Dynamical Downscaling of ECMWF Seasonal Forecasts:

case studies over Eastern and QWeCI southern Africa domains

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Thanks to RegCM Team

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Outline

1. **Motivation**

2. **Past work with ECMWF cycle 29r2 over East Africa**

3. **ECMWF Sys 3 Ensemble data and RegCM set up**

4. **Perfect boundary condition run**

5. **ECMWF ENSEMBLE forcing runs**

6. **Summary and Future work**

Motivation

- Limited area models(eg. MM5, WRF, RegCM,...) have been used for downscaling short range weather forecasts and/or climate change studies

- *For example, RegCM has been extensively validated on various domain for its ability to have an "added" value compared to the global climate models*

- There is a growing demand from impact models for a detailed (localized) seasonal forecasts

- Do regional climate models improve seasonal forecasts and able to reproduce the year to year fluctuation?

ECMWF and RegCM3 JJAS hindcast climatology
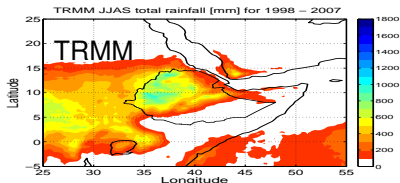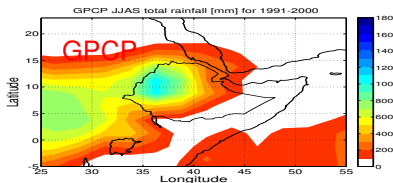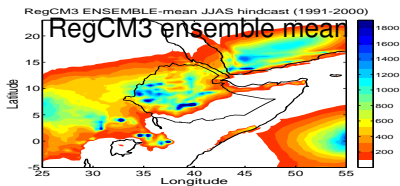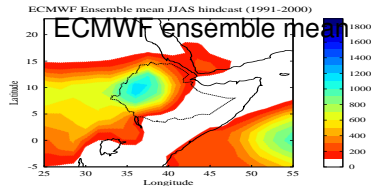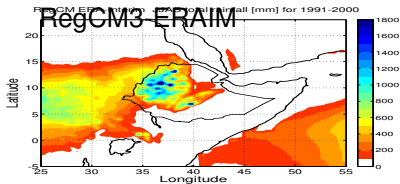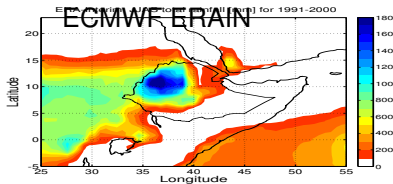
Perfect boundary run: Inter-annual variability
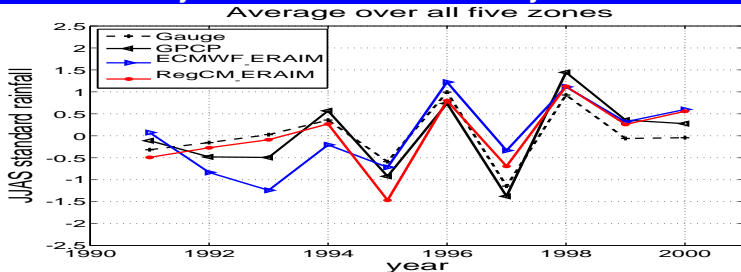
Table: Correlation of ERA-Interim and RegCM3 with observations

	Gauge	GPCP
ECMWF-ERA Interim	0.63	0.77
RegCM-ERA Int. forced	0.83	0.88
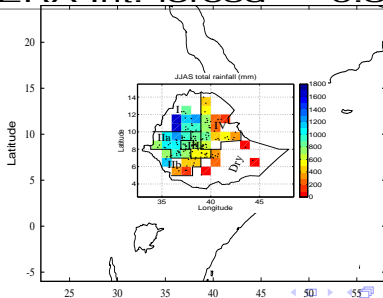
ECMWF cycle 29r2 with RegCM: 1998 - 1997

Propagation of error from GCM to RCM
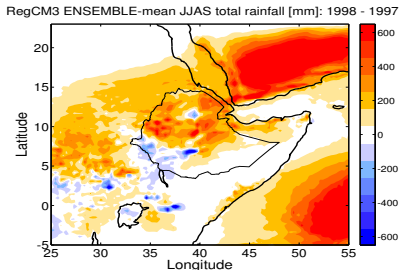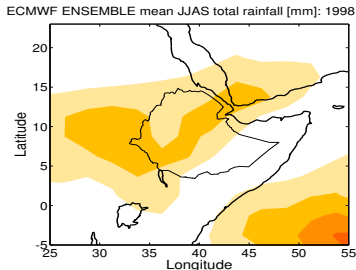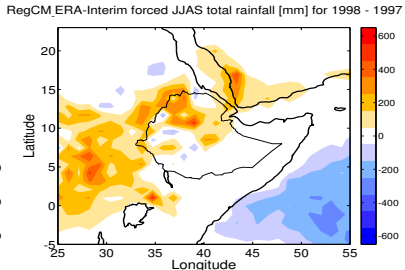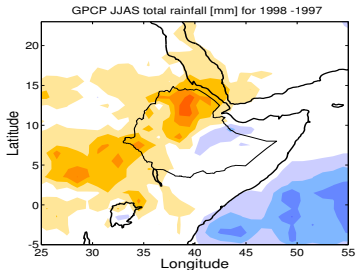
GPCP JJAS total rainfall [mm] for 1998 -1997

RegCM_ERA-Interim forced JJAS total rainfall [mm] for 1998 - 1997

ECMWF ENSEMBLE mean JJAS total rainfall [mm]: 1998 - 1997

RegCM3 ENSEMBLE-mean JJAS total rainfall [mm]: 1998 - 1997

Propagation of error: ENSO vs western Indian ocean SST teleconnection

ERA–Interim JJAS Skin temperature [1998 – 1997]

ECMWF Ensemble mean hindcast for JJAS skin temperature [1998 – 1997]

Probabilistic verification: ROCS

- Area under ROC curve (ROCA)
- Compares against a random forecast
- A skillful forecast $\rightarrow$ ROCA > 0.5
- or $\rightarrow 2*$ (ROC area -0.5) > 0

Table: ROC Area (Area under the roc curve) over Ethiopia

ROCs	Dry		Normal		Wet	
	Gauge	GPCP	Gauge	GPCP	Gauge	GPCP
ECMWF-ENSEMBLE	0.67	0.86	0.54	0.75	0.55	0.90
RegCM3	0.86	0.64	0.69	0.38	0.71	0.86
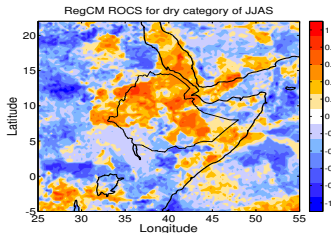
ECMWF cycle 29r2 with RegCM: RPSS

- $RPS = \frac{1}{K-1}\left[\sum_{i=1}^{K}\left(CDF_{forc,i} - CDF_{obs,i}\right)^2\right]$

- $RPSS\_D = 1 - \frac{RPS_{forc}}{\left(RPS_{clim} + RPS_{clim} * \frac{1}{M}\right)}$

- A skillful forecast $\rightarrow$ RPSS > 0
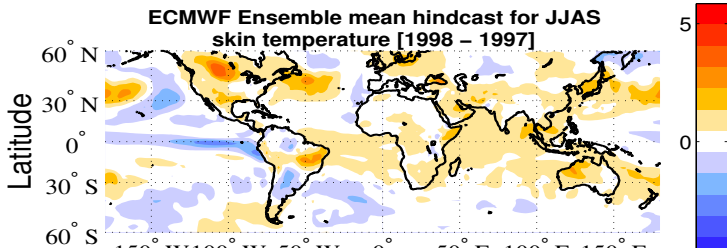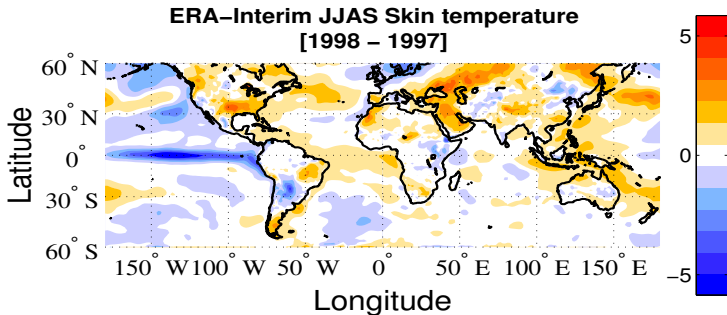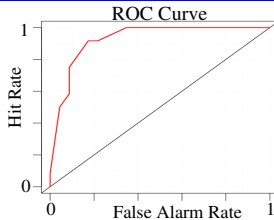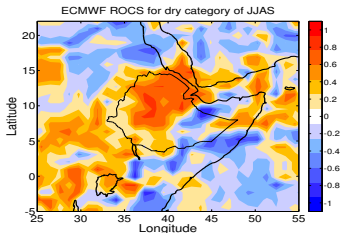
Motivation

Past work with ECMWF cycle 29r2 over East Africa
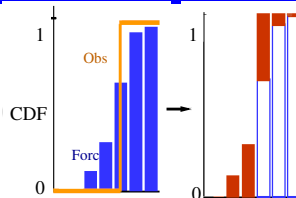
ECMWF Sys 3 Ensemble data and RegCM set up

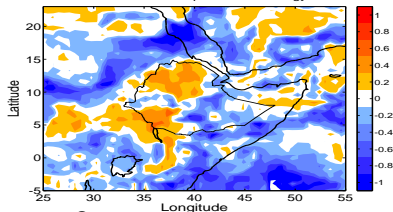Perfect boundary condition run

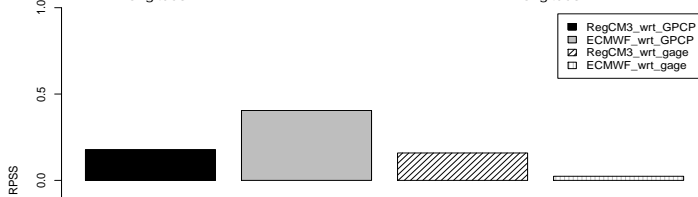ECMWF ENSEMBLE forcing runs

Summary and Future work

Mean debiased RPSS with respect to climatology for ECMWF

Mean debiased RPSS with respect to climatology for RegCM3
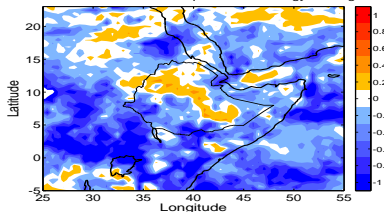
RegCM3_wrt_GPCP
ECMWF_wrt_GPCP
RegCM3_wrt_gage
ECMWF_wrt_gage

ECMWF ensemble hindcasts from 33r1

- Resolution : $1.125^0 \times 1.125^0$ in horizontal and 62L in vertical

- Hindcast period: 1991-2001

- 9 member ensembles

- addressing forecast uncertainty

- *uncertainty in initial condition: Perturbed initial conditions*
- *model error: Perturbed physics*

- Two start dates (May and November): here we used the Nov 1st start for Malawi domain

- 6 month hindcasts starting from November 1st

Model setup and experimental design

- Resolution : 25km (288x200) in horizontal and 18 levels in the vertical
- Convection scheme: Grell over land and Emanuel over the ocean
- Three experiments were carried out:
  - 'Perfect' boundary condition run
    - with climate mode: continuous run
    - with seasonal forecast mode: initialize every year from Nov 1st
  - seasonal hindcasts boundary condition
- For the 'perfect' boundary simulation:
  - ERA-Interim re-analysis,OI-weekly SST
  - simulation period: Jan 1990 to May 2002
- For hindcasts simulation
  - The 9 ECMWF ensemble members from 33r1 cycle are downscaled independently
  - simulation period: Nov 1st to May 1st every year between 1991 and 2002

Model domain and Topography
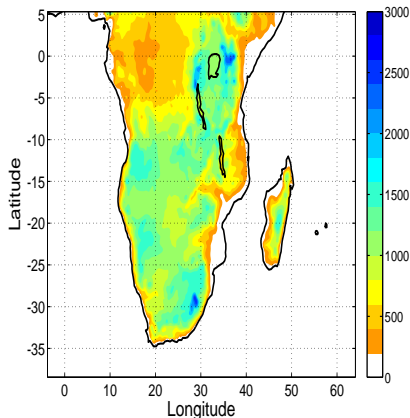
Motivation

Past work with
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ECMWF Sys
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Perfect
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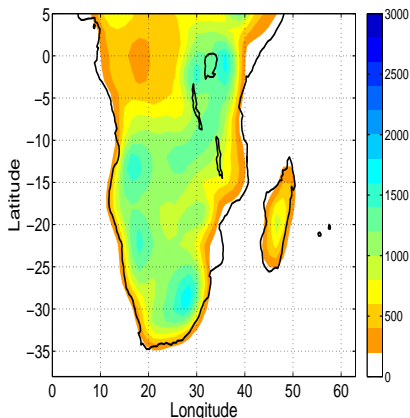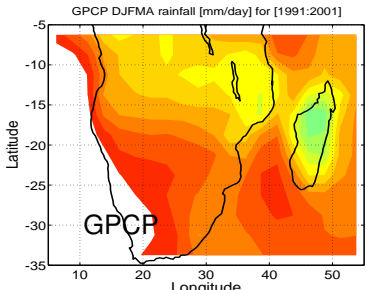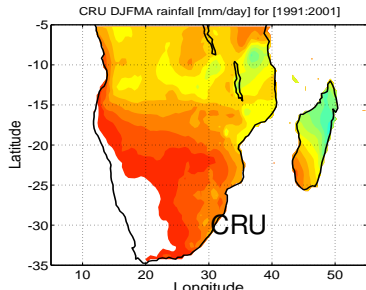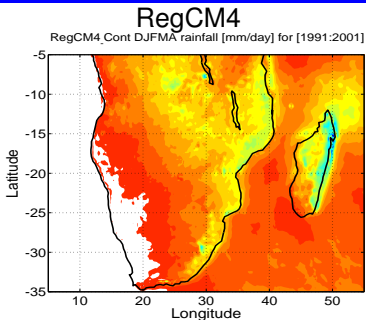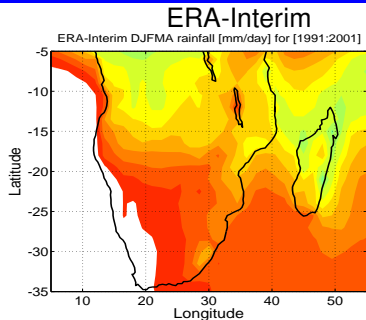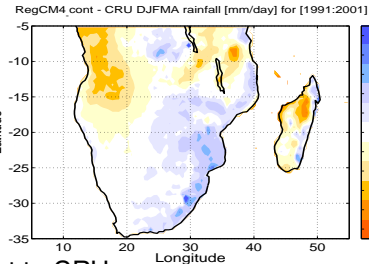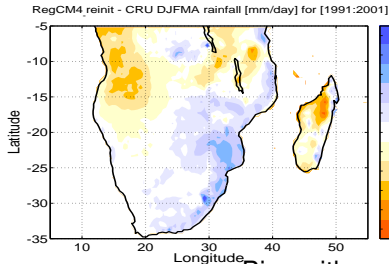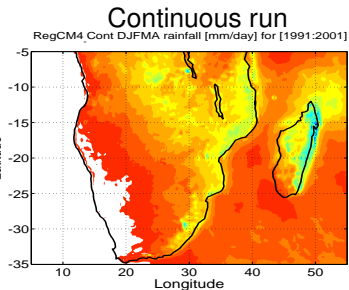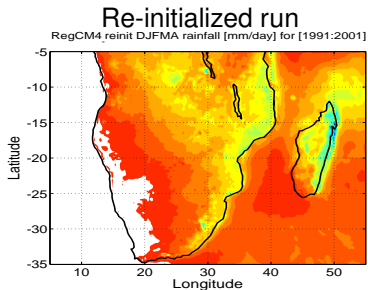
ECMWF
ENSEMBLE
forcing runs

Summary and
Future work

RegCM has a better realistic surface features due to its high resolution.

Perfect boundary run: mean DJFMA Climatology

ERA-Interim

ERA-Interim DJFMA rainfall [mm/day] for [1991:2001]

RegCM4

RegCM4_Cont DJFMA rainfall [mm/day] for [1991:2001]

CRU DJFMA rainfall [mm/day] for [1991:2001]

CRU

GPCP DJFMA rainfall [mm/day] for [1991:2001]

GPCP

Impact of land surface initialization: mean DJFMA Climatology

Re-initialized run

RegCM4_reinit DJFMA rainfall [mm/day] for [1991:2001]

Continuous run

RegCM4_Cont DJFMA rainfall [mm/day] for [1991:2001]

RegCM4_reinit - CRU DJFMA rainfall [mm/day] for [1991:2001]

RegCM4_cont - CRU DJFMA rainfall [mm/day] for [1991:2001]

Bias with respect to CRU

Impact of land surface initialization: interannual variability
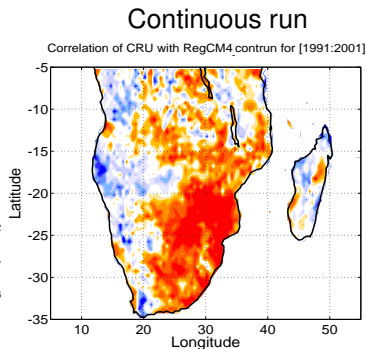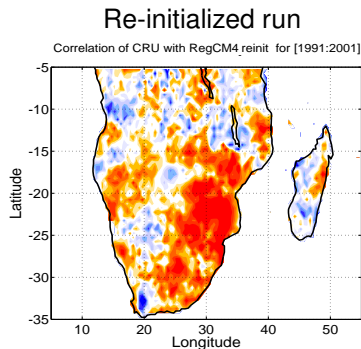
- In both integrations (i.e. the climate and seasonal forecasting modes), the bias and correlation pattern is similar

- This suggests that a one month spin up is a good compromise

Mean Climate (DJFMA) : ENSEMBLE forcing

ECMWF ensemble mean
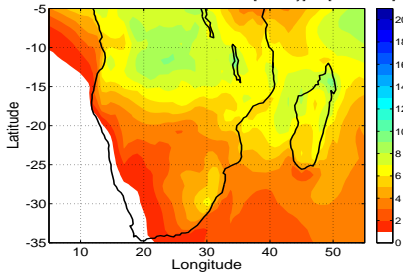
ECMWF ensemble spread
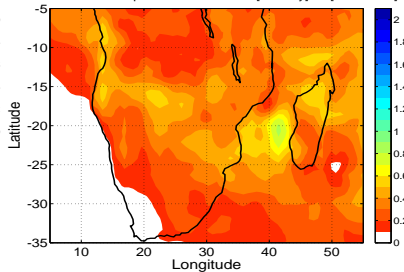
RegCM ensemble mean
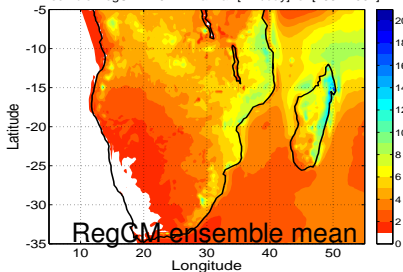
RegCM ensemble spread
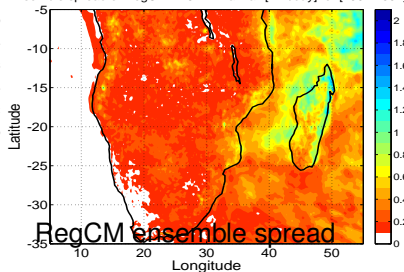
For RegCM, the ensemble spread over land (except over Madagascar) is smaller

Mean Climate (DJFMA) : Biases compared to CRU

ECMWF ens mean - CRU DJFMA rainfall [mm/day] for [1991:2001]
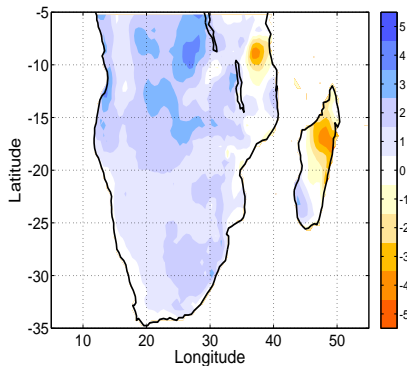
ECMWF

RegCM4 ensmean - CRU DJFMA rainfall [mm/day] for [1991:2001]
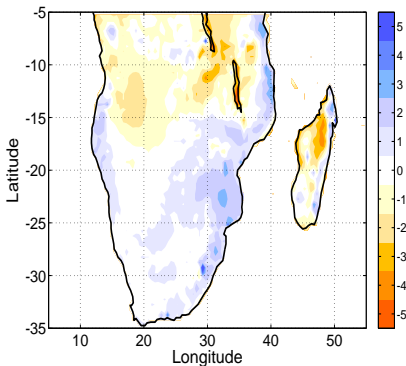
RegCM

- RegCM is able to reduce most of the biases of the ECMWF GCM

Inter-annual variability (DJFMA): ensemble mean correlation with CRU

Correlation of CRU with ECMWF ens mean for [1991:2001]   Correlation of CRU with RegCM4 ensmean for [1991:2001]

ECMWF   RegCM
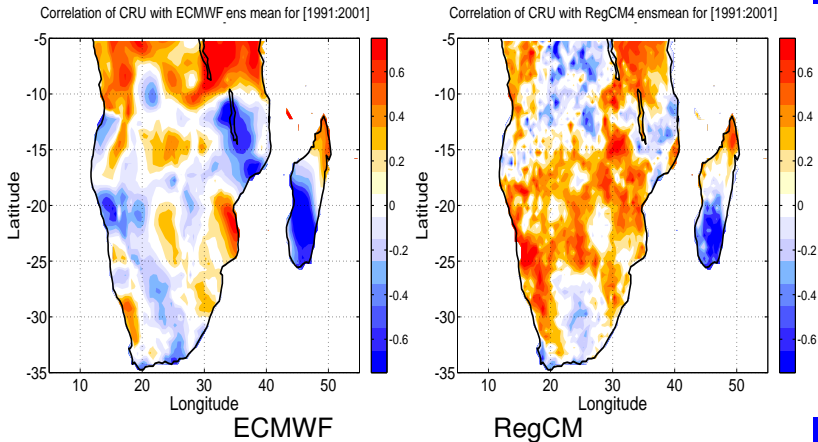
- RegCM improves the DJFMA (1 to 5 months lead time) mean correlation over most part of southern Africa compared to the driving GCM but still not good over Malawi

Skill as a function of lead time
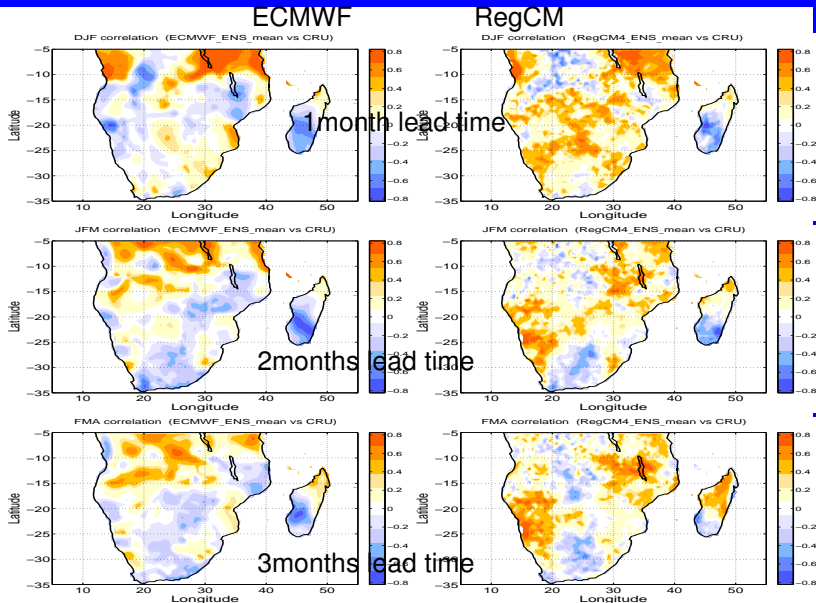
ECMWF   RegCM

Summary

- *For East Africa, RegCM is performing better than ECMWF only when compared over a large area-average and with high resolution gage dataset*

- *Errors could propagate from GCM to RegCM and affect the result of the simulation e.g.WIO SST*

- *RegCM4 reproduced the mean seasonal climate over the southern Africa when forced by ERA-interim*

- *the impact of land surface initialization on skill of the RegCM forecast is smaller for malawi domain*

- *RegCM4 has an added value i.e. reduced the bias and increased the temporal correlation of ECMWF ensemble seasonal hindcast*

- *Further analysis should be done w.r.t probabilistic assessment*

Thanks