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The New High-Resolution Optimally Interpolated SST Dataset (1982-2012): Validation and Time Series Analysis over the Mediterranean Sea

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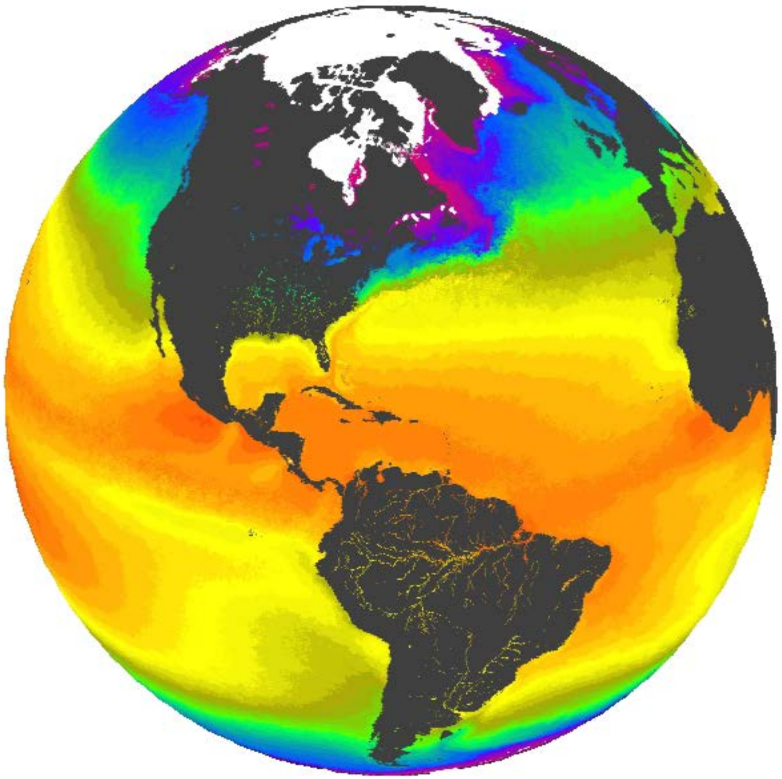
Consiglio Nazionale delle Ricerche

General Understanding

The *AVHRR Pathfinder V5.2* (PFV52) dataset (1982–2012) has been used to build daily (nighttime) gap-free sea surface temperature (SST) maps (L4) for the Mediterranean Sea



Climatological map from Casey et al., 2012

Purposes:

- Extend and improve previous reprocessed L4 SST datasets (e.g., Marullo et al. 2007)
- Validation over the entire satellite period using all the available in situ observations
- Quantify the product accuracy
- Evaluate the product stability
- Analyze SST trends over the Mediterranean Sea

➢ REP L4 analysis effort is part of the Copernicus activities, as well as the L3S and L4 NRT production

➢ Pisano et al., 2015. *Under Review* on RSE

The Data

Product Data Sheets

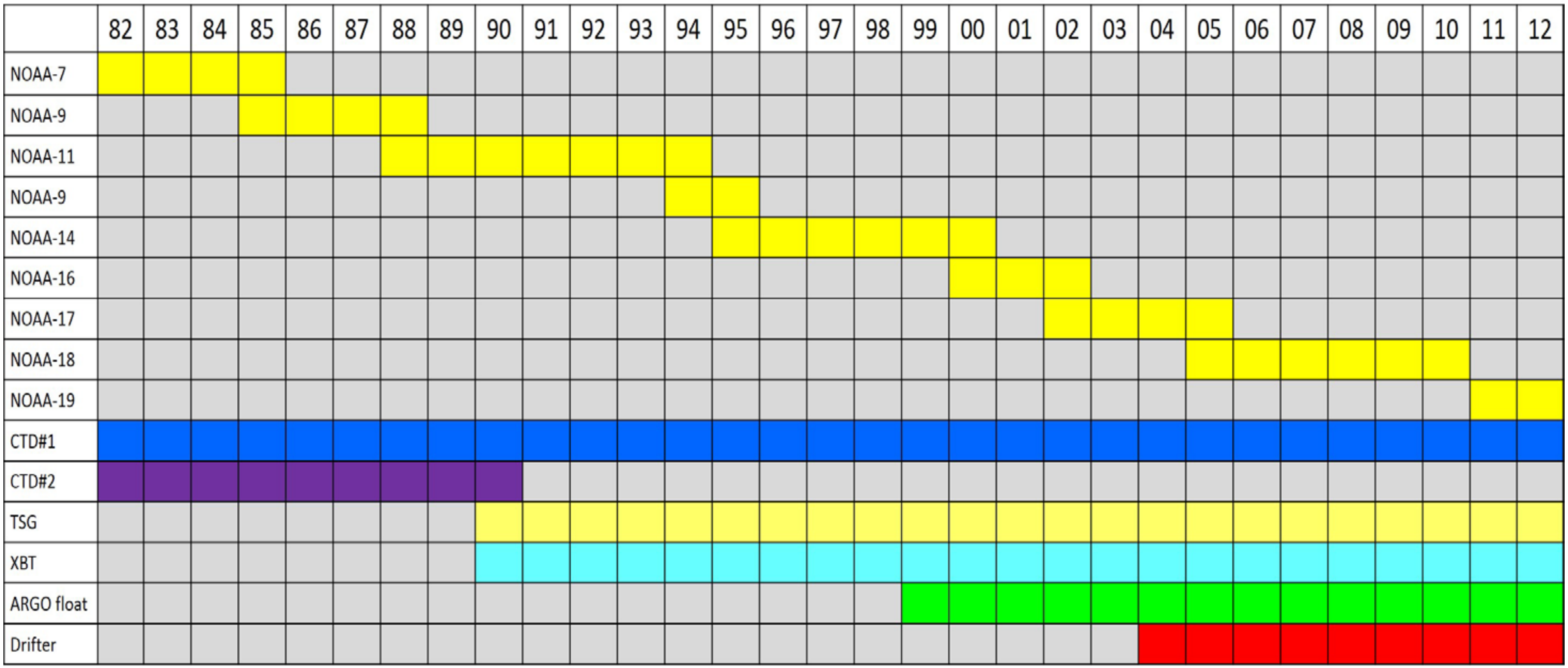
Satellite Dataset PFV52	
Data Type:	AVHRR/NOAA
Geo. Coverage:	GLOBAL
Sp. Resolution:	4 km
Temp. Resolution:	Daily (day/night)
Temp. Cov.:	1982-2012
File Type:	L3C

In Situ Dataset Copernicus In Situ-TAC	
Data Type:	Drifter/TSL/CTD XBT/Argo Float
Geo. Coverage:	GLOBAL
Sp. Resolution:	---
Temp. Resolution:	Hourly
Temp. Cov.:	1982-2012
File Type:	NetCDF

- PFV52 dataset: used for SST L4 creation
- In Situ dataset: used for validation

The Data

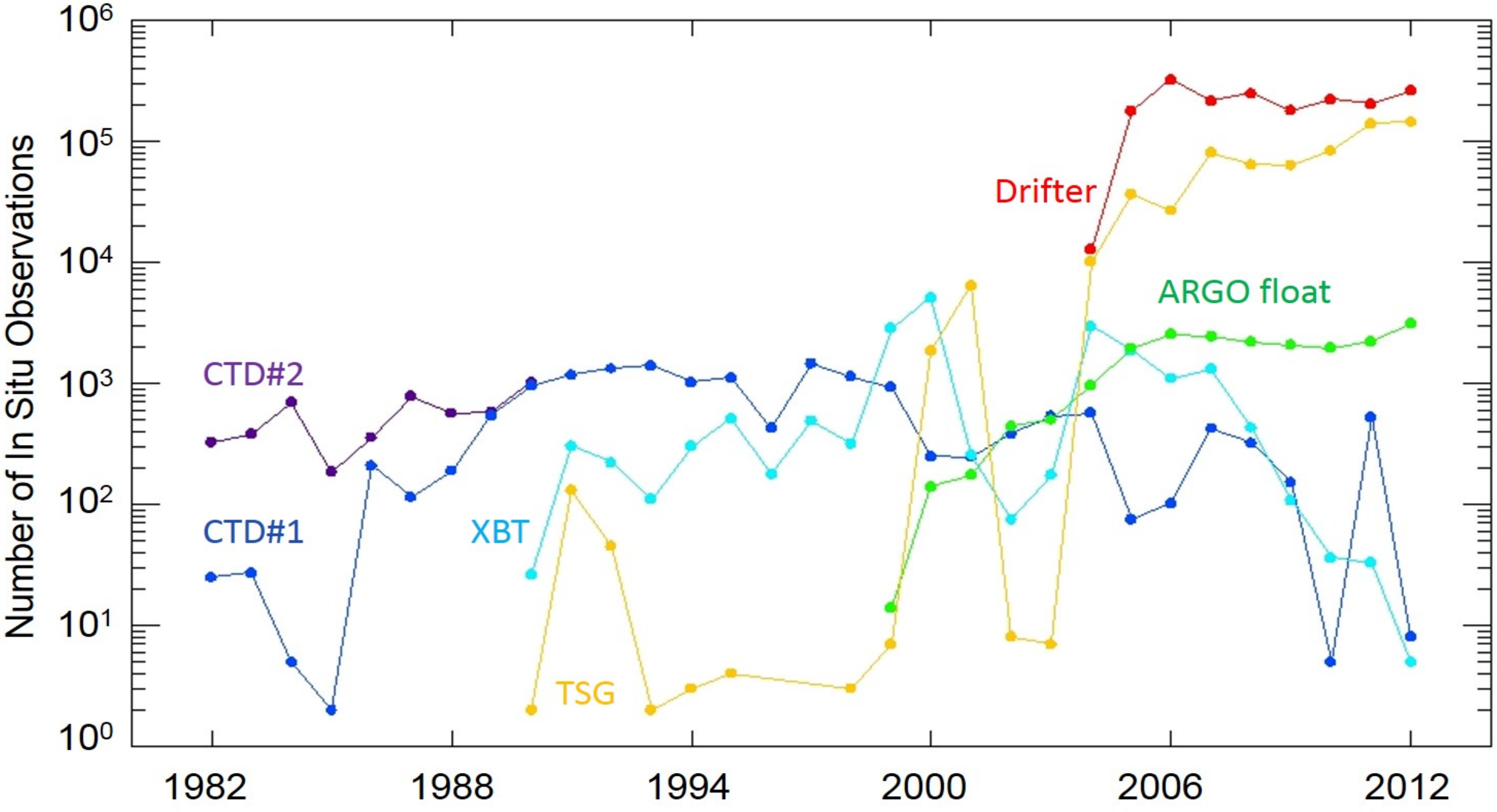
Timeline of the entire NOAA satellite and in situ time series



- Only CTD obs. provided an unbroken and continuous *in situ* time series
- CTD#2: CTD data from SeaDataNet

The Data

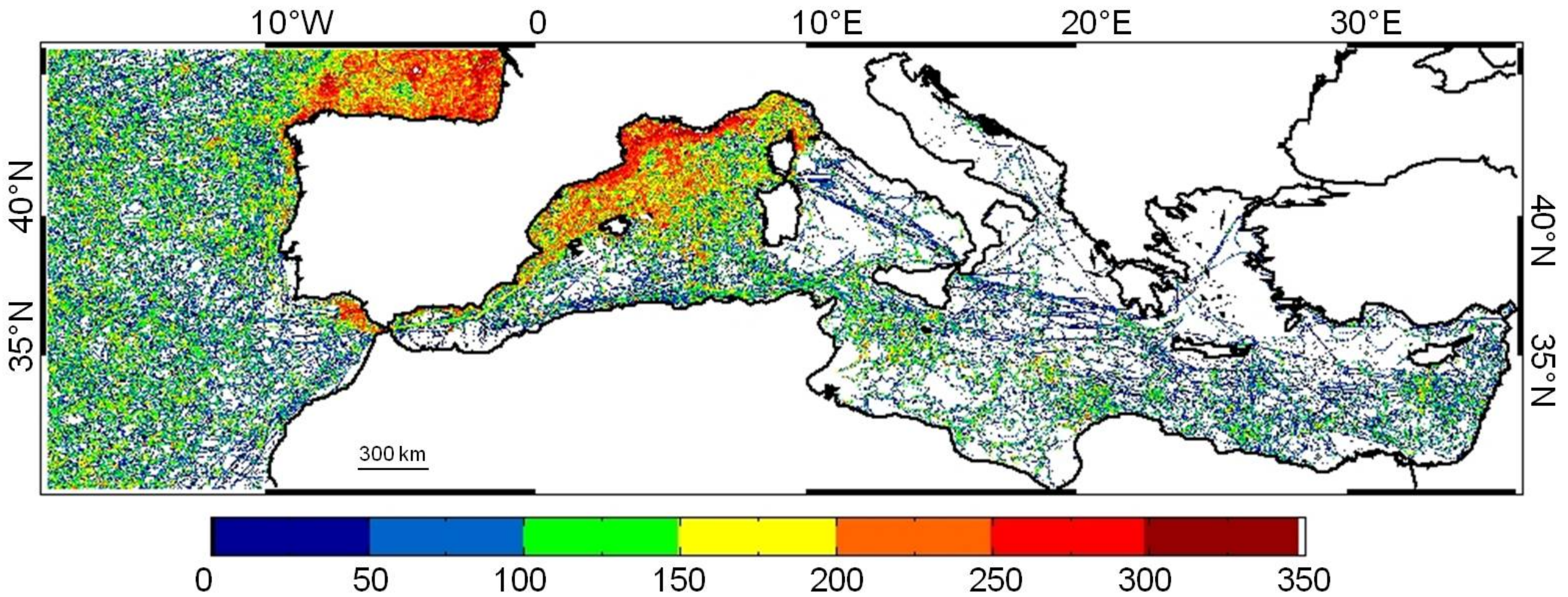
[Temporal]() distribution of the entire in situ time series, 1982-2012.



- Drifter/TSG: fixed depth (0.5 m and 4 m, respectively)
- CTD/XBT/FLOAT: from near-surface (~ 1 m) to bottom

The Data

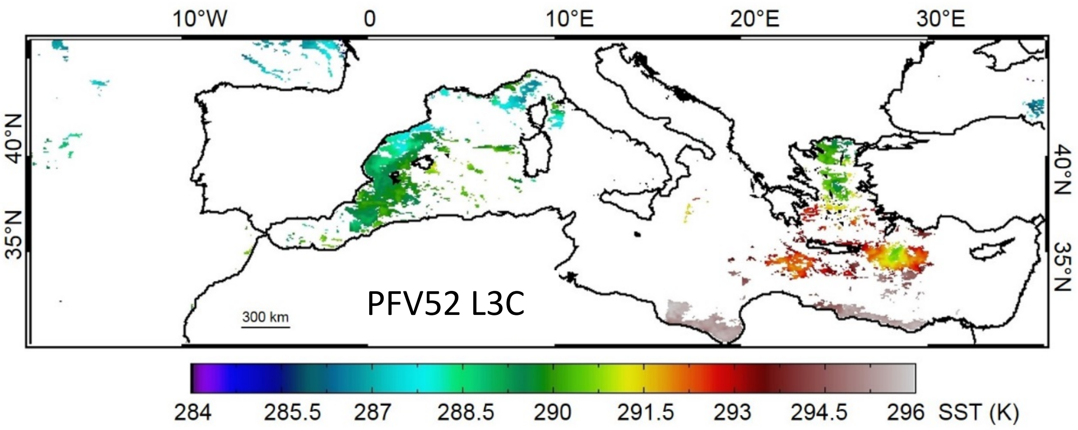
Spatial distribution of the entire in situ time series, 1982-2012.



Total number of observations in each grid box

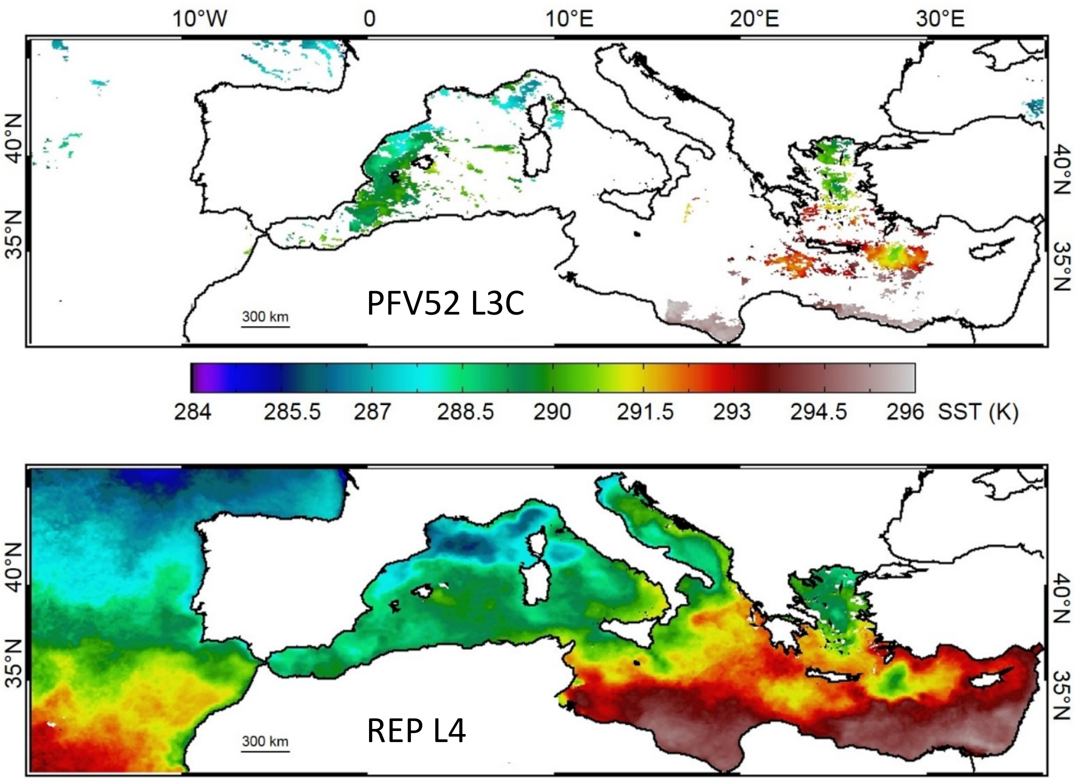
- Spatial coverage quite homogeneous except for the North Adriatic and North Aegean Seas, low numb. obs. in Copernicus and SeaDataNET databases.

SST Optimal Interpolation (OI) Analysis



1.) Only nighttime PFV52 L3C files (→foundation temperature)

SST Optimal Interpolation (OI) Analysis



1.) Only nighttime PFV52 L3C files (→foundation temperature)

2.) Through a space-time OI analysis, we obtained SST gap-free L4 data (Buongiorno Nardelli et al., 2013/2015)

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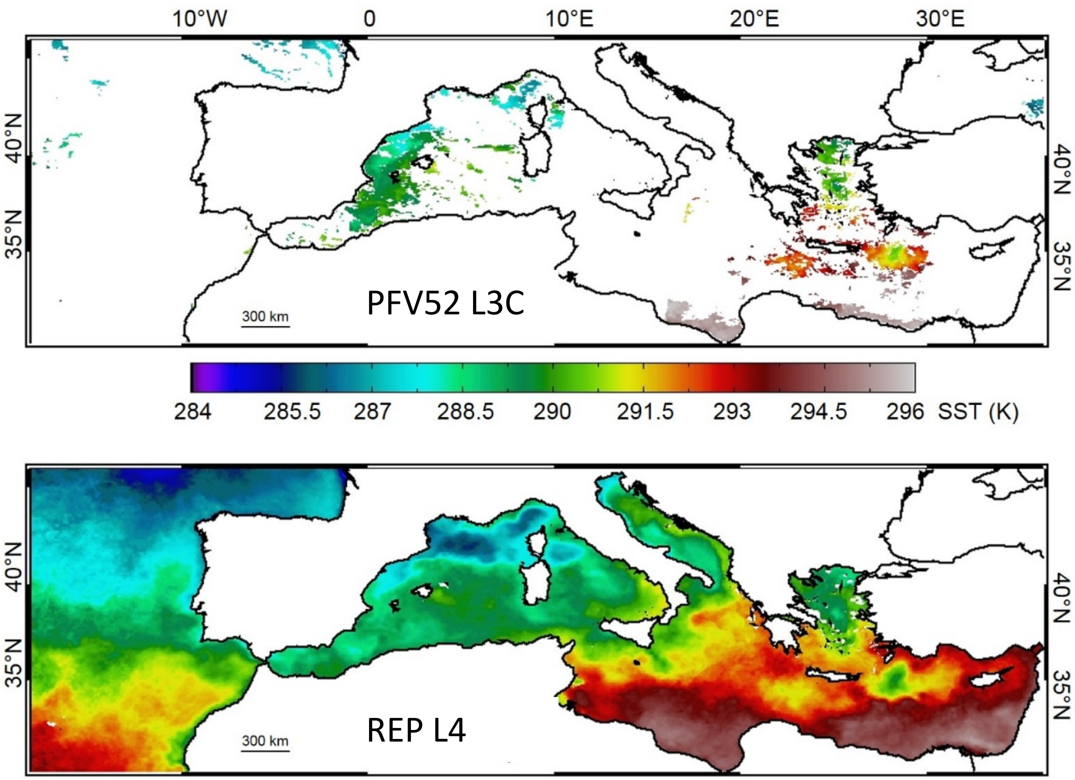

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- <u>Background</u>: daily pentad climatology

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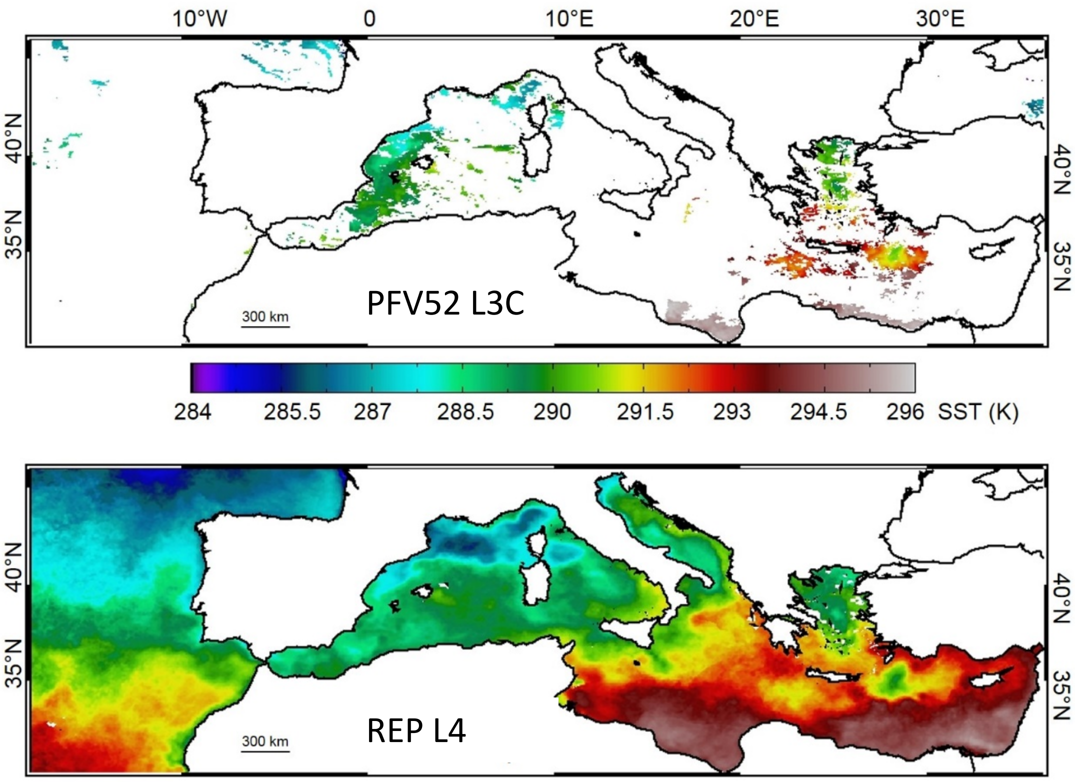

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- <u>Background</u>: daily pentad climatology
- <u>Covariance model</u>: $C(\Delta t)\, C(\Delta r) = exp(-\Delta t/\tau) * (1 + (\Delta r)^2 /2\alpha L^2)^{-\alpha}$

L, τ: spatially varying decorrelation space and time lengths
α: non-negative spatially varying parameter

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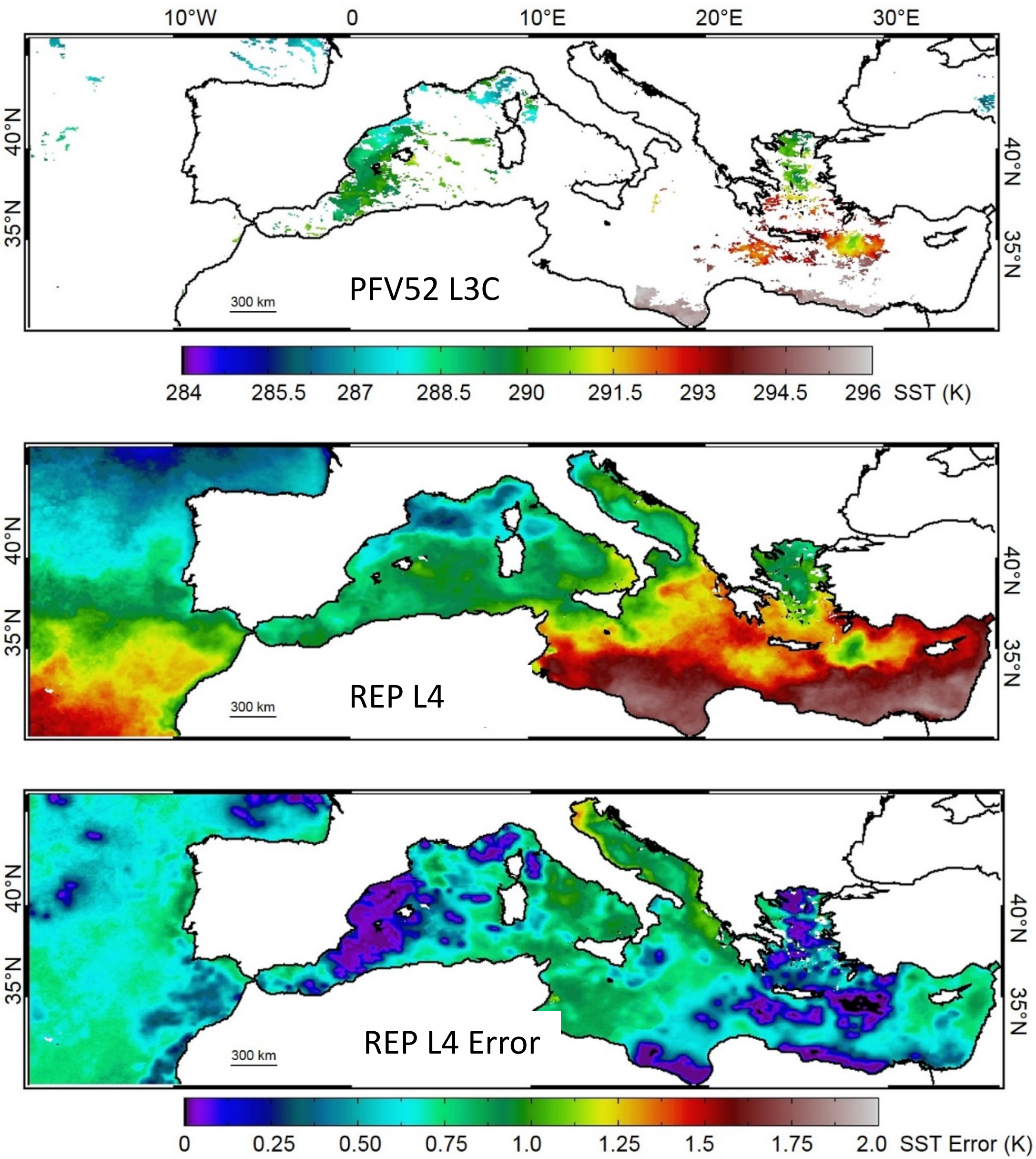

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2.) Through a space-time OI analysis, we obtained SST gap-free L4 data (Buongiorno Nardelli et al., 2013/2015)

3.) Quality of the OI analysis: SST error maps (°K)

Validation of PFV52 and REP L4 data

- We built a <u>matchup database</u> of collocated observations between satellite and in situ measurements, for the period 1982 – 2012

- Selection criterion: we only considered

  a.) the highest quality in situ observations

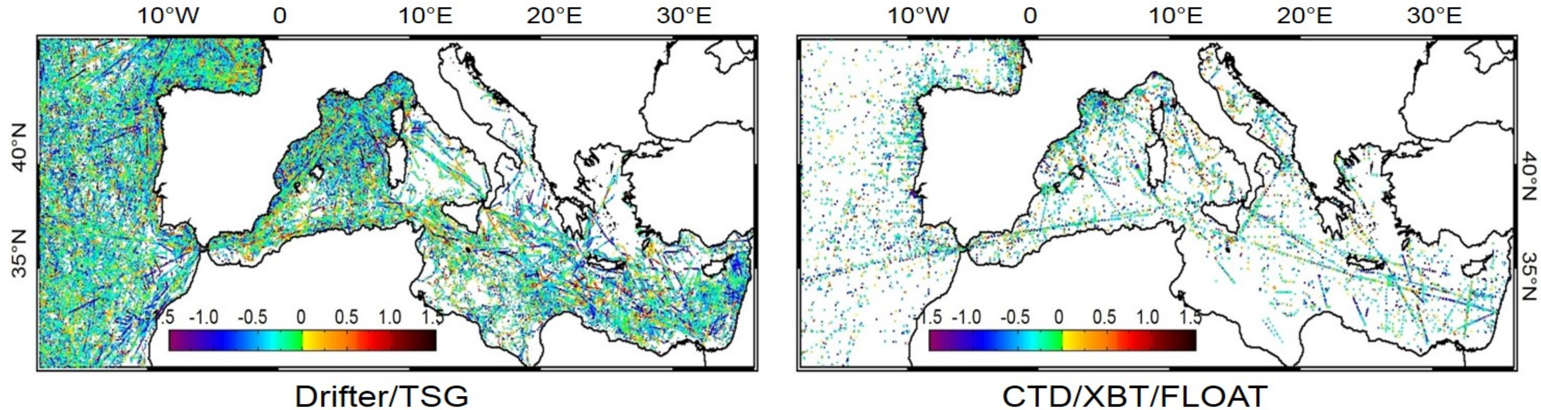
  b.) the profiler data closest to 3 m

  c.) in situ obs. falling within the binned satellite pixel

  AND closest (in time) to the reference satellite time (00:00 local time)

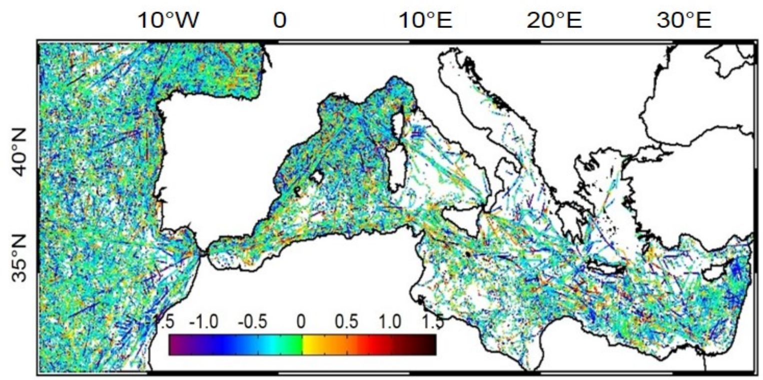
Validation: Summary Results (I)

- Spatial distribution of matchup points between REP L4 and in situ dataset
- Associated SST mean bias (satellite - in situ temp. difference)

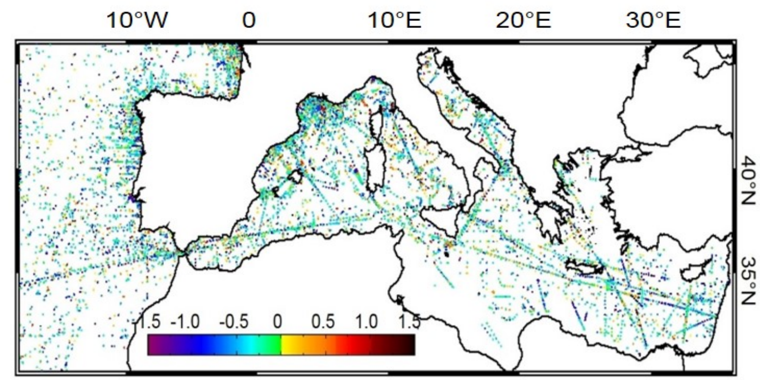


Validation: Summary Results (I)

- Spatial distribution of matchup points between L4 SST and in situ dataset
- Associated SST mean bias (satellite - in situ temp. difference)



Drifter/TSG



CTD/XBT/FLOAT

- Statistical parameters for the difference satellite - in situ measurements

PFV52 L3C

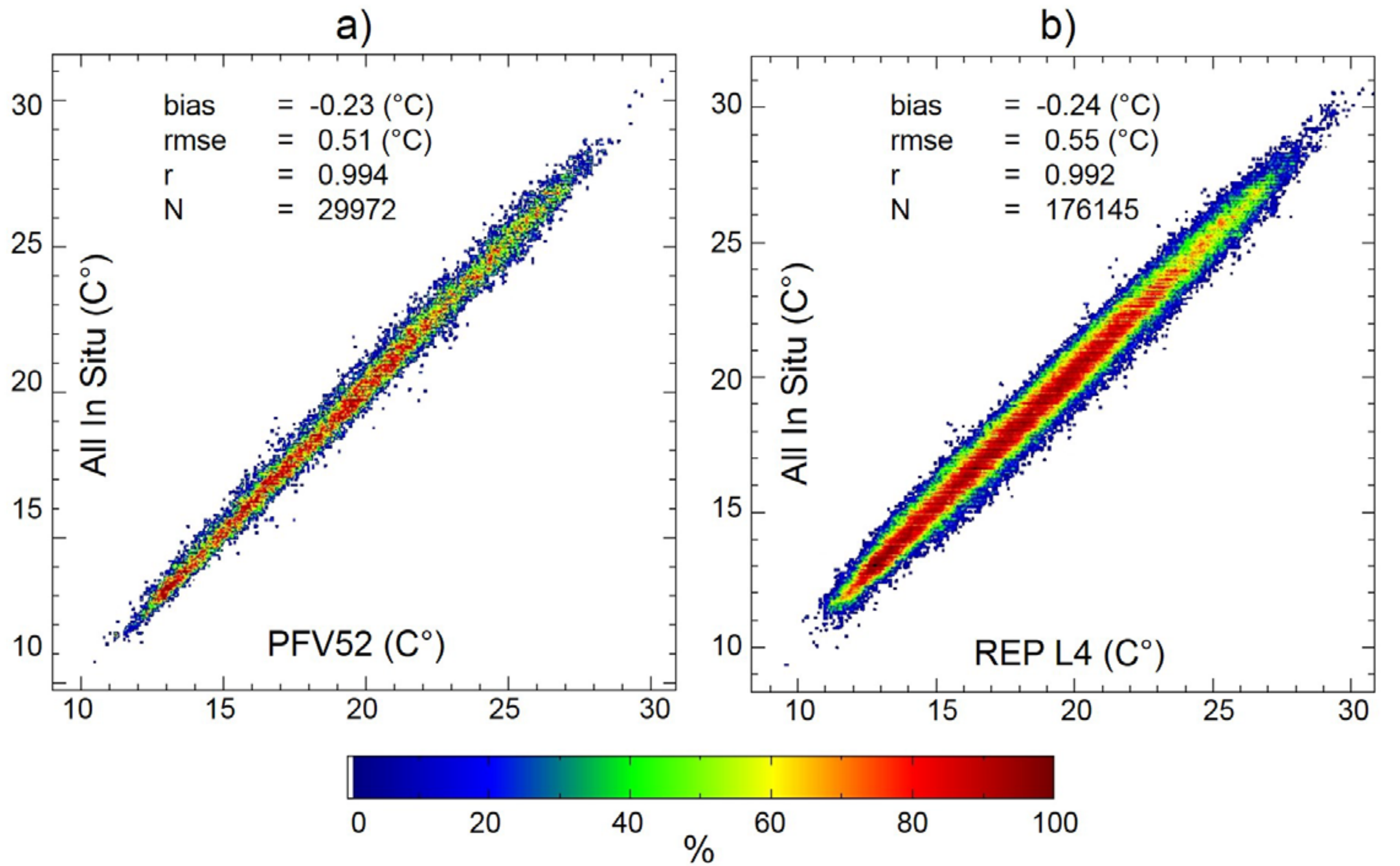
Data Type	**Bias** (°C)	**RMSE** (°C)	N_mup
Drifter	-0.23±0.01	0.51±0.01	14747
TSG	-0.23±0.01	0.53±0.01	10842
CTD	-0.20±0.03	0.54±0.03	1574
XBT	-0.16±0.03	0.47±0.03	1193
ARGO Float	-0.08±0.08	0.50±0.06	164
All data	-0.23±0.01	0.51±0.01	29972

REP L4

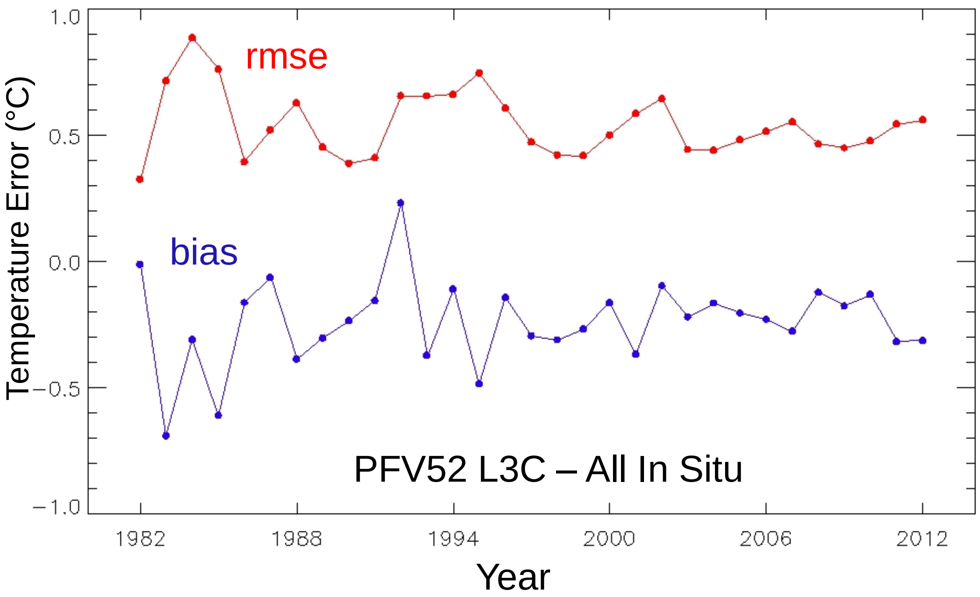
Data Type	**Bias** (°C)	**RMSE** (°C)	N mup
Drifter	-0.233±0.003	0.520±0.003	102164
TSG	-0.250±0.004	0.581±0.004	57369
CTD	-0.22±0.01	0.57±0.01	9916
XBT	-0.29±0.01	0.58±0.01	5927
ARGO Float	-0.18±0.04	0.54±0.03	769
All data	-0.240±0.002	0.545±0.002	176145

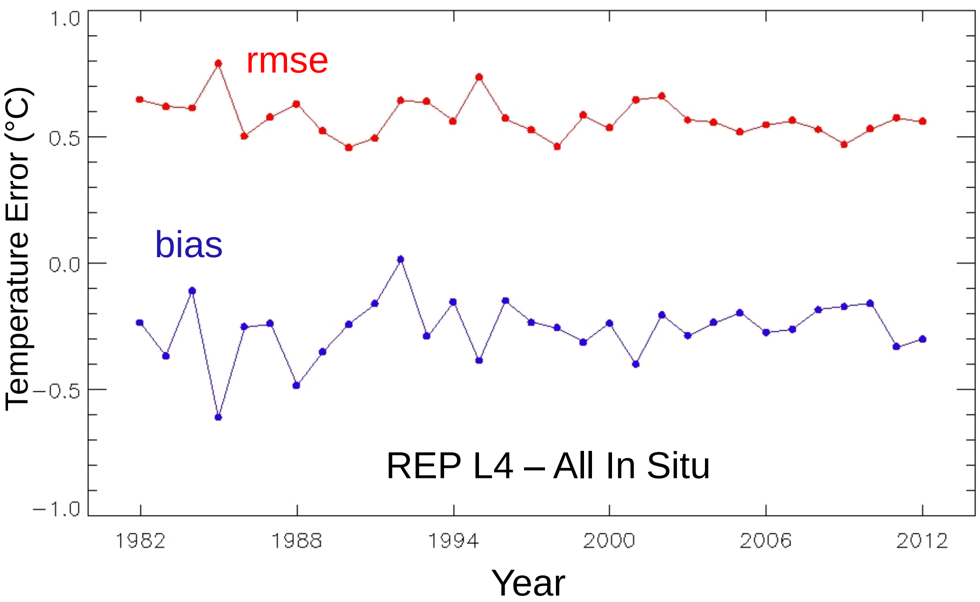
Validation: Summary Results (II)

- Density scatter plots for (a) all in situ data vs. PFV52; (b) all in situ data vs. REP L4.



Validation: Summary Results (III)

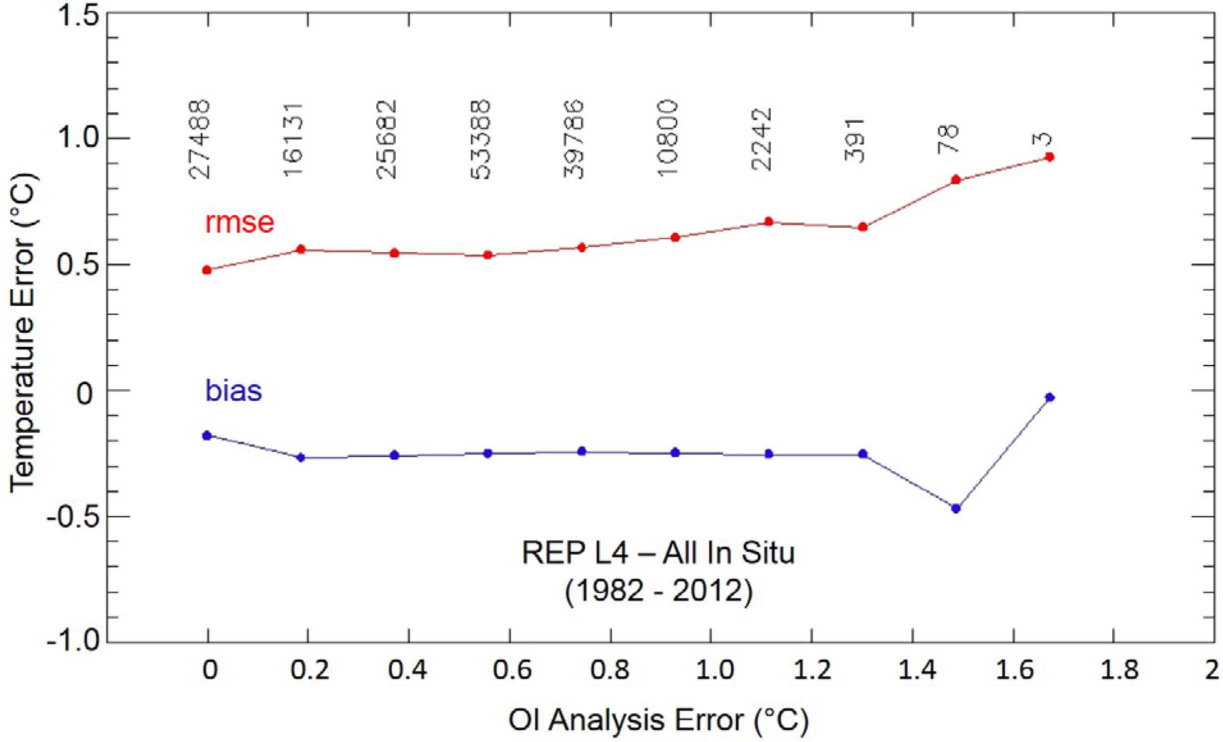




- Yearly rmse and mean bias of the differences (°C) between satellite and all in situ data matchups
- The uniform behavior of the satellite data RMSE demonstrates the consistency of the time series, excluding sensor drifts
- Appropriateness of its usage for climate studies

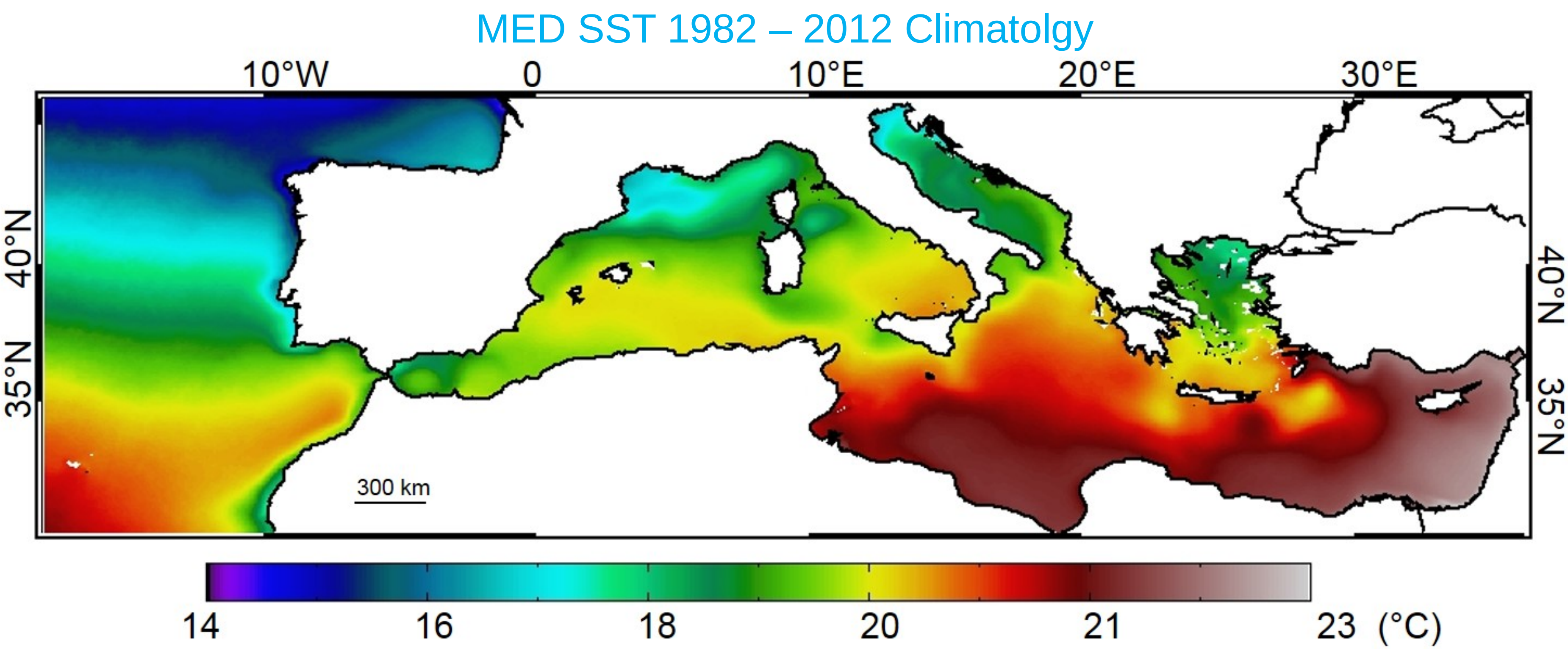
Validation: Summary Results (IV)

- RMSE and mean bias of the differences between REP L4 and all in situ data as function of the interpolation error.



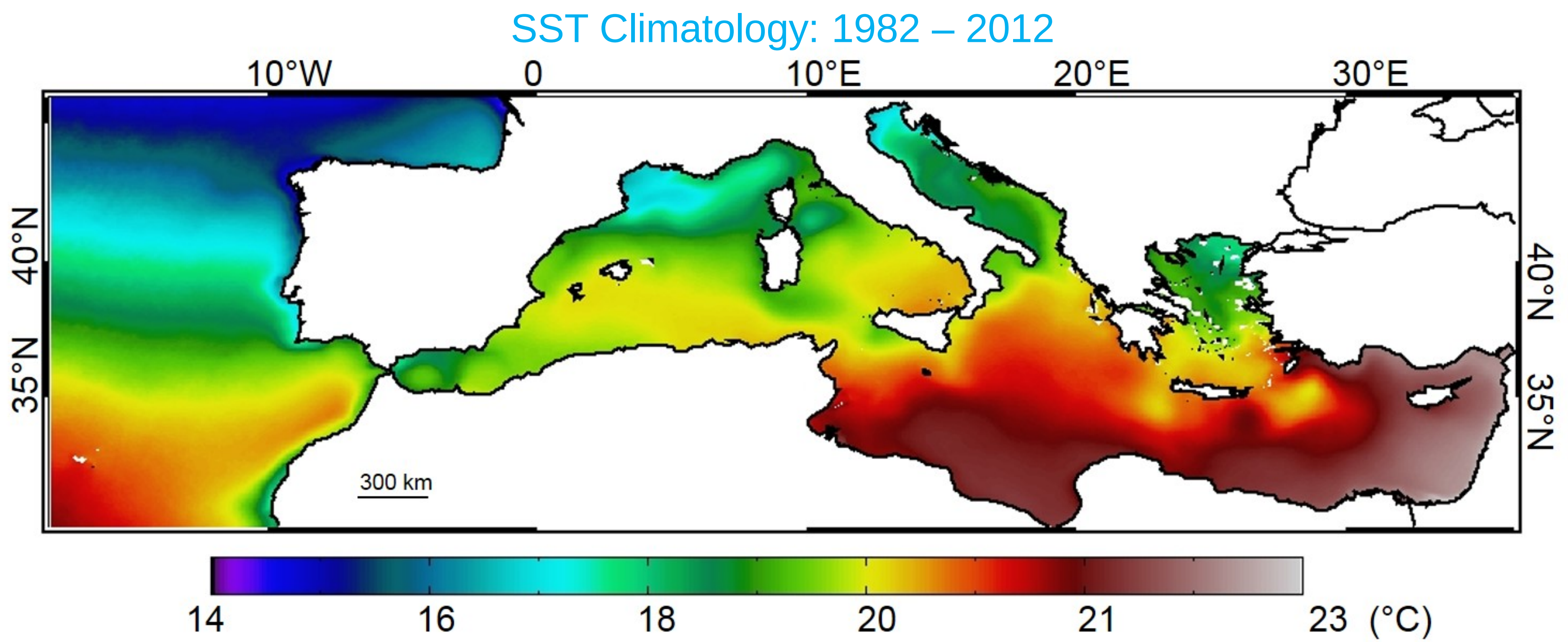
1. when the interpolation error → 0 °C (all observations, no data voids) the corresponding RMSE is about 0.4 °C;
2. RMSE remains practically constant, i.e. around 0.5 °C

Time Series Analysis: SST Climatology



- SST climatology is characterized by latitudinal patterns with the northern region colder than the southern region (zonal solar irradiance gradient)
- Atlantic Sea: cold temperatures characterize the upwelling regions of Portugal and of the north-western African coasts (and along the Southern Sicily coast)

Time Series Analysis: SST Climatology



- <u>Mediterranean Sea</u>:

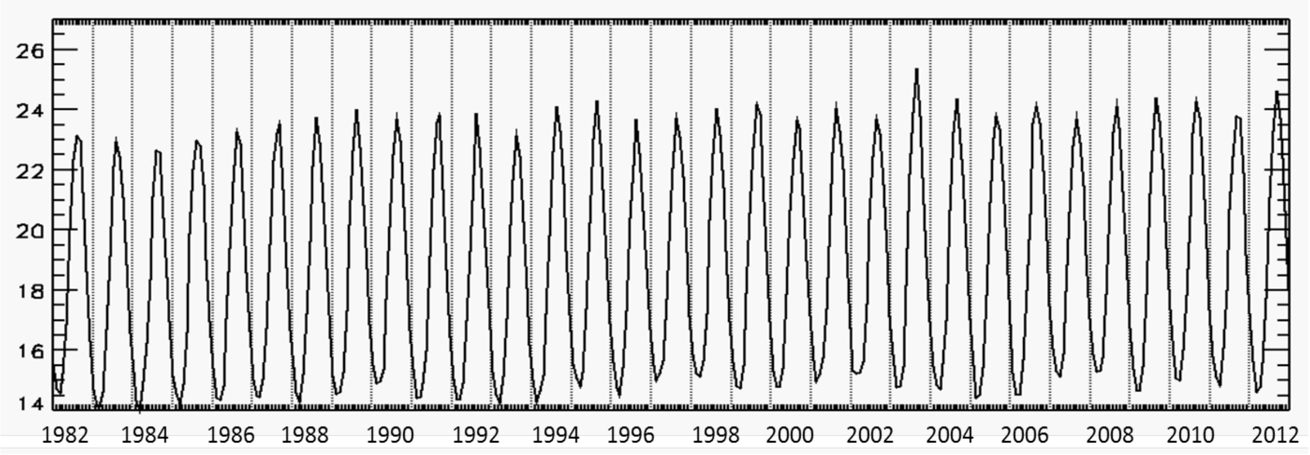
❖ Low temp. typify the anticyclonic gyre in the Alboran Sea and the North Aegean Sea, which are linked to the inflow of the cold water from the Atlantic and Black Seas

❖ Low temp. characterize Gulf of Lions, the Liguro-Provençal current, the North Tyrrhenian Gyre and the North Adriatic Sea

❖ Highest SST are found in Levantine basin and in the Gulf of Gabès

Time Series Analysis: SST Trend Methodology

SST time series from 1982 to 2012



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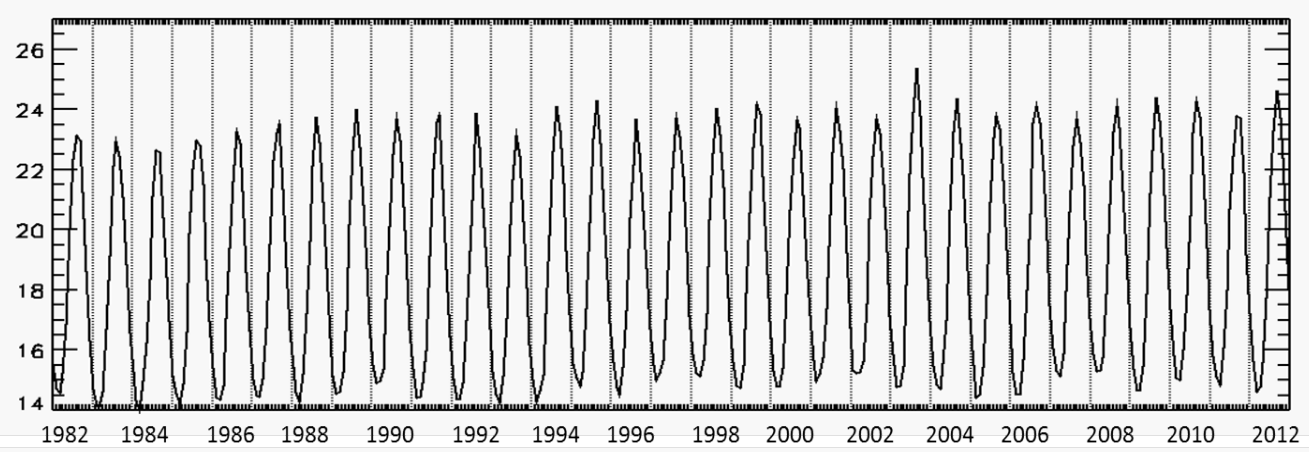

- By using the X-11 seasonal adjustment methodology (Findley et al., 1998), we obtained the:

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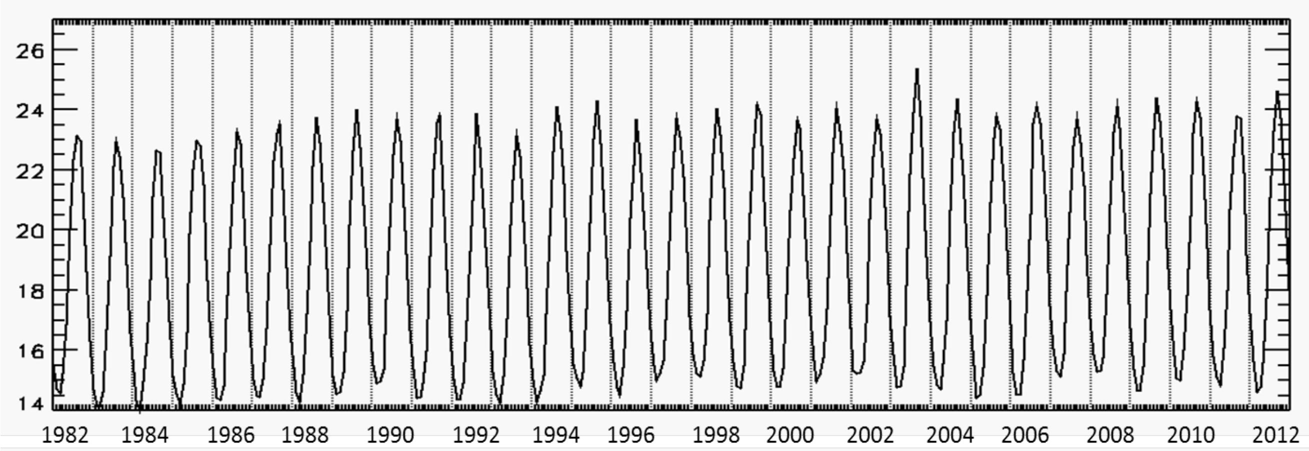

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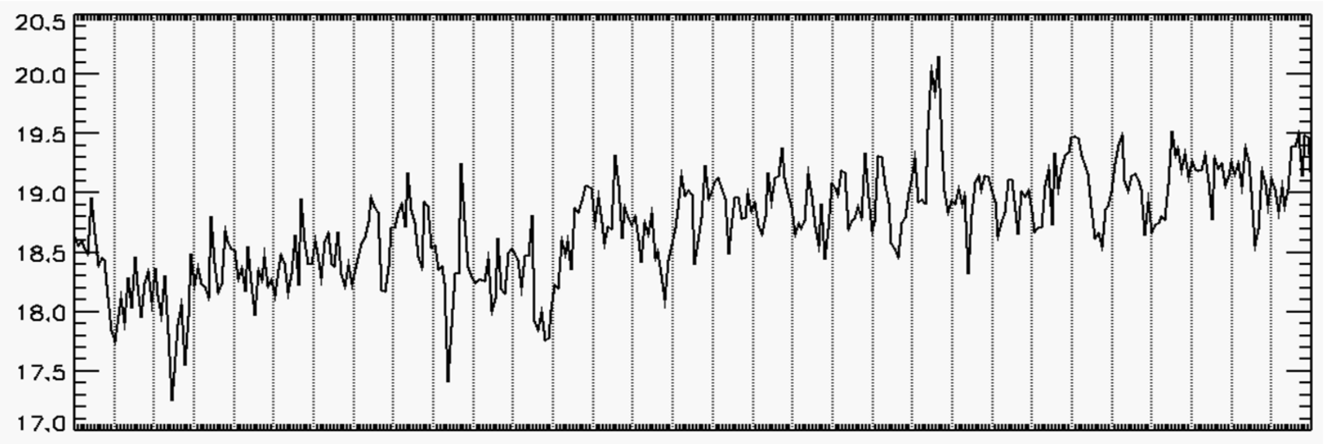
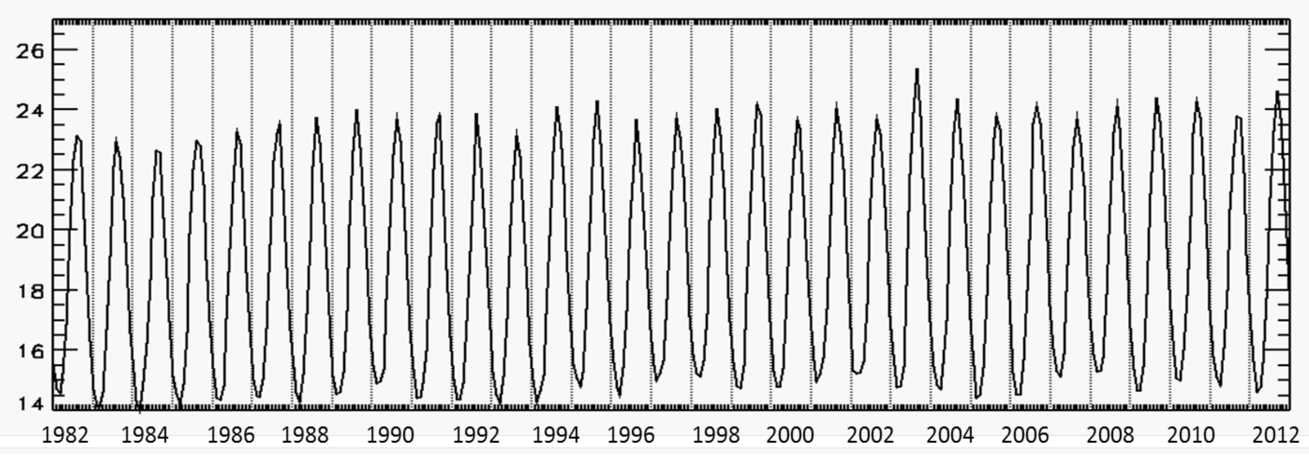
Deseasonalized SST time series



Evident the warming of the sea water and the inter-annual variability of SST

Time Series Analysis: SST Trend Methodology

SST time series from 1982 to 2012



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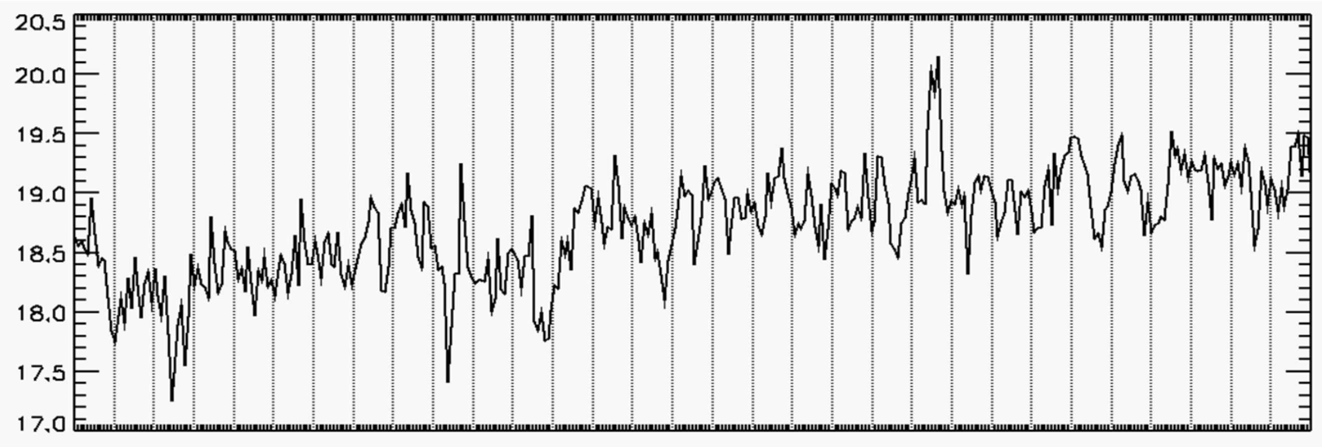
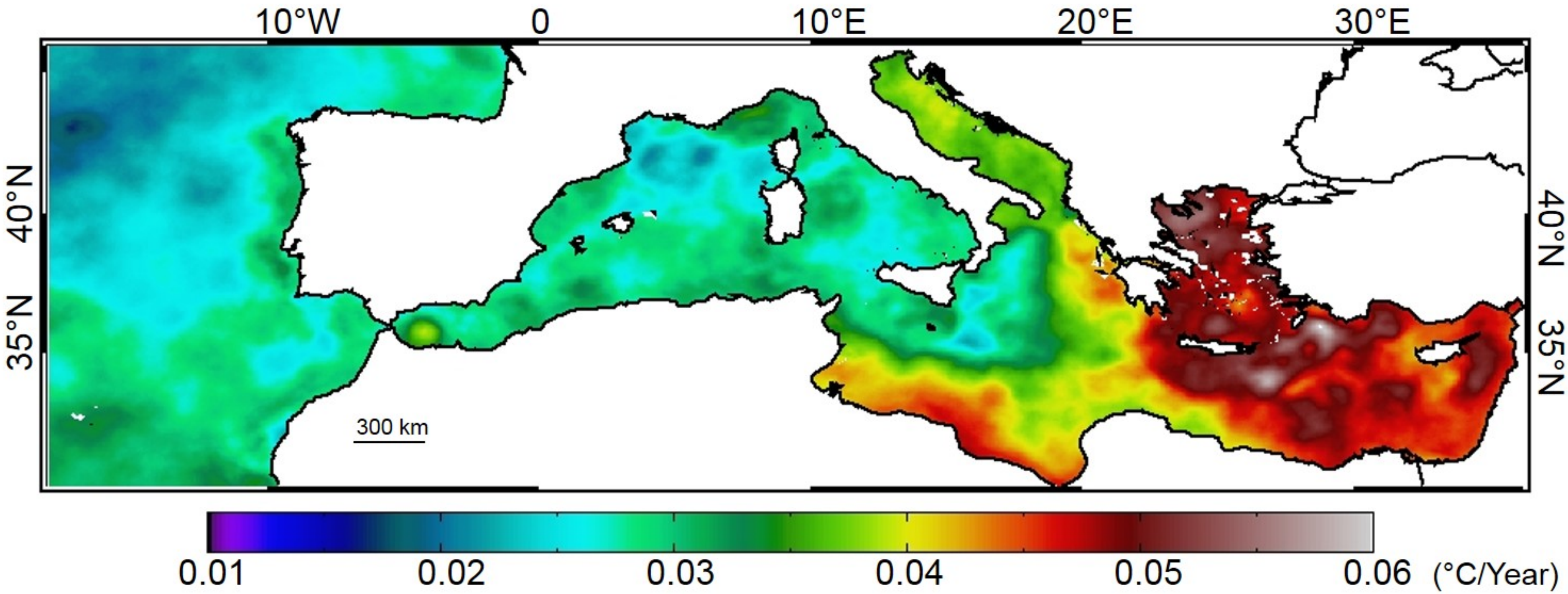


- Mann-Kendall test and Sens's method were applied to estimate the trend and confidence level

Evident the warming of the sea water and the inter-annual variability of SST

Time Series Analysis: SST Trend Results

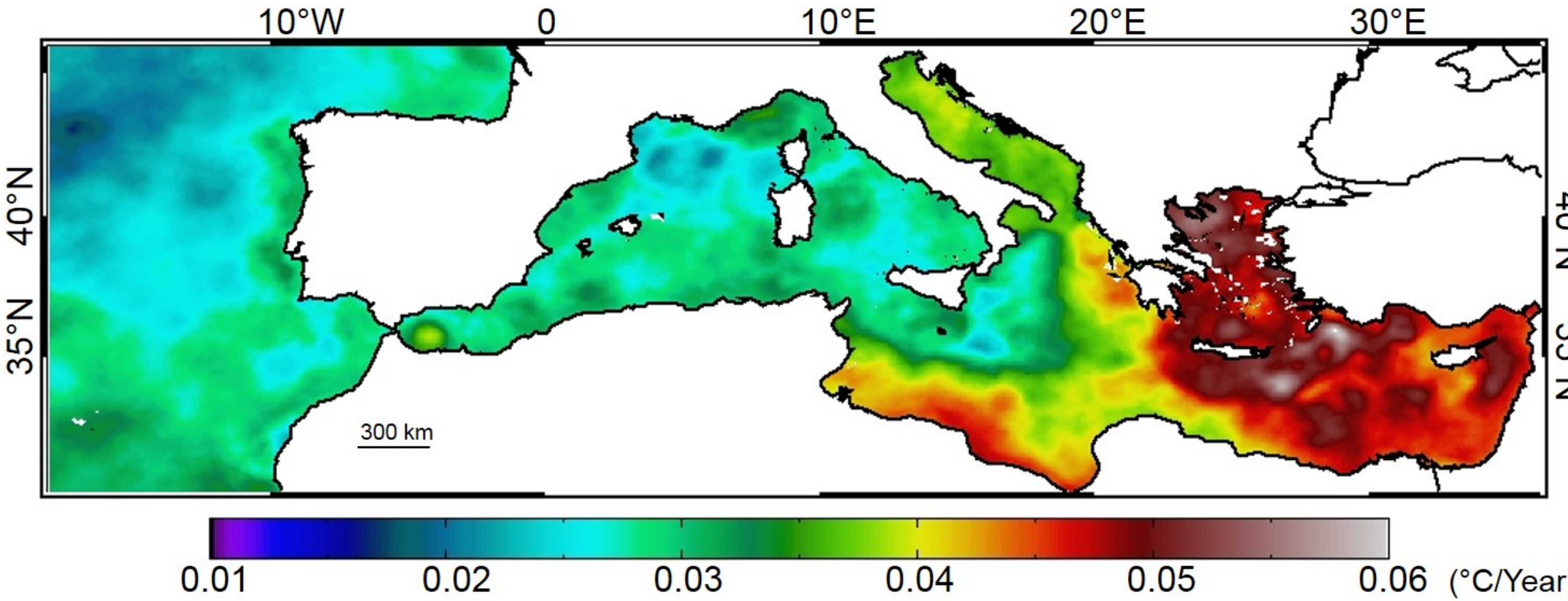
SST Annual Trend (°C year^{-1}), 1982 – 2012, at 90% confidence level



- The spatial pattern of the SST trend shows a general surface warming of the region examined
- The magnitude of the trend increases moving eastwards: minima trend values in the Atlantic region and in the Western basin of the Mediterranean Sea and maxima in the Cretan Arc and in the North Aegean Sea.

Time Series Analysis: SST Trend

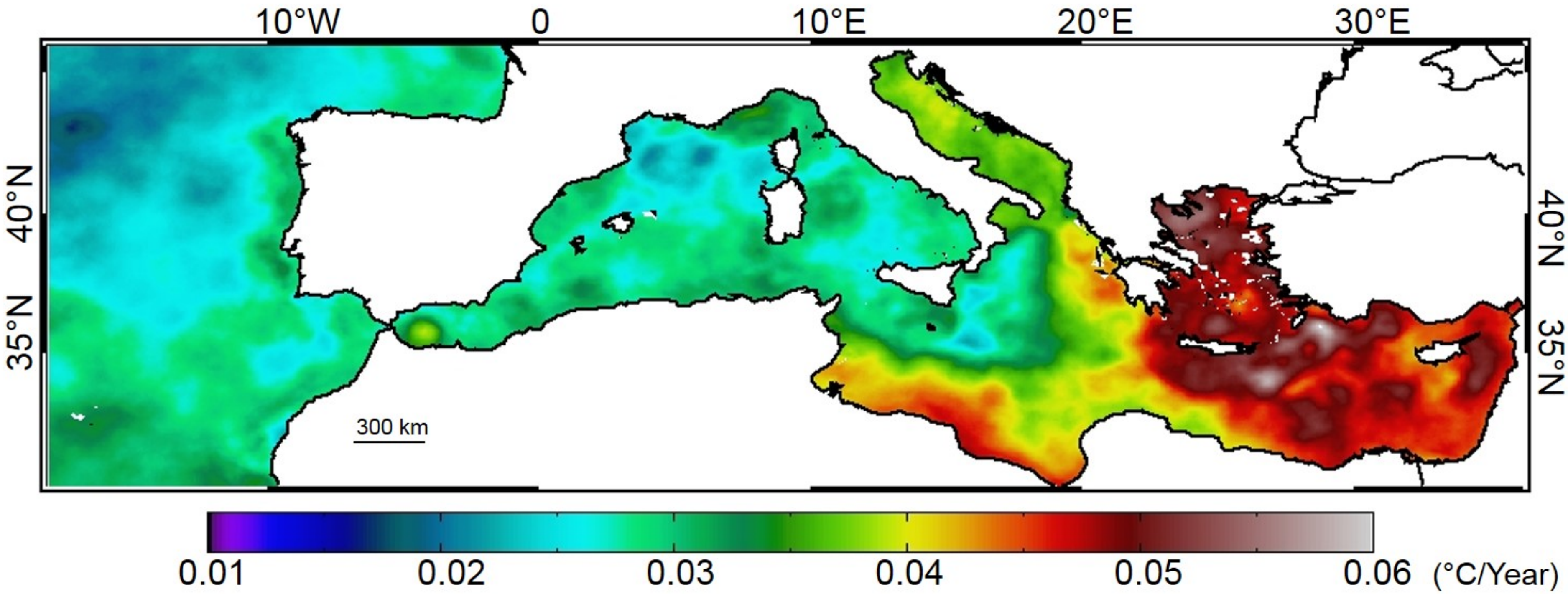
SST Annual Trend (°C year^{-1}), 1982 – 2012, at 90% confidence interval



- The positive trend of the coastal regions of Portugal and Sicily stresses that the coastal upwelling processes are weakening. Lemos and Pires (2004) link this phenomenon off the coast of Portugal to a weakening of the northerly upwelling favorable winds, and it is possible to suppose the same mechanism also for the Sicilian coasts.

Time Series Analysis: SST Trend

SST Annual Trend (°C year^{-1}), 1982 – 2012, at 90% confidence level



- Mean SST Trend of ~0.05° C/Yr and 1.5 °C over the 31-year rep. period
- Accordance with previous studies which detect a global warming of the Med. sea water temperature (Lionello et al.,2006,Levitus et al., 2000, López García and Camarasa Belmonte, 2011, Skliris et al., 2011)

References

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