Multiscale techniques for the extraction of quantitative information from chlorophyll and SST maps

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Overview

. Velocity PDF.

. Singularity Spectrum.

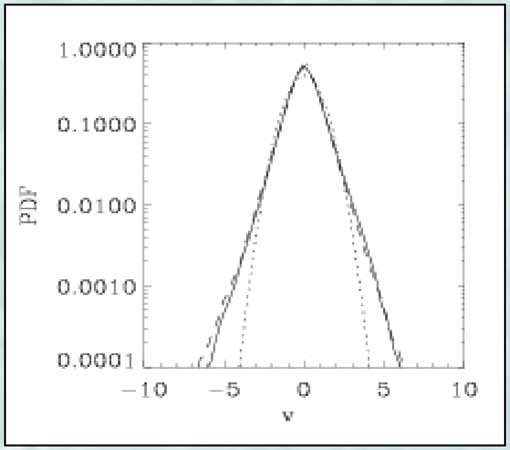
. Examples of application.

. Scale analysis.

. Scale invariance properties.

. Conclusions.

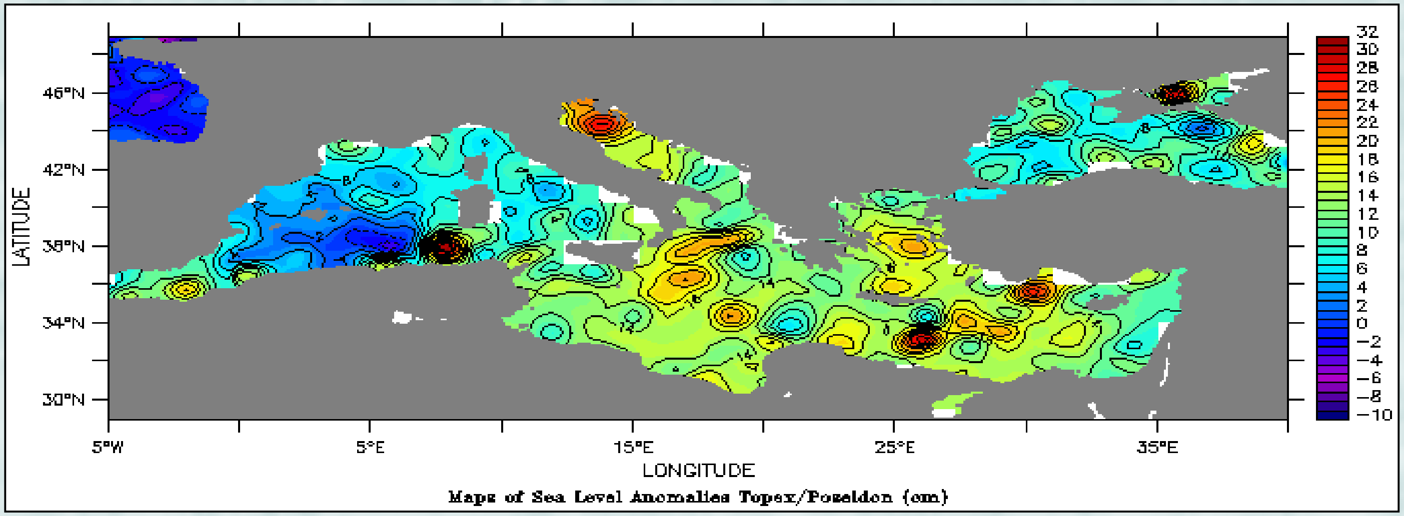
Velocity Probability Density Functions



. Non-Gaussian character of PDF: ocean features, e.g., eddies.

. Vortices: key role in ocean dynamics.

(J. Isern-Fontanet et al., 2006, JPO)



Velocity Probability Density Functions

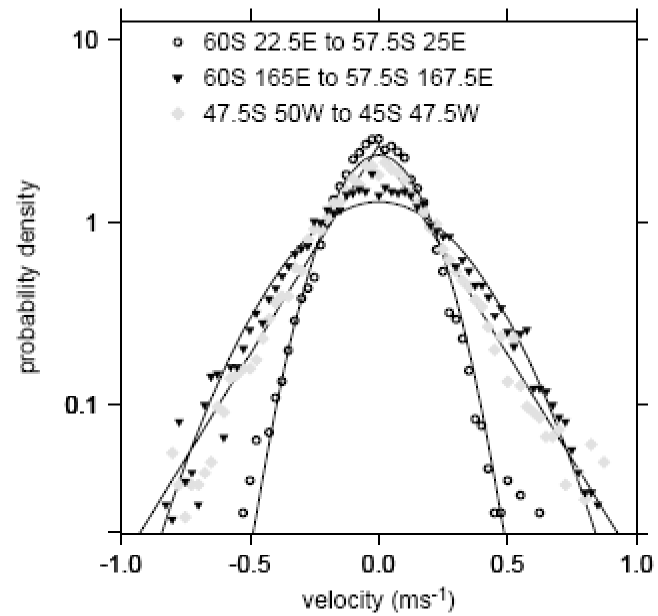


FIG. 1. Observed velocity pdfs for three 2.5° boxes. Open circles are from the South Atlantic, black triangles from the South Pacific Ocean, and gray diamonds from the energetically varying Malvinas Current in the South Atlantic, an exponential distribution. Solid lines show best fit Gaussian or exponential pdfs.

. Global scale:
spatial inhomogeneity of EKE.

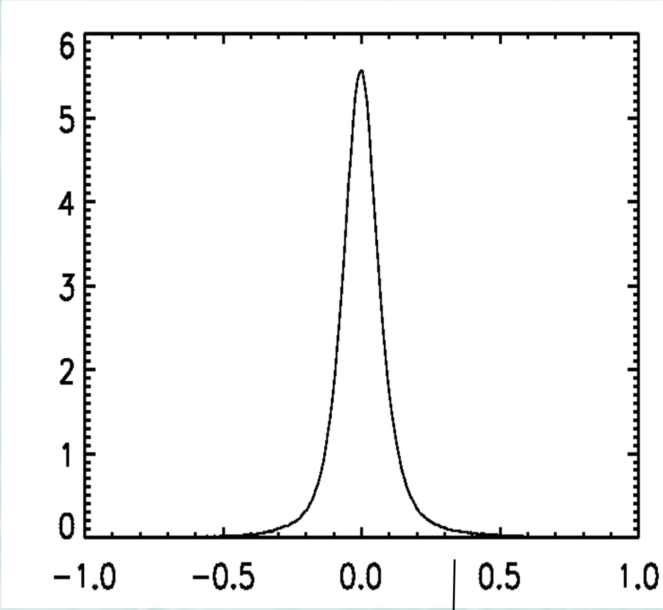
. PDF appearance changes:
domain size, lat. and lon.

. S. G. Llewellyn Smith et al., 1998, Phys. Rev. Letters.

PDF comparison between different satellite variables

GULF STREAM

Velocity-SLA
(m/s)



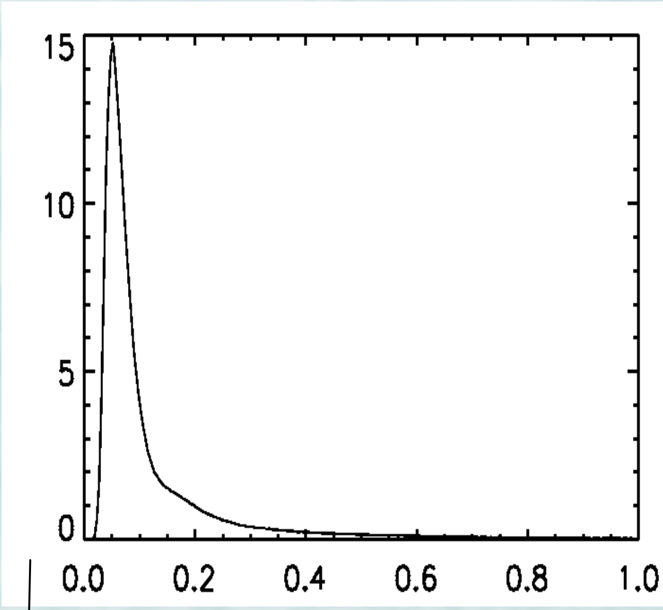
. T/P improved by ERS, CLS.

. Subtracting 4-years mean: systematic deviations.

. Lanczos filter (noise) + long wavelength errors.

. Res. 1/3 deg., 10 days.

CHL1 (MER+MOD+SWF)
(mg/m3)



. GlobColour, ESA.

. Level-3 ocean color.

. GSM: merging method.

. Res. 1/24 deg., daily.

* Is there any COMMON MECHANISM acting on the different scalars?

SINGULARITY SPECTRUM: distribution NOT subjected to scalar, scale, or region.

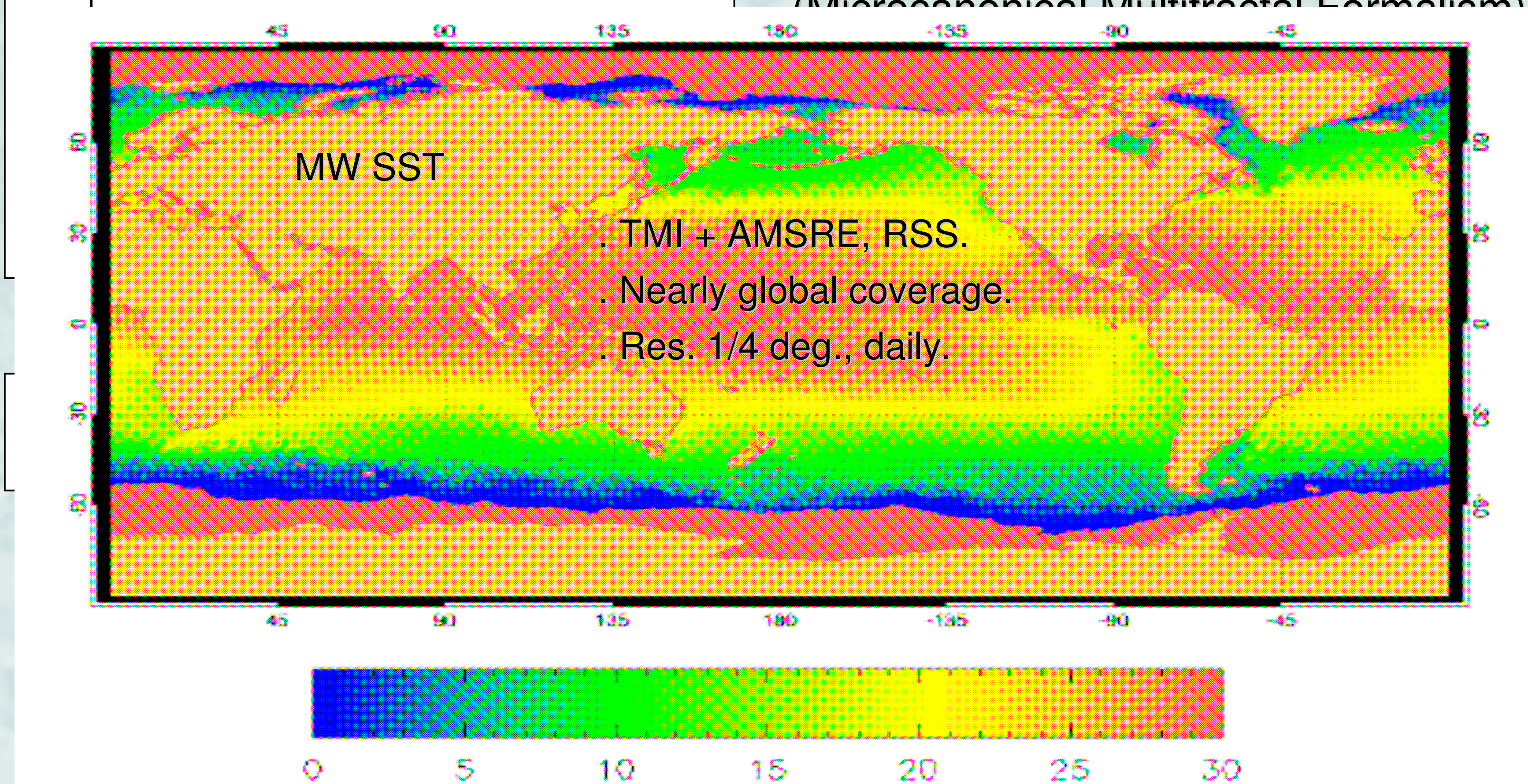
Singularity Spectrum

$$|\nabla s|(\vec{x}, r) \sim r^{h(\vec{x})}$$

$D(h)$: Singularity Spectrum

...stribution scaling exponents

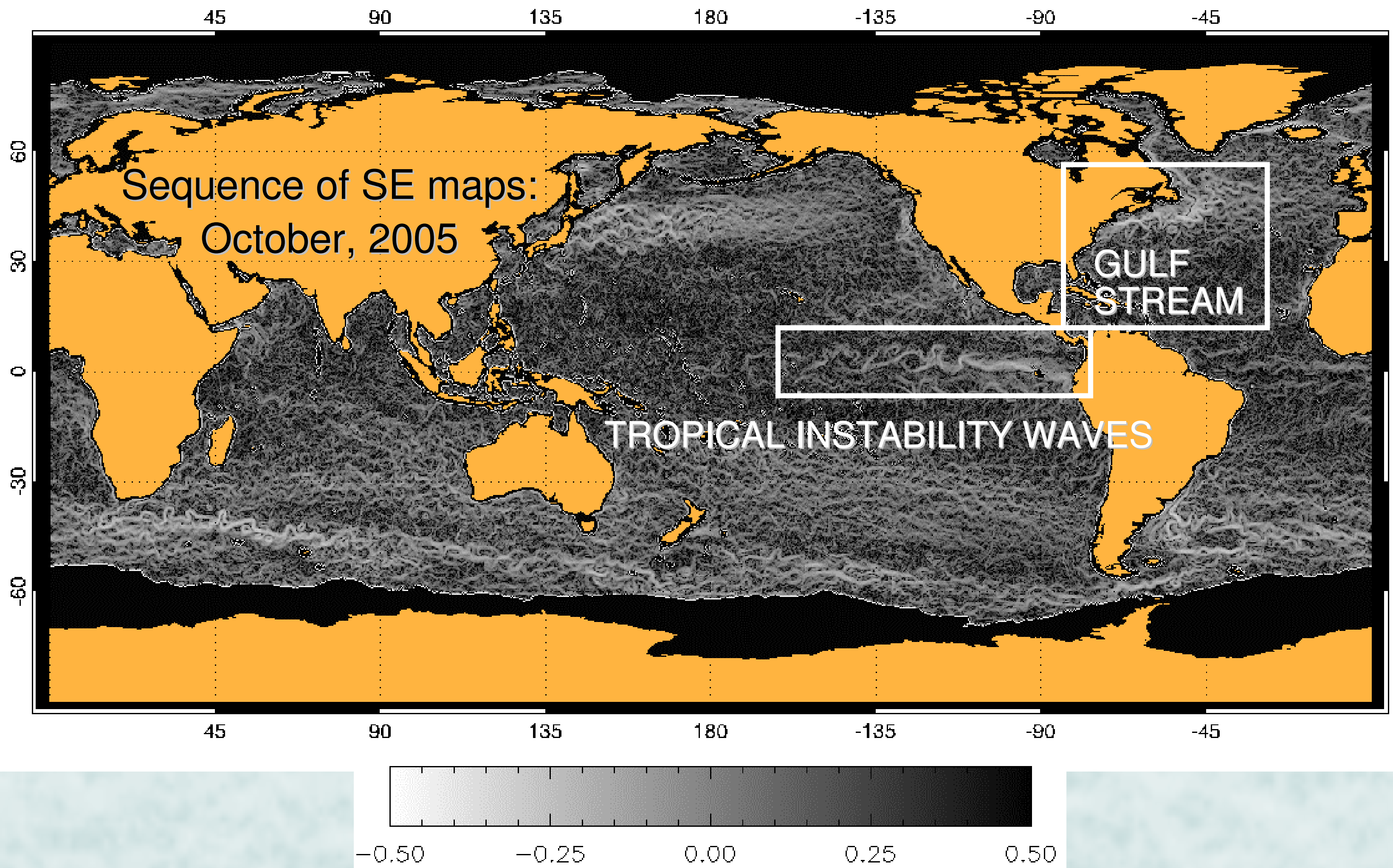
(Microcanonical Multifractal Formalism)



* DOMINANT ADVECTION: scalars - tracers of ocean dynamics.

Singularity exponents map from MW SST

$$|\nabla s|(\vec{x}, r) \sim r^{h(\vec{x})}$$

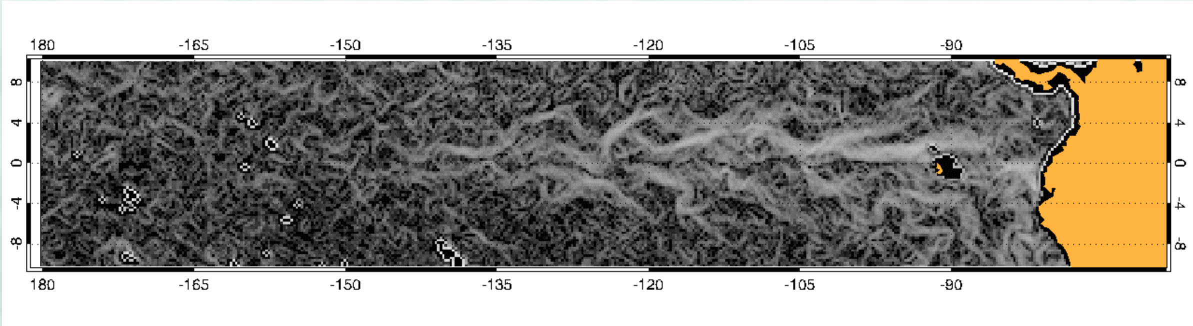


Singularity exponents map from MW SST

Sequence of SE maps: TIW

August

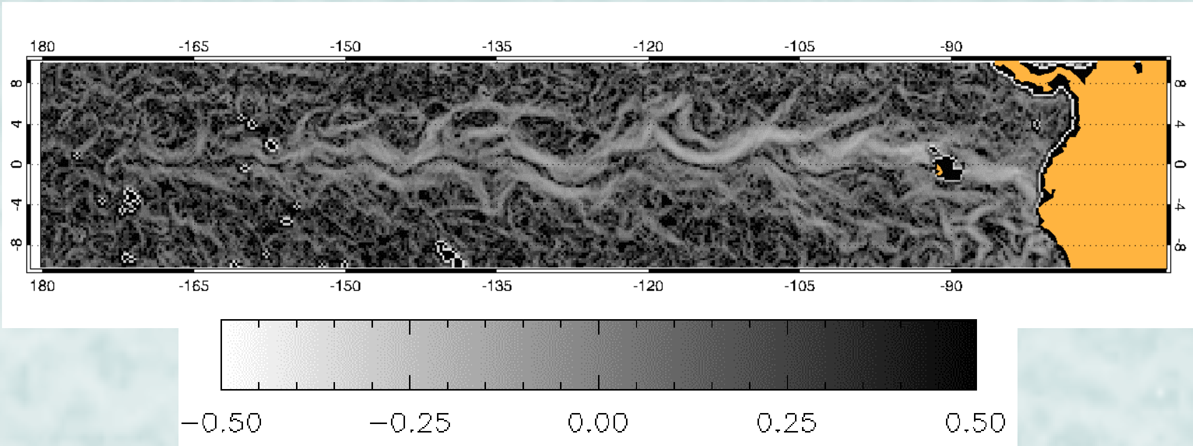
2002:



EQUATORIAL ZONE

August

2005:

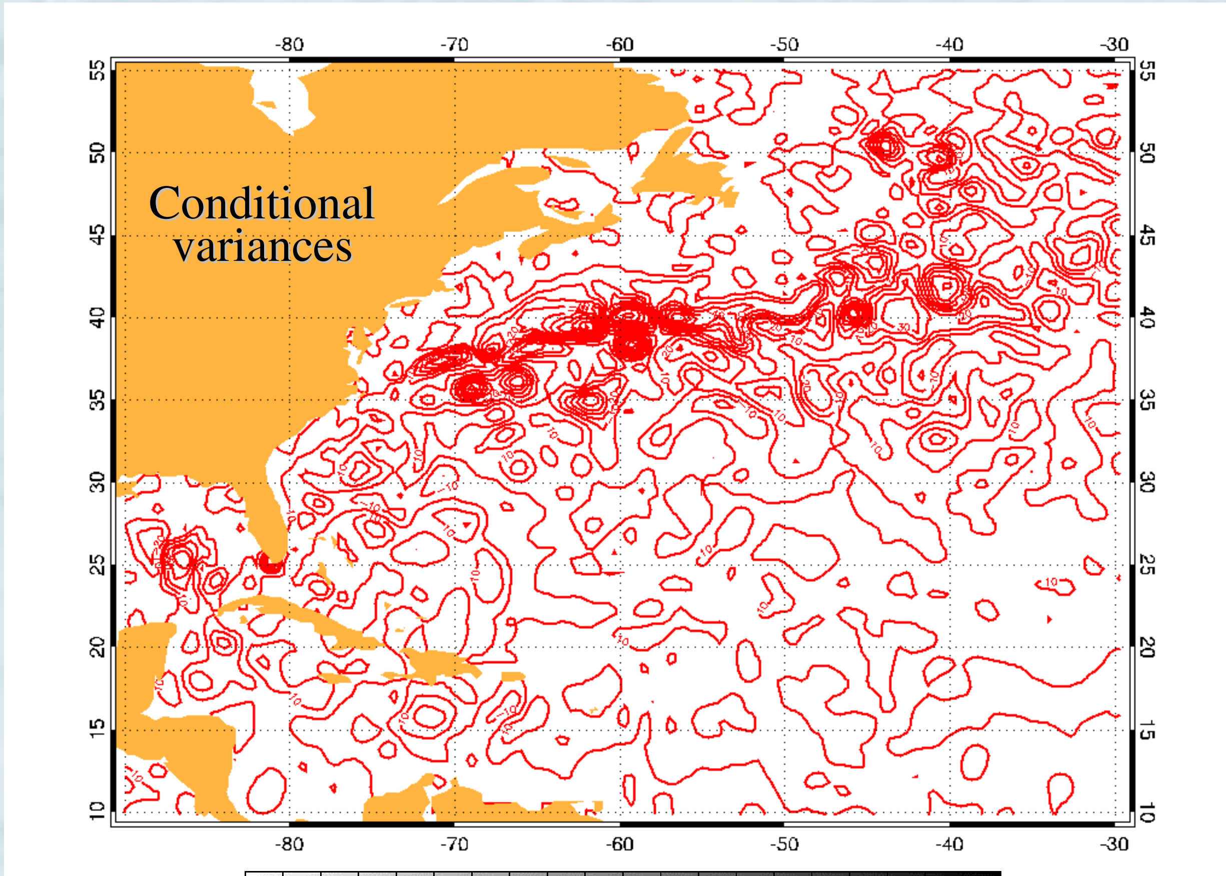


. Flow agitation state transmitted to SE:
underlying physics of FDT.

. Reliable approximation of REAL FLOWS behavior.

. NEW PERSPECTIVE of turbulent flow events.

SLA map



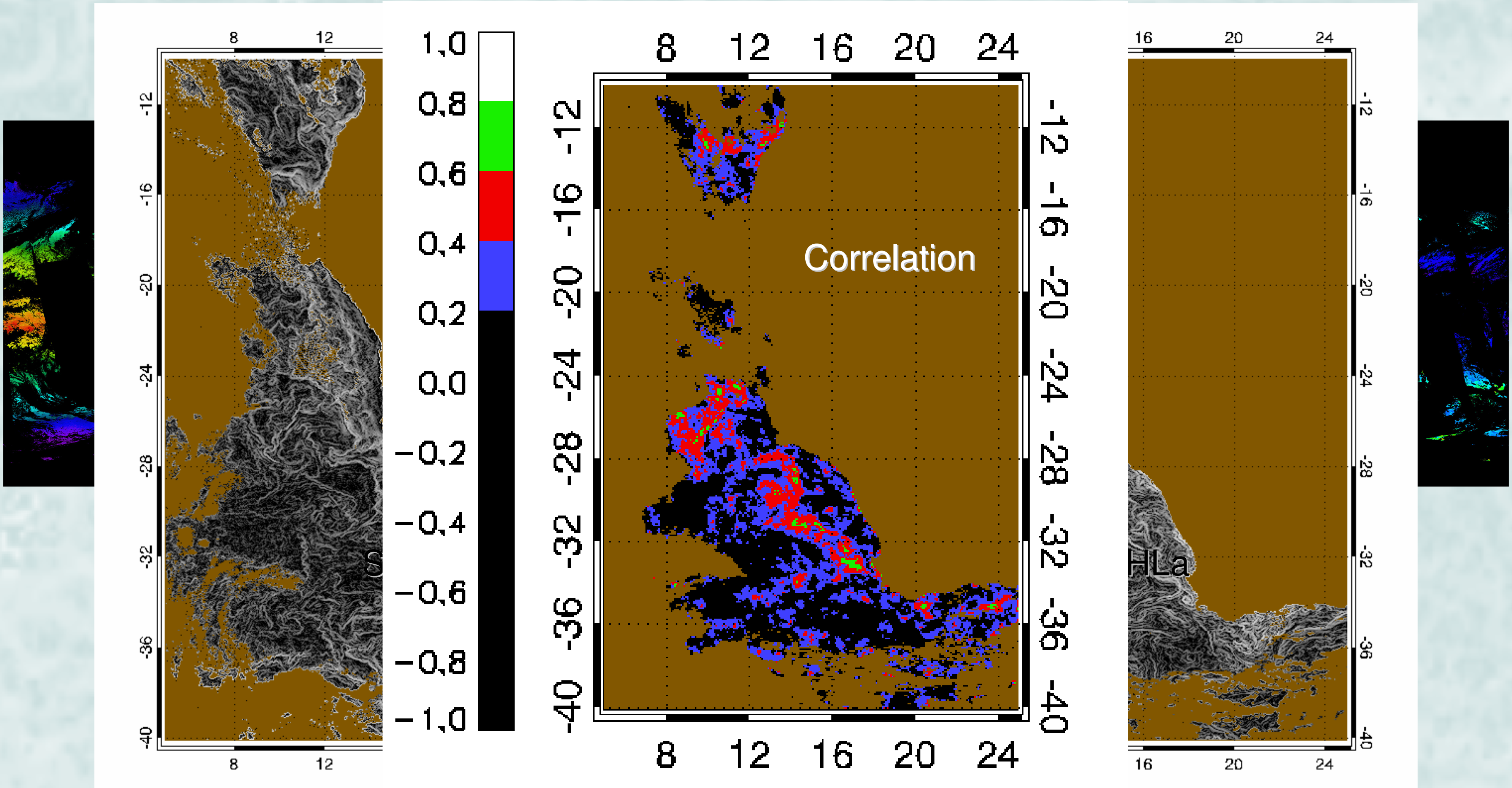
GULF STREAM

. A. Turiel, J. Sole, V. Nieves, J. Ballabrera-Poy, and E. Garcia-Ladona, 2007, RSE.

. A. Turiel, J. Sole, V. Nieves, and E. Garcia-Ladona, 2007, IGARSS.

Comparison between SE from different variables

SE from different advected tracers must coincide:



. Application standpoint: SST can be used as a PROXY of CC.

Singularity spectrum for SST and CHL a

. The Singularity Spectrum is the same FOR ANY SCALAR.

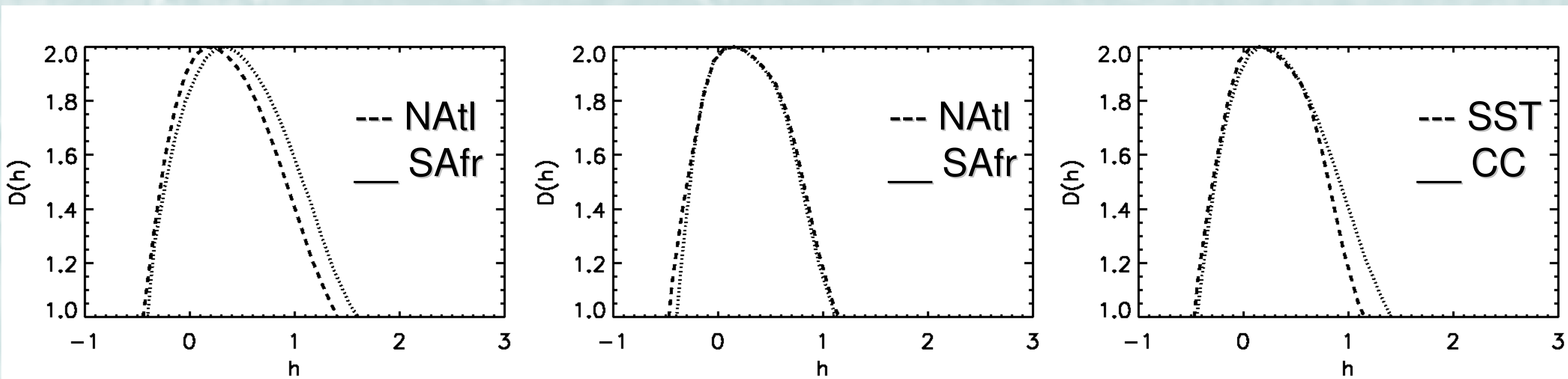
Verification of cascade process: statistical turbulent signatures.

. Singularity Spectrum:

$$D(h) = d - \frac{\log\left(\frac{\rho(h)}{\rho(h_1)}\right)}{\log r}$$

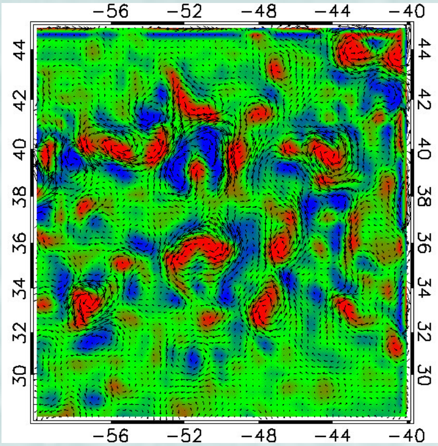
. *ρ(h)* - empirical histogram.
. *r* - resolution scale.

(Turiel et al., 2006, JCP.)



SST CC Whole dataset

. V. Nieves et al., 2007, Geophys. Res. Lett.

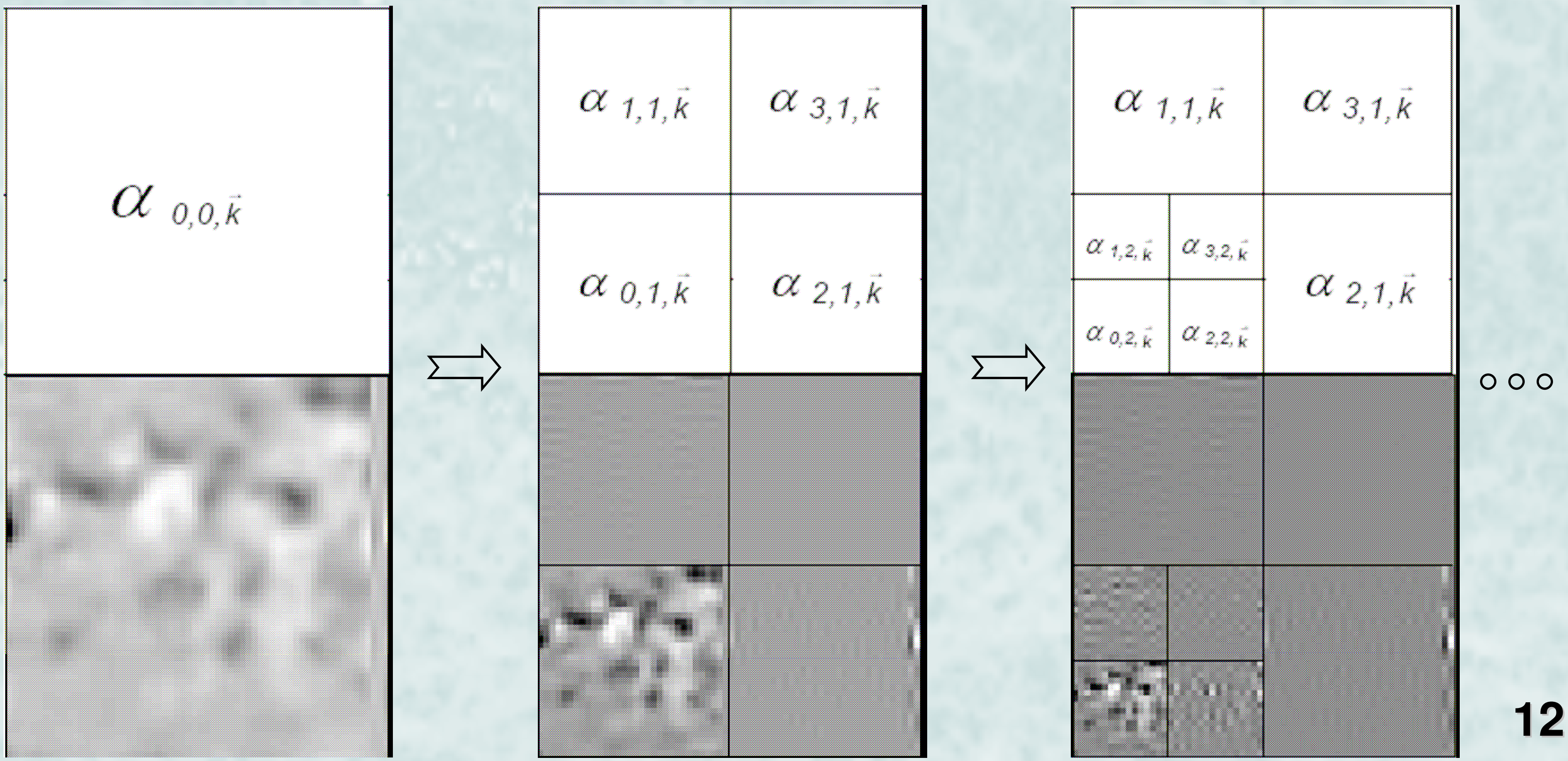


Scale analysis

$$s(\vec{x}) = \sum_{r=1,2,3} \sum_{j=1}^{J} \sum_{\vec{k}} \alpha_{rj\vec{k}} \psi_{rj\vec{k}}(\vec{x})$$

$$\psi_{rjk}(r) = 2^j \psi_r(2^j r - k)$$

. V. Nieves et al., J. Mar. Syst., in press.

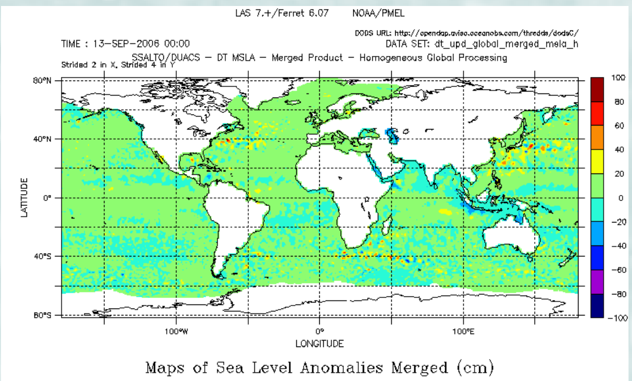


Scale analysis of satellite variables

$$T_\Psi s(\vec{x}, r)$$

$$s(\vec{x}) = \sum_{r=1,2,3} \sum_{j=1}^{J} \sum_{\vec{k}} \alpha_{rj\vec{k}} \psi_{rj\vec{k}}(\vec{x})$$

Velocity (SLA)



. CLS, AVISO server.

. T/P improved by ERS.

. Subtract 4-year mean:

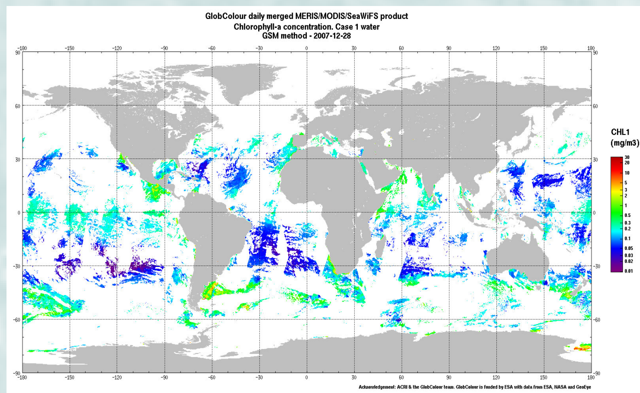
systematic deviations.

. Lanczos filter +

long wavelength errors.

* Res.1/3 deg., 10 days.

CHL1 (MER+MOD+SWF)



. GlobColour, ESA.

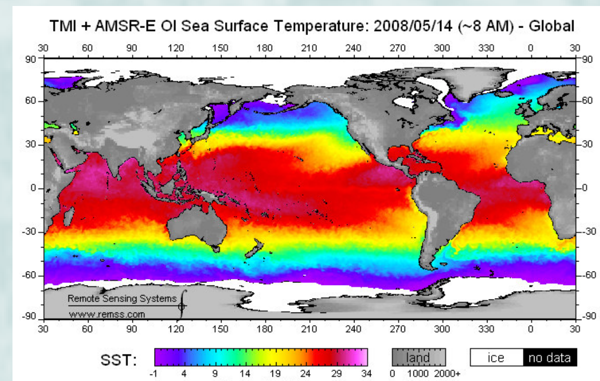
. Level-3 ocean color:

MERIS+MODIS+SeaWiFS.

. GSM: merging method.

* Res. 1/24 deg., daily.

MW SST (TMI+AMSRE)



. Rem. Sen. Syst., NASA.

. Interpol. techniques:

missing data resolved.

. Nearly global coverage.

* Res. 1/4 deg., daily.

Scale analysis of the Singularity Spectrum

. Scale analysis of SS allows detecting interpolation artifacts.

$$T_\Psi|\nabla s|(\vec{x}, r) \sim r^{h(\vec{x})}$$

. SS shape of interpolated data corrected by:

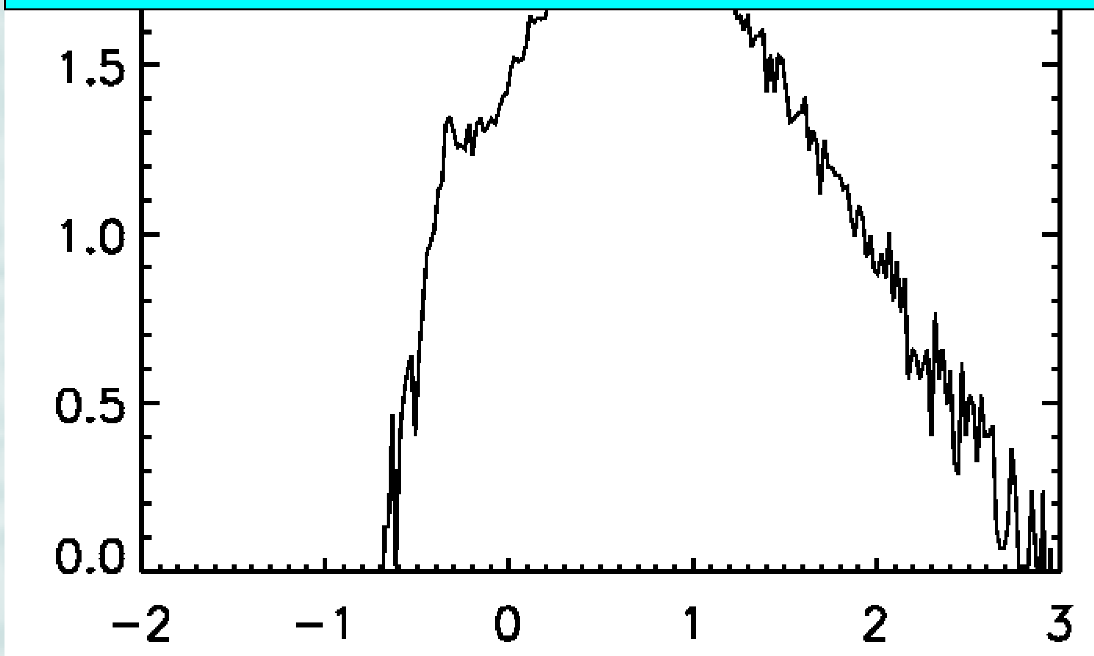
- Increasing statistics.
- Reducing resolution.

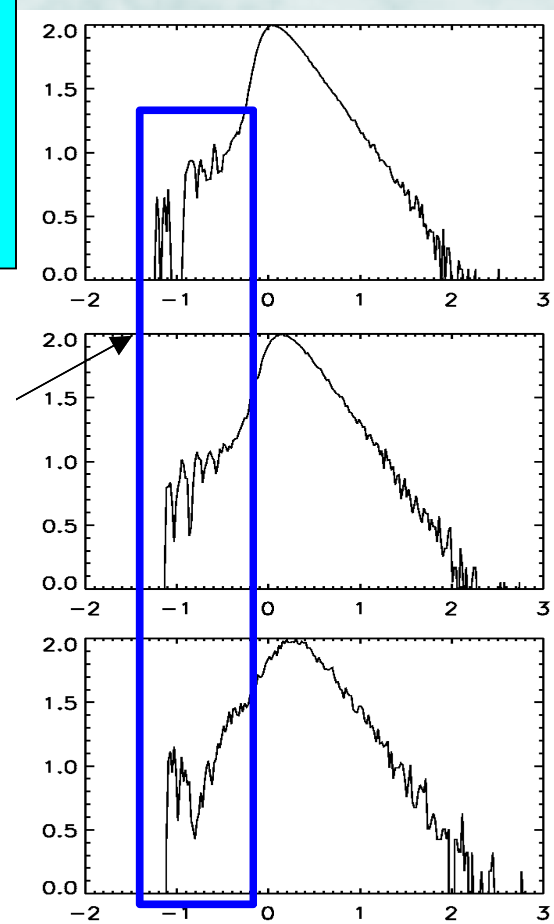
Velocity (SLA) **CHL1 (MER+MOD+SWF)** **MW SST (TMI+AMSRE)**

256x256

128x128

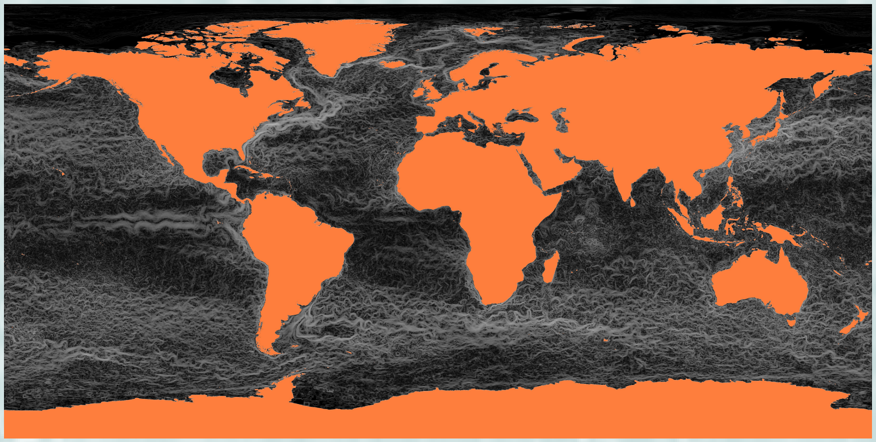
64x64





Detection of interpolation artifacts

OSTIA: Operational Sea Surface Temperature and Sea Ice Analysis



. Satellite (GHRSST) + in-situ data.

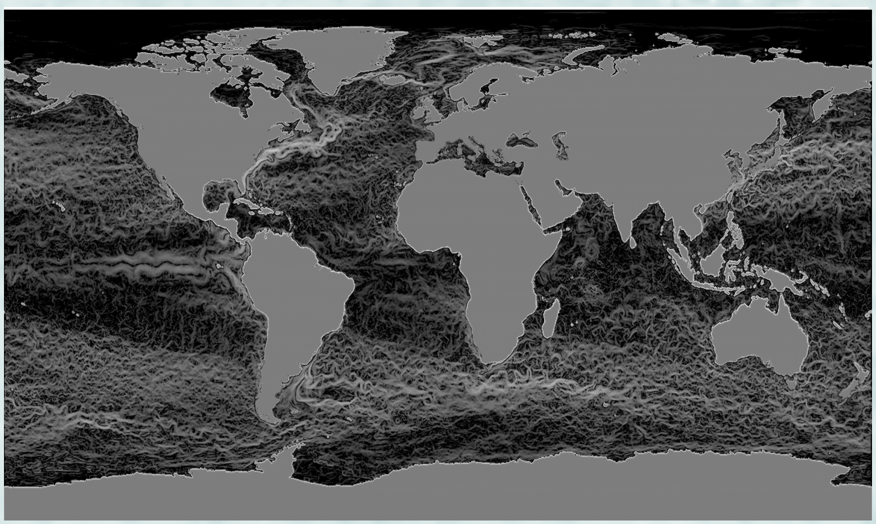
. Optimal Interpolation Analysis:

AMRSE + TMI + Pathfinder + MODIS.

* Res. 1/20 deg., daily.

INTERPOLATED DATA:
NOMINAL RES. X 5 = DATA

AMSRE-E:



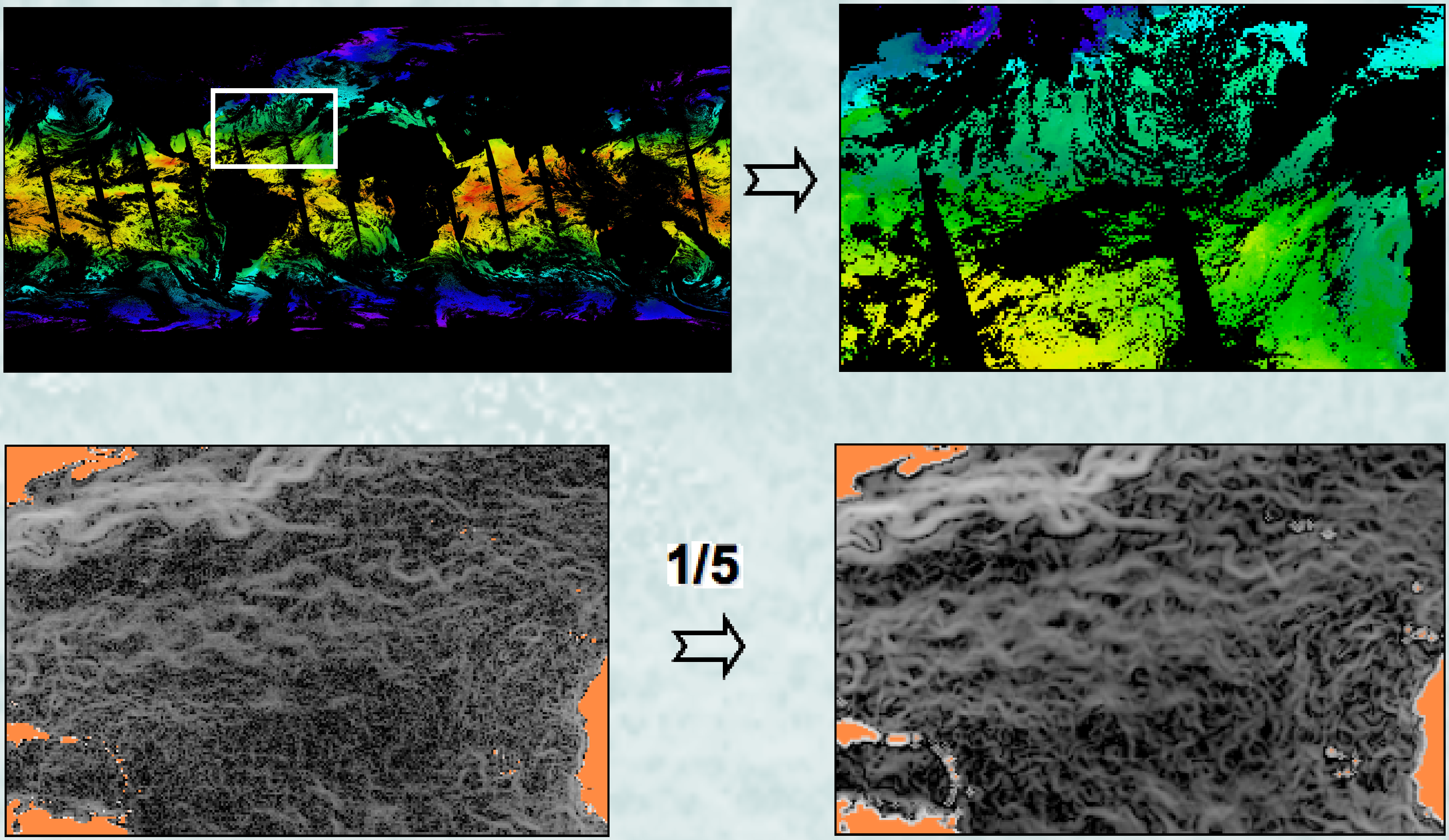
. Rem. Sen. Syst., NASA.

. Capability through clouds.

* Res. 1/4 deg., daily.

Detection of interpolation artifacts

Aqua - MODIS ocean color sensor: daytime SST, res. 1/24 deg., daily.



Conclusions

. Local **degree of correspondence** between SE of different satellite **data**.

. SE of adequate scalar vs. other maps with gaps - **inference**.

- Future merging / interpolation.
- Improvement of ocean modelling, bio-physical, and climatic studies.

. SS allows describing scaling properties: **scale-invariance**.

. **Interpolated** satellite **products** show some **limitations**.

. This **can be overcome** - increasing data statistics and resolution.

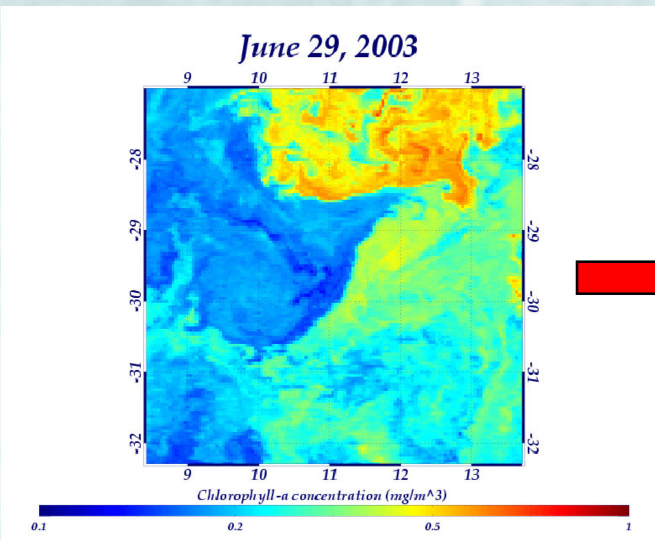
http://www.icm.csic.es/oce/people/vnieves/

THANK YOU

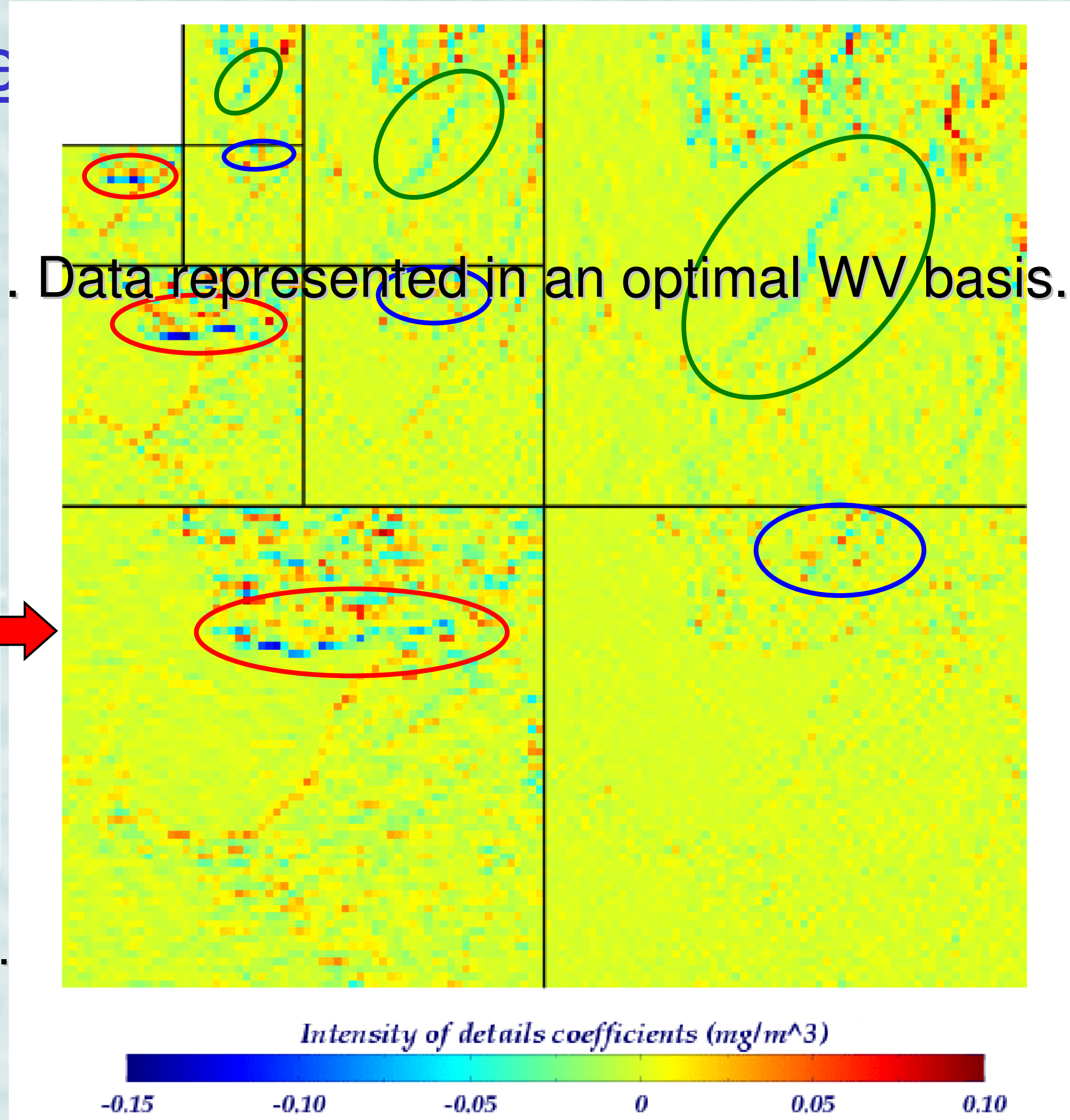
FOR YOUR ATTENTION!

Infe

$$s(\vec{x}) = \sum_{r=1,2,3} \sum_{j=1}^{J} \sum_{\vec{k}} \alpha_{rj\vec{k}} \, \psi_{rj\vec{k}}(\vec{x})$$



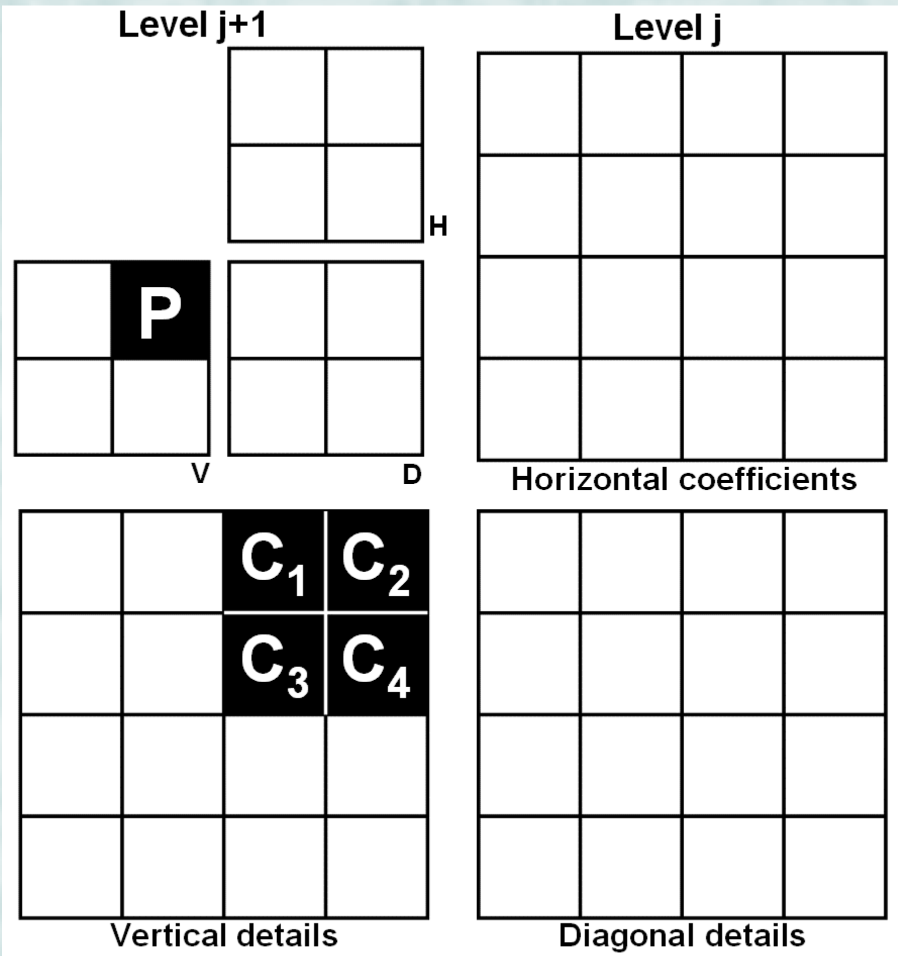
. C. Pottier et al., RSE,2008.



. Data represented in an optimal WV basis.

Inferring missing data

- Cascade relation between scales is used: Every father coefficient is inferred from its 4 children.
- The most probable value is selected for the gap area.



$$\alpha_C = \eta . \alpha_P \Rightarrow \log_2|\alpha_C| = \log_2|\eta| + \log_2|\alpha_P|$$

$$\Downarrow$$

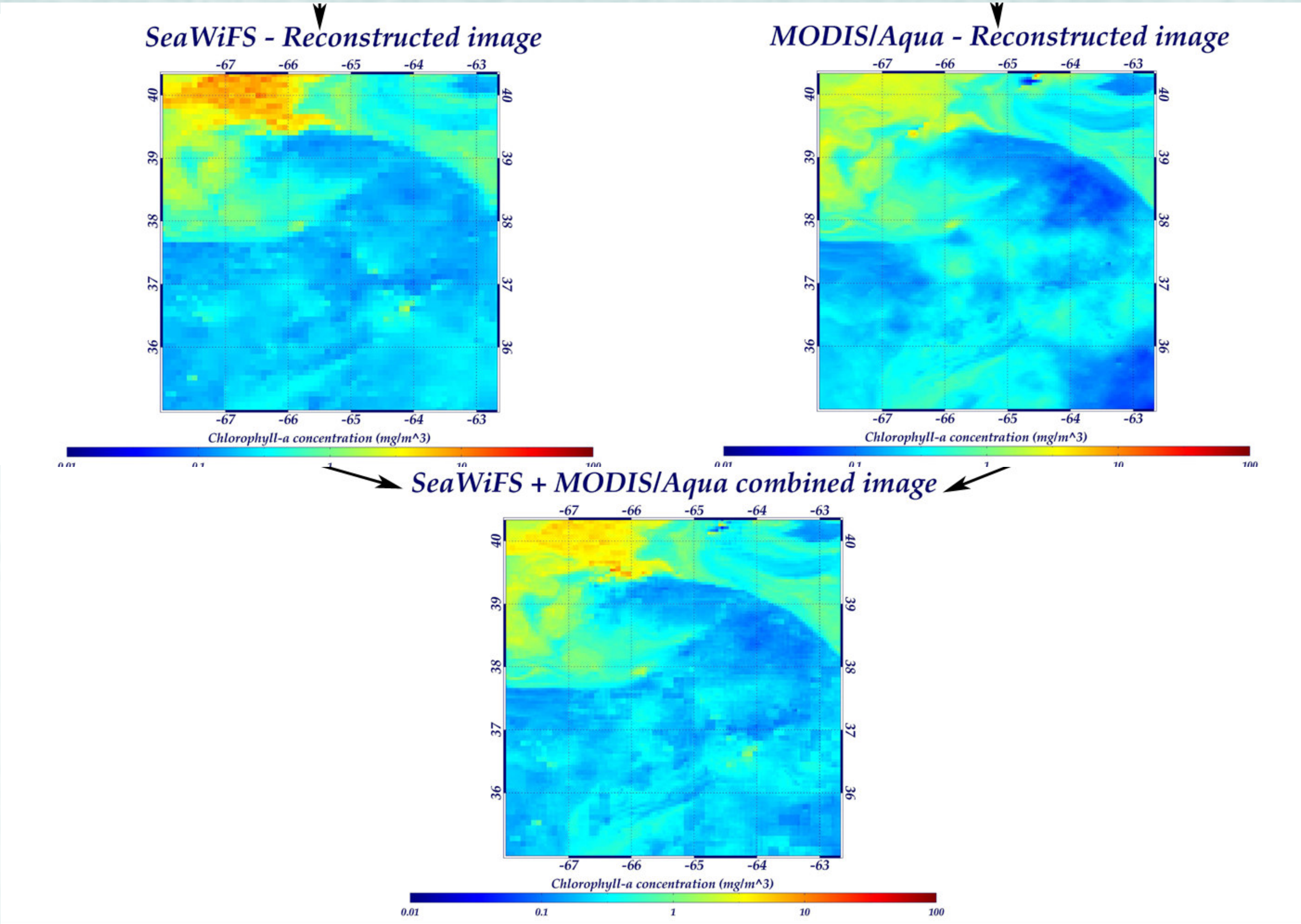
$$\log_2|\alpha_{C_1}| - \log_2|\alpha_P| = \log_2|\eta_1|$$

$$\log_2|\alpha_{C_2}| - \log_2|\alpha_P| = \log_2|\eta_2|$$

$$\log_2|\alpha_{C_3}| - \log_2|\alpha_P| = \log_2|\eta_3|$$

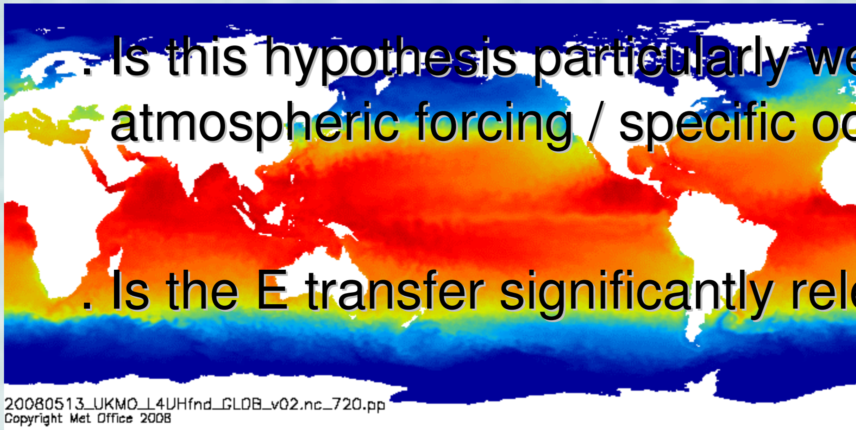
$$\log_2|\alpha_{C_4}| - \log_2|\alpha_P| = \log_2|\eta_4|$$

Inferring missing data



E transfers: cascade process

OSTIA:



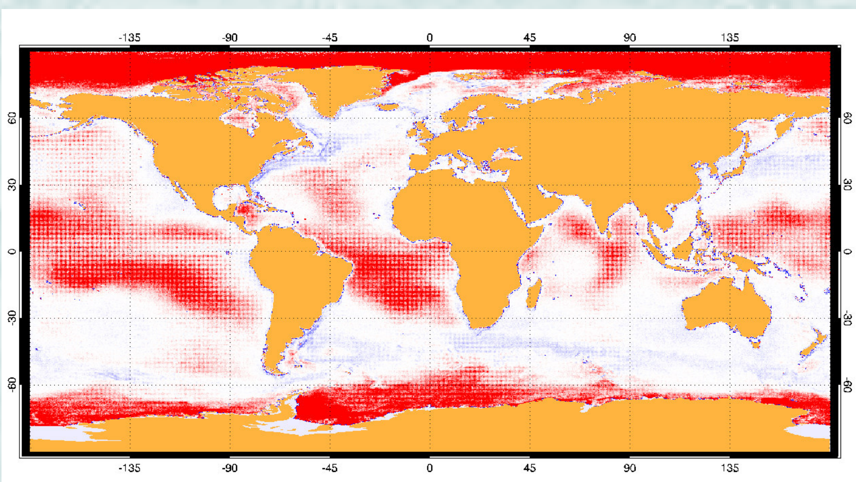
. Is this hypothesis particularly well behaved under atmospheric forcing / specific ocean conditions?

. Is the E transfer significantly relevant at any particular scale?

$$s(\vec{x}) = \sum_{r=1,2,3}\sum_{j=1}^{J}\sum_{\vec{k}} \alpha_{rj\vec{k}}\,\psi_{rj\vec{k}}(\vec{x})$$

$$\alpha_{rj\vec{k}} \doteq \eta_{rj\vec{k}}\,\alpha_{r,j+1,\left[\frac{\vec{k}}{2}\right]}$$

Ratio between scales: there is a background **E dissipation**.



$$\eta_{rj\vec{k}} = \frac{\alpha_{rj\vec{k}}}{\alpha_{r,j+1,\left[\frac{\vec{k}}{2}\right]}}$$

. O. Pont et al., in preparation.