IWRA XVIII World Water Congress

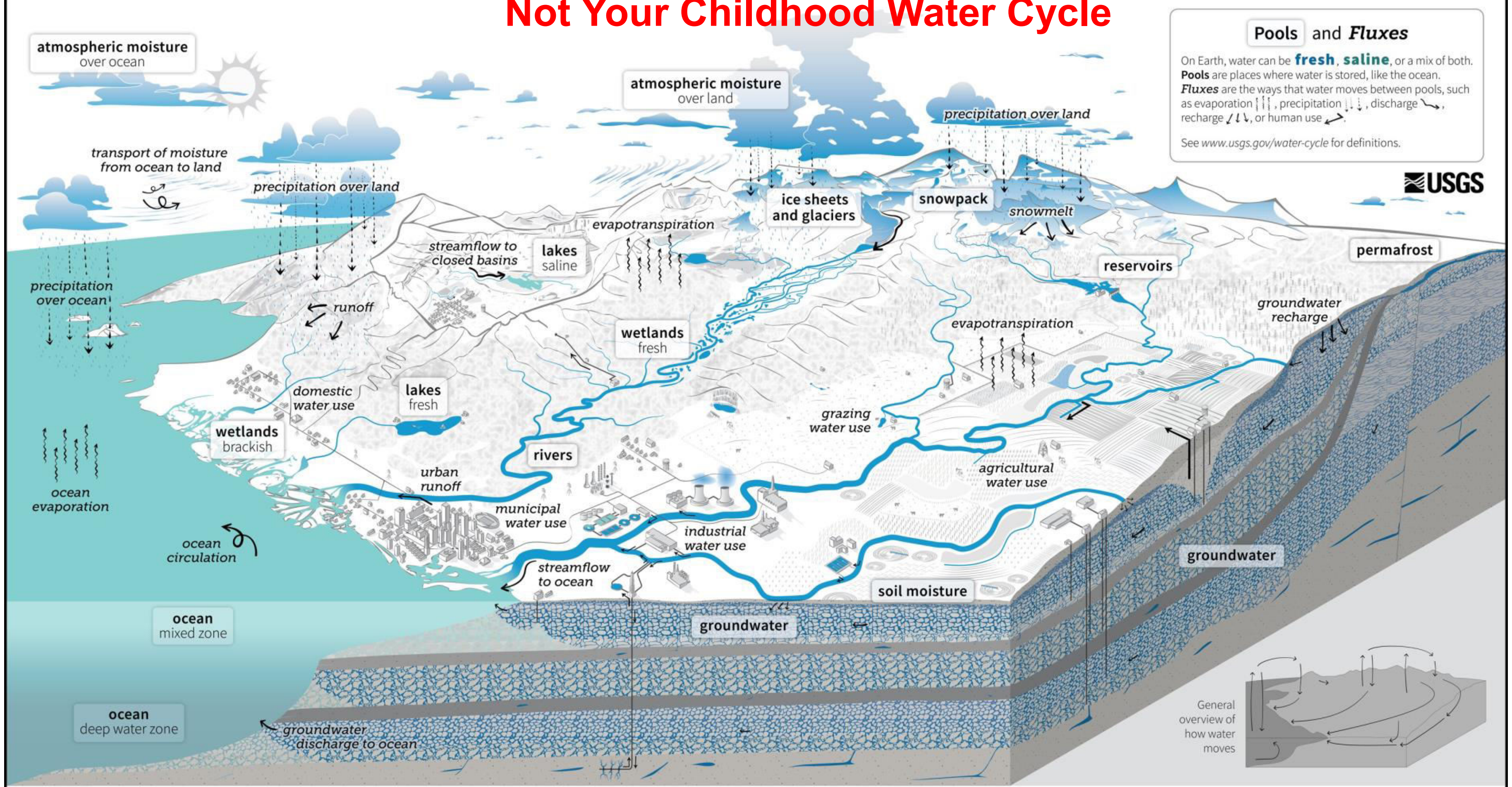
Special session SS 3-2
Debate – Flooding: A social issue? A natural science challenge? An engineering problem?

ICFM

Prof. S.P. Simonovic (Canada), Prof. X. Cheng (China) and Prof. S. Karmakar (India)
Moderator: Prof. Z. Cheng (China)

“Flooding: A natural science challenge”

Not Your Childhood Water Cycle



The Water Cycle

The water cycle describes where water is on Earth and how it moves. Water is stored in the atmosphere, on the land surface, and below the ground. It can be a liquid, a solid, or a gas. Liquid water can be fresh, saline (salty), or a mix (brackish). Water moves between the places it is stored. Water moves at large scales and at very small scales. Water moves naturally and because of human actions. Human water use affects where water is stored, how it moves, and how clean it is.

Pools store water. 96% of all water is stored in **oceans** and is saline. On land, saline water is stored in **saline lakes**. Fresh water is stored in liquid form in **freshwater lakes**, artificial **reservoirs**, **rivers**, and **wetlands**. Water is stored in solid, frozen form in **ice sheets** and **glaciers**, and in **snowpack** at high elevations or near the Earth’s poles. Water vapor is a gas and is stored as **atmospheric moisture** over the ocean and land. In the soil, frozen water is stored as **permafrost** and liquid water is stored as **soil moisture.** Deeper below ground, liquid water is stored as **groundwater** in aquifers, within cracks and pores in the rock.

Fluxes move water between pools. As it moves, water can change form between liquid, solid, and gas. **Circulation** mixes water in the oceans and transports water vapor in the atmosphere. Water moves between the atmosphere and the surface through **evaporation**, **evapotranspiration**, and **precipitation**. Water moves across the surface through **snowmelt**, **runoff**, and **streamflow**. Water moves into the ground through infiltration and **groundwater recharge**. Underground, groundwater flows within aquifers. It can return to the surface through natural **groundwater discharge** into rivers, the ocean, and from **springs**.

We alter the water cycle. We redirect rivers. We build dams to store water. We drain water from wetlands for development. We use water from rivers, lakes, reservoirs, and groundwater aquifers. We use that water to supply our **homes** and **communities.** We use it for **agricultural** irrigation and **grazing** livestock. We use it in **industrial** activities like thermoelectric power generation, mining, and aquaculture. The amount of water that is available depends on how much water is in each pool (water quantity). It also depends on when and how fast water moves (water timing), how much water we use (water use), and how clean the water is (water quality).

We affect **water quality**. In agricultural and urban areas, irrigation and precipitation wash fertilizers and pesticides into rivers and groundwater. Power plants and factories return heated and contaminated water to rivers. Runoff carries chemicals, sediment, and sewage into rivers and lakes. Downstream from these sources, contaminated water can cause harmful algal blooms, spread diseases, and harm habitats. **Climate change** is affecting the water cycle. It is affecting water quality, quantity, timing, and use. It is causing ocean acidification, sea level rise, and more extreme weather. By understanding these impacts, we can work toward using water sustainably.

(https://eos.org/articles)

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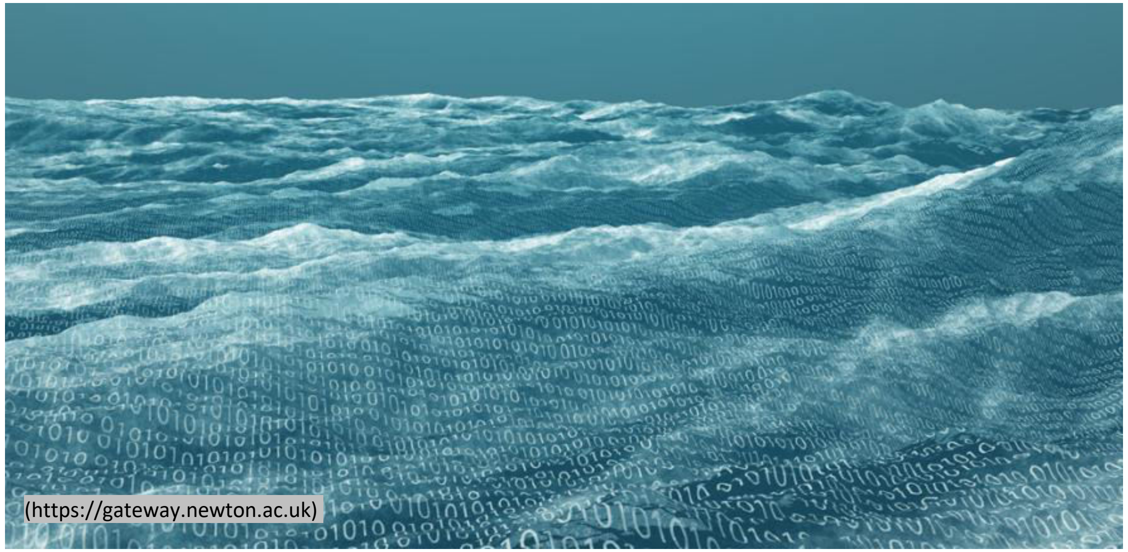
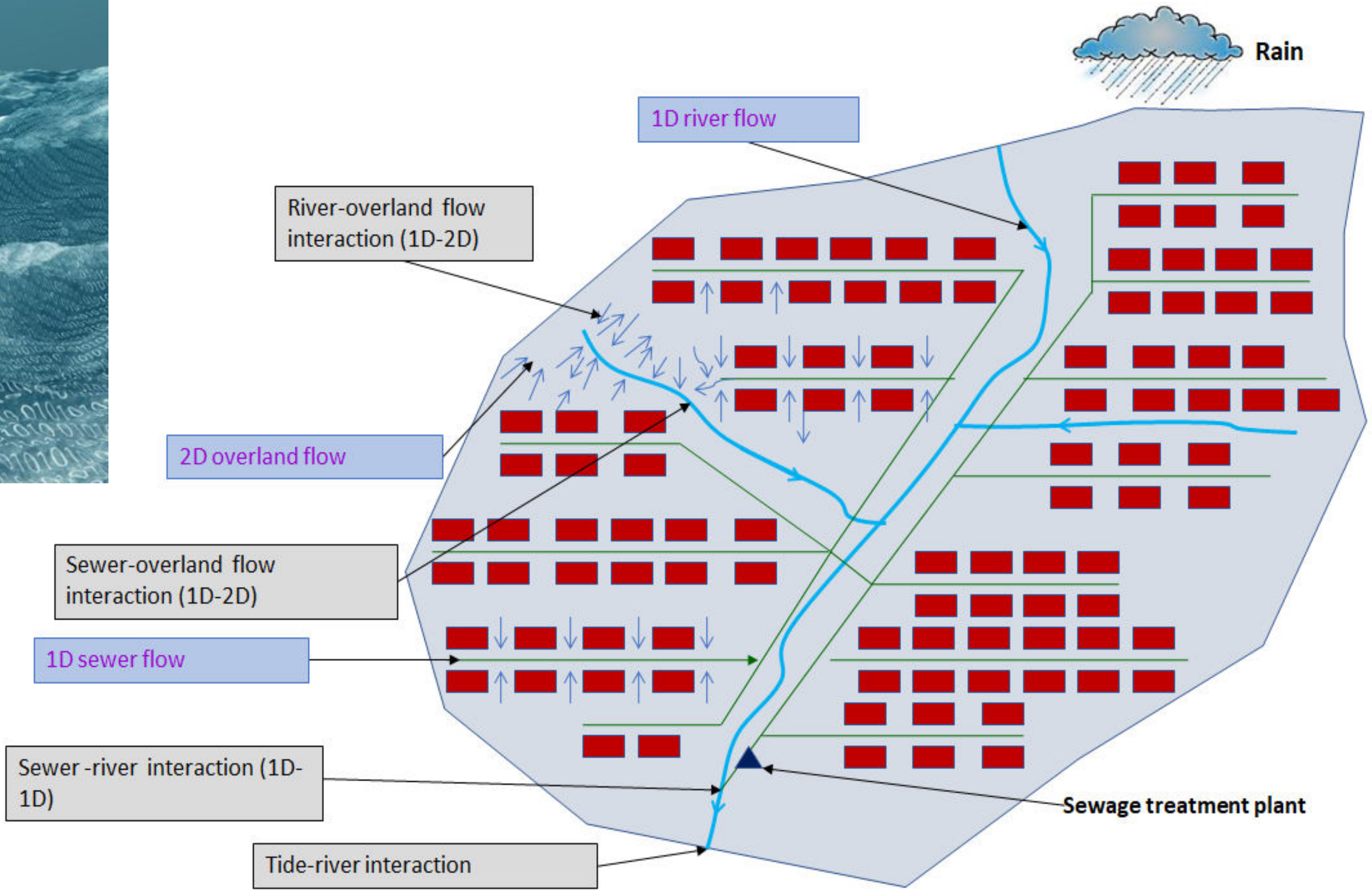
Hydrodynamics



Spatio-temporal modeling of
- ***Inundation***
- ***Velocity***
- ***Momentum***

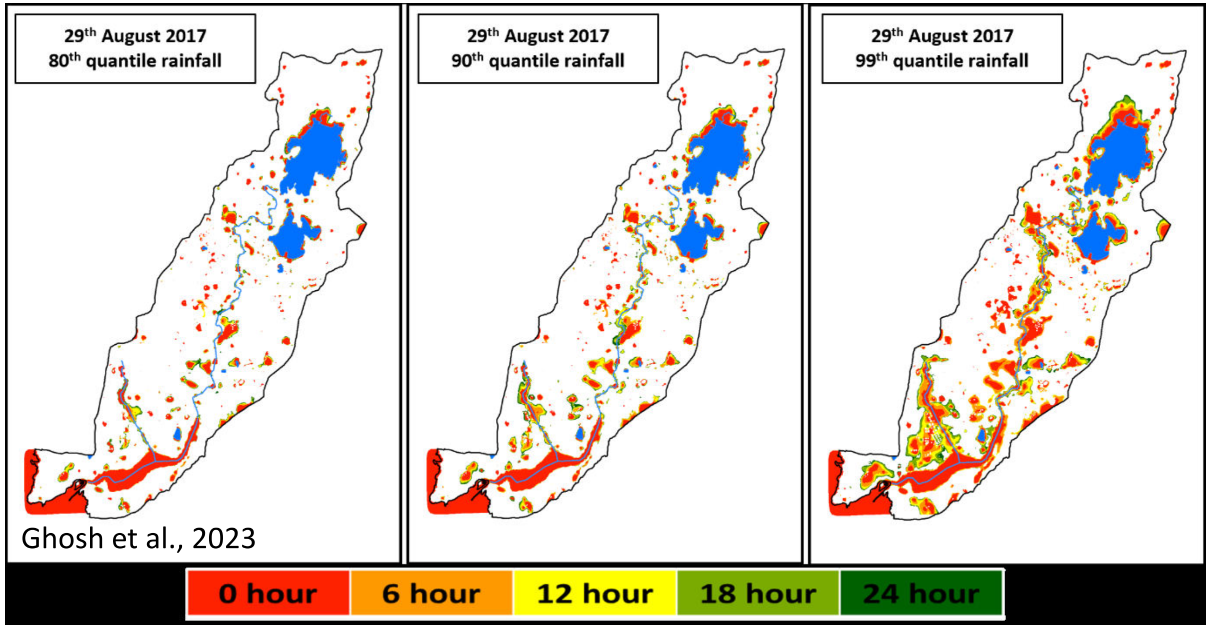
Coupled Flood Modeling



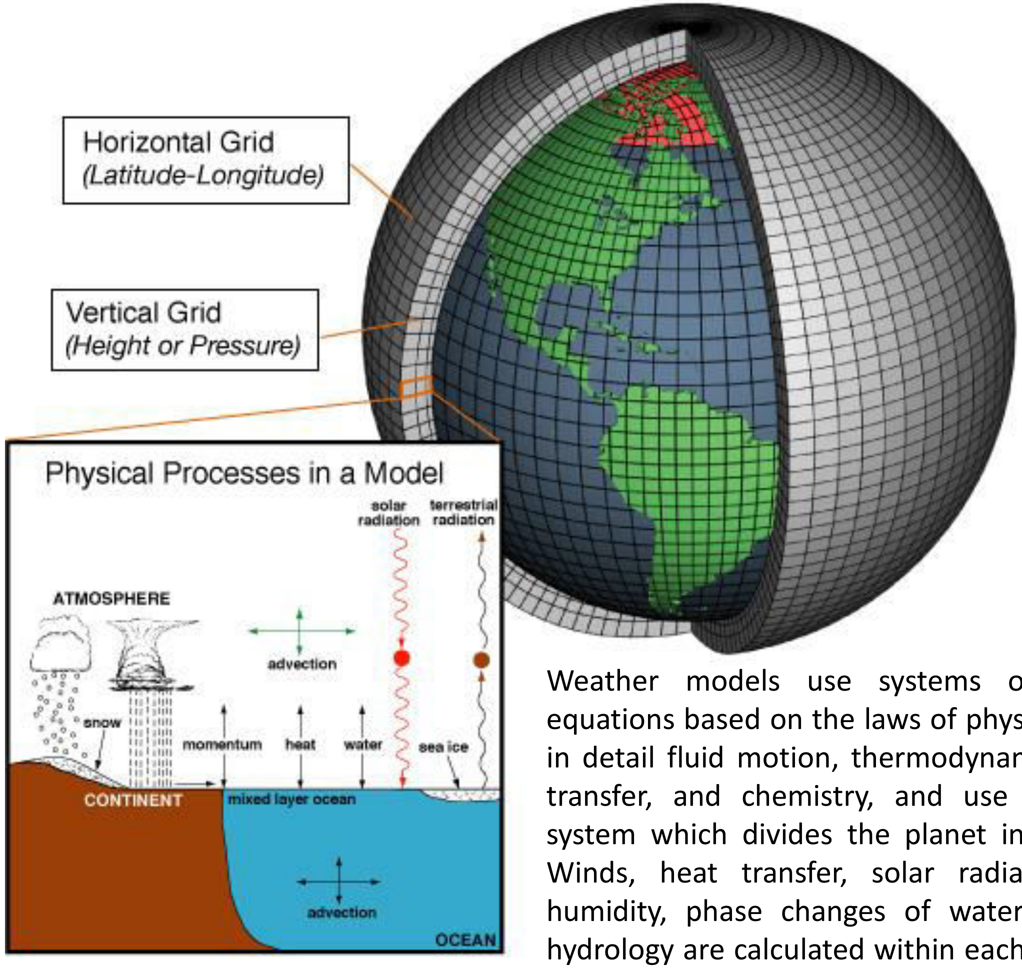
1. Overland flow, 2. River/channel flow, 3. Sewer flow

Numerical Weather Modeling – *Nowcasting & Forecasting*

is complex and not always accurate



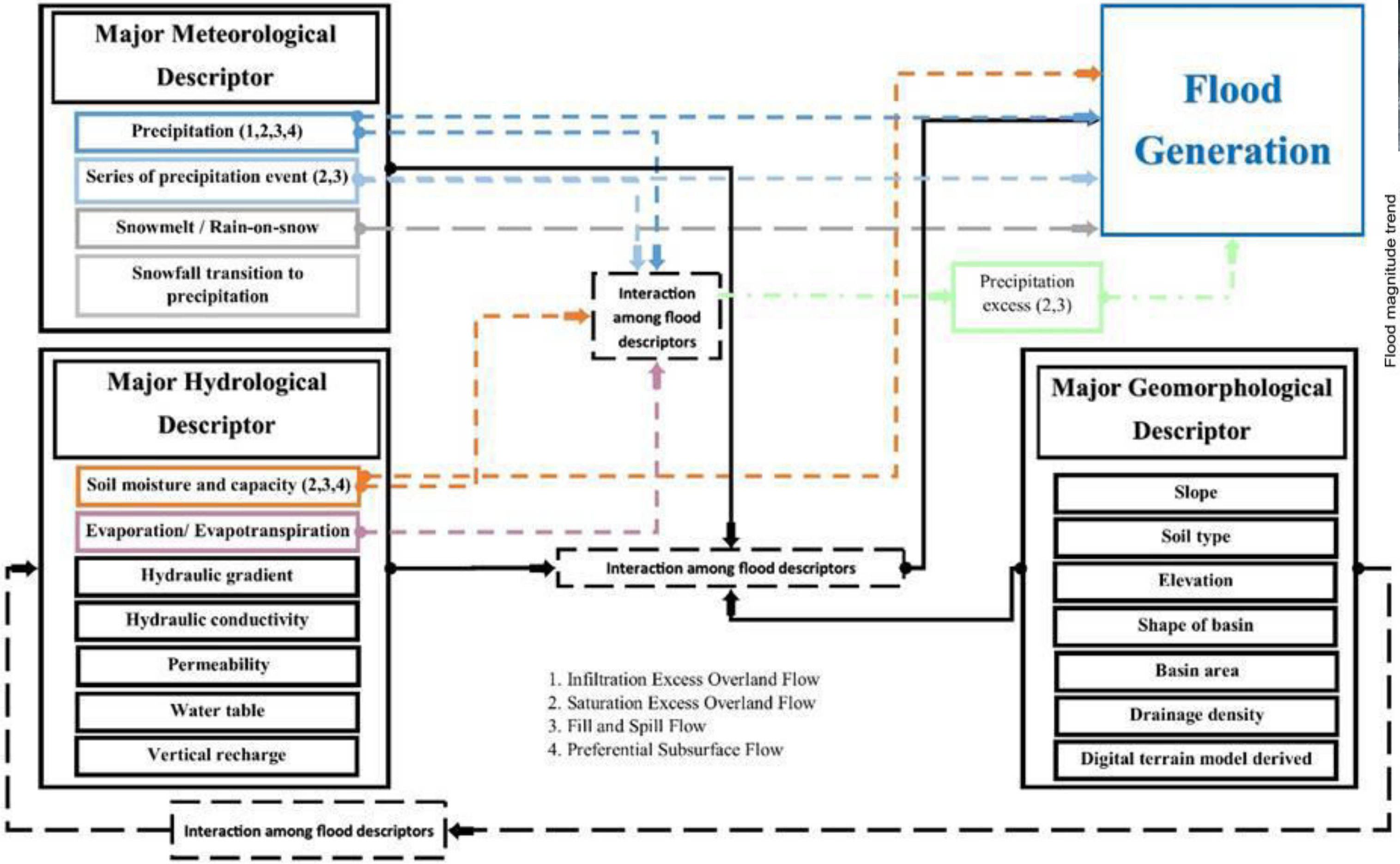
- Improved physics understanding
- addressing the uncertainty of initial conditions
- developing physical parametrization models or schemes
- developing operational ensemble prediction systems



Weather models use systems of differential equations based on the laws of physics, which are in detail fluid motion, thermodynamics, radiative transfer, and chemistry, and use a coordinate system which divides the planet into a 3D grid. Winds, heat transfer, solar radiation, relative humidity, phase changes of water and surface hydrology are calculated within each grid cell, and the interactions with neighboring cells are used to calculate atmospheric properties in the future.

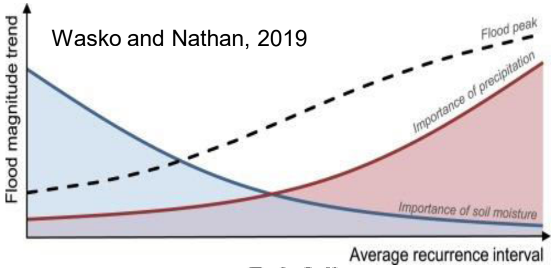
"Flooding: A natural science challenge"

Identification of Flood Drivers

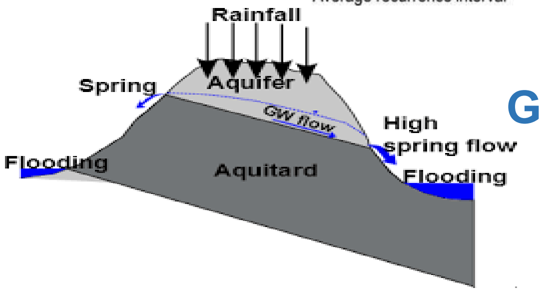


Multiple direct and indirect influencer of flood generation

Snowfall driven



Soil moisture
or
Rainfall driven



Groundwater driven

Hydrological Processes

RESEARCH ARTICLE | Full Access

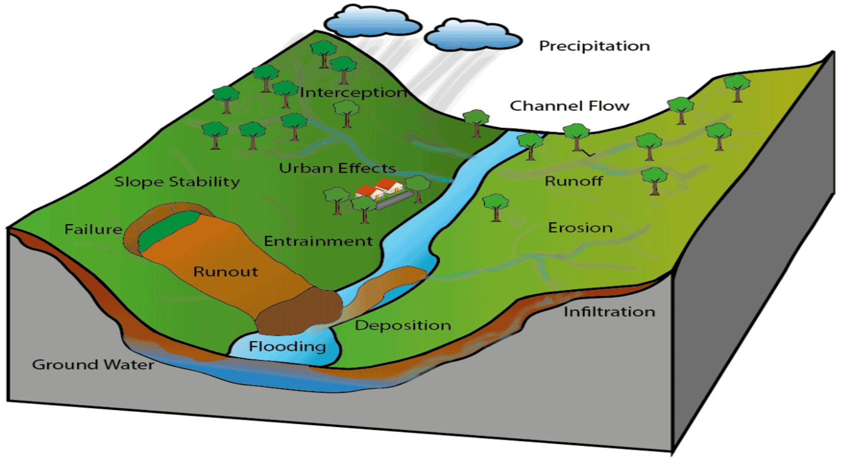
Identification of flood seasonality and drivers across Canada

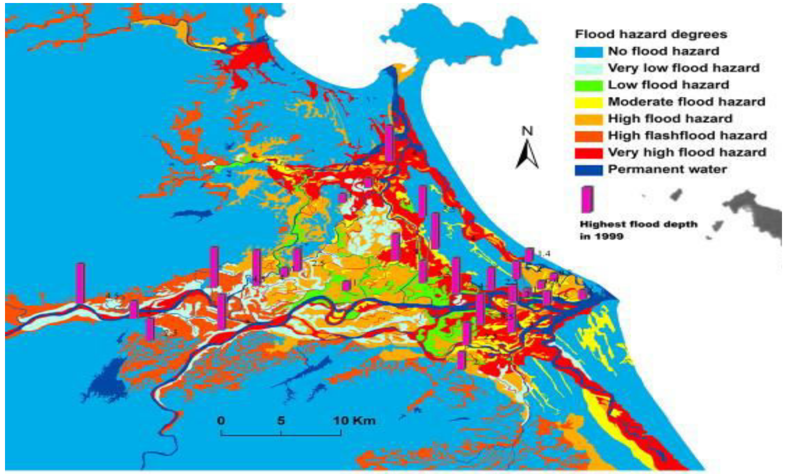
Jitendra Singh, Subimal Ghosh, Slobodan P. Simonovic, Subhankar Karmakar

“Flooding: A natural science challenge”

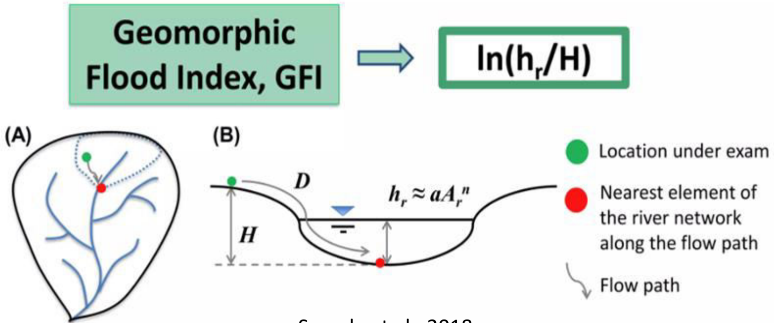
Geomorphology

=> Contributing area, Flow path distance, Elevation difference to nearest channel, Profile curvature, slope and many more..

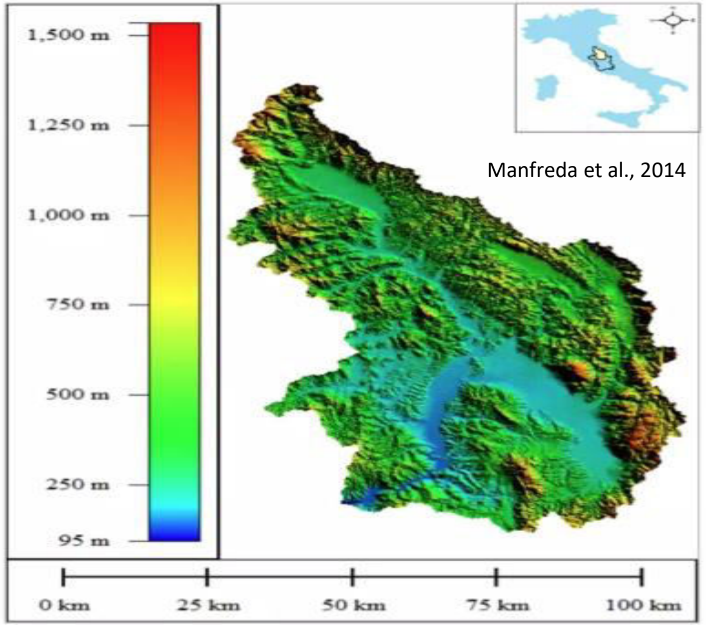




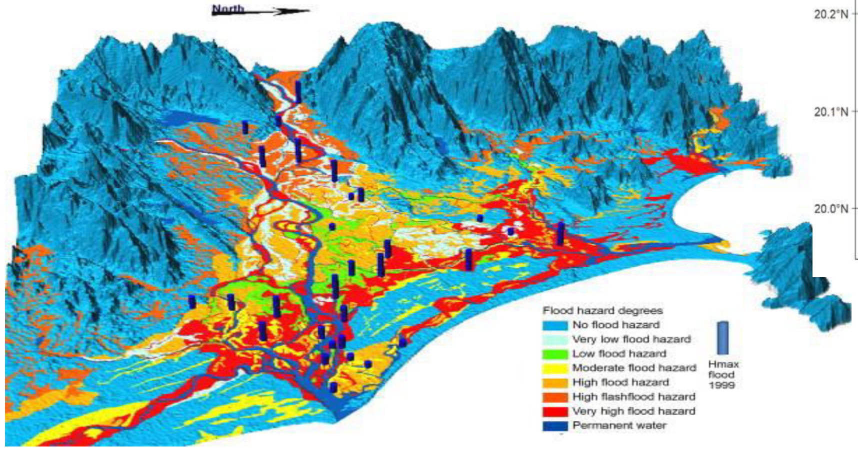
Ho and Umitsu, 2011

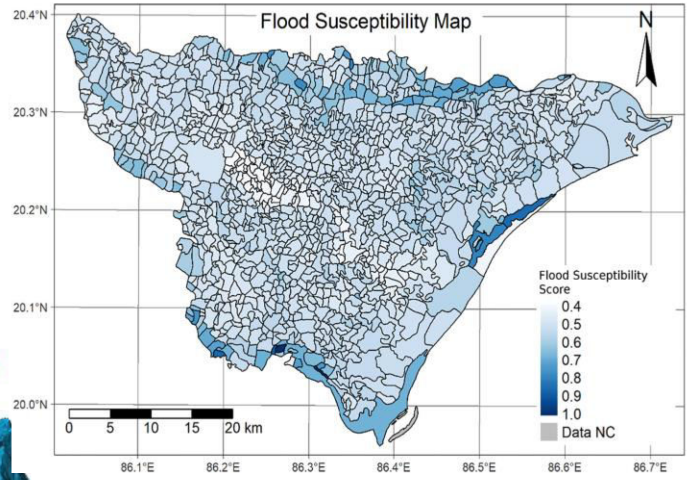


Samela et al., 2018



Manfreda et al., 2014



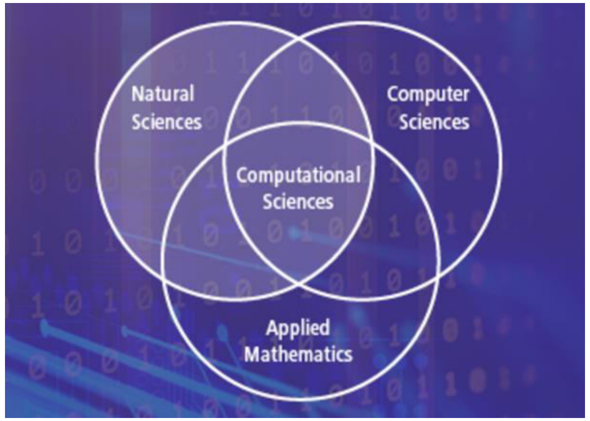


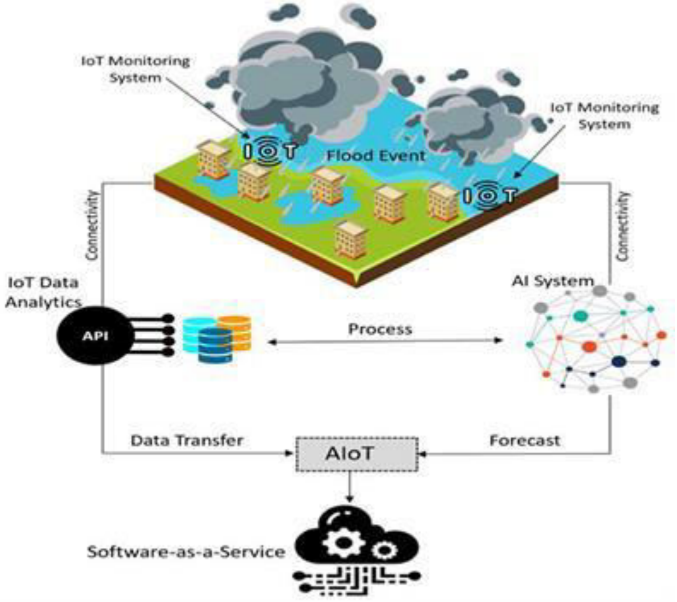
Deroliya et al., 2022

Flood susceptibility map

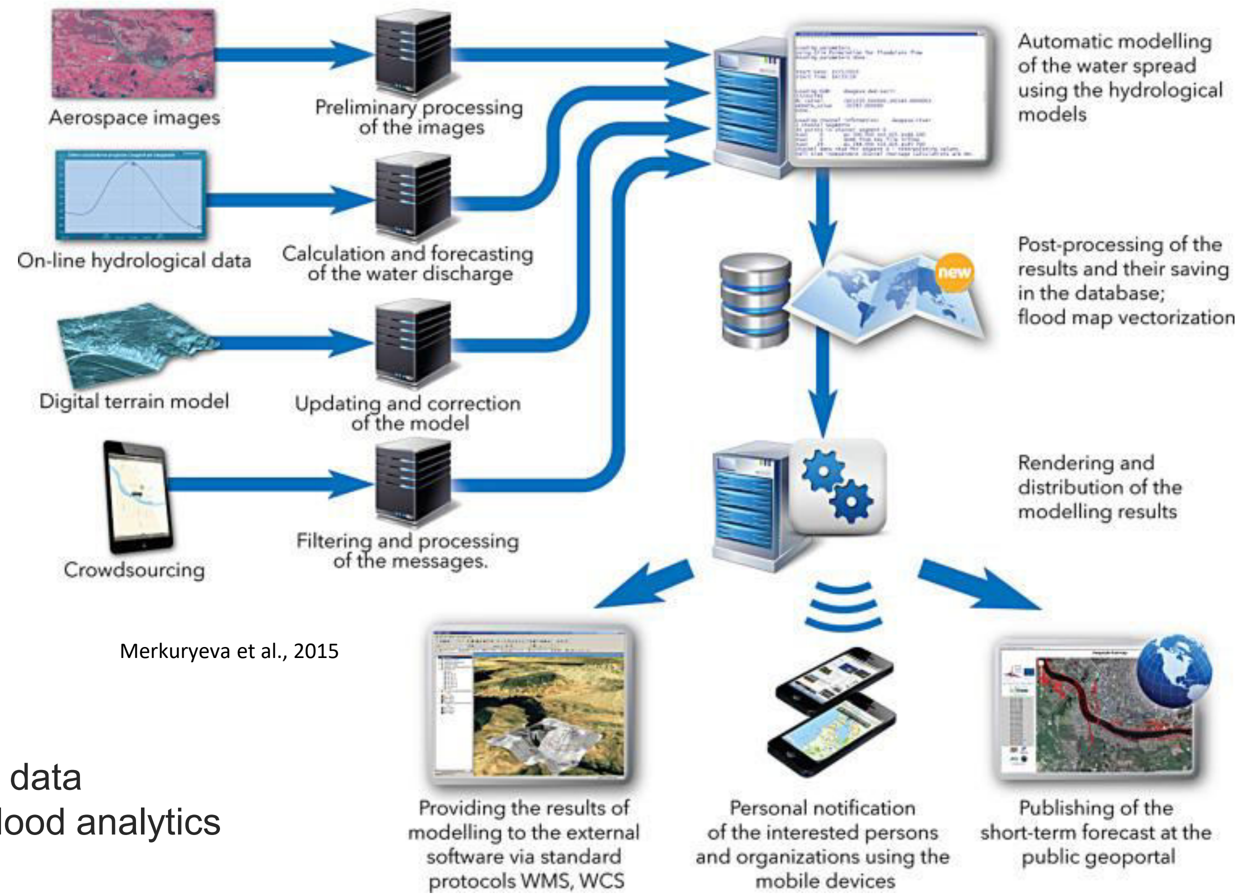
Computational Science

a discipline concerned with the design, implementation and use of mathematical models to analyze and solve scientific problems





AI, IoT, and big data
for advancing flood analytics



Merkuryeva et al., 2015

Advanced river flood monitoring, modelling and forecasting

“Flooding: A natural science challenge”

The extent and severity of flooding are often quantified through scientific understanding of physical and mathematical sciences.

- Hydrology and hydrodynamics
- Physics-based and statistical forecasting
- Identification of causes/ drivers of flooding
- Geomorphological characteristics
- Advancement of computational science