Evaluation of Weather Research and Forecasting (WRF) model physics options for West African Monsoon (WAM) applications

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Introduction

- The West African summer season is apparently dominated by the West African Monsoon (WAM), which provides most of the rainfall in the region.

- It is a complex interaction of many dynamical atmospheric rainfall-producing features such as;
  - monsoon flow ≈ 925mb,
  - African Easterly Jet (AEJ) ≈ 600-700mb,
  - Tropical Easterly Jet (TEJ) ≈ 200mb,
  - African Easterly Waves (AEW), and
  - Mesoscale Convective Systems (MCS).

- These features interact in a complex way to not only provide the summer monsoon rainfall but also determine the amount and variability of the produced rainfall (Redelsperger *et al*., 2002)

Aim and Objectives

Motivation

Identify a regional weather and climate model --> OUTPUTS

⇩ *INTEGRAL INPUT*

to inform decision and policy making both at national and regional level

Aim

- Evaluate WRF model physics in simulating the West African monsoon (WAM) and its associated features.

Objective

Investigate the sensitivity of WAM regime (2 months in 2007) to three model physics [Cumulus (CU), Microphysics (MP) and Planetary boundary layer (PBL) parameterization schemes]

Data and Methods

Study Area

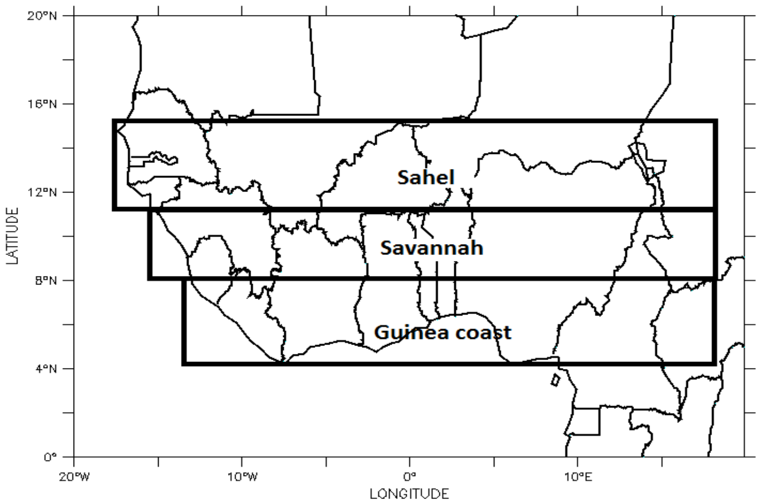


Figure 1: Map of West Africa showing the different climate zones adapted from Omotosho and Abiodun (2007)

i. Guinea Coast (4°-8°N), a sub-humid climate
ii. Savannah (8°-11°N), a semi-arid zone, and
iii. Sahel (11-16°N), arid zone

-WRFV3.8.1 with 20x20km resolution domain and 50 model levels

Outlining

-West African region (0-20°N, 20°W-20°E)

-Evaluation area (5-15°N, 10°W-10°E)

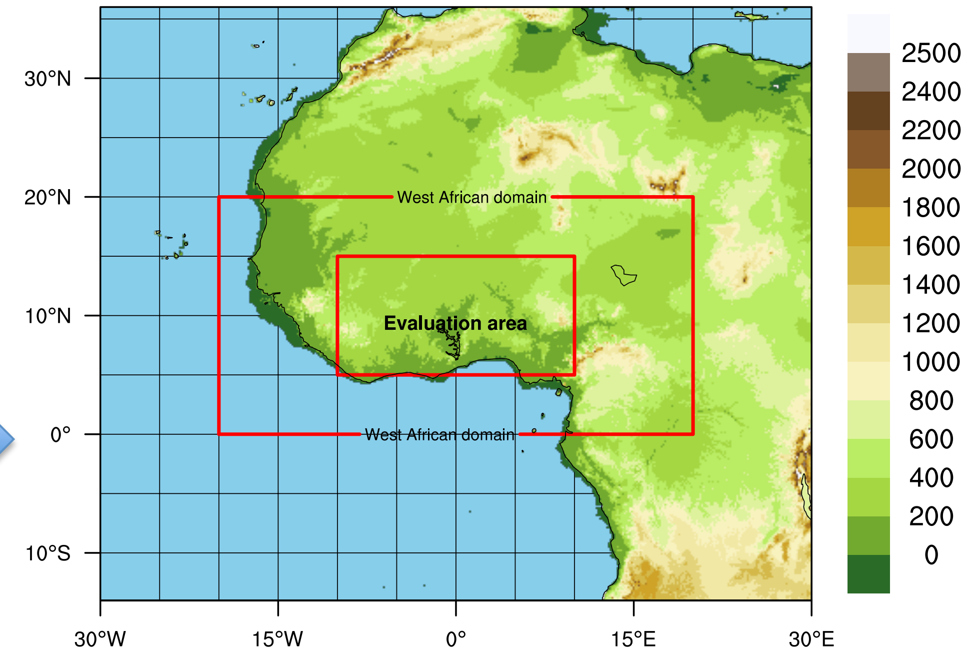


Figure 2: Model domain with topographic height in meters

- Data

A) TWO Boundary conditions from

i. 1°x1° NCEP-FNL (Source: CISL RDA)—Soil moisture and temperature data

→ Consistent with the Unified Noah-MP Land-Surface model

ii. 0.7°x0.7° ECMWF ERA Interim (Dee et al. 2011)– Lower and pressure level atmospheric variables

B) Validation and Evaluation datasets

i) Precipitation – TRMM, GPCP (Huffman *et al*. 2007, 2016) and CMORPH (Joyce et al. 2004)

ii) Temperature -- ERA interim , NCEP, MERRA(Rienecker et al. 2011) and GSAT (ensemble of ERA, NCEP & MERRA)

Physics Matrices

- Sensitivity test simulation for months (Aug-Sep, 2007 → Normal WAM year)
- 27 model runs from

RAD → RRTMG
LSM → Noah-MP

  - 2 Microphysics schemes
    - **WSM5**→WRF Single Moment 5 (Hong, Dudhia and Chen 2004, MWR)
    - **GD**→Goddard (Tao, Simpson and McCumber 1989, MWR)
  - 6 Cumulus parameterization schemes
    - **KFS**→Kain-Fritsch (Kain 2004, JAM)
    - **BMJ**→Betts-Miller-Janjic (Janjic 1994, MWR; 2000, JAS)
    - **GFS**→Grell-Freitas (Grell and Freitas 2013)
    - **TDK**→New Tiedtke (Tiedtke 1989, MWR; Zhang, Wang and Hamilton 2011, MWR)
    - **SAS**→New Simplified Arakawa-Schubert (Han and Pan 2010)
    - **nGFS**→New Grell-Freitas (WRFV3.9)
  - 3 Planetary boundary layer schemes
    - **YSU**→Yonsei University (Hong, Noh and Dudhia 2006, MWR)
    - **MYJ**→Mellor-Yamada-Janjic TKE (Janjic 1994, MWR)
    - **MYNN**→Mellor-Yamada- Nakanishi-Niino 2.5 level TKE scheme (Nakanishi and Niino 2004, 2006)

Table 1: List of model physics combinations

S/n	Models
1	WSM5-MYNN-TDK
2	WSM5-MYNN-SAS
3	WSM5-MYNN-BMJ
4	WSM5-MYJ-TDK
5	WSM5-MYJ-BMJ
6	WSM5-MYJ-SAS
7	WSM5-MYNN-GFS
8	WSM5-YSU-TDK
9	WSM5-YSU-BMJ
10	WSM5-YSU-SAS
11	WSM5-MYNN-KFS
12	WSM5-YSU-GFS
13	WSM5-MYJ-KFS
14	WSM5-MYJ-GFS
15	WSM5-YSU-KFS
16	GD-MYJ-BMJ
17	GD-MYJ-SAS
18	GD-YSU-TDK
19	GD-MYNN-SAS
20	GD-MYNN-TDK
21	GD-MYJ-TDK
22	GD-MYNN-BMJ
23	GD-YSU-BMJ
24	GD-YSU-SAS
25	WSM5-YSU-nGFS*
26	WSM5-MYJ-nGFS*
27	WSM5-MYNN-nGFS*

(***Note:*** *nGFS* are model runs from modified GFS in WRFV3.9*)

RESULTS

Precipitation Analysis (August-September 2007)

Diurnal cycle of precipitation (mm/hr)

- Precipitation diurnal cycle average of the three PBL (YSU-MYJ-MYNN) schemes
- Models reproduced similar diurnal cycle as observed
- It is interesting to note that both TRMM and CMORPH have different observed peak time
- TDK, BMJ and KFS agree with TRMM peak time while SAS and GFSs agree with CMORPH, which produce less precipitation at night
- KFS and nGFS produce more precipitation during the day time and night time, respectively, than other CU schemes

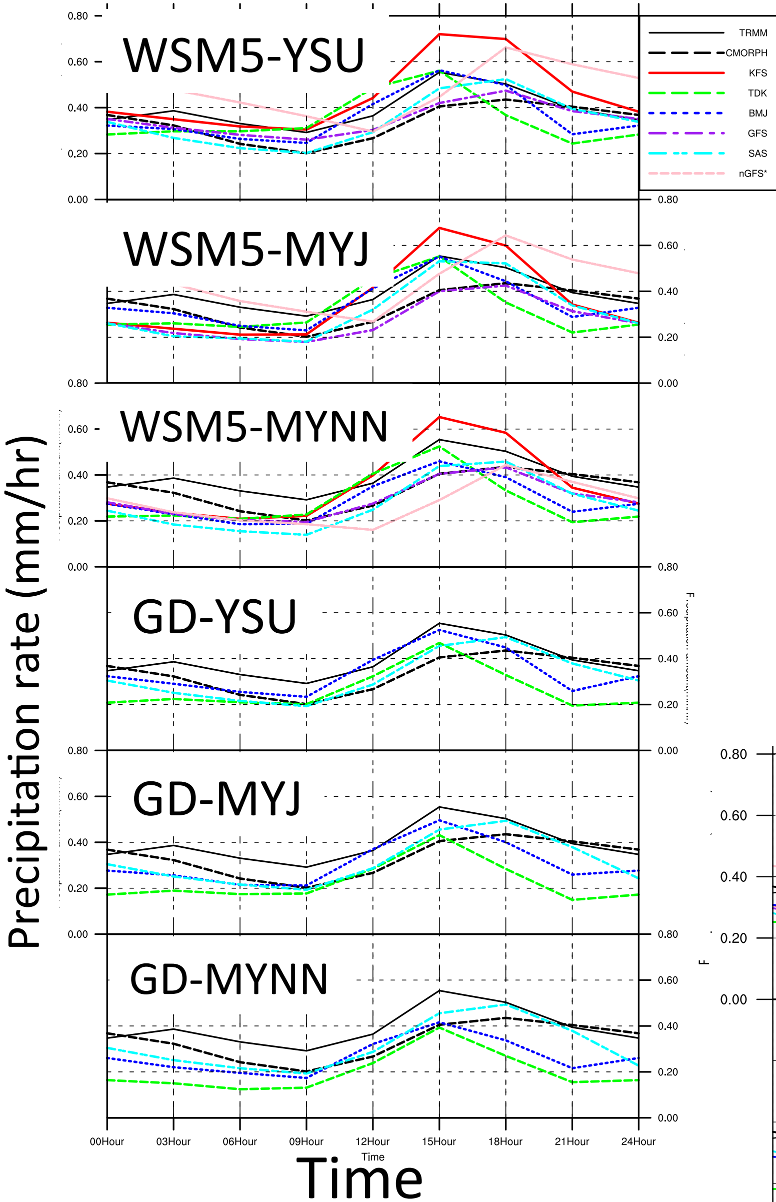


Fig 3a: Diurnal cycle of precipitation (mm/hr) averaged over 5-15N and 10W-10E

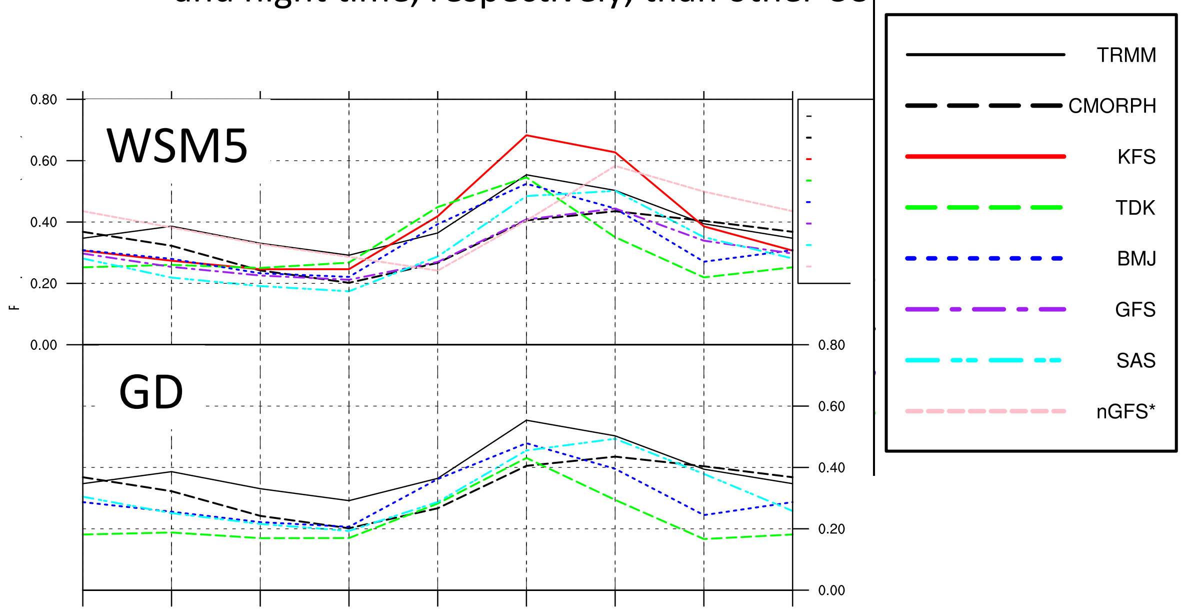
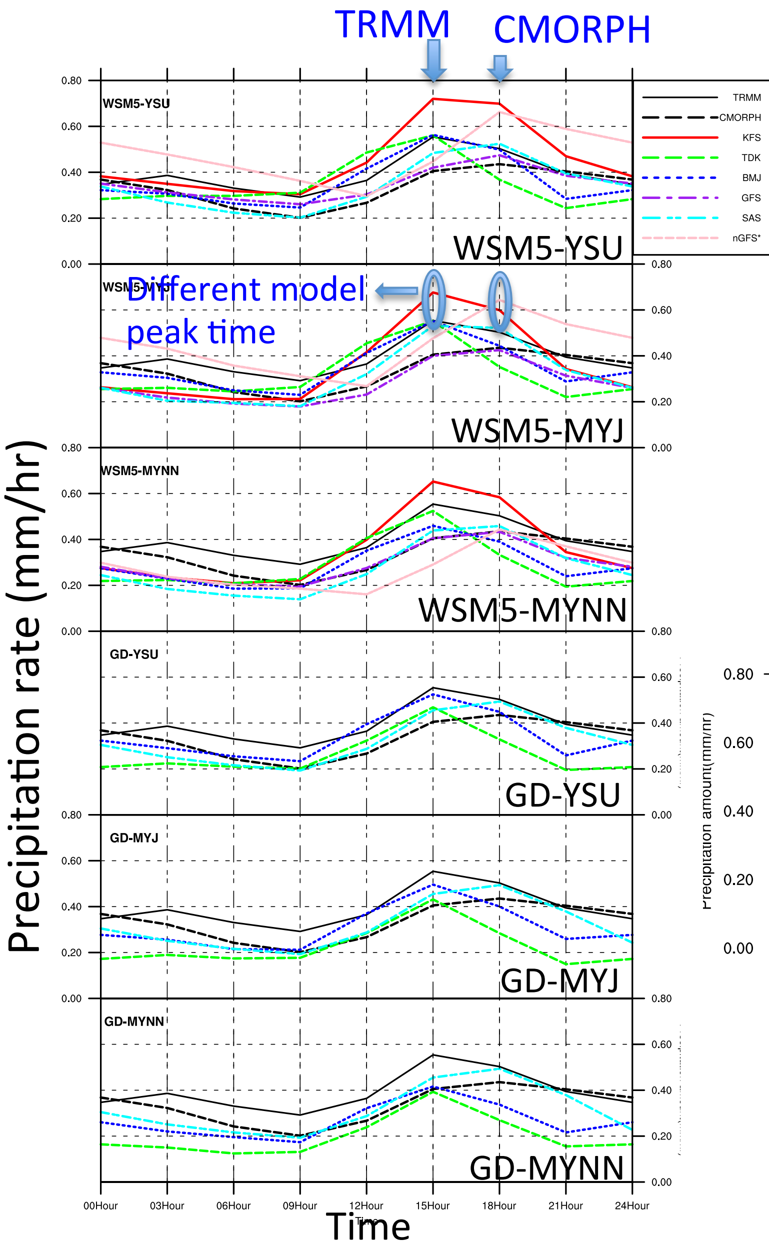


Fig 3b: Average diurnal cycle of precipitation (mm/hr) of the CU schemes

Diurnal cycle of precipitation (mm/hr)



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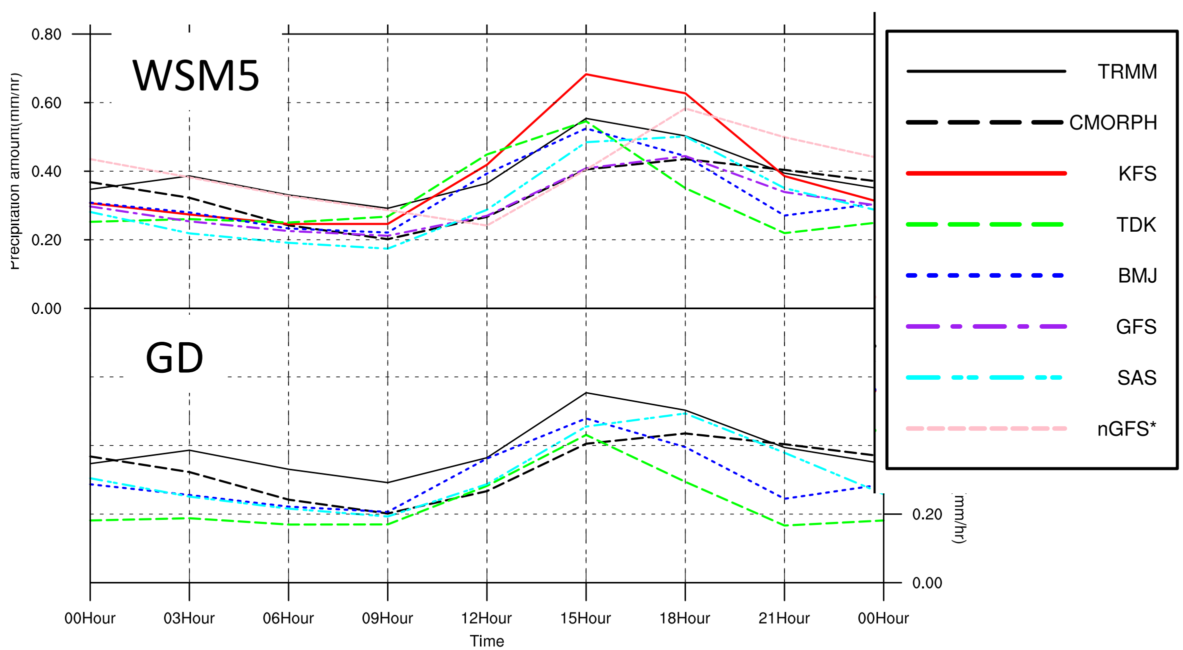


Fig 3b: Average diurnal cycle of precipitation (mm/hr) of the CU schemes

Daily time series of precipitation amount

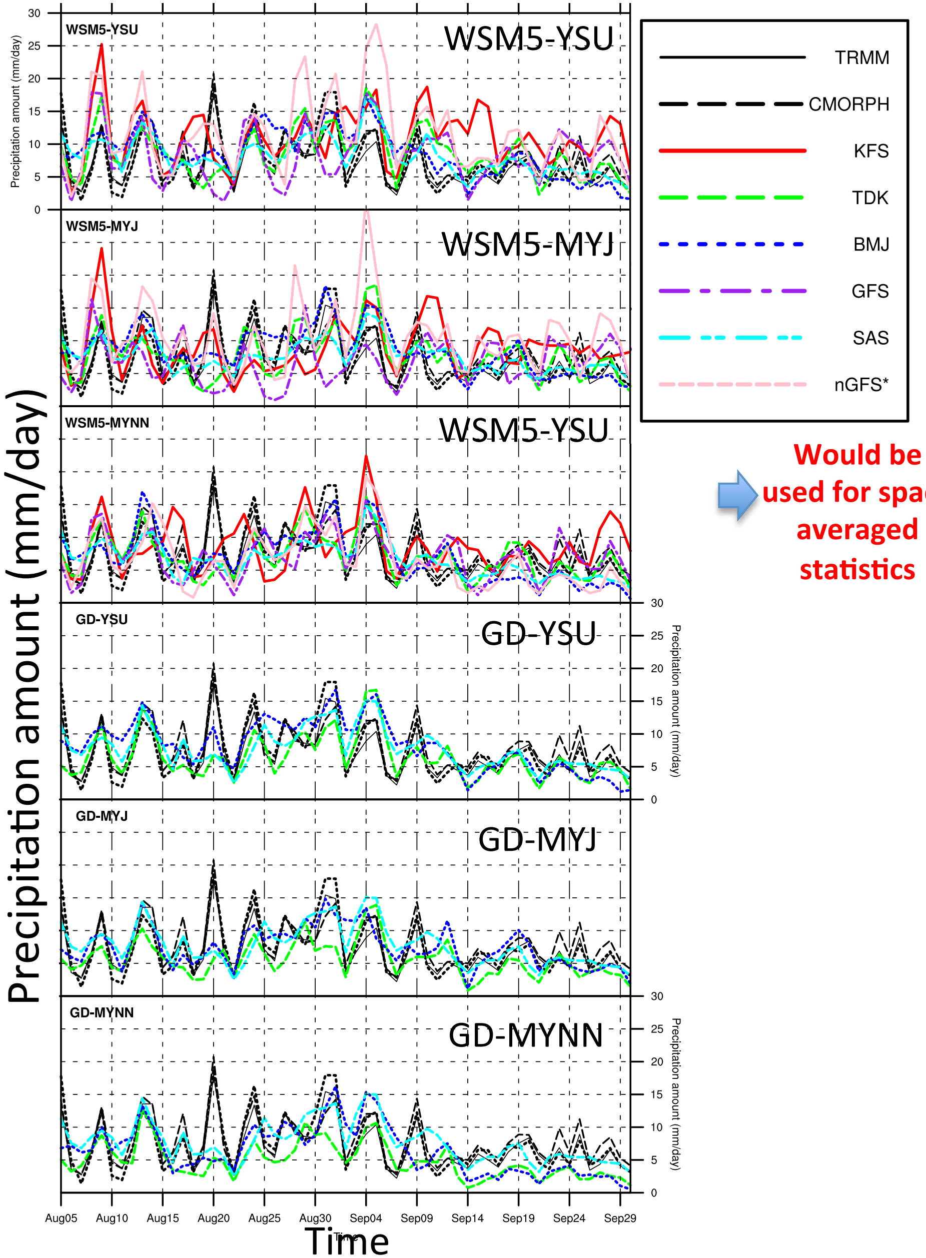
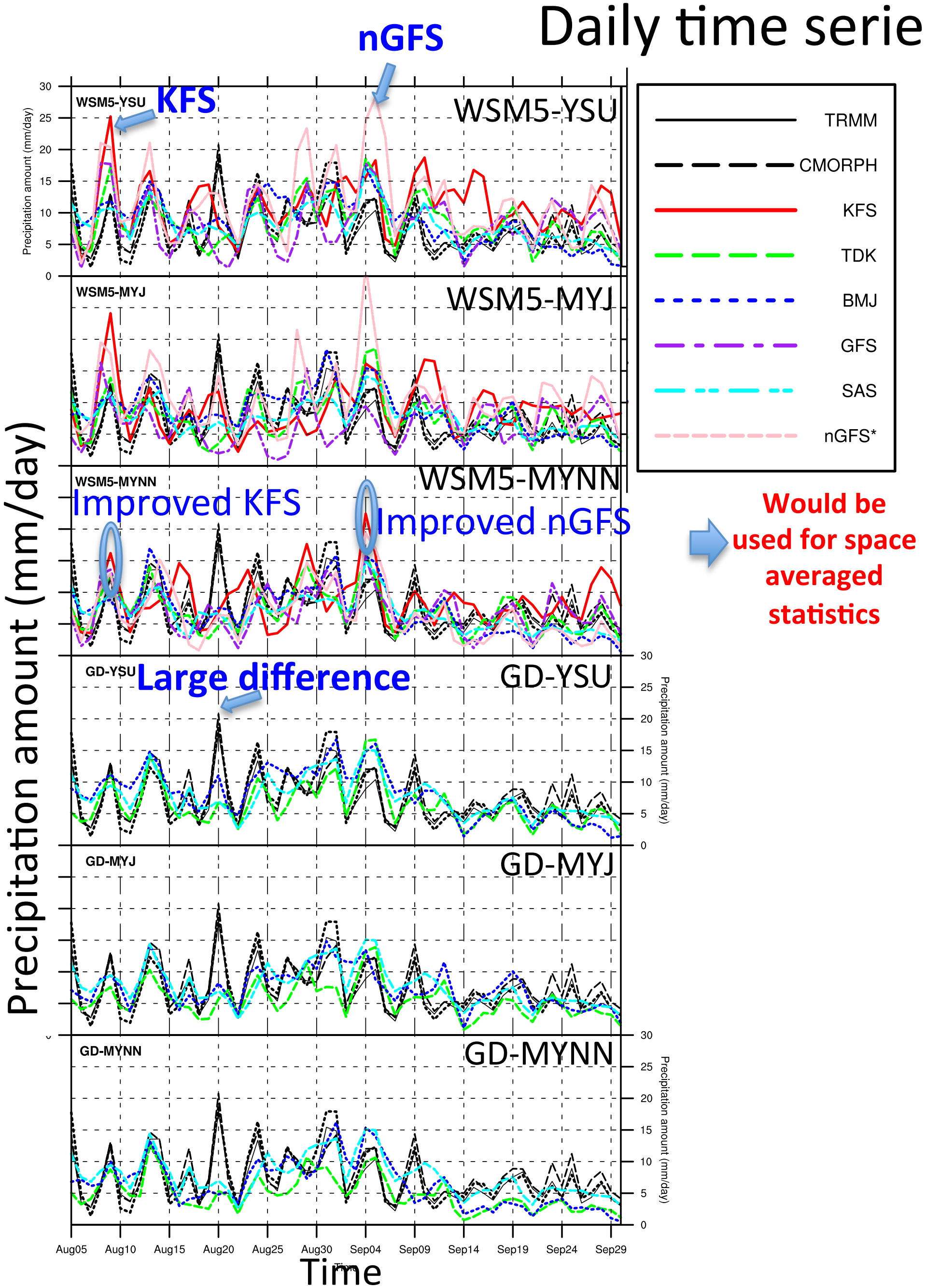


Fig 4: Time series of daily average precipitation amount (mm/day)

Would be used for space averaged statistics

- The satellite products seems to agree with each other
- Both KFS and nGFSs simulate excess precipitation amount during some cases with WSM5-YSU and MYJ
- Other model runs gives similar daily precipitation patterns as observed by TRMM but with varying magnitudes
- Wet period in August and dry period in September

Daily time series of precipitation amount



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Precipitation biases

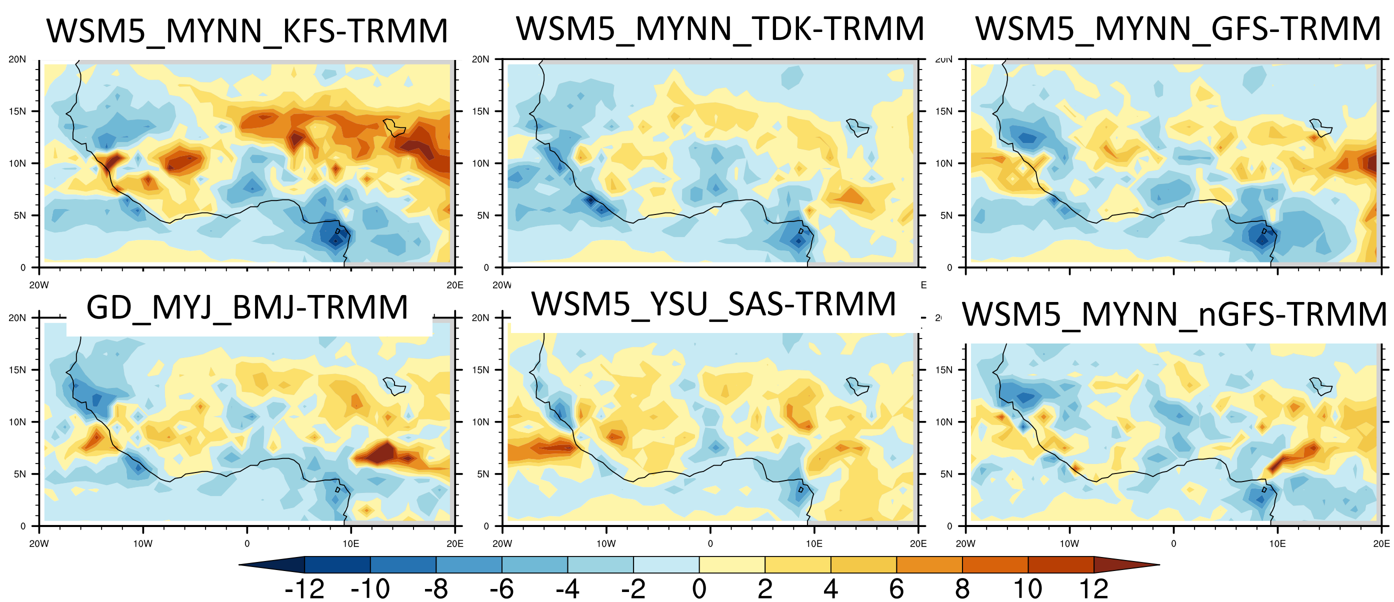


Fig 5: Precipitation bias (mm/day) averaged over the period of Aug-Sep 2007

- There exist noticeable spatial systematic error in all simulations
- However, this error varies in location and magnitudes
- KFS produces wet precipitation bias >10mmday^{-1} between 10-15N latitude band and dry bias around the coastal regions
- Other cumulus schemes have moderate wet and dry precipitation bias

Time-Longitude cross section (Hovmoller) of daily precipitation

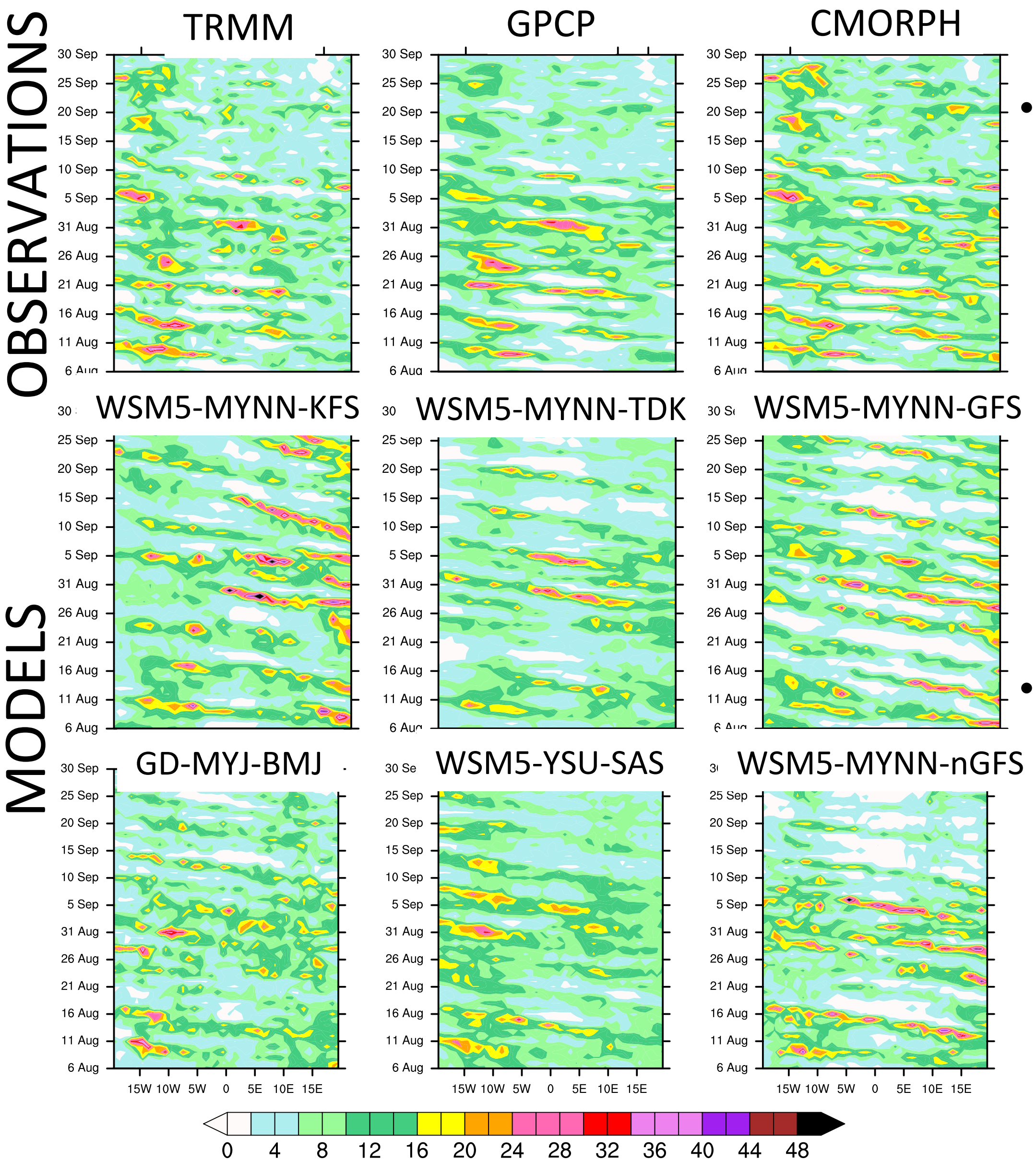


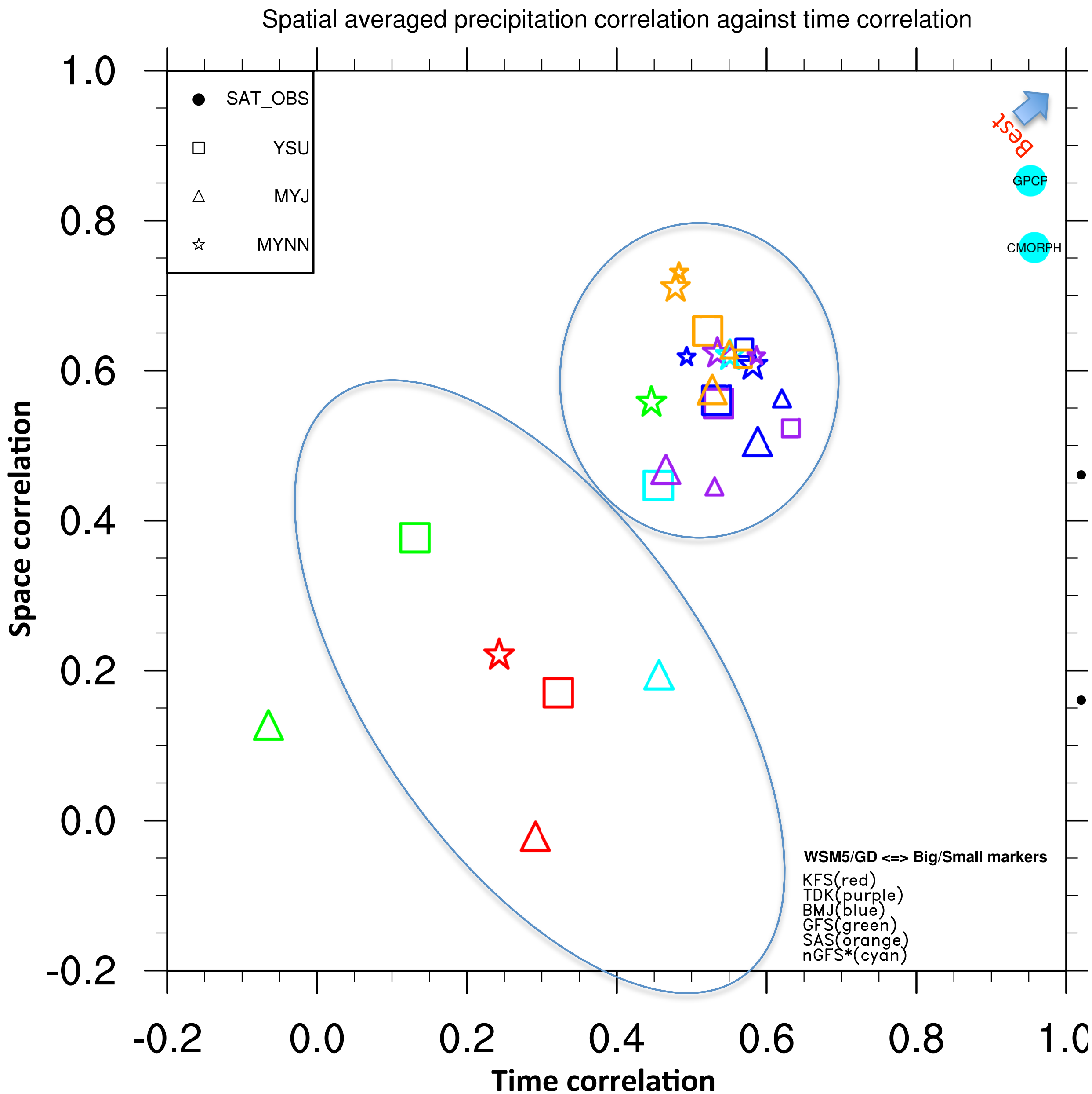
Fig 6: Time-Longitude cross section (Hovmoller) of daily precipitation amount (mm/day) averaged over 5-15N

- All satellite observations show more active westward-propagating precipitation maxima associated with African easterly waves (AEWs) in August and less in September

  The AEWs is more active all through the considered period in KFS and GFS but however more realistic in TDK, BMJ and nGFS

- In BMJ, the waves are less organized and looks more like episodic events while others show well structured linear propagation of the AEW

Scatter plot for precipitation



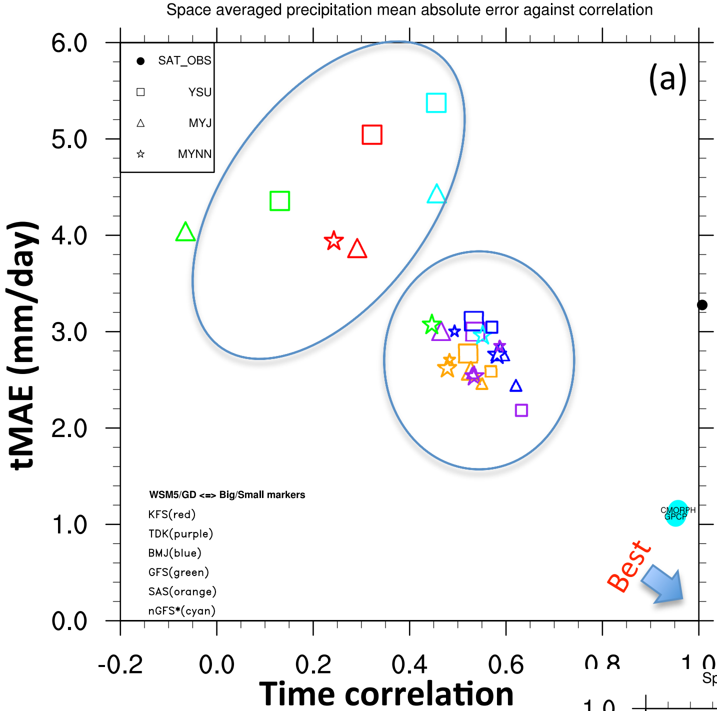
- GPCP and CMORPH agree with TRMM in MAEs and correlations
- The TDK, BMJ and SAS show higher skill
- Most simulations of KFS and GFS stands out with correlation lesser than 0.4 and MAE above 3mm/day
- Improved nGFS with MYNN

KEY

WSM5/GD ⇔ Big/Small markers
KFS
TDK
BMJ
GFS
SAS
nGFS*

Fig 7: Scatter plots for precipitation

Scatter plots for precipitation



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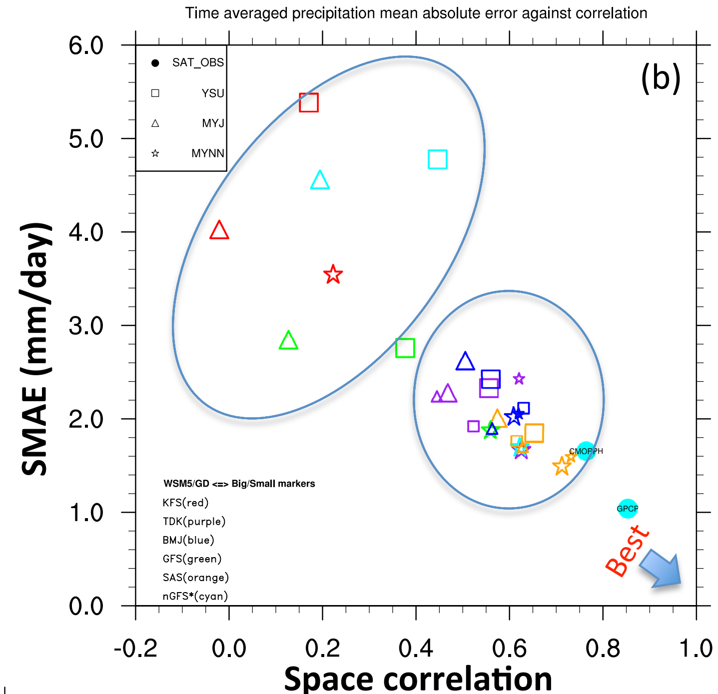

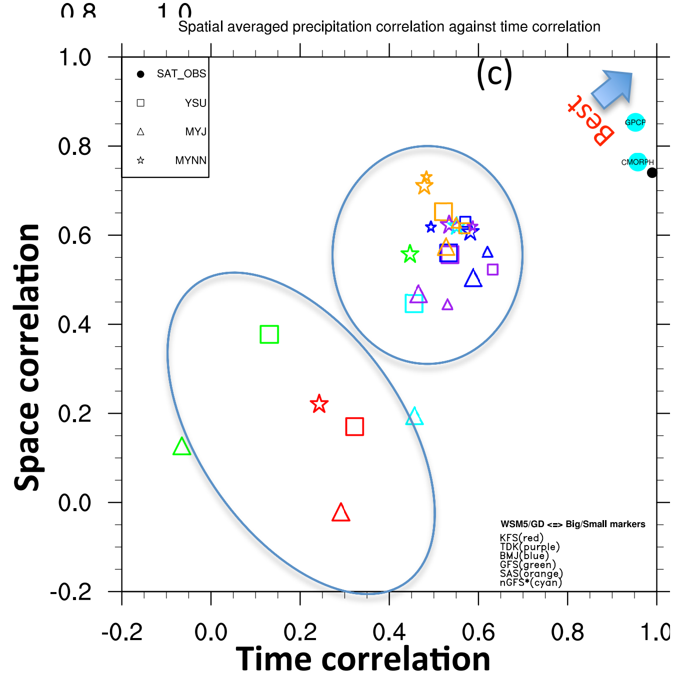

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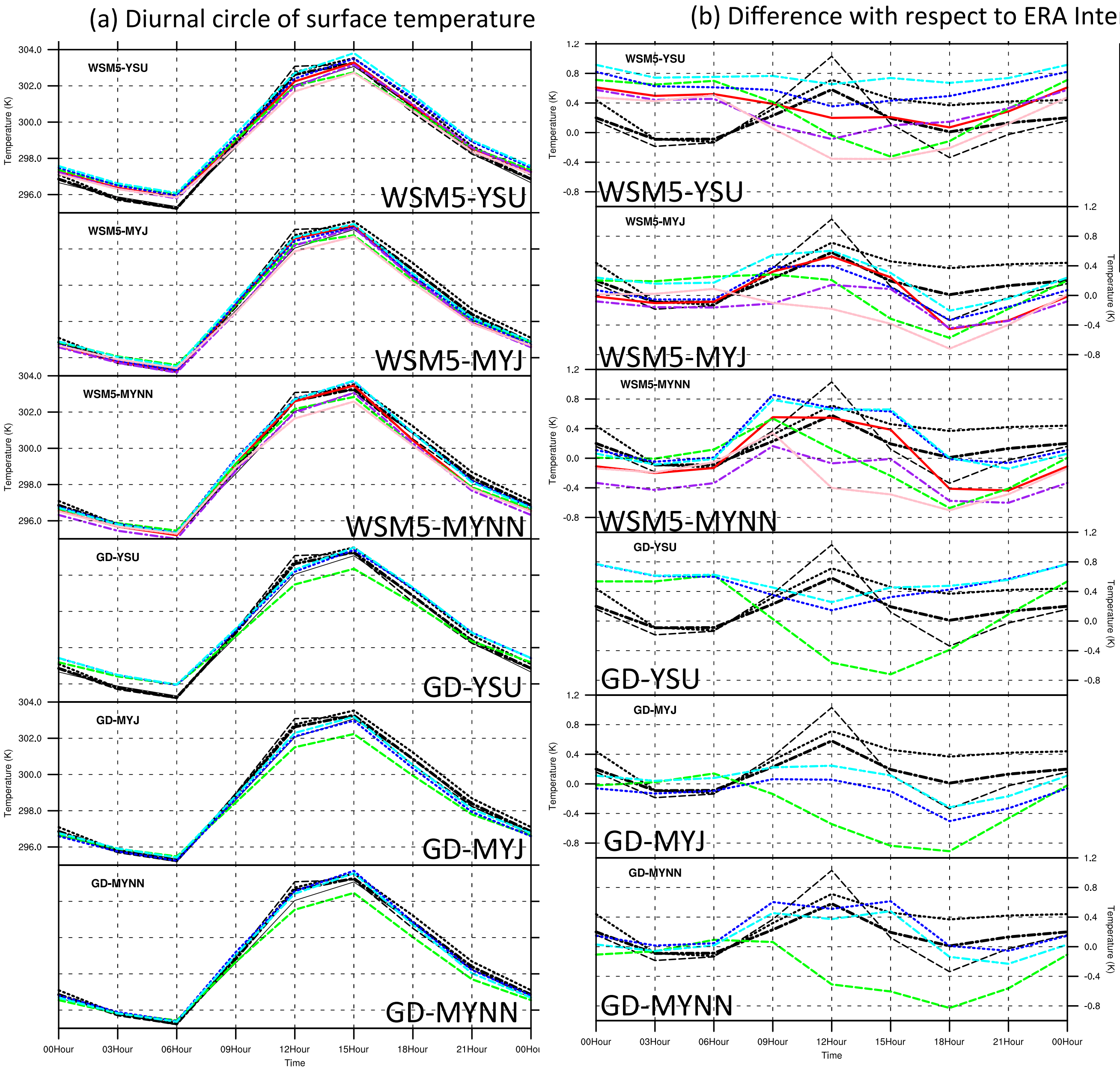
SAS

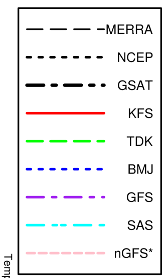
nGFS*

Fig 7: Scatter plots for precipitation

Temperature Analysis (August-September 2007)

Diurnal Cycle of surface temperature

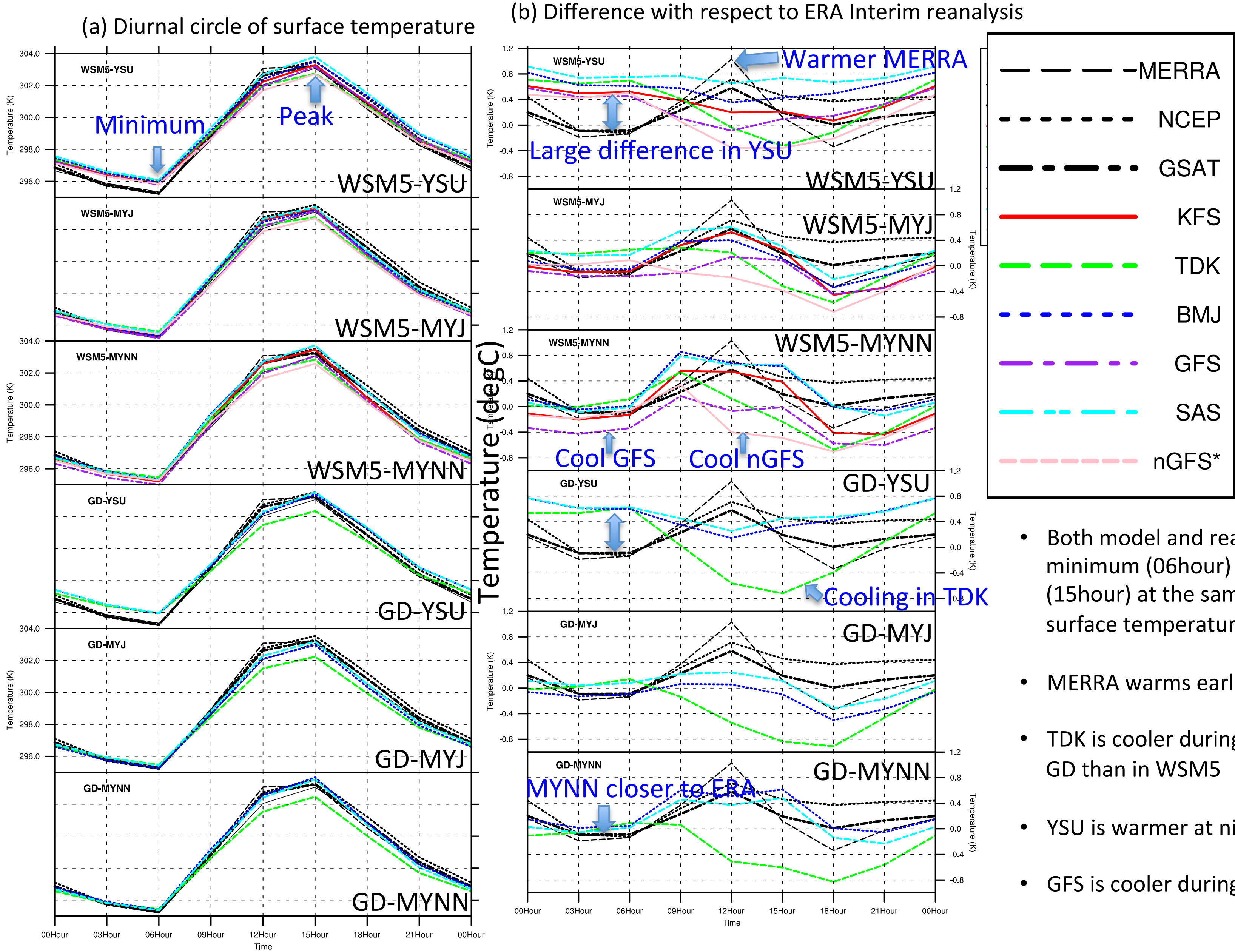




- Both model and reanalysis reach minimum (06hour) and peak (15hour) at the same time for surface temperature at 2m
- MERRA warms earlier at 12hour
- TDK is cooler during day time with GD than in WSM5
- YSU is warmer at night
- GFS is cooler during day time

Fig 8: Diurnal circle of surface temperature for Aug-Sep 2007

Diurnal Cycle of surface temperature



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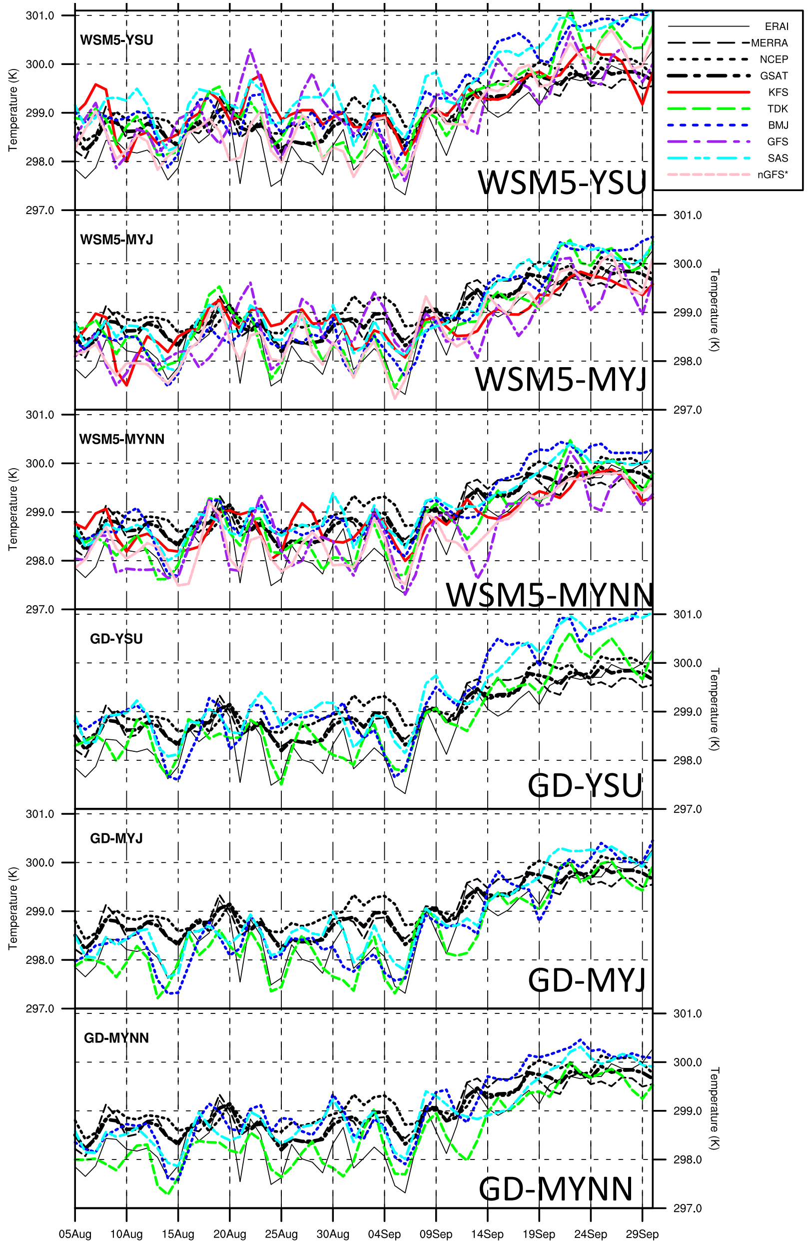
Time series of daily T2m



- There exist bias between ERA and NCEP, MERRA and GSAT, that is ERA is mostly cooler than other reanalysis
- On average, all series are warmer in September by 1-2^{o}C
- The magnitude of the daily series is higher in YSU but more consistent in MYJ and MYNN, especially in September
- One distinguishing difference between GFS and nGFS is that the GFS is mostly out of phase with ERA than nGFS

Fig 9: Time series of daily surface temperature at 2m averaged over the 5-15N and 10W-10E

Time series of daily T2m

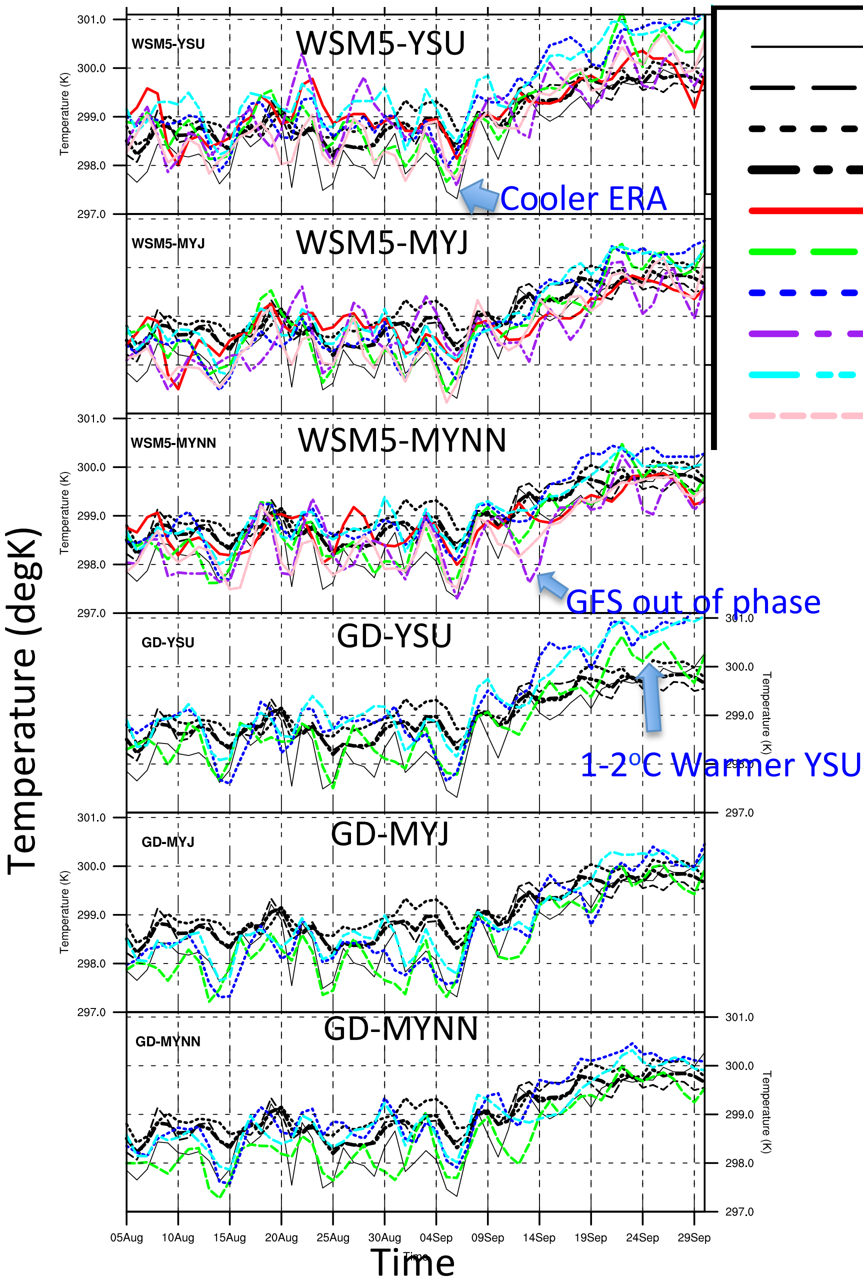


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Fig 9: Time series of daily surface temperature at 2m averaged over the 5-15N and 10W-10E

Spatial surface temperature bias

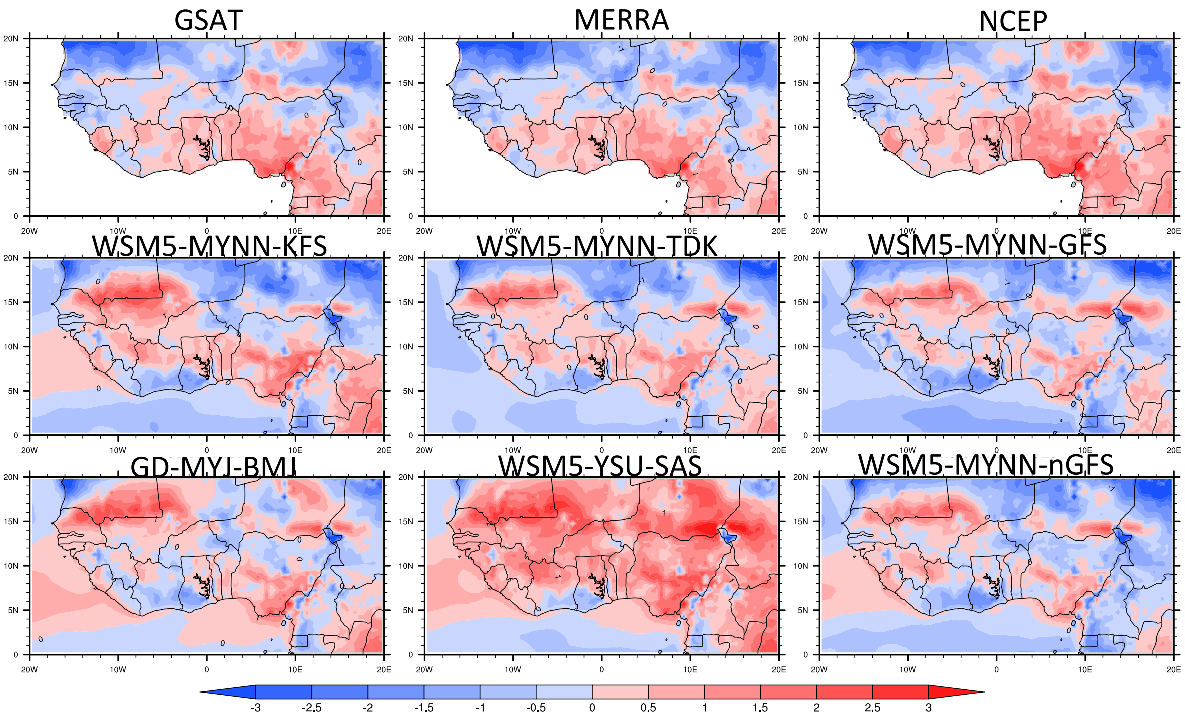
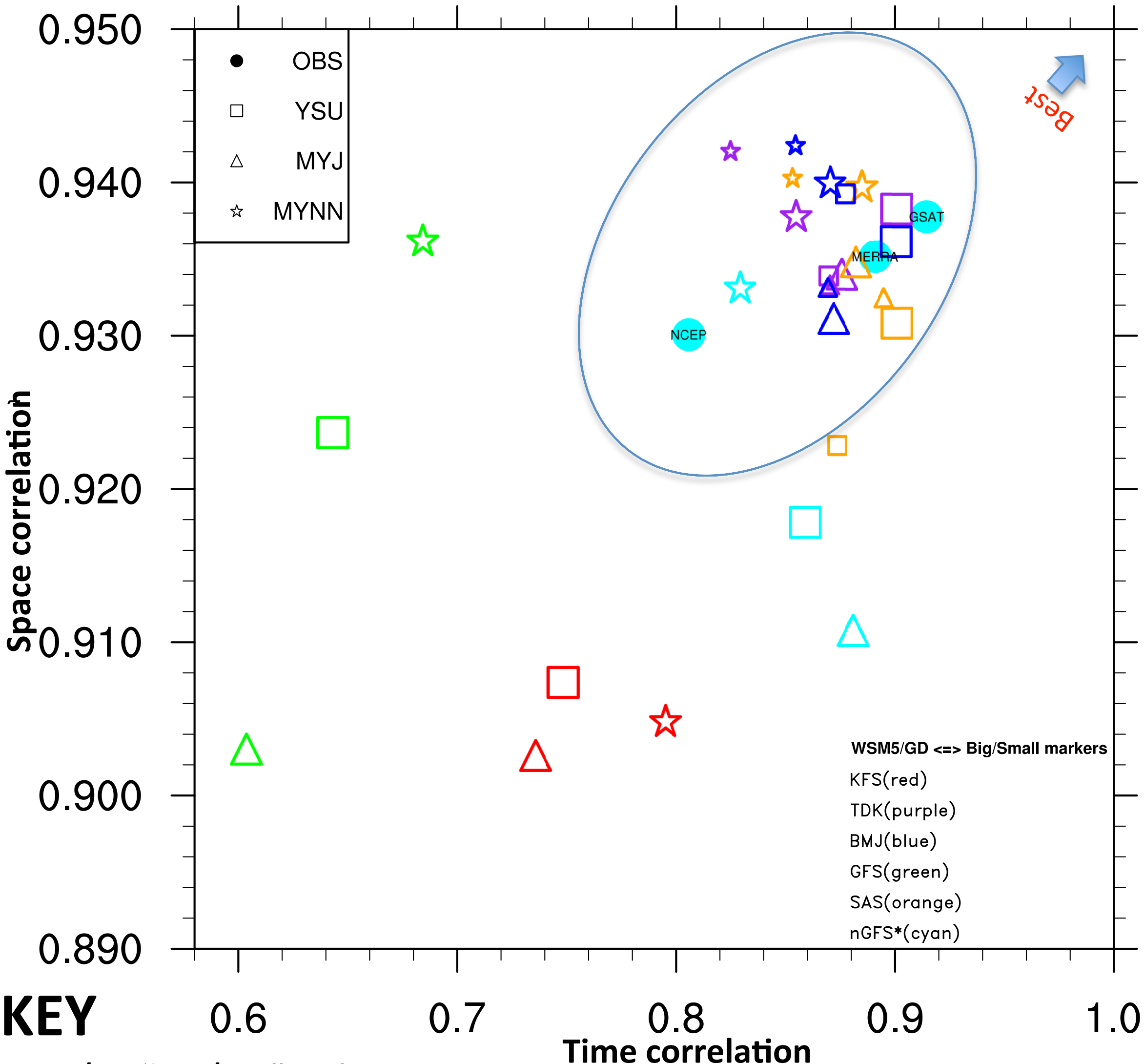


Fig 10: Spatial bias of T2m for the period of Aug-Sep

- Model and reanalyses T2m differ from ERA within the range of -3 to 3°C
- All reanalyses are cooler than ERA in the Sahel
- The models simulate cooling over some parts of the Sahel in agreement with reanalyses

- Combination of SAS with WSM5-YSU simulate a general warming over land and some parts of the ocean.
- Over the ocean the bias can be negative or positive

Scatter plot for surface temperature



KEY

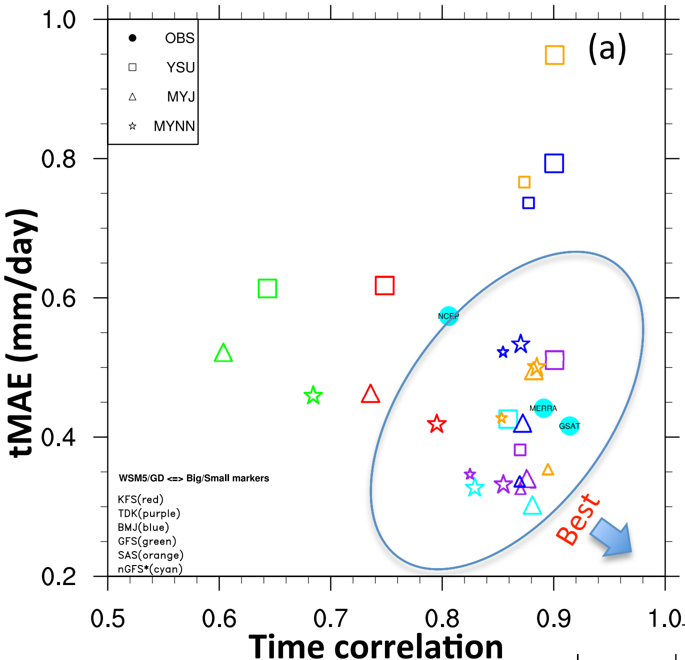
WSM5/GD ⇔ Big/Small markers
KFS
TDK
BMJ
GFS
SAS
nGFS*

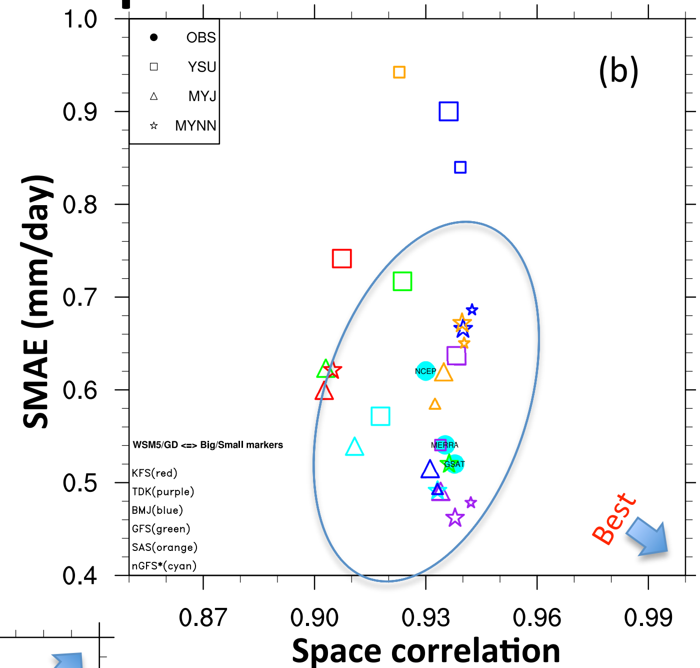
Fig 11: Scatter plots for surface temperature

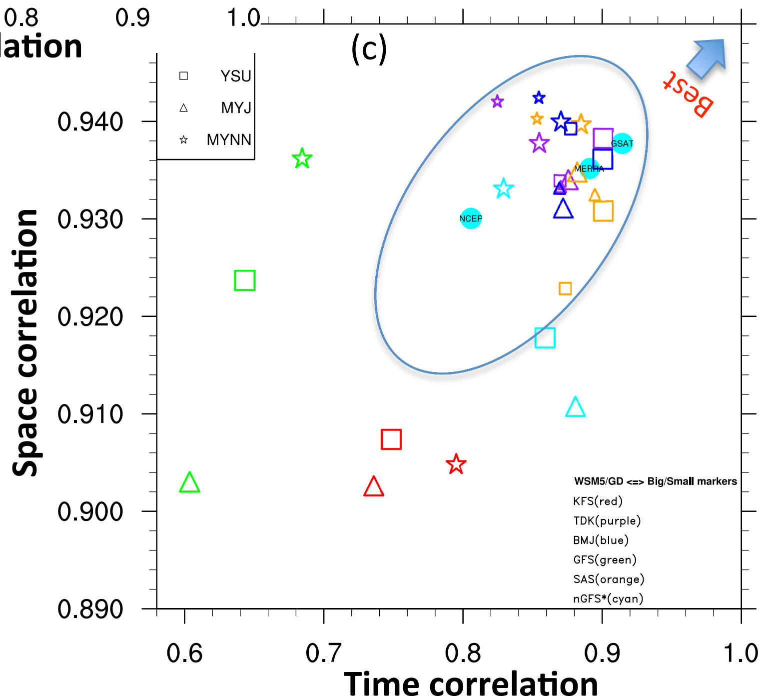
- Model differences are comparable to reanalysis differences in simulating T2m
- The models performs better with time correlation than in space correlation
- The role of MP scheme is not clearly seen with T2m

- KFS and GFS stands out to perform poorly in the overall simulation (as was seen in precipitation)
- The nGFS show a very large improvement in r and MAE compared to the old GFS, most especially with the MYNN run

Scatter plots for surface temperature







KEY

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KFS
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- YSU(squares) performs poorly both in space and time average statistics, especially with SAS and BMJ simulations

- nGFS and TDK gives better estimates of T2m and competes favorably with low MAE

Fig 11: Scatter plots for surface temperature

MODEL EVALUATION

COMPUTATION OF MODEL SKILL SCORE (MSS)

- The comparative model skill score (*MSS*) was computed from the summed normalized (X_{norm}) values of both time (t) and space (S) correlation coefficient (r), bias (B) and mean absolute error (MAE).

$$Normalized\ (X_{norm}) = \frac{X_i - X_{min}}{X_{max} - X_{min}}$$

$$\text{Such that} \quad 0 \leq X_{norm} \leq 1$$

- Where *X* could be either time or space averaged r, |B| and MAE

$$MSS = \underset{1}{Sr_{norm}} + \underset{2}{(1 - |B|_{norm})} + \underset{3}{(1 - SMAE_{norm})} + \underset{4}{tr_{norm}} + \underset{5}{(1 - tMAE_{norm})}$$

$$\text{Note that} \quad |B|_{norm} = S|B|_{norm} = t|B|_{norm}$$

- 0 (Poor performance) 🡨 *MSS* 🡪 5 (better performance)

Precipitation statistics

RAW ➔ NORMALIZED

Table 2: Raw and normalized statistics of precipitation averaged over 5-15N and 10W-10E

MODEL	Raw Statistics						Normalized statistics					MSS
	tr	t|B|	tMAE	Sr	S|B|	SMAE	tr_{norm}	$1\text{-}tMAE_{norm}$	Sr_{norm}	$1\text{-}S\|B\|_{norm}$	$1\text{-}SMAE_{norm}$	
WSM5-YSU-KFS	0.32	55.59	5.05	0.17	55.59	5.39	0.55	0.09	0.26	0.07	0.00	0.97
WSM5-YSU-TDK	0.54	20.11	3.00	0.56	20.11	2.33	0.88	0.75	0.83	0.67	0.81	3.95
WSM5-YSU-BMJ	0.53	22.62	3.11	0.56	22.62	2.43	0.91	0.76	0.87	0.63	0.80	3.98
WSM5-YSU-GFS	0.13	18.79	4.36	0.38	18.79	2.76	0.28	0.31	0.56	0.70	0.69	2.54
WSM5-YSU-SAS	0.52	14.02	2.77	0.65	14.02	1.85	0.84	0.81	0.92	0.75	0.88	4.20
WSM5-YSU-nGFS	0.46	61.22	5.37	0.45	61.22	4.78	0.73	0.00	0.65	0.00	0.18	1.55
WSM5-MYJ-KFS	0.29	25.66	3.87	-0.02	25.66	4.03	0.53	0.48	0.00	0.59	0.35	1.95
WSM5-MYJ-TDK	0.47	9.65	3.01	0.47	9.65	2.28	0.75	0.72	0.65	0.84	0.81	3.78
WSM5-MYJ-BMJ	0.59	17.68	2.80	0.50	17.68	2.62	0.93	0.78	0.80	0.70	0.74	3.94
WSM5-MYJ-GFS	-0.07	7.03	4.04	0.13	7.03	2.85	0.00	0.39	0.19	0.91	0.66	2.16
WSM5-MYJ-SAS	0.53	7.33	2.60	0.57	7.33	2.01	0.82	0.86	0.81	0.88	0.86	4.22
WSM5-MYJ-nGFS	0.46	46.67	4.44	0.19	46.67	4.56	0.72	0.22	0.34	0.20	0.20	1.66
WSM5-MYNN-KFS	0.24	22.25	3.95	0.22	22.25	3.55	0.47	0.43	0.30	0.62	0.44	2.25
WSM5-MYNN-TDK	0.53	1.76	2.55	0.62	1.76	1.68	0.86	0.87	0.89	0.99	0.95	4.57
WSM5-MYNN-BMJ	0.58	3.73	2.77	0.61	3.73	2.03	0.95	0.81	0.96	0.98	0.89	4.59
WSM5-MYNN-GFS	0.45	1.21	3.08	0.56	1.21	1.89	0.75	0.73	0.81	1.00	0.89	4.17
WSM5-MYNN-SAS	0.48	8.01	2.63	0.71	8.01	1.50	0.80	0.86	1.00	0.89	1.00	4.55
WSM5-MYNN-nGFS	0.55	8.34	2.97	0.62	8.34	1.70	0.87	0.74	0.86	0.89	0.93	4.29
GD-YSU-TDK	0.63	8.91	2.18	0.52	8.91	1.92	1.00	1.00	0.70	0.87	0.89	4.45
GD-YSU-BMJ	0.57	15.39	3.05	0.63	15.39	2.12	0.93	0.72	0.91	0.75	0.85	4.17
GD-YSU-SAS	0.57	7.62	2.59	0.62	7.62	1.76	0.90	0.86	0.85	0.86	0.92	4.40
GD-MYJ-TDK	0.53	20.82	2.57	0.45	20.82	2.24	0.84	0.86	0.67	0.66	0.85	3.87
GD-MYJ-BMJ	0.62	5.11	2.44	0.56	5.11	1.90	0.98	0.92	0.85	0.93	0.90	4.57
GD-MYJ-SAS	0.55	1.01	2.46	0.63	1.01	1.70	0.88	0.91	0.87	0.97	0.93	4.55
GD-MYNN-TDK	0.59	31.09	2.86	0.62	31.09	2.44	0.95	0.78	0.89	0.49	0.80	3.91
GD-MYNN-BMJ	0.49	10.70	3.01	0.62	10.70	2.06	0.82	0.75	0.97	0.86	0.89	4.28
GD-MYNN-SAS	0.48	14.75	2.72	0.73	14.75	1.60	0.79	0.84	1.02	0.78	0.99	4.41

An example of how normalization is done

1 = Best and 0 = worst

Overall scores for the combination of temperature and precipitation

All 27 MODEL RUN SCORE RANKING

Table 5: Overall MSS ranking for the combination of temperature and precipitation

Precipitation Score			2m Temperature Score			Precipitation and Temperature Score		
Ranking	**Model**	**MSS(5)**	**Ranking**	**Model**	**MSS(5)**	**Ranking**	**Model**	**MSS(10)**
1	GD-MYJ-SAS	4.63	1	WSM5-MYNN-TDK	4.60	1	WSM5-MYNN-TDK	9.18
2	WSM5-MYNN-TDK	4.57	2	GD-MYNN-TDK	4.58	2	GD-MYJ-BMJ	9.07
3	GD-MYJ-BMJ	4.53	3	GD-MYJ-BMJ	4.54	3	GD-MYJ-SAS	8.87
4	WSM5-MYNN-SAS	4.53	4	GD-MYJ-TDK	4.48	4	WSM5-MYNN-nGFS	8.76
5	GD-YSU-TDK	4.50	5	WSM5-MYJ-TDK	4.43	5	GD-YSU-TDK	8.75
6	GD-YSU-SAS	4.48	6	WSM5-MYNN-nGFS	4.42	6	GD-MYNN-TDK	8.44
7	WSM5-MYNN-BMJ	4.42	7	GD-YSU-TDK	4.25	7	GD-MYNN-SAS	8.40
8	GD-MYNN-SAS	4.39	8	GD-MYJ-SAS	4.24	8	GD-MYJ-TDK	8.34
9	WSM5-MYNN-nGFS	4.34	9	WSM5-MYJ-BMJ	4.14	9	WSM5-MYNN-SAS	8.33
10	WSM5-MYJ-SAS	4.30	10	WSM5-MYJ-nGFS	4.02	10	WSM5-MYNN-BMJ	8.26
11	WSM5-YSU-SAS	4.27	11	GD-MYNN-SAS	4.00	11	WSM5-MYJ-TDK	8.12
12	WSM5-MYNN-GFS	4.14	12	WSM5-YSU-TDK	3.82	12	WSM5-MYJ-BMJ	8.09
13	GD-YSU-BMJ	4.13	13	WSM5-MYNN-SAS	3.81	13	GD-MYNN-BMJ	8.04
14	GD-MYNN-BMJ	4.11	14	WSM5-MYJ-SAS	3.79	14	WSM5-MYJ-SAS	7.90
15	WSM5-MYJ-BMJ	3.90	15	WSM5-MYNN-GFS	3.75	15	WSM5-MYNN-GFS	7.84
16	WSM5-YSU-TDK	3.86	16	GD-MYNN-BMJ	3.73	16	WSM5-YSU-TDK	7.68
17	GD-MYNN-TDK	3.86	17	WSM5-MYNN-BMJ	3.70	17	GD-YSU-BMJ	7.01
18	GD-MYJ-TDK	3.85	18	WSM5-YSU-nGFS	3.59	18	WSM5-YSU-BMJ	6.62
19	WSM5-MYJ-TDK	3.83	19	WSM5-MYNN-KFS	3.02	19	GD-YSU-SAS	6.34
20	WSM5-YSU-BMJ	3.77	20	GD-YSU-BMJ	2.88	20	WSM5-YSU-SAS	6.03
21	WSM5-YSU-GFS	2.53	21	WSM5-MYJ-KFS	2.74	21	WSM5-MYJ-nGFS	5.81
22	WSM5-MYNN-KFS	2.34	22	WSM5-YSU-BMJ	2.58	22	WSM5-MYNN-KFS	5.36
23	WSM5-MYJ-GFS	2.18	23	WSM5-MYJ-GFS	2.33	23	WSM5-YSU-GFS	5.13
24	WSM5-MYJ-KFS	1.92	24	WSM5-YSU-GFS	2.30	24	WSM5-YSU-nGFS	4.83
25	WSM5-MYJ-nGFS	1.79	25	GD-YSU-SAS	2.15	25	WSM5-MYJ-KFS	4.67
26	WSM5-YSU-nGFS	1.54	26	WSM5-YSU-KFS	2.08	26	WSM5-MYJ-GFS	4.51
27	WSM5-YSU-KFS	1.01	27	WSM5-YSU-SAS	1.75	27	WSM5-YSU-KFS	3.09

All 27 MODEL RUN SCORE RANKING

Table 3: Overall MSS ranking for the combination of temperature and precipitation

Precipitation Score		
Ranking	**Model**	**MSS(5)**
1	GD-MYJ-SAS	4.63
2	WSM5-MYNN-TDK	4.57
3	GD-MYJ-BMJ	4.53
4	WSM5-MYNN-SAS	4.53
5	GD-YSU-TDK	4.50
6	GD-YSU-SAS	4.48
7	WSM5-MYNN-BMJ	4.42
8	GD-MYNN-SAS	4.39
9	WSM5-MYNN-nGFS	4.34
10	WSM5-MYJ-SAS	4.30
11	WSM5-YSU-SAS	4.27
12	WSM5-MYNN-GFS	4.14
13	GD-YSU-BMJ	4.13
14	GD-MYNN-BMJ	4.11
15	WSM5-MYJ-BMJ	3.90
16	WSM5-YSU-TDK	3.86
17	GD-MYNN-TDK	3.86
18	GD-MYJ-TDK	3.85
19	WSM5-MYJ-TDK	3.83
20	WSM5-YSU-BMJ	3.77
21	WSM5-YSU-GFS	2.53
22	WSM5-MYNN-KFS	2.34
23	WSM5-MYJ-GFS	2.18
24	WSM5-MYJ-KFS	1.92
25	WSM5-MYJ-nGFS	1.79
26	WSM5-YSU-nGFS	1.54
27	WSM5-YSU-KFS	1.01

2m Temperature Score		
Ranking	**Model**	**MSS(5)**
1	WSM5-MYNN-TDK	4.60
2	GD-MYNN-TDK	4.58
3	GD-MYJ-BMJ	4.54
4	GD-MYJ-TDK	4.48
5	WSM5-MYJ-TDK	4.43
6	WSM5-MYNN-nGFS	4.42
7	GD-YSU-TDK	4.25
8	GD-MYJ-SAS	4.24
9	WSM5-MYJ-BMJ	4.14
10	WSM5-MYJ-nGFS	4.02
11	GD-MYNN-SAS	4.00
12	WSM5-YSU-TDK	3.82
13	WSM5-MYNN-SAS	3.81
14	WSM5-MYJ-SAS	3.79
15	WSM5-MYNN-GFS	3.75
16	GD-MYNN-BMJ	3.73
17	WSM5-MYNN-BMJ	3.70
18	WSM5-YSU-nGFS	3.59
19	WSM5-MYNN-KFS	3.02
20	GD-YSU-BMJ	2.88
21	WSM5-MYJ-KFS	2.74
22	WSM5-YSU-BMJ	2.58
23	WSM5-MYJ-GFS	2.33
24	WSM5-YSU-GFS	2.30
25	GD-YSU-SAS	2.15
26	WSM5-YSU-KFS	2.08
27	WSM5-YSU-SAS	1.75

Precipitation and Temperature Score		
Ranking	**Model**	**MSS(10)**
1	WSM5-MYNN-TDK	9.18
2	GD-MYJ-BMJ	9.07
3	GD-MYJ-SAS	8.87
4	WSM5-MYNN-nGFS	8.76
5	GD-YSU-TDK	8.75
6	GD-MYNN-TDK	8.44
7	GD-MYNN-SAS	8.40
8	GD-MYJ-TDK	8.34
9	WSM5-MYNN-SAS	8.33
10	WSM5-MYNN-BMJ	8.26
11	WSM5-MYJ-TDK	8.12
12	WSM5-MYJ-BMJ	8.09
13	GD-MYNN-BMJ	8.04
14	WSM5-MYJ-SAS	7.90
15	WSM5-MYNN-GFS	7.84
16	WSM5-YSU-TDK	7.68
17	GD-YSU-BMJ	7.01
18	WSM5-YSU-BMJ	6.62
19	GD-YSU-SAS	6.34
20	WSM5-YSU-SAS	6.03
21	WSM5-MYJ-nGFS	5.81
22	WSM5-MYNN-KFS	5.36
23	WSM5-YSU-GFS	5.13
24	WSM5-YSU-nGFS	4.83
25	WSM5-MYJ-KFS	4.67
26	WSM5-MYJ-GFS	4.51
27	WSM5-YSU-KFS	3.09

PERFORMANCE➔ MSS ≥ 7.5 is GOOD; 5 ≤ MSS < 7.5 is MODERATE; MSS < 5 is POOR

CONCLUSION

- All models appear to simulate the diurnal cycles of both precipitation and surface temperature however, with some biases.

- Some models were able to simulate the westward propagation of precipitation maxima → AEWs

- MSSs are higher for surface temperature than in precipitation

- nGFS simulates improved precipitation and surface temperature much better when combined with MYNN in WRFV3.9

Conclusion contd.

- SAS and TDK produced better simulation of precipitation and surface temperature, respectively.

- GD and MYNN runs performed better for both variables.

- Based on overall MSS the best performing physics combinations in both surface temperature and precipitation for the period of study are WSM5-MYNN-TDK and GD-MYJ-BMJ

- This evaluation study helped in identifying the better performing physics combinations to be selected for assessing not only the seasonal, annual and decadal variability of WAM but also its future (climate) outlook

FUTURE PLANS…….

Use the best performing physics combinations to

i. evaluate the performance of the model in representing the dynamic and thermodynamic features of WAM for 8 months period with a few selected years and;

ii. project the future outlook of WAM for three RCPs (RCP8.5, 6.0 and 4.5).

Thank you

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