A fast retrieval of Outgoing Longwave Radiation from infrared sounders: Application to 17 years of IASI observation

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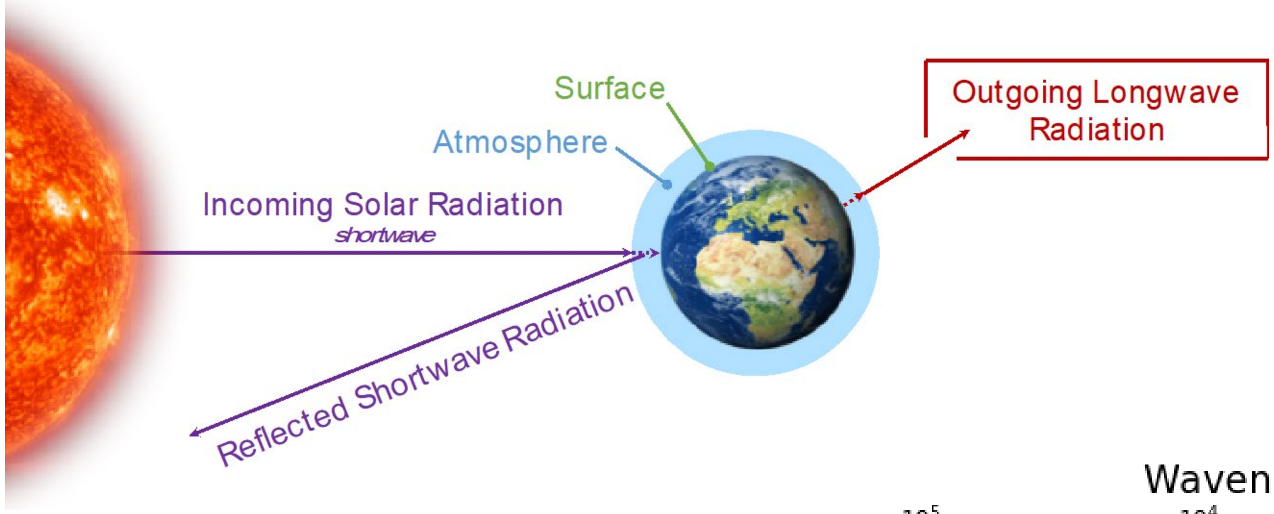
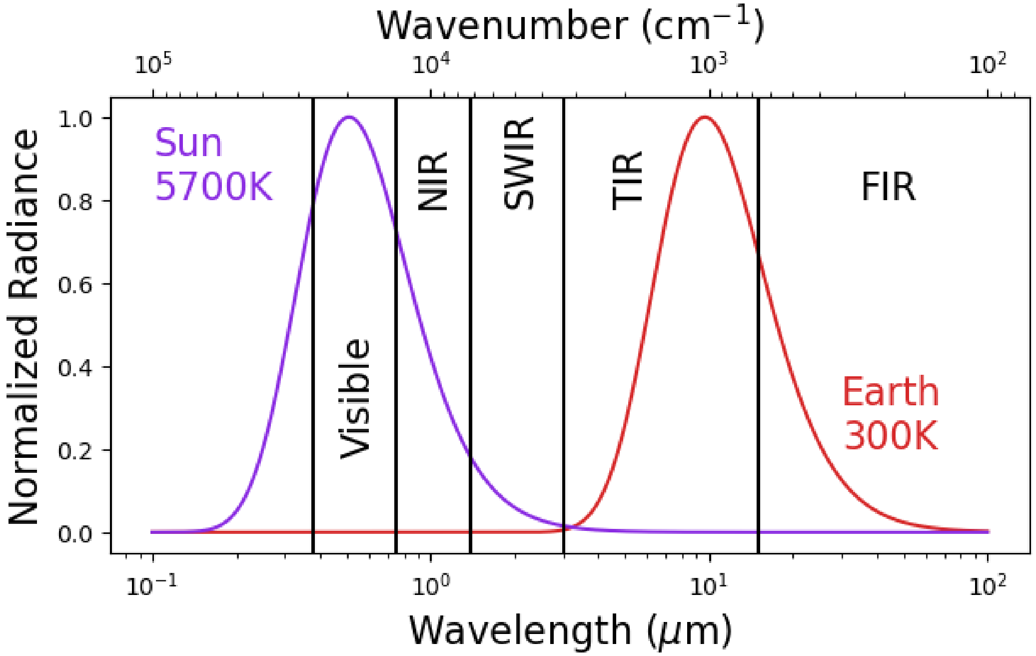
Introduction



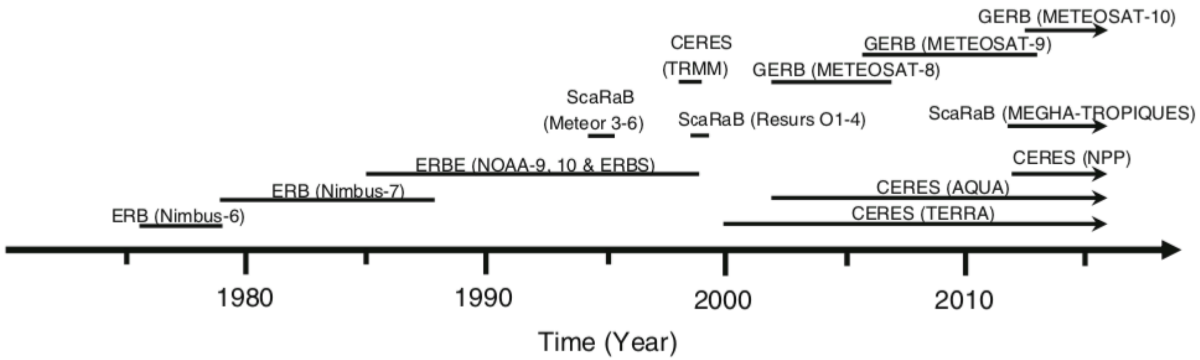
- The Earth Radiation Budget is defined by
  - Incoming solar radiation (ISR)
  - Outgoing reflected shortwave (RSW)
  - Outgoing longwave radiation (OLR)
- This equilibrium is the main driver of the climate system



Measurement of OLR from space

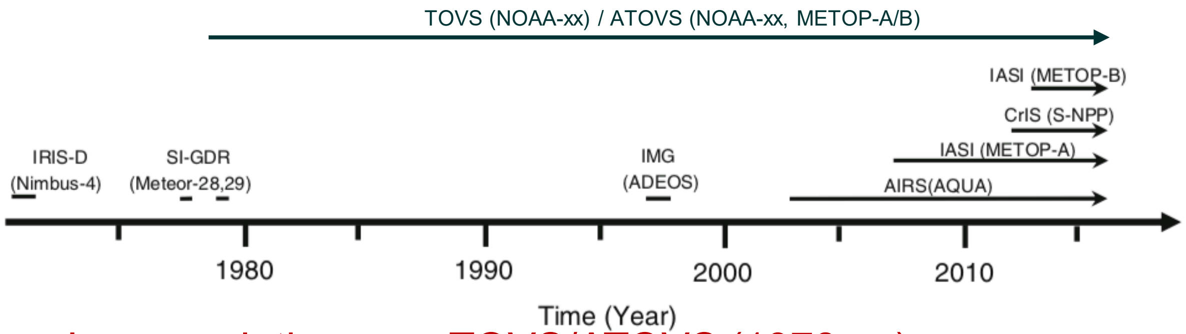
Source : Brindley et Bantges (2013)

Broadband radiometers



- e.g. ERB, CERES, ScaRaB (1975-…)

IR sounders



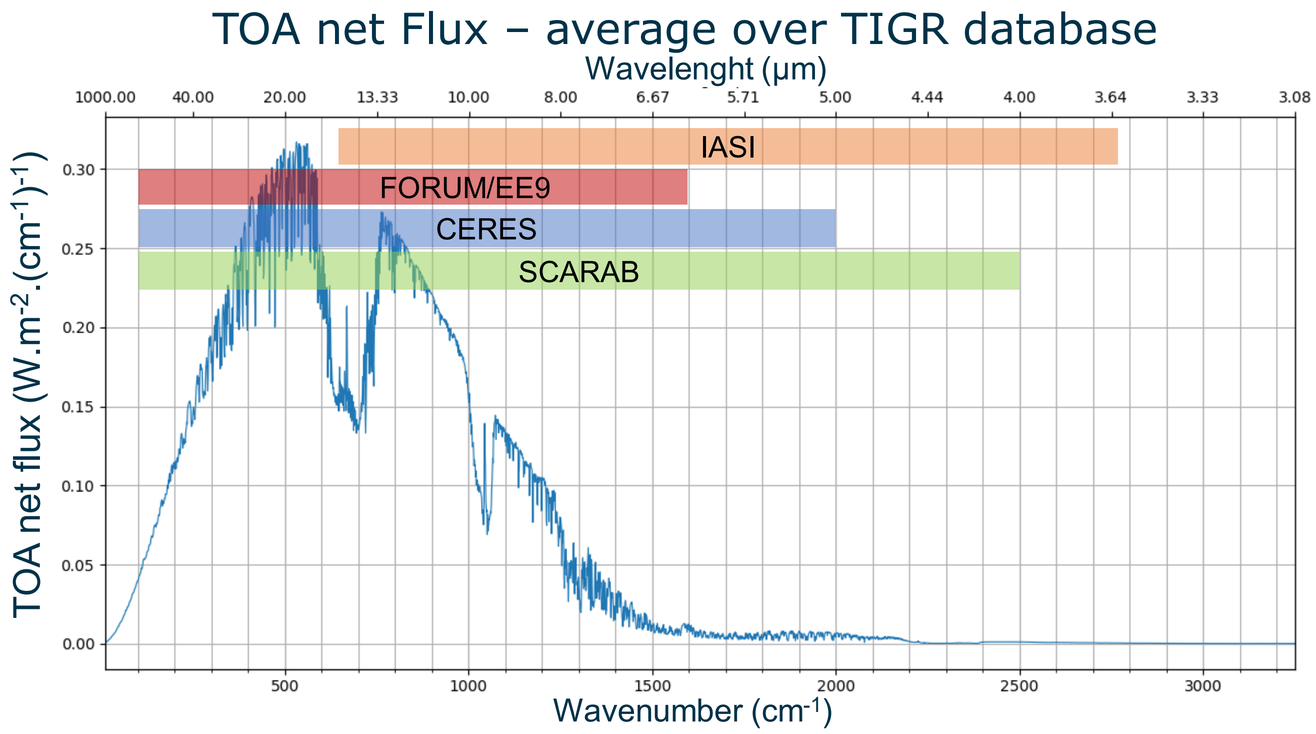
- Low resolution: e.g. TOVS/ATOVS (1978-…)
- High resolution: e.g. AIRS, IASI, CrIS (2002-…)

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**
IASI	645 – 2760	112.68	50.7
FORUM	100 – 1600	217.42	97.8
FORUM+IASI	100 – 2760	220.67	99.3
CERES	100 – 2000	219.55	98.8
SCARAB	100 – 2500	220.50	99.2

IR Sounders: IASI, FORUM, FORUM+IASI
Broadband radiometers: CERES, SCARAB

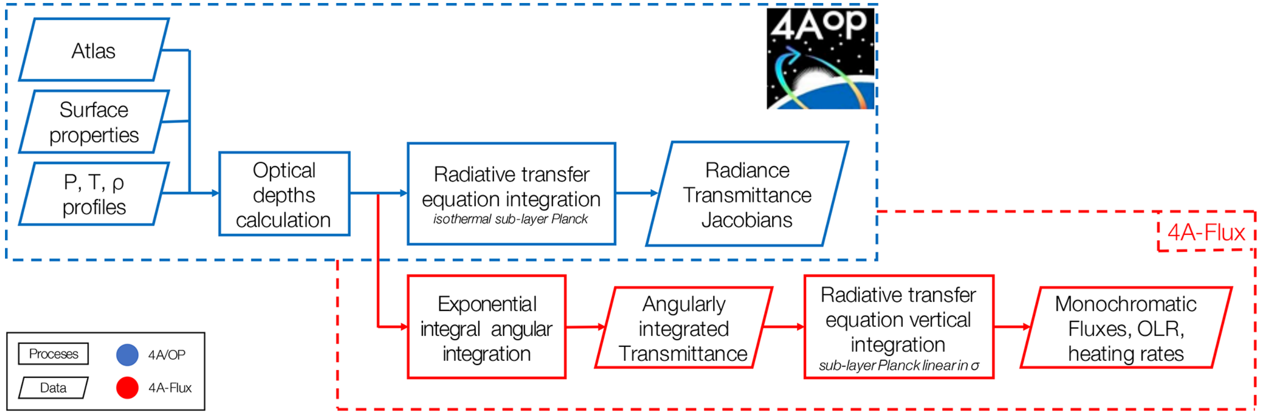
Challenges using IASI measurement to retrieve OLR and heating rate

- 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

4A/OP and 4A-flux radiative transfer codes

- This work relies on **4A/OP radiative transfert code** (Scott and Chédin 1981):
  - Fast line-by-line code based on atlases of optical depths
  - Reference code for the preparation and validation of IASI, IASI-NG, MicroCarb and Merlin at CNES
  - Can be used to simulate any instrument with any spectrosocpic database (here, use of latest edition of GEISA)

- A **4A-Flux module** has been included in 4A/OP:
  - to compute OLR and heating rates from any atmospheric situation.
  - Validated in RFMIP (Radiative Forcing Model Intercomparison Project) experiment.



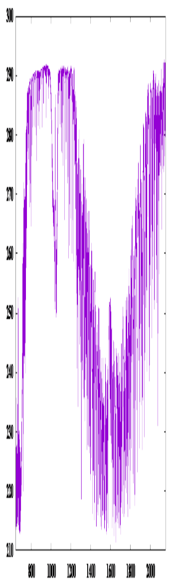
Tellier, Y., et al
Computation of longwave radiative flux and vertical heating rate with 4A-Flux v1.0 as an integral part of the radiative transfer code 4A/OP v1.5
Geosci. Model Dev., 2022

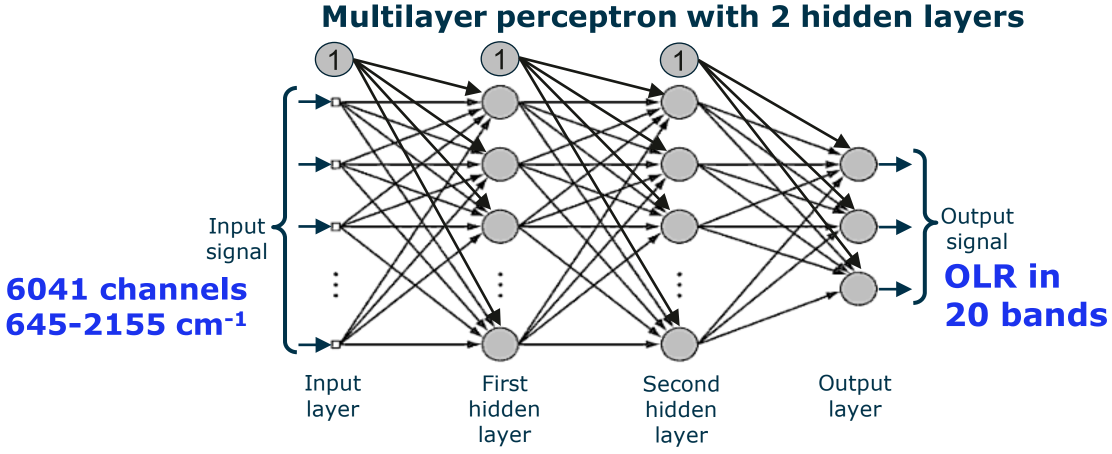
Pincus, et al.
Benchmark calculations of radiative forcing by greenhouse gases. *J. Geophys. Res. Atmos.*, 2020

Available at: https://4aop.aeris-data.fr/

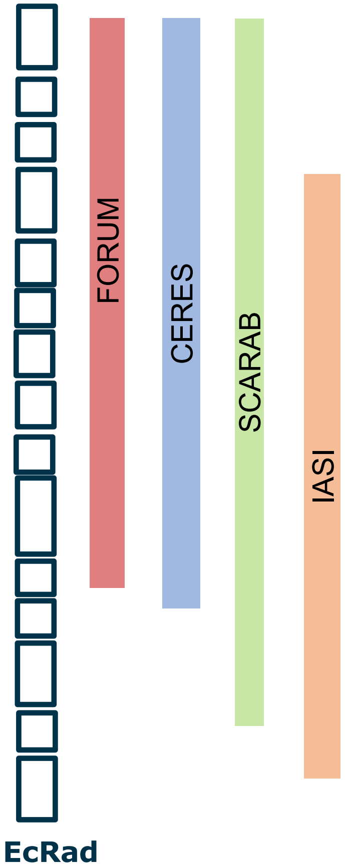
OLR retrieval in 20 spectral bands using neural networks

A suite of 30 Multilayer perceptrons has been trained using 4A/OP and the TIGR atmospheric database 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



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

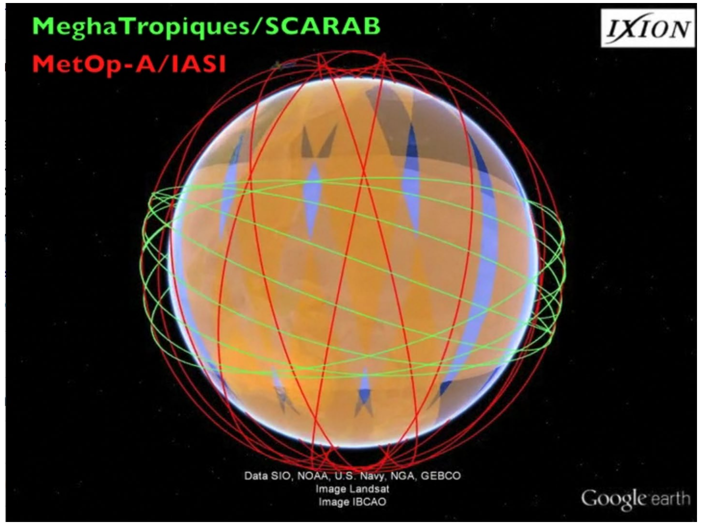
→ Computation time:

- 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…

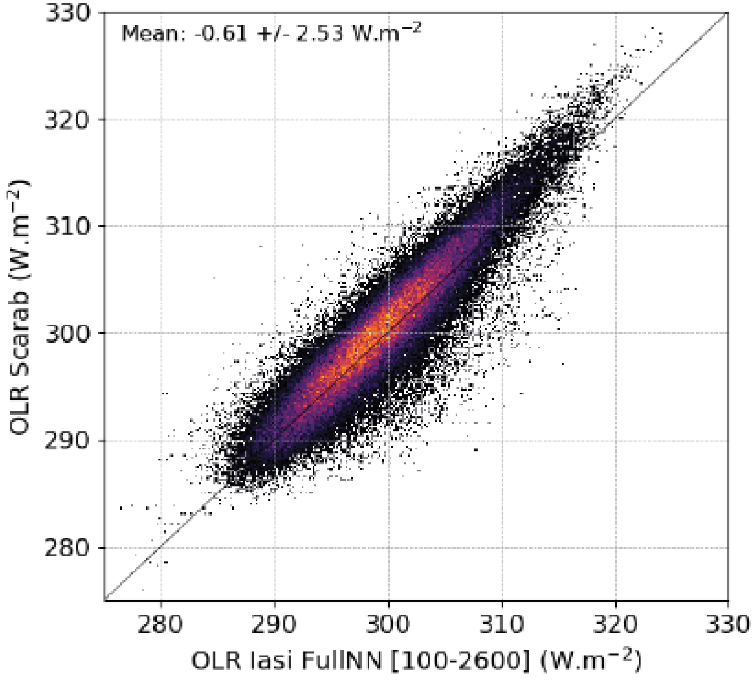
Validation of IASI OLR with SCARAB OLR

DATASET: 124988 collocated points IASI/Scarab for 2016.
Collocation criteria:

- Nearest neighbors
- Maximum distance: 25 km
- Maximum time shift: ± 3 h
- Close nadir observations only
- Tropical atmospheric type
- Ocean surface
- Clear-sky only
- Night only
- Instrument PSF not taken into account



SCARAB OLR vs. IASI OLR



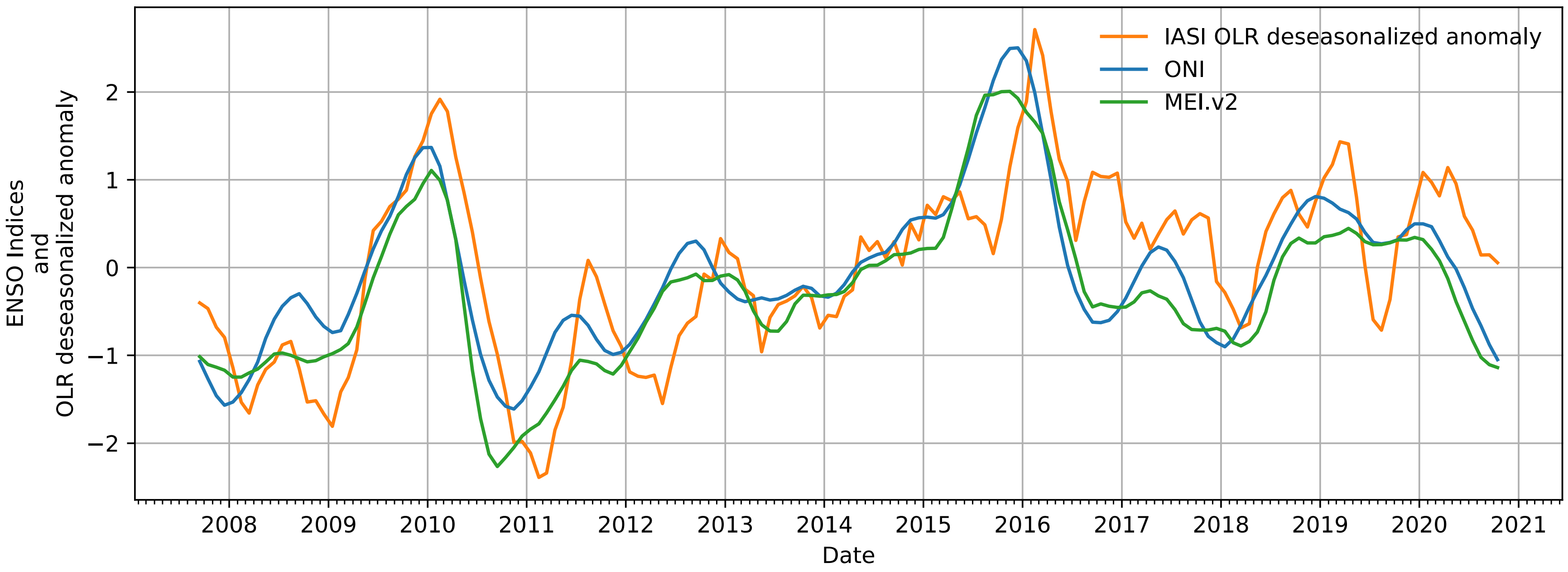
IASI-SCARAB OLR = -0.61 ± 2.53 W.m^{-2}

To be compared with:

OLR Bias and stdev. [Scarab–CERES] (*Roca et al., 2015*)	-0.74 ± 6.60 W. m^{-2}
OLR Stdev. [AIRS–CERES] for all scenes (*Sun et al., 2010*)	less than 3 W. m^{-2}

OLR anomaly from IASI and comparison with ENSO indexes

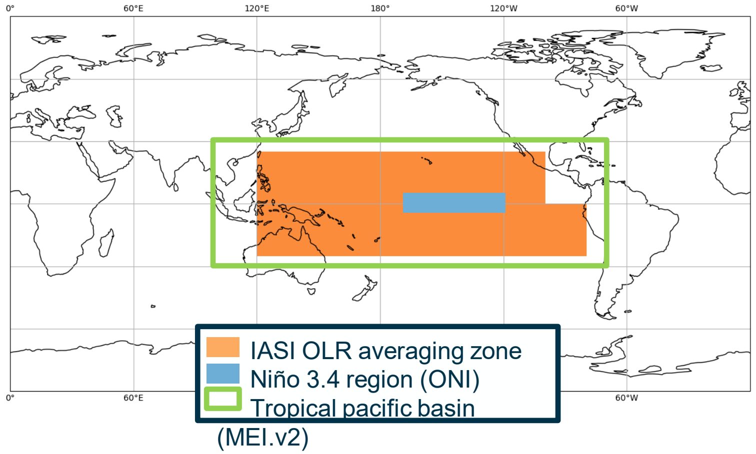
5 month moving average of the deseasonalised OLR anomalies over tropical Pacific



Reference ENSO indexes

ONI: Oceanic Niño Index SST in Niño 3.4 region

MEI.v2: Multivariate ENSO Index Version 2

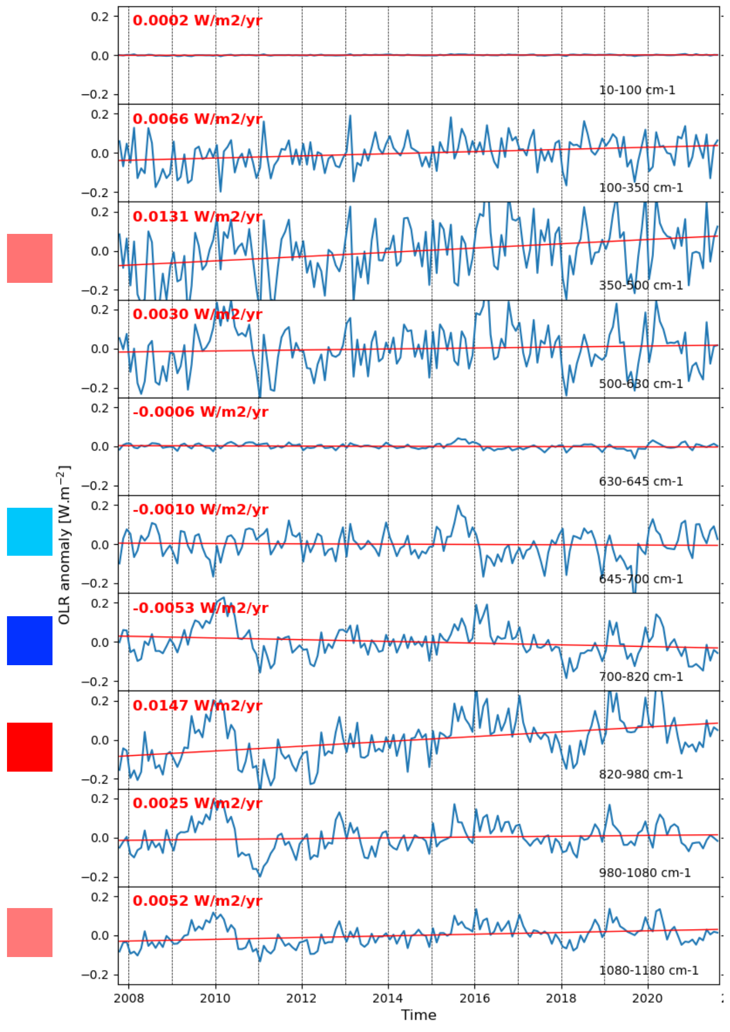


Preliminary Results:

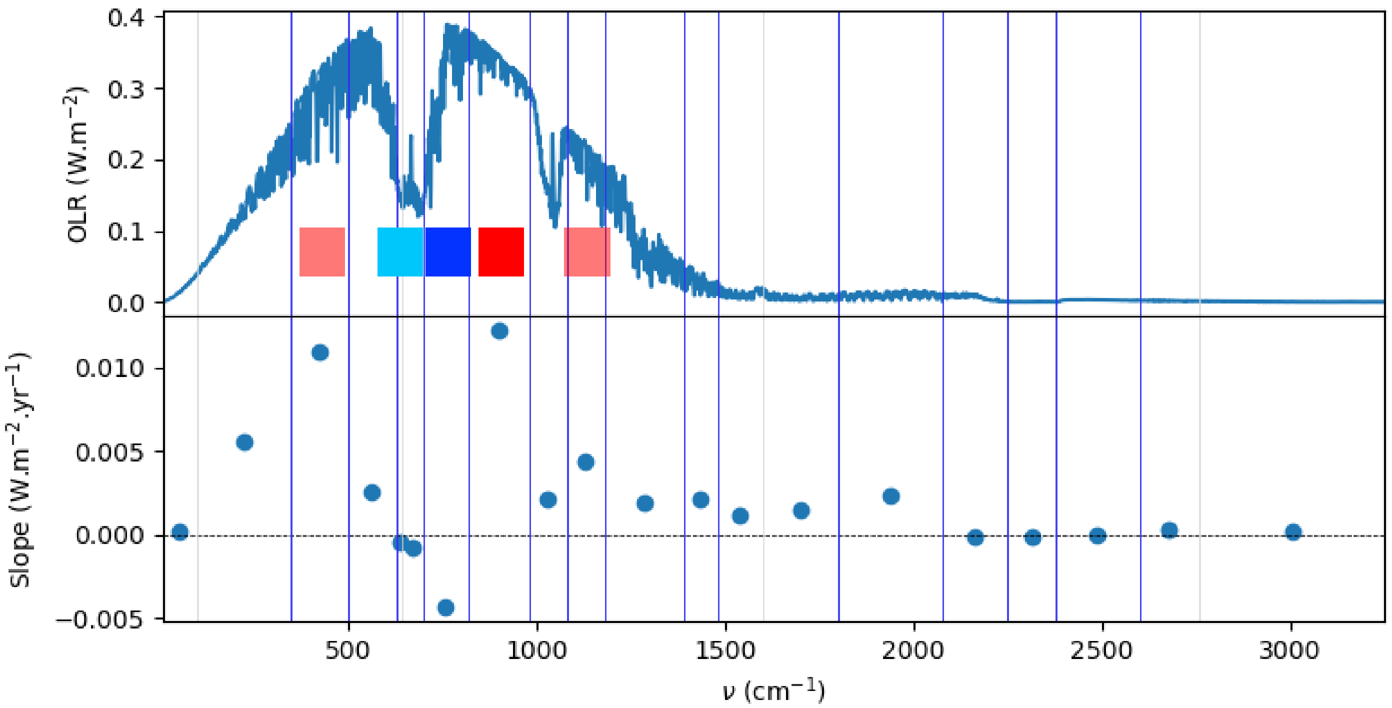
- IASI OLR anomaly follows expected climate variation
- Good correlation between the 3 datasets, even if some seasonal shifts
- El Niño events of 2009-2010 and 2015-2016 are well seen

IASI OLR trend over 17 years in the 20 targeted spectral bands

IASI OLR 2007-2021, Sea, tropical



Spectral OLR and slope over 2007-2021 for the 20 spectral bands

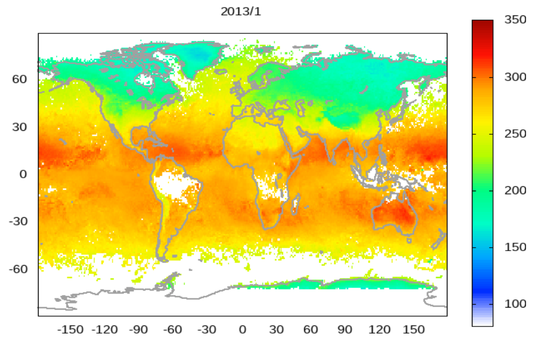


Over 2007-2021, IASI detects:

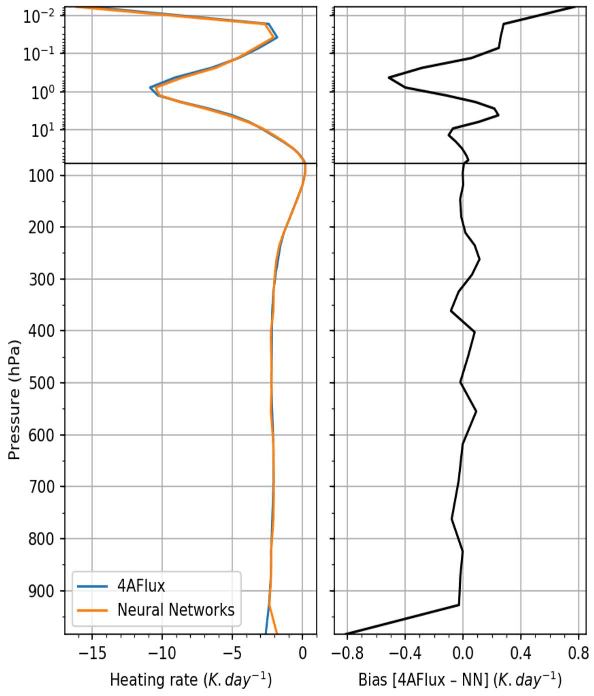
- Increase in the **window bands**, consistent with increase in SST
- Decrease in the **15µm band** (CO_2), consistent with increase in CO_2 concentration

Conclusion and perspetives

- A multi-layer perceptron (MLP) suite has been developed to estimate clear-sky OLR and vertical heating rates 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



First results on the retrieval of Heating Rate from IASI



Perspectives:

- Continue validation over land and sea, with other dataset (e.g. CERES)
- Improvement of the MLP method applied to the determination of the vertical heating rate
- Prepare the adaptation of the retrieval scheme to IASI-NG, IRS/MTG and FORUM instruments