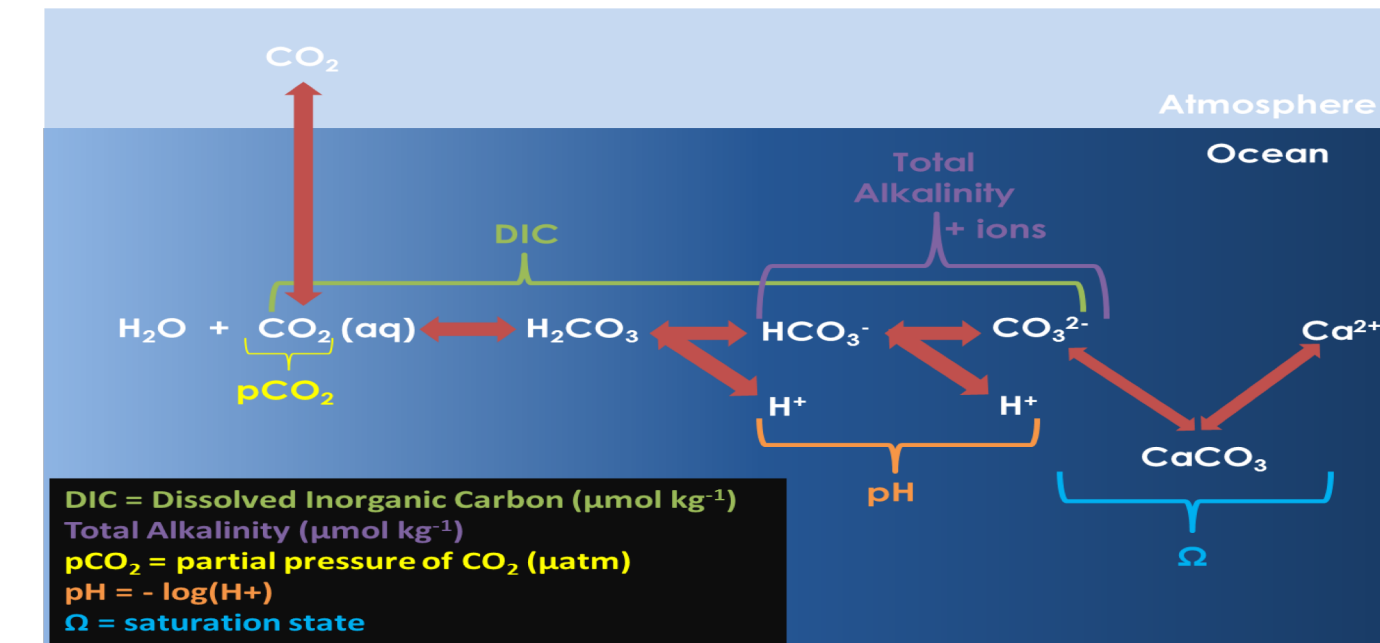




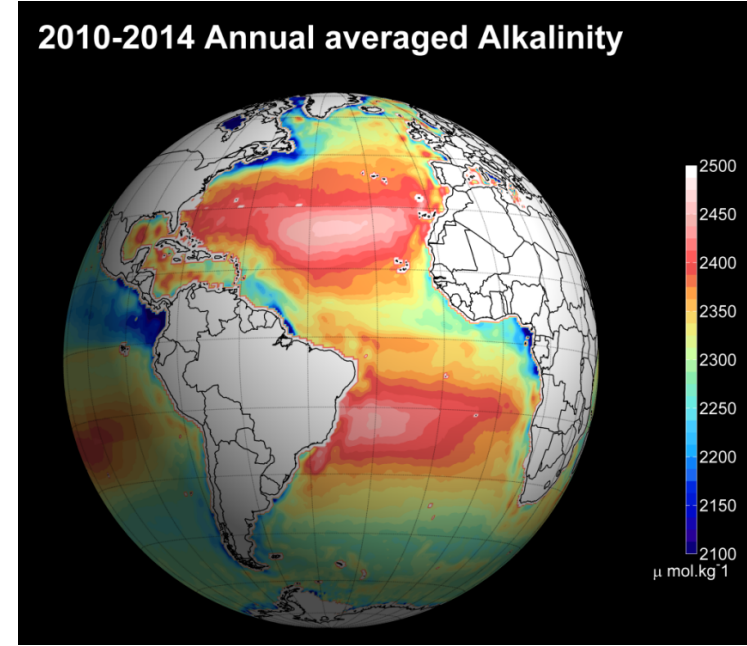
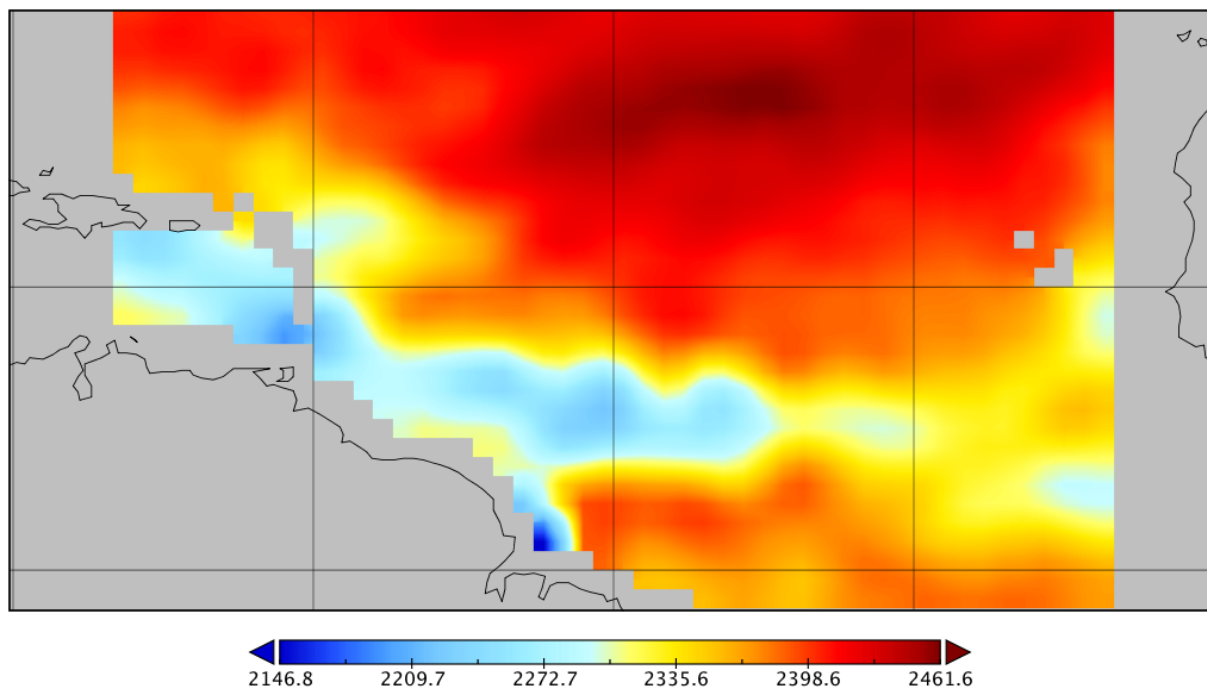
## I. Ocean Acidification and marine carbonate system parameters

- The **surface ocean** currently absorbs approximately one third of the excess atmospheric carbon dioxide (CO<sub>2</sub>), **mitigating the impact of global warming**. This anthropogenic CO<sub>2</sub> absorption by seawater determines, however, a **reduction of both ocean pH and the concentration of carbonate ion**.
- The overall process is referred to as **Ocean Acidification (OA)**, with profound impacts at **scientific and socio-economic level**. This can also lead to a **decrease in calcium carbonate saturation state Ω**, with potential implications for marine animals, especially calcifying organisms and the overall trophic chain.
- Areas that are particularly **vulnerable** to OA include **upwelling regions**, the **Polar oceans** and **coastal regions** that receive freshwater discharge.



CO<sub>2</sub> seawater absorption and chemical speciation (courtesy: J. Shutler, Univ. Exeter)

TA calculated in the Amazon Plume (Takahashi algorithm with SMOS data, and WOA NO3)



Pathfinders-OA Total Alkalinity estimates in the Amazon plume (credits J. Shutler/P. Land)

- International efforts aim at a **coordinated strategy for monitoring OA**, with an eager need for global and frequent observations of OA-relevant parameters. Yet, datasets acquired are mostly relevant to **in-situ** measurements, **laboratory-controlled experiments** and **models** run.
- Remote sensing technology** can be integrated by providing **synoptic and frequent OA-related observations**, complementing in-situ carbonate chemistry measurements at different s/t scales, especially during episodic events.
- Preliminary products developed are mainly **regional** or derived with a **limited variety of satellite datasets**.
- ESA **STSE Pathfinders-OA** project collated a database of EO/in-situ matchups to develop/validate algorithms to retrieve OA parameters from space. Satellite datasets (mainly **SSS**, **SST** and **Chl-a**) inputs have been related to carbonate system parameters in a round-robin exercise.

## II. Total Alkalinity and the Med

- TA**: buffering capacity of a water body. Measure of the ability of a solution to neutralize acids and thus to resist to changes in pH; TA variability attributed for 80% to SSS
- TA** – ops defined as the sum of weak bases (carbonate, bicarbonate, boron, etc.) which can combine with free protons.
- Evap concentrates compounds thus increasing TA; opposite for Precip.
- [Lee et al., 2006] AT and [Takahashi and Sutherland, 2013] formulation; Different (5 or 24) parameterizations for the various ocean basins
- Mediterranean Sea** – land-locked, relatively small, highly dynamic, high anthropic pressure, -> 'laboratory basin' (ocean in miniature) suffering dramatic physical and biogeochemical changes. Prone to absorb and store CO<sub>2</sub> and active overturning circulation
- TA in the Med** significantly higher than in the open ocean. West-east increasing gradient. In the surface layers, TA has a remarkable seasonal cycle.
- In the Med**, different regions present different TA/SSS relationships -> positively correlated in the open sea areas of the Med; negatively in regions of fw influence. Not possible to study this basin relying on global parameterizations.



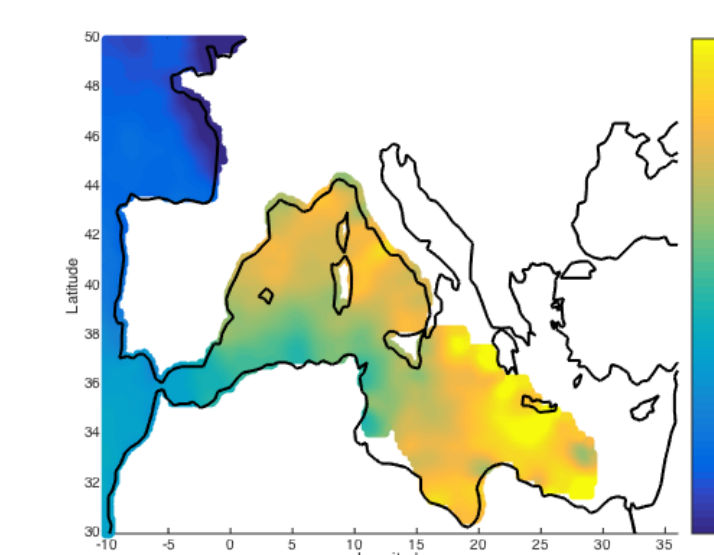
ESA SMOS satellite

## III. ESA SMOS satellite

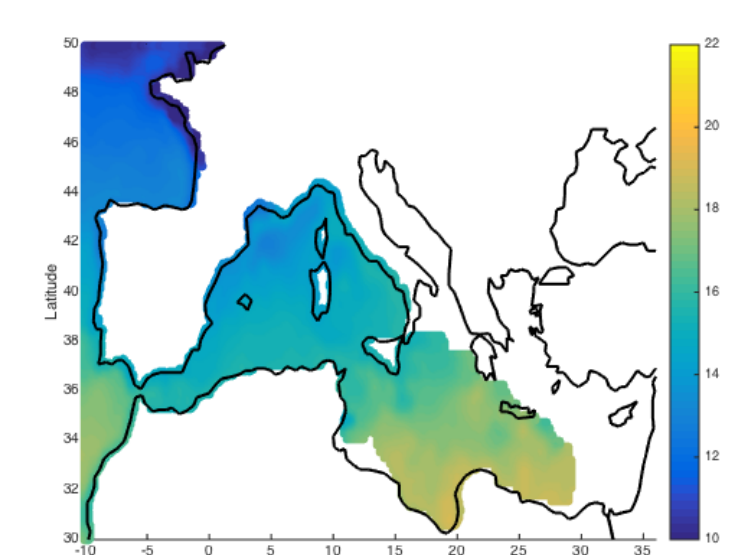
- SMOS is an ESA **Earth Explorer** Opportunity Mission - Living Planet program
- SMOS in orbit since ~9 years**, Launched November 2nd, 2009 (currently extended until end of 2019) -
- Advantages of L-Band**: All weather tool; low impact of vegetation and heavy rainfall, atmosphere almost transparent
- L-Band (SMOS, SMAP) supports a **large variety of products and scientific and operational applications** for the Earth Water Cycle over land and ocean
- New operational products in 2018**: severe wind speeds, soil freeze/thaw, SMOS+Cryosat sea ice thickness

## IV. BEC-GHER salinity products

- Approach**: **debiased non-Bayesian** [Olmedo et al, 2017]
- Addressing Land Sea Contamination and the permanent RFIs**
- Residual time-dependent biases** characterized by EOF decomposition [Alvera-Azcárate, et al. 2016].
- Objectively-analyzed SMOS L3 SSS 9-day maps at 0.25°**.
- SMOS L4 SSS maps generated by merging the L3 SMOS SSS 9-day maps with OSTIA SST daily maps at 0.05°** using a of multifractal fusion scheme [Umbert et al, 2014].
- Remapped over a monthly timescale**.
- Quality assessment** provided in [Olmedo et al, 2018].



SMOS SSS



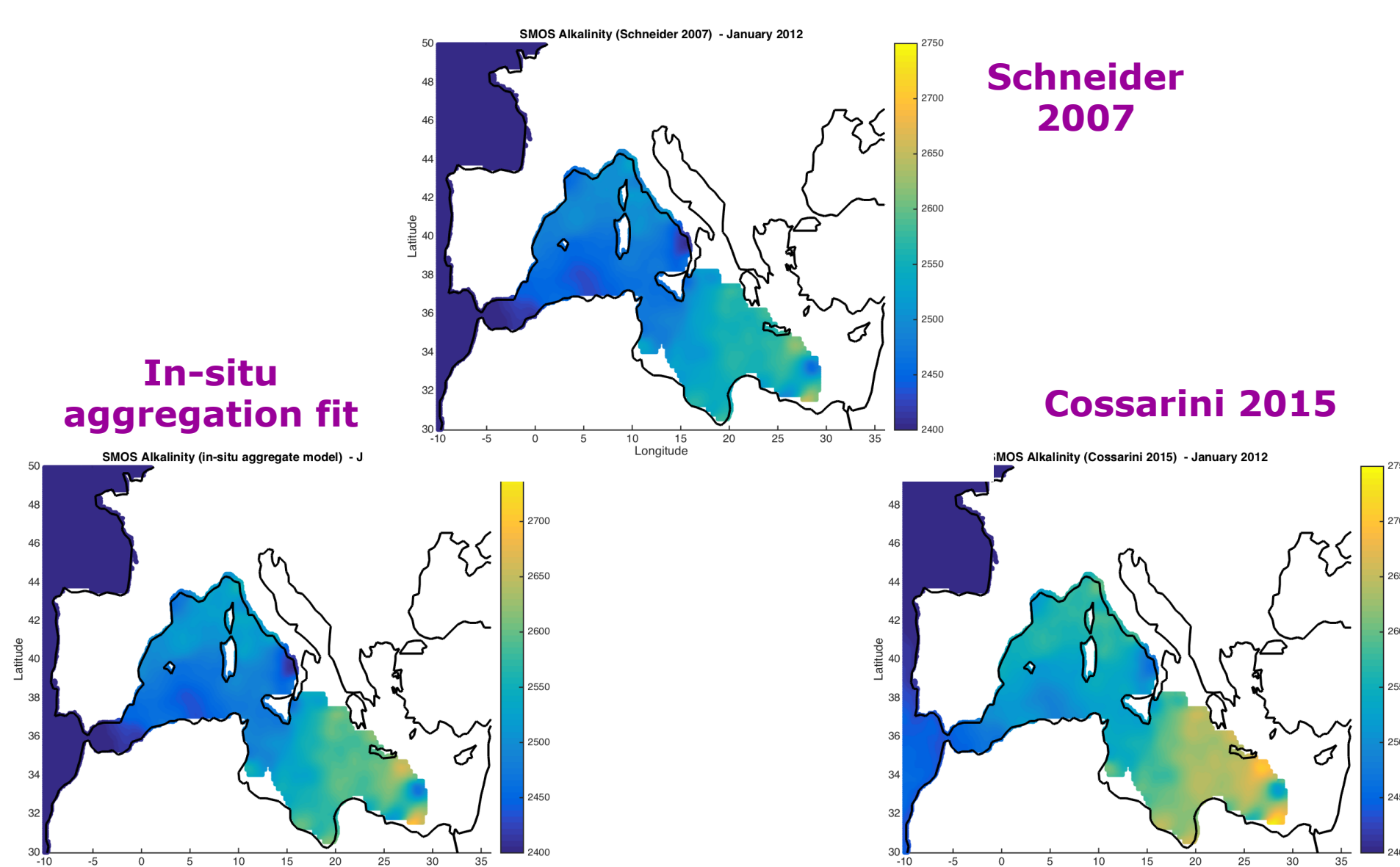
OSTIA SST

## V. Results

### Experiments

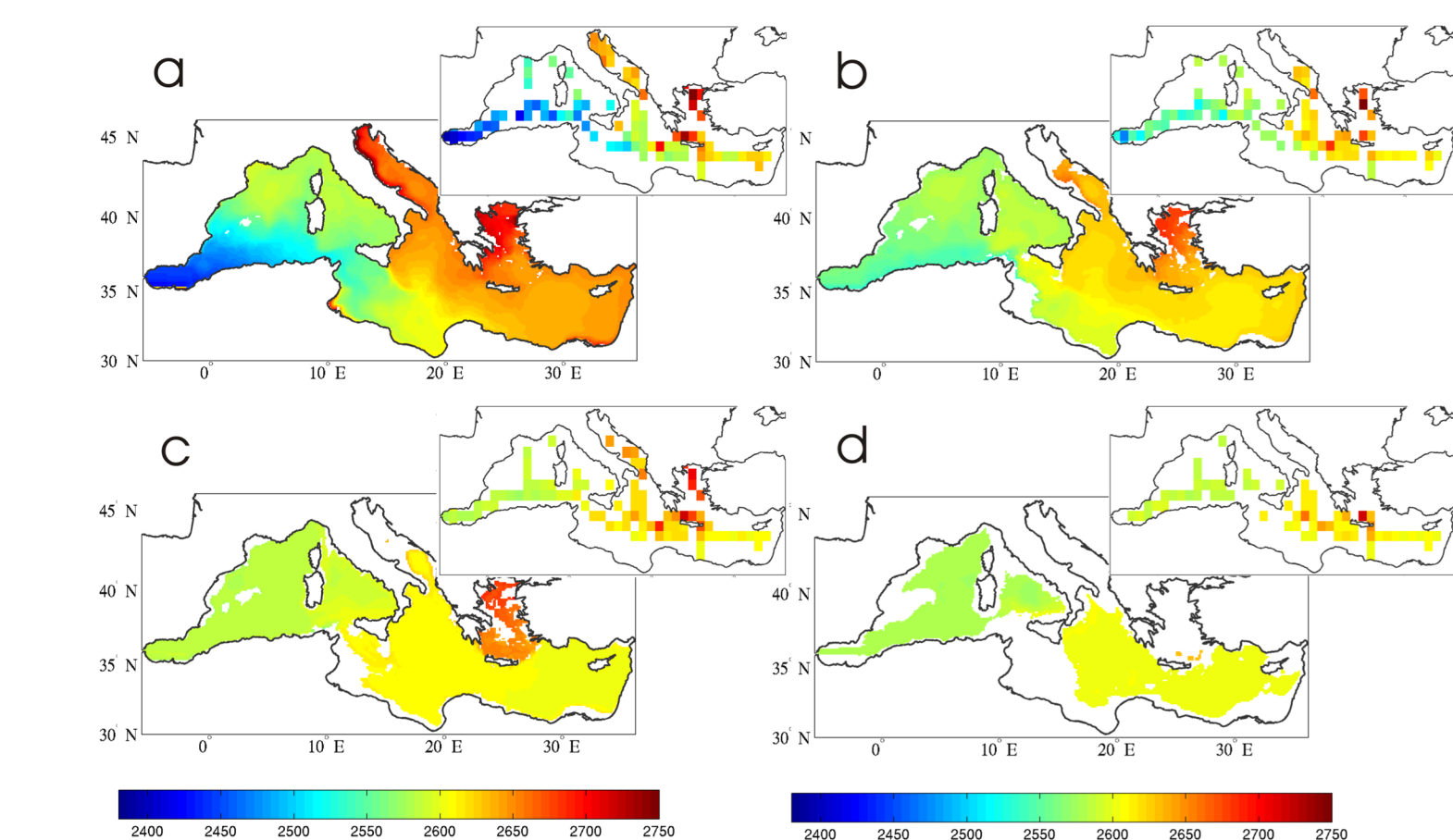
- Comparison of three different parametrizations**
- (Cossarini-2015) parametrization chosen [BGS, 2015]
- Implementation of (Cossarini-2015) seasonal parameterizations**
- Assessment of seasonal variability and inter-annual variability**
- Preliminary validation to show consistency**
- Derivation of TA with a very recent upgraded BEC product with extended coverage and improved RFI mitigation**

### SMOS-derived Total Alkalinity

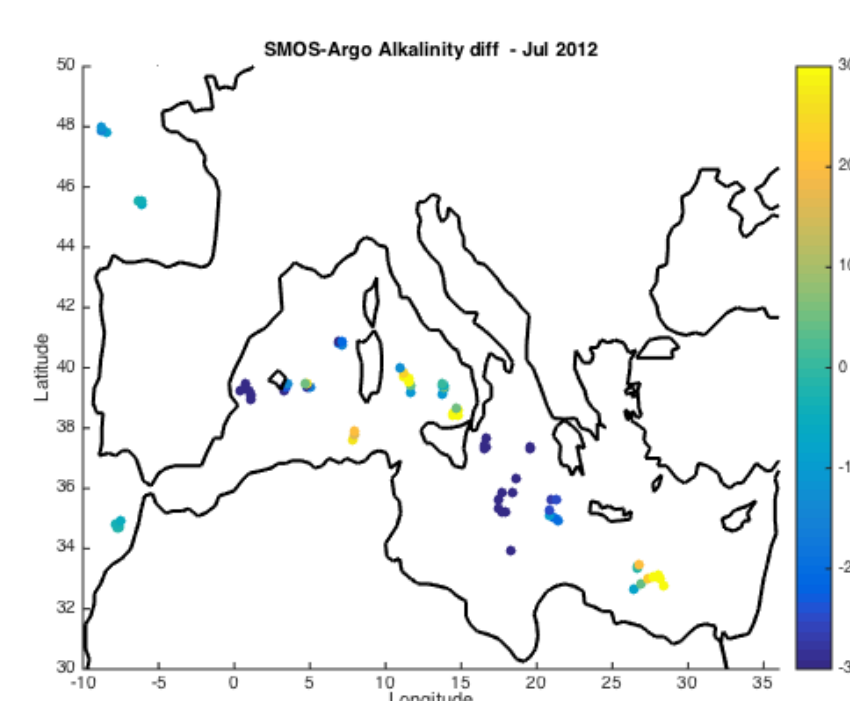


Schneider 2007

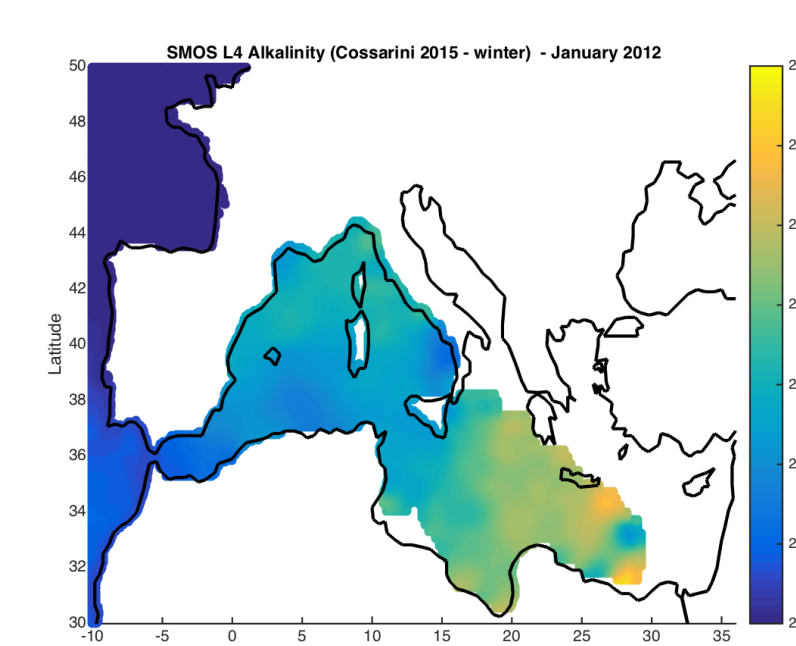
Cossarini 2015



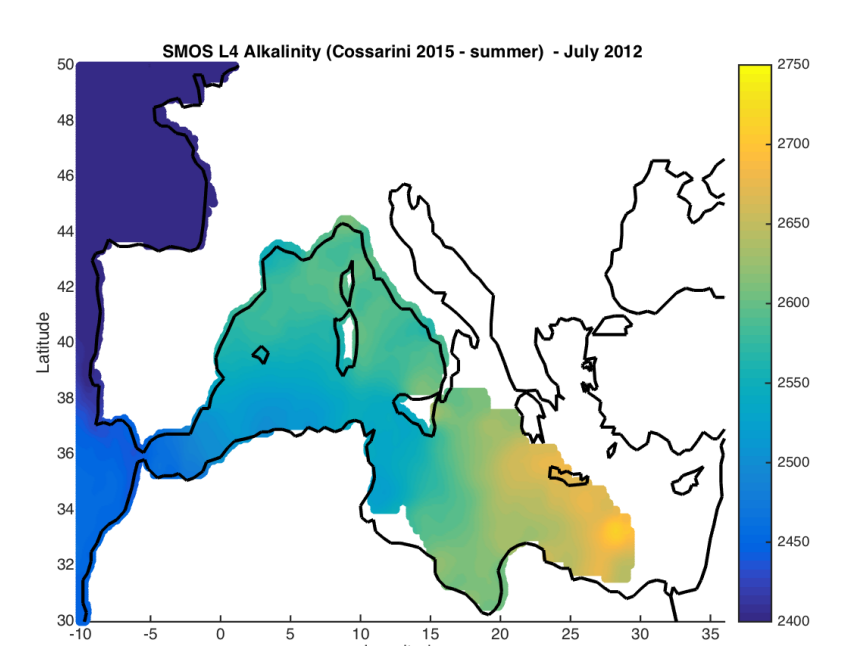
Alkalinity modelled maps from [Cossarini et al., 2015, Biogeosciences - a) surface layer]



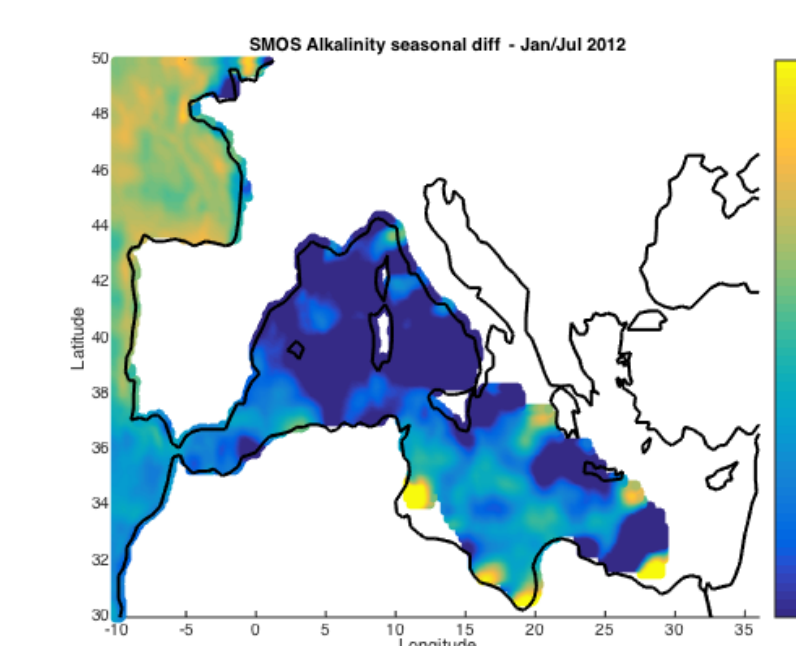
Preliminary consistency check with Argo derived alkalinity data



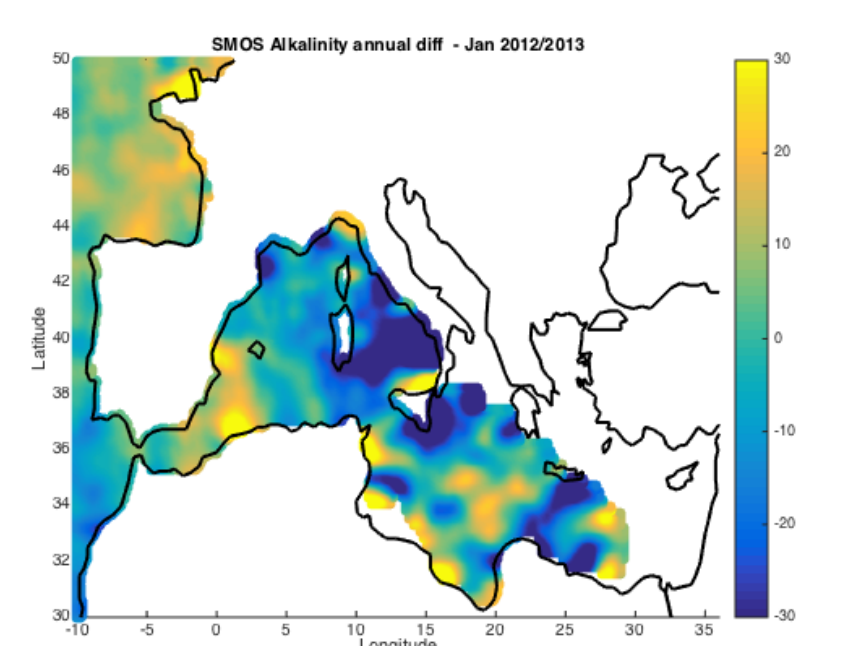
Seasonal winter Cossarini 2015 parameterization



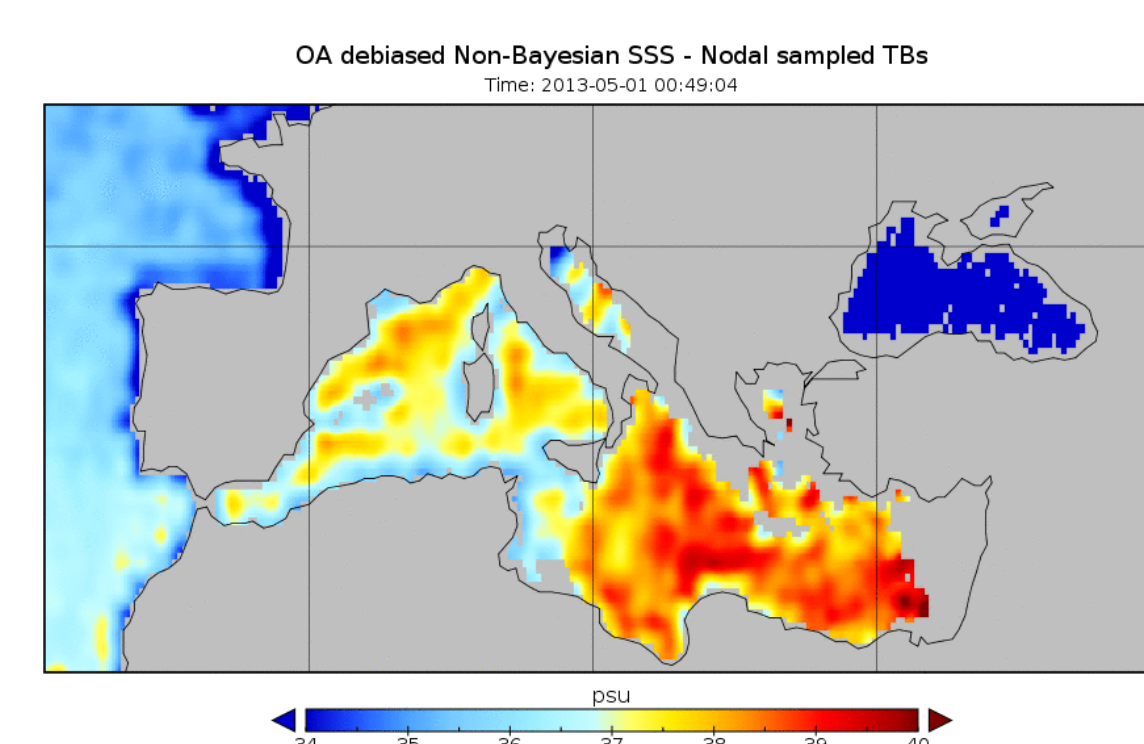
Seasonal summer Cossarini 2015 parameterization



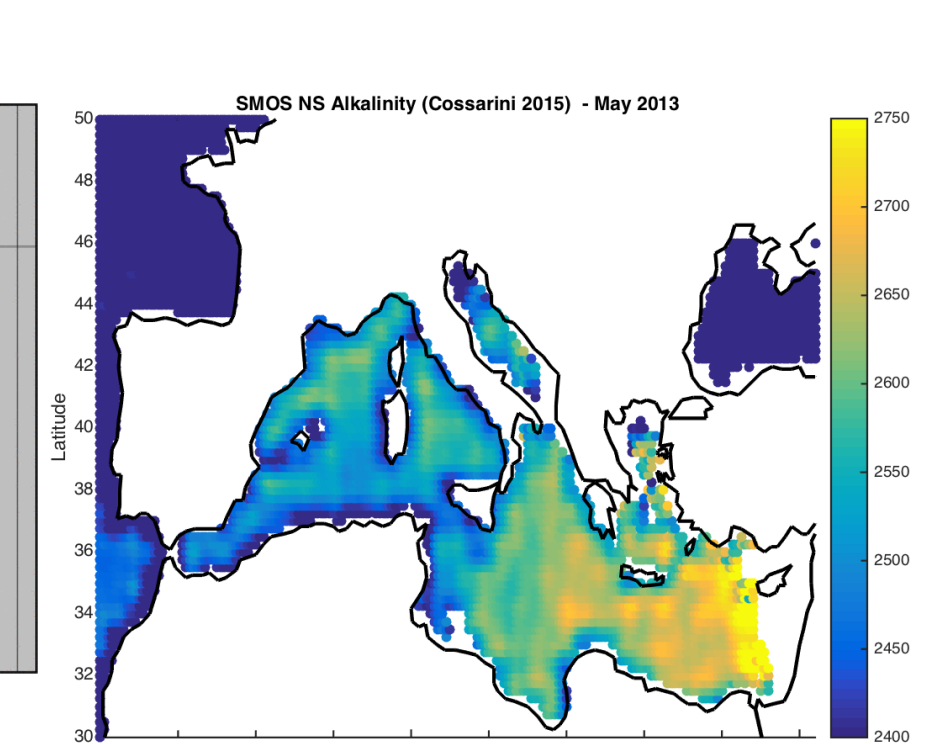
Seasonal variability (Jan-Jul 2012)  
Mean: -25.4 μmol/kg  
Std: 26.5 μmol/kg



Inter-annual variability (Jan 2012-2013)  
Mean: -6.8 μmol/kg  
Std: 21.0 μmol/kg



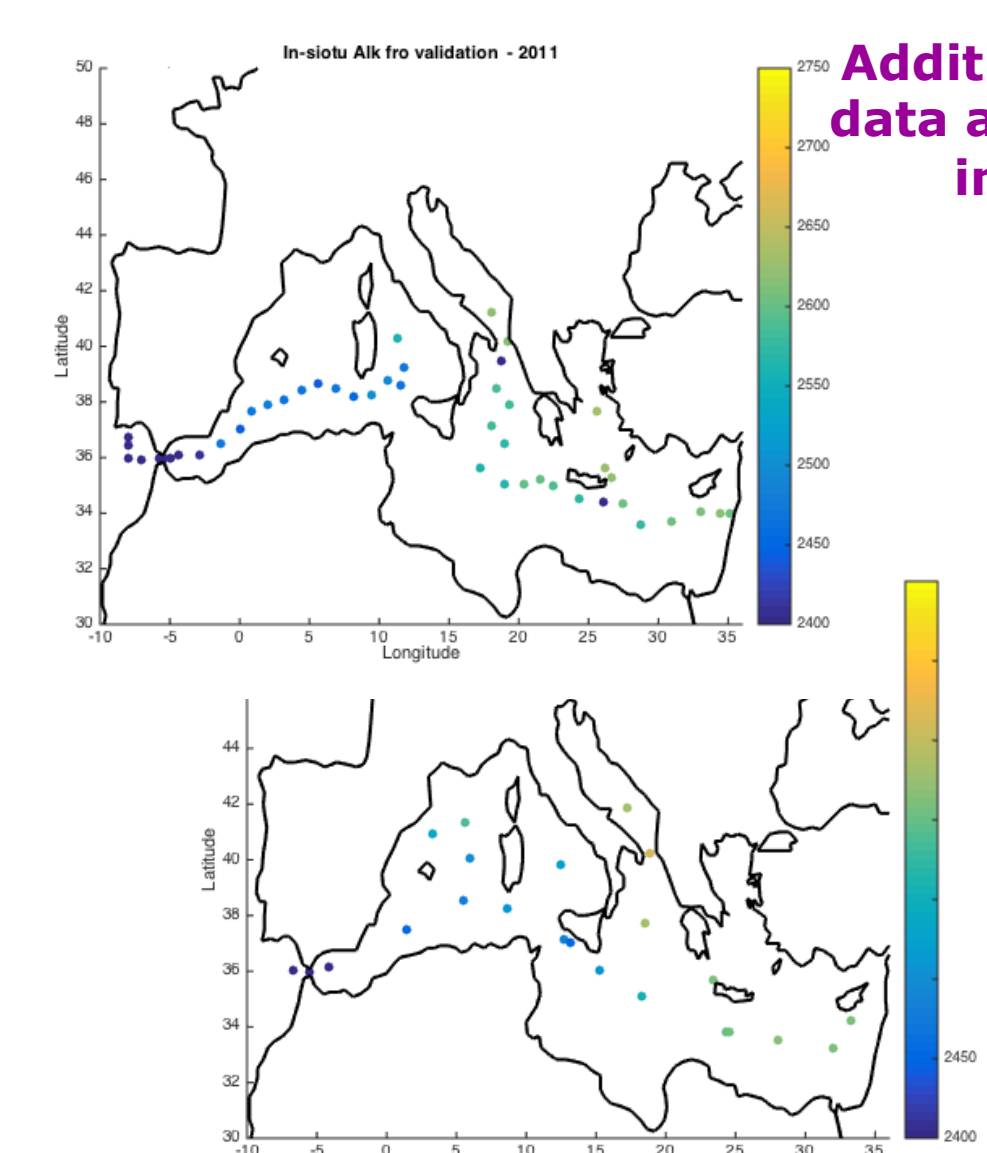
Novel preliminary approach (Nodal sampling) to tackle RFIs and extend coverage



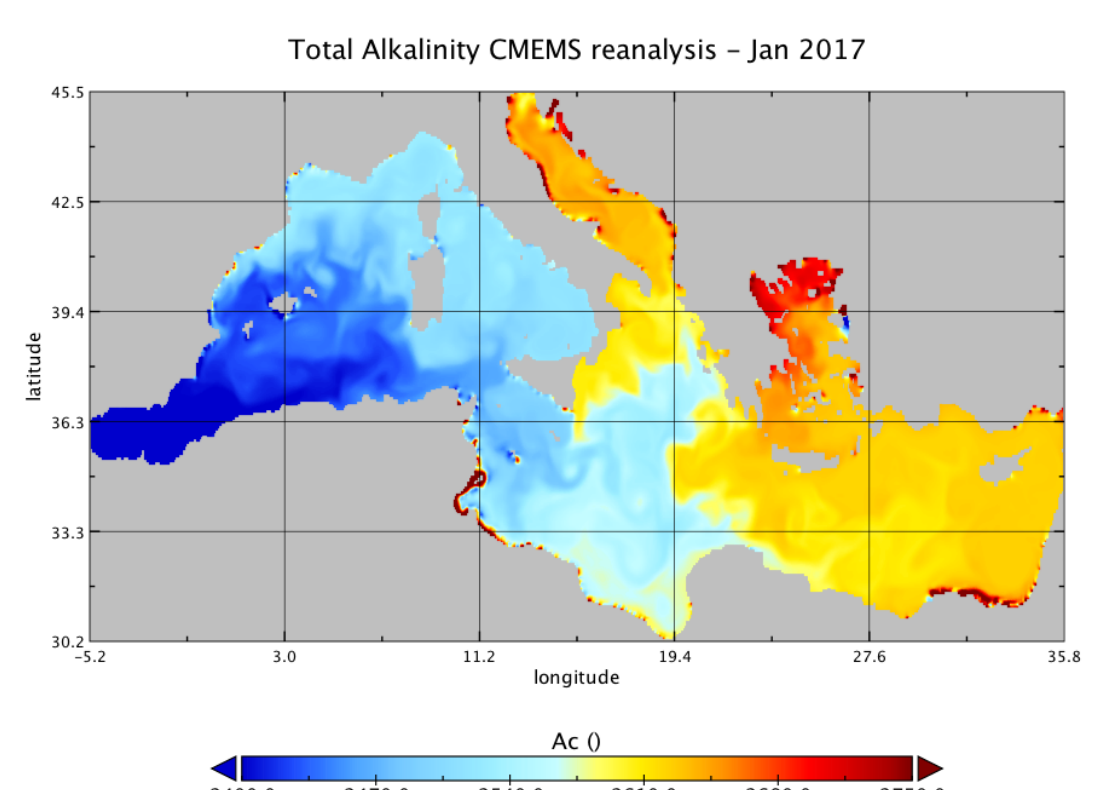
Derived Alkalinity with upgraded product for a sample month

## VI. Summary and perspectives

- Ocean Acidification** – topical issue, recently approached also with remote sensing techniques
- Total Alkalinity** – carbonate system parameter; buffering capacity of a water body. Strictly linked with Sea Surface Salinity
- Interest in studying **Alkalinity in the Med** – basin experiencing dramatic physical and biogeochemical changes and prone to absorb CO<sub>2</sub>
- SMOS** was the first ever satellite measurement of **Sea Surface Salinity**
- Being a one-of-a-kind measurement with a disruptive novel technology (synthetic aperture radiometry), was inherently prone to technical and scientific challenges (RFI, LSC, external noise sources contamination)
- Novel processing techniques** developed at BEC-GHER allow overcoming several of these issues and estimating SSS in the Med.
- Attempt to estimate Alkalinity in the Med profiting from various **recent parameterizations**. **Seasonal, inter-annual variability** of the derived estimates shown. Preliminary validation to show consistency.
- Systematic validation** upcoming and error propagation/budget assessment



Additional in-situ alkalinity data available for validation in 2011 and 2013



CMEMS monthly reanalyses for comparison