South East European Virtual Climate Change Center

Overland hydrology modeling

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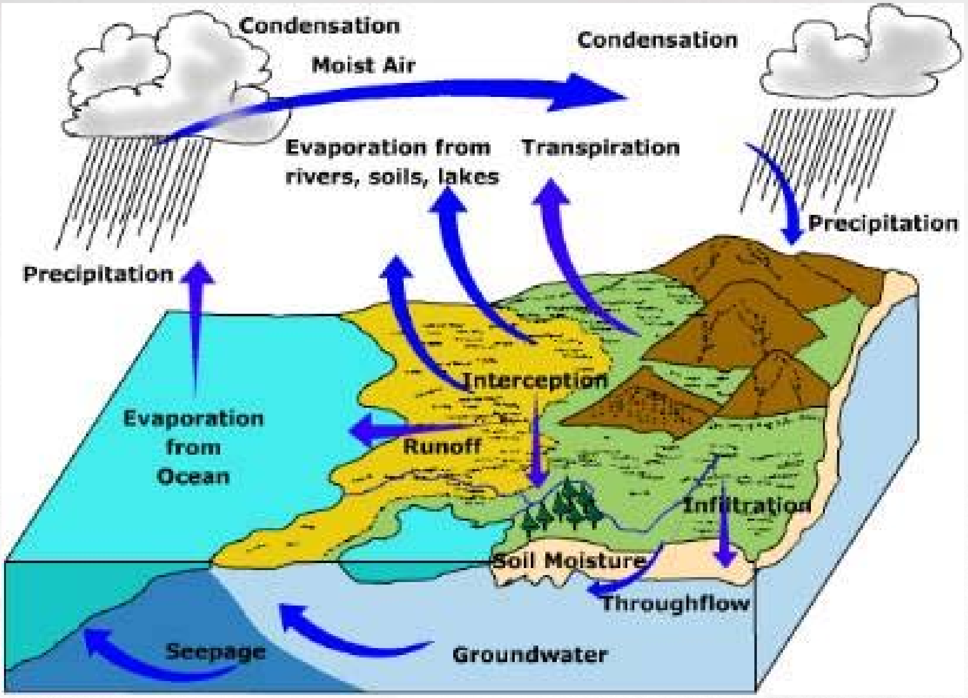
Hydrologic cycle and its modeling

- **atmosphere model:**
  cloud microphysics
  precipitation

- **land surface model:**
  soil moisture
  evapotranspiration
  interception
  snowmelt
  infiltration
  surface runoff
  subsurface runoff

- **hydrology model:**
  overland flow
  underground flow
  river discharge

- **ocean model**



- **available high-resolution datasets on:**
  topography
  land use, land cover
  soil types, soil texture
  vegetation cover

Hydrological models

- **statistical models** correlation between precipitation amount and river discharge
- **conceptual models** simple equations, lot of parameters that should be calibrated
- **physically based models** differential equations based on physical lows, but often oversimplified (kinematical approximation), fewer parameters for calibration

Hydrological model should:

- dynamically treat overland and underground flow
- be universal (easy to apply on any watershed, short and long term integrations)
- be a callable routine within an atmospheric model
- be computationally efficient

HYdrology PROgnostic Model

- **atmosphere:**

  NCEP's Numerical Mesoscale Model
  NMM-E non-hydrostatic model

- **land:**

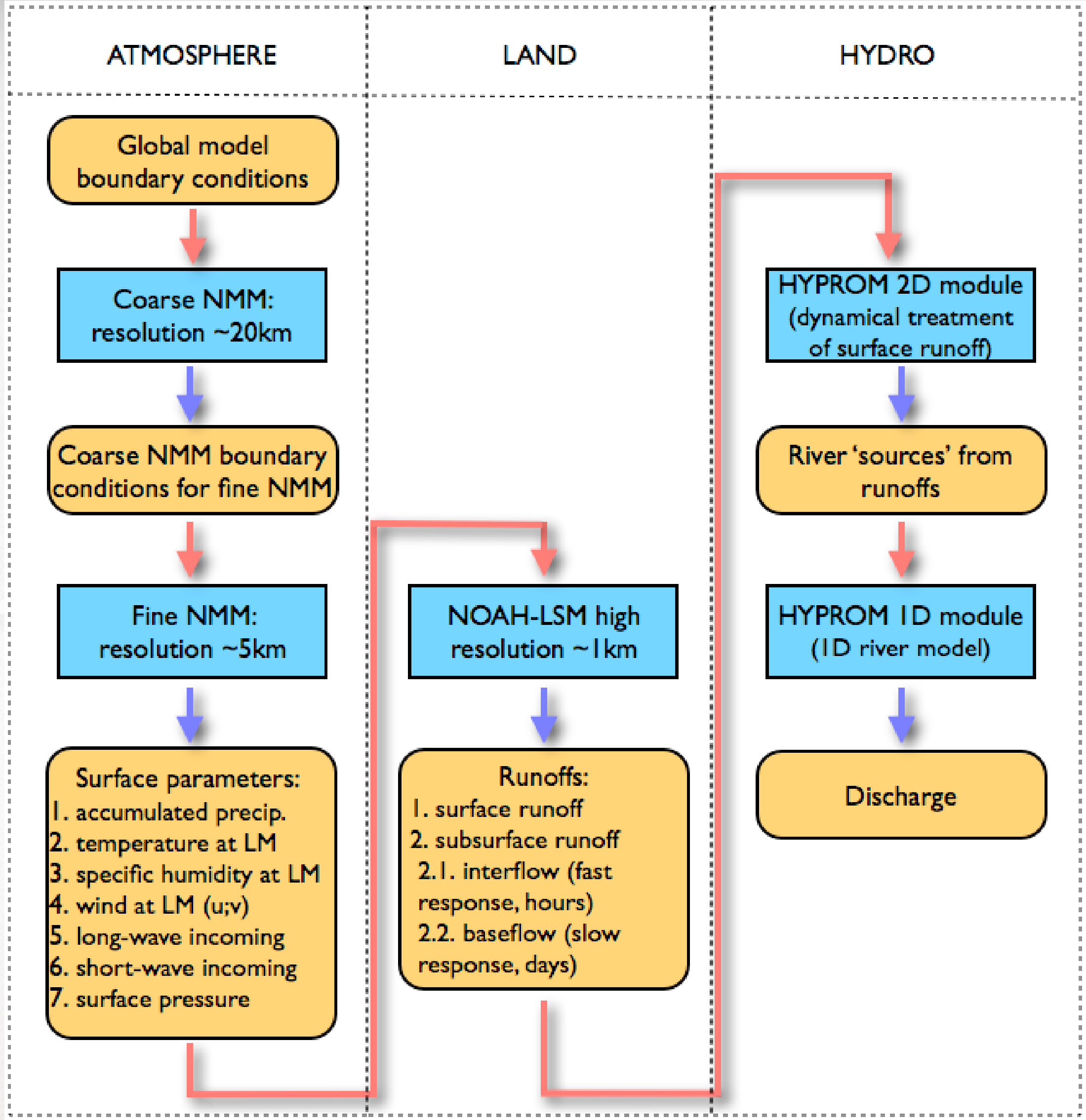
  NOAH land surface scheme

- **hydrology:**

  HYPROM2d: surface runoff
  HYPROM1d: river routing

- **datasets:**

  HYDRO1km USGS topography
  FAO soil texture data
  USGS landuse data



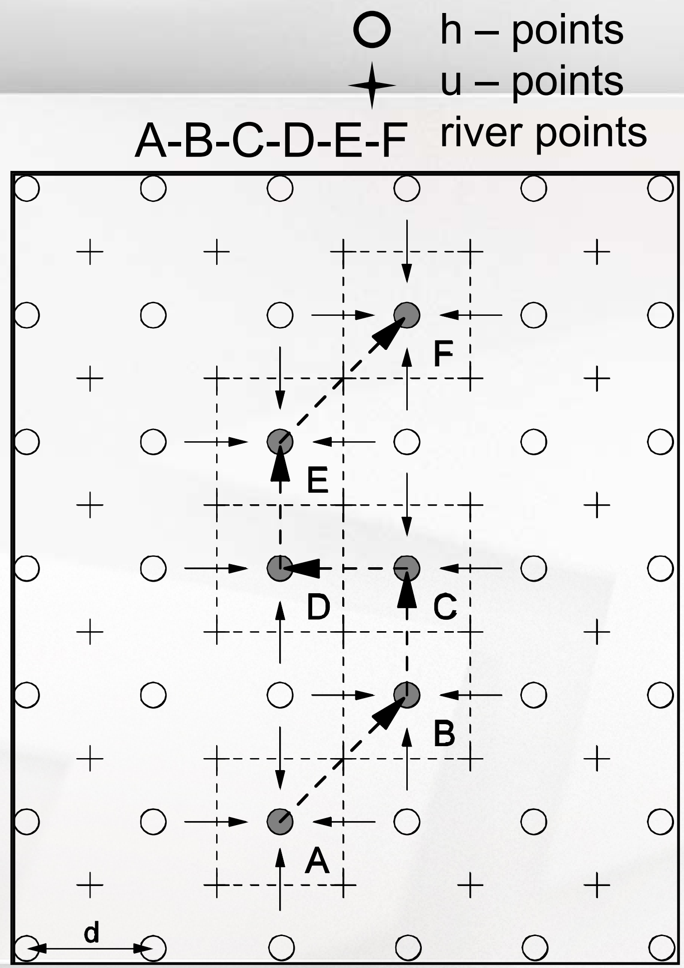
LM - lowest atmospheric model level

Governing equations:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+g\left[\frac{\partial h}{\partial x}+S_{fx}-S_{0x}\right]=0$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+g\left[\frac{\partial h}{\partial y}+S_{fy}-S_{0y}\right]=0$$

$$\frac{\partial h}{\partial t}+\frac{\partial (hu)}{\partial x}+\frac{\partial (hv)}{\partial y}+\dot{H}=0$$



- Dynamical treatment of overland flow (NO kinematical approximation!)
- Numerically stabile implicit time scheme for the friction term
- New numerical scheme for preventing grid decoupling noise
- Horizontal advection scheme is mass conserving and positive definite

- **Reference:**

Nickovic et al., 2010, HYPROM Hydrology Surface-Runoff Prognostic model, Water Resources Research, 46, W11506

LSM as a vertical hydrology component

Liquid water content forecast: Darcy's Law

$$\frac{\partial W_l}{\partial t} = \frac{\partial}{\partial z}\left(K_w \frac{\partial W_l}{\partial z} + \gamma_w \right) + R_{ex}$$

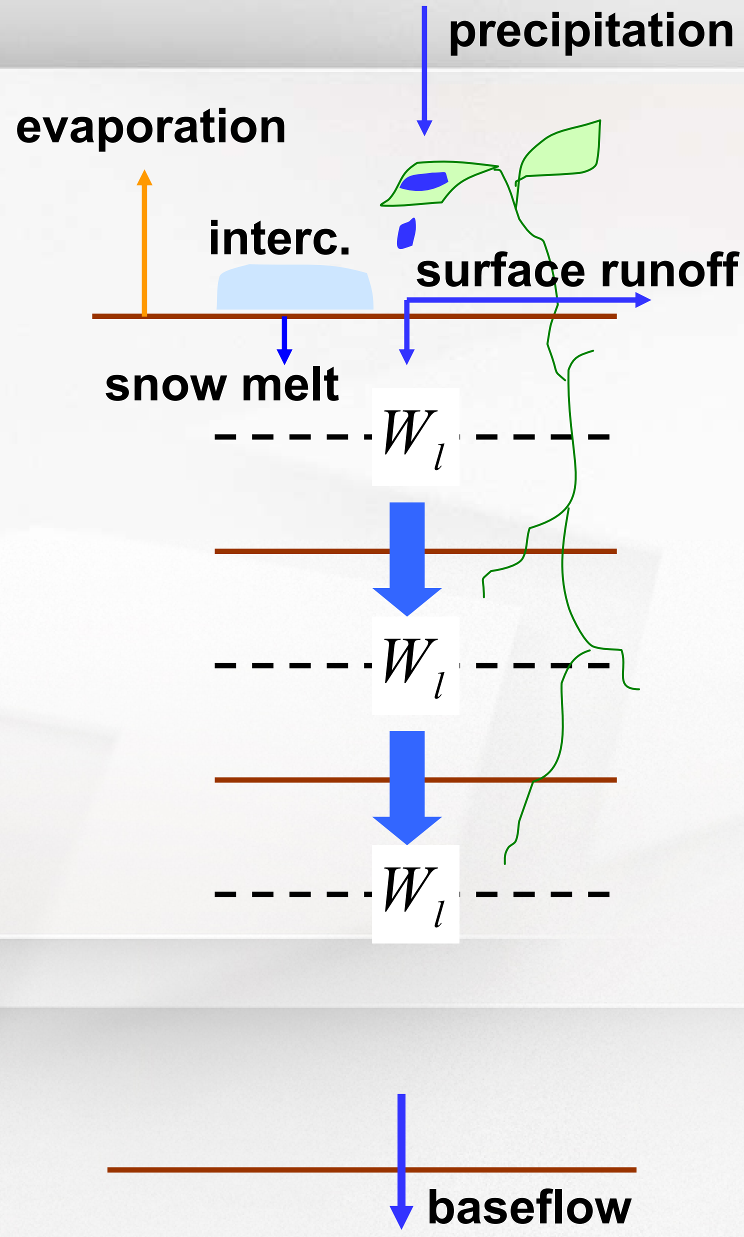
diffusivity

$$K_w = K_{ws}\left(\frac{W_l}{W_s}\right)^{b+2}$$

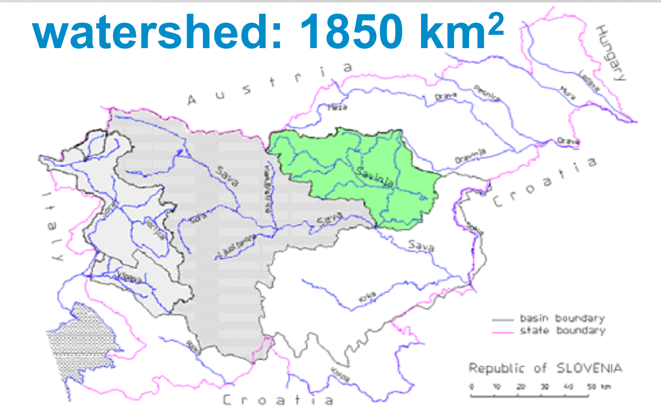
conductivity

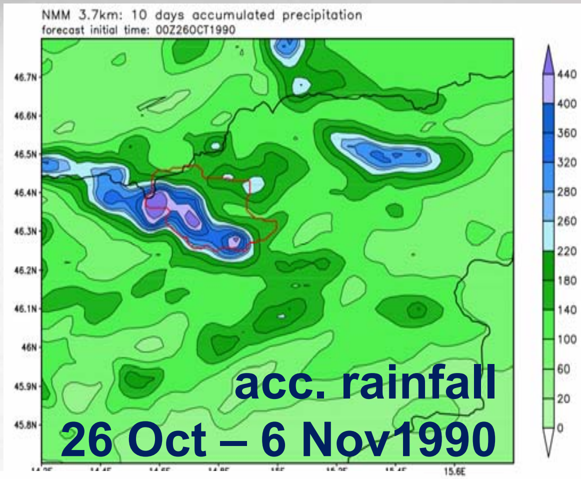
$$\gamma_w = \gamma_{ws}\left(\frac{W_l}{W_s}\right)^{2b+3}$$

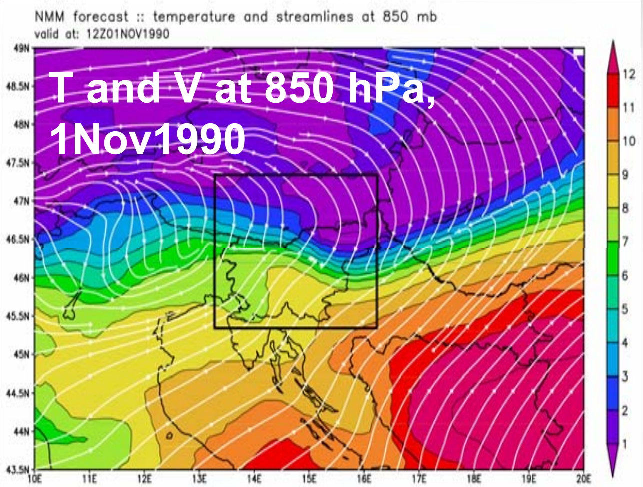
K_{ws}	saturated diffusivity
γ_{ws}	saturated conductivity
W_s	porosity (max. soil moisture content)
b	Clapp-Horneberger constant



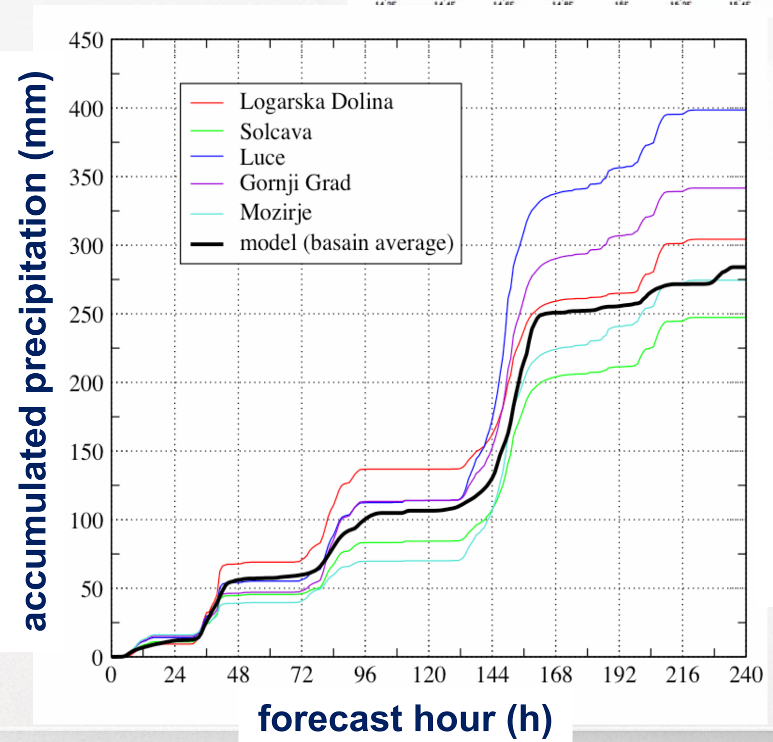
Case study: the Savinja river, flash flood event

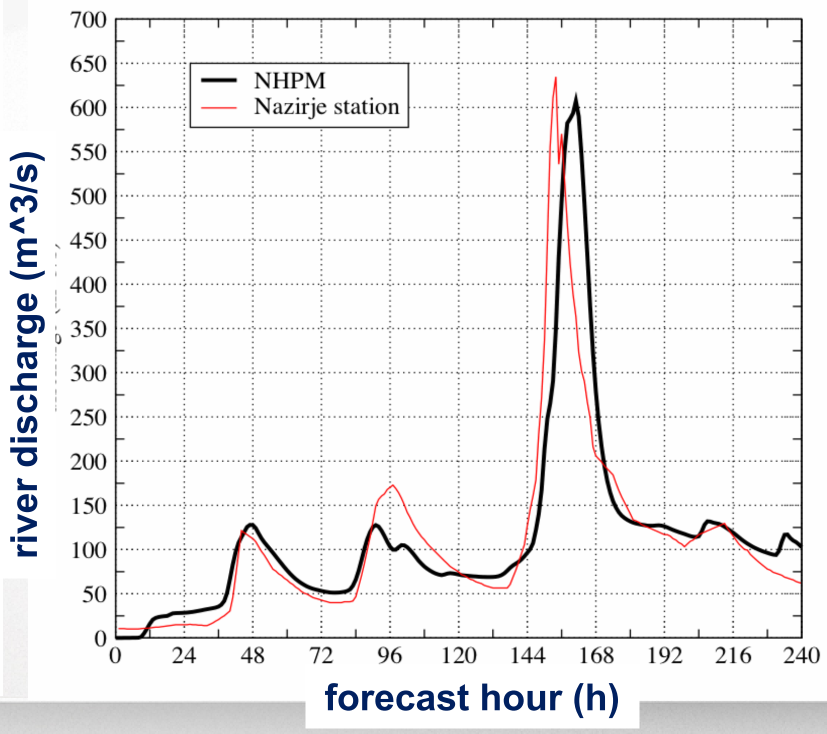




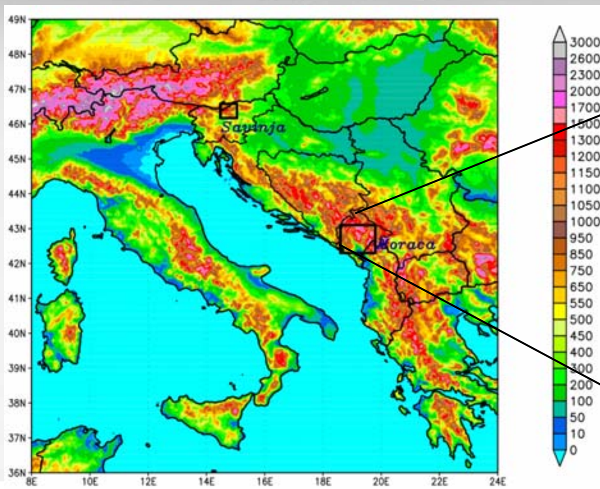


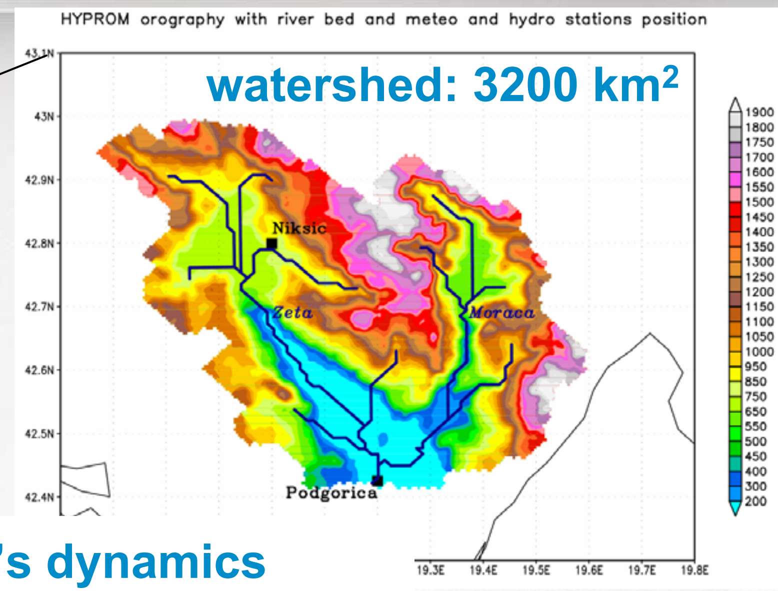
model .vs. observations





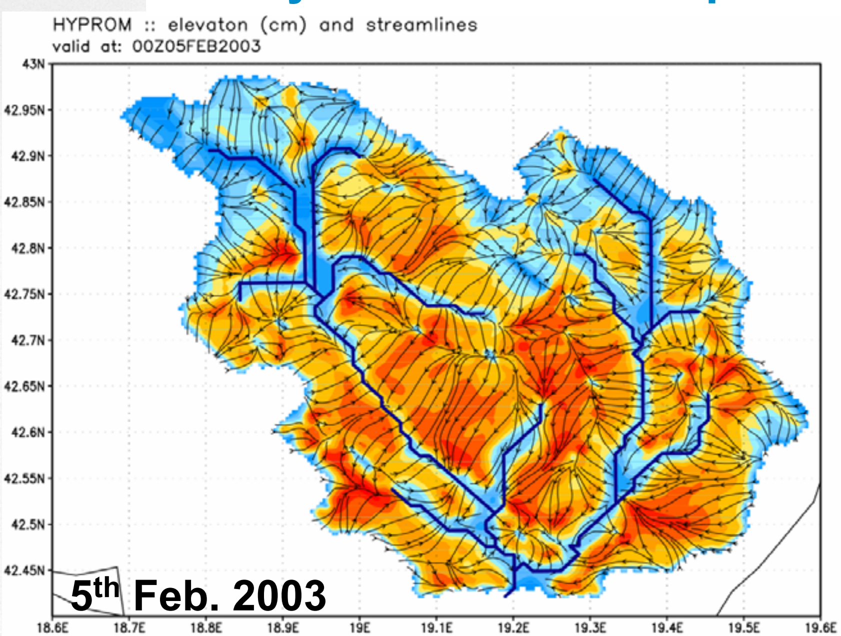
Case study: the Moraca river

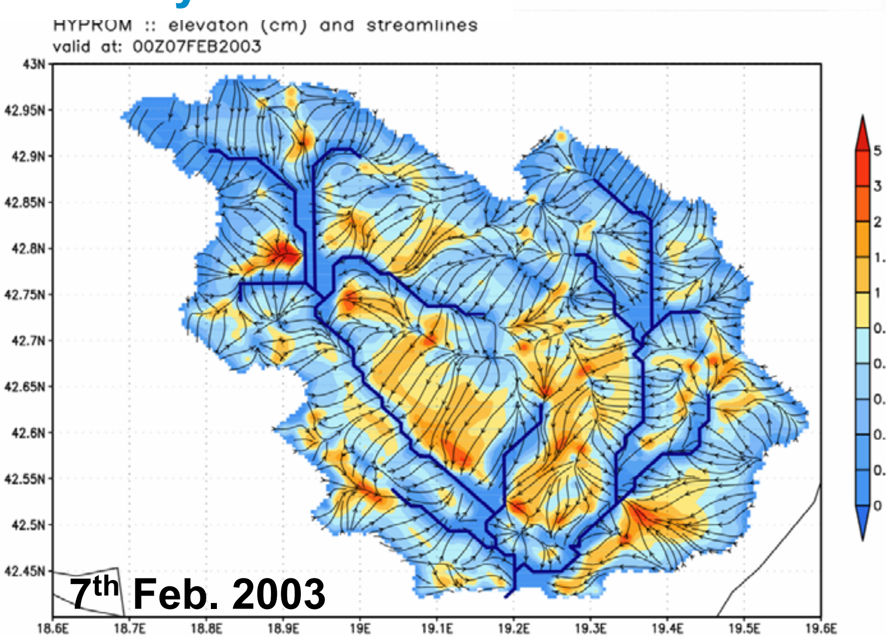




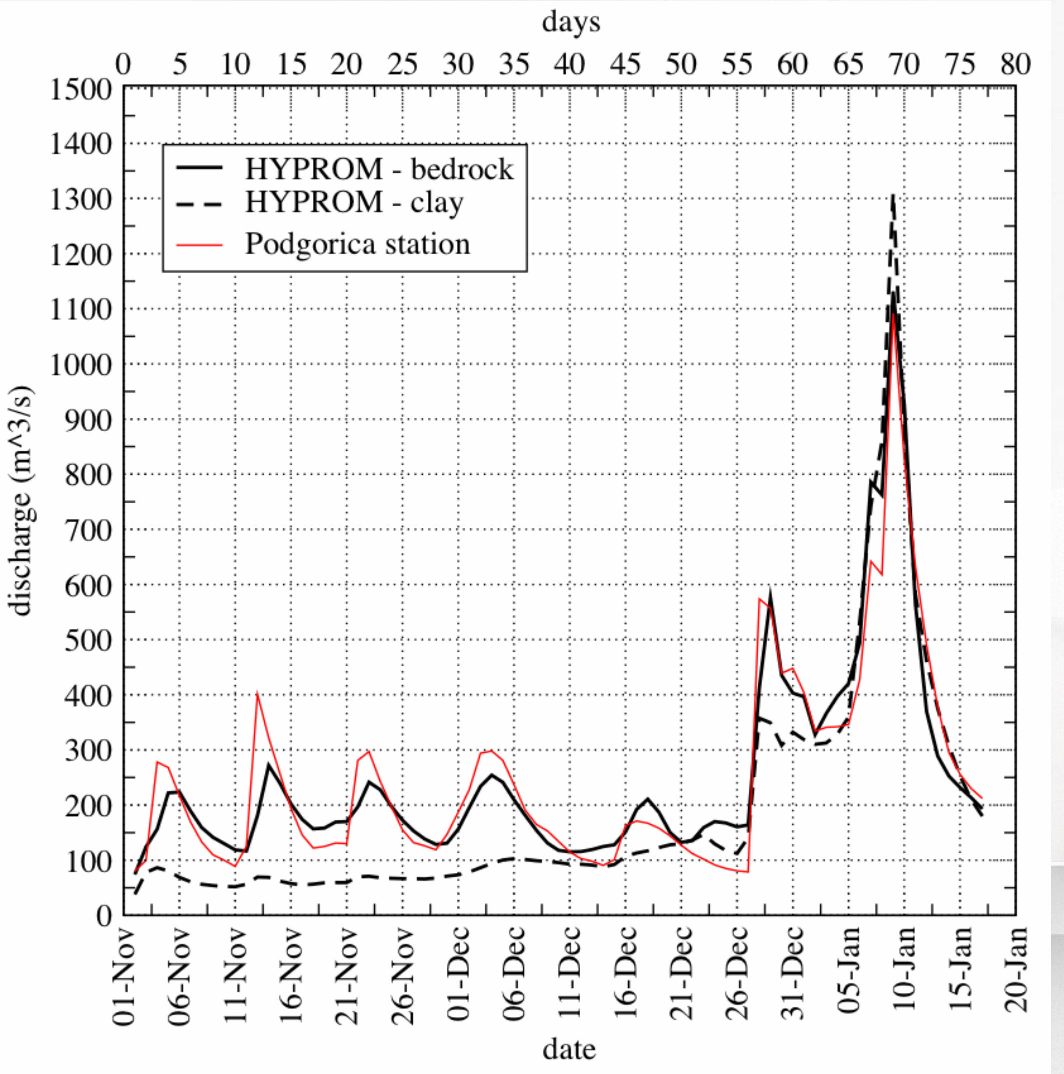
heavy rain event: example of model's dynamics

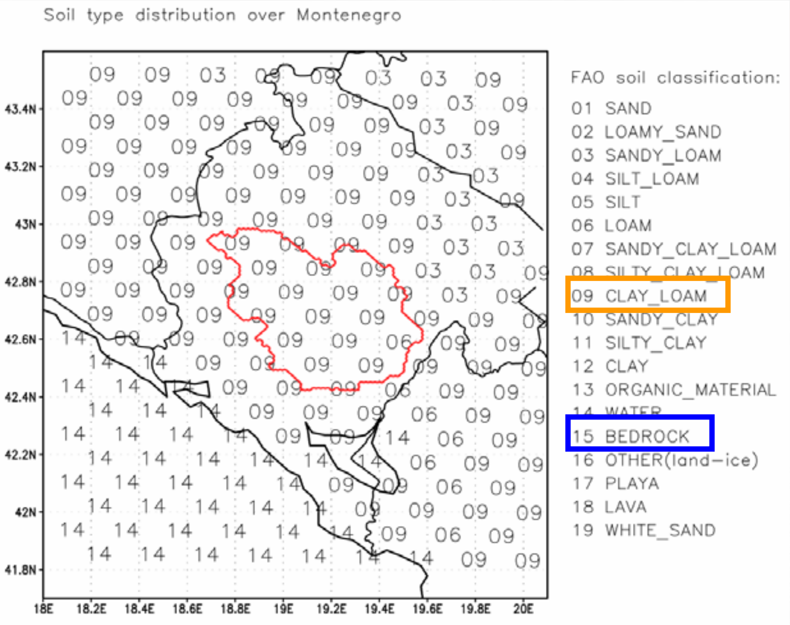
surface runoff and streamlines





River discharge sensitivity to soil types

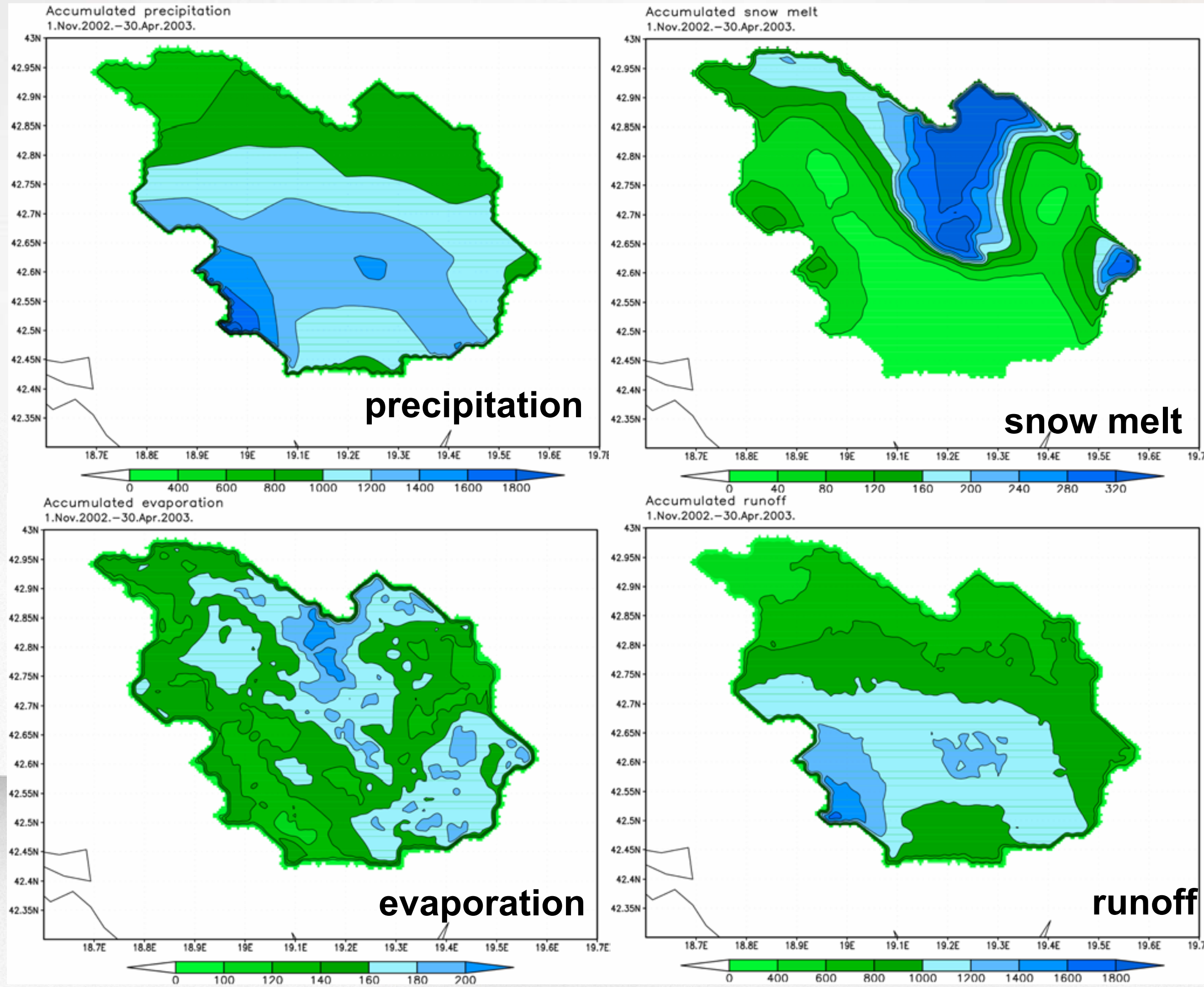




parameter	Clay Loam (09)	Bedrock (15)
sat. diffusivity	0.113×10^{-4}	0.136×10^{-3}
sat. conductivity	2.45×10^{-6}	1.41×10^{-4}
porosity	0.465	0.20
CH constant	8.17	2.79

Water budget components: six months accumulations

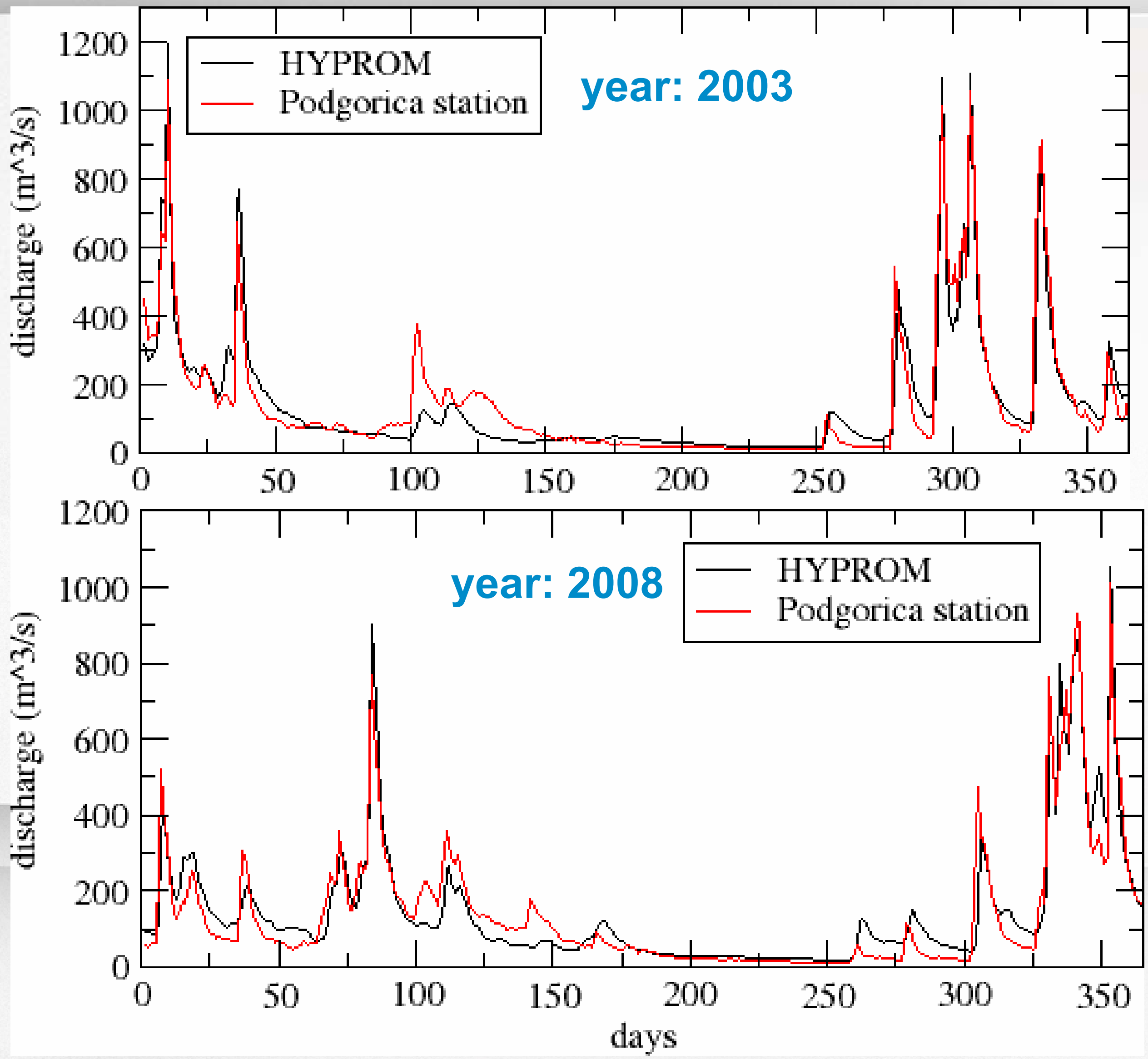
November 2002 – April 2003



One year runs: river discharge

BIAS: - 2.43
MAE: 35.48
RMSE: 55.48
CC: 0.94
FEC: 0.87

model .vs. observations



Case study: the Skadar lake, climate simulations

the Skadar lake watershed: 5180 km²

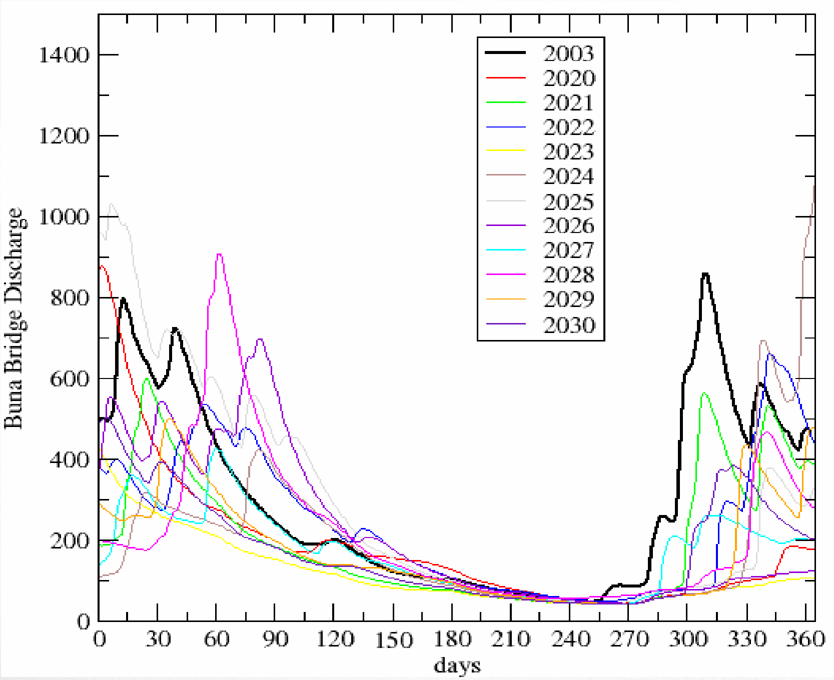
RCM-SEEVCCC: resolution ~35km, A1B SRES/IPCC scenario

NMM-E nesting: resolution ~8km

control year: 2003

simulation: 2020 - 2030

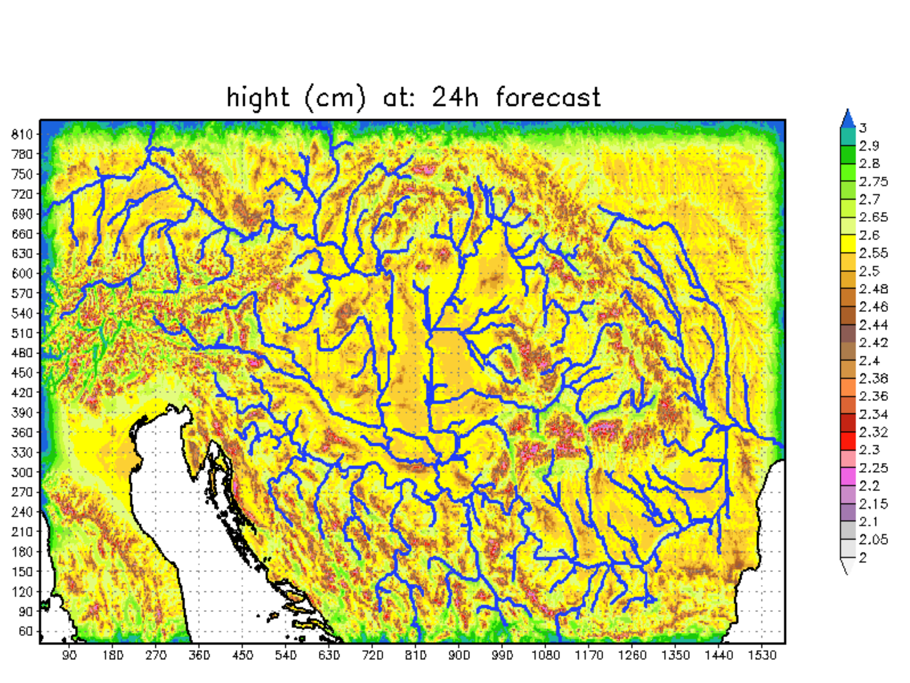
modeled river discharge on the Bojana river



HYPROM conclusions:

- Dynamical treatment of overland flow
- Suitable for long term and flash flood simulations
- Applicative to small and large watersheds
- Off-line and on-line mode
- No calibration needed
- Computationally efficient

- Couple with NMM-B + LISS
- Dynamical treatment of subsurface flow (if possible)



HYPROM example for the Danube watershed

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