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Operational Flood forecasting Needs from Numerical Weather Prediction (NWP)

GDPFS Symposium on Requirements for NWP Data and Products

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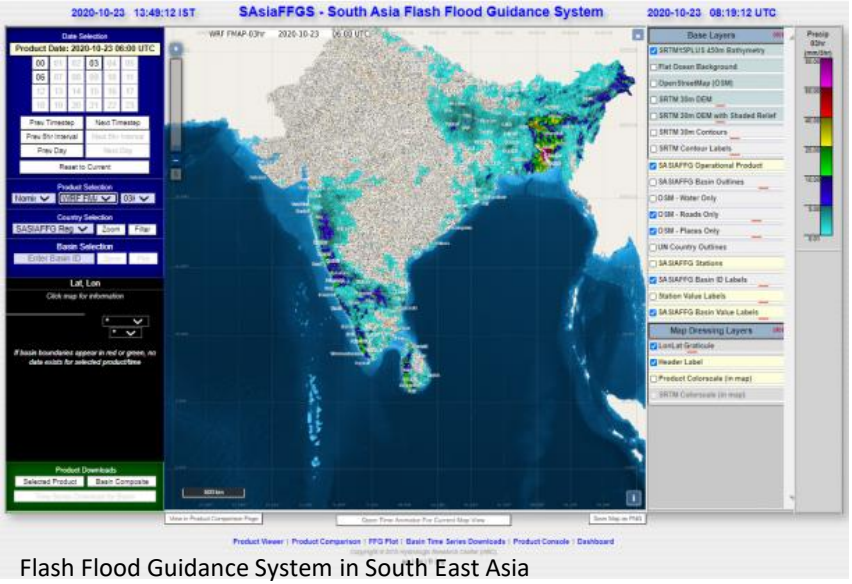
Flood Forecasting and NWP

- Floods accounted 43% of casualties among all natural disasters in 2019 only (CRED, 2020)[1]
- Flood forecasting is a key of Multi-Hazard early Warning Systems (MHEWS)
- All operational flood forecasting require Meteorological Numerical Weather Predictions (NWP)



Flash Flood Guidance System in South East Asia

There are a number of flood forecasting projects on a global, regional, as well as national scale supported by WMO **Flood Forecasting Initiative (FFI)** such as the **Flash Flood Guidance System and CIFI (Coastal Inundation Forecasting Initiative),** which require NWP.

[1]CRED, 2020: CRED Crunch 58 - Disaster Year in Review (2019) available at https://cred.be/sites/default/files/CC58.pdf

Operational Flood Forecasting requirements

There are specific requirements, particularly in relation to the **flood forecasting model** in use such as:

- Domain
- Spatial and temporal resolution
- Forecast time lead
- Output products format, etc.

- However, the FFI Strategy Plan identified that in many cases the NWP data, provided to hydrological forecasters do not entirely meet the needs. Thus, describing the hydrological forecasting needs from NWP would **increase the synergy between NWP and flood forecasting projects (FFGS, CIFI)**, and enhance interoperability with severe weather oriented programmes (TCP, SWFP), **resulting in more effective Multi-Hazard Early Warning Systems (MHEWS)**

Background

- **A flood** can be considered as the transformation of incoming rain or snow-melt waters into runoff resulting in streamflow via a watershed or river basin.
- In accordance with the prevailing flood formation processes, a number of flood types are considered (WMO Guide to Hydrological Practices, 2009).

There are different types of floods:

- **Riverine floods:** flood in river valley mostly on a flood plain or wash land as a result of flow exceeding the capacity of the stream channels and spilling over the natural banks or artificial embankments.
- **Flash Flood:** is a flood of short duration (typically less than 6 hours between peak flood and causative event) with relatively high peak discharge (International glossary on hydrology, 2012). (fast responding basin characterized by mountainous regions

Riverine Flood

Flash Flood

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Types of Floods and their requirements for NWP

- **Riverine Floods:** They need longer maximum lead time requirement for NWP precipitation forecasts than flash floods.
- **Flash Floods:** They have a more stringent spatio-temporal resolution requirement for operational mesoscale NWP precipitation forecasts than large rivers.

Basin characteristics need to be considered for NWP

- The scale of river basin dynamics and processes depend on the **basin size and topography** – the smaller the basin is, and the steeper the basin slopes are - the faster the "response" of the basin to rainfall events.

- River basins located on **plain areas are more homogeneous** than basins located on steep areas in terms of spatial variability of flood formation factors.

- Relief makes a significant contribution towards the spatial uniformness of rainfall amount as well as air temperature distribution across the area.

Plain Relief

Montainous Relief

Basin characteristics need to be considered for NWP

- **Spatial homogeneity** is a factor allowing the modeling of flood formation processes with coarser resolution.

- Therefore, the area of the selected basin defines the requirements to the spatial (as well as temporal) resolution of setting the forcing into the hydrological model.

- As the size of the watershed also describes the speed of flood formation process, it might be necessary to **calculate the water cycle with increased time step**. Hence the basin characteristics have an influence also on the requirements for the temporal resolution of the NWP.

- In summary, **the physiographic characteristics of the basin and the meteorological forcing data are of vital importance to flood forecasting models, particularly for rainfall-runoff models.**

NWP needs for Operational Flood Forecast

Domain

The hydrological forecaster should provide information on river basin boundaries and characteristics which prone to floods. Depending on the geomorphological features of the area there could be one single domain or two domains.

- One single domain in case of homogenous relief
- Two domains in case of both flat and mountainous relief

Lead-time

The main goal of flood forecasting is to provide maximum lead time with sufficient accuracy to the end users, so that appropriate mitigation and adaptation measures can be applied.

- Deterministic: up to 72 hours
- Probabilistic (Ensemble): up to 5 – 7 days

Spatial resolution

Depending on the domain feature; watershed size, and hydrological model structure (distributed, semi-distributed) requirements for NWP resolution may differ.

- Plain (Flat basins): 5 -7 km or higher resolution
- Mountainous and Urban areas: 2 km and higher resolution

Temporal resolution

For mountainous areas flash flood forecasting products (including FFGS) are being issued every 1 hour for the next 1, 3 6 hours, hence requirements in terms of temporal resolution of NWP output should not be coarser than 1 hour. For large river basins and plain topography temporal resolution can be coarser.

- Plain (Flat basins): 3 – 6 hours
- Mountainous and Urban areas: 1 hour and less

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NWP needs for Operational Flood Forecast

Meteorological Elements

For operational flood forecasting most models are based on rainfall-runoff models forced with meteorological data mainly precipitation and air temperature. However, other elements can be used to derive evapotranspiration.

- Amount of accumulated precipitation in mm
- Precipitation type
- Surface air temperature in C °
- Dew point temperature in C °

Ensemble products

Ensemble forecasting in operational hydrology allows the effect of a wide range of sources of uncertainty on hydrological forecasts to be accounted for.

Using the output from a number of ensemble NWP, the relative frequency of events from the ensemble can be used directly to estimate the probability of a given flood event.

- Preferable to have

NWP output formats

Only digital formats can be used for hydrological forecasting, no image formats such as JPEG PNG are not applicable.

- **Gridded Formats** (included but not limited to GRIB, GRIB2, NetCDF)

Nowcasting products

Nowcasting products are of great importance to hydrological forcasting especially in regard to small and fast responsive basins.

Nowcasting up to 12 h with 1 km resolution can significantly increase flash flood forecast

- Needed, especially for mountainous and urban areas

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Flood Forecasting Models and Calibration part of met elements

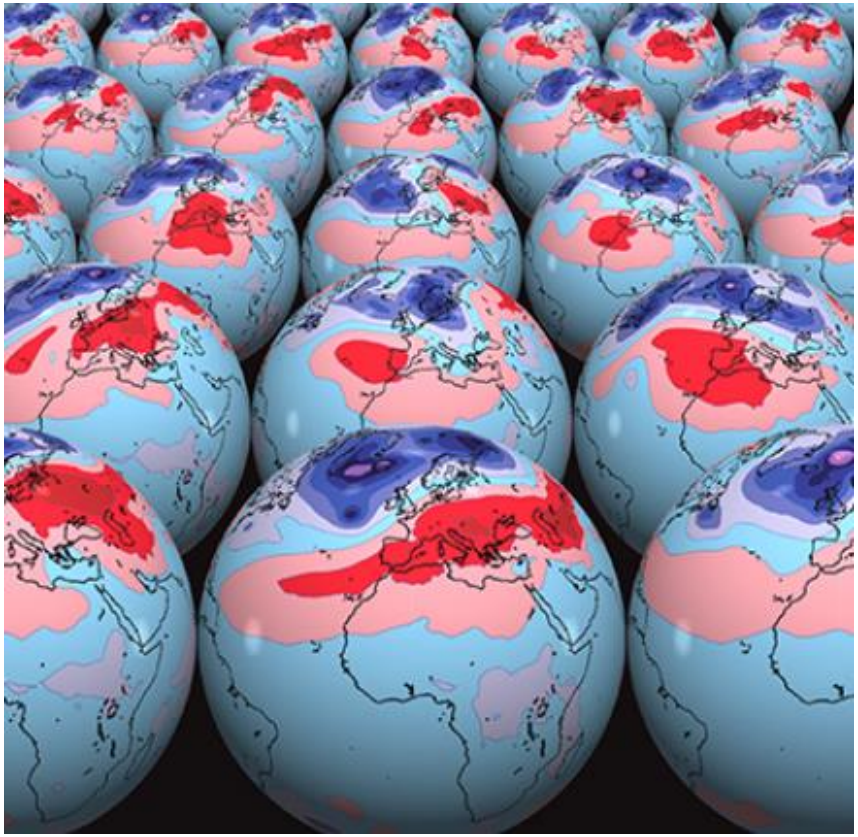
- **Flood forecasting models need to be well calibrated**.

- It is beneficial to include NWP output series of the meteorological listed elements (pcp, tmp, surface dew point tmp, surface air tmp), to try and catch trends of rainfall events forecasting.

- It may be useful for operational hydrology to have SWFP (Severe Weather Forecast Projects) providing forecasts of land-surface fluxes and of other land-surface variables in order to allow the reliable estimation of potential evapotranspiration.

Uncertainty of NWP Products

- **Hydrological forecasts contain uncertainty** of different nature **including NWP products uncertainty**.
- Uncertainty of NWP (especially rainfall forecasts) is the **primary source of uncertainty in hydrological forecasts**.
- One of the most successful ways of dealing with this is the **use of ensembles**.
- Ensemble forecasting in operational hydrology allows the effect of a wide range of sources of uncertainty on hydrological forecasts to be accounted for.
- Using the output from several ensemble NWP, the relative frequency of events from the ensemble can be used directly to estimate the probability of a given flood event.



NWP Validation

- The validation for NWP precipitation and surface air temperature forecasts on Spatio-temporal scales for hydro-climatologically and geo-morphologically uniform sub-regions is an important requirement for operational hydrology.

- In particular, for establishing their utility and uncertainties as an input to the hydrological forecasting system for various forecast lead times, it is important to **validate the NWP in terms of spatial scales of 5 – 100 km^2, temporal scales of 1 – 48 hours**, **and precipitation amounts greater than certain thresholds over a given interval (e.g. hourly, 3 hourly, 6 hourly and daily**). The validation results should be made available to the hydrologic users.

NWP Lead Time				
Verification Criteria	1 hours	3 hours	6 hours	24 hours
Spatial Scale (5 - 100 km2)	V	X	X	V
Time scale (1 – 48 hrs)	X	X	V	X
Threshold	V	V	V	X

NWP Validation

- The validation of the precipitation type in the operational mesoscale NWP forecast is also of significance to operational hydrology. It is important that the operational NWP models correctly predict whether there will be snow or rain on the ground.
- It will be particularly important to validate the temporal vector of concurrent forecasts of surface temperature and precipitation amount rather than validating only each of the components independently. Validating the vector will provide a better understanding of the uncertainties in simulating and forecasting snow melt (both from temperature surface melt and from rain-on-snow events) in an operational environment.

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Thank you
Merci

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