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Influence of ocean-atmosphere coupling *and resolution on typhoons* in the CORDEX Southeast Asia domain

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Motivation

Challenges of atmosphere-only global circulation models especially over the tropics:

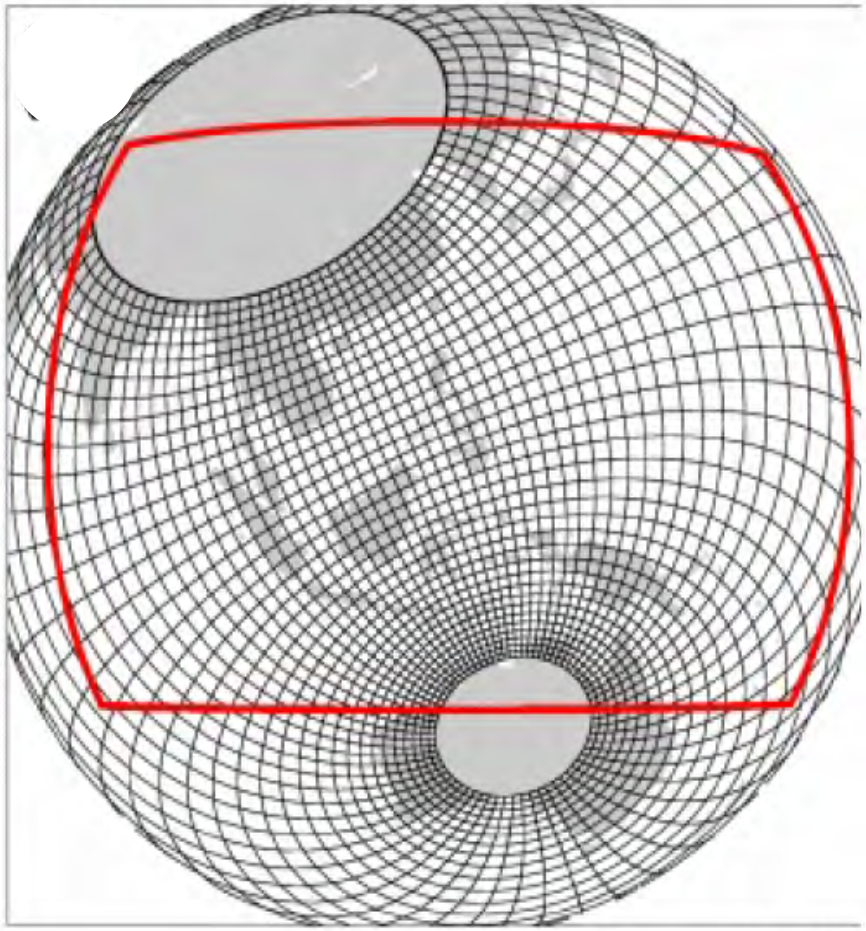
- Overestimation of tropical cyclone tracks and intensity e.g. in Northwest Pacific (Manganello et al., 2012)
  - studies on tropical cyclones need to have sufficient resolution to simulate its intensity and structure

Possible solution: modelling system using a global ocean coupled with a regional atmosphere model (Sein et al, 2015: North Atlantic Ocean impacts on the North Atlantic and European climate)

Research Questions:

- Does a **coupled ocean-atmosphere modelling system** improve the uncoupled climate simulations?
  - What are the **climate impacts** (including in **typhoon activities**) of increasing the **resolution** from ~50 km to 25 km?

Methods: REMO – OASIS – MPIOM (ROM)



Sein et al, 2015

MPIOM grid (every 12th grid line is shown)

REMO setup

MPIOM (Marsland, et al., 2002):

- Horizontal resolution: ~10-30 km in coupled area, ~100 – 130 km in far grid points
- Vertical resolution: 40 levels

REMO (Jacob, 2001):

- Horizontal resolution: ~50 and ~25 km
- Vertical resolution: **27 hybrid levels**

Coupling via **OASIS** (Valcke et al., 2003): 1 hr

Experiments driven by ERA-Interim Reanalysis, 1980-2012

1. uncoupled: REMO with prescribed SSTs
   → REMO_50 and ROM_50
2. coupled: ROM
   → REMO_25 and ROM_25

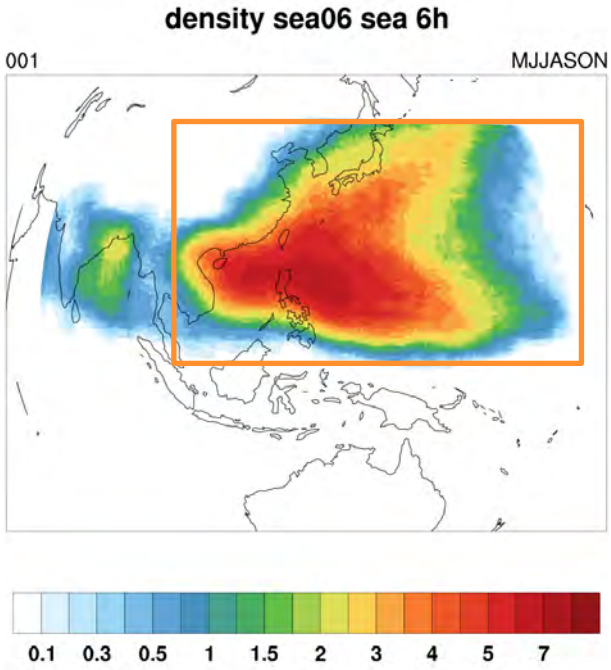
~50 km: CORDEX-EA, **3-hourly output**

~25 km: CORDEX-SEA, **hourly output**

Observational and reanalysis datasets: (1983-2012)

- GPCP, TRMM, ERA-Interim

Methods: TRACK



Mean track densities of tropical storms as number density per season per unit area equivalent to a 5°spherical cap for IBTrACS during MJJASON, 1983-2012

TRACK Algorithm (Hodges, 1994):

- identifies and tracks storms that are identified explicitly in the model data using an objective feature-tracking methodology
- derives statistical diagnostic fields such as track genesis, density

TC Identification criteria:

1. Surface wind speed threshold
2. Difference in vorticity between 850 and 200 hPa (a warm core condition)
3. Vorticity max at each level between 850 and 250 hPA (a coherent vertical structure condition)

TRACK Algorithm can track tropical storms with wind speeds ≥ 17 m/s

→ For typhoon studies: ≥33 m/s

→ IBTrACS – International Best Track Archive for Climate Stewardship (1983-2012)

→ Typhoon season: MJJASON

Focus on the **Northwestern Pacific Region**

→ Lon: 99° to 187 °

→ Lat: -5 ° to 50 °

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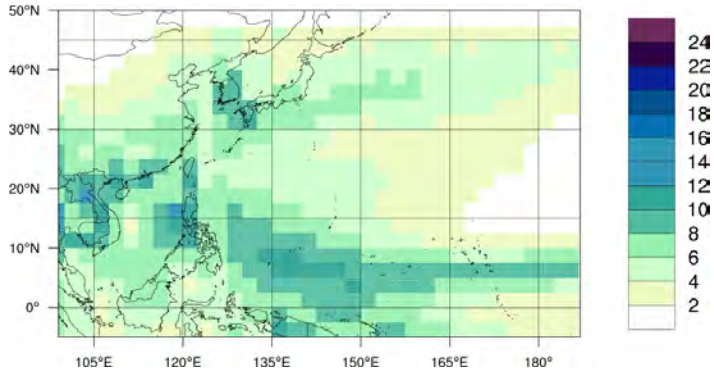
Model evaluation: impacts of coupling

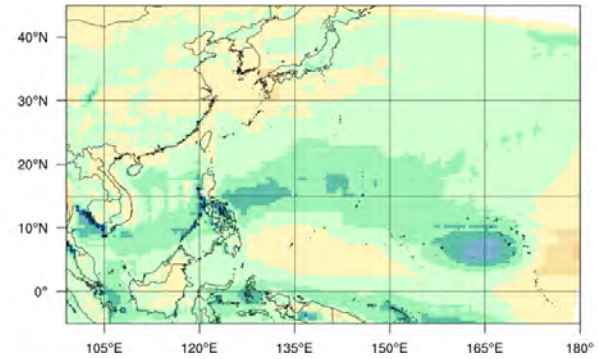
OBS JJA PRECIPITATION (mm/day)

GPCP 0.5 (30years)

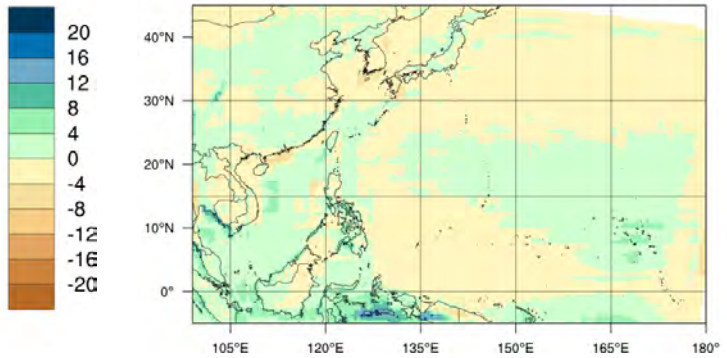


MODEL BIAS (mm/day)

REMO50 – GPCP



ROM50 – GPCP

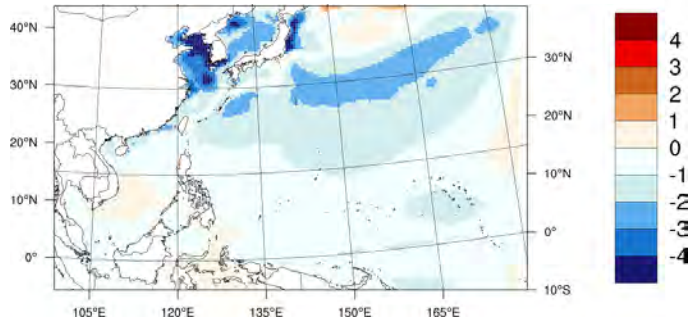


Regions of observed precipitation maxima can be identified

- → REMO is wetter than GPCP with biases of 12-16 mm/day
- → ROM reduces the wet bias of REMO in the Pacific by about 2-6 mm/day (about 20-40%) and tends to be dry in some areas
- → due to the coupling of atmosphere and ocean (exchange of water and atmosphere fluxes), SSTs are lower in ROM than in REMO by up to 4 K

SST MODEL DIFF *(K)*

ROM50 – REMO50



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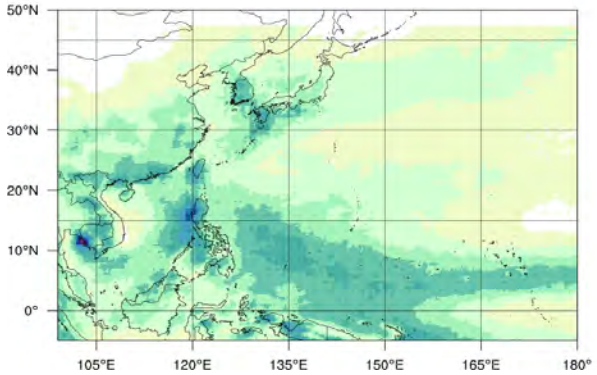
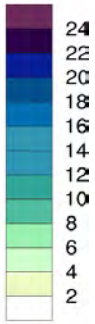
Model evaluation: impacts of coupling and resolution

OBS JJA PRECIPITATION (mm/day)

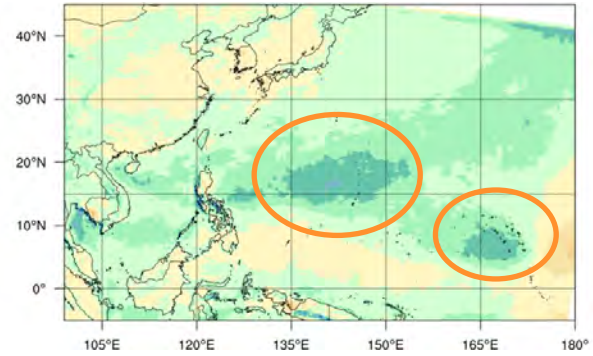
TRMM0.25 (11years)

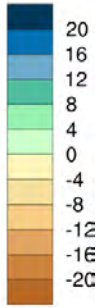




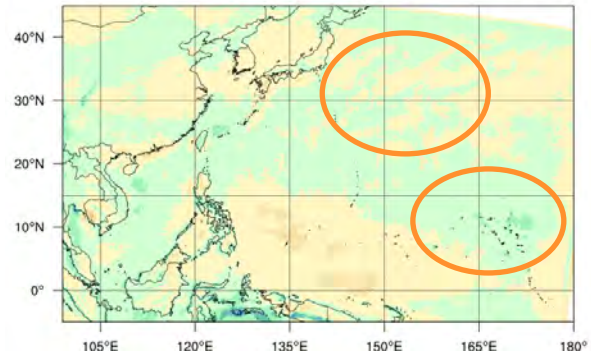
MODEL BIAS (mm/day)

REMO25 – TRMM





ROM25 – TRMM

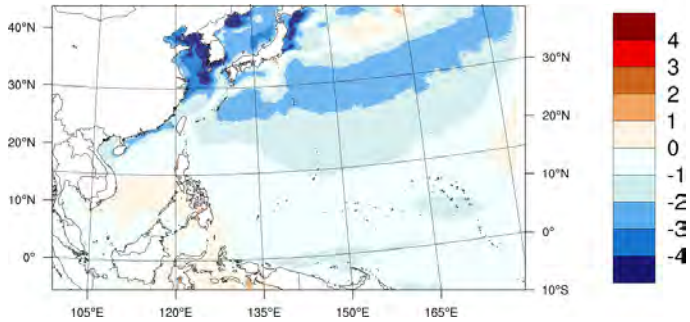


Similar regions of observed precipitation maxima

- → slight changes in wet bias in REMO25 compared to REMO50
- → ROM reduces the wet bias of REMO25 in the Pacific and less dry bias compared to REMO50
- → differences in SSTs are similar at both resolutions
- → Impacts of resolution are not drastic due to observational data limitation at high resolution

SST MODEL DIFF *(K)*

ROM25 – REMO25



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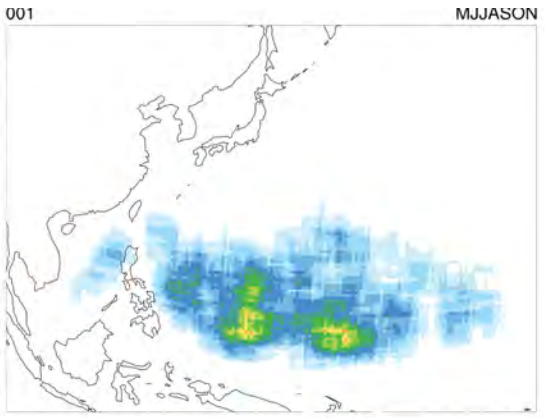
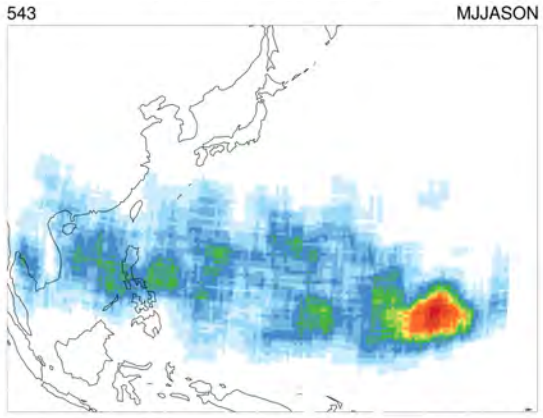
Track genesis during MJJASON 1983-2012

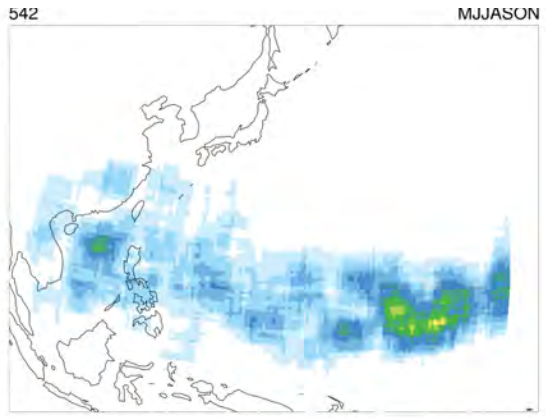
IBTrACS

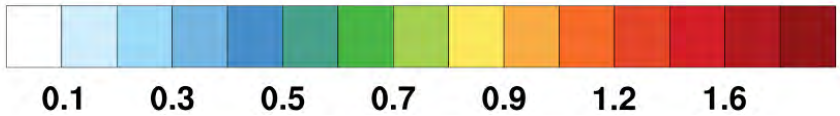


REMO_50



ROM_50



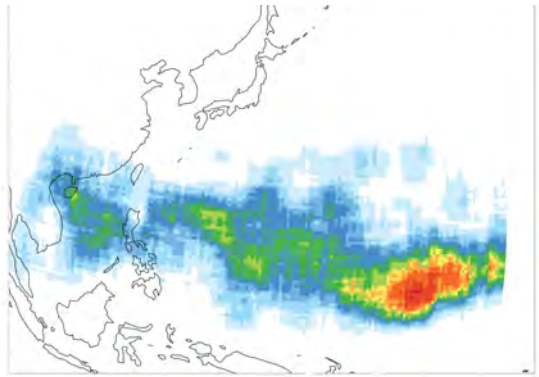


Mean genesis per month

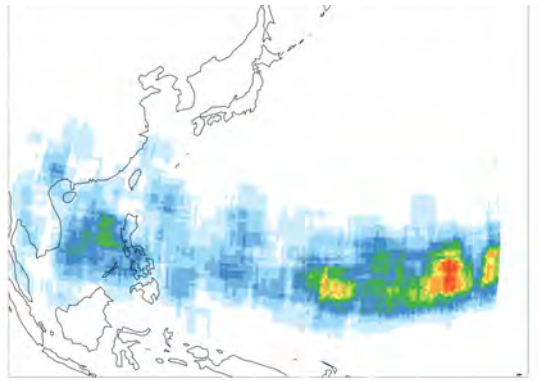
Identify regions of cyclogenesis

- → Due to coupling, lower number of typhoons are generated further east in ROM than REMO
- → With higher resolution and output frequency, higher number of typhoons are generated further east at 25 km than 50 km

REMO_25



ROM_25



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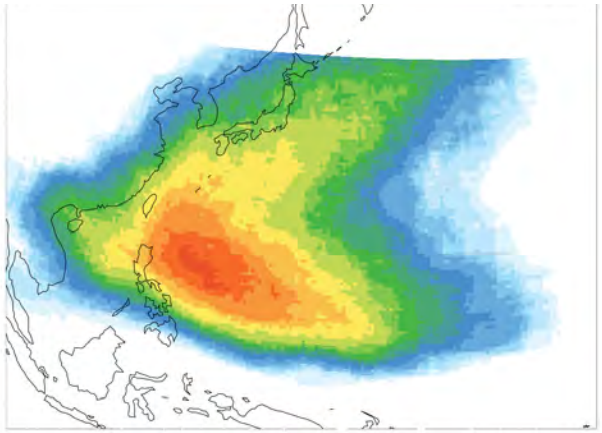
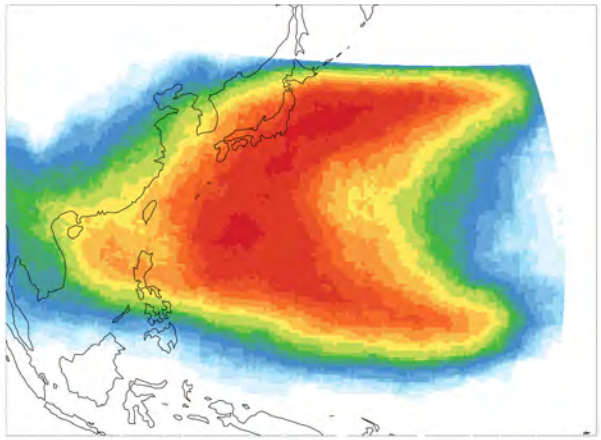
Track densities during MJJASON 1983-2012

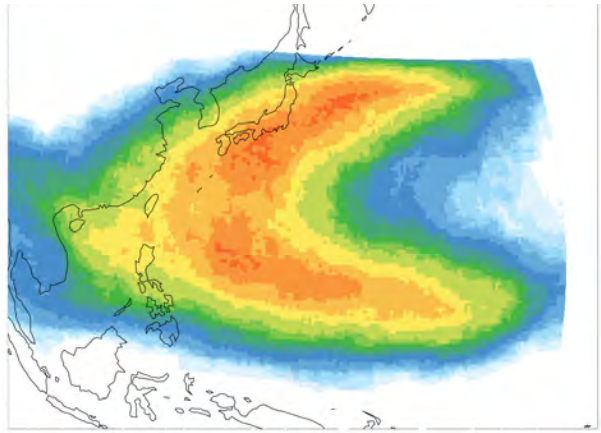
IBTrACS

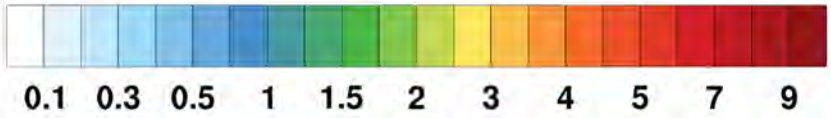


REMO_50



ROM_50



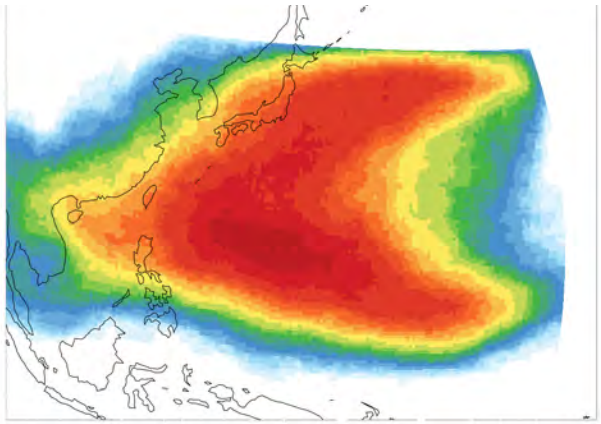


Mean density per month

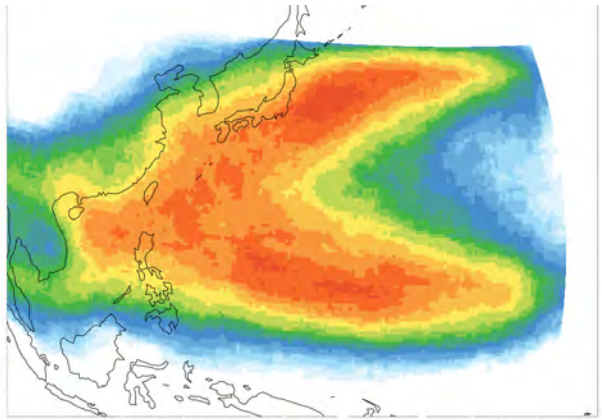
Identify regions of typhoon occurrences

- → Due to coupling, lower number of typhoons are detected in ROM than REMO
- → With higher resolution and output frequency, higher number of typhoons are detected at 25 km than 50 km

REMO_25



ROM_25



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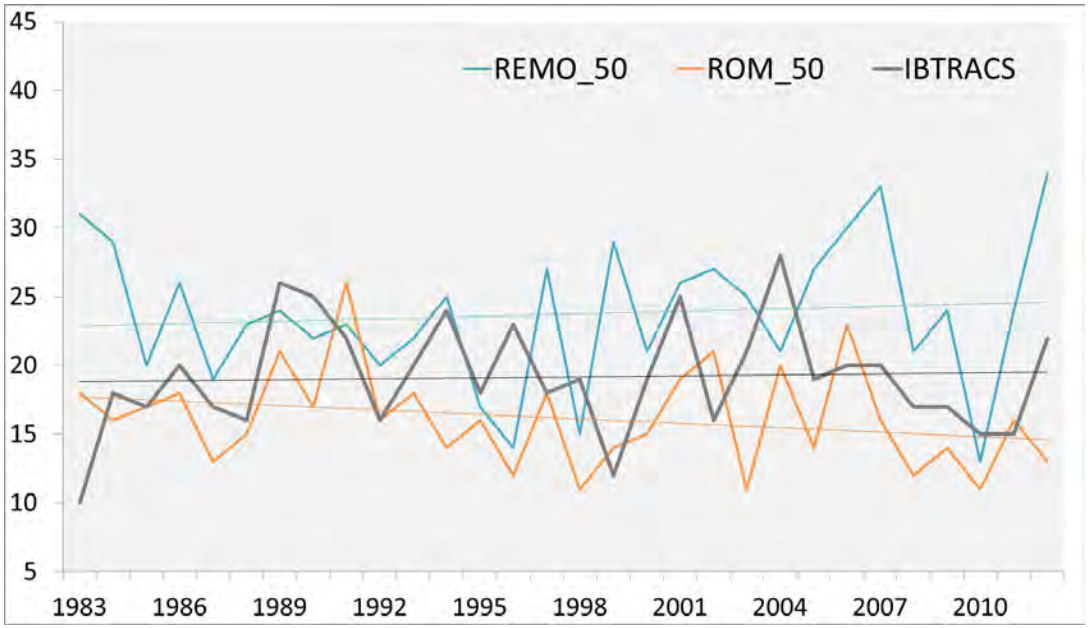
Typhoons: impacts of coupling



Time series of typhoons in the NWP Region (MJJASON, 1983-2012)

- ROM lower typhoon frequency than REMO
  → similar to IBTrACS

MJJASON	IBTRACS	REMO_50	ROM_50
output	6-hr	3-hr	3-hr
Total typhoon frequency (mean)	536 (17.9)	712 (23.7)	485 (16.2)
Mean wind intensity (m/s)	49	43	42

- Simulated mean wind intensity at 50 km is lower than the observed

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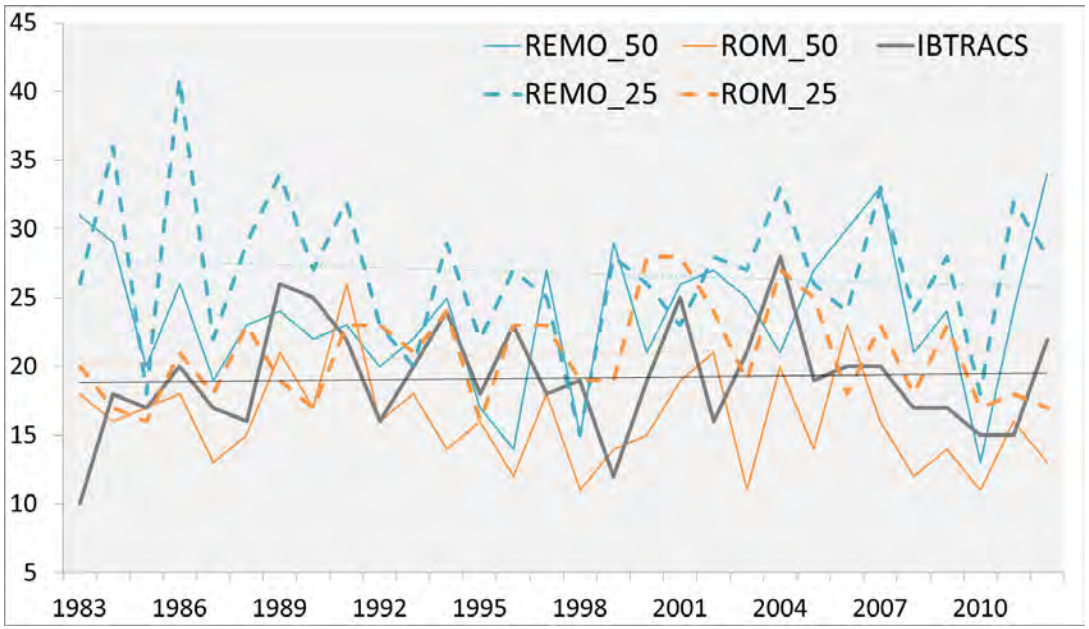
Typhoons: impacts of coupling and resolution



Time series of typhoons in the NWP Region (MJJASON, 1983-2012)

- ROM lower typhoon frequency than REMO
  - → similar to IBTrACS
- Simulations at 25 km have slightly higher frequency of typhoons than 50 km

MJJASON	IBTRACS	REMO_50	ROM_50	REMO_25	ROM_25
output	6-hr	3-hr	3-hr	1hr	1hr
Total typhoon frequency (mean)	536 (17.9)	712 (23.7)	485 (16.2)	804 (26.8)	627 (20.9)
Mean wind intensity (m/s)	49	43	42	51	48

- Simulated mean wind intensity at 50 km is lower than the observed
- Simulated mean wind intensity at 25 km is higher than at 50 km
  - → Comparable to IBTrACS

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Conclusions

- Impacts of ocean-atmosphere coupling and resolution on climate:
  - ROM have lower SSTs compared to REMO → inhibits convection → lower precipitation → lower wet bias over the ocean
  - Similar biases over the ocean were depicted at higher resolution → but limitation of available observational datasets (land and ocean)
- Impacts of coupling and resolution on typhoons:
  - Typhoon track genesis and densities in all the models were higher than the observed but ROM tends to have lower values than REMO
  - Simulated frequency of typhoons in ROM were similar to the observed values than REMO
  - Simulated mean typhoon intensities were comparable at 25 km to the observed than at 50 km

Next steps:

→ Increase the vertical levels at high resolution

→ ROM could be used for investigating the changes in tropical cyclones in global warming scenarios

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Tack!

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