SST diurnal cycle and heat budget estimates over the Mediterranean Sea

by

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A Joint Research Project in the framework of the bilateral scientific cooperation protocol between USA and Italy :

COmbining Satellite, In-situ and MOdeling approaches to reconstruct the Diurnal Sea Surface Temperature Variation in the Mediterranean Sea: Impact on the basin heat budget and climate. (**COSIMO**)

Objectives:

1. To **Evaluate the impact** of the Diurnal Warming on the heat budget of the Mediterranean Sea

2. To better **Understand the Physics** of diurnal warming events using models and field experiments.

Why focusing on the Mediterranean Sea?

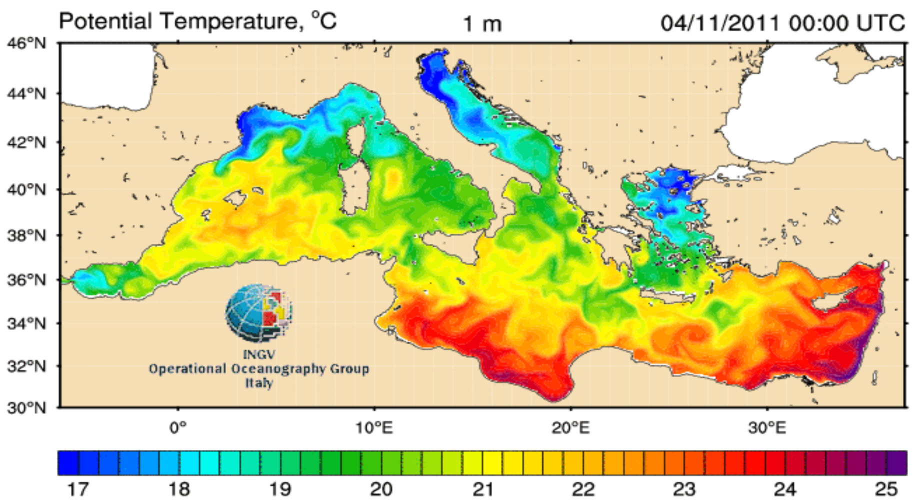
- The Mediterranean Sea is a concentration basin: E>(P+R) is balanced by the water exchange at Gibraltar Strait.
- Basin heat loss is balanced by the heat gain through Gibraltar.
- Local Heat fluxes are important for deep and intermediated water formation.
- Mediterranean intermediated waters contributes to the Atlantic conveyor belt.
- Then the Mediterranean Sea is the perfect natural laboratory to test the DV impacts on Heat budget estimate.

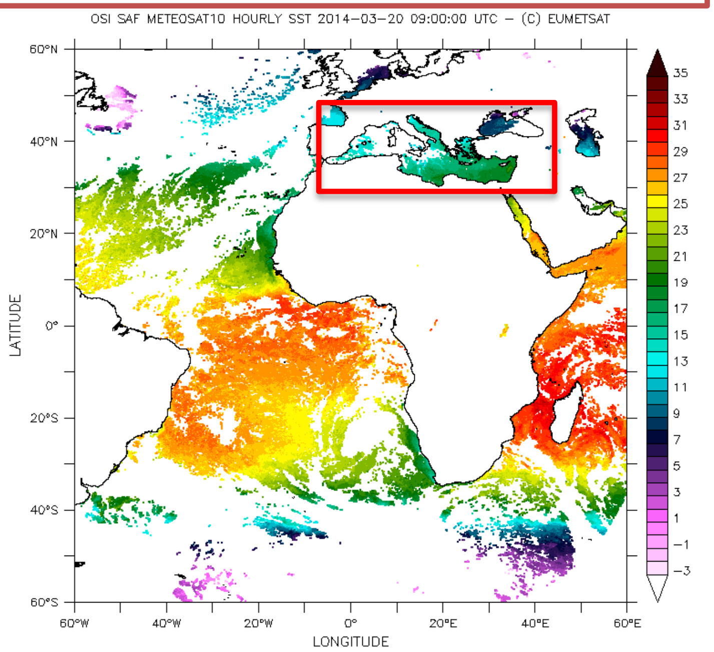
The SST Diurnal Cycle: Data and methods

The ingredients to produce the hourly L4 SST Time series:

Satellite data: hourly SEVIRI SST fields, distributed by OSI-SAF

MyOcean/CMEMS Mediterranean MFS data

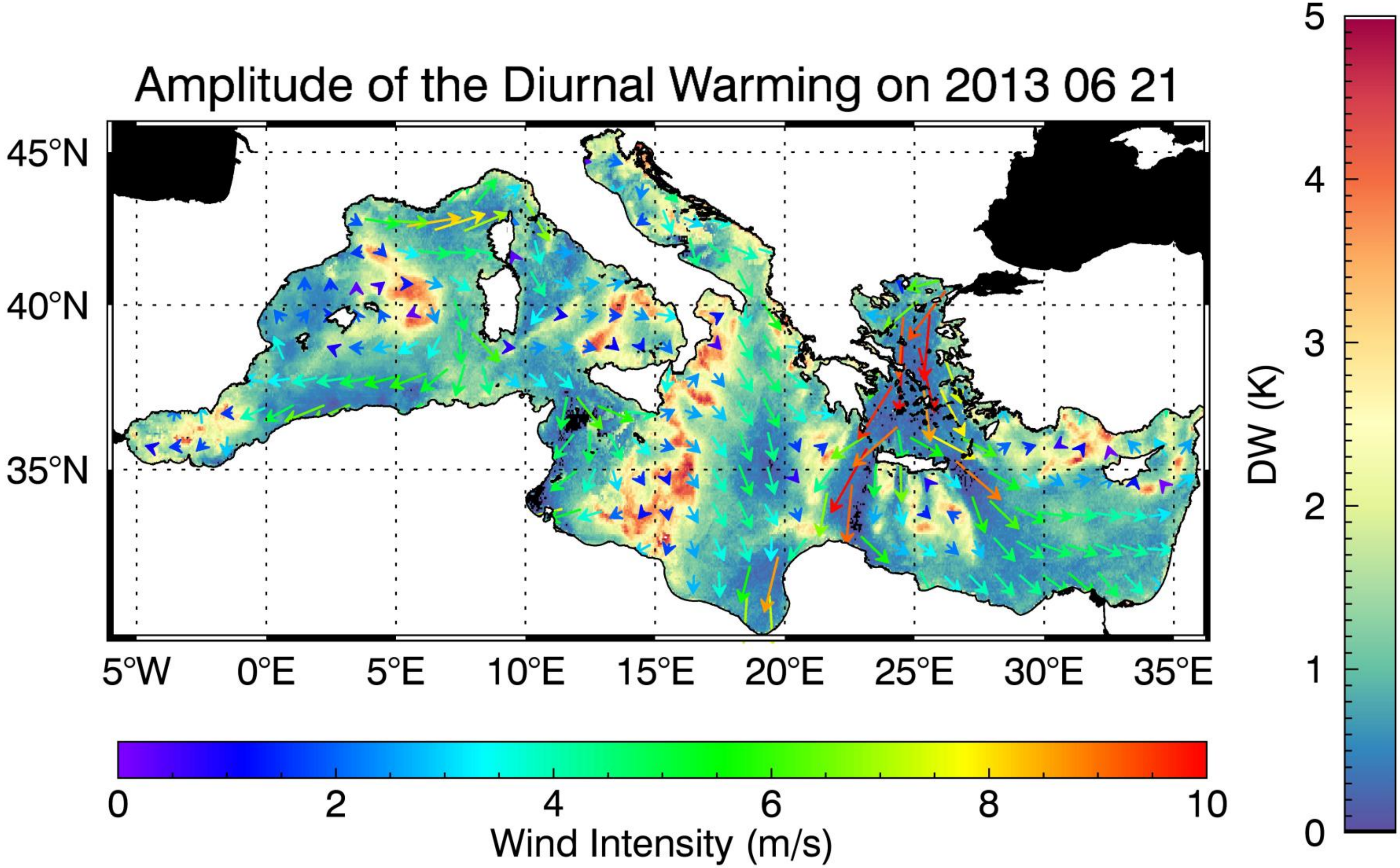




Hourly reconstructed SST maps are obtained by **combining numerical model** analyses and **geostationary satellite data** in the context of the Optimal Interpolation theory (Marullo et al. RSE, 2014). In the next future this L4 method will be implemented in the Copernicus CMEMS.

The SST diurnal cycle and the Mediterranean heat budget:

Analysis of year 2013

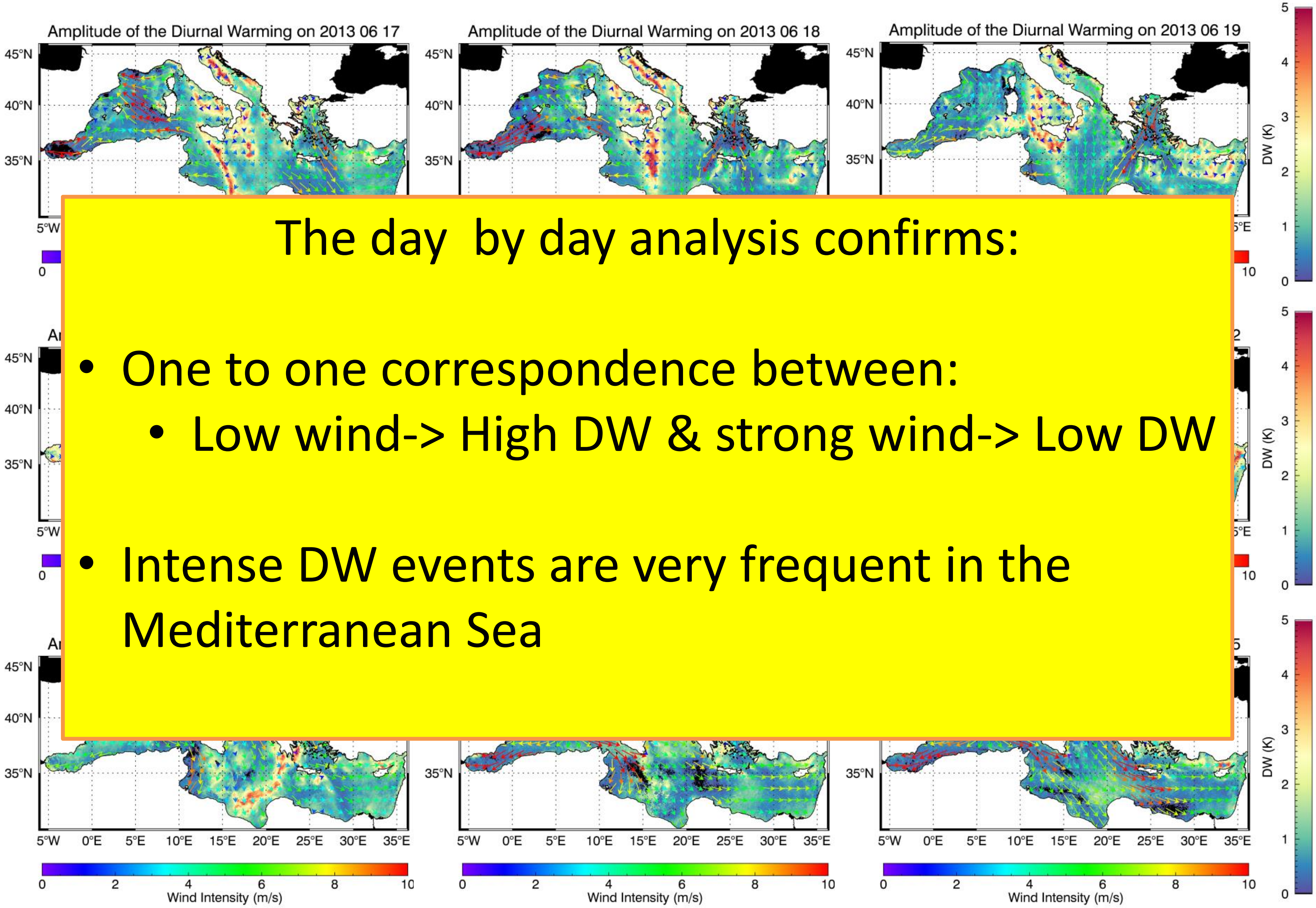


DW: difference between the actual, daytime, SST and *the mean SST of the previous night*

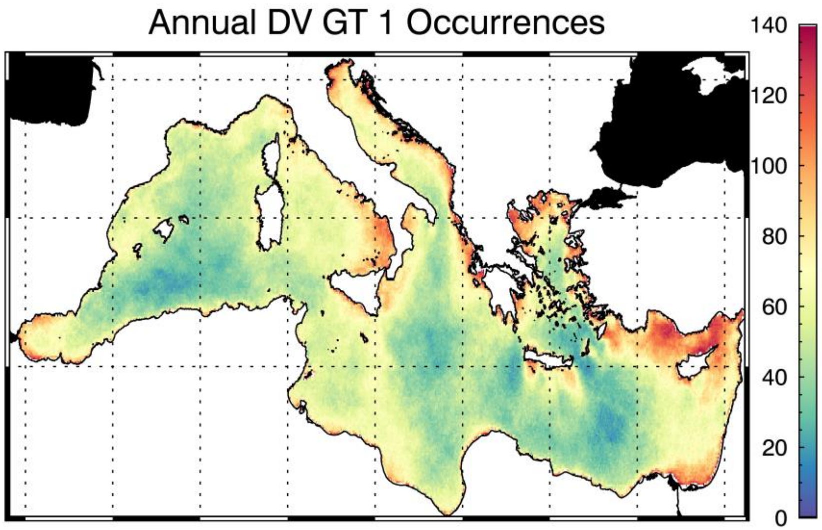
Large areas of DW (>2° K) coincide with areas of wind calm (< 2 m/s)
The Etesian strong winds produce nearly zero DW
In several locations DW exceeds 4°K

The day by day analysis confirms:

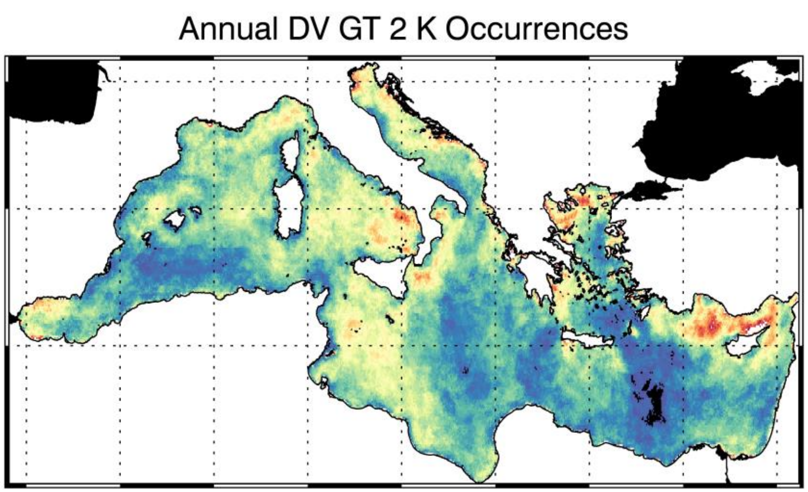
- One to one correspondence between:
  - Low wind-> High DW & strong wind-> Low DW
- Intense DW events are very frequent in the Mediterranean Sea

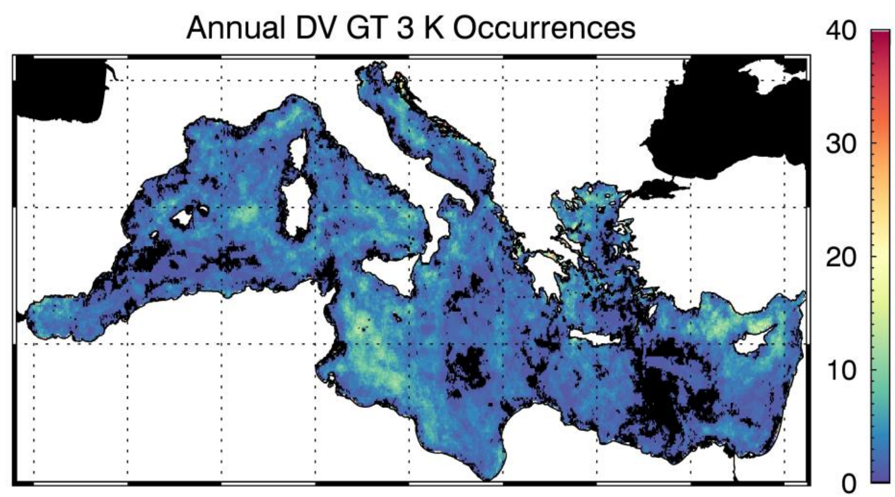


Number of DW Events during 2013



High occurrence of Diurnal warming events in the Mediterranean Sea (in the average more then 20% of the day shows DW GT 1 K events!)
Higher values are observed in the eastern Mediterranean Sea and in the South Tyrrhenian Sea





Ocean Surface Heat Fluxes

The net surface heat flux at the air-sea interface (Q_{tot}), consists of the absorbed solar radiation (Q_s) minus the back radiation (Q_b), latent (Q_e) and sensible (Q_h) heat flux:

$$Q_{tot} = Q_s - (Q_h + Q_b + Q_e)$$

Meteorological data from ECMWF Analysis. SST from SEVIRI. Turbulent exchange coefficients from wind speed dependent curves (Kondo, 1975). Shortwave radiation budget from Reed 1977 corrected for Transmittance using Tragou & Lascaratos 2003

$$Q_s = (1 - 0.[illegible]2C + 0.0019h)Q_0(1 - A)$$

$$Q_b = \varepsilon \cdot \sigma \cdot T_s^4 - \left[\sigma \cdot T_a^4 \cdot (0.653 + 0.00535 \cdot e)\right] \cdot (1 + 0.1762 \cdot C)$$

(Bignami et al. 1995)

$$Q_e = \rho \cdot C_e \cdot w \cdot (q_s - q) \cdot L$$

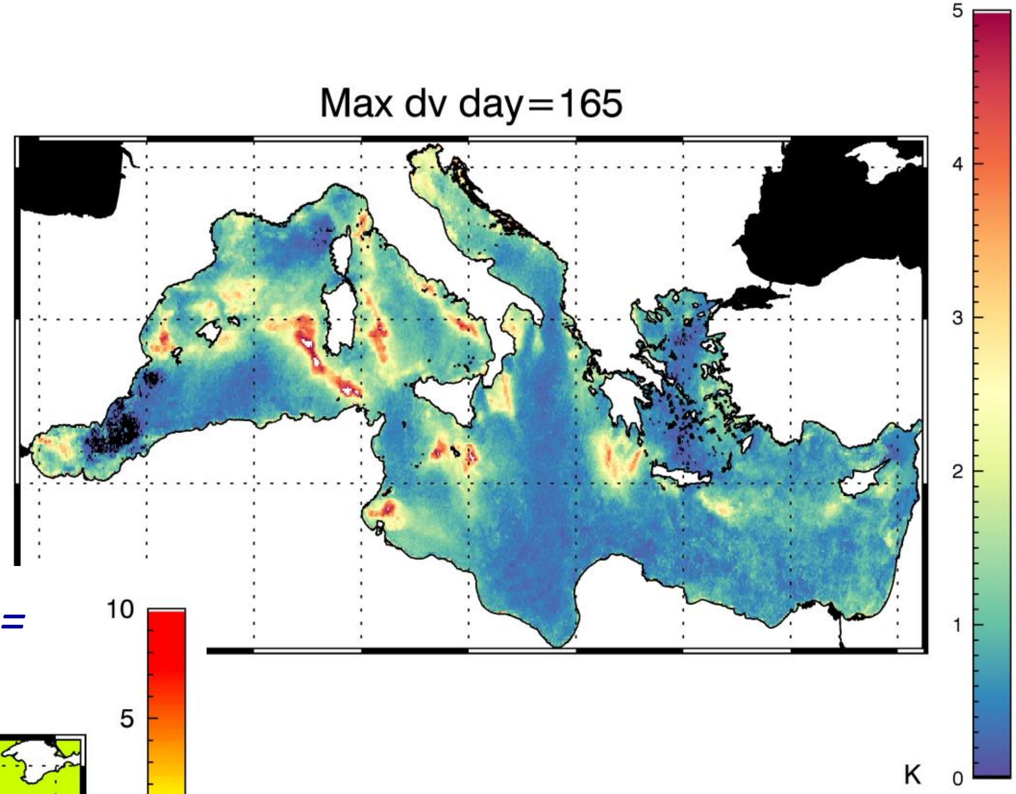
$$Q_h = \rho \cdot C_p \cdot C_h \cdot w \cdot (T_s - T_a) \cdot w$$

Heat budget computation using:

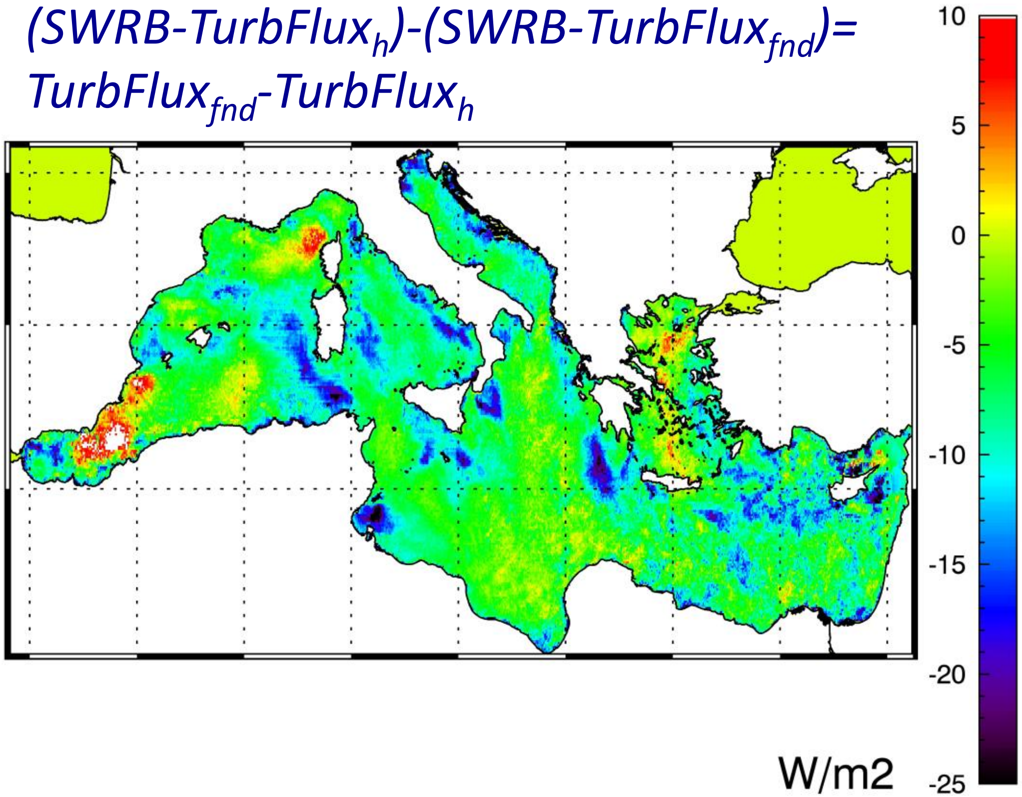
- *Diurnally varying Satellite SST (hourly DOISST)*
- *Non diurnally varying Satellite SST (FND)*

Diurnal Warming events: day 165 (June 14th 2013)

Impact on the Heat Budget at daily scale

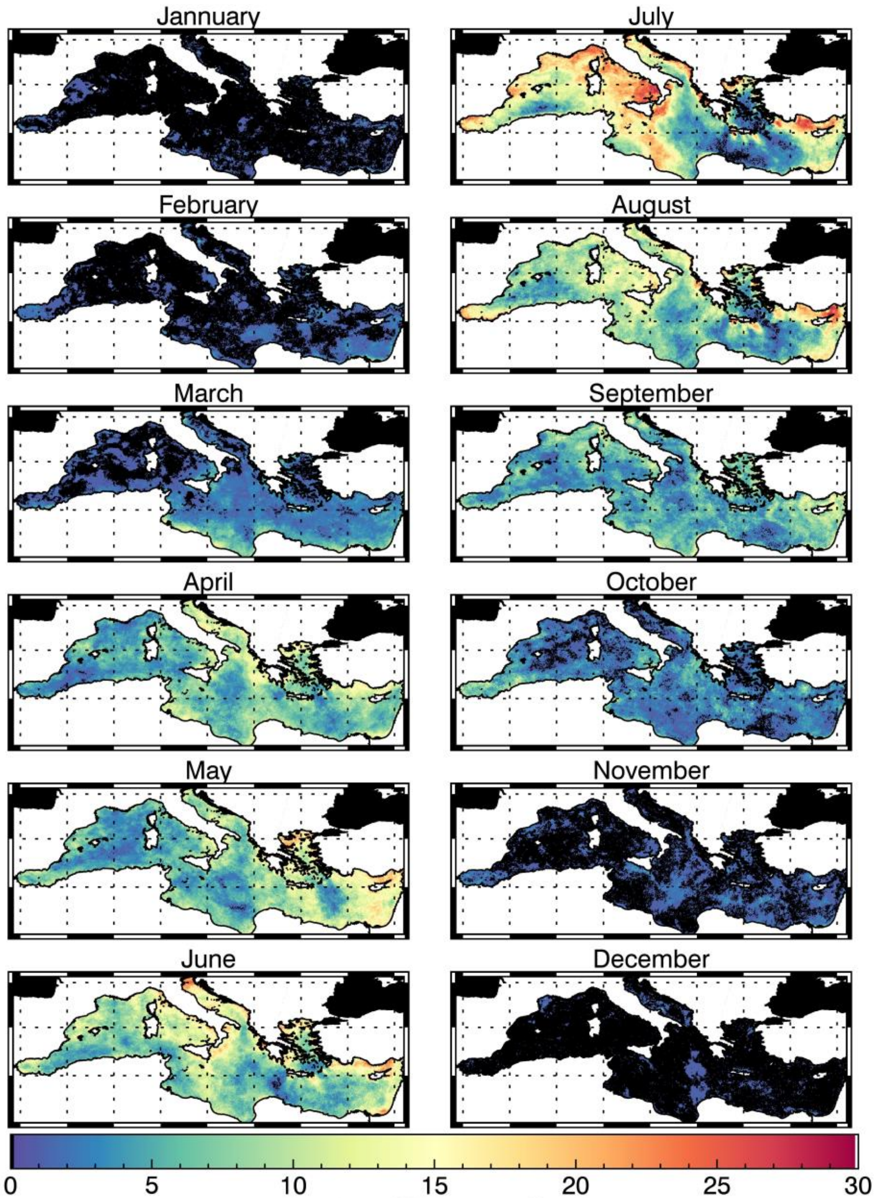


$$Dif = Qtot_h - Qtot_{fnd} = (SWRB - TurbFlux_h) - (SWRB - TurbFlux_{fnd}) = TurbFlux_{fnd} - TurbFlux_h$$

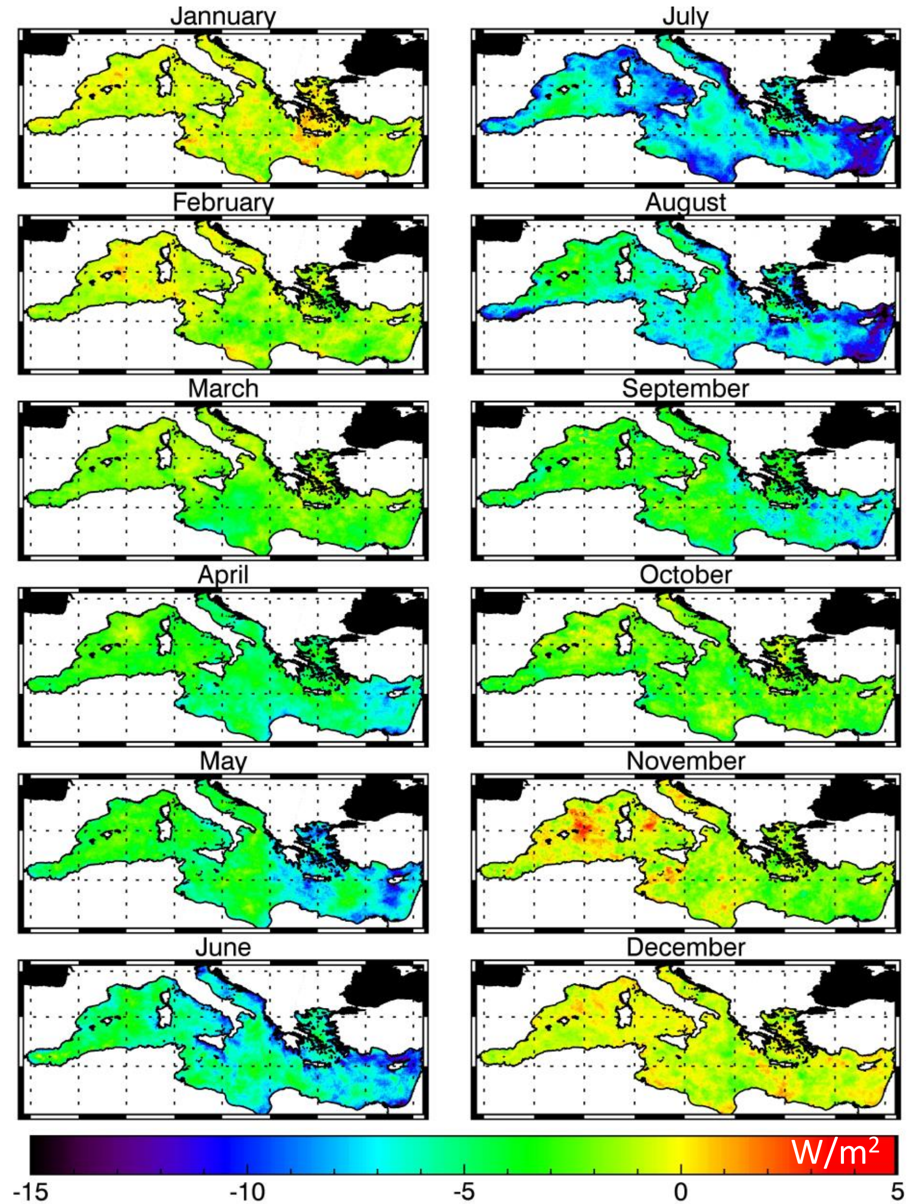


Difference in the net Heat Flux caused by a non-diurnal varying SST for June 14th 2013. Negative values indicate that the Diurnally varying turbulent heat loss is more intense (up to 25 W/m²) than the heat lost computed using non-diurnally varying SST.

Number of DW Events

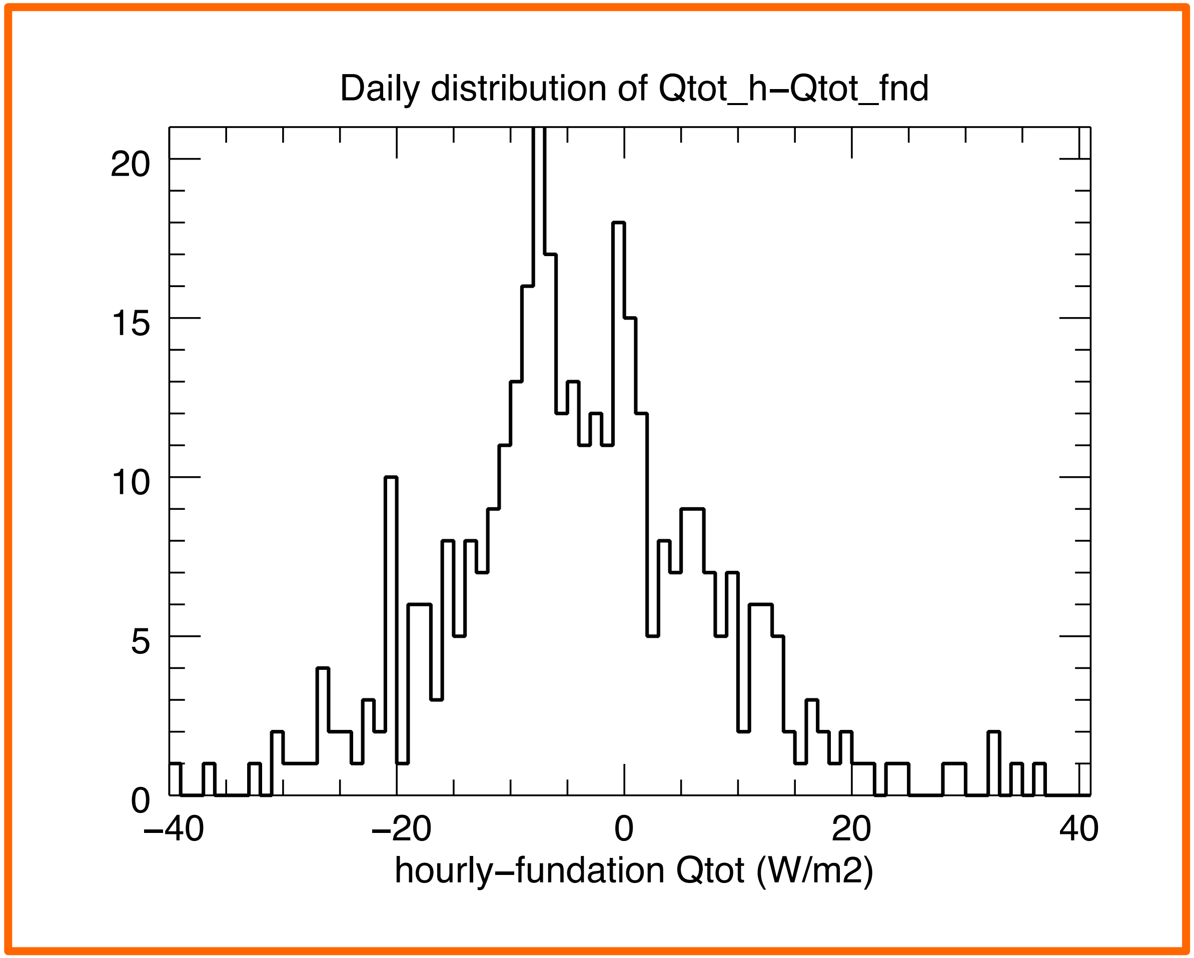


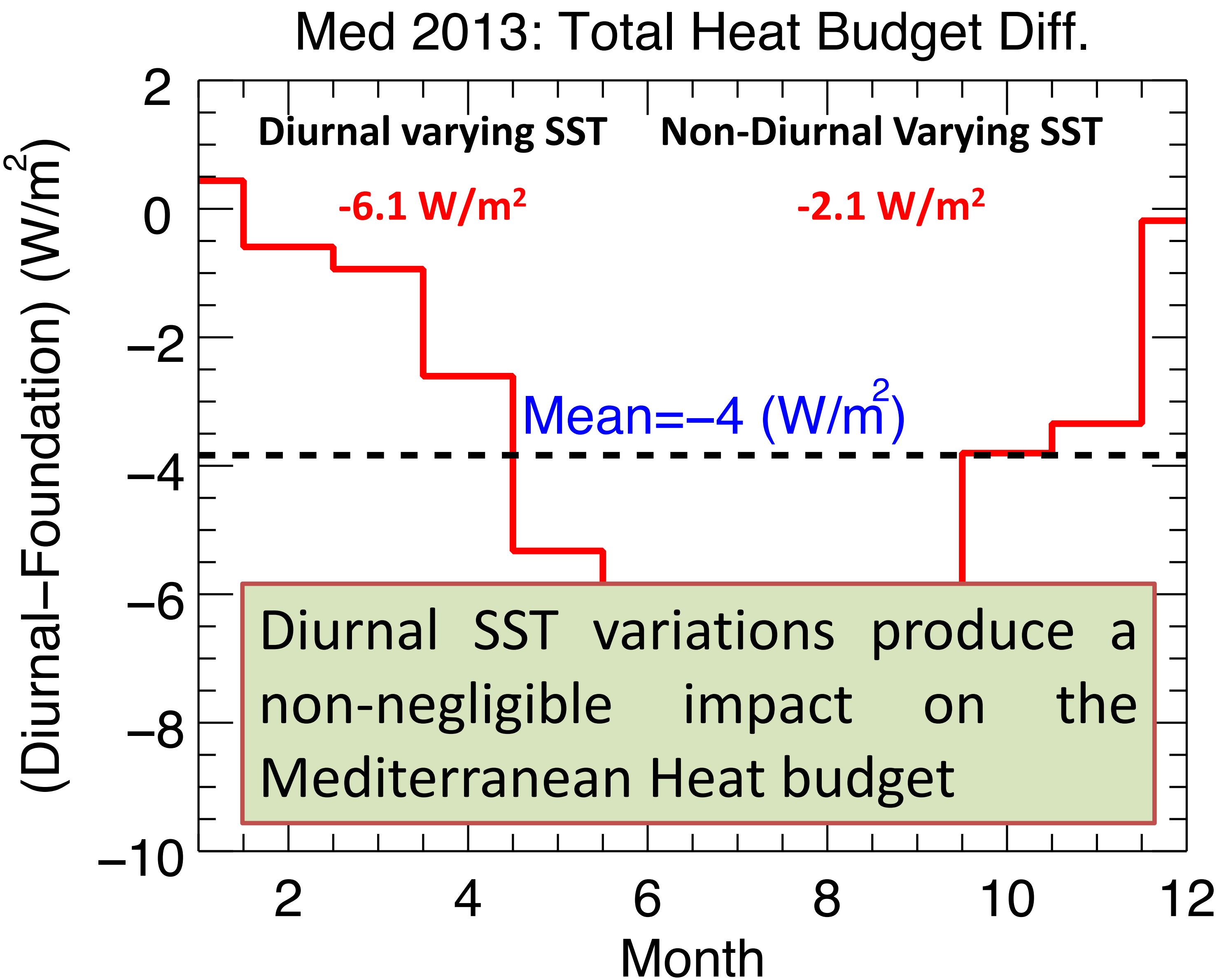
Net heat flux difference (diurnal-foundation)



DW has a strong signature on the Net Heat Fluxes at monthly scale. Up to - 10 W/m2

Daily Heat flux distribution differences



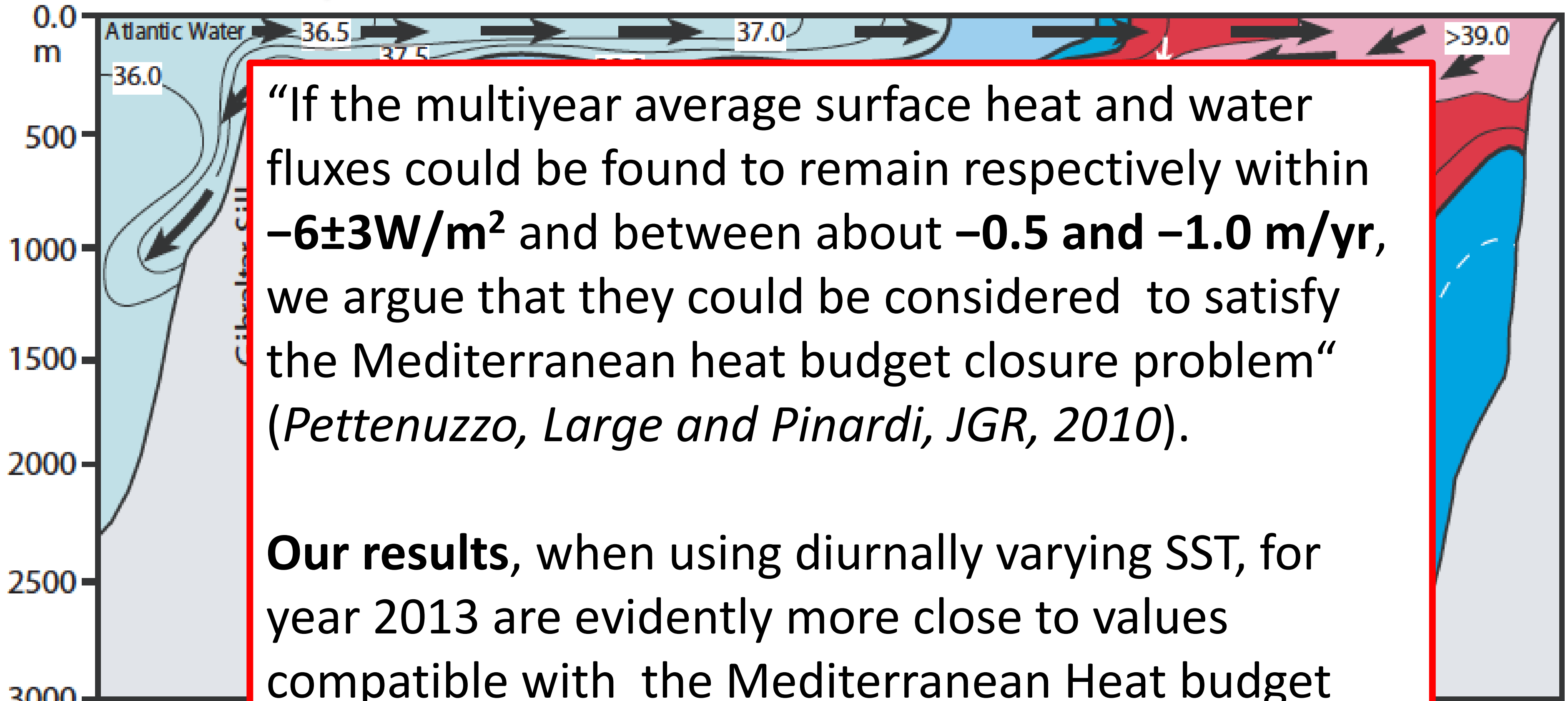

Med 2013: Total Heat Budget Diff.
Diurnal varying SST
Non-Diurnal Varying SST
-6.1 W/m²
-2.1 W/m²
Mean=–4 (W/m²)
(Diurnal–Foundation) (W/m²)
2
0
–2
–4
–6
–8
–10
2
4
6
8
10
12
Month
Diurnal SST variations produce a non-negligible impact on the Mediterranean Heat budget

$5.2 \pm 1.3\ W/m^2$
$7 \pm 3\ W/m^2$

Evaporation > P + R

-1.0 m/yr
-0.71±0.07 m/yr
-0.6 m/yr
-0.5 to -0.7 m/yr

SWR-(LWR+Qe+Qh)

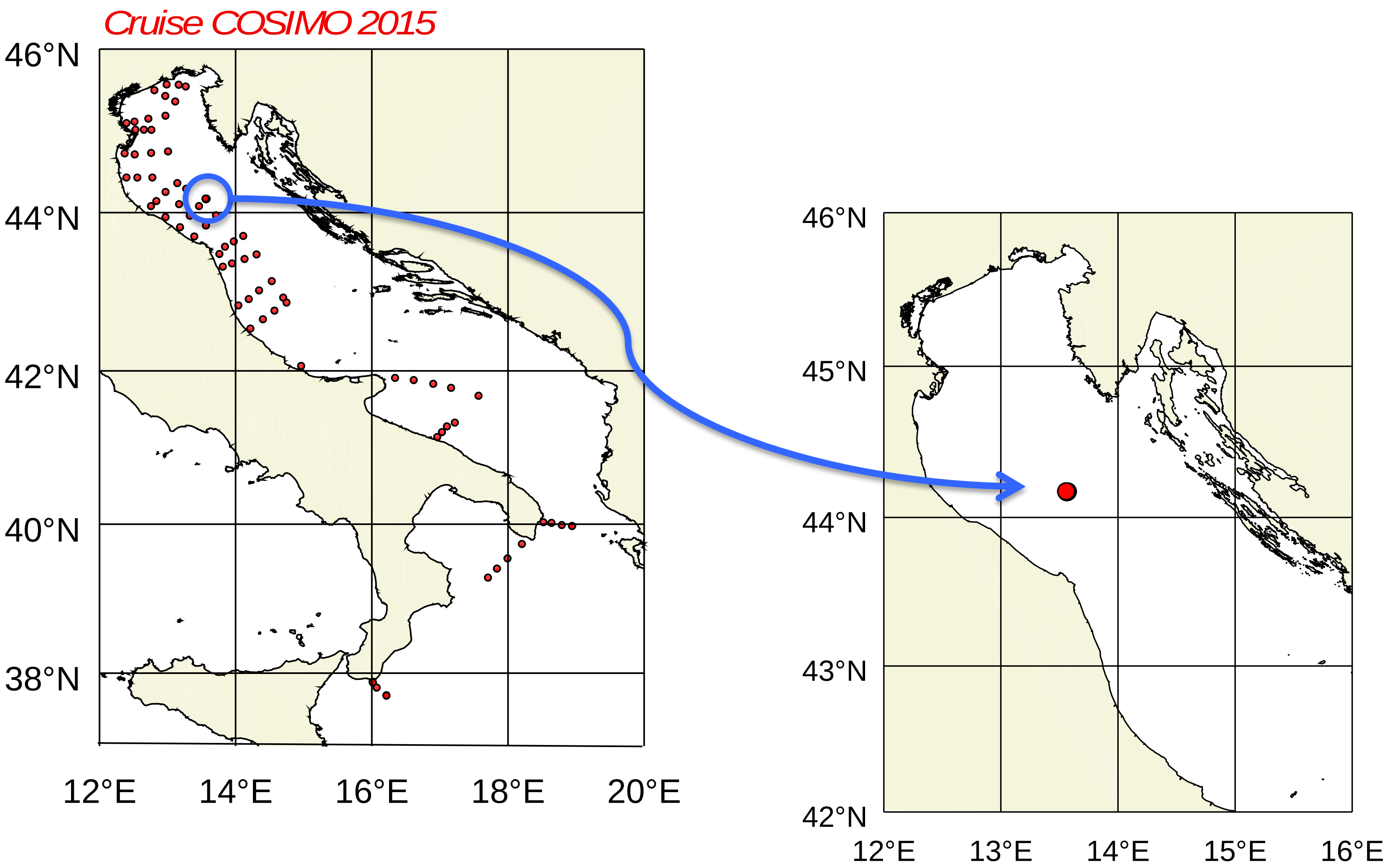


“If the multiyear average surface heat and water fluxes could be found to remain respectively within **−6±3W/m²** and between about **−0.5 and −1.0 m/yr**, we argue that they could be considered to satisfy the Mediterranean heat budget closure problem“ (*Pettenuzzo, Large and Pinardi, JGR, 2010*).

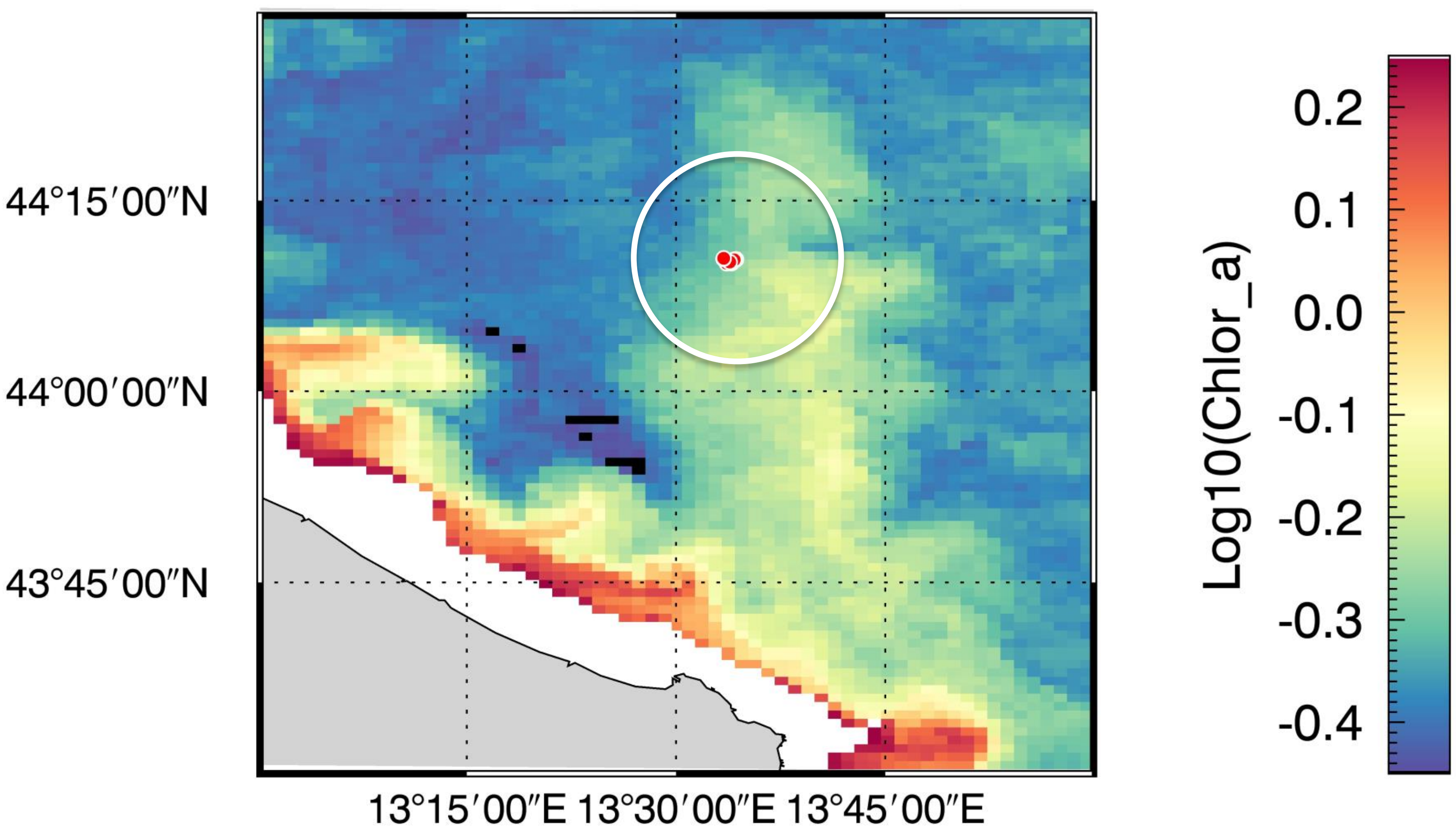
Our results, when using diurnally varying SST, for year 2013 are evidently more close to values compatible with the Mediterranean Heat budget closure.

Figure 2: We… rranean Sea during wi… cate the direction of water circulation in the Mediterranean Sea (Rohling et al., 2008a).

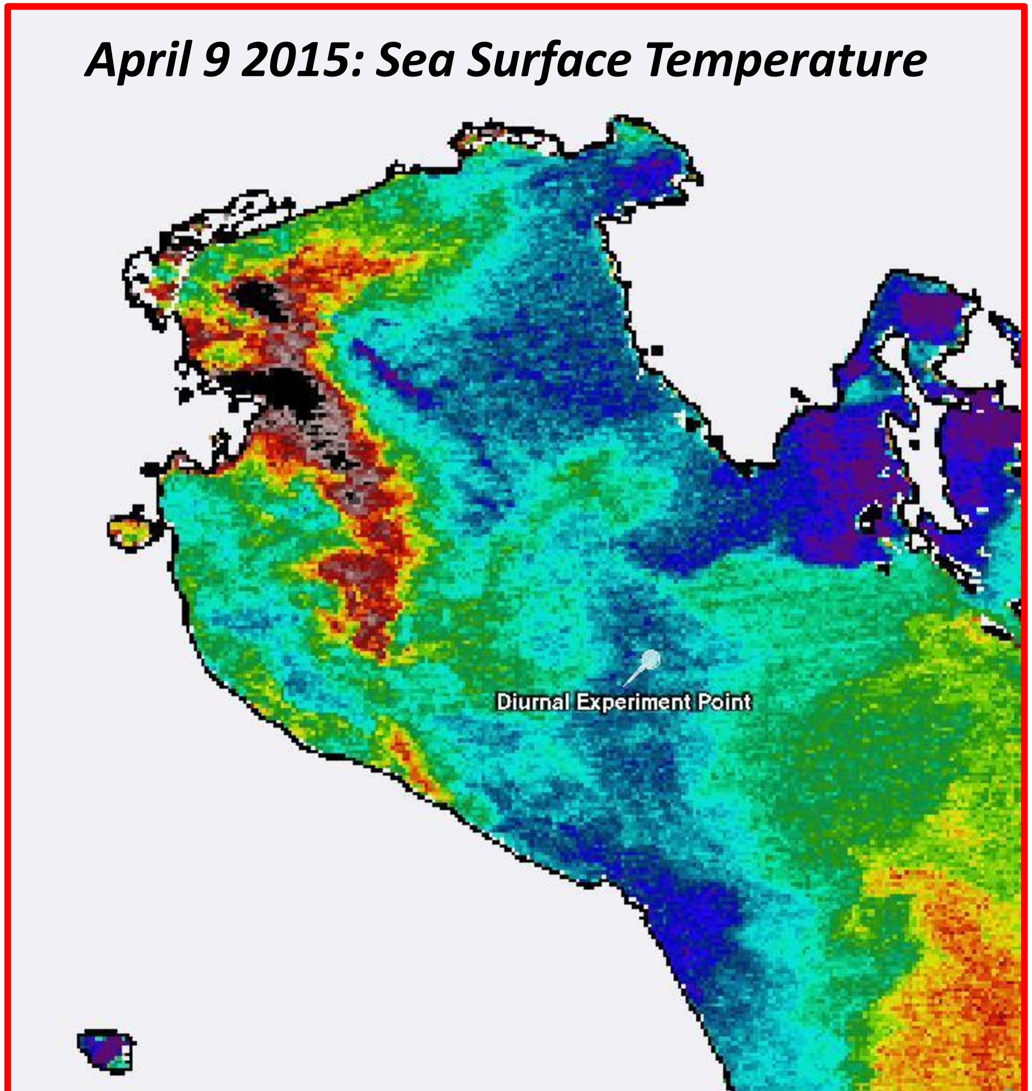
COSIMO 2015 Med Cruise: “The diurnal cycle experiment”



The diurnal experiment: satellite view

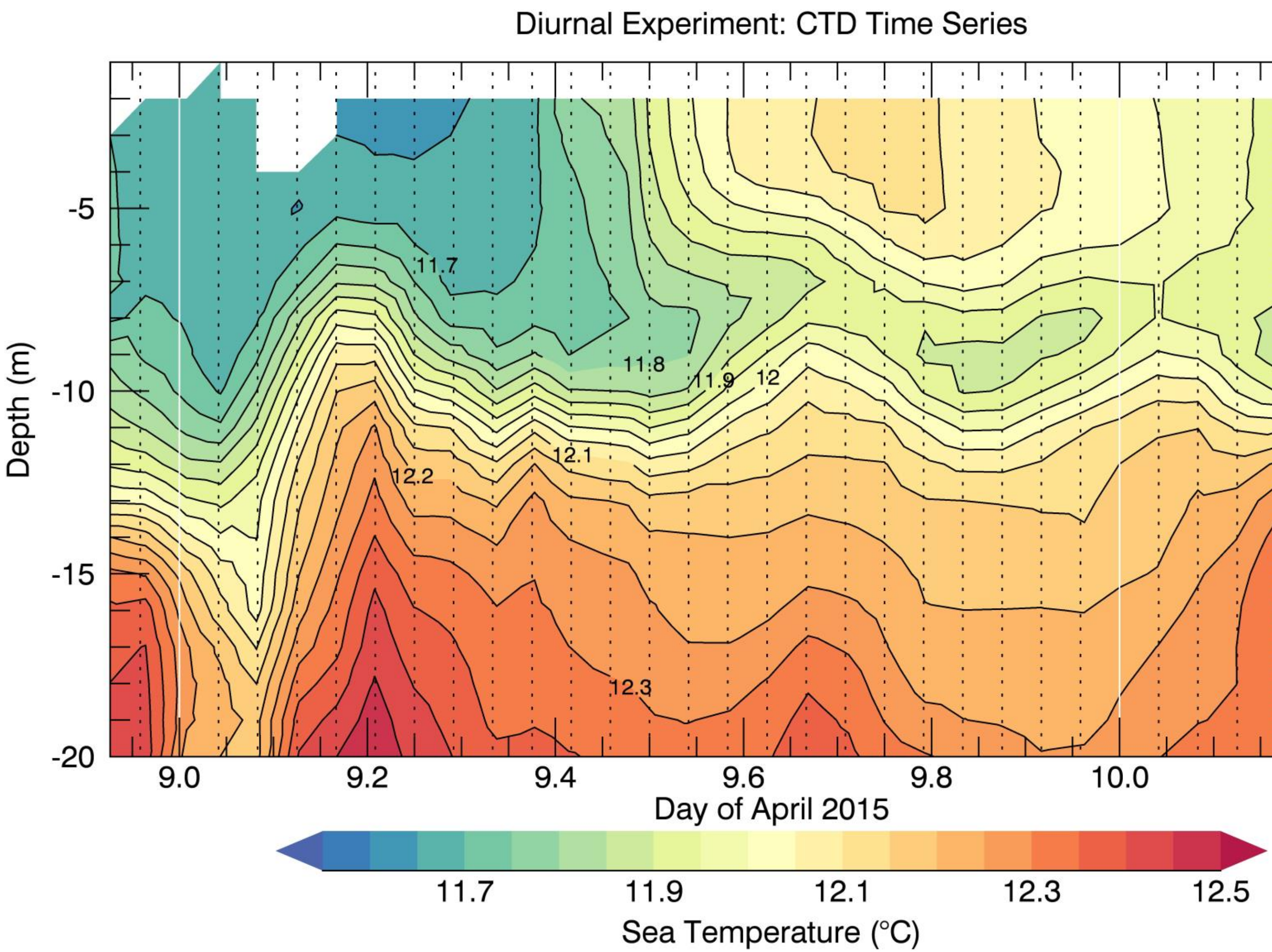


The diurnal experiment: satellite view

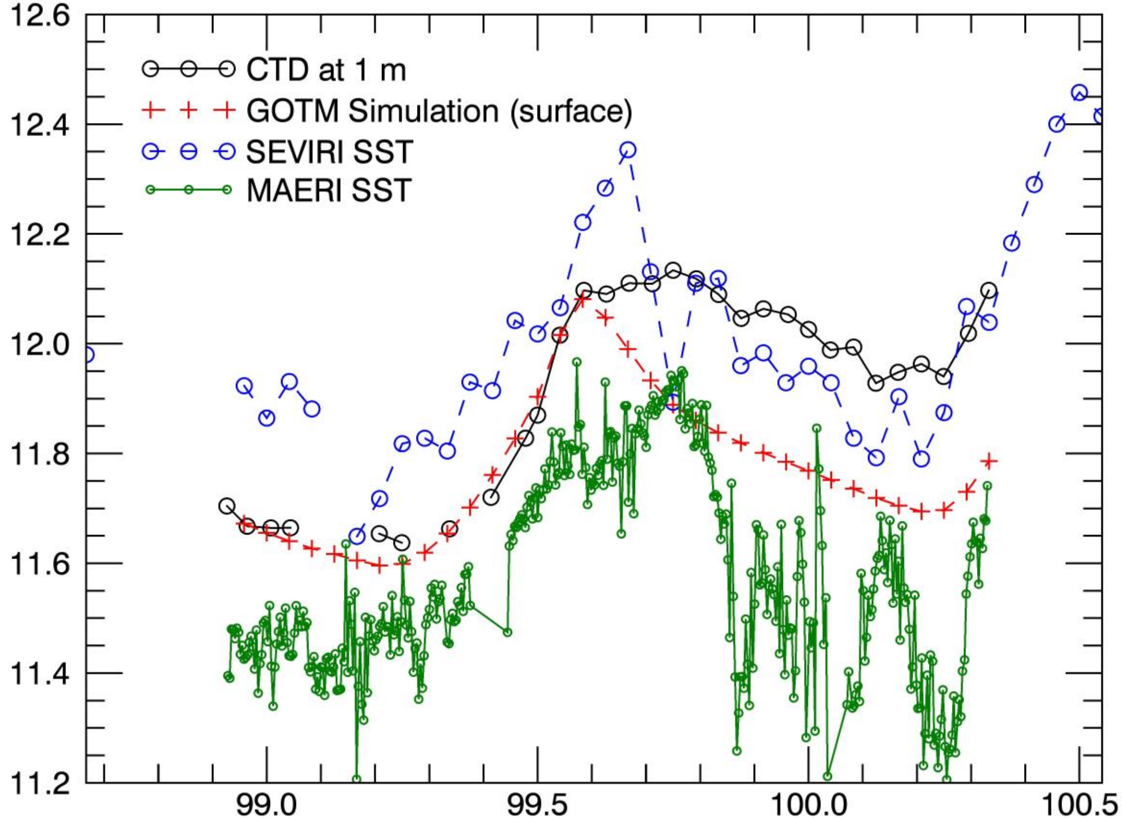


Modis AQUA SST on April 9th 2015

The diurnal experiment: In Situ



The diurnal experiment
(Preliminary data processing and analysis)



Conclusions

① *The Analysis of 2013 SEVERI data confirms that the Mediterranean Sea is one of the world ocean region in which DW events are more frequent (20-30% of days are affected by DW)*

② *The diurnally warming affects the fluxes of latent heat, sensible heat, and upwelling longwave radiation.*

③ *The diurnally varying SST has an important impact on the Mediterranean heat budget (FND=-2.1 W/m^2 while DVSST=-6.1 W/m^2).*

④ *Comparison of fluxes produced by hourly varying SST and foundation SST demonstrates that significant portions of the Mediterranean experience differences up to 8 W/m^2 on monthly basin average base and up to 30 (or more) W/m^2 on daily basis*

⑤ *The Diurnal Experiment confirmed that Skin SSTs can substantially differ from bulk measurements and contributed to better understand the physics of heat transfer in the upper ocean also for modeling applications.*

① *Use past and f* ... *imates to reduce*
bulk formulae ...

② *Two more crui* ...

③ *Investigate dif* ... *on M-SSA*

④ *Increase the n* ... *ements.*

⑤ *A new fully eq* ... *days in the*
Mediterranean ... *t of Sicily).*