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Predicting and understanding African climate drivers using the HadGEM3 modelling system

Wilfran Moufouma-Okia

CORDEX conference, Trieste, Italy, 24 March 2011

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Outline

- Strategy for “seamless” weather and climate predictions
- Performance of HadGEM3 global climate model
    - Impact of horizontal resolution
- Regional scale drivers of model errors
    - Evaluation of HadGEM3RA regional climate model
    - Sensitivity to model formulation and aerosols
- Conclusions

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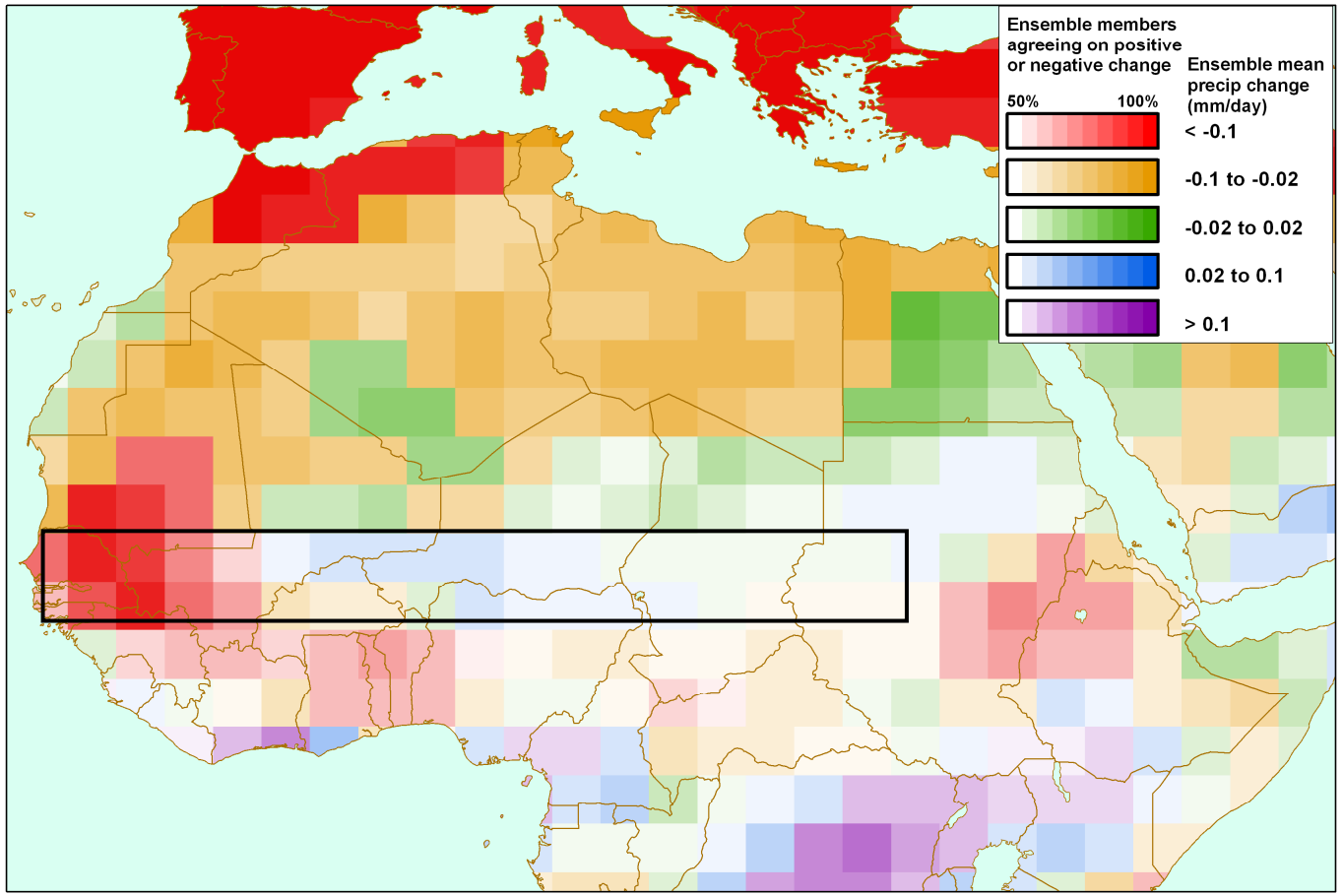
Context

Challenges for making decisions on mitigation and adaptation

- Uncertainty
- Resolution
- Complexity
- Timescale

Change in jja precipitation for ar4 ensemble (Difference)



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Strategy for seamless predictions

- To separate earth system from the physical model development

➢ **HadGEM2**: Quantify Earth System feedbacks and understanding the uncertainty related to Earth System processes

➢ **HadGEM3**: A new model that is 'fit' for purpose for application across 1-Day – Seasonal-Decadal-Centennial scales and for regional prediction.

- To exploit the Unified Modelling infrastructure towards a seamless-timescale prediction system (" we unify the Unified Model")
- To better measure improvements of model performance
- To explore the value of enhanced resolution

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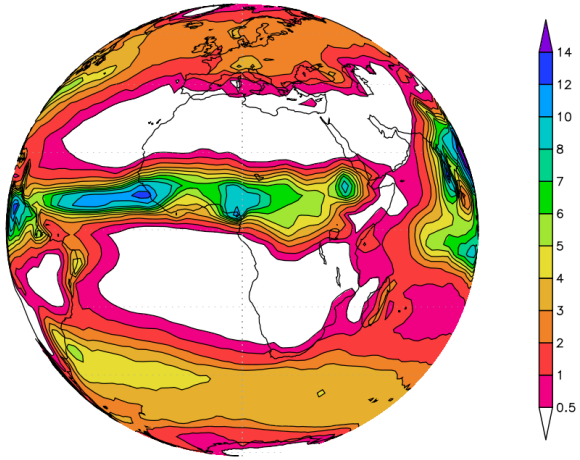
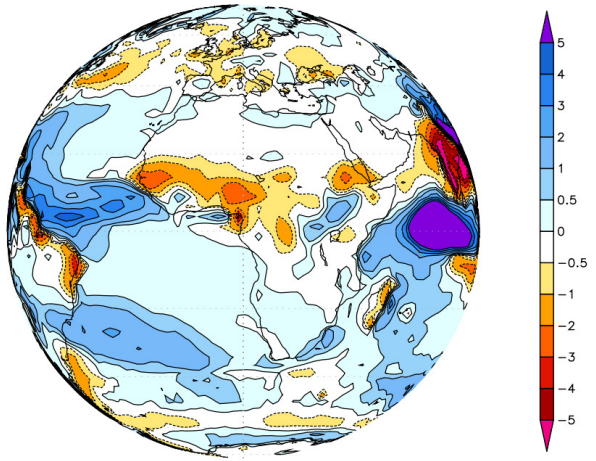
Rainfall systematic errors over Africa (JJA): Similarity between NWP and Climate

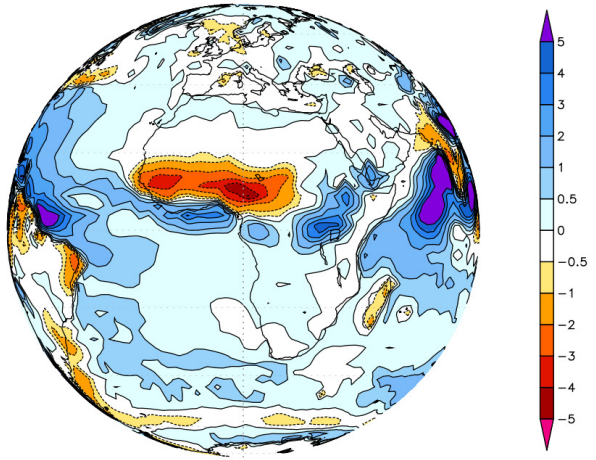
GPCP: 1992-2007



HadGEM2 - GPCP



NWP 1day - GPCP



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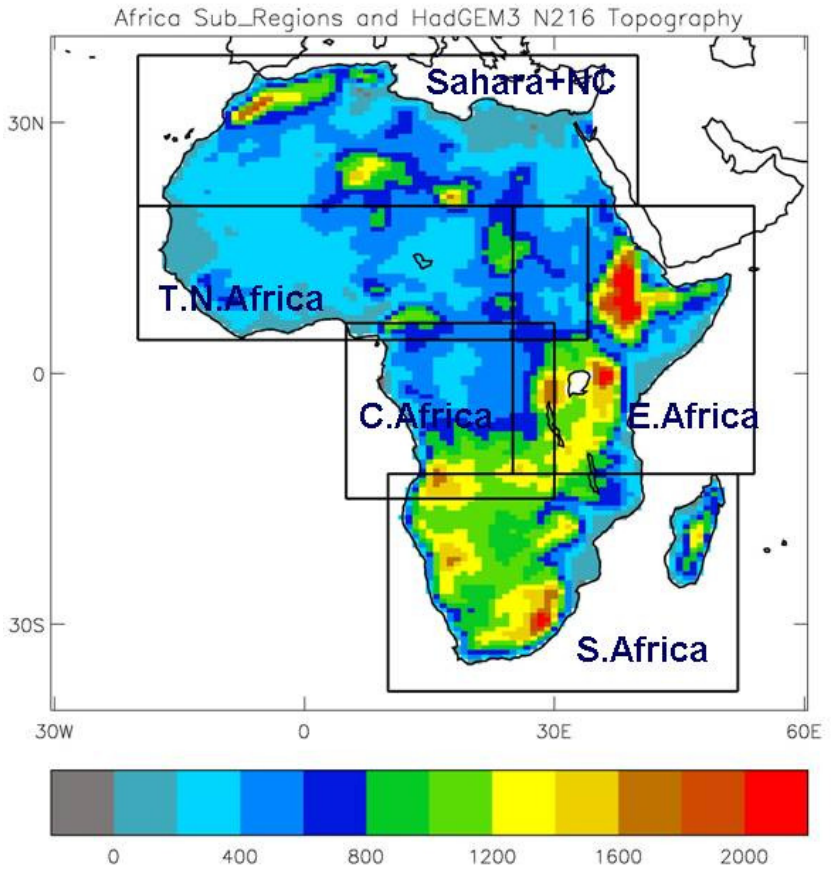
HadGEM3-Atmosphere only runs (1982-2008)

Model configuration:

- Non-hydrostatic, semi-Lagrangian advection
- 85 vertical levels (**85km**)
- Horizontal resolutions: **135km, 60km, 40km**
- Interactive aerosols: dust Dust443, Sulphur Cycle, Soot (Black Carbon), Biomass smoke, Sea-salt
- Land surface: **JULES**
- River routing
- New large scale hydrology (wetlands)
- **Prognostic cloud PC2**
- Smoothed forced detrainment
- Critical water content a function of cloud depth
- New termination condition for shallow convection
- Switch off ocean TKE scheme
- W-based CAPE
- Van Genuchten soil hydrology
- **Daily SST (Reynolds)…etc**



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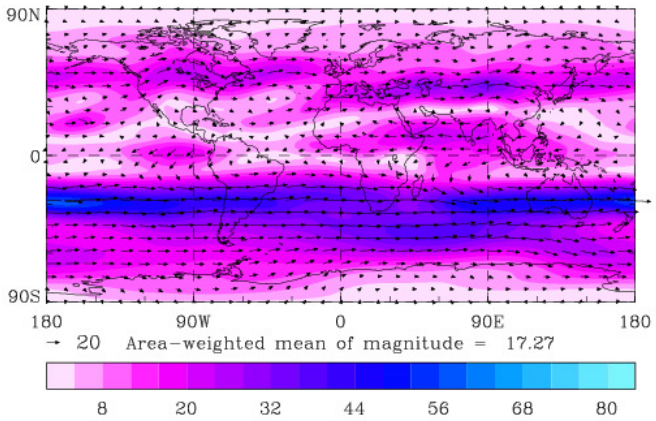
Climatology of 1989-2000 mean seasonal June-August (JJA) wind at 200hPa (m/s)

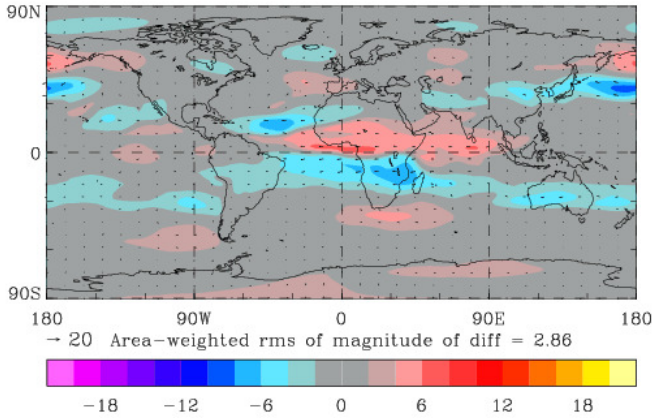
TEJ increases with resolution

Reduced biases over Africa

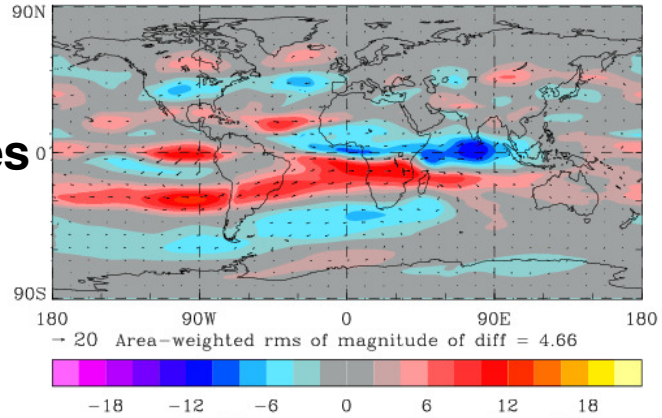
HadGEM3 N320 (~40km)



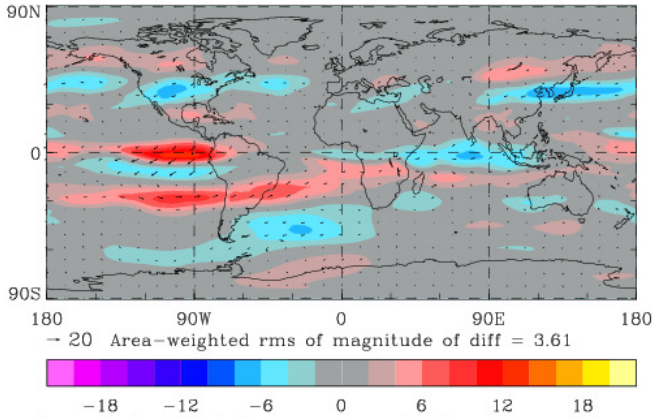
N320 minus N96 (~135km)



N96 (~135km) minus ERAINT



N320 (~40km) minus ERAINT



In difference plots, colours show difference between the magnitudes of the two vector fields.

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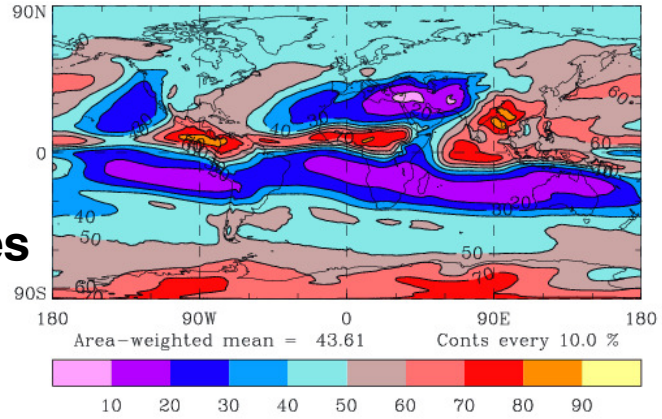
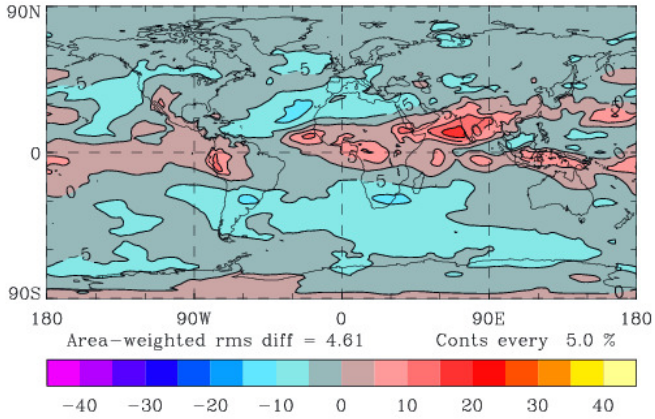
Climatology of 1989-2008 mean seasonal June-August (JJA) tropospheric humidity

Reduced biases in the tropics

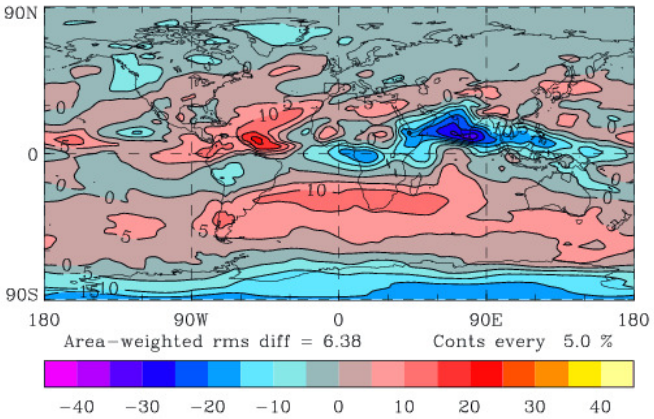
HadGEM3 N320 (~40km)



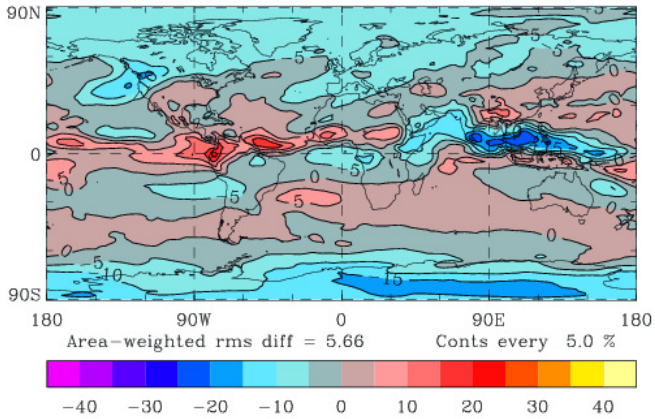
N320 minus N96 (~135km)



N96 (~135km) minus ERAINT



N320 (~40km) minus ERAINT



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Climatology of 1989-2000 mean seasonal June-August (JJA) precipitation (mm/d)

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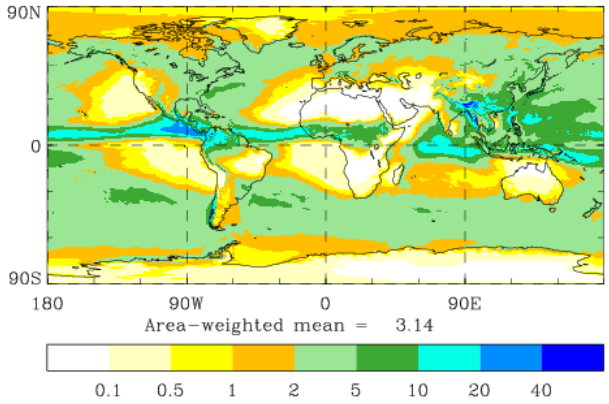
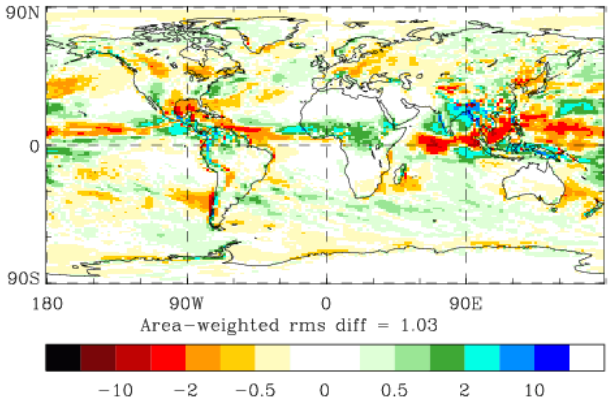
- **<u>Benefit:</u> Reduced biases in West Africa**
- **<u>Issue:</u> Increased wet bias in Central and Southern Africa**

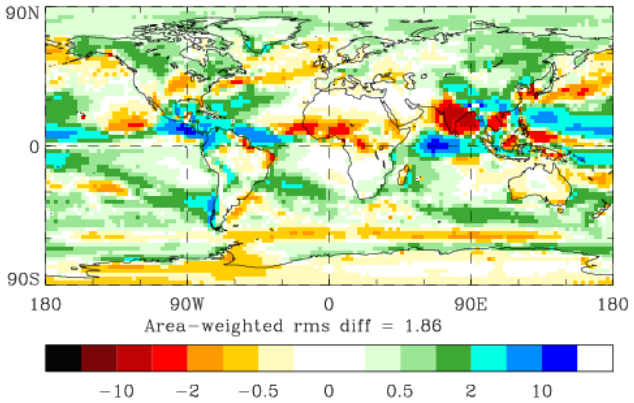
HadGEM3 N320 (~40km)



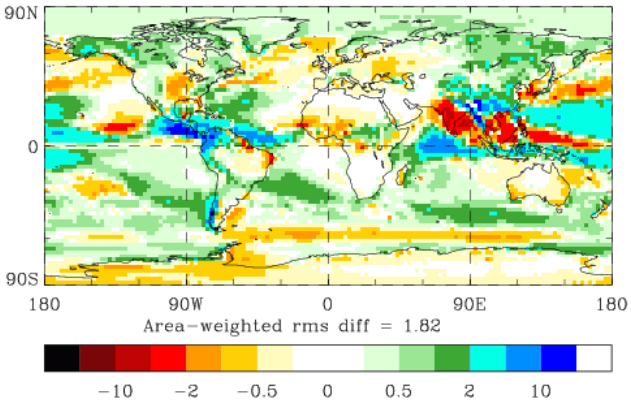
N320 minus N96 (~135km)



N96 (~135km) minus GPCP



N320 (~40km) minus GPCP



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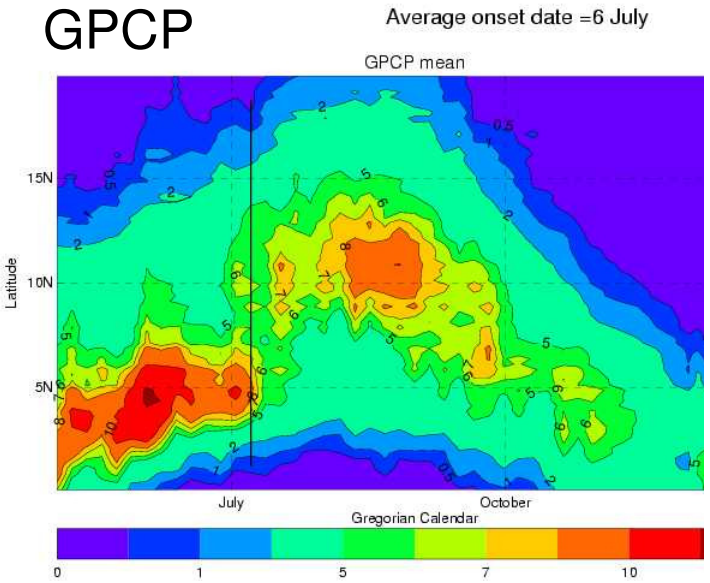
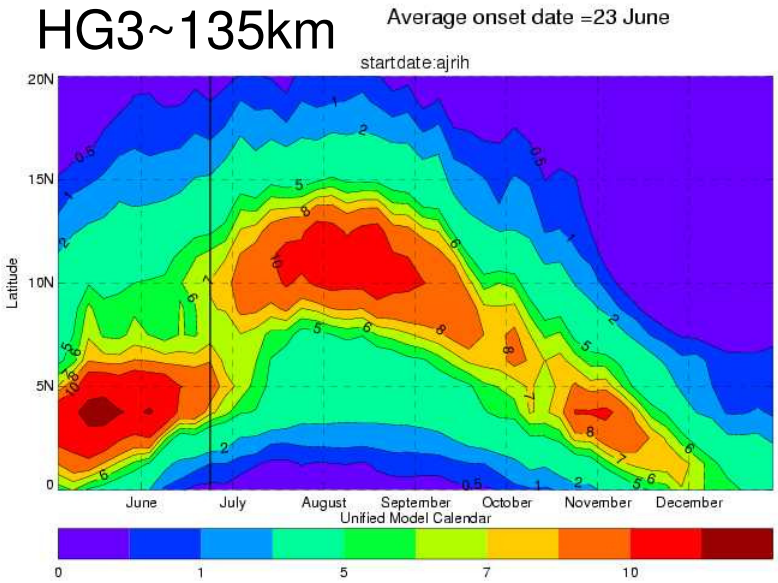
Onset for the West African Monsoon

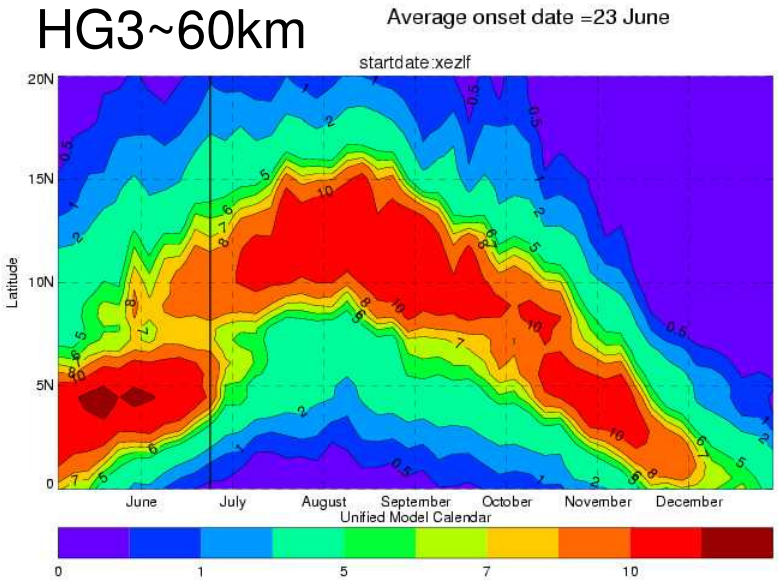
GPCP



HG3~135km



HG3~60km



Definition of Onset: Date at which the main precipitation area migrates north of 10°N (using temporally smoothed data averaged over 10°W-10°E)

ice

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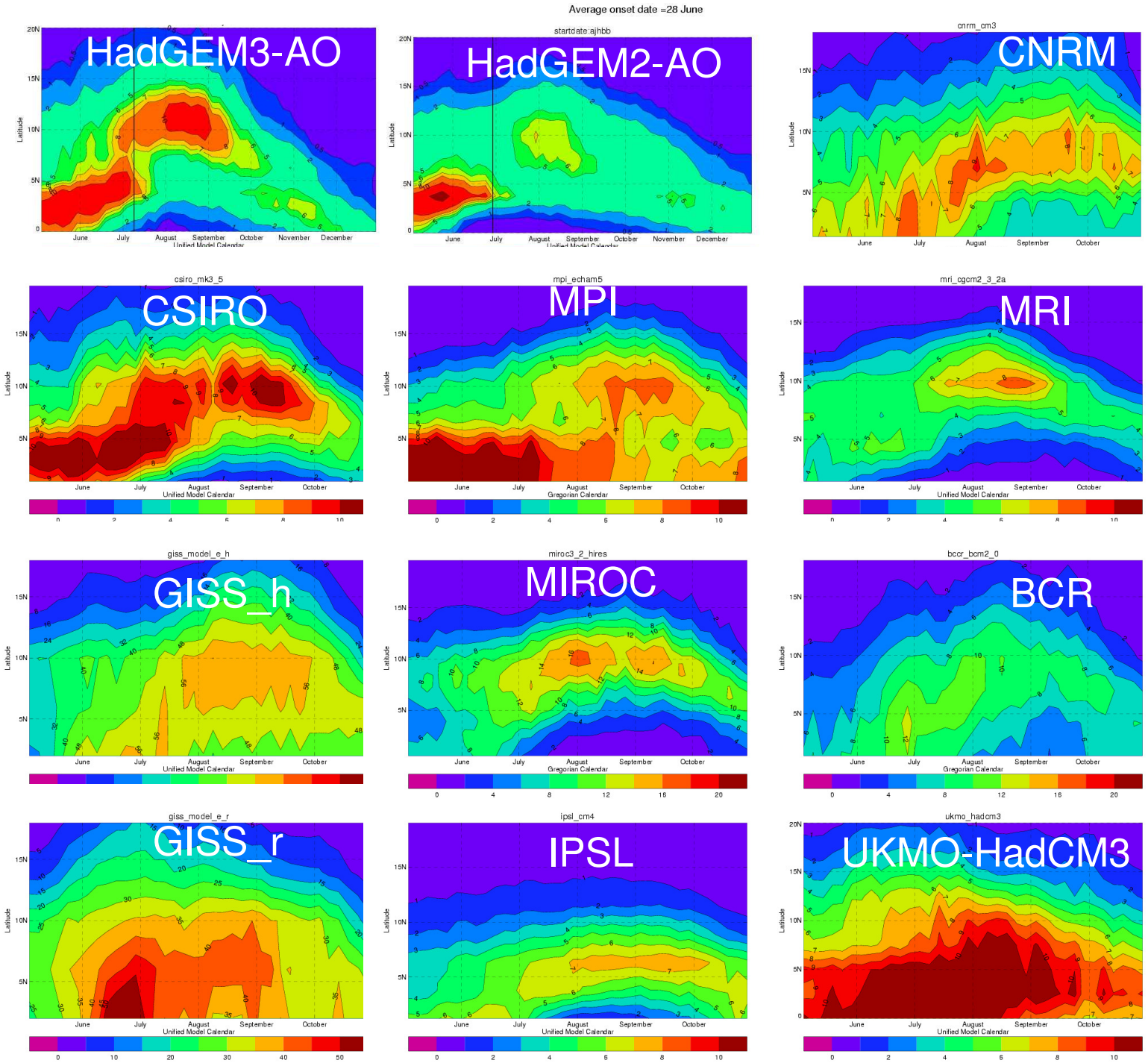
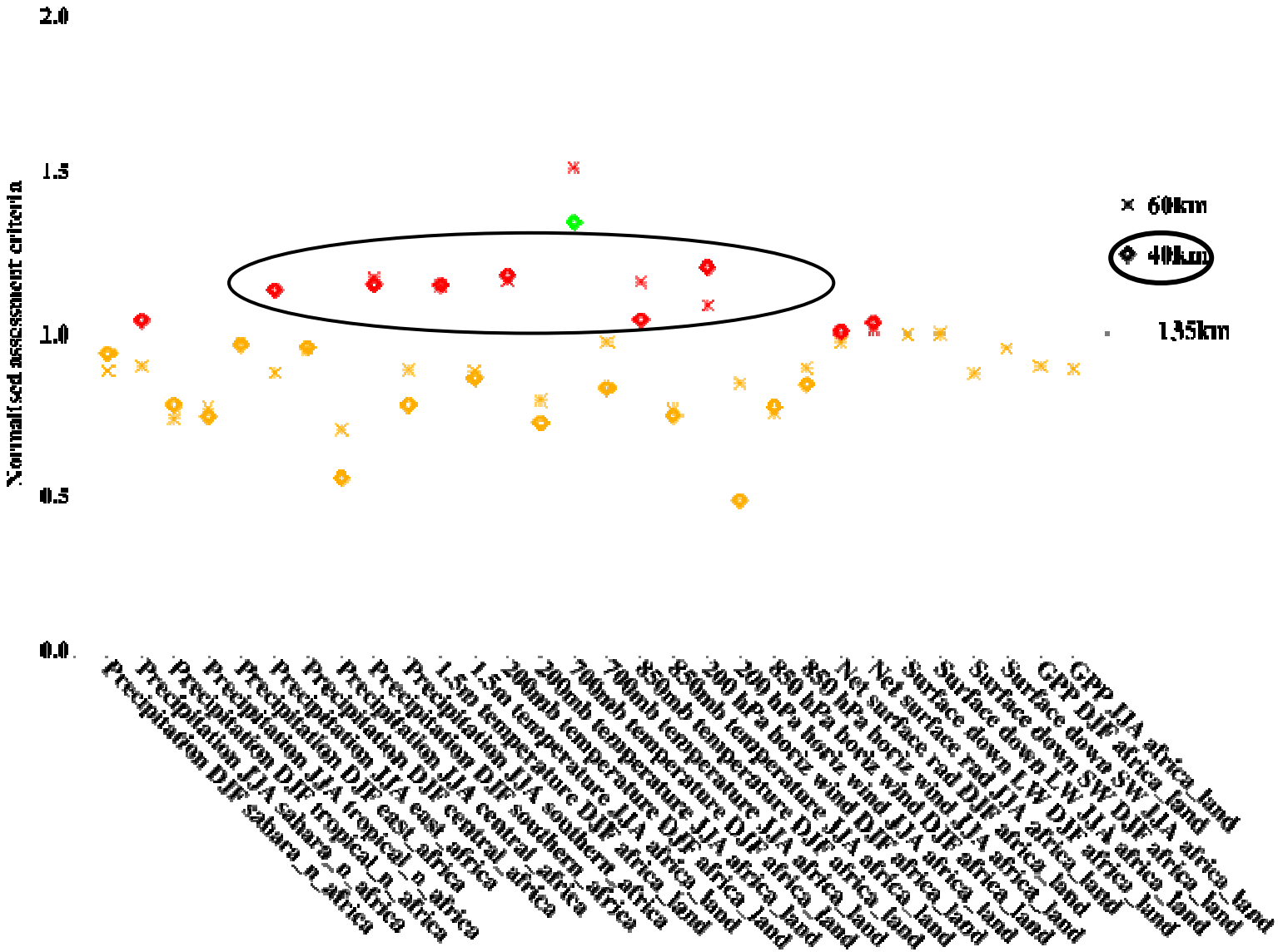
The abrupt monsoon jump is not apparent in most of the CMIP3 coupled AO models



Model assessment metric (versus HG3~135km)

$$\frac{RMSE_{HadGEM3}}{RMSE_{135km}}$$



worse, **better**, **within observational uncertainty**

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The HadGEM3RA regional climate model

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Model features:

- Non-hydrostatic, semi-Lagrangian and semi implicit
- Fully consistent with HadGEM3 physical formulation
- Land surface: Jules

Experiments with 50km grid spacing over CORDEX-Africa

1. CONTROL: HadGEM3RA with standard physics (**GA2R)**
2. Physics Change: HadGEM3RA with light rain package (**GA3R)**
3. Sensitivity to aerosols: GA2R + Aerosols climatology (**Aerosols**)
4. PRECIS + MOSES1 land surface: **PRECISM1**
5. PRECIS + MOSES2 land surface**: PRECISM2**

Integration period: **1989-2008** with Reynolds SST and ERAINTERIM

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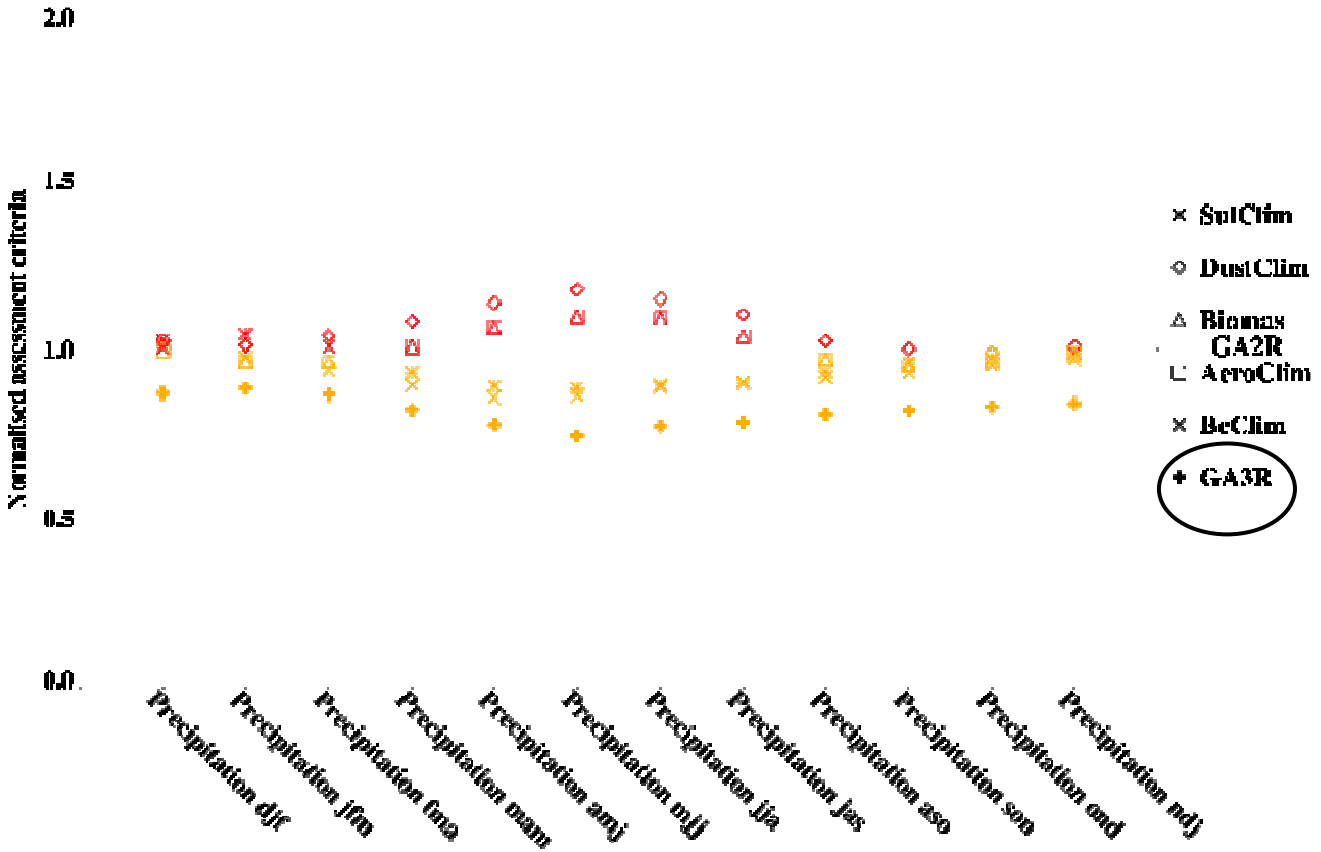
Impact of light rain package on precipitation

$$\frac{RMSE_{HadGEM3RA}}{RMSE_{GA2R}}$$



Root mean square errors of mean seasonal precipitation

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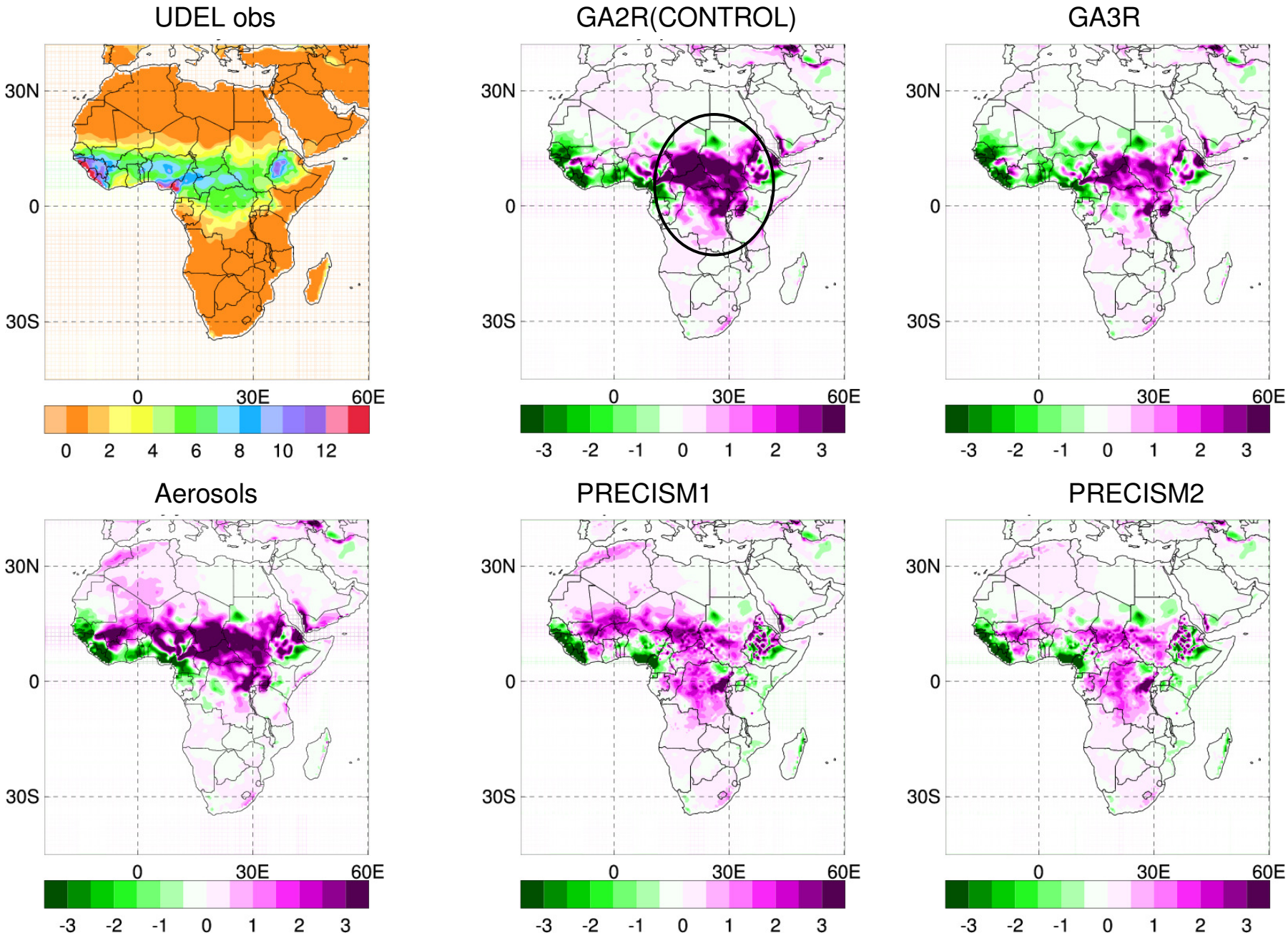

Averaged Precipitation errors (mm/d) in June-August 1991-2008

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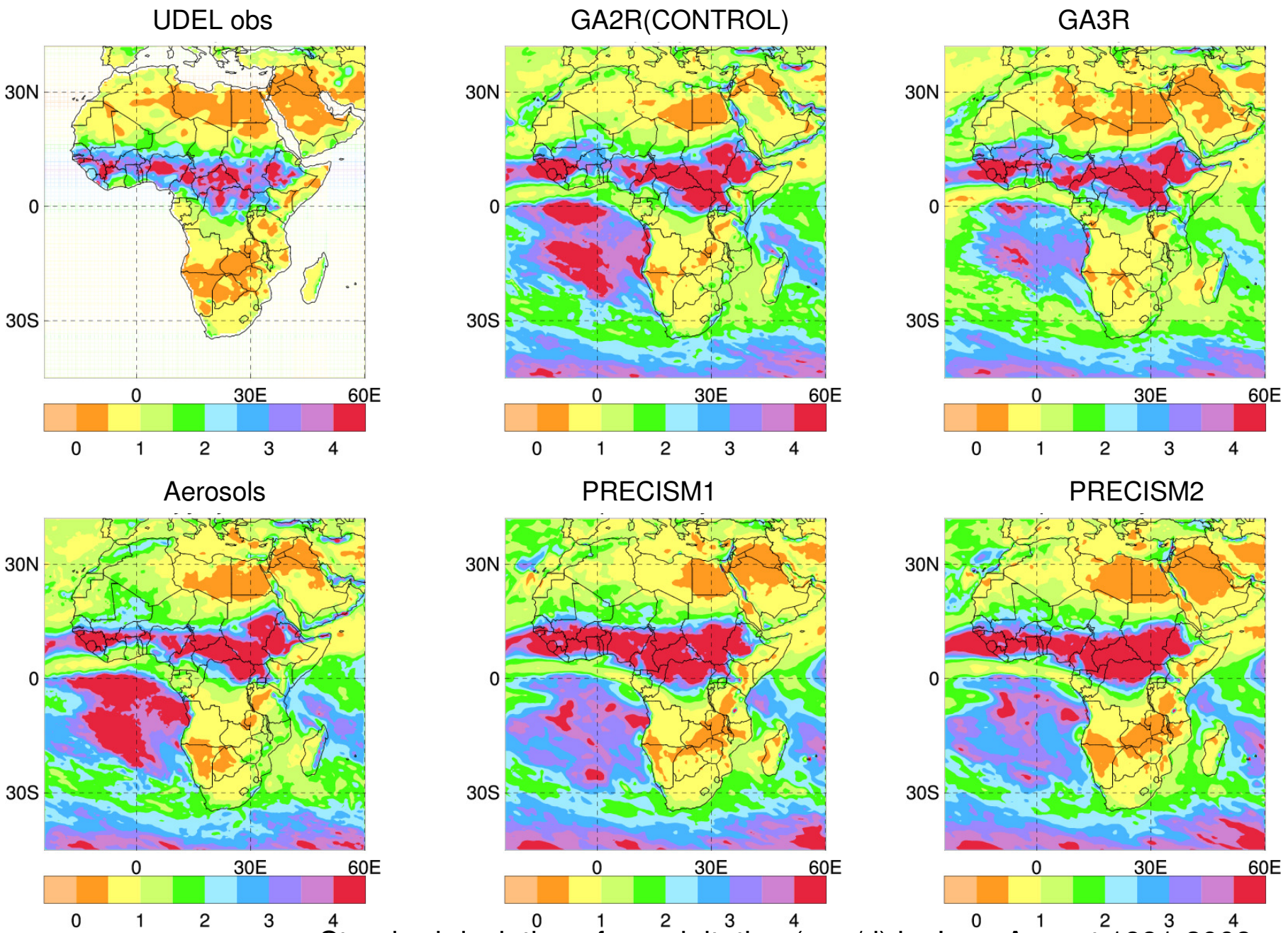

Standard deviation of precipitation (mm/d) in June-August 1991-2008

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Mean Annual cycle of monsoon circulations

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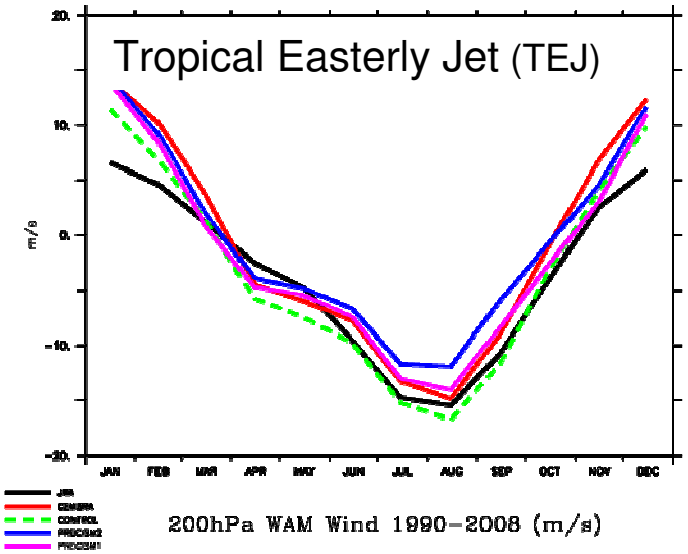
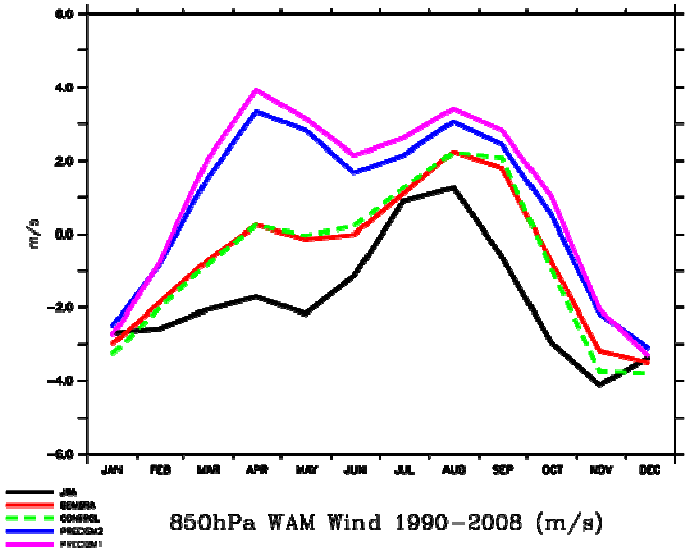
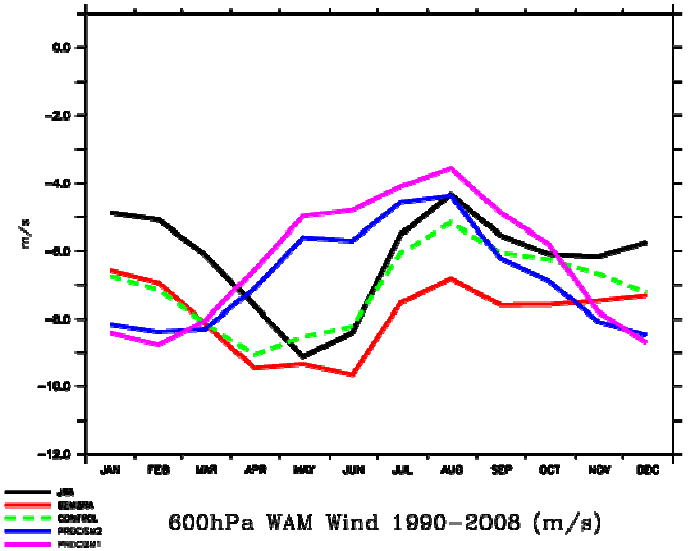
- Reanalysis
- GA2R (CONTROL)
- G3R (Light rain)
- PRECISM1
- PRECISM2



Monsoon flow



African Easterly Jet (AEJ)



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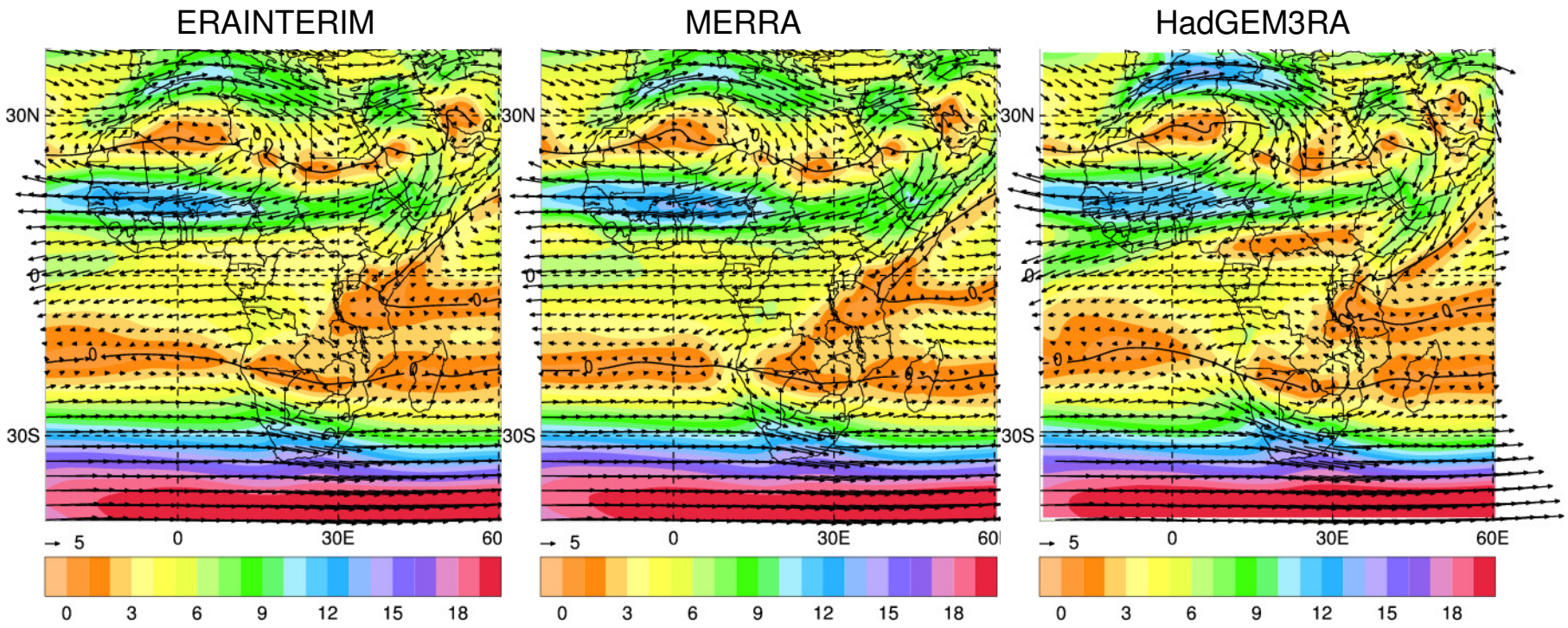
Spatial distribution of monsoon circulations

- HadGEM3-RA captures reasonably well the spatial distribution of 600hPa wind across the continent, despite the large size of the CORDEX-Africa domain



600hPa wind (m/s) in June-August 1991-2008

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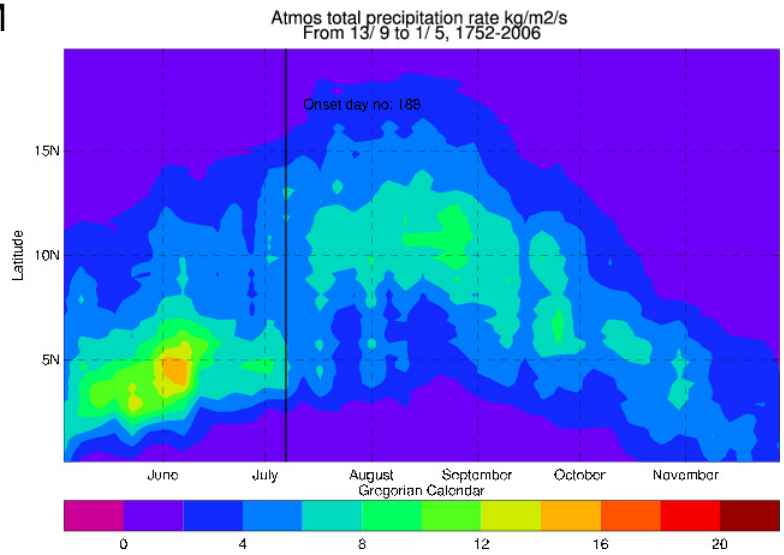
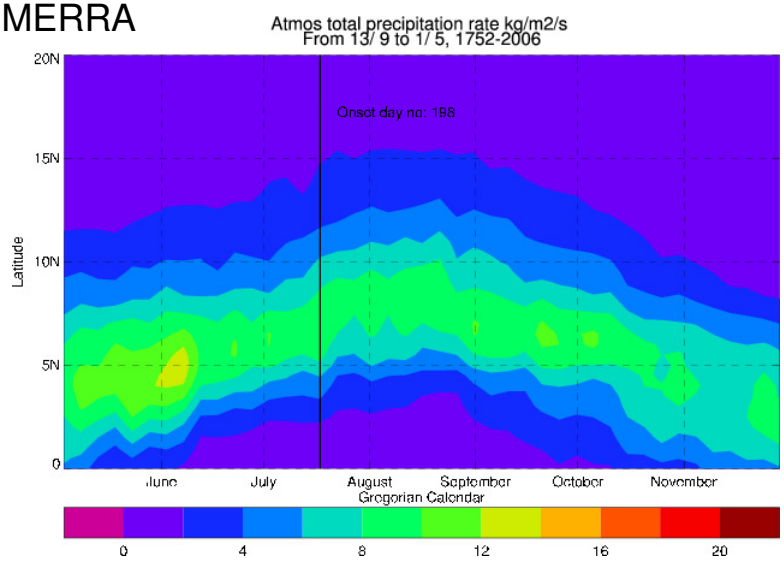
West African monsoon onset date

TRMM

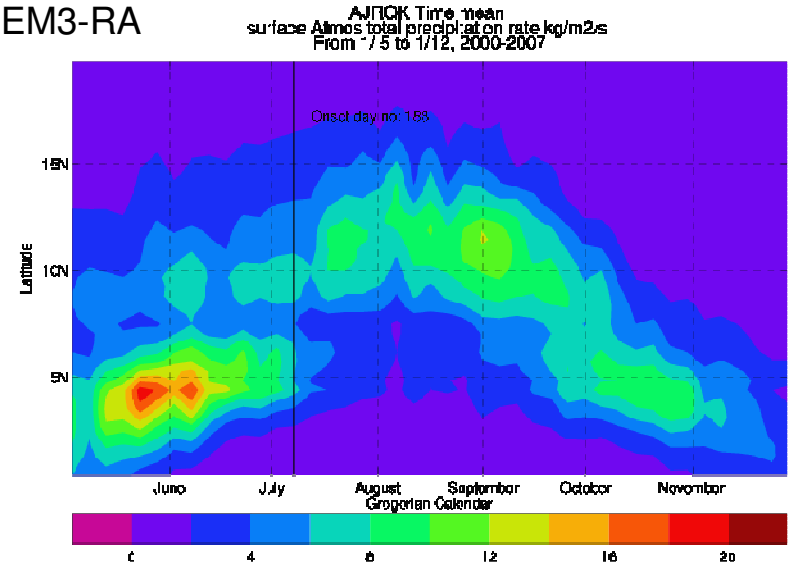


- HadGEM3-RA captures reasonably well the northward abrupt jump from 5°N to 10°N and the onset date in late June

MERRA



HadGEM3-RA



Time-latitude evolution of daily rainfall (mm/d) in 2001-2007, averaged over 10°W-10°E

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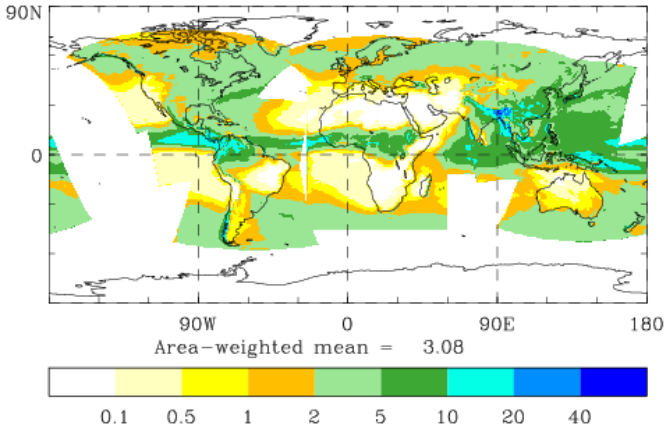
HadGEM3RA precipitation over 9 CORDEX regions (GA3R versus GA2R)

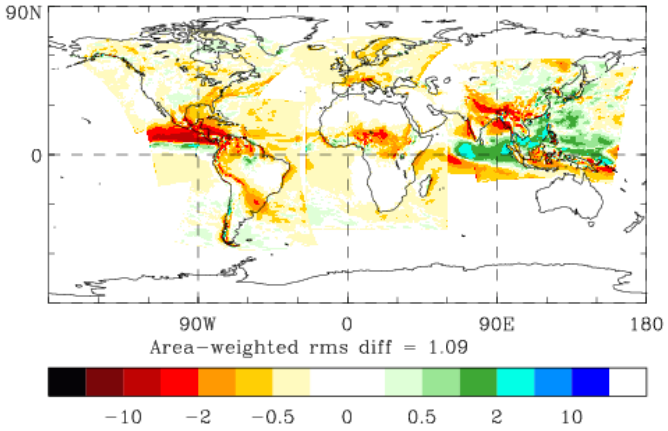
Decreased land precipitation (light rain package)

Reduced precipitation to the west of Central America (reduced deep convection)

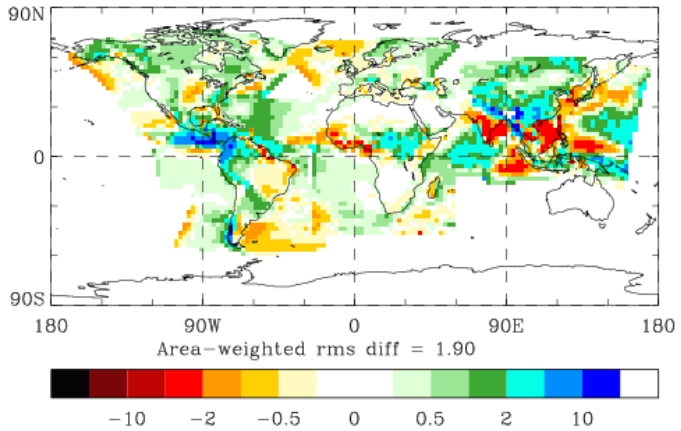
GA3R (Light rain package)



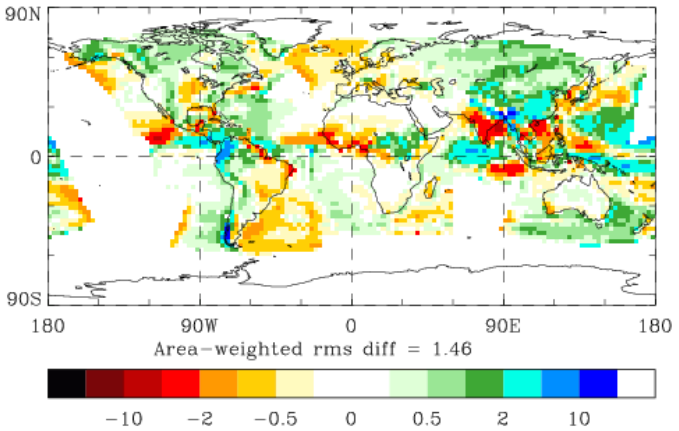
GA3R minus GA2R



GA2R minus GPCP



GA3R minus GPCP



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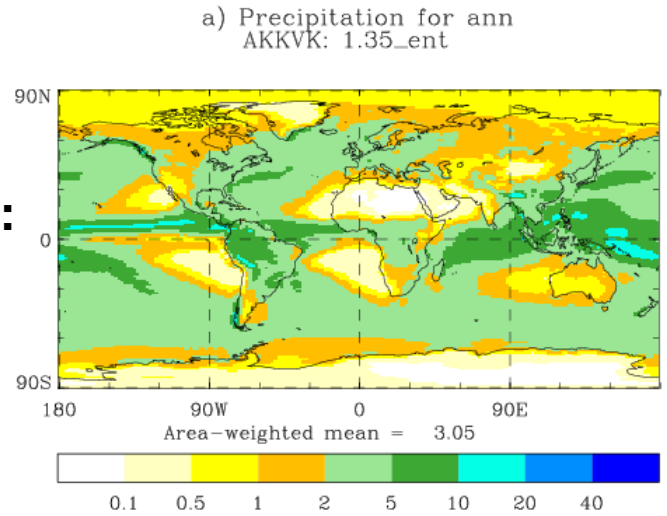
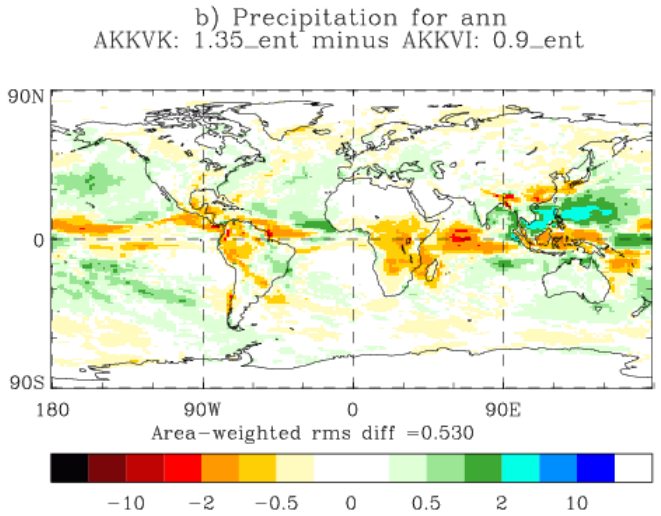
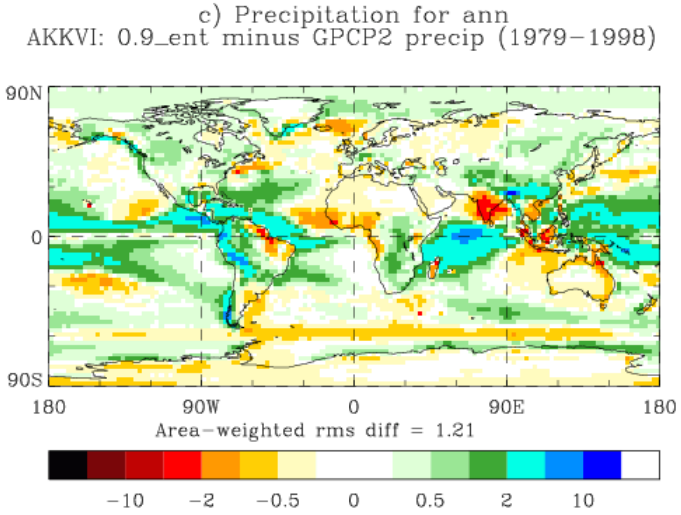
Ongoing tests with changes in the entrainment….

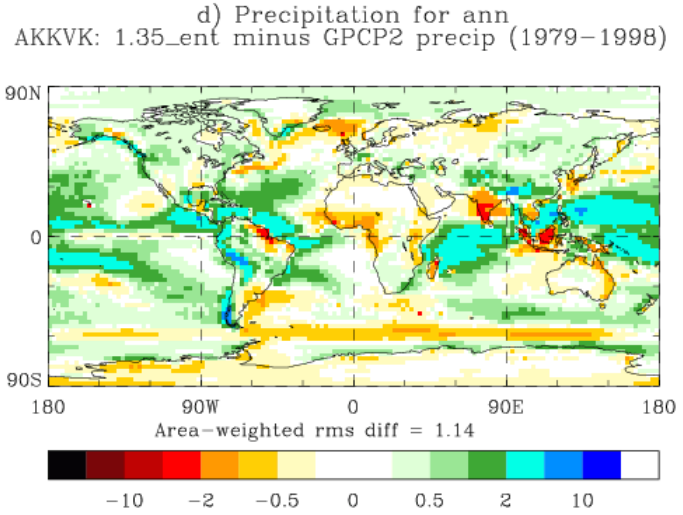
<u>GCM Experiment</u>: Entrainment parameter in convection: 0.9 vs 1.35

Reduced significantly precipitation biases over Central and Southern Africa









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Summary and future plans

- The HadGEM3RA is the new generation of Met Office Hadley Centre regional climate models, fully consistent with the physical formulation of the HadGEM3 global model which is used for prediction across time and space scale.

- HadGEM3RA has been used in the CORDEX framework with 50km grid spacing to investigate the regional scale drivers of HadGEM3 errors over Africa and inform the model development cycle.

- Series of 20-yr integrations of HadGEM3RA nested within the ERAINTERIM reanalysis data have been conducted successfully over Africa with/without the light rain package and aerosols climatology in order to improve the model performance the CORDEX regions

- Results indicate relatively good performance of the model in capturing many features of the contemporary African climate, including monsoon onset date.

- Further assessment and work on understanding the driving mechanisms behind HadGEM3RA errors in Africa is ongoing.

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Thank you

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There has been lot of effort to investigate and improve model errors. Recent examples include

- Improved soil thermal conductivity
- Coastal drag fix
- Include Wenyi Zhong spectral file
- Updated soil and vegetation ancillaries
- Increased cloud erosion rate
- 8C boundary layer scheme
- Remove negative effective extinctions in LW scheme
- Himalayan stability changes
- PC2 bug fixes
- New dust scheme (dust 443)
- Smoothed forced detrainment
- Larger polar filtered zone
- Critical water content a function of cloud depth
- Dynamics bug fixes
- Switch off mid level convection in the stratosphere and mesosphere
- New termination condition for shallow convection
- Switch off ocean TKE scheme
- W-based CAPE
- New orography ancillary
- BLLEVS_fixes
- Use Rosenlof ozone
- Include OCFF
- PS20 microphysics
- Tibet snow melt fix
- Brown and Francis Ice Particle Densities
- Effect of orographic slopes on radiation
- Hogan solver using maximum random overlap
- Van Genuchten with HWSD
- New large scale hydrology
- mixing of convective increments in the subcloud layer (MIXINC)
- Call cloud radiation every timestep
- Correct surface exchange iteration in convective boundary layers
- Snow melt fix
- Reduce orographic form drag
- New L63 start dump that has spun up aerosols and soil
- Increase RDet to 0.75
- Include detrainment and entrainment tunings
- Increase USSP gravity wave launch amplitude by 10%
- Fix river routing diagnostics
- Canopy snow
- 3-hourly atmos-ocean coupling
- Switch boundary layer stability function to using MES tails over land
- Update the levels of aerosol emissions to better fit L63 and L85 models
- BL fixes
- Update melt fix
- RHCrit bug fixes
- Reduced upper level CMT
- River routing fixes
- Conv_diag bug fix
- 1.5 hour CAPE
- Minimum albedo of sea ice changed
- Daily SSTs used in AMIP runs.
- NEMO bug fixes
- CICE bug fixes
- Droplet settling
- Improved handling of number of calls to the solver during resubmission
- Dynamics optimisation

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