General methodology for the derivation of high resolution oceanic data through information fusion at different scales

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Abstract

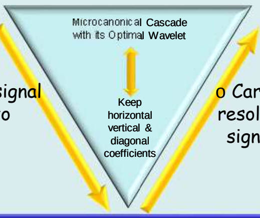
Derivation of high-resolution (HR) spatial distribution of data is a fundamental problem in Earth Observation. The problem can be solved through **information fusion at different scales**.

- New method based on an **approximation of the energy of Microcanonical Cascade (MC)**, expressed in a **Multiscale Microcanonical Formulation (MMF)**, for physical intensive variables of Fully Developed Turbulence (FDT) encountered in satellite Oceanography and Ocean/Climate interactions.
- The **generality of the approach** offers the opportunity to infer different oceanic turbulent signals from Low Resolution (LR) to HR. Basic idea:
  - **optimal cascading** to decrease the spatial resolution of the HR signal,
  - use the signal available at LR, **transmit that information along the scales back** to higher spatial resolution using the cascade to obtain a new HR signal.
- The process has been successfully used **to obtain oceanic currents** [1,2], **oceanic partial pressure of CO_2** [3].
- **Extension to many Essential Climate Variables** both in the ocean and atmosphere critical for characterizing Earth's climate and its changes.

1 General concept of the MMF/MC method

HR Signal with FDT

o Obtain a relevant signal with SST and MMF to carry through the resolution (descent)

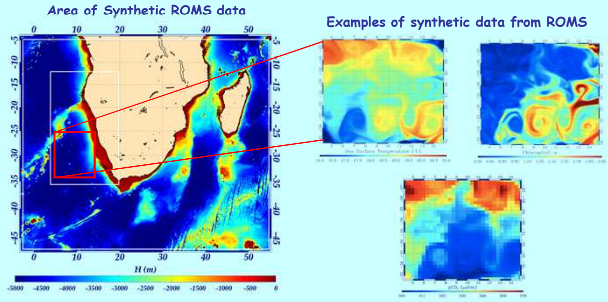


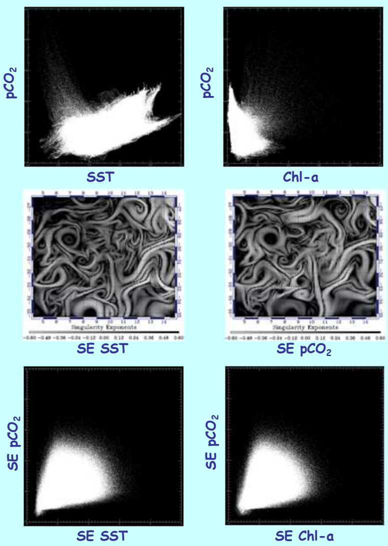
New HR inferred signal

o Carry back through the resolution (ascent) a new signal only known at LR

Replace the approximation of the signal by LR Information to make the inference

2 Relationship between the different oceanic signals: To use the general concept (1), we need to verify the « linearity » between HR and LR signals.





The properties diagrams using 10 years of ROMS data : Complex relationship between the different data.

Cannot use directly the data to apply the method described in (1)

Compute the Singularity Exponents (SE) of each signal by using a functional.

SE corresponds to h(x) in the functional:

$$\mathbb{T}_r(s)(\mathbf{x}) = \alpha(\mathbf{x})\, r^{h(\mathbf{x})} + o(r^{h(\mathbf{x})})\ (r \to 0)$$

The properties diagrams using 10 years of singularity exponents of ROMS data : series of linear relationship

Use the SE of oceanographic data to apply the method described in (1)

Method to obtain HR pCO_2 using HR SST, HR Chl-a, LR pCO_2

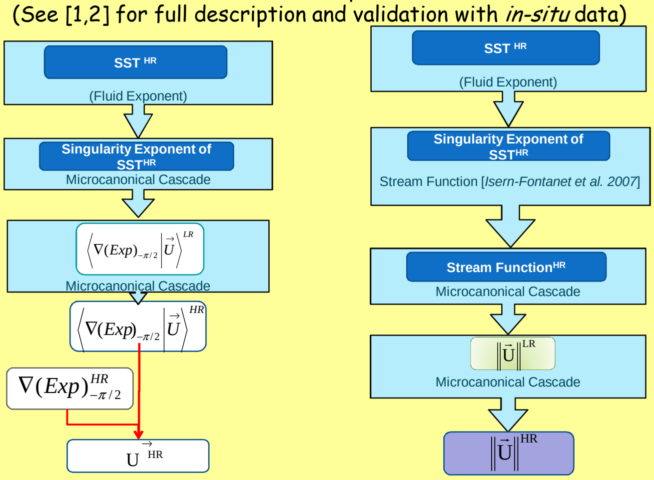
1) $A(x)\ SE\_SST_{HR}(x,t) + B(x)\ SE\_Chl_{HR}(x,t) + C(x)\ SE\_pCO_{2LR}(x,t) + D(x) = Proxy[SE\_pCO_{2HR}(x,t)]$

   A(x),B(x),C(x), D(x): coefficients of the multi-linear regression computed using Roms data

2) Apply the general concept to the Proxy[$SE\_pCO_{2HR}(x,t)$] :
   For each time t, compute SE of satellite data,
   Injection in the multi-linear regression above to obtain the Proxy[$SE\_pCO_{2HR}(x,t)$]
   Use the proxy as « HR signal with FDT », and the pCO_{2LR} replace the approximation coefficients in the general concept.

This method is fully described and validated with *in-situ* data in [3].

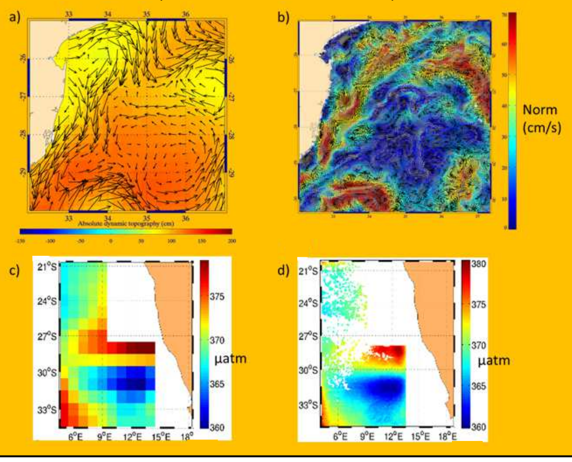
3 To obtain Oceanic current at HR : Separation of Norm and Direction (See [1,2] for full description and validation with *in-situ* data)



Direction Algorithm

Norm Algorithm

4 Examples of data obtained by the MMF/MC method



Maps of :

a) absolute dynamic topography at 1/4° and the LR current (geostrophic and Ekman components) associated

b) inferred HR current at 1/24° [1,2]

c) LR ocean pCO_2 from Carbon Tracker at 1°

d) inferred HR pCO_2 at 1/32° [3]

Conclusion and Future Work

- **Evidencing multiscale geometric structures in synthetic ROMS data and satellite data data through the Multiscale Microcanonical Formalism**
- **Validation of algorithms on synthetic ROMS data**
- **Application of the algorithms on satellite data**
- **Validation of the new HR satellite data with *in-situ* data**
- **Future Work: Application of this general method for Altimetry (SWOT project submitted on OST-ST/TOSCA)**

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