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OESCHGER CENTRE CLIMATE CHANGE RESEARCH

Sensitivity of high-resolution precipitation to physics parameterization options in WRF over equatorial regions

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Motivation

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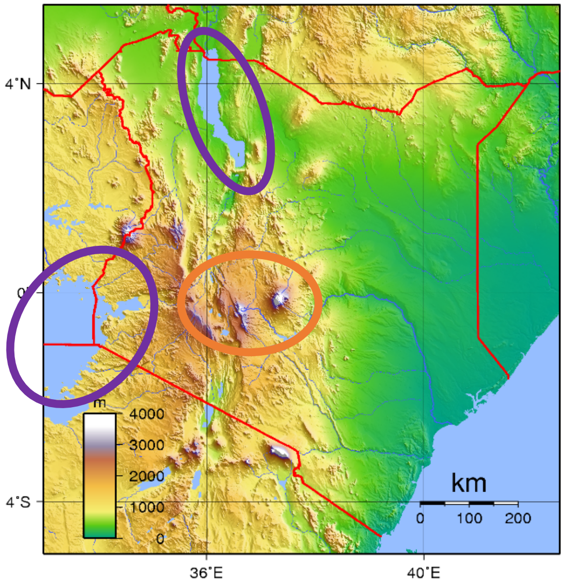
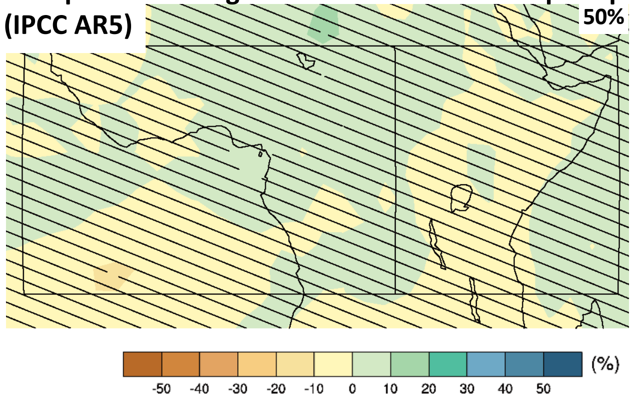
Topography of Kenya



Precipitation change RCP4.5 in 2016-2035: Apr-Sept (IPCC AR5)



Highly heterogeneous and complex regions due to:

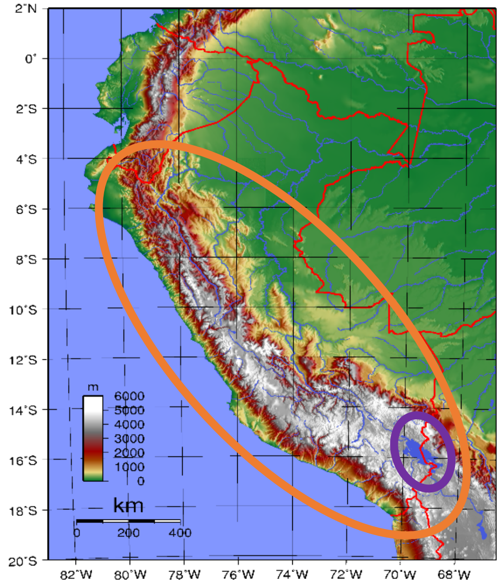
Topography, lakes and surrounding **Oceans**

Implications for precipitation and temperature patterns, which again influence **water availability**, **biodiversity** and **ecosystem services.**

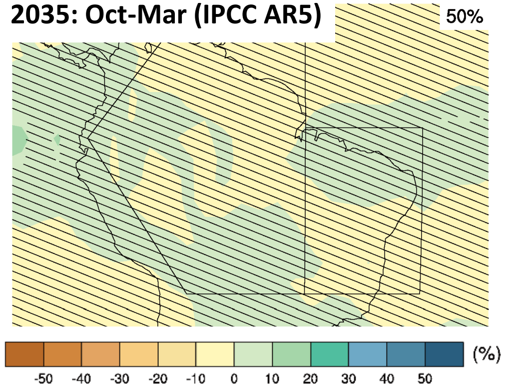
But: coarse climate models cannot provide relevant information on regional scales to people.

Regional Climate Models are needed for high resolution analyses, particularly at convection permitting scales (> 5 km).

Topography of Peru



Precipitation change RCP4.5 in 2016-2035: Oct-Mar (IPCC AR5)



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Objectives:

- Evaluate the impact of different **physics parameterizations** and different **nesting configurations** on precipitation patterns obtained from high-resolution experiments performed with WRF.

Approach:

- Compare monthly spatial patterns obtained from WRF with gridded datasets.
- Compare daily precipitation amounts obtained from WRF with station data.

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Model And Experimental Design

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- WRF (V3.8.1) is run with initial and boundary conditions provided by ERA5 (2 months spin-up).
- Output compared to WMO stations and stations installed and maintained by CETRAD (Kenya only).
- The following sensitivity experiments are applied to different nest configurations for the year 2008.

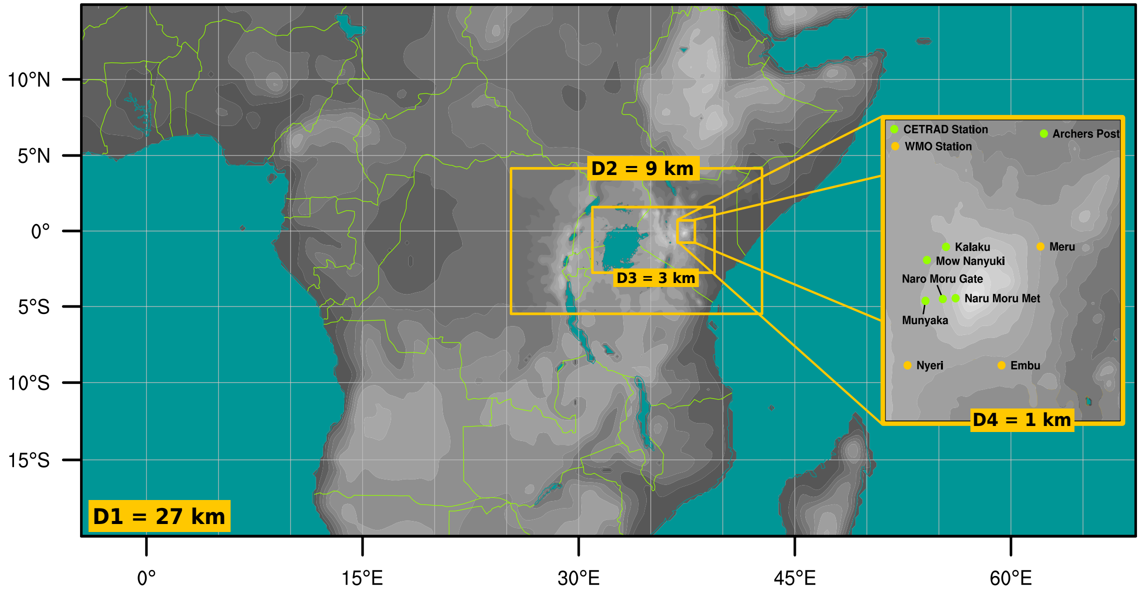
Description	Cumulus	LW-Radiation	PBL	Nesting
Europe	Grell-Freitas	CAM Longwave	Asymmetric Convection Model 2	2-way
South America	Kain-Fritsch	RRTM Longwave	Yonsei University	2-way
Cumulus 3	Grell-Freitas	RRTM Longwave	Yonsei University	2-way
Cumulus 3 1-way	Grell-Freitas	RRTM Longwave	Yonsei University	1-way
No Cumulus	-	RRTM Longwave	Yonsei University	1-way

Other options: WRF Single-moment-6-class (microphysics), Dudhia Shortwave and Noah-MP land surface model

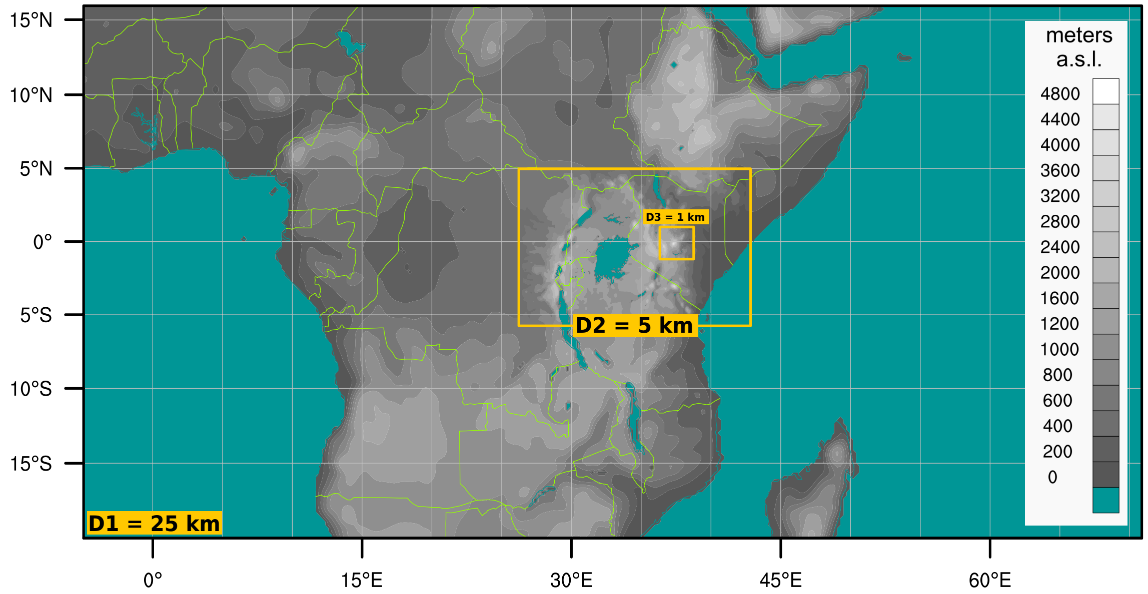
Model And Experimental Design: Kenya

Examples of nesting options

Nesting ratio 1:3



Nesting ratio 1:5



8 stations within the 1-km domain are used for comparison (3 WMO stations and 5 CETRAD stations)

Results: Kenya — temporal analysis (1 km)

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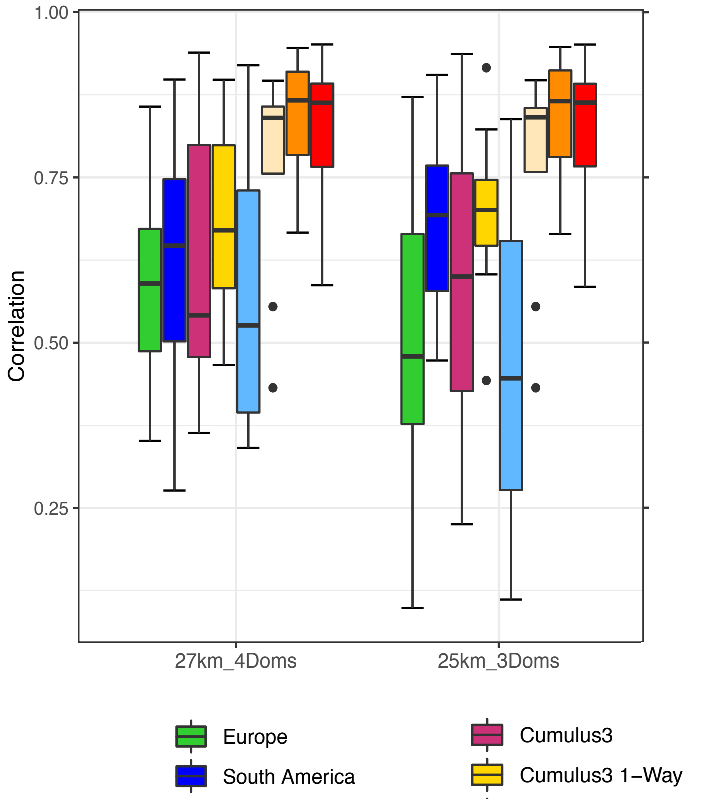
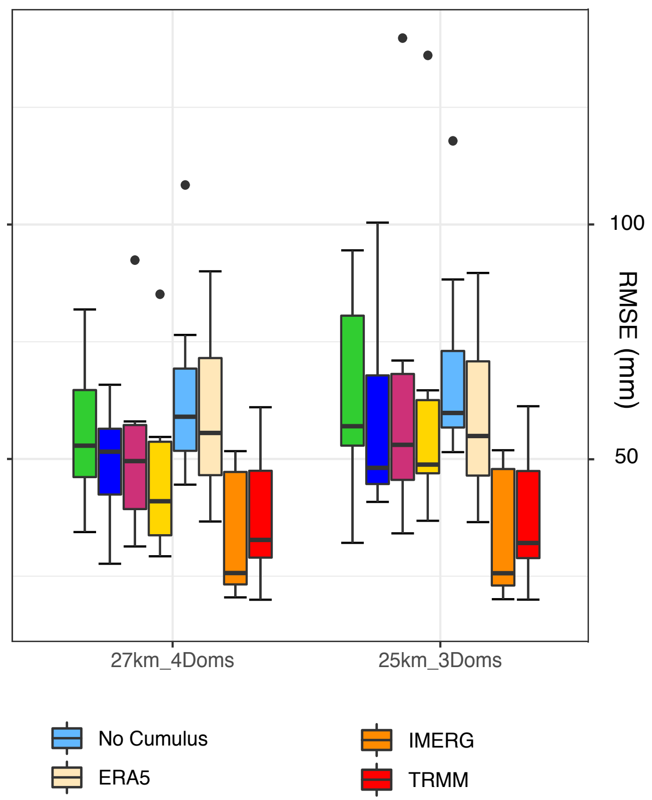
Correlation (monthly) for 1-km domains



RMSE [mm] (monthly) for 1-km domains



- Both observational datasets (**IMERG** and **TRMM**) obtained the highest correlations and smallest RSME values compared to station data.
- For the simulations **Cumulus3 1-way** setup obtains highest correlations and smallest RSMEs.
- **Europe** and **No Cumulus** settings obtain the poorest results.
- **ERA5** has high correlation to station data, but relatively poor RMSEs.
- Also the different nesting options are responsible for changes in correlations.

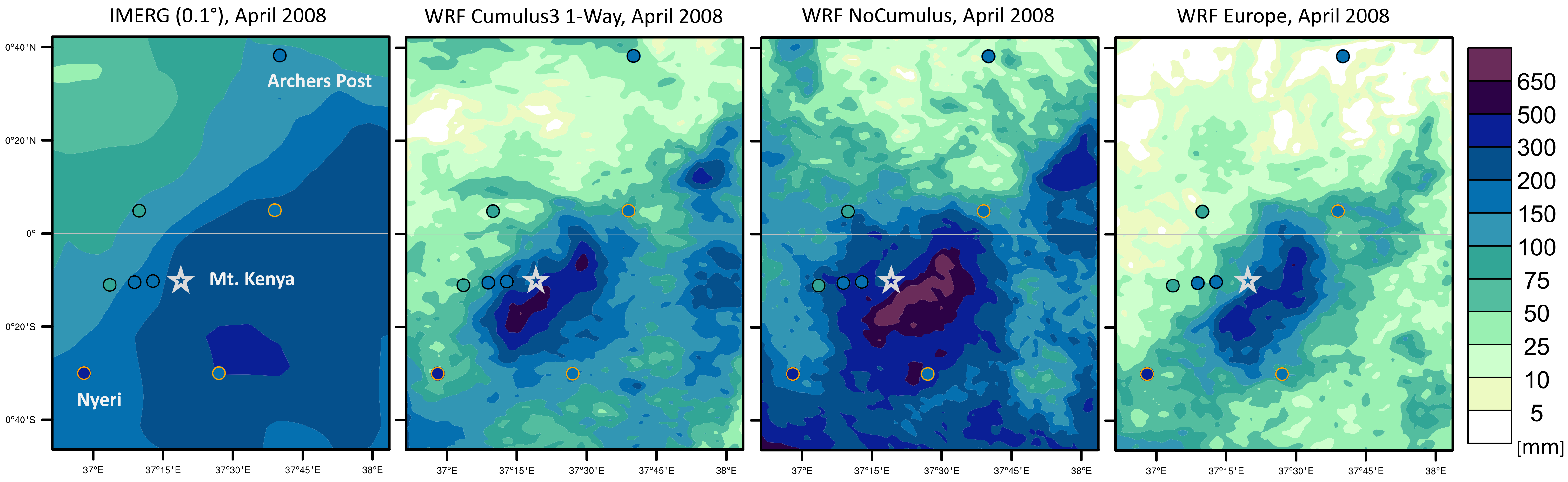
Results: Kenya — spatial analysis (1 km)

	Europe		S. America		Cum3		Cum3-1w		No Cum		ERA5		IMERG		TRMM	
	27km D4	25km D3	27km D4	25km D3	27km D4	25km D3	27km D4	25km D3	27km D4	25km D3	27km D4	25km D3	27km D4	25km D3	27km D4	25km D3
Jan	-0.07	0.05	0.05	-0.14	-0.05	0.02	0.10	0.02	-0.10	0.10	-0.48	-0.48	0.64	0.64	0.05	0.10
Feb	0.65	0.73	0.41	0.37	0.44	0.44	0.38	0.37	0.48	0.66	0.86	0.86	0.60	0.68	0.91	0.91
Mar	0.52	0.02	0.50	0.71	0.55	0.55	0.67	0.60	0.83	0.33	0.88	0.88	0.69	0.69	1.00	1.00
Apr	0.48	0.05	-0.02	-0.05	0.05	-0.14	0.12	-0.12	-0.24	0.02	-0.07	-0.24	0.55	0.55	0.19	0.29
May	0.26	0.21	0.86	0.74	-0.10	0.33	0.71	0.64	0.45	0.76	0.52	0.52	0.71	0.71	0.60	0.60
Jun	0.38	0.38	0.66	0.62	0.54	0.61	0.49	0.48	0.56	0.69	0.41	0.41	0.53	0.53	-0.01	-0.01
Jul	0.74	0.81	0.67	0.81	0.81	0.88	0.88	0.81	0.79	0.81	0.83	0.79	0.90	0.90	0.67	0.67
Aug	0.93	0.93	0.48	0.81	0.79	0.93	0.90	0.83	0.79	0.79	0.90	0.90	0.79	0.79	0.95	0.95
Sep	1.00	0.98	0.93	0.98	0.98	0.93	0.83	0.98	1.00	0.98	0.95	0.95	0.62	0.62	0.83	0.79
Oct	0.14	0.52	0.67	0.36	0.76	0.81	0.86	0.55	0.38	0.71	0.38	0.38	0.86	0.83	0.60	0.64
Nov	0.31	0.43	0.71	0.79	0.98	0.83	0.81	0.98	0.71	0.45	0.31	0.31	0.83	0.83	0.55	0.55
Dec	0.73	0.39	0.39	0.34	0.51	0.29	0.41	0.46	0.78	0.90	0.68	0.68	0.56	0.63	0.56	0.56
	5	4	**6**	**7**	5	5	**7**	5	**6**	**8**	**6**	**6**	**7**	**9**	5	**6**

- **IMERG** shows a very high level of agreement with the station data. It should be considered as reference for pattern correlations.
- **No Cumulus**, but also **Cumulus3 1-way** option provide a good correlation half of the year.
- The dry season (Jul-Sep) is particularly well simulated by most of the experiments.
- **Cumulus3** options stand out in November, which is part of the "short rain" season.
- Interestingly, **No Cumulus** option seems to provide relatively good spatial patterns, compared to the temporal correlations.

Coloured correlations are significant **(α = 10%, using a Spearman test, n = 8)**

Results: Kenya – spatial analysis (1 km) monthly precipitation sums for D4, "Long rains"



- April (rainy season) shows well, that **Cumulus3 1-way** agrees well with the stations (except for Archers Post & Nyeri).
- The **NoCumulus** setting is a bit too wet in this example and the **Europe** setting is generally to dry.
- Nevertheless, they all reproduce the spatial pattern relatively similarly.

Results: Kenya — spatial analysis (1 km) monthly precipitation sums for D4, "Dry Season"

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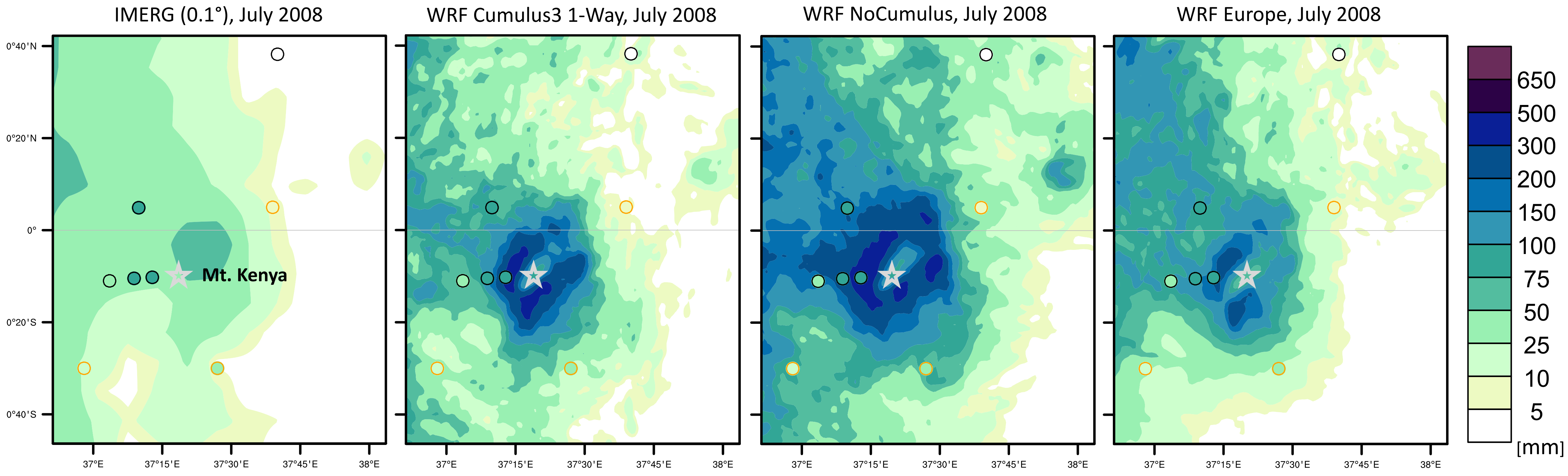

- All the WRF simulations are a bit too wet at the slopes of Mt Kenya, but all capture the pattern well.
- **Cumulus3 1-way** captures the pattern relatively well, but also the **Europe** setting is reasonable in the dry season.
- **NoCumulus** is too wet in July.

Results: Kenya – spatial analysis (1 km)
Pattern correlations, IMERG (0.1 °) as reference

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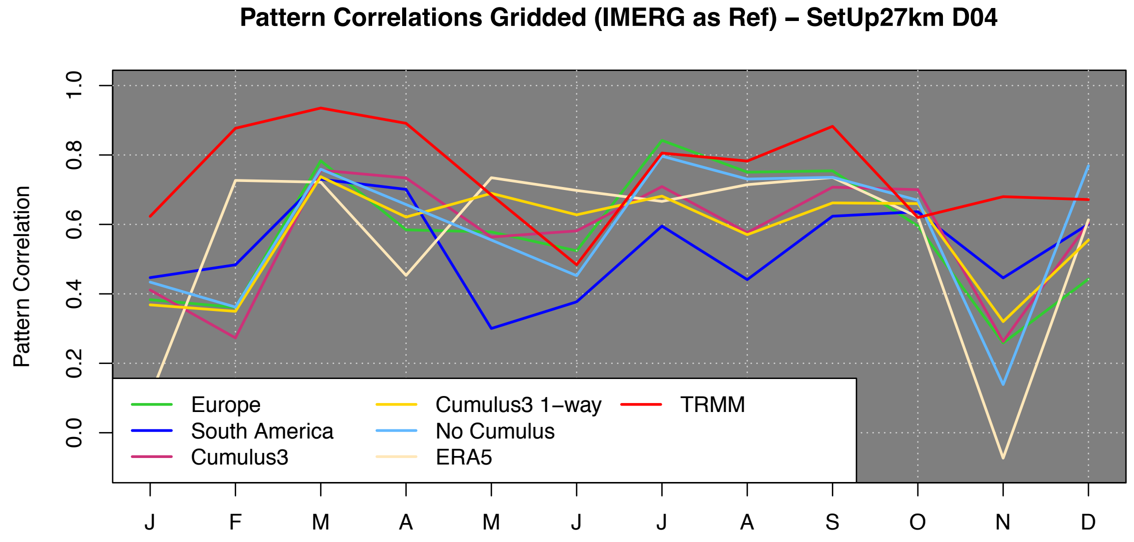
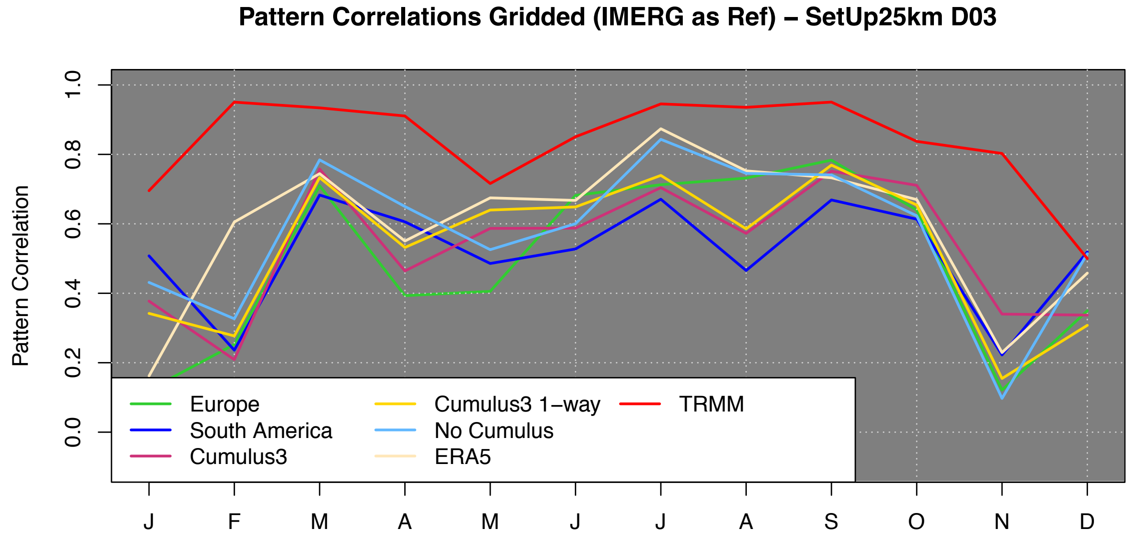


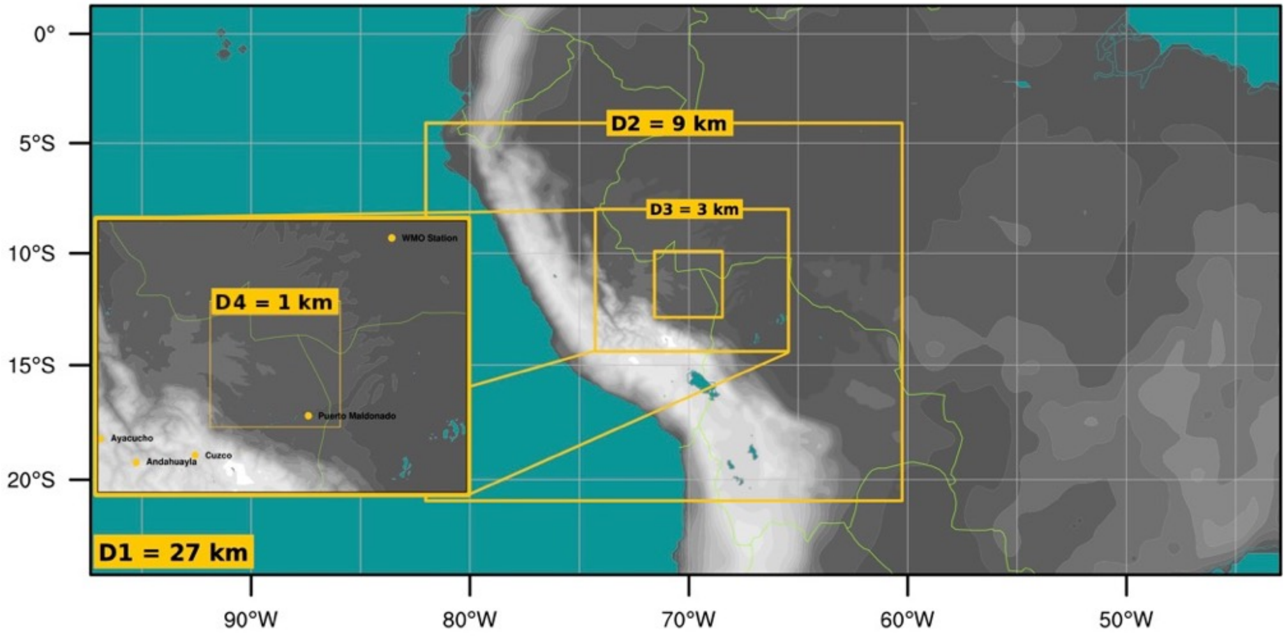


- Not surprisingly **TRMM** show the best pattern correlation compared to IMERG.
- Also **ERA5** has good spatial correlations.
- Best scores of WRF-simulations is obtained by **Cumulus3 1-way** and **NoCumulus** experiments.
- November-February almost no correlation obtained by simulations.
- Part of the "long rains" in March-May is relatively well captured.
- The **Europe** and **South America** settings show the worst pattern correlations.

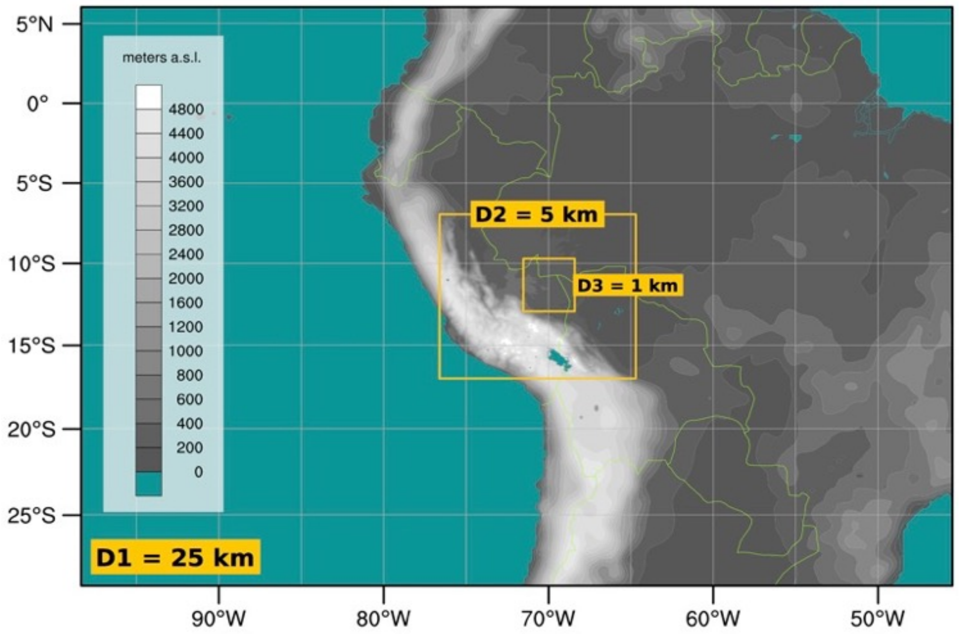
Model And Experimental Design: Peru

Examples of nesting options

Nesting ratio 1:3



Nesting ratio 1:5



4 WMO stations within the 3 and 9 WMO stations within the 5-km domain are used for comparison at the moment

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Results: Peru — temporal analysis (3 or 5 km)

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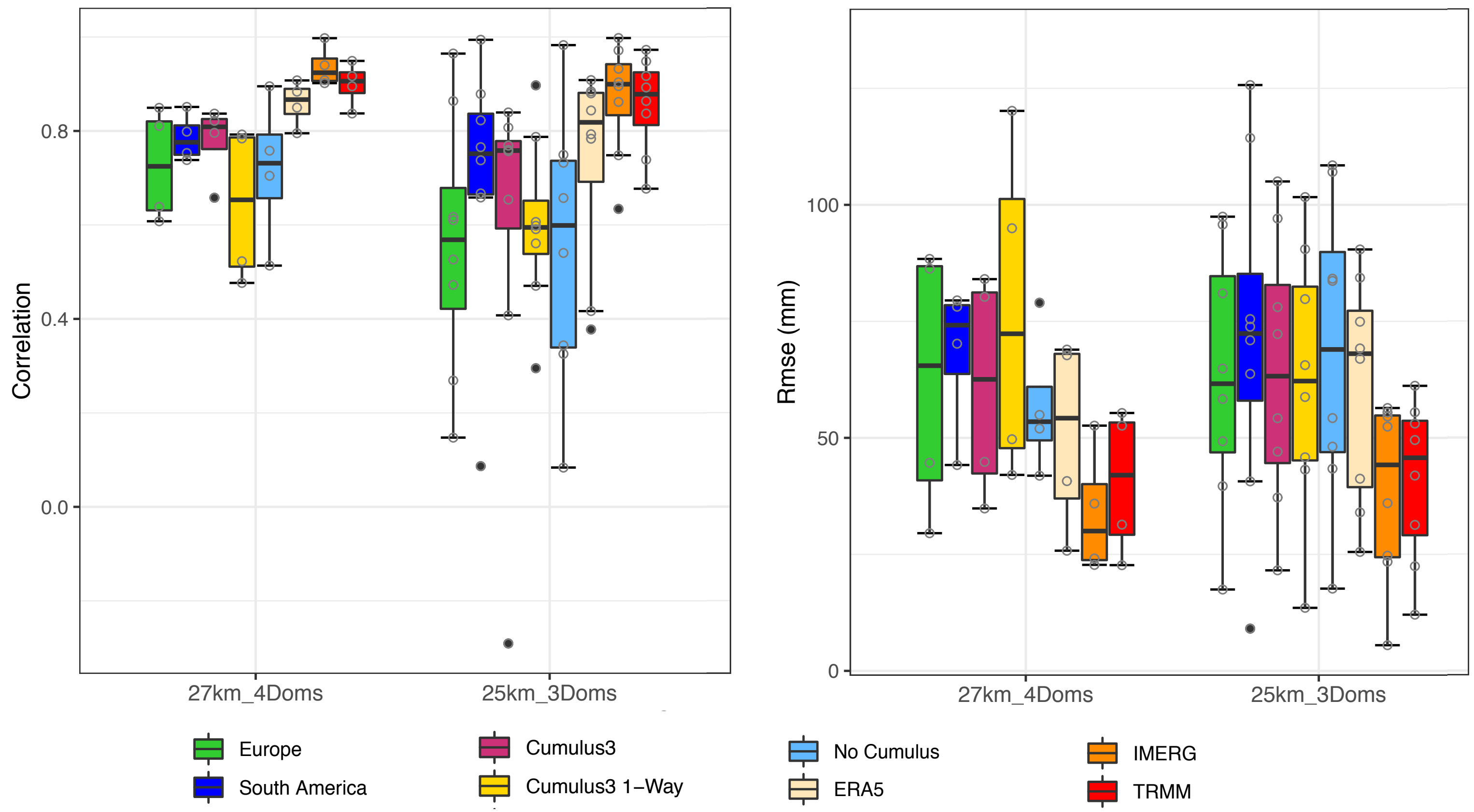
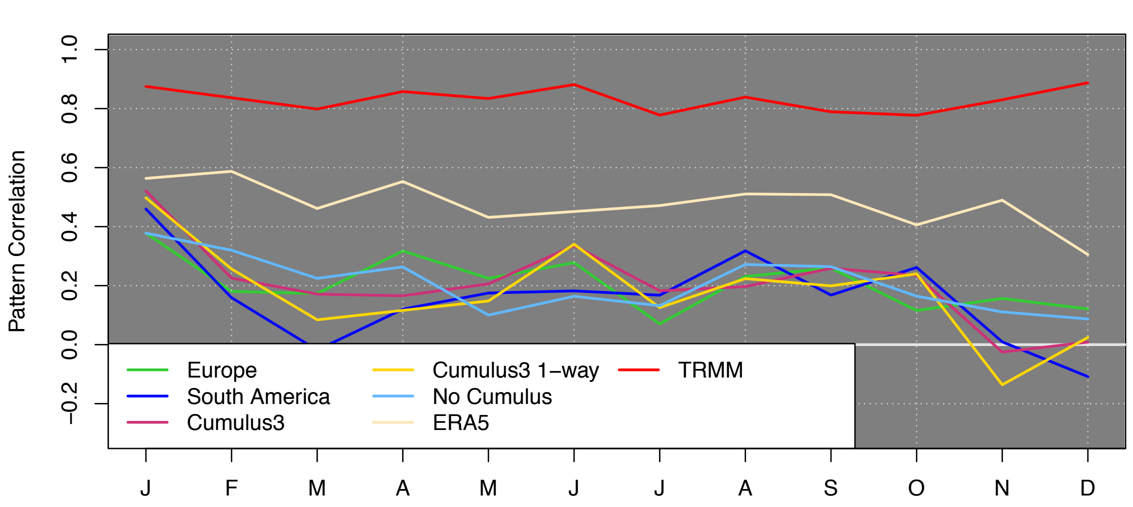
Correlation (monthly) for 3 and 5 km domains

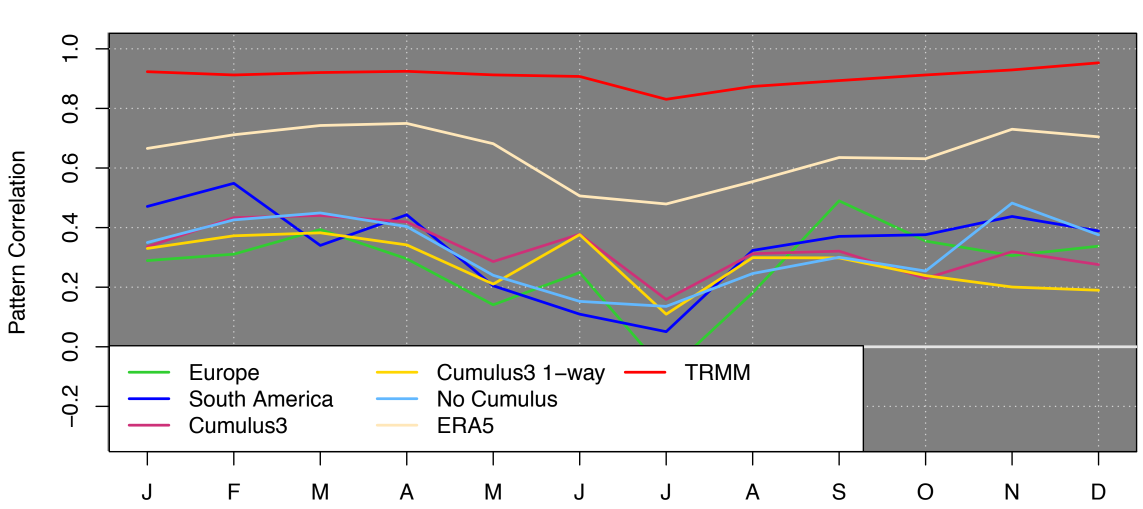
RMSE [mm] (monthly) for 3 and 5 km domains



- Both observational datasets (**IMERG** and **TRMM**) obtained the highest correlations and smallest RSME values compared to station data.
- **ERA5** has high correlation to station data, but relatively poor RMSEs.
- **South America** shows the highest correlations, but similar RMSE to other experiments.
- 4 stations only in the 3 km domain complicates the evaluation of the performance. With more stations in 5 km domain, similar RMSEs are observed for most of the experiments.

Results: Peru — spatial analysis (3 or 5 km)
Pattern correlations, IMERG (0.1 °) as reference





- Low correlations for all of the WRF experiments.
- Also **ERA5** has an especially bad performance in D3 of the 27km setup.
- The pattern correlation is slightly better in the wet (Nov-Mar) than in the dry season (Apr-Oct).
- Both **Cumulus3** experiments are more consistent in the course of the year.
- **South America** and **Europe** obtained good scores in some months, but not in others.

* All the correlations are significant **(α = 5%),** except for SA in Mar and Nov, C3 in Nov and Dec, and C3-1W in Dec in the D03 of SetUp 27km.

Results: Peru – spatial analysis (5 km) monthly precipitation sums for D2, "Wet Season"

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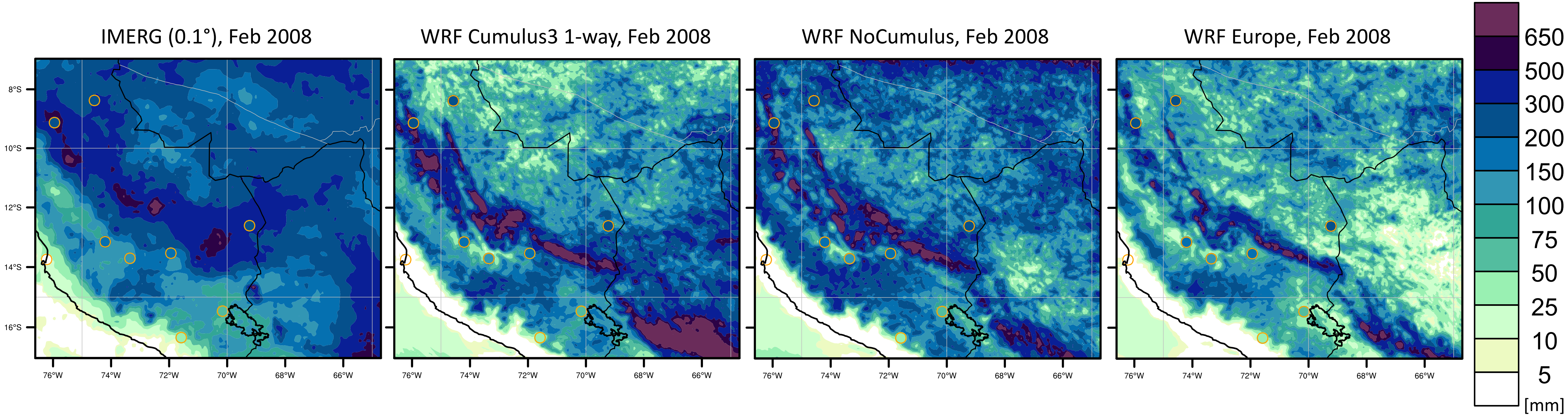

- Even though the pattern correlation is poor compared to **IMERG**, WRF is still able to capture some of the structure.
- There is a large discrepancy in the way the north-eastern slopes of the Andes are described in IMERG and WRF, which could be due to the difference in resolution that is especially important in complex terrain.
- The flatlands are mainly underestimated, except for the **NoCumulus** options (but this is not true for all months).
- The reason for the underestimation needs to be identified and analysed in a next step.

Conclusions

Kenya:

- IMERG and the independent CETRAD station data agree well at slopes of Mt. Kenya → reliable stations.
- **Cumulus3 1-way** provides the best temporal agreement with observations.
- **NoCumulus** and **Cumulus3 1-way** obtain the best pattern correlations, albeit the **NoCumulus** setting is a bit too wet.
- For further studies on Kenya and in particular Mt. Kenya, we recommend to use **Cumulus3 1-way** parameterizations.

Peru:

- All the experiments simulate drier conditions than the observed ones. However, some of them are able to capture the patterns in some seasons correctly.
- Both **Cumulus3** experiments are more consistent in the course of the year.
- **But:** as the station data base is very small in the highly complex terrain, the Peruvian domain certainly needs some further analysis before the best parameterization options can be chosen.

Further Information

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