HRCP Workshop 13-15 April 2016

Tropical Cyclones-Ocean interaction as represented by a 25km resolution CGCM: the role of the coupling frequency

Enrico Scoccimarro[1,2], P.G. Fogli [2], K. Reed [3], S. Gualdi[1,2],S. Masina[1,2], A. Navarra[1,2]

[1]INGV - Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy

[2]CMCC - Centro Euro-Mediterraneo sui Cambiamenti Climatici, Bologna, Italy

(3) Stony Brook University, NY, U.S.A.

Enrico Scoccimarro[1,2], P.G. Fogli [2], K. Reed [3], S. Gualdi[1,2], S. Masina[1,2], A. Navarra[1,2]

[1]INGV - Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy [2]CMCC - Centro Euro-Mediterraneo sui Cambiamenti Climatici, Bologna, Italy

(3) Stony Brook University NY, U.S.A.

outline

1. SCIENTIFIC QUESTION

Since the ocean is the source of energy supply for Tropical Cyclone (TC) development and intensification, *to what extent the feedback with the ocean affects TC activity?*

2. EXPERIMENT DESIGN

The high resolution climate modelling framework and simulation settings.

3. RESULTS

Effects of different Atmosphere-Ocean coupling frequencies on TC statistics and case study results.

4. TAKE HOME MESSAGES

1. SCIENTIFIC QUESTION

to what extent the feedback with the ocean affects TC activity?

The interaction between Tropical Cyclones (TCs) and ocean is a major mechanism responsible for energy exchange between the atmosphere and the ocean.

The wind structure associated with TCs is responsible for **two important atmosphere–ocean feedbacks**:

- The **first feedback** — positive — is driven by the latent heat associated with the enhanced evaporation rate and leads to an increase of the available energy for TC.

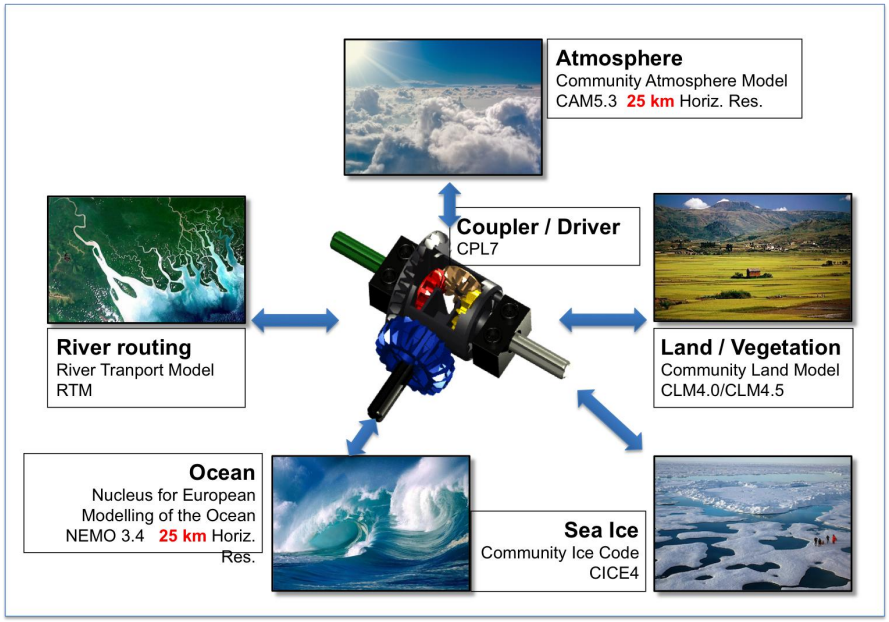
- The **second feedback** — negative — is *due to the cold water* upwelling induced by the increased wind stress at the ocean surface and by the shear-induced mixing at the base of the mixed layer. *The induced cooling of the sea surface leads to a weakening of the TC intensity* due to the reduction of the total heat flux into the atmosphere. This cooling effect is a function of the initial ocean condition, TC intensity, TC travelling speed and TC size (Huang et al. 2015).

Can we quantify the role of cyclone-induced changes on the upper ocean, on TC activity?

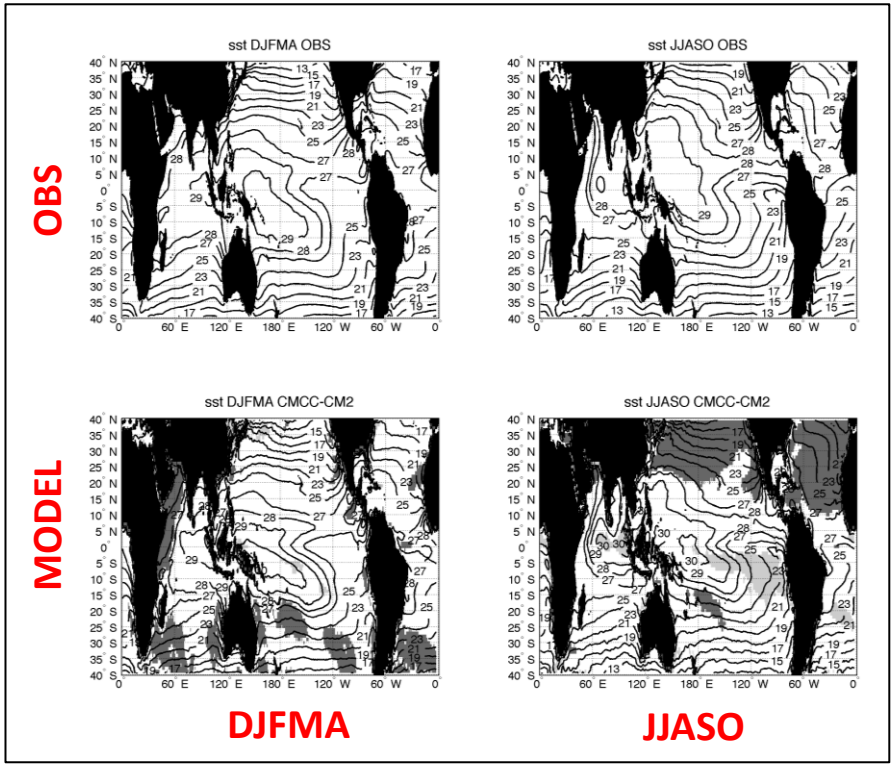
2. EXPERIMENT DESIGN

The very high resolution climate modelling framework

The CMCC-CM2VHR fully coupled General Circulation Model



The CMCC-CM2 (Fogli and Iovino 2014) model in its highest resolution configuration (VHR): 25 km in both atmospheric and ocean components.



Seasonal averages of **Sea Surface Temperature** as obtained from the observations (1981-2000 HadISST climatology, upper panels) and the model (lower panels). Light (dark) gray shaded patterns indicate regions where the SST difference between model and observations is larger (smaller) than 1 (-1) ^{o}C.

Ref :
Fogli P.G., Iovino D.C., 2014
CMCC–CESM–NEMO: toward the new CMCC Earth System Model,
CMCC Research Papers RP0248.

2. EXPERIMENT DESIGN

simulation settings

3 runs :

Atmosphere
Community Atmosphere Model
CAM5.3 **25 km** Horiz. Res.

obs SST

Atmosphere only

1. **FORCED**

Stand-alone Atmospheric simulation
FORCED by observed SSTs

Atmosphere
Community Atmosphere Model
CAM5.3 **25 km** Horiz. Res.

HEAT, MASS and MOMENTUM fluxes exchange

Ocean
Nucleus for European Modelling of the Ocean
NEMO 3.4 **25 km** Horiz. Res.

Coupled configurations

2. **LF**

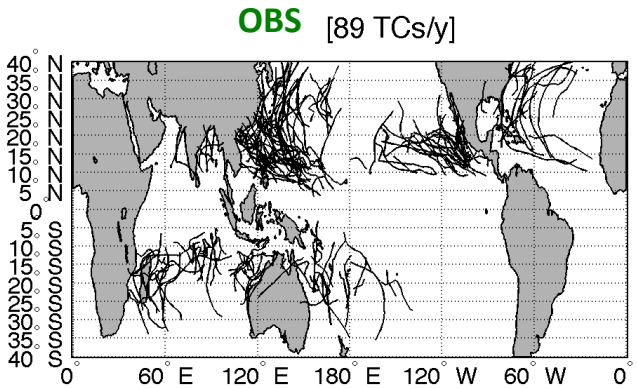
Atmosphere-Ocean COUPLED simulation with
Low Frequency (daily) coupling

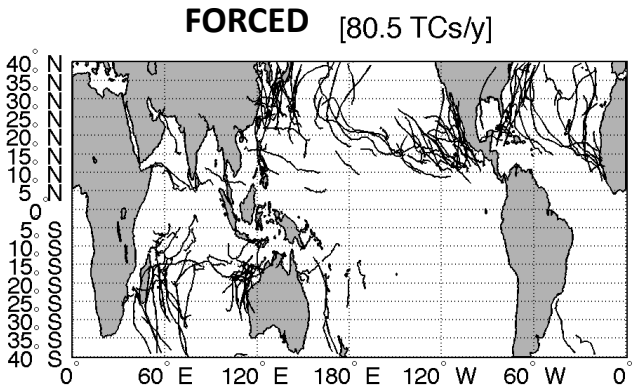
3. **HF**

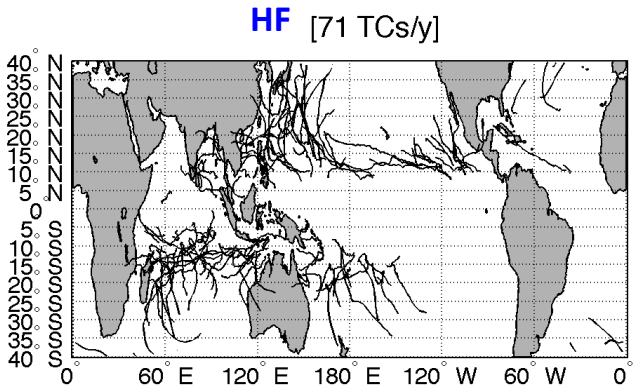
Atmosphere-Ocean COUPLED simulation with
High Frequency (hourly) coupling

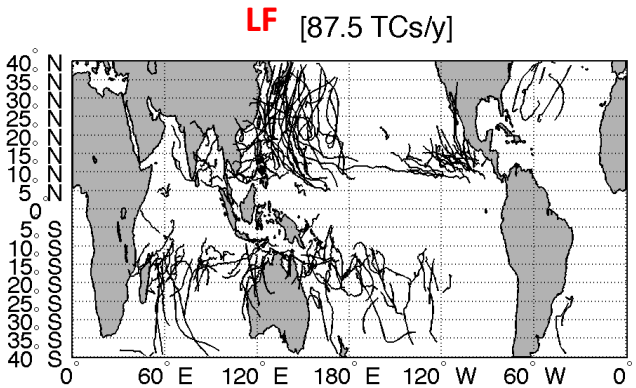
3. RESULTS

two years TC tracks









FORCED: forced run (atm only)

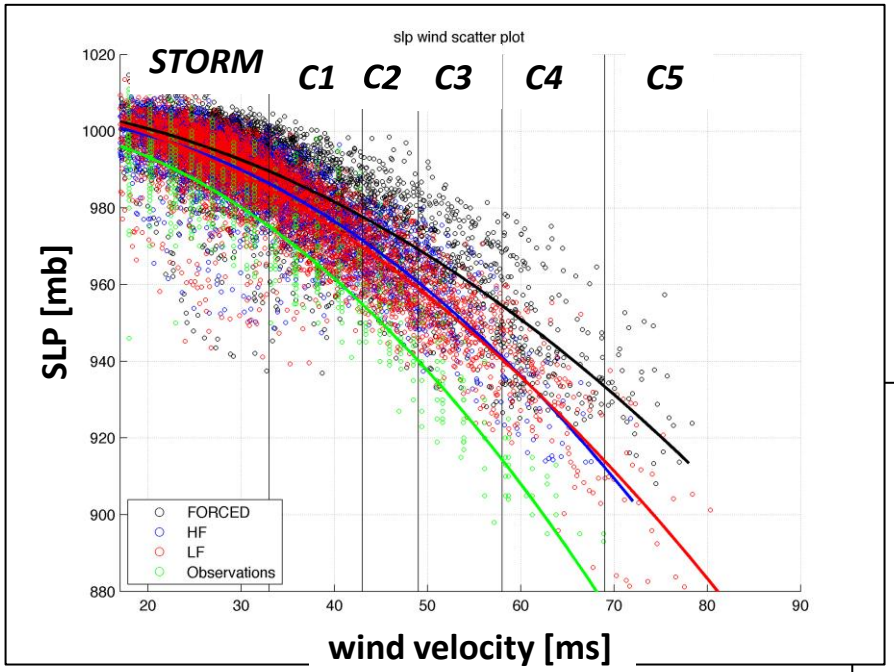
LF: hourly atm-oce coupling

HF: daily atm-oce coupling

Observations: IBTraCS

3. RESULTS

TC classification

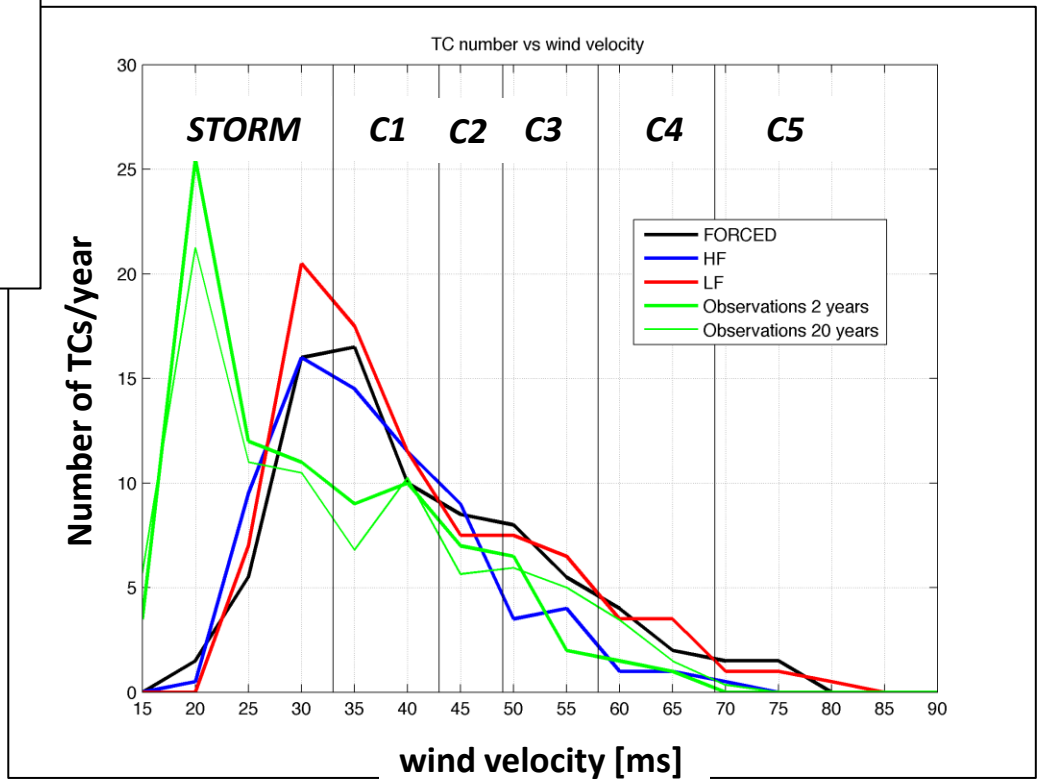


FORCED: forced run (atm only)

LF: hourly atm-oce coupling

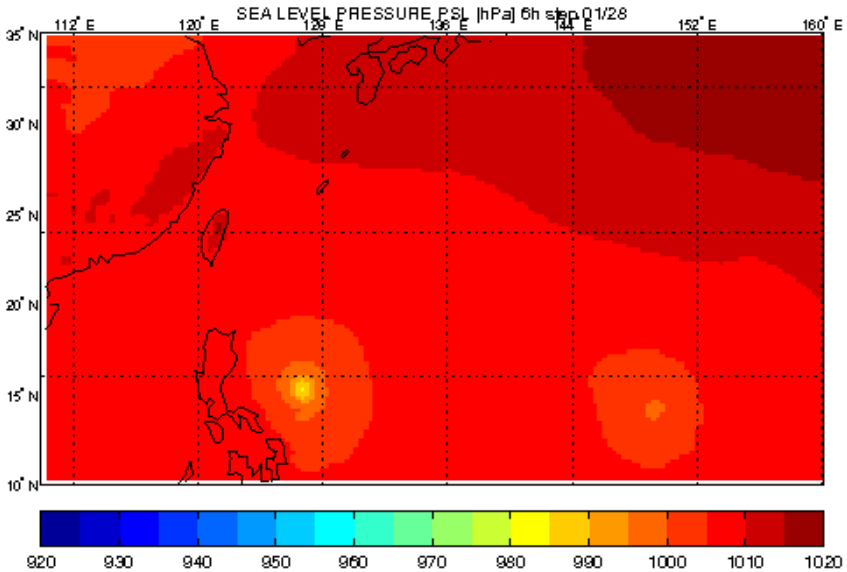
HF: daily atm-oce coupling

Observations: IBTraCS

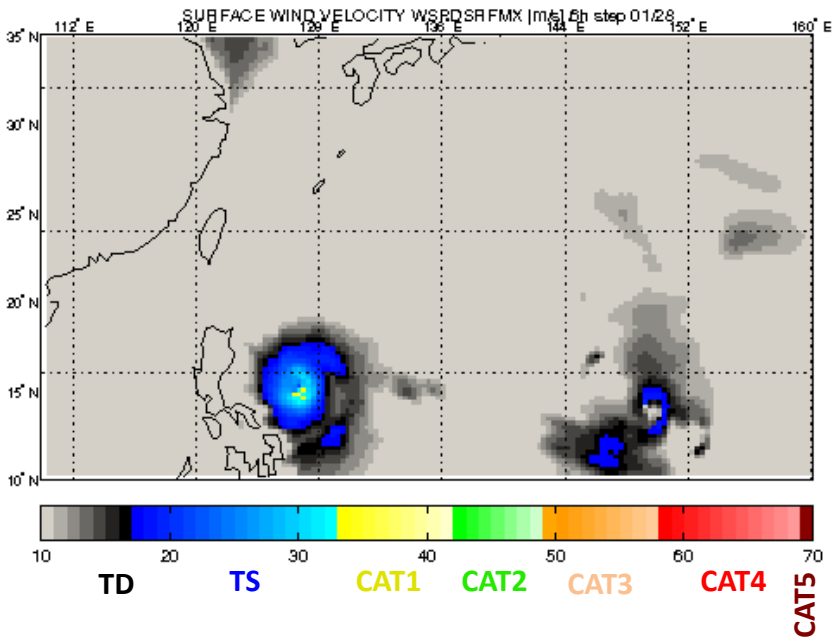


Twin Typhoons in HF simulation (hourly Atm-Oce coupling)

SLP [hPa]



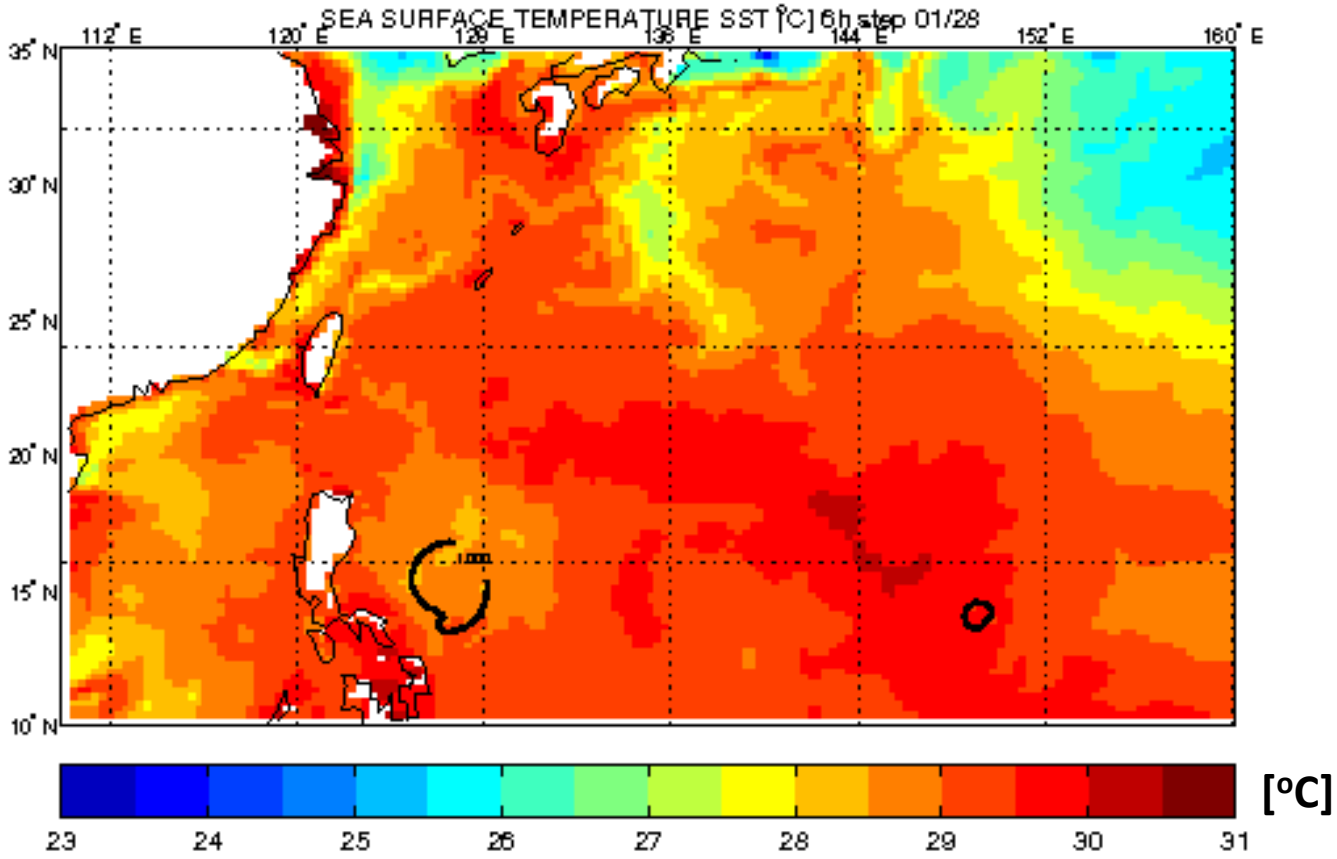
10m wind [m/s]



[*6 hourly steps covering one week*]

A simulated CAT5 Typhoon in HF simulation (hourly Atm-Oce coupling)

SST [patterns] and SLP [contours]

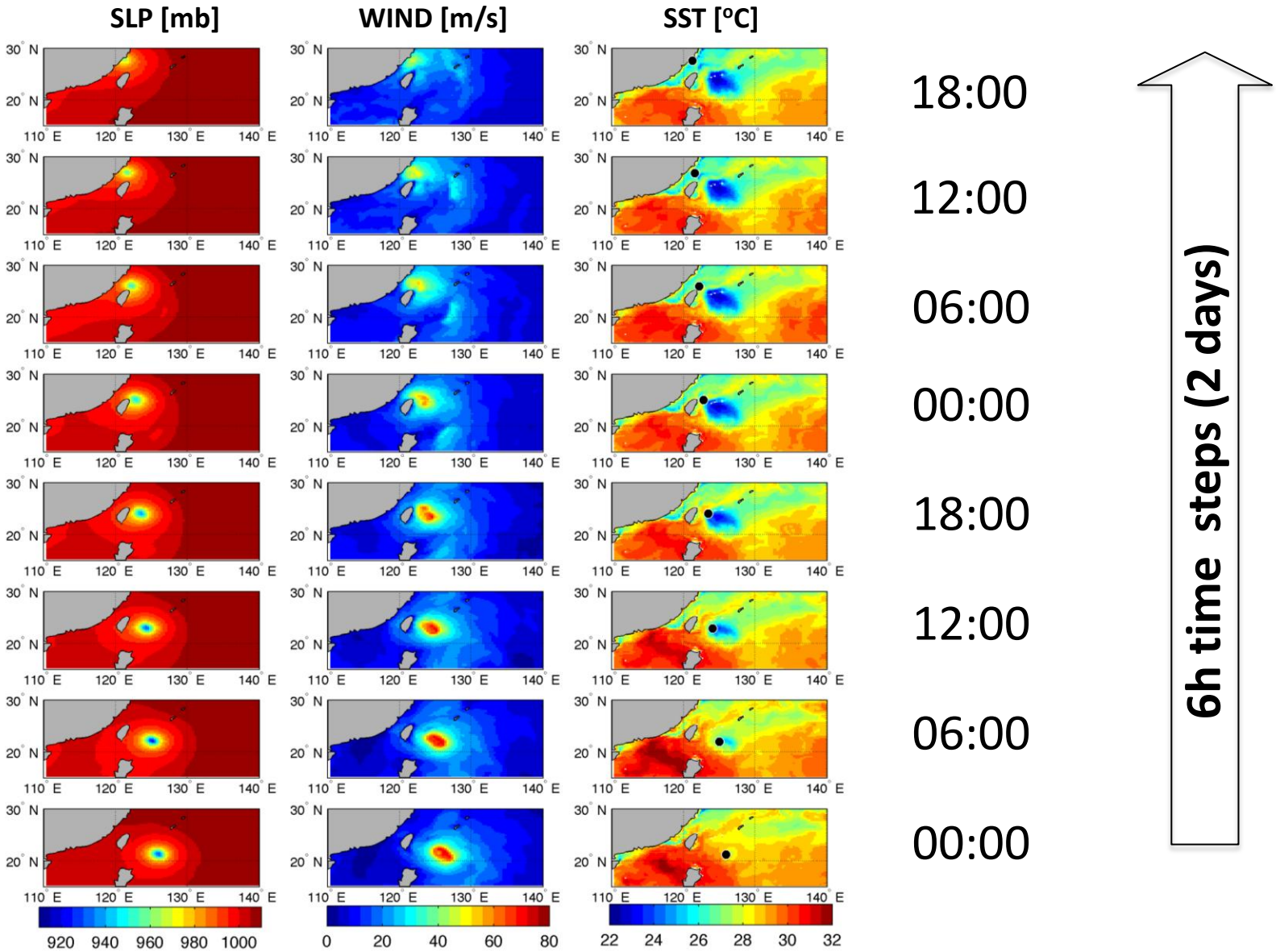


[6 hourly steps covering one week]

3. RESULTS

A case study: the most intense TC in HF

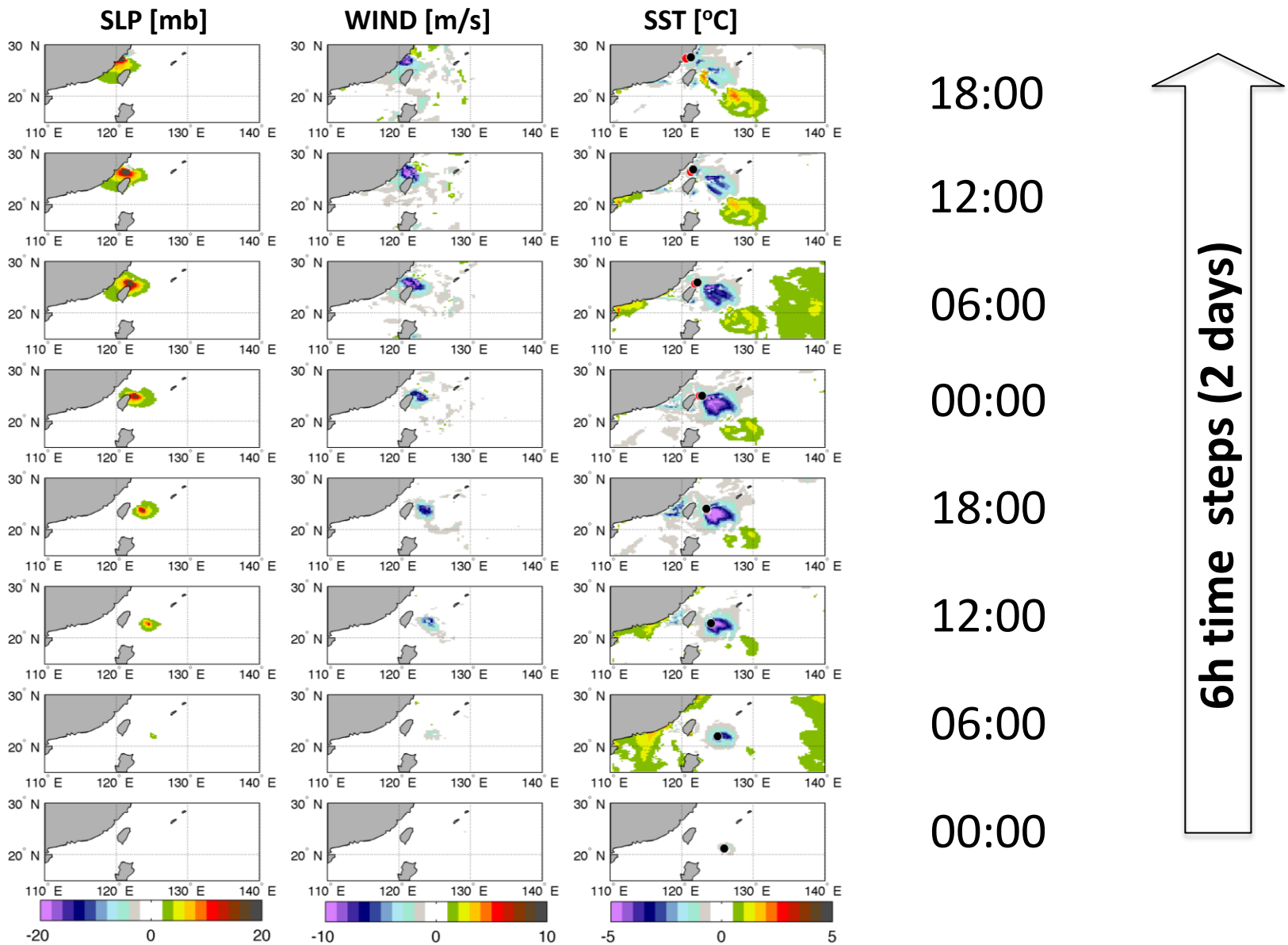
HF (hourly coupling)



3. RESULTS

A case study: rerunning the most intense TC in HF under LF settings

HF-LF (difference between hourly and daily coupling results)



3. RESULTS

An integrated measure for TC activity

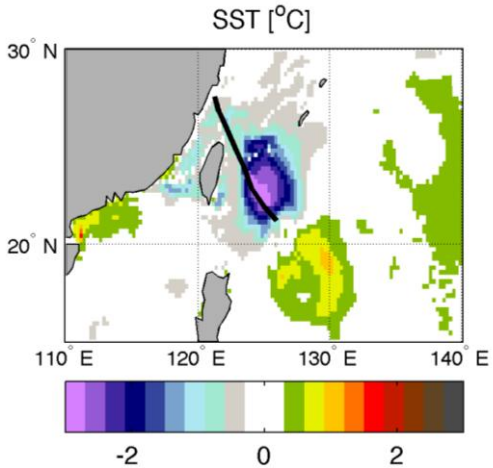
Power Dissipation Index (**PDI**, Emanuel, 2005) integrated over the entire period, is a well recognized indicator of Tropical Cyclone activity considering both storm frequency and intensity. It is **the cube of the maximum sustained wind integrated along the TC tracks.** Although not a perfect measure of net power dissipation, this index is a **better indicator of tropical cyclone threat than storm frequency or intensity alone**.

Also, the total power dissipation is of direct interest from the point of view of tropical cyclone contributions to upper ocean mixing and the thermohaline circulation.

global scale	OBS	FORCED	LF *daily ATM-OCE coupling*	HF *hourly Atm-Oce coupling*
PDI ([m^3/s^2] *e+12)	**1.52**	2.70	2.56	1.63
PDI BIAS [%]		**+77%**	**+68%**	**+7%**

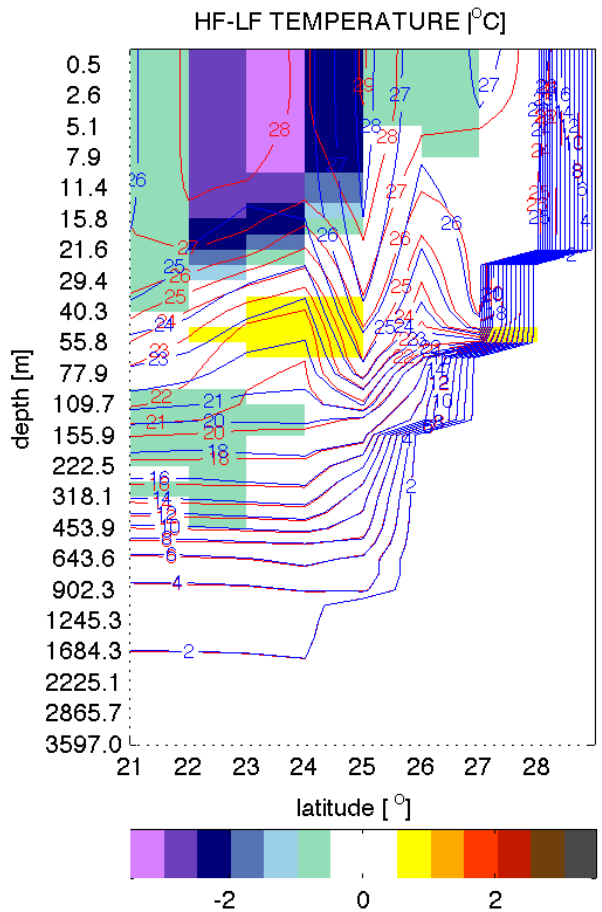
3. RESULTS

vertical section along the TC track: differences between HF and LF averaged over the two days

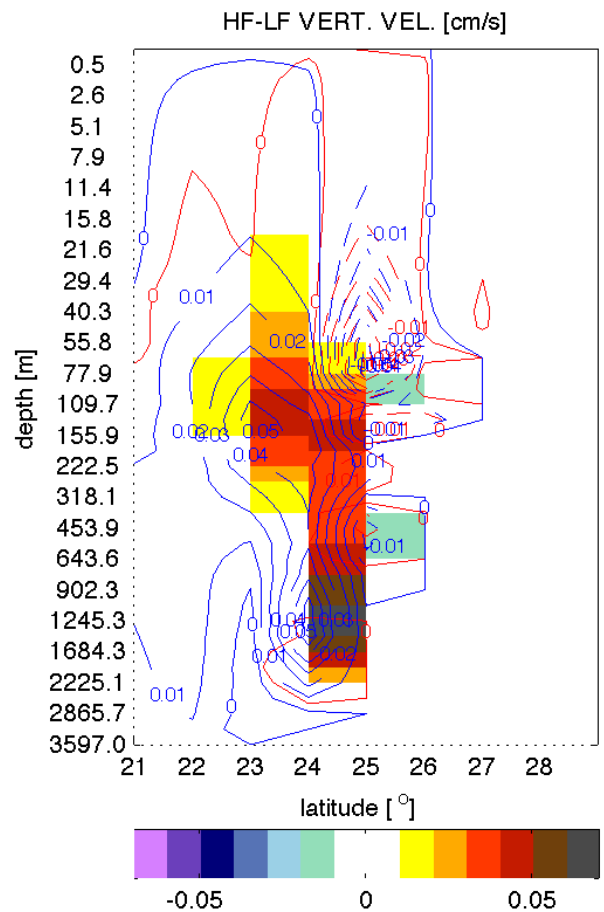


HF-LF (difference between hourly and daily coupling results)

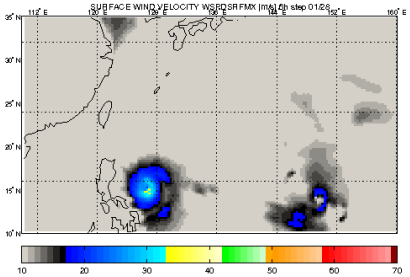
TEMPERATURE DIFFERENCE



VERTICAL VELOCITY DIFFERENCE



4. TAKE HOME MESSAGES



- New generation fully Coupled General Circulation Models (HighResMIP) are **able** to **represent CAT5 Hurricanes**/Typhoons (see also GFDL model results - *Murakami et al. 2015 JCLI*).

- A **detailed** (high frequency) **representation of TC-Ocean interaction reduces** the **overestimated** number of very **intense TCs**.

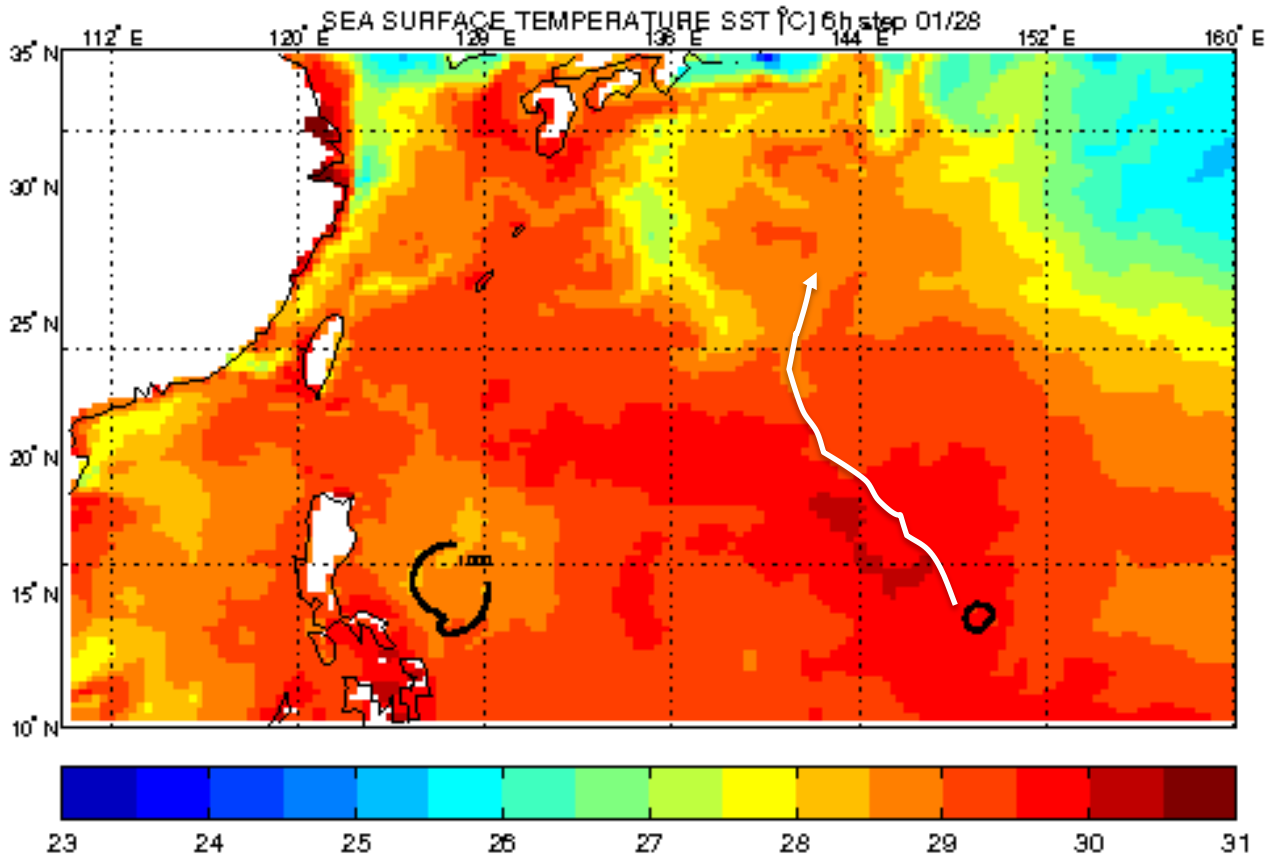
- In terms of **Power Dissipation Index** by TCs, the high frequency coupling reduces model **bias from 70% to 7%** .

- The **TC fingerprint** is still present at more than **1000 meter depth**.

Tropical Cyclones-Ocean interaction as represented by a 25km resolution CGCM: the role of the coupling frequency

just sumbitted

Sea Surface Temperature [°C]



Thank you!

Enrico Scoccimarro[1,2], P.G. Fogli [2], K. Reed [3], S. Gualdi[1,2], S. Masina[1,2], A. Navarra[1,2]

[1]INGV - Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy

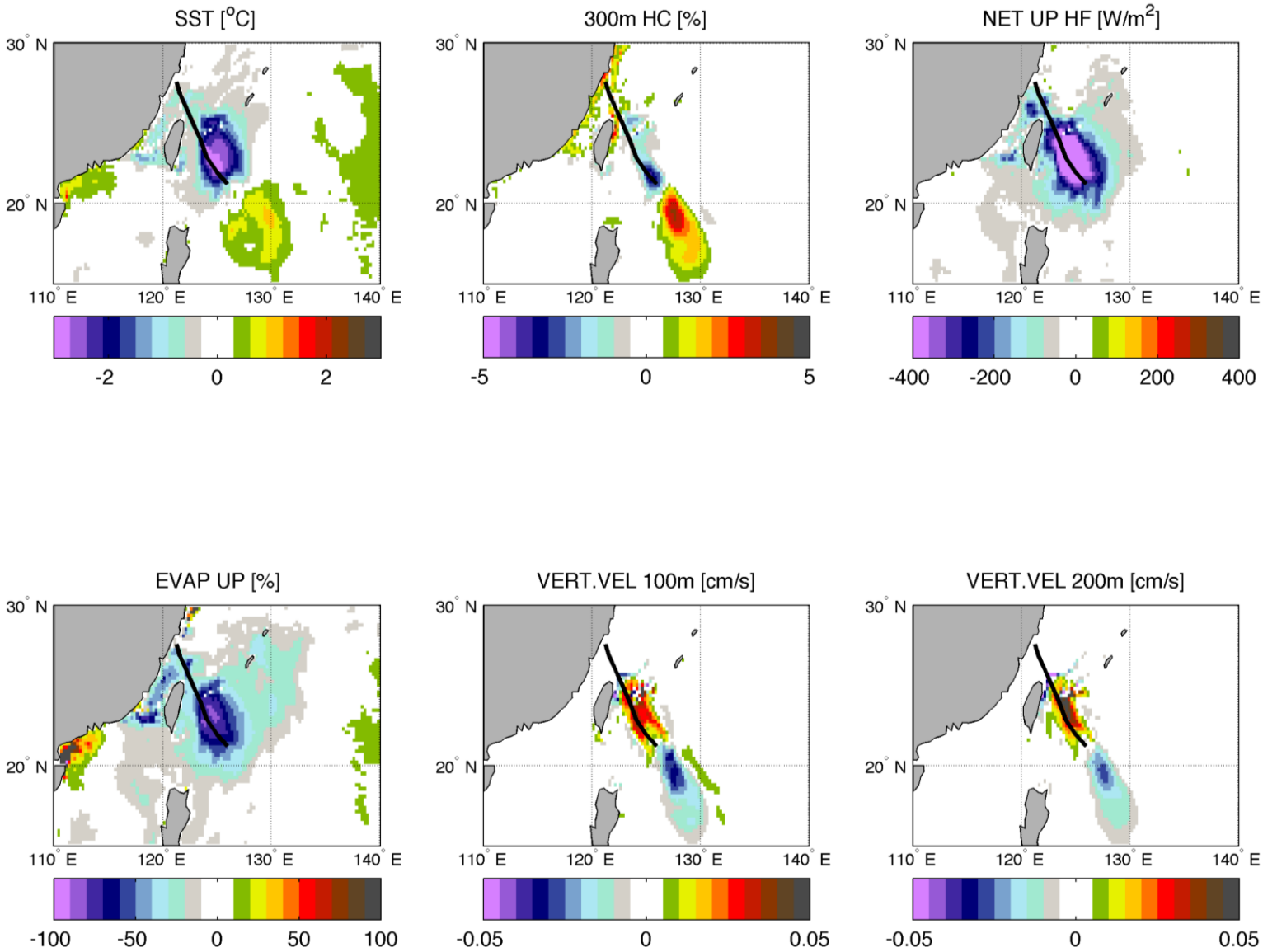
[2]CMCC - Centro Euro-Mediterraneo sui Cambiamenti Climatici, Bologna, Italy

[3] Stony Brook University NY, U.S.A.

3. RESULTS

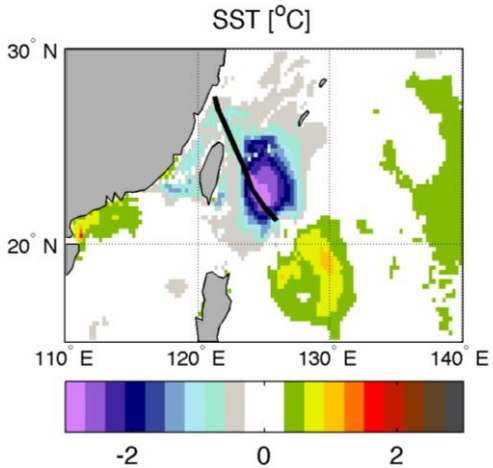
the ocean side: differences between HF and LF averaged over the two days

HF-LF (difference between hourly and daily coupling results)



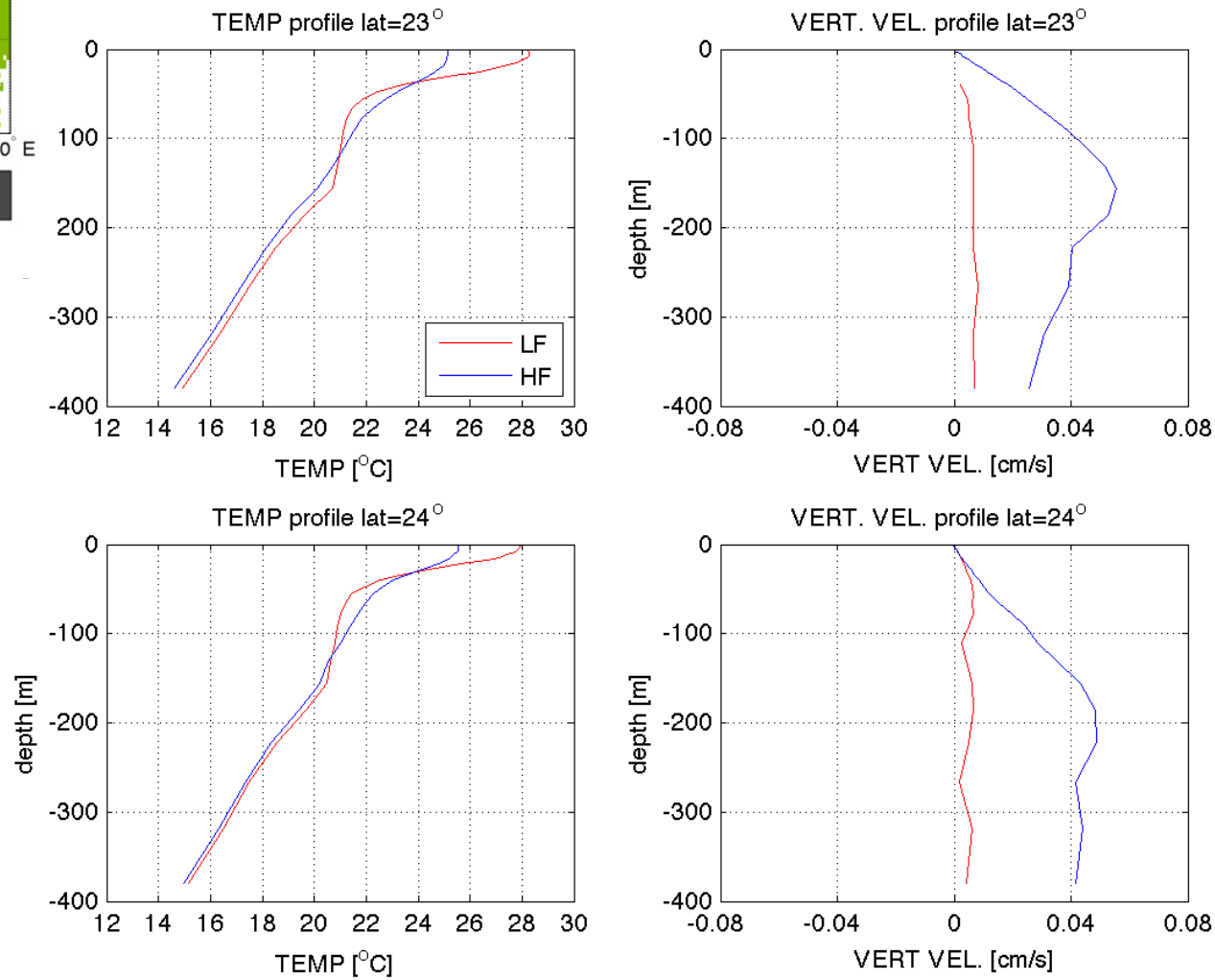
3. RESULTS

vertical profiles along the TC track: differences between HF and LF averaged over the two days



HF-LF (difference between hourly and daily coupling results)

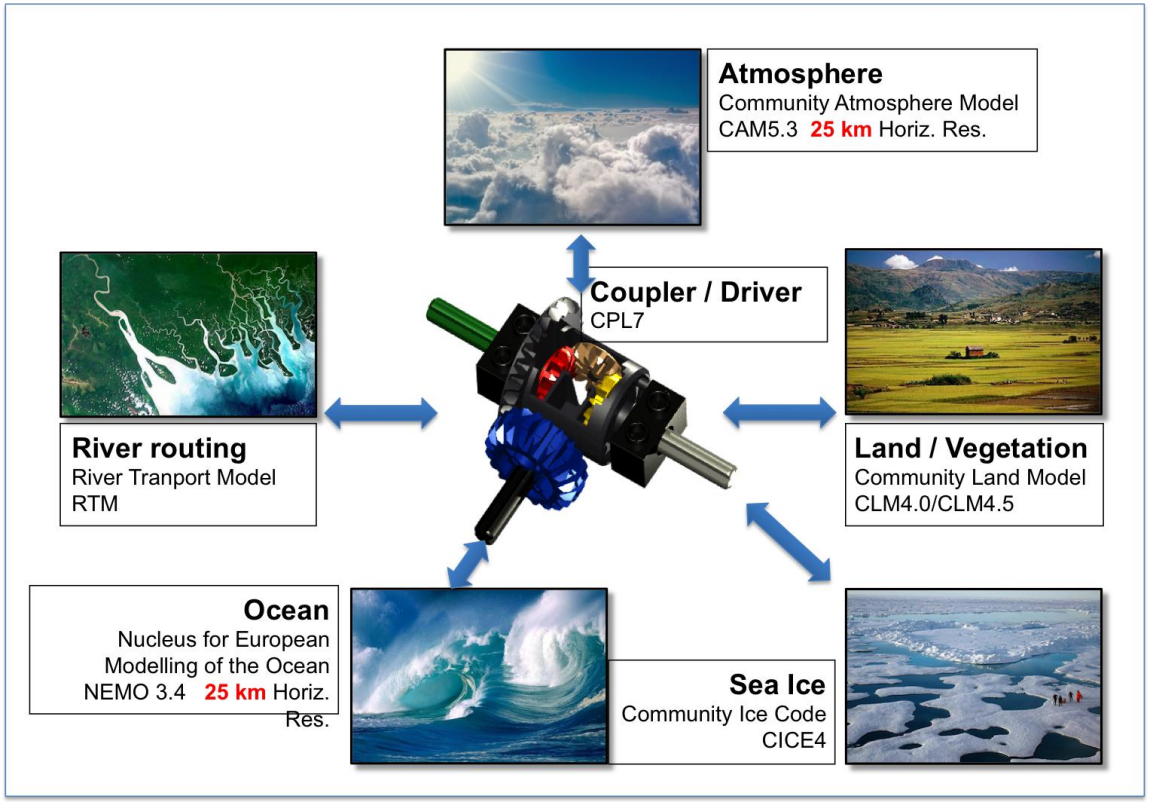
TEMPERATURE | **VERTICAL VELOCITY**



23°N

24°N

The CMCC-CM2VHR fully coupled General Circulation Model



CAM (at 25 km of horiz. res. & 30 vertical levels) convective parameterization.

The CAM5 physical parameterization package uses the Zhang and McFarlane (1995) deep convective parameterization and the University of Washington (UW) shallow convection scheme (Park and Bretherton 2009). The convective parameterization includes a dilute entraining plume (Neale et al. 2008) and a convective momentum transport approximation as used in the previous version of the model, CAM4 (Richter and Rasch 2008). The moist boundary layer turbulence scheme is that of Bretherton and Park (2009). A description of the surface flux parameterizations, an important driver for tropical cyclogenesis, is described in Neale et al. (2012).