

FORECASTING COMPOUND FLOOD IMPACTS USING EXTREMES DT

DE_370A DELTARES

Kun Yan, Albrecht Weerts, Frederiek Sperna Weiland and many other colleagues
Deltares

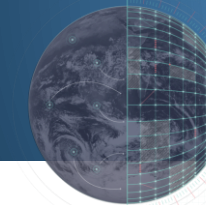


Funded by
the European Union

Destination Earth

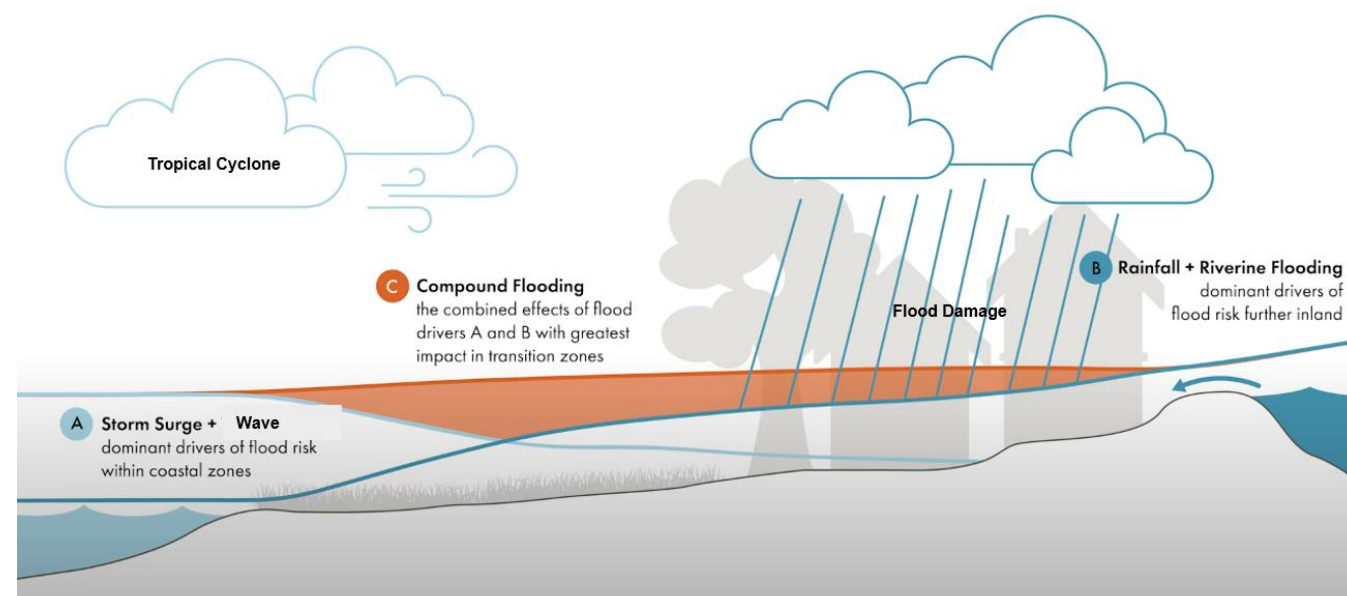
implemented by



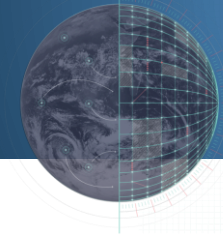


OBJECTIVE DE_370A

- Focus on impact sector of **Compound flooding**
- DT demonstrators for climate adaptation and disaster mitigation
 - **Five use cases:** Humber estuary (UK), Reunion, Philippines, Basque (Spain), Caribbean Netherlands
 - **User requirements** via co-creation
 - Leverage **Extremes DT** and **Climate DT data**
- Connect to existing platforms/services
 - Yet flexible in models, forecast product, forcing, boundary condition used
 - Global to local approach
 - Connect to DEDL

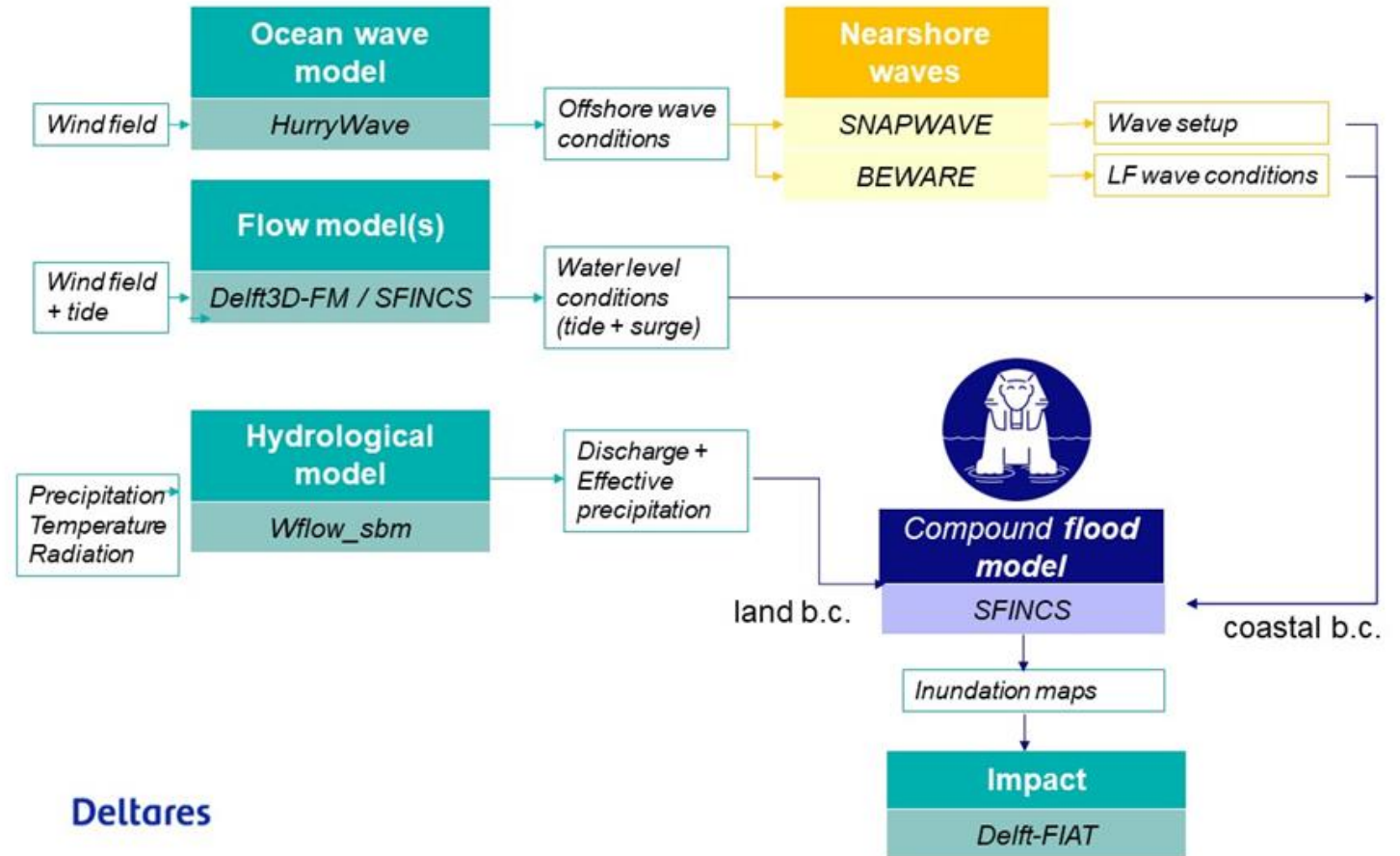


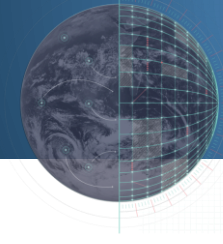
Credit: modified based on compound flooding research of The Water Institute



MODEL WORKFLOW

- Meteorological input from ECMWF: ERA5, IFS or **Extremes DT**
- Hydrological model WFLOW can be replaced by e.g. local, or **GLOFAS**
- Coastal hydrodynamics downscaled from **GTSM**, simulated by DFLOW-FM
- Offshore waves provided by **Hurrywave** regional and local models
- Flood extent simulated by **SFINCS**
- Impact estimated by **Delft-FIAT**





DT CAPABILITY PROVISION

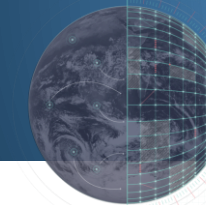
- **Real data**
 - Global data and local measurements
 - Extreme DT and Climate DT
- **Real physics**
 - With five unique compound flooding use cases
 - Flash flood, tide + surge dominated, wave dominated, tropical cyclone driven;
 - Deltas & (small) islands
- **Integration**
 - All models connected via global to local approach
 - Runs in DestinE Data Lake
 - Considering user`s existing system
- **Interactivity/Co-creation**
 - DestinE user requirement



USER ENGAGEMENT

- Compound flooding is important issue to address
 - **EA:** Humber estuary is difficult to model due to complex interaction between rivers and sea
- Extreme DT improves high resolution flood forecasting
 - **Red Cross NL:** A quality flood forecast will enable the Red Cross to use limited humanitarian funds more efficiently
 - **DEAL – Reunion:** High resolution NWP is very important for rainfall and flash forecasting in La Reunion
- **Deltares:** We are working towards the UN's Early Warnings for All initiative by leveraging DT's services in DestinE.





RESEARCH QUESTION

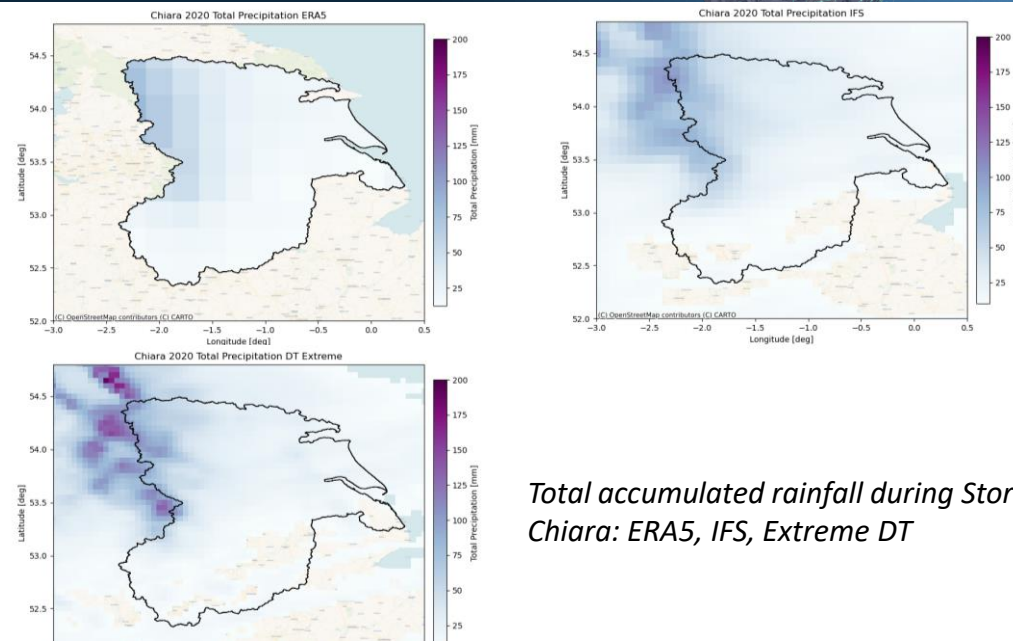
Will high resolution NWP of Extremes DT leads to improved flood impact simulation?



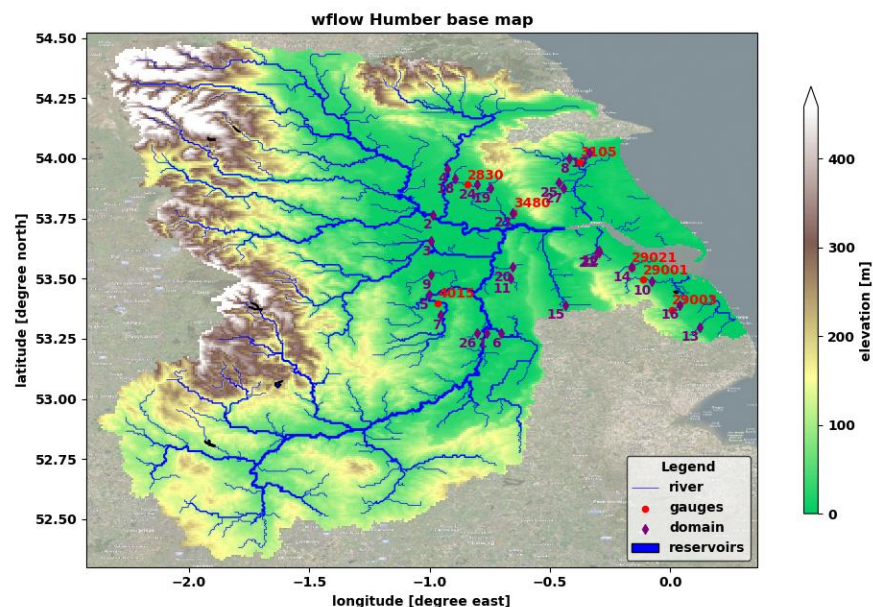


HYDROLOGICAL MODELLING

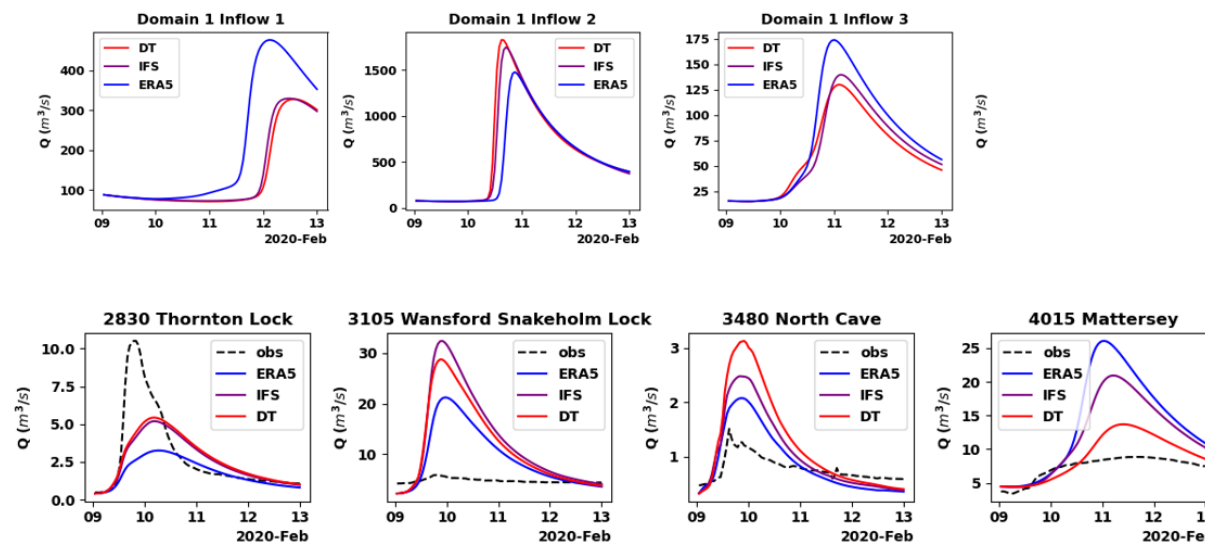
- High resolution total accumulated precipitation during storm **Ciara** in Humber estuary, UK
- River discharge forecasts show mixed results
- Likely due to most rainfall occurring outside the catchment and hydraulic structures



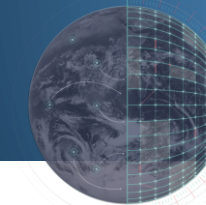
Total accumulated rainfall during Storm Ciara: ERA5, IFS, Extreme DT



Humber catchment, UK

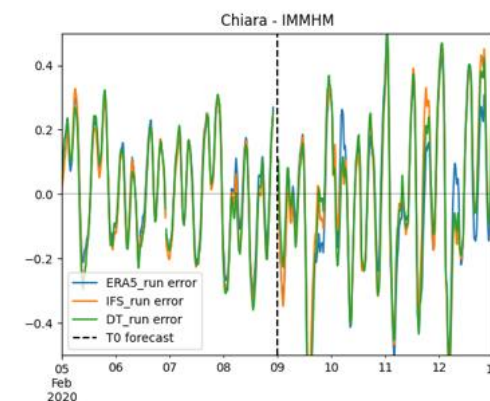
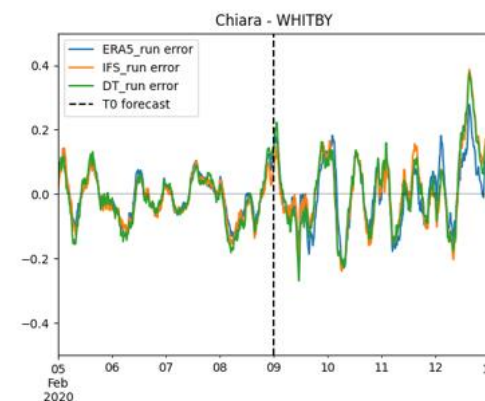
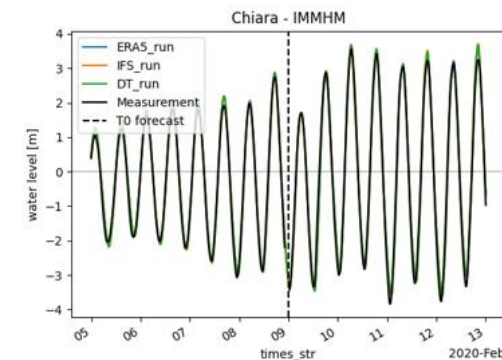
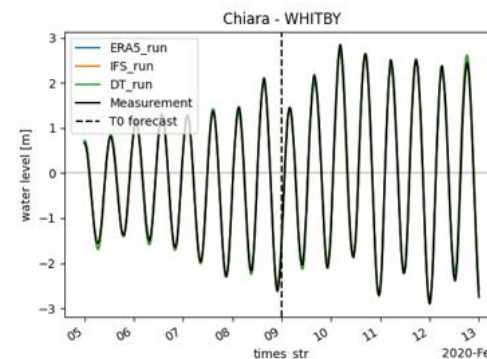


River discharge forecasts during Chiara at various stations in Humber catchment

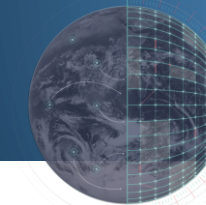


STORM SURGE MODELLING

- Storm Ciara 2020, Humber estuary, UK
- Small differences spotted among models forced by meteorological forcings
- Likely due to combination of large-scale wind patterns in the North Sea and local bathymetry

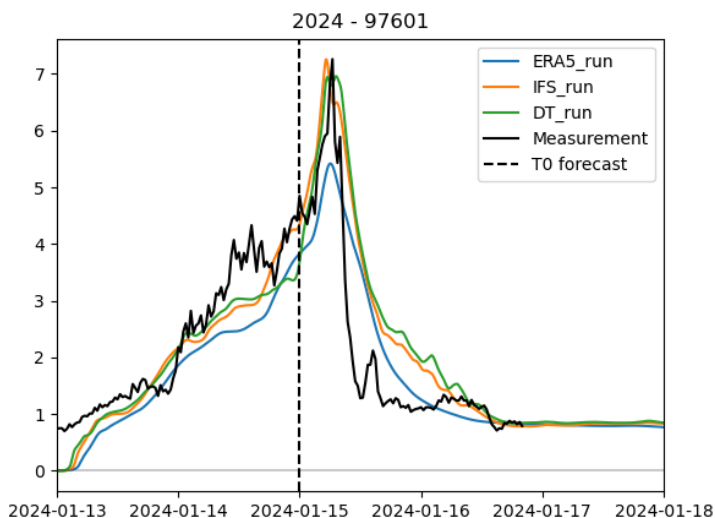


Water level timeseries (tide + surge) of forecasts based on different meteorological forcings during Storm Ciara. Forecast error are shown in the bottom row

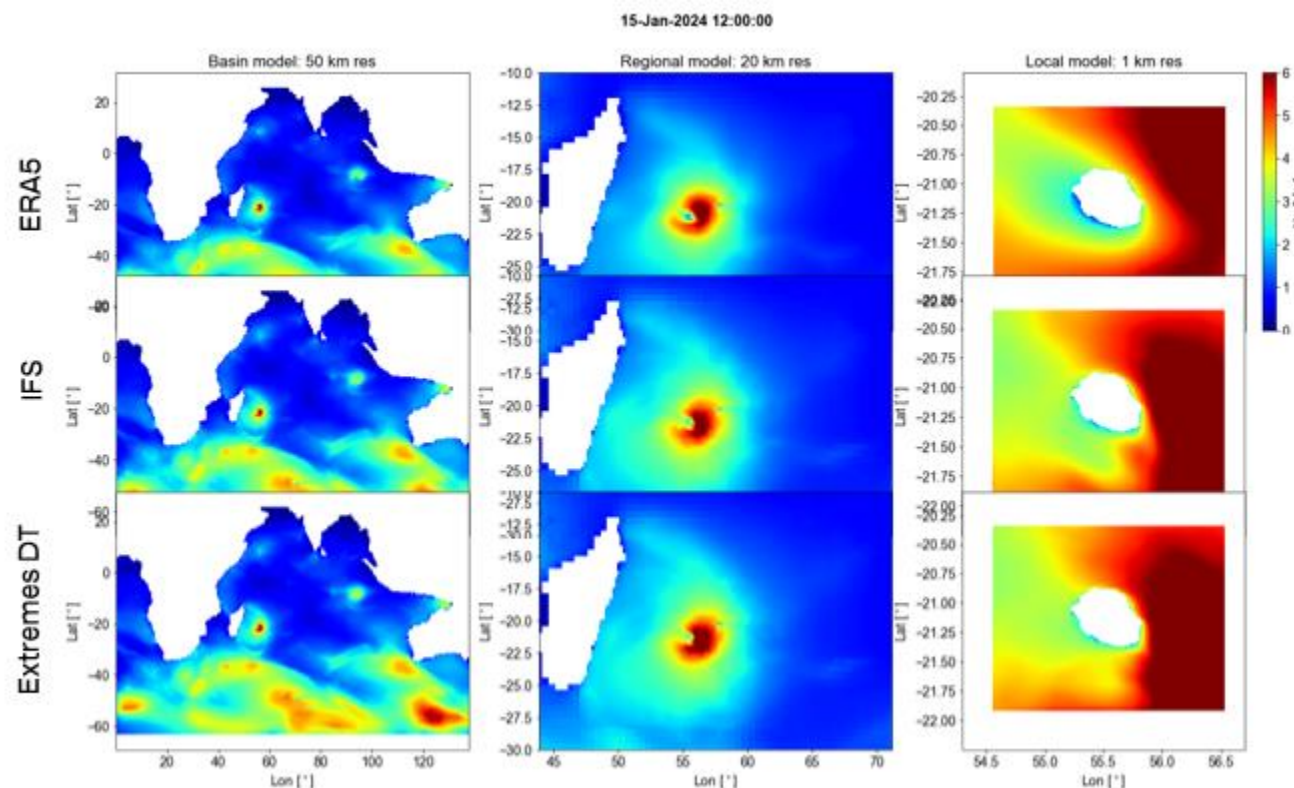


OFFSHOARE WAVES

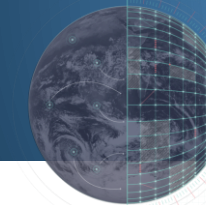
- Tropical Cyclone Belal 2024, Reunion
- Local differences in wave height around Reunion between ERA5 and IFS/Extremes DT
- Good validation results with global (low-resolution) bathymetric data



Significant wave height validation at station North of island during TC Belal, Reunion

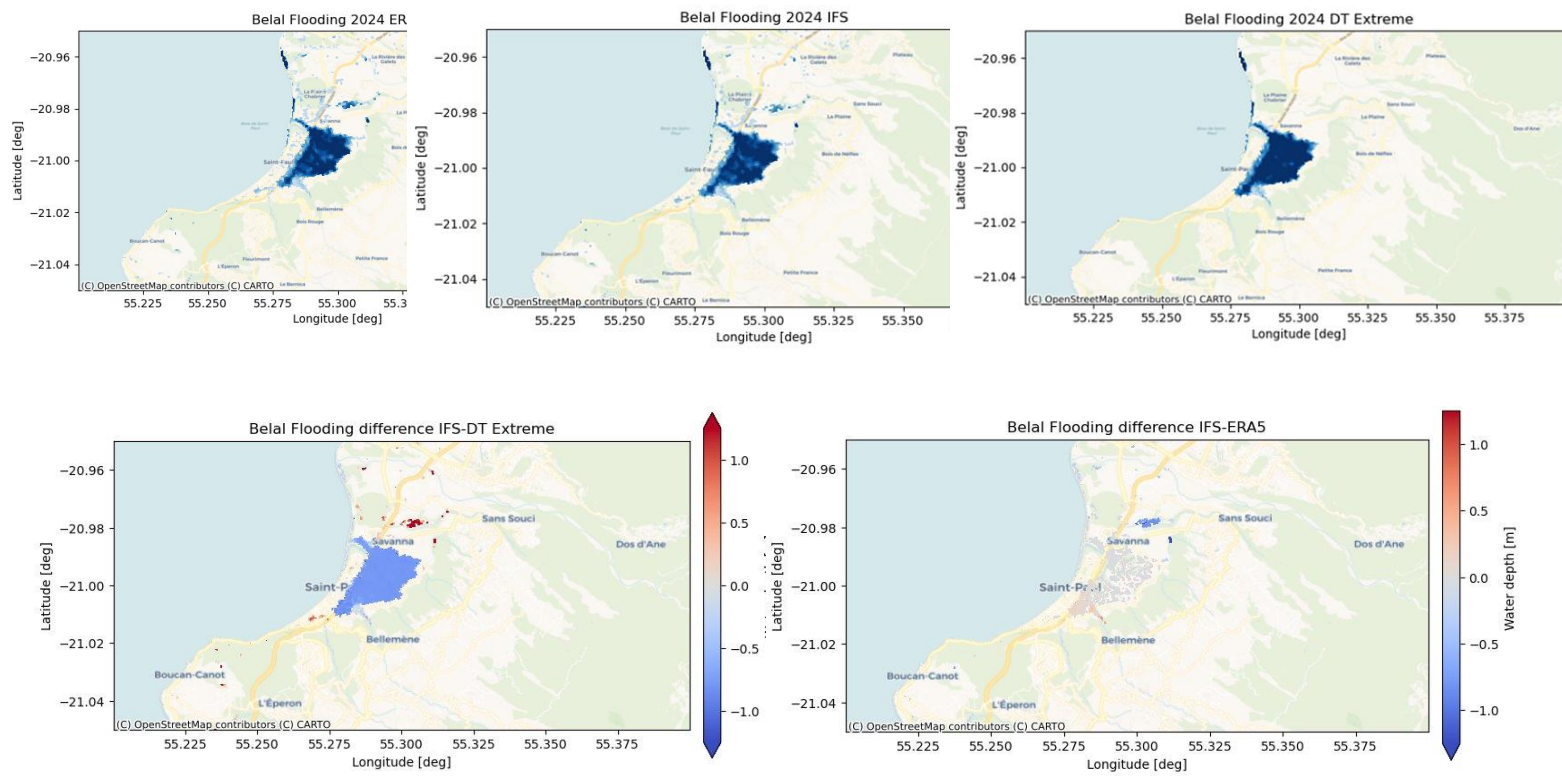


Significant wave height comparisons during TC Belal, Reunion



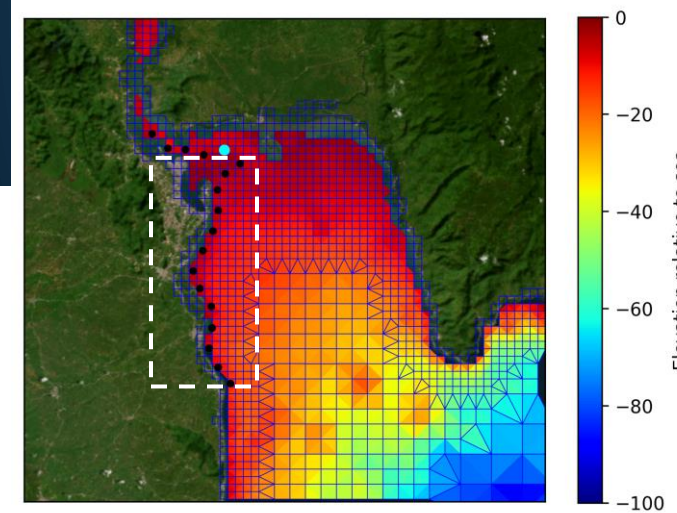
FLOOD EXTENT MODELLING

- Tropical Cyclone Belal 2024, Reunion
- Flood extents (fluvial flooding dominate) are very similar among various forcings, the flood depths are different, especially in Extremes DT results
- As ERA5 underestimates TC intensity, this might indicate improved performance of Extremes DT

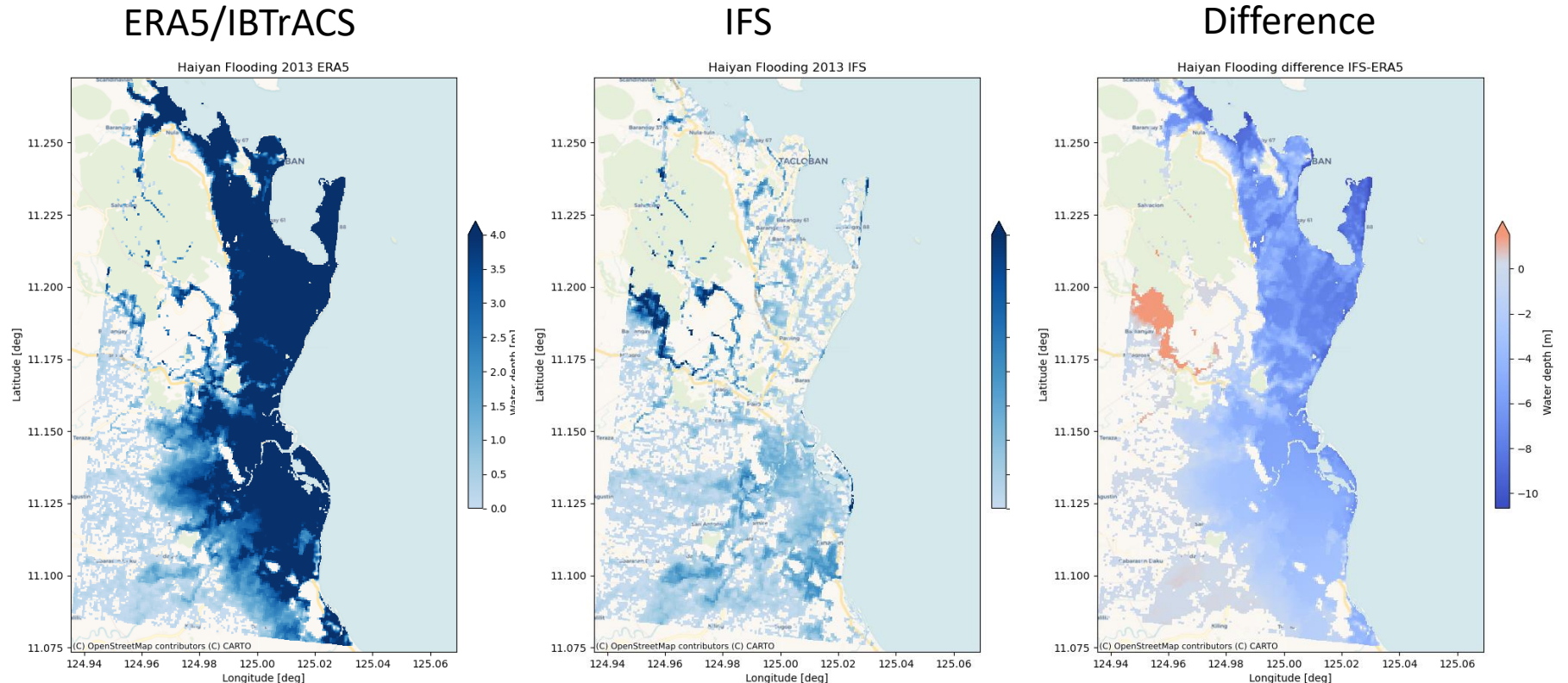


Flood maps for TC Belal in the northwest of La Réunion: a) ERA5; b) IFS; c) Extremes DT; d) flood depth of IFS-Extremes DT; e) flood depth of IFS-ERA5

FLOOD EXTENT MODELLING



- TC Haiyan 2013, Philippines
- More coastal floodings for ERA5/IBTrACS vs IFS as main flood driver is storm surge



Flood maps for TC Haiyan near Tacloban Philippines: a) ERA5/IBTrACS; b) IFS; c) Difference;

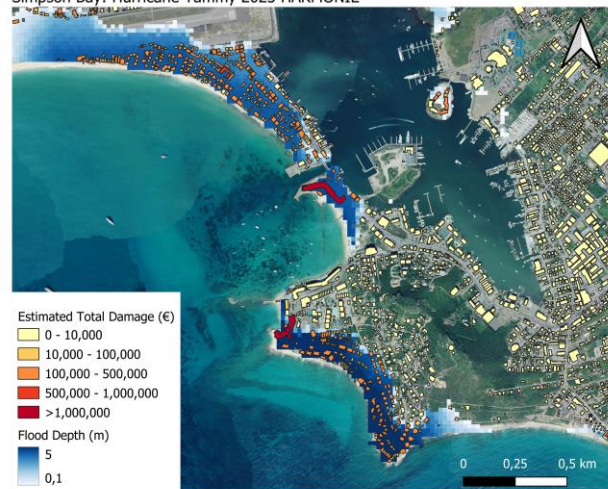
FLOOD IMPACT MODELLING

- Based on maximum flood depth, building, land use
- Damage per building
- Damage per administrative region

Simpson Bay: Hurricane Tammy 2023 DT



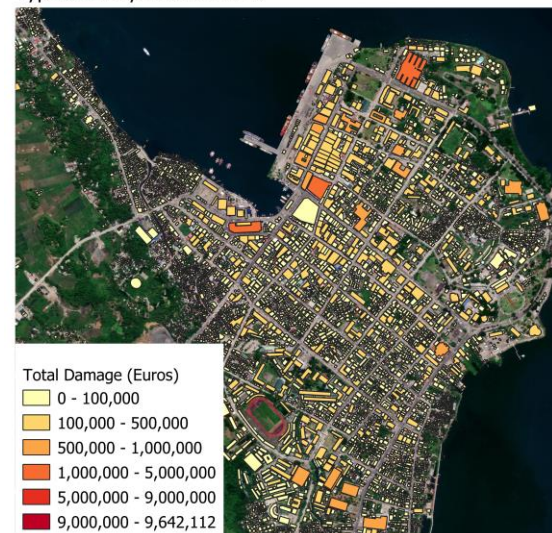
Simpson Bay: Hurricane Tammy 2023 HARMONIE



Flood damage per building for TC Tammy 2023 in St Maarten:

a) Extremes DT; b) Harmonie;

Typhoon Haiyan 2013 ERA5

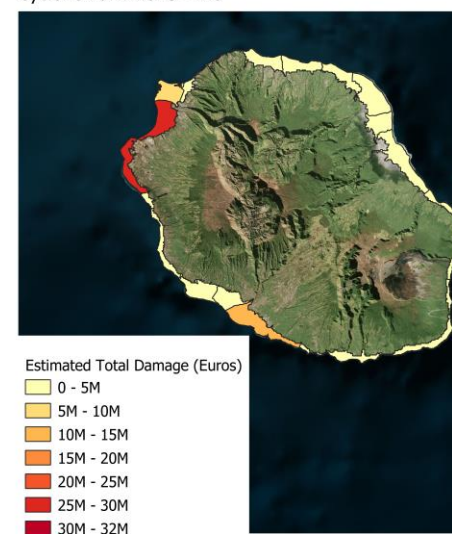


Typhoon Haiyan 2013 IFS

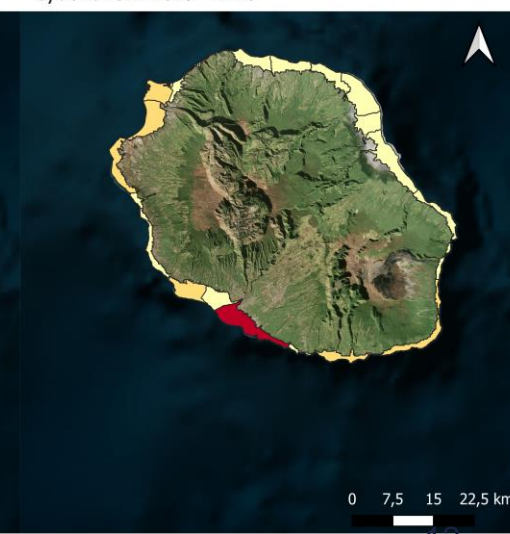


Flood damage per building for TC Haiyan near Tacloban Philippines: a) ERA5/IBTrACS; b) IFS;

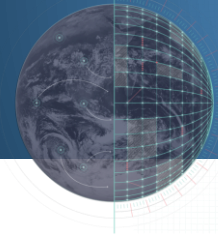
Cyclone Fakir 2018 - IFS



Cyclone Fakir 2018 - ERA5

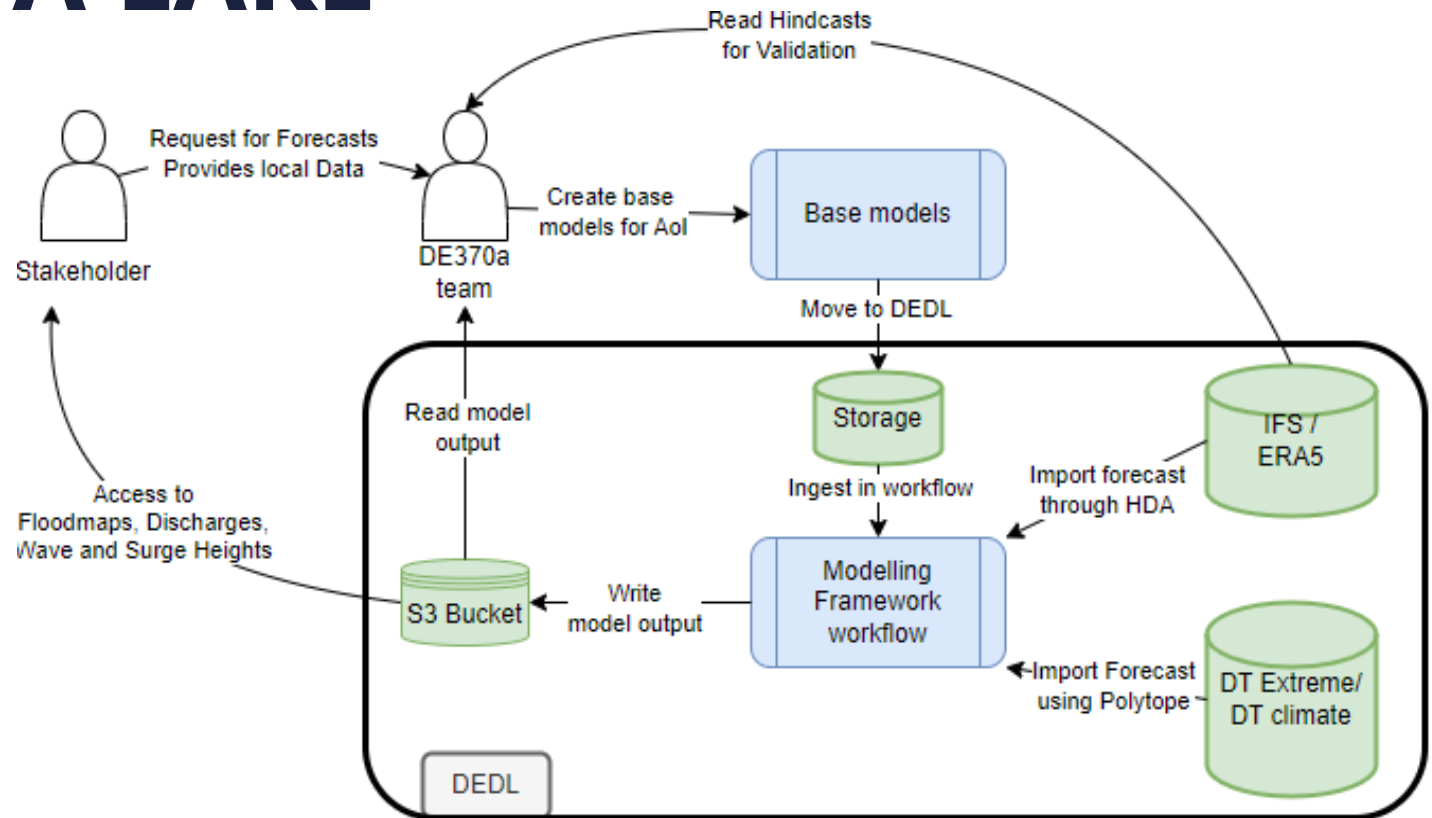


Flood damage per region for TC Belal in Reunion: a) IFS; b) ERA5

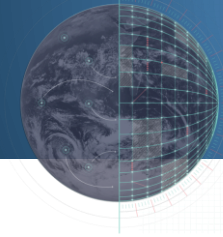


CONNECT TO DATA LAKE

- Integration in DestinE Data Lake
 - Request DT extreme data from EuroHPC/data lake;
 - Run on scalable infra (Kubernetes clusters)
- Towards operational DTs
 - Semi-automated quick compound flood model setup for new use cases
 - Make data available for users directly from the Data Lake



Compound flooding Workflow in DestinE Data Lake



RECOMMENDATION TO SERVICE EVOLUTION

- **Validate Extremes DT:**
 - Validate using more recent and historical flood events.
- **Develop Pilot Service:**
 - Create an operational compound flood forecasting service.
- **Include Uncertainty:**
 - Process-based flood models require high computational costs.
 - Extremes DT currently provides deterministic forecasts.
- **Explore AI-Based Applications:**
 - Use AI-based emulators or surrogate models.
- **Improve Data Access and API:**
 - Enhance data access and API capabilities.



QUESTIONS?

