Towards hydrometeorological forecast systems

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

Hydrometeorological modelling in Norway

Collaboration, division of responsibility, and concentration for research, development and education

http://www4.nve.no/no/arrangementen/HYDMET-Seminar-9-10122015-in-Lillehammer/
Improving forecast skill

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.
Extreme events - flooding

UK 2007

Drivers and Formation of the FFC - Summer Floods 2007

Norway 2011 & 2013

Foto: Torbjørn Olsen/Gudbrandsdalen
European Flood Awareness System (EFAS)

The European Flood Awareness System (EFAS) is the first operational European system monitoring and forecasting floods across Europe. It provides complementary, flood early warning information up to 10 days in advance to its partners: the National/Regional Hydrological Services and the European Response and Coordination Centre (ERCC).

The Operational EFAS consists of four centres executed by different consortia:

- **EFAS Computational centre** - European Centre for Medium-Range Weather Forecasts (UK) executes forecasts and hosts the EFAS Information System platform
- **EFAS Dissemination centre** - Swedish Meteorological and Hydrological Institute, Rijkswaterstaat (NL) and Slovak Hydro-Meteorological Institute analyse EFAS on a daily basis and disseminate information to the partners and the ERCC
- **EFAS Hydrological data collection centre** - REDIAM (ES) and ELIMCO (ES) collect historic and realtime discharge and water level data across Europe
- **EFAS Meteorological data collection centre** – KISTERS AG and Deutscher Wetterdienst collect historic and realtime meteorological data across Europe.

EFAS is an operational service under the umbrella of the Copernicus emergency management service and is fully operational since October 2012.
European Flood Awareness System EFAS

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

Forecasting chain

Preprocessing/calibration

Feedback to the model

Verification

Hydrology

LISFLOOD

Postprocessing

Warning

ECMWF

COSMO

EPS
Observed stream flow data...

...is heavily used for calibration of hydrology models. Also used for assimilation. But coverage of data is limited in space!
European Flood Awareness System EFAS

Forecasting chain in future EFAS

Preprocessing/calibration

Feedback to the model

Verication

Multimodel

Hydraulics

Assimilation

S2S

Hydrology

Postprocessing

Warning

ECMWF

EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS
Remote sensing products for hydrology

- **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.
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

**Analysis**

- **SAFRAN**
- **Input**
- **Meteorological analyses**
- **Surface observations**
- **Output**
- **Atmospheric forcing**

**Land surface scheme**

- **ISBA-SURFEX**
- **Energy and water transfers**

**Hydrological model**

- **MODCOU**
- **Retroaction of aquifer to soil wetness**
- **Discharge**
- **Aquifer**

**Input**

- Qr

**Output**

- Qi

**Energy and water transfers**

- H
- G
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

[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

SYNOP
river stream flow
satellite radiances

Soil & hydrology
SURFEX + EnKF

Upper air analysis
ALADIN-HIRLAM
system / HARMONIE-
AROME config (EPS)

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

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!? 
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 components

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 components

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.
Use observed stream flow and/or remote sensing products over river/lakes.
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.
Use EnKF methods, perturbation methods and possibly some particle filter methods to create the EPS members.

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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.