Trends in climate variable

Fast spectral retrieval of Outgoing Longwave Radiation and heating rate from infrared sounders applied to the long time series obtained with IASI A,B and C observations

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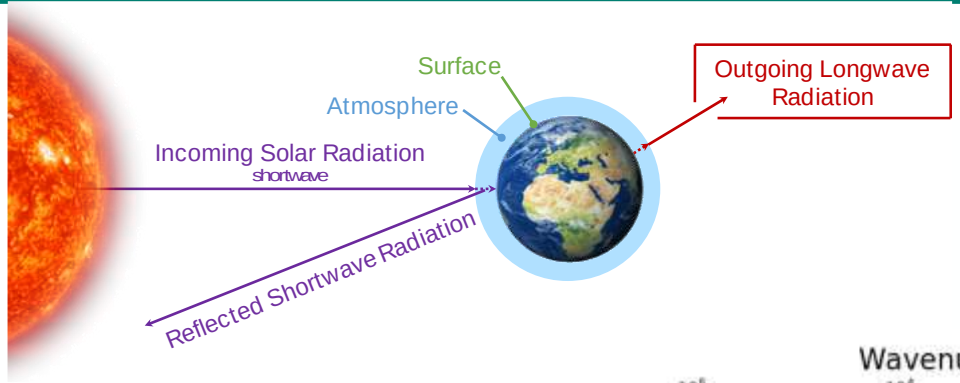
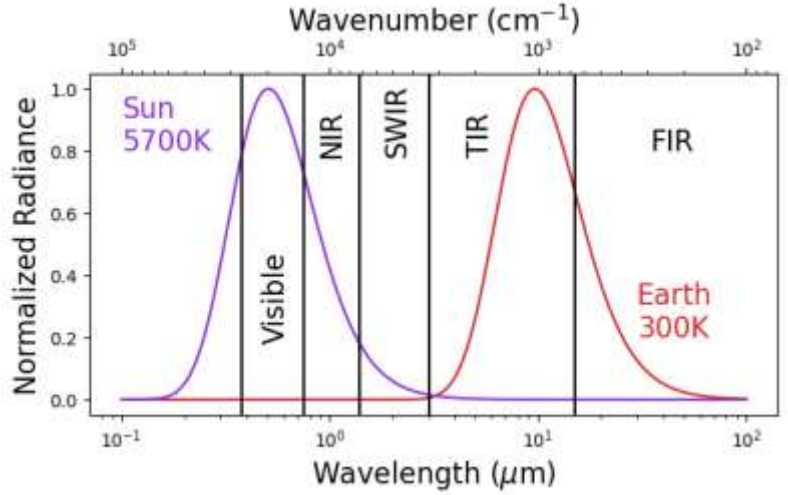
Introduction

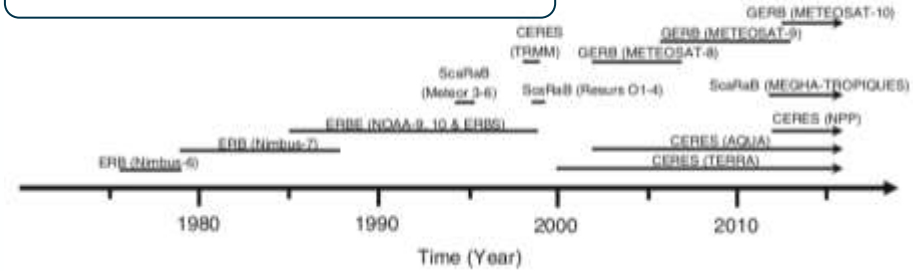


- The Earth Radiation Budget is defined by
  - Incoming solar radiation (ISR)
  - Outgoing reflected shortwave (RSW)
  - Outgoing longwave radiation (OLR)
- This equilibrium is the main driver of the climate system



Measurement of OLR from space

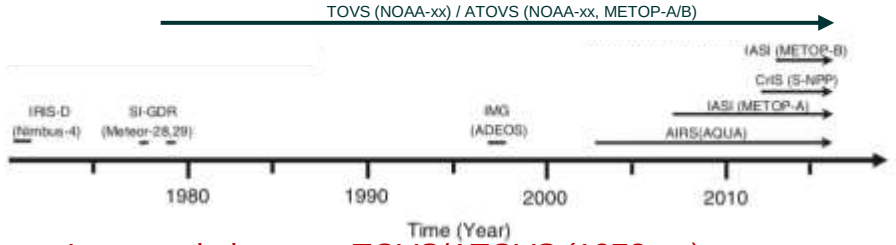
Broadband radiometers



- e.g. ERB, CERES, ScaRaB (1975-…)

IR sounders

Source : Brindley et Bantges (2013)



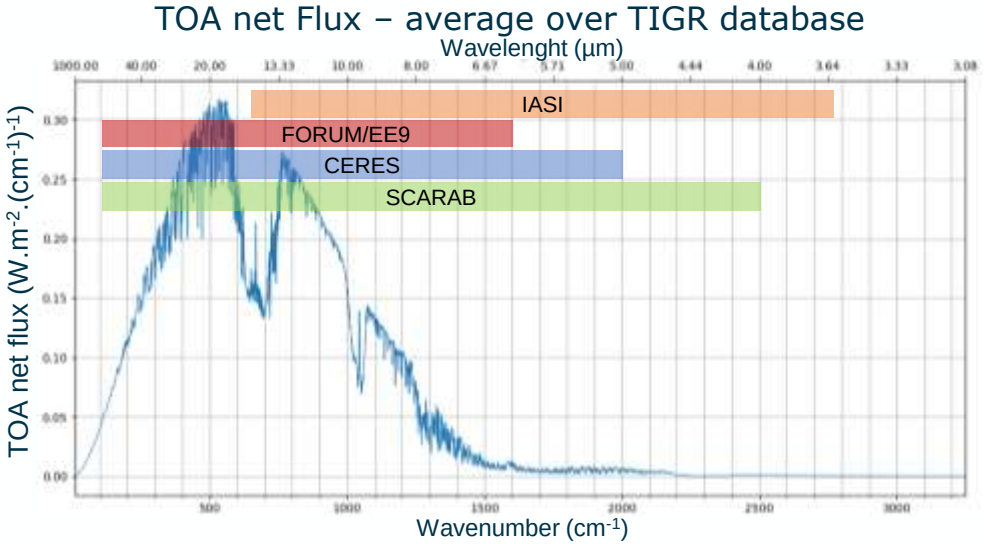
- Low resolution: e.g. TOVS/ATOVS (1978-…)
- High resolution: e.g. AIRS, IASI, CrIS (2002-…)

Broadband Radiometers	Accessible Variables	IR sounders
✓	TOA Net flux (OLR)	✓
x	Radiative Flux and cooling rate spectra	✓
x	Radiative Flux and cooling rate profiles	✓

- IASI combines a high spectral and radiometric stability and long term coverage (20 years)
- IASI offers a continuous coverage of the TIR spectrum from 645 to 2760 cm^{-1} (3,63 – 15,5 μm)
- IR Radiative flux estimation → One of the main objectives of IASI

➔ Preparing the synergy between IASI-NG (swath) with FORUM (FIR)

Spectral distribution of net flux at the top of the atmosphere



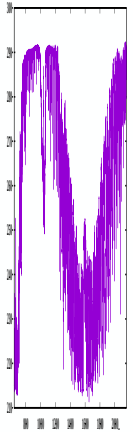
	Spectral band (cm^{-1})		TOA net flux ($W.m^{-2}$)	% of all
	All	**10 – 3250**	**222.22**	**100.0**
IR Sounders	IASI	645 – 2760	112.68	50.7
IR Sounders	FORUM	100 – 1600	217.42	97.8
IR Sounders	FORUM+IASI	100 – 2760	220.67	99.3
Broadband radiometers	CERES	100 – 2000	219.55	98.8
Broadband radiometers	SCARAB	100 – 2500	220.50	99.2

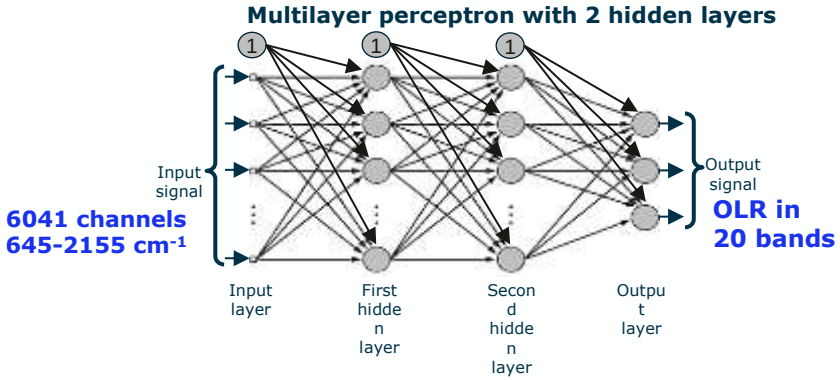
Challenges using IASI measurement to retrieve OLR

- Spectral coverage: the longwave spectrum is not entirely covered by IASI
  - IASI [645 – 2760] cm^{-1} – Longwave [10 – 3250] cm^{-1}
- Angular measurement: The measurement is not performed at all angles
  - IASI measures radiances with angles ranging from 0° to 57° – Fluxes are integrated over all angles

OLR retrieval in 20 spectral bands using neural networks

A suite of 30 MultiLayer Perceptron has been trained using simulation with 4A/OP* (***Tellier et al, 2022 and Pincus et al 2020***) and the TIGR atmospheric database (test =ARSA radiosoundings) to process IASI spectral acquired at all scan angles $(0,58°)$





1	Band 1 :	10-100
	Band 2 :	100-350
2	Band 3 :	350-500
3	Band 4 :	500-630
4	Band 5 :	630-645
	Band 6 :	645-700
5	Band 7 :	700-820
6	Band 8 :	820-980
7	Band 9 :	980-1080
8	Band 10 :	1080-1180
9	Band 11 :	1180-1390
10	Band 12 :	1390-1480
11	Band 13 :	1480-1600
	Band 14 :	1600-1800
12	Band 15 :	1800-2080
13	Band 16 :	2080-2250
14	Band 17 :	2250-2380
15	Band 18 :	2380-2600
16	Band 19 :	2600-2760
	Band 20 :	2760-3250

EcRad

FORUM

CERES

SCARAB

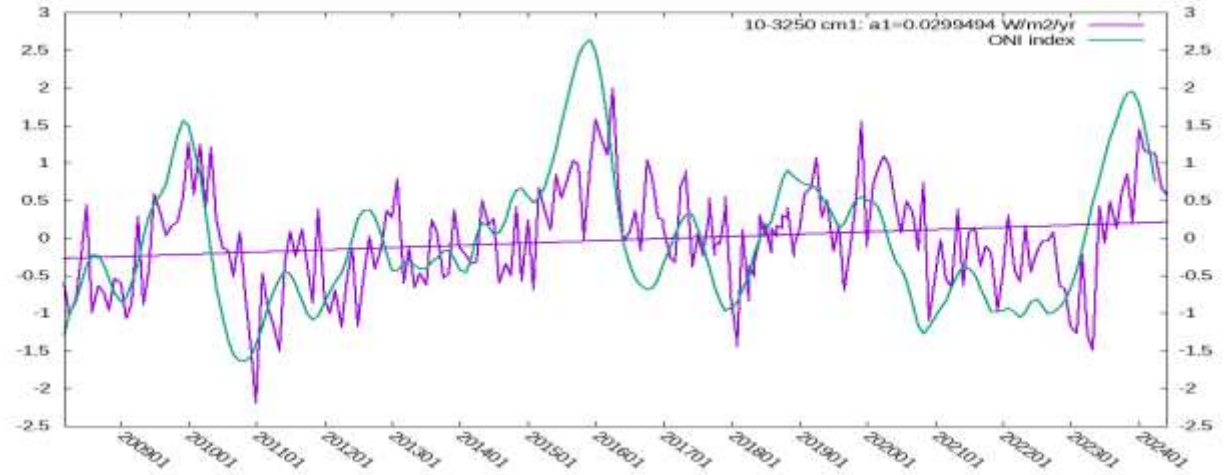
IASI

→ Computation time:
- For 1 atmosphere: 5ms vs. 390s for direct OLR computation with 4A/OP using IASI Level2
- For 1 month of IASI data: 2h14 vs. 26 years…

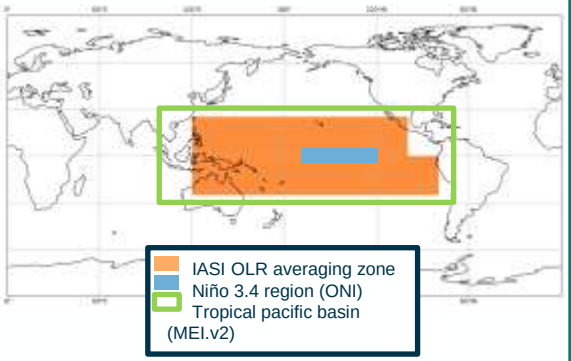
- Thanks to the 20 bands: it is possible to directly compare IASI/LMD OLR with various other OLR datasets

OLR anomaly from IASI and comparison with ENSO indexes

monthly deseasonalised OLR anomalies over tropical Pacific



Oceanic Niño Index (ONI) [3 month running mean of ERSST.v5 SST anomalies in the Niño 3.4 region (5ºN-5ºS, 120º-170ºW)],

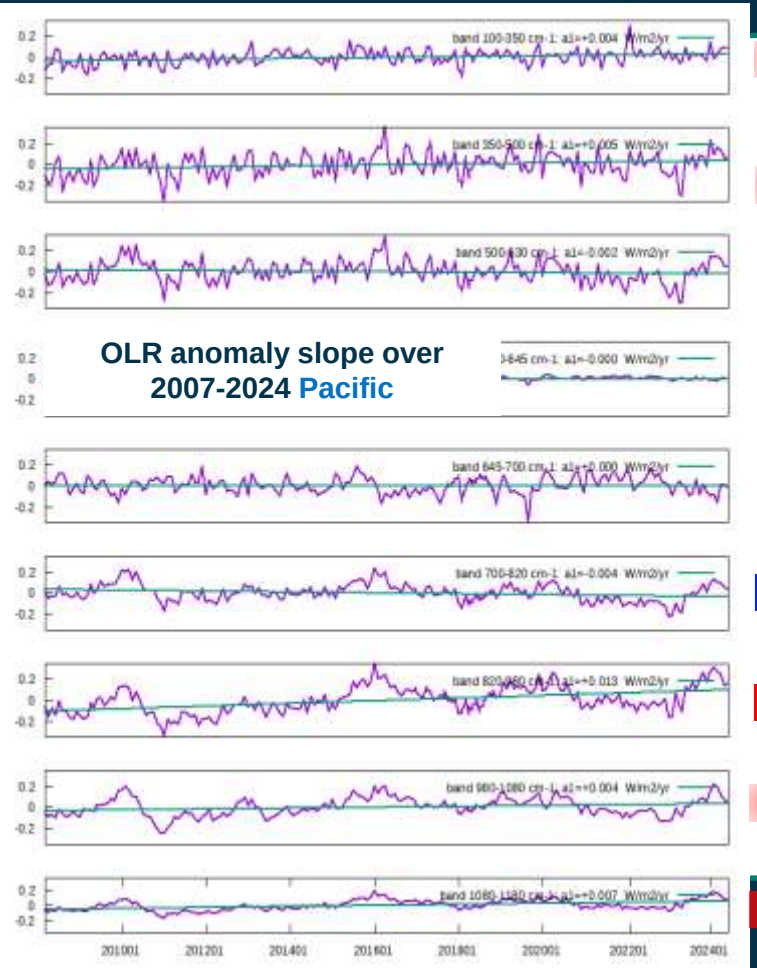


Total OLR 10:3250 cm-1

Preliminary Results:

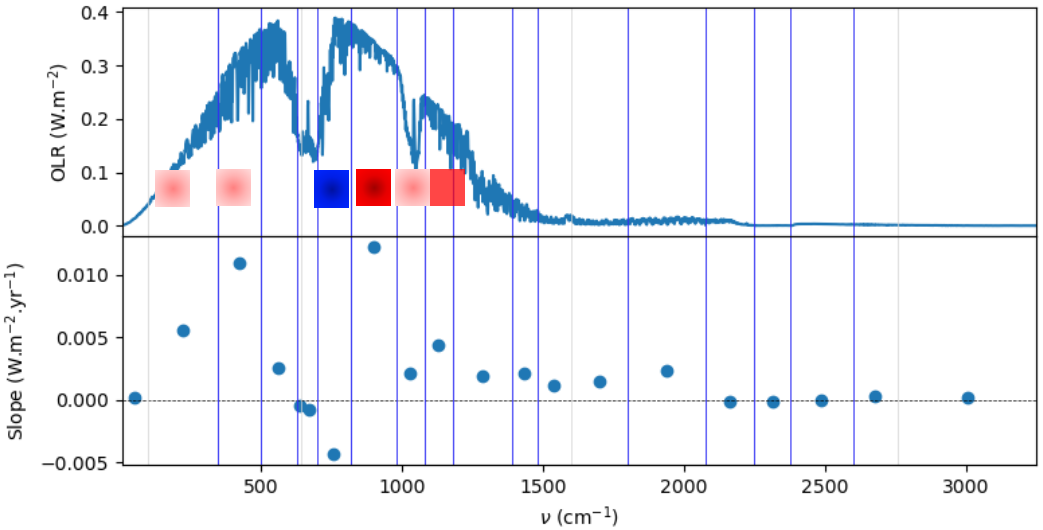
- IASI OLR anomaly follows expected climate variation
- Good correlation between the 2 datasets, even if some seasonal shifts
- El Niño events of 2009-2010, 2015-2016 and 2023-2024 are well seen

IASI OLR anomaly trend over 17 years in the targeted spectral bands



OLR anomaly slope over 2007-2024 Pacific

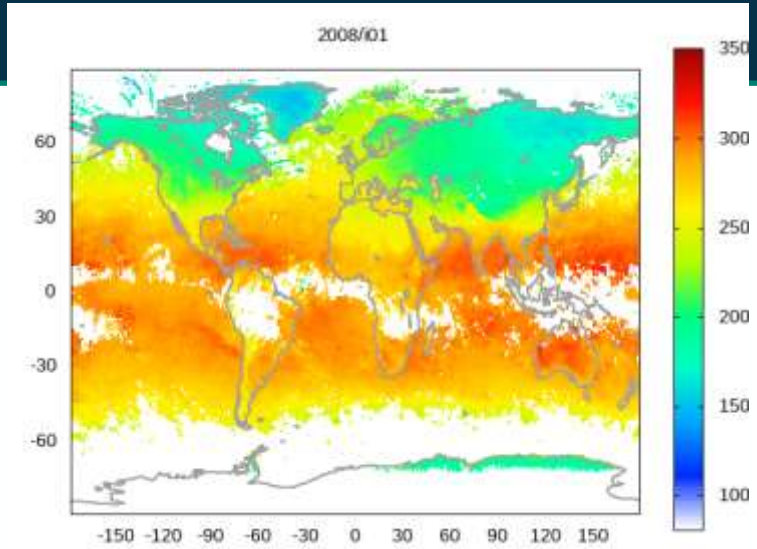
OLR and OLR anomaly slope over 2007-2024 sea/tropical



Over 2007-2024, IASI detects:

- Increase in the **window bands**, consistent with increase in SST
- Decrease in the **15 µm band** (CO_2), consistent with increase in CO_2 concentration

Conclusion for OLR



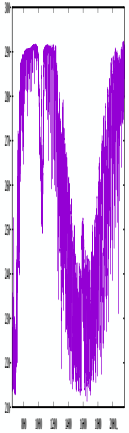
- A multi-layer perceptron (MLP) suite has been developed to estimate clear-sky OLR from IASI measured radiance spectra
- Estimated IASI-A OLR validation with collocated Scarab/Megha-Tropiques OLR observations yielding a difference of $-0.61 \pm 2.53\ W.m^{-2}$
- IASI-A time series representative of some climate signatures such as ENSO and first spectral OLR climate trend made

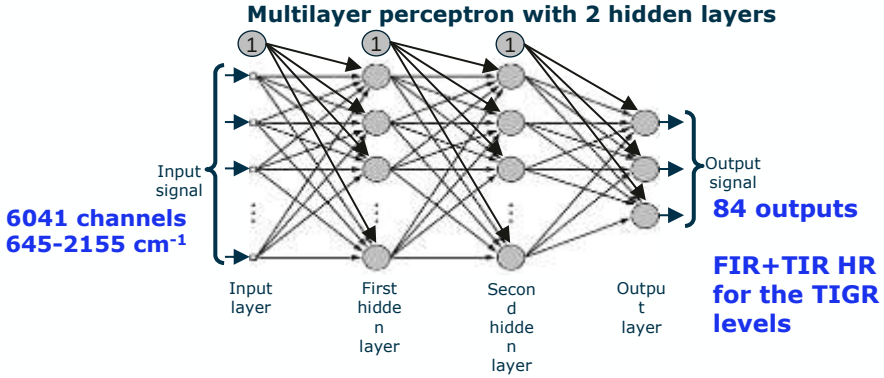
Challenges using IASI measurement to retrieve **Heating Rate**

- Spectral coverage: the longwave spectrum is not entirely covered by IASI
  - IASI [645 – 2760] cm^{-1} – Longwave [10 – 3250] cm^{-1}
- Angular measurement: The measurement is not performed at all angles
  - IASI measures radiances with angles ranging from 0° to 57° – Fluxes are integrated over all angles
- Vertical distribution: Channels in the TIR are only sensitive to a part of the atmosphere (Weighting function)

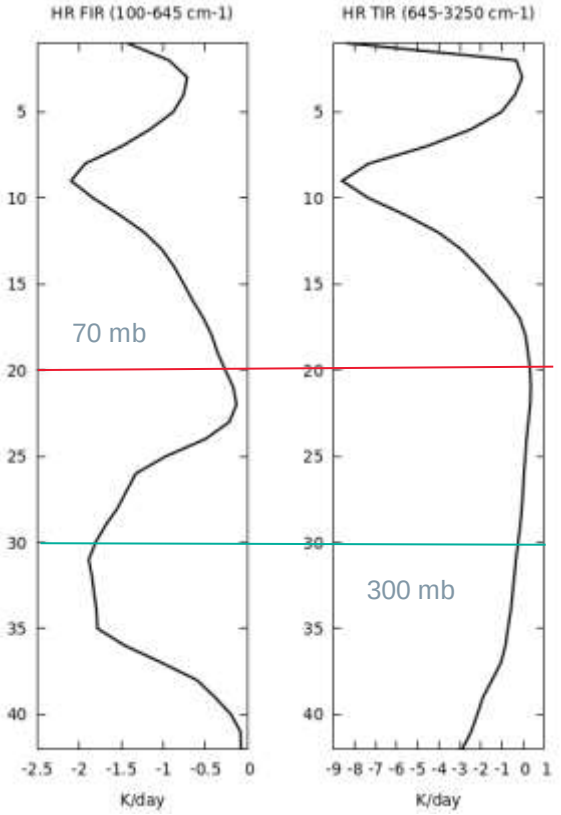
Heating Rate retrieval in the TIR and the FIR using neural networks

A suite of 30 MultiLayer Perceptron has been trained using 4A/OP and the TIGR atmospheric database to process IASI spectral acquired at all scan angles (0,58°)

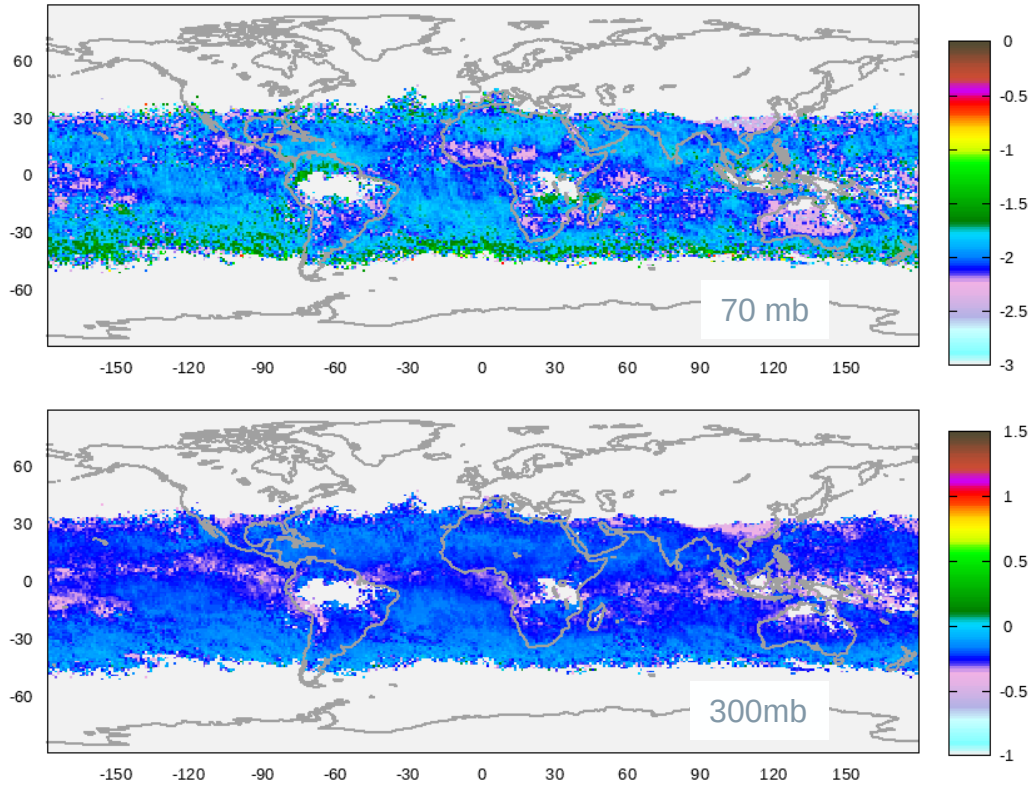




- 2 * 42 heating rate levels from surface to 0.05 mb (TIGR pressure levels)
- Tropical airmass
- 2008/01 to 2024/06

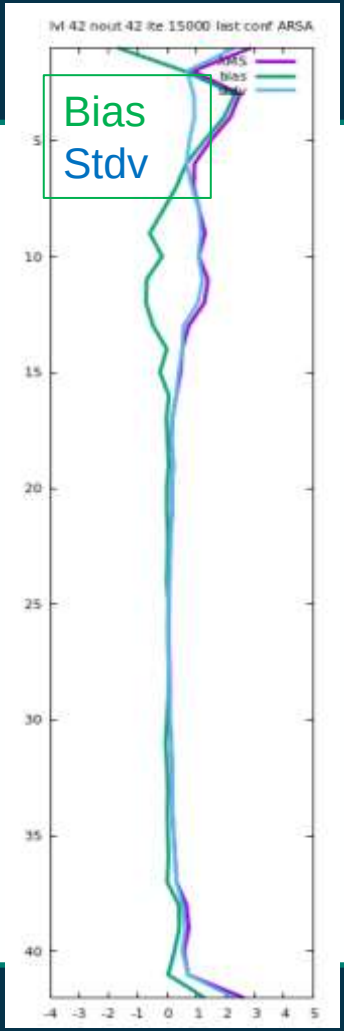


Heating Rate from IASI maps (january 2024): 70 and 300 mb



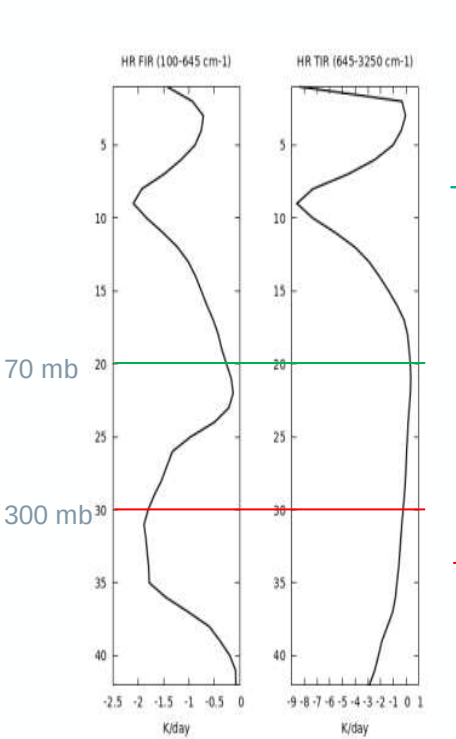
analysis in progress:

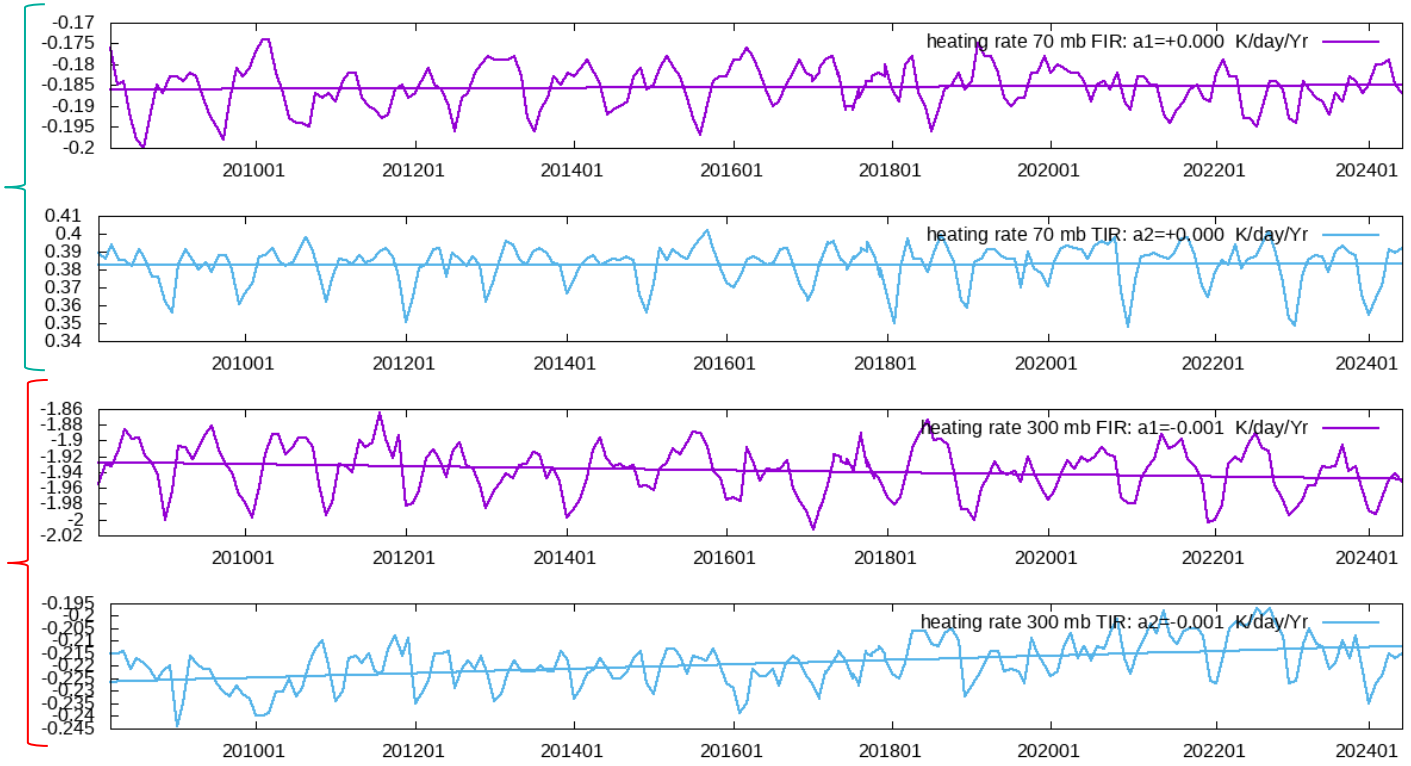
- Tropic airmasses
- NN more noisy for lower pressure
- Effects at the interface between 2 airmass ➔ correction in progress with the new TIGR-2024 database (8 airmass)
- Bias in the upper part but due to the small sensitivity of the IASI channels
- Bias and stdv very close to the surface ➔ emissivity and tsurf over land



IASI Heating Rate trend over 17 years

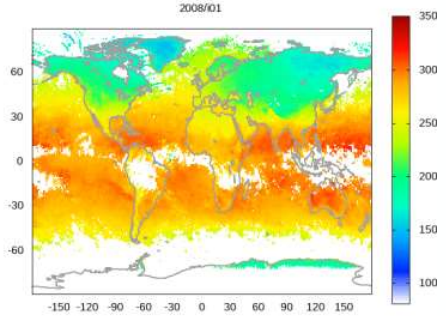
IASI 2007-2024, Sea, tropical: FIR and TIR





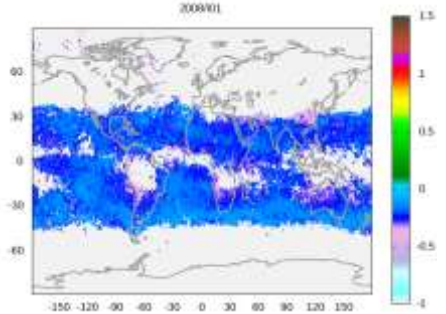
Conclusion and perspetives

- A multi-layer perceptron (MLP) suite has been developed to estimate clear-sky **OLR** (global) and **vertical heating rates** (tropical) from IASI measured radiance spectra
- Estimated IASI-A OLR validation with collocated Scarab/Megha-Tropiques OLR observations yielding a difference of $-0.61 \pm 2.53\ W.m^{-2}$
- IASI-A time series representative of some climate signatures such as ENSO and spectral OLR climate trend made
- Analysis in progress of 17 years of IASI Heating rate in the FIR and in the TIR (little trends in the troposphere (negative in the FIR, positive in the TIR)), latitutde/longitude patterns, …



OLR

Heating rate



Perspectives:

- Continue validation OLR over land and sea, with other dataset (e.g. CERES, whitburn IASI OLR, …)
- Improvement of the MLP method applied to the determination of the vertical heating rate (airmass, stdv in the stratosphere;, …)
- Try validation of heating rte : MAESTRO camapign (2024, aircraft)
- Prepare the adaptation of the retrieval scheme to IASI-NG, IRS/MTG and FORUM instruments