Spectrally resolved OLR from IASI measurements

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What ?

Spectrally resolved Outgoing Longwave Radiation (OLR) derived from the measurements of the **IASI sounder**

- For clear-sky observations only
- At the spectral sampling of the instrument (0.25 cm^{-1}),
- Between 645 cm^{-1} and 2300 cm^{-1}

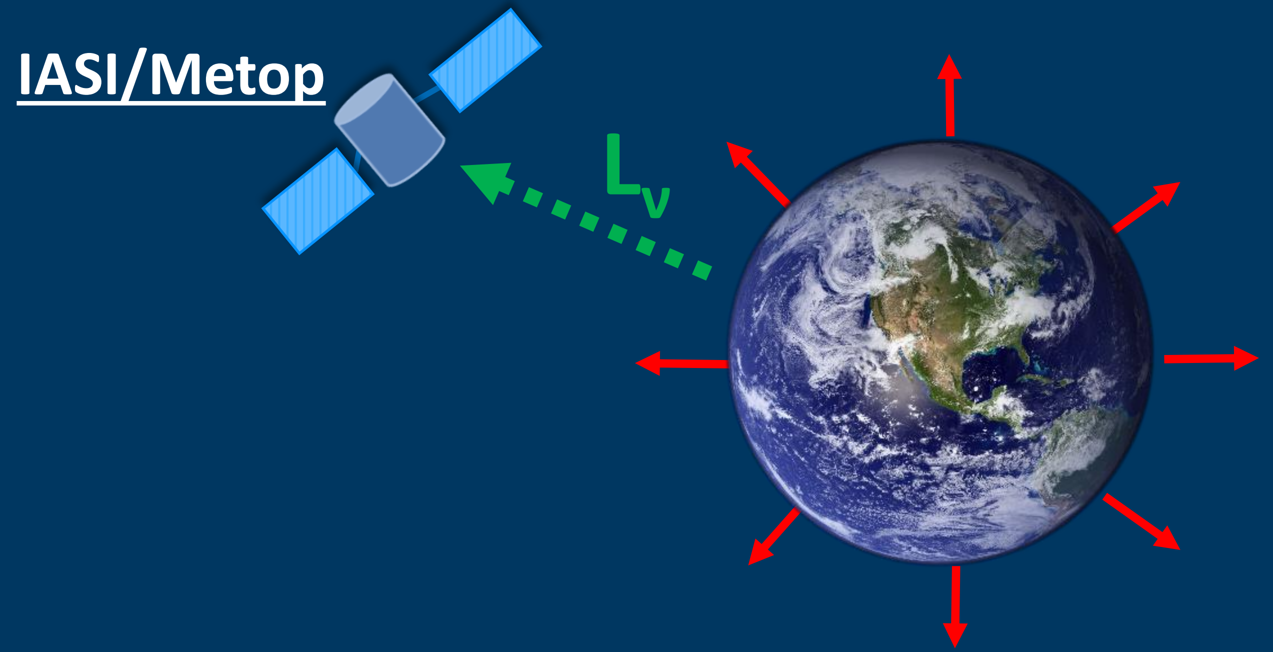
→ First time at such spectral resolution, with any instrument !

Why ?

1. Tracking the impact of parameters affecting OLR (e.g. greenhouse gases)
2. Identify deficiencies in climate models

Retrieval of the OLR from the radiance intensities

L_ν [W m^{-2} sr^{-1} (cm^{-1})$^{-1}$] → F_ν [W m^{-2} (cm^{-1})$^{-1}$]



$$F_\nu = 2\pi \int_0^{\pi/2} L_\nu(\theta)\, sin(\theta)\, cos(\theta)\, d\theta$$

θ = zenith angle direction

- IASI = single viewing angle direction (for a given scene)
  → Direct integration over all the angles direction θ not possible
- Anisotropy of the atmosphere taken into account through scene type dependent spectral correction factors $R_\nu(\theta)$:

$$F_\nu = \frac{\pi\, L_\nu(\theta)}{R_\nu(\theta)}$$

Method

$R_\nu(\theta)$ **depends on many surface and atmospheric parameters:**

Tskin, Tprof, ε_s, H_2O, CO_2, O_3, CO, CH_4, N_2O, …

1. **Key Step** - Construction of a *Look-up Table* (LUT) of $R_\nu(\theta)$
   - For a set of representative atmospheric and surface conditions (T_s, T_a, H_2O, O_3, CO_2, CH_4, N_2O, CO, ε_s; >100,000 different scenes in total)
   - From forward simulations using *Atmosphit*
   - For different viewing angles (θ)

2. Retrieval of the spectral OLR from IASI radiances by applying the right correction factor with the closest scene type.

$$F_\nu = \frac{\pi L_\nu(\theta)}{R_\nu(\theta)}$$

IASI-derived OLR retrieval algorithm

1. Building set of ADMs

CAMS 6-hourly
T, q, O_3, CO, CH_4 profiles

IASI/Metop
Emissivity (ε)

Dissimilarity-based subset selection →

CAMS 6-hourly
T, q, O_3, CO, CH_4 profiles

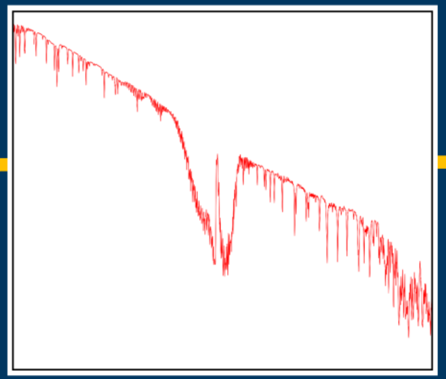
IASI ancillary data
Emissivity (ε)

CO_2: [380,400,420] ppm
N_2O: [320, 335] ppb

7 satellite angles θ

IASI spectra forward simulations

Atmosphit line-by-line radiative transfer model



$F_\nu \approx \sum_{i=1}^{n} \omega_i L_\nu(\cos(\Theta_i))$

$R_\nu(\Theta) = \frac{\pi L_\nu(\Theta)}{F_\nu}$

R LUT

Interpolation
- CO_2 and N_2O
- IASI angles

2. ADM-LUT OLR retrieval

IASI/Metop

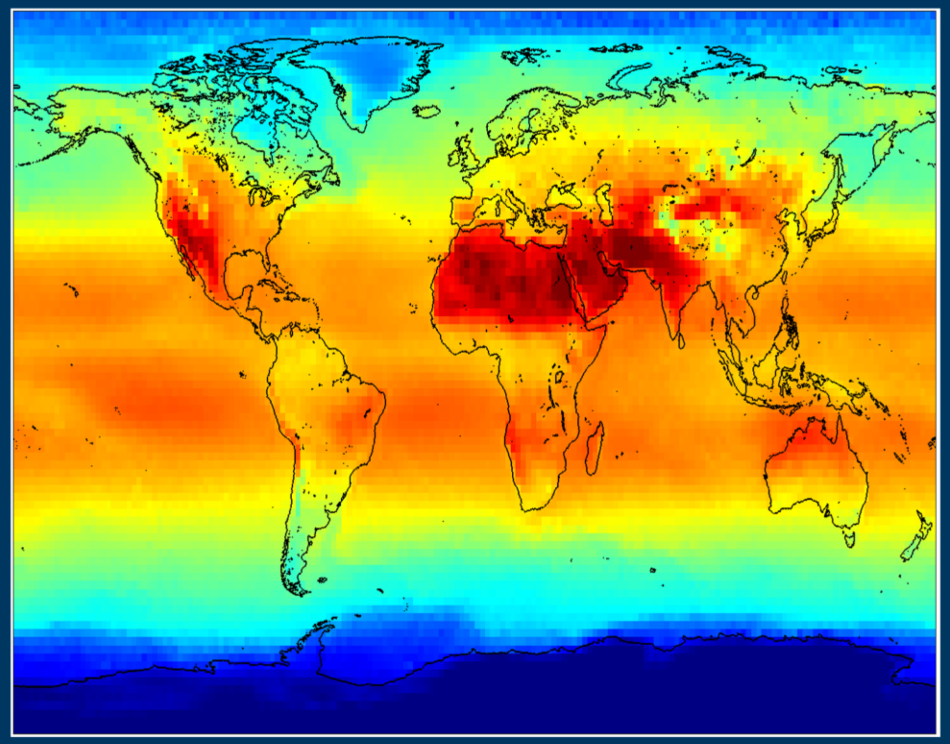
CAMS 6-hourly
T, q, O_3, CO, CH_4

EUMETSAT L1C (cloud free)
Lat, Lon, Time, SZA, L_ν

IASI ancillary data
Emissivity (ε)

Ancillary data
CO_2, N_2O

$$F_\nu = \frac{\pi L_\nu(\Theta)}{R_\nu(\Theta)}$$



Spectrally resolved fluxes from IASI data: Retrieval algorithm for clear-sky measurements

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Abstract | PDF

Abstract

Space-based measurements of the Outgoing Longwave Radiation (OLR) are essential for the study of the Earth's climate system. While the CERES instrument provides accurate measurements of this quantity, its measurements are not spectrally resolved. Here we present a high-resolution OLR product (sampled at 0.25 cm^{-1}), derived from measurements of the IASI satellite sounder. The applied methodology relies on pre-calculated Angular Dependent Models (ADMs). These are usually calculated for ten to hundreds of different scene types (characterized by surface and atmosphere parameters). To guarantee accurate results in the range 645-2300 cm^{-1} covered by IASI, we constructed ADMs for over 140,000 scenes. These were selected from one year of CAMS reanalysis data. A dissimilarity-based selection algorithm was applied to choose these scenes as different from each other as possible, thereby maximizing the performance on real data, whilst keeping the number of scenes manageable. A comparison of the IASI OLR integrated over the 645-2300

Method described in details in:

Whitburn et al. (2020) – JCLI

Applications

I. OLR TRENDS ANALYSIS

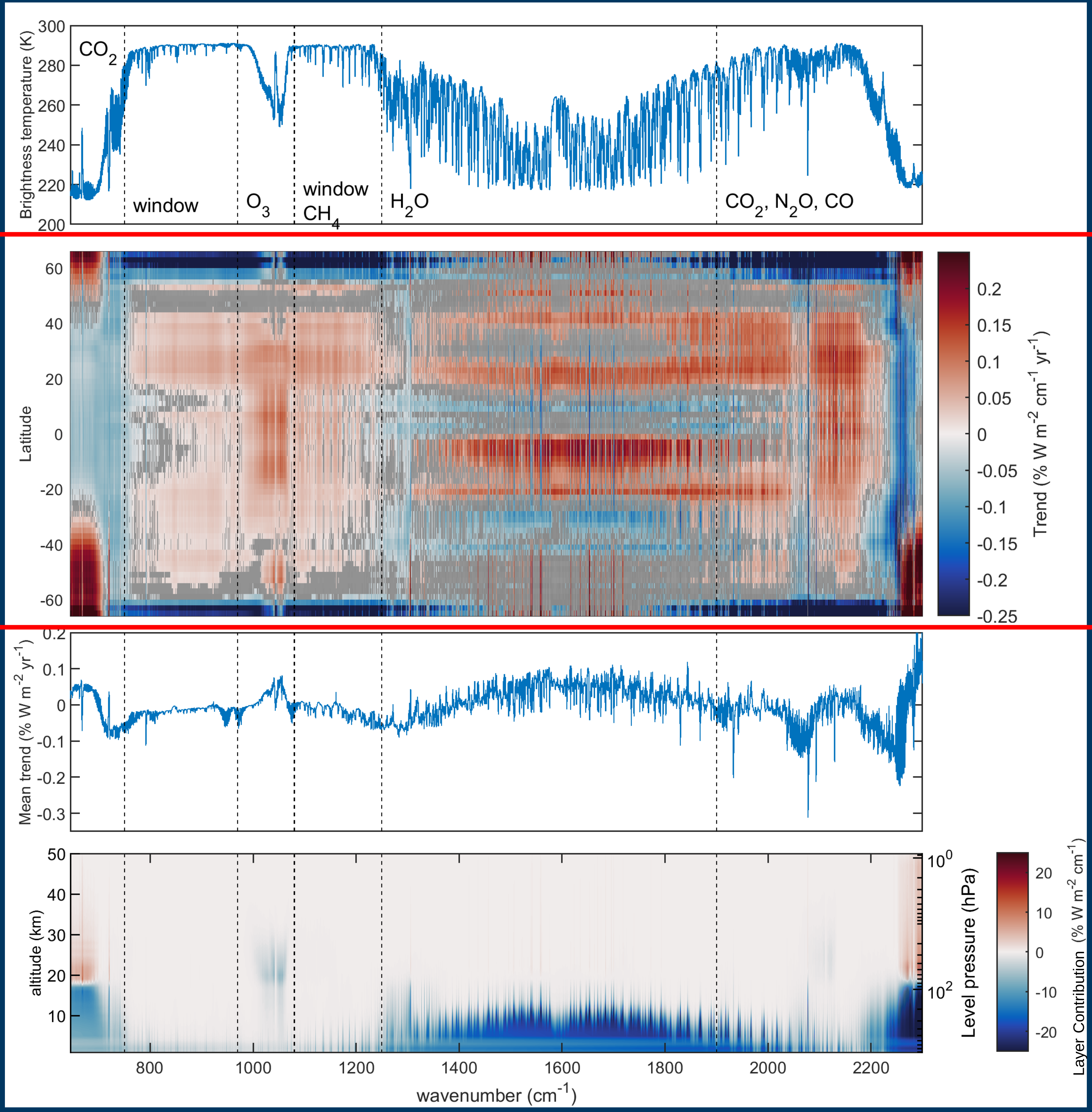
Long term variability

1. OLR trends calculated for all IASI channels between 645-2300 cm^{-1}

- From the daily mean OLR (2°x2° grid, daytime) …
- … Averaged per band of 2° of latitude
- Period: 2008-2017
- Sea measurements only
- Between 66°N and 66°S
- Using the bootstrap resampling analysis technique (*Gardiner et al. 2008*)

Preliminary results !

Example of IASI spectrum



Trends expressed in % W m^{-2} cm^{-1} yr^{-1} (normalized by the first year)
In gray, statistically non-significant trend

Trends averaged over all latitude bands

IASI channel layer contribution
= Altitude from which most radiation comes from.

Contribution of each layer expressed in % variations compared to the previous layer: $(L_{(i+1)}-L_i)/L_i*100$

Preliminary results !

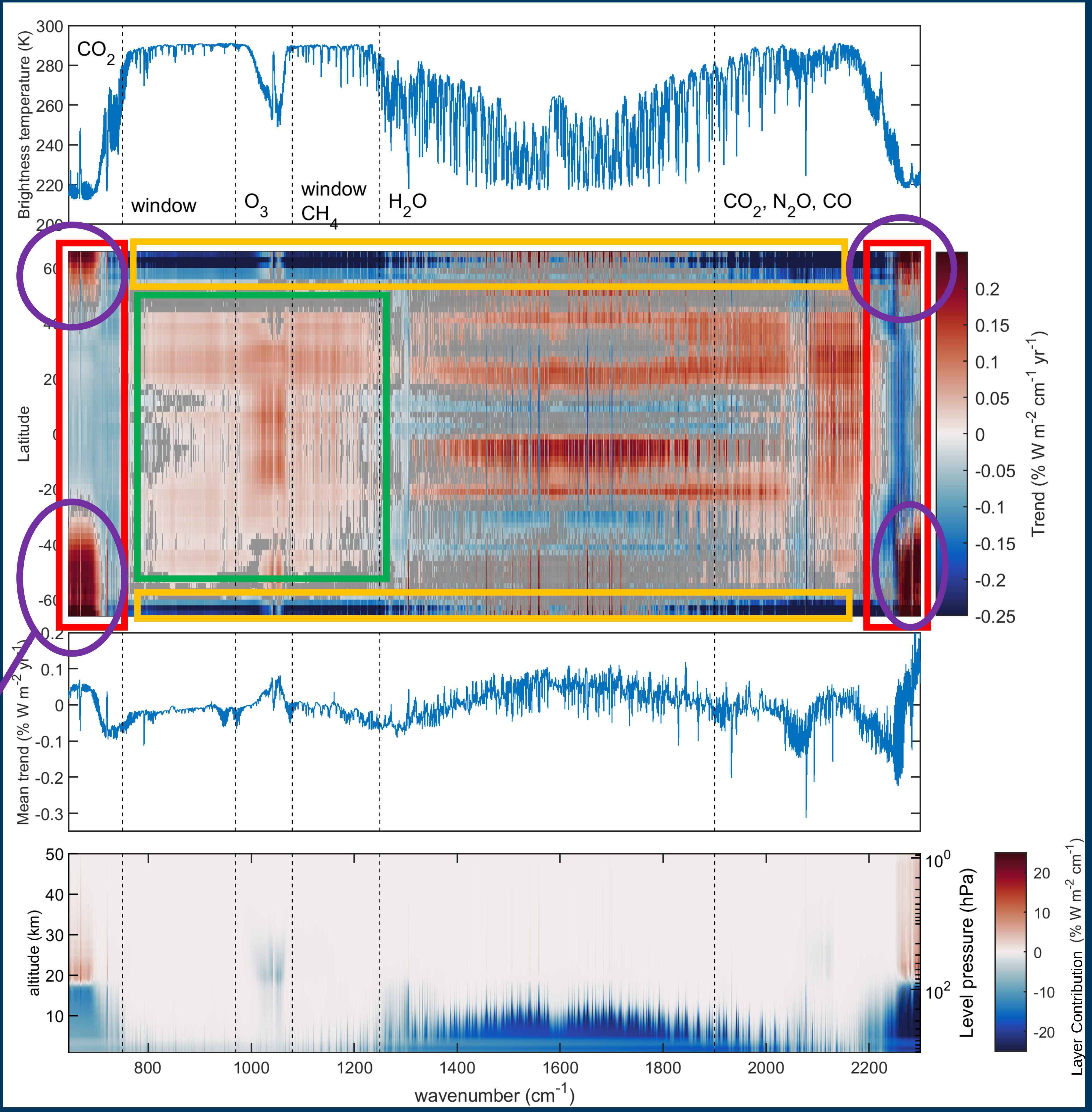
Positive trends in the region 800-1200 cm^{-1} due to the increase of surface temperatures

Negative trends in the OLR in the CO_2 absorption bands. Cooling of the stratosphere due to the increase of CO_2 concentrations.

Negative trends at high latitude. WHY? Further investigation needed. Reason?

- Lower number of observations available …
- … And higher variability in the OLR at high latitude → period too short?
- Bad cloud detection?
- For the NH, negative trend related to the North Atlantic Warming Hole (Cold Blob) ? (see also slide 12)

Positive trend due to ??
Warming of upper troposphere
at high latitudes ?

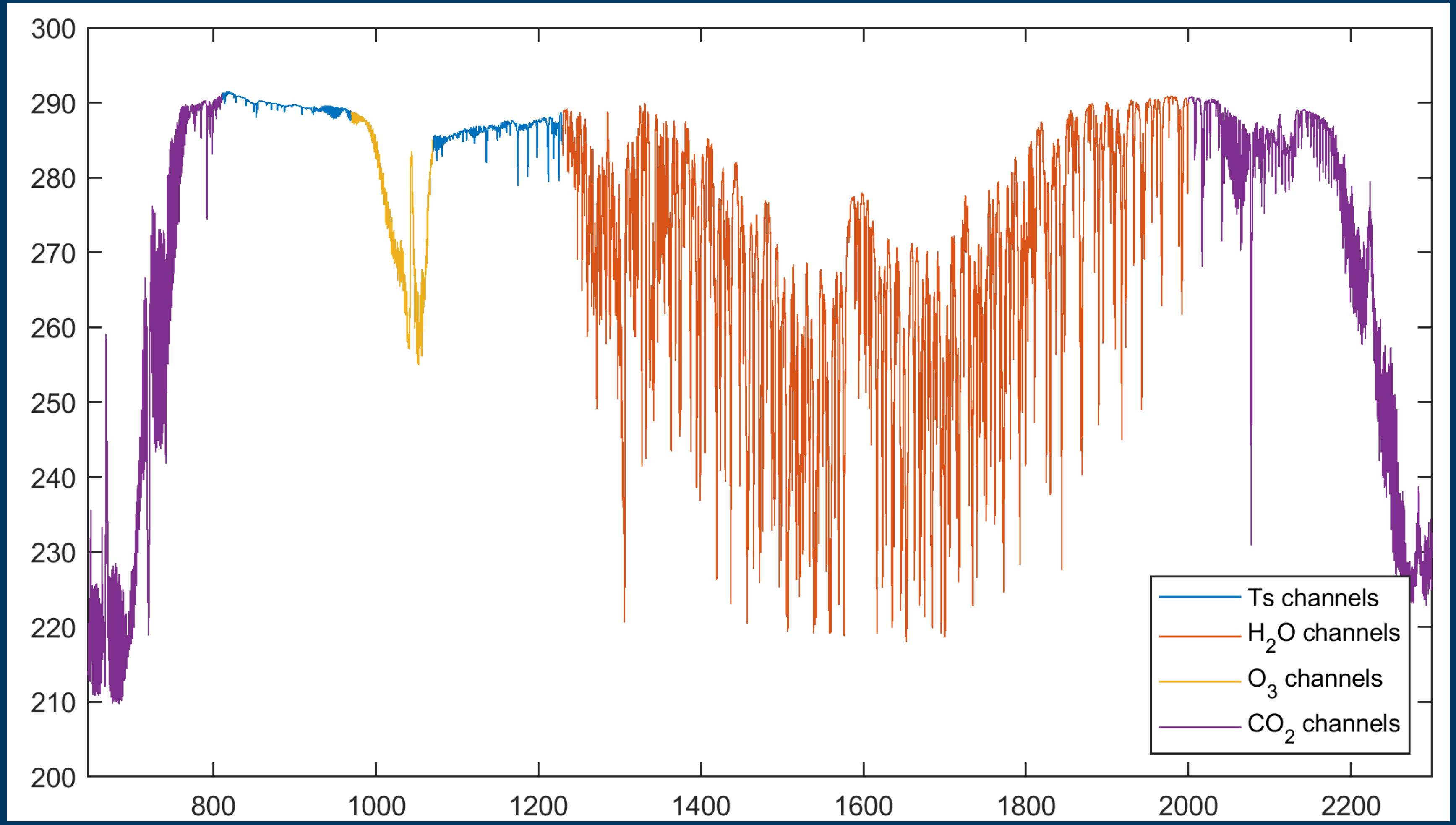


Deeper analysis required

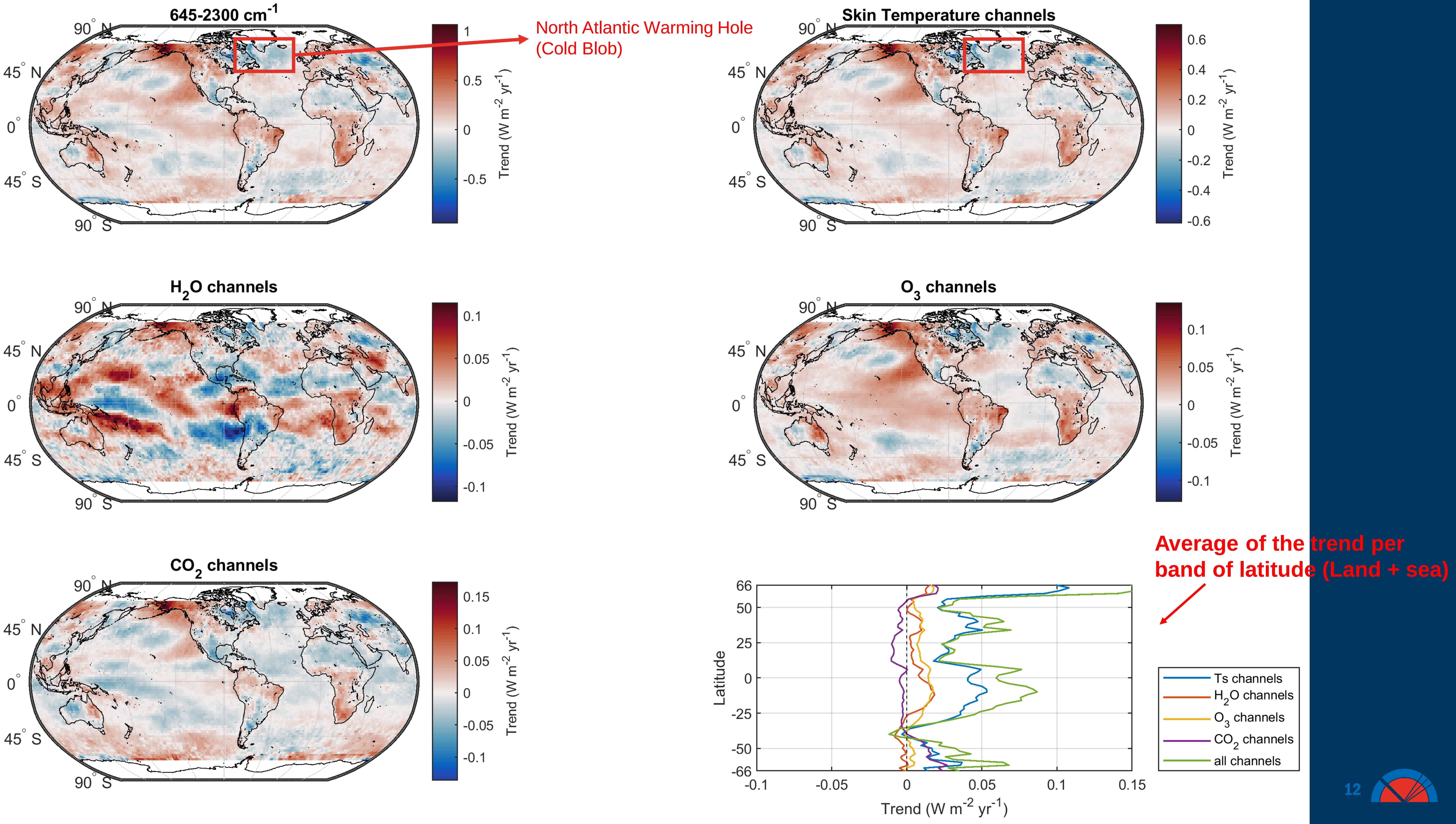
2. OLR trends for integrated spectral bands

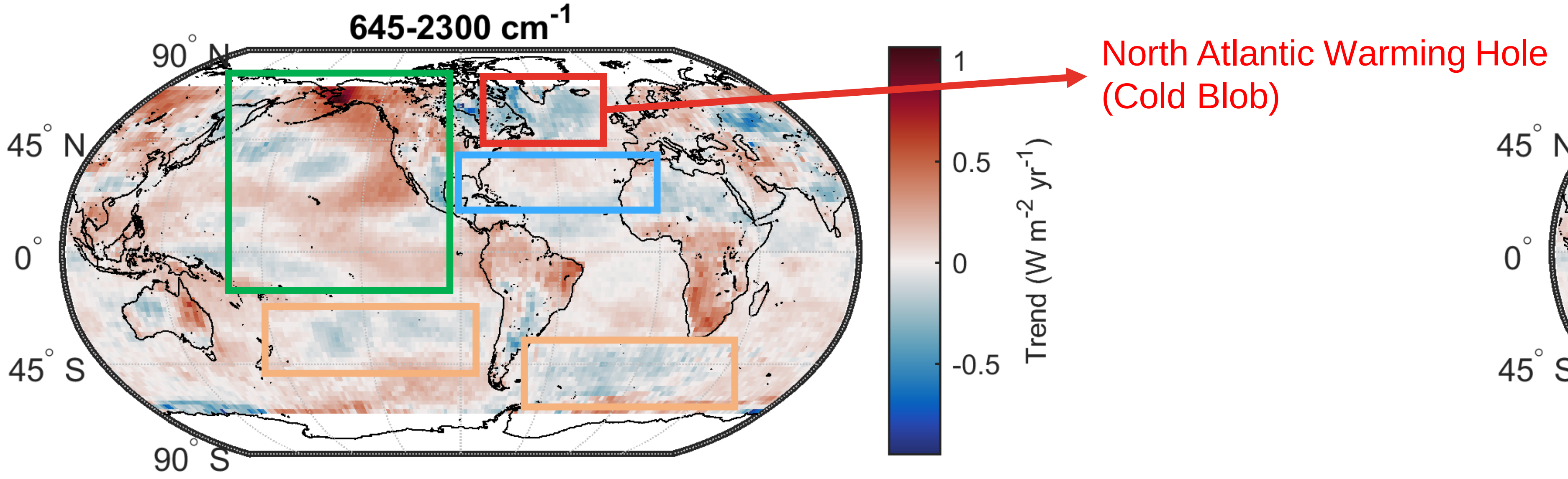
Preparation: Channel selection

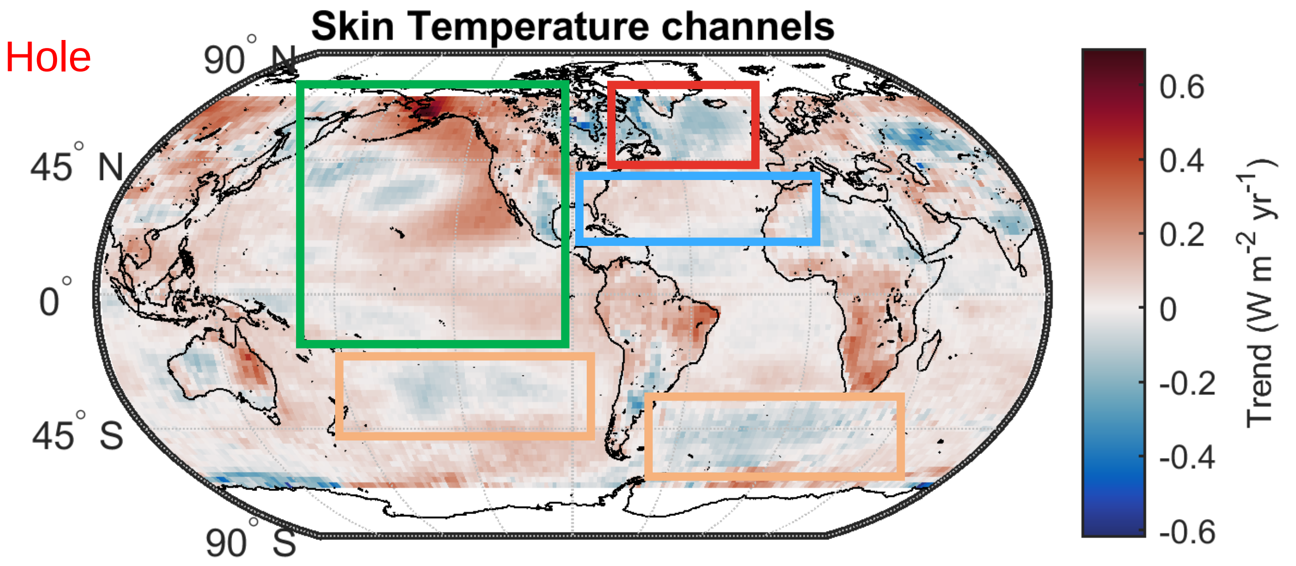
- IASI channels (in the range 645:2300 cm^{-1}) divided in 5 groups:
  - CO_2: 645→810 & 2000→2300 cm^{-1}
  - Ts: 810→970 & 1070→1230 cm^{-1}
  - H_2O: 1230→2000 cm^{-1}
  - O_3: 970→1070 cm^{-1}
  - ALL: 645→2300 cm^{-1}

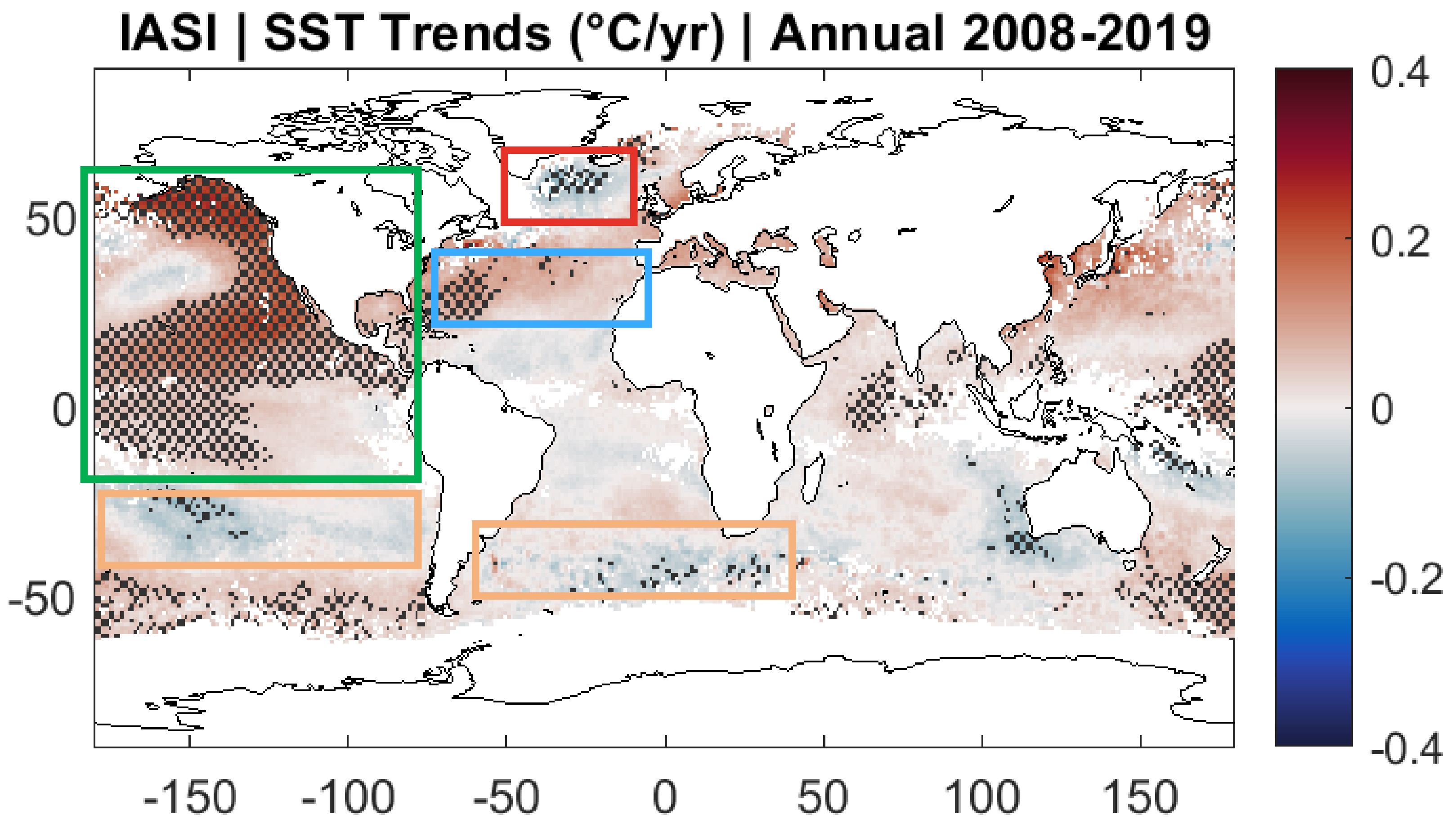


- Trends
  - From the **daily mean** OLR (2°x2° grid)
  - Period: 2008→2017
  - **Daytime** measurements
  - Between 66°N and 66°S
  - Using the **bootstrap resampling trend** analysis (*Gardiner et al. 2008*)


645-2300 cm^{-1}
North Atlantic Warming Hole
(Cold Blob)
Skin Temperature channels
H_2O channels
O_3 channels
CO_2 channels
Trend ($W\,m^{-2}\,yr^{-1}$)
90° N
45° N
0°
45° S
90° S
Average of the trend per band of latitude (Land + sea)
Latitude
Trend ($W\,m^{-2}\,yr^{-1}$)
Ts channels
H_2O channels
O_3 channels
CO_2 channels
all channels







<u>For comparison:</u> SST trends derived from IASI (figure from Parracho et al. 2020 – under review). Same main patterns observed.

Applications

II. INTERANNUAL VARIABILITY

Climate factors

Preliminary results !

EOF analysis (Empirical Orthogonal Function)

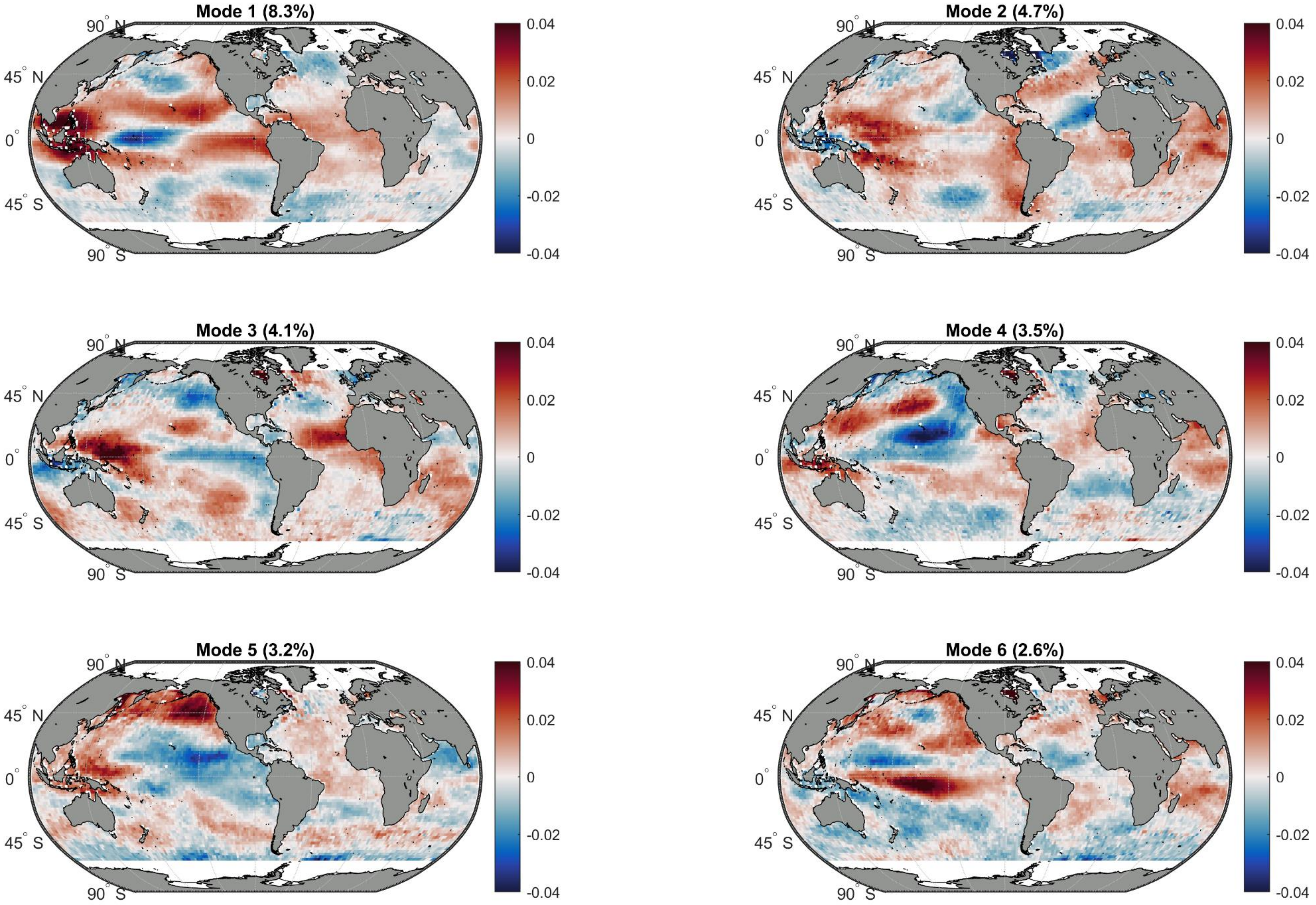
Calculation of the eigenmode maps of variability and corresponding principal component time series.

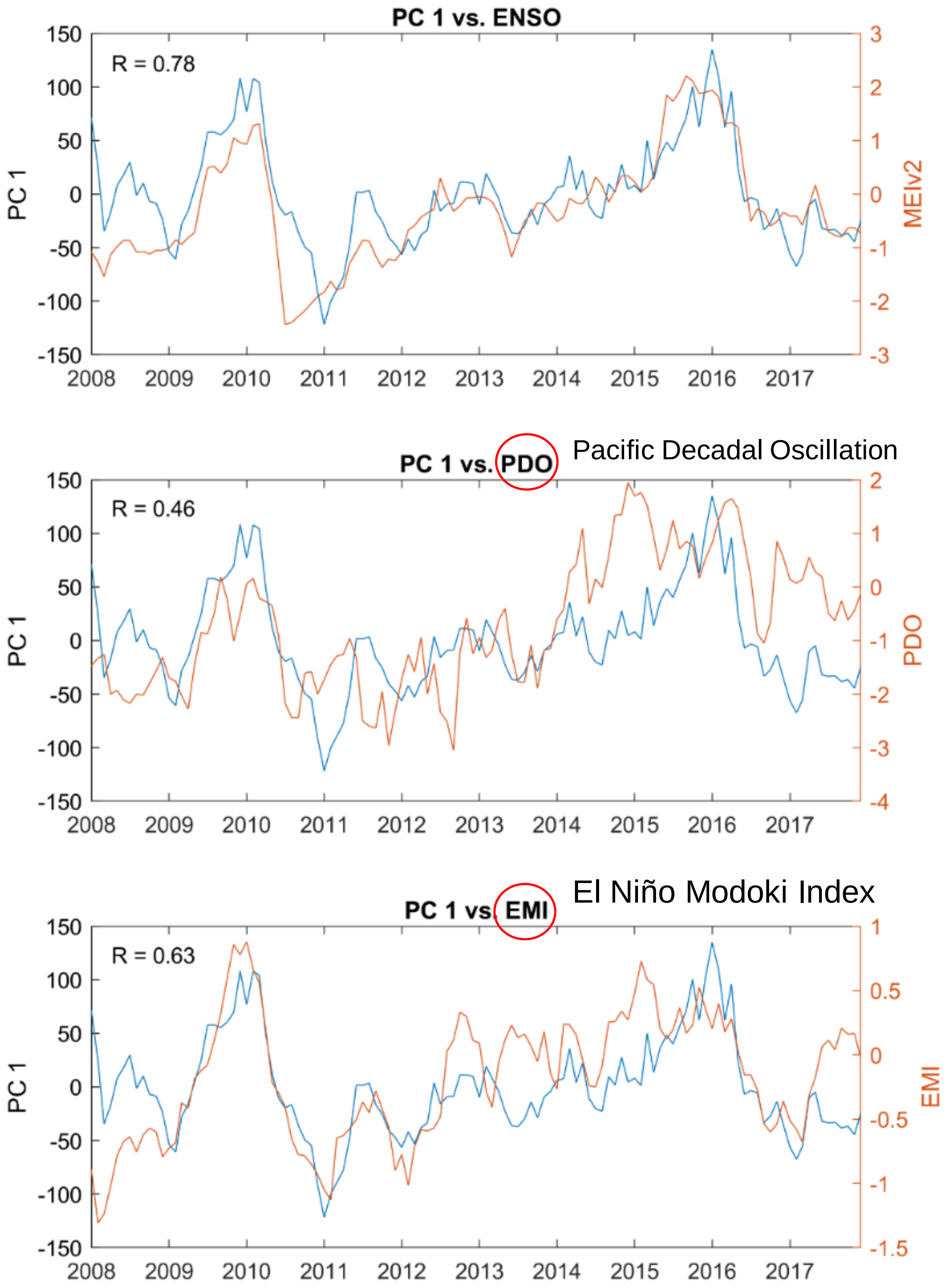
- From the **daily mean** OLR (2008→2017)
- **Daytime** measurements gridded per 2° by 2°
- **Deseasonalized** and **detrended** data
- Over **integrated spectral bands** (T_s, H_2O, 645-2300 cm^{-1} spectral range)

WHY ?

- Identify the climate phenomena that influence the most the interannual variability.
- Are these phenomena independant or intercorrelated?
- Are the EOFs and normal modes similar if we look at small regions? What is the explained variability in smaller regions? How these climate factors are affecting the OLR in the tropics, atlantic ocean, etc.

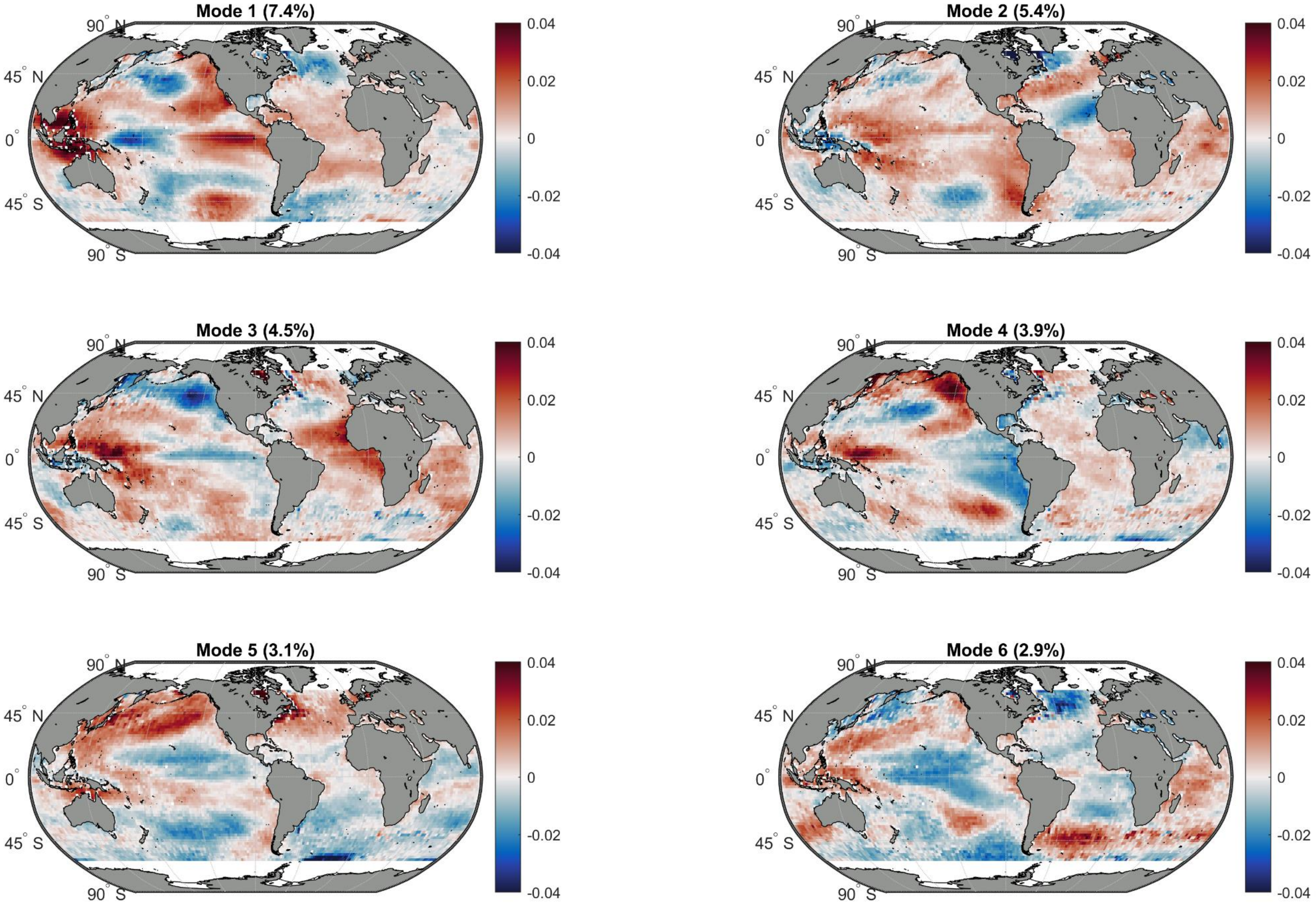
DAY - 645 – 2300 cm^{-1}

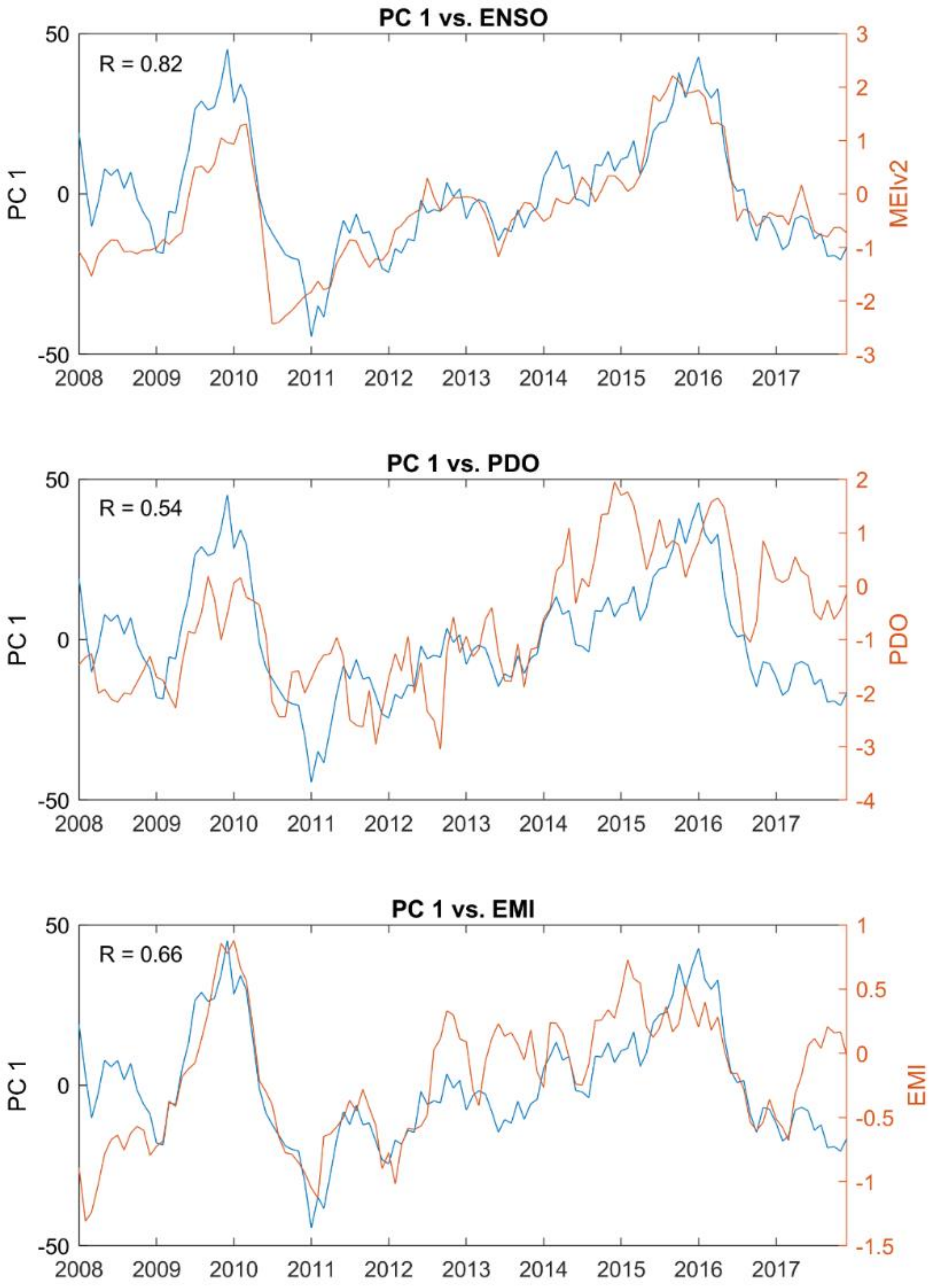




- 8.3% of the variability in OLR globally = ENSO (+ PDO)
- ENSO and PDO correlated in the period 2008-2017

DAY - Skin Temperature channels





Very similar to the one calculated from the 645-2300 cm^{-1} range for the 4 first modes.

DAY - H_2O channels