Role of point-wise scale invariance in geophysical turbulence: applications in oceanography

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Singularity analysis

SA is a technique to extract relevant structures from maps of scalar variables, in connection with turbulence theory.

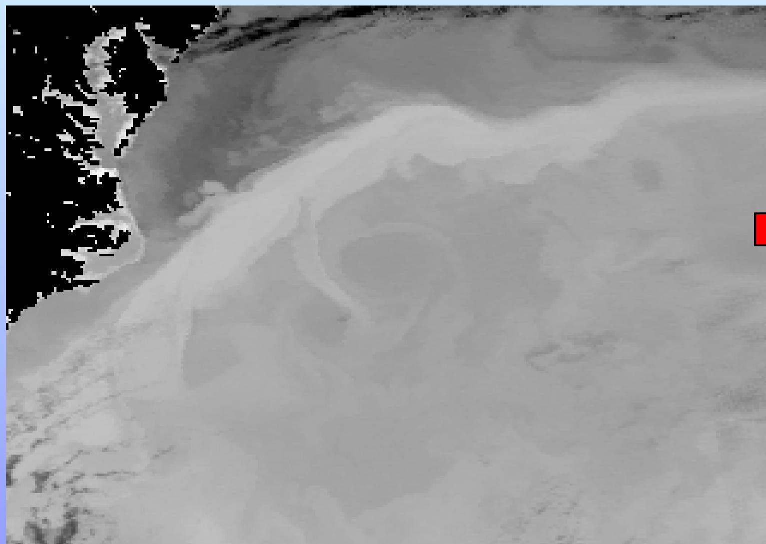
The singularity exponents h(x) at each point x are calculated according the following formula:

$$\boxed{T_\Psi|\nabla\theta|(\vec{x},r) \equiv \int d\vec{x}' \, |\nabla\theta|(\vec{x}')\Psi\left(\frac{\vec{x}-\vec{x}'}{r}\right) = \alpha_\Psi(\vec{x})r^{h(\vec{x})} + o\left(r^{h(\vec{x})}\right)}$$

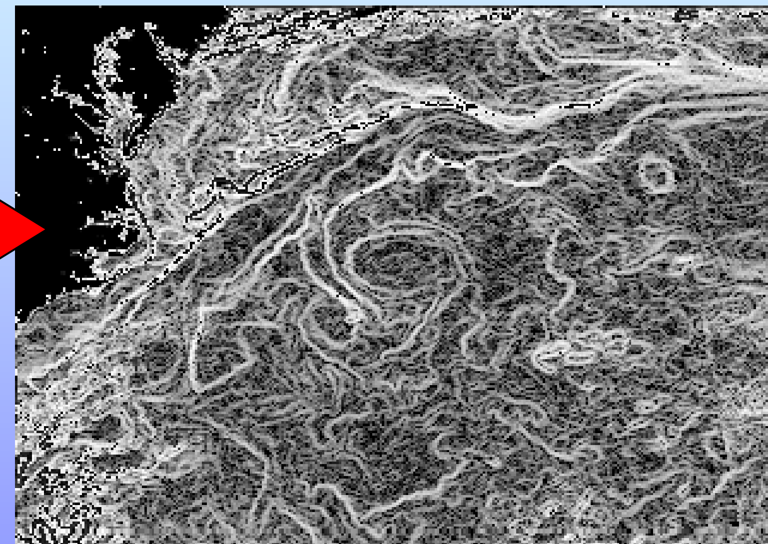
Singularity analysis for pattern recognition

Singularity exponents are dimensionless, spatially coherent and unaffected by changes in local amplitude.

They are hence very useful to detect structures, even subtle.



Pathfinder SST Image
(Hatteras Cape, May 8, 2000)



Associated singularity exponents

J. Isern-Fontanet, A. Turiel, E. García-Ladona and J. Font
Journal of Geophysical Research 112, C05024 (2007)

Singularity analysis for dynamic assessment of flows

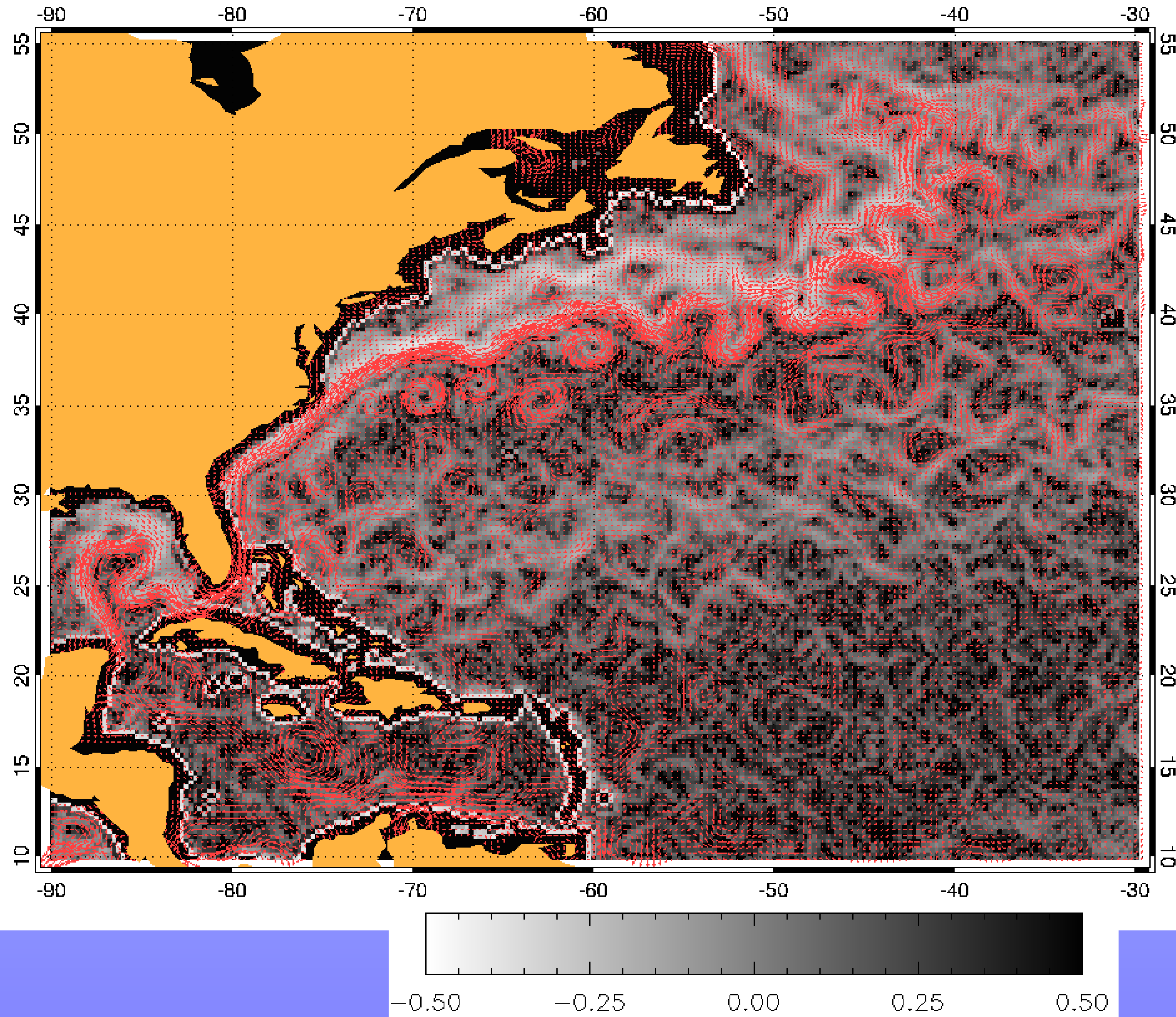
Singularity analysis is specially effective when the system under analysis is of a special, scale-invariant type (multifractal, MF).

The archetypes of MF systems are turbulent flows. Singularity analysis is very effective in oceans and atmosphere.

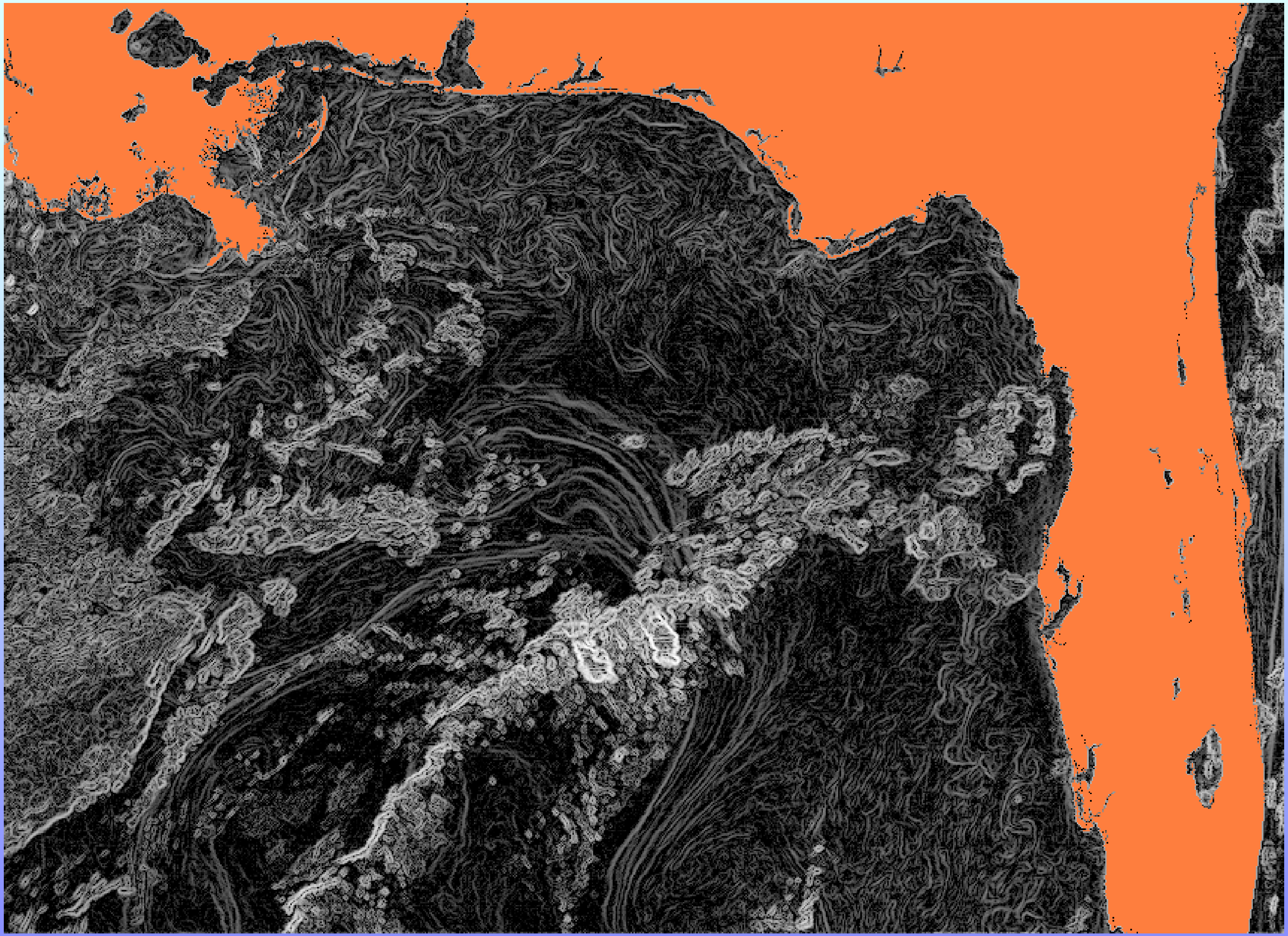
In particular, we have shown that when satellite images of Sea Surface Temperature (L4 AMSR-E+TMI) are analyzed streamlines are obtained.

Our results have been validated with independent measurements (high-res L4 altimetry - SURCOUF)

A. Turiel, V. Nieves, E. García-Ladona, J. Font,
M.-H. Rio, and G. Larnicol
Ocean Science 5, 447-460 (2009)

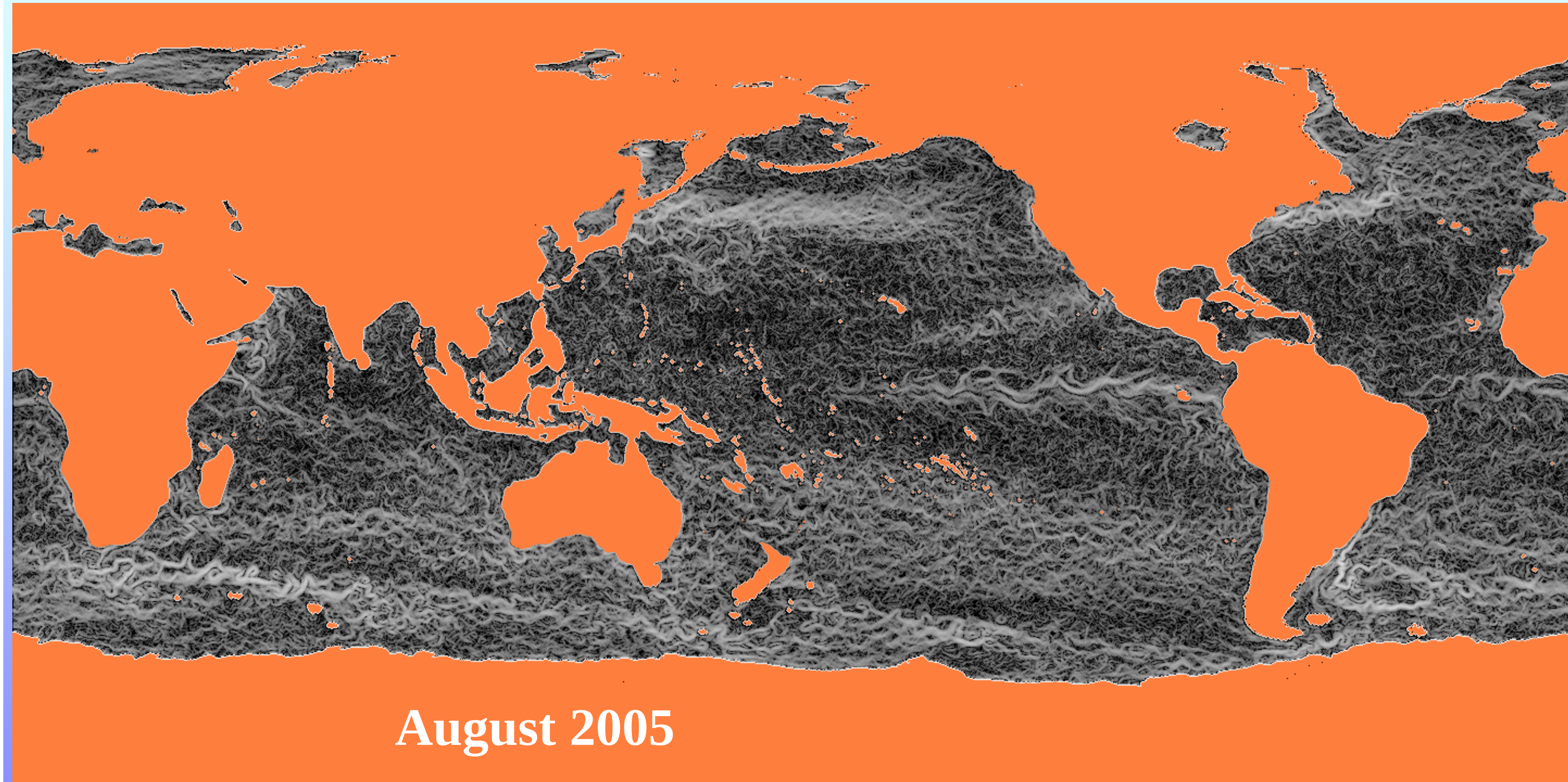


SA is useful to reveal circulation patterns at higher resolutions



Derived from Terra L2 SST 4μ, acquired in May 7, 2010 at Gulf area

SA can also be used to track currents during long periods



Derived from AMSR-E + TMI L4 SST product

Application to ASCAT data

We analyze scalar variables: modulus and velocity components

$$\boxed{T_\Psi|\nabla \parallel \vec{v} \parallel|(\vec{x},r) \;=\; \alpha(\vec{x})r^{h(\vec{x})}}$$

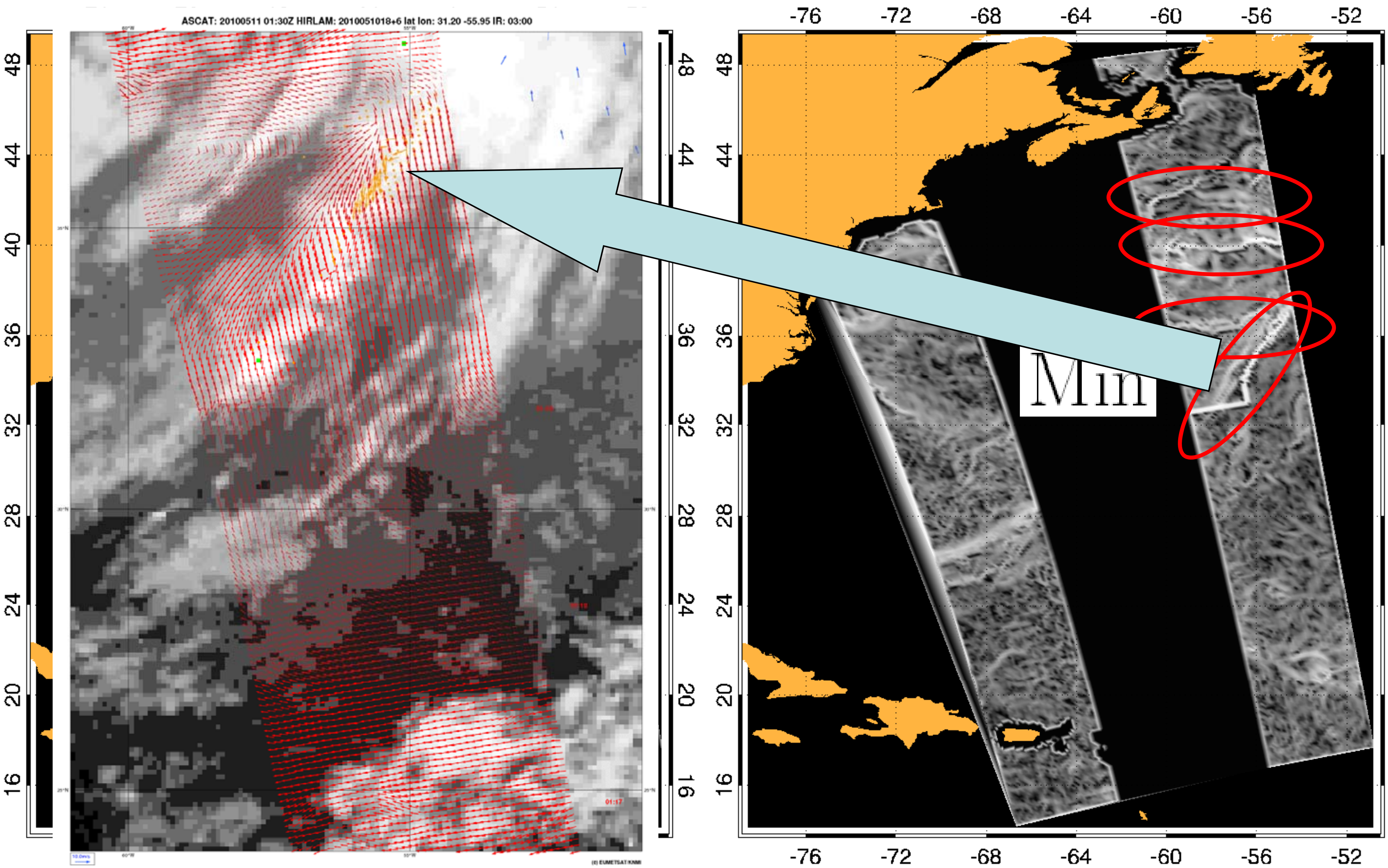
$$\boxed{T_\Psi|\nabla u|(\vec{x},r) \;=\; \alpha_u(\vec{x})r^{h_u(\vec{x})}}$$

$$\boxed{T_\Psi|\nabla v|(\vec{x},r) \;=\; \alpha_v(\vec{x})r^{h_v(\vec{x})}}$$

Isotropic exponents are always sharper than directional ones

$$\boxed{h(\vec{x}) \;=\; \mathrm{Min}\left(h_u(\vec{x}), h_v(\vec{x})\right)}$$

SA allows to detect mismatches in component separation



Conclusions

SA is a powerful technique to extract the dynamic structures of a turbulent flow.

It can also be used to detect subtle transitions, difficult to characterize by other means.

Applications of SA range from obtaining circulation patterns to improve quality in wind retrieval.

http://www.icm.csic.es/oce/es/content/turiel