Nicolas Rascle

« On the interpretation of surface current signatures on SAR/sun glitter images »

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«On the interpretation of surface current signatures on SAR/sun glitter images »

Background: PhD thesis on wave/current interactions in 2007

Position: postdoc at IFREMER, Brest, France

Funding: European Space Agency MESO3D project and French National Research Agency REDHOT project

Collaborations:

Remote sensing expertise: Bertrand Chapron, Fabrice Collard,

Wave expertise: Fabrice Ardhuin,

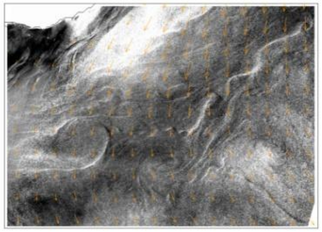
Ocean expertise: Patrice Klein, Xavier Capet, Aurélien Ponte

Introduction

Purpose of the present work:

A better understanding of roughness images

In particular which property of the surface currents they highlight?



Outline:

1)Introduce roughness images

2)Current properties

3)Perspectives

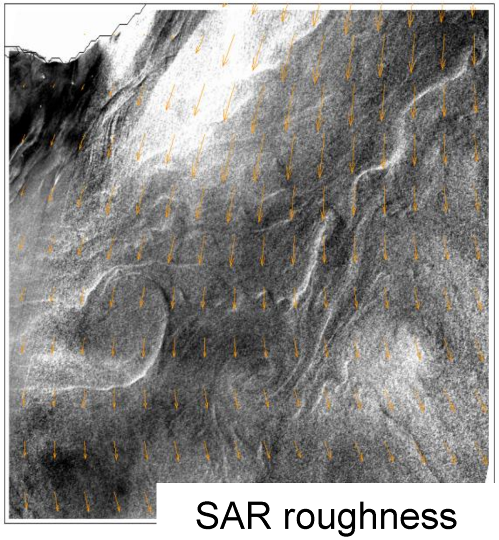
1) Surface roughness

Surface roughness images

-radar (SAR): intensity of the backscatter, similar to scatterometry

or

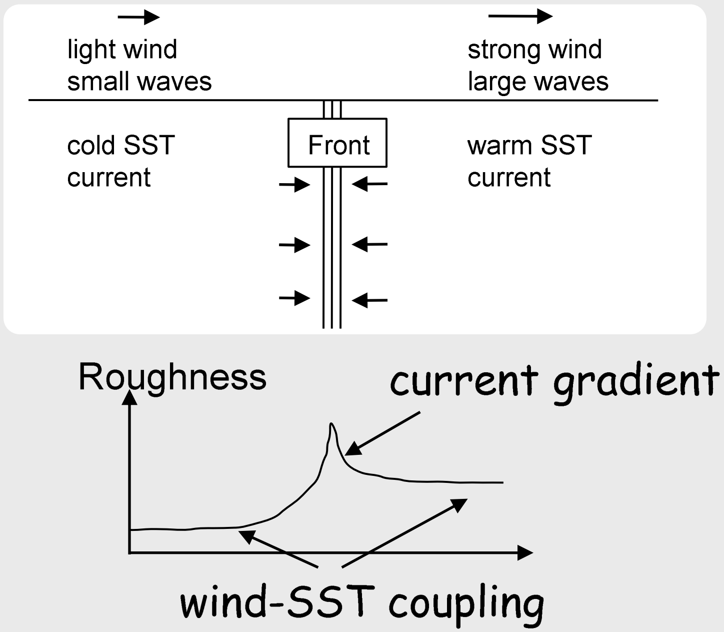
-optical: sunglitter seen by optical radiometers (Meris, Modis,…)

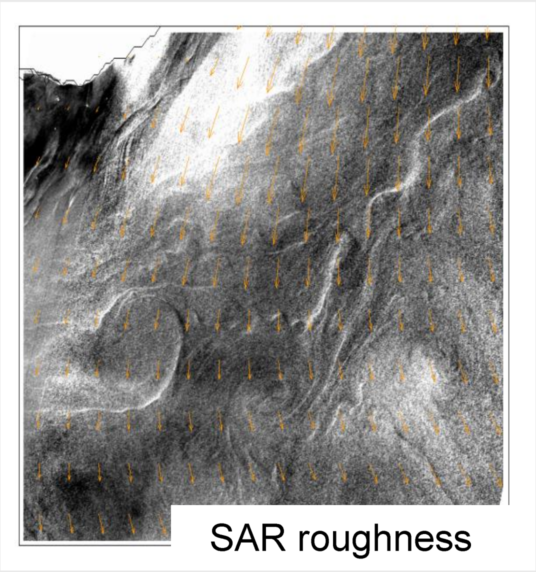


SAR roughness

Essentially related to the surface slope (mean square slope MSS) of short waves (roughly 1-10 cm)
Those waves are related to local wind and current (and surfactants)

1) Surface roughness

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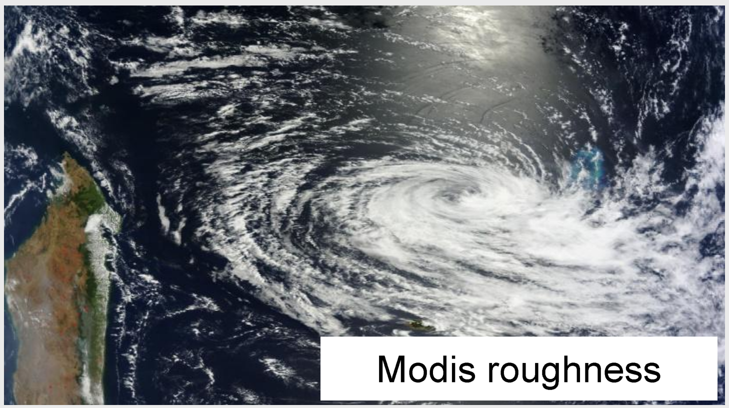
Those waves are related to local wind and **current** (and surfactants)

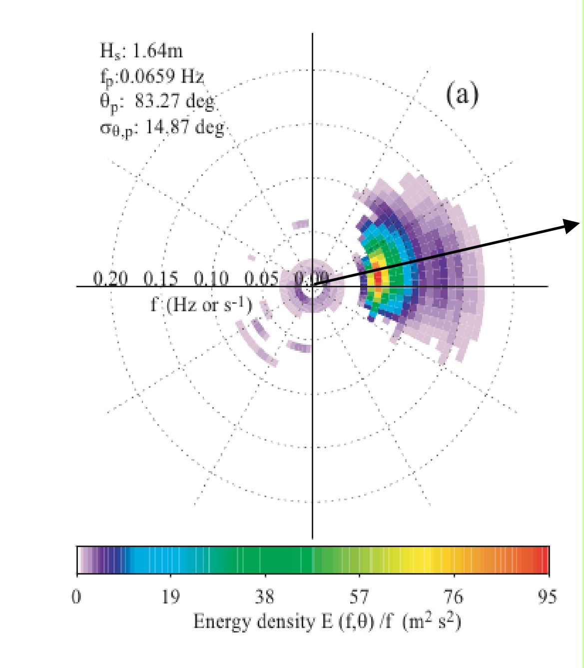
1) Surface roughness

Internal waves images



"Current gradient"
Which deformation property of the surface currents?

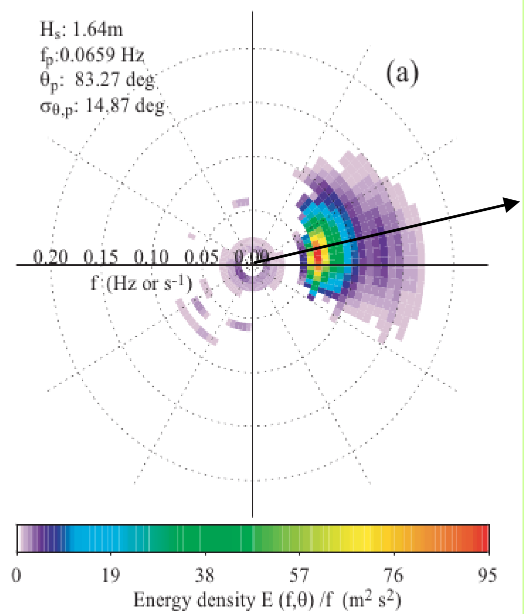
Background wave spectrum



Waves in the presence of current

2) Roughness and current deformation properties

Background wave spectrum



Evolution of wave spectrum in the current

$$\frac{\partial N(\mathbf{k})}{\partial t} + (c_{gi} + u_i)\frac{\partial N}{\partial x_i} = -k_j \frac{\partial u_j}{\partial x_i}\frac{\partial N}{\partial k_i} + Q$$

Propagation Current Sources, Sinks

(wind, breaking,...)

Waves short enough to neglect propagation
Without current, equilibrium wind/breaking

Spectrum anomaly

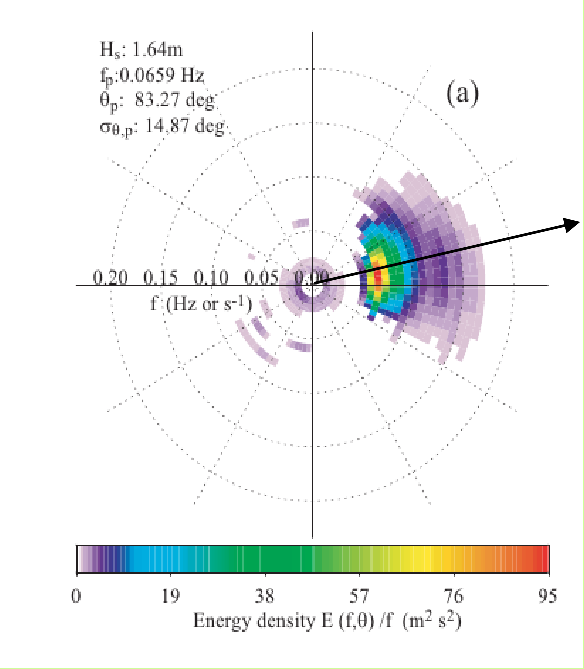
$$\tilde{N}(\mathbf{x}, k, \phi) = \tau_c \begin{bmatrix} \cos\phi & \sin\phi \end{bmatrix} \begin{bmatrix} \frac{\partial u}{\partial x} & \frac{\partial u}{\partial y} \\ \frac{\partial v}{\partial x} & \frac{\partial v}{\partial y} \end{bmatrix} \begin{bmatrix} \cos\phi & -\sin\phi \\ \sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} \frac{\partial N_0}{\partial \ln k} \\ \frac{\partial N_0}{\partial \phi} \end{bmatrix}$$

Corresponding slope (mss) anomaly

$$\widetilde{mss}_x(\mathbf{x}) = \int_k \int_\phi \omega^{-1} k \tilde{N} \; k^2 \cos^2\phi \; \mathrm{d}k\mathrm{d}\phi$$

2) Roughness and current deformation properties

Wave spectrum



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$$\widetilde{mss}_x(\mathbf{x}) = \int_k \int_\phi \omega^{-1} k \tilde{N} \; k^2 \cos^2\phi \; \mathrm{dkd}\phi$$

•For a spectrum symmetrical about the wind direction
•For wind in the x-direction

-> 2 types of currents will give no mss anomaly

$$\begin{bmatrix} \frac{\partial u}{\partial x} & \frac{\partial u}{\partial y} \\ \frac{\partial v}{\partial x} & \frac{\partial v}{\partial y} \end{bmatrix}$$

-> Only 2 over 4 types of current deformations will sign on the roughness image.

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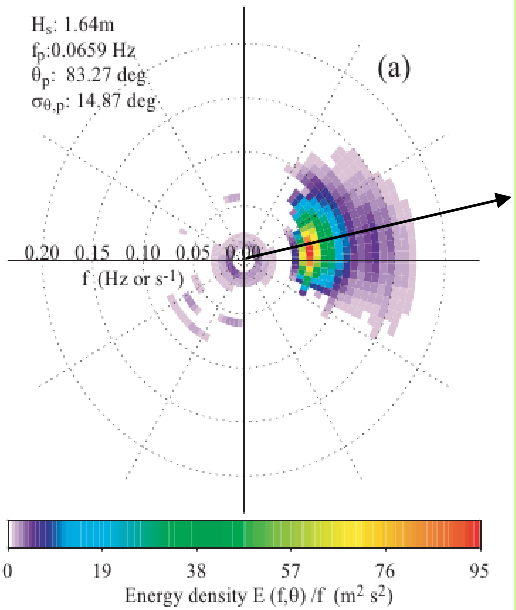
Wave spectrum



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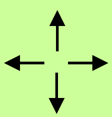
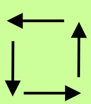
2) Roughness and current deformation properties

Only 2 over 4 types of current deformations will sign on the roughness image.

Another way to look at it:

$$\begin{bmatrix} \frac{\partial u}{\partial x} & \frac{\partial u}{\partial y} \\ \frac{\partial v}{\partial x} & \frac{\partial v}{\partial y} \end{bmatrix} = \frac{1}{2}\begin{bmatrix} D + S_t & -R + S_h \\ R + S_h & D - S_t \end{bmatrix}$$





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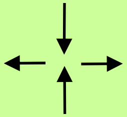
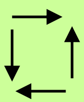
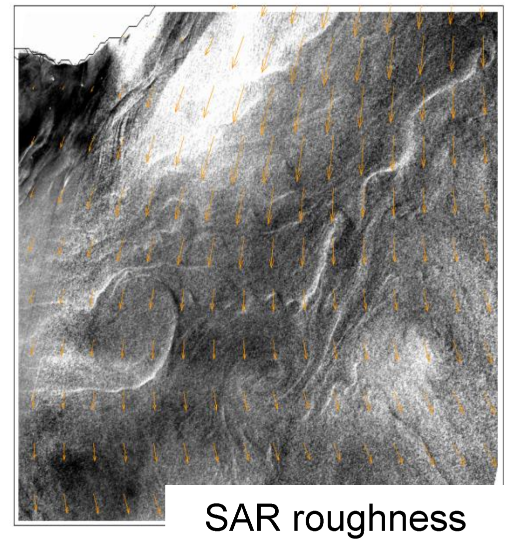




Which type of currents will sign?
- rotational currents
- divergent currents
- shear in the wind direction
- stretch in the wind direction


SAR roughness

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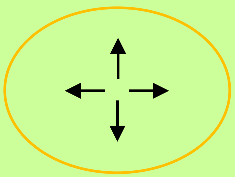

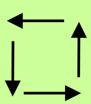

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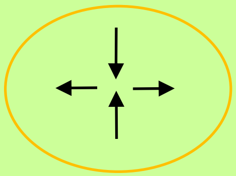

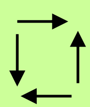

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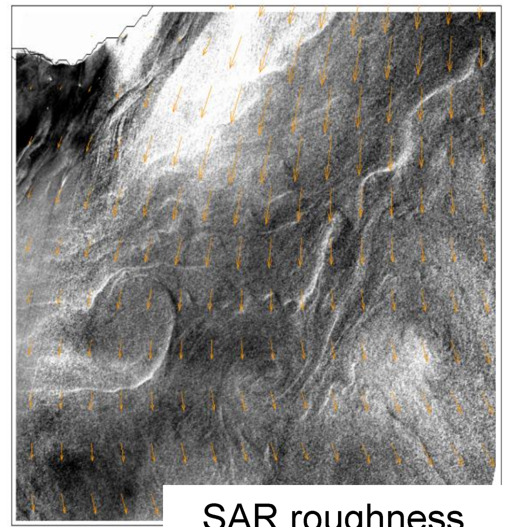
- ~~rotational currents~~
- **divergent currents**
- ~~shear in the wind direction~~
- **stretch in the wind direction**



SAR roughness

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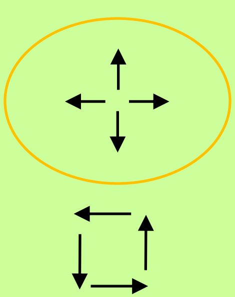

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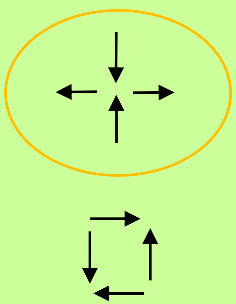

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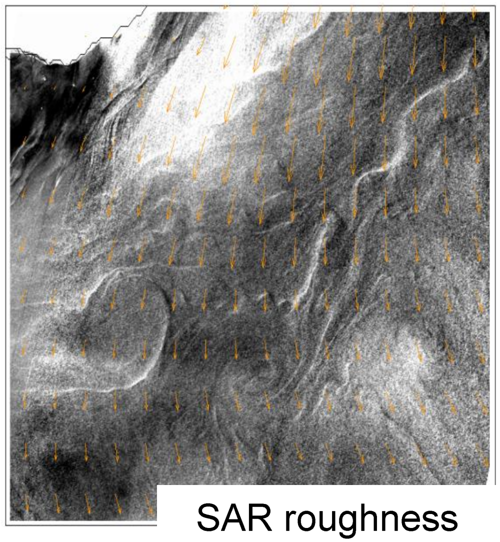
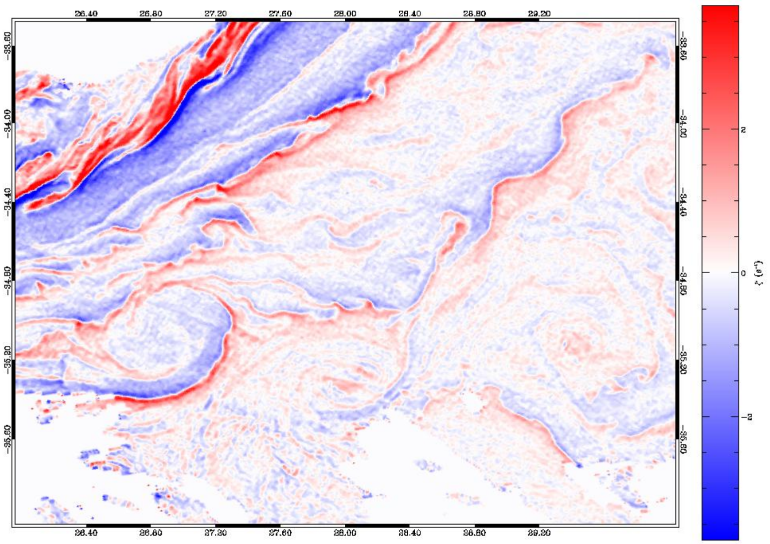


SAR roughness

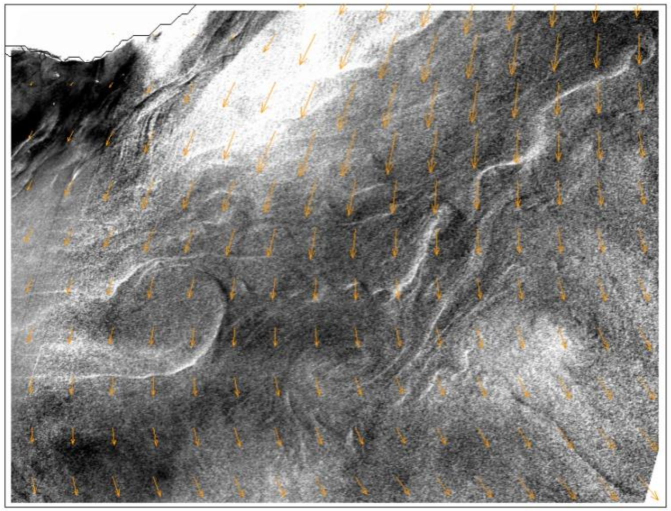
- Divergent currents appear independently of the wind direction

- Non divergent currents appear with a 45°-sensitivity to the wind/current angle.

2) Roughness and current deformation properties

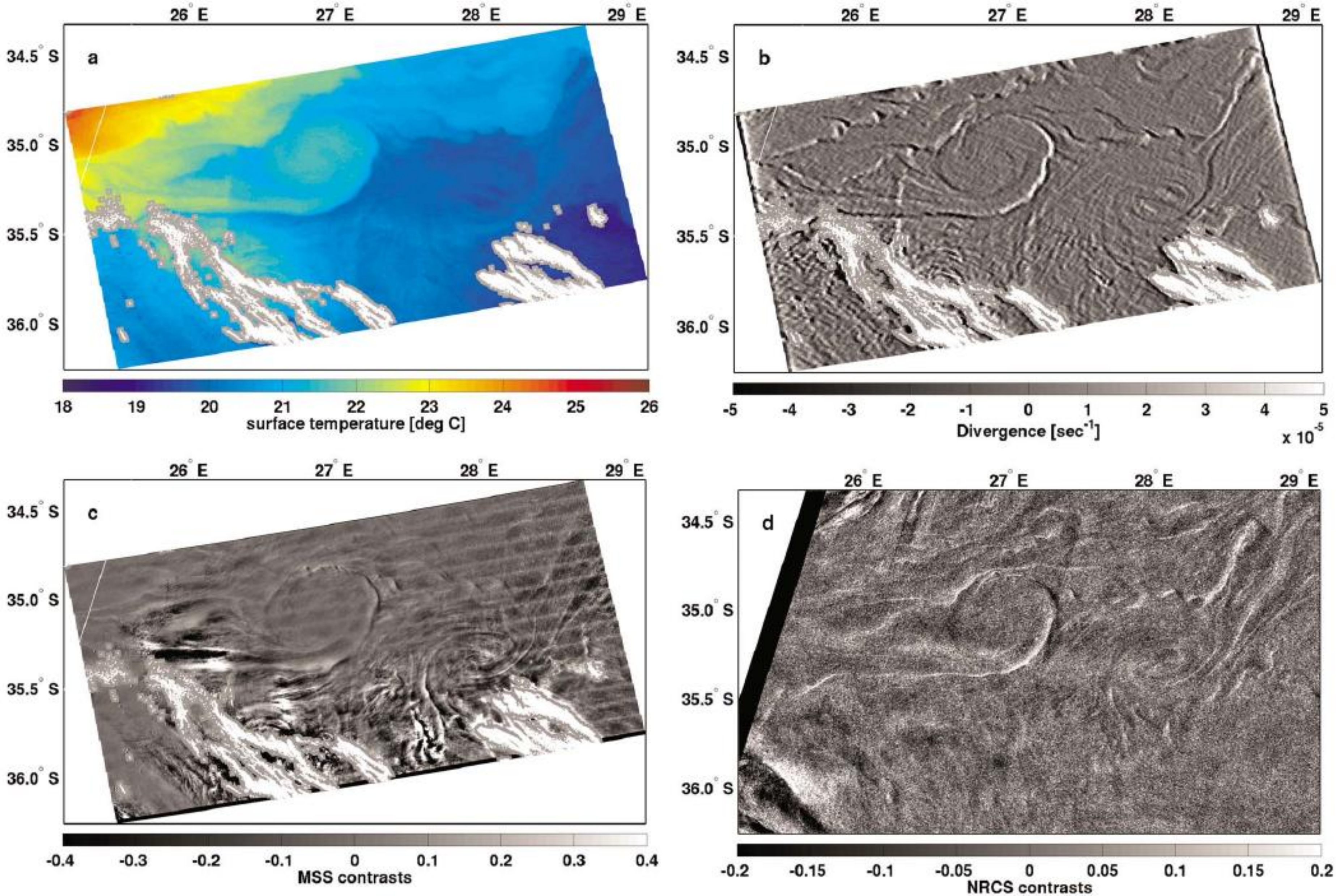


Reconstructed divergence



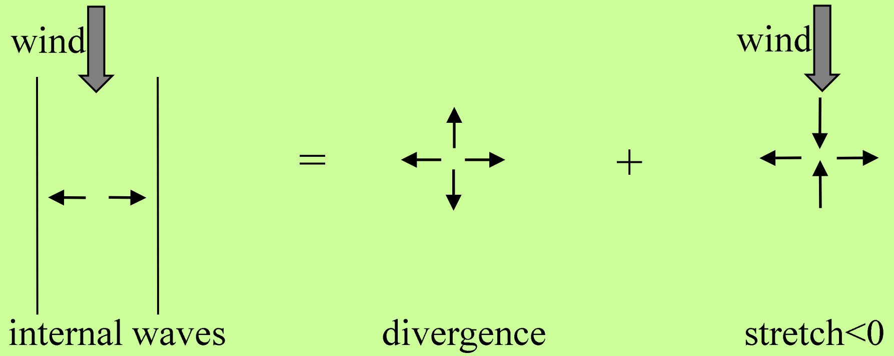
Surface roughness from Envisat SAR

2) Roughness and current deformation properties



3) Roughness response to stretched currents

Better understanding of the stretch signature

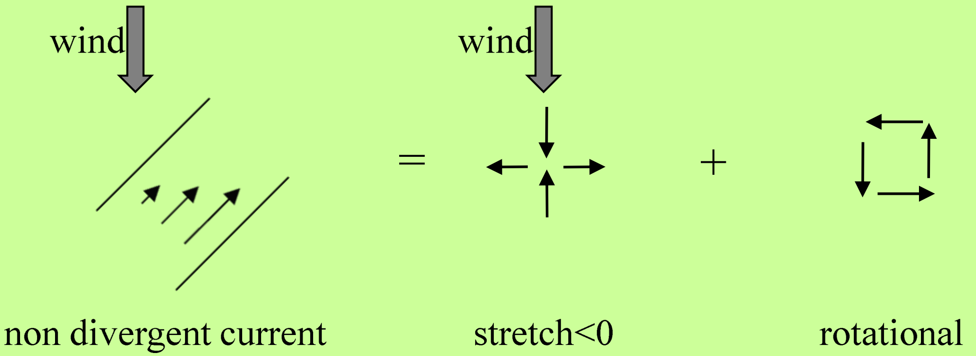


[Response to divergence 3x dominates that to stretch of similar amplitude]

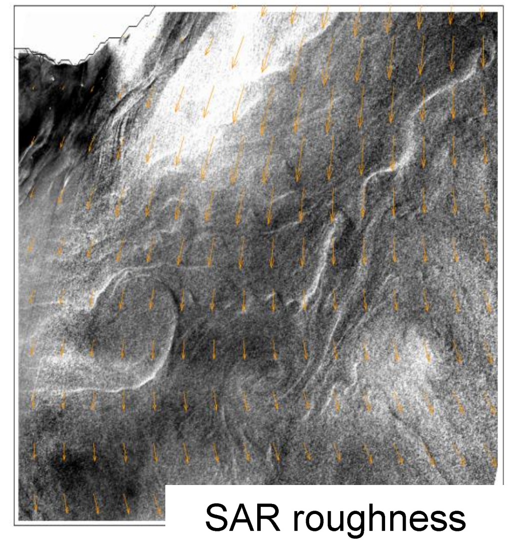
Roughness anomaly will have a sign independent (only a ± 30 % modulation) on the wind direction or sensor look direction

3) Roughness response to stretched currents

Better understanding of the stretch signature



1) Only slanting currents will appear
Sign of the signature will change when the wind direction changes



SAR roughness

3) Roughness response to stretched currents

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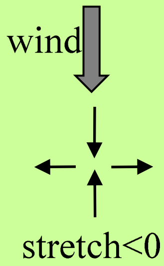


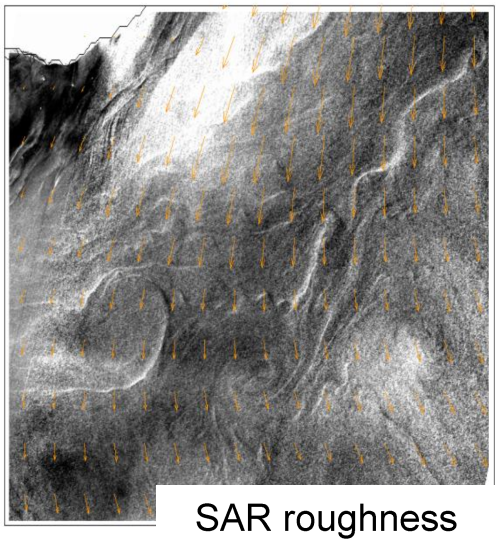
2)Alongwind waves are compressed
Crosswind waves are elongated

So sign of the roughness **might** change if the sensor looks upwind and crosswind

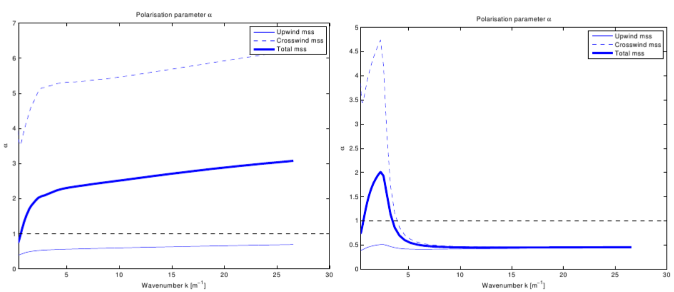
Results from the RIM:

•Full model : upwind and crosswind mss variations have the same sign

•Model without generation of short waves by longer breaking waves: upwind and crosswind have opposite signs

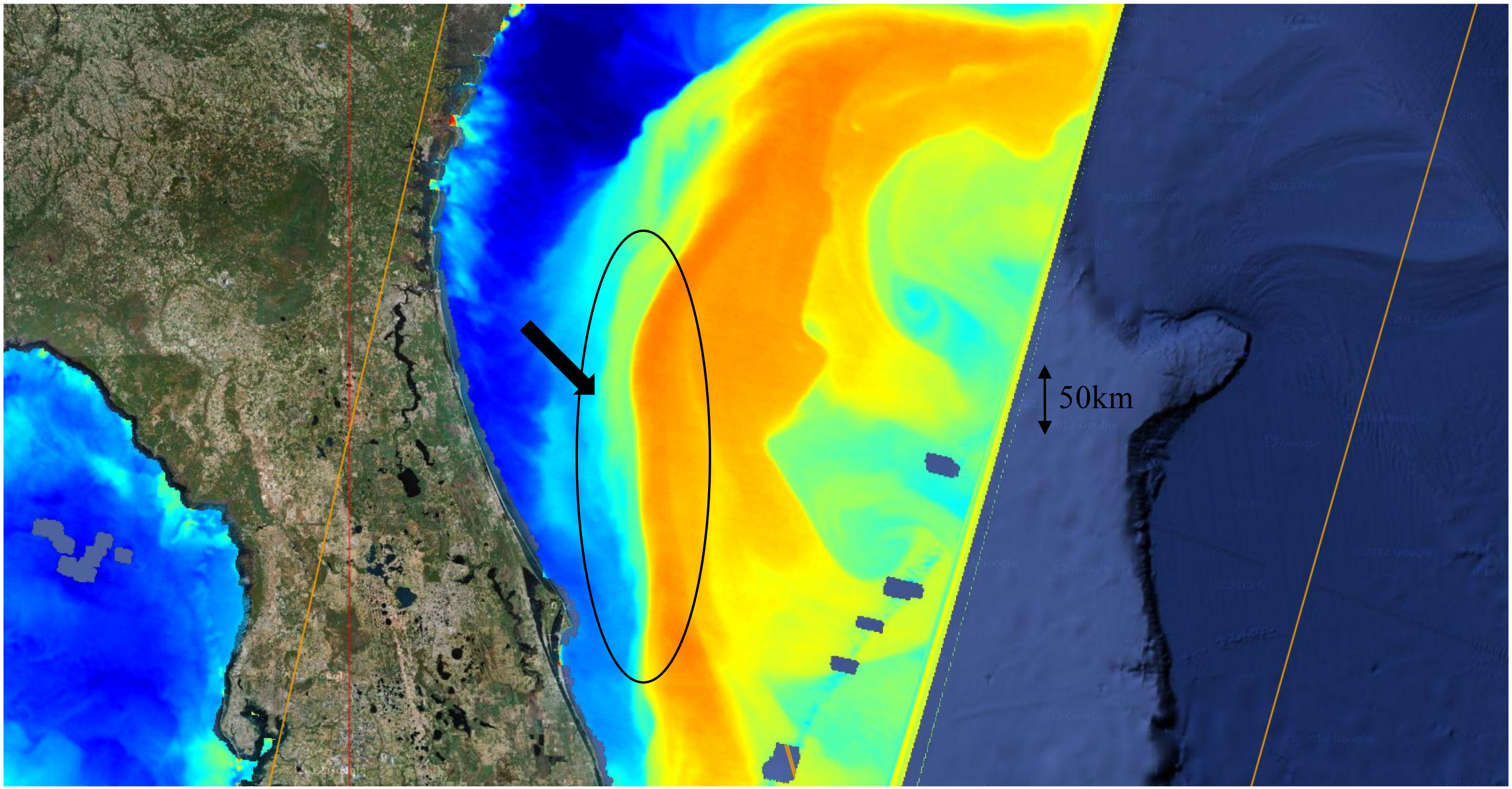


SAR roughness



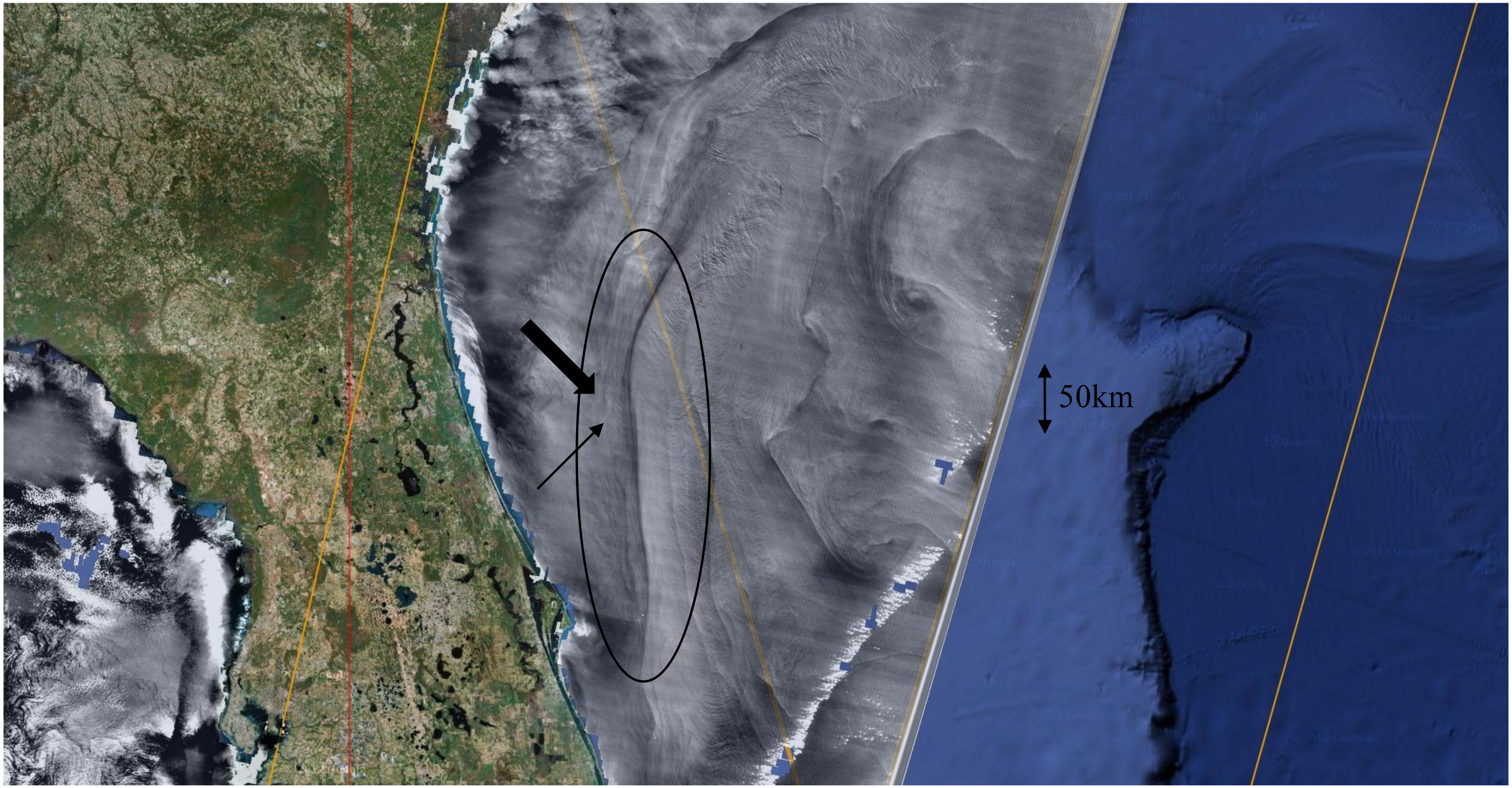
3) Roughness response to stretched currents

Results from the observation?
upwind and crosswind have opposite signs



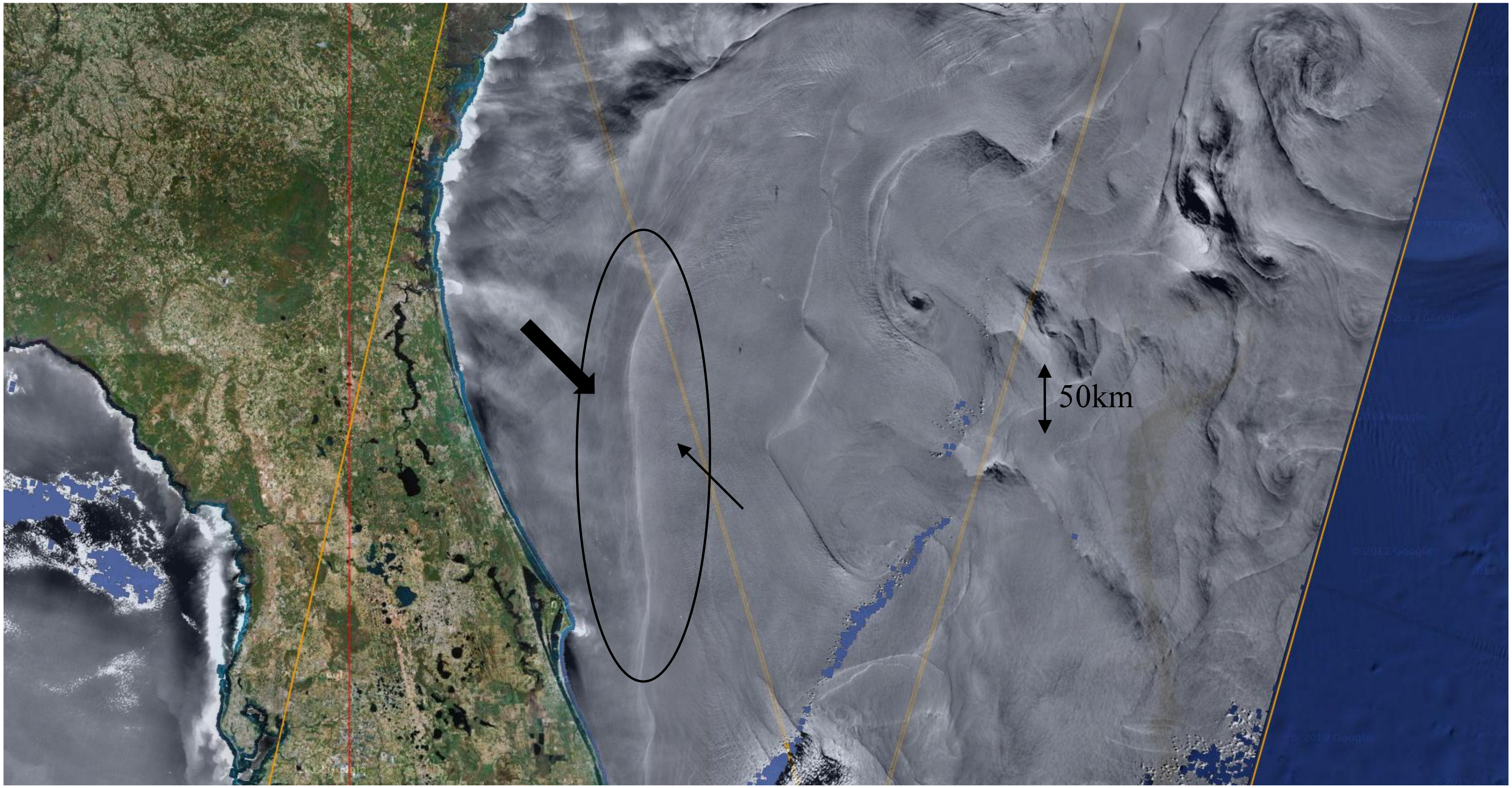
Modis SST

3) Roughness response to stretched currents



Modis glitter

3) Roughness response to stretched currents



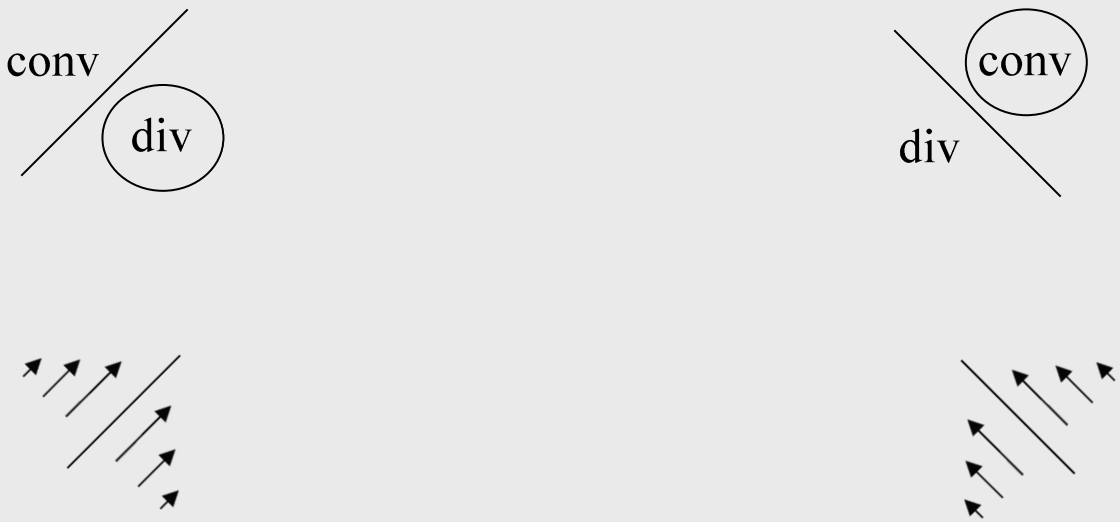
Meris glitter

3) Roughness response to stretched currents

Quadripolar principle of Dr Fab:

Northern Hemisphere:

Wind ↓



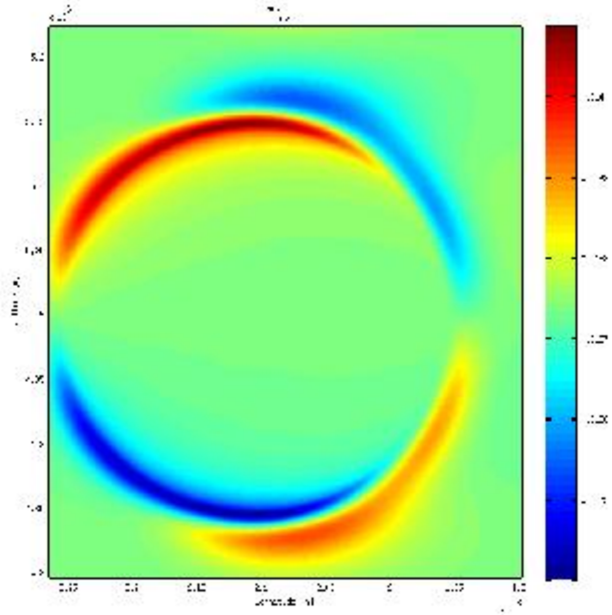
-We must add propagation effects,

-We must study cases with multiple images with multiple sensor look directions

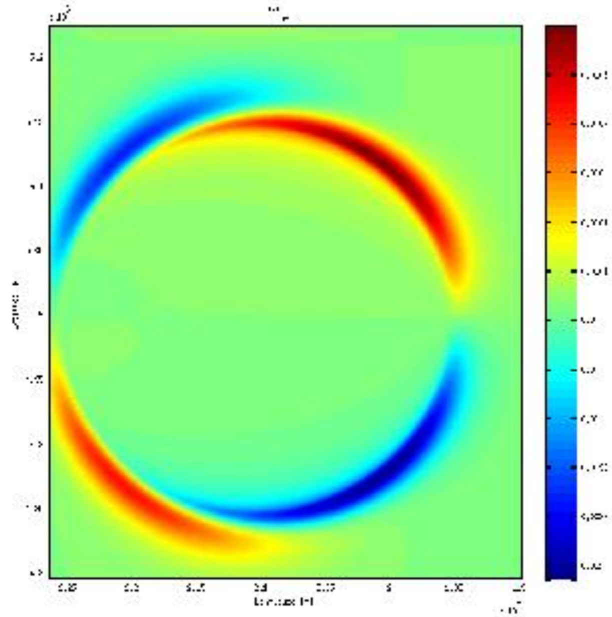
Mss response to stretch:

Cyclonic non-divergent eddy

Wind



Upwind mss



crosswind mss

RIM full model results

-We must add propagation effects,

-We must study cases with multiple images with multiple sensor look directions

Conclusion

As a summary,

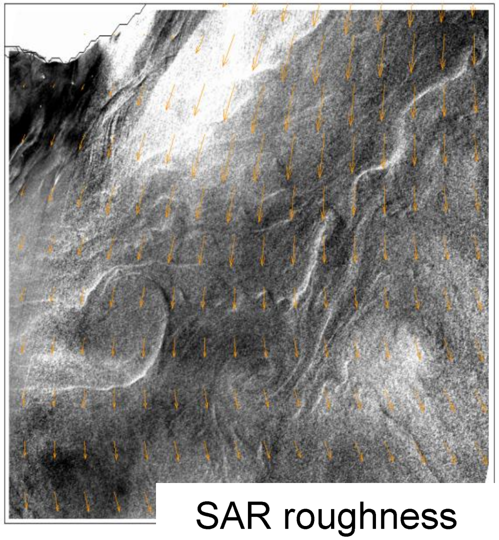
-The surface roughness responds to current divergence **and** stretch in the wind direction

-If we want to remove the stretch to access the divergence (i.e. vertical velocities)

2 unknowns (divergence and stretch)

-> we might need **2** roughness images

Either we wait for the wind to turn by 90º
Either we take 2 simultaneous images with 90º incidence angles
Need to better understand the conditions of inversion of the stretch signature.


SAR roughness

Perspectives

1 Roughness imaging is a **powerful tool** to observe **high resolution surface current deformations**.

2 Multiple sensors + scatterometers might deliver direct observations of **divergence** and **vertical velocities**. It is a challenge (but salinity from space was a greater one!)

3 We expect a lot from **collocations** of roughness gradients with **SST** and **color**.

4 **SWOT** will deliver stripes of surface roughness collocated with high resolution altimetry.

Perspectives

But also:

5 Insights into the **ocean-waves-atmosphere coupled system** at high resolution