Meridional distribution of moisture transport associated to Tropical Cyclones

Daniele Peano, Enrico Scoccimarro, Alessio Bellucci, Malcolm Roberts, Annalisa Cherchi, Alessandro D'Anca, Fabrizio Antonio, Sandro Fiore, Silvio Gualdi

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Introduction

Tropical cyclones (TCs) transport energy and moisture along their pathways interacting with the climate system and TCs activities are expected to extend further poleward during the 21st century.

For this reason, it is important to assess the ability of state-of-the-art climate models in reproducing an accurate meridional distribution of TCs as well as a reasonable meridional portrait of moisture transport associated with TCs.

Since high resolutions are required to reconstruct observed TCs activity, the present work is based on the simulations performed as part of HighResMIP in the framework of the community CMIP6 effort. To inspect this feature, two horizontal resolutions for each climate model are considered. Besides, the impact of boundary conditions, i.e. observed ocean surface state, is examined by considering both coupled and atmosphere-only configurations.

In the present work, the north Atlantic region is analyzed as a sample region.

The main focus of this analysis is on the impact of resolution on TCs' ability in representing water transport.

Model
CMCC-CM2-HR4 -> 1° Atm. and ¼° Ocean
CMCC-CM2-VHR4 -> ¼° Atm. and ¼° Ocean

Observation
IBTRACS + JRA55

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Methodology

Tropical cyclones Tracks

- TCs tracks are needed to evaluate moisture transport associated to TCs:

  Models → Track Algorithmn TRACK (Hodges, 2017)

  Observations → Best track (IBTRACS)

Integrated water vapor transport

- Specific Humidity (q), zonal (u) and meridional (v) wind components are used to compute the integrated water vapor transport (IVT). Observation data are taken from JRA55.

$$IVT = \sqrt{\left(\frac{1}{g}\int_{1000}^{250} qu\, dp\right)^2 + \left(\frac{1}{g}\int_{1000}^{250} qv\, dp\right)^2}$$

IVT computation starting from Lavers et al. (2012).

$$IMVT = \left(\frac{1}{g}\int_{1000}^{250} qv\, dp\right)$$

IMVT accounts for the meridional component of the water transport.

Note: Variables are discretized over seven pressure levels (7plev).

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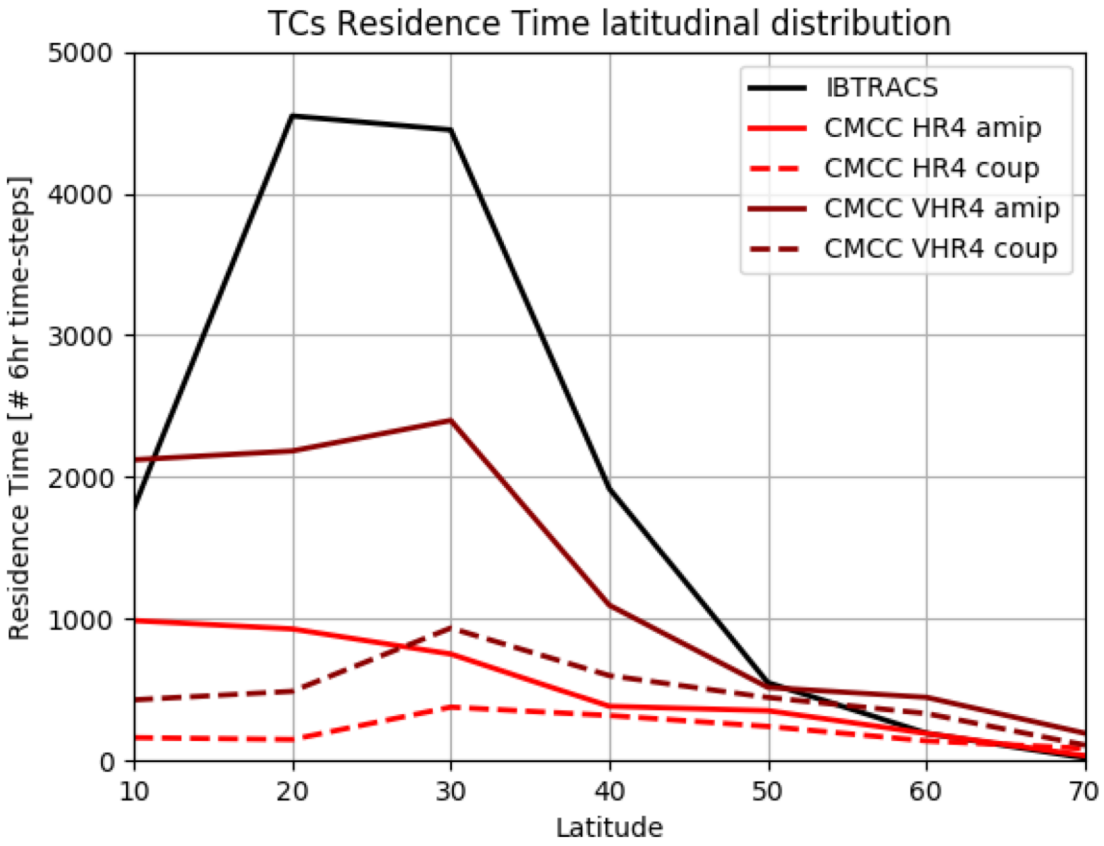
Lavers et al. (2012), The detection of atmospheric rivers in atmospheric reanalyses and their links to British winter floods and the large-scale climatic circulation, *J. Geophys. Res.*

Results – TCs residence time



Along the TCs tracks it is possible to evaluate the latitudinal distribution of TCs Residence Time.

IBTRACS exhibit the maximum of TCs residence time between 15 and 35 degrees North.

CMCC-CM2-VHR4 exhibit better results than CMCC-CM2-HR4

Independently from resolution, CMCC-CM2 Atmosphere-only simulations lead to distributions closer to the observed one compared to CMCC-CM2 coupled simulations.

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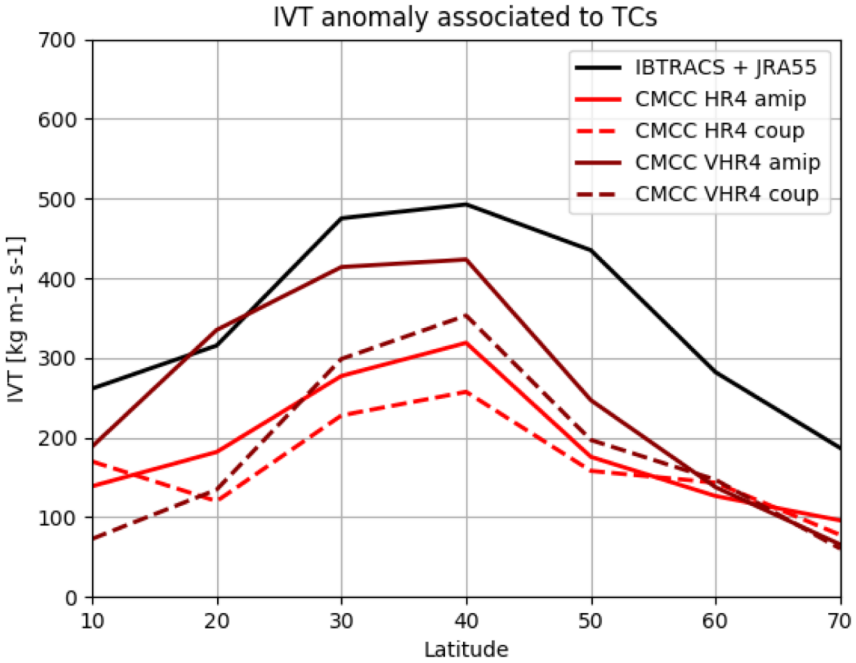
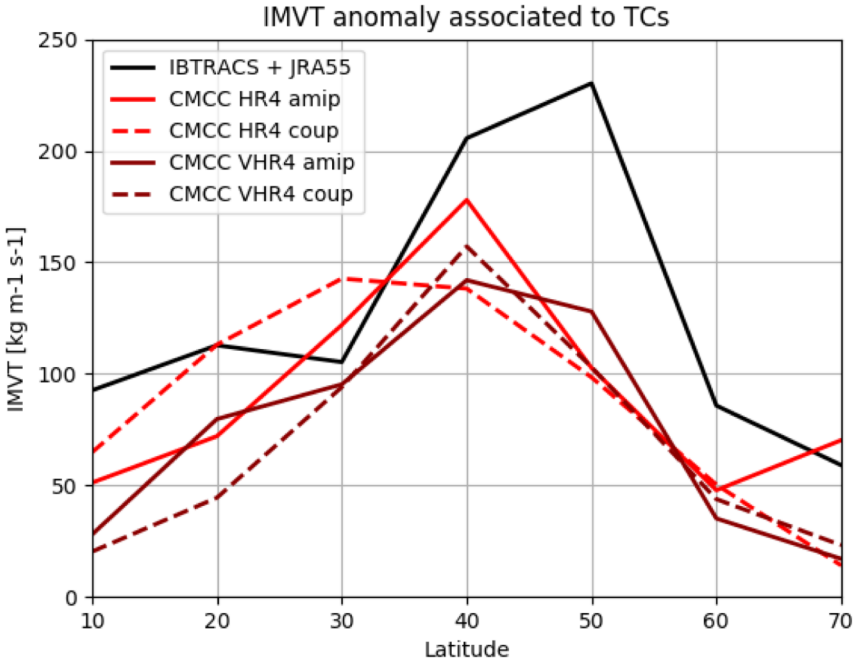
Results – Integrated water vapor transport





- Observed maximum anomaly in IVT occur between 25 and 55°N;
- CMCC-CM2 captures the peak at 40°N;
- CMCC-CM2-VHR4 exhibit results closer to observation than CMCC-CM2-HR4;
- AMIP simulations are better than coupled ones.

- Observed maximum anomaly in IMVT occur between 35 and 55°N;
- CMCC-CM2 exhibits a southern peak in IMVT;
- CMCC-CM2-VHR4 exhibit better distribution than CMCC-CM2-HR4;
- AMIP simulations are better than coupled ones.

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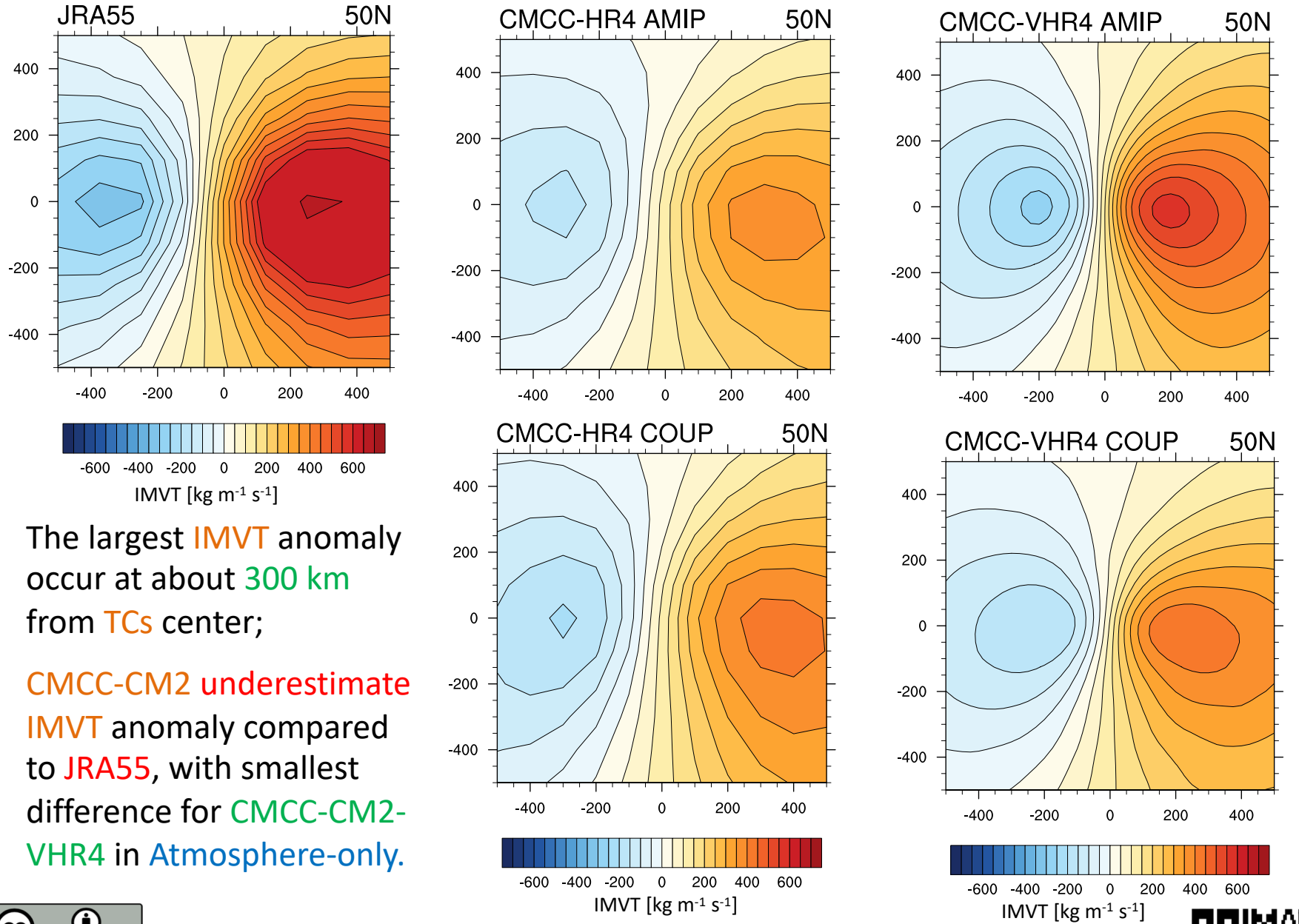
Results – Meridional water vapor transport



The largest IMVT anomaly occur at about 300 km from TCs center;

CMCC-CM2 underestimate IMVT anomaly compared to JRA55, with smallest difference for CMCC-CM2-VHR4 in Atmosphere-only.

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Conclusions

- Increase in resolution lead to improved representation of the latitudinal distribution of TCs Residence Time over the North Atlantic region;
- The use of observed ocean surface state help in better reproduce the TCs Residence Time latitudinal distribution;
- Similarly, atmosphere-only and high resolution model (e.g CMCC-CM2-VHR4 AMIP) exhibits better representation of moisture transport associated to TCs in both IVT and IMVT;
- Generally, CMCC-CM2 model simulate a southern peak of IMVT anomaly compared to observed IMVT anomalies;
- Focusing on IMVT at 45-55°N (observed maximum IMVT anomaly latitudinal band) both observation and CMCC-CM2 model show the maximum of IMVT anomaly associated to TCs at about 300km from TCs center;
- Northward transport associated to TCs at 50°N is higher than southern one;
- Generally, CMCC-CM2 underestimate observed IMVT anomaly.
- Outlook: other GCMs will be added in this analysis to obtain a multi-model analysis.

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