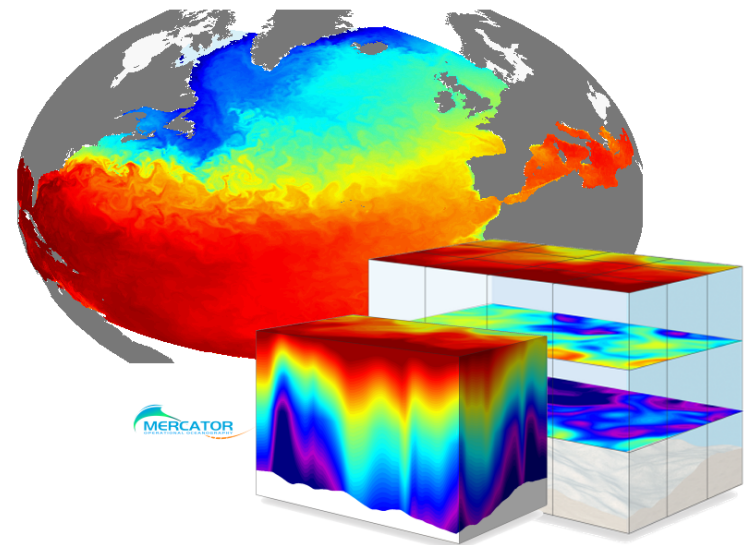


# Data Assimilation of altimeter SSH in a regional model with atmospheric pressure forcing

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# The regional model

## NEMO 1/12 system over the European Atlantic & West of Med Sea:

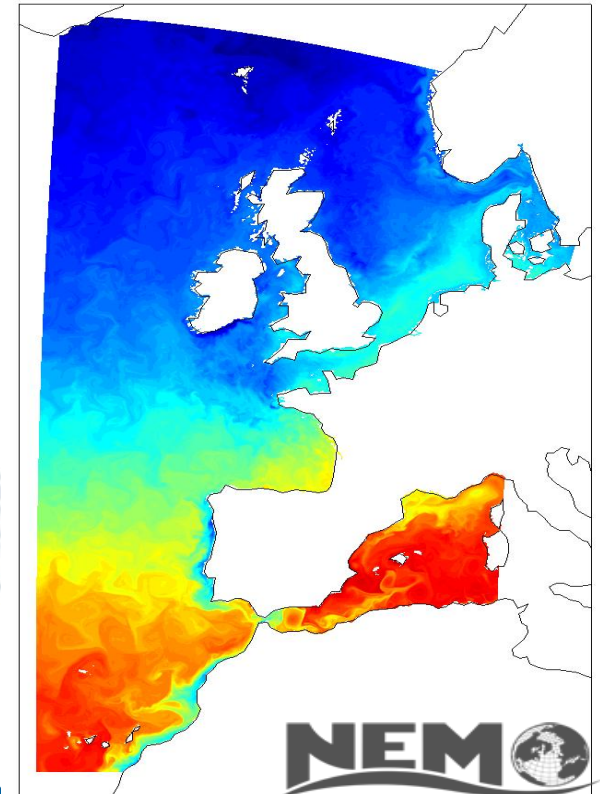
- **Explicit free surface, « time splitting »** + Variable volume formulation
- **Tides (including potential) : M2, S2, K2, N2, K1, O1, P1, Q1, M4, Mf, Mm**
- **Wind & Atmospheric pressure forcing**
- Open boundaries from GLORYS2V1  $\frac{1}{4}^{\circ}$  reanalysis (daily)

## Data Assimilation:

- Reduced order Kalman Filter (SEEK formulation)
- 3D-VAR Bias corrections : for T and S
- Incremental Analysis Updates (IAU) : Analysis J-2.5

## Assimilated Observations:

- **Along track SLA** observations from AVISO
- **In situ profiles T,S** from CORA3.1 data base
- Reynolds AVHRR  $\frac{1}{4}^{\circ}$  **SST**



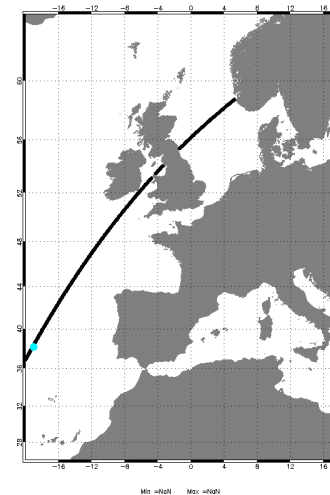
# Along-track SLA observations

- **TAPAS working group** during the Eu-MyOcean project
  - Initiated in 2010 and lead by the Sea Level Thematic Assembly Center (CLS)
  - Involves all the MyOcean regional and global Monitoring & Forecasting Centers
  - to design **T**ailored **A**ltimeter **P**roducts for **A**ssimilation **S**ystems
- 4 workshops since 2010
- **Experimental data** production and DA tests with **regional models**
- **Thematics** at the heart of **altimetry-model synergy** among them : **Physical content**
- TAPAS **experimental products** adding to AVISO SLA the **High\_Frequency Corrections**:
  - **Dynamic Atmospheric Correction (DAC)** : computed with 2Dmodel forced by atm.
  - **Long-Wave-Errors Correction (LWE)** : an empirical correction absorbing residual errors at the end of SLA computation

SLa (TAPAS) Data : Track 163

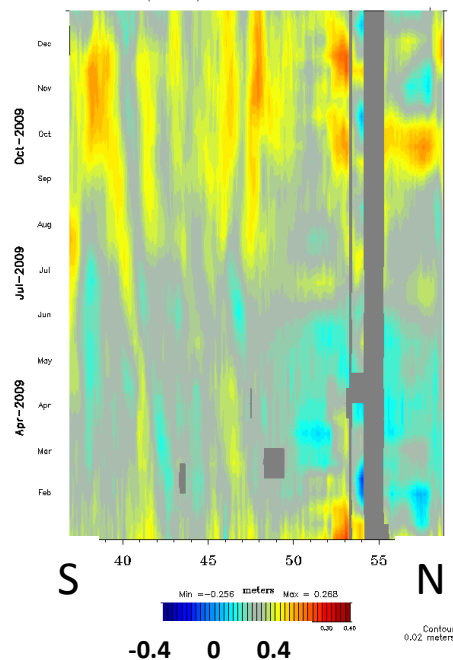


Jason : Position of the track : 163



$$SLA_{VXXC} = SLA^{sat} - TIDE - DAC - LWE$$

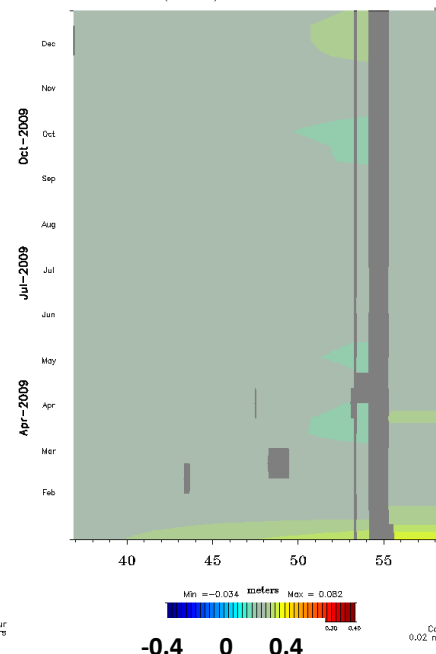
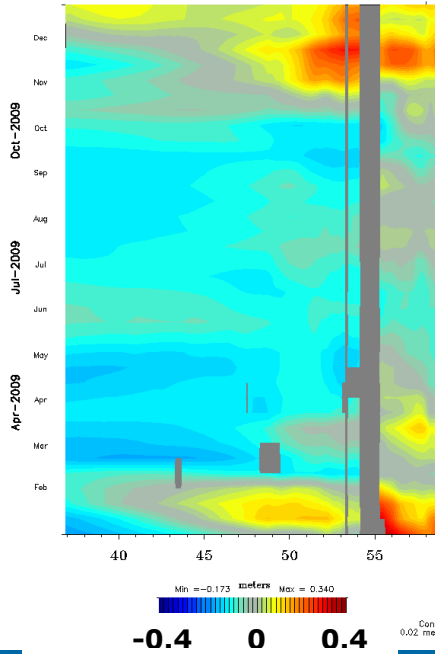
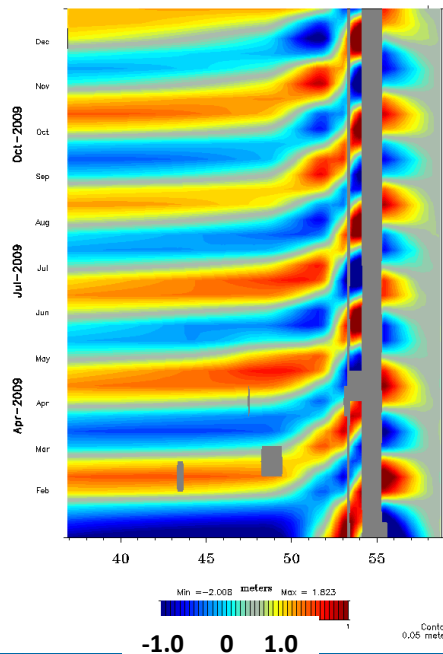
**DAC : not negligible, Large Scale  
LWE negligible compared to DAC**



TIDE (TAPAS) Data : Track 163

Dac (TAPAS) Data : Track 163

LWERR (TAPAS) Data : Track 163



SLA and HF  
corrections  
along Jason2  
track #163



## Assimilation of TAPAS SLA

**Objective :** Evaluate the impact of the assimilation of **along-track altimeter with or without High-Frequency signal** ( $DAC = IB_{LF} + MOG2D_{HF}$ ) in the regional model forced by Wind and Atmospheric Pressure.

**Time period :** 1 year (2009)

Experience	Atm. Pressure forcing in Model	High-frequency signal in altimeter SSH
MOD_HF	Yes	No
ASSIM_HF	Yes	Yes



# Model Background

MOD\_HF

$p_A$  : Atmospheric pressure

mean\_press : Mean (global) Atmospheric pressure

$$\text{NEMO: } \left\{ \begin{array}{l} \frac{\partial U}{\partial t} = \dots - \frac{1}{\rho_0} \nabla p_A + \dots \\ \text{OBC: } \text{ssh} = \text{ssh} - \frac{1}{g\rho_0} (p_A - \text{mean\_press}) \end{array} \right.$$

Modeled SLA :  $\frac{(\text{SSH} - \text{SSH}_{\text{TIDE}})}{25\text{h}} - \text{MDT} - \text{Equivalent(DAC)}$

Observed SLA:  $\text{SLA} - \text{TIDE} - \text{DAC} - \text{LWE}$

# Model Background

ASSIM\_HF

$p_A$  : Atmospheric pressure

mean\_press : Mean (global) Atmospheric pressure

NEMO :

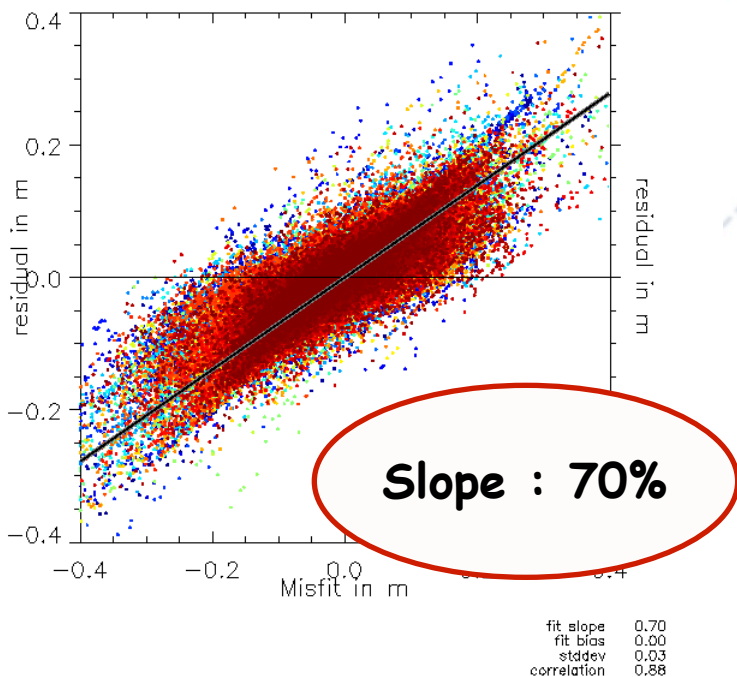
$$\left\{ \begin{array}{l} \frac{\partial U}{\partial t} = \dots - \frac{1}{\rho_0} \nabla p_A + \dots \\ \text{OBC : ssh} = \text{ssh} - \frac{1}{g\rho_0} (p_A - \text{mean\_press}) \end{array} \right.$$

Modeled SLA :  $\frac{(\text{SSH} - \text{SSH}_{\text{TIDE}})}{25\text{h}} - \text{MDT} - \text{Equivalent(DAC)}$

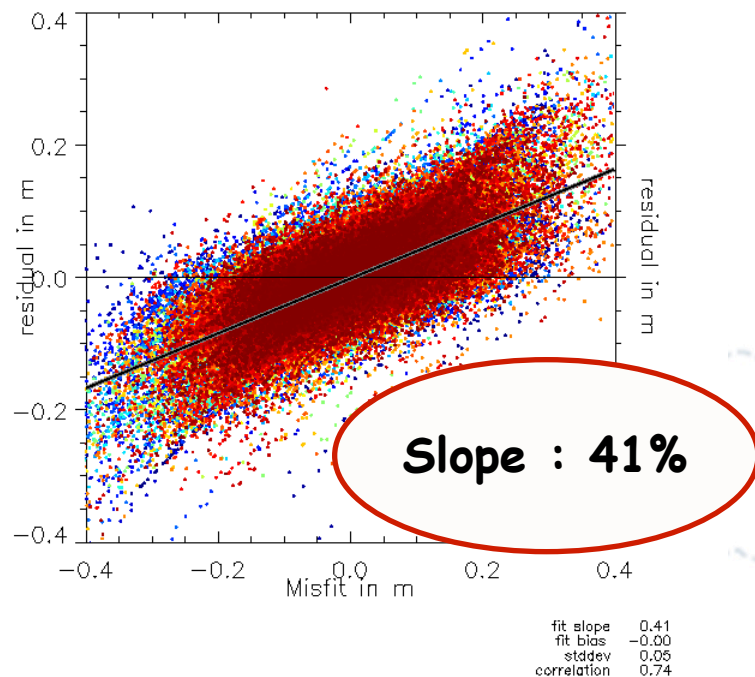
Observed SLA :  $\text{SLA} - \text{TIDE} - \text{DAC} - \text{LWE}$

# An HF signal efficiently assimilated

residual vs Misfit in SLA on 2009 **MOD\_HF**



residual vs Misfit in SLA on 2009 **ASSIM\_HF**



Residual = Misfit - Analysis

$$\text{Misfit} = \text{Data} - \text{Model}_{\text{forecast}}$$

**Reduced slope =**  
**A larger part of misfit has been**  
**ingested in the model**



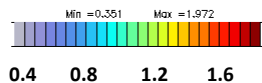
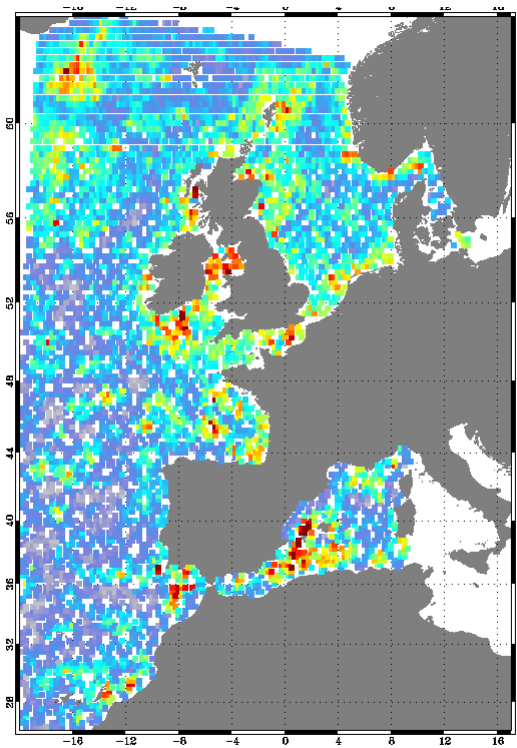
# Improved Comparison to SLA

**MOD\_HF**

$$\text{Misfit} = \text{Data} - \text{Model}_{\text{forecast}}$$

**ASSIM\_HF**

RMS(Misfit)/RMS(Data) in box (0.25x0.25), 2009 (RUN0)



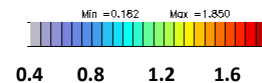
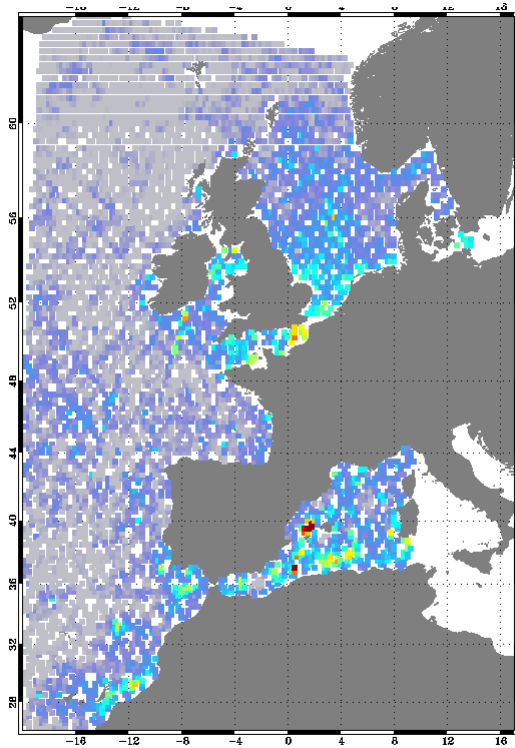
Mean=0.80

**Rms(Misfit) :**  
Increase  
but calculated with HF data

**Rms(Misfit)/Rms(Data):**  
improvement overall the basin  
In Open Ocean (Ratio < 0.4 )

The model is able to better explain the observed signal variability with the HF data.

RMS(Misfit)/RMS(Data) in box (0.25x0.25), 2009 (RUN4)



Mean=0.51

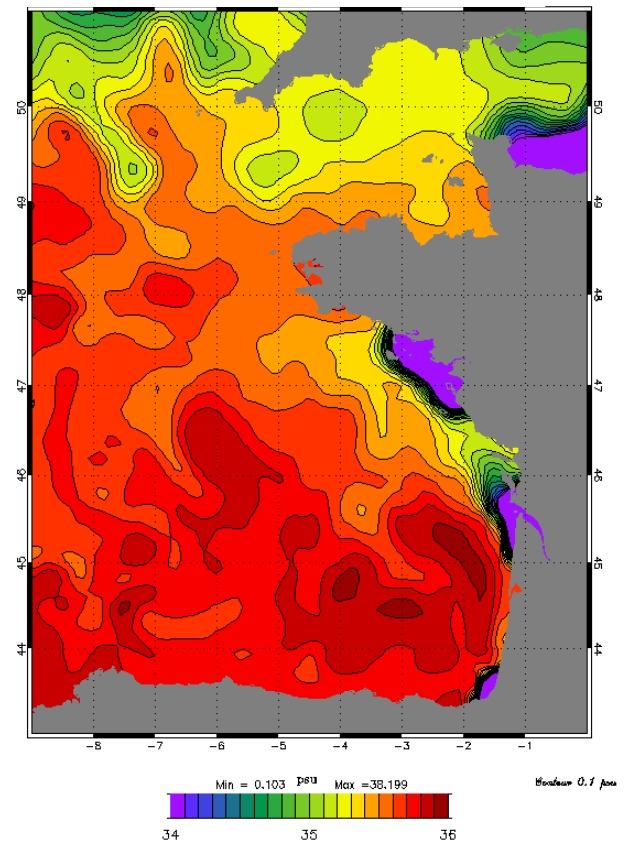
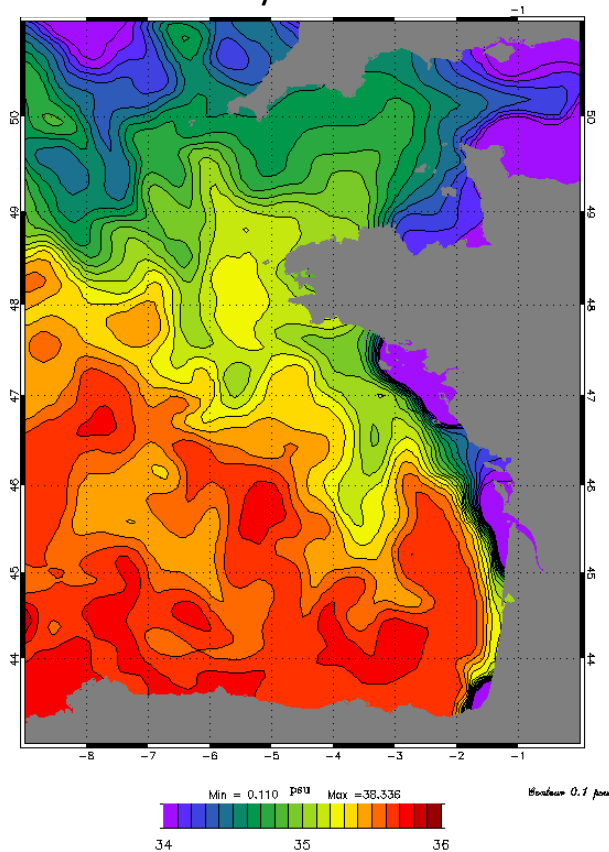
# Impact on Sea Surface Salinity

MOD\_HF

ASSIM\_HF

Sea Surface Salinity 15 Dec 2009 (c)

Sea Surface Salinity 15 Dec 2009 )



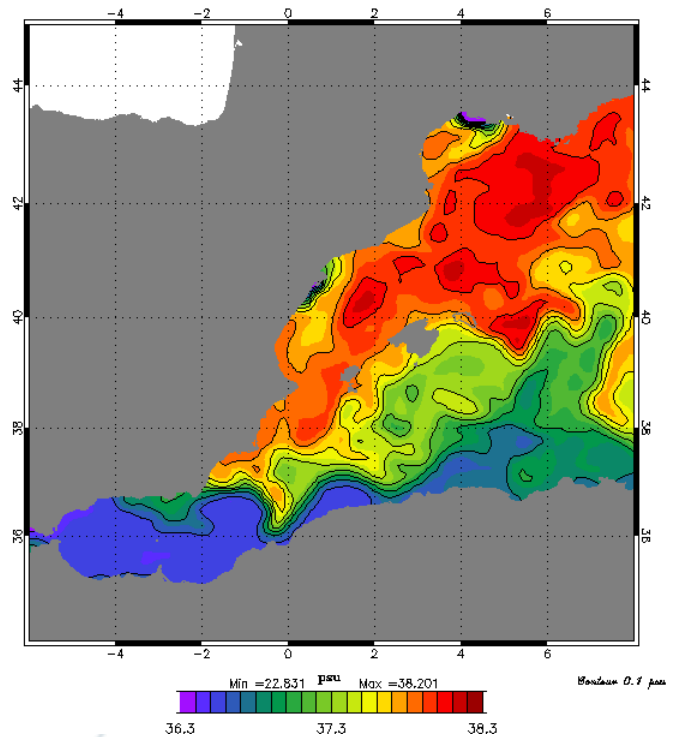
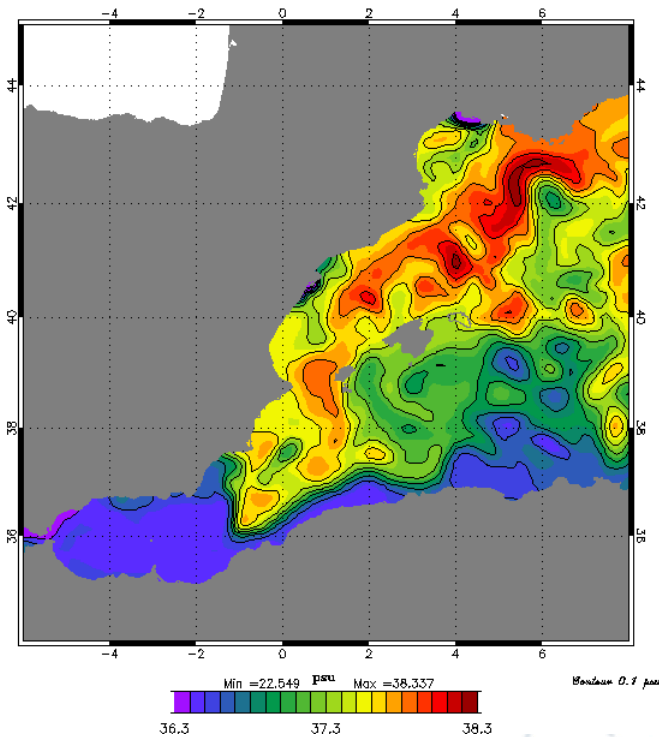
# Impact on Sea Surface Salinity

MOD\_HF

ASSIM\_HF

Sea Surface Salinity 15 Dec 2009

Sea Surface Salinity 15 Dec 2009 (c)



Qualitatively, a better representation of water masses (Algerian current, Almeria-Oran front)

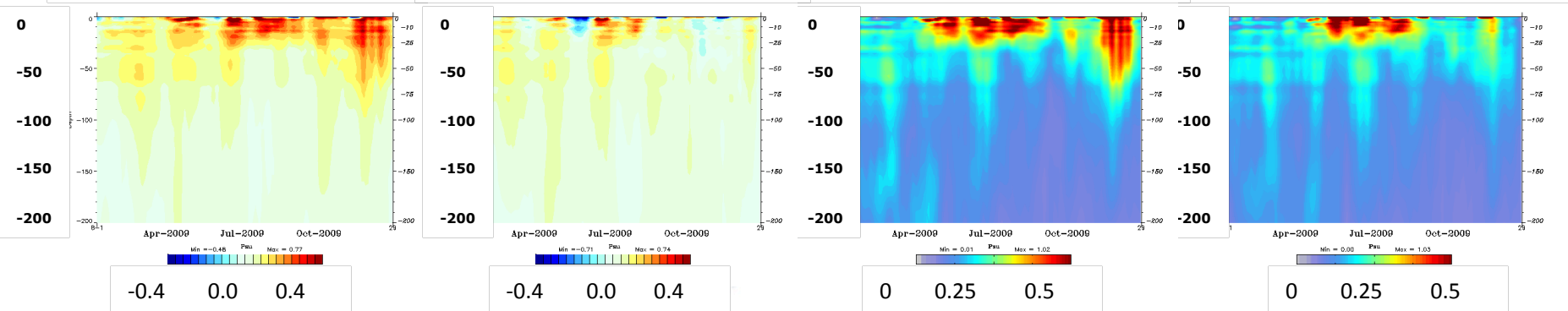
# Improved comparison to salinity profiles

Mean misfit ( MOD\_HF )

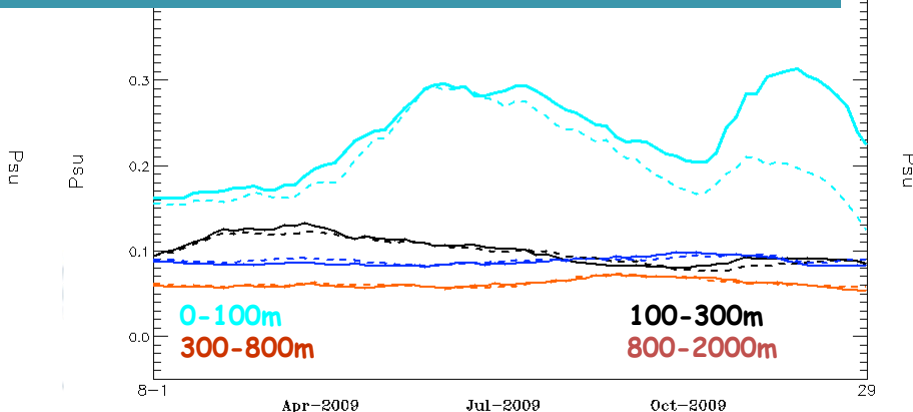
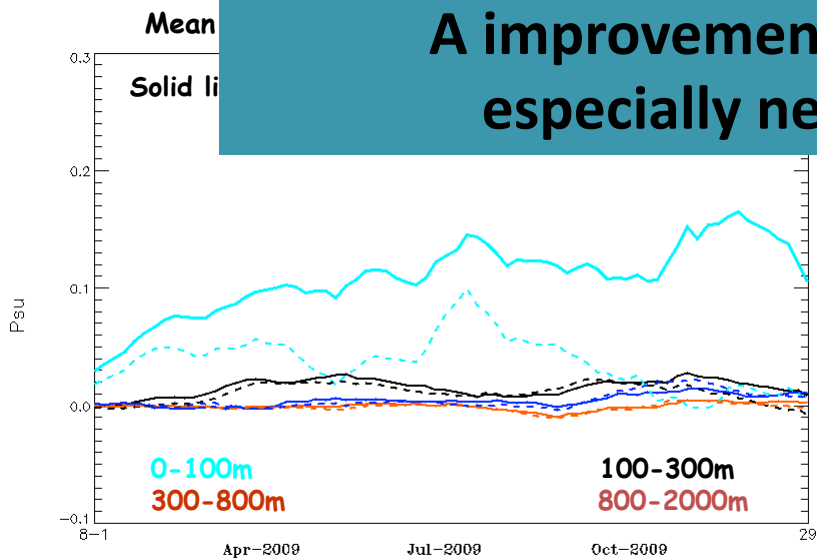
Mean misfit ( ASSIM\_HF )

Rms misfit ( MOF\_HF )

Rms misfit ( ASSIM\_HF )



**A improvement in both Mean and RMS especially near the surface(0-100m)**

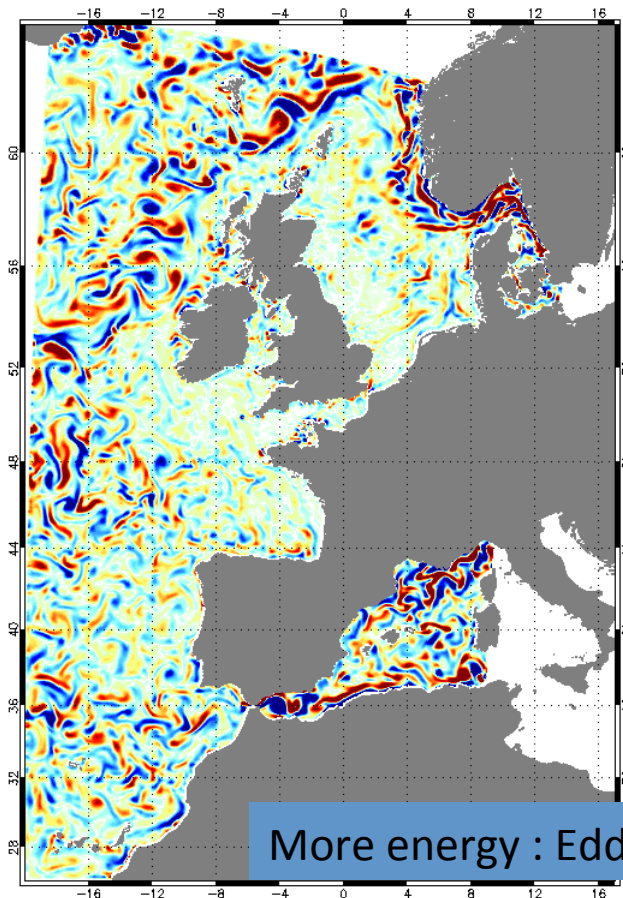


Solid lines=MOD\_HF dashed lines = ASSIM\_HF



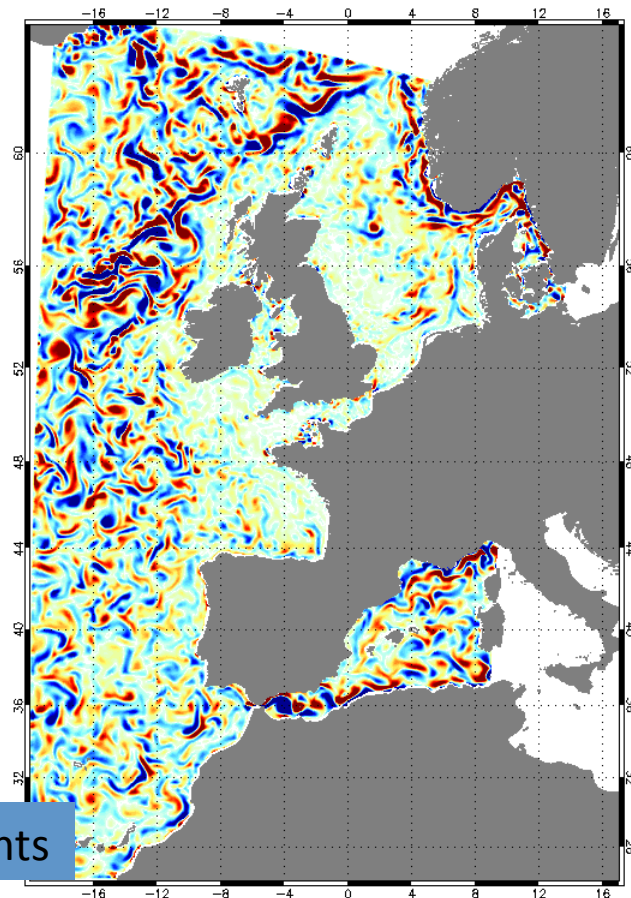
# Impact on Surface Relative Vorticity

Vorticity (MOD\_HF) fro 05/12/2009



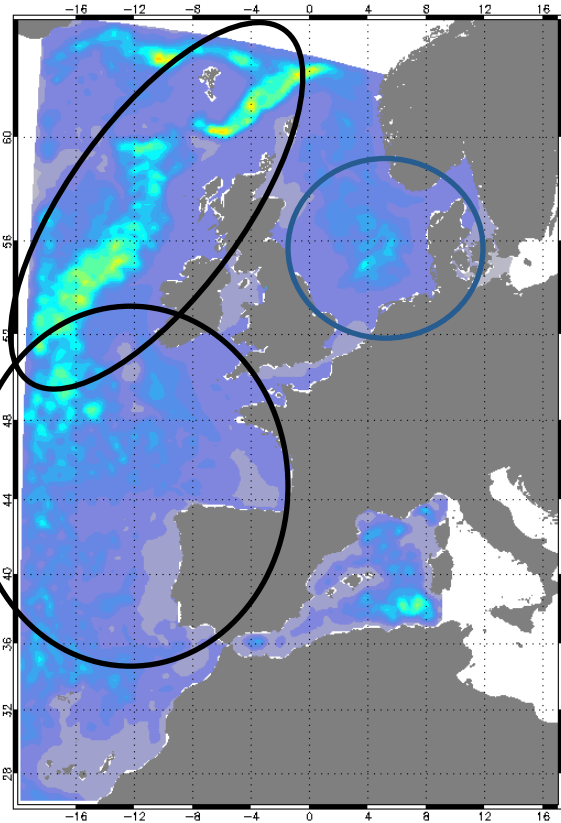
More energy : Eddies, filaments

Vorticity (ASSIM\_HF) fro 05/12/2009

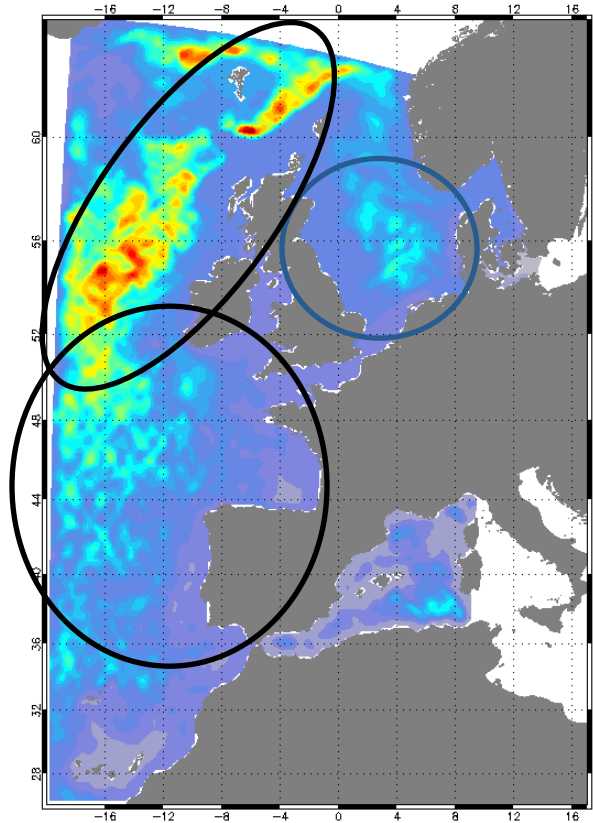


# Impact of HF on SLA Increment

Std Sla Increment (MOD\_HF) in 2009



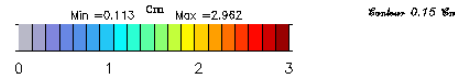
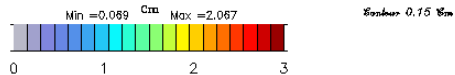
Std Sla Increment (ASSIM\_HF) in 2009



- More variable increment in the highest-eddy-energy regions

- Position of the tracks

**LWE?**

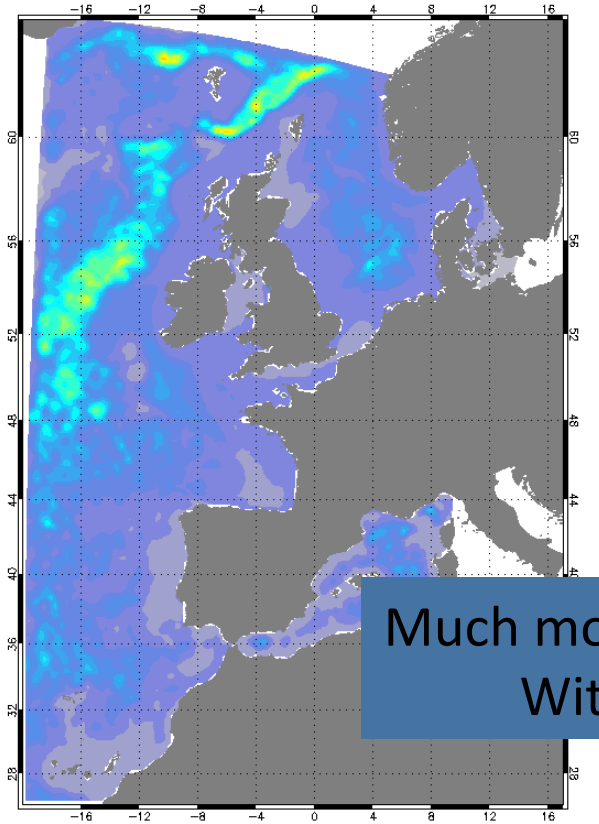


$$SLA_{obs} = SLA^{sat} - TIDE - LWE - DAC$$

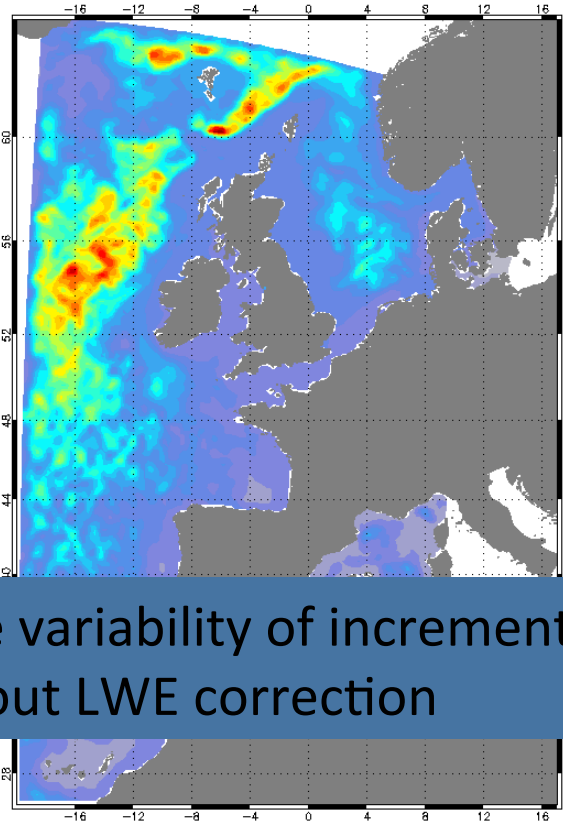
$$SLA_{obs} = SLA^{sat} - TIDE - LWE$$

# Impact of HF on SLA Increment

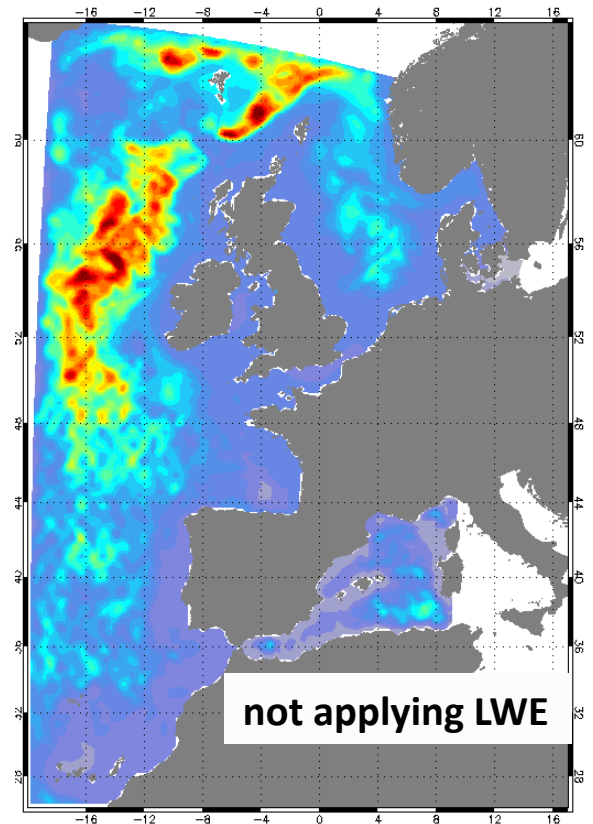
Std Sla Increment (MOD\_HF) in 2009



Std Sla Increment (ASSIM\_HF) in 2009

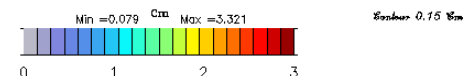
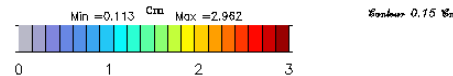
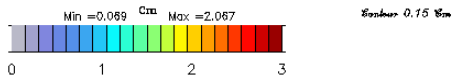


Std Sla Increment (NO\_LWE) in 2009



Much more variability of increment  
Without LWE correction

not applying LWE



$$SLA_{obs} = SLA^{sat} - TIDE - LWE - DAC$$

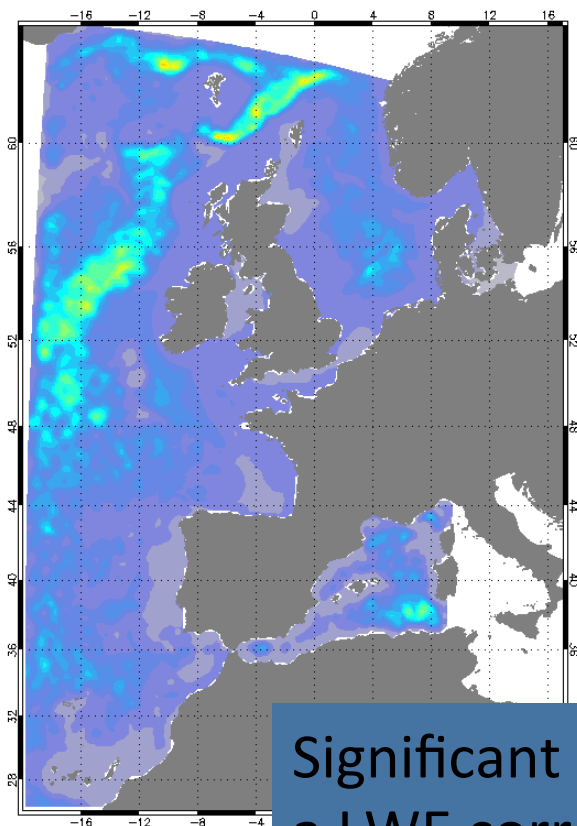
$$SLA_{obs} = SLA^{sat} - TIDE - LWE$$

$$SLA_{obs} = SLA^{sat} - TIDE$$

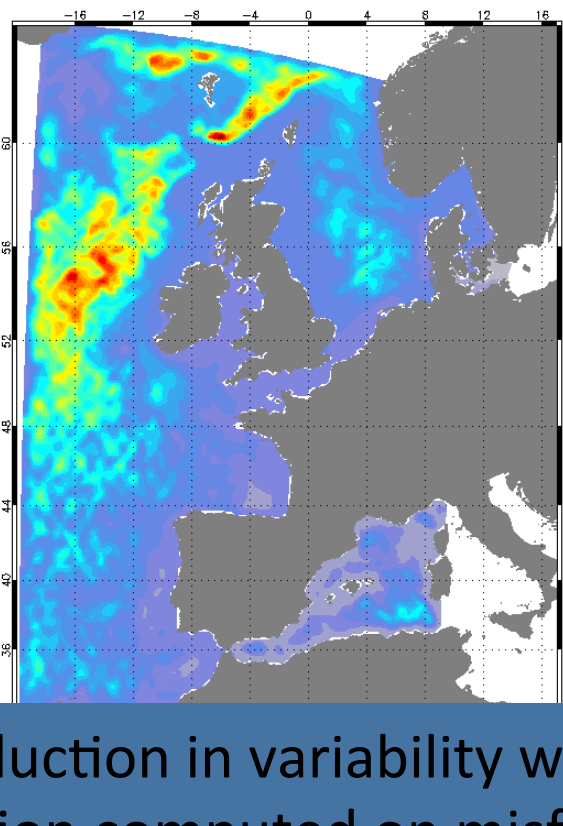


# Impact of HF on SLA Increment

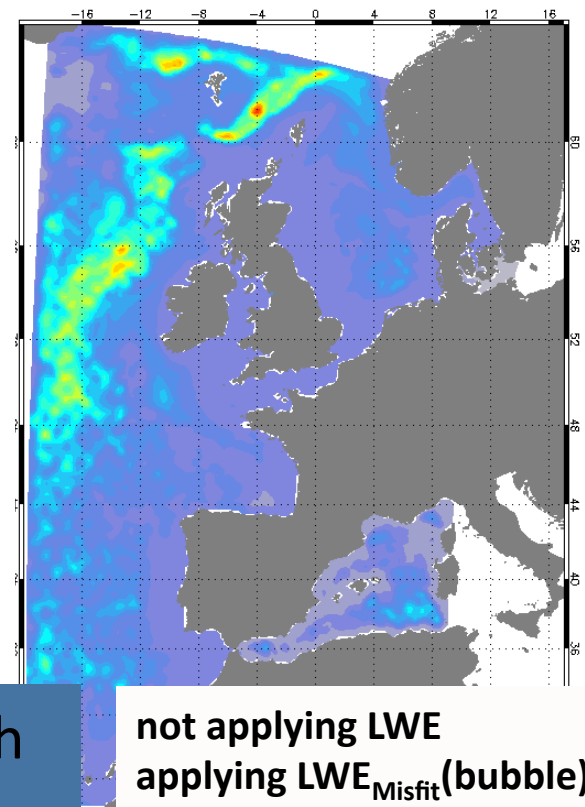
Std Sla Increment (MOD\_HF) in 2009



Std Sla Increment (ASSIM\_HF) in 2009

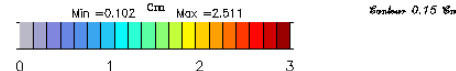
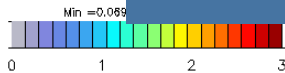


Std Sla Increment (LWE equivalent) in 2009



Significant reduction in variability with a LWE correction computed on misfit

not applying LWE  
applying LWE<sub>Misfit</sub> (bubble)



$$SLA_{obs} = SLA^{sat} - TIDE - LWE - DAC$$

ORK

$$SLA_{obs} = SLA^{sat} - TIDE - LWE$$

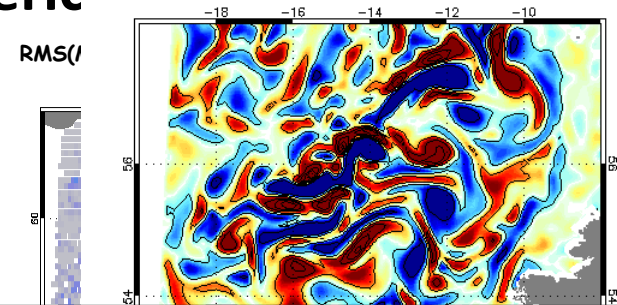
$$SLA_{obs} = SLA^{sat} - TIDE - LWE_{Misfit} (bubble)$$



# Conclusion

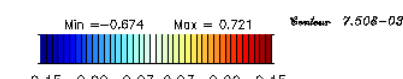
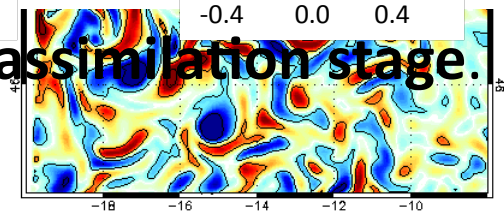
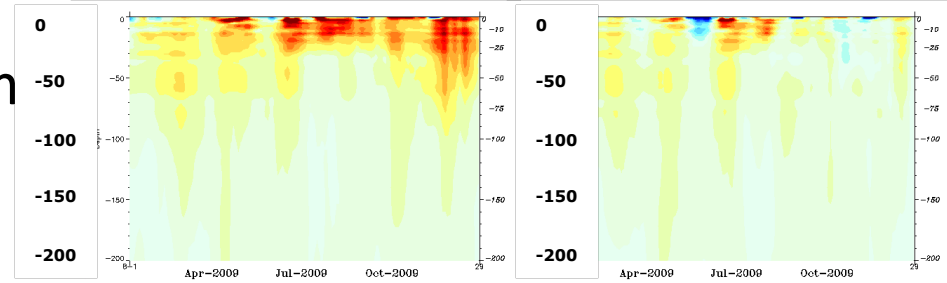
- In a regional **model forced with atmospheric** improvement of assimilation diagnostics **altimeter data**.
- More energy even at small scales
- Salinity improvement 0-100 m
- **LWE also not to be applied** but in this case, need to be computed during assimilation stage.

Vorticity (RUN4) for 20091205



Mean misfit ( Sal,RUN0 )

Mean misfit ( Sal,RUN4 )



# Conclusion

- **TAPAS** : already a fruitful synergy between altimeter data producers and regional (EU) modelers → new NRT AVISO SLA (Dobricic et al. 2011, Oddo et al, in prep., Benkiran et al, in prep)
- Issues also addressed : **along-track resolution** (filtering) , **observation errors** and reference surface (MDT)
- **Unfiltered** NRT SLA : exist but **not used** (Med Sea System)
- Link with the GODAE-OV COSS-TT

Thank you for your  
attention

