# Integrated Climate Change Impact Assessment in the Lake Victoria Basin (LVB)

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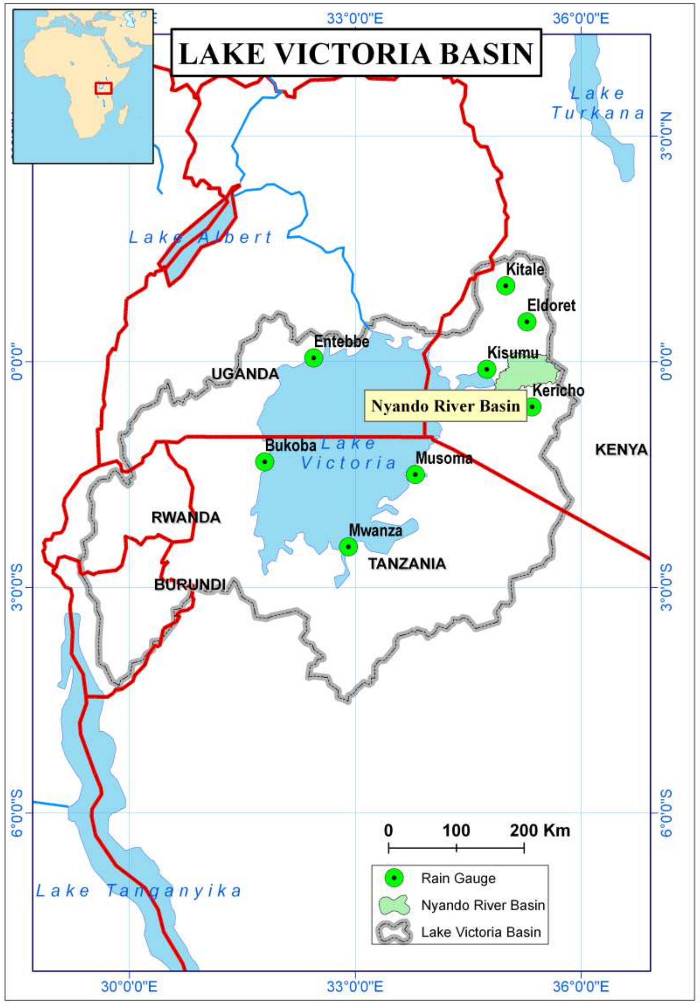
# Outline

- Needs, objective and framework
- Basin scale climate change (Nyando R. Basin)
- Regional changes in Extreme weather (LVB)
- Numerical weather prediction and downscaling of weather forecasts in the LVB
- Conclusions and recommendations

# Background

- Extreme weather and climate events can lead to disasters *(Field et al., 2012)*
- Extreme weather events have increased in the past century *(Easterling and Evans, 2000; Rahmstorf and Coumou, 2011; Coumou and Rahmstorf, 2012)*
- A major concern with climate change is that future extreme events will increase *(Easterling et al., 2000; Treut et al., 2007)*
- Extreme rainfall and associated floods has been the leading disasters globally with more than six million lives lost between 1900-2012 *( EMDAT, 2012)*
- Integrated multi-dimensional impact assessment and extreme weather forecasting (for adaptation) approaches are few e.g. (*Black et al., 2011; Jarvis et al., 2011; Arndt et al., 2010; Vuuren et al., 2009).*

# Why Lake Victoria Basin?




- LVB is trans-national, supports millions of livelihoods, source of Power for Uganda and Kenya
- Key source of R. Nile
- Population :
  - Most vulnerable to climate change
  - Increased poverty assoc. with climate change
- Loss of lives/incomes due to floods in Nyando, Yala, and other river basins
- Freak weather responsible for about 4000-5000 deaths each year over the Lake
- Its river basins synonymous with flooding

# Vulnerability to climate change LVB..

JUMUIYA YA AFRIKA MASHARIKI

EAST AFRICAN COMMUNITY
LAKE VICTORIA BASIN COMMISSION

VULNERABILITY ASSESSMENT
TO CLIMATE CHANGE IN LAKE VICTORIA BASIN



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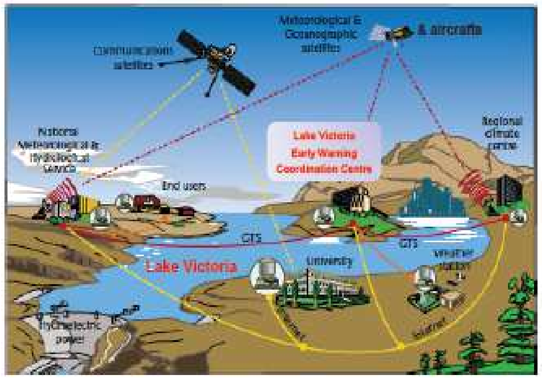
- Climate change a significant factor contributing to poverty
- limited studies that address the complex interactions between the diverse factors and the coping mechanisms
- the majority of people in the LVB are vulnerable
- Prevalent conditions of extreme weather
- Unsustainable development
- prone to catastrophic diseases and do not have access to adequate healthcare

(Lake Victoria Basin Commission, 2011)

# Prevailing weather-related issues

Enhancing Safety of Navigation and Efficient Exploitation of Natural Resources over Lake Victoria and Its Basin by Strengthening Meteorological Services on the Lake

CML
Climate Modeling Laboratory




Final Report
26 October 2011

**LVBC commissioned feasibility study**

Key Needs:

Assess :-

- The existing weather observation network
- Data processing capabilities
- Timeliness of dissemination
- Weather products on the lake and its basin
- Identify existing inadequacies and
- Make suitable recommendations

*(Semazzi et al., 2011)*

# OUTCOME : Enhancing Safety of Navigation and Efficient Exploitation of Natural Resources over Lake Victoria....

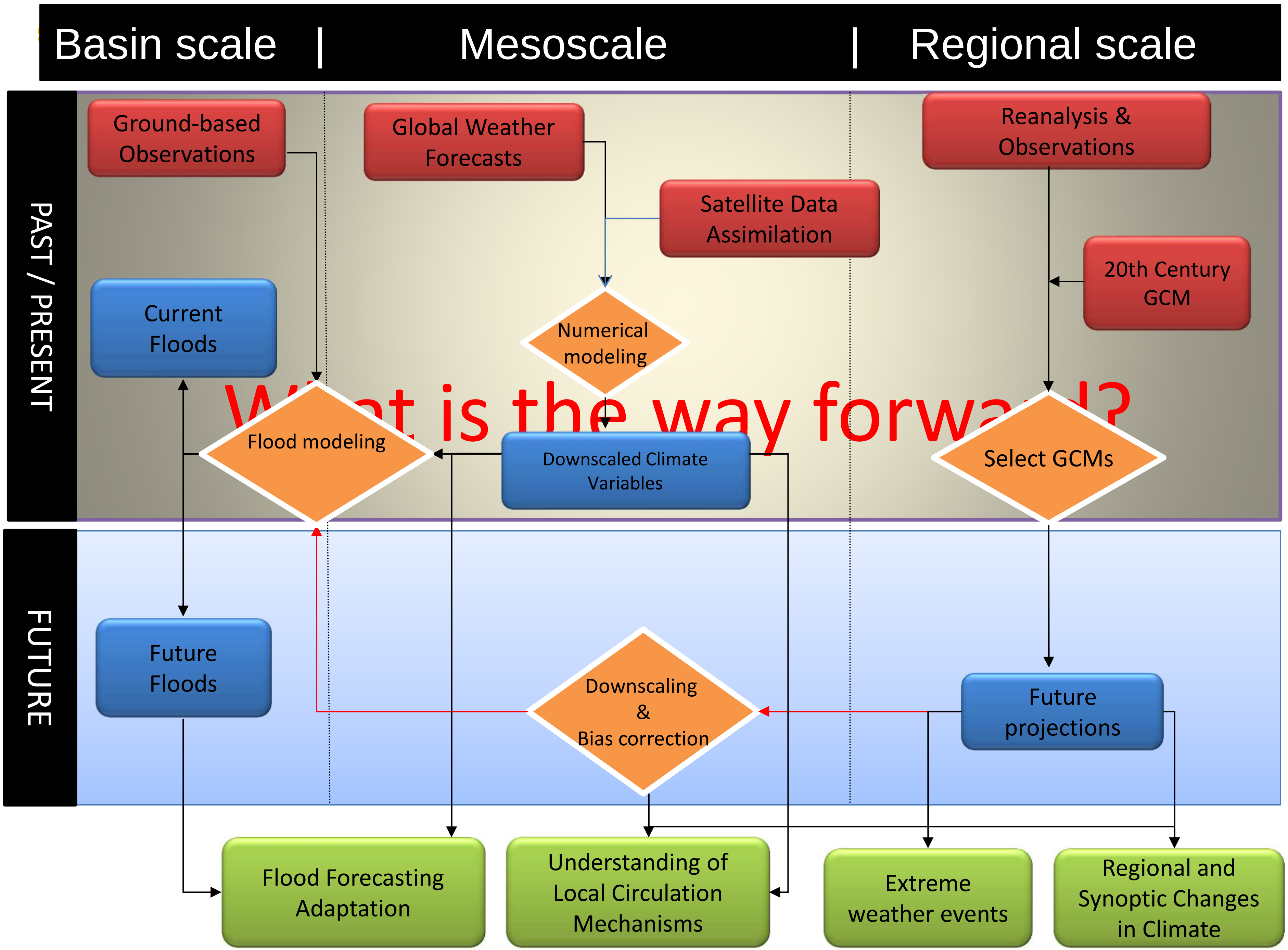
*Semazzi et al., 2011*

- Extreme weather : big challenge to transportation in the LVB
- More than 5,000 marine accident deaths / year
- Lack of reliable and useful weather forecasts
- Proposals
  - Marine and Atmospheric Special Observing Period (SOP) for LVB Project-
  - Plan for a Navigation Early Warning System (NEWS)
  - plan for a Hotspots Atlas (CTOR2)
  - plan for a Centre for Meteorological Services (CMS) for the Lake Victoria Basin (CTOR5).

# What is needed?

- Climate change assessment – : Scientific
  - Need for an integrated approach
  - Multi-scale analysis → e.g. link basin + regional scales
  - Multi-temporal approach
  - Multi-analytical approach (data, numerical, methods)

- Climate change adaptation – : Operationalization
  - Improved local scale resilience to a changing climate
  - Improved forecasting of "increasing" extreme weather
  - coordinated International efforts
  - Real time solutions e.g. realtime obs., realtime forecasts

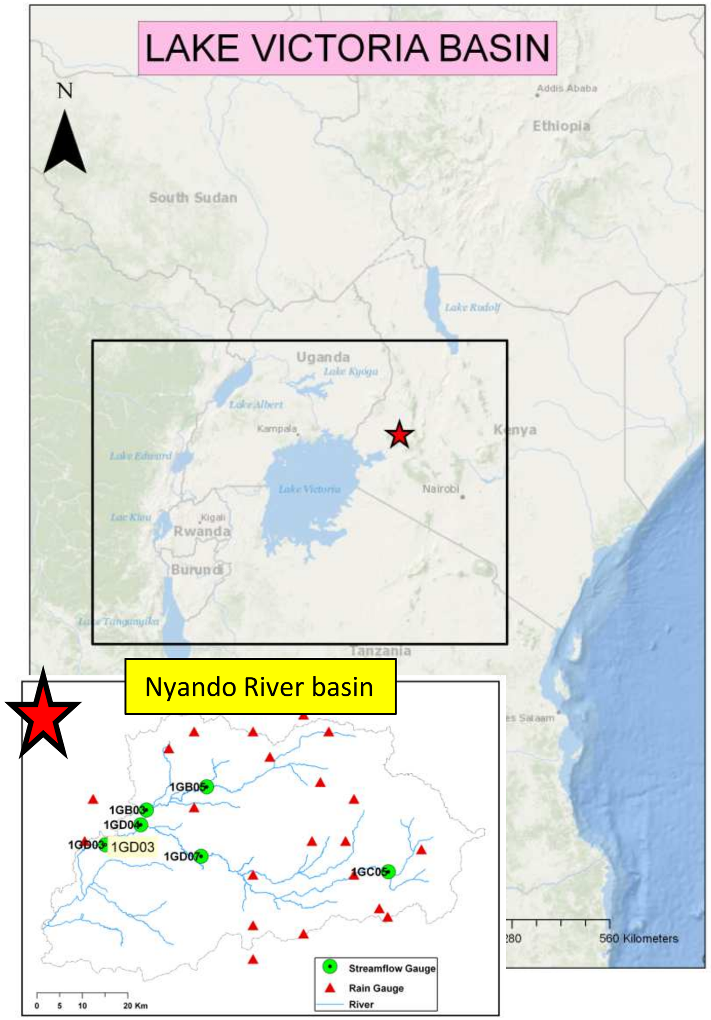


Basin scale | Mesoscale | Regional scale
PAST / PRESENT
FUTURE
Ground-based Observations
Global Weather Forecasts
Reanalysis & Observations
Satellite Data Assimilation
20th Century GCM
Current Floods
Numerical modeling
What is the way forward?
Flood modeling
Downscaled Climate Variables
Select GCMs
Future Floods
Downscaling & Bias correction
Future projections
Flood Forecasting Adaptation
Understanding of Local Circulation Mechanisms
Extreme weather events
Regional and Synoptic Changes in Climate

# A. Multi-scale climate change assessment in the LVB

- To investigate projected changes in rainfall at river basin scale through downscaling of CMIP3 climate projections
- To investigate projected changes in flow regimes in Nyando river basin(within LVB)
- To investigate associated regional climatic changes and associated extreme weather event mechanisms

# A.0. Basin scale climate change




**NYANDO RIVER BASIN**

**Area : 3,500** sqr. Km

**Elevation**: 1000 – 3000 m Asl

**Rainfall** : 800 – 1600 mm/year

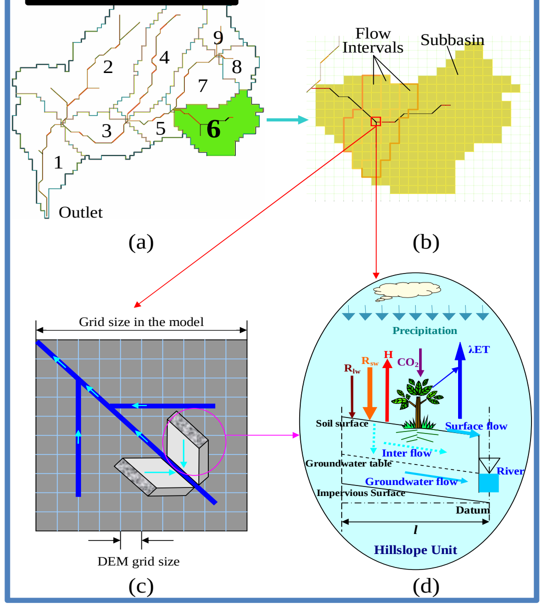
**Population** : ~ 1 Million

**Soil** : Loamy Sand

**Landuse** : Agriculture

**Discharge** : ~ 15 $m^3 s^{-1}$

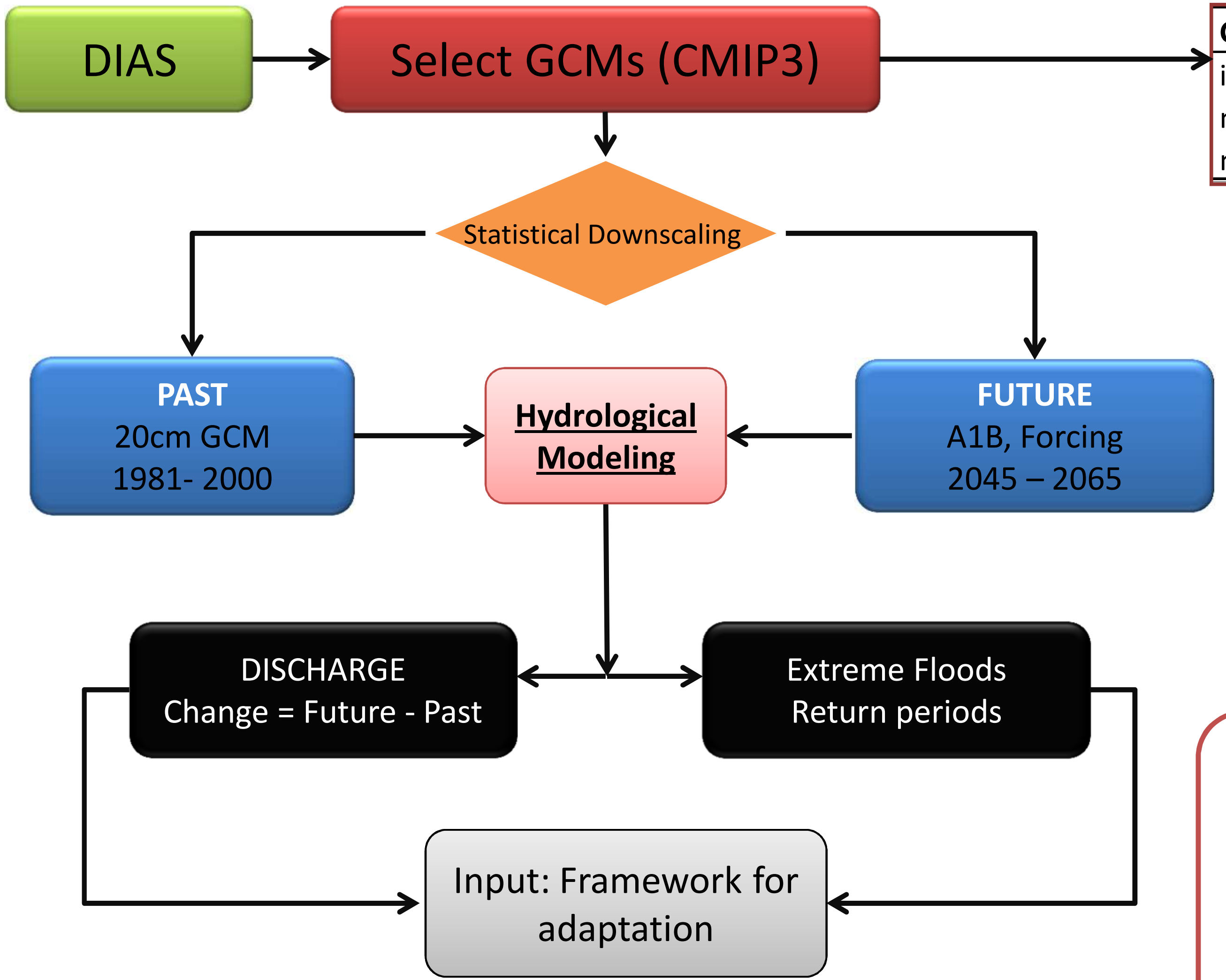
**WEB-DHM**




*(Wang et al., 2009a,2009b)*

- Perennial flood basin
- > 750,000 persons
- High levels of poverty
- Agriculture-based economy

# A.1. Methodology




| GCM | Acronym |
|---|---|
| ingv_echam4 | ingv |
| mpi_echam5 | mpi |
| mri_cgcm2_3_2a | mri |

**Model Selection**

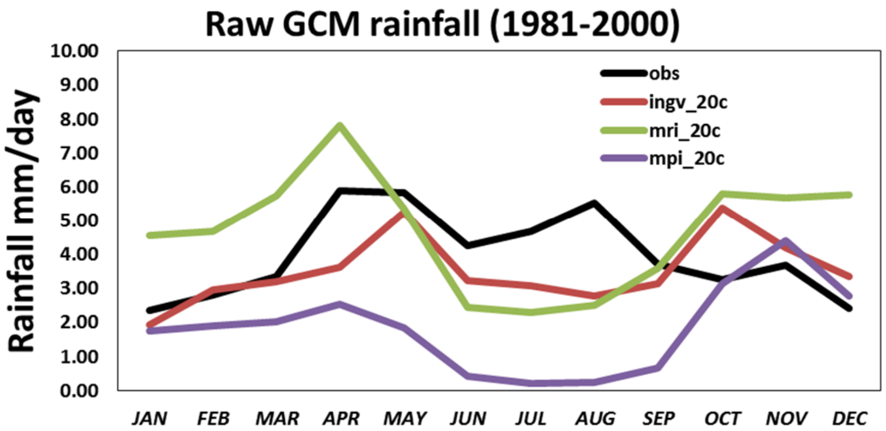
GCM Vs. Reanalysis

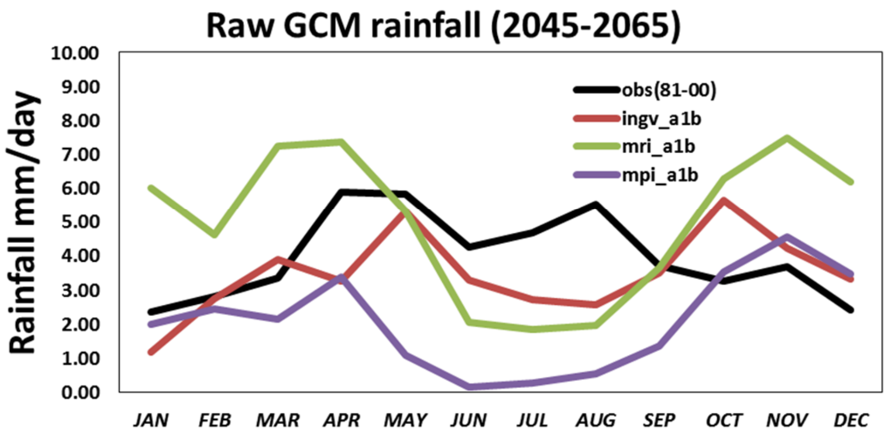
*Statistics*:
- Minimum RMSE
- High spatial correlation with obs.
- Good seasonality
- Minimum bias

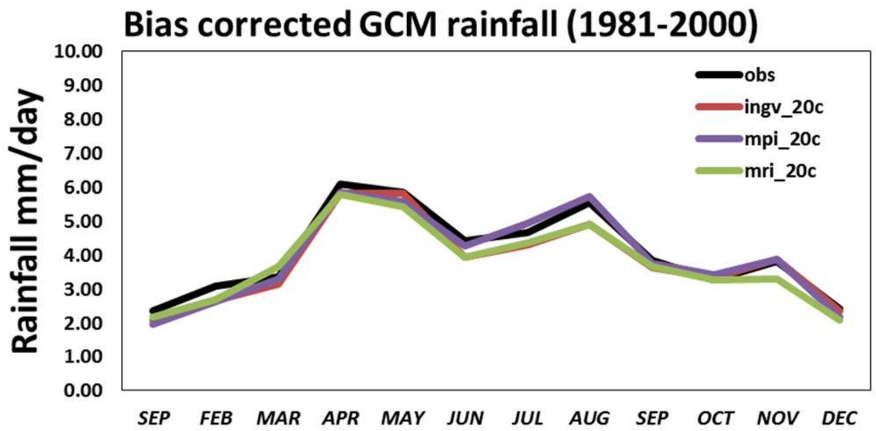
**Downscaling**

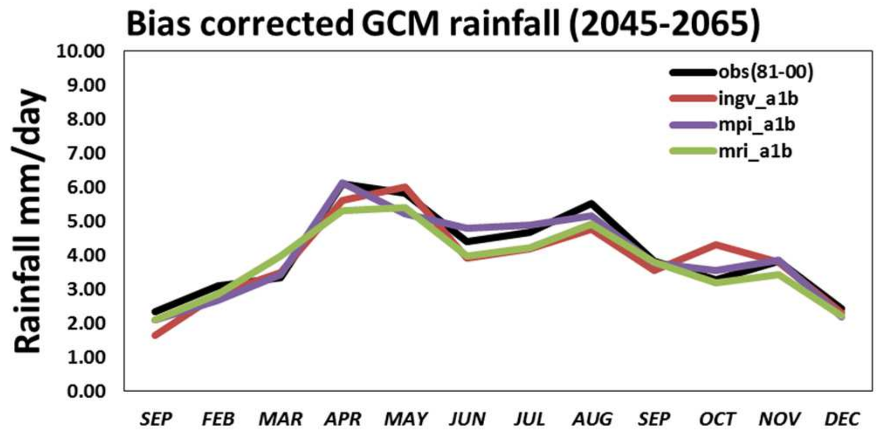
Statistical
- No-rain days : frequency
- Normal Rain : Gamma CDF
- Extreme : Extreme distribution functions

# A.2. Projected changes in rainfall (basin scale)

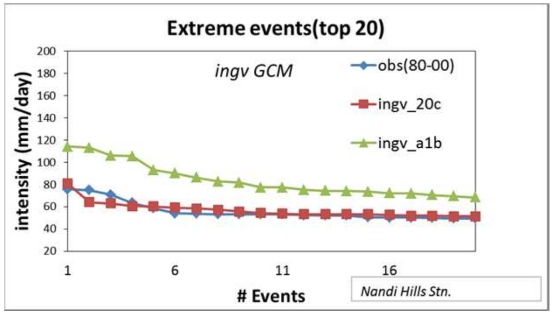


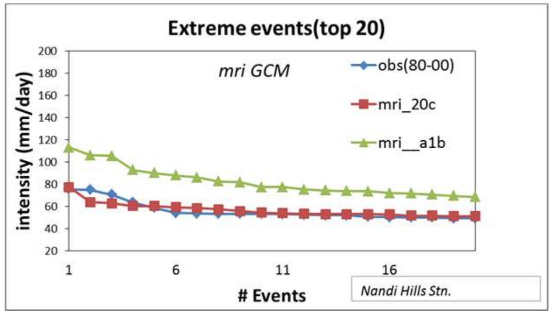



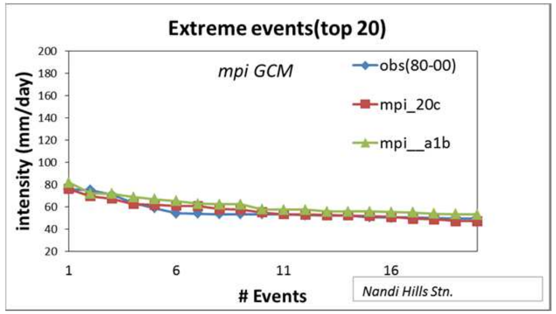



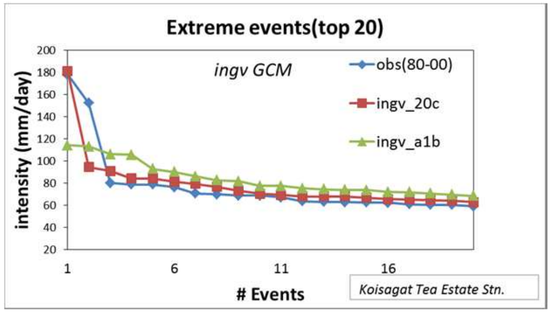



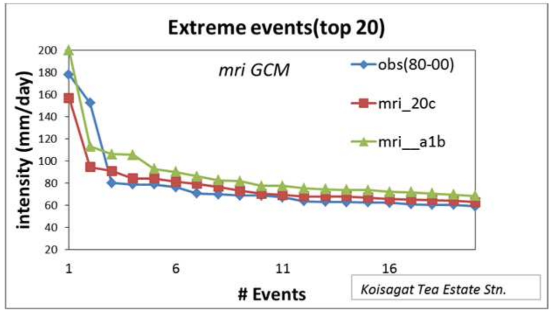
# A.3. Extreme rainfall events

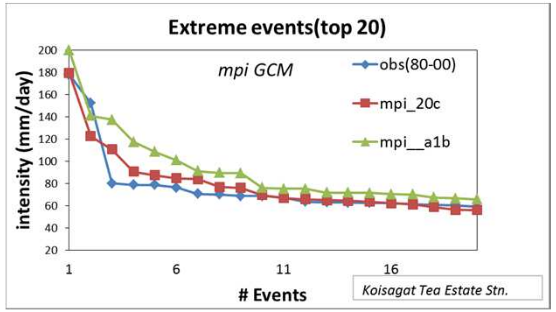


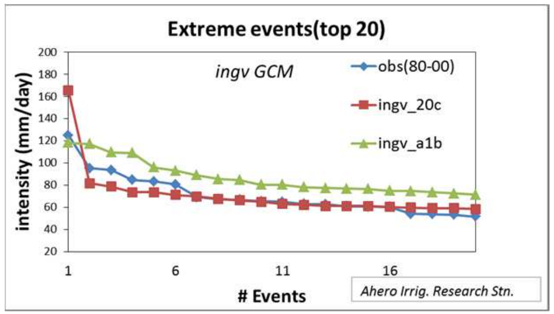



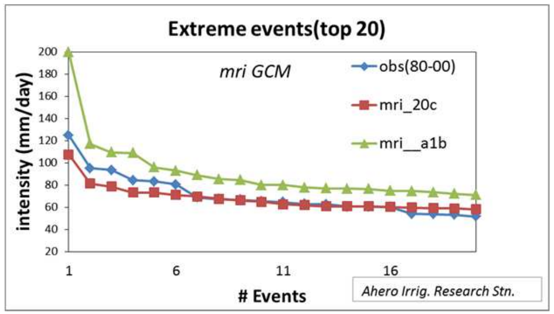



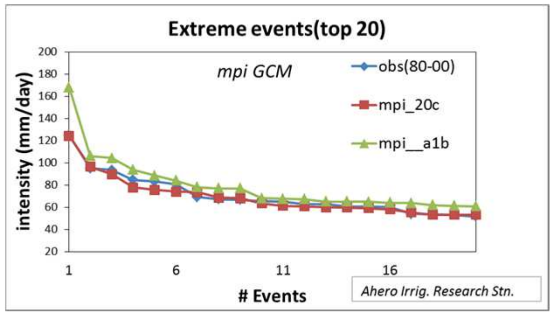



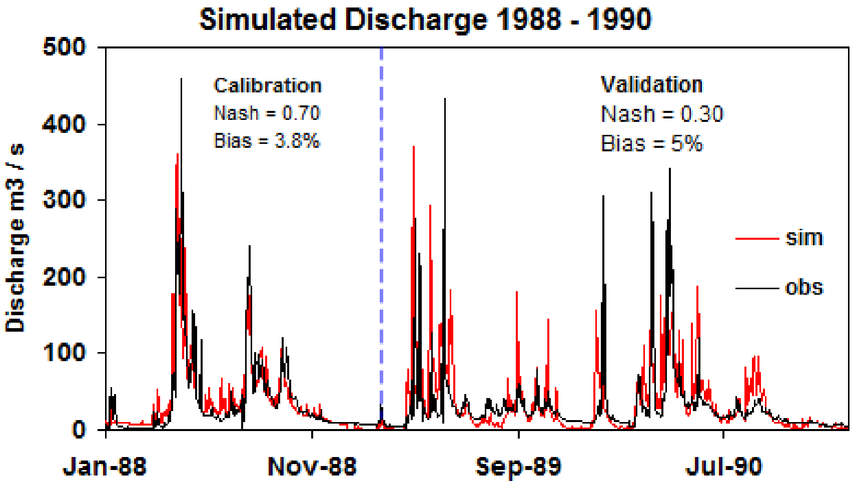



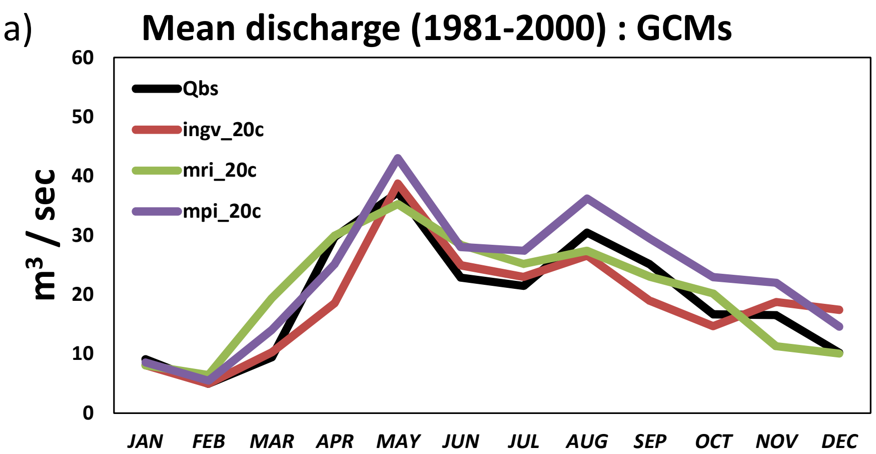



# A.4. Projected changes in flow regimes

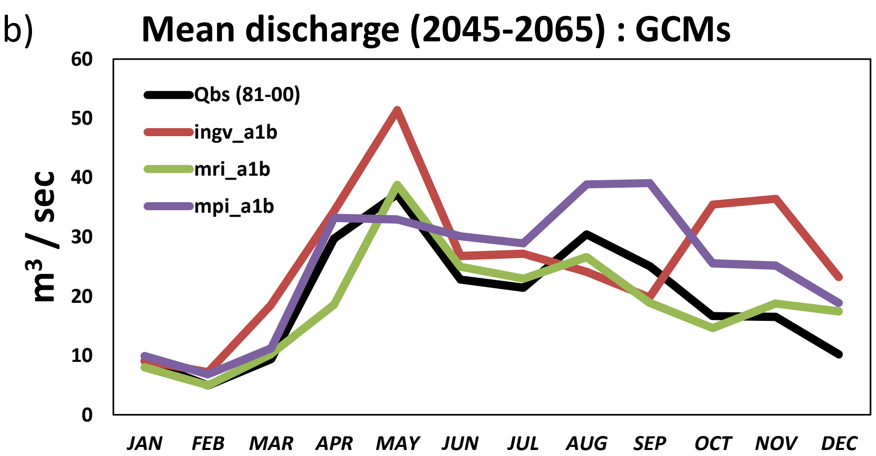



- Increasing trend : all GCM
- OND : largest projected increase
- Higher uncertainty due to inherent model bias in October: models disagree

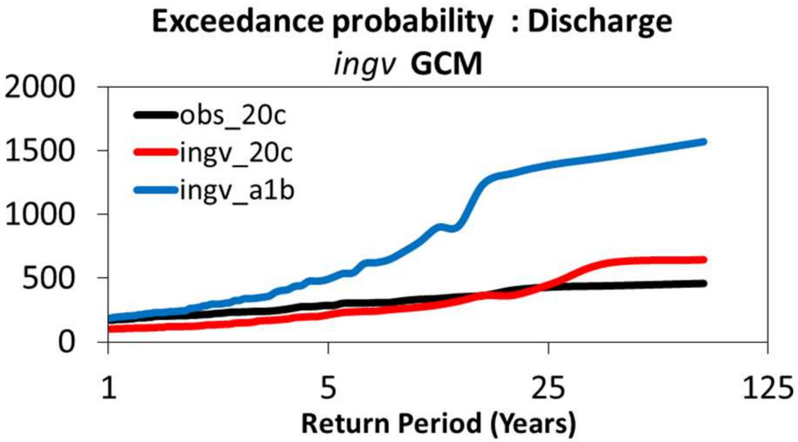
a)

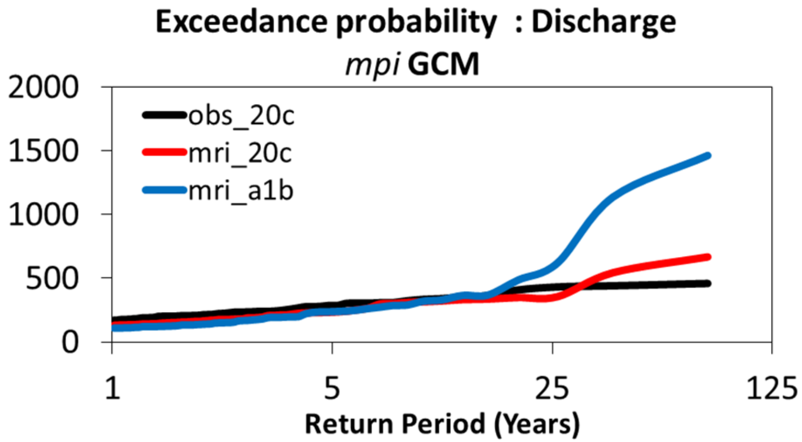


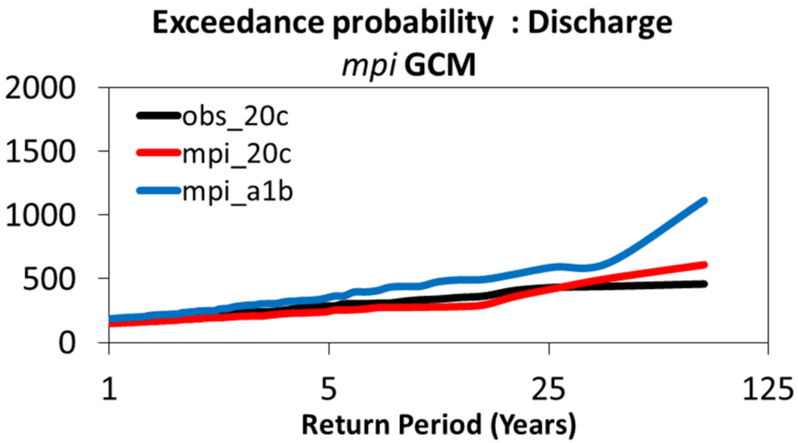

b)



# A.5. Flood extremes under climate change

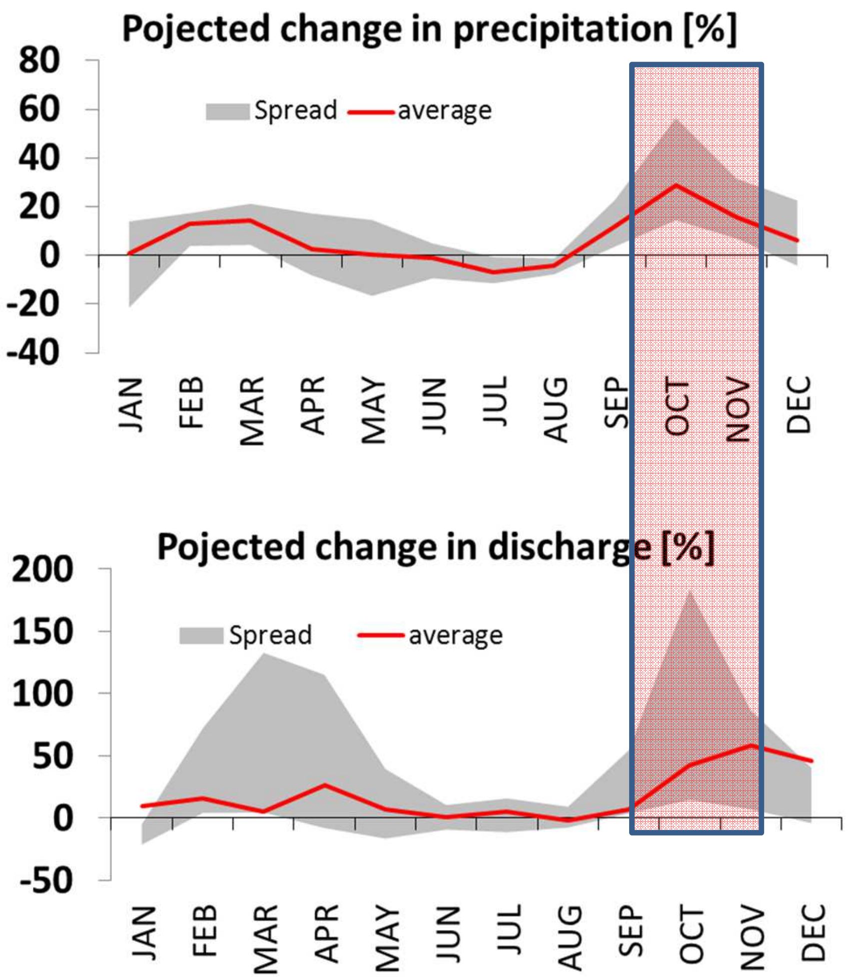


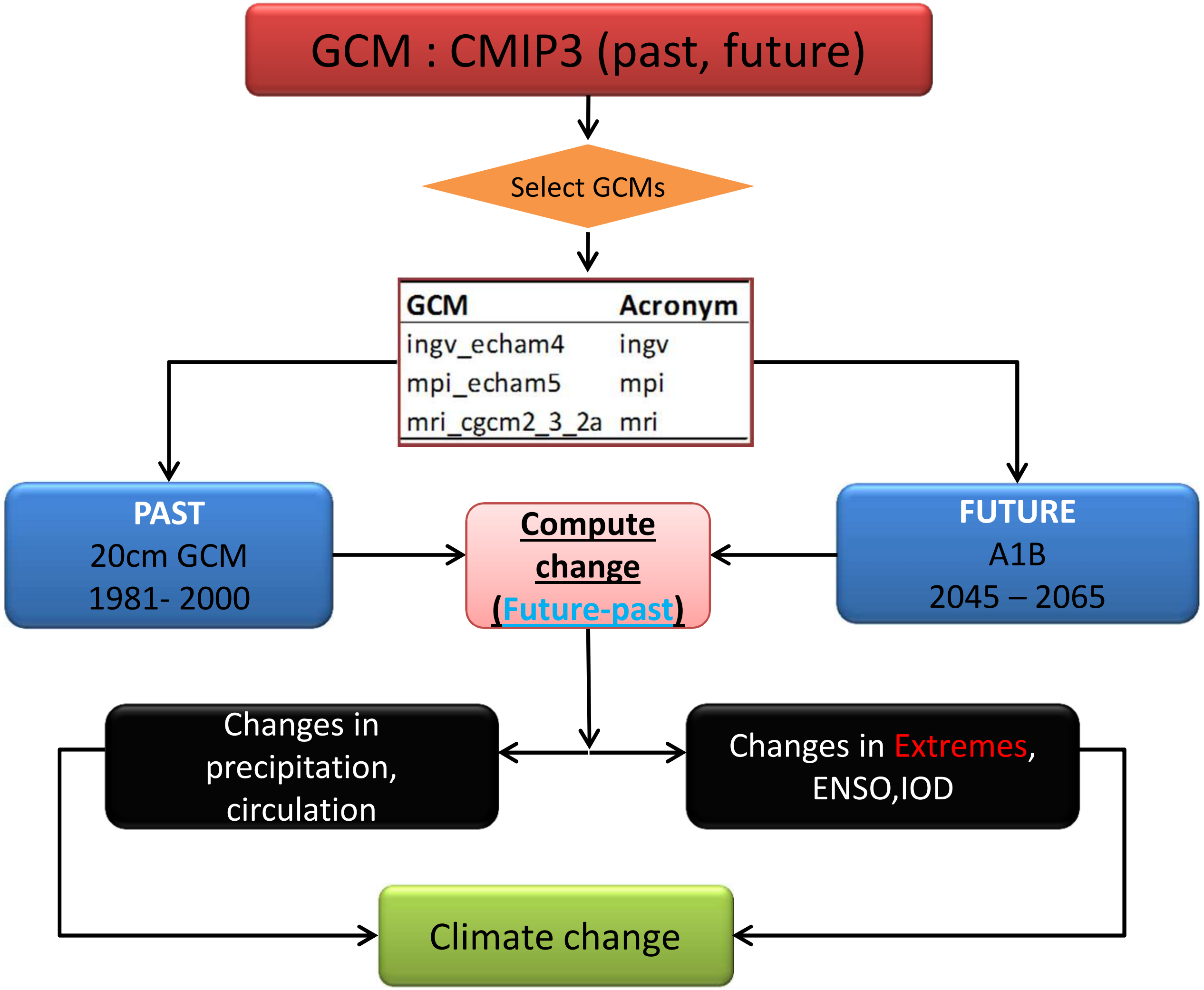

- Models project increase in extremes
- Ingv projects the largest increase
- MPI projects a moderate increase

# A.6. GCM Uncertainty

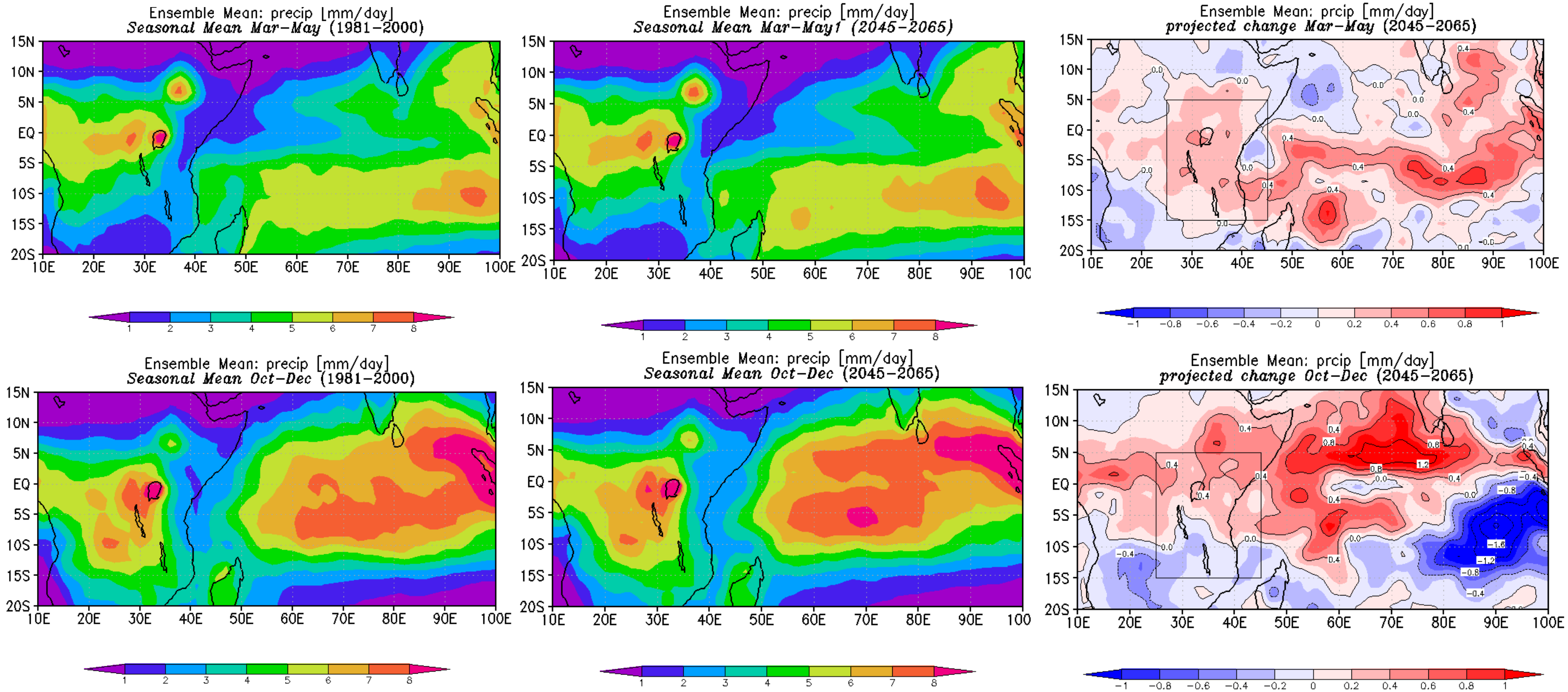



- Consistency in increased rains and floods
- Both seasons MAM and OND likely to flood
- Uncertainty between models highest in OND and MAR-APR

# A.7. Regional climate change

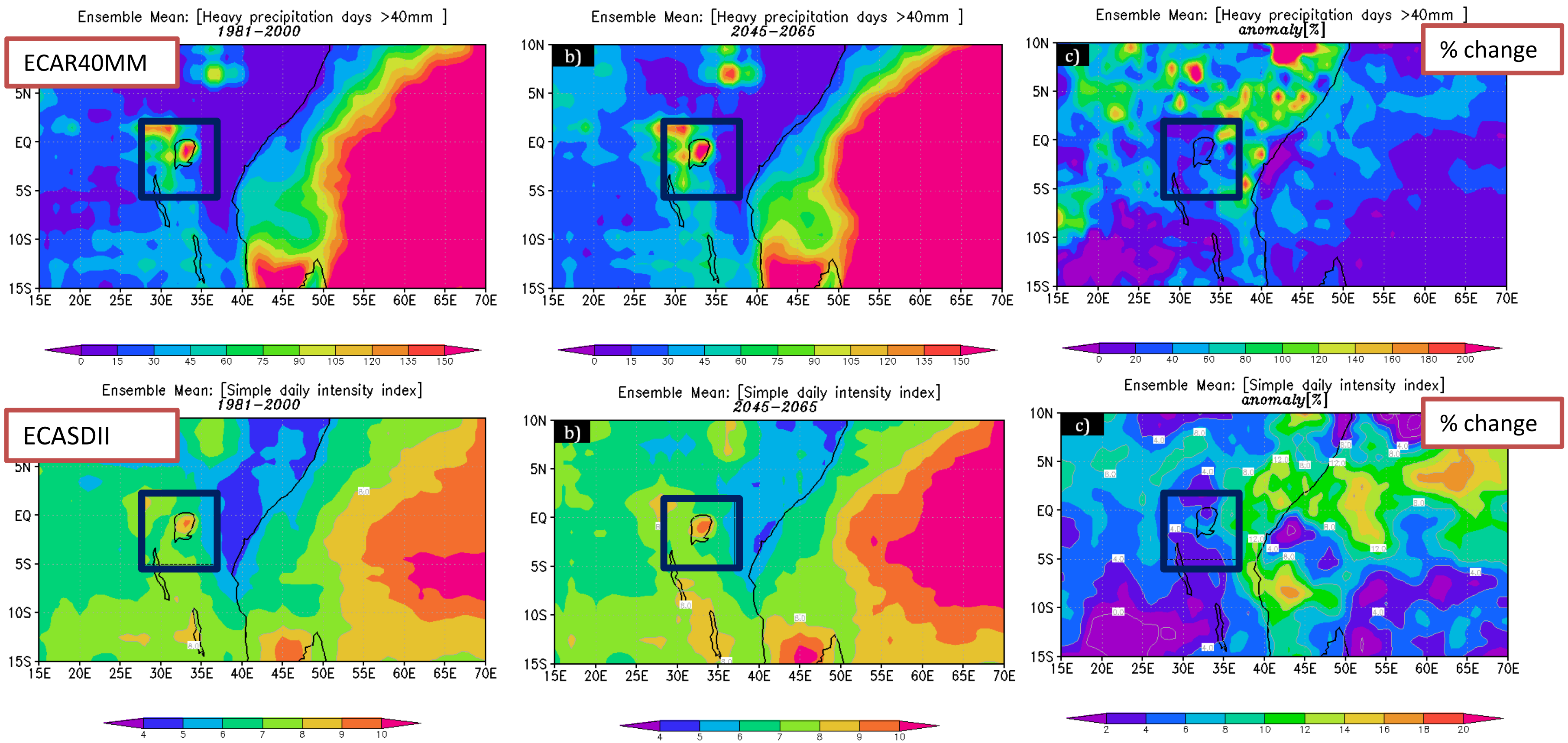


# A.8. Regional changes in rainfall




- **Both seasons projected to experience enhanced rainfall**
- **More pronounced in OND season**

# A.9.Extreme weather indices




- **EXTREMES**: Over 50% increase in rainfall events > 40mm, more pronounced over E. of LVB
- **INTENSITY**: Intensity likely to increase by about 2-15 %

# A.10. Summary

- To investigate projected changes in rainfall and flow regimes at river basin scale through downscaling
  - Models project an increase in rainfall in the basin
  - General trend of increasing rainfall extremes
  - Higher probability of floods in Nyando basin most likely under the SRES A1B scenario
- To investigate projected regional climatic changes using CMIP3 GCMs
  - Increase in rainfall over the LVB, consistent with IPCC AR4
  - NE regions projected to experience more extreme rainfall
  - There's need to investigate characteristics of the extreme events

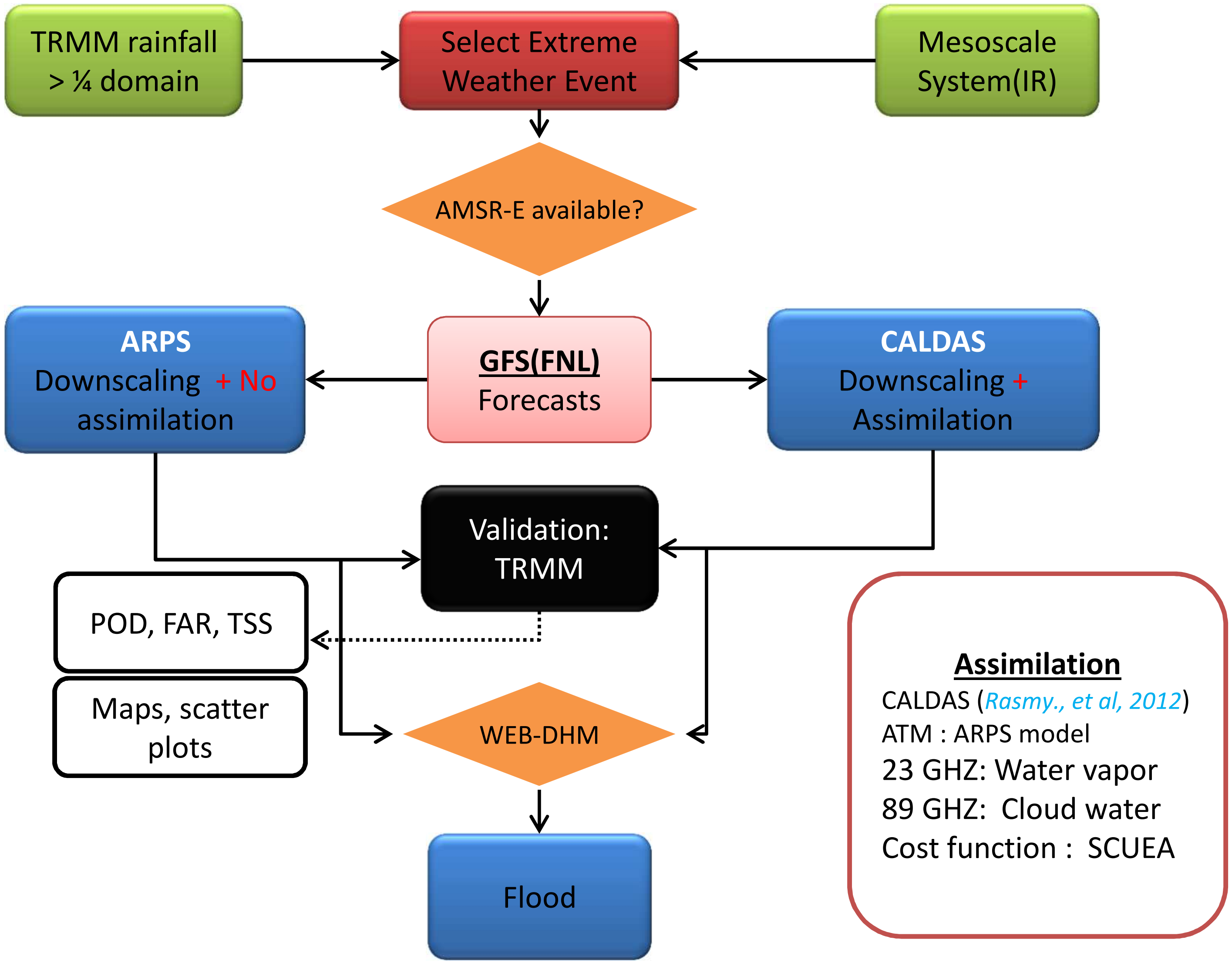
# B. Improving weather forecasting in the LVB. An adaptation option?

- To dynamically downscale global weather forecasts and improve extreme rainfall event prediction in the LVB through satellite data assimilation (AMSR-E)
- To Investigate applicability of downscaled forecasts as forcing for hydrological flood simulation

# B.0. Improved weather prediction as a climate change adaptation strategy!

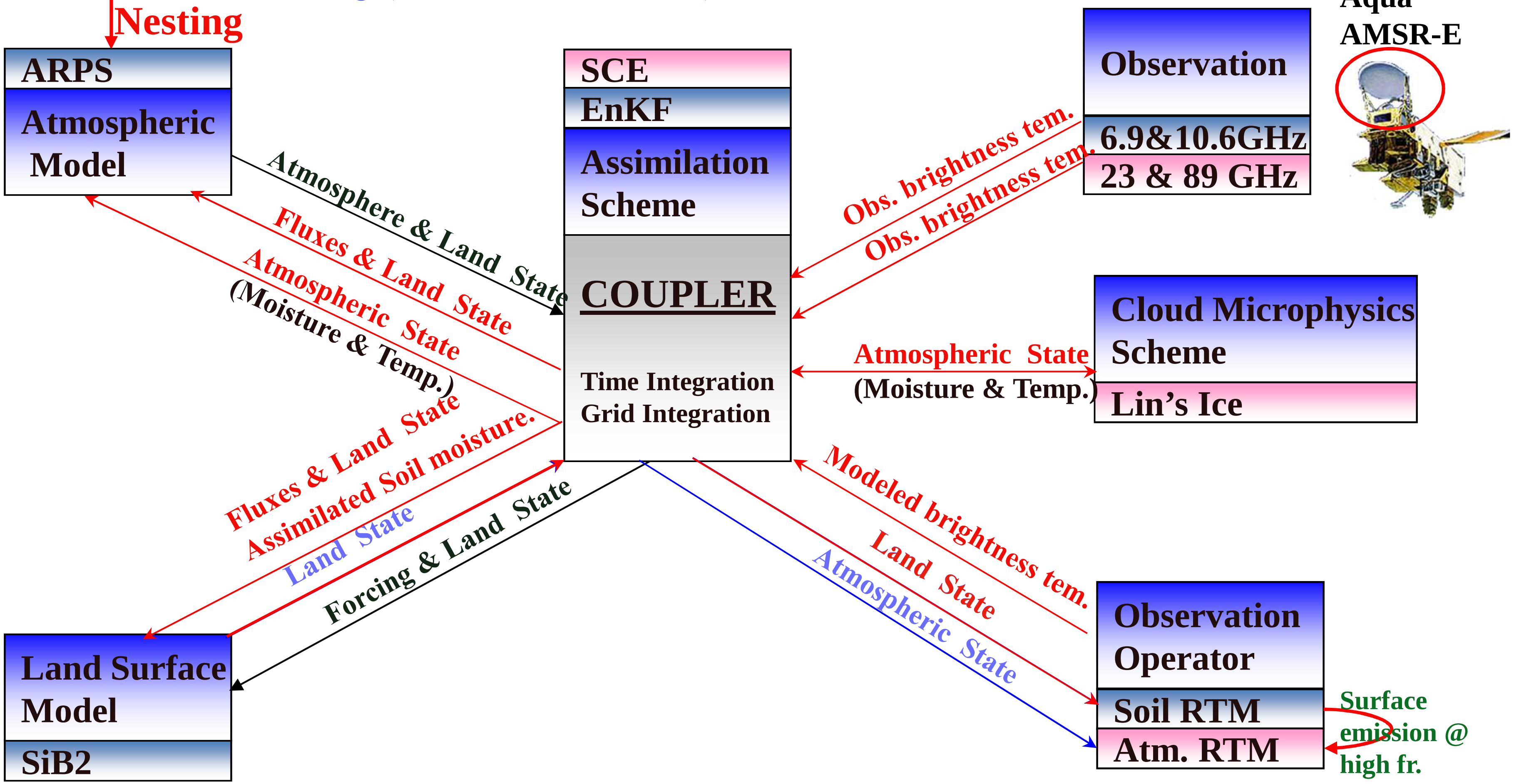
- Improved observation system e.g. radar can lead to better prediction of storm systems→ better timely flash flood forecasts
- improved forecasts can be better integrated into river flood forecasts for real-time solutions
- Improvement of the weather forecasts for use in flood mitigation would offset some of the deleterious effects of such intensification due to global warming
- Seasonal forecasts can be used for dam optimization during dry / very wet years
- Reliable seasonal forecasts can be used in farming decision making processes

# B.1. Methodology



# Coupled Atmosphere and Land Data Assimilation System (CALDAS)

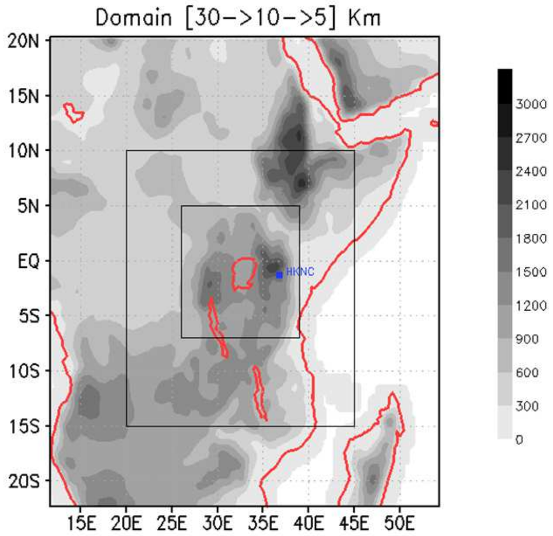
Forcing (radiation & rainfall) → cloud assimilations




(Rasmy., et al, 2012)

**SCE – Shuffled Complex Evolution**

# B.2. Domain and model set up




- **ARPS mesoscale Model**
  - Nested run 30 → 10 → 5km
  - SiB2 Land surface scheme
  - Kain and Fritsch cumulus parameterization outer grids only
  - NCEP FNL → Boundary + initial conditions
- **Assimilation / Prediction**
  - AMSR-E @ 23: 10
  - Prediction run : 00hrs + (12hrs)

**KEY EXPERIMENTS**

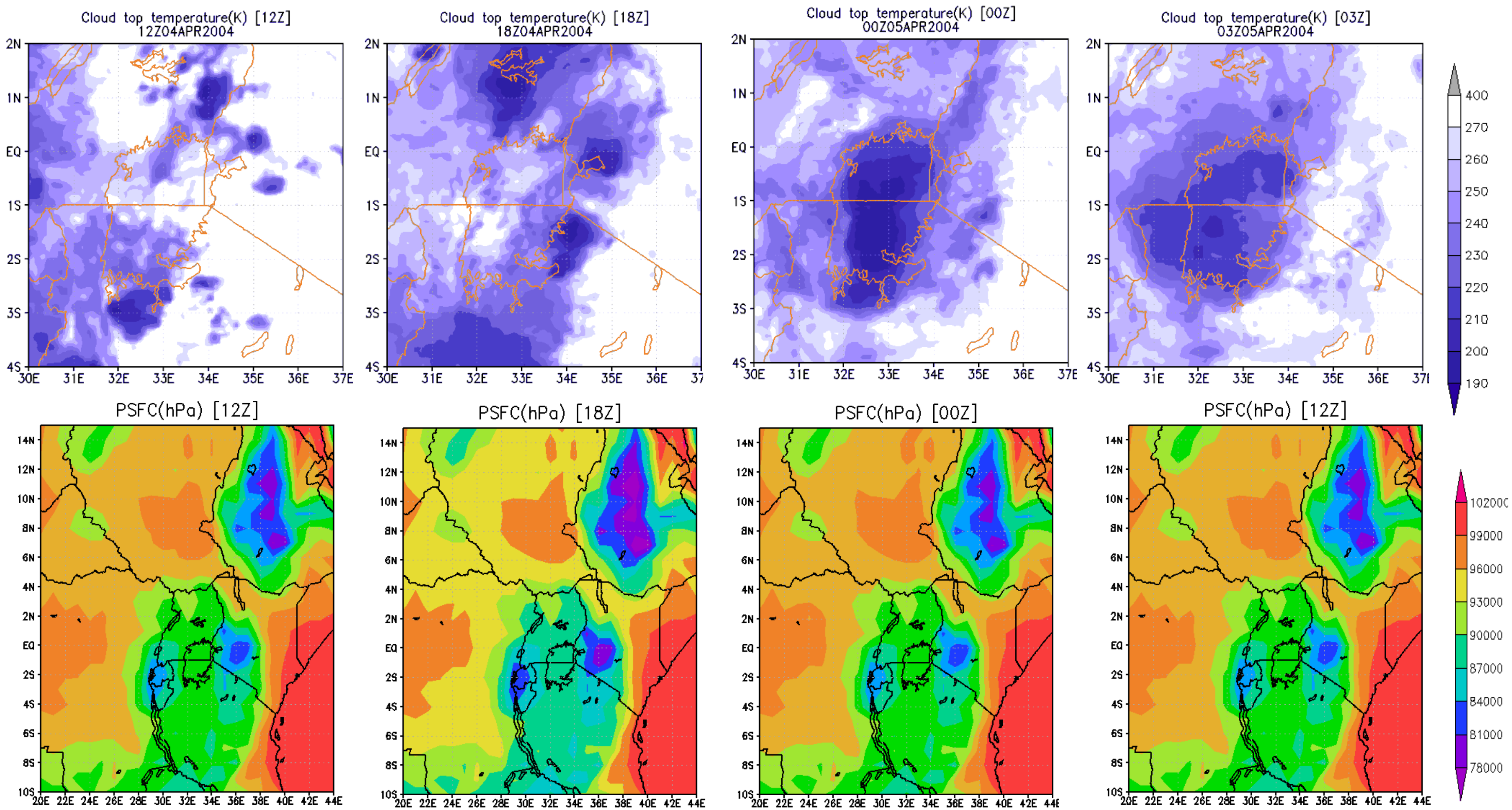
**Date**: **2004.04.04** – AMSR-E available, reasonably extreme event present

**ARPS** : First experiment **without assimilation** (just downscaling)

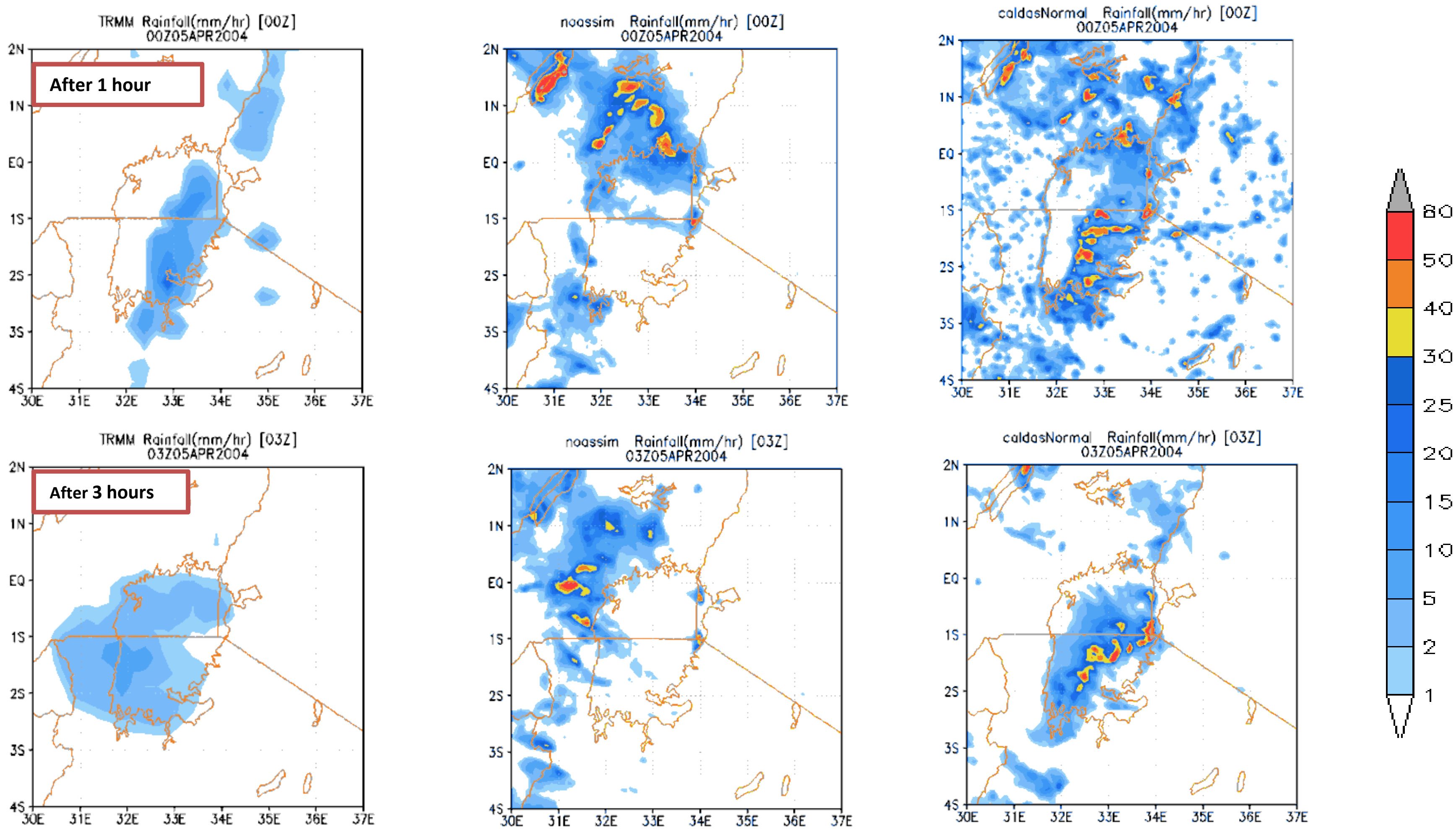
**CALDAS** : Second experiment with assimilation (AMSR-E) + sensitivity experiments

**Validation** : TRMM, 3hourly, + Globally merged IR (cloud top)

# B.3. Numerical Experiment (04.04.2004)

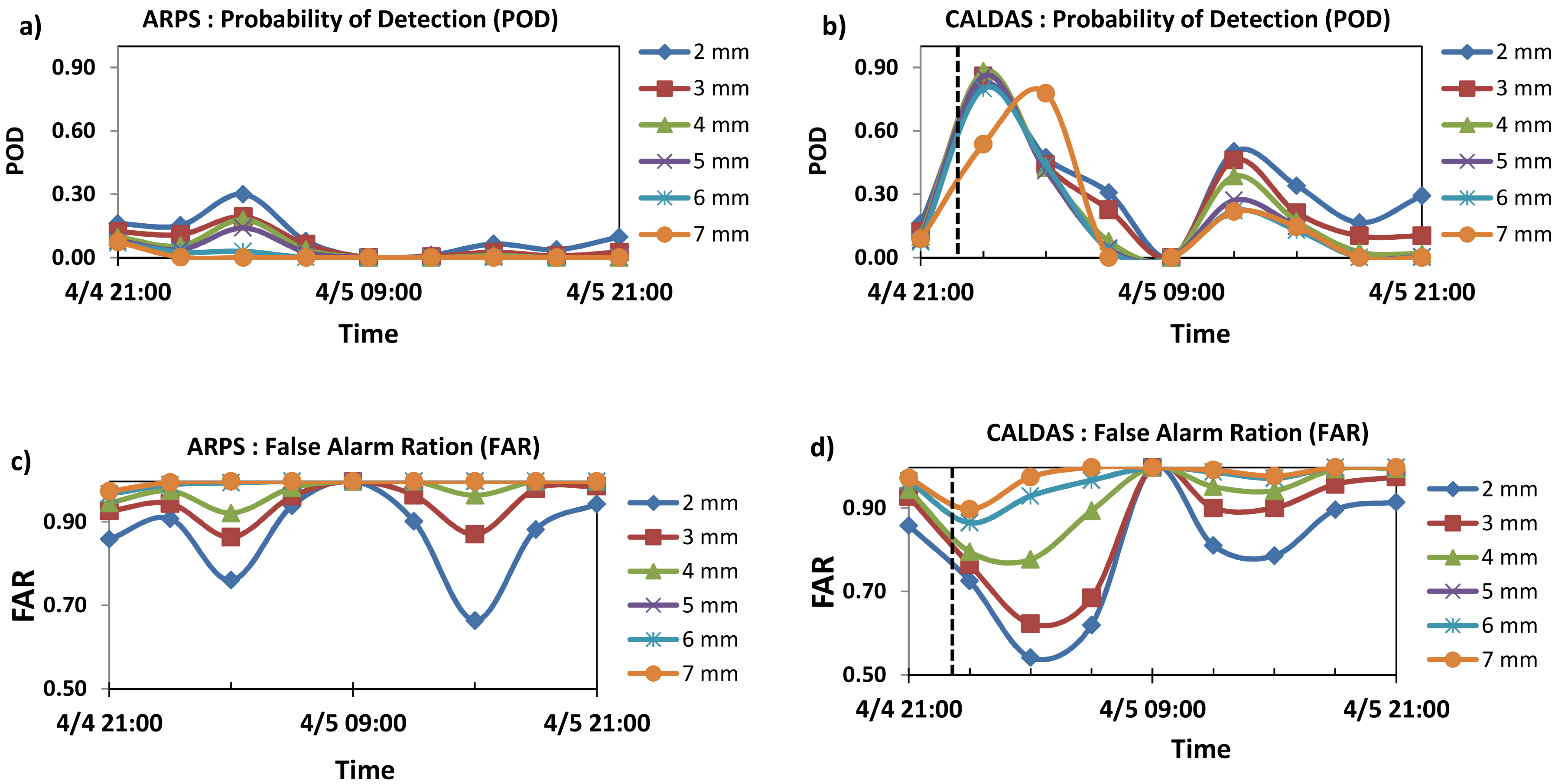


| TRMM (Obs.) | No assimilation | Assimilation **(qv,qc,qs,qi)** |
|---|---|---|



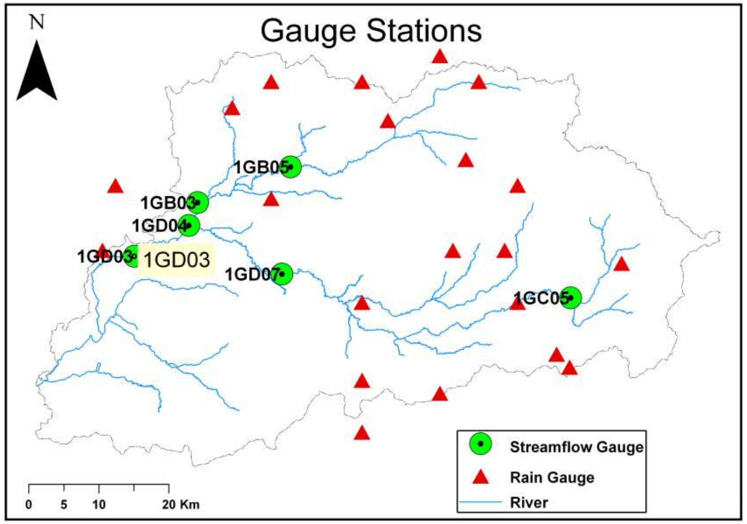

| TRMM (Obs.) | No assimilation | Assimilation |
|---|---|---|
| **TRMM (Obs.)** | • No assimilation → poor simulation of the event<br>• Simulates the event→ wrong place<br>• Persistent overestimation NW ~(32E,0N) | • Assimilation improves fore cast<br>• Spatial pattern similar to observed(TRMM)<br>• Quantitatively: still a way to go |

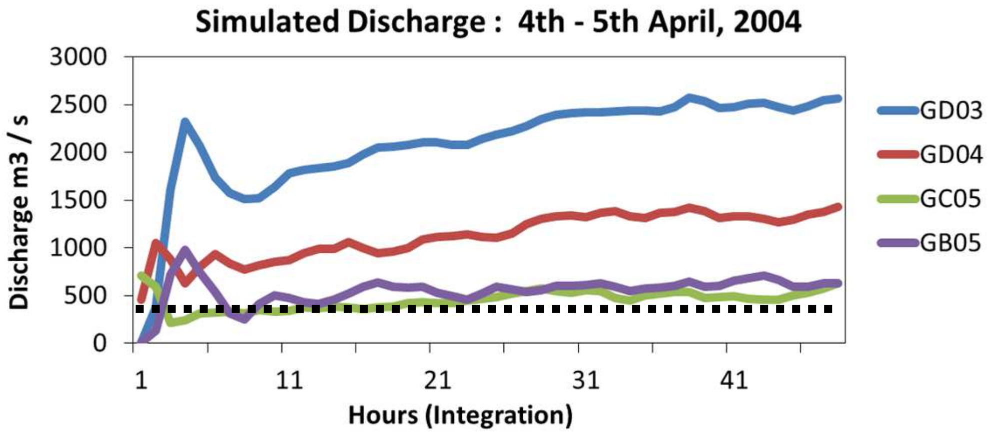
# B.4. Assessment of accuracy




The black line on **b)** and **d)** shows the assimilation time (23:10 UTC 4th April, 2004)

# B.5. CALDAS-based flood forecast




*Historical flood max.*

- Simulated discharge far and above historical floods
- Too much rainfall from CALDAS
  - There's a need to improve the forecast quantitatively = classical NWP problem
  - Need to consider ensemble forecasting

# B.6. Summary

- To dynamically downscale global weather forecasts and improve extreme rainfall event prediction in the LVB through data assimilation
  - Assimilation of AMSR-E improves QPF forecast
  - QPF reasonable for early warning, but still far from operational use
- To Investigate applicability of downscaled forecasts as forcing for hydrological flood simulation
  - Reasonable performance, but with overestimation
  - Needed: quantitative improvement in weather forecasts

# Discussion

- Multi-scale climate change reveals a projected increase in extreme weather
- Likely increase in floods at basin scale
- NWP with assimilation produces a reasonable precipitation forecast
- Qualitatively-:promising, quantitatively-:need more work
- Improved weather forecasting useful for adaptation to climate change

# Challenges

- **Data**
  - Availability, short-term and access restrictions
  - Quality and temporal resolutions (only daily)
  - Sparse and missing values
  - Storage limitation (Satellite, Climate projections)
- **Technical**
  - Limited computing power and skill
  - Limited manpower
  - Independent initiatives
- **Organizational**
  - Funding
  - Coordination

# Proposals (1)

## Space Agencies (NASA,JAXA,NASRDA,ESA… )

- Develop integrated datasets for the LVB
- Ease of access to satellite products

## Numerical Weather prediction centers (JMA,ECMWF, NOAA…)

- Provide short and mid-term weather forecasts in real-time
- Provide long term reanalysis with finer resolution

## Climate centers (JMA,ECMWF, NCEP…)

- Provide climate projections with all variables → dynamic downscaling
- Numerical modelling support

# Proposals (2)

**Research community(CORDEX,ICPAC, Universities…)**

- Coordinated research efforts e.g. support for dynamic downscaling of climate projections
- Multi-scale integrated studies

**ODA donors (JICA, UN,GEO, Governments…)**

- Provide support for capacity-building e.g. training courses
- Provide support for long term monitoring systems
- Provide support for acquisition and installation of Real-time systems (prototypes)

# Thank you.