WRF model performance and sensitivity to model physics in a medium and high-resolution downscaling experiment for West Africa

Cornelia Klein[1,2], Jan Bliefernicht[2], Dominikus Heinzeller[1], Joel Arnault[1,2], Harald Kunstmann[1,2]

1: Karlsruhe Institute of Technology, Germany
2: University of Augsburg, Germany

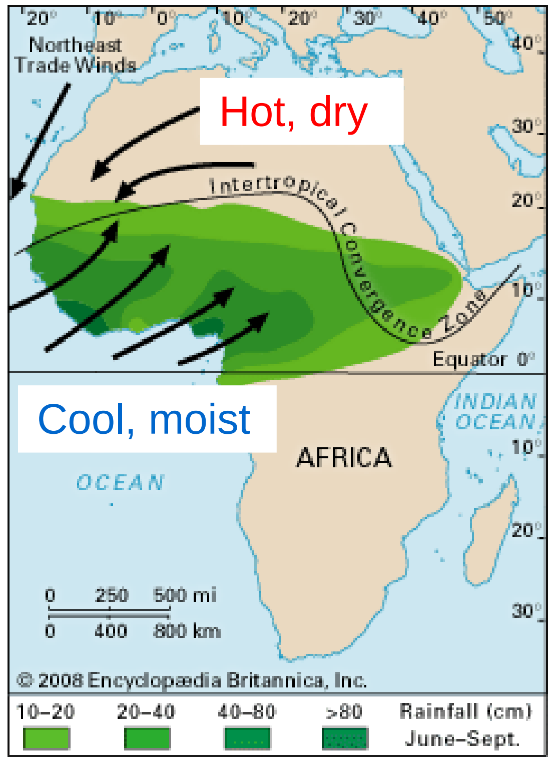
Bundesministerium für Bildung und Forschung

WASCAL

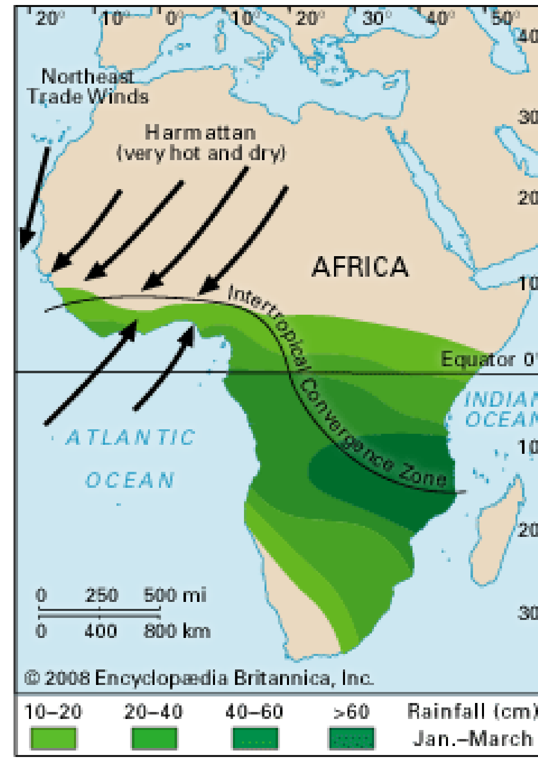
Background: West African summer monsoon

- Key feature of the West African climate
- Movement of rainband from south to north – following ITCZ
- Northernmost position: August

Jul - Sep



Jan - Mar



Objectives

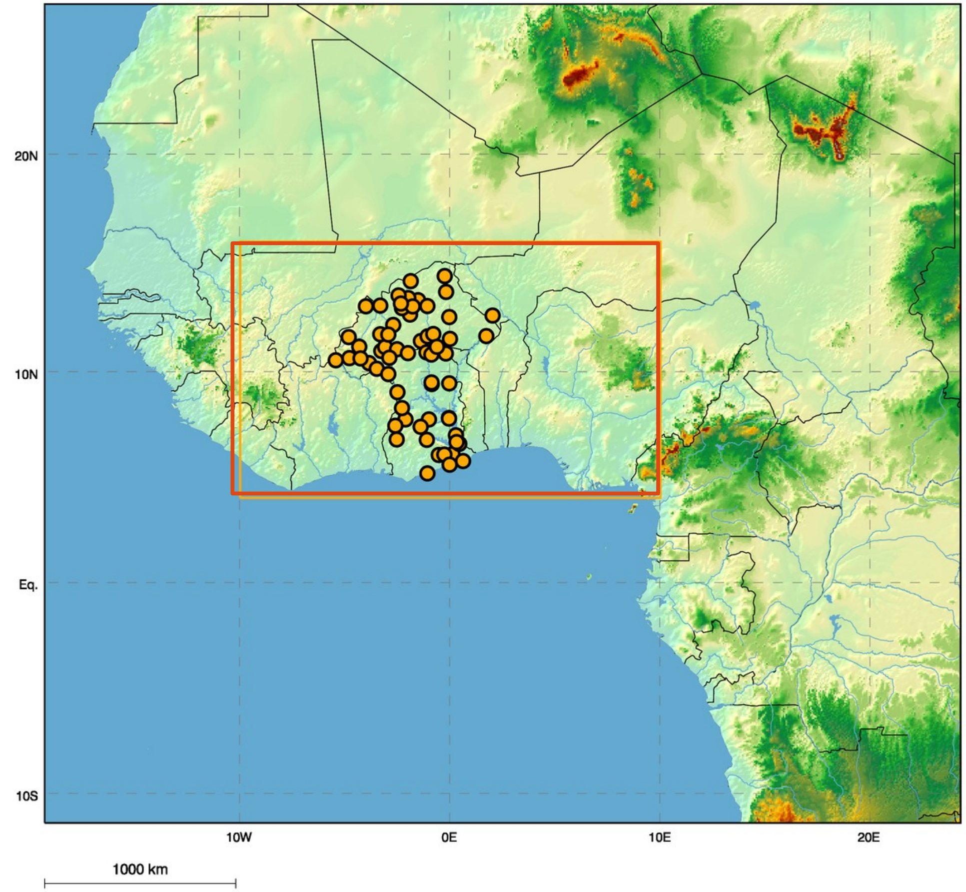
Setting up the model for West Africa:

- Model parameterization combinations –
  differences and representation of the monsoon? (WRF24)

- Convection-allowing configuration –
  improvement of representation of intense events? (WRF4)

Study region

Study area: 10°W - 10°E
4°N – 16°N
Ocean masked out



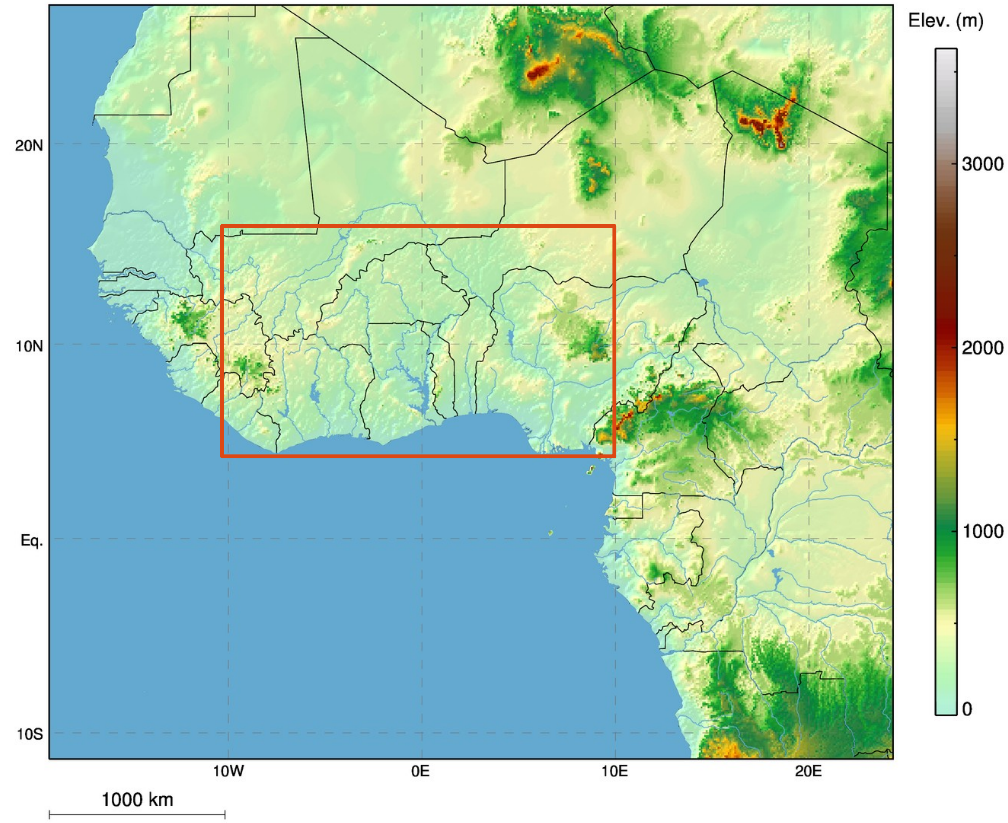
Focus: model precipitation

Observations: TRMM 3B42 V7 (daily, 3h)
Stations
(Met Services: Burkina Faso, Ghana)

Regional downscaling set-up: WRF24

Forcing Data	ERA-Interim
Resolution	24km
Time period	Mar-Oct 1999 /2002
Vert. Layers	36 / 10 hPa
Spin-Up	1 month
External SST	NCDC, daily
Other Options	SST/LAI/ALB update Adjusted lake T MODIS Landcover
Invariant Physics	Noah LSM Dudhia SW RRTM LW

WRF24 Domain



Tested WRF24 configurations

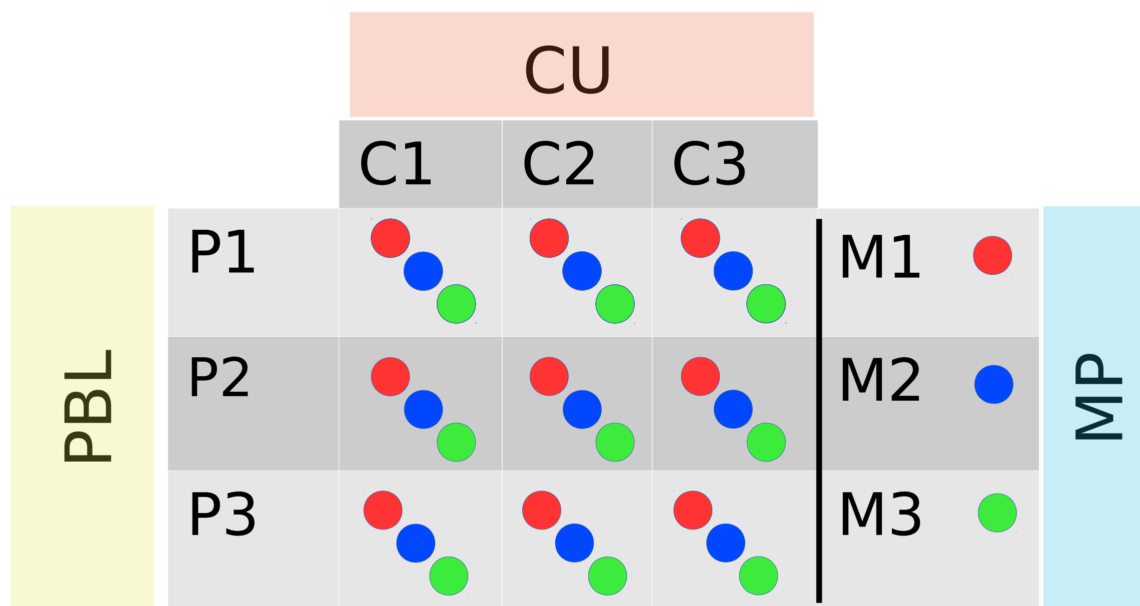
Cumulus Schemes (CU):
- Betts-Miller-Janjic (C1)
- Grell-Freitas (C2)
- Kain-Fritsch (C3)

Planetary Boundary Layer Schemes (PBL):
- Asymmetric Convective Model, V.2 (P1)
- Mellor-Yamada-Janjic (P2)
- Yonsei University (P3)

Microphysics Schemes (MP):
- Lin Purdue (M1)
- Thompson (M2)
- WRF Single Moment 3 (M3)

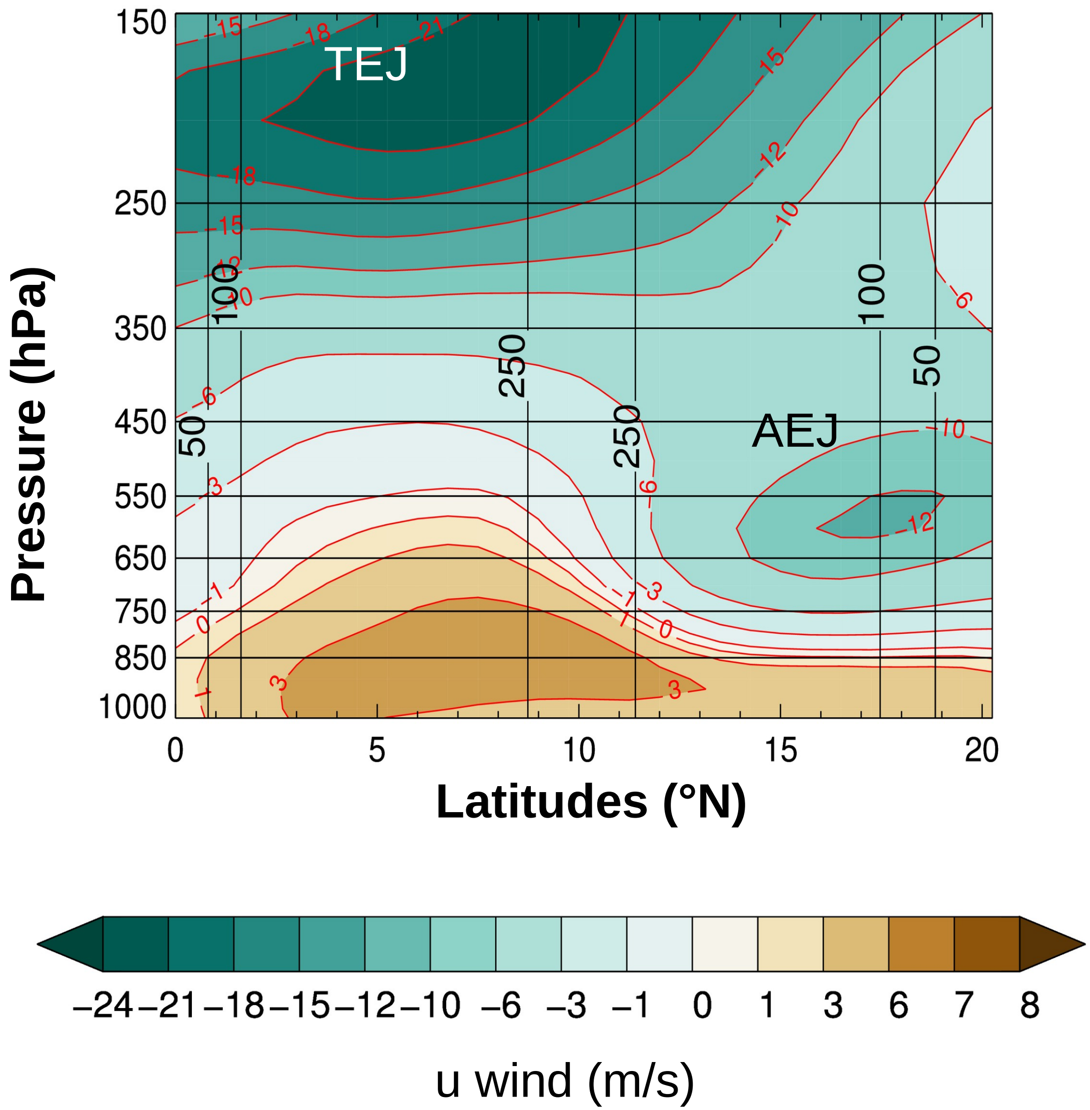
References:
- NCAR 2013 (R1)
- Noble et al. 2013 (R2)

27 + 2 simulations



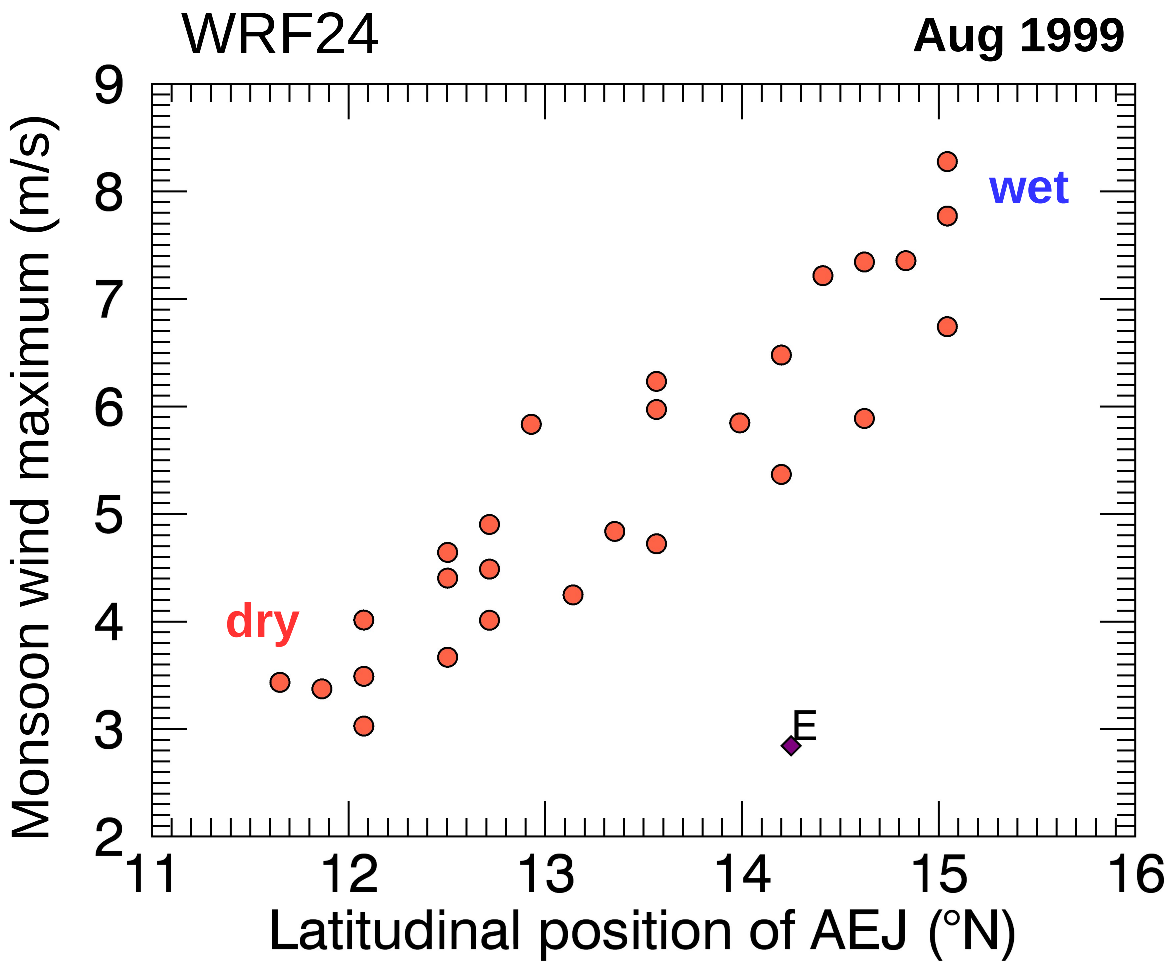
West Africas dynamical ingredients

Aug 1999 (10°W - 10°E)
ERA-I

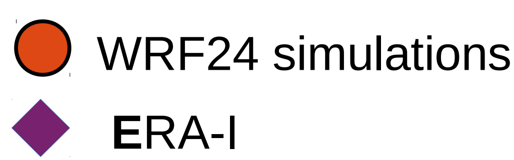


TEJ: Tropical Easterly Jet
AEJ: African Easterly Jet
— Precipitation (mm/month)

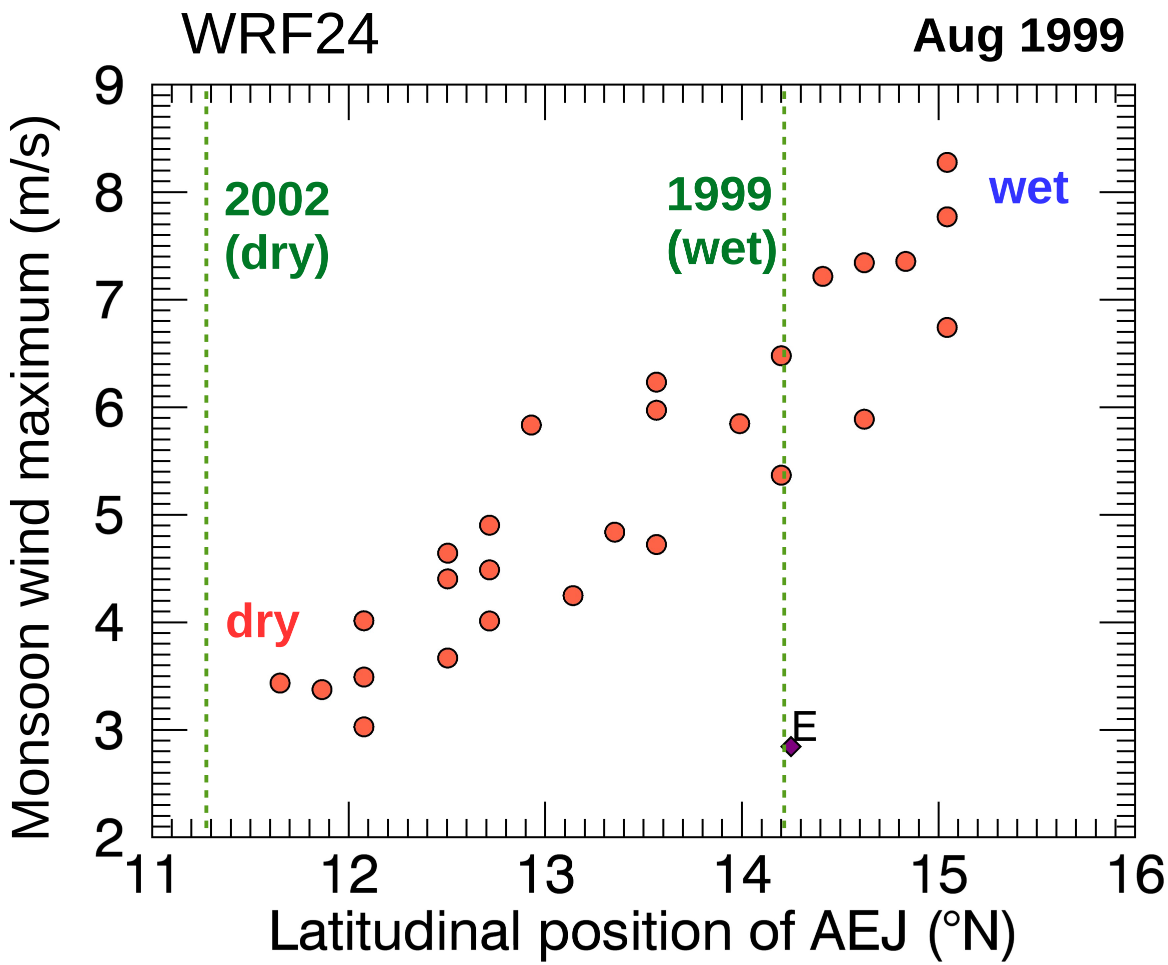
The AEJ position: a regime indicator



AEJ: African Easterly Jet:
“northern border of rainband”



Same forcing data – altered dynamics



AEJ: African Easterly Jet:
“northern border of rainband”

WRF24 simulations

ERA-I

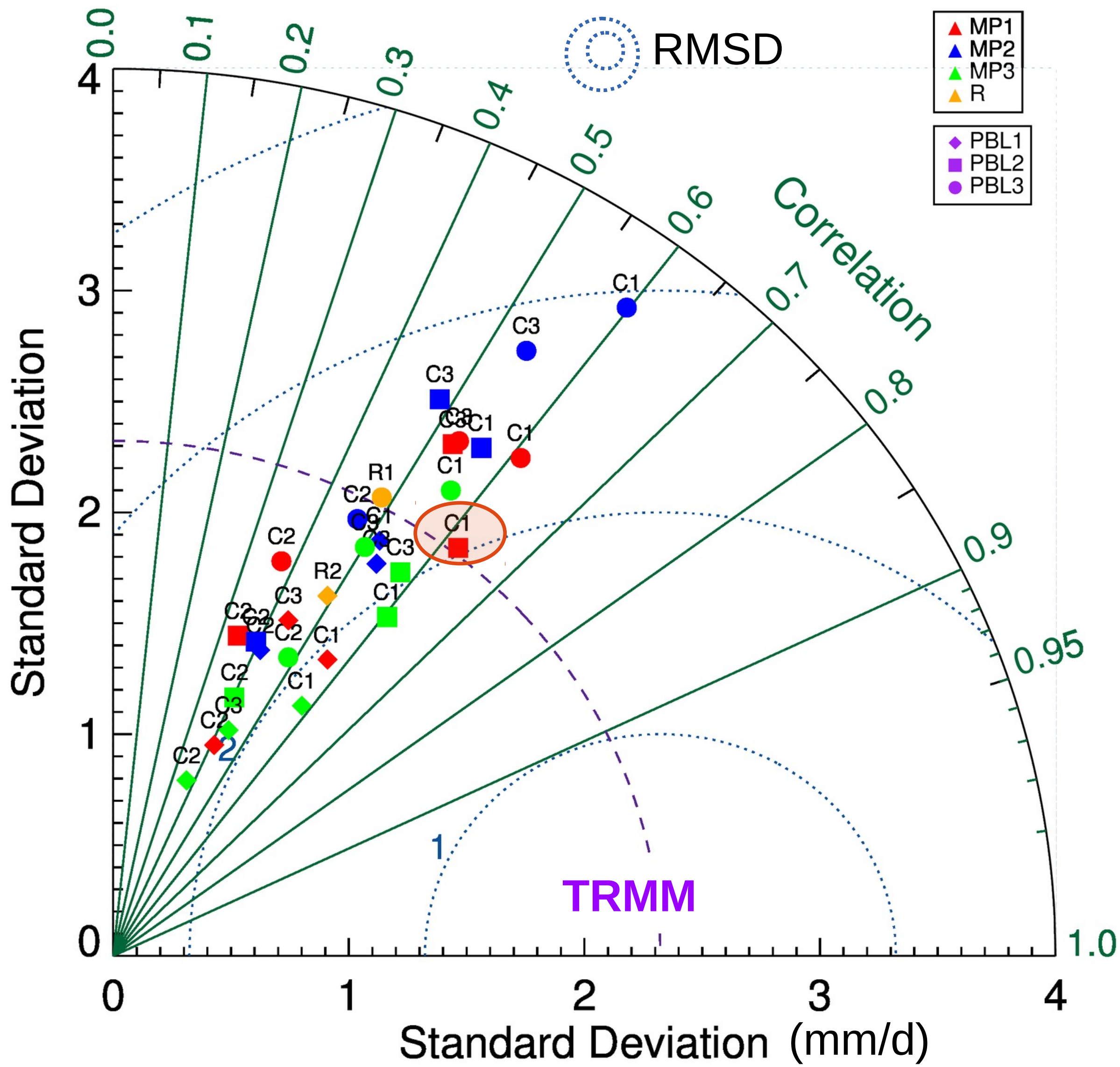
AEJ position:
11.5 – 15°N

Finding a WRF24 base configuration

WRF24
Precipitation (mm/d)
Apr-Sep 1999 / 2002

BMJ_LIN_MYJ

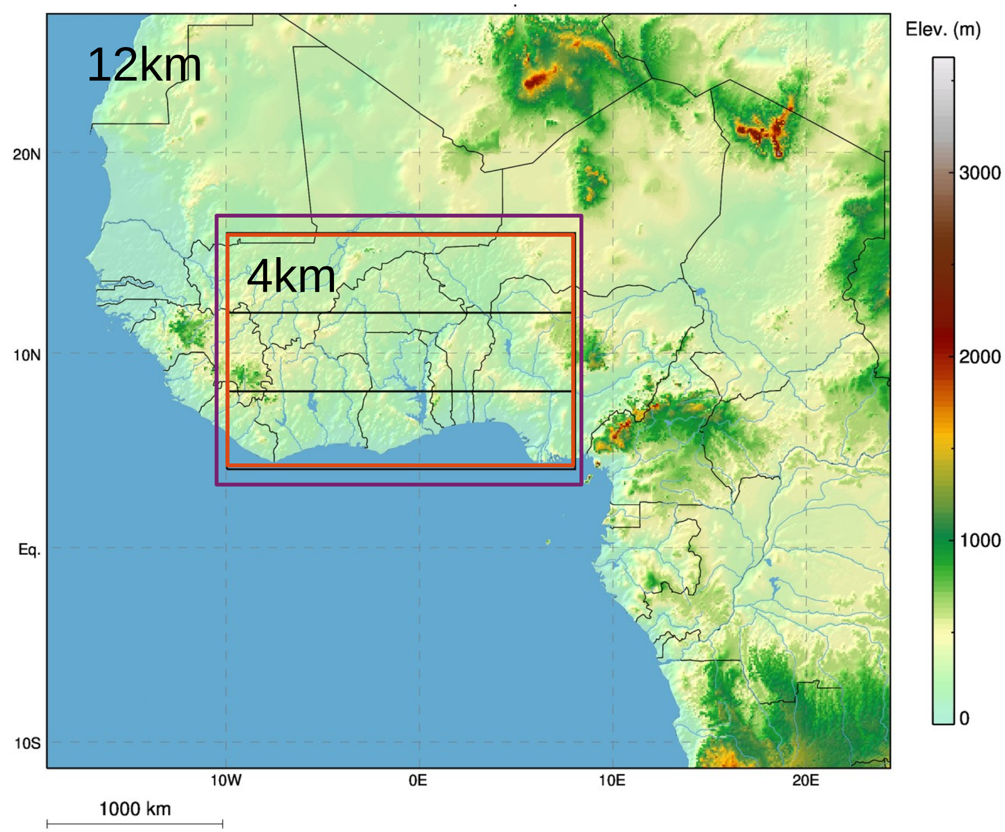
CU: Betts-Miller-Janjic
MP: Lin Purdue
PBL: Mellor-Yamada-Janjic



Regional downscaling set-up: WRF4

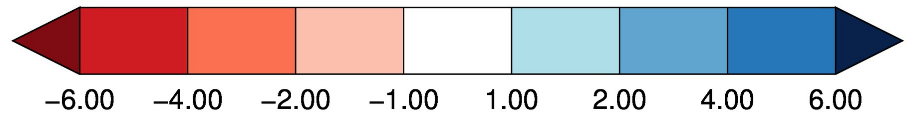
Same as WRF24 but ..	
Resolution	12km / 4km
Time period	Mar-Oct 1999
Physics	**12km: BMJ_LIN_MYJ** **4km: no CU**

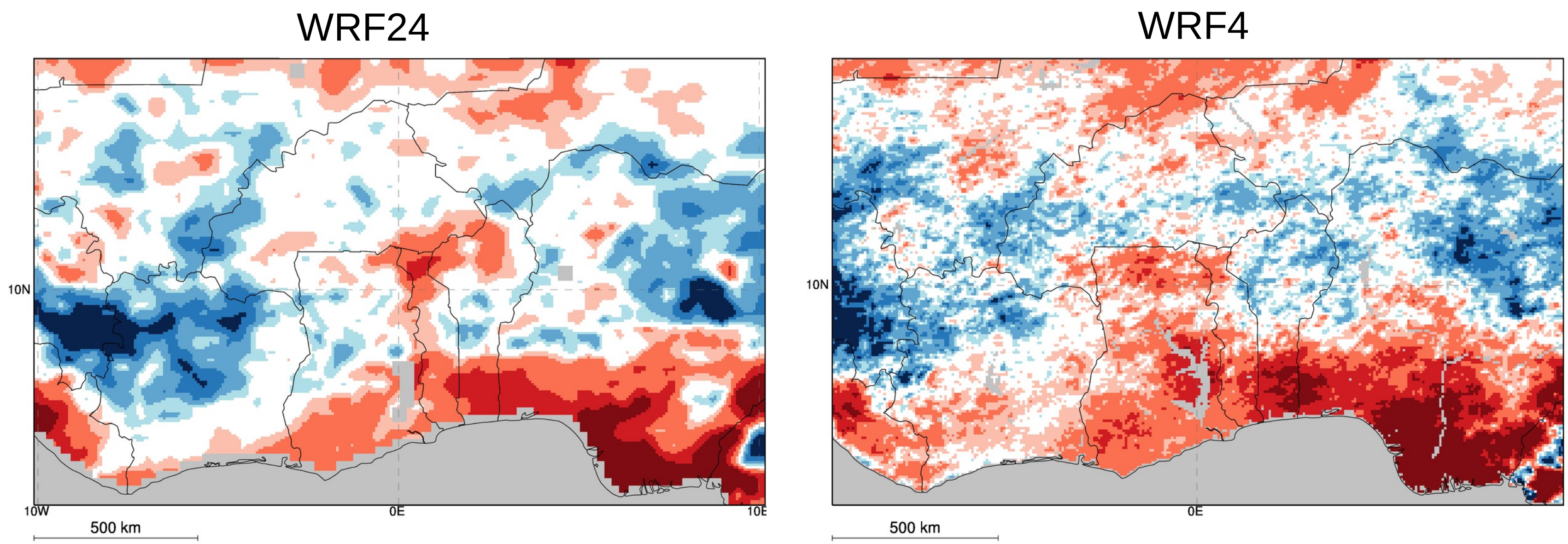
Study area: 10°W - 10°E
4°N – 16°N
Time period: Jul-Sep 1999



WRF24 vs. WRF4 – where is my added value?

Reference: TRMM
Jul-Sep 1999



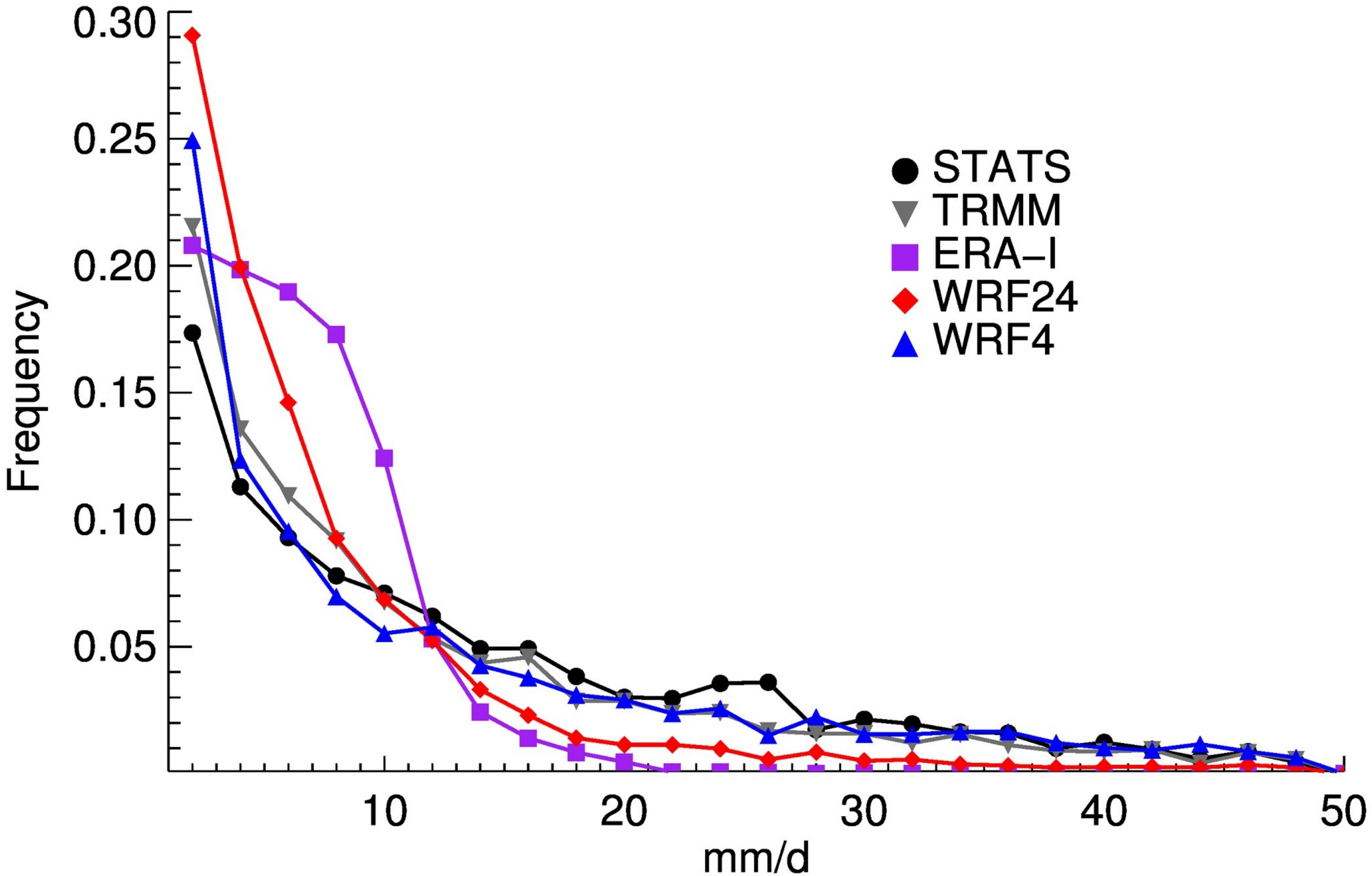


Spatial mean	Bias (mm/d)	MAD (mm/d)	Corr
WRF24	-0.14	2.69	0.38
WRF4	-0.32	2.60	0.44

} minor differences

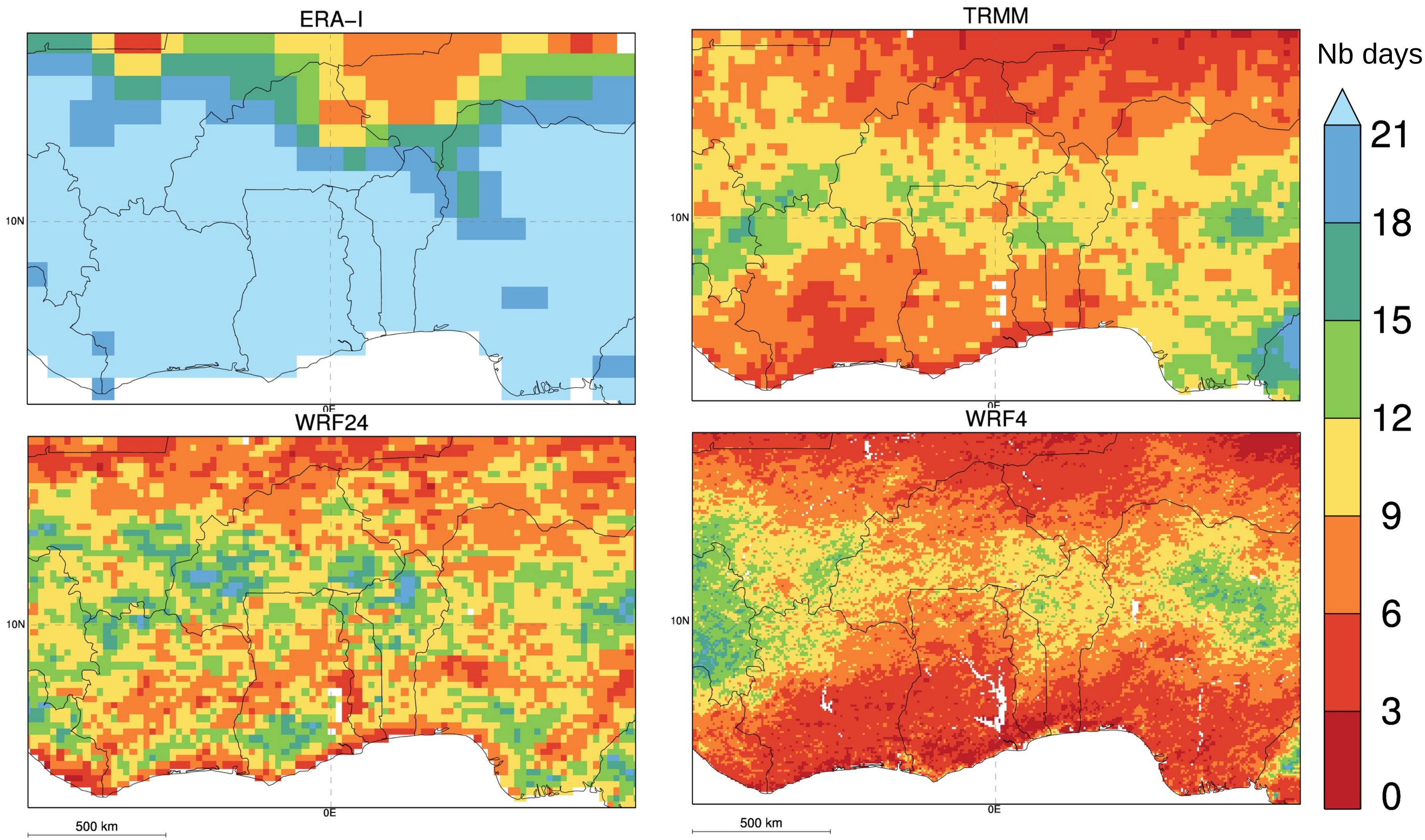
Differences in event frequencies

Jul-Sep 1999: Daily precipitation frequency, nearest grid-point to stations
Number of stations: 62

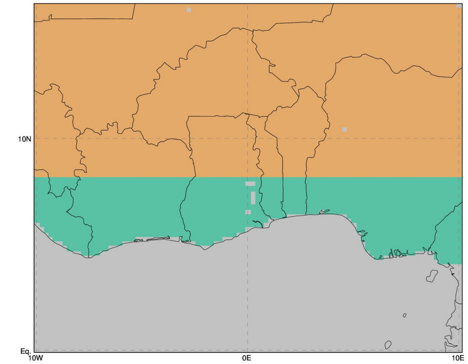


Intense precipitation events

Jul-Sep 1999: After how many days are 50% of the total precipitation reached?

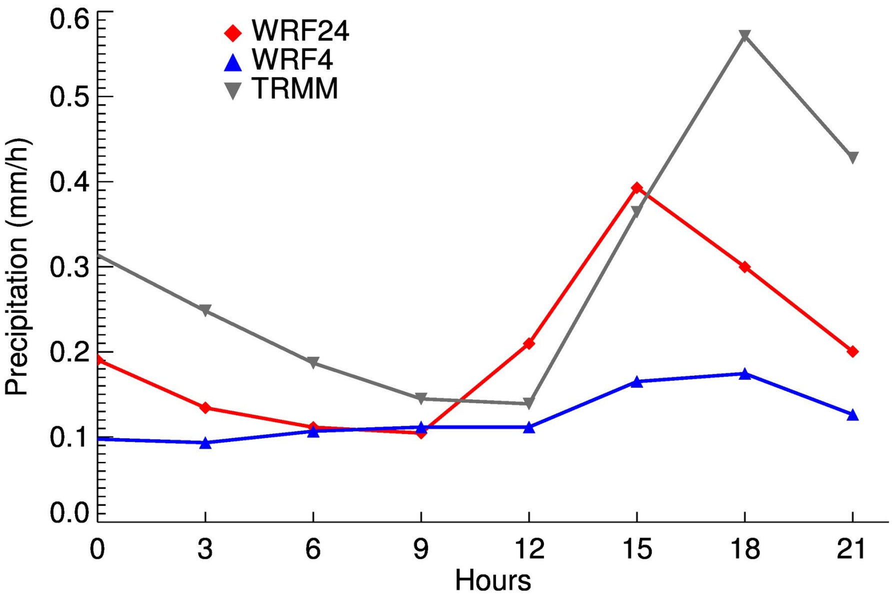


Diurnal cycle

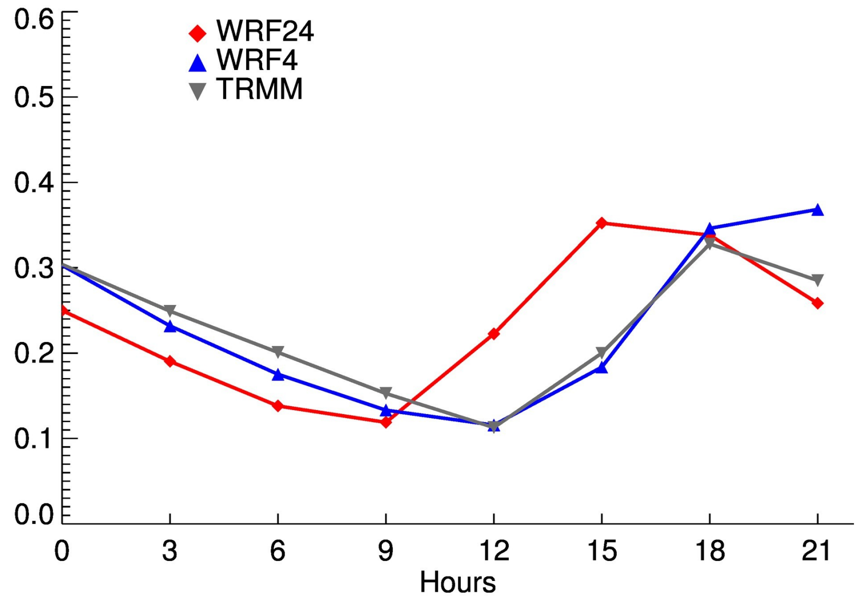


Jul-Sep 1999
Diurnal cycle (mm/h)

Guinean Coast (4-8°N)



Soudano-Sahel & Sahel (8-16°N)



Convective forcing:
Local-scale showers

Dynamical forcing:
Mesoscale convective systems

Conclusions

Sensitivity to parameterizations:

- Strong influence of regional processes on dynamics
- Model spread: from “dry” to “wet” years
  → testing necessary

Medium- vs. high-resolution:

- Little difference for precipitation totals
  → medium resolution sufficient

Convection allowing simulation:

- better captures precipitation frequencies and intense events
- avoids CU parameterization problems in reproducing phase/ amplitude of diurnal cycle for dynamically forced conditions

→ High resolution necessary for point-scale applications
→ Could even higher resolution reduce the dry bias / improve the representation of local convection?

Thank you for your attention!

References:

- Weather Research & Forecasting ARW, Version 3 Modeling System User's Guide, National Center for Atmospheric Research, 2013
- Noble, E., Druyan, L., Fulakeza, M.: The sensitivity of WRF daily summertime simulations over West Africa to alternative parameterizations. Part 1: African wave circulation, Monthly Weather Review, 2013