Exploring the links between hydrological forecast skill and multiple flood hazard drivers in southern Africa

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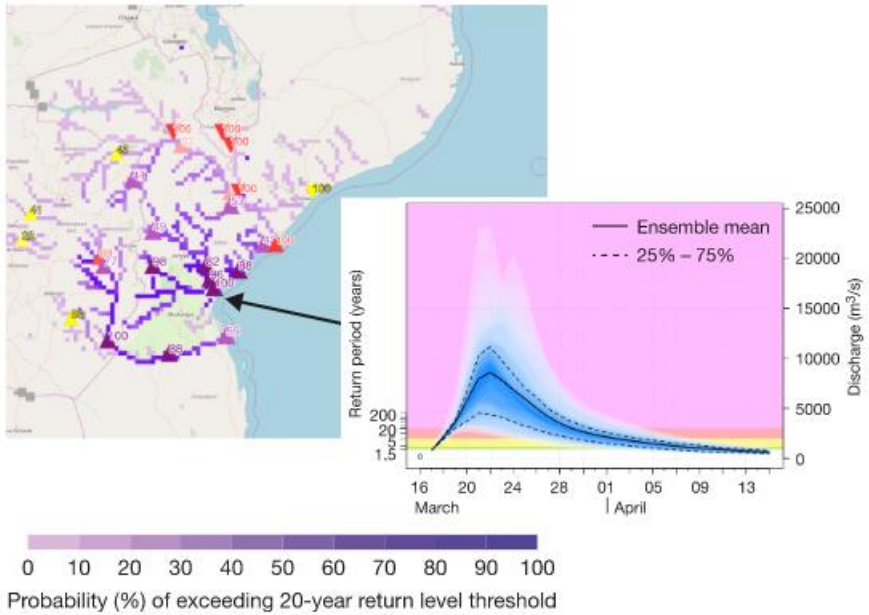
Research Questions

- Is there **any strong link between flood forecast skill and meteorological drivers** of flooding, such as Tropical Cyclones?
- **Is forecast skill sufficient to provide actionable information** for humanitarian agencies, e.g. support Forecast-based Financing (FbF) protocols (i.e. allocating humanitarian cash ahead of extreme events)?
- **How extreme are the characteristics of riverine floods from TCs** in Mozambique compared to other types of drivers? Are flood characteristics, such as flood timing and duration, more predictable for TCs-driven events?



Flood forecasts issued on 16 March, ahead of TC Idai's floods, from Copernicus Emergency Management Service-GloFAS (http://www.globalfloods.eu/)

International response teams deploy helicopters and WFP trucks at Beira Airport on 20 March 2019, to supply products for humanitarian support *(Jorge Rungo, FATHUM, Mozambique)*

People gather on the roof of a house submerged by floods in Buzi on March 18, 2019 *(INGC and Jorge Rungo, FATHUM, Mozambique)*

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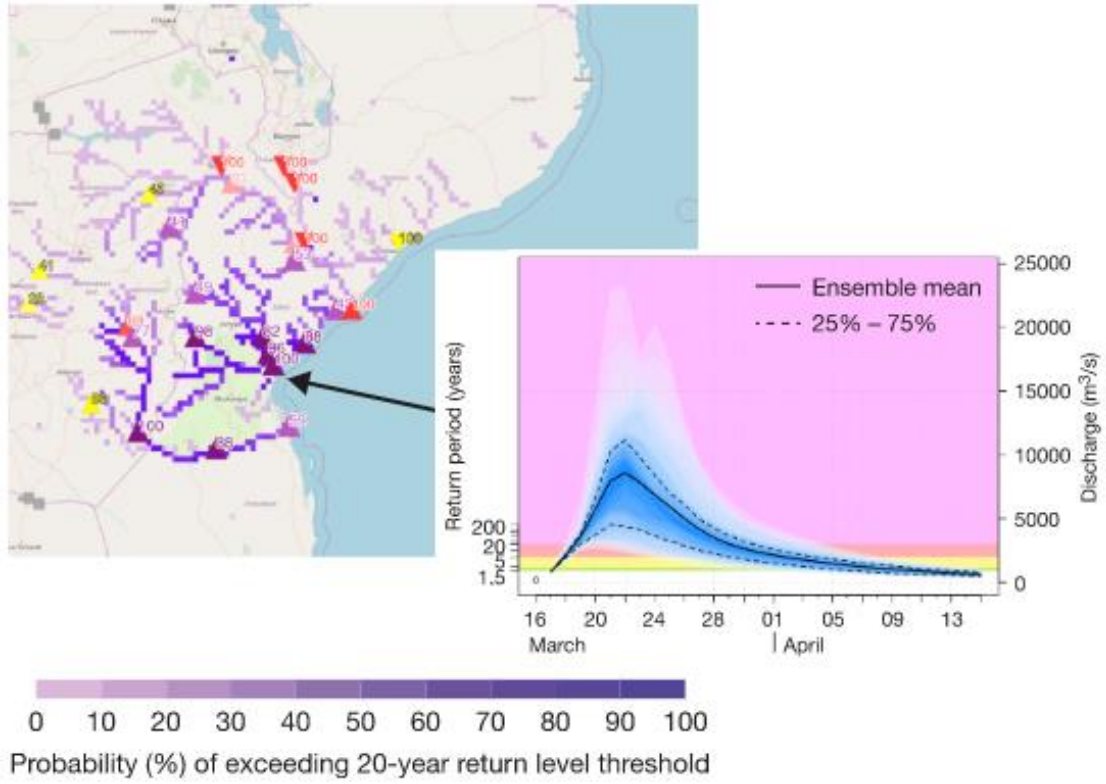
Forecast data and model: the Global Flood Awareness System (GloFAS)

- **Copernicus Emergency Management Service (CEMS) delivered by European Commission and ECMWF**
- **Real-time probabilistic flood warnings**
- **Transboundary operational system**
- **Open access: http://www.globalfloods.eu**
- **GloFAS inputs:** hydro-meteorological initial conditions & meteorological forecasts from the ECMWF ensemble NWP (IFS, 51 members)
- GloFAS couples the **HTESSEL** land-surface model with the **LISFLOOD** hydrological and channel routing model
- **Data used:**
  - **GloFAS extended-range reforecasts with 30-day lead time** (Alfieri et al. 2013) over the **period 1997-2019**
  - **GloFAS reanalysis** (w/ ECMWF reanalysis as inputs, i.e. ERA-I/Land and ERA5; Balsamo et al. 2015; Harrigan et al. 2020) over the **period 1979-2019**



Flood forecasts issued on 16 March 2019, ahead of Idai's floods, from GloFAS *(Magnusson et al. 2019)*

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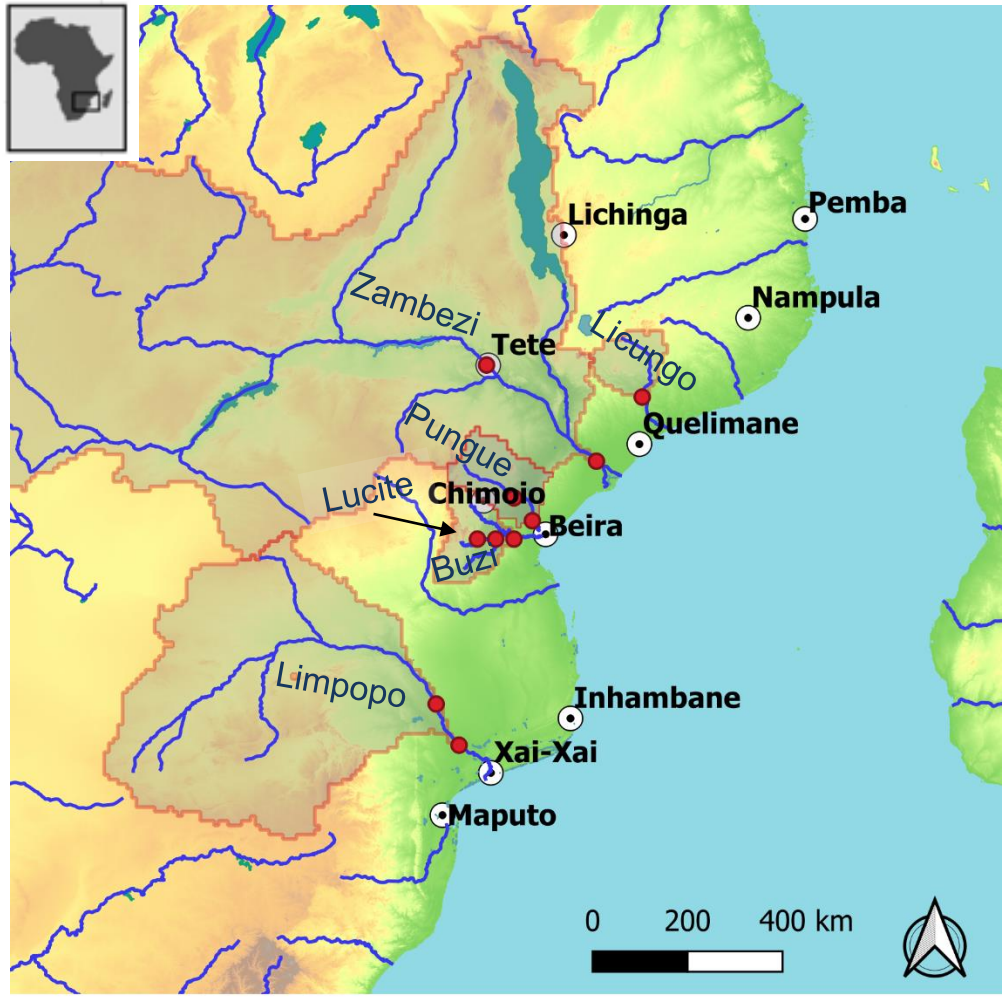
Case studies and observations in Mozambique



Mean elevation (m) *

- 0
- 400
- 825
- 1250
- 1700
- 2150
- 2600
- 3050
- 3416

River gaging station

River basin boundaries (elevation color shaded *)

- **6 basins selected based on their interest as FbF pilots** by Mozambique Red Cross (CVM):
  - Zambezi (area > 1.35M km^2)
  - Limpopo (catchment area > 330k km^2)
  - Pungwe (area ~30k km^2)
  - Buzi (area ~ 26k km^2)
  - Licungo (area ~ 20k km^2)
  - Lucite, Buzi tributary (area ~4.8k km^2)
- **River flow observations** available at 10 points across these 6 major basins of Mozambique (source: DNGRH, Mozambique): daily **over ~1973-2018**
- **Stratification of flood events** based on TC- and non-TC-driven events, around 50% each
- Over the period 1948-2008, landfalling tropical systems (cyclones, depressions, storms and lows) from the southwest Indian Ocean contributed to *"about 50% of widespread heavy rainfall events" (Malherbe et al. 2012)*

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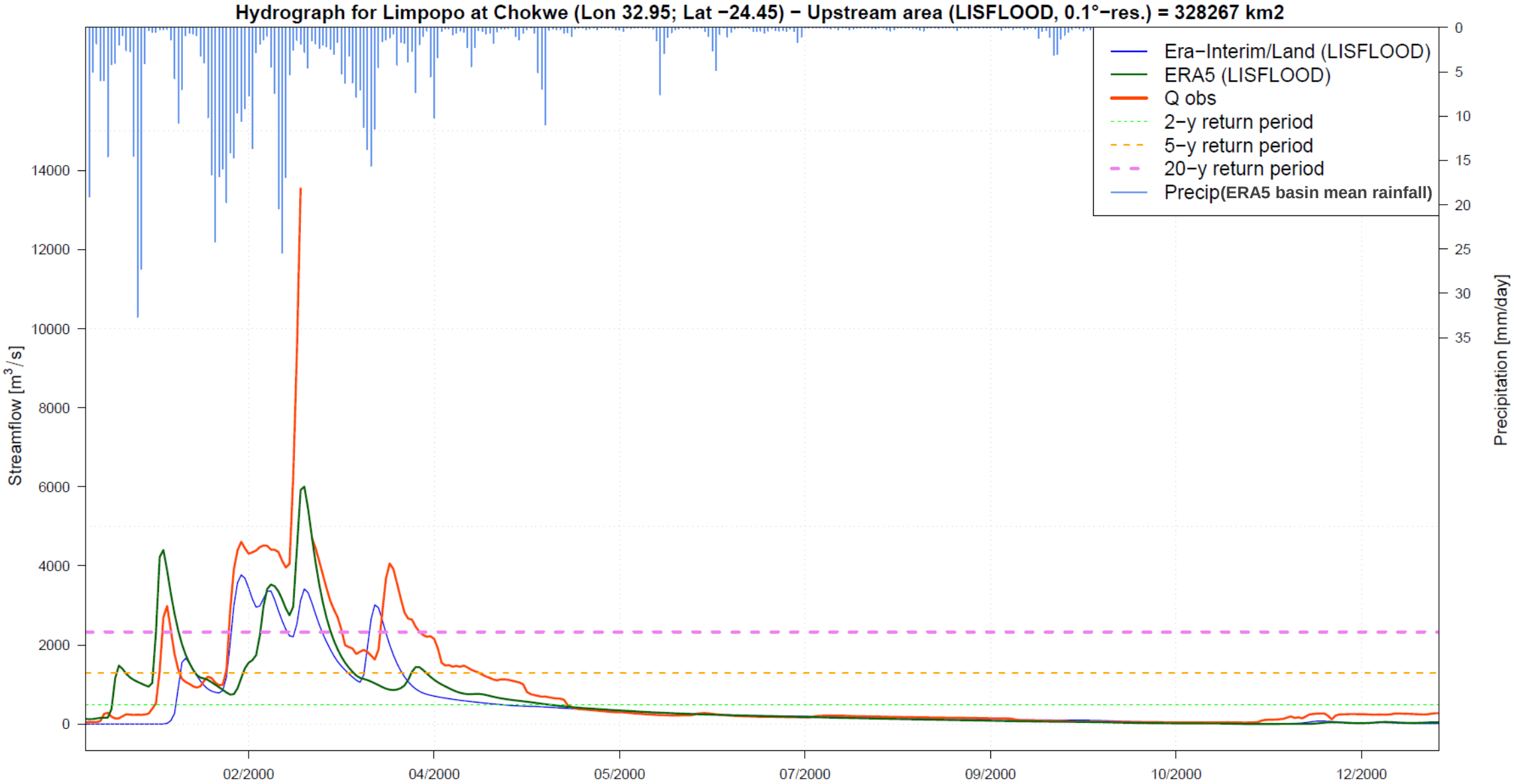
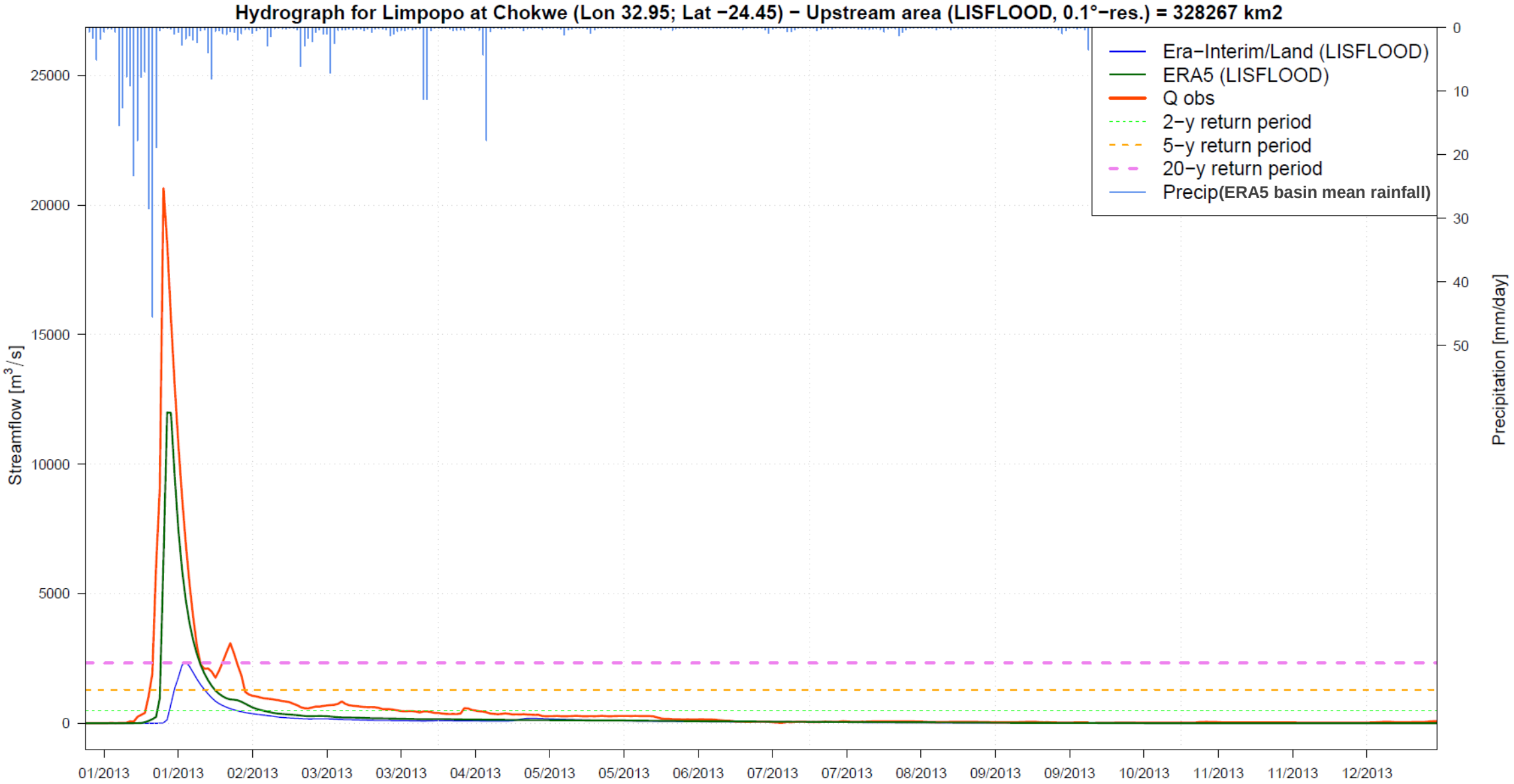
Example of TC-driven event: 2000 flood in the Limpopo (TC Eline)

EXAMPLE 1/2: TROPICAL CYCLONE-DRIVEN FLOODS



Example of non-TC-driven event : 2013 flood in the Limpopo (heavy rainfall)

EXAMPLE 2/2: NON-TC-DRIVEN FLOODS



Perspectives: ongoing work and open questions

- **Calculation of user-relevant skill metrics, e.g. False Alarm Ratios and ROC curves** discriminating between TC- and non-TC-driven flood events…
  - What are the skilful lead times in each basin?
  - Are there differences in skill between the samples of TC- and non-TC-driven events?
  - Are flood characteristics, such as flood timing and duration, more predictable for TC-driven events?
  - How forecasts of flood timing compare with a reference climatology (Ficchi and Stephens, 2019)?

- **Non-TC-driven floods in Mozambique can be as devastating and extreme in magnitude as TC-driven** (e.g. 2013 vs. 2000 floods in the Limpopo basin) → are there differences in other flood characteristics?

- **Constant dialogue and effective communication with humanitarians and DMs**, to exchange on the relevant information for action, and build trust in the forecasts when/where possible
- Reflect on the **many challenges of real-time flood forecasting and forecast evaluation for FbF & humanitarian action**, e.g. tailoring information based on users needs and actions, knowing what users want and who they are (e.g. Coughlan de Perez et al. 2016; Emerton et al. 2020, under review)

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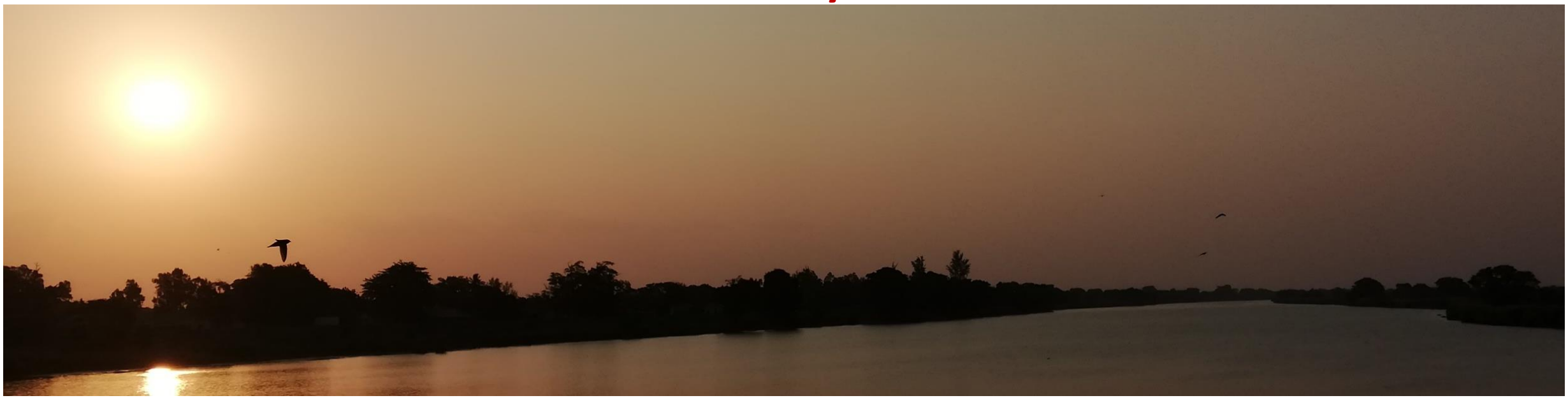
Any questions? This is still ongoing work, any comments or remarks on concepts and design are very welcome!

Thank you!



Limpopo River at Macarretane Dam, Mozambique, 16 September 2019 *(Photo: Andrea Ficchì)*

Dr Andrea Ficchì, Prof Hannah Cloke, Ervin Zsoter, Prof Christel Prudhomme, and Dr Elisabeth Stephens

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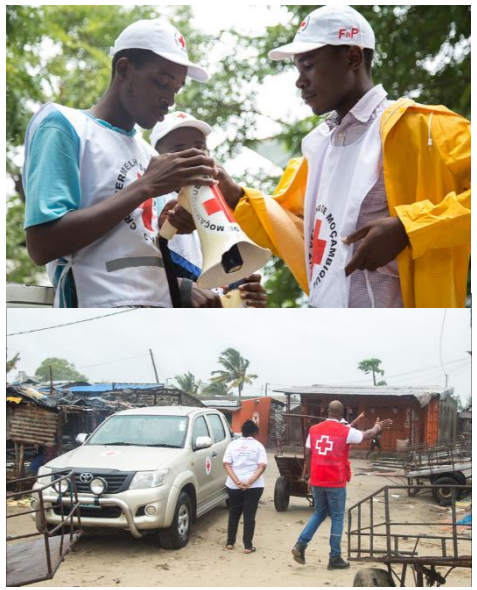
Tropical Cyclones and Floods

- **Tropical Cyclones (TCs)** making landfall in southern Africa often lead to devastating floods
- **In 2019 TCs Idai and Kenneth** brought extreme winds and severe flooding, killing more than 1300 people and affecting over 3M people across Mozambique, Madagascar, Malawi and Zimbabwe
- Flooding from TCs include **riverine floods,** flash floods from excess rainfall and storm surge that can combine with tidal waves
- **International aid agencies** contribute and complement efforts from local governments and agencies to prepare and respond to such natural catastrophes

Satellite image of cyclone Idai on March 11, 2019 over the Mozambique Channel (*NASA VIIRS, Suomi NPP*)

On March 14, 2019, an FbF activation in Mozambique supported CVM (Moz. Red Cross). Aid workers and volunteers disseminated warnings and provided emergency relief items to vulnerable population (Photo credits: IFRC, CVM)



- Appropriate and effective humanitarian action before a disaster can be supported by **Forecast-based Financing (FbF)** allocating humanitarian cash ahead of extreme events
- FbF is pioneered by the **IFRC & Red Cross/Crescent Climate Centre** and is used also in case of TCs and floods, with Early-Action Protocols
- For effective FbF, it's important to **understand forecast skill** and to **stratify skill based on meteorological drivers**, e.g. TC-driven floods

Climate Centre

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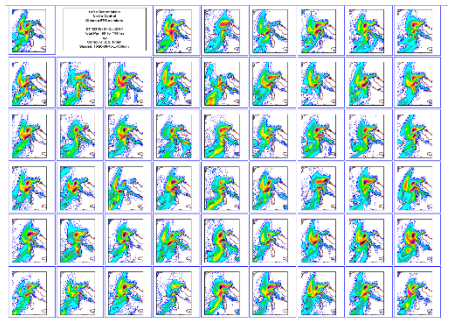
GloFAS: how it works

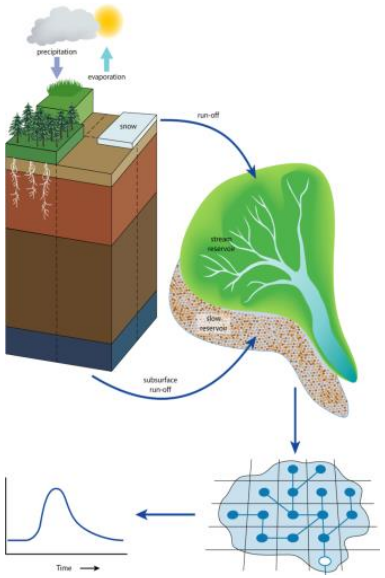
Input observations (satellite & in-situ)

Hydro-met. initial conditions (e.g.ERA5, ERA-Interim)

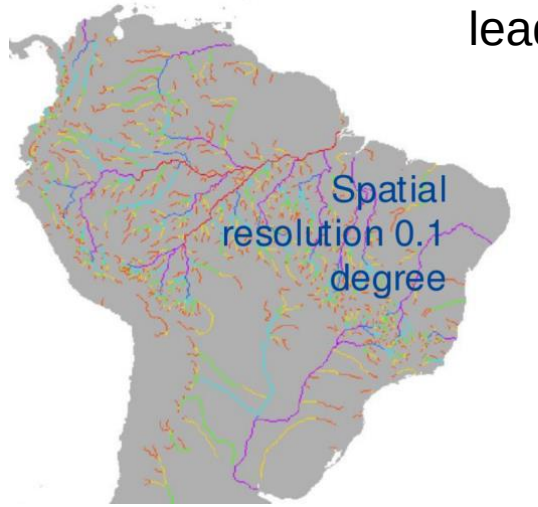
Meteorological forecasts



Hydrological model



Outputs



Post-processing

probability of exceedance at different lead time, graphs, maps

Global ensemble forecasts (ECMWF NWP) ~18km

HTESSEL (ECMWF) + LISFLOOD (JRC) ~10km

River discharge up to 30 days on 0.1 degree Probabilistic forecasts

http://www.globalfloods.eu/

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