

CLOUD CLIMATOLOGY IN AFRICA-CORDEX DOMAIN FROM CMIP5 MODELS AND WRF

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 - Total Cloud Cover
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 - 15 years experiment
 - 5 years multi-physics
 - 5 years downscaling methods
4. Conclusions

CLOUD COVER

- More than 50% of Earth surface is covered at, any time
- High temporal and spatial variability



RADIATIVE BALANCE

- Reflect and absorb shortwave radiation
- Absorb and emit longwave radiation



LARGE UNCERTAINTIES

- Complex processes in formation and developing
- Difficult to parameterize
- Great scientific efforts, such as:



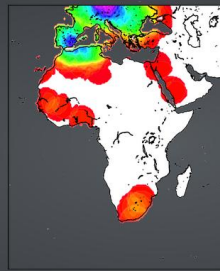
DATA

- Observational data: ISCCP, CRU
- Computational data: CMIP5 models and WRF
- Domain (CORDEX):



CRU TS. WHY NOT?

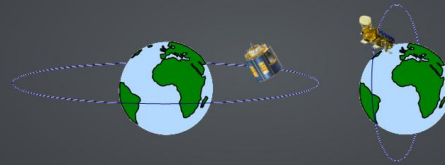
- Climate Research Unit (CRU), University of East Anglia
- Observational gaps in Africa



Number of ground stations per CRU grid point

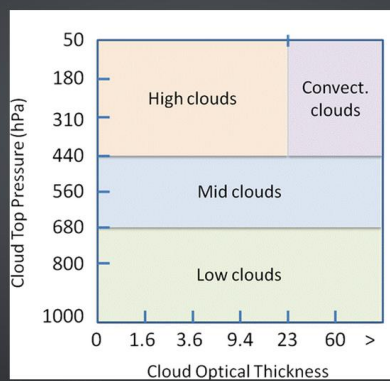
ISCCP

- International Satellite Cloud Climatology Project (ISCCP)
- 1983 - present
- Geostationary and polar orbiter satellites
- Global Coverage



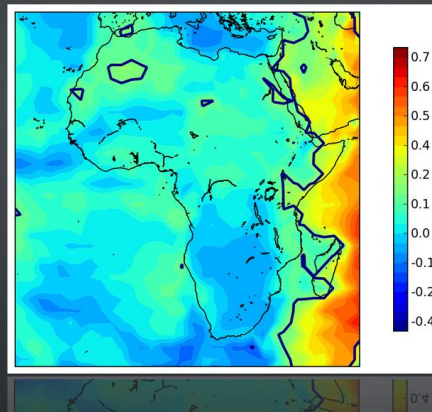
ISCCP DATA

- ISCCP D2 monthly data ... and D1.
- 280 km equal-area grid -> $2.5 \times 2.5^\circ$
- Multiple cloud top heights and optical thickness



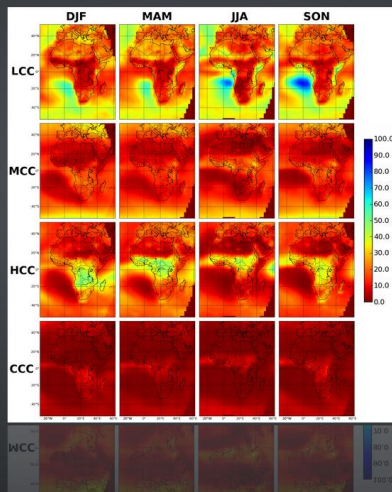
ISCCP DATA: POSSIBLE PROBLEMS ⚠

- Satellites and sensors changes and updates
- Correlation between $1/(\text{satellite zenith angle})$ and total cloud cover



ISCCP CLOUD COVER: CLOUD TYPES

1984-2005 seasonal means



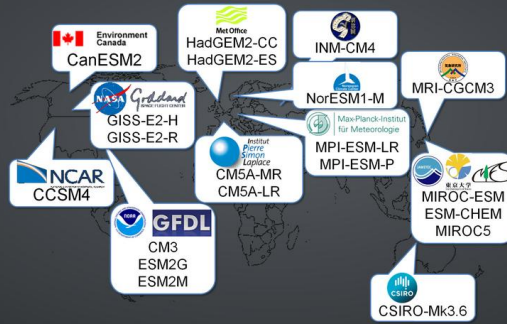
MODELS

CMIP5 & WRF



CMIP5

- Coupled Model Intercomparison Project Phase 5
- Involves 20 climate modeling groups from around the world



CMIP5 MODELS

- Accessed models
- Historical experiment
- Variables: *clt* & *ISCCP cloud simulator* output

Model identification	Institution (Country)	Atmosphere resolution	Ensemble size	
			clt	isccp
CanESM2	Canadian Centre for Climate Modeling and Analysis (Canada)	1.9°x1.9°		1
CCSM4	National Center for Atmospheric Research (USA)	0.9°x1.25°	6	
CSIRO-Mk3.6	Commonwealth Scientific and Industrial Research Organisation (Australia)	1.875°x1.875°	10	
GFDL-CM3	NOAA Geophysical Fluid Dynamics Laboratory (USA)	~200km	5	
GFDL-ESM2G			1	
GFDL-ESM2M			1	
GISS-E2-H	NASA Goddard Institute for Space Studies (USA)	2°x2.5°	15	
GISS-E2-R		2°x2.5°	16	
HadGEM2-CC	Met Office (UK)	1.875°x1.25°	3	
HadGEM2-ES		1.875°x1.25°	4	
IPSL-CM5A-MR	Institut Pierre Simon Laplace (France)	1.25°x2.5°	1	
IPSL-CM5A-LR		1.9°x3.75°		5
MIROC-ESM-CHEM	University of Tokyo, Japan Agency for Marine-Earth Science and Technology, and National Institute for Environmental Studies (Japan)	~2.8°x2.8°	1	1
MIROC-ESM		~2.8°x2.8°	3	3
MIROC5		1.4°x1.4°	4	3
MPI-ESM-LR	Max Planck Institute for Meteorology (Germany)	1.8°x1.8°	3	1
MPI-ESM-P		1.8°x1.8°	3	
MRI-CGCM3	Meteorological Research Institute (Japan)	~280km	5	1
NorESM1-M	Norwegian Climate Centre (Norway)	1.9°x2.5°	1	
INM-CM4	Institute for Numerical Mathematics (Russia)	2°x1.5°	1	

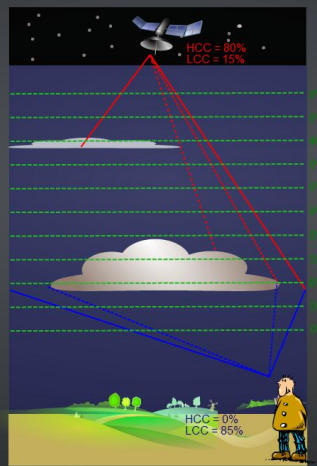
WRF

- WRF 3.1.1
- Spatial resolution: 50km -> degraded to 2.5°
- Cordex domain: Africa
- Driven by ERA Interim reanalysis
- WRF variables
 - cldfrac (cloud fraction per level)
 - Pressure
- Outputs
 - Total cloud fraction (clt)
 - Cloud types: cloud fraction for low, mid, high and convective clouds



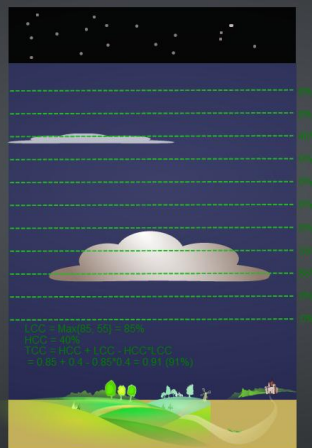
DIFFERENT VIEWS

Satellite Ground Models



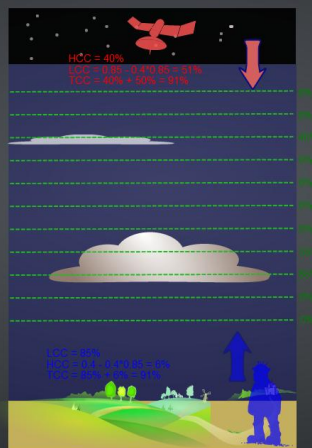
OVERLAP ASSUMPTIONS: TOTAL CLOUD COVER

Maximum Random **Random-maximum**



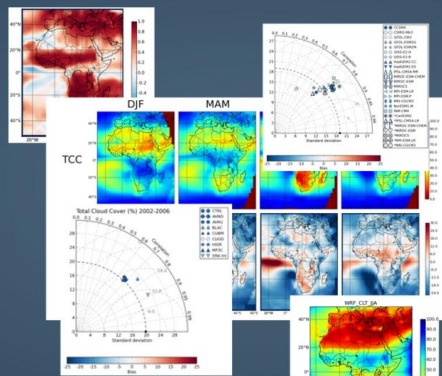
SATELLITE VIEW: CLOUD TYPES

Top - down



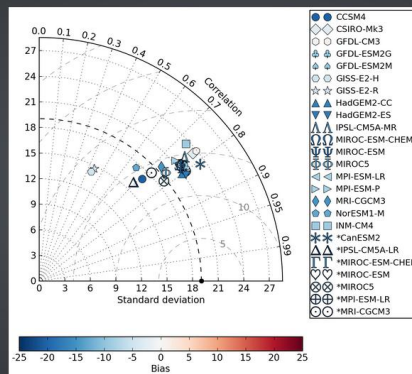
RESULTS

CMIP5 WRF



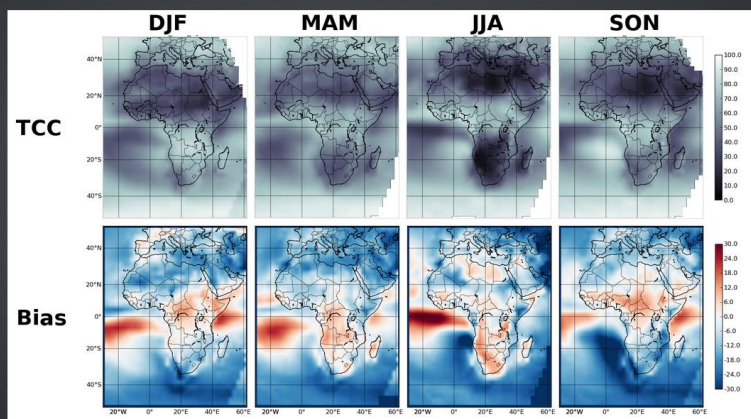
CMIP5 TOTAL CLOUD COVER

Taylor diagram



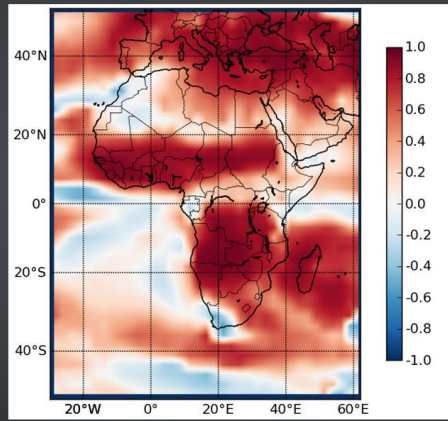
CMIP5 TOTAL CLOUD COVER

Seasonal Bias of Models' Ensemble



CMIP5 TOTAL CLOUD COVER

Correlation of Models' Ensemble

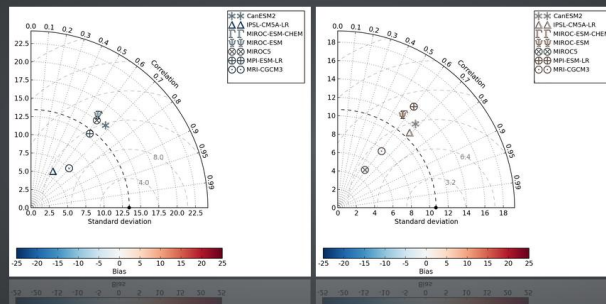


CMIP5 CLOUD COVER

Taylor diagrams

Low cloud cover

High cloud cover



WRF 15 YEARS SIMULATION

Configuration

Cumulus	Boundary Layer	Micro-physics	Radiation	Land Surface	Vert. Levels	Nudging
Kain-Fritsch	YSU	WDM6	RRTMG	Noah	30	None

1990 - 2004

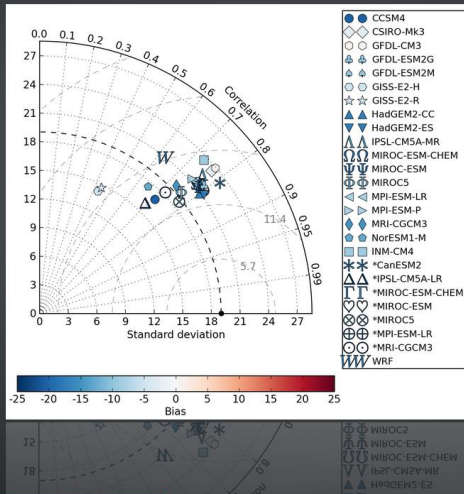
YSU - Yonsei University scheme

WDM6 - WRF Double-Moment 6-class scheme

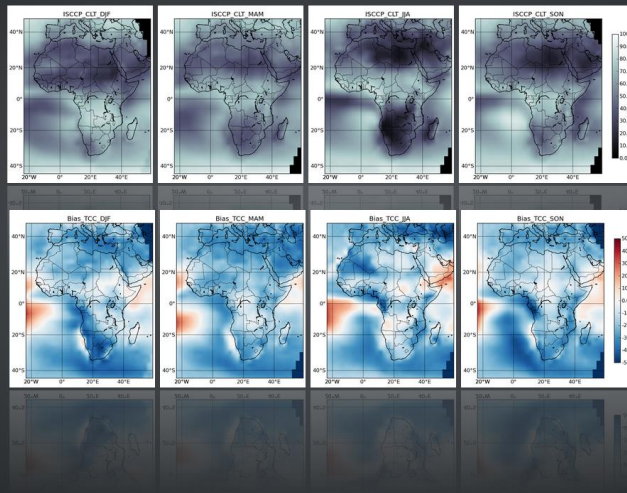
RRTMG - A new version of RRTM

WRF-15Y TOTAL CLOUD COVER

Taylor diagram



WRF-15Y TOTAL CLOUD COVER

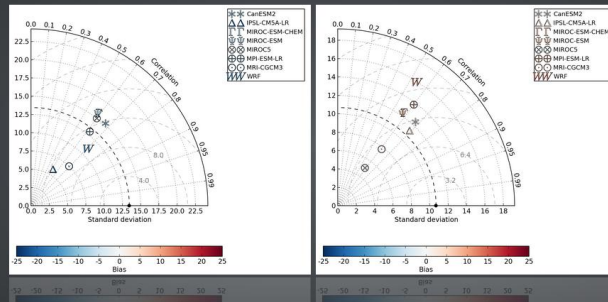


WRF-15Y CLOUD COVER

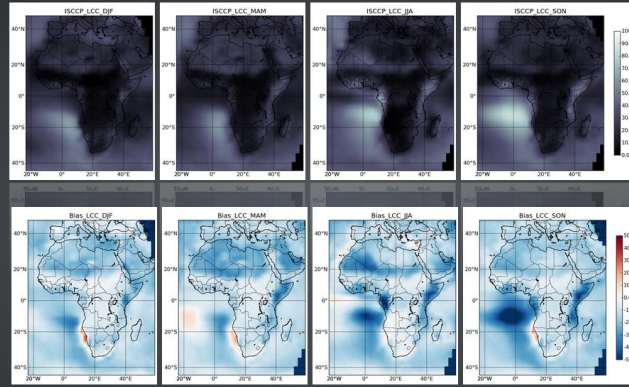
Taylor diagrams

Low cloud cover

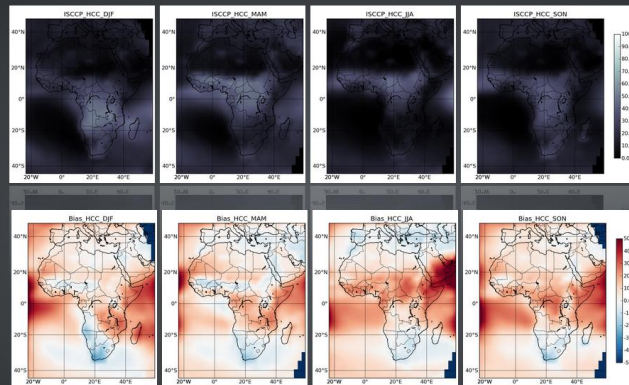
High cloud cover



WRF-15Y LOW CLOUD COVER

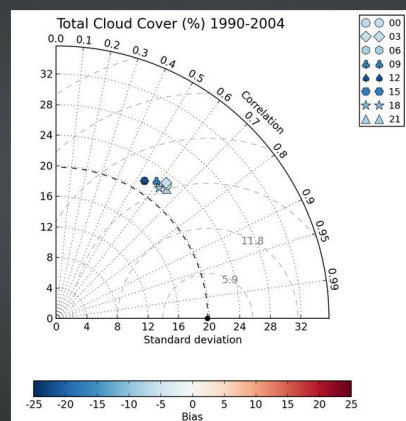


WRF-15Y HIGH CLOUD COVER

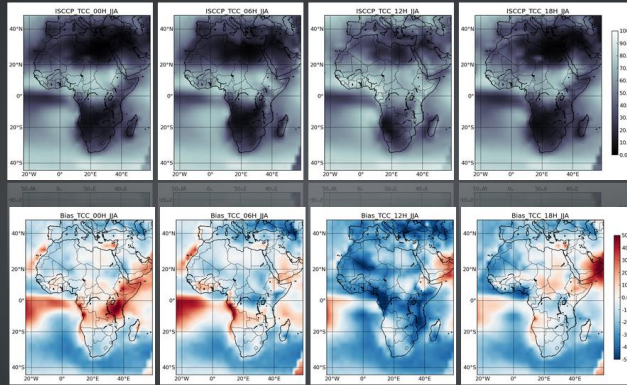


WRF-15Y TCC (DIURNAL VARIATION)

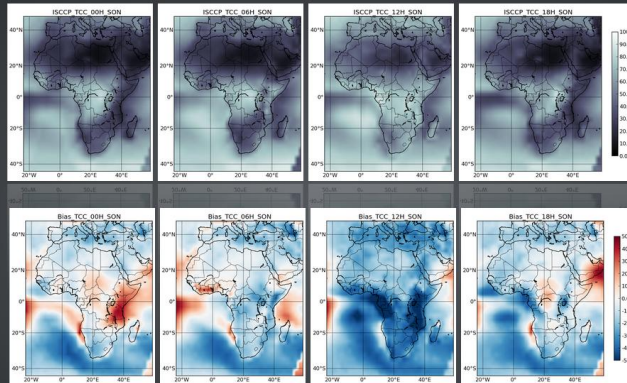
Taylor diagram



WRF-15Y TCC (DIURNAL VARIATION - JJA)



WRF-15Y TCC (DIURNAL VARIATION - SON)



WRF 5 YEARS MULTI-PHYSICS EXPERIMENT



Configuration (2002 - 2006)

Exp.	Cumulus	Boundary Layer	Micro-physics	Land Surface	Hydrostatic	Land Use
CTRL	KF	YSU	WSM5	RUC	No	MODIS
CUBM	BMJ	YSU	WSM5	RUC	No	MODIS
CUGD	GD	YSU	WSM5	RUC	No	MODIS
BLAC	KF	AC	WSM5	RUC	No	MODIS
MP3C	KF	YSU	WMS3	RUC	No	MODIS
AVNO	KF	YSU	WSM5	Noah	No	AVHRR
AVRU	KF	YSU	WSM5	RUC	No	AVHRR
HIDR	KF	YSU	WSM5	RUC	Yes	MODIS

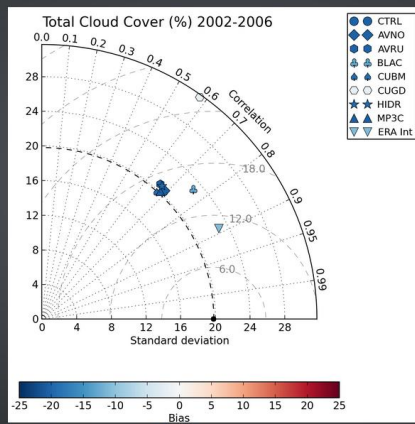
KF - Kain-Fritsch || BMJ - Betts-Miller-Janjic || GD - Grell-Devenyi

YSU - Yonsei University scheme || AC - ACM2 PBL: Asymmetric Convective Model

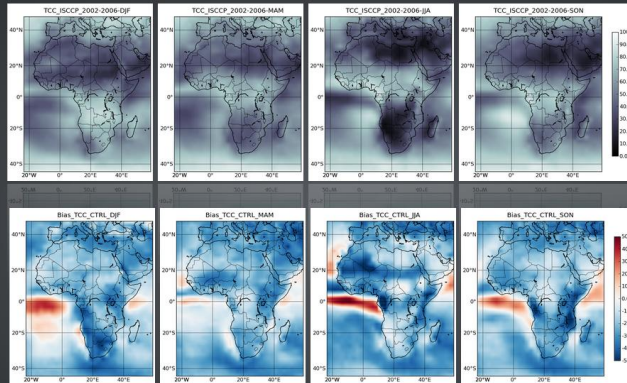
WSM5 - WRF Single-Moment 5-class scheme || WSM3 - WRF Single-Moment 3-class scheme

WRF-5Y MULTI-PHYSICS: TOTAL CLOUD COVER

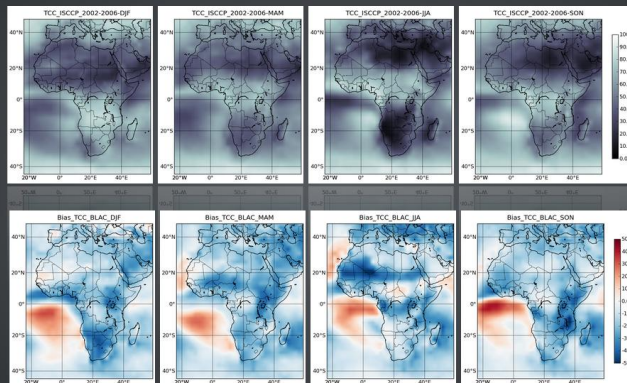
Taylor diagram



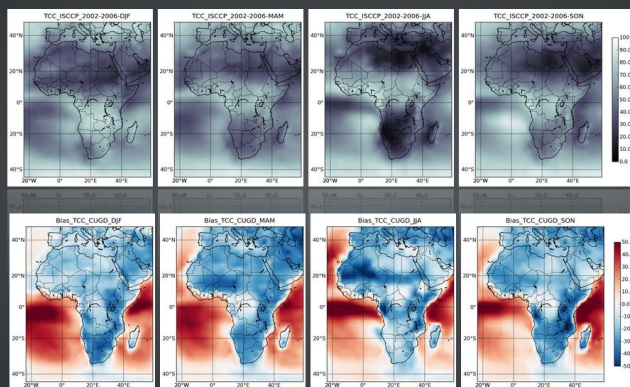
WRF-5Y MULTI-PHYSICS: CONTROL EXPERIMENT



WRF-5Y MULTI-PHYSICS: BOUNDARY LAYER = ASYMMETRIC CONVECTIVE MODEL

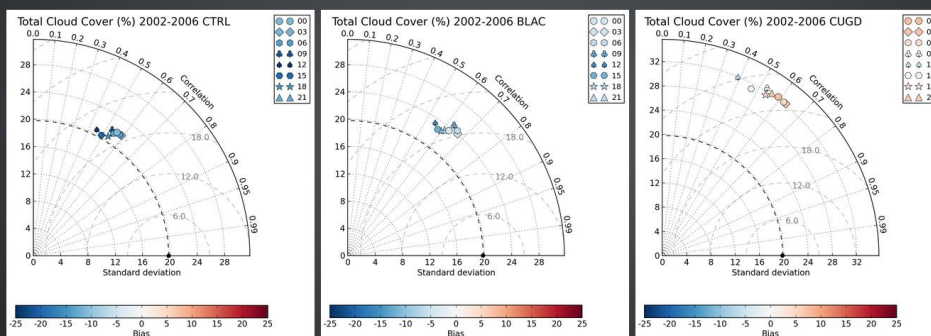


WRF-5Y MULTI-PHYSICS: CUMULUS = GRELL-DEVENYI

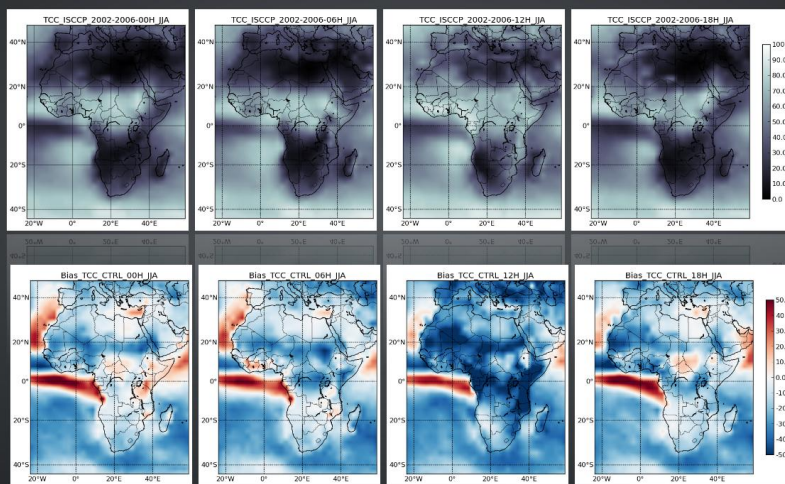


WRF-5Y MP TCC (DIURNAL VARIATION)

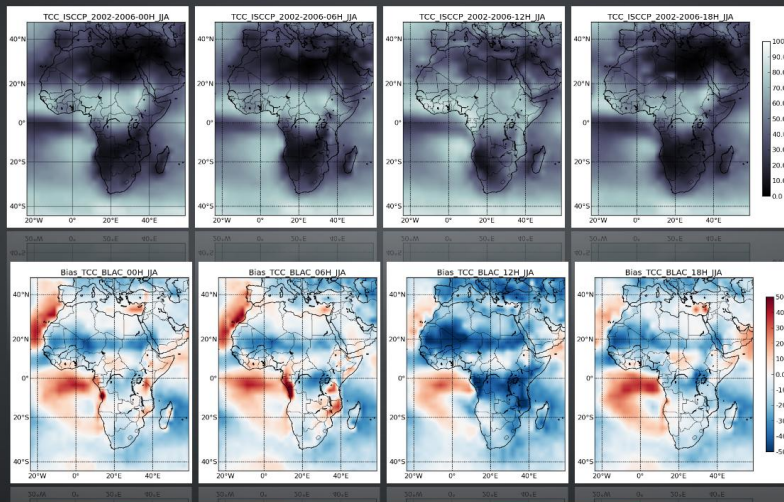
Taylor diagrams



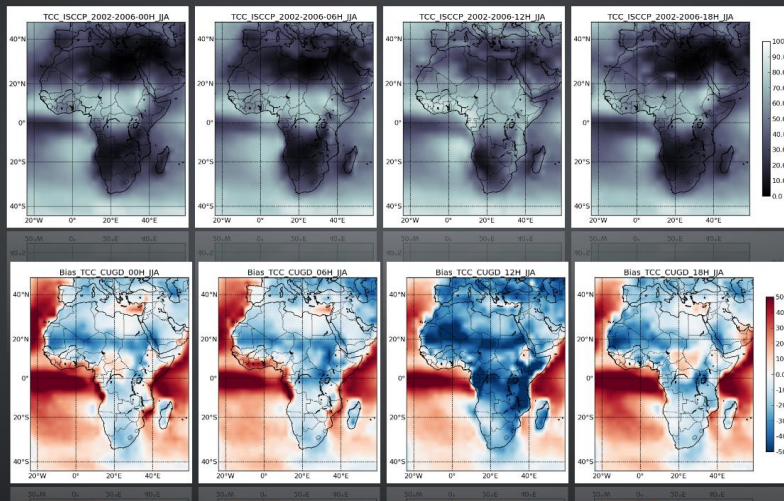
WRF-5Y MP TCC (DIURNAL VARIATION - JJA - CTRL)



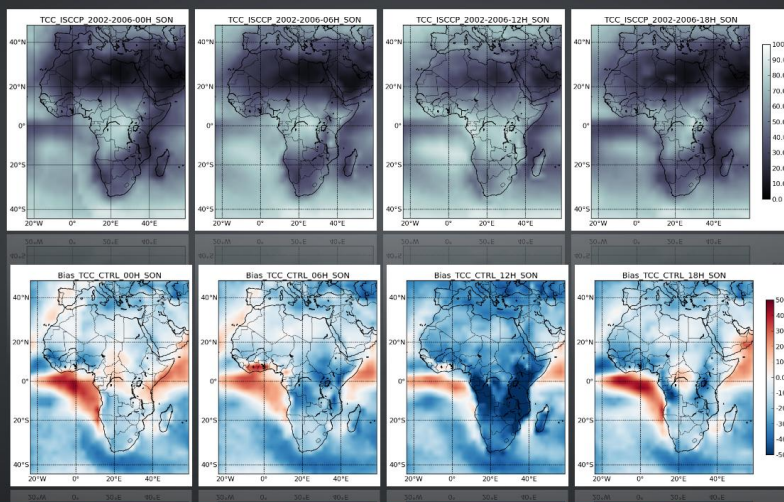
WRF-5Y MP TCC (DIURNAL VARIATION - JJA - BLAC)



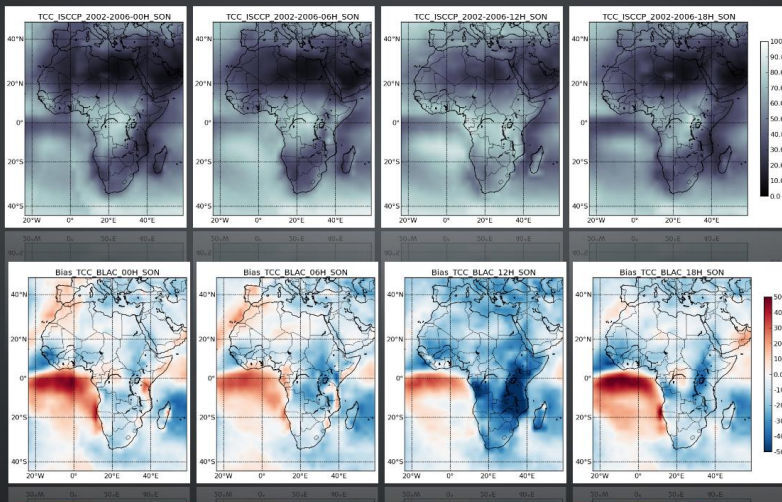
WRF-5Y MP TCC (DIURNAL VARIATION - JJA - CUGD)



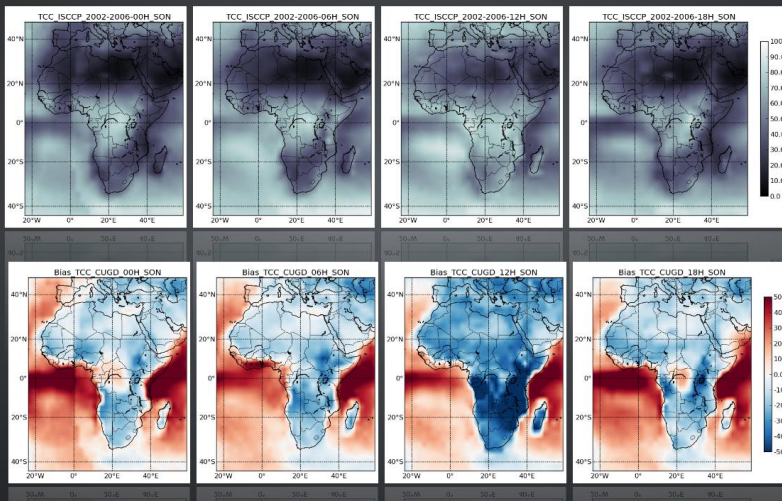
WRF-5Y MP TCC (DIURNAL VARIATION - SON - CTRL)



WRF-5Y MP TCC (DIURNAL VARIATION - SON - BLAC)



WRF-5Y MP TCC (DIURNAL VARIATION - SON - CUGD)



WRF 5 YEARS: DOWNSCALING METHODS

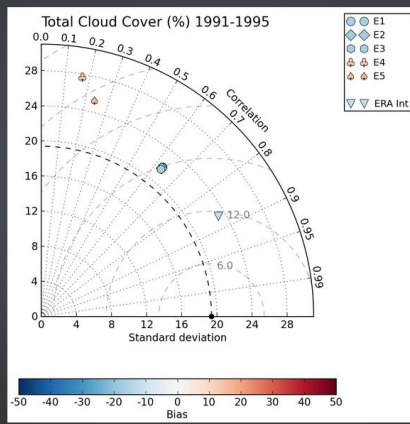
Configuration (1991 - 1995)

Experiment	Atmosphere Re-initialization	Surface Re-initialization	Nudging
E1	Monthly	Monthly	None
E2	None	None	None
E3	Monthly	None	None
E4	None	None	Whole column
E5	None	None	Above PBL

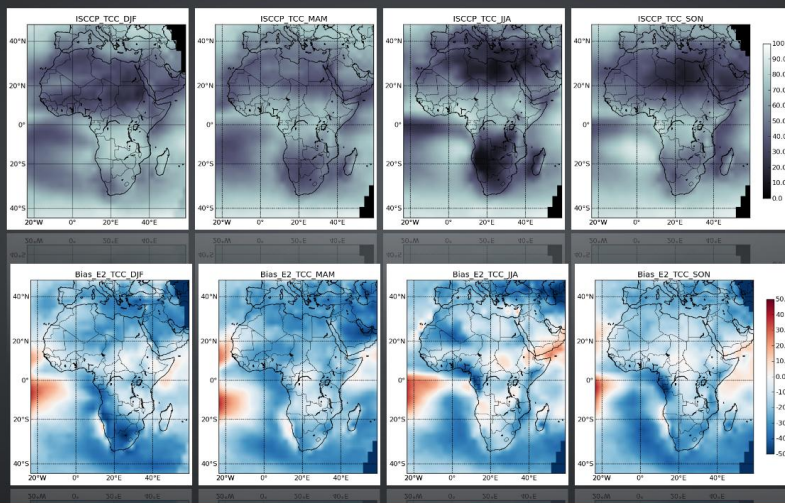
Parameterizations as in WRF-15Y experiment

WRF-5Y DS-METHODS: TOTAL CLOUD COVER

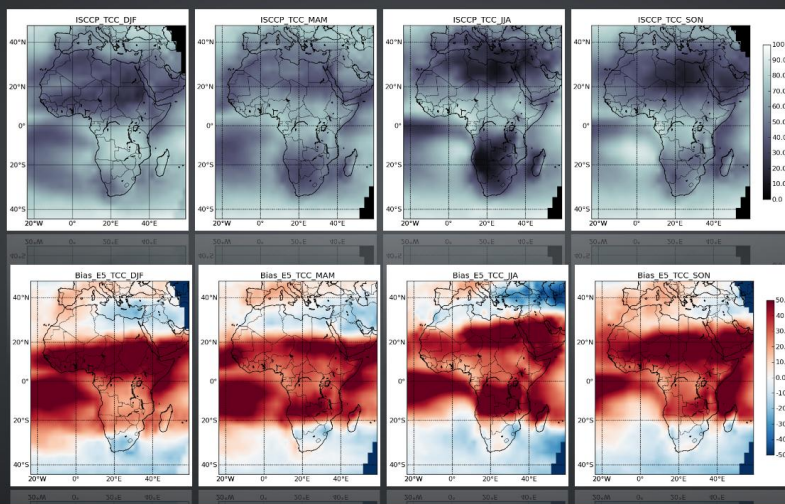
Taylor diagram



WRF-5Y DS-METHODS: TOTAL CLOUD COVER (E2)



WRF-5Y DS-METHODS: TOTAL CLOUD COVER (E5)

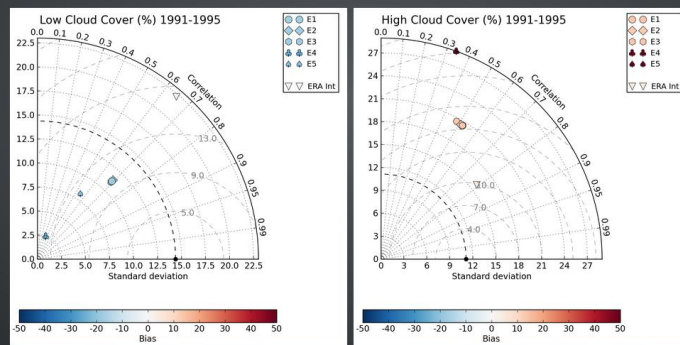


WRF-5Y DS-METHODS: CLOUD COVER

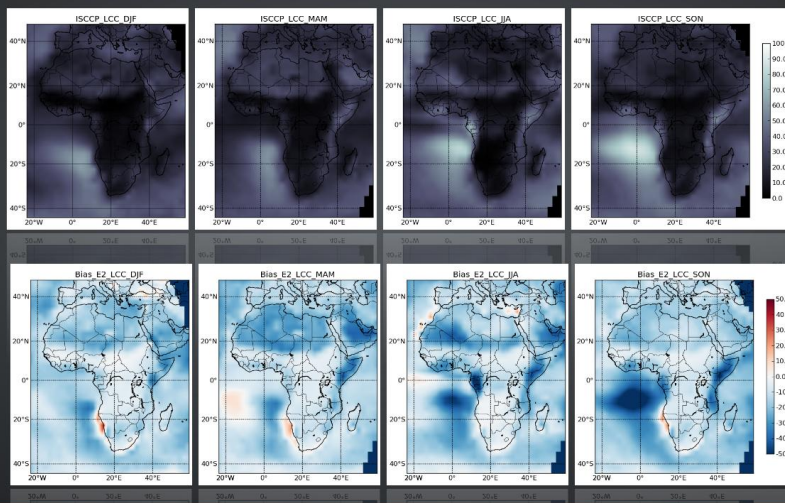
Taylor diagrams

Low cloud cover

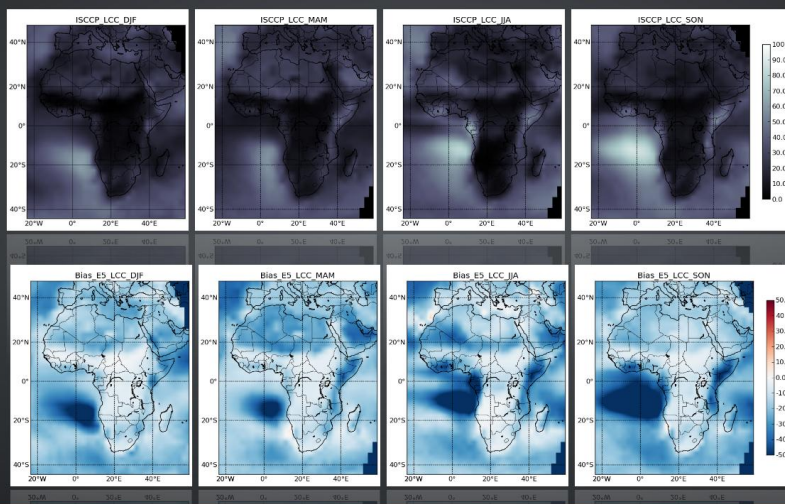
High cloud cover



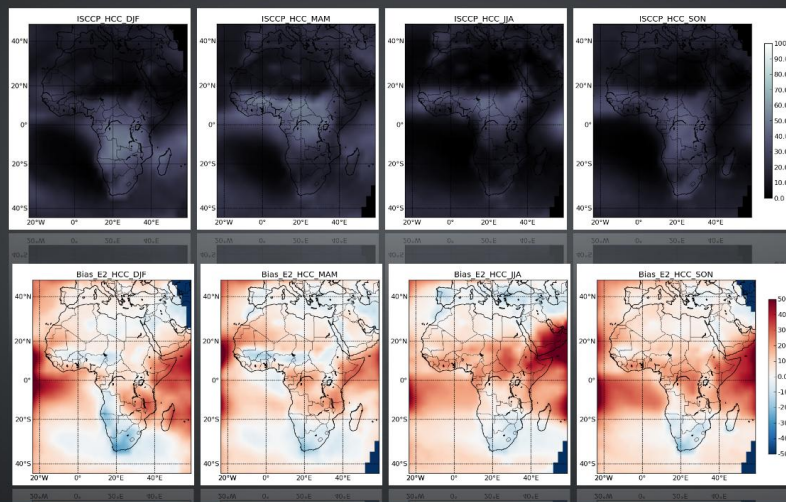
WRF-5Y DS-METHODS: LOW CLOUD COVER (E2)



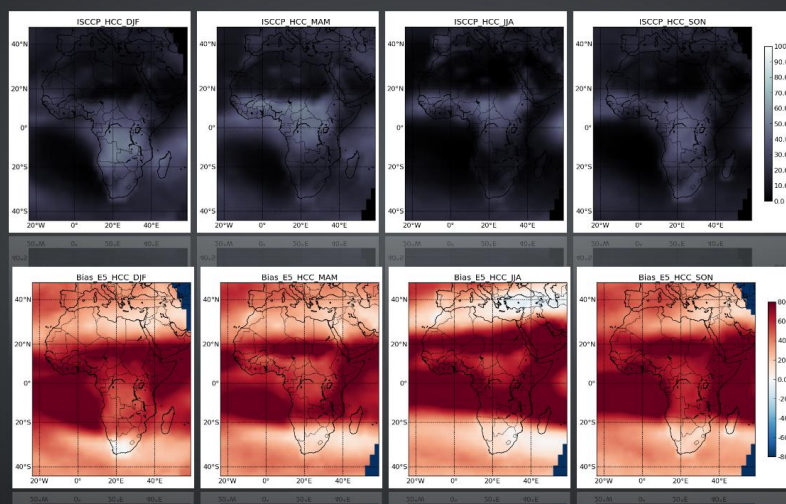
WRF-5Y DS-METHODS: LOW CLOUD COVER (E5)



WRF-5Y DS-METHODS: HIGH CLOUD COVER (E2)



WRF-5Y DS-METHODS: HIGH CLOUD COVER (E5)



CONCLUSIONS

- We have not got definitive conclusions. This is a preliminary study.
- Some WRF simulations have been performed:
 - Multi-physics
 - Main differences: Grell-Devenyi cumulus scheme (worst results)
 - AC2 PBL scheme slightly improves TCC simulation
 - Downscaling methods
 - No differences with different reinitialization strategies
 - Nudging not recommended for clouds
- General underestimation of low clouds and overestimation of high clouds.
- Very similar to CMIP5 models' results: large scale fields.

FUTURE WORKS

- Analysis of the causes of systematic deviations.
- Concentration in particular areas.
- Update WRF: new schemes for clouds.
- Other satellite data
- Other variables, such as LWP.



THANK YOU

Questions

