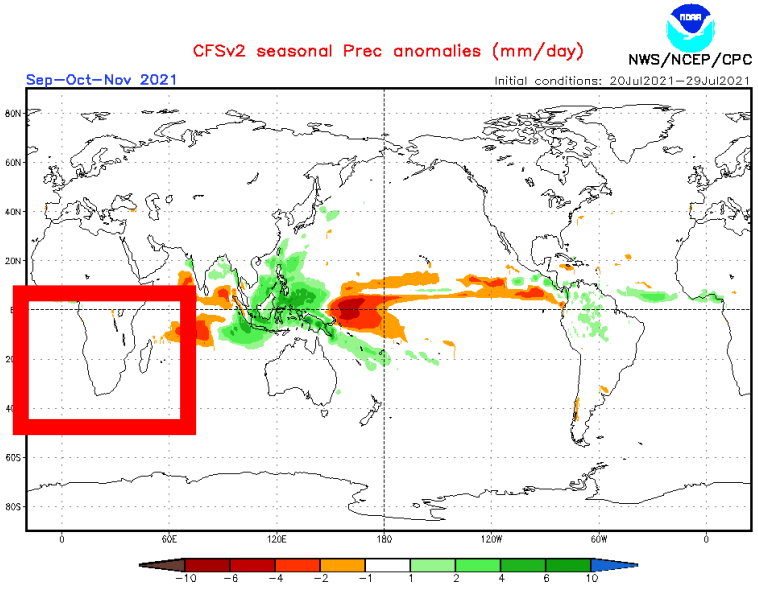
DOWNSCALING SEASONAL WEATHER FORECASTS FOR CROP YIELD FORECASTING OVER ZIMBABWE

SINCLAIR CHINYOKA AND GERT-JAN STEENEVELD

Meteorology and Air Quality Section, Wageningen University, Wageningen, The Netherlands

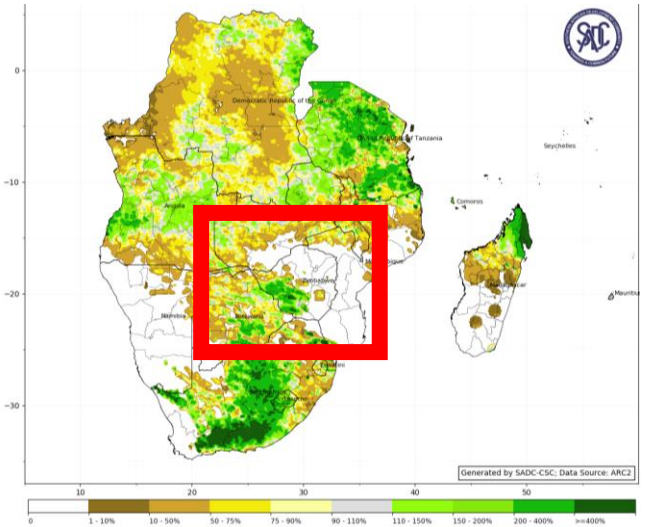
INTRODUCTION

GLOBAL



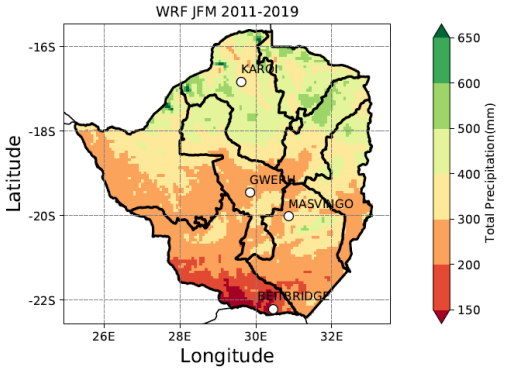
Source :https://www.cpc.ncep.noaa.gov

REGIONAL



Source: http://csc.sadc.int/en/

LOCAL



WRF output

CROP YIELD

https://www.world-grain.com/

BACKGROUND INFORMATION

- Rainfed agriculture
  - 90% of smallholder farmers
- Erratic rainfall seasons
  - Severe droughts
  - Floods and tropical cyclones
- High poverty and food insecurity
  - 5.3 mil (population ~12.5 mil)

Newsday,2015 : severe droughts in 2015-2016 season

Food aid from several NGOs

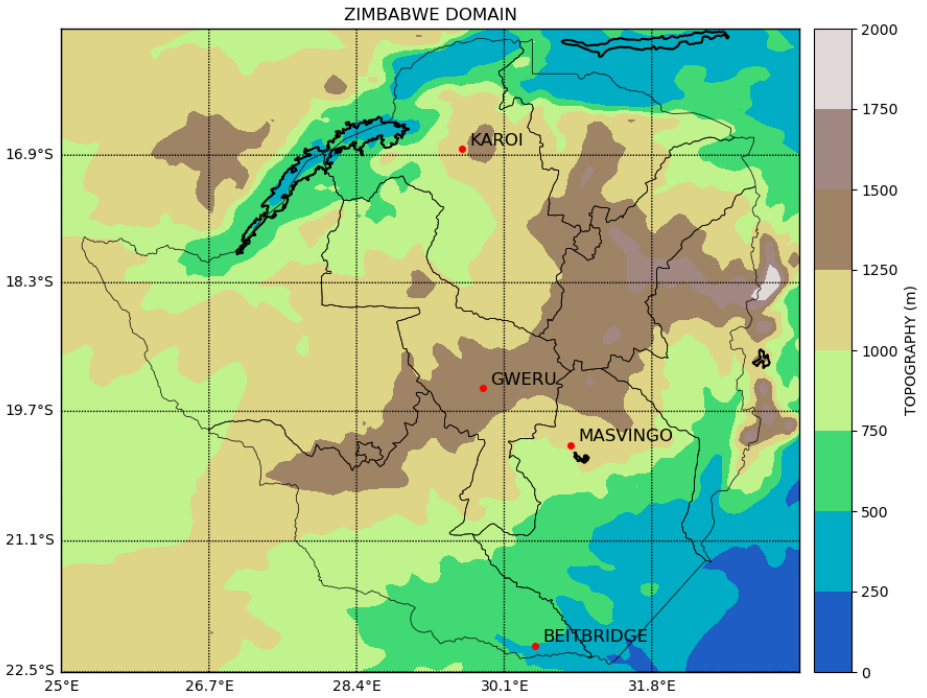
Damages from cyclone Idai, 2019

Research Objectives and Questions

- To assess the impact of downscaling Climate Forecast System version 2 (CFSv2) in terms of
  - Model skill
  - Impact on crop yield forecasting
- Research questions
  - Does CFSv2 reproduce Zimbabwe rainfall season?
  - Does downscaled CFSv2 improve seasonal rainfall predictions?
  - Is there an added value in downscaling CFSv2 in maize and sorghum yield forecasting?
  - Which crop can be recommended per region?

Study area

Google maps



- Landlocked
- Southern tropical region
- Central watershed (1250-1750m)
- Main lakes :
  - Chivero
  - Kariba
- Two main rivers
  - Limpopo
  - Zambezi

CLIMATE OF ZIMBABWE

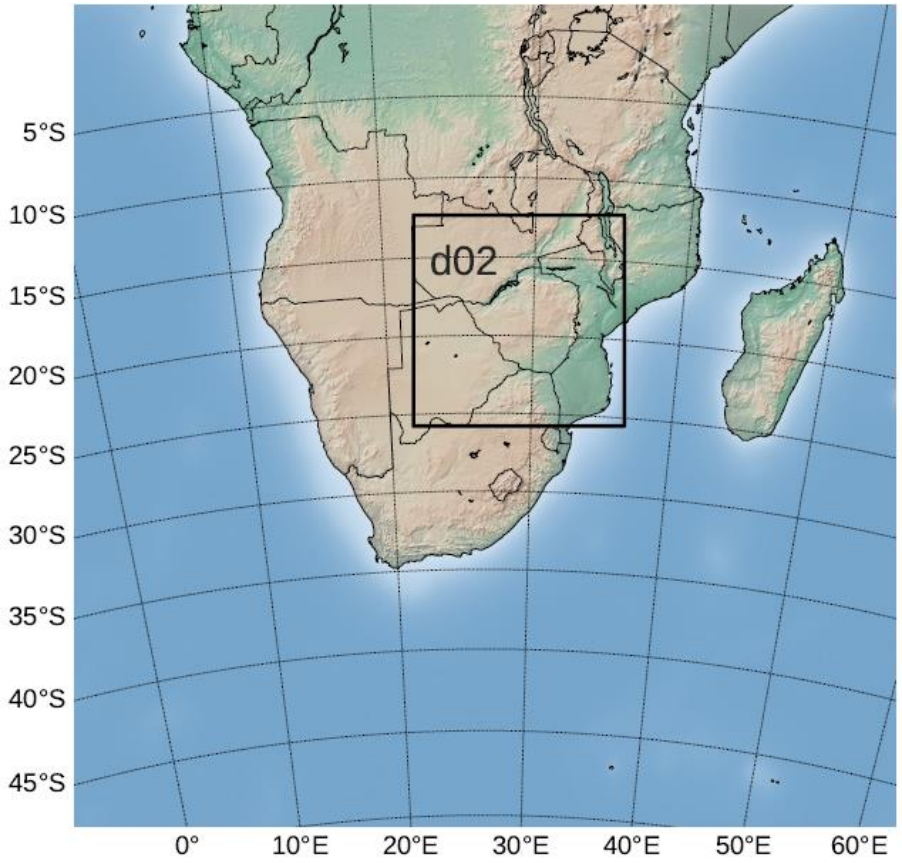
- Two distinct seasons:
  - Dry season (April-Sept)
  - Wet season (October-March)
- Intertropical convergence zone (ITCZ)
- Mean Annual rainfall
  - Wet areas : 3000mm
  - Dry areas : 300mm
- Mean Annual temperatures
  - Minimum : 15°C
  - Maximum : 25 °C

DATA

- Station rainfall data
  - 35 stations around Zimbabwe (Ordinary rain gauges)
- Climate Hazards Group InfraRed Precipitation with station data(CHIRPS)
  - For spatial analysis
  - Resolution (4km)
- ECMWF ReAnalysis (ERA5)
  - Weather data for WOFOST model
  - “*Observed crop yield”*
  - *31 km resolution*
- NCEP Climate Forecast System Version 2 (CFSv2)
  - Used for retrospective reforecasts and operational forecasting
  - Resolution of 100km.
  - Produce forecasts at *9 months* ,1 season,45 days
  - Has 64 sigma-pressure levels

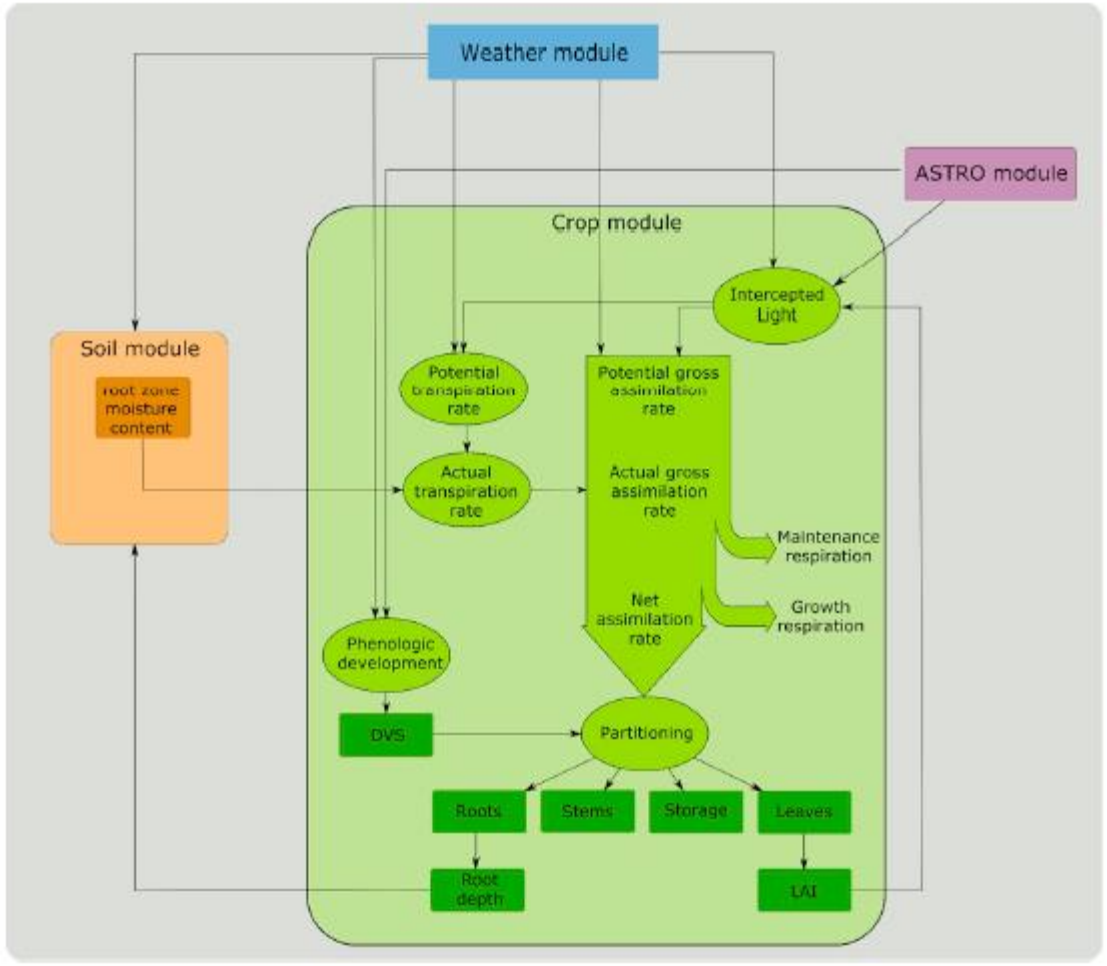
METHODS

- Downscaling NCEP CFSv2:
  - Weather research and Forecasting (WRF v4.1.2)
  - Grid spacing : 21km(d01) and 7km (d02)
  - 40 vertical levels up to 20hPa
  - Time integration : 1st Sept -1st April , 6hrs BC
- Rainfall seasons were characterized in terms :
  - Drought using Standardized Precipitation Index (SPI)
    - D(dry) (SPI<-1)
    - N (Neutral) (-1<SPI<1)
    - W (wet)(SPI>1)
  - Tercile forecasts (T)
    - Below normal (BN) : (T<75%)
    - Near Normal (NN) : 75 <T<125 %
    - Above normal (AN) : T>125%



WRF domain settings

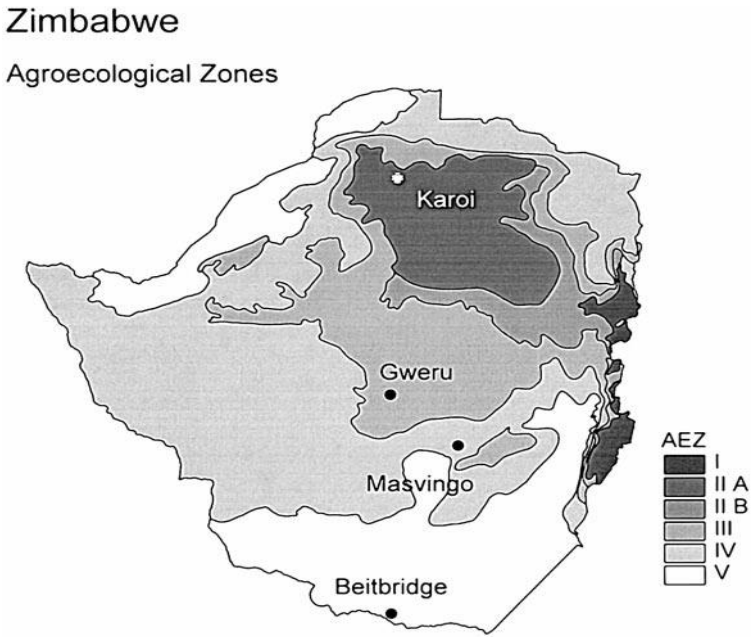
CROP FORECAST: WOFOST



de Wit et al., 2019

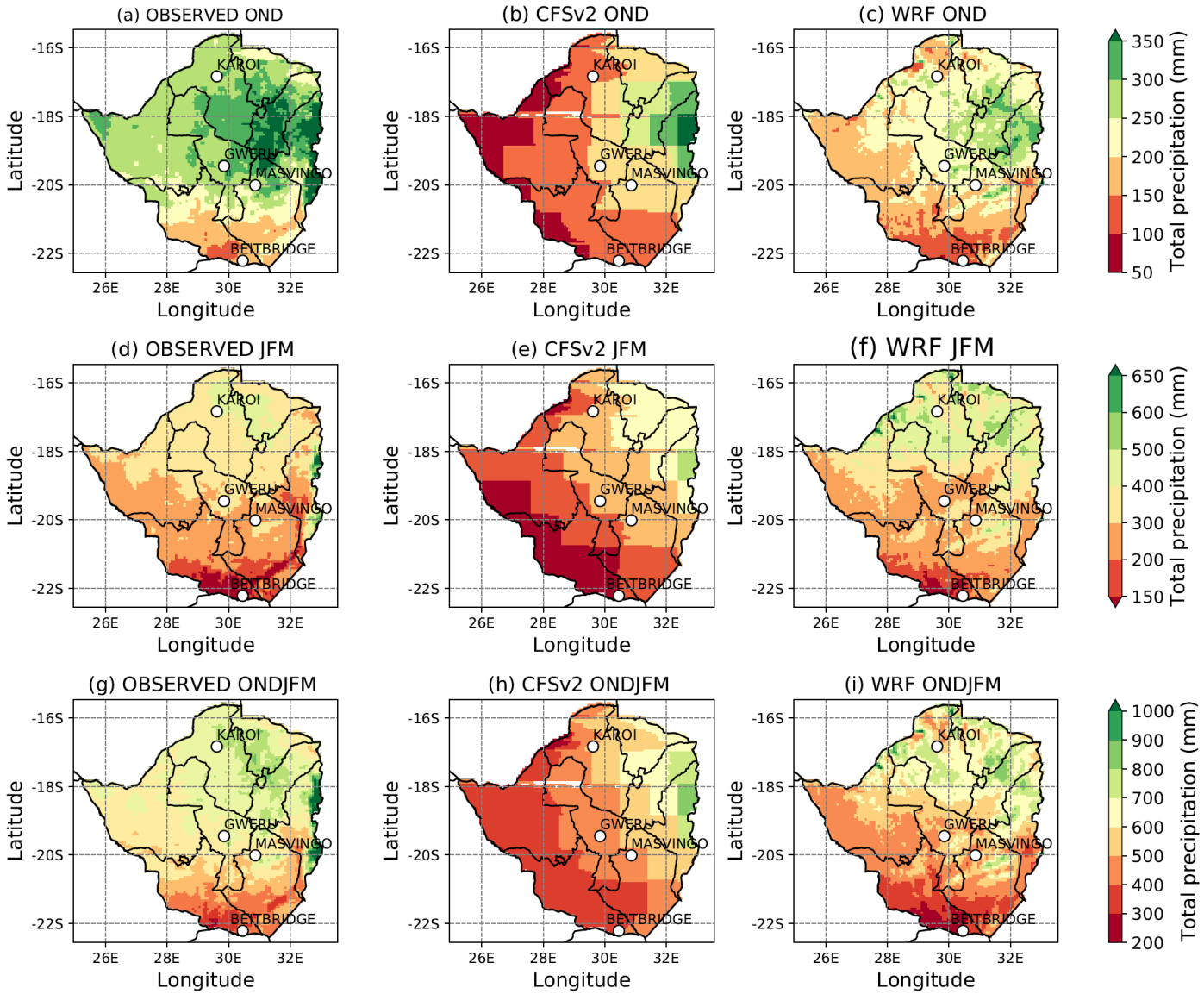
- CFSv2
- WRF
- ERA5 (observed yield)

- ISRIC (https://www.isric.org/)
  - Soil depth (200 cm)
  - Water holding capacity
- For four sites :



Phillips et al., 1998

RESULTS

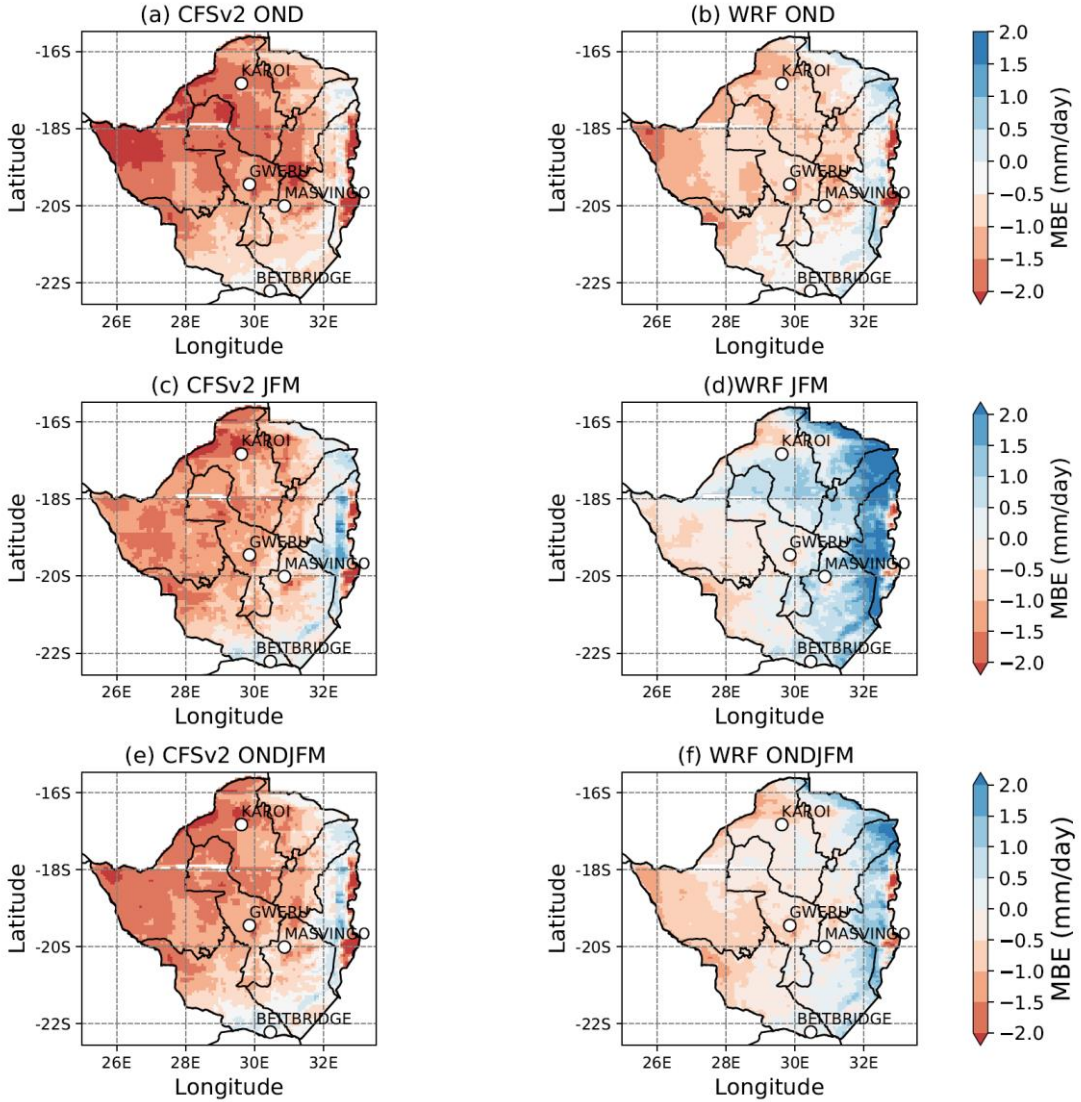


(a) Mean modelled and observed seasonal rainfall for the period 2011-2019

SPATIOTEMPORAL RAINFALL DISTRIBUTION

- Complete season October-March (ONDJFM)
  - Poor spatial coverage of rainfall forecasts by CFSv2
  - CFSv2 is drier (underestimate) seasonal rainfall in Zimbabwe
  - WRF forecasts is drier but an improvement of CFSv2
  - WRF improved spatiotemporal distribution of rainfall forecasts
- WRF underestimated the orographic induced precipitation eastern side of Zimbabwe
  - Can be due to the current grid spacing (7km)
- Two main rainfall bearing systems
  - OND : Tropical temperate troughs (cloud bands)
  - JFM : Intertropical convergence zone (ITCZ)
    - CFSv2 fails to reproduce the ITCZ
    - WRF improved the representation of ITCZ
- Overall WRF performed reasonably considering
  - Tropical cyclone Dineo (2016-2017)
  - Tropical cyclone Idai (2018-2019)

STATISTICAL ANALYSIS OF SEASONAL RAINFALL



(a) Average seasonal MBE for CFSv2 and WRF for the seasons 2011-2019.

MEAN BIAS ERROR (MBE)

- Both WRF and CFSv2 underestimated OND season for the large of the country
- Overestimation of JFM seasonal forecasts by WRF for the large part of the country
- MBE improved from -1.5mm/day to 0.5mm/day for the large part of the country in OND
- Overall improvement from -2mm/day to 0.5mm/day for the large part of the country in ONDJFM season
- Improvement of rainfall forecast in OND by WRF is a welcome result since it determines the onset of rainfall season as well as farming season

TERCILE AND SPI DRIVEN RAINFALL CATEGORISATION

TERCILE									
ONDJFM	REGION 1			REGION 2			REGION 3		
SEASONS	OBS	WRF	CFS	OBS	WRF	CFS	OBS	WRF	CFS
2011-2012	NN	**NN**	AN	NN	**NN**	BN	NN	BN	**NN**
2012-2013	NN	**NN**	BN	NN	**NN**	**NN**	NN	**NN**	**NN**
2013-2014	AN	NN	BN	AN	NN	BN	NN	**NN**	BN
2014-2015	NN	BN	**NN**	NN	BN	BN	NN	**NN**	**NN**
2015-2016	NN	**NN**	BN	BN	**BN**	**BN**	BN	**BN**	**BN**
2016-2017	AN	**AN**	NN	AN	NN	NN	AN	NN	**AN**
2017-2018	AN	NN	NN	NN	**NN**	**NN**	NN	**NN**	**NN**
2018-2019	BN	**BN**	**BN**	BN	**BN**	**BN**	NN	BN	BN
PC (%)		**62.5**	25		**62.5**	50		62.5	**75**

(a) Tercile driven forecasts for region 1 (Beitbridge), region 2 (Gweru and Masvingo) and region 3 (Karoi)

TERCILE ONDJFM

- CFSv2 – bias towards below normal rainfall (BN)
  - As confirmed by MBE results
- WRF – improved CFSv2 in region 1 and 2
  - Accuracy above 50 % in all regions indicating improved spatial coverage

SPI categorization									
ONDJFM	REGION 1			REGION 2			REGION 3		
SEASONS	OBS	WRF	CFSv2	OBS	WRF	CFSv2	OBS	WRF	CFSv2
2011-2012	N	**N**	**N**	N	**N**	D	N	**D**	D
2012-2013	N	**N**	D	N	**N**	**N**	N	**N**	**N**
2013-2014	N	**N**	D	N	**N**	D	N	**N**	D
2014-2015	N	D	**N**	N	**N**	D	N	**N**	**N**
2015-2016	N	**N**	D	D	**D**	**D**	D	**D**	**D**
2016-2017	W	N	**W**	N	**N**	**N**	N	**N**	**N**
2017-2018	N	**N**	**N**	N	**N**	**N**	N	**N**	**N**
2018-2019	D	**D**	**D**	D	**D**	**D**	N	D	D
PC (%)		**75**	62.5		**100**	62.5		**75**	62.5

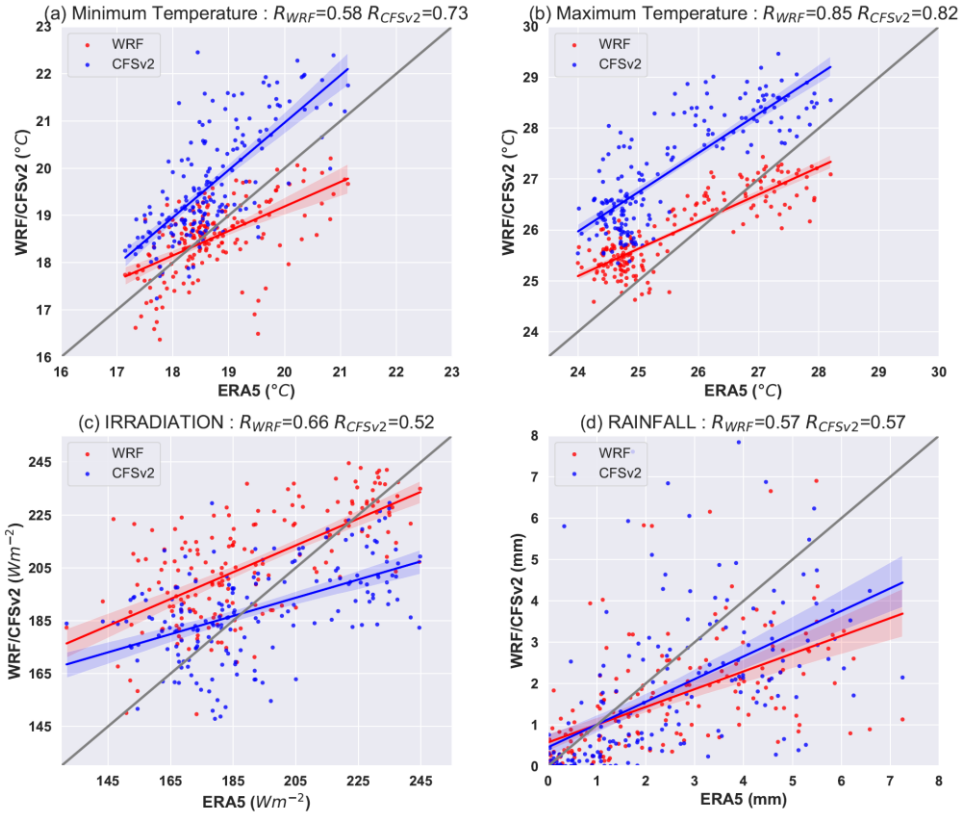
(b) SPI driven forecasts for region 1 (Beitbridge), region 2 (Gweru and Masvingo) and region 3 (Karoi)

SPI DRIVEN

- CFSv2 -62.5%
  - Drier than WRF
- WRF – 75-100%
- WRF outperforms CFSv2 in all regions

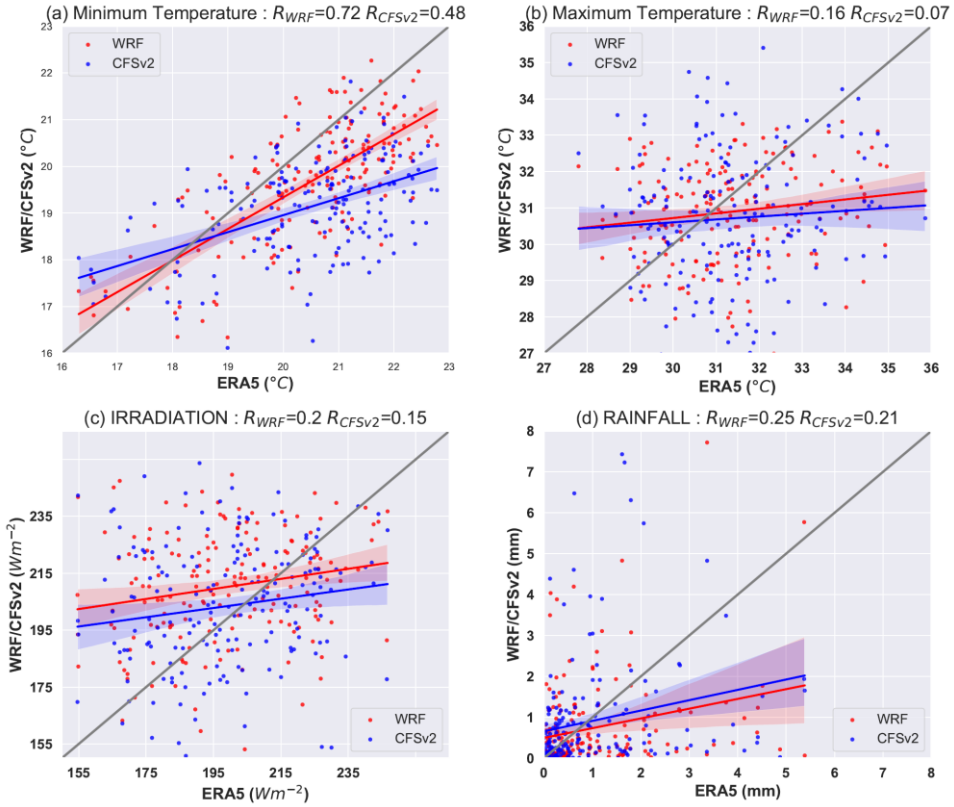
WEATHER PARAMETERS FOR WOrld FOod STudies (WOFOST)

MAIZE PRODUCING SITE (KAROI)



(a) Karoi site scatter plots (shading is the 90% confidence interval)

- Max temperature -WRF
- Min temperature – CFSv2
- Irradiation- WRF

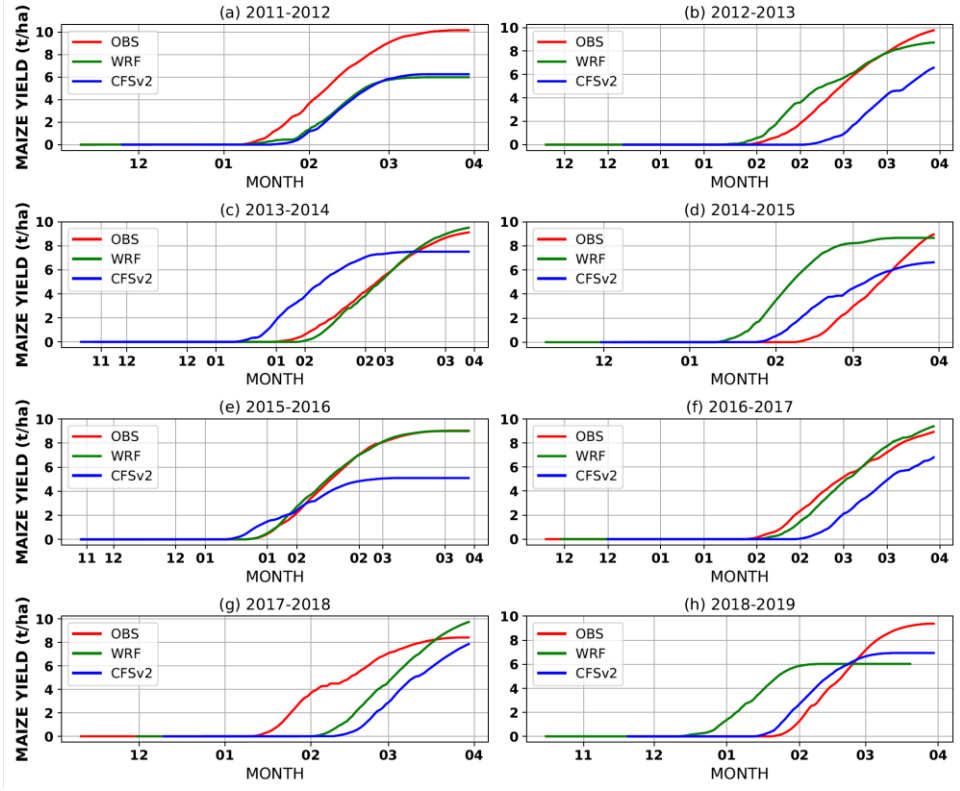


BEITBRIDGE

- Max temp -WRF
- Min temp – WRF
- Irradiation- WRF
- Poor cropping site

(b) Beitbridge site scatter plots (shading is the 90% confidence interval)

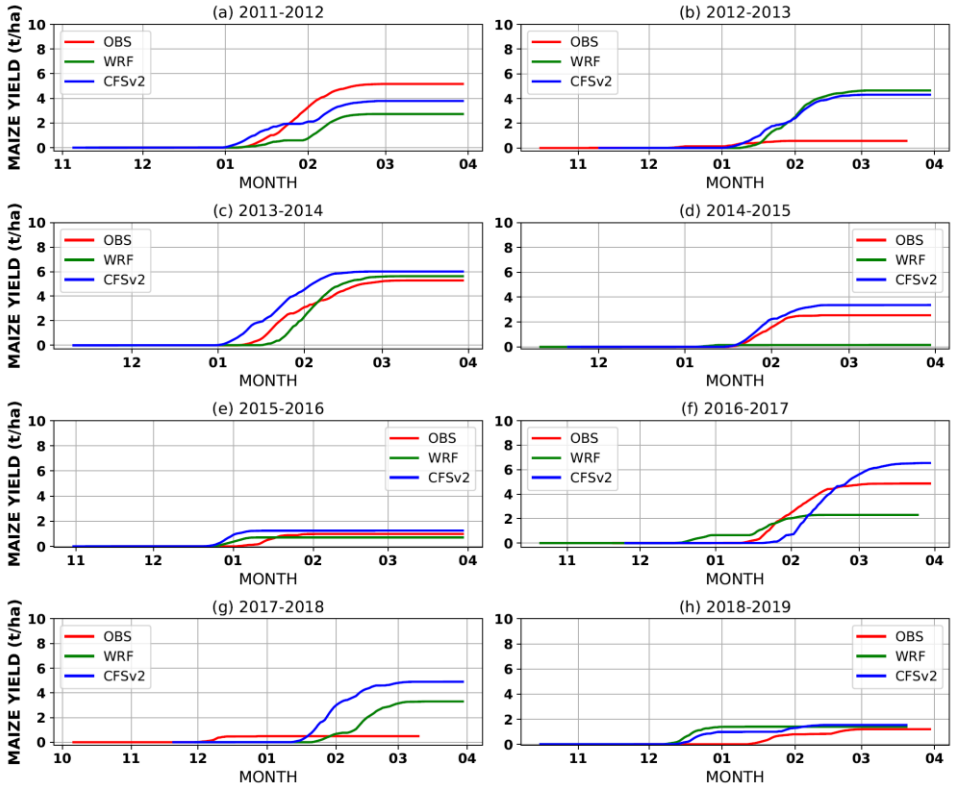
MAIZE YIELD SIMULATION



(a) Karoi site maize yield

MAIZE PRODUCING SITE (KAROI)

- WRF-forced simulations outperformed CFSv2-forced
- Improved prediction of rainfall onset dates by WRF
- Same seasonal yield but poor onset (e.g 2014-2015)
  - The model is punished

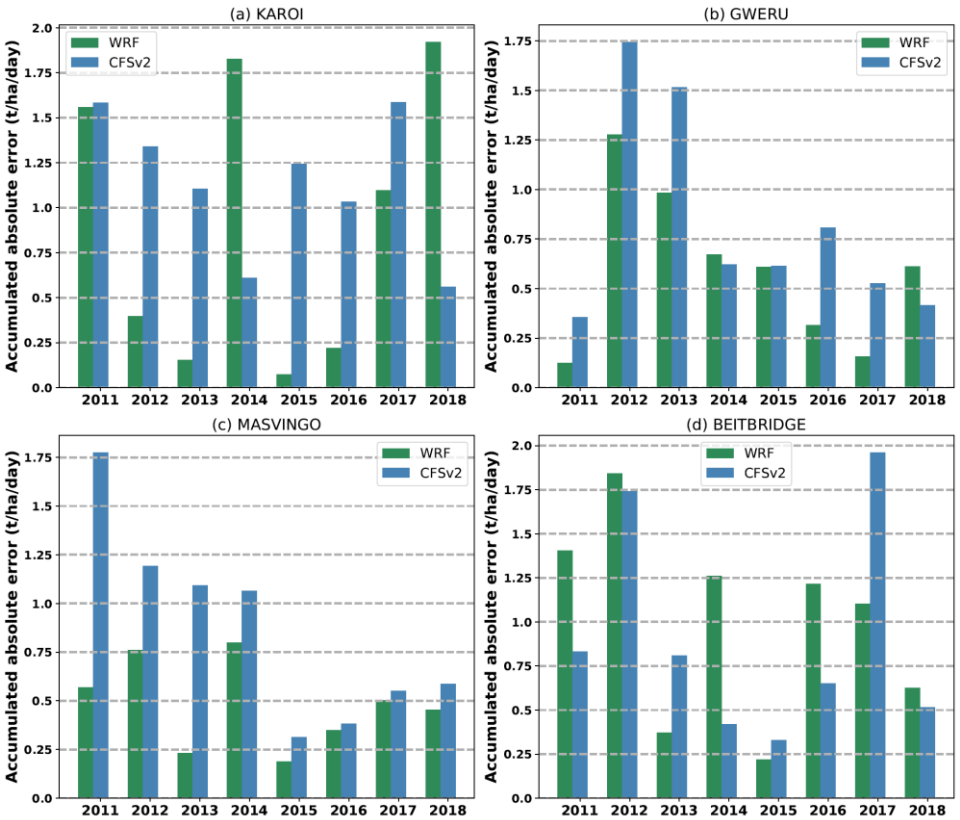


(b) Beitbridge site maize yield

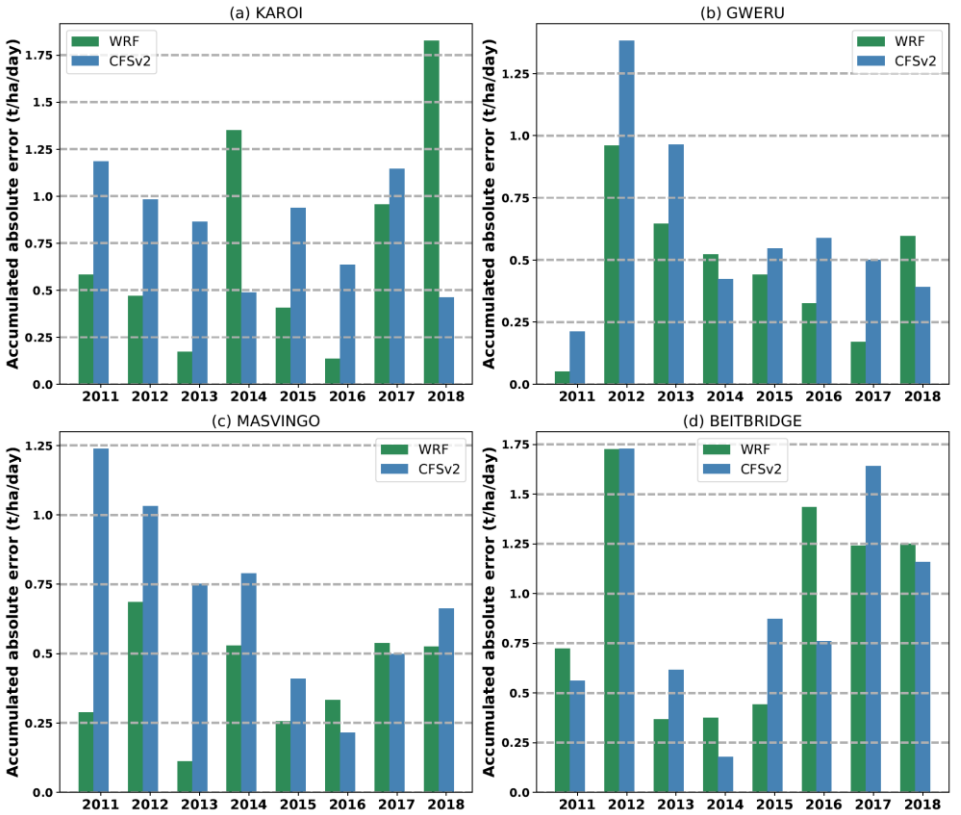
BEITBRIDGE

- Low maize yield
- High crop failure
- Not cropping site

ACCURACY OF CROP FORECASTS



(a) Maize yield accumulated absolute error for all sites



(b) Sorghum yield accumulated absolute error for all sites

MAIZE YIELD FORECASTS

- WRF-forced crop forecasts outperforms CFSv2 (6/8)
- Poor onset greatly affected model performance particularly CFSv2
- Poor maize yield forecasts at Beitbridge site
- Karoi best maize yield site

SORGHUM YIELD FORECASTS

- Sorghum yield forecasts have low accumulated error compared maize yield
- Maize and sorghum responds different to rainfall distributions.

CONCLUSIONS

- Does CFSv2 reproduce Zimbabwe rainfall season?
  - Good spatial rainfall distribution though under forecasting rainfall amounts
- Does downscaled CFSv2 improve rainfall predictions?
  - Improvement in terms of rainfall amounts
  - Very good performance in predicting drought seasons
  - A reduction of MBE from -2 mm/day to about 0.5 mm/day by WRF in ONDJFM season
- Does downscaled CFSv2 improve maize yield forecasting?
  - Improvement in prediction onset of rainfall season hence higher accuracy in crop forecasting by WRF
  - CFSv2 was punished for failure to capture onset of farming season as well as low maize yield
- Does downscaled CFSv2 improve sorghum yield forecasting?
  - WRF-forced sorghum forecasts outperforms CFSv2-forced forecasts
  - Sorghum yield forecasts are much better than maize yield forecasts at all sites

References

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