Sub-Seasonal to Seasonal Forecasts of Water Resource and Hydro-Power Production

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SESSION II - WATER:
MODELLING AND PREDICTING THE WATER CYCLE FOR IMPROVED DRR & RESOURCE MANAGEMENT

Thanks to my colleagues Joël Gailhard, Matthieu Lelait, Pierre Bernard, Marie Berthelot,
Overview

Water resource management:

- Why is it important?
- What are the current methods?
- Do dynamical monthly forecasts improve hydropower management in France?
- What about seasonal forecasts? (France, French Guiana, New-Zealand)
- Summary
Why is it important?

Water for EDF
- an opportunity (hydropower production, cooling for thermal plants)
- a constraint (shared resource)
- a threat (safety & security)

Stakes
- Anticipation & monitoring (safety of production means)
- Respect of regulations (anticipation on constraints)
- Hydropower production optimization
Why is it important?

Peak demand requires production flexibility → Hydro and imports

Sources: RTE, [www.rte-france.com](http://www.rte-france.com)
Water resources: a strong interannual variability & a forecasting challenge

Effects of a warm year on the arrival of water in dams stocks

Daily variations of French hydro power production capacity in 2003

- Good winter!
- Dry spring / early and quick melting
- Drought & heat wave
- Floods...

TOOLS

Power production forecasts

OBSERVATIONS

1200 points

MODELING (Hydrology- Water Temperature)

And/or forecaster’s expertise

Hydrometeo Centers

Adaptation to the operating needs

SERVICES

Providing of real-time hydro-meteo data for operating

Monitoring & assistance 24h a day

Short term forecasts

• Daily hydro-meteorological bulletins (6 days a week)
• Warning on detection of exceeded thresholds or flood
• Warning in case of dangerous weather phenomenon (storm, snow ...)
• Water temperature forecasts bulletins

Long term forecasts

• Dams inflow forecasts
• Forecasts of France hydro-power production capacity
• Lowest water levels forecasts

CAS TECHNICAL CONFERENCE ON RESPONDING TO THE ENVIRONMENTAL STRESSORS OF THE 21ST CENTURY
(Antalya, Turkey, 18-19 November 2013)
Deterministic forecasts
Input: AROME, ARPEGE, ECMWF

Ensemble forecasts
Input: EPS (ECMWF) + Analogs

Probabilistic forecasts
Input: Precip. & Temp. climatology

Monitoring
Safety

Water resource management & system optimization

Drainage basins with operational hydrological model

What about hydrological predictability?

Hydrological lead times & forecasts @ EDF
Medium-term ensemble forecasts

[Durance@SerrePoncon - 2011-2012]

Predictability ~ 6 days

Predictability ~ 12 days

Hydrology predictability = weather predictability + intrinsic predictability
Longer lead-times: reference method

Observations (Temp, precipitations, pression ...)

Archives T, Precip

Hydrological model

Production management tools

Inflow forecasts

Cumulated inflow on the melting period

Flow (m³/s)

1-jan 1-feb 1-mar 1-apr 1-may 1-jun 1-jul

Q obs Q mod

Probabilized inflow distributions

Inflow (mm)

0.0 0.25 0.5 0.75 1.0
Seasonal forecasts

**Weather inputs:** rainfall & temperature climatologies [~0 predictability]

**Output:** probabilistic forecasts of river flow and cumulated volume up to 6 months

- **Mountain basins:** use of the relationship between winter snow stock and spring run-off (via the hydrological model)
  - ✓ High intrinsic predictability

- **Plain basins:** use of the relationship between spring ground water stock and summer low river flows (via the hydrological model)
  - ✓ Lower intrinsic predictability
Seasonal forecasts

Low level flow forecasts [Meuse@Chooz - 1990-2011]

Hydrological intrinsic predictability depends on each basin

Predictability > 30 days

Predictability ~20 days
Monthly forecasts

- There is skill in T2m and geopotential forecasts up to 3-4 weeks

- Is there any added value of monthly forecasts over 14 days for hydropower applications?

- Is there an additional gain to the intrinsic predictability of the river basins?

*Criterion for improvement* = Gain in predictability with respect to the reference method (using T&P climatologies)
Monthly forecasts from ECMWF, Precipitation

Provide Precip forecasts up to 32 days ...
Monthly forecasts from ECMWF, Precipitation

Provide Precip forecasts up to 32 days ...

... but skill is weak
The analogs method

Analogs method

Weather Archive
- NCEP Reanalysis
  - Z700 & Z1000
  - 1953 -> 2010

Precipitation Archive
- Gauge data
  - 1953 -> 2010

Weather Forecasts
- ECMWF Monthly Forecasts D+32
- Z700 & Z1000
- Oct 2004 -> Oct 2010

Analogs selection

Corresponding analog dates ensemble

Conditionnal distributions

Probabilistic Forecasts

Output for each prediction:
- 50 selected analogs x 50 members -> 2500 monthly precipitation analogues forecasts (d+1 to d+32)
- Oct 2004 -> Oct 2010
Domain & hydrological model

The MORDOR model

Atmosphere

- Evapotranspiration

Surface

- Precipitation
- Rain
- Snow

Ground

- Evaporation

Input data:
- Daily precipitation
- Mean daily air temperature

Runoff

River streamflow

Routing

Applied to 43 basins in S/SE France
3 types of forecasts

- **Streamflow Climatology**
- **Hydrological model forced with T&P historical time series**
- **Hydrological model forced by analogue T&P forecasts**
- **Observations**
Precipitation & Air temperature

Anomaly Correlation Coefficient

Performance de prévision : Pluie

**Precipitation**

- 5-11 days
- 13-18 days
- 19-25 days
- 26-32 days

Predictability ~ 1 week

Performance de prévision : Tair

**Temperature**

- 5-11 days
- 13-18 days
- 19-25 days
- 26-32 days

Predictability ~ 2 weeks
River Flow: gain in Anomaly Correlation Coefficient

Average improvement from weather forecasts ~ 15-20 days
**Example: Drac@Sautet - 1 month lead time**

**Spring:** high hydrological intrinsic predictability, but ~no improvement from weather forecasts

**Autumn:** low hydrological intrinsic predictability, significant improvement from weather forecasts
Monthly forecasts of river discharge using ECMWF products + in house post-processing methods

- ECMWF Monthly fcst (Z700 & Z1000)
- Analog Method
- Local T2m & Precip over 43 basins
- Hydrological Model
- Streamflow Prob fcsts

- Streamflow climatology
- Hydro Model forced by T2m & Precip climatology (1969-2008)
- Hydro Model forced by Analog T2m & Precip
- Observation

⇒ This model is operational, an extension to seasonal forecasts is under progress for France

What about longer timescales?

Additional value brought by a 1 month Lead-Time atmospheric seasonal forecast for MAM [Singla et al., 2012, doi:10.5194/hess-16-201-2012]

Regions where the seasonal hydrological forecast using atmospheric seasonal forecasts outperforms the forecast using random atmospheric forcing (yellow to red colours).

SWI (Soil Weteness Index)

Q (River Flow)

Courtesy of Jean-Pierre Ceron, Météo-France
Seasonal forecasts of river discharge in French Guiana

Petit-Saut reservoir & dam:
- ~70% of Guiana's power production
- Volume: 3.5 billion m³
- Useful capacity: 2.2 billion m³

ECMWF Seasonal forecast (Z500 & Rainfall)

We found skill in some seasons up to 3-4 months

A pre-operational test is ongoing (Nov. 2013-Oct. 2014) with dam's managers

REFERENCE (1969-2009)
Another example: Seasonal Forecasts in New Zealand

NZ Electricity Generation
- Hydro dominated (~60%)
- 75% of total capacity renewable
- Government target 90% renewable by 2025

Why seasonal forecasting?
- Meridian hydro storage 2780 GWh
- ~18% of Meridian's generation
- 17 weeks storage

Another example: Seasonal Forecasts in New Zealand

Seasonal Inflow Forecast Models

- Created from research conducted in early 2000s (Purdie & Bardsley, 2010, IJC)
- Run every 3 months to predict Waitaki total inflow for next 3 months
- Use statistical approaches to quantify relationships between large scale ocean-atmosphere state variables and at site hydrology
- PCA & MLR
- Use these relationships to create seasonal forecasts of rainfall and inflows in the Waitaki catchment
- Forecasts tested against validation data using cross-validation techniques and random testing
- Predictors:
  - SSTs & SLPs
  - Z700
  - Local inflow, rainfall & temperature data
  - ENSO (SOI)
  - QBO
  - SLP indices (Trenberth indices)

![Graph showing seasonal inflow forecasts](graph.png)

Another example: Seasonal Forecasts in New Zealand

Forecast skill

- Explained Variance: 10 - 24%
- Significantly better than random chance
- Significantly better than climatology

Summary

- On monthly & seasonal time scales, hydrological predictability = Weather predictability
  - forecast skill has improved in the last decade
  + Intrinsic predictability of the basin
    - high in spring for mountain basins (melting of winter snow stock)
    - significant in spring for ground water basins in plains

- Recent developments in monthly forecasts (ECMWF) bring significant improvements in weather forecasts, hence in hydrological forecasts.

- First results on seasonal time scales are encouraging
In the last ~10-15 years, much progress was achieved in NMHSs and research centers on monthly to seasonal time scales.

Active collaboration & partnership between Meteo-France (& ECMWF) and EDF allowed to take advantage of these scientific advances in operational applications.

Dialog between Providers & Users is essential to translate improvements in science into business improvements.

Communication & training is very important (for both energy & meteorology people).

Upstream collaboration and partnership should be encouraged.
Teşekkür ederim
Merci
Thank you
EDF Group worldwide
(Consolidated data at December 31, 2012)
Climate change and hydro-power generation

Box 3.1. Projected Changes in Hydropower Generation

Modeling by the Norwegian University of Science and Technology examined climate impacts on river flows and hydropower generation to 2050. Systems at highest risk had both a high dependence on hydropower generation for electricity and a declining trend in runoff. South Africa is quoted as one example with a potential reduction of 70 GWh per year in generation by 2050. Afghanistan, Tajikistan, Venezuela, and parts of Brazil face similar challenges.

Source: Hamududu, Norwegian University of Science and Technology