Systematic RCM Errors in the CORDEX-Africa Hindcast Experiment

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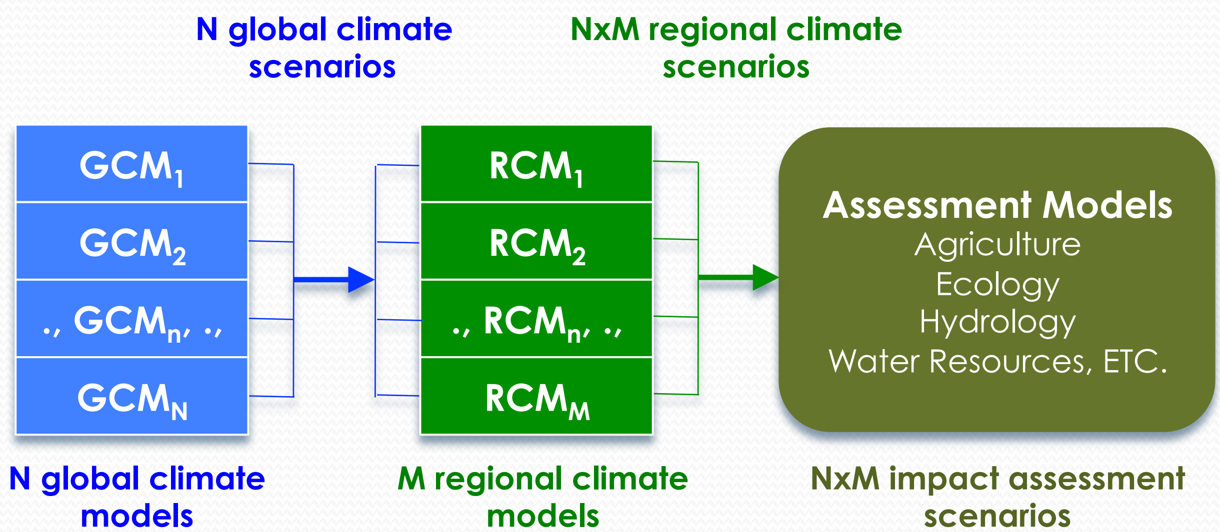
Climate change and impact assessments

- With the confirmation of the global climate change of anthropogenic origins, *assessing the impact of climate change on regional sectors* has become an important concern.
- Climate change impact assessment is based on nested modeling methods.



A schematic illustration of information flow in assessing climate change impacts on regional sectors

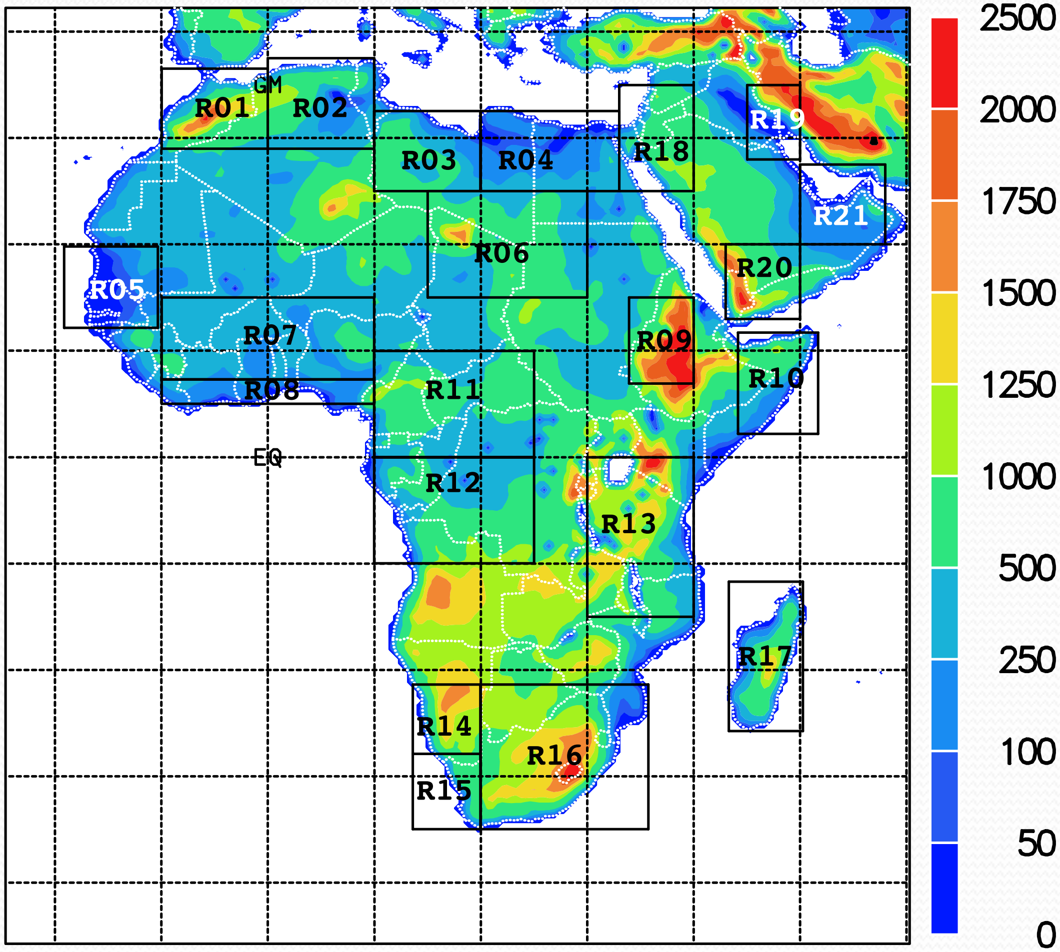
- Model biases are among the main sources of uncertainties in impact assessments.
- Model evaluation is the key for uncertainty assessments as well as bias correction and multi-model ensemble.

This study

- Examines the RCM skill in simulating precipitation and cloudiness with special emphasis on the presence of systematic model biases.
- Takes advantage of the RCM datasets generated in the CORDEX-Africa Hindcast Experiment:
  - A large number (9-10) of RCMs provide simulation data
  - Closely coordinated experimental design

CORDEX-Africa analysis domain

- Regularly spaced at 0.44 degree resolutions
  - RCM data are interpolated prior to the evaluation onto the domain by SMHI.
- 21 subregions are introduced to examine the geographical variations in RCM skill

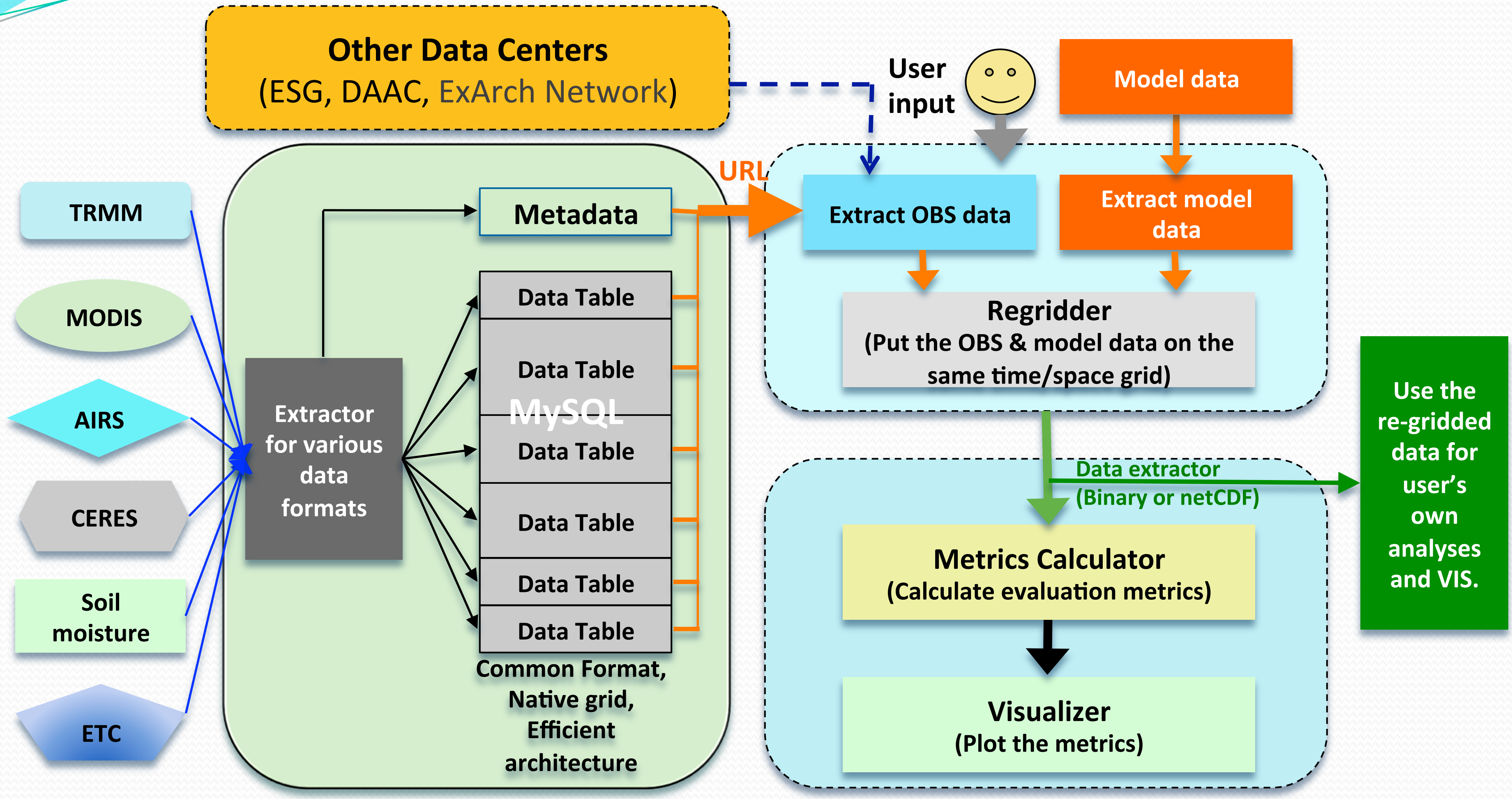


Observational data and data processing

- Baseline evaluations utilize the *CRU* surface station analysis data, *version 3.1*:
  - 1901-(near) present
  - 0.5deg horizontal resolution
  - Global, land-surface only
  - Monthly-mean values only
  - Major source of uncertainties is the density of observational stations
- Spaceborne remote sensing data for sensitivity investigation:
  - TRMM precipitation
  - MODIS cloudiness
- The Regional Climate Model Evaluation System (RCMES) has been utilized to process the observational and model data for evaluation.
  - RCMES combines observational database and analysis toolkit to facilitate the access to and analysis of observational datasets for model evaluation.
  - Details of RCMES has been presented by Paul Ramirez at JPL in the morning session.

RCMES2.0

Initiated as a JPL-UCLA joint project – Ready for open access and wider collaboration



Raw Data:
Various sources, formats, Resolutions, Coverage

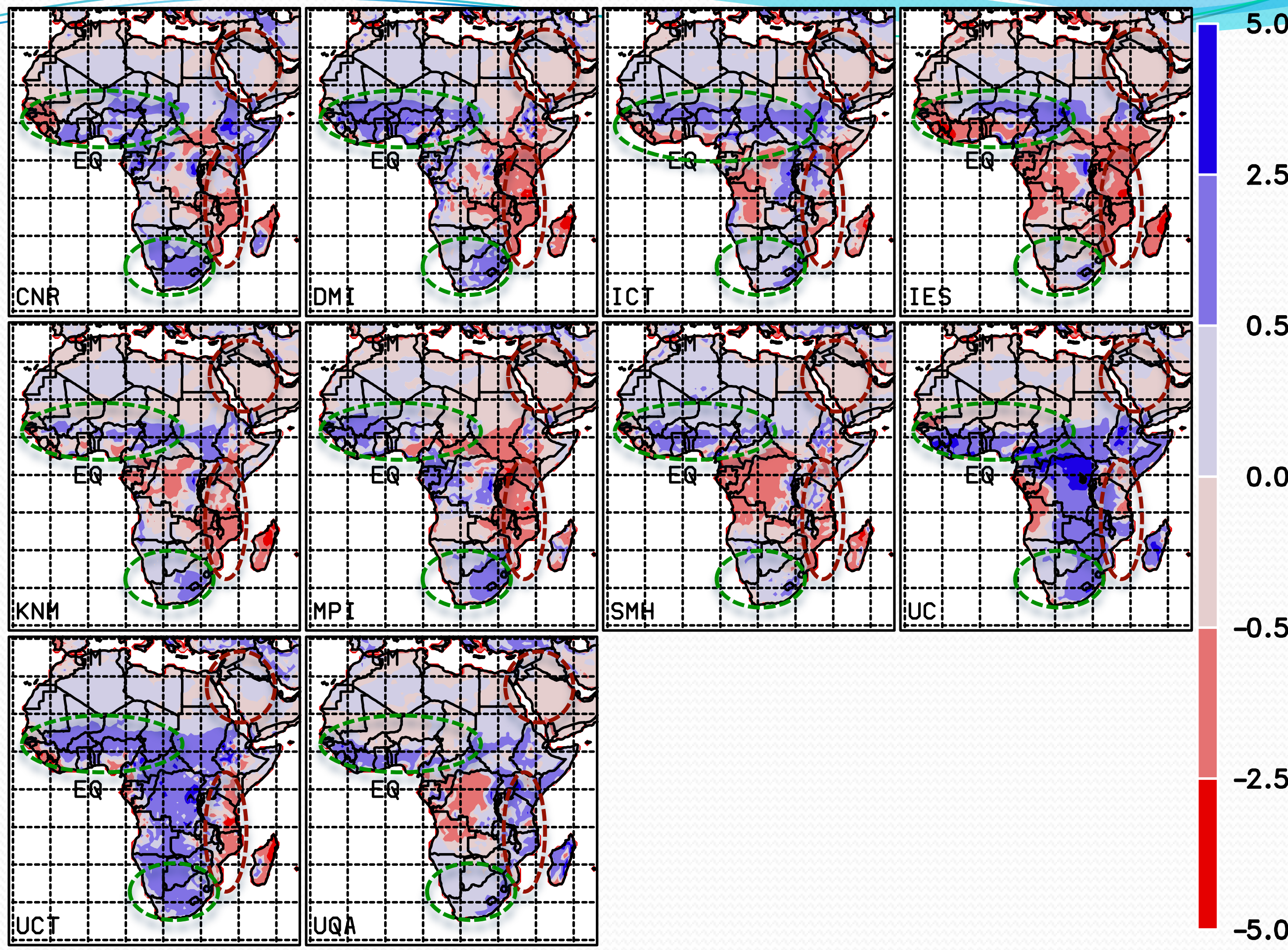
RCMED
(Regional Climate Model Evaluation Database)
A large scalable database to store data from variety of sources in a common format

RCMET
(Regional Climate Model Evaluation Tool)
A library of codes for extracting data from RCMED and model and for calculating evaluation metrics

[1] Precipitation evaluation
10 RCMs and their ensemble vs. CRU monthly rain-gauge analysis

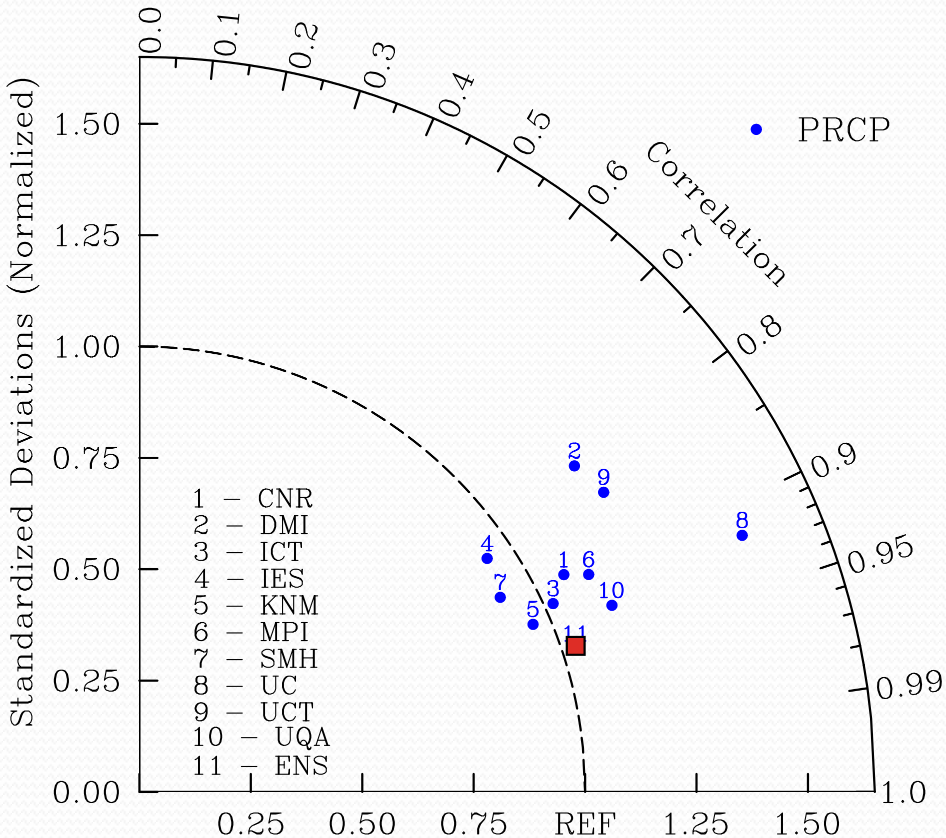
- 18 years: 1990-2007
- Overland only – *Limited by the coverage of the CRU analysis*
- Spatial variability of the annual-mean precipitation
- Annual cycle
- Interannual variability of wet-season precipitation in the western sub-Sahara and Nile headwater basin (Ethiopian Heights).

Annual-mean precipitation bias: Africa 1990-2007



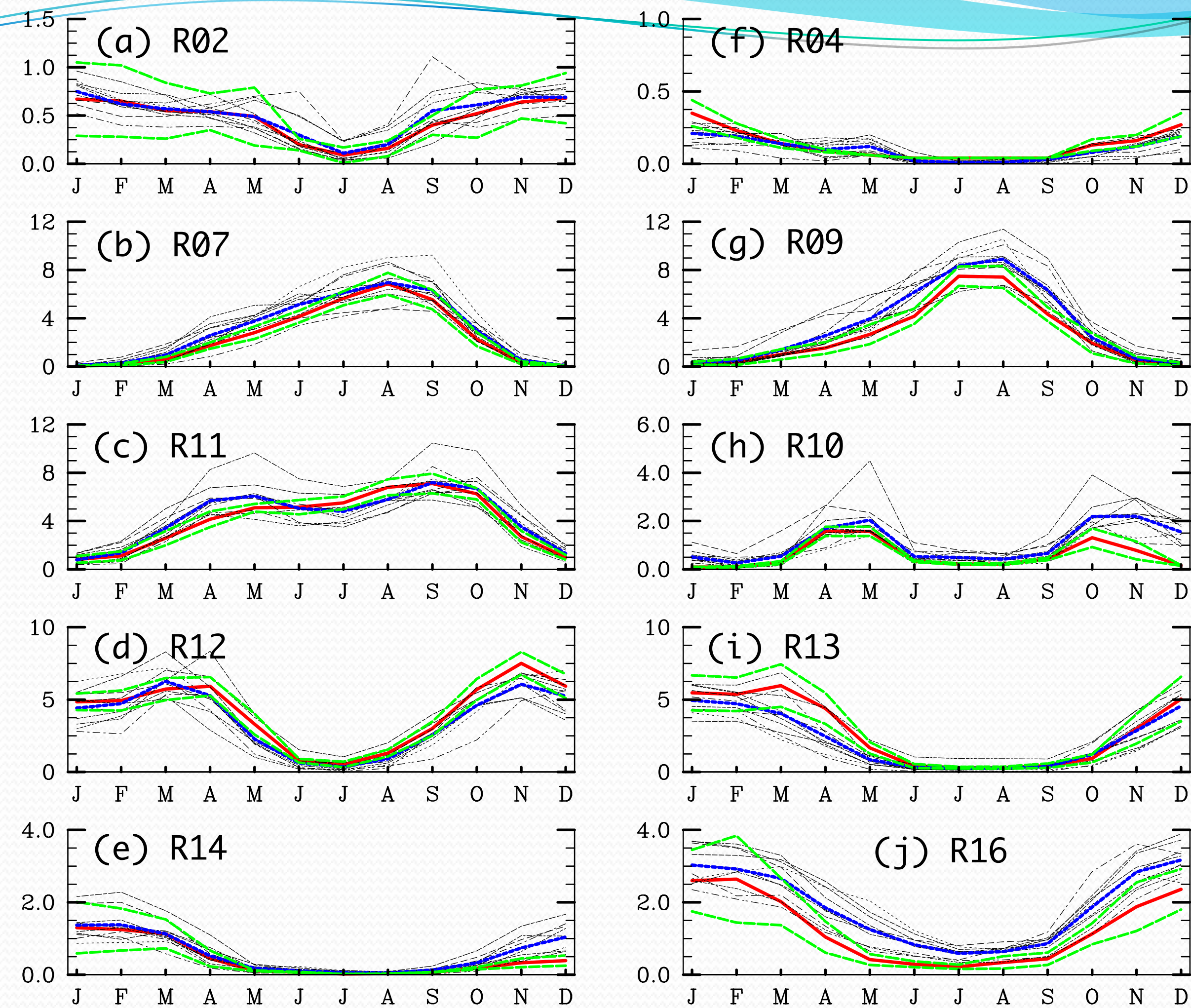
- Model biases vary widely among RCMs in some regions.
- There also exist model biases common to all or a majority of RCMs
  - Wet biases in South Africa, E. sub-Sahara
  - Dry biases in E. Africa coastal regions, interior of the Arabia Peninsula

Spatial variation of the annual-mean precipitation



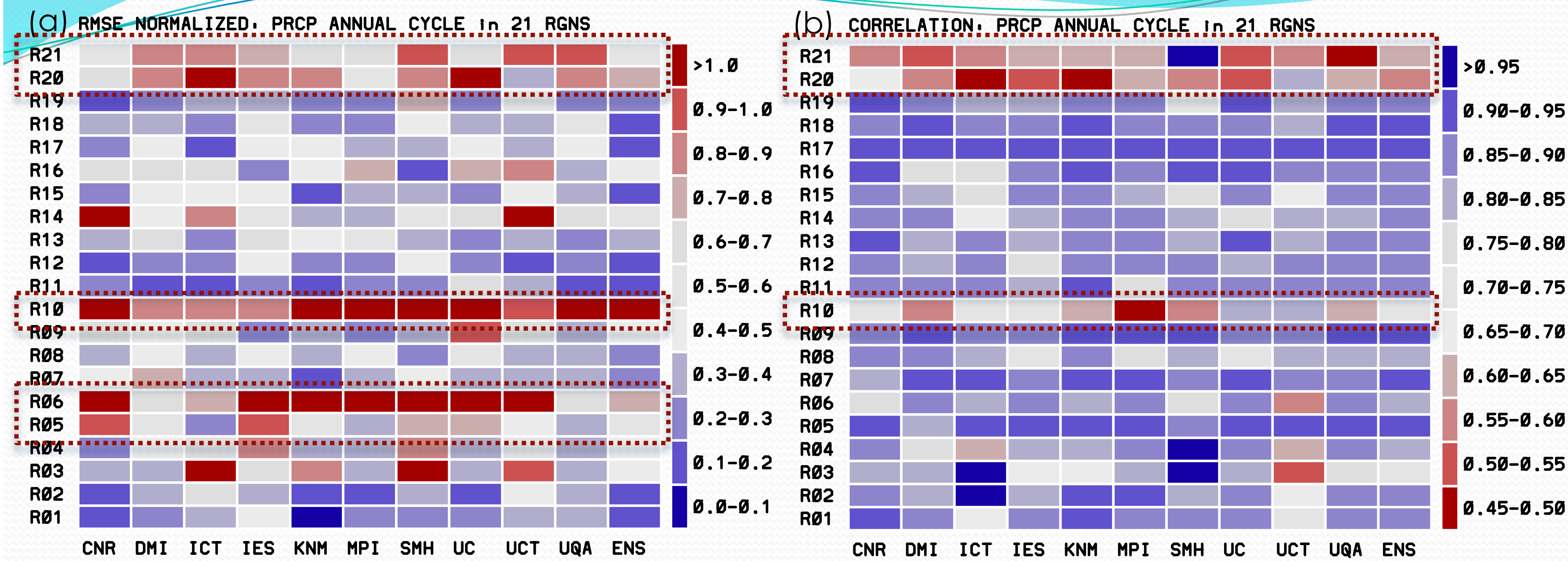
- All RCMs have simulated the observed spatial pattern of the annual-mean precipitation reasonably well.
- The simulated spatial variability varies more widely than the pattern.
- ENS (red square) outperforms individual models within ENS.
  - *Smallest RMSE* (smaller than any model in the ensemble)
  - *Highest spatial pattern correlation*
  - *Spatial variability is smaller than most models, although comparable to the CRU data.*

Precipitation annual cycle simulation skill – Regional variations



- All RCMs simulate the observed annual cycle reasonably well, at least its phase.
- Models generally perform better for the West Africa region than the East Africa region:
  - ENS is within ±1σ range from the CRU data for the Mediterranean and West Africa regions.
  - ENS is generally out of the ±1σ range for the north-central and East Africa regions.

Precipitation annual cycle simulation skill – Regional variations

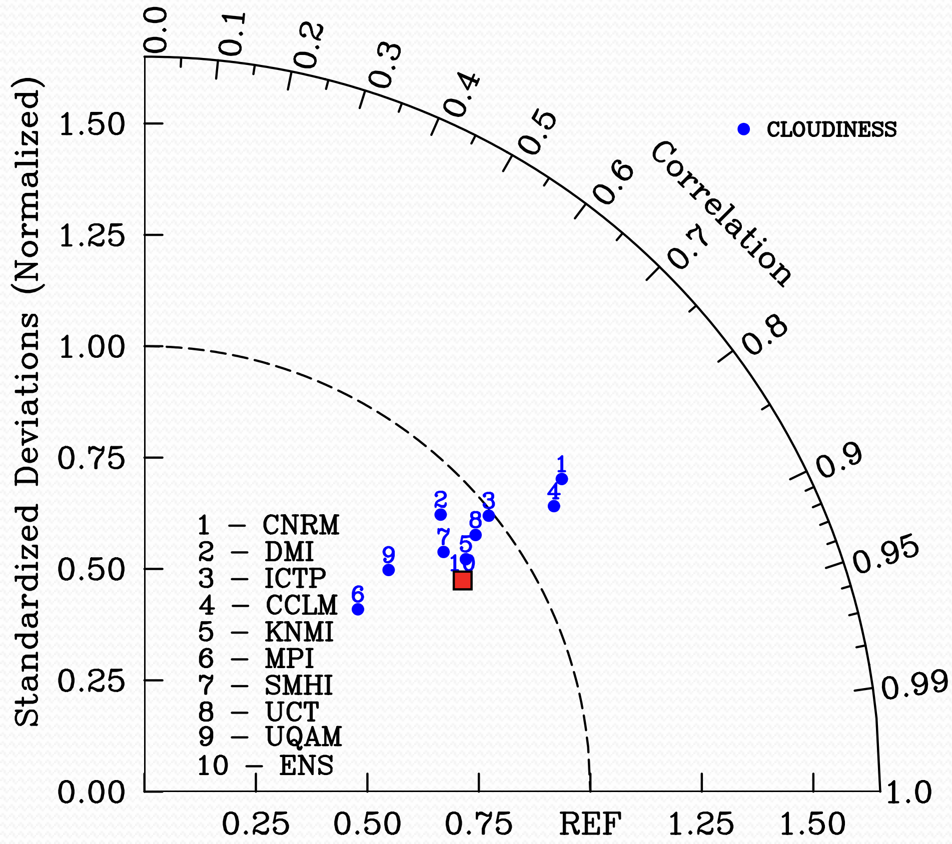


- Most models well simulate the phase/shape of the annual cycle (CORR COEFF > 0.8) in most regions, except the eastern Arabia Peninsula (R20, R21) and the Horn of Africa (R10) regions.
- The RMSE in the simulated annual cycle also indicates similar regional variations. In addition to the regions of poor phase simulation, the RMSE is large (RMSE > 0.5 Mean) in the dry regions of W. & E. Sahara (R05, R06).
- The regions of good skill varies according to the selected metrics.

[2] Cloudiness
Nine RCMs and their ensemble vs. CRU analysis

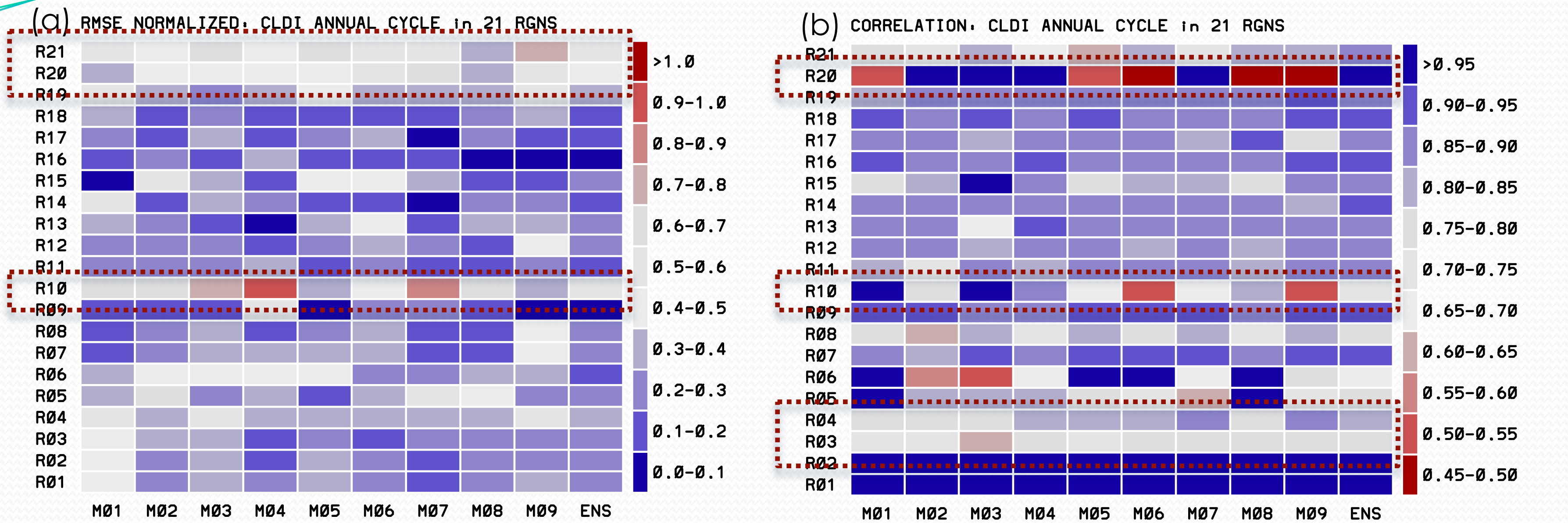
- 18 years: 1990-2007
- CRU monthly mean cloudiness analysis
- Overland only

Spatial distribution of the annual-mean cloudiness (2001-2008) Baseline evaluation against CRU3.1



- All RCMs show similar skill in simulating the spatial pattern of the annual-mean cloudiness with the spatial correlation coefficient of ~0.8 with the CRU analysis.
- RCM performance in simulating the spatial variability varies widely - the standardized deviation varies from 0.6 to >1.25.
- The model ensemble shows the highest spatial correlation and smallest RMSE.

Cloudiness annual cycle simulation skill – Regional variations

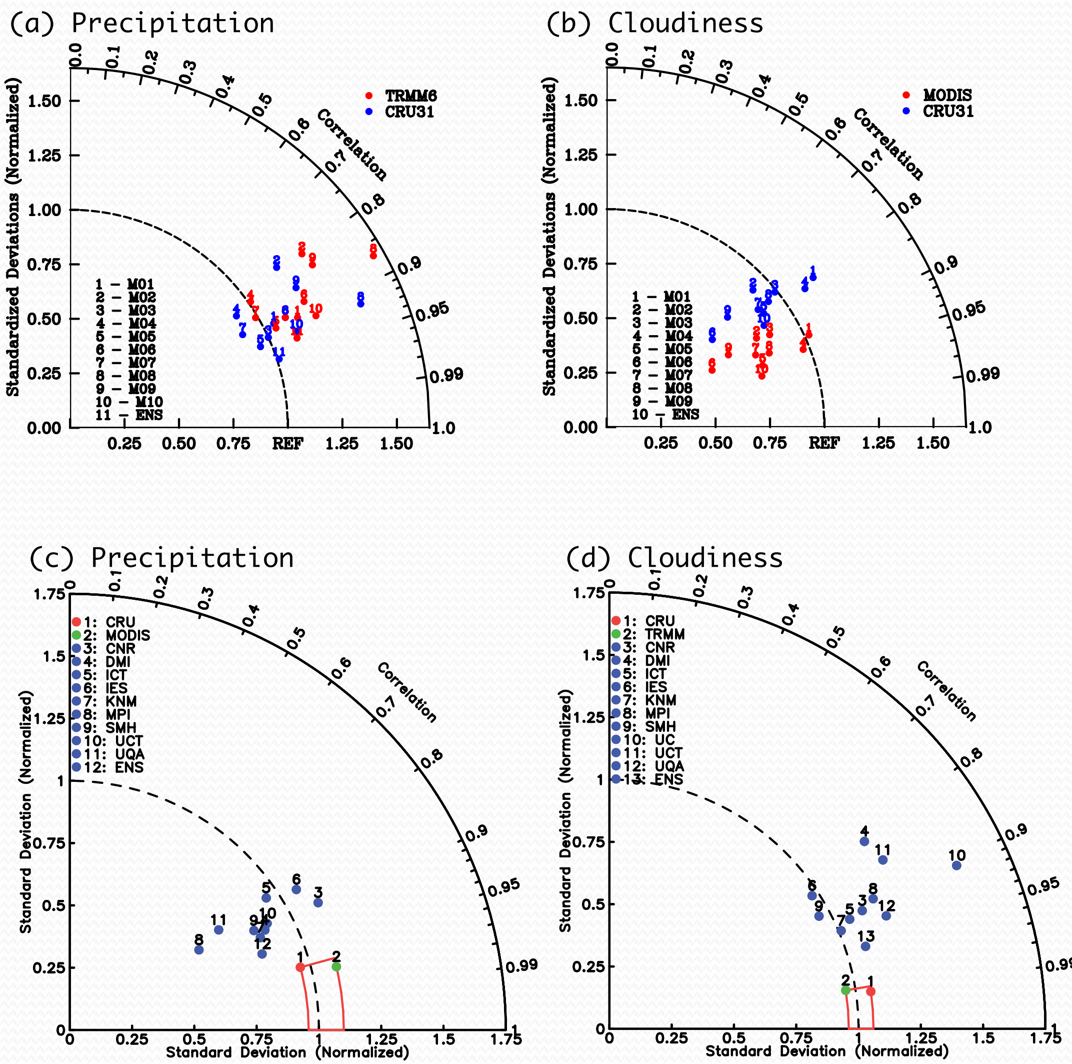


- The *normalized RMSE* and *correlation coefficients* show that RCM skill in simulating the annual cycle is generally lower or highly variable in the eastern Mediterranean (R03, R04), eastern Sahara (R06), Somalia (R10), and eastern Arabia Peninsula (R20, R21) regions.
- The regions of large RMSE tend to coincide with those of smaller correlation coefficients, but the measure of model performance also varies for the choice of metrics.

[3] Uncertainties related with observational datasets

- Precipitation evaluation against CRU (0.5^ox0.5^o) and TRMM (0.5^ox0.5^o)
- Cloudiness evaluation against CRU (0.5^ox0.5^o) and MODIS (1^ox1^o)

Annual-mean precipitation & cloudiness evaluation vs. 2 REF datasets



- (a) Evaluation of the annual-mean precipitation is not very sensitive to the reference data
- (b) The simulated cloudiness evaluates better against the MODIS than CRU data
- None of the RCMs, even their ENS, is within the range of uncertainties defined by multiple reference datasets (c & d).
- Cross-examination and evaluation of reference data is important for reliable model evaluations.

Summary and Conclusions

- Climate model evaluation is a fundamental step in projecting climate change and assessing their impacts.

- Monthly-mean precipitation and cloudiness from multiple RCMs participating in the CORDEX-Africa experiment are evaluated.
  - All RCMs successfully simulate qualitative features of the observed climatology.
  - Performance of individual models vary widely.
  - Multi-model ensemble generally performs better than individual RCM.

- *There exist model biases common to all or a majority of RCMs*
  - *These systematic biases vary according to regions, metrics, and variables*.
  - *This makes defining a single index to define overall model performance difficult*.
  - *Multi-model ensemble construction based on model performance may be performed separately for individual regions, variables, and seasons*.

- Differences between REF datasets can be a significant source of uncertainties.
  - REF datasets need to be cross-examined and independently evaluated in order to minimize uncertainties in measuring model performance.

Next steps

- RCMES will be further developed with new datasets and improved toolkit
  - Special emphasis on remote sensing data (e.g., sea-level heights, water vapor, clouds, snowpack).
  - Geography-specific data processing (e.g., watersheds, geopolitical boundaries).
- We plan to closely collaborate with the CORDEX community in future RCMES developments.
  - Metrics calculations and visualization to support multiple CORDEX domains, most immediately *South Asia*, *East Asia* and *Arctic*, in addition to ***Africa*** & ***North America***.
  - Data collection will focus on obtaining fine-resolution reference datasets suitable for RCM evaluations, *with special emphasis on the spaceborne remote sensors*.
  - Develop data processing to support the application of regional climate projection data to impact assessments for various regions and sectors – inputs from regional assessment community are crucial for the success in this activity.
  - Use of formalism in variable names and file-naming convention will facilitate handling multiple model data files as has been done for the CORDEX-Africa data.
  - Identifying *local stakeholders* and *issues* will allow us to develop specific metrics and visualization suite to support specific local uses – *this is among the most crucial part of climate modeling projects*.