Qualifier seminar

Seasonal and sub-seasonal rainfall and river flow prediction over Northern Ethiopia

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Supervisory Committee:

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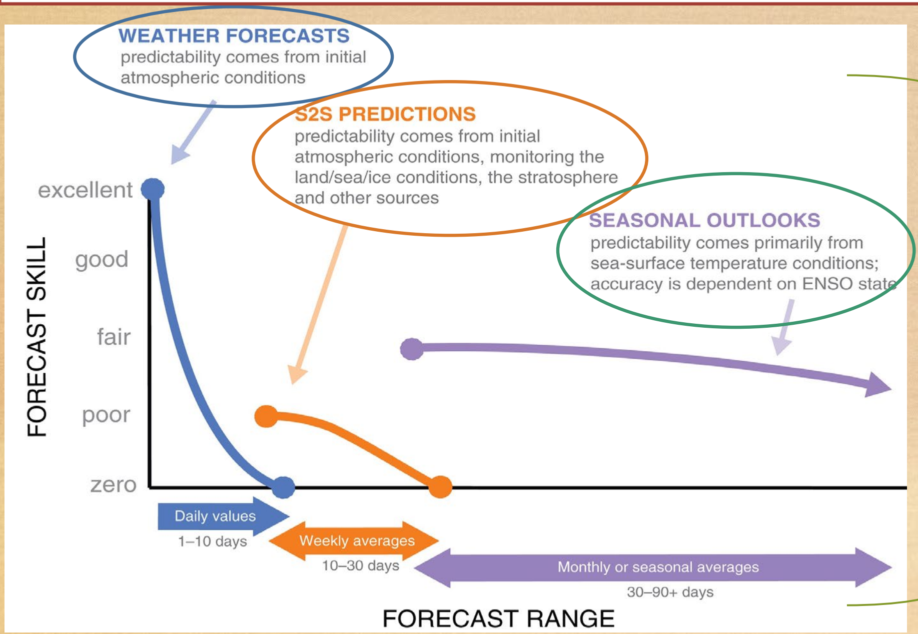
Presentation outline

- ✓Introduction
- ✓Problem of statement
- ✓Research objective
- ✓Research design and methods
- ✓Expected output
- ✓ Work plan

Introduction

State-of-the-art weather and climate prediction system

- Globally, high demand for reliable and accurate weather and climate predictions
- However, this is a challenging task due to the chaotic ocean-atmosphere-land surface interaction
- Three types of weather and climate predictions (White et al. 2017):



This can be performed based on three approaches:

a) Statistical

b) Numerical and

c) Hybrid methods

Introduction

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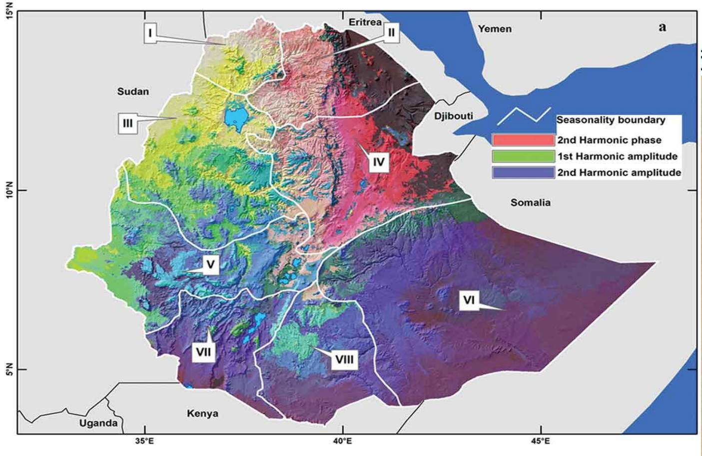
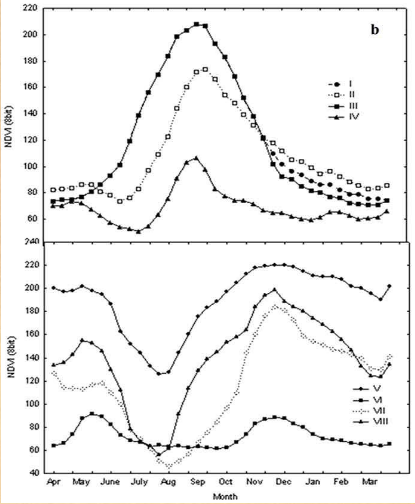
Statement of problem

- Similarly, in Ethiopia, there is high demand for skilful hydrometeorological prediction and simulations
  - GTP II
  - Frequent and severe droughts
- However, achieving accurate predictions is the most difficult task, due to complex climate system,
  - Numerous ocean-atmospheric factors
  - Complex topography (-76 up to 4550 m.a.s.l)





Seasonality code	Description (season)
I	Unimodal: one rainy
II	Unimodal: short rainy
III	Unimodal: one long rainy
IV	Bimodal: two short rainy
V	Unimodal to bimodal
VI	Bimodal: short spring and long-er summer rainy
VII	Bimodal: short spring and long-er summer rainy season
VIII	Bimodal: two short rainy

Figure 1: Ethiopian Seasonality map (Girma et al., 2016)

Introduction

Statement of problem

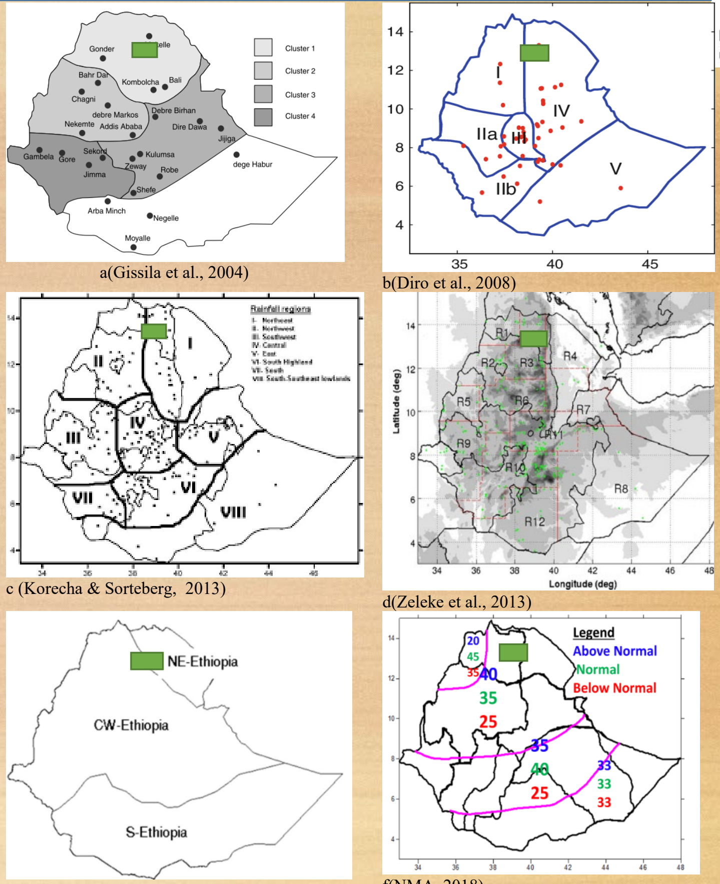
- For example, there are some studies on Ethiopian rainfall predictions, based on statistical relationships

- However , their findings is inconsistent

  I. Use different homogenous prediction regions

  II. Based on insufficient historical data

  III. Homogenous regions with correlation < 51%.



a(Gissila et al., 2004)

b(Diro et al., 2008)

c (Korecha & Sorteberg, 2013)

d(Zeleke et al., 2013)

e(Degefu et al., 2017)

f(NMA, 2018)

Figure 2.2 Homogenous regions for seasonal rainfall prediction

Introduction

Statement of problem

- Nevertheless, the Ethiopian MA prediction system uses analogue year method (Korecha & Sorteberg, 2013)
    - ✓ only trends of ENSO anomalies with
    - ✓ PRSS of 10%-weak to moderate skill
    - ✓ worst for the extreme conditions
- Moreover, studies on site specific hydrometeorological (rainfall, runoff and soil moisture) predictions at s2s and seasonal temporal scales using either numerically or hybrid models are limited

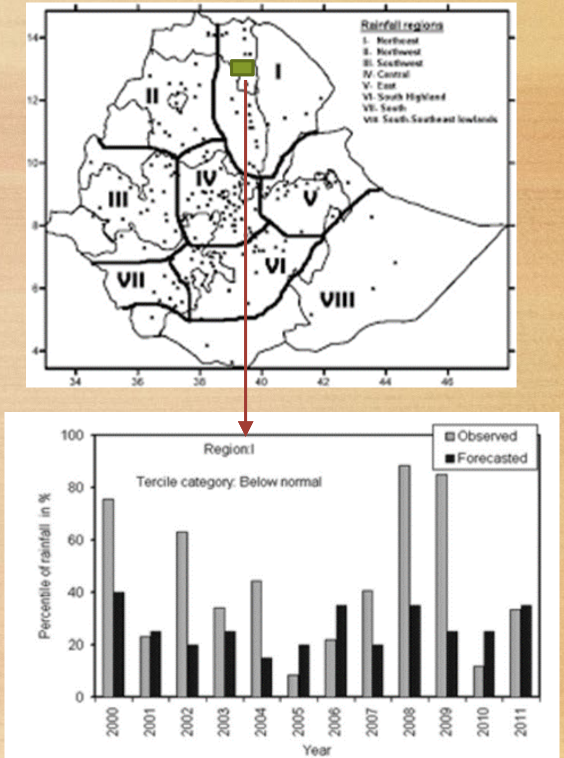


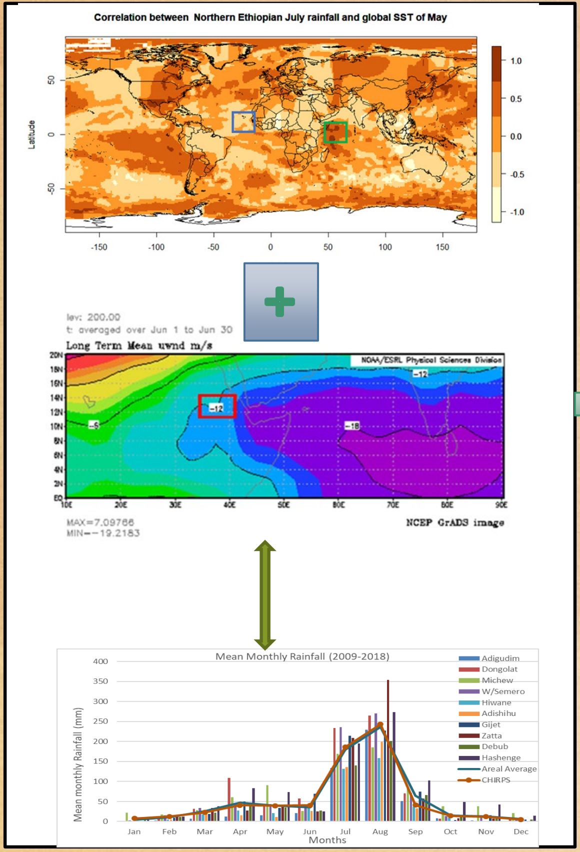
Figure1.1: observed vs predicted rainfall (Korecha and Sorteberg, 2013)

Objective

- **General objective** is:
  - to improve hydrometeorological (rainfall, river flow and soil moisture) predictions with a lead time of 10 days to four months (JJAS rainfall) over Northern Ethiopia.
- **Research objectives (RO):**
  - ✓ RO1: Investigate the teleconnections between the major climate driving factors and seasonal and sub-seasonal rainfall variation over Northern Ethiopia
  - ✓ RO2: Customize a coupled numerical model (WRF model) as a regional climate model for seasonal and sub-seasonal rainfall predictions over Northern Ethiopia
  - ✓ RO3: couple the atmosphere to the terrestrial models (WRF-Hydro) for seasonal and sub-seasonal hydrological predictions of the Upper Tekeze Basin in Northern Ethiopia

Research design and methods

RO1: Investigate the teleconnections between global climate driving factors and seasonal and sub-seasonal rainfall variations over Northern Ethiopia



Review related weather and climate prediction literatures

Oceanic-atmospheric data
- SSTs
- Zonal winds

Gridded observed rainfall data
- Station-based from NMA
- Satellite- based from CHIRPS

Land surface information
- DEM/ base map

Identify and analyze teleconnections and develop a regression model

Identify the teleconnections:
Correlation maps starting with 1-3 months lead time

Analyze overfitting and multi-collinearity effect
- Regression sensitivity test and
- Variance Inflation Factor, $VIF = \frac{1}{1-R_i^2} \ldots \ldots (Equ. 4.1)$

Develop multiple linear regression model

Sensitivity and accuracy analysis
- Mean Error for biasness
- Pearson's correlation coefficient for statistical association
- Root Mean Square Error (RMSE) for accuracy
- Skill Score (SS) to measure skill improvements

Comparisons with
- The NMA's forecasting system
- Previous studies in the area

Statistical method for seasonal and subseasonal rainfall predictions

Oceanic- atmospheric variables that link to JJAS rainfall variations

Research design and methods

RO2: Customize a coupled numerical model (the WRF model) as a regional climate model for seasonal and sub-seasonal rainfall prediction over Northern Ethiopia

The WRF model

- WRF-ARW model (version 4.0…)

- It is non-hydrostatic, mesoscale NWCP and atmospheric simulation system (Skamarock et al., 2008)

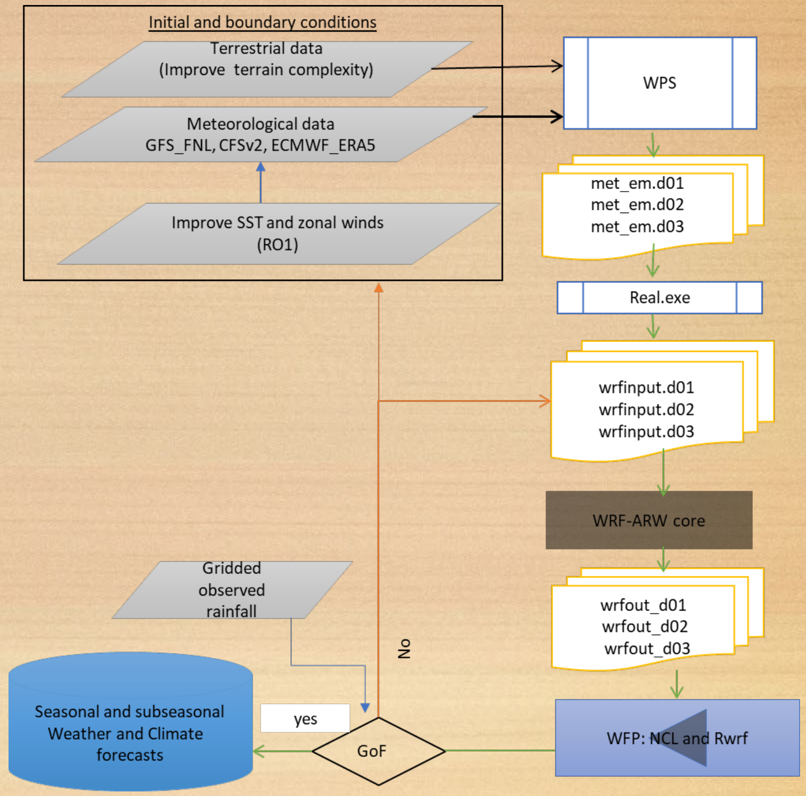
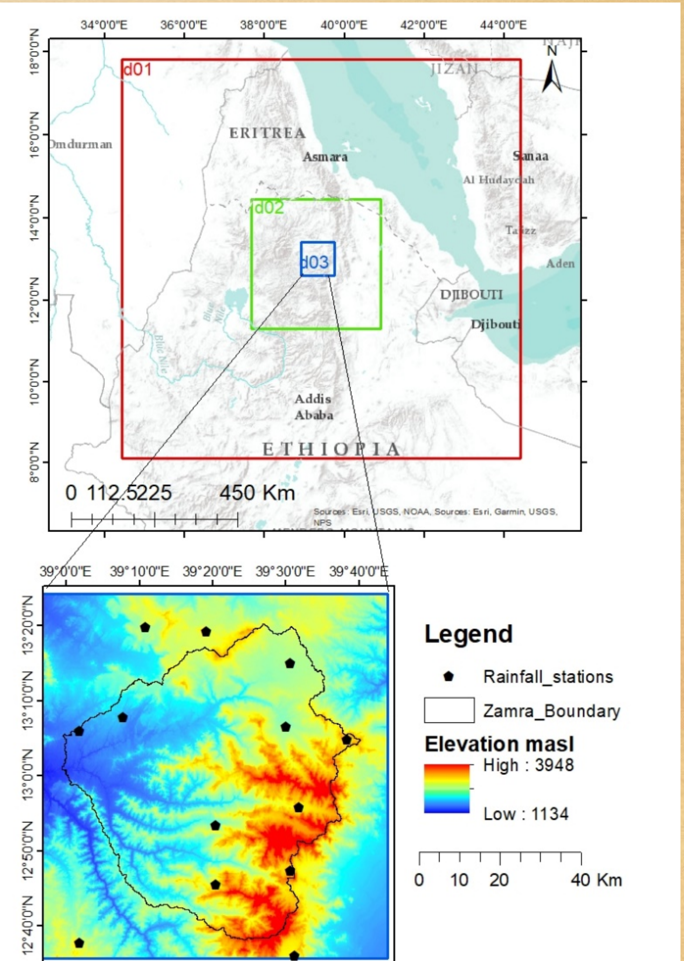


Figure 4.4: Schematic methodological flowchart

Research design and methods

RO2: Domain configuration-control

Centre	13^0 N and 39.4^0 E
Nesting	Two-way with 1:3 ratio
Domains	d01, d02 and d03
HR	27 km, 9 km and 3 km
Area (Grid cells),	41X41, 40X40 & 31X31
Vertical resolution	L28 with 5000Pa
VCS	HVC (default)



Research design and methods

RO2: Model configurations- control

WRF model requirement	Schemes	Configurations
Forcing initials	Geographical input: high resolution mandatory fields	MODIS, 30s
	Meteorological input: ECMWF-ERA5 reanalysis	6-hourly daily data at 31km horizontal resolution
Physical options	Cumulus convection (CU)	Kain-Fritsch (KF)
• Abdelwares et al., 2017;	Microphysics (MP)	WRF Single-Moment 6-Class scheme (WSM6)
	Planetary Boundary Layer (PBL)	Mellor-Yamada-Janjic (MYJ)
• Kerandi et al., 2017;	Long-wave radiation (LW)	NCAR Community Atmosphere Model (CAM)
• Pohl et al., 2011	shortwave radiation (SW)	CAM
	Land surface model (LSM)	Noah Land Surface model (Noah-LSM)
Simulation time	6 months for 4/5 years (2015-2019)	Simulation starts at April 01, 2015 and integrates on September 30, 2015

Research design and methods

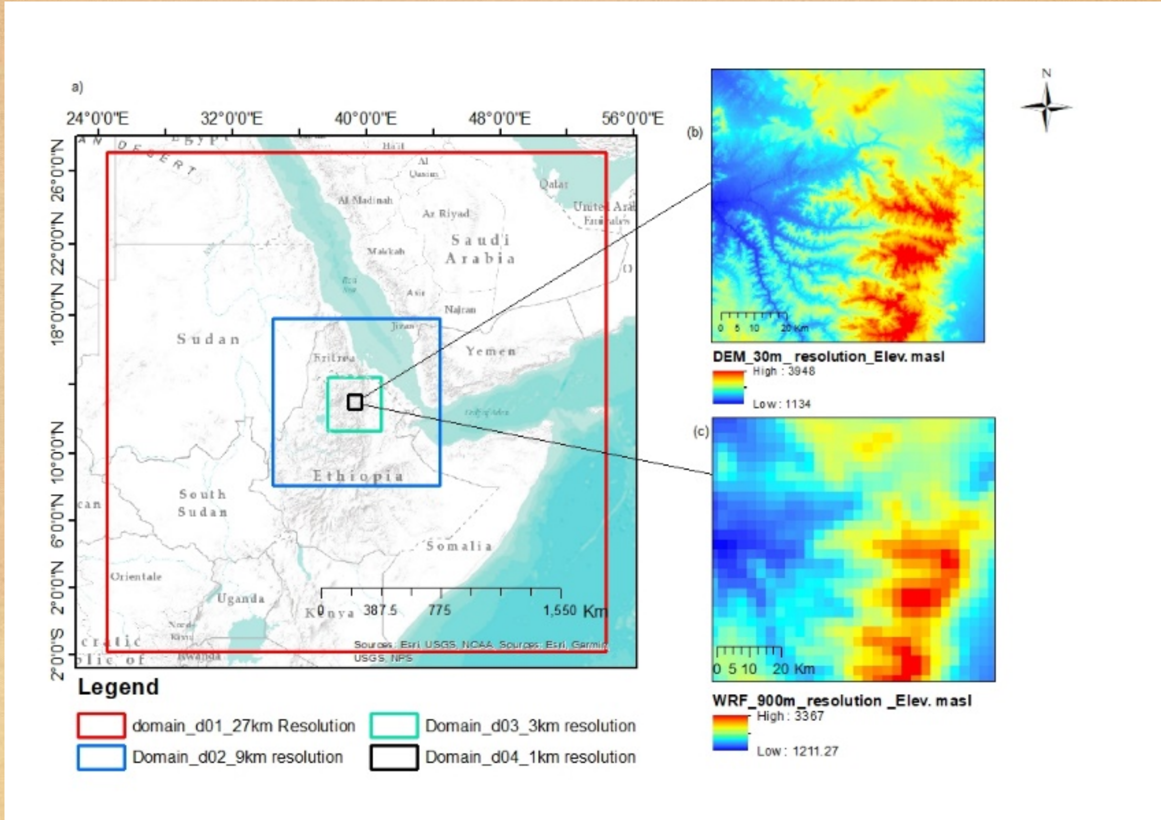
RO2: WRF model optimizations- Experiments

In areas with complex topography and climate system, what will be the prediction skill of WRF model if…?

Experiments	Schemes	Configurations
1. Physical options	Cumulus convection (CU)	KF, BMJ & GFl
	Microphysics (MP)	Lin, WSM6 & Morrison
	Planetary Boundary Layer (PBL)	MYJ, YSU & ACM2
	Long-wave radiation (LW)	CAM, RRTM & RRTMG_K
	shortwave radiation (SW)	CAM, Dudhia & Goddard
2. Initial and boundary conditions	GFS-FNL	6-hourly daily forecasts at 0.25^0 horizontal resolution
	CFSv2	6-hourly daily forecasts at 0.2^0 horizontal resolution
3. Vertical resolution and coordination system	Vertical resolution	51 layers with 1000Pa
	Vertical coordination system	Terrain-following system
4. Horizontal resolution	Domain name	Parent domain (d01), d02, d03 and d04
	Domain Horizontal resolution	27 km, 9 km, 3km and 1km
	Area coverage (grid cells)	121X121, 41X41, 40x40 & 31x31
5. Geographical input	Topography, land use and soil type	• Compare model representations with the reality • Improving through resampling techniques
6. Teleconnection (RO1)	SST and Zonal wind	• Sensitivity test, especially +/- SST anomalies and topography
Method of optimization		Step-wise evaluations

Research design and methods

RO2: Example, horizontal resolution and topography



Research design and methods

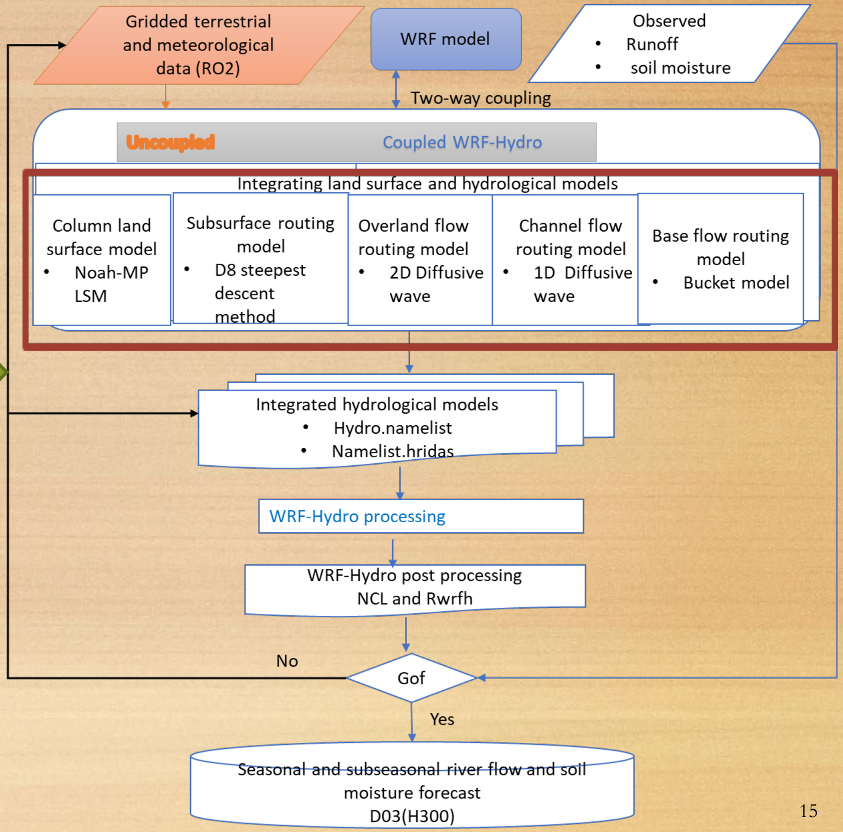
RO2: Methods of analysis and performance evaluation

- Analysis will be at two temporal scales.
  - For the s2s prediction: daily simulation (10 to 60 days) and/or weekly averages
  - For the seasonal predictions: monthly and seasonal averages
- The performance of the WRF model configurations using verification tools such as Model Evaluation Toolkit (MET)
  - ✓ The accuracy indices (ME, RMSE),
  - ✓ Skill score
  - ✓ Correlation coefficients (temporal and spatial relationships)
  - ✓ Taylor diagrams

Research design and methods

RO3: Couple the atmospheric to a terrestrial model using WRF-Hydro for seasonal and sub-seasonal hydrometeorological predictions of the Upper Tekeze River Basin in Northern Ethiopia

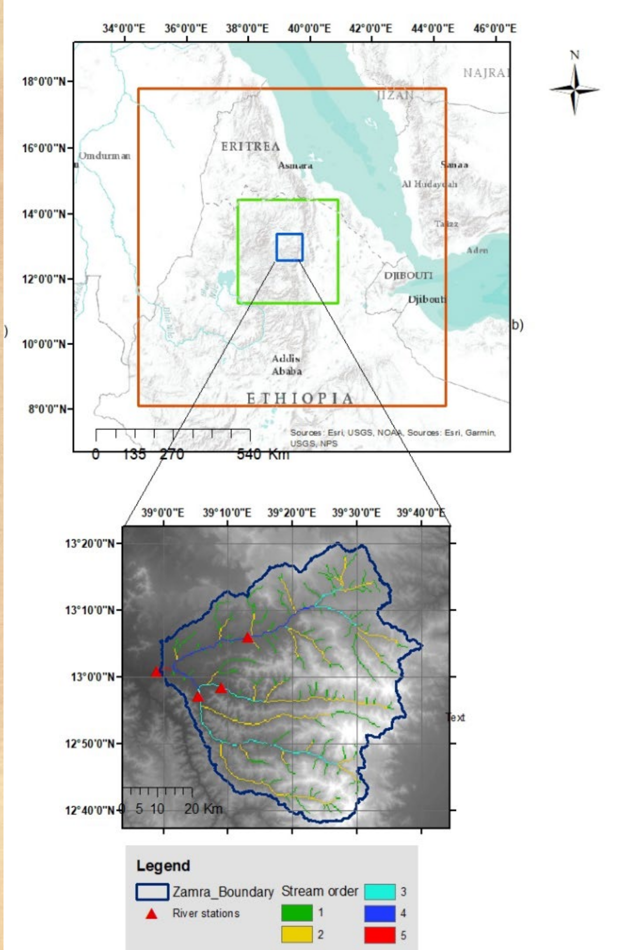
- The current WRF-Hydro (version 5.0)
- The WRF model extension,
- Fully distributed hydrological modelling system
  - ✓ Integrates five models



Research design and methods

RO3: Model configuration (spatial transformation)

- Hydrological routing and channel network will be defined:
  - Using WRF-Hydro GIS pre-processing tool (version 5)
  - For hydrological routing, the LSM with 3 km resolution will be disaggregated to 300 m resolution using disaggregation factor of 10
  - To define streams, a threshold of 80 contributing grid cells with routing timesteps of the 20 seconds
  - Four layers soil column : 7cm, 28cm, 100cm and 1.89 cm



Research design and methods

RO3: Model calibration and performance evaluation

- One year (2019) for calibration and one year (2020) for validation
- Two-steps manual calibration (Kerandi et al., 2018; Yucel et al., 2015)

1. Infiltration scaling factor
2. Surface retention depth parameter

} Volume of hydrological response

3. Overland flow roughness parameter
4. Manning's roughness coefficient factor

} Temporal variation

- The model performance will be assessed using:
  - ✓ MRSE, NSE, Correlation studies, and Taylor diagram

Expected output

- Seasonal and sub seasonal rainfall, streamflow and soil moister prediction models
- Three (four) paper in high impact peer-reviewed journals;
  - Investigate the teleconnection between global climate driving factors and seasonal and sub-seasonal rainfall variation over Northern Ethiopia
  - Customize the WRF model as a regional climate model for seasonal and sub-seasonal rainfall prediction in Northern Ethiopia
  - Sensitivity analysis of global SST and zonal winds in a complex topography in prediction of the JJAS rainfall at seasonal and sub-seasonal timescales over northern Ethiopia.
  - Joint atmospheric-terrestrial (WRF-Hydro) modelling for seasonal and sub-seasonal hydrometeorological predictions in Upper Tekeze basin, Northern Ethiopia.
- One PhD thesis, two MSc thesis and policy briefs

Research and academic work plan

No	Activity	Years															
		I (July 2018- June 2019)				II (July 2019- June 2020)				III (July 2020- June 2021)				IV (July 2021- June 2022)			
		ITC, UT			MU, Ethiopia				ITC, UT		MU, Ethiopia				ITC, UT		
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Literature review																
2	Proposal development																
3	Coursework and Training																
4	Qualifier																
5	Year I. Progress Report																
6	Fieldwork 1: data collection for Objective 1 and 2																
7	Data analysis and paper write up of for objectives 1 and 2 and submission paper 1 and 2 for publication																
8	Seminar participation																
9	Year II. Progress Report																
7	Fieldwork 2: data collection for Objective 3																
8	Data analysis and paper write up for Objective 3 and 4 and submission 3rd paper for publication																
9	Year III. Progress Report																
10	Fourth paper write up and submission for publication																
11	Incorporate comments and suggestions																
12	Final thesis organization, synthesis, and submission																
13	Defense																

Thank you for listening

Preliminary results from three days WRF runs