Showcasing the use of ensembles in operational flood forecasting - examples of EFAS and GloFAS

Authors: **Karen O'Regan**, Arthur Eduardo Ramos Amaral, Calum Baugh, Christopher Barnard, Cinzia Mazzetti, Corentin Carton de Wiart, Dimitar Tasev, Eleanor Hansford, Ervin Zsoter, Francesca Moschini, Fredrik Wetterhall, Gwyneth Matthews, Juan Pereira Colonese, Michel Wortmann, Shaun Harrigan, Christel Prudhomme (ECMWF)

Introduction

Early warning systems (EWS) play a crucial role in the preparation for natural hazards and mitigation of their devastating impacts. The European and Global Flood Awareness Systems (EFAS and GloFAS) from the Copernicus Emergency Management Service employ ensemble forecasting to provide beneficial probabilistic flood forecasts (Wu et al., 2020). By leveraging **ensemble numerical weather prediction** (NWP) meteorological forecasts as input to a calibrated hydrological model (LISFLOOD Open-Source), CEMS-Flood produce an ensemble of daily hydrological forecasts for lead time up to 30 days (GloFAS), updated twice daily in the case of EFAS. The use of ENS forcing datasets in the EFAS and GloFAS operational flood forecasting systems are illustrated here. A case study presenting how hydrological forecast products can effectively communicate uncertainty in the forecasts for Tropical Cyclone Freddy in Mozambique, February 2023 is shown

Incorporating ensembles in CEMS operational flood forecasting

CEMS-Flood uses **multi-model / ensemble NWP** to force the meteorological component of the forecasting chain to produce reliable probabilistic outputs

GloFAS NWP forcing

Deterministic	Ensemble
ECMWF-HRES	ECMWF-ENS

EFAS NWP forcing

Deterministic	Ensemble
ECMWF-HRES	ECMWF-ENS
DWD-ICON	COSMO-LEPS

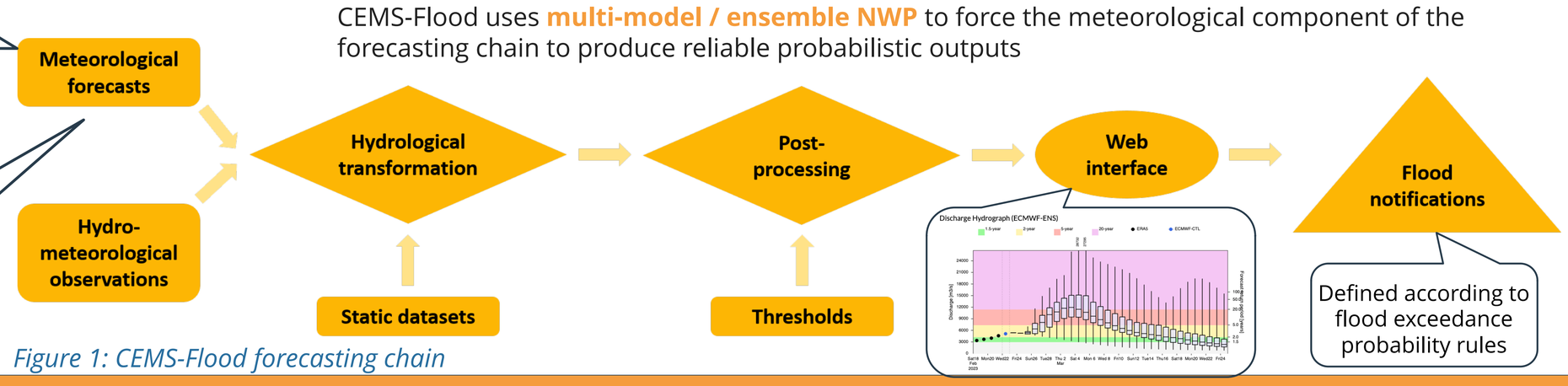
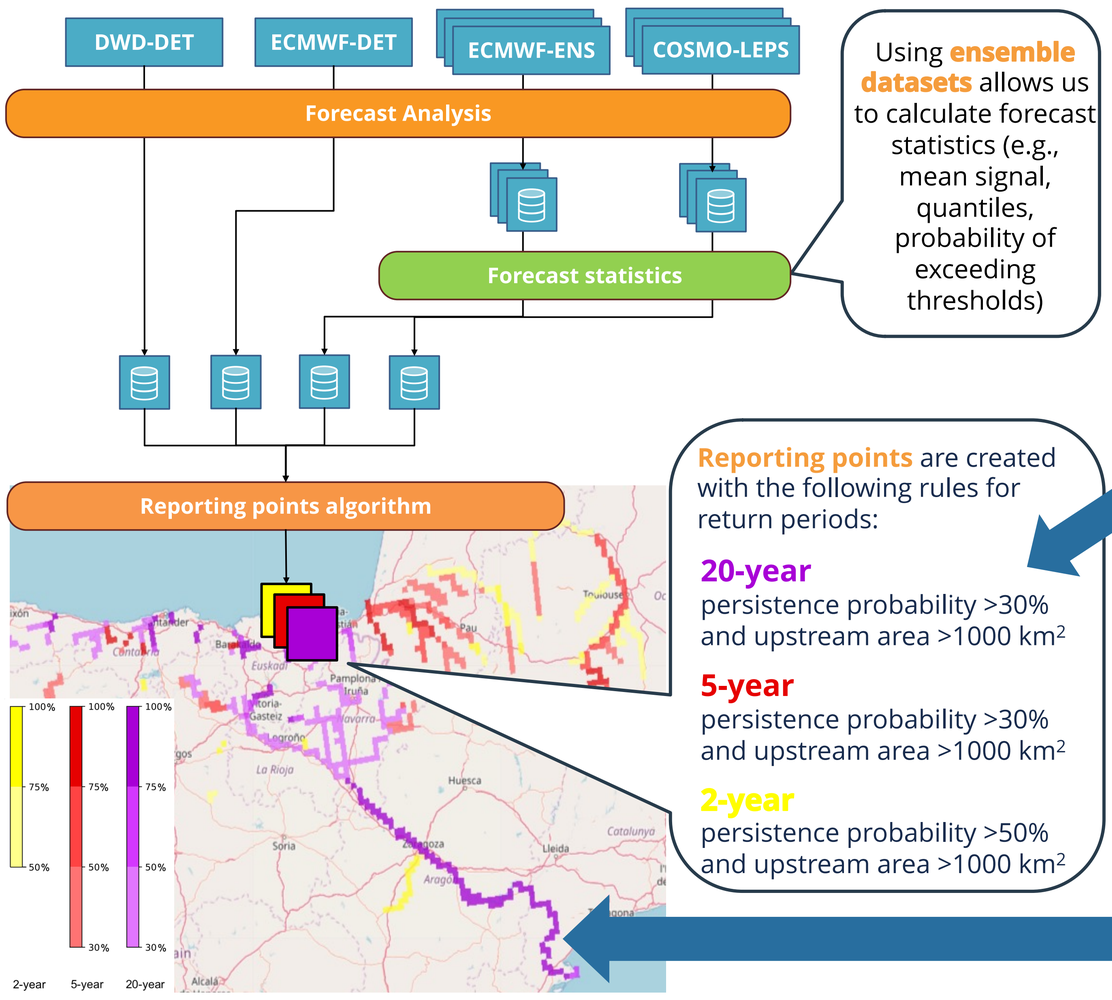


Figure 1: CEMS-Flood forecasting chain

How EFAS uses ensembles?



Using **ensemble datasets** allows us to calculate forecast statistics (e.g., mean signal, quantiles, probability of exceeding thresholds)

Reporting points are created with the following rules for return periods:

20-year
persistence probability >30% and upstream area >1000 km^2

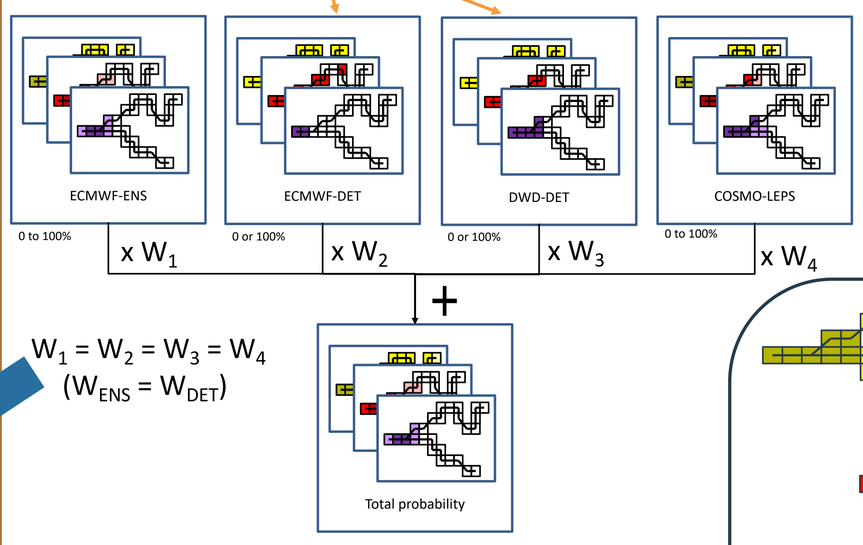
5-year
persistence probability >30% and upstream area >1000 km^2

2-year
persistence probability >50% and upstream area >1000 km^2

Figure 2: Overview of CEMS-Flood forecasting system algorithm, from NWP ingestion to flood persistence layer calculation and reporting point generation.

Calculating flood probability of exceedance

50% of the flood probability signal comes from binary deterministic forecasts



Probabilistic flood forecasts provide a more comprehensive assessment of the flood risk, assisting decision makers (ERCC, FCDO, EFAS Partners, etc) with flood preparedness mitigation of impacts.

Figure 4: Total probability forecasts are generated in EFAS by blending DET and ENS using a simple weighted sum

EFAS **probability persistence layer** displays combines the flood severity level together with flood probability, averaged from the two most recent forecast runs. It shows all EFAS rivers with an expected flood signal in the next 10 days

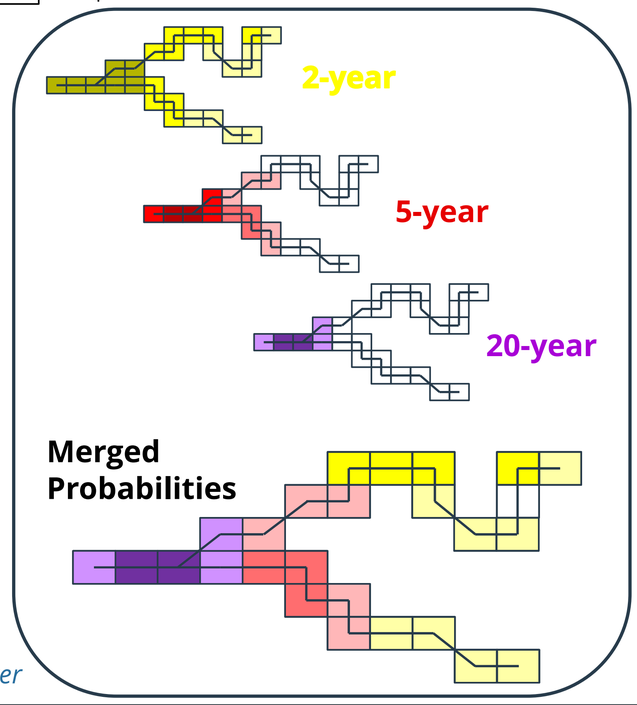


Figure 5: Construction of the flood probability persistence layer

Extracting information from ensembles in EFAS and GloFAS

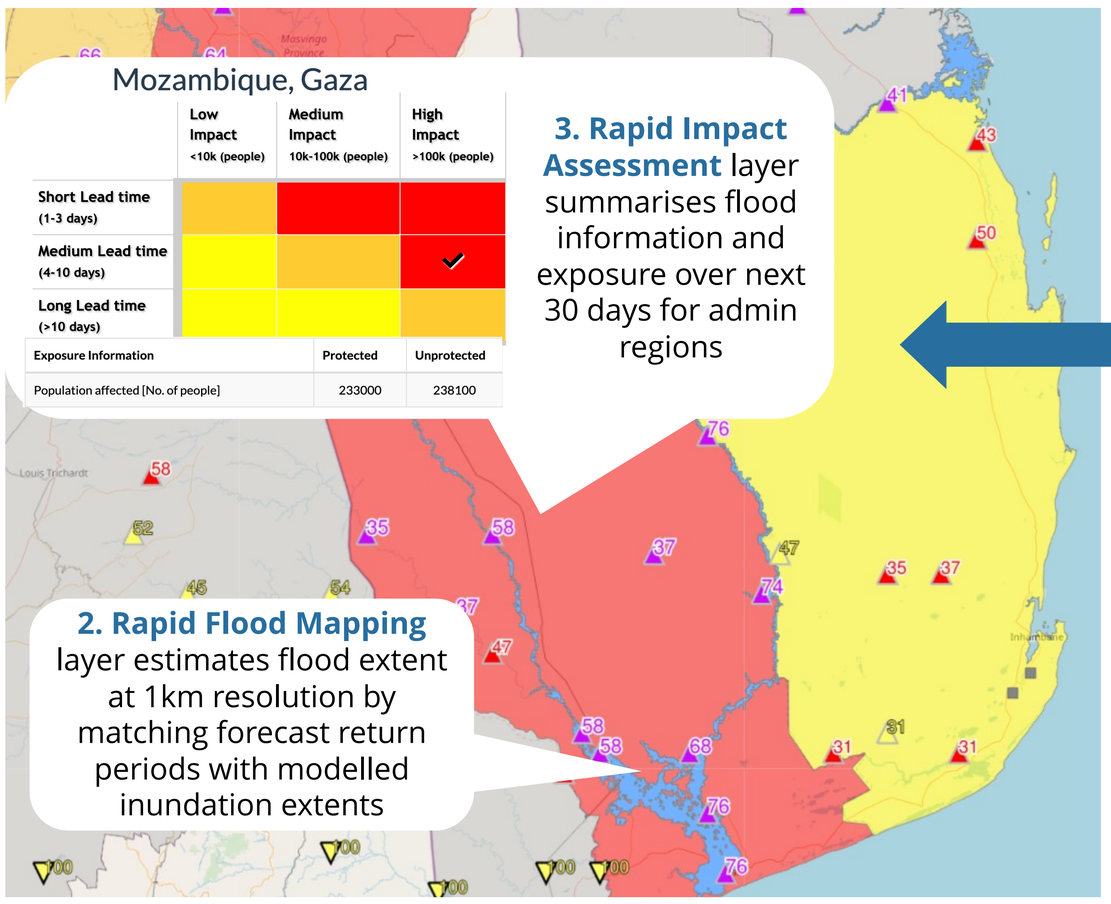
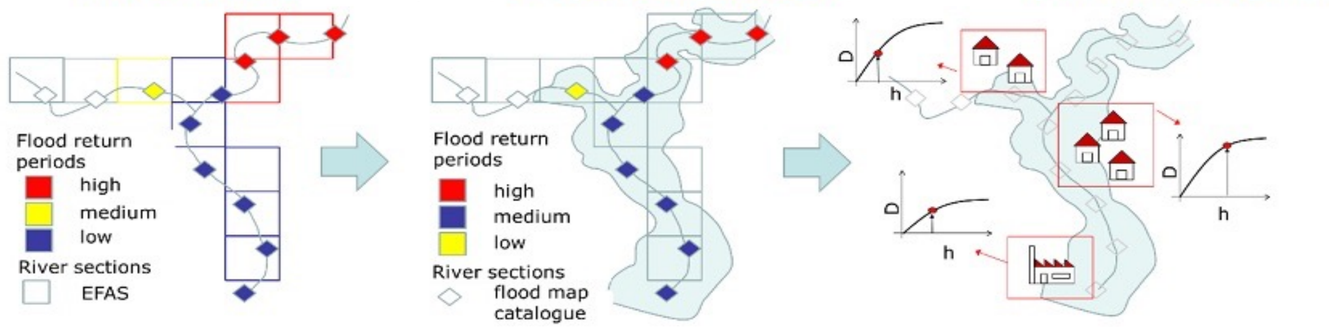


Figure 6: GloFAS forecast of TC Freddy flood impacts in Mozambique on 23 Feb

CEMS-Flood hydrological forecasts are combined with event-based rapid flood mapping to translate predicted river flows into explicit flood and impact maps, based on three components. The information is a visual help to **quickly identify areas expected to impact most people**.



1. **Medium-range flood forecasts**
   Magnitude of the peak forecasted discharge (based on ECMWF-ENS EFAS/GloFAS ensemble forecast **median**) compared against estimate local flood protection levels.
2. **Event-based rapid flood mapping**
   For each river section in (1), flood prone areas are identified using a catalogue of flood hazard maps (~1km res).
3. **Impact assessment**
   Event-based hazard maps are combined with exposure information to assess regional impacts at admin region level

Figure 6: Components of flood impact forecasting in EFAS and GloFAS.

Tropical Cyclone Freddy, Mozambique –23/02/ 2023

1. **Flood forecast** hydrograph indicates exceedances of 5-year flood in the next 4 days
2. **Rapid Impact Assessment** highlights forecast situation for Gaza, Mozambique showing medium likelihood of flooding with high impact for Mozambique on 23/02/2023
3. **Rapid Flood Mapping** shows potential flood extent for Limpopo river over the next 10 days

EFAS/GloFAS are products and services of the Copernicus Emergency Management Service. The Joint Research Centre of the European Commission is the entrusted entity responsible for CEMS EFAS and GloFAS in terms of management, technical implementation and evolution. ECMWF is the designated contractor to implement the operational functionalities of CEMS-COMP.

References
https://github.com/ec-jrc/lisflood-code
https://doi.org/10.5194/nhess-17-1111-2017

https://emergency.copernicus.eu/
@CopernicusEMS

#UEF2023