Do convection-permitting ensembles lead to more skillful short-range probabilistic rainfall forecasts over tropical East Africa ?

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BACKGROUND MOTIVATION

1. **Floods** and droughts are the top hazards for economic losses and deaths in Africa for 1970-2019 (*WMO, 2020 State of Climate Services*)

2. Nearly **75% of the total seasonal precipitation in tropical West and East Africa** consists of **strong convective rainfall** and **mesoscale convective systems.** (*Dezfuli et al, 2017*).

3. Global models with **parametrized convection** have **poor skill** in the tropics (e.g. *Vogel et al.* (2018) and *Vogel et al.* (2020)), even when used as an ensemble. The use of convection-permitting (CP) ensembles (or deterministic) was advocated.

4. Slight **improvement by CP deterministic** wrt to the global model in East Africa for the Lake Victoria basin (*Woodhams et al., 2018*). Other studies (e.g. *Marsham et al.* (2013), *Birch et al. (2014)* found CP models representing better the West African monsoon).

5. **Few studies** about **CP ensembles (CP-ENS)** over tropical Africa across different time scales:

   - a) **short range**: *Torn et al.* (2010), *Maurer et al.* (2017) (West Africa)
   - b) seasonal: *Mori et al.* (2020) (East Africa)
   - c) climate: *Stratton et al.* (2018) (Pan-Africa)

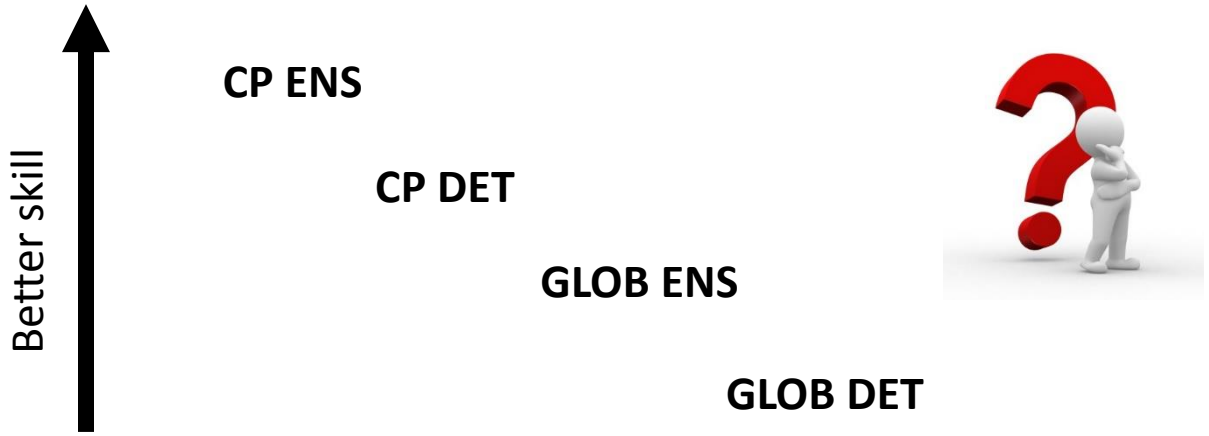
Flood in Kano, Nigeria, 6 August 2020.
Credits: K. Lawal

FORECAST TESTBED

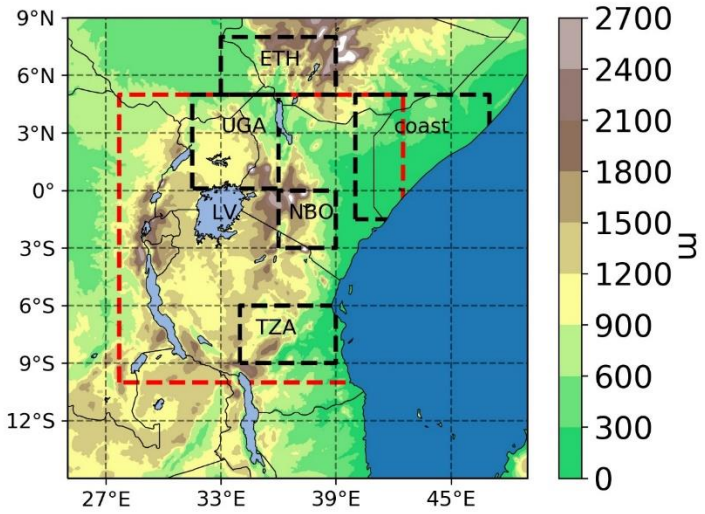
For the first time, CP-ENS were run for the **testbed in East Africa** (April-May 2019) by the UK Met Office to test the real-time use of ensembles to predict convective storms *(https://africanswift.org/wp-content/uploads/sites/84/2020/04/Testbed1_Report_Final.pdf)*

Verification

Are the **CP probabilistic forecasts** more skilful with respect to
CP deterministic and
Global Ensembles/Deterministic ones ?



DOMAIN



East Africa domain covered by CP Ensemble, in red the box where the spatial verification is performed, in black where rainfall and ensemble characteristics are evaluated.

MODEL DATA

- **4.4 km**, dt=120 s
- configuration: RA1T (Bush et al., 2019)
- 600 x 600 points
- L80, 38.5km lid
- Runs to **T+72**.
- Downscaling from the **UK Met Office Global Ensemble** (MOGREPS-G)
- 00Z, 06Z, **12Z** and 18Z initialization
- 24 cases (20 Apr – 13 May 2019)

- Unperturbed members used as a proxy for deterministic forecasts

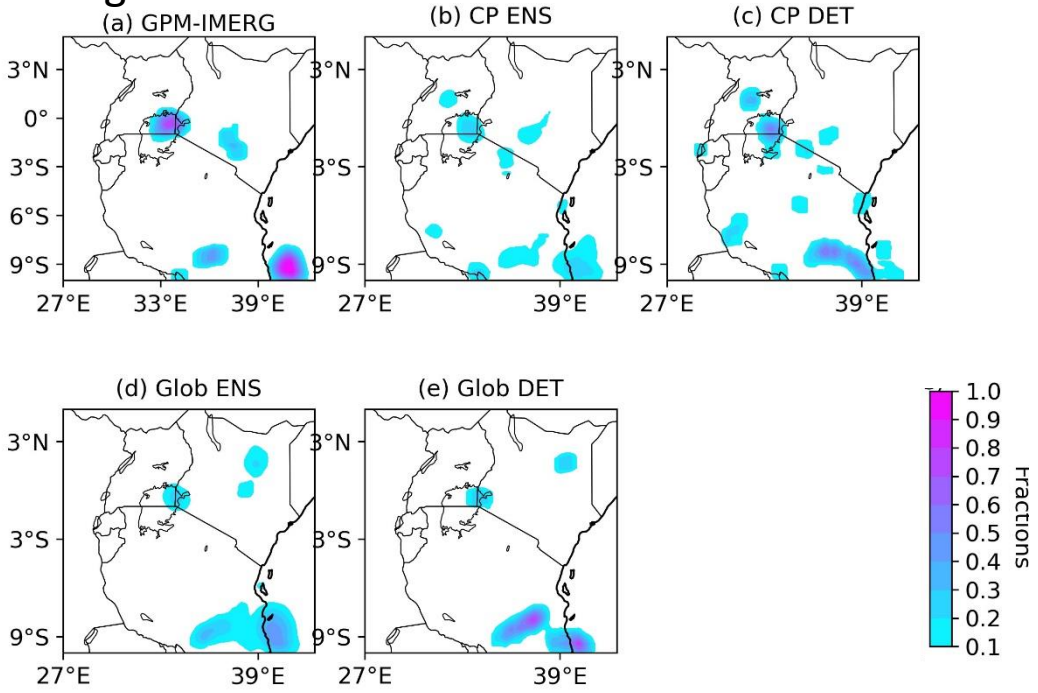
OBSERVATIONS

- Satellite estimates: **GPM-IMERG**
- dx=0.1°, every 30 min
- GPM-IMERG generally reproduce well the spatial pattern of rainfall, not necessarily the amounts *(Stein et al., 2019)*

Methodology: probabilistic forecasts generation and verification

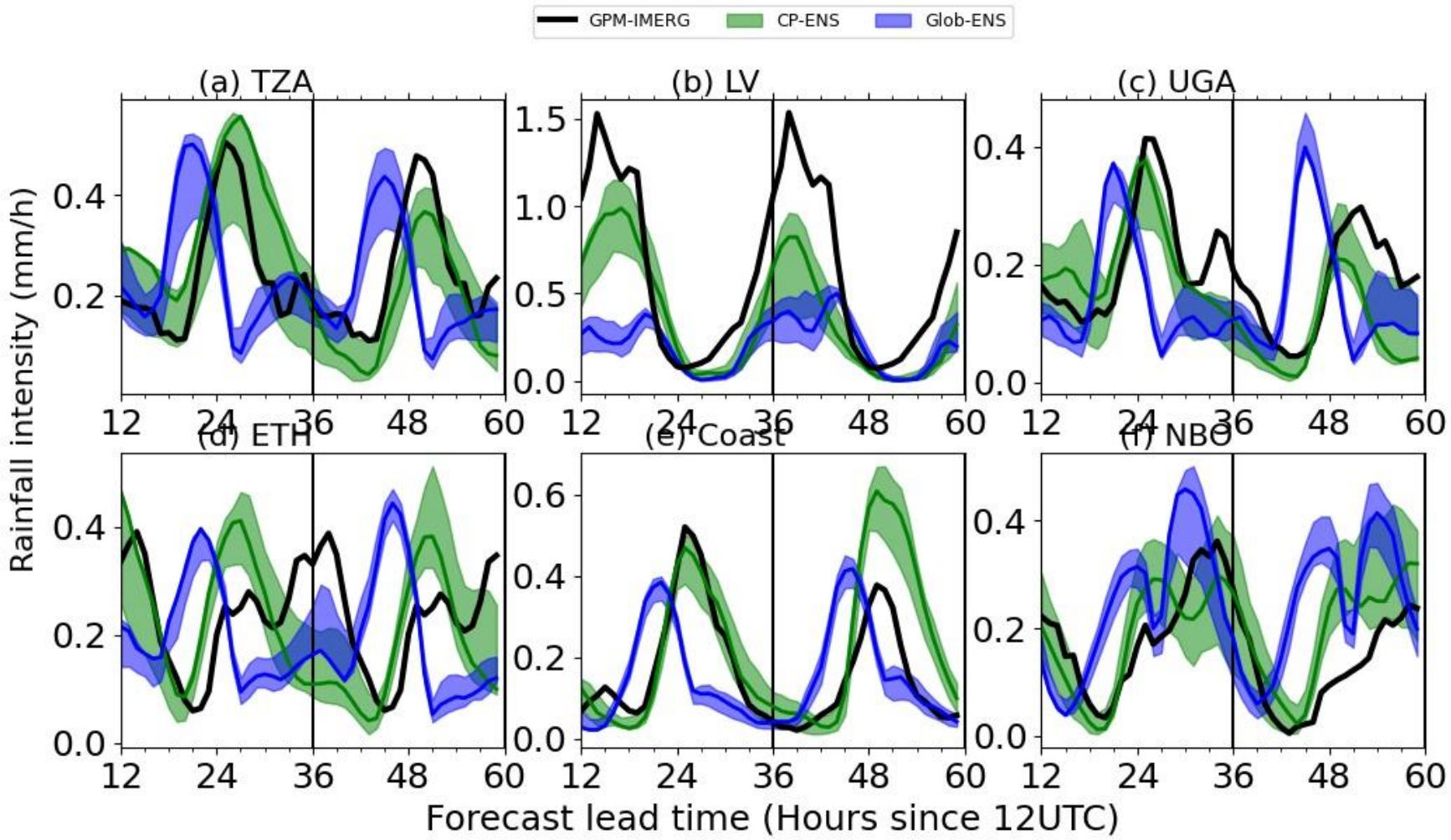
1. Define the event (e.g. rainfall accumulation exceeding a threshold);
2. Define square neighbourhood with a given length around a given grid-point.
3. Calculate the fraction of grid-points exceeding the threshold in that neighbourhood. Repeat this for each point on the native grid.
4. Apply this either to single field (e.g. observations or control member) or to multiple members to obtain probabilistic forecasts.
5. Verification on the observation grid using **fractions skill score** and roc areas for different neighbourhood lengths.

Smoothing method (*Theis et al., 2005 – Sobash and Schwartz, 2017*)



Event: 5 mm over 3h

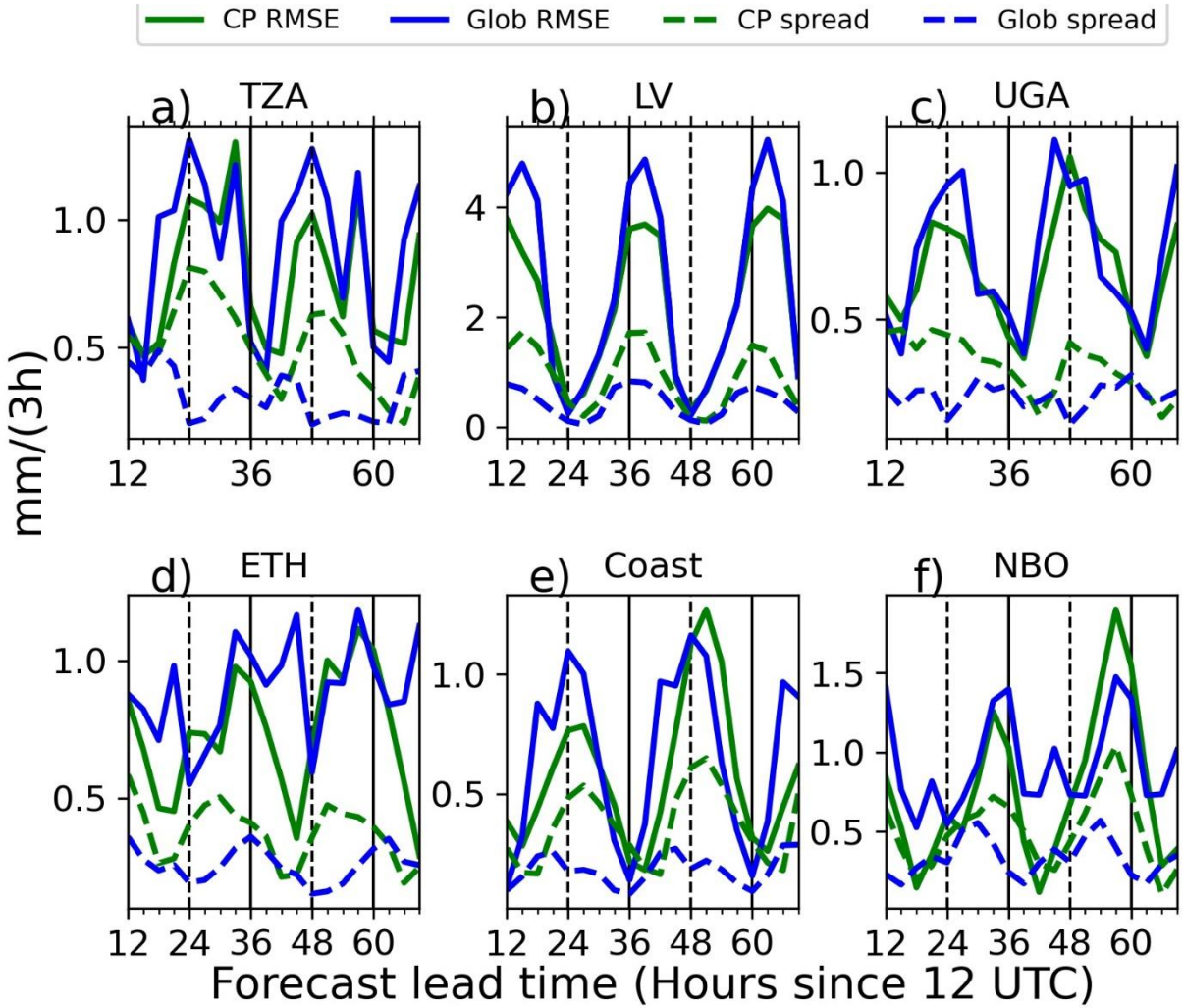
MEAN DIURNAL CYCLES



Mean hourly rainfall accumulation for the different regions and models.

- **Generally, CP-ENS represents better the diurnal cycle of precipitation than Glob-ENS.**

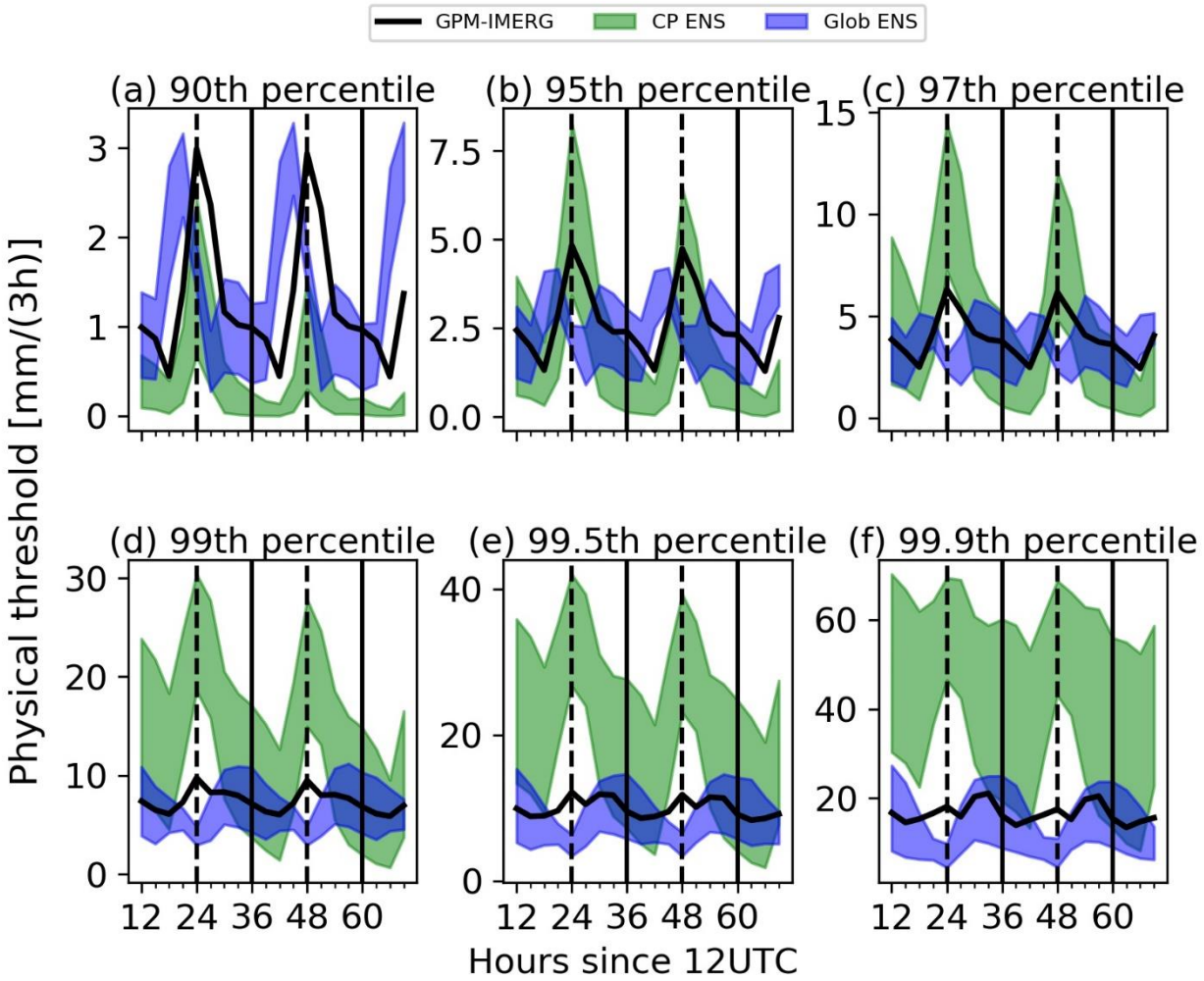
SPREAD/SKILL RELATIONSHIP



- Both models are **underdispersive**, Glob-ENS more.
- Spread peaks at the same time as RMSE

RMSE (solid) and ensemble spread (dashed) of the domain averaged rainfall.

MODEL BIAS



- CP underestimates light rainfall and overestimates heavy rainfall.
- Global model does the opposite.

Physical thresholds corresponding to the different percentiles

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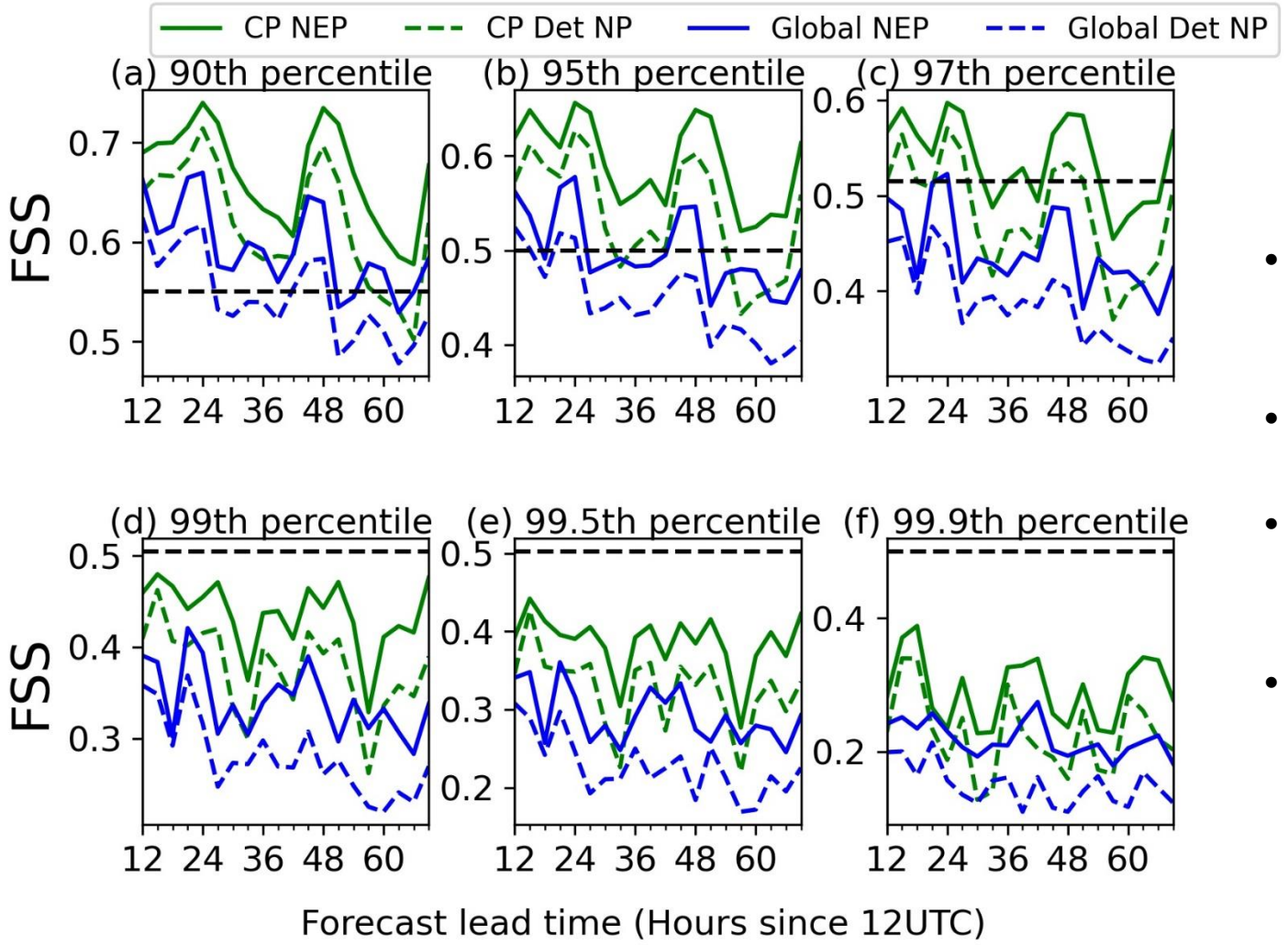
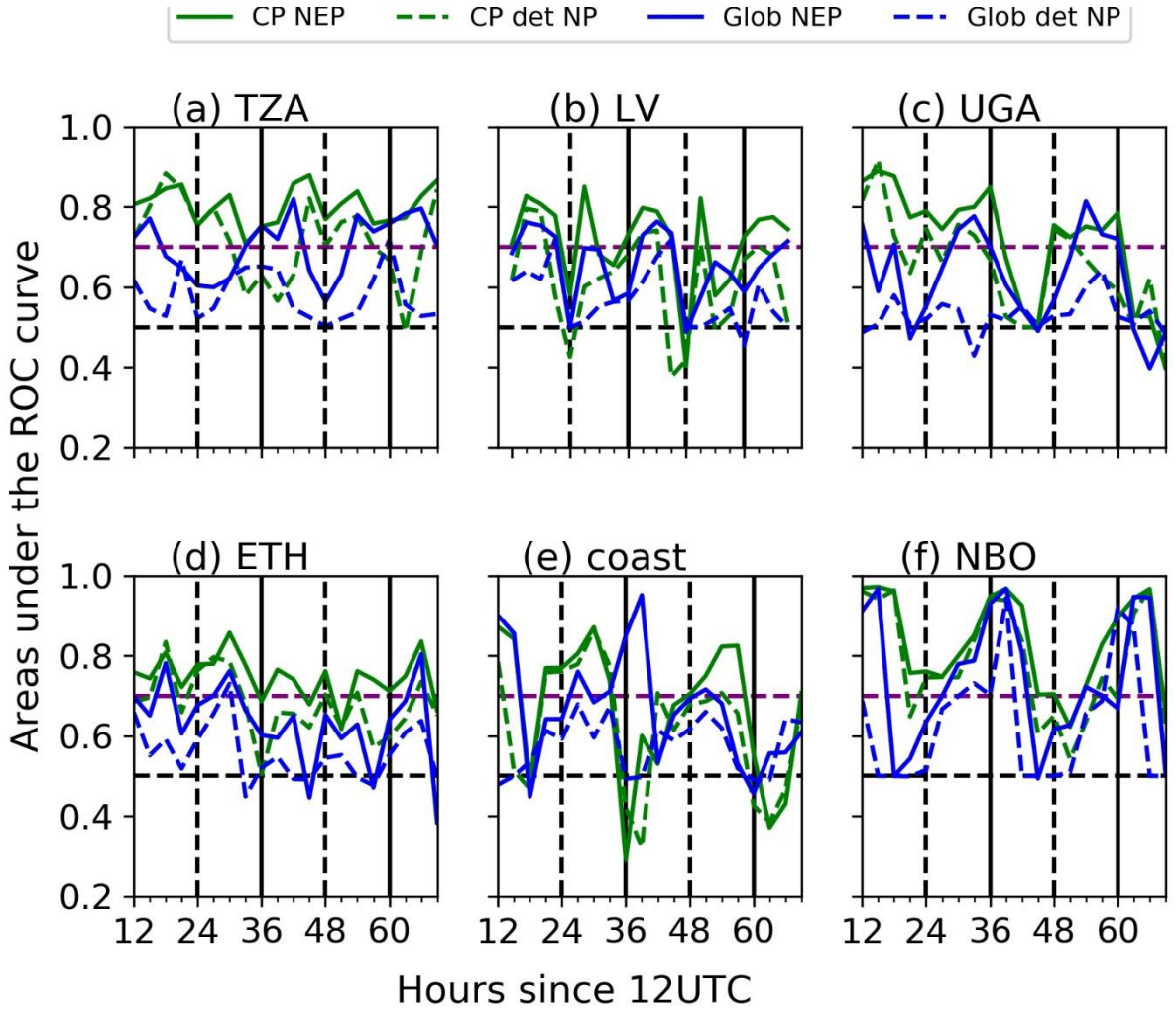
Spatial verification: Fractions skill score



- Mean FSS over n=23 grid points (~265 km) for the 3h rainfall accumulation.
- FSS decreases with percentiles.
- Diurnal signals in the skill (as in *Schwartz, 2019*)
- CP ENS > CP Det > Glob ENS > Glob Det (in order of skill)

Verification for different sub-domains: ROC area



- Event: probability of 3h rainfall accumulation > 10 mm for different subdomains on a neighbourhood of n=23 grid points.
- Skill generally peaks at different times for the different regions. This could be related to the spatial distribution of rainfall (e.g. organized vs scattered)
- As for FSS, CP ENS is the most skillful forecast.

Conclusions

- **Convection-permitting ensembles (CP-ENS)** have been tested for the **first time** in East Africa to support a forecasting testbed.

- The impacts of high-resolution and of the ensembles were both assessed by comparing CP-ENS relative to global ensemble and their deterministic counterpart.

- **CP-ENS** was found to be the **most skilful forecast** both in terms of predicting the location of rainfall (**Fractions skill score**) and discriminating events and no-events (**area under the ROC**), followed generally by CP deterministic and global Ensemble.

- Verification of the **timing of convection initiation** will be part of future investigations.

Thank you for your attention

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For more info regarding the project: https://africanswift.org/

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