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.
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\(^{(1)}\)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.

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**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) °C.

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

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## 2. EXPERIMENT DESIGN

### Simulation settings

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- **Atmosphere**
  - Community Atmosphere Model CAM5.3 25 km Horiz. Res.
  - Forced by observed SSTs

- **Ocean**

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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

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3. RESULTS

A case study

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

SLP [hPa]

10m wind [m/s]

[6 hourly steps covering one week]

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3. RESULTS

A case study

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

SST [patterns] and SLP [contours]

6 hourly steps covering one week

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3. RESULTS

A case study: the most intense TC in HF

HF (hourly coupling)

SLP [mb]  WIND [m/s]  SST [°C]

18:00
12:00
06:00
00:00
18:00
12:00
06:00
00:00

6h time steps (2 days)
3. RESULTS

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

HF-LF (difference between hourly and daily coupling results)
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.
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
HF-LF TEMPERATURE [°C]

VERTICAL VELOCITY DIFFERENCE
HF-LF VERT. VEL. [cm/s]
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.
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just submitted

Thank you!

Enrico Scoccimarro\textsuperscript{(1,2)}, P.G. Fogli \textsuperscript{(2)}, K. Reed \textsuperscript{(3)}, S. Gualdi\textsuperscript{(1,2)}, S. Masina\textsuperscript{(1,2)}, A. Navarra\textsuperscript{(1,2)}

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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

TEMP profile lat=23°
VERT. VEL. profile lat=23°

TEMP profile lat=24°
VERT. VEL. profile lat=24°

23°N

24°N
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).