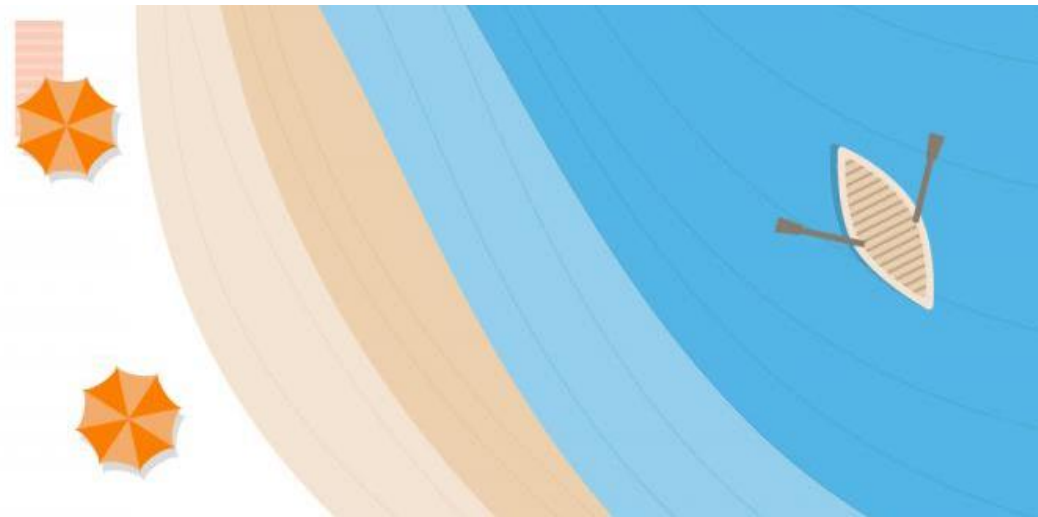


GESTIONE E PREVENZIONE
DEL **RISCHIO COSTIERO**
DI UN TERRITORIO
IN EVOLUZIONE

PISA 8 OTTOBRE 2019

Scuola Normale Superiore
Piazza dei Cavalieri
9:00 - 17:30



Analisi di eventi meteomarini estremi nel Mediterraneo Nord-Occidentale

Ricchi A. (1,4), **Bonaldo D.** (1), **Miglietta M. M.** (2), **Cioni G.** (3), **Ferretti R.** (4),
Brandini C. (5), **Carniel S.** (1)

(1) **CNR-ISMAR Venice**

(2) **CNR-ISAC**

(3) **Max Planck Institut fur Meteorologie**

(4) **Università dell'Aquila – CETEMPS**

(5) **CNR - Consorzio LAMMA**



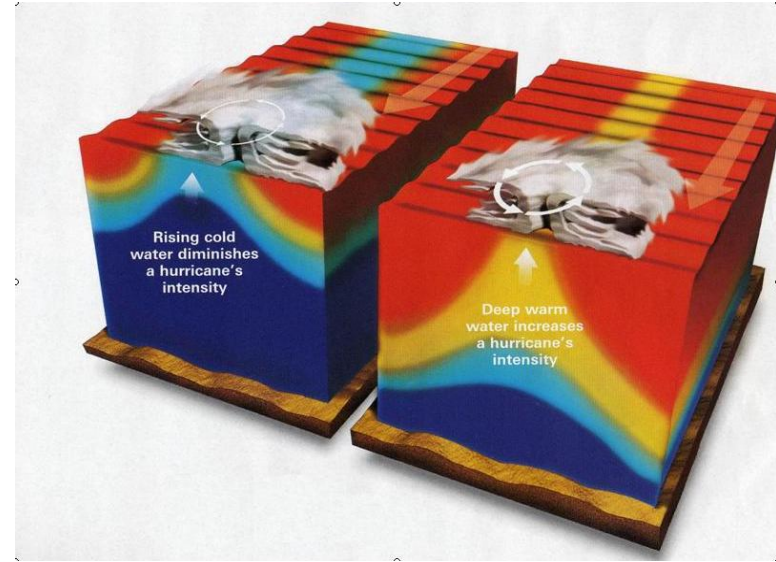
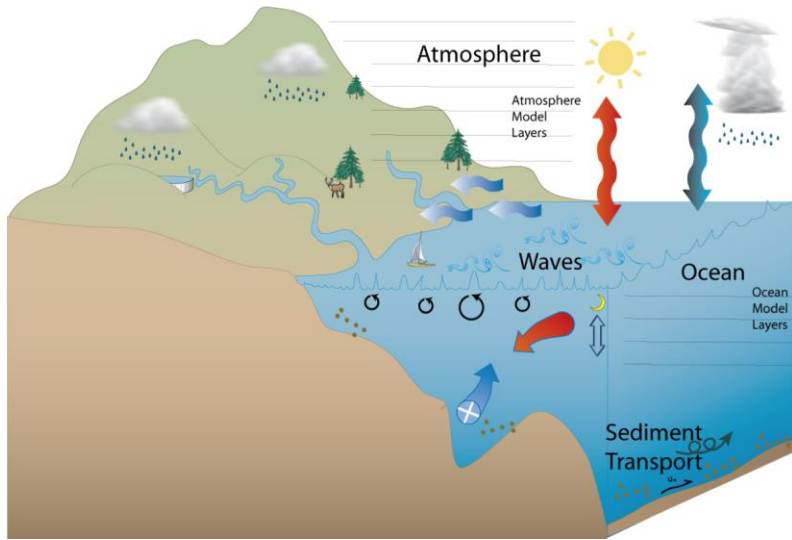
La cooperazione al cuore del Mediterraneo



MARITTIMO-IT FR-MARITIME

Fondo Europeo di Sviluppo Regionale

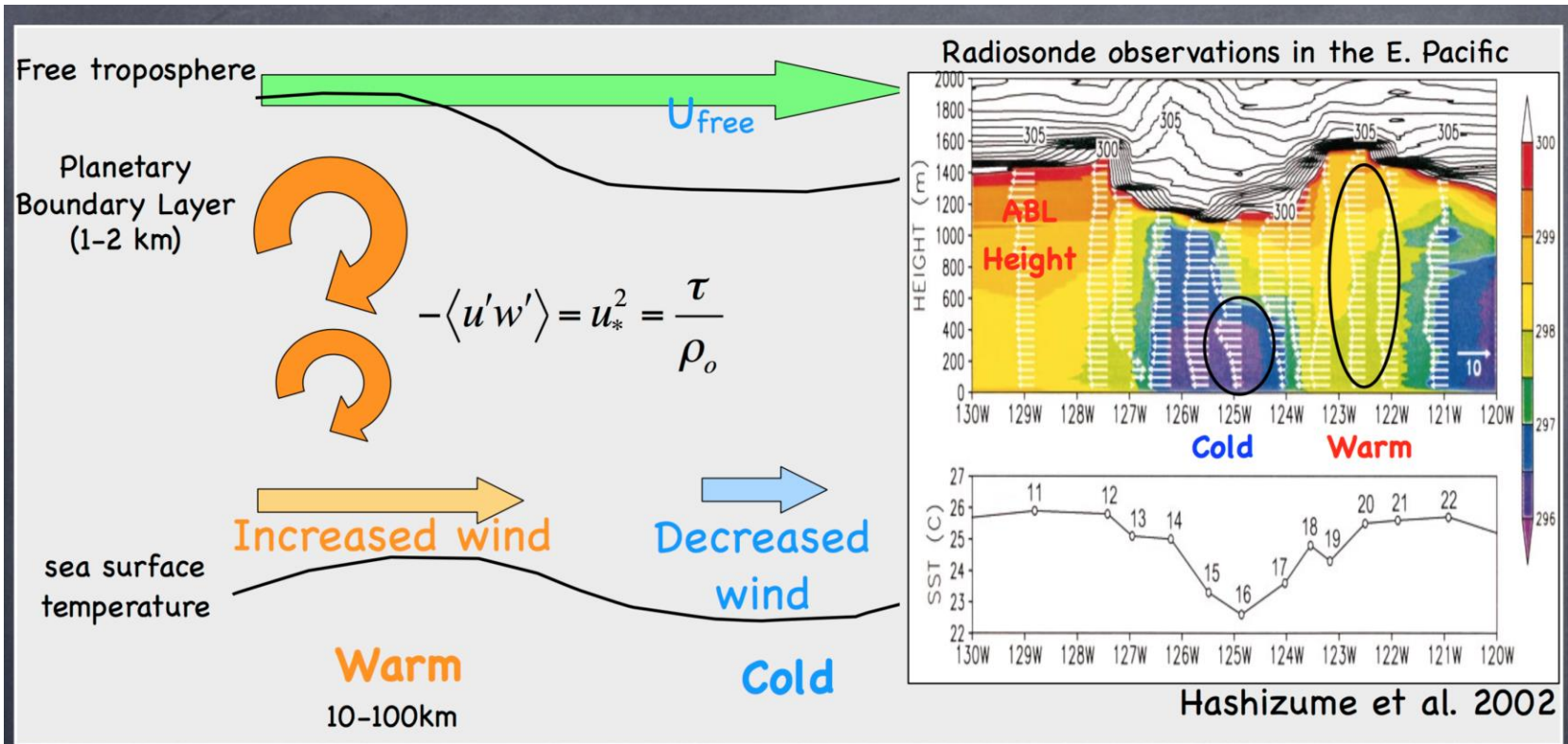
Atmosphere-ocean interactions



The aim of this work is to answer to the question:

- Are coupled numerical models the best solution for the environmental simulations?
- How much does the SST influence the dynamics of the PBL?
- Is it necessary to implement a coupled numerical model to simulate extreme events?
- How important is the role of SST in coastal extreme phenomena?

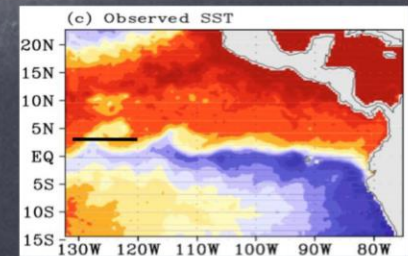
Atmosphere-ocean interaction (SST <-> WIND)



Unstable boundary layer and increased mixing Decoupled stable boundary layer

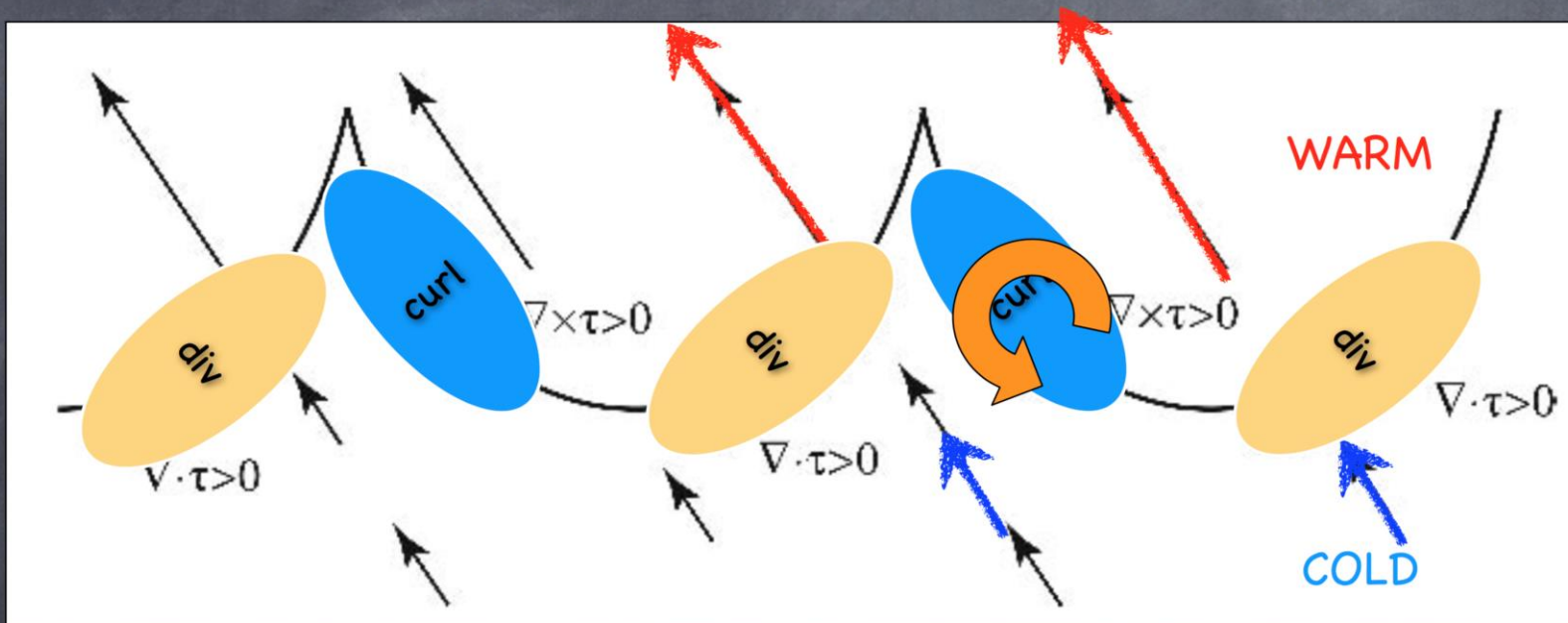
$T' \rightarrow$ PBL stability \rightarrow WS

Wallace et al. 1989



Chelton et al 2001,2005,2007; O'Neill 2005,2010; Neroli et al 2018;

How do this coupling affect the ocean and atmosphere?



Chelton et al. 2004

• Wind curl → Ekman pumping → Ocean circulation

$$W'_{ek} = \nabla \times \frac{\bar{\tau}'}{\rho(f + \zeta)}$$

• Wind convergence and divergence → Atmospheric vertical motion and planetary-scale circulation

$$\nabla \cdot \bar{u} \approx -\nabla^2 SST$$

$$w \approx \frac{1}{\rho_o} \left(\frac{\epsilon z}{\epsilon^2 + f^2} \right) \nabla^2 SST$$

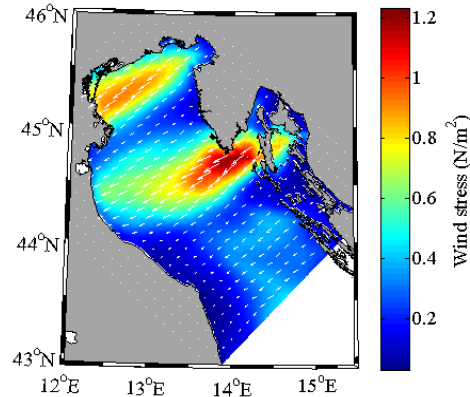
Chelton et al 2001,2005,2007; O'Neill 2005,2010; Neroli et al 2018

COAWST Modeling System

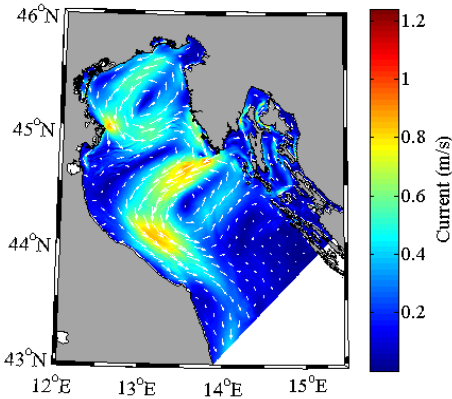
ATMOSPHERE (WRF)

UV_{wind}, P_{atm}, RH, T_{air},
cloud, rain, evap,
SWrad, LWrad, LH, HFX,
UV_{stress}

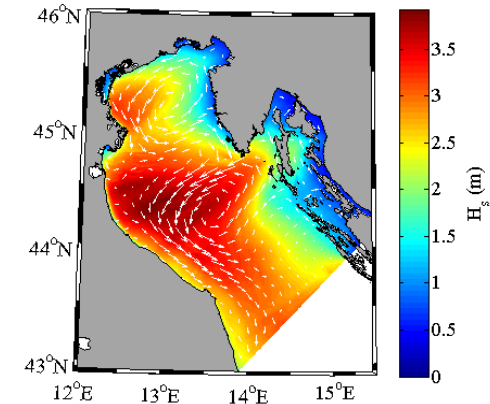
UV_s, h, Zeta, Z₀



H_{wave}, L_{wave}, D_{wave},
TP_{surf}, TP_{bot}, Q_b, Diss,
UV_{wind}



Chemical-scheme
(Marine Spray)



OCEAN (ROMS)

H_{wave}, L_{wave}, D_{wave}

UV_s, Zeta

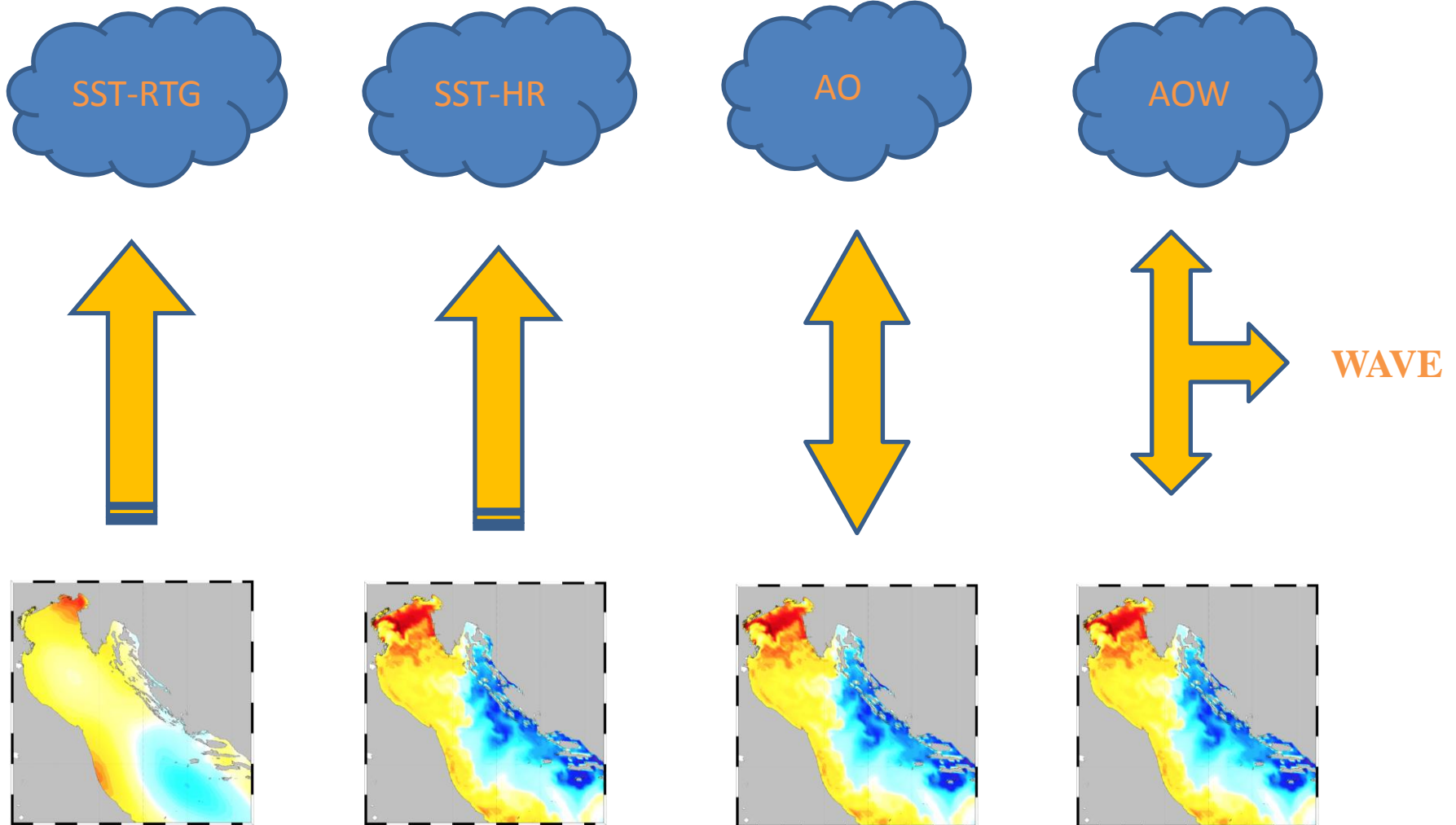
WAVES (SWAN)

Sediment Model

Vegetation Model

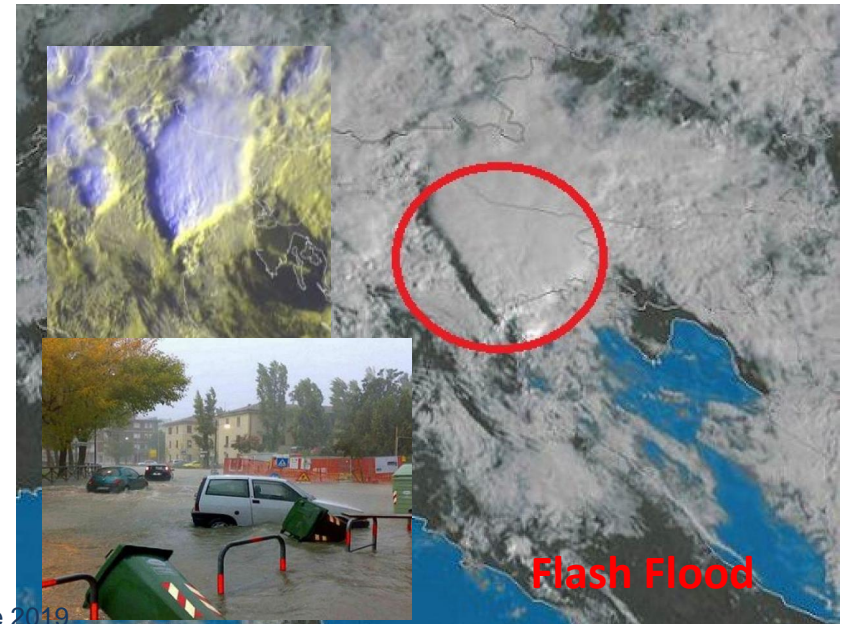
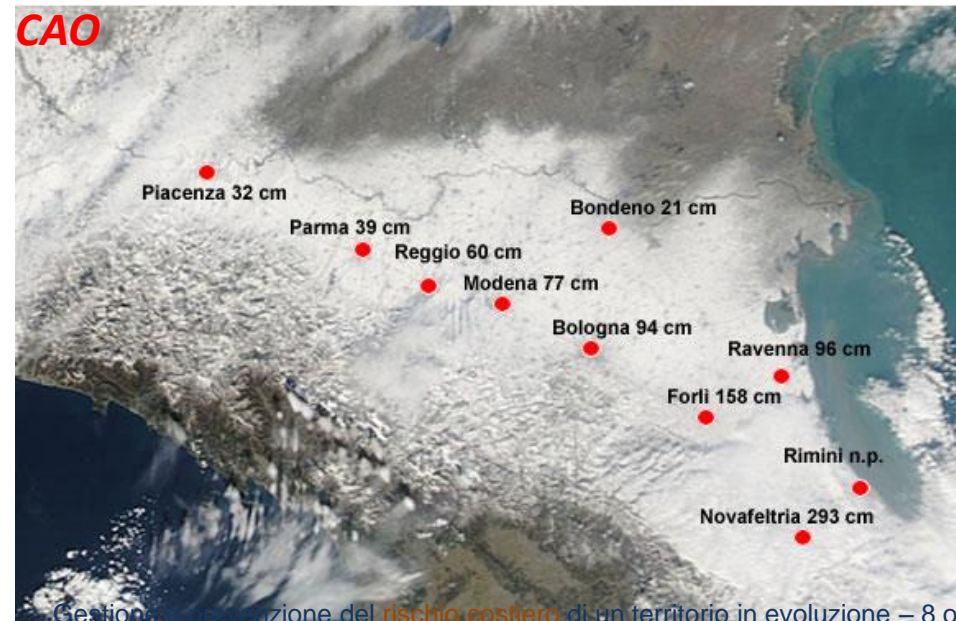
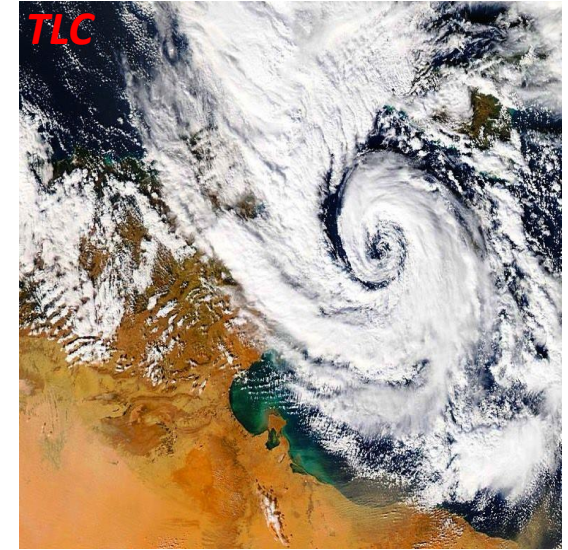
Bio-geo-Chemical Model

Numerical Approach

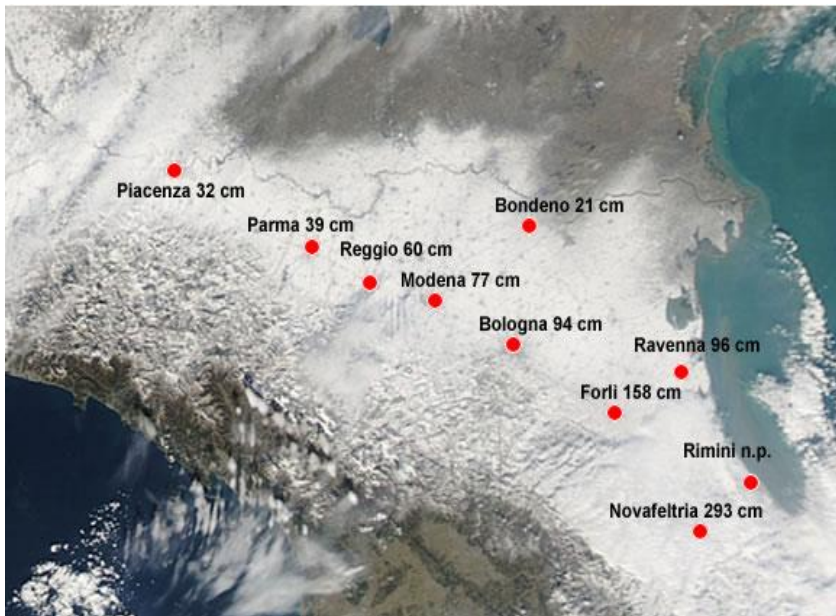
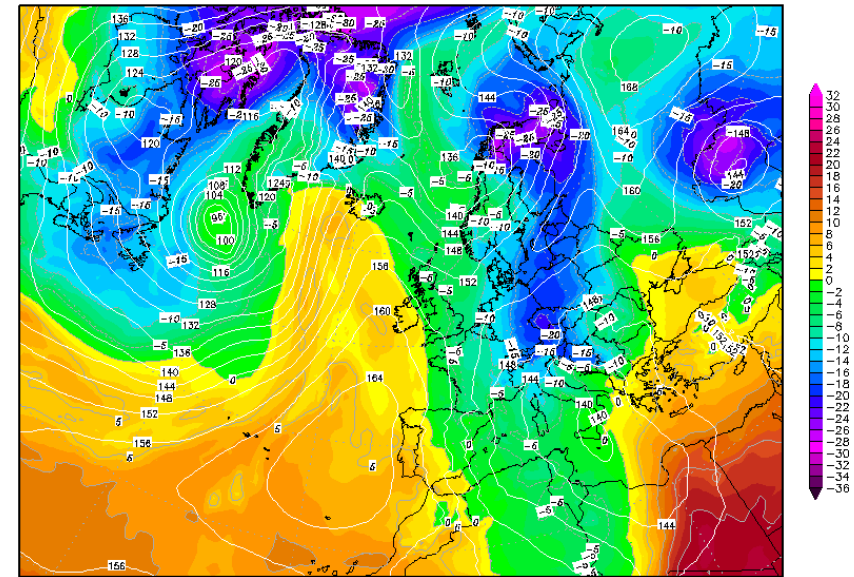
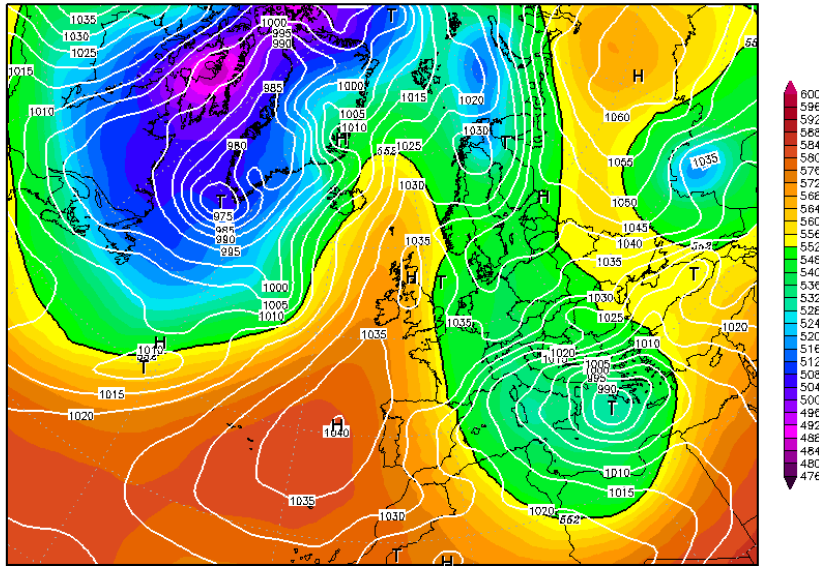


Application

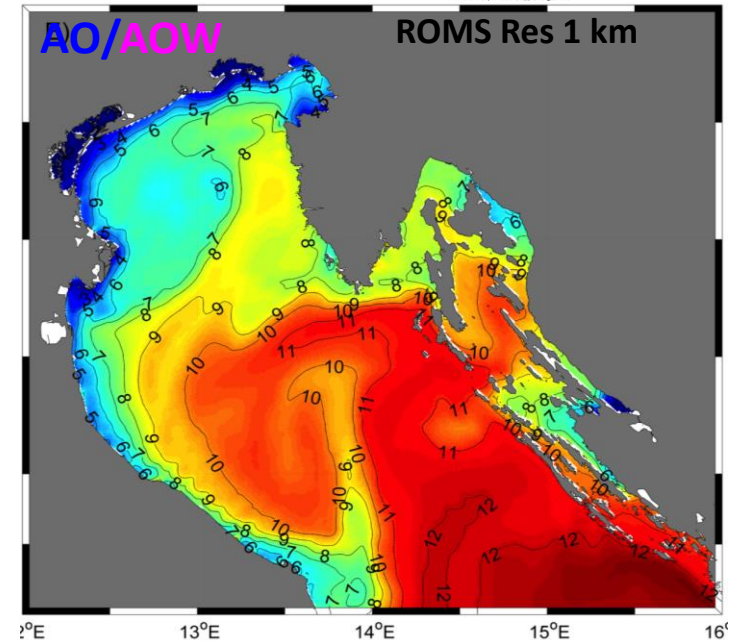
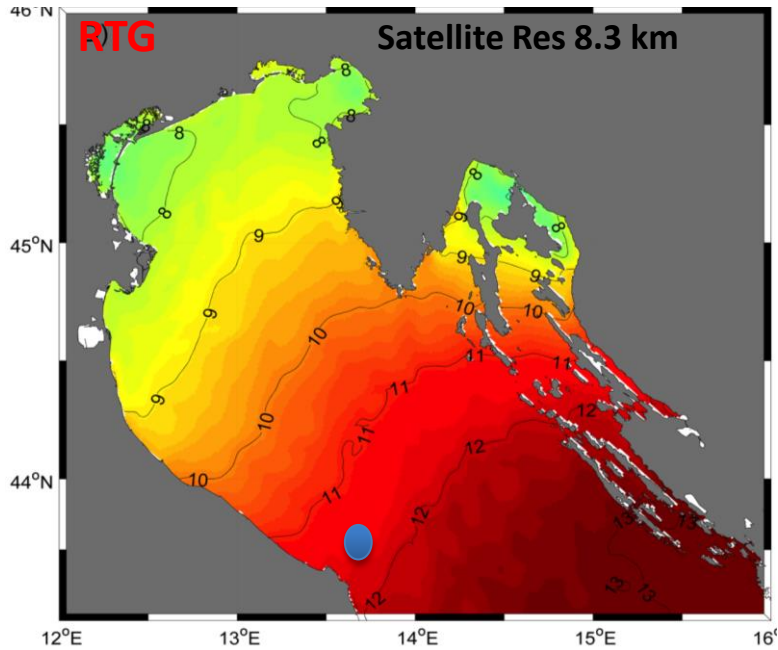
- CAO (Cold Air Outbreak)
- Dense water formation
- TLC (Tropical like Cyclones)
- Flash Flood
- “Rapid” (or “Bomb”) Ciclogenesis



Cold Air Outbreak (CAO)

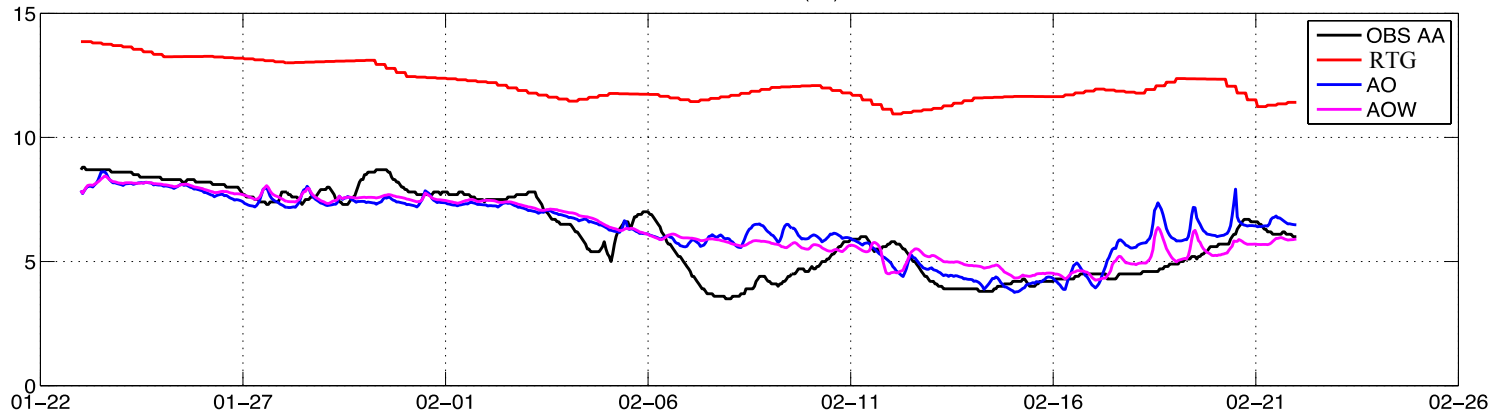


CAO Event. SST in North Adriatic Sea

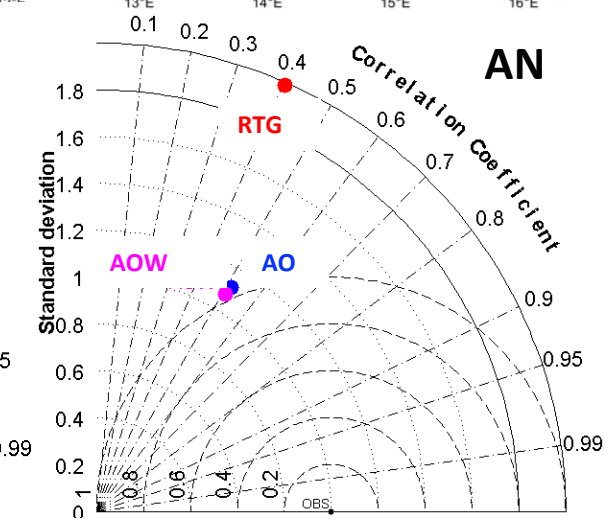
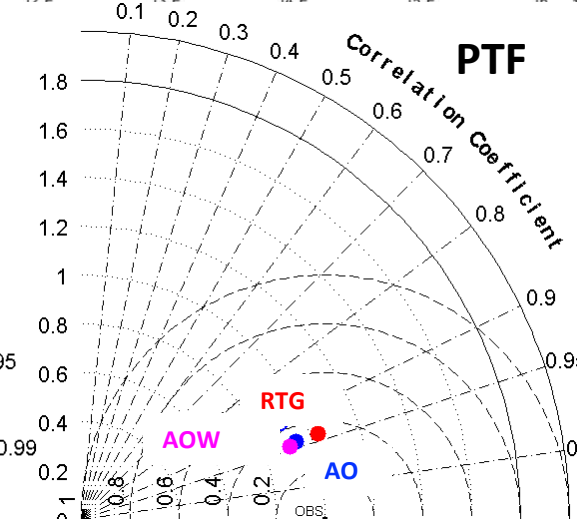
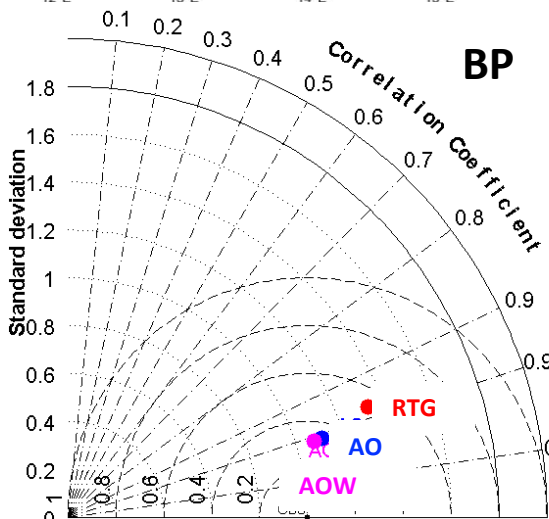
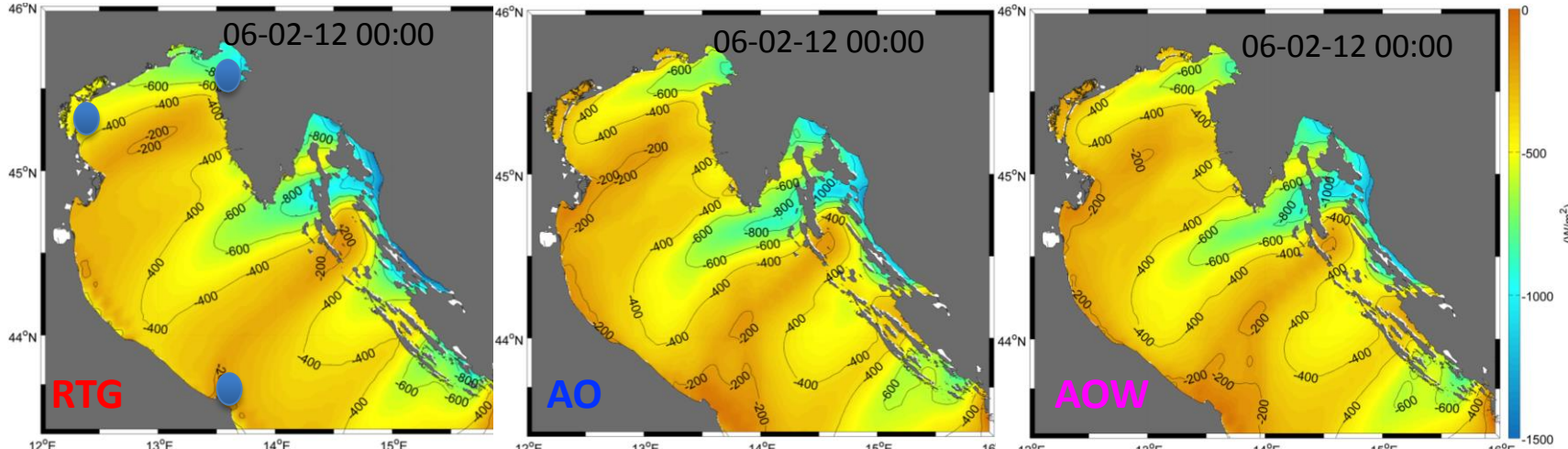


The images show the surface temperature in the northern Adriatic Sea in the 2012 CAO event. You can see large differences between the data taken from the satellite and the data produced by our model at 1 km resolution. In most parts of the NA model results match the ground truth observation (Ancona Harbour) much better than the satellite data.

ANCONA SST (°C)



(CAO) Results: Heat fluxes (W/m²)

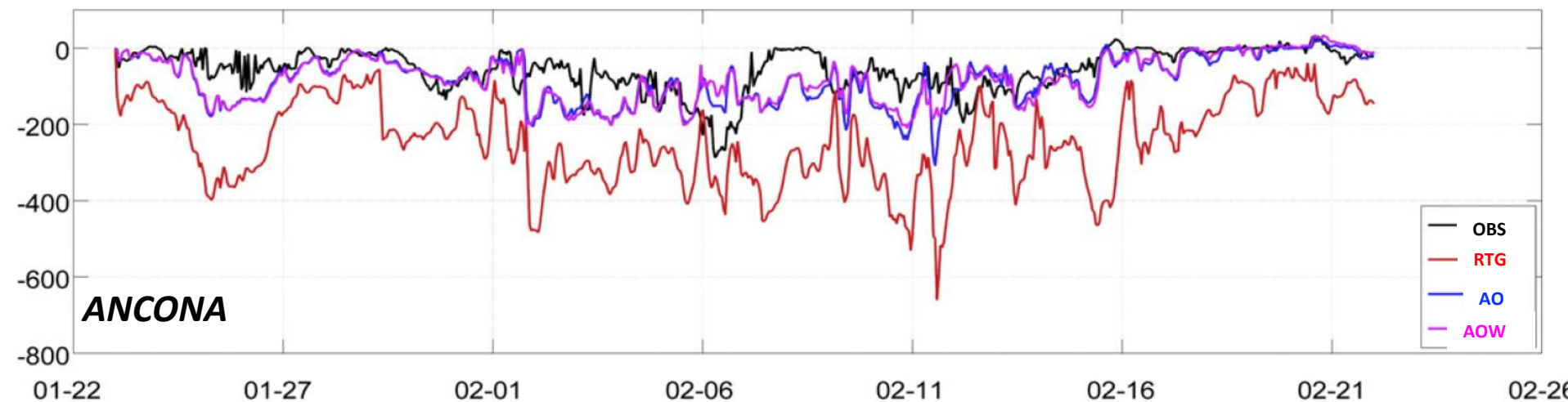
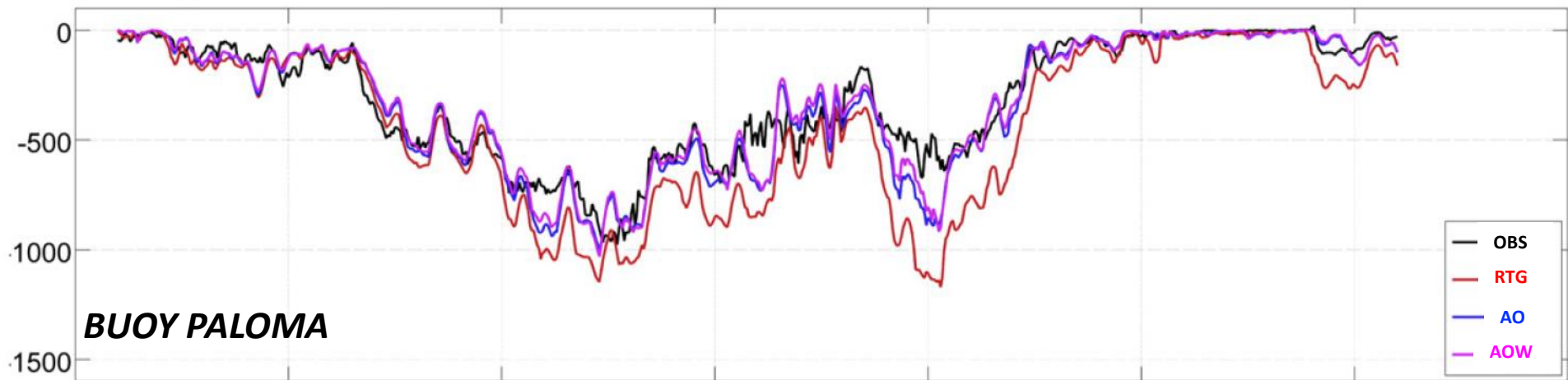


... and global instantaneous patterns

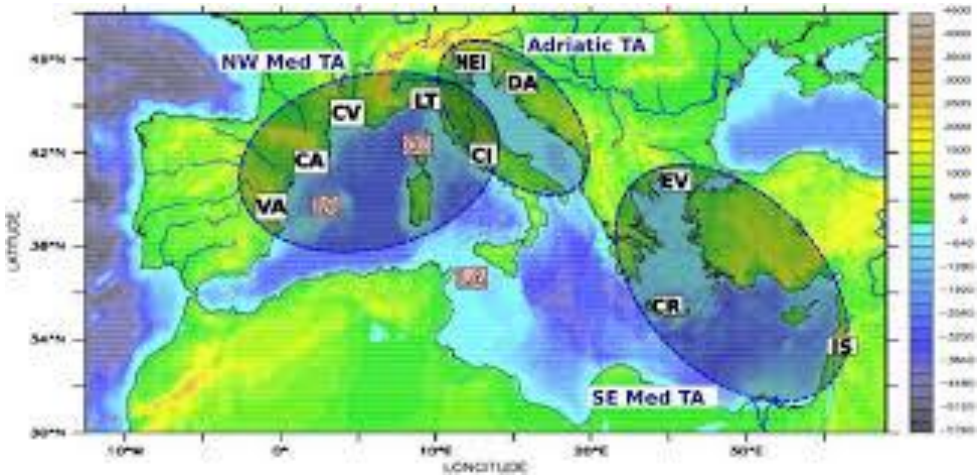
Local evolution statistics

- BP : Paloma Buoy
- PTF : Acqua Alta piattaforma
- AN : Ancona Harbour

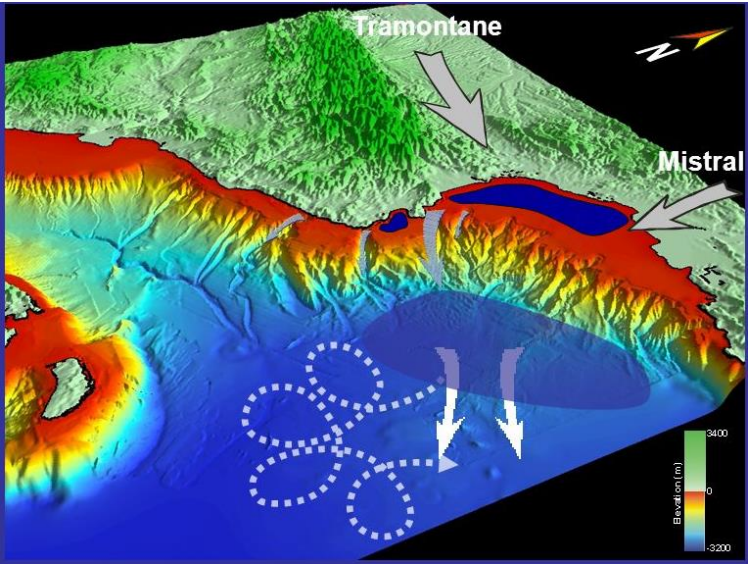
Results : Heat fluxes timeseries



Dense Water formation



GULF OF LIGURE

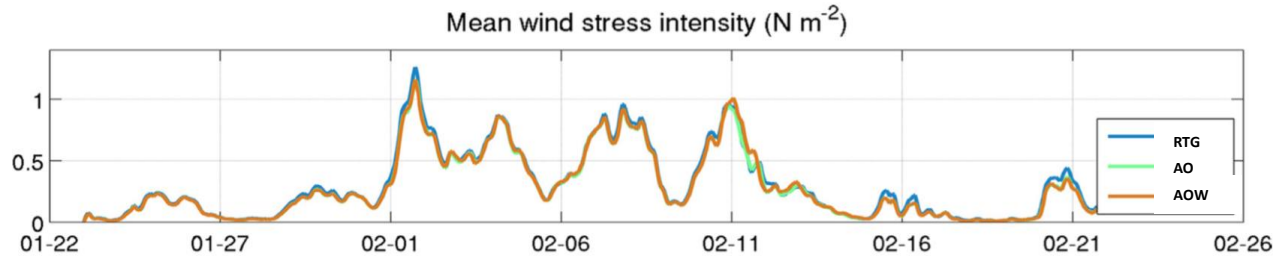


ADRIATIC SEA

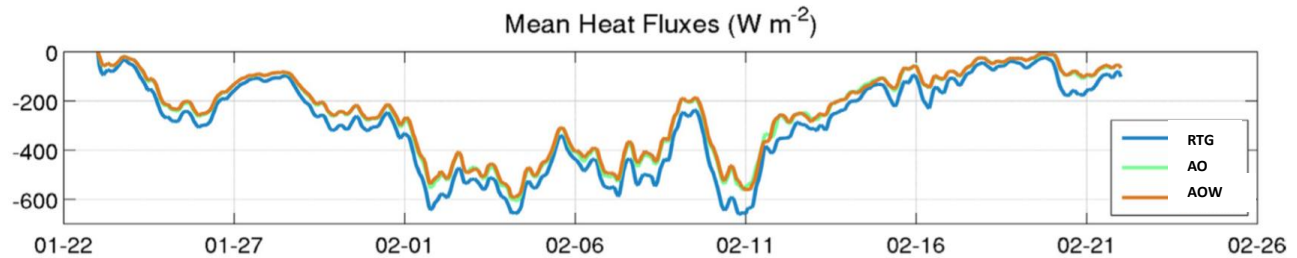


Dense Water Formation

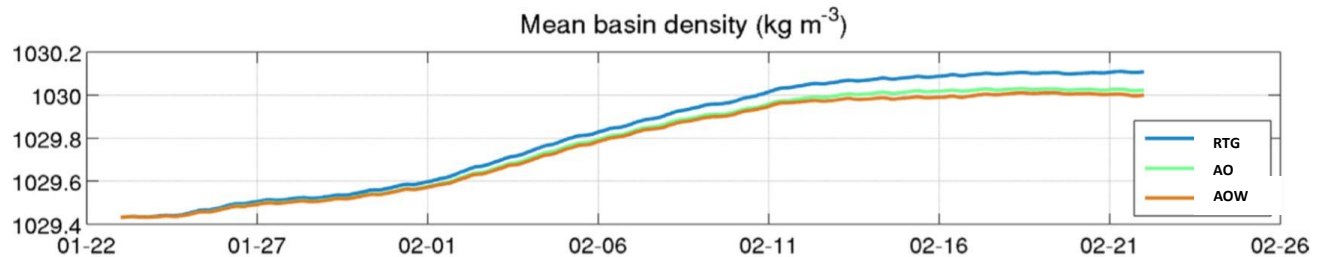
Wind Stress:
Strong wind in
Uncoupled runs
Caused by
higher SST



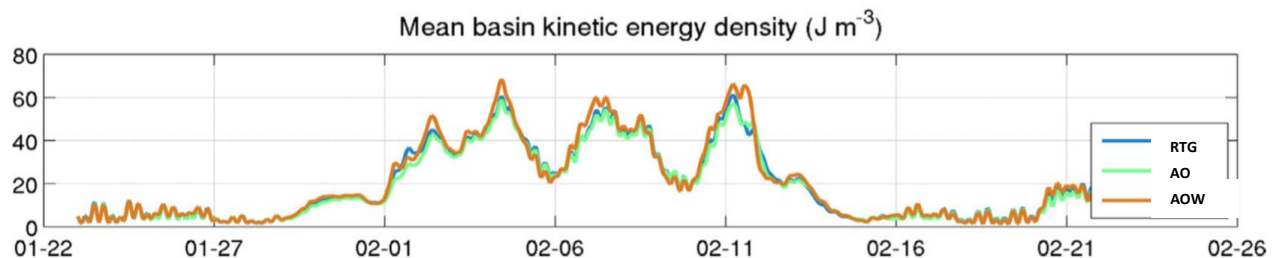
Mean Heat Fluxes:
Higher HF, in UNCPL
Runs caused by large
Delta between SST and
2 meters temperature



Mean density basin:
Higher dense water
Formation in UNCL run
caused by Higher HF

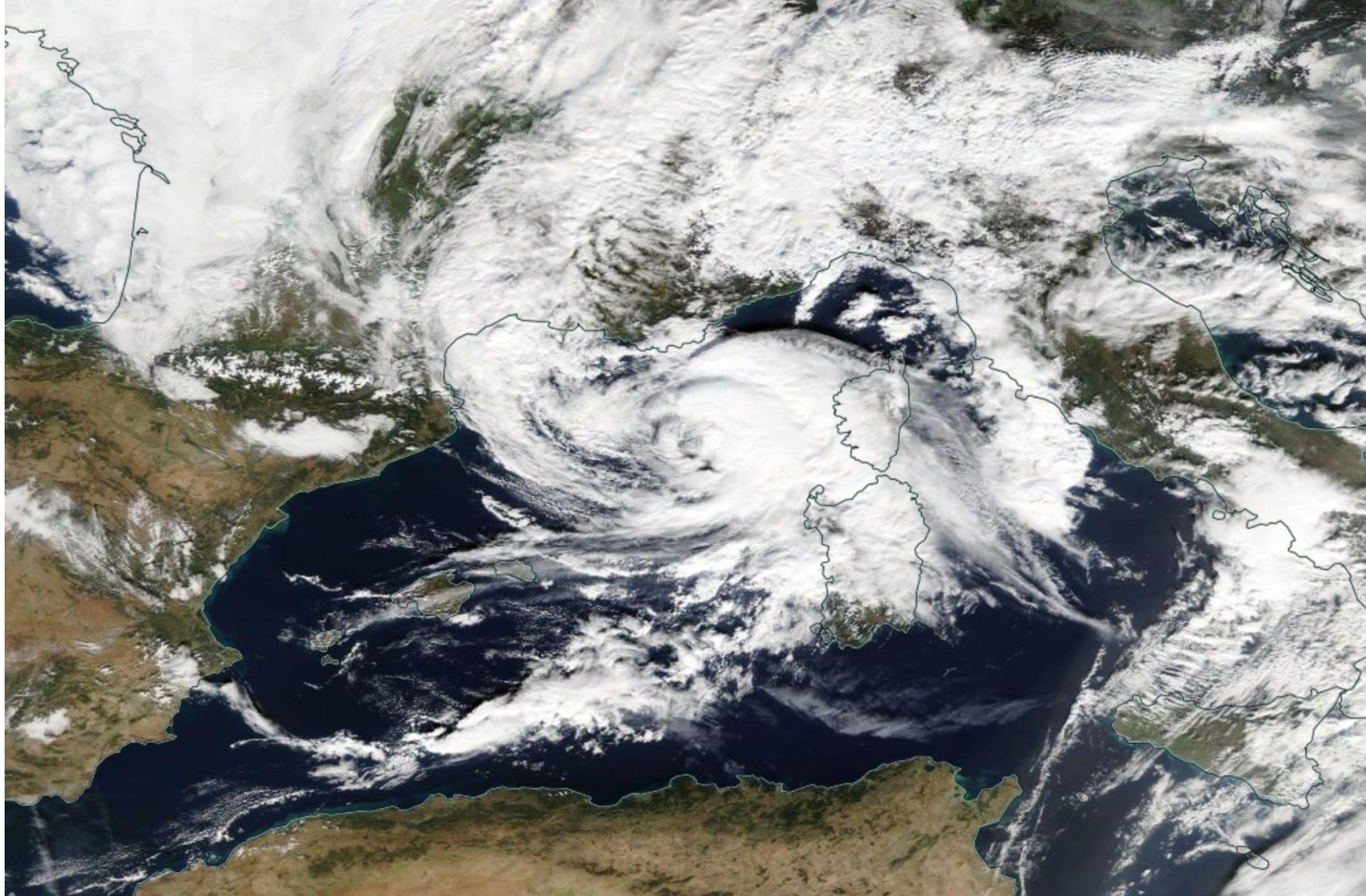


Mean TKE basin:
Higher TKE in AOW
Runs caused by wave
mixing



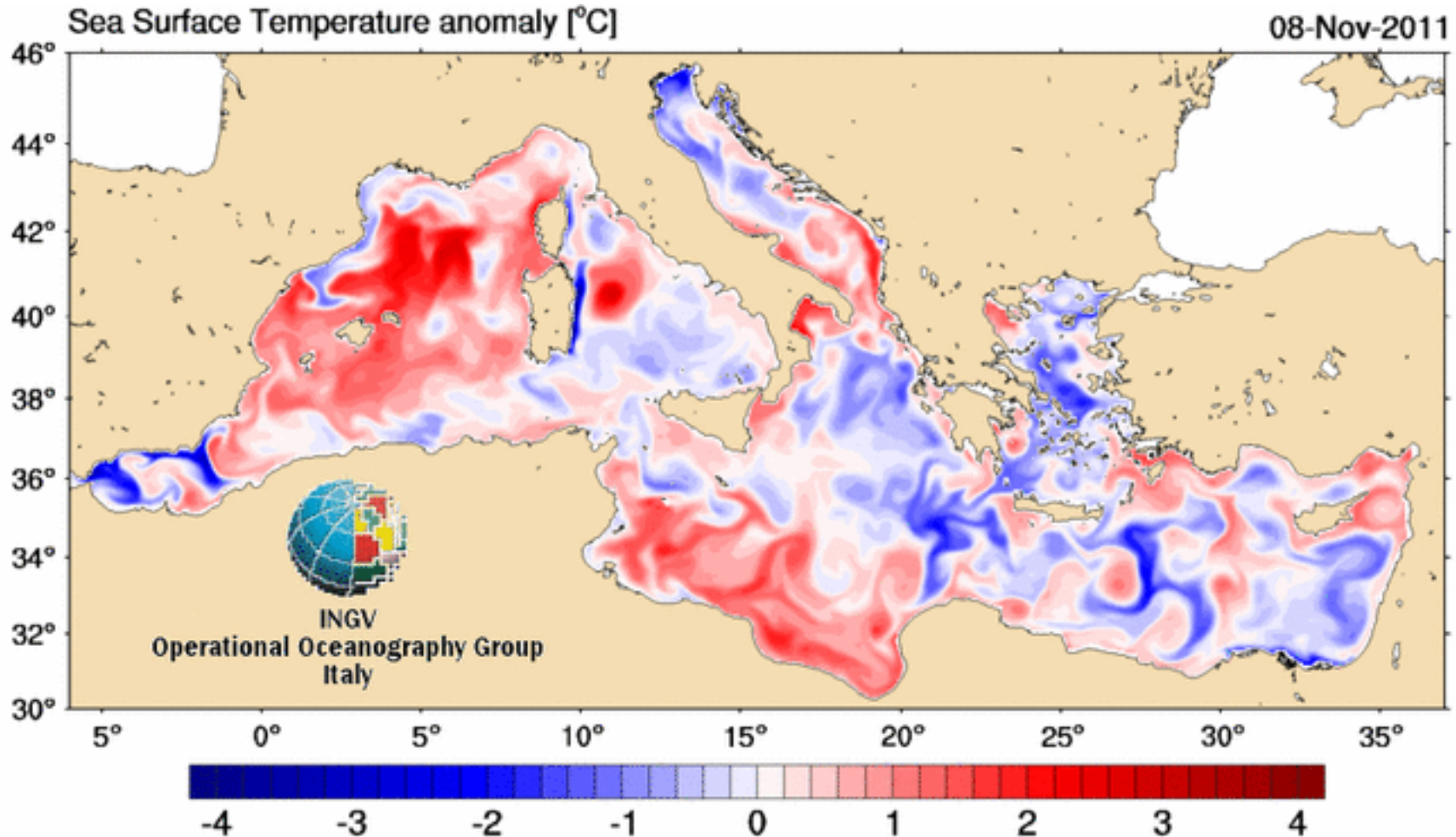
TLC "ROLF" : 6-9 Novembre 2011

08/11/2011 12 UTC



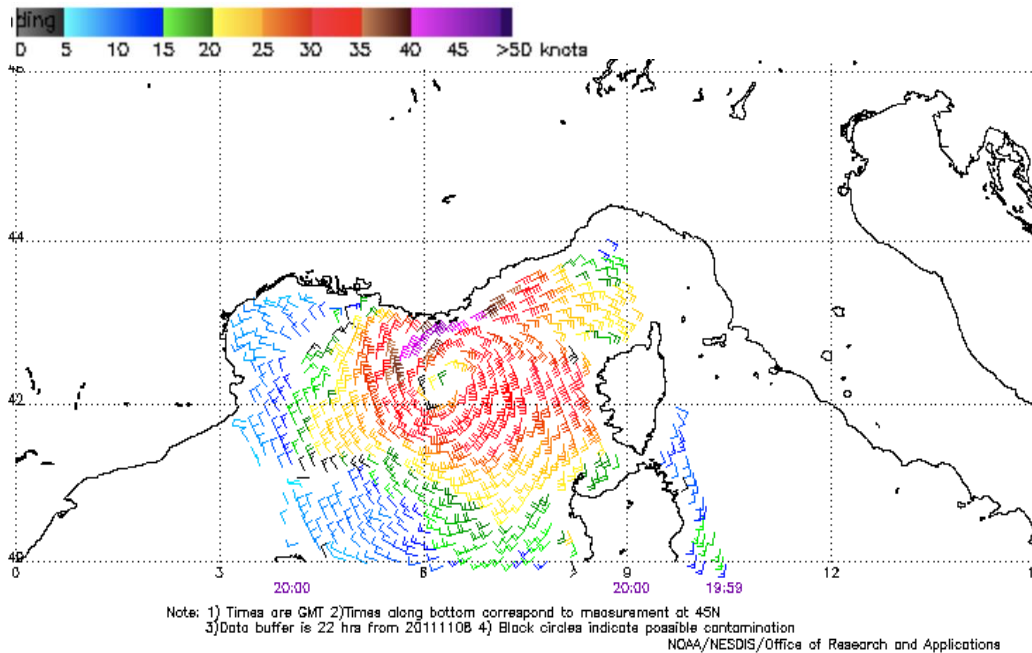
TLC "ROLF" : 6-9 Novembre 2011

Sea Surface Temperature Anomaly: 8th Nov 2011 over the Mediterranean Sea before MEDICane ROLF generation

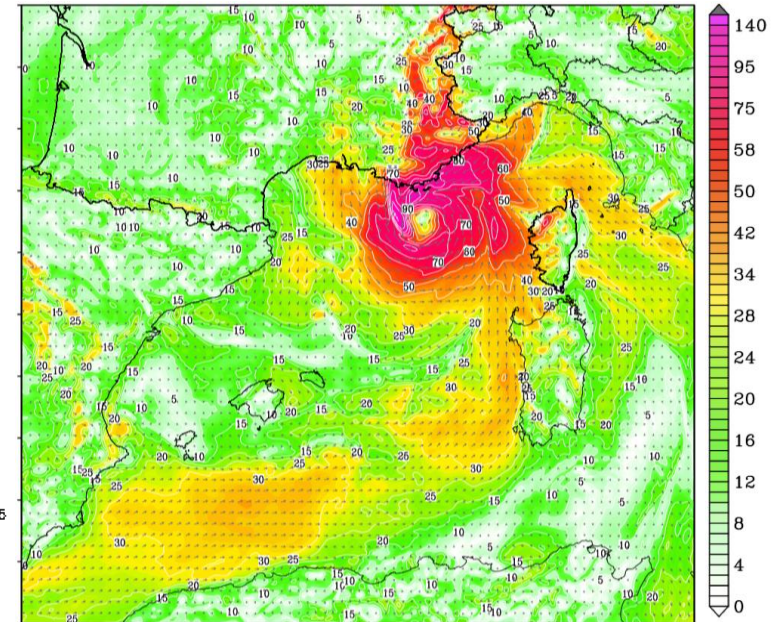


TLC "ROLF" : 6-9 Novembre 2011

Wind speed and direction obtained from scatterometer satellite data (OSCAT-ASCAT) at 20:00 08/11/2011. In the right side it's proposed the **coupled atm-ocn-wav** model result at the same time.



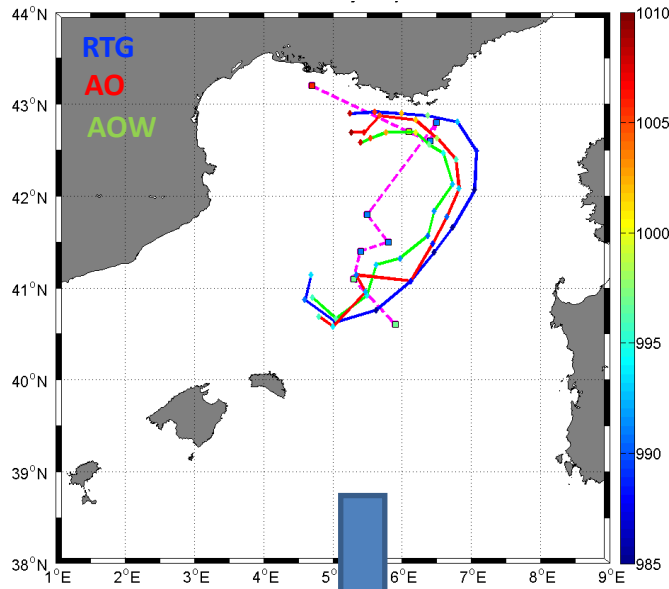
OSCAT-ASCAT scatterometer



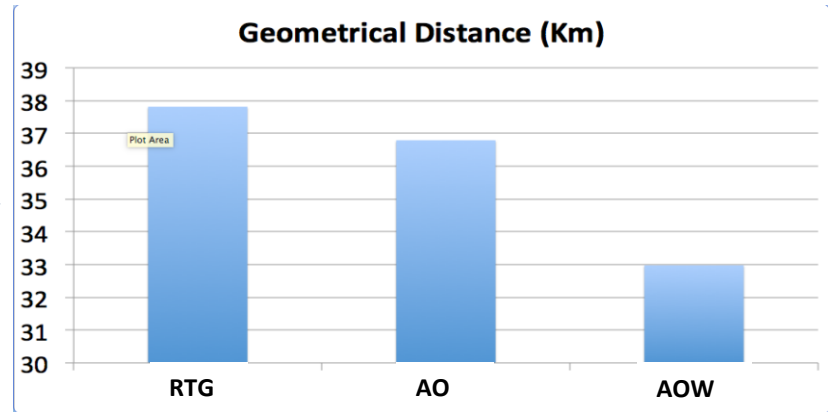
COAWST model coupled atm-ocn-wav

TLC "ROLF" : 6-9 Novembre 2011

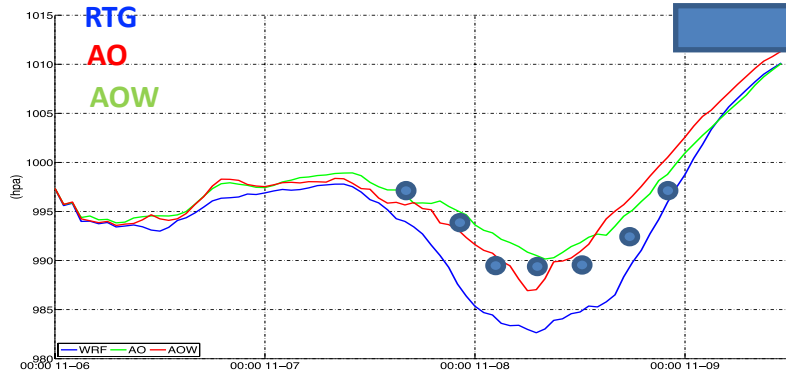
Trajectory of TLC simulated and real (purple)



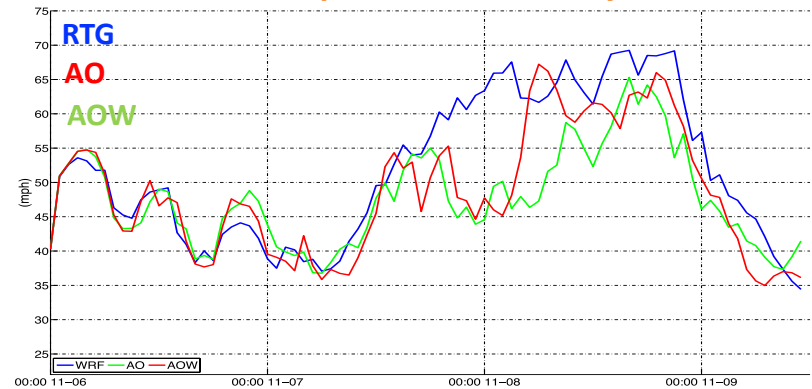
Mean geometrical distance between NOAA traj. and other runs



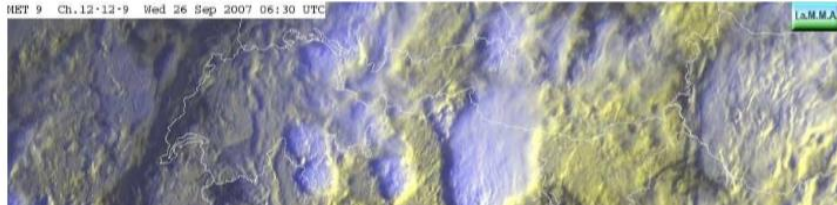
Pressure minimum



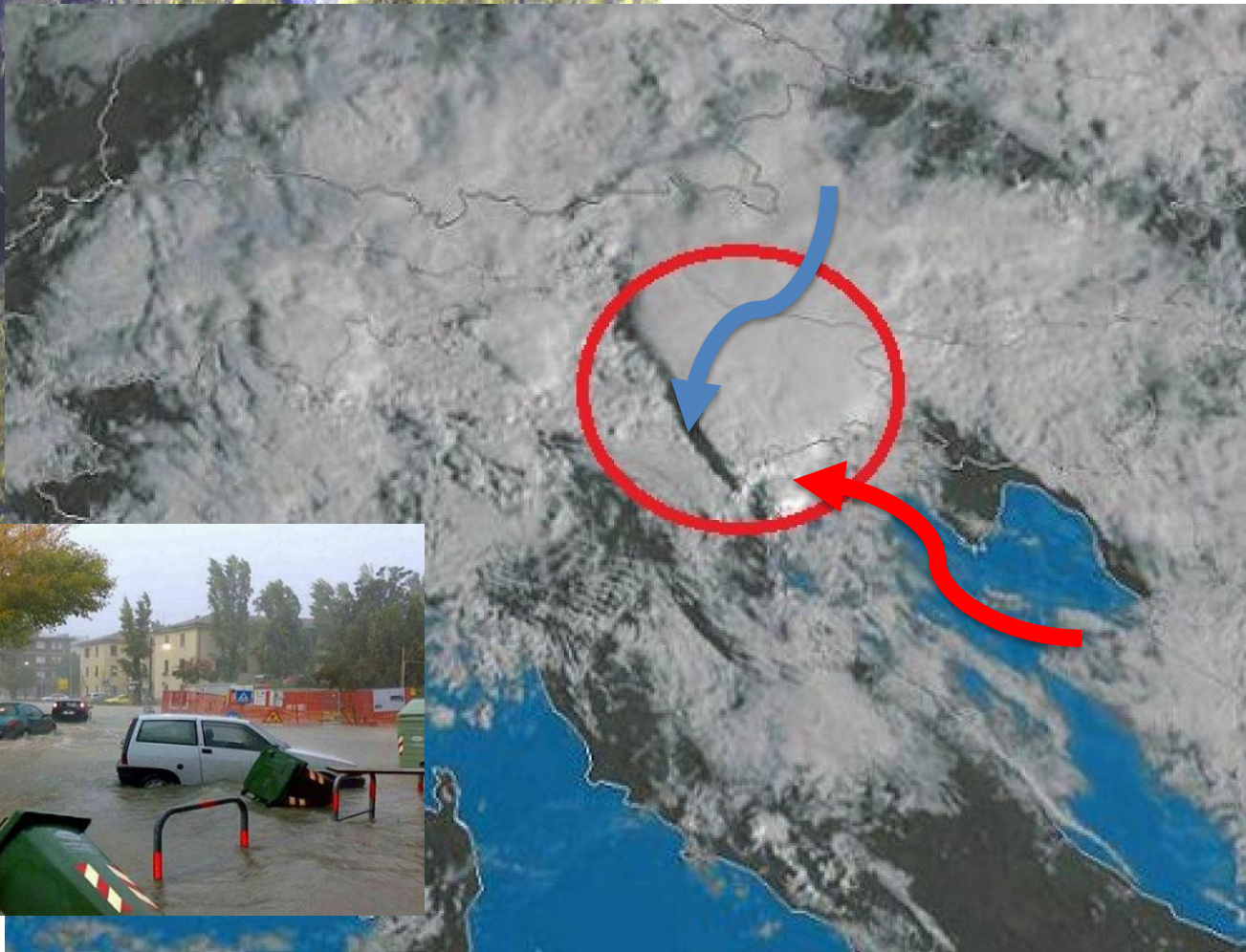
Wind speed around the eye



Venice Flash-Flood



26/09/2007 06:00 UTC
320 mm accumulated
in 3 hours

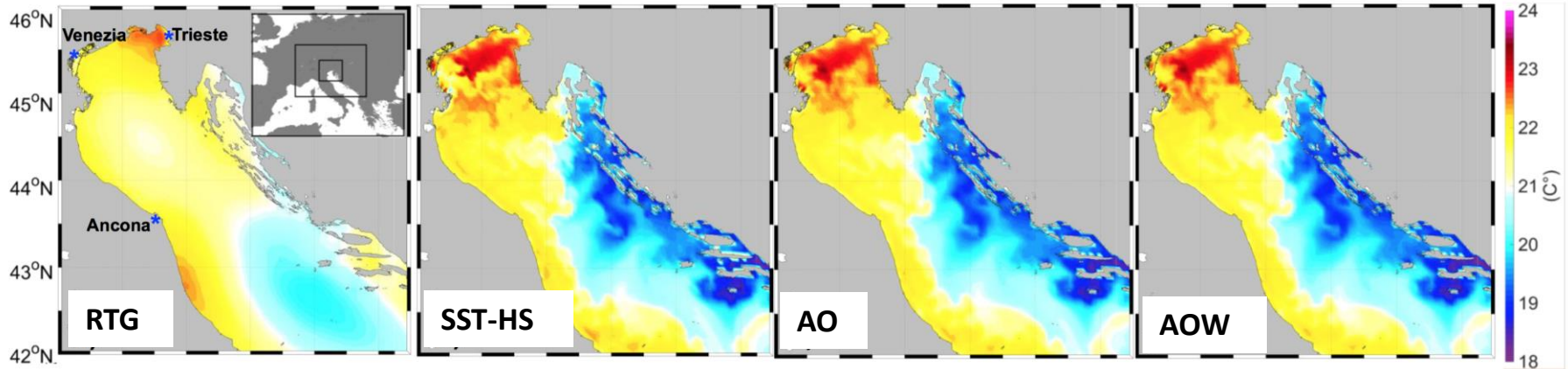


(b)

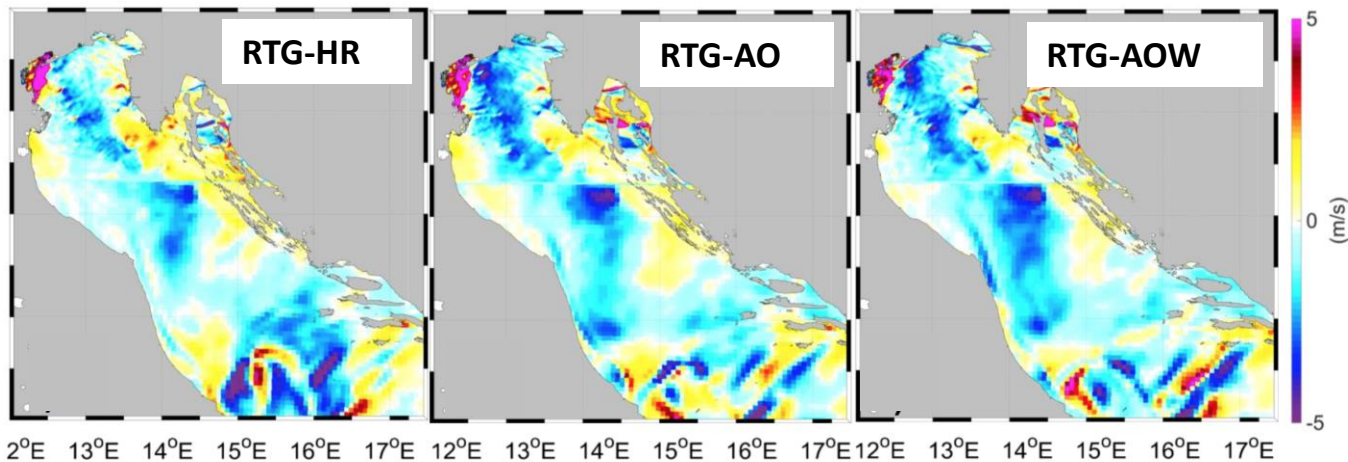


Venice Flash-Flood

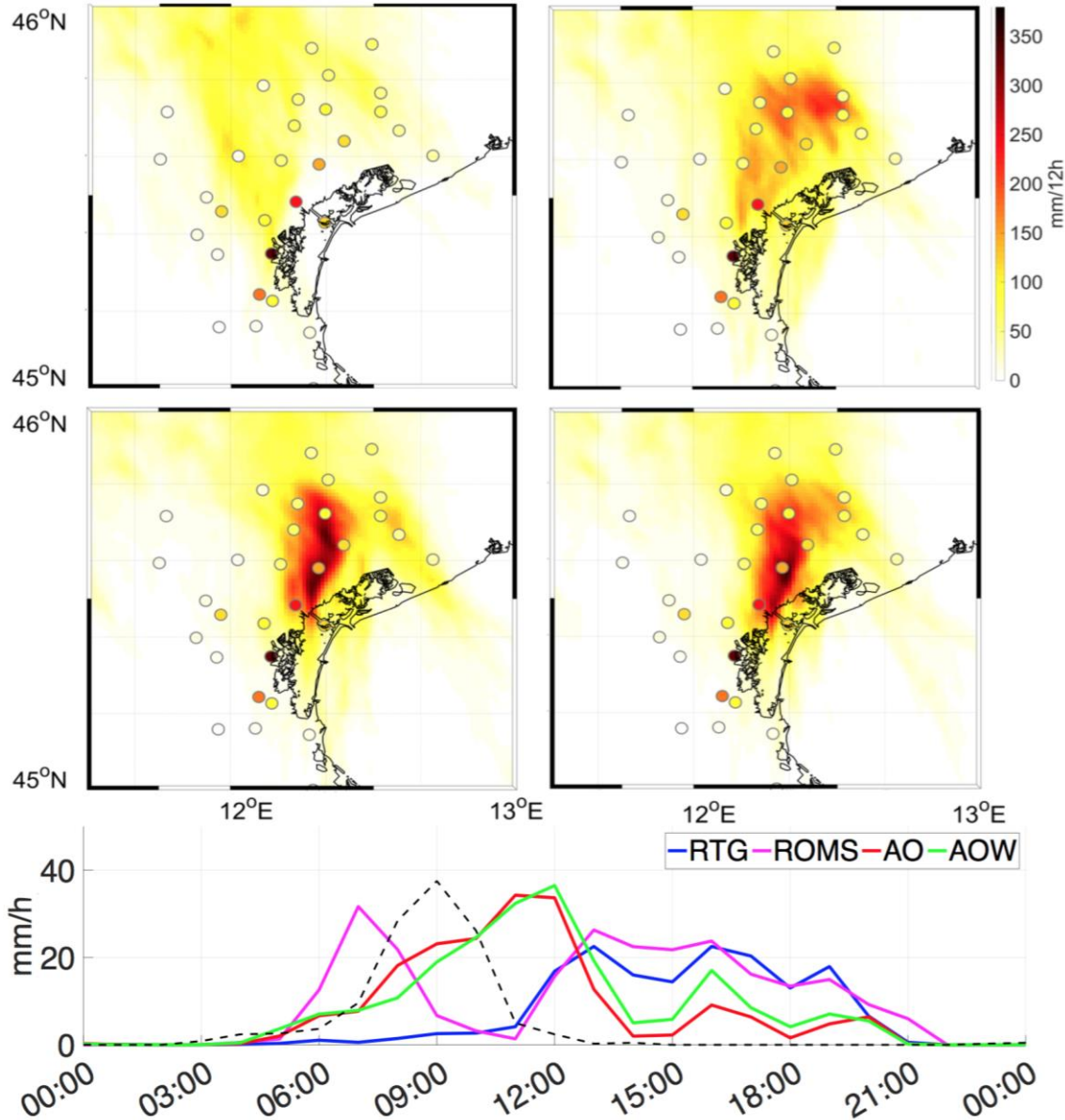
- *Sea Surface Temperature*



- *WINDS SPEED (10m) Difference between RTG run and HR, AO, AOW*



Venice Flash-Flood

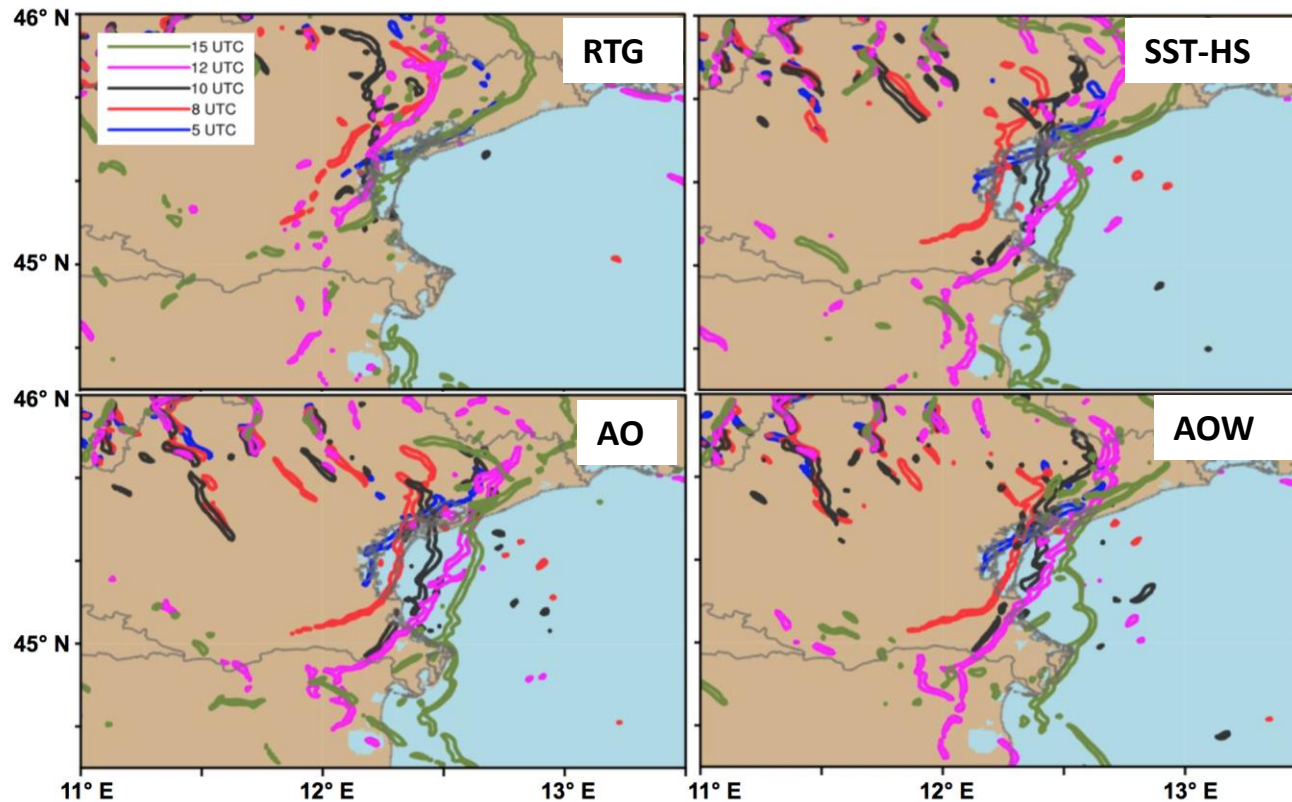


- Shaded :Total accum. rainfall
- Scatter: Observed rainfall

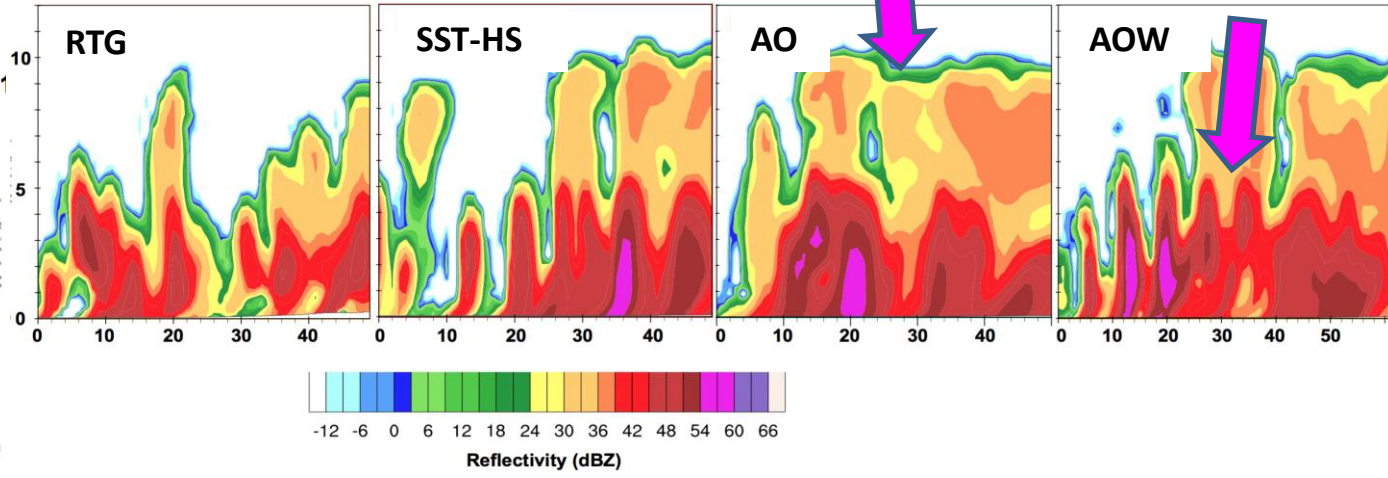
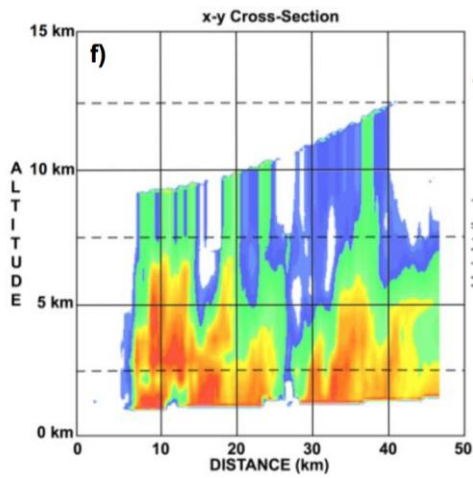
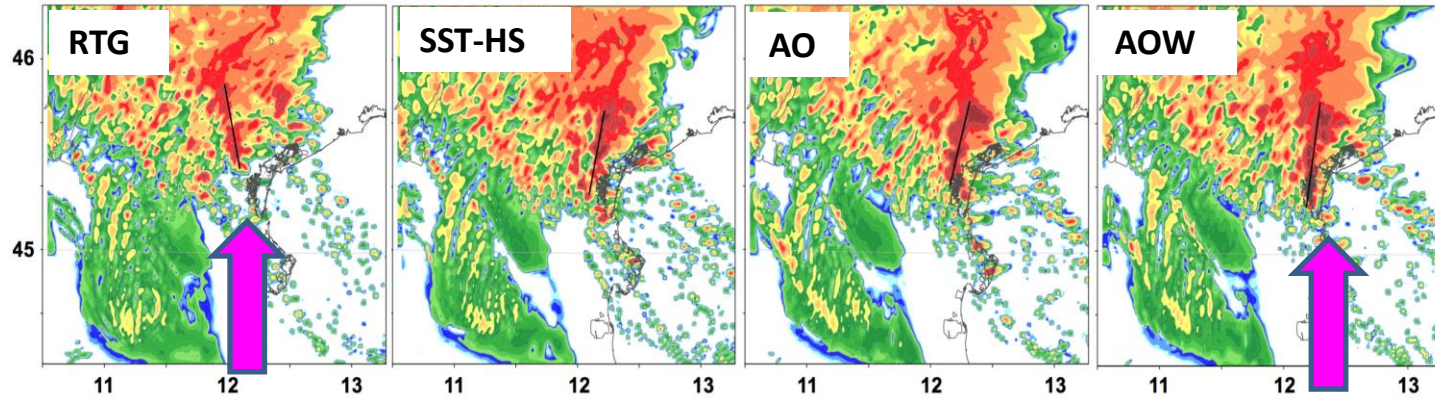
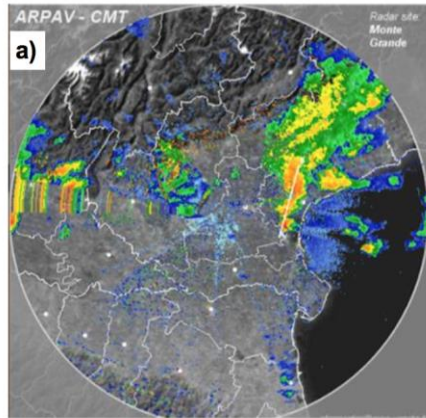
- Hourly mean rainfall value over plotted area

Venice Flash-Flood

- Timing of convergence line evolution, from mainland to sea



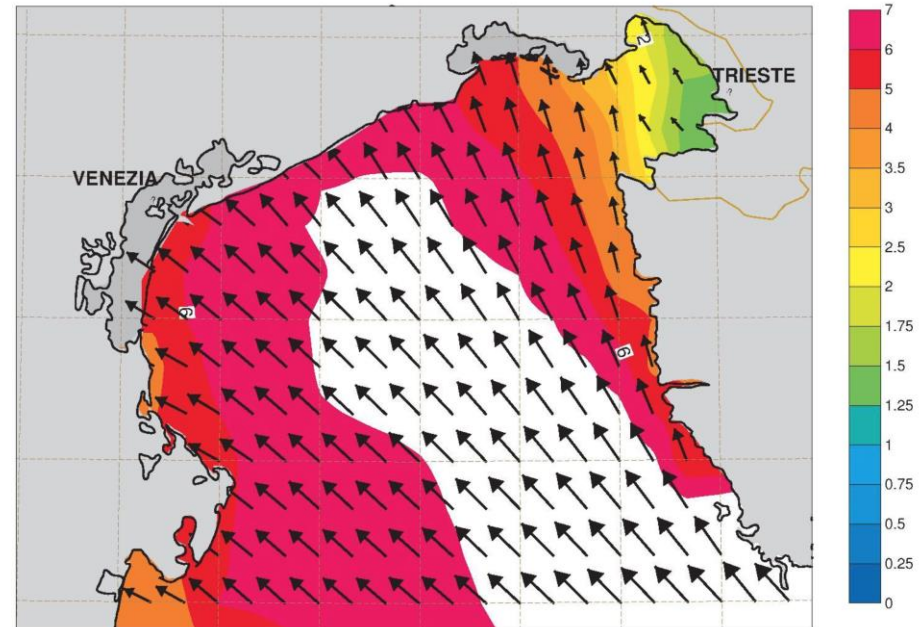
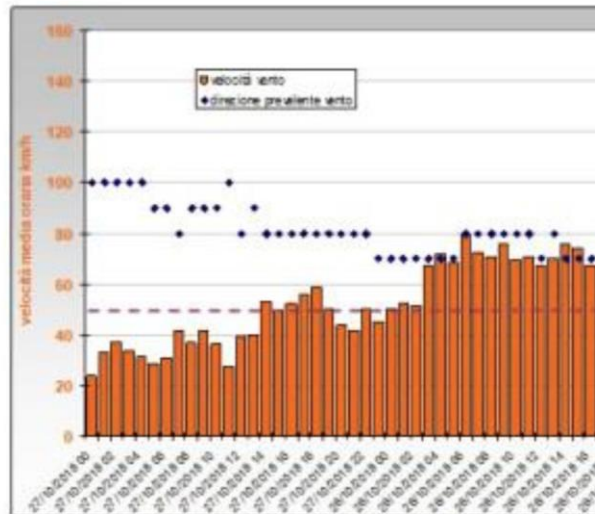
Venice Flash-Flood



- Flash-Flood development direction
- Multi-cell system and deep convection
- Coupled runs reproduce more accurately timing, intensity and location of F.Flood

VAIA CYCLONE - FROM 26TH TO 30TH OCTOBER 2018

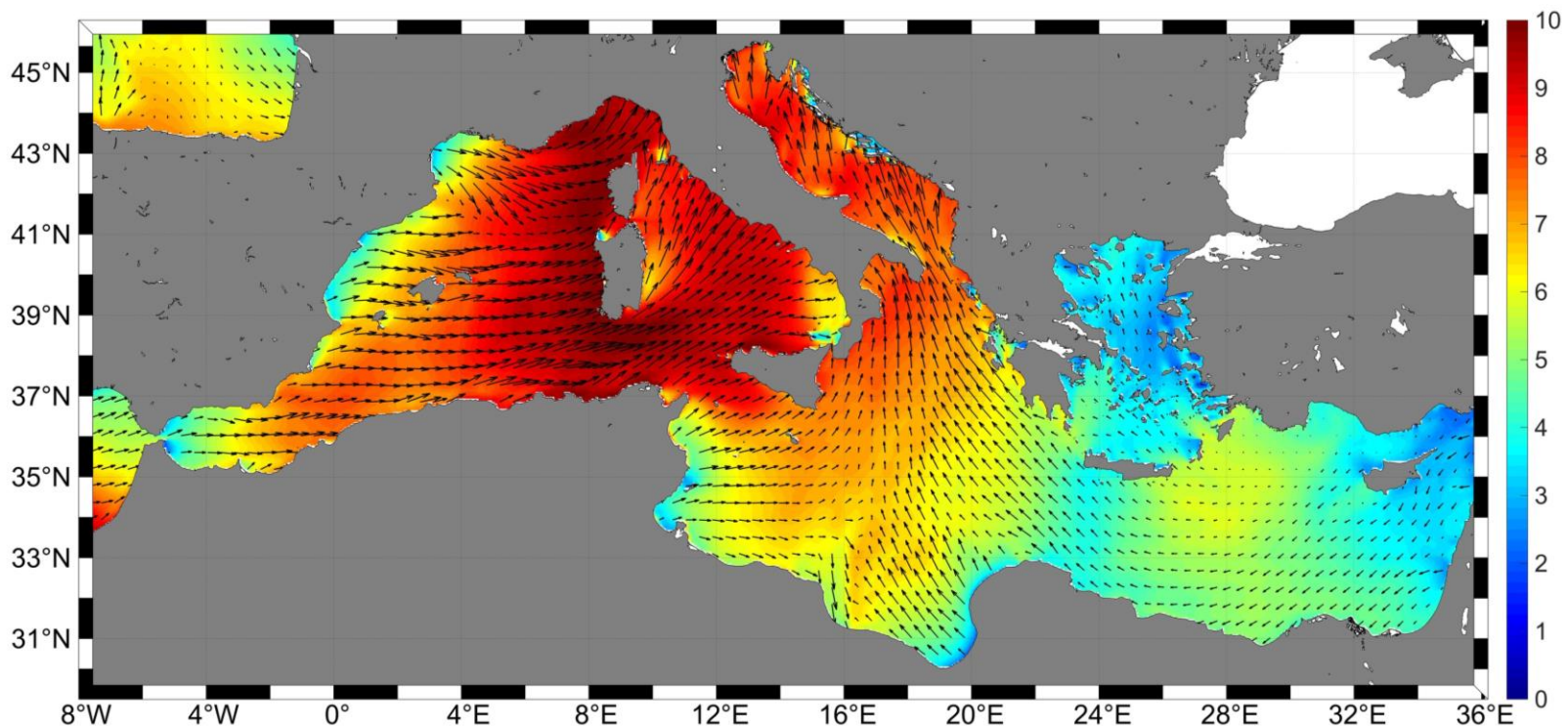
1. Understanding the causes that have generated this intense cyclogenesis
2. Understanding the role of ocean interaction with atmosphere
3. Understanding the role of high atmosphere dynamics



Magics 2.15.5 - Tue Oct 30 00:47:47 2018 - wave forecast ISMAR-CNR ICPSM - meteo data CNMCA

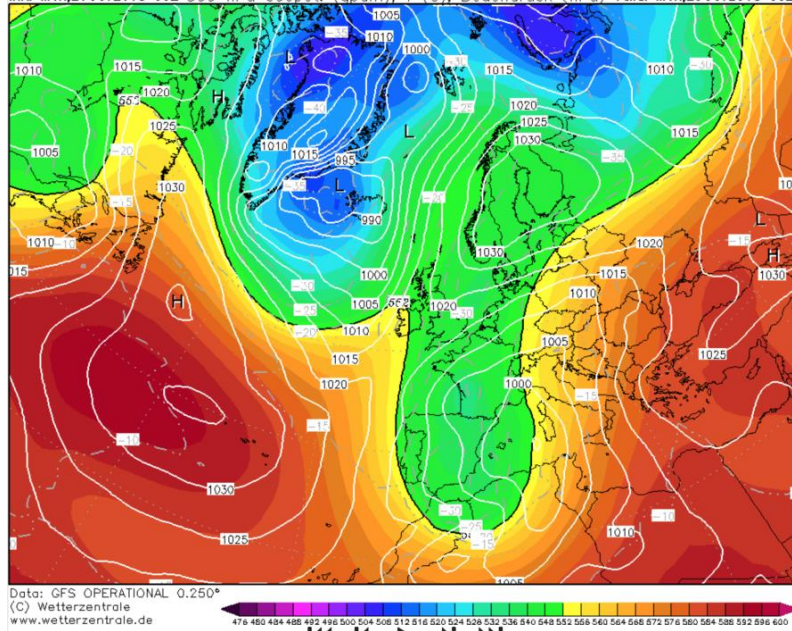
VAIA CYCLONE - FROM 26TH TO 30TH OCTOBER 2018

1. Understanding the causes that have generated this intense cyclogenesis
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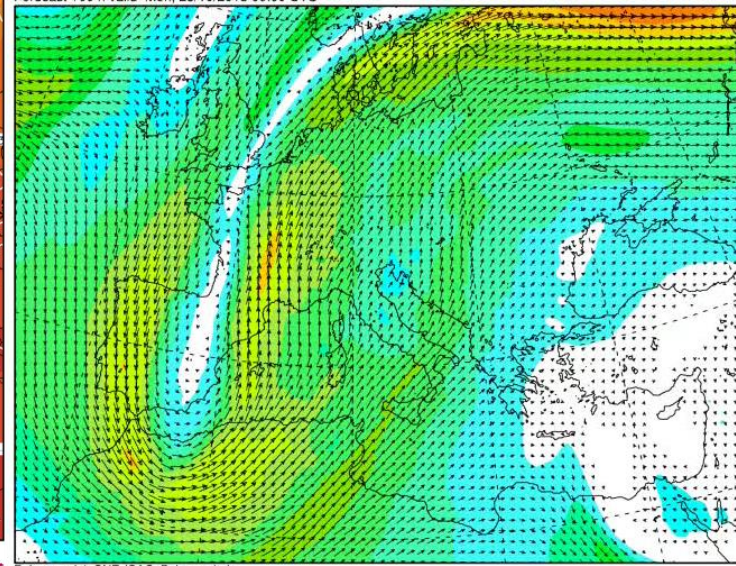
SYNOPTIC ANALYSIS

Init: Mon,29OCT2018 00Z 500 hPa Geopot. (gpm), T (C), Bodendruck (hPa) Valid: Mon,29OCT2018 00Z



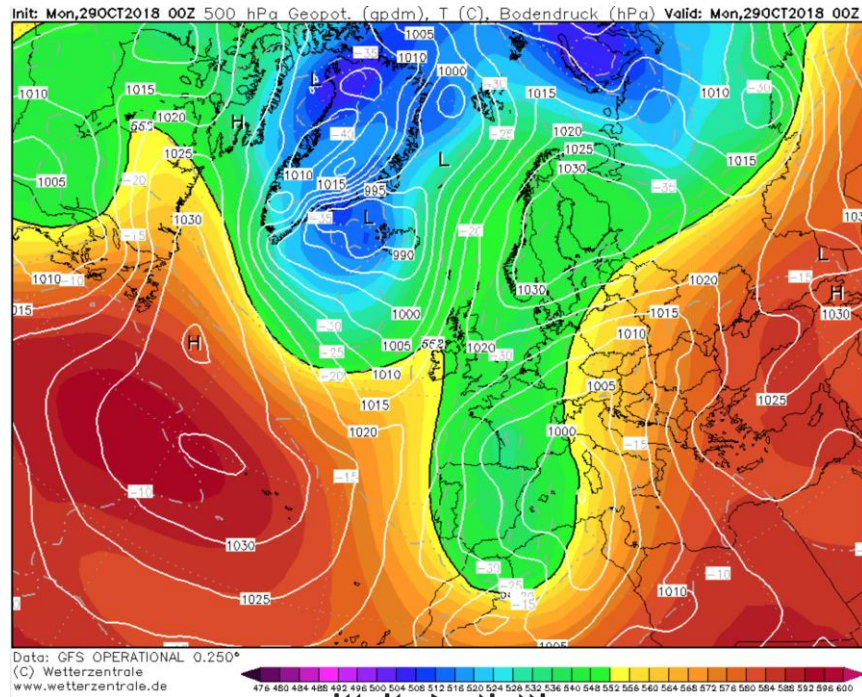
Wind at 300 hPa (m/s)

Initial time Mon, 29/10/2018 00:00 UTC
Forecast +00 h valid Mon, 29/10/2018 00:00 UTC



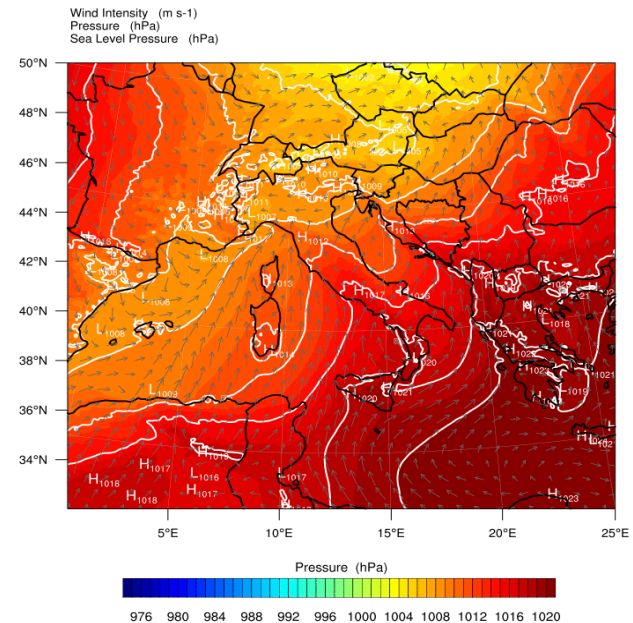
- From 26th to 30th October 2018
- Baroclinic wave was generated inside a strong meridional elongation of Jet Stream
- Characterized by very slow zonal movement
- The last minimum produce a horizontal gradient close to 15hpa (from Genova to Trieste)...20hpa during the landfall (*model data)

Sea level pressure and geopotential at 500 hpa



Sea level pressure animation over italian sea from 26-29 oct 2018

Init: 2018-10-27_00:00:00
Valid: 2018-10-27_00:00:00

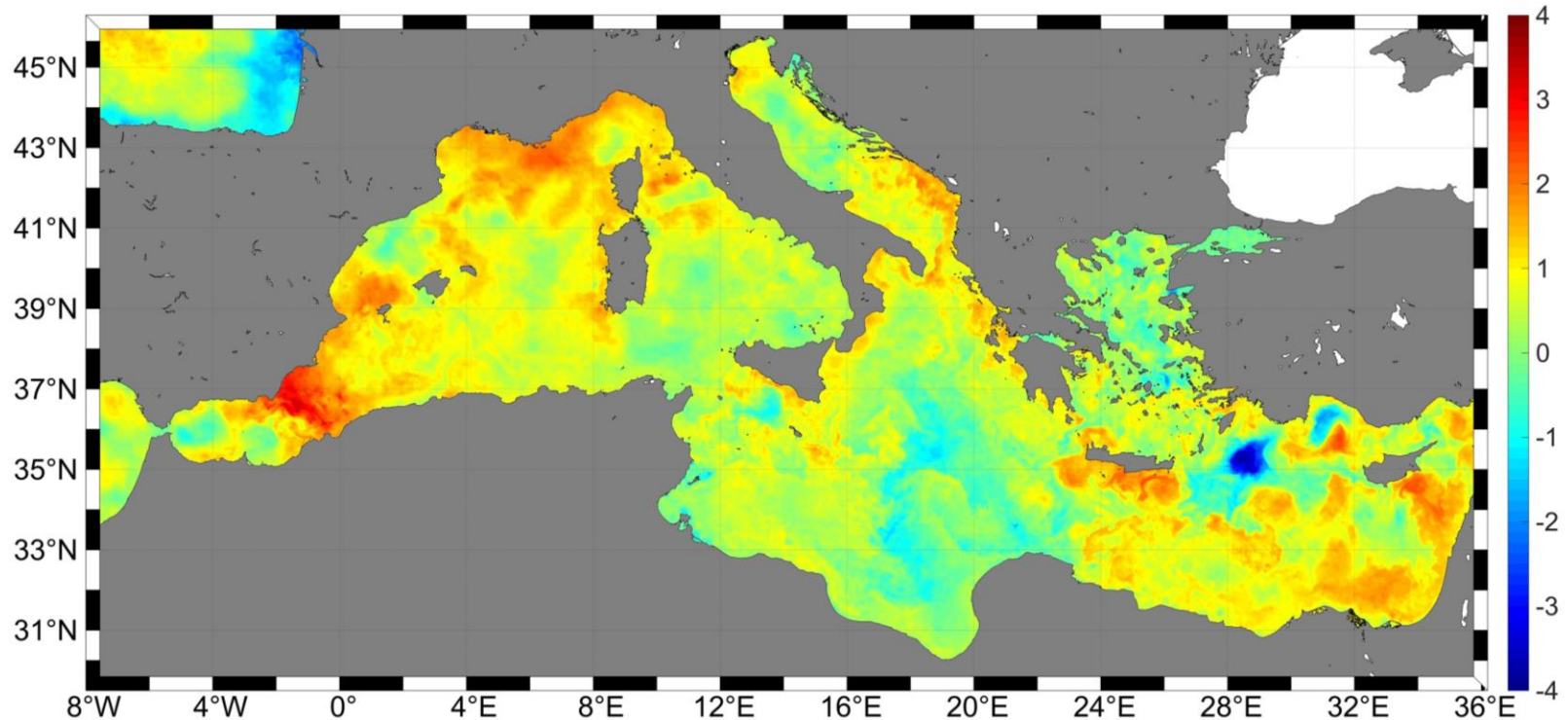


OUTPUT FROM WRF V3.9.1.1 MODEL
WE = 659 ; SN = 542 ; Levels = 90 ; Dis = 4km ; Phys Opt = 8 ; PBL Opt = 2 ; Cu Opt = 1

- From 26th to 30th October 2018
- Baroclinic wave was generated inside a strong meridional elongation of Jet Stream
- Characterized by very slow zonal movement
- The last minimum produced a horizontal gradient close to 15hpa (from Genova to Trieste)...20hpa during the landfall (*model data)

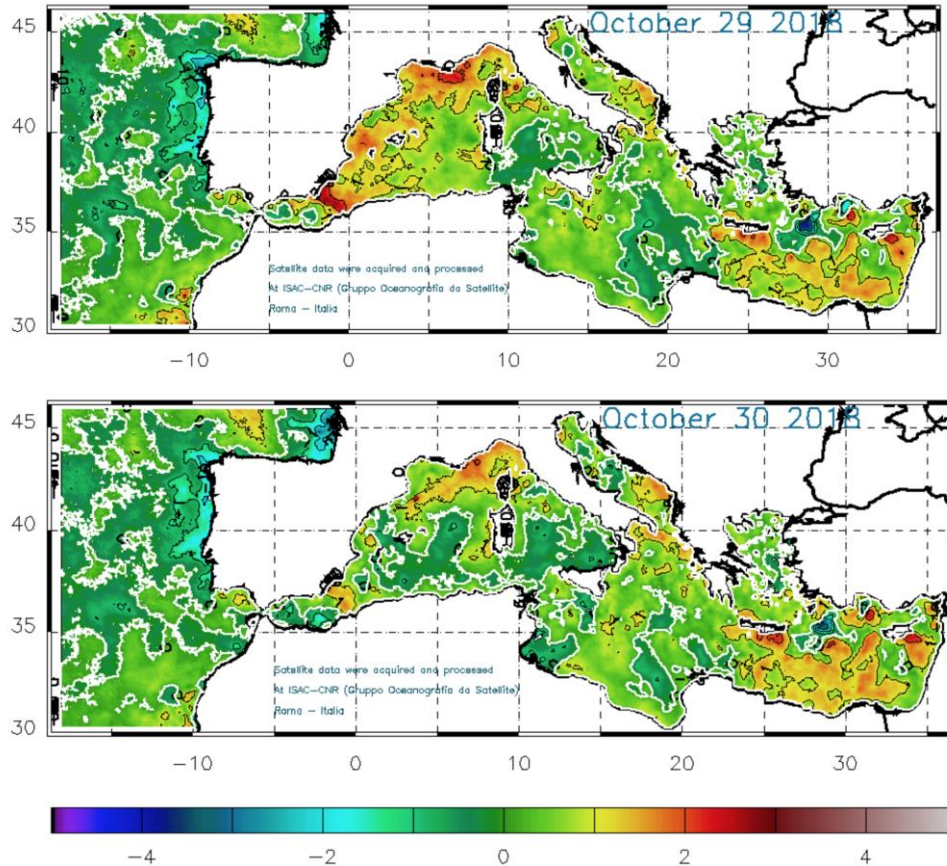
SEA SURF. TEMP ANOMALY

Sea Surface Temperature Anomaly: 27th October 2018 over the Mediterranean Sea before VAIA generation



Data from CNR - ISMAR (GOS)

SEA SURF. TEMP ANOMALY



SST decrease by $-1.5\text{ }^{\circ}\text{C}$ in 24 h
From 28th to 29th October 2018 over the
Western Mediterranean Sea after the VAIA
movement

28th Oct

29th Oct

Daily SST anomaly (GOS – ISAC CNR)

WRF SST-ENSEMBLE simulation :

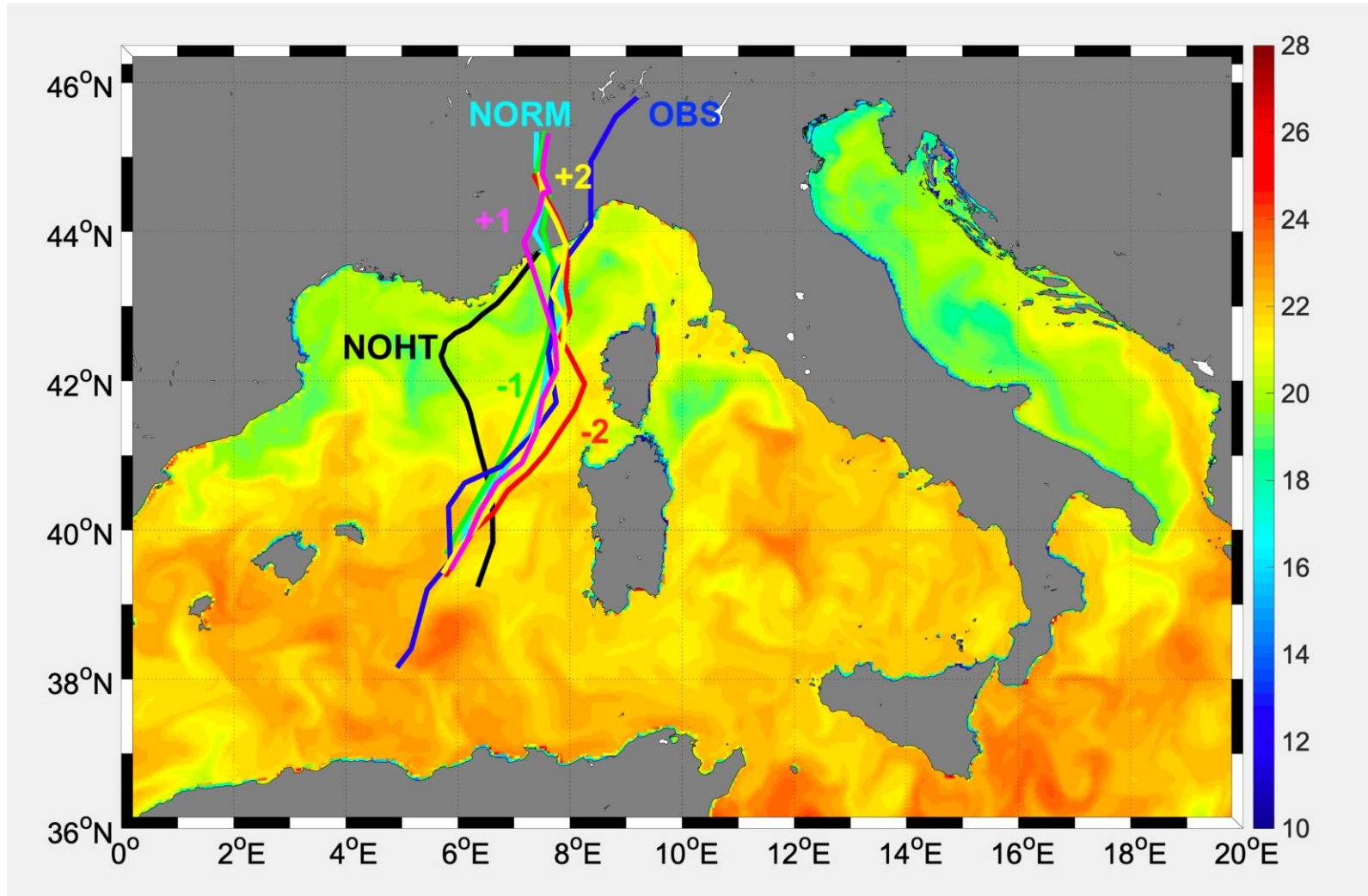
- 1) *OML 1D (WRF + SST 4km res + Mixed Layer Depth 4km res)*
- 2) *without HF in Microphysics (same OML1D conf, but remove heat fluxes in MP)*
- 3) *SST -1°C (same OML1D but decrease SST -1°C)*
- 4) *SST +1°C (same OML1D but increase SST +1°C)*
- 5) *SST -2°C (same OML1D but decrease SST -2°C)*
- 6) *SST +2°C (same OML1D but increase SST +2°C)*

DOMAIN CONFIGURATION :

- RES : 20-4km (ECMWF init and boundary)
- 90 vertical hybrid levels
- Cumulus parametr. : Kain–Fritsch (KF) (Kain 2004)
- Microphysics : Thompson (Thompson et al 2008)
- SST and Mixed Layer Depth from Copernicus dataset (Pinardi et al 2008)

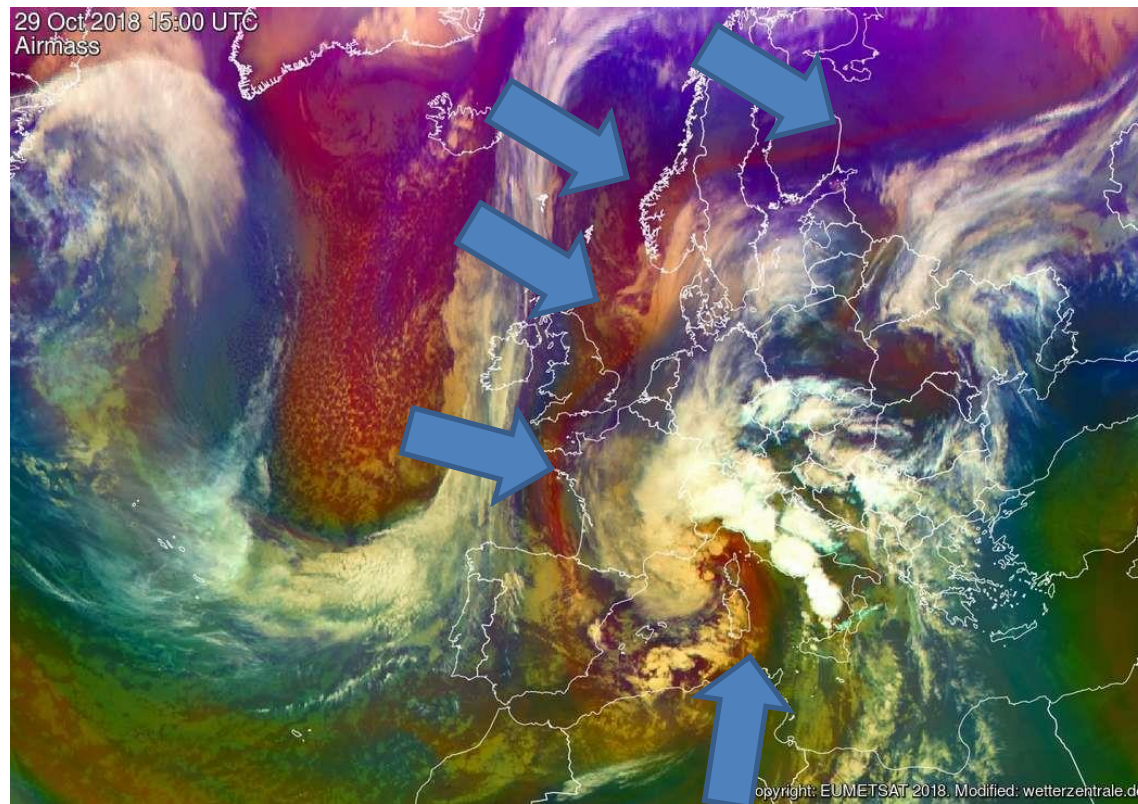


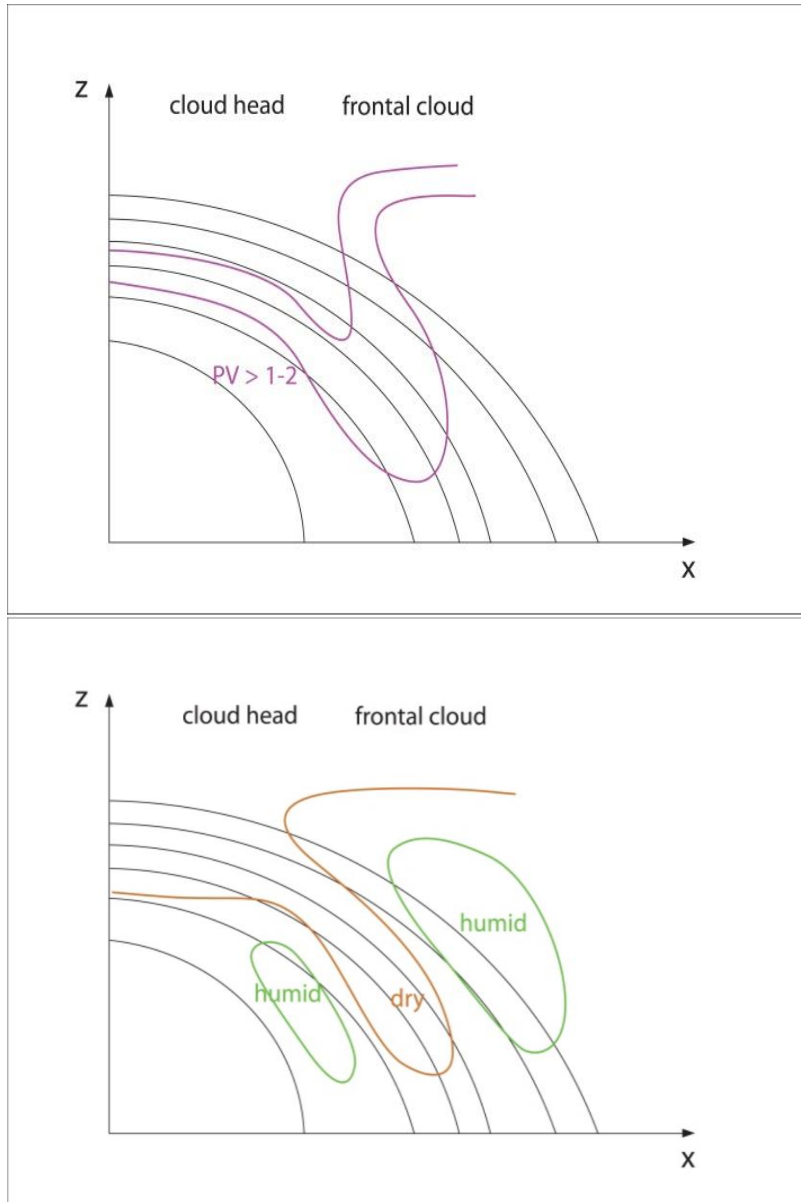
WRF-ENSEMBLE SST trajectories compared real trajectory (OBS)



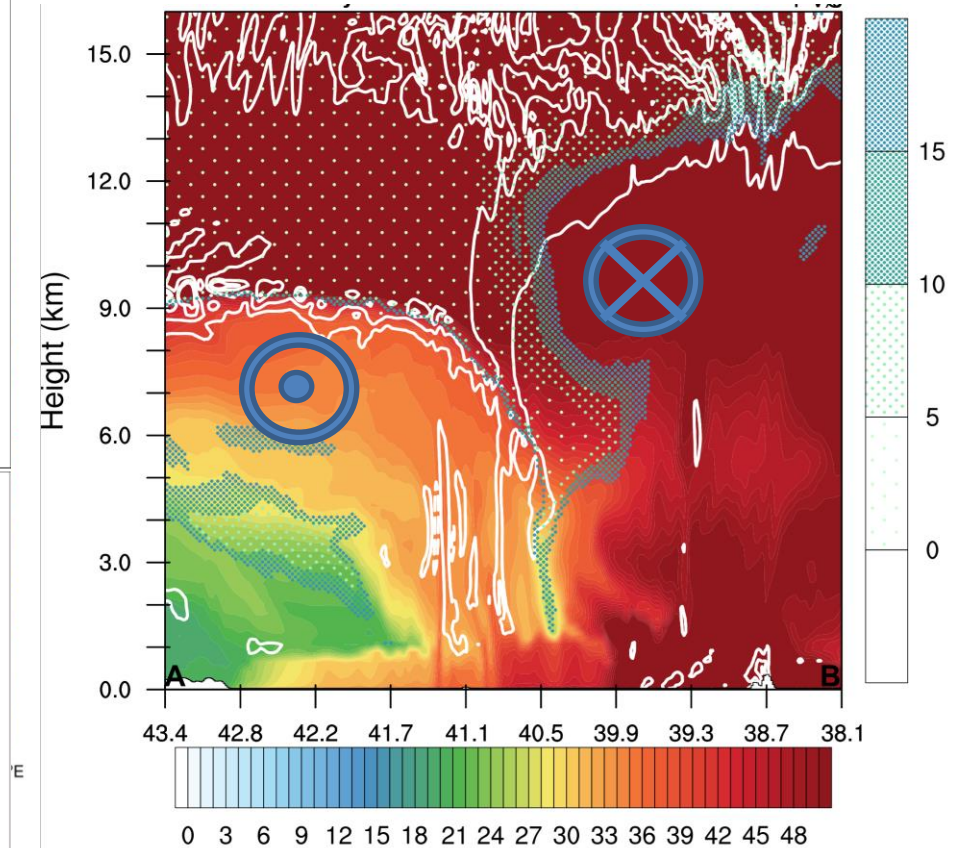
UPPER LAYER ANALYSIS - SATELLITE IMAGE

The intensification of the cyclone is not caused by the SST ... but ... then what caused this sudden increase in speed of cyclone (and therefore horizontal gradient) and intensity of the minimum?





Cross section along line A-B of RH (%), tetha-e and PV



Conclusion

1. In phenomena which are strongly linked to the air-sea interaction, the coupled numerical models play a fundamental role and has the most advanced numerical technology.
2. In the situation analyzed, the SST has a strong impact on the intensity of the wind over the sea (and less impact on its direction) caused by SST horizontal gradient (0-100km) and not only by absolute value.
3. The effect of the coupling is transferred up to the PBL by several hundred meters, affecting the amount of humidity that is moving from the coast. Coupling effects are therefore not just limited to the air-sea interface.
4. Strongly localized and intense events such as the ones described are ideally better analyzed with fully-coupled models in particular because this approach are able to describe a strong gradient of SST area and near the coastal zone.
5. Extreme events (in particularly coastal phenomena) are much more sensitive to the use of coupled model

Future perspectives : Operational application.

**Fully Coupled ATM-OCN-WAVES-MARINE SPRAY
Rain effect on waves (white capping) evolution**

Software :Vapor. Phenomena :TLC "Rolf"

