Multi-scale analysis of atmospheric and oceanic pCO_2 time series and of their difference

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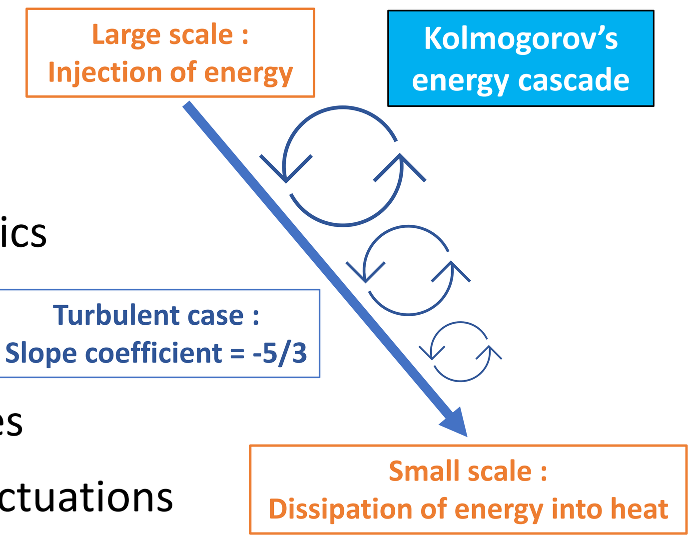
Introduction: pCO_2 dynamics in a turbulent context

pCO_2 dynamics

- ➔ The ocean plays a key role for pCO_2 dynamics (source/sink of CO_2)
- ➔ CO_2 is exchanged between the ocean and the atmosphere (biological & physical pumps)[1]
- ➔ pCO_2 is usually observed at large temporal scale (trends…) → here we look at the multi-scale dynamics

Turbulence and spectral analysis

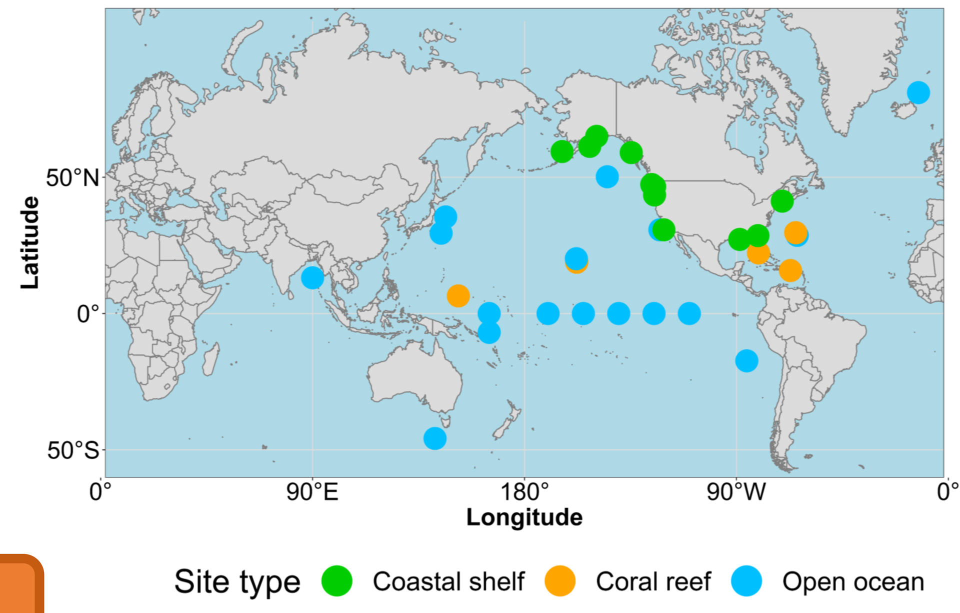
- ➔ Spectral analysis allows to look at the dynamics of the energy between largest scales and finest scales
- ➔ Turbulence linked to different problematics: melt in the ocean; strong, unpredictable and chaotic fluctuations
- ➔ Kolmogorov theory (1941): a passive scalar in turbulent flows showing a spectral slope equal to -5/3
- ➔ A deviation from -5/3 value may implies a biological or chemical activity (active scalar of the turbulence)[2, 3]



Materials & Methods

Data source

- ➔ Data source: Sutton et al., 2019 (ESSD) → SST, SSS, oceanic and atmospheric pCO_2 from 40 fixed buoys (only 38 used here)[4]
- ➔ In the Pacific, Indian, Southern and Atlantic oceans; classified into 3 types: open ocean, coastal shelf and coral reef sites
- ➔ Sampling frequency: 3 hours
- ➔ Optical sensor (based on infrared absorption by the air)[5]



Fourier spectral analysis

- ➔ Theorem of Wiener-Khintchine : the Fourier transform of the autocorrelation function of the signal gives the Fourier spectral density spectrum of the same signal

Calculation of autocorrelation function A(x) from the basic signal x(t) ▶ Calculation of the Fourier transform of A(x) ▶ Log-log representation of the spectrum (log10) ▶ Calculation of the spectral slope (mean squared method)

Find the data here

Conclusions & Perspectives

- ➔ pCO_2 act as a passive scalar of turbulence → role of biology and chemistry
- ➔ $pCO_{2\ sw}$ is less active than $pCO_{2\ air}$
- ➔ ΔpCO_2 depends more of $pCO_{2\ sw}$ than $pCO_{2\ air}$ ones → activities of $pCO_{2\ sw}$ and ΔpCO_2 are similar
- ➔ Intermittency will be studied with EMD-HSA method next for some buoys[10]

Aknowledgements

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References

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Results & Discussions

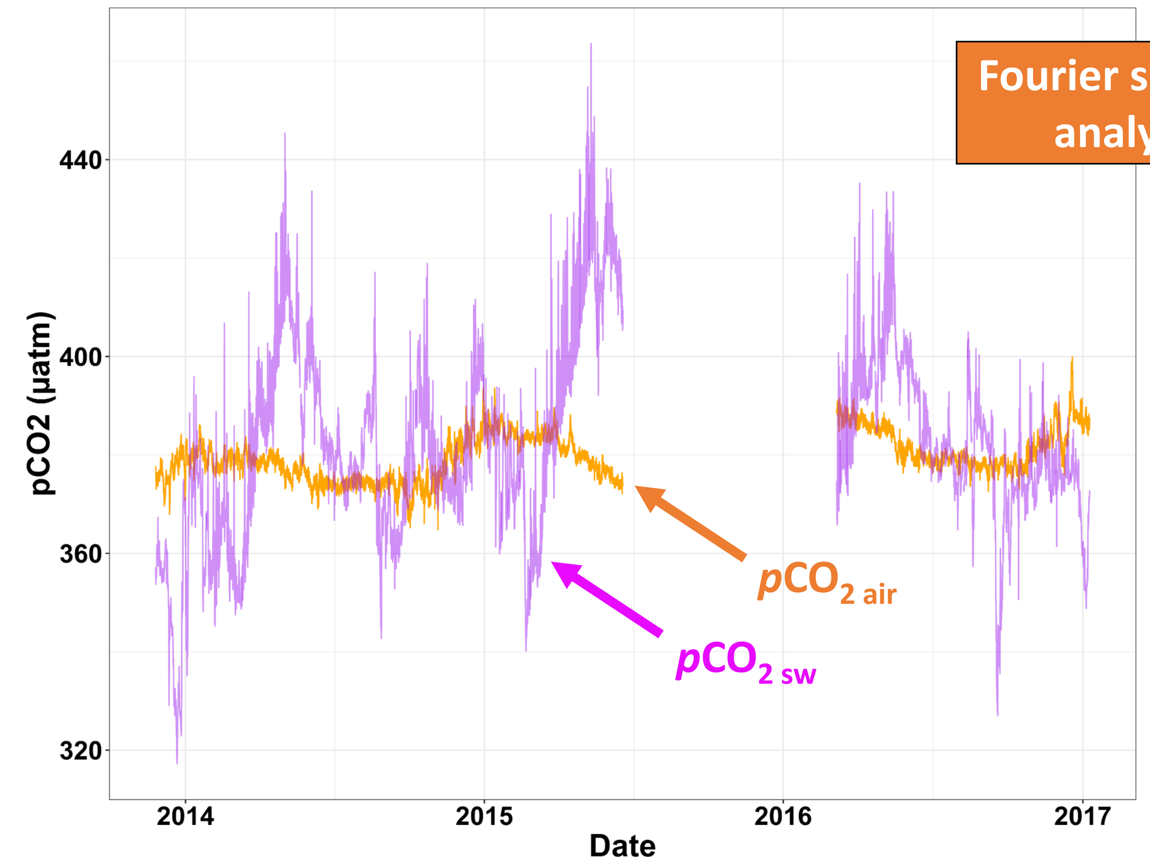

Figure 1: *Oceanic (purple) and atmospheric (orange) pCO_2 data from BOBOA buoy (Bengal Bay, Indian Ocean).*

Fourier spectral analysis

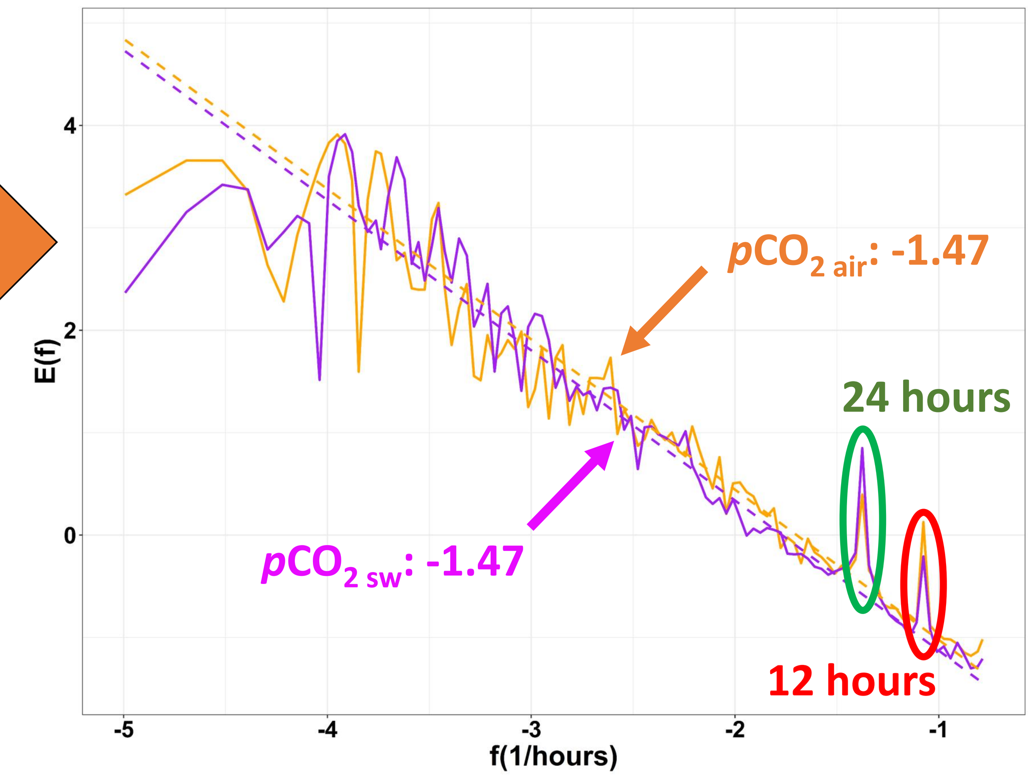

Figure 2: *Averaged oceanic (purple) and atmospheric (orange) pCO_2 Fourier power density spectrum (data from BOBOA buoy, Bengal Bay, Indian Ocean).*

- ➔ $pCO_{2\ sw}$ fluctuates more than $pCO_{2\ air}$ (fig.1)
- ➔ Visible periodicities of 12 hours (possibly tidal cycle) and 24 hours (daily cycle; fig.2)

Extraction of coefficients

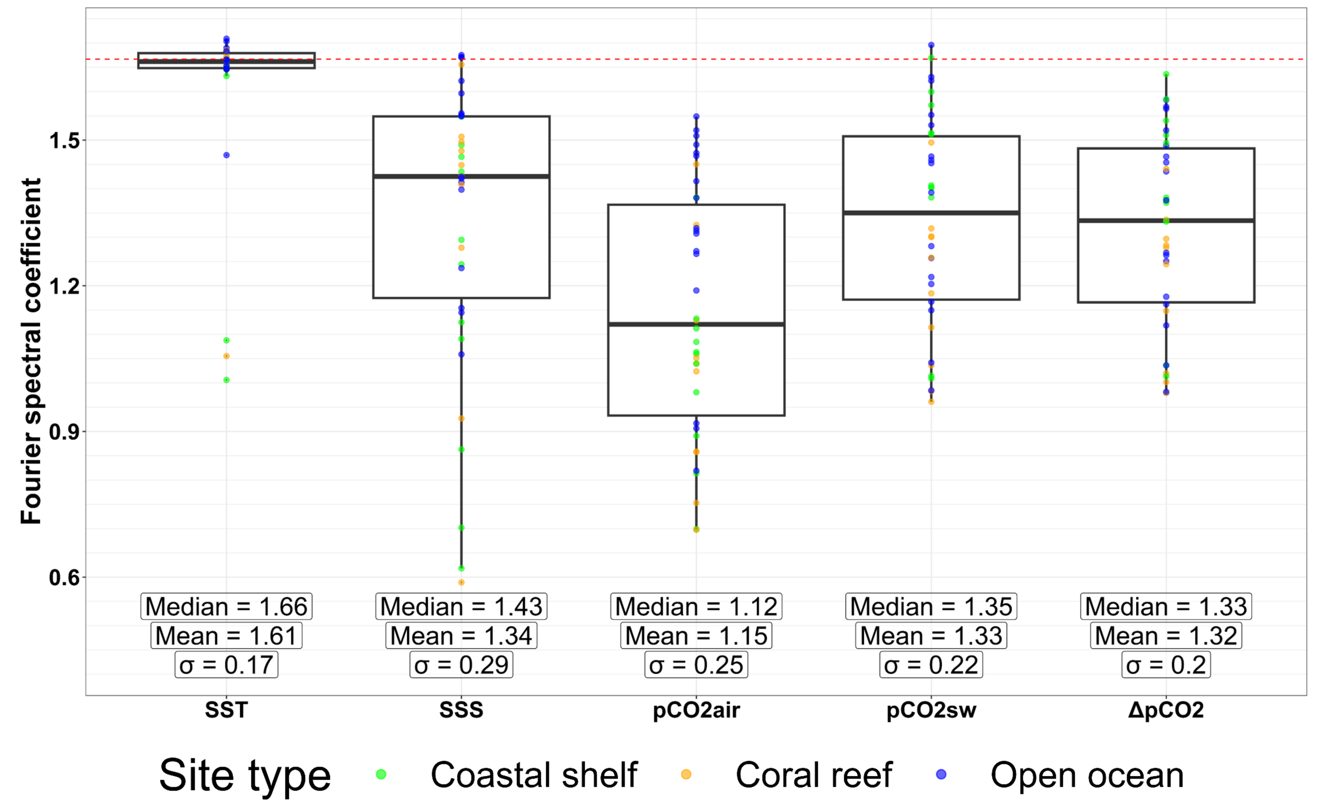

Figure 3: *Boxplots of the different scalars for all the different sites. Point colour depending on the classification made by Sutton et al. (2019). The 5/3 value is represented by a dashed red line.*

- ➔ SST = passive scalar of the turbulence (near to the value 5/3); SSS and pCO_2 = active scalars of the turbulence (fig.3)
- ➔ SSS, $pCO_{2\ sw}$ and ΔpCO_2 boxplots look similar (means of 1.34, 1.33 and 1.32; fig.3) → due to the marine dynamics
- ➔ $pCO_{2\ air}$ is the more active scalar (mean of 1.15) and is less active for open ocean sites than the others (fig.3)
- ➔ Pattern of $pCO_{2\ air}$ activity along the American coasts (more active; fig.4) → **anthropogenic activity ? Terrestrial biology activity ?**[6]
- ➔ Gradient of activity for active scalars along the Pacific from the East (less active) to the West (more active; fig.4) → **effect of upwelling/rain ?**[7, 8, 9]

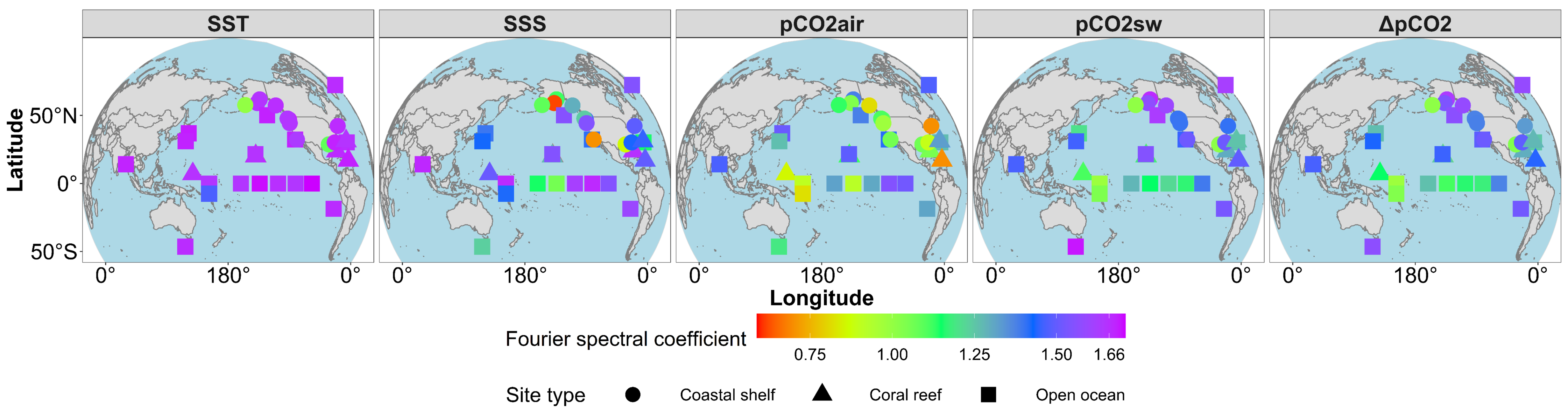

Figure 4: *Map representation of the different Fourier spectral coefficients. The point shape depending on the classification made by Sutton et al. (2019).*