Towards hydrometeorological forecast systems

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Background

The inspiration for this presentation comes from a Workshop arranged December 2015 in Lillehammer, Norway, hosted by MetNorway, UiO and NVE:

http://www4.nve.no/no/arrangementer/HYDMET-Seminar-9-10122015-in-Lillehammer/

Improving forecast skill

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Resolution

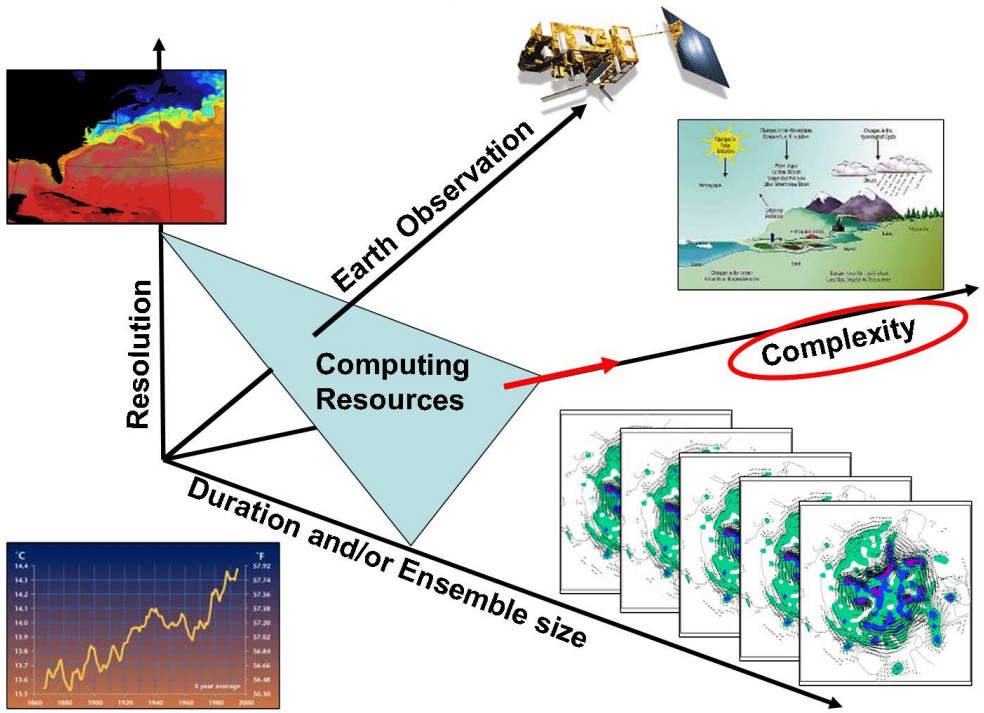
Increase resolution

Uncertainty

Use of earth observations
Increase ensemble size

Complexity

Increased complexity has been
less explored to increase skill at shorter lead-time.
E.g. through coupling of different components, like
hydrology/routing, within the same forecast system.
The UK Environmental Prediction project focuses on this.



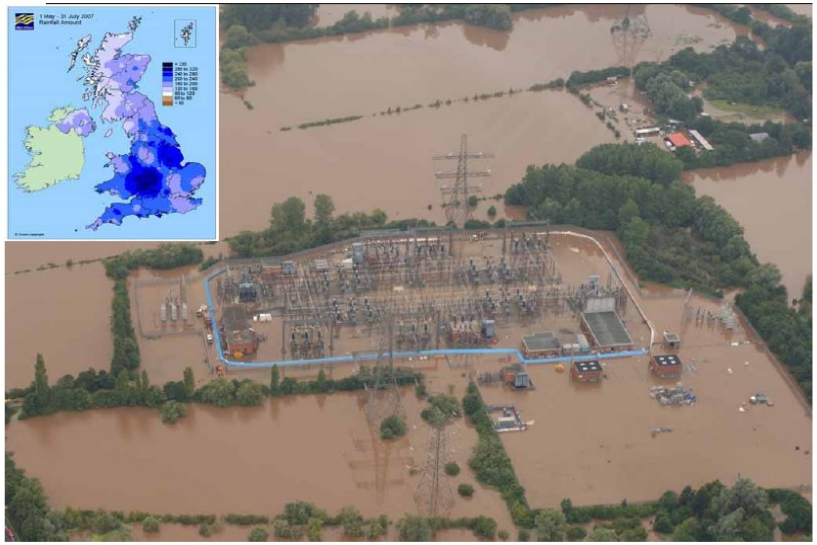
Met Office
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL
National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL
PML Plymouth Marine Laboratory

Extreme events - flooding

UK 2007

Drivers and Formation of the FFC - Summer Floods 2007

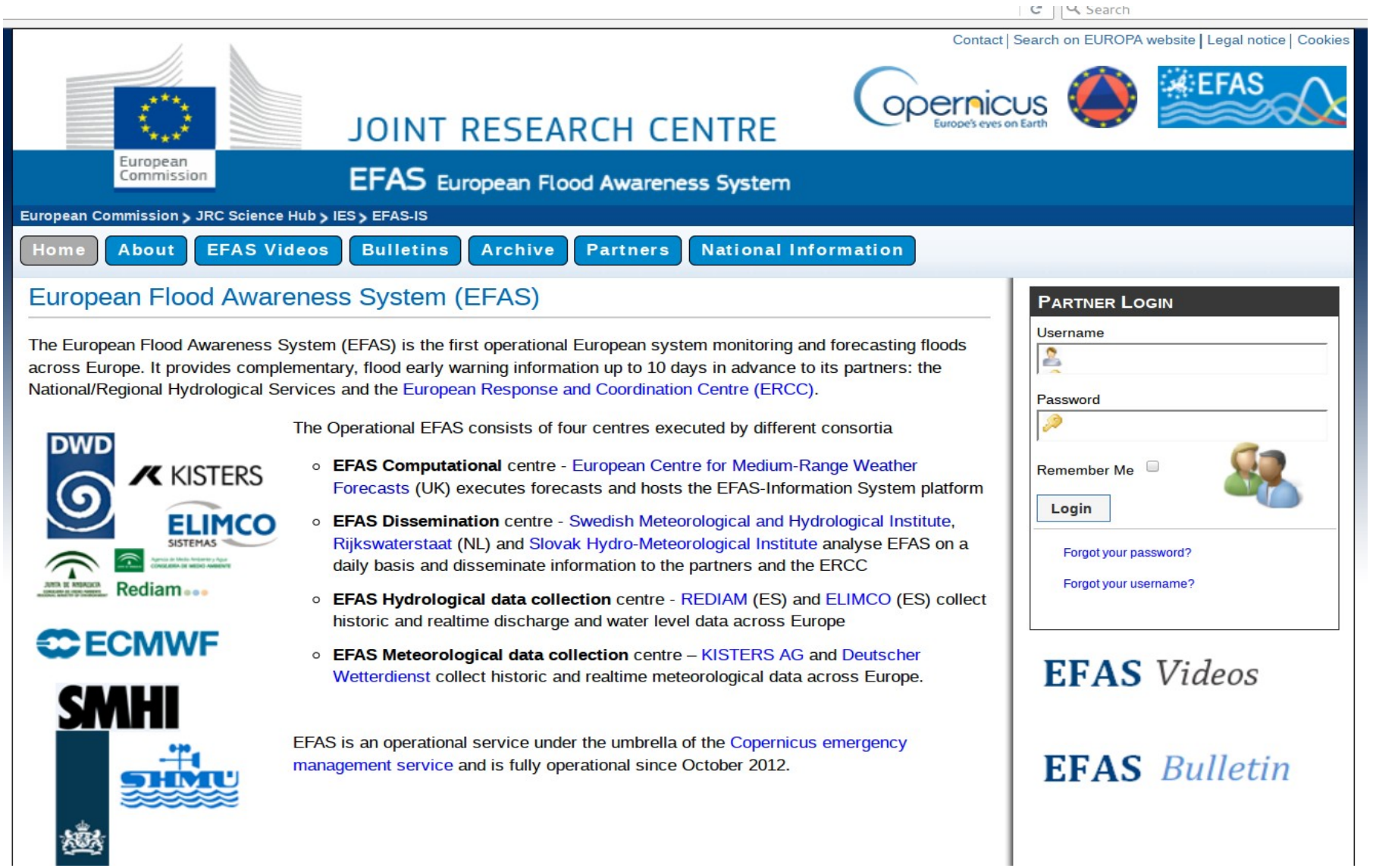
FLOODFORECASTINGCENTRE
a working partnership between Environment Agency | Met Office



Norway 2011 & 2013

Foto: Torbjørn Olsen/Gudbrandsdølen

European Flood Awareness System EFAS



European Flood Awareness System EFAS

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Early probabilistic flood warnings across Europe

Transboundary

50 partners

Partners provide:
- Observations
- Feedback on warning performance
- Development of decisions

EFAS has the largest collection of hydro-meteorological observations in Europe!

European Flood Awareness System EFAS

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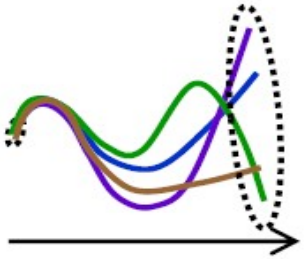
Forecasting chain

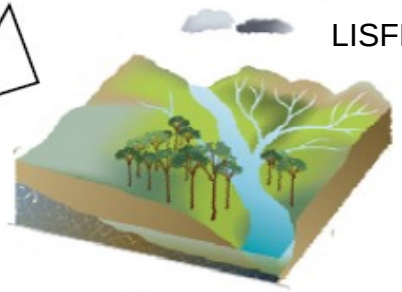


ECMWF
COSMO

EPS

Preprocessing/
calibration

Hydrology



LISFLOOD

Feedback to
the model

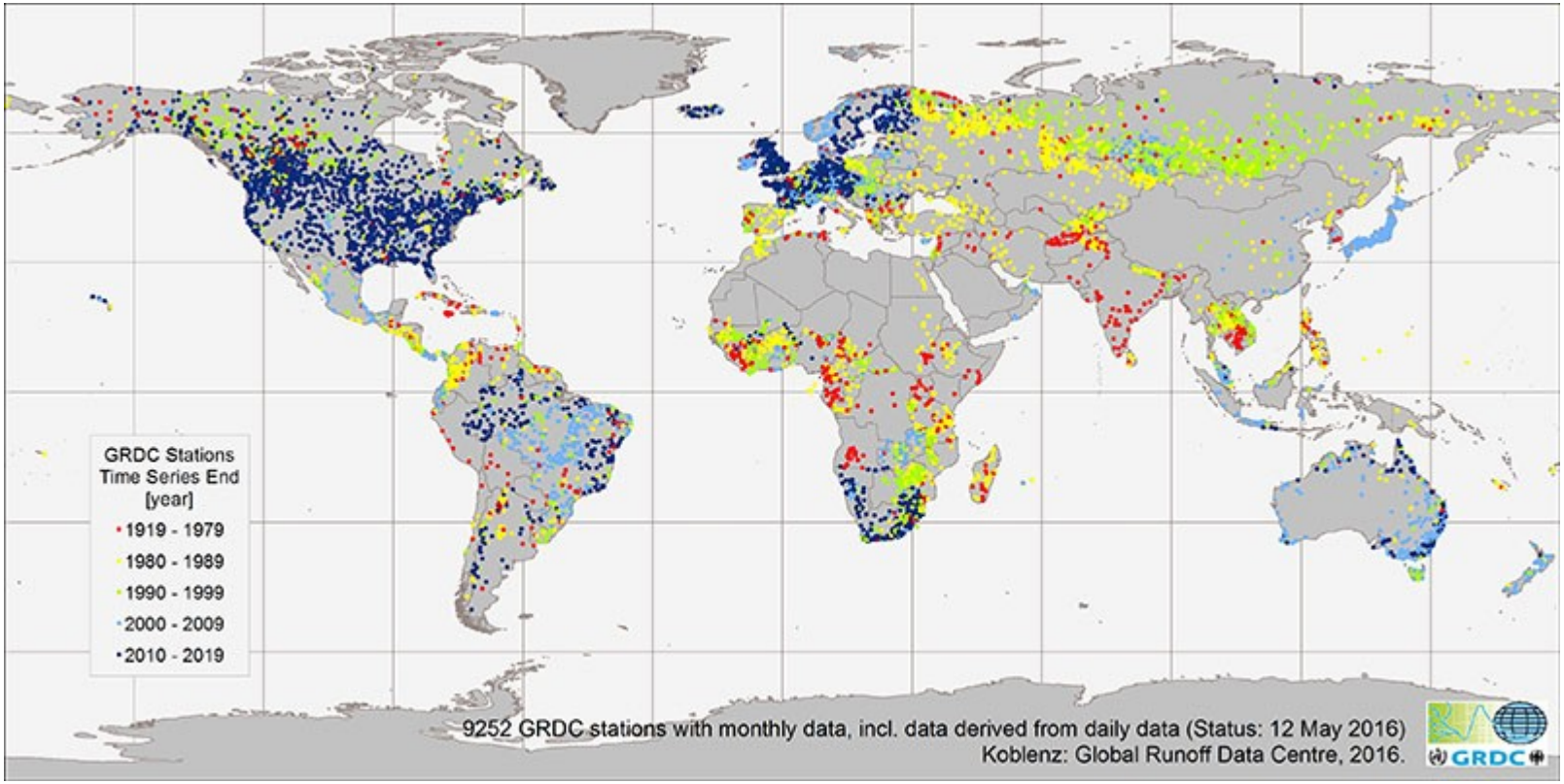
Postprocessing

Warning

Verification

Observed stream flow data...

...is heavily used for calibration of hydrology models. Also used for assimilation. But coverage of data is limited in space!



http://www.bafg.de/GRDC/EN/Home/homepage_node.html

European Flood Awareness System EFAS

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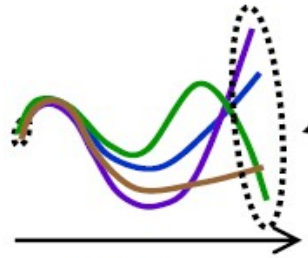
Forecasting chain in future EFAS



EPS

Multimodel

Hydrology

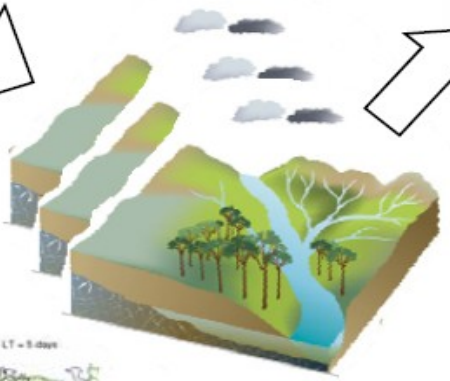
Hydraulics

SENTINEL 3

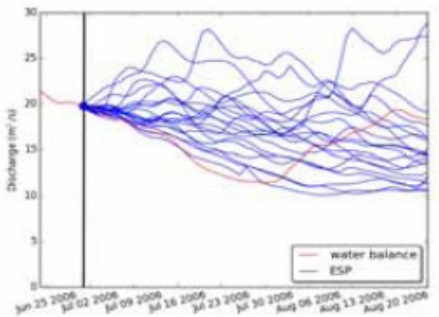
Assimilation

S2S

Preprocessing/
calibration



Feedback to
the model



Postprocessing

Verification

Warning

Remote sensing products for hydrology

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- **Altimetric data for water levels in rivers and lakes**

  satellite/instrument examples in literature: ENVISAT/RA-2, ERS-2/RA, TOPEX-Poseidon/NRA, SWOT/Altimeter

- **Satellite imagery data to map river/lake extent**

  satellite/instrument examples in literature: ENVISAT/ASAR, ERS-2/AMI-SAR, Aqua/AMSR-E, TRMM/VIRS

Use of these data requires information of river dimensions for the hydraulic modelling.

European Flood Awareness System EFAS

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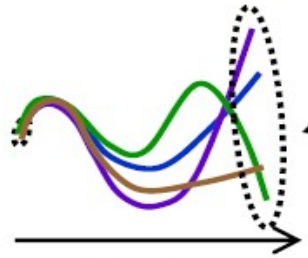
Forecasting chain in future EFAS



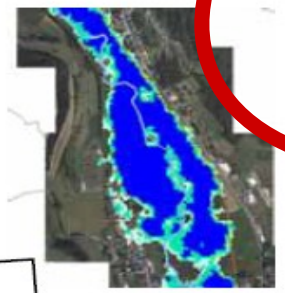
EPS

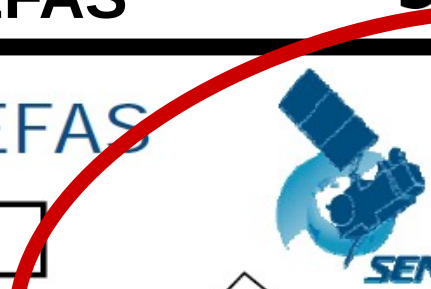
Multimodel

!?

Hydrology

Hydraulics



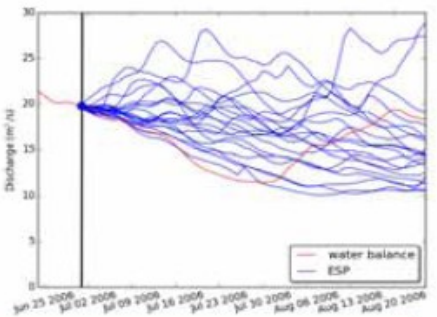


Assimilation

S2S

Preprocessing/
calibration

Feedback to
the model



Postprocessing

Verification

Warning

ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

Hydrological soil water ≠ Meteorological soil water!?

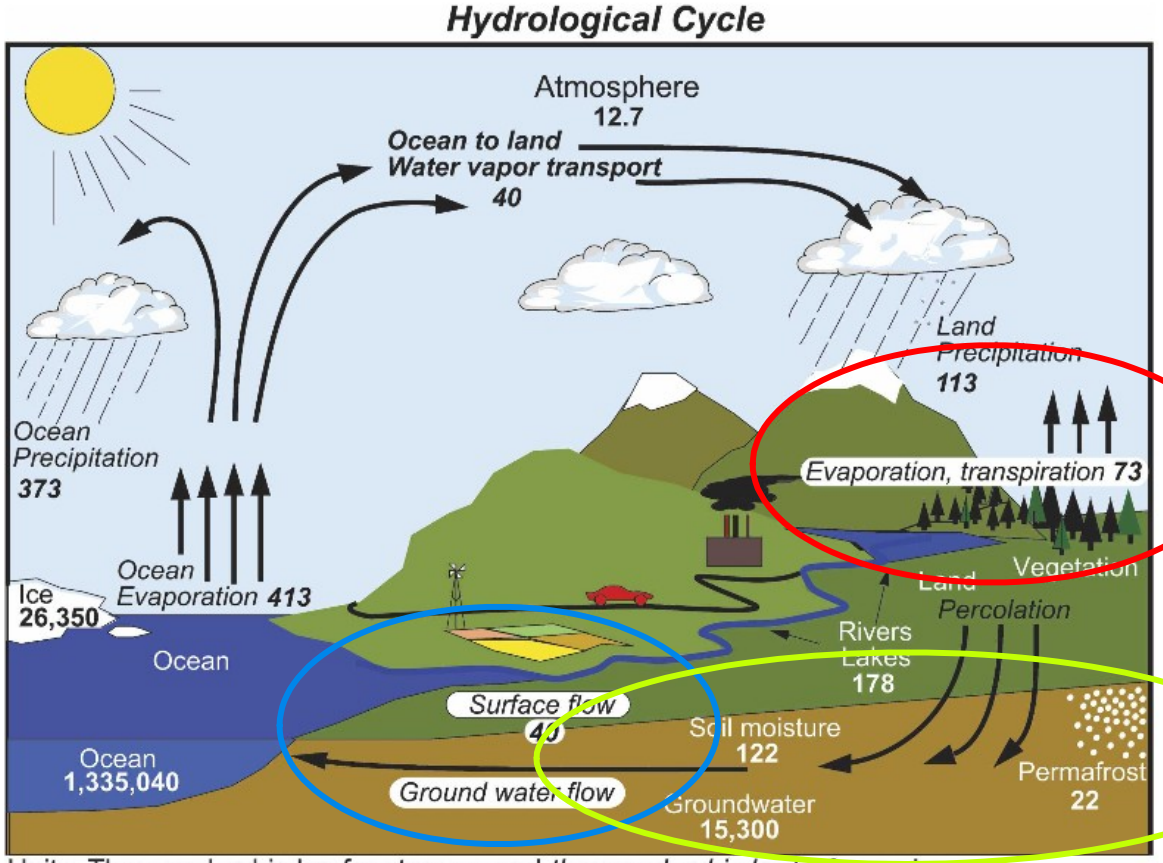


FIG. 1. The hydrological cycle. Estimates of the main water reservoirs, given in plain font in 10^3 km^3, and the flow of moisture through the system, given in slant font (10^3 km^3 yr^{-1}), equivalent to Eg (10^{18} g) yr^{-1}.

Martin Best:
The soil moisture is more of a wetness indicator than an actual value. This has arisen because we do not have representative observations of soil moisture.

Trenberth et al., 2007. JHM, 8, 758-769

French SIM model system

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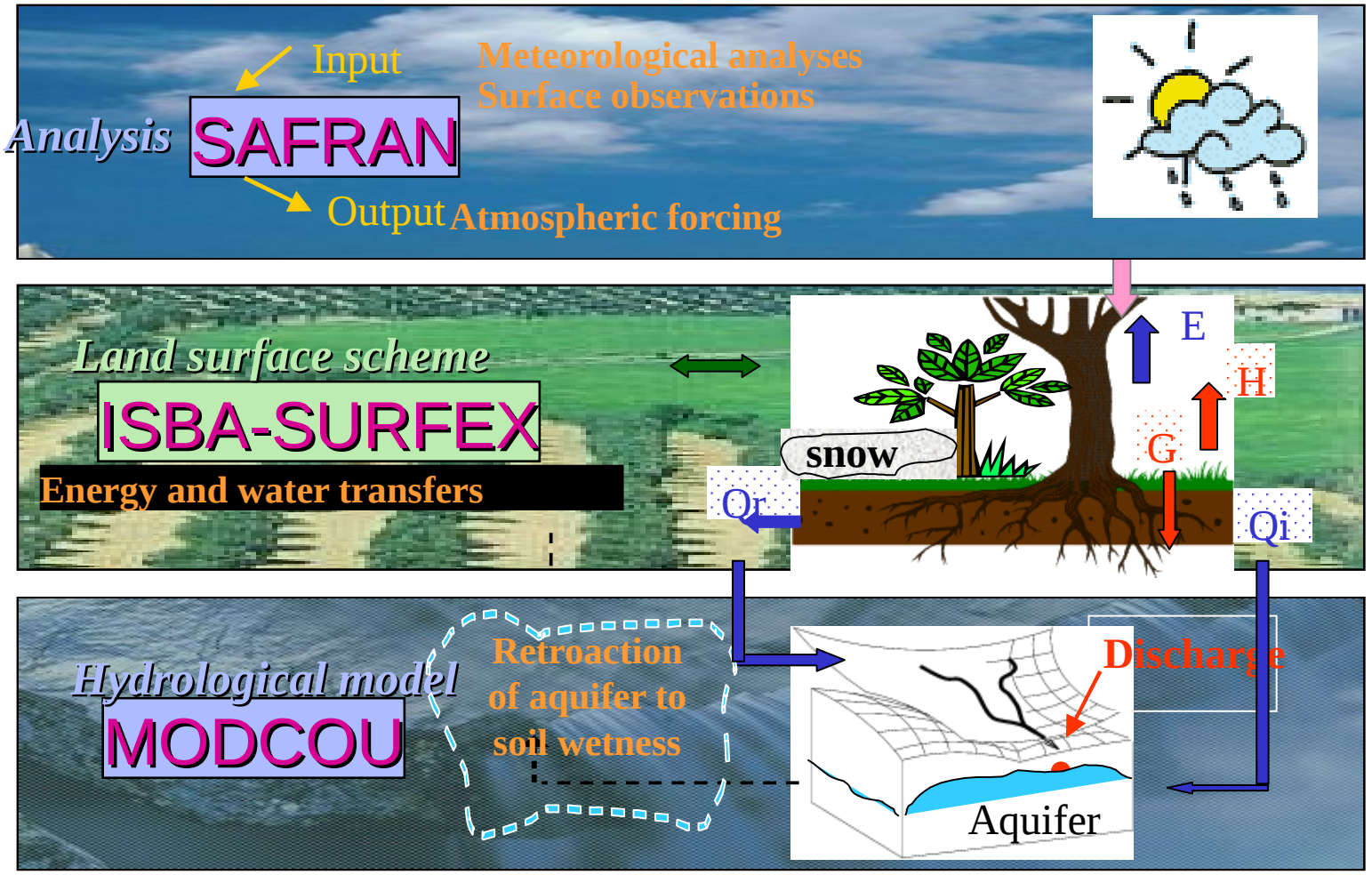
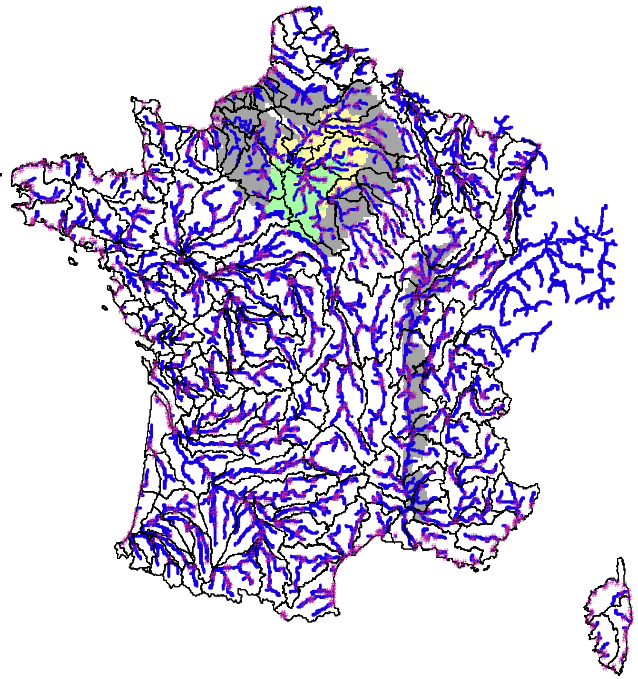


French SIM model system

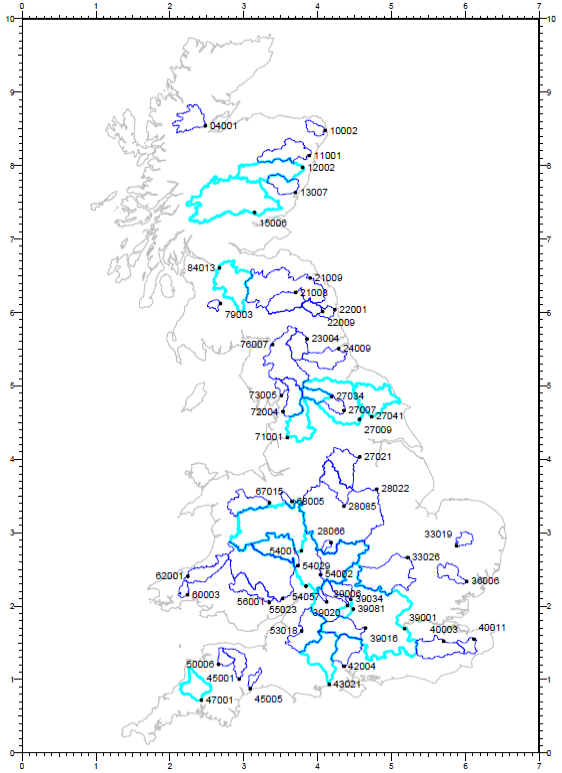


SIM (or HEPS) is applied operationally at Météo-France using ECMWF EPS-system as forcing for mid-range lead-times on 3-10 days. SIM results are made available to the French Flood Forecasting Service SCHAPI.

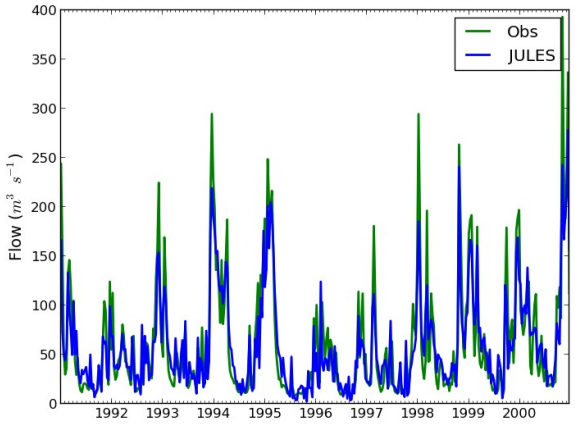
Conclusions and development needs:

- Assimilation of hydrological data is important.
- Assimilate soil moisture (river discharge itself has too short memory).
- Increased realism in soil physics gives better modelling of hydrological processes and better utilization of e.g. soil moisture observations.
- Reservoirs need better representation (low flow periods).
- Assimilation of LAI has good impact on model scores.

km-scale river routing in JULES land surface model

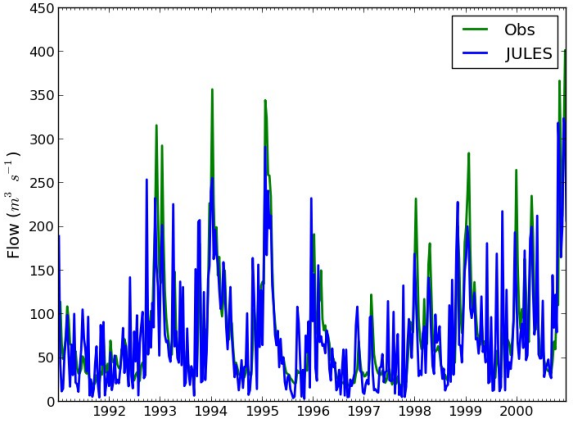


54001, ceh-vg, conf=1.0, bpdm=0.25

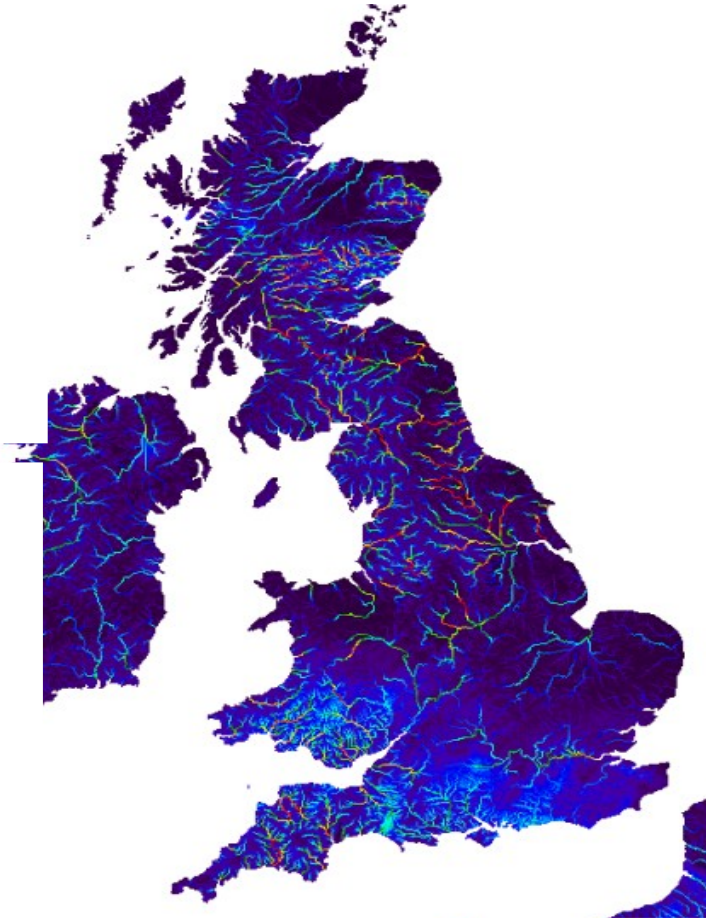


Bias=-5.76 NS=0.81 MM=16.49 FD=24.70 mmfd=41.19

39001, ceh-vg, conf=1.0, bpdm=0.25



Bias=-5.89 NS=0.56 MM=22.84 FD=27.48 mmfd=50.32

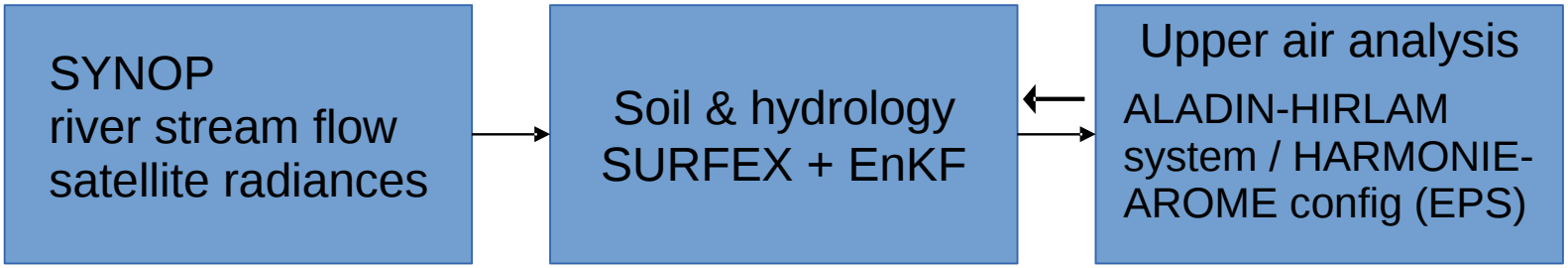


[Alberto Martinez de La Torre, Eleanor Blyth, Emma Robinson, Helen Davies, Vicky Bell, Huw Lewis]

Hydromet assimilation projects at SMHI

RSLAND (SNSB) 2015-2017
EU IMPREX 2015-2018

In collaboration with NILU, MetNorway, HIRLAM/ALADIN/ Météo-France



Assimilation of satellite-based measurements of the hydrosphere
- towards a combined meteorological-hydrological forecasting system

GCOM-W1/AMSR-2

SMOS/MIRAS

Sentinel-1/SAR-C

Assimilation methods

SMOS/MIRAS
GCOM-W1/AMSR-2
Sentinel-1/SAR-C

Currently we perform optimal interpolation (OI) of observed near-surface quantities like T2m, Rh2m, snow and perform column wise OI for increments.

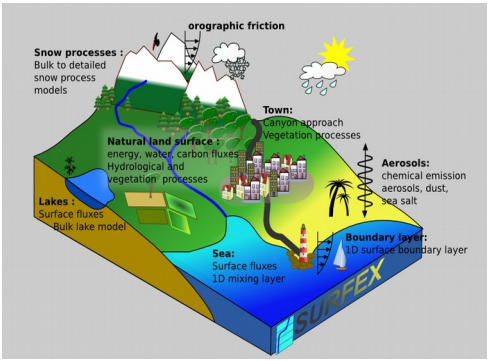
Our future plan is a 3D Ensemble Kalman Filter (EnKF) surface assimilation system.

Satellite products do exist for e.g. snow and soil moisture but the proper assimilation method is to utilize the raw satellite radiances/backscatter via observation operators (based on model quantities). Each radiance needs its unique observation operator!

How to create the ensemble for the surface variables and what processes/variables do we need from the surface model for the observation operators?

Assimilation of river discharge data and EO fresh-water levels!?

Surface model SURFEX components



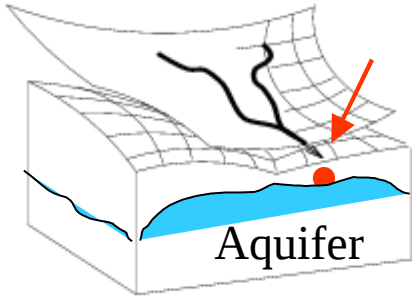
Currently in NWP we use SURFEXv7.3

- Force-restore with 2 and 3 layers for soil temperature and moisture, respectively
- Composite snow layer (D95).
- Town-Energy Balance
- Very simple inland water.

SURFEXv8 provides the potential to utilize:

- Diffusion soil scheme (~14 layers) (thin top layer).
- Explicit snow scheme (default 12 layers) with snow-crystal based albedo formulation.
- Multi-Energy Balance with separate canopy vegetation and ground/snow.
- ISBA-A-gs prognostic LAI
- Town-Energy Balance
- Explicit lake model (FLake) with prognostic ice.
- OASIS coupler for e.g. hydrological model.

Hydrology/routing componenets



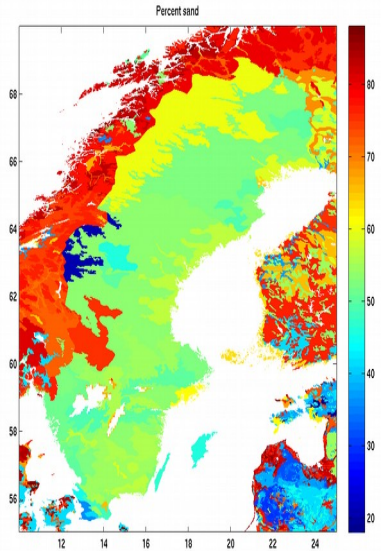
For current NWP, nothing to mention...

Current SMHI hydrology:
HYPE (as compared to e.g. TRIP, CaMaFlood, MODUCO) is well developed for Nordic conditions where delay factor due to lakes is well considered but the hydraulic component where river flow speed depend on water level is not included.

Hydrology/routing components

- For assimilation of EO water levels we need to consider hydraulic processes.
- For assimilation of observed river discharge the routing system must be very precise with respect to river network. No automatic system supports such level of preciseness...
- Potential hydro/routing systems for OASIS coupling: HYPE ”light” (routing part of Swedish, European and Arctic HYPE-applications, i.e. only lake+river part of model), ….

Physiography componenets



Physically-based distributed models like SURFEX are in general more dependent on detailed physiography data than semi-distributed conceptual models like HYPE.

Currently in HIRLAM NWP:
The model resolution is 2.5 km and uses 1 km resolution of land-use (ECOCLIMAP), 1 km (50 m) topography, 10 km (1 km) sand/clay.

Future needs in physiography :
For detailed down-scaling higher resolution land-use than 1 km is needed.
More details in land-use types, e.g. 90% of Stockholm is represented as two town types only.
Land-use characteristics need updates, e.g. town character parameters like building height/shape.

Integrated hydrometeorological system

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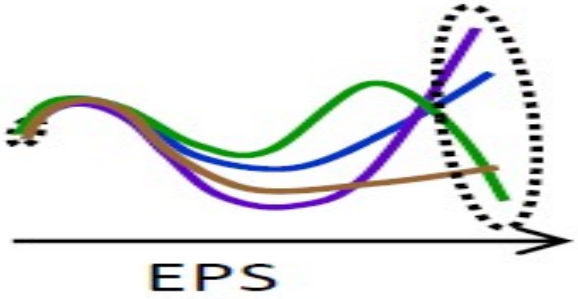
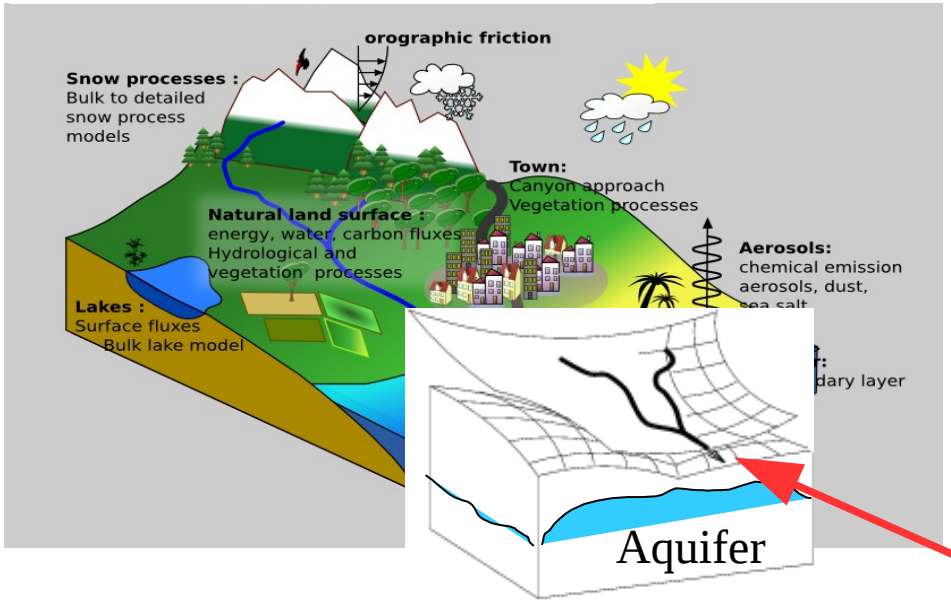
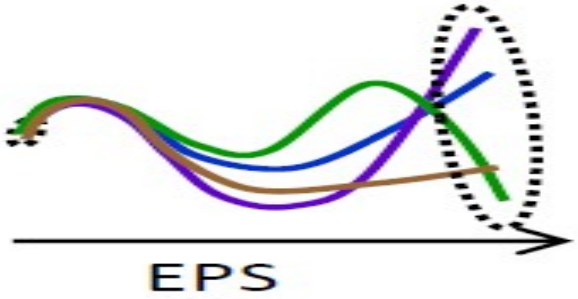
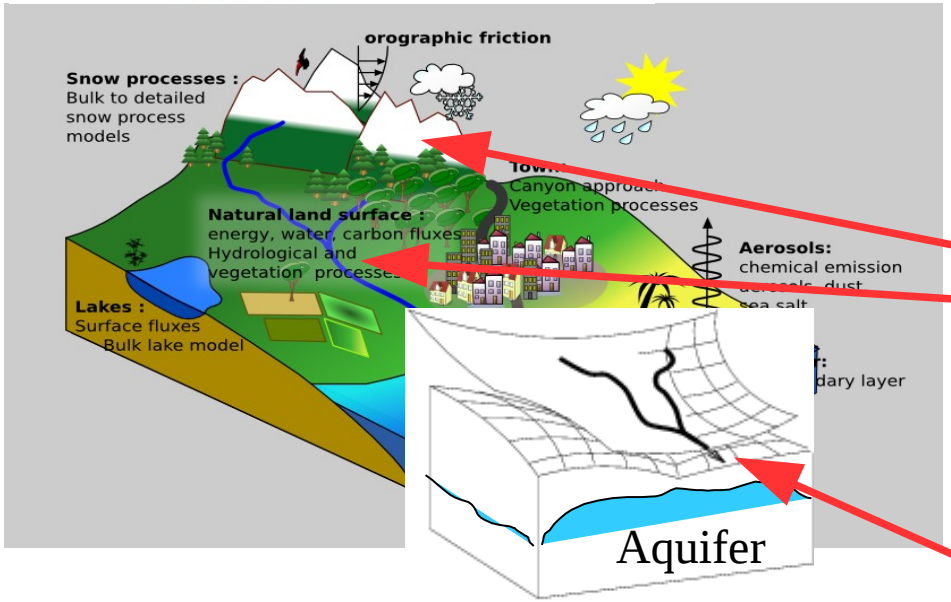




Use observed stream flow and/or remote sensing products over river/lakes.

Integrated hydrometeorological system

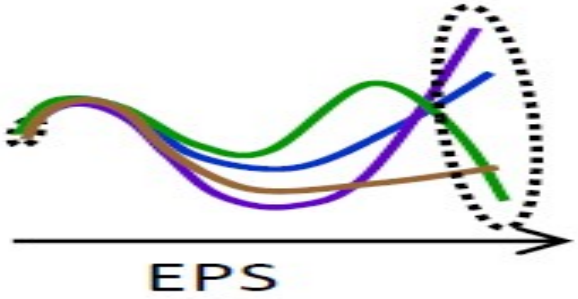




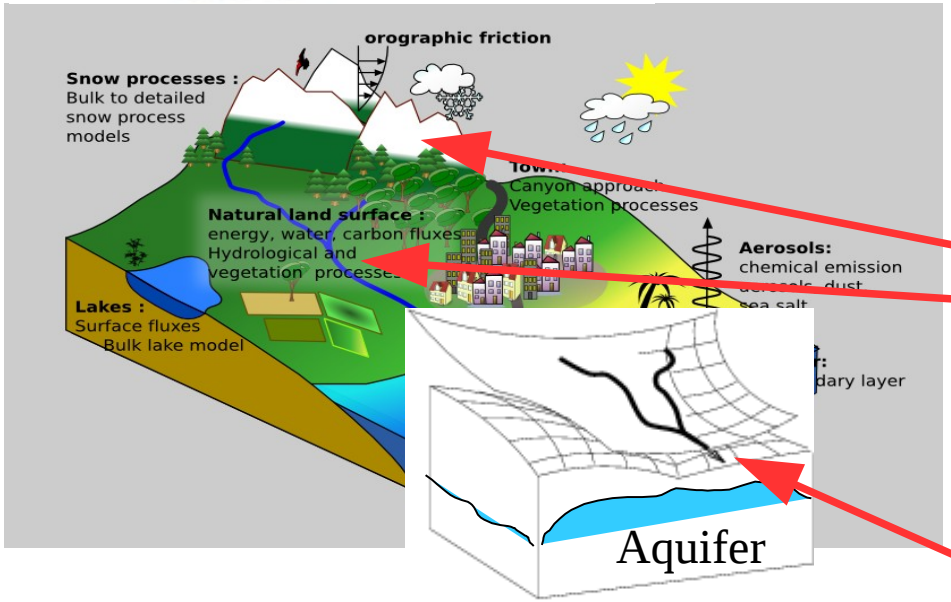
Utilize this to assimilate slow/large storages of water as snow and deep soil moisture. These are typically ~days ahead of observed river/lake conditions.

Use observed stream flow and/or remote sensing products over river/lakes.

Integrated hydrometeorological system



Use EnKF methods, perturbation methods and possibly some particle filter methods to create the EPS members.



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deep soil moisture.
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Comments

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At DWD (COSMO) a possible seamless prediction system could provide improved forecast of heavy and long standing precipitation events for better input to flash flood warnings (belongs to federal hydrological agencies).

In UK a full hydrometeorological system is considered as part of their Environmental Prediction project.

At Météo-France their SIM modelling system now runs with EPS input from ECMWF, soon also with AROME-EPS input.

Ok, so meteorology and hydrology do approach each other but there are still some efforts before we can join around a common “soil moisture”...
Not only scientific questions but also organisation questions since meteorology and hydrology services are often separated in different agencies.