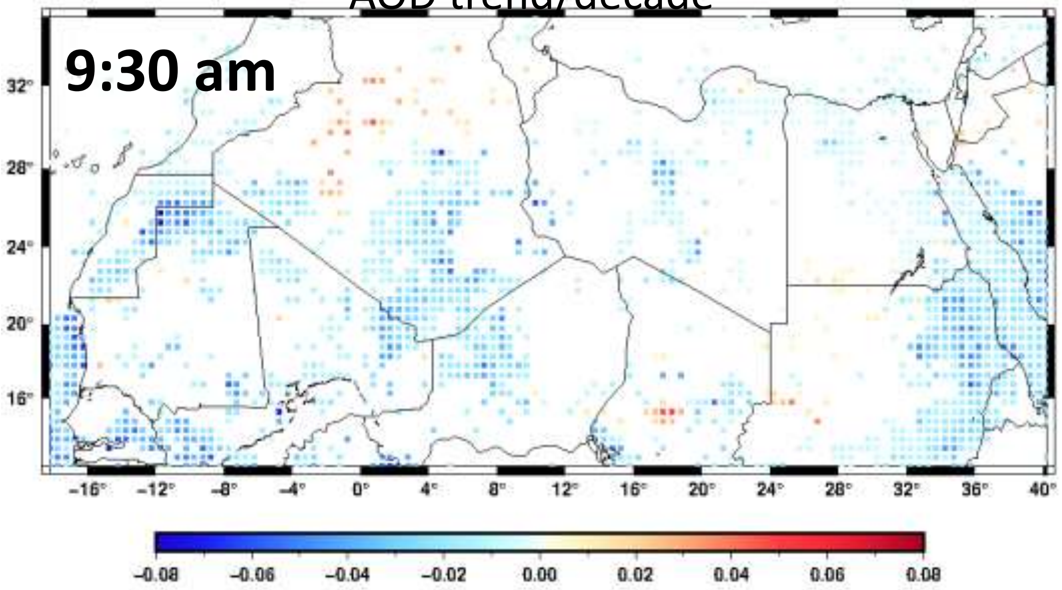


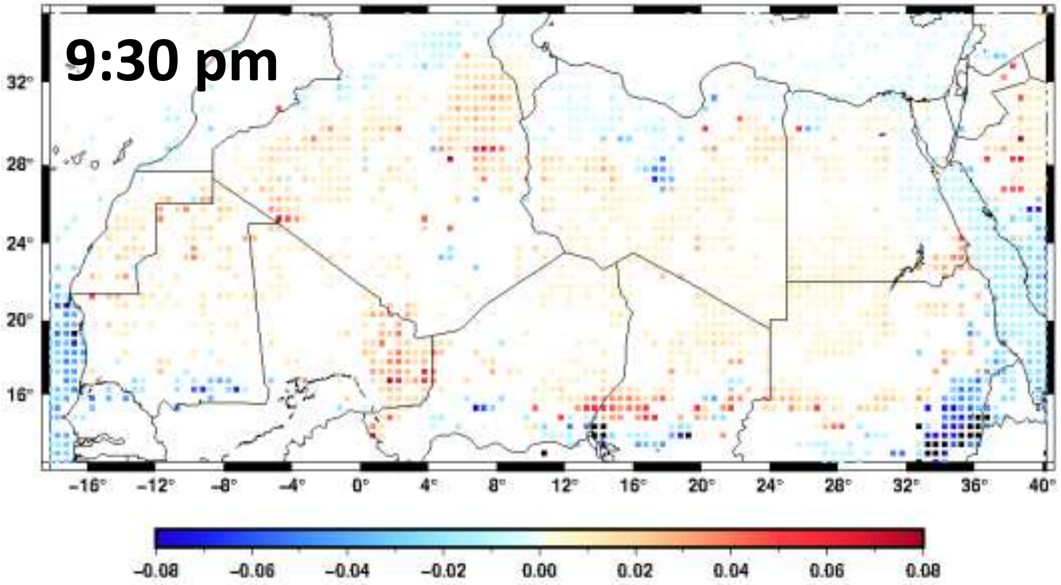
How to detect trends on ECV: a case-study with dust aerosols

Trend computation:

- Trends are determined using the **non-parametric Theil-Sen slope estimator** followed by **the Mann-Kendall statistical test**
- Only trends with **at least 95% confidence** are kept

AOD trend/decade



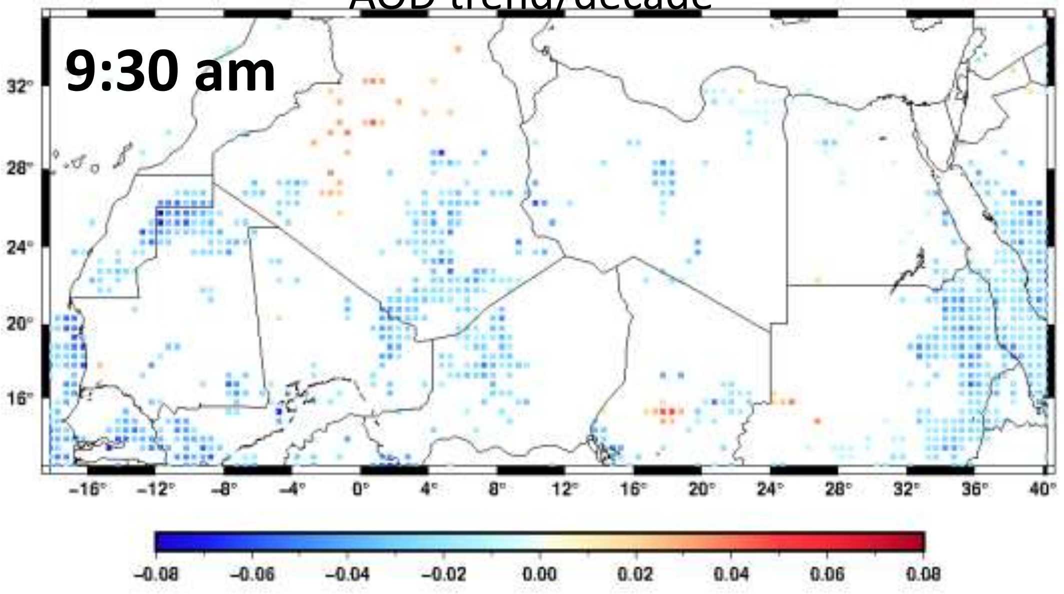


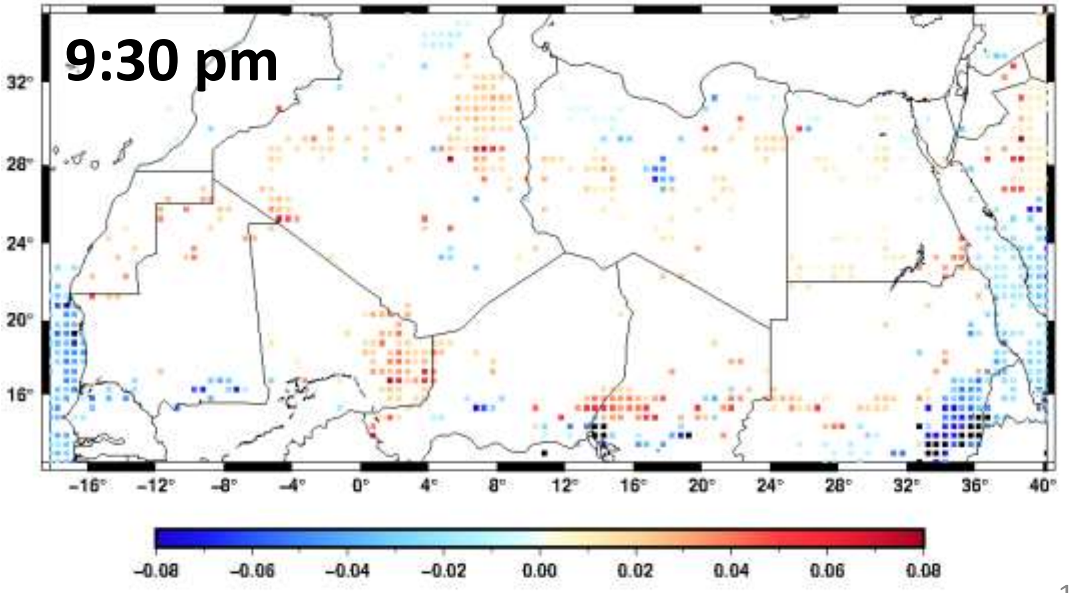
How to detect trends on ECV: a case-study with dust aerosols

Trend computation:

- Trends are determined using the **non-parametric Theil-Sen slope estimator** followed by **the Mann-Kendall statistical test**
- Only trends with **at least 95% confidence** are kept
- Only trends with the number of years of data required to detect a "real" trend of a specified magnitude **with probability 0.9** ("probability-assigned real" trend following Tiao et al. (1990)) are kept
- **Conclusions on AOD trends:**
  - Significant trend are principally located in the main potential dust source regions
  - Trends are essentially negative in the morning, in agreement with the literature (AERONET, etc..), except for the Bodele. There are mostly positive in the evening.
  - This day/night difference might be related to the different uplift processes involved throughout the day.

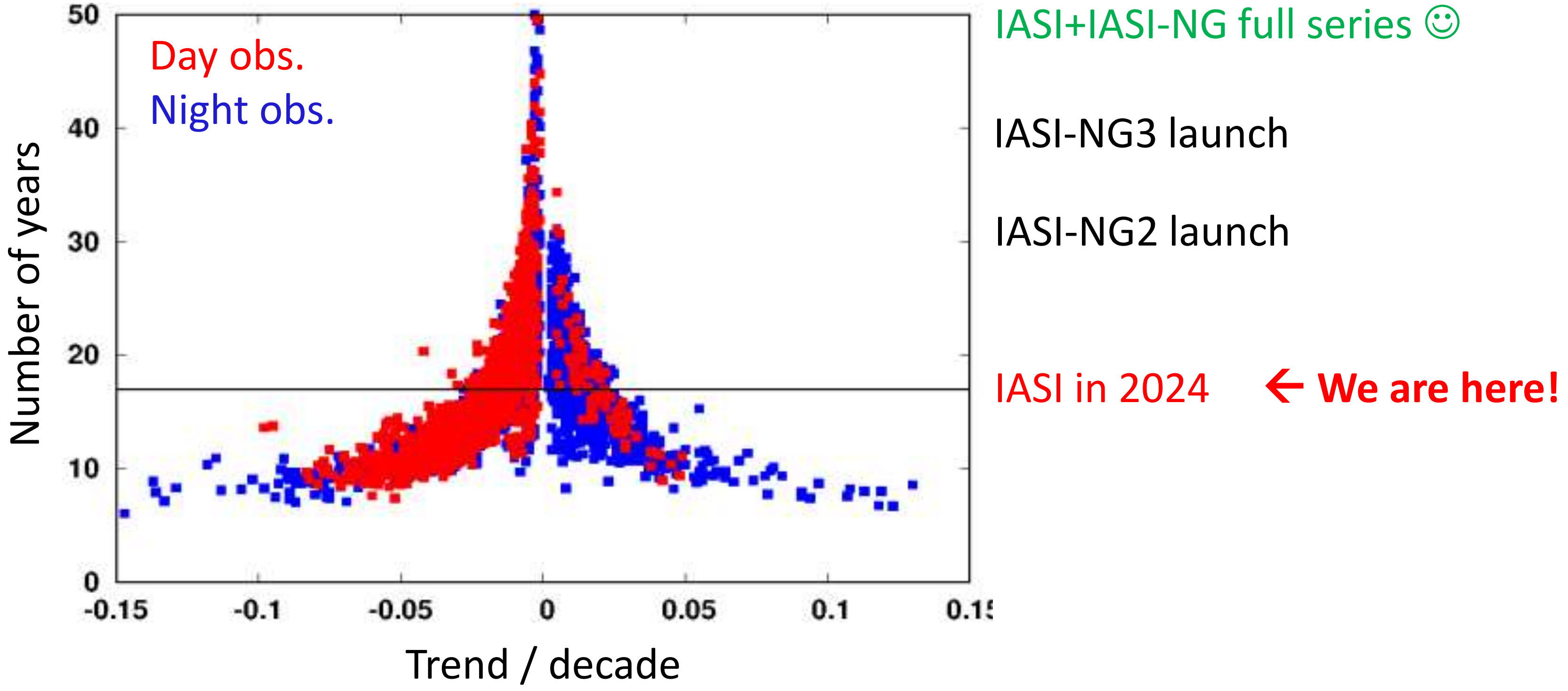
AOD trend/decade





How to detect trends on ECV: a case-study with dust aerosols

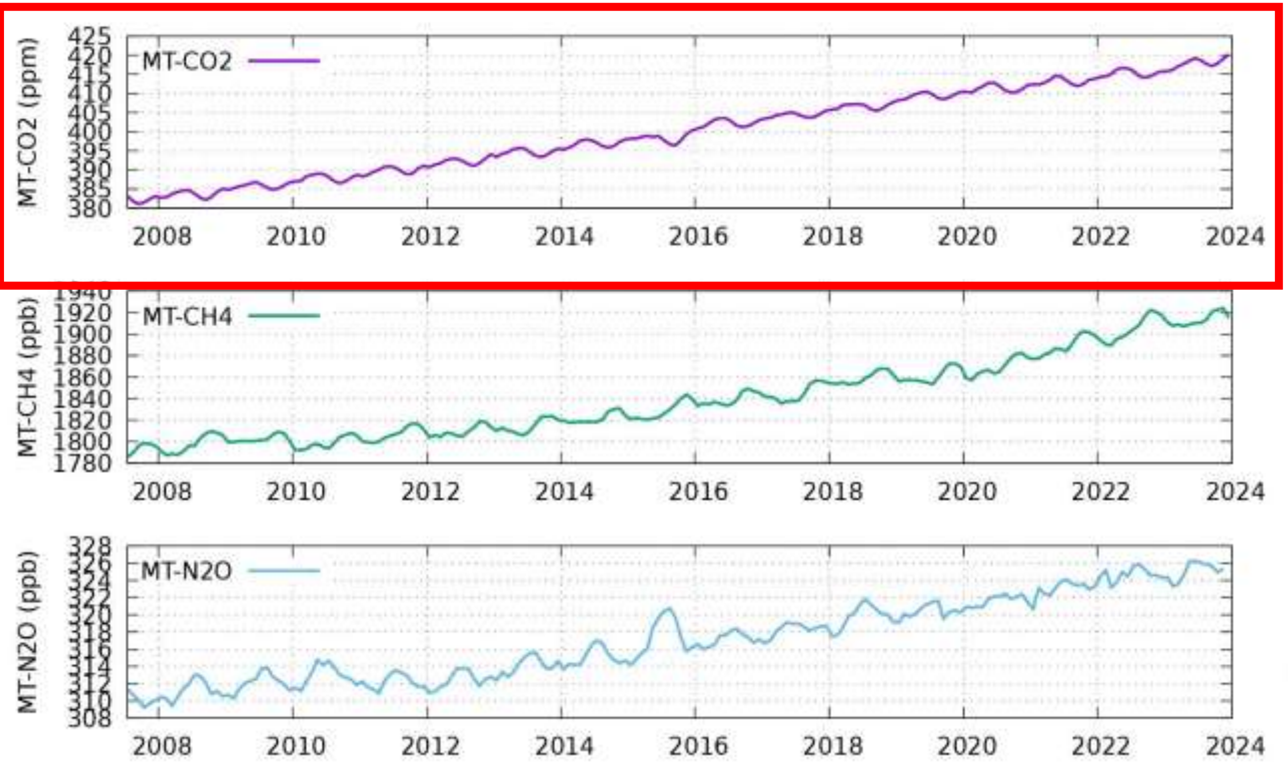
number of years required for a 'real' trend to be assigned a probability of 0.9 wrt the 95% confidence level trend



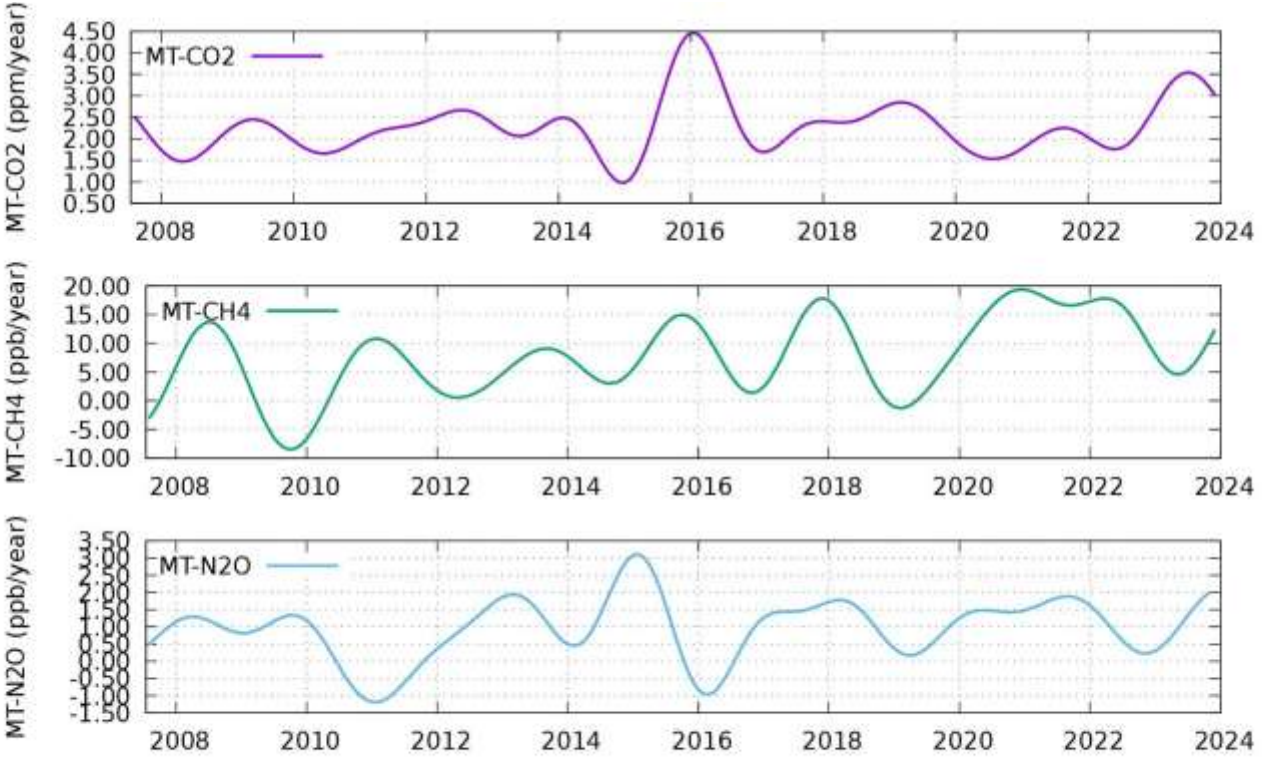
→ **Keeping only 0.9 probability trend discard many regions where low trends might be detected.**
→ **Moderate trends require more than 20 years to be consolidated.**
→ **Combining IASI with IASI-NG will be a clear asset for trend attribution!**

The strongest and unambiguous trends: anthropogenic greenhouse gases

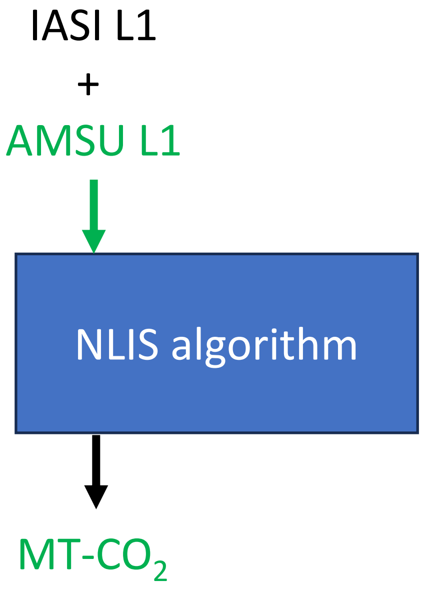
Monthly time series of mid-tropospheric CO_2, CH_4 and N_2O



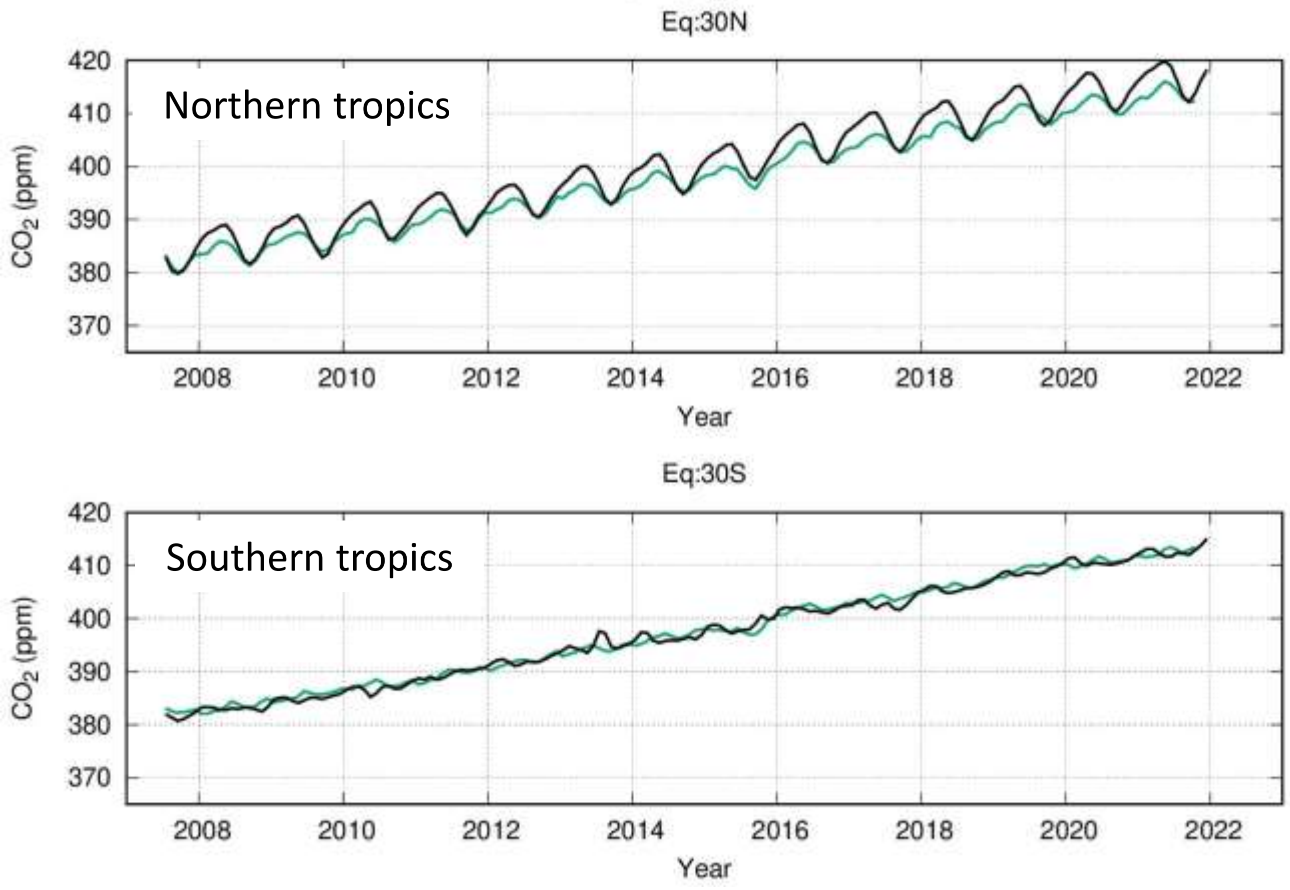
Associated annual growth rates



The strongest and unambiguous trends: anthropogenic greenhouse gases



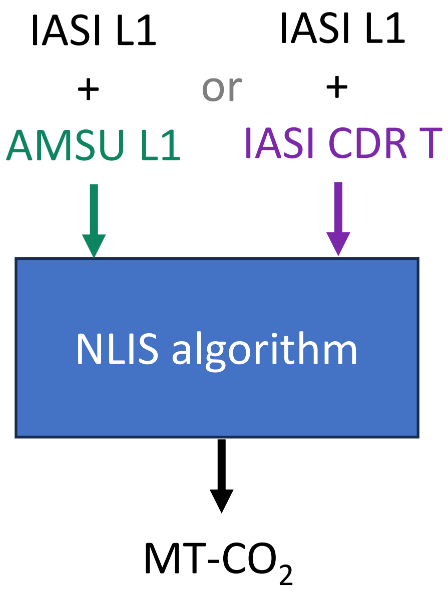
Monthly time series of Mid-Tropospheric CO_2



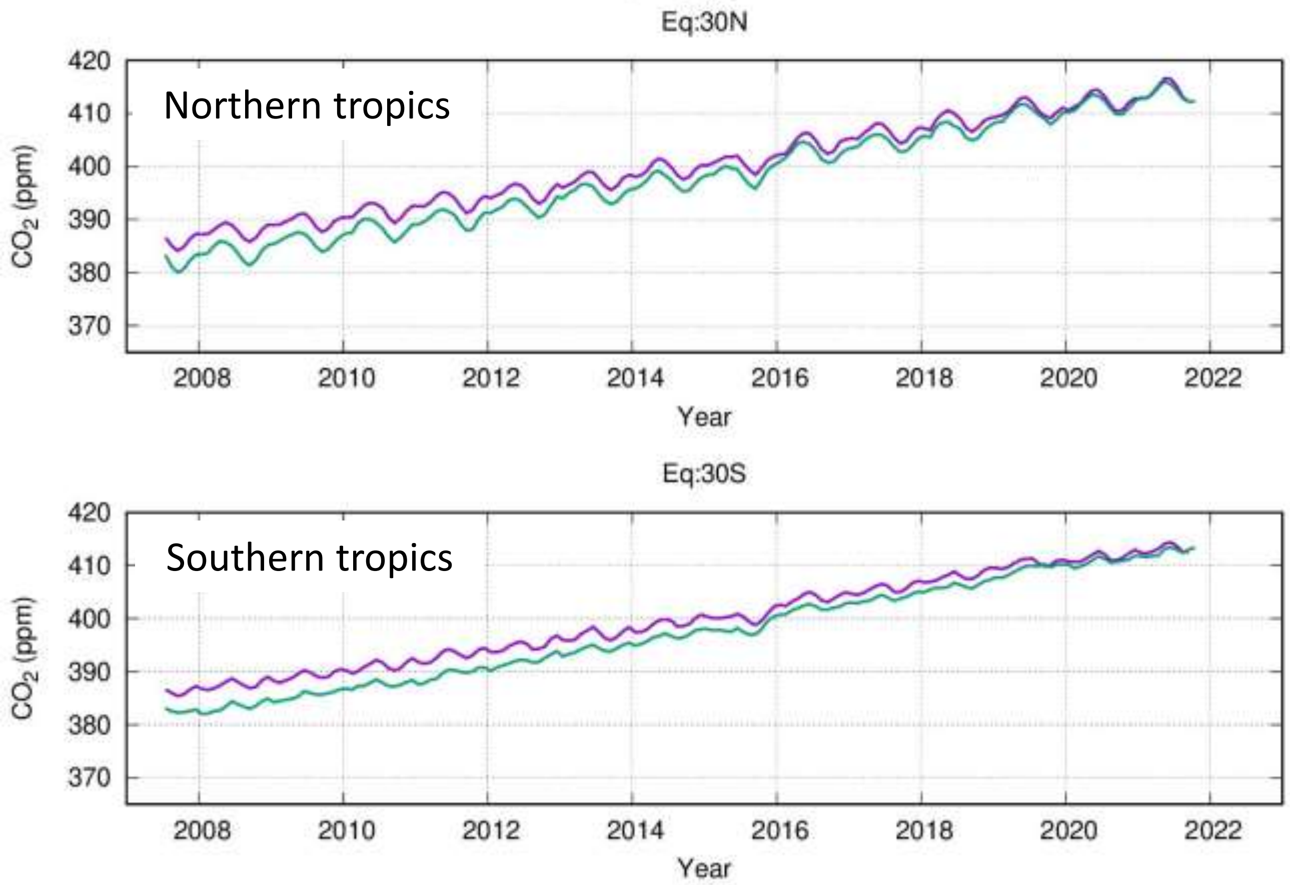
When using…	Trend
… AMSU L1	2.32 ppm yr^{-1}
Surface network reference	2.42 ppm yr^{-1}

When using…	Trend
… AMSU L1	2.28 ppm yr^{-1}
Surface network reference	2.30 ppm yr^{-1}

The strongest and unambiguous trends: anthropogenic greenhouse gases



Monthly time series of Mid-Tropospheric CO_2

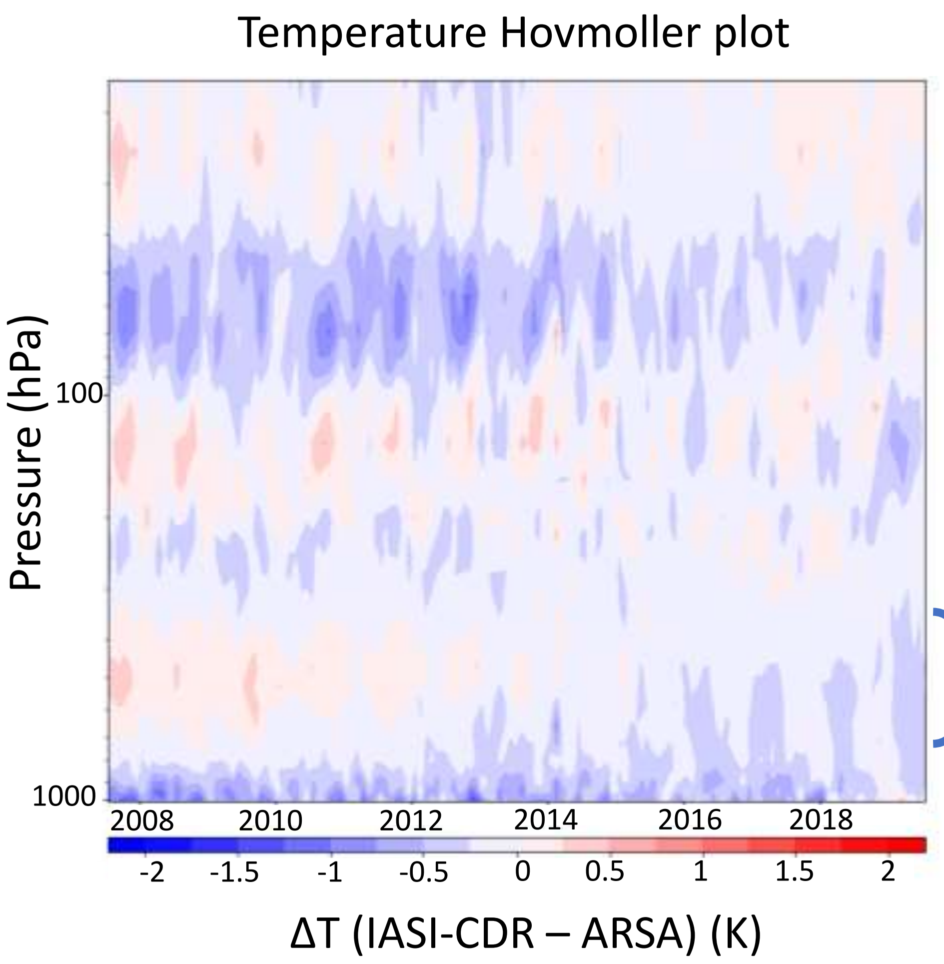


When using…	Trend
… AMSU L1	2.32 ppm yr^{-1}
Surface network reference	2.42 ppm yr^{-1}
… IASI CDR T	2.08 ppm yr^{-1}

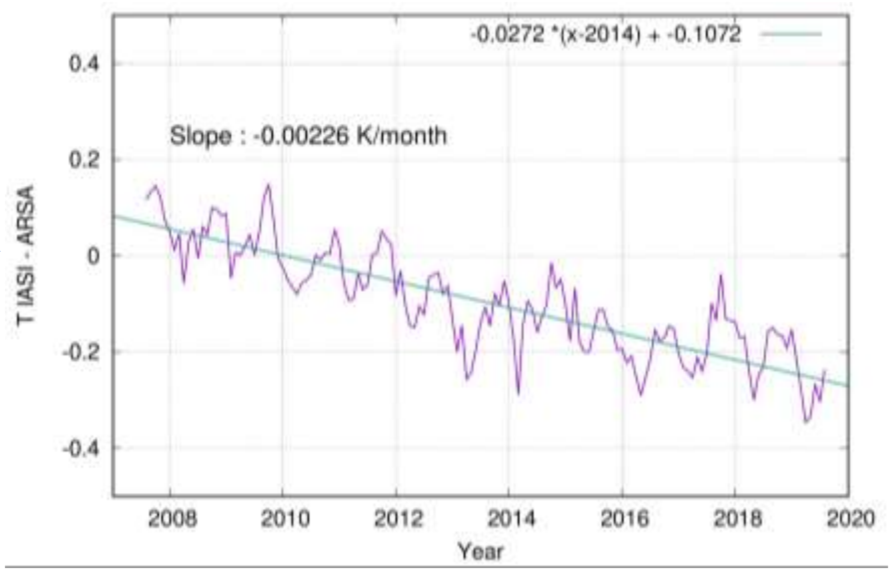
When using…	Trend
… AMSU L1	2.28 ppm yr^{-1}
Surface network reference	2.30 ppm yr^{-1}
… IASI CDR T	2.04 ppm yr^{-1}

Thanks to the 15 years available, it is possible to detect a spurious trend in CO_2 retrieved when using temperature from CDR 1.1 that is not seen on the CDR-free retrieval based on AMSU.
→ But where does it come from?

Evaluation of IASI temperature CDR 1.1 with radiosondes from ARSA database



"a decrease in mean difference and standard deviation in the lower troposphere beginning at the end of 2014 until the end of the time series [is seen]. An explanation could reside in the PWLR3 training dataset, consisting of data from 2015 and 2016. Indirect effects on retrievals are possible if the training dataset is not fully representative in all geophysical respects of the times series the retrievals are applied to." [EUMETSAT CDR validation report]



A very slow 'false trend' on IASI L2 T of 0.027 K / year, well below IASI specifications, but enough to generate a spurious trend in other L2.
It needs to be corrected for future release.

Conclusions, lessons learned and recommendations

Conclusions on IASI:

- IASI can be considered as a climate mission, as shown at both Level1 and Level2.
  →long-term, evolution of ECVs, detection of climate signatures, etc.
- IASI is the WMO/GSICS reference for thermal IR.
- IASI performances are well below initial specifications.

Strong implications on L1 and L2 monitoring and validation!

- Careful checking of L1 to avoid any slight and not-understood changes in the instrument (calibration, etc)
- Systematic checking of **stability, consistency, and continuity**.
  → Those criteria need to be met for any Level2 data to be named a Climate Data Record.
- Specific attention must be put in baseline products such a temperature/humidity that are often used as inputs to derived other L2.

Strong hope for IASI-NG!!!

- Need for careful intercomparison between IASI and IASI-NG.
  → Strong interest in the tandem flight, that should be repeated for any new launch in the future!
- Long-term monitoring of IASI-NG Level1 AND Level2 data is essential.
- Regular reanalysis is needed to account for any detected artefact or instrumental change.