Republic Hydrometeorological Service of Serbia
(establishted 1888, WMO member since 1947)

SEE VCCC

NMM model as a driver for aerosol and hydrology modelling

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(host of the South East Euro Virtual Climate Change Centre – SEEVCCC)

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Modelling concepts at RHMSS, Serbia

- **Model-integrations concept**
  - Atmospheric NMMB(or E): the major driver for other Earth system models (ocean, aerosol, hydrology, soil, ...)
  - 1-way or 2-way interactions
- **Seamless prediction concept**
  - Follows WMO WWRP-WCRP recomendations (use same model for different scales)
  - Accepted for SEEVCCC -> SEECOP transition

2007 Seamless transition **2016**

SEE VCCC

SEECOP

South East European Centre for Climate Change

(SEEVCCC)

- Regional climate modelling
- Global and regional NMM
- Use for monthly/seasonal predictions and climate assessments in the region

The South East European Consortium for Operational weather Prediction (SEECOP)

- Mesoscale to local NWP
- Global/regional/local chain based on NMMB

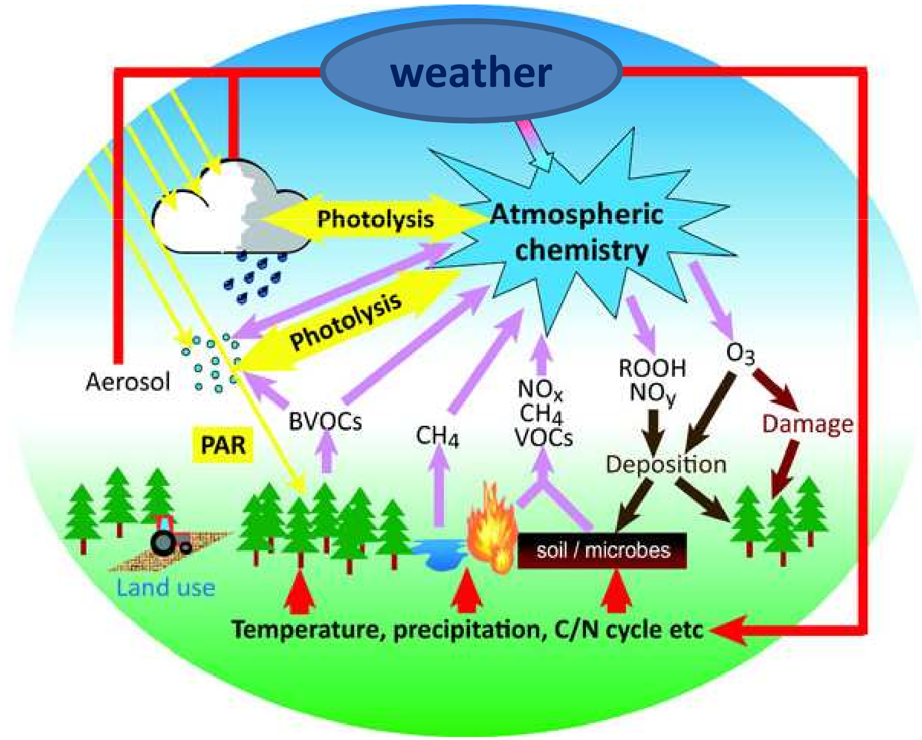
Major model feedbacks under development at RHMSS

- **Aerosol-atmosphere interactions**
  - Cloud-aerosol interactions (indirect aerosol effects)
  - 2-way integration

- **Hydrological-meteorological interactions**
  - One-way forcing
  - Two-way interactions

Aerosols in clouds

- **MACC – an example of chemical weather forecast**
  - Intention to improve NWP by adding atm. composition
  - Concept of online running atmospheric and composition
  -
- **<u>Cold clouds</u> – especially poorly described in NWP. Why?**
  - Ice nucleation (IN) concentration prescribed as a constant
  - Till recently – unknown which aerosol types are critical for IN
  - Missing aerosol-atmospheric operational models

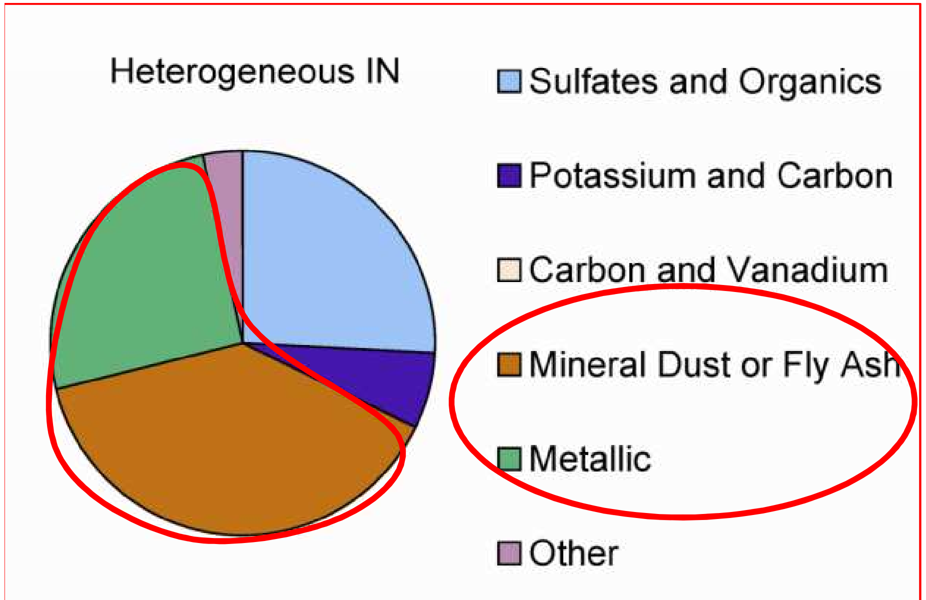


Adaptred from http://www.metoffice.gov.uk

What dust does to cold clouds??

Breakthrough in understanding the role of dust in IN process

- **Cziczo et al., Science (2013)**
  - Heterogeneous IN dominant (95%)
  - Dust in 2/3 ice crystals
  - Sampling done 1000-s km far from dust sources
- **Atkinson et al, Nature (2013)**
  - Some minerals in dust (feldspar) - orders of magnitude more efficient than others
- **Opportunity now to exploit this findings in NWP**



Cziczo et al, 2013, Science

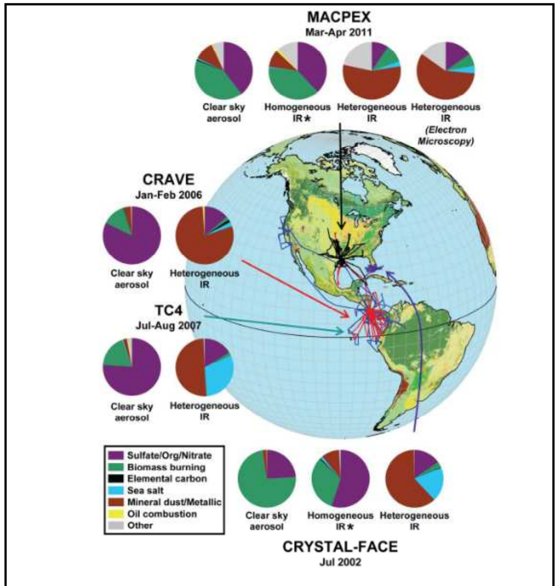


Fig. 1. Flight tracks of ice cloud residual measurements for four aircraft campaigns spanning a range of geographic regions and seasons. The composition of cirrus ice residuals and near-cloud

IN concentration due to dust (n_{IN}) in cloud schemes

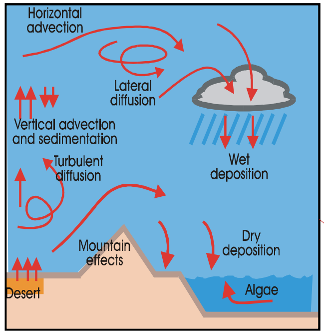
- Typical today's cloud schemes use:
  - $n_{IN} = const$ or
  - n_{IN} = climatology

$$n_{IN} = const$$

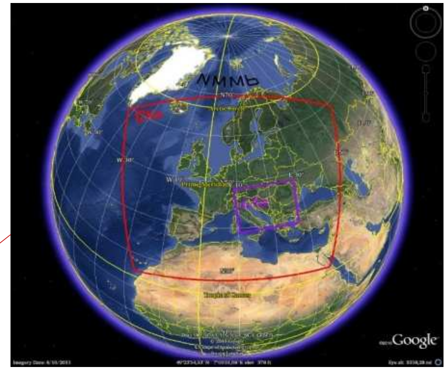
$$\frac{\partial N_{ice}}{\partial t} = \ldots - \frac{N_c(n_{IN})}{q_{ice}} ICE$$

$$\frac{\partial q_{ice}}{\partial t} = \ldots - f(ICE)$$

‘Cooking’ cold clouds: our recipe



DREAM model



NMM model

Dust C

T, RH

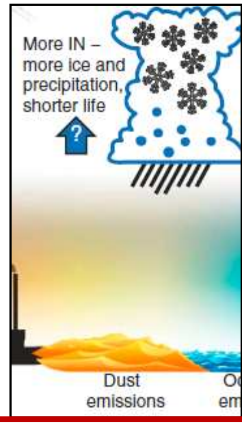
DeMott (2015) [-35°C <T<-5°C]

$$n_{IN} = C(n_{dust})^{(\alpha(273.16-T)+\beta)} \exp^{(\gamma(273.16-T)+\delta)}$$

Steinke et al (2015) [-55°C <T<-35°C]

$$n_{IN} = S_{dust} 1.88 \cdot 10^{5} e^{-pT+q(RH_{ice}-100\%)}$$

n_{IN}



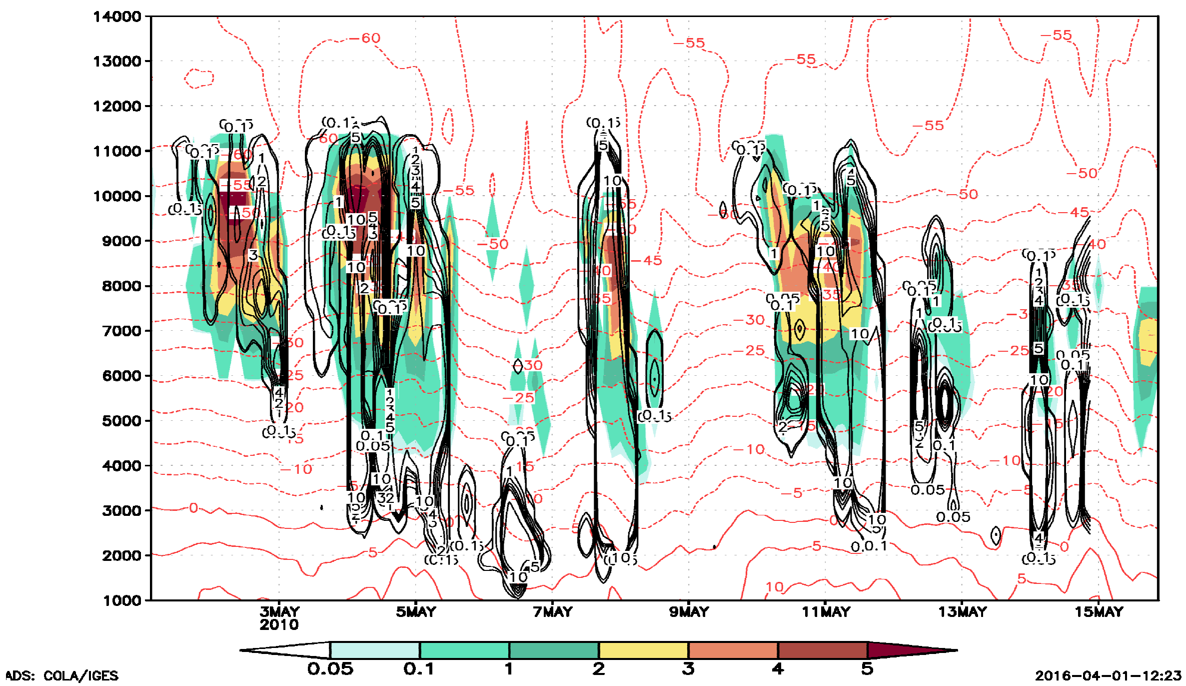
NMMB Thompson dust-friendly cold cloud micrphysics

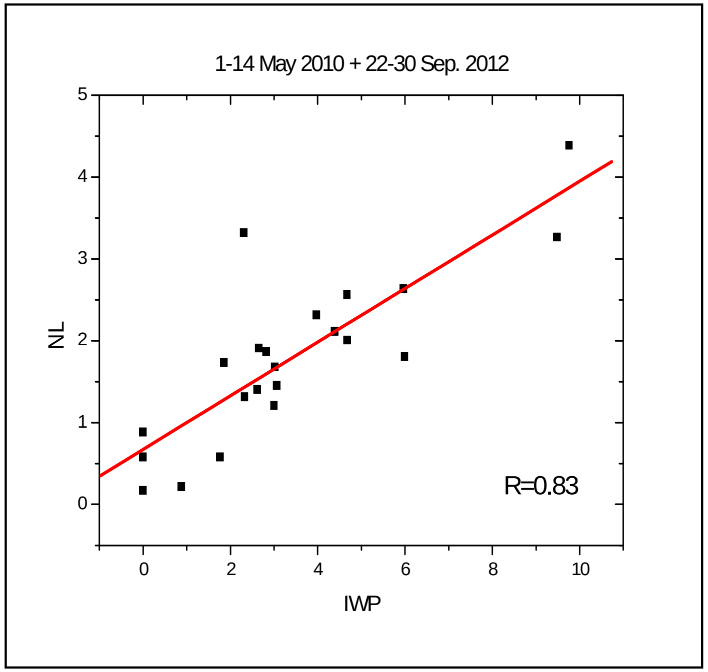
Nickovic et al, 2016, Atmos. Chem. Phys., 16, 11367–11378

Validating #IN parameterization

- **Model runs:** **May 2010 and Sep 2012**

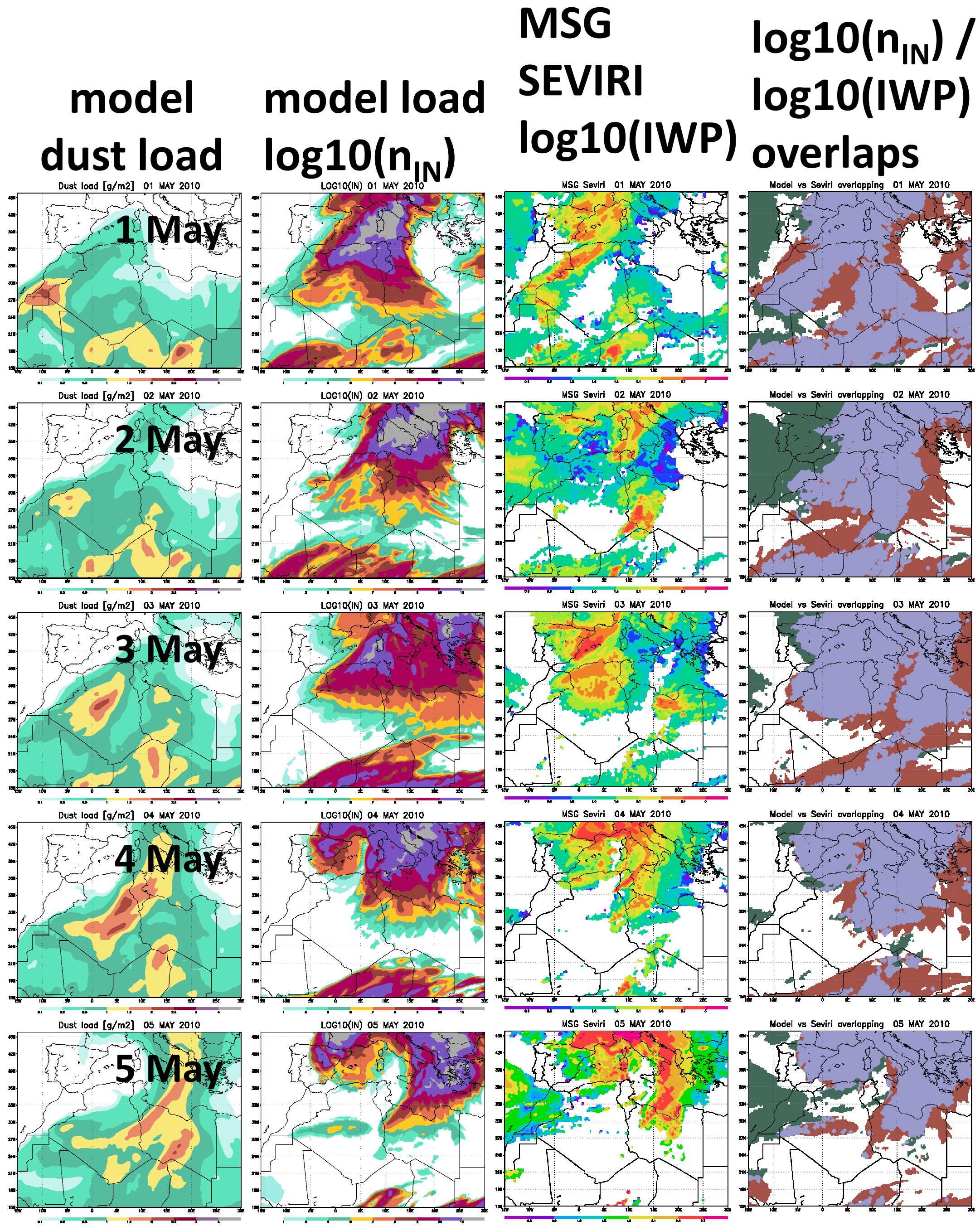
Model vs. Cloud radar/lidar Ice Water Content (IWC) observations (Potenza)





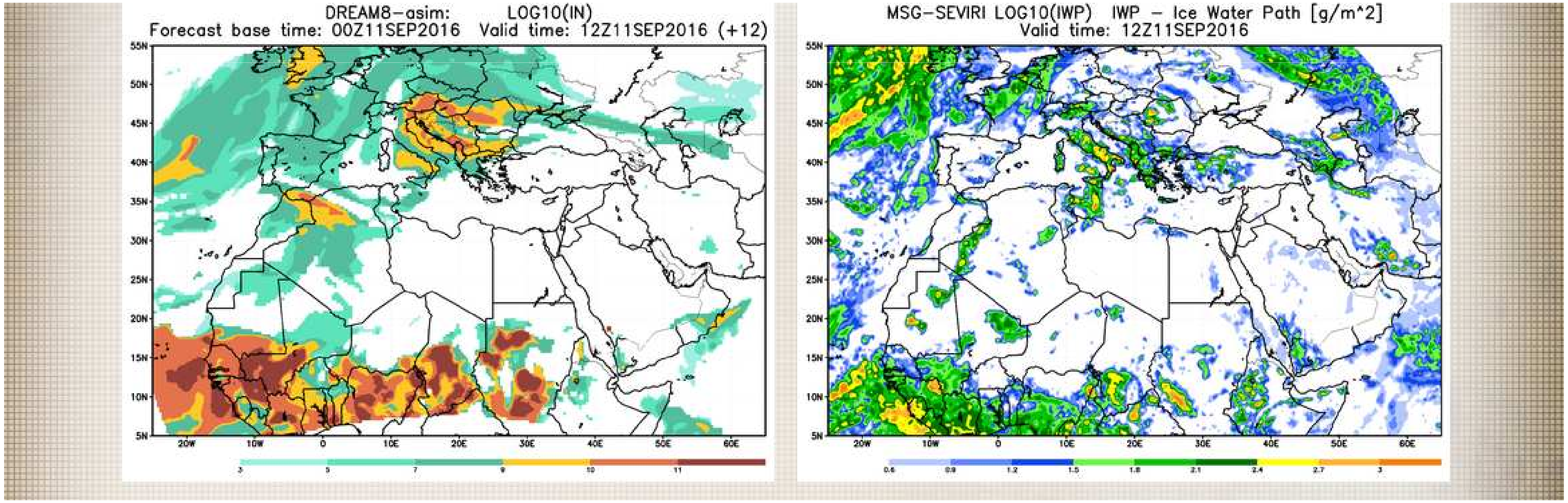
Nickovic et al, 2016, Atmos. Chem. Phys., 16, 11367–11378

Model vs. MSG SEVIRI Ice Water Path



Daily #IN maps at

http://dream.ipb.ac.rs/ice_nucleation_forecast.html



NWP groups interested to use daily #IN forecasts will soon have it available through the WMO SDS-WAS (dust) project

Integrated dynamic hydrology

- Most of todays distributed hydrology models use Manning-like approximation
  - u,v – diagnostic; h- prognostic
  - ➔ losing part of the dynamics

- Hydrology Prognostic Model (HYPROM)* of the RHMSS instead predicts u,v,h simultaneously

* Nickovic et al, 2011

HYPROM governing equations

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

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

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

Friction slope terms

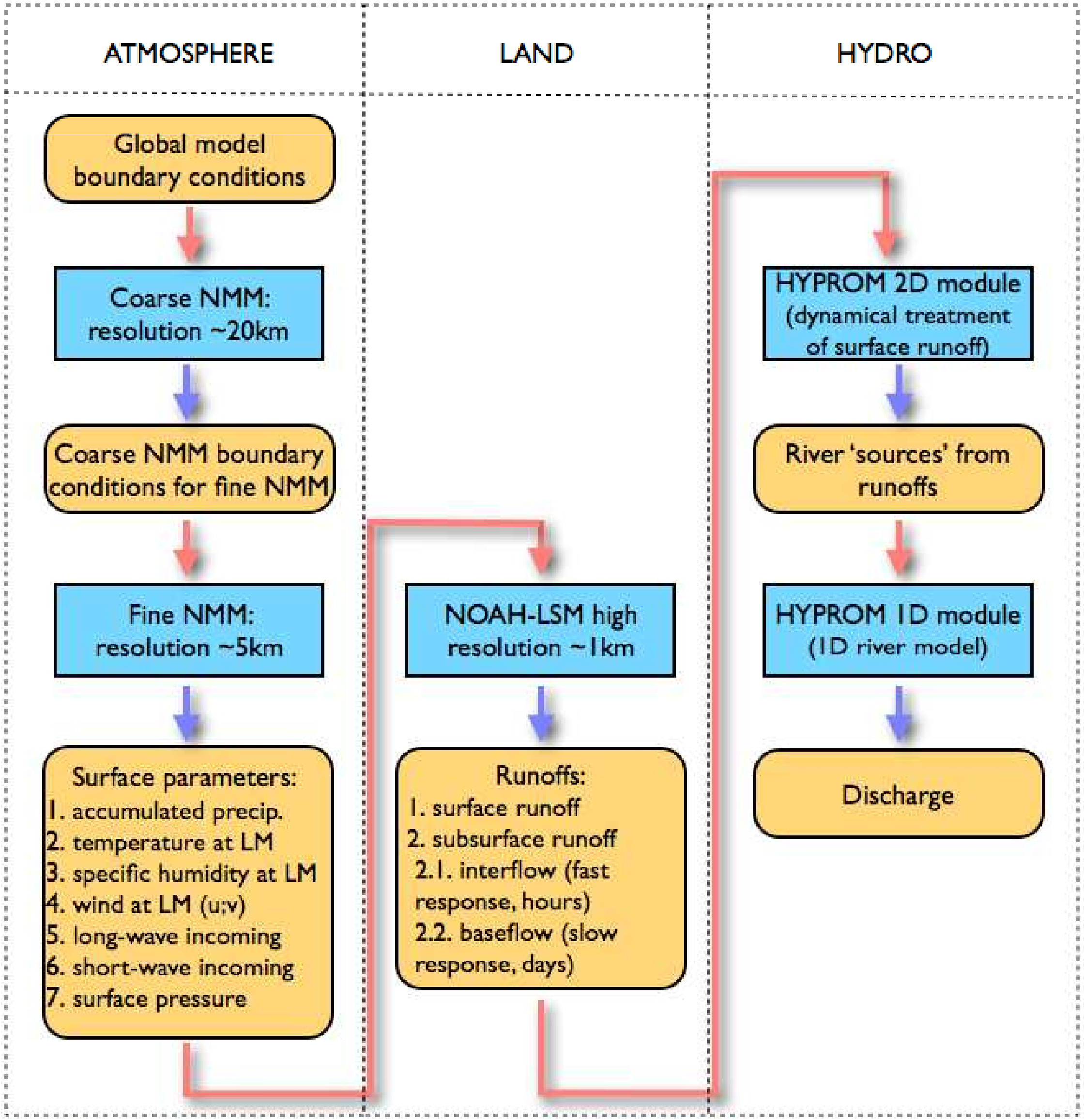
$$S_{fx}=\frac{n^2u\sqrt{u^2+v^2}}{h^{4/3}}$$

$$S_{fy}=\frac{n^2v\sqrt{u^2+v^2}}{h^{4/3}}$$

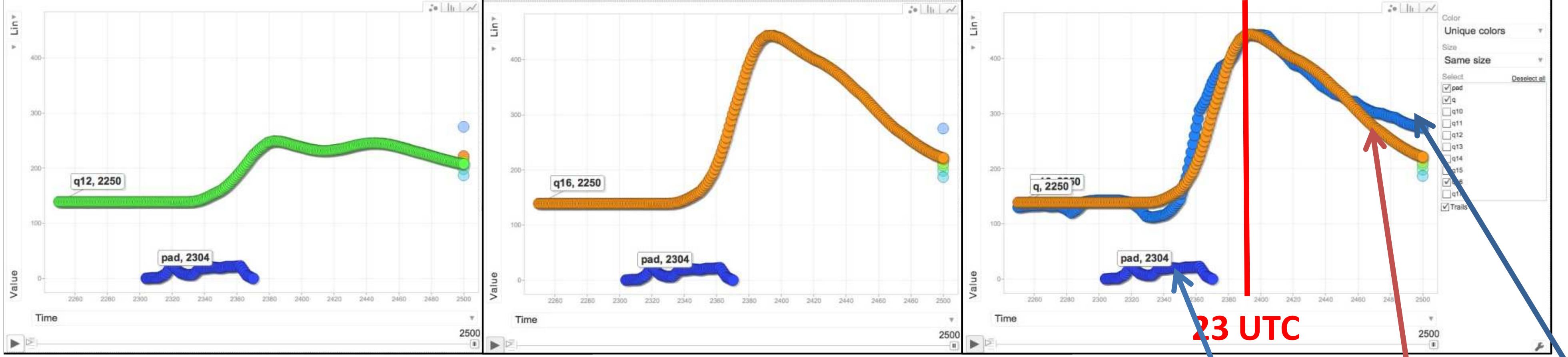
$$\boxed{}=0$$

Kinematic approximation
neglects inertia forces !! which we want to avoid

HYPROM integrated with the NCEP/NMM atmospheric model



LM - lowest atmospheric model level



12UTC 14UTC 16UTC

S. Morava River flash flood case

23 Jan 2015

disasterous consequences

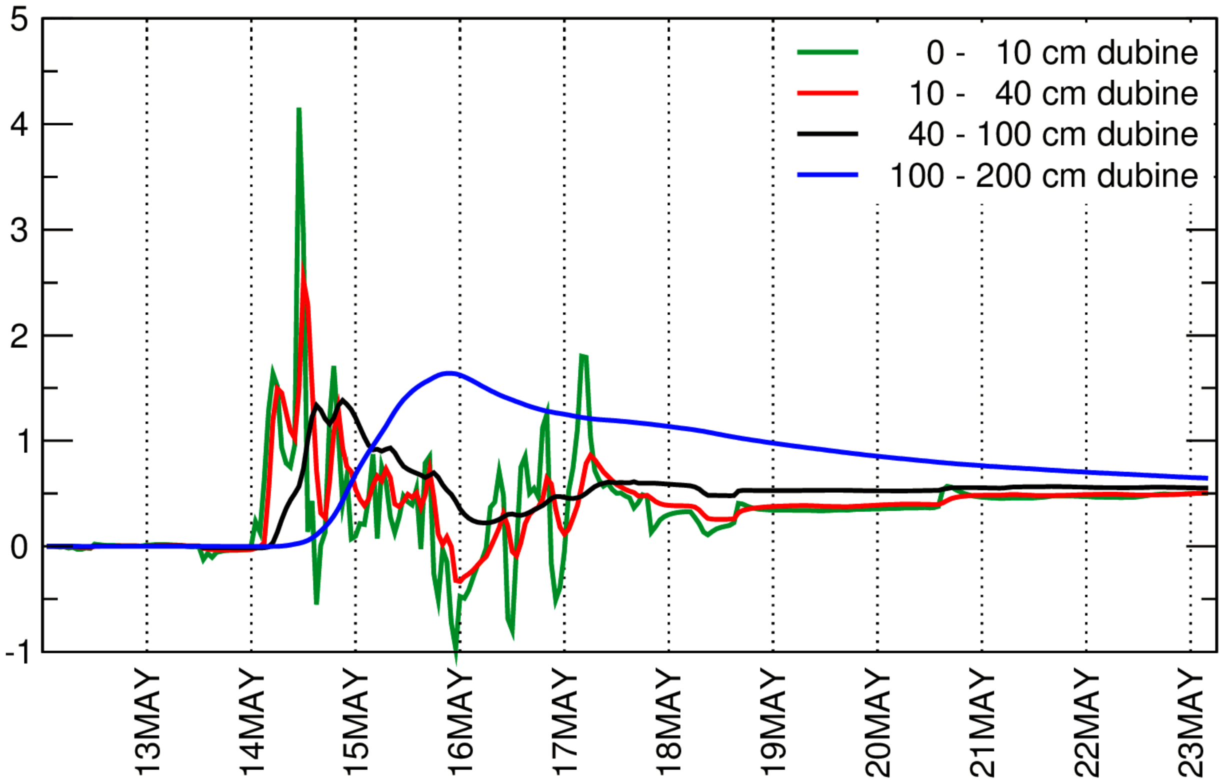
HYPROM run

Driven by radar precipitation

Predicted correctly the max discharge 7 hours in advance

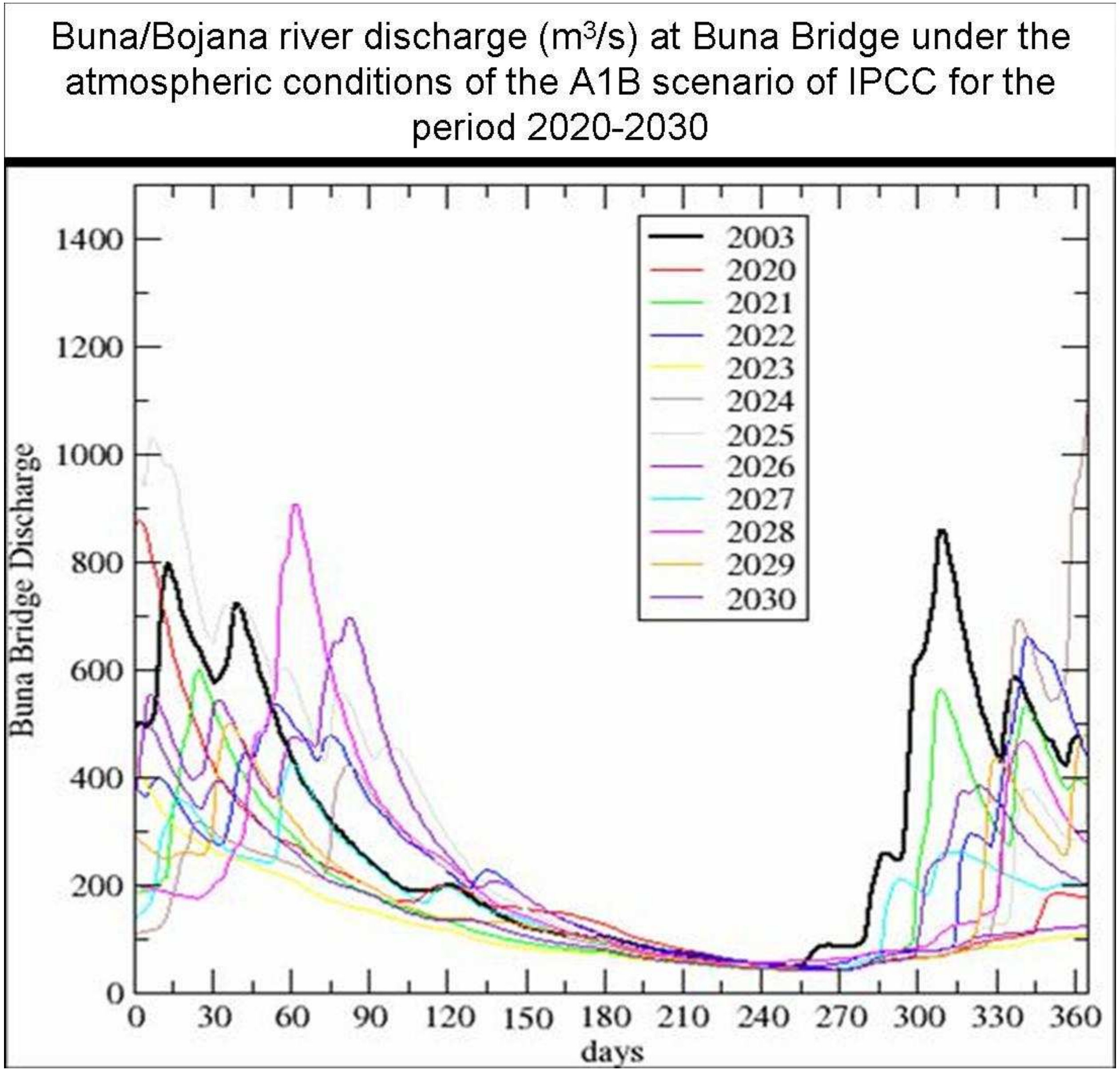
Most recent developments

- HYPROM dynamics has been fully coupled with the NCEP/NMMB non-hydrostatic atmospheric model
- a two-way interaction (atmosphere-hydrology feedbacks) *(Vujadinovic-Mandic, 2015; PhD Thesis)*



Volumetric soil moisture difference ctrl-feedback exp at 4 model soil levels

HYPROM and climate/seasonal assessments



Djurdjevic et al, 2011