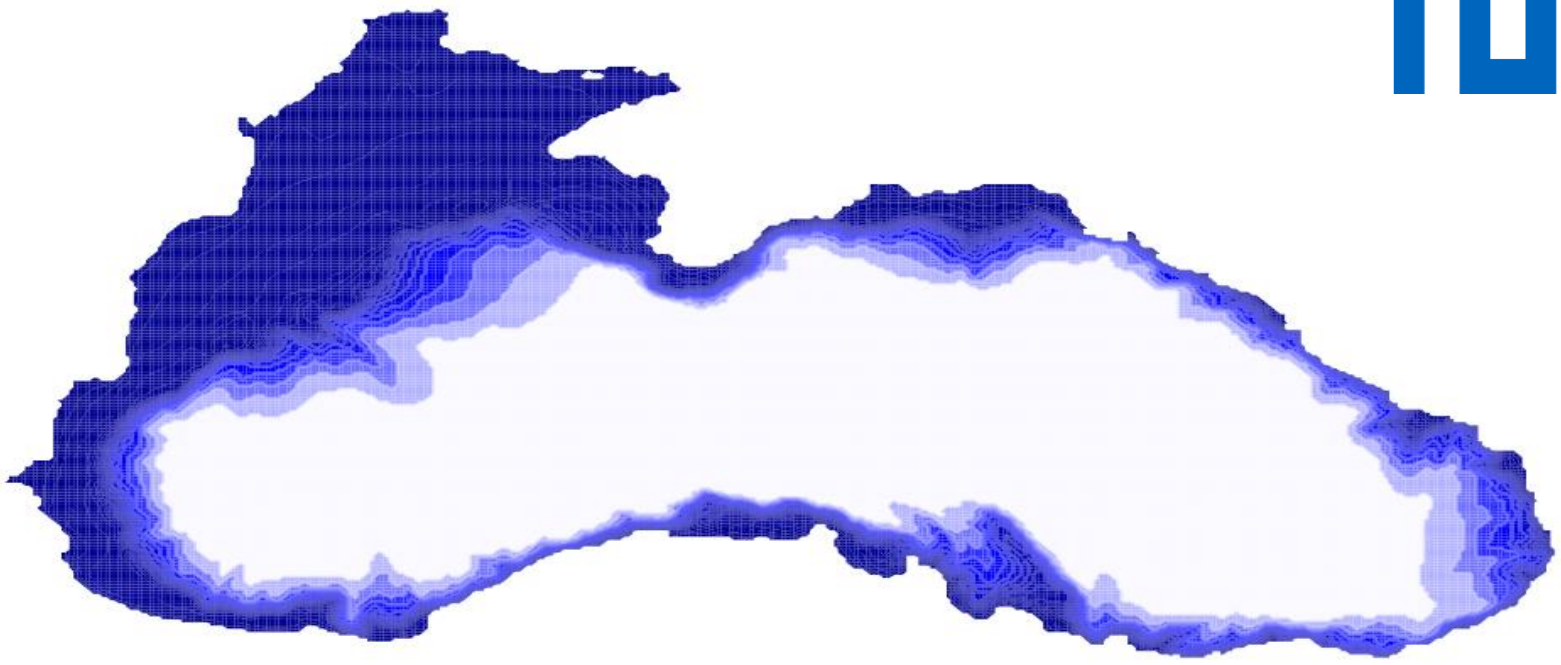
Impact of coastal altimetry data in the Black Sea physical ocean analysis system

A. Bonaduce [1,3], M. Passaro [2] A . Storto [3]

[1] Mercator-Ocean, Toulouse, France

[2] DGFI-TUM, Munchen, Germany

[3] CMCC, Bologna, Italy



10th Coastal Altimetry Workshop (CAW-10), 21-24 February 2017, Florence, Italy

Outline

- ***Black Sea physical ocean analysis system***
  - ***Black Sea Monitoring and Forecasting Center (BS-MFC)***
  - ***Ocean General Circulation Model (OGCM)***
  - ***3-Dimensional Variational Assimilation Scheme (3D-VAR)***

- ***Coastal Altimetry Data***
  - ***ALES sub waveform coastal retracker***

- ***Experimental Set-up***
  - ***Ocean simulation and analysis (with data assimilation) using conventional and coastal satellite altimetry data (Jason-2 mission)***

- ***Preliminary Results***
- ***- Impact of coastal altimetry data in BS physical ocean analysis system: SLA, Temperature and Salinity***

Objectives

Pilot study to investigate the capabilities of the BS physical ocean analysis system to consider coastal altimetry data

Asses the impact of coastal altimetry data in the system both at the surface and in the water column

Outline

- ***Black Sea physical ocean analysis system***
  - ***Black Sea Monitoring and Forecastion Center (BS-MFC)***
  - ***Ocean General Circulation Model (OGCM)***
  - ***3-Dimensional Variational Assimilation Scheme (3D-VAR)***

- ***Coastal Altimetry Data***
  - ***ALES sub waveform coastal retracker***

- ***Experimental Set-up***
  - ***Ocean simulation and analysis (with data assimilation) using conventional and coastal satellite altimetry data (Jason-2 mission)***

- ***Preliminary Results***
- ***- Impact of coastal altimetry data in BS physical ocean analysis system: SLA, Temperature and Salinity***

Objectives

Investigate the capabilities of the BS physical ocean analysis system to consider coastal altimetry data sampled both at 1 Hz and 20 Hz

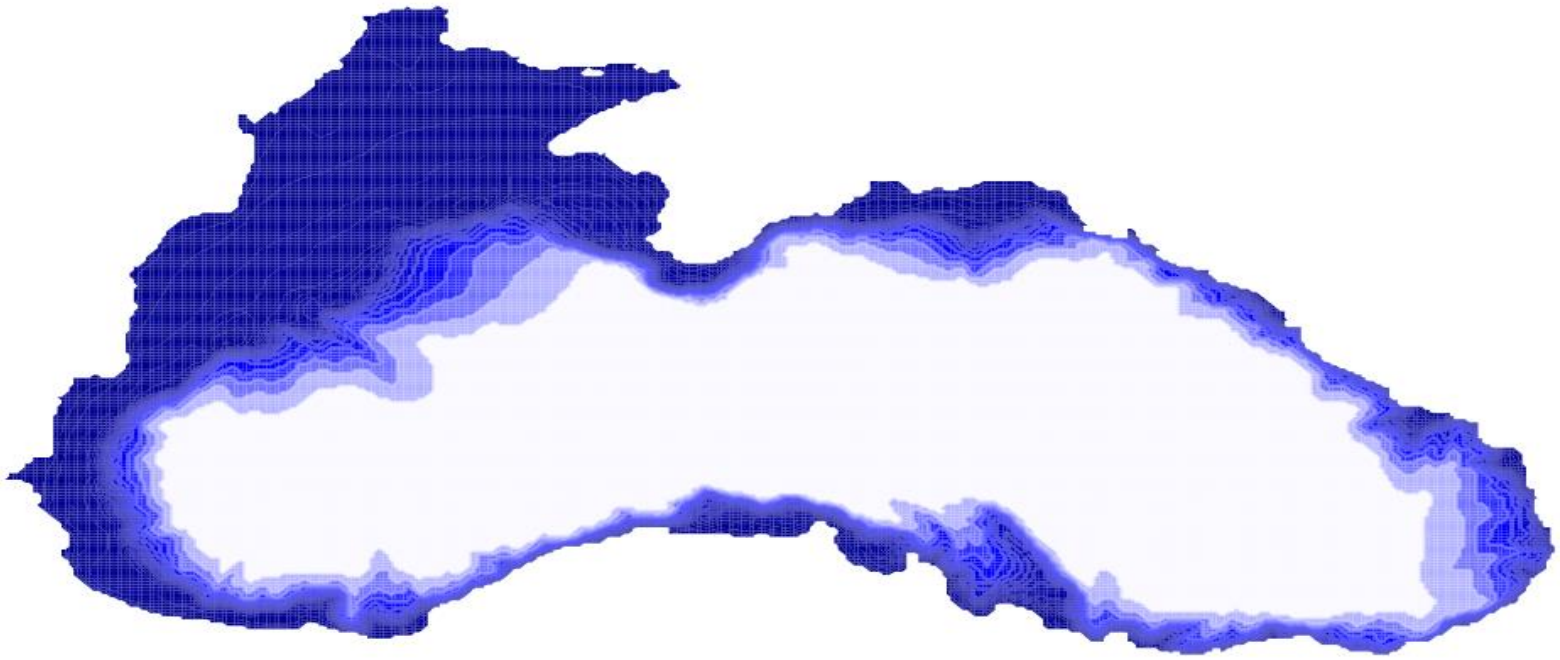
Asses the impact of coastal altimetry data in the system both at the surface and in the water column

Black Sea – Monitoring and Forecasting Center (BS-MFC)

- *The BS-MFC has 2 main components*

1. Ocean General Circulation Model** (OGCM) **NEMO** in the **Black-Sea

- *3 km horizontal resolution*
- *31 vertical z-levels with partial steps*



***2. Three Dimensional Variational Assimilation Scheme** (**3D-VAR**; Storto et al., 2011)*

3D-VAR: Background and Observation errors

- *3 Dimensional Variational **Assimilation Scheme** (**3D-VAR**)*

*- **Background Error**: bivariate vertical EOFs for Temperature and Salinity (not from altimetry)*

*- **Recursive filter:** horizontal operator to model the horizontal propagation of the background error covariances (which determines observation impact)*

*- **Observations Error**: Instrumental + Representativity Error*

*- **Obs Pre-processing**:*
Quality check with respect to the climatology and to the background.

3D-VAR : Observation systems considered

***- In-situ Observations**: ARGO floats*

***- Remote Sensing Obs.:** Satellite Radiometry (**SST**), Satellite Altimetry (**SLA**).*

***1) SST :** L4 Optimally Interpolated data (Buongiorno N. et al.,2013,2015)*

***2) SLA**: along-track data (L3) for Jason2, Cryosat, Altika (Dibarboure et al., 2011; Pujol et al., 2016 in review).*

***- SLA** propagated in the vertical using the dynamic height equation (height related to density (T,S)).*

***- SLA representativeness** error derived from SLA spatial variability of L4 gridded products*

Configuration of Analysis System

SST Data	BLACK_SEA SST L4 (CNR/CMEMS)
SST Assimilation	Nudging (Heat flux adjustment) + 3DVAR assimilation
SLA Data	BLACK_SEA Along-track CLS/AVISO [Jason-2, Altika, Cryosat-2], **ALES Jason-2**
SLA Assimilation	T/S correction with basin-averaged SLA removed
MDT	Mean SSH from model simulation – Time-Mean Mapped SLA during model simulation for referencing to 1993-2012 SLA reference period
In-situ Data	CMEMS In-situ Real-Time data
In-situ Assimilation	Vertical thinning for floats with high vertical sampling
Background-error Covariances	15-mode gridpoint-wise multivariate monthly EOFS computed from 5-year long model simulation
Background-error Horizontal operator	Third-order recursive filter
Background-error correlation scales	2D, Same for T/S, as a function of distance from shoreline
Assimilation time-window	7-day
Assimilation frequency	3-days

Outline

- *Black Sea physical ocean analysis system*
  - *Black Sea Monitoring and Forecastion Center (BS-MFC)*
  - *Ocean General Circulation Model (OGCM)*
  - *3-Dimensional Variational Assimilation Scheme (3D-VAR)*

- ***Coastal Altimetry Data***
  - ***ALES sub waveform coastal retracker***

- *Experimental Set-up*
  - *Ocean simulation and analysis (with data assimilation) using conventional and coastal satellite altimetry data (Jason-2 mission)*

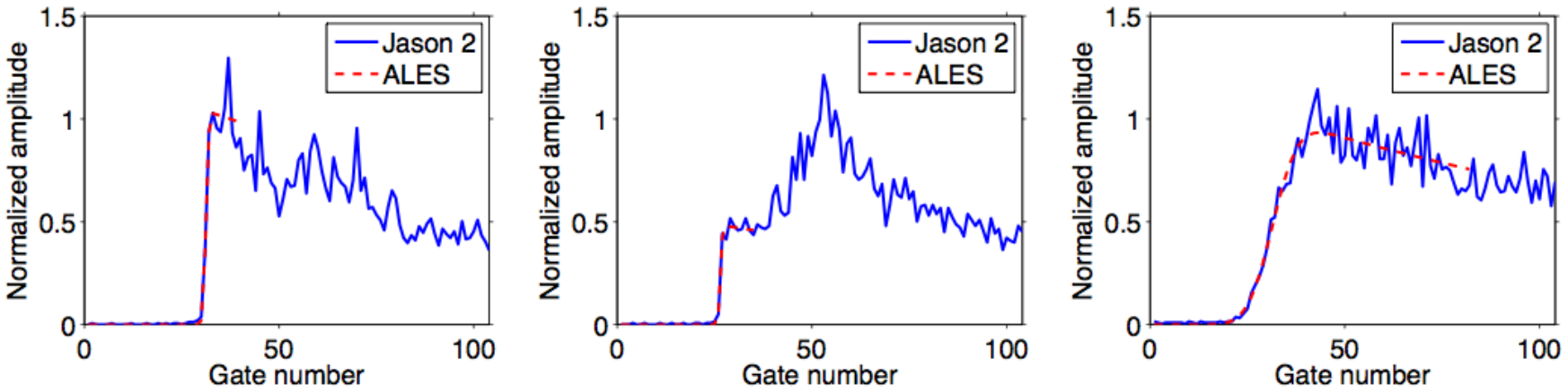
- *Preliminary Results*
- *- Impact of coastal altimetry data in BS physical ocean analysis system: SLA, Temperature and Salinity*

Objectives

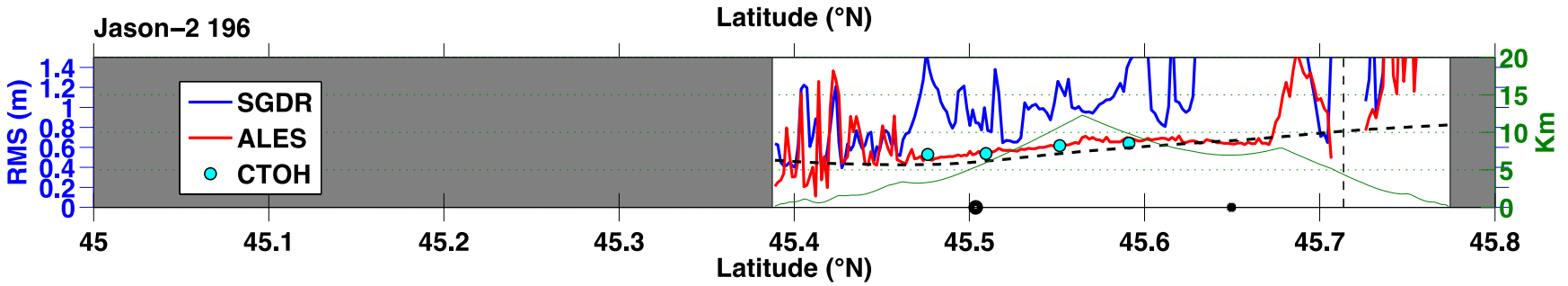
Investigate the capabilities of the BS physical ocean analysis system to consider coastal altimetry data sampled both at 1 Hz and 20 Hz

Asses the impact of coastal altimetry data in the system both at the surface and in the water column

Coastal Altimetry data: ALES retracker



ALES, the Adaptive Leading Edge Subwaveform retracker

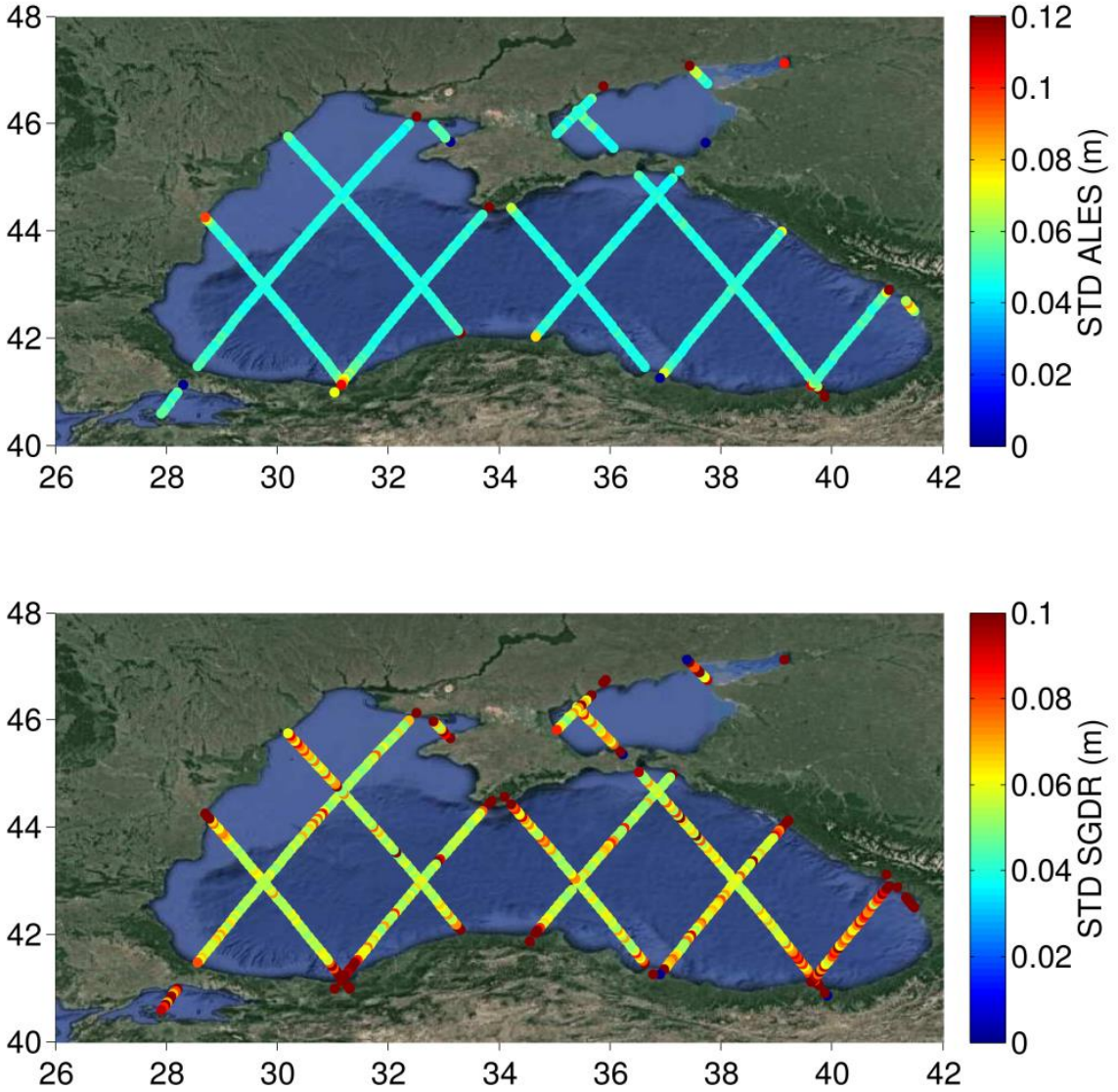


Certified: improves data quality in the coastal zone (see RMS against tide gauge in the Gulf of Trieste)

Coastal Altimetry data: ALES retracker

Mean HF-noise ALES vs standard product (same processing) computed at 1Hz points (last 5 km flagged)

Bigger improvement in shallow waters



Outline

- *Black Sea physical ocean analysis system*
  - *Black Sea Monitoring and Forecastion Center (BS-MFC)*
  - *Ocean General Circulation Model (OGCM)*
  - *3-Dimensional Variational Assimilation Scheme (3D-VAR)*

- *Coastal Altimetry Data*
  - *ALES sub waveform coastal retracker*

- ***Experimental Set-up***
  - ***Ocean simulation and analysis (with data assimilation) using conventional and coastal satellite altimetry data (Jason-2 mission)***

- *Preliminary Results*
- *- Impact of coastal altimetry data in BS physical ocean analysis system: SLA, Temperature and Salinity*

Objectives

Investigate the capabilities of the BS physical ocean analysis system to consider coastal altimetry data sampled both at 1 Hz and 20 Hz

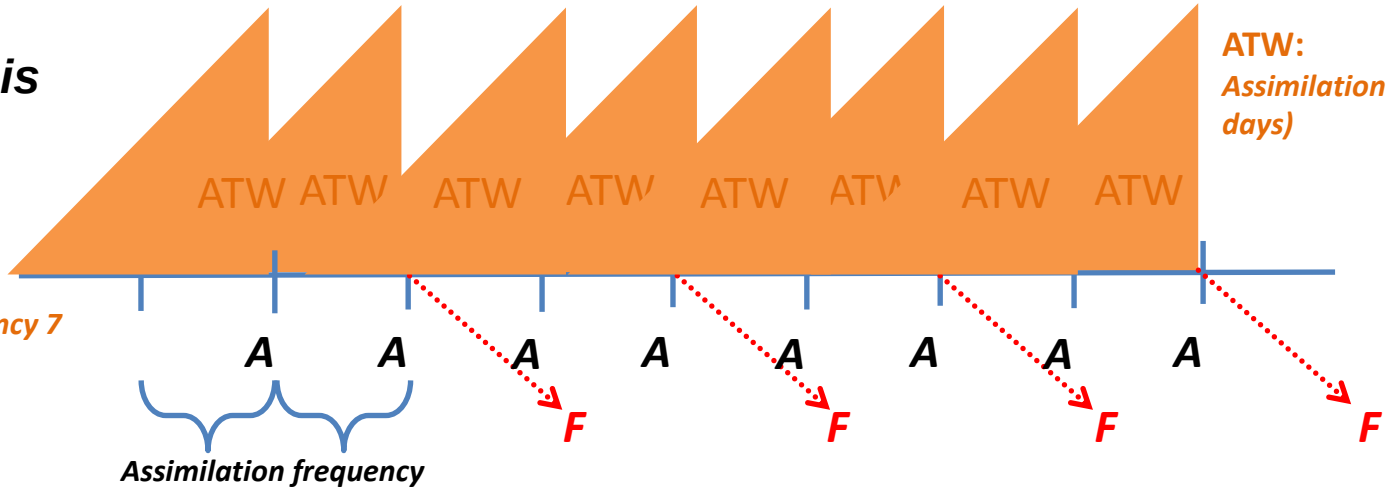
Asses the impact of coastal altimetry data in the system both at the surface and in the water column

Experimental Set-up: Data Assimilation configuration

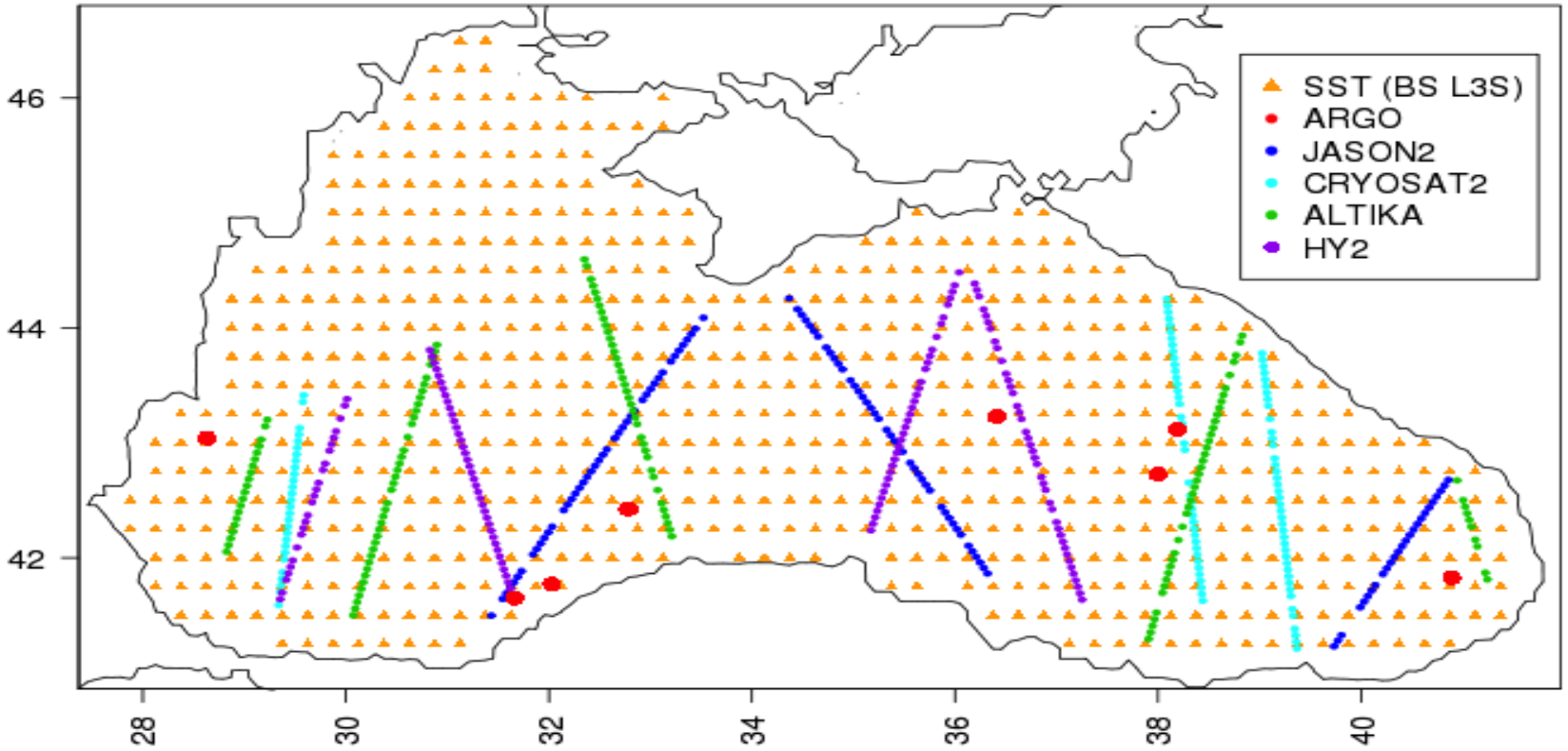
A = Analysis

F = Forecast

Assimilation frequency 7 days (from -7 to 0)



ATW:
Assimilation time-window (3 days)



Experimental Set-up: Satellite Altimetry Data

*In order to investigate the impact of coastal altimetry data in BS physical ocean analysis system **4 Experiments** designed considering a **3 years** time window: **2013 - 2016***

SIM	**NO**	-
AN	**YES**	**CLS/AVISO:** Jason-2, Cryosat and Altika
ALES 1Hz	**YES**	**CLS/AVISO:** Cryosat and Altika **ALES: Jason-2 1 Hz**
ALES 20 Hz	**YES**	**CLS/AVISO:** Cryosat and Altika **ALES: Jason-2 20 Hz**

*The experiments differ in the type of satellite altimetry data considered for the **Jason-2** mission. The configuration of the data-assimilation system and the other observations considered, both in-situ and remote sensing, are the same in all the analysis experiments.*

Outline

- ***Black Sea physical ocean analysis system***
  - ***Black Sea Monitoring and Forecasting Center (BS-MFC)***
  - ***Ocean General Circulation Model (OGCM)***
  - ***3-Dimensional Variational Assimilation Scheme (3D-VAR)***

- ***Coastal Altimetry Data***
  - ***ALES sub waveform coastal retracker***

- ***Experimental Set-up***
  - ***Ocean simulation and analysis (with data assimilation) using conventional and coastal satellite altimetry data (Jason-2 mission)***

- ***Preliminary Results***
- ***- Impact of coastal altimetry data in BS physical ocean analysis system: SLA, Temperature and Salinity***

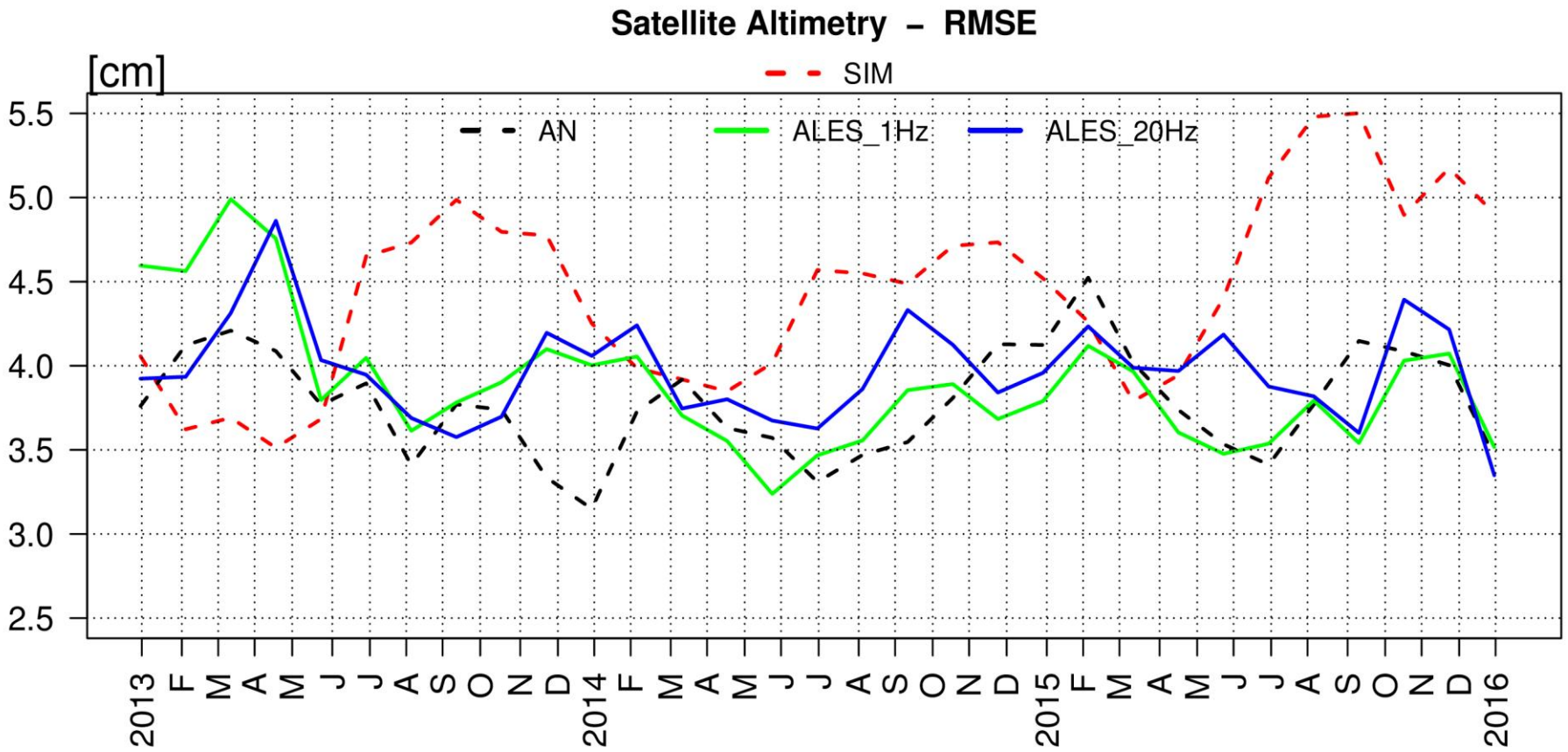
Objectives

Investigate the capabilities of the BS physical ocean analysis system to consider coastal altimetry data sampled both at 1 Hz and 20 Hz

Asses the impact of coastal altimetry data in the system both at the surface and in the water column

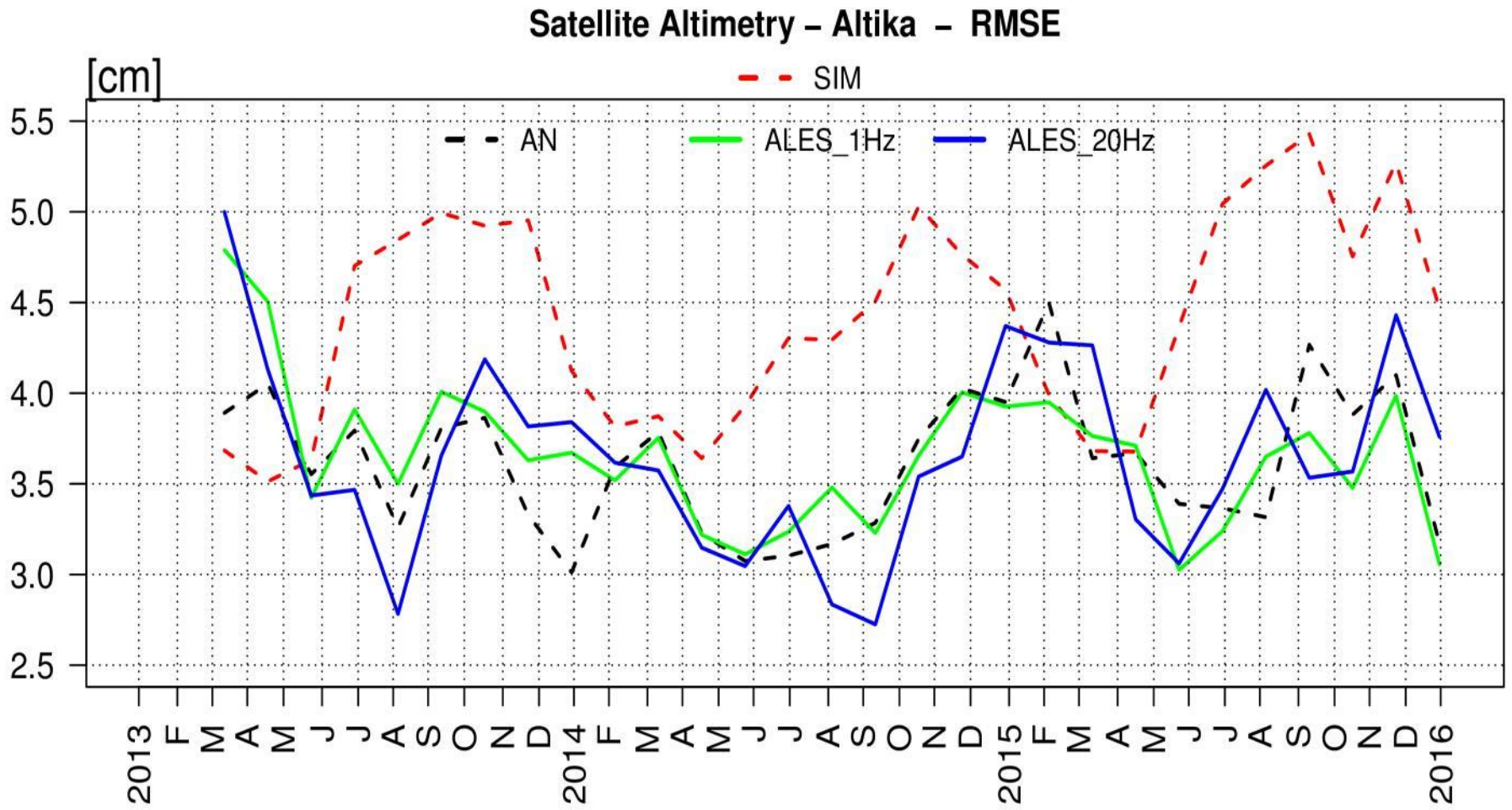
Impact on SLA: RMSE with respect to Jason-2, Cryosat2 and Altika [cm]

SIM	AN	ALES 1Hz	ALES 20Hz
~4.5	~3.8	~3.8	~3.9



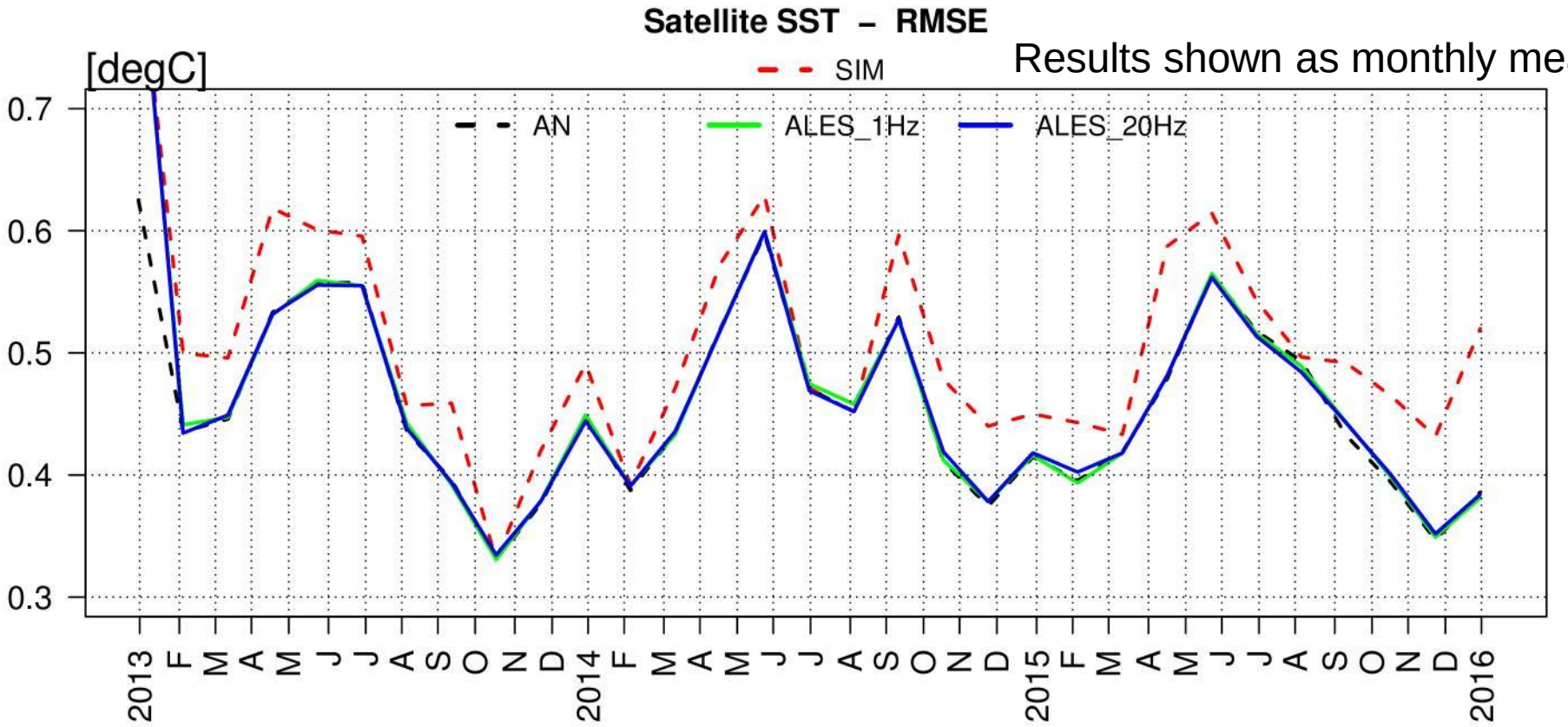
Impact on SLA: RMSE with respect to Altika [cm]

SIM	AN	ALES 1Hz	ALES 20Hz
~4.5	~3.6	~3.6	~3.6



Impact on SST: RMSE with respect to remote sensing data [degC]

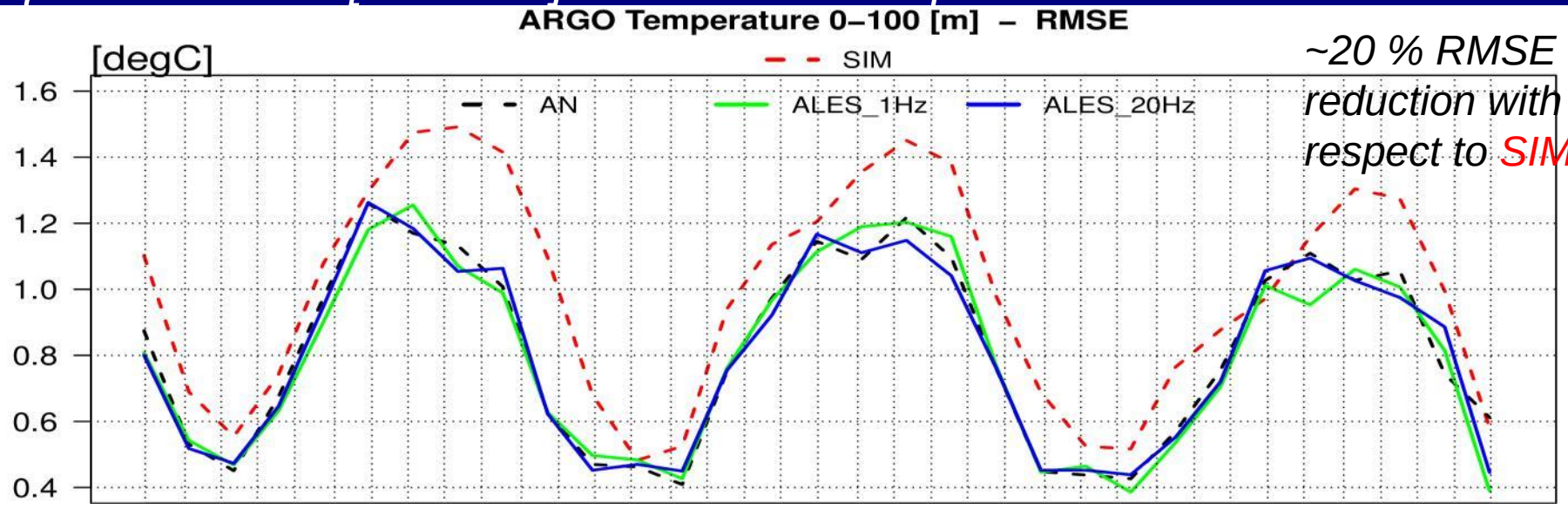
SIM	AN	ALES 1Hz	ALES 20Hz
0.55	~0.5	~0.5	~0.5



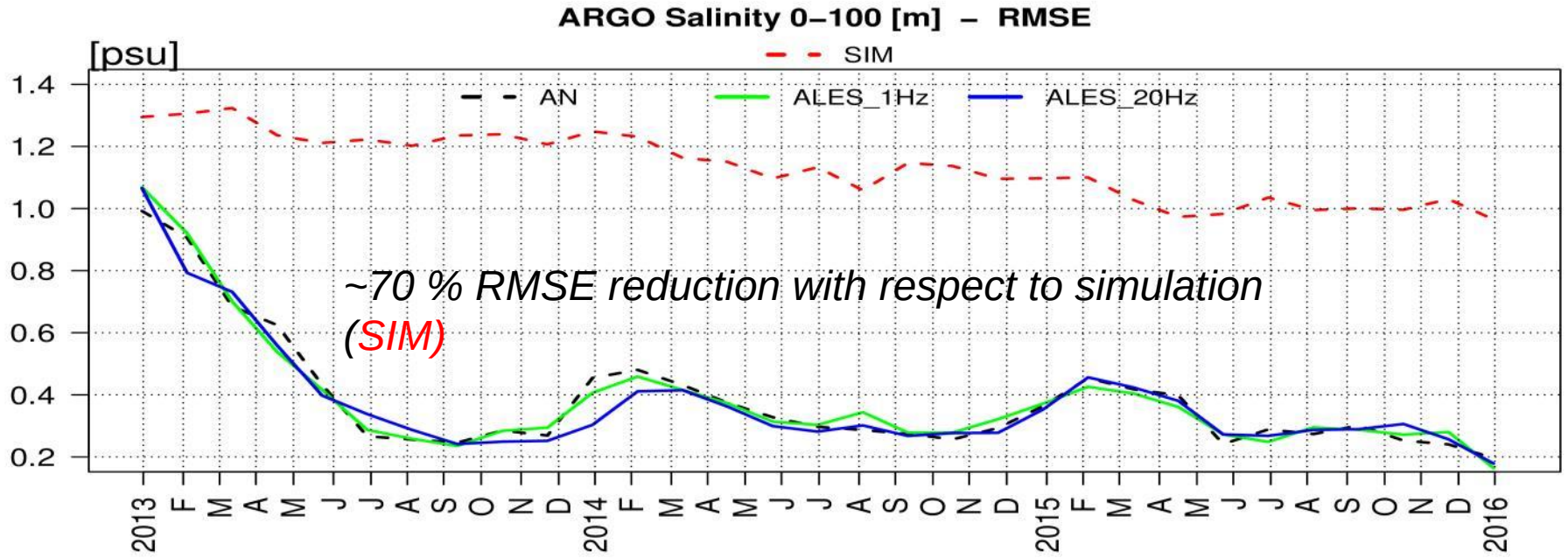
Results shown as monthly mean

The results are consistent in all the analysis experiments.

Impact on T & S [0-100 m]: RMSE with respect to ARGO floats



~20 % RMSE reduction with respect to SIM

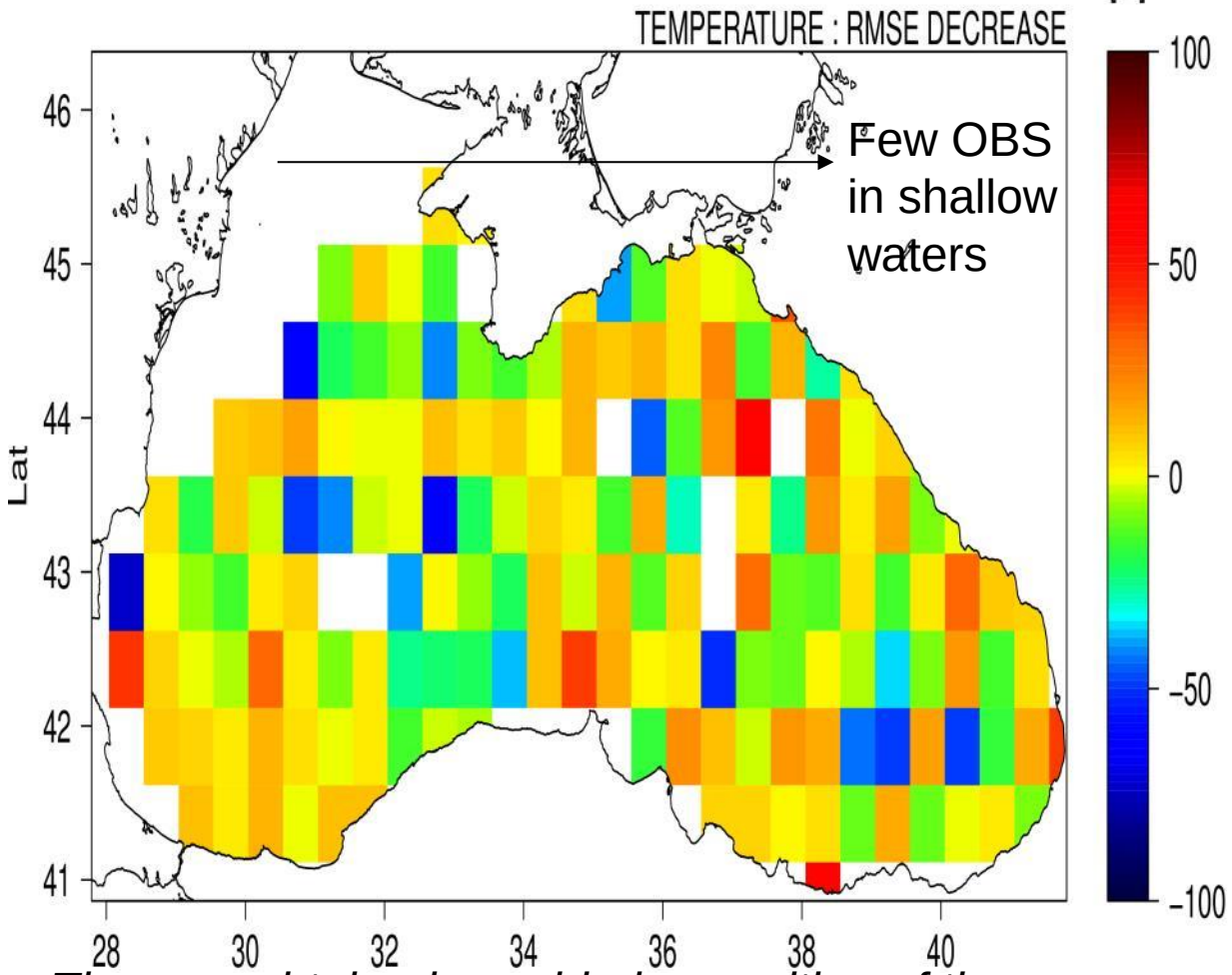


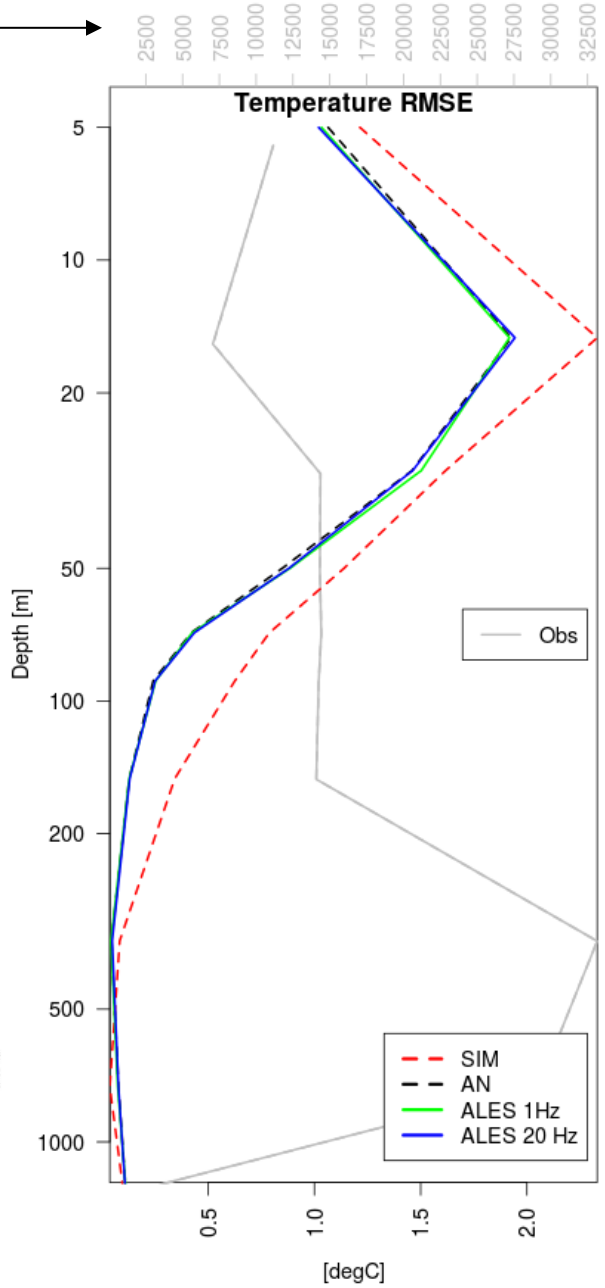
~70 % RMSE reduction with respect to simulation (SIM)

Temperature RMSE Decrease [(RMS_AN-RMS_ALES)/RMS_AN]

Map of RMSE Decrease
ALES 20 Hz** with respect to **AN

N. OBS





*The map obtained considering position of the **ARGO floats** and remapping the RMSE values over a coarser grid*

Final Remarks

The physical ocean analysis system implemented in the Black Sea is capable to consider the contribution of coastal altimetry data.

The results obtained considering Jason-2 retracked data (ALES) are consistent with the results of the reference experiment (AN) both at the surface and in the water column, considering the ***Temperature****,* ***Salinity*** *and* ***SLA****.*

Considering ***SLA****,* ***RMSE*** *values range between* ***4-5 cm****.*

RMSE decrease *(with respect to simulation) up to the order of* ***70 %*** *observed for* ***Salinity***

Temperature RMSE decrease *with respect to the analysis reference experiment (AN) shows that results are* ***dependent on the position*** *of the observation within the basin.*

In this ***preliminary study*** *coastal altimetry data were considered only for the Jason-2 satellite mission. This was a* ***first effort*** *of* ***collaboration*** *between the ocean modeling and coastal altimetry scientific communities.*

Further investigations (in the near future) will allow to look also at the impact of coastal altimetry data obtained from other satellite missions, such as ***Jason-1, Jason-3, ERS and Envisat*** *and to asses their impact in the system.*

FOOD FOR THOUGHT

Why have coastal altimetry still not made the difference?

1) *Most of the improvement areas are actually taken out -> no possibility of propagation in the vertical*

2) *Latest improvements in ALES dataset still not included (see Passaro and Calafat talk)*

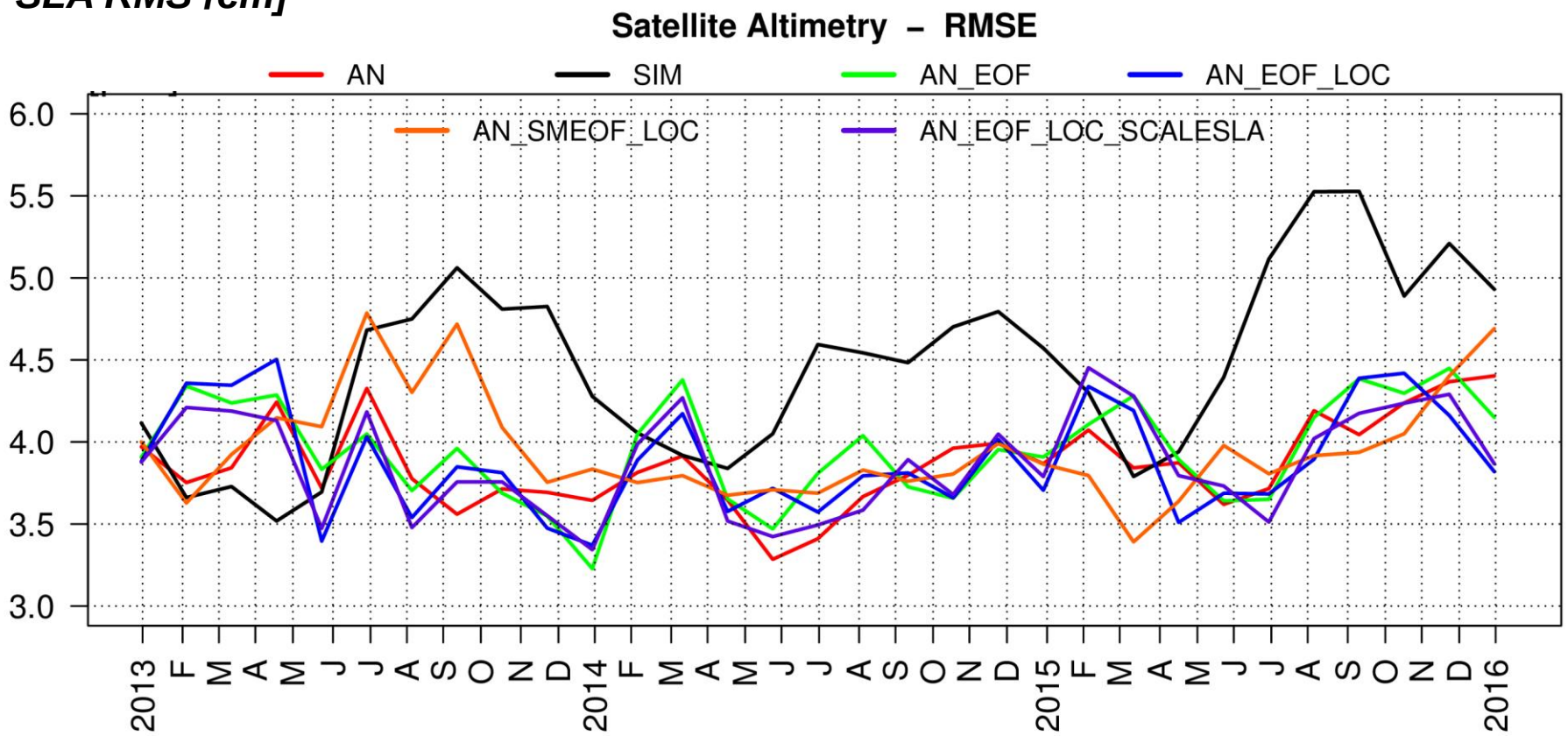
3) *Heterogeneity of the altimetry dataset (need more coastal altimetry data)*

MORE WORK TO COME BEFORE SUCCESS!!!...but we‘re on the right way

Additional Slides:
BS-MFC Sensitivity Experiments

BS-MFC – Sensitivity Experiments

Impact of different formulations and estimates of background-error covariances on SLA RMS [cm]



AN = EOF from an initial simulation (3 years).

SIM = Simulation with improved physics (bulk formula)

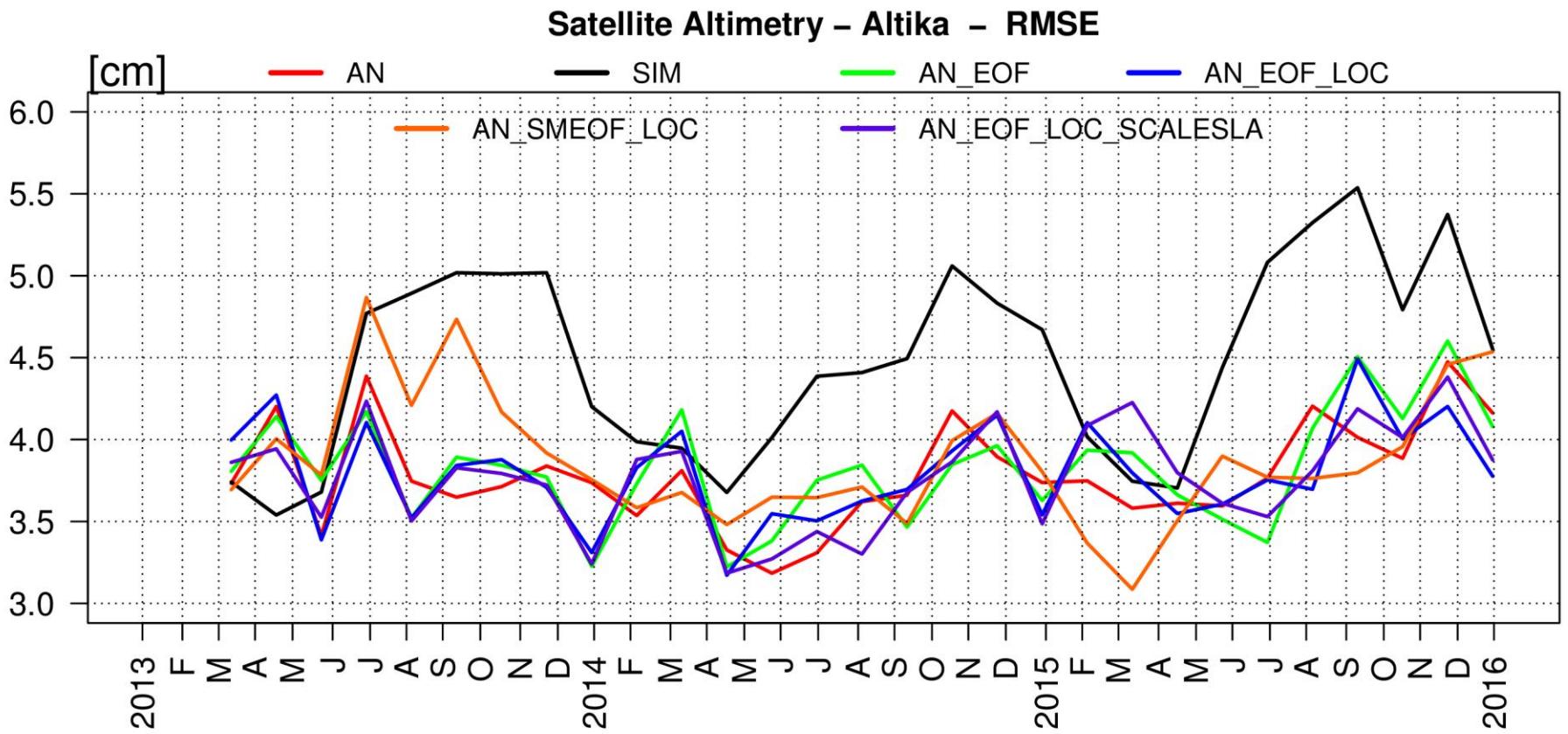
AN_EOF = EOF from **AN**

AN_SMEOF_LOC = weighted EOF from **SIM**

AN_EOF_LOC = weighted EOF from **AN**

AN_EOF_LOC_SCALESLA = weighted EOF from **AN** and SLA error refined

BS-MFC – Impact on Altika



AN = 3.8 cm (16 %)*

SIM = 4.5 cm

AN_EOF = 3.8 cm (15%)

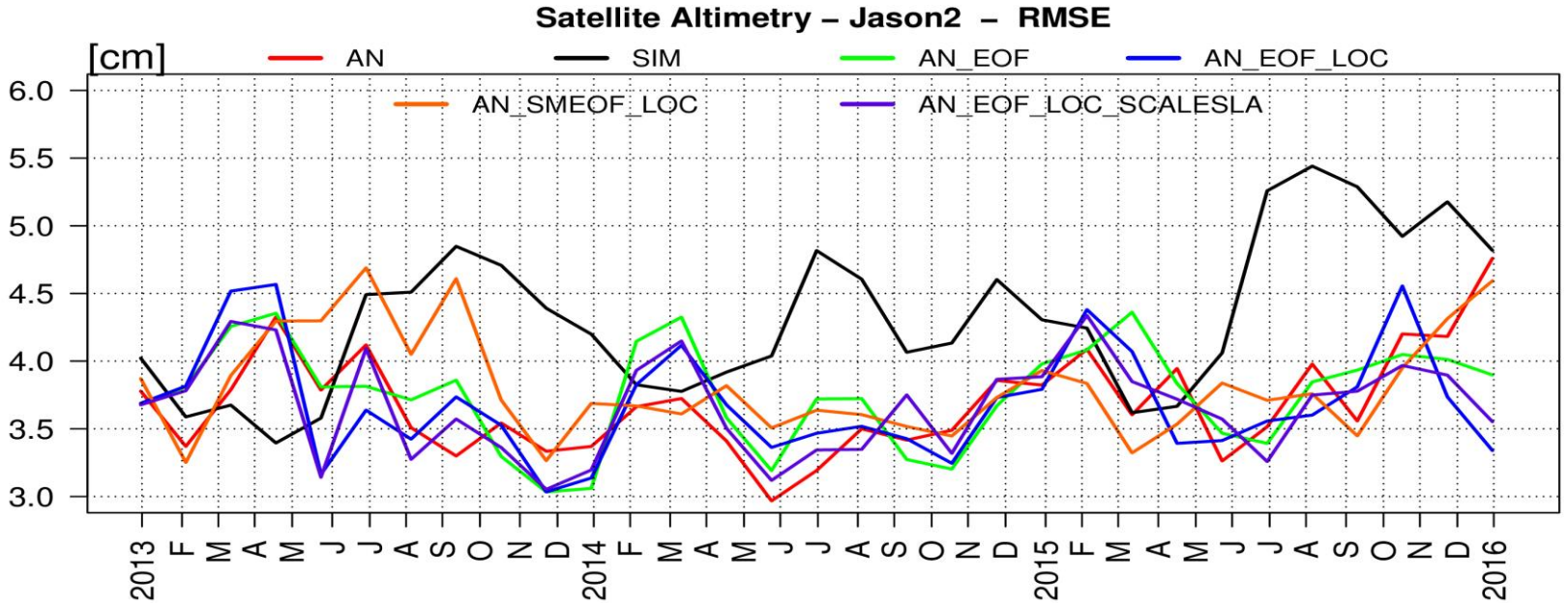
AN_SMEOF_LOC = 3.9 cm (14 %)

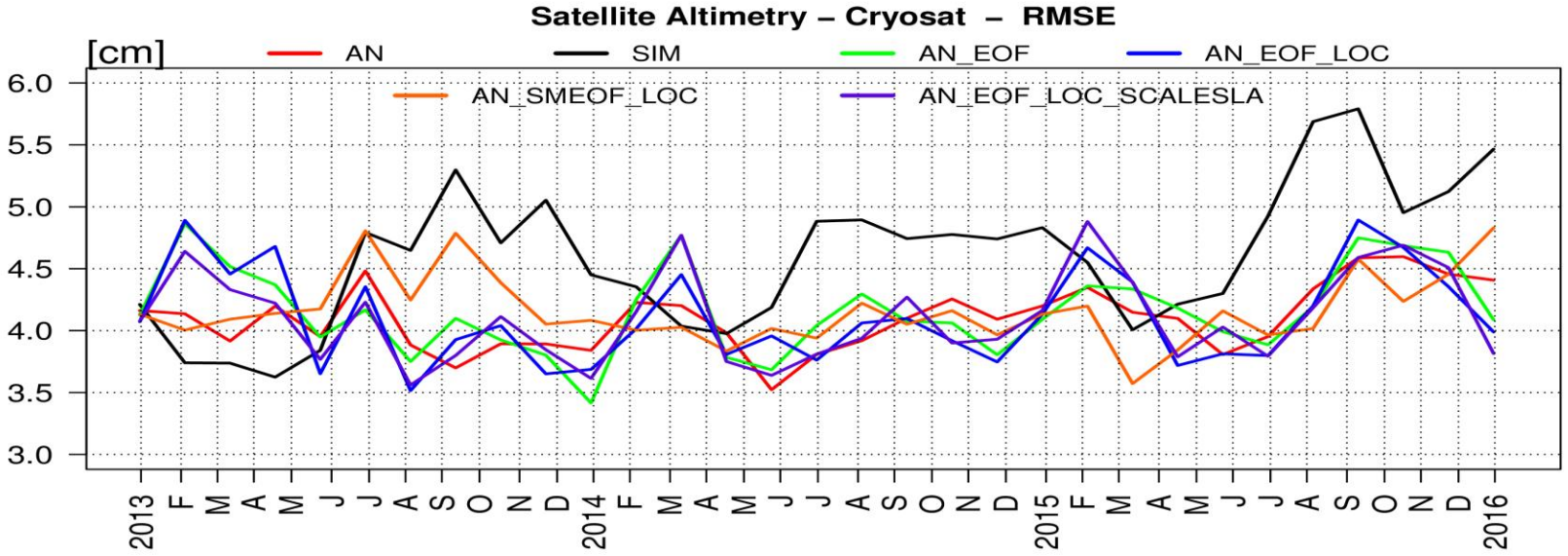
AN_EOF_LOC = 3.8 cm (16 %)

AN_EOF_LOC_SCALESLA = 3.7 cm (16.5%)

*** in the brackets: RMSE decrease (%) with respect to simulation (SIM)**

BS-MFC – Impact on Jason2 and Cryosat





Impact on SLA: RMSE with respect to Jason-2 [cm]

SIM	AN	ALES 1Hz	ALES 20Hz
4.2	3.5	3.7	~4.0