Monthly & Seasonal Forecasts in the French Power System

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Thanks to

- *Pierre Bernard, Marie Berthelot, Christophe Chaussin, Joël Gailhard, Julien Najac (EDF)*
- *Sophie Morel & Julien Dessagne (METNEXT)*

Outline

1. Power system optimization
2. Monthly forecasts: temperature in France
3. Monthly forecasts: precipitation and river flow in France
4. Seasonal forecasts: river flow in French Guiana
5. Summary

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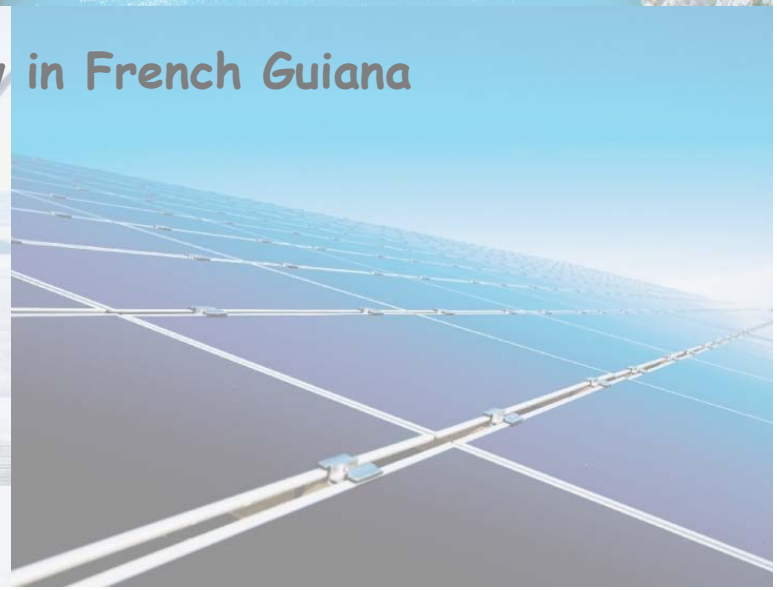
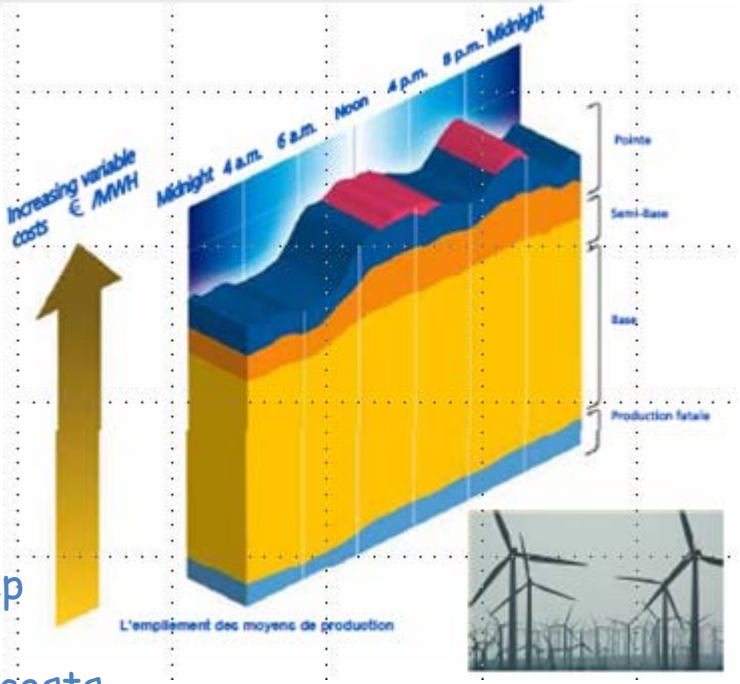


Power Offer/Demand balance: a complex problem

Production units' program:
- 58 nuclear reactors
- 435 hydro power units
- ~50 thermal (coal, gas, fuel)
- ~900 Wind farms
- ~250,000 solar (including households)



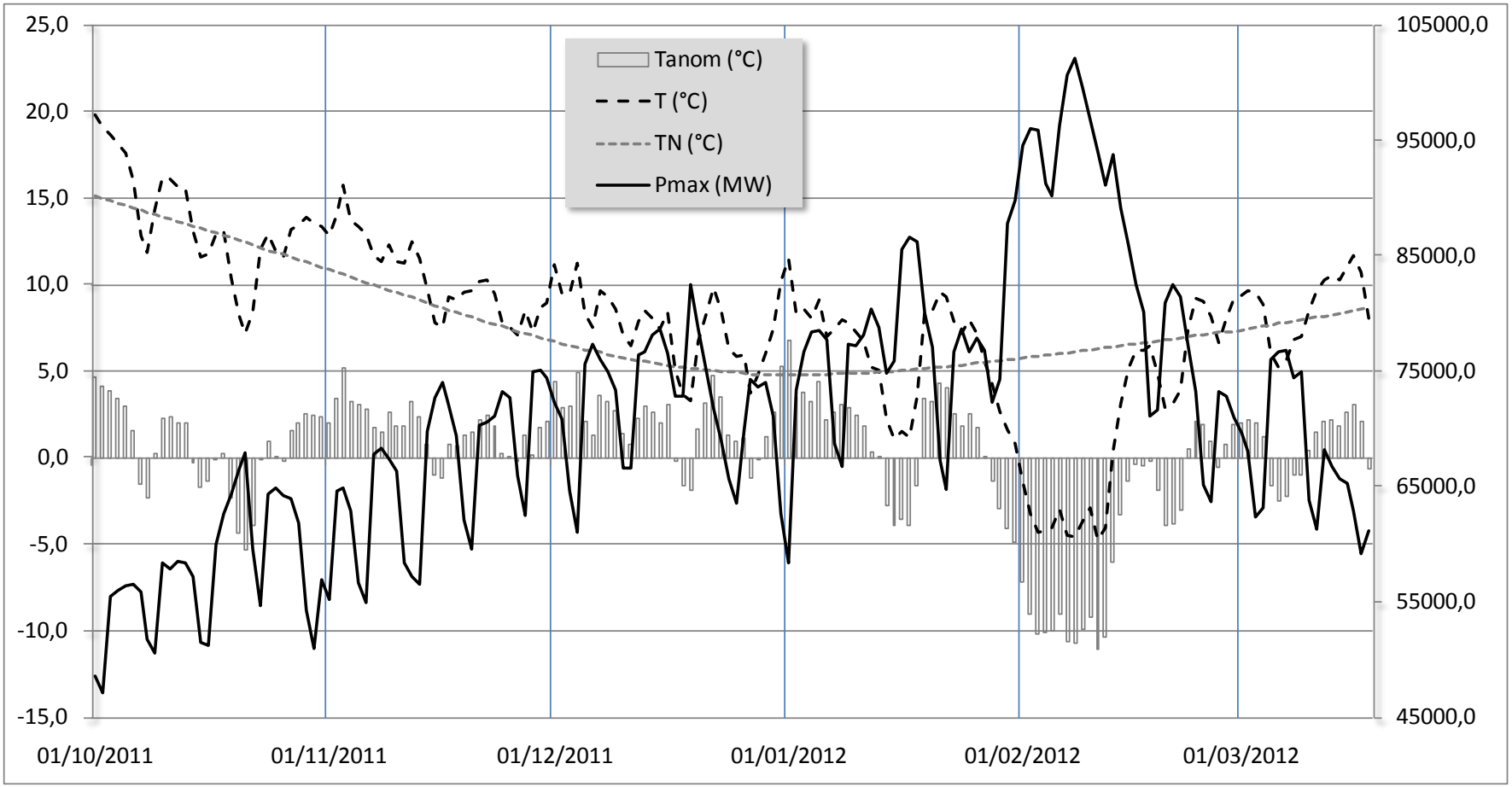
Problems:
- Production=Demand at each time step
- Many constraints
- Financial optimization of production costs

Huge optimization problem: 1 000 000 variables & 10 000 000 constraints for day+2 30 minutes forecasts

Highly non convex and non linear, discrete and continuous variables

Highly demanding on optimality (1% difference➔several millions euros/year) and feasibility (all technical constraints must be satisfied)

Demand depends on temperature



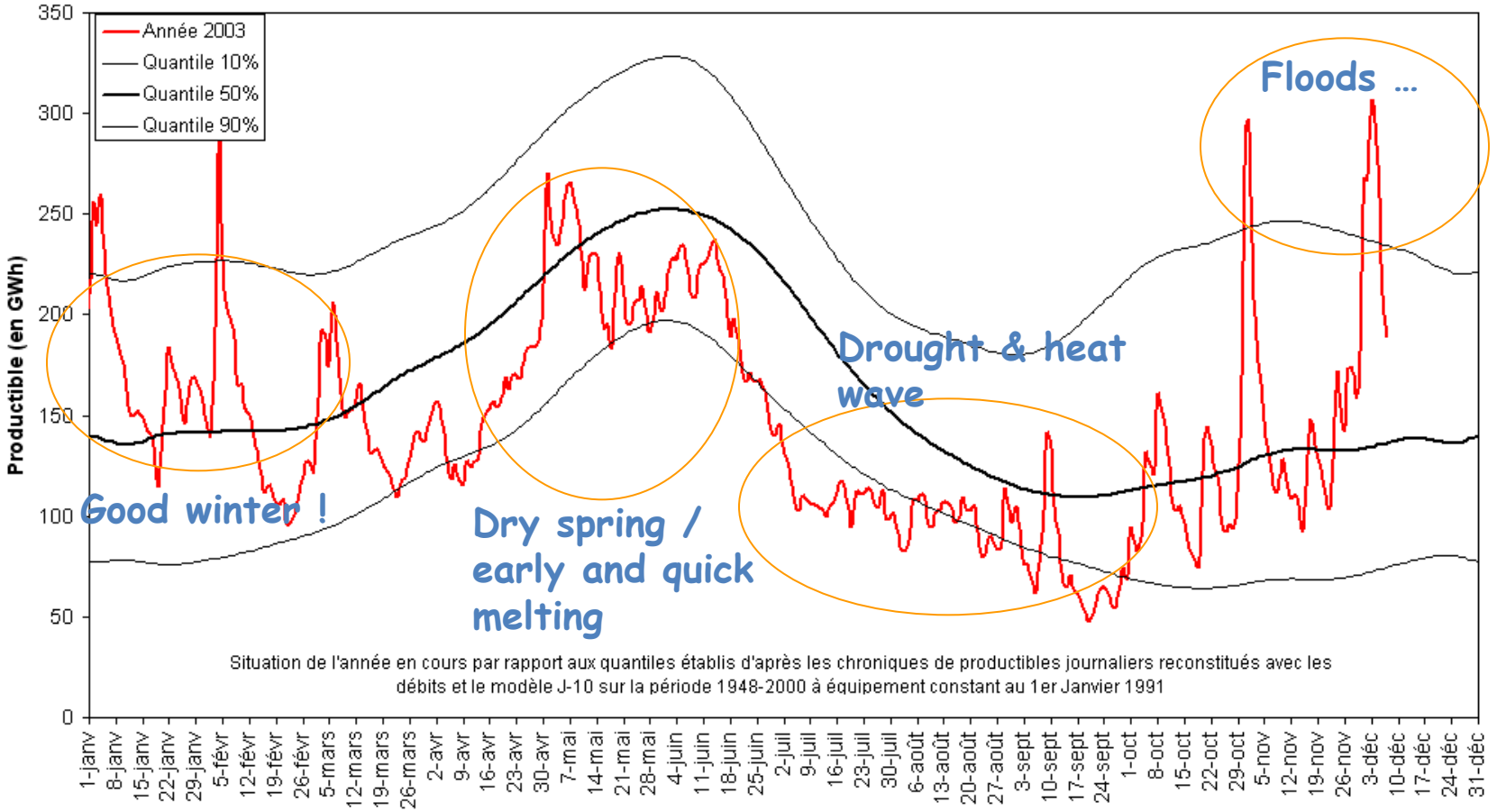
In France, power demand is highly dependent on temperature.

- in winter : -1°C dT ➔ +2 100 MW of extra production ~ 20 M€ hedging
- in summer : +1°C dT ➔ +400-500 MW of extra production

Water resource: 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



Weather & climate forecasts @ EDF … quite a long history

- EDF has been using weather forecasts for more than 30 years
- Main provider (operational contract) is Météo-France
- Research with Météo-France, ECMWF, IPSL, Private companies …
- European projects (SF / S2D): PROVOST - (DEMETER) – ENSEMBLES – EUPORIAS…
- Applications: ANEMOS, SafeWind, COST Action WIRE …
- Real-time forecasts / medium-term / monthly-seasonal-annual forecasts / climate change projections

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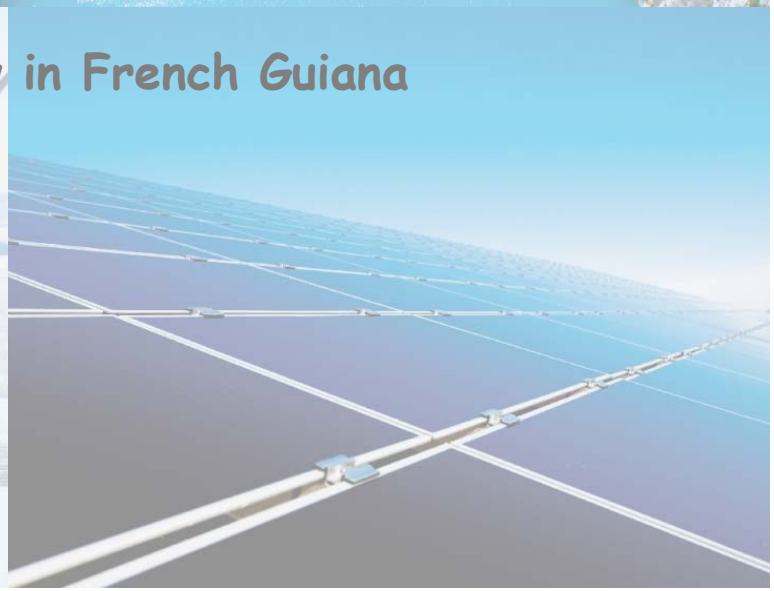
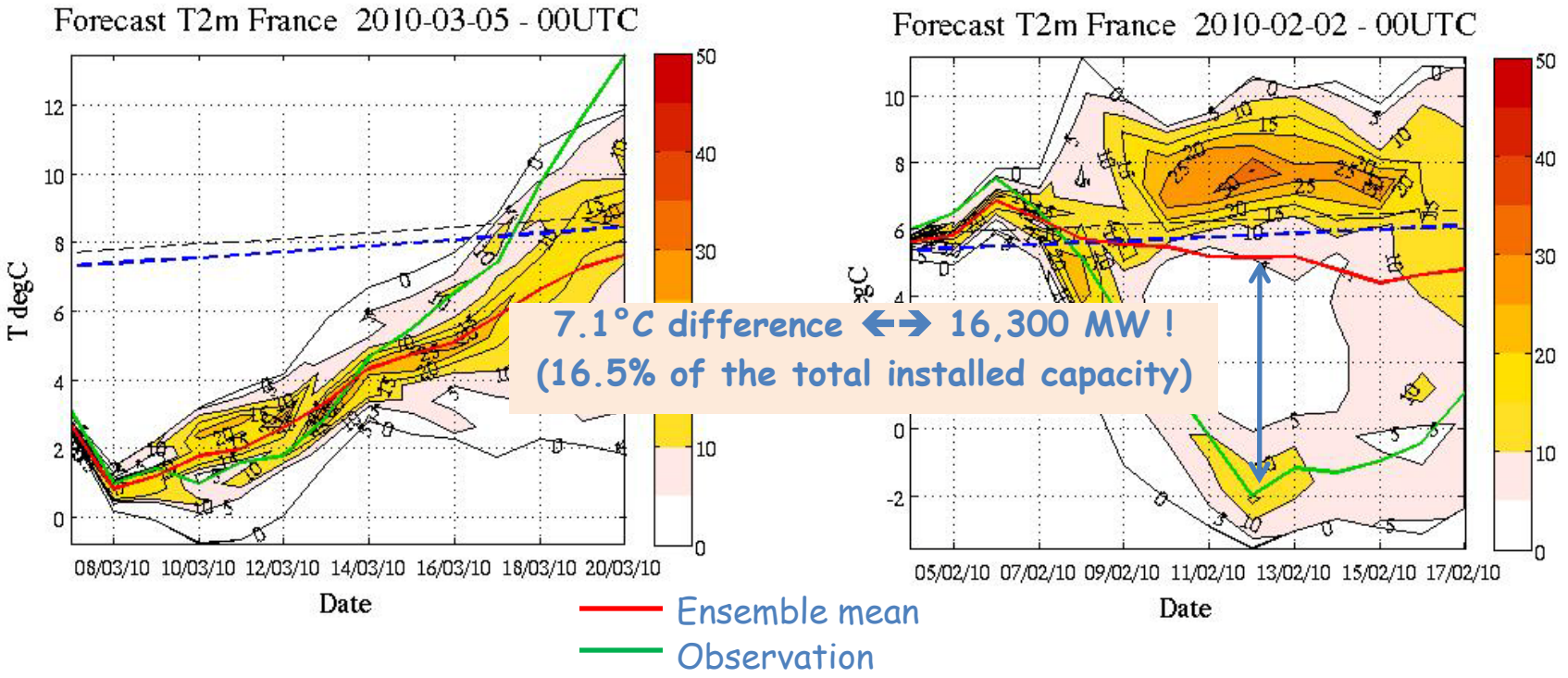


A trivial (?) consideration

➔Increasing use of probabilistic temperature forecasts (ECMWF VarEPS)

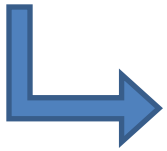


➔ **Main difficulty : integration of probabilistic information into (complex) existing operational processes**

What for ?

From D to D+14, temperature forecasts from the EPS are used to:

- forecast power demand & energy prices on the market
- compute financial risk indicators and determine hedging strategies

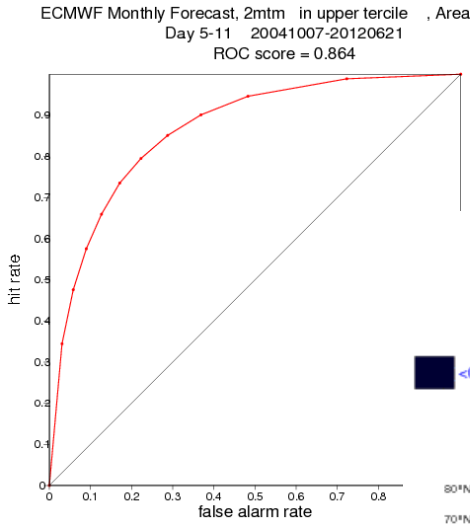


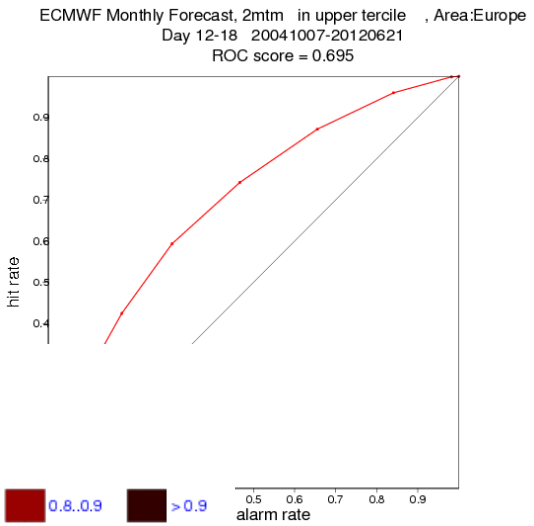
« 1% Risk »: what is the lowest 1% temperature likely to occur during the period considered ?

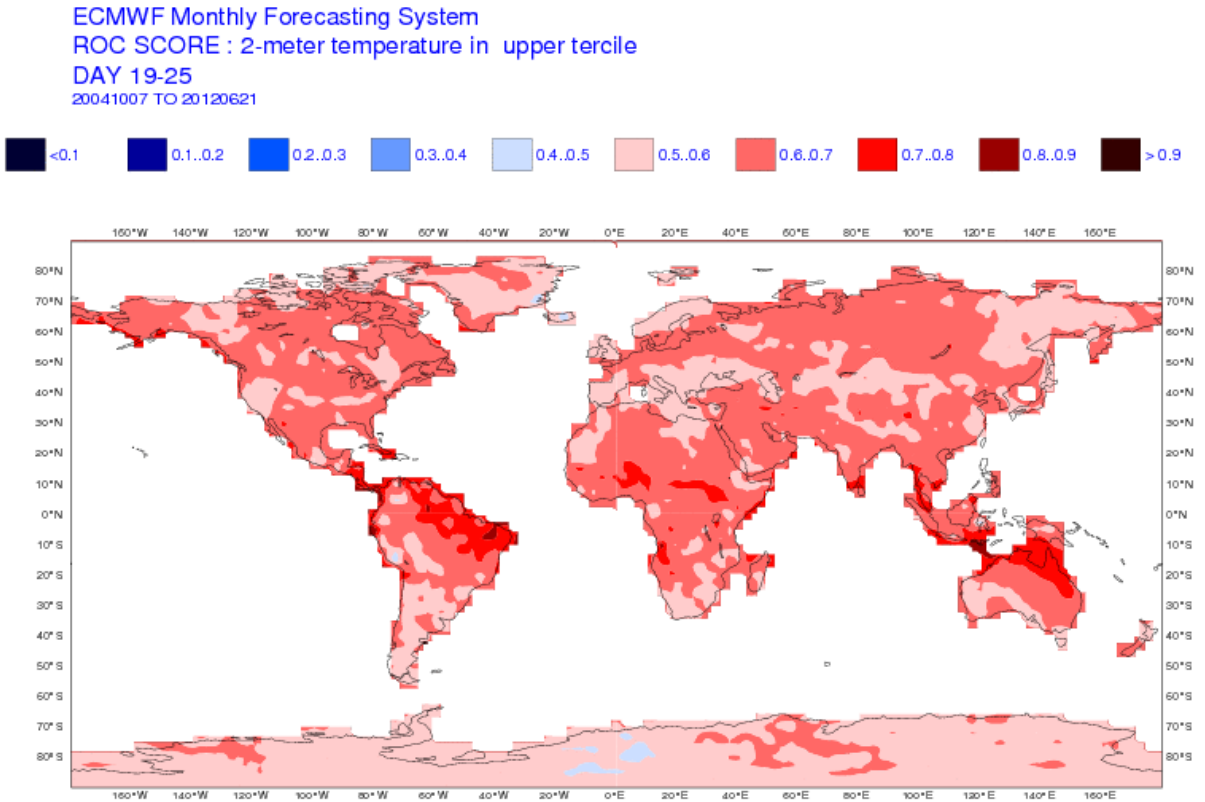
For 1 year optimization processes, historical time series are used

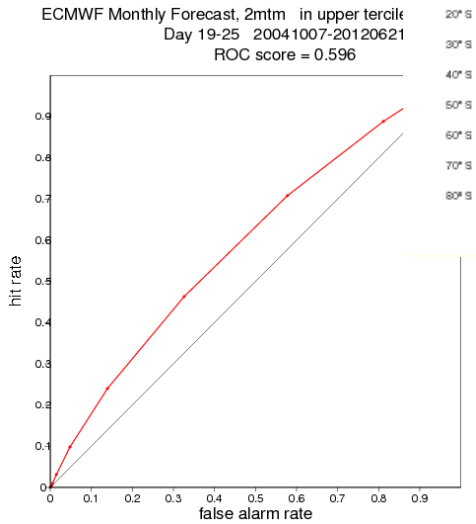
Question: Can monthly forecasts bring useful information ?

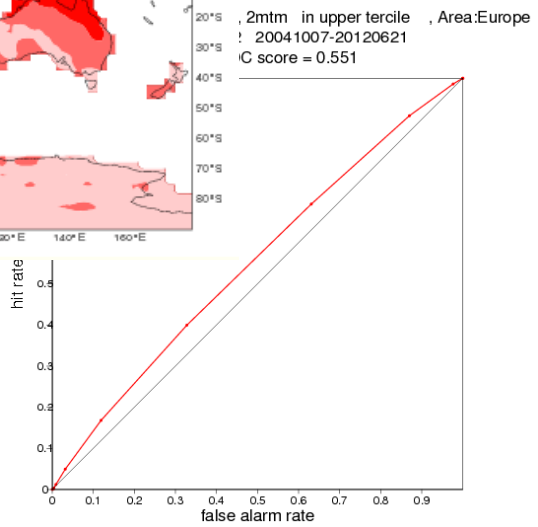
Skill in Europe









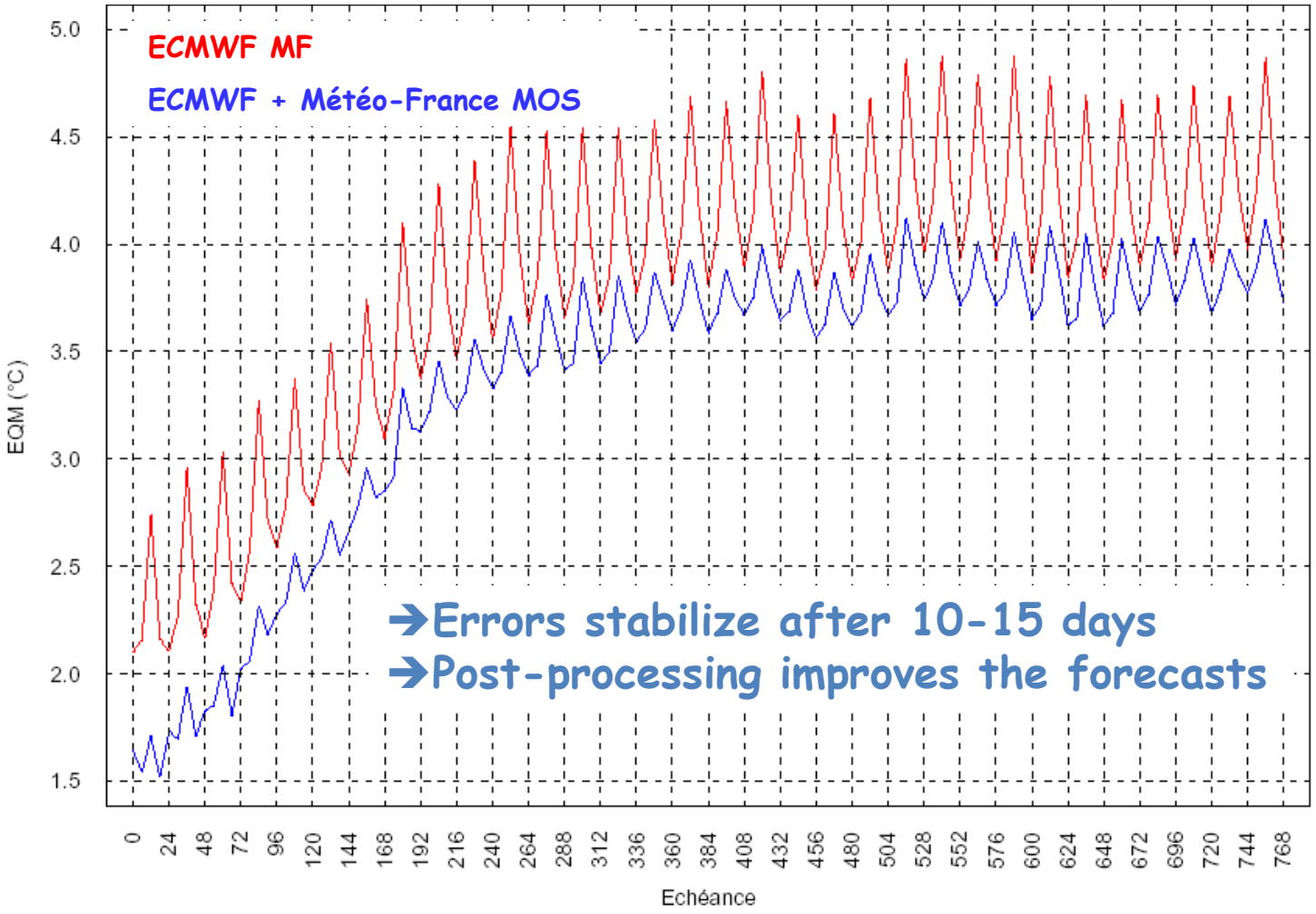


al Prediction

Statistical Post-Processing by Météo-France

ECMWF Monthly forecasts + Météo-France statistical adaptation

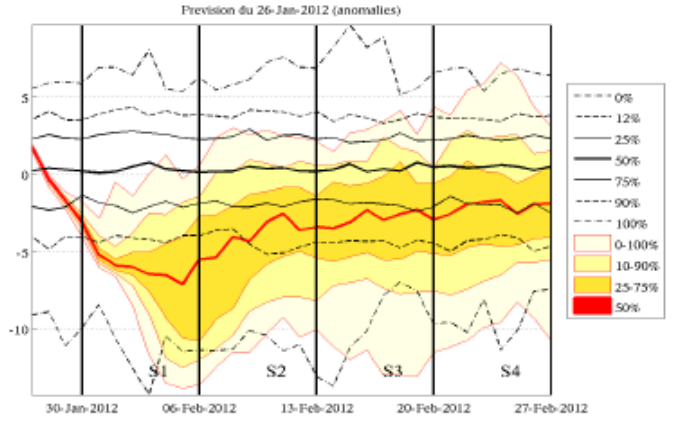
RMSE (average over 26 stations, june 2002-feb 2008)

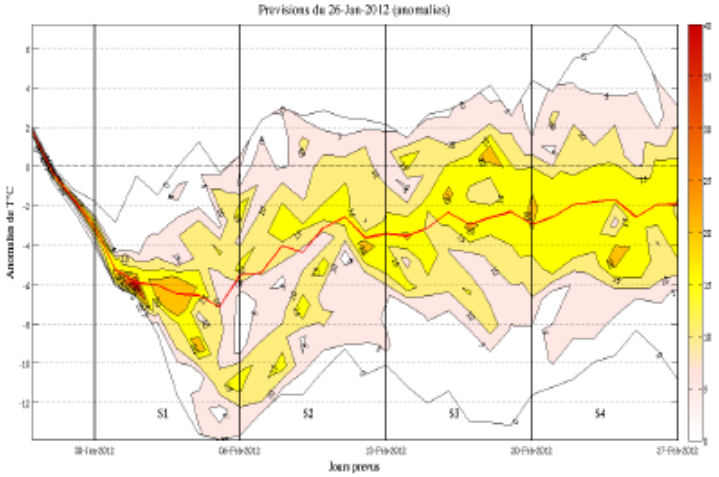


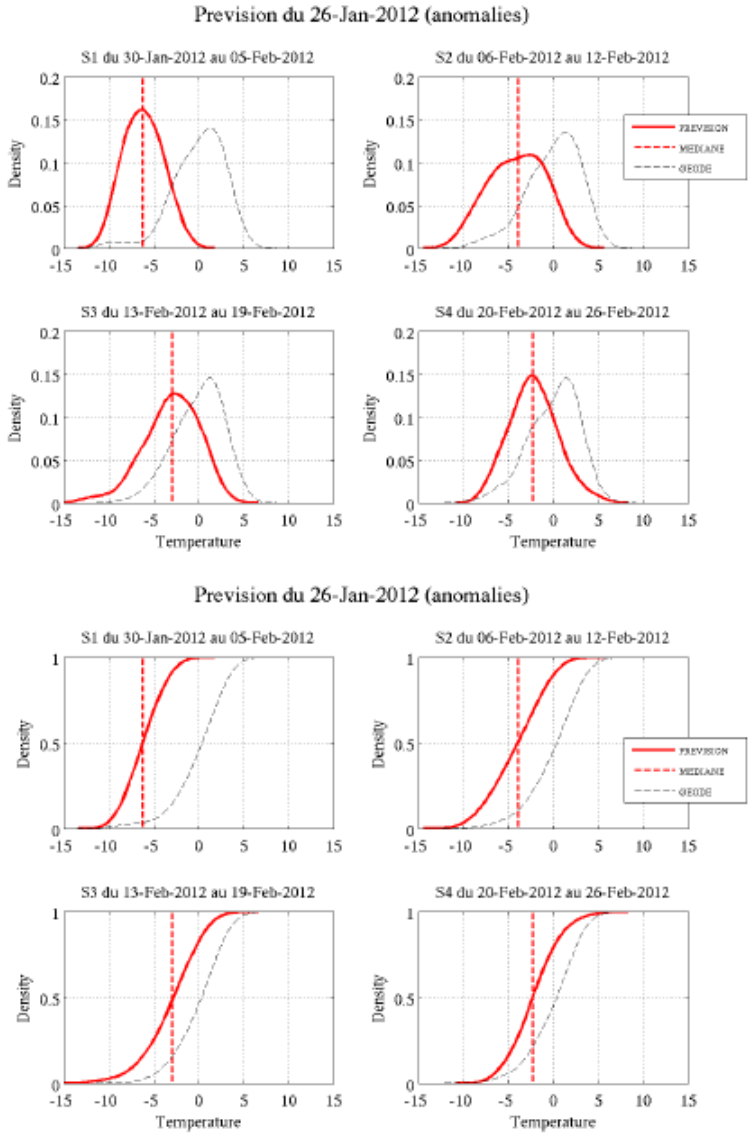
Bulletin d'information sur les prévisions mensuelles du 26/01/2012

Commentaires :

Le signal froid anticipé jeudi et lundi derniers est confirmé par la dernière prévision. 2 scénarios à -4 deg C et -10 deg C sous les normales sont plausibles sur fin de S1 et début de S2, dont l'évolution devra être surveillée dans les P16. Le signal froid s'atténue ensuite mais reste présent jusqu'en fin de période.



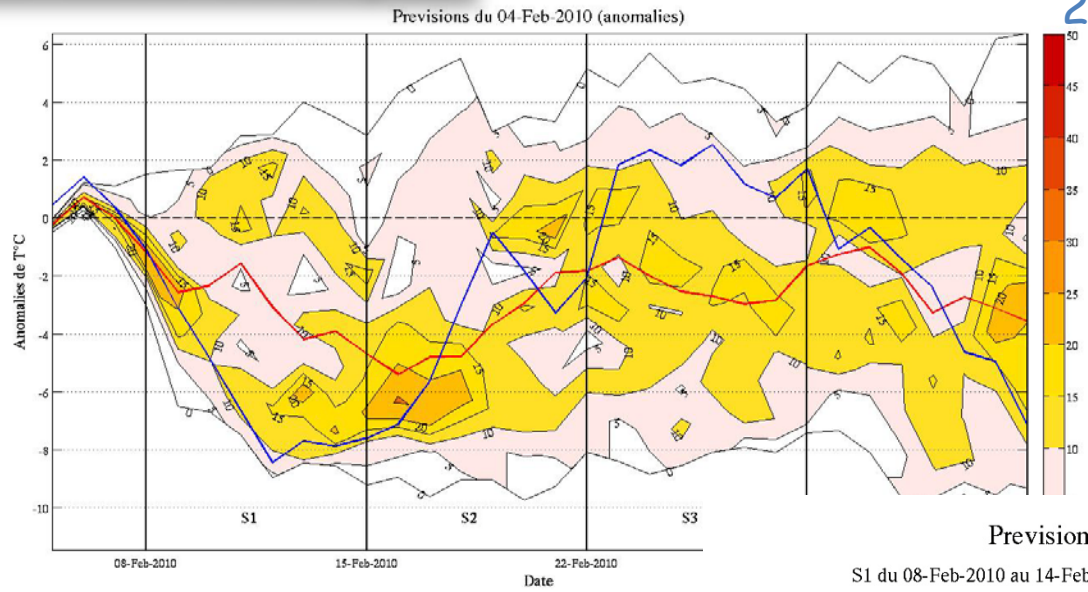




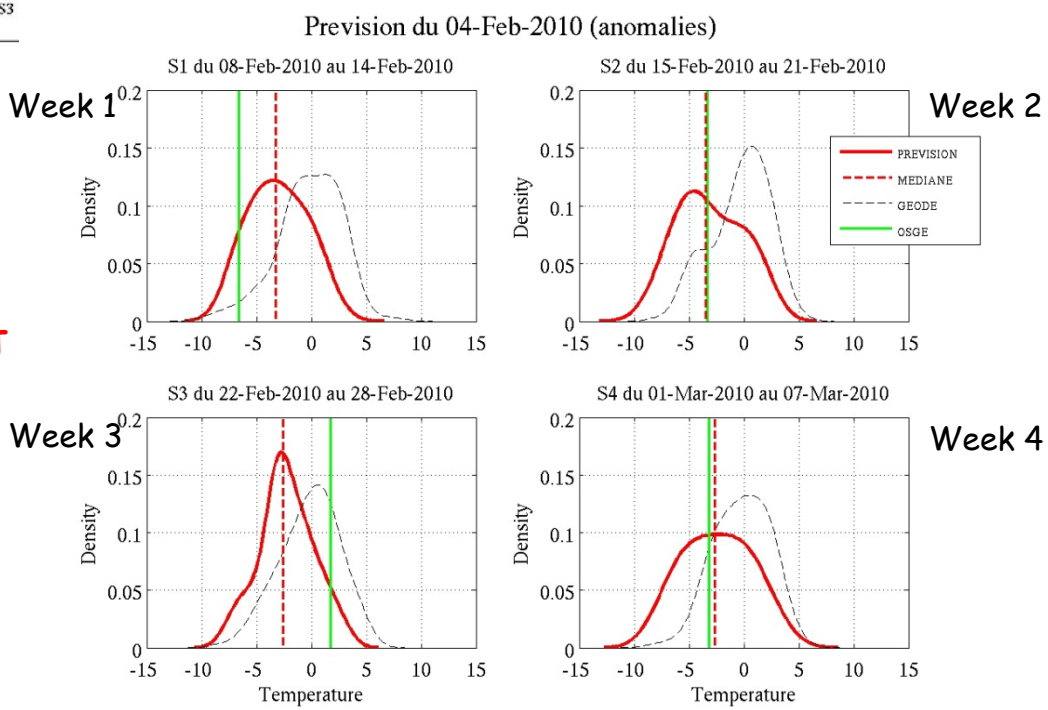
Bulletin d'information expérimental basé sur des données et produits du Centre Européen pour les Prévisions Météorologiques à Moyen Terme et de Météo-France.

Feb 2010 cold spell

ECMWF Monthly Forecast 2010/02/04. T2m over France

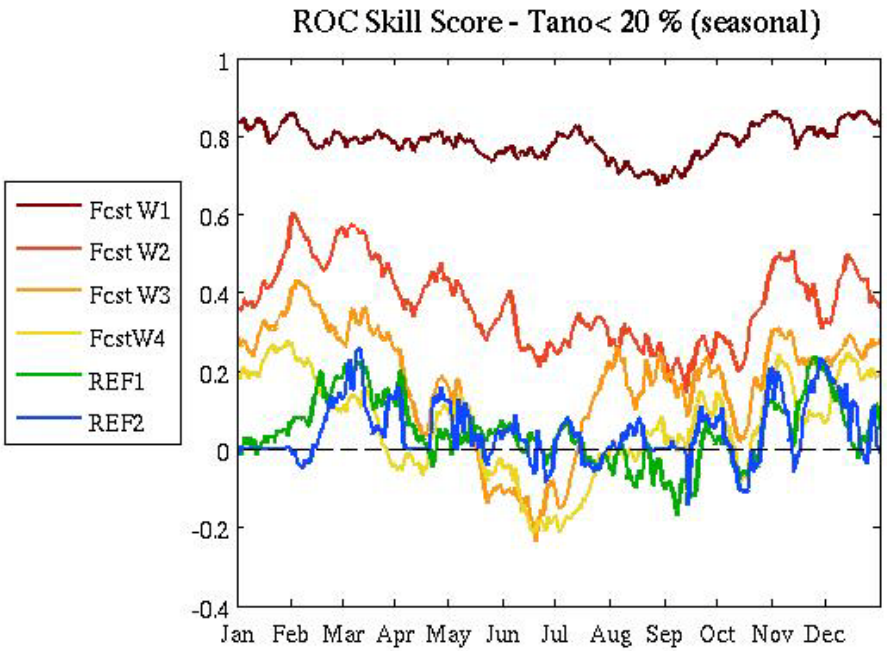


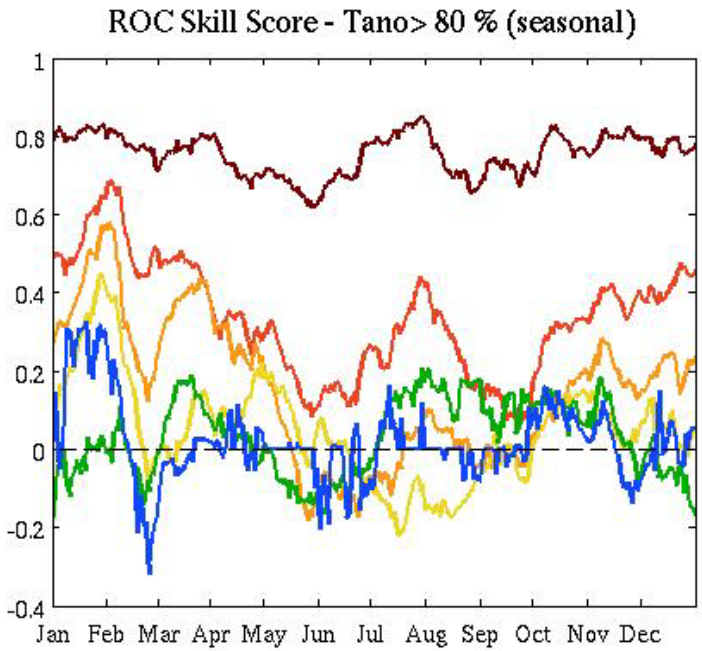
Climatology
Monthly fcst
Observation



Verification (10/2004 – 03/2012)

- Deterministic & probabilistic scores (MAE, RMSE, ACC, BS, ROC)
- Comparison with 2 reference datasets





Key results

- There is information up to week 3 (4), in particular in winter and/or when the observed anomaly is strong

  ➔ **MoF are used routinely as support to decision making**

- Progress has been made in the use of probabilistic forecasts, but difficulties remain:
  - end-users' undestanding of probabilistic forecasts
  - how to introduce these forecasts in (complex) existing operational tools ?
  - how to compute extreme values (Q1% for instance) from 51 runs ?
  - how to mix 14 days/monthly and longer lead times approaches ?
- Need of provider/user collaboration & communication to develop the use of probabilistic forecasts

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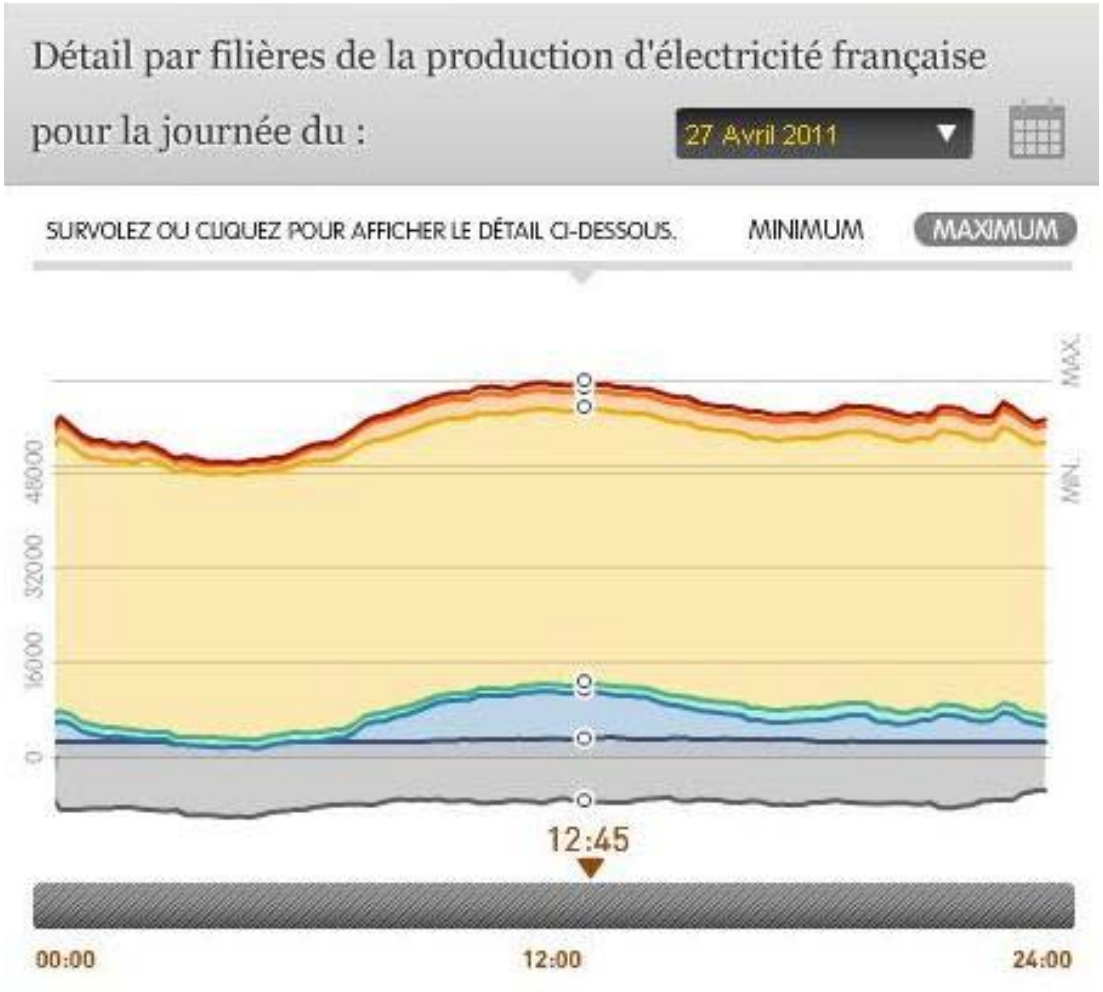
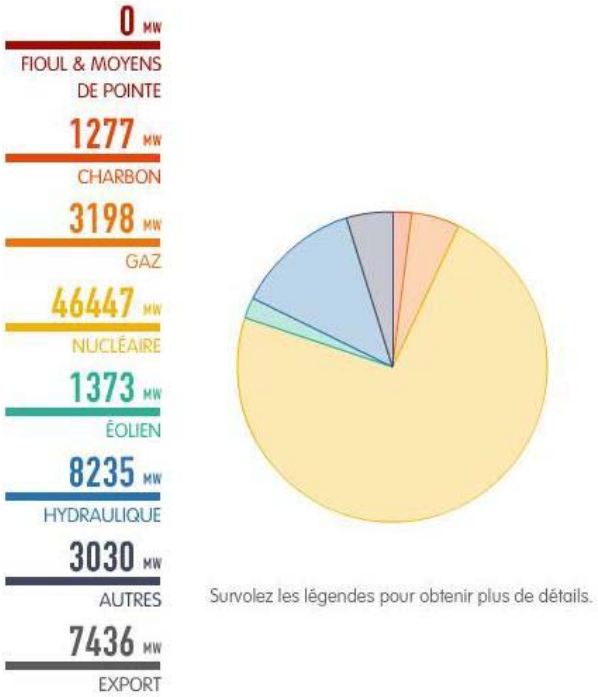
Water resource: a strong interannual variability & a forecasting challenge



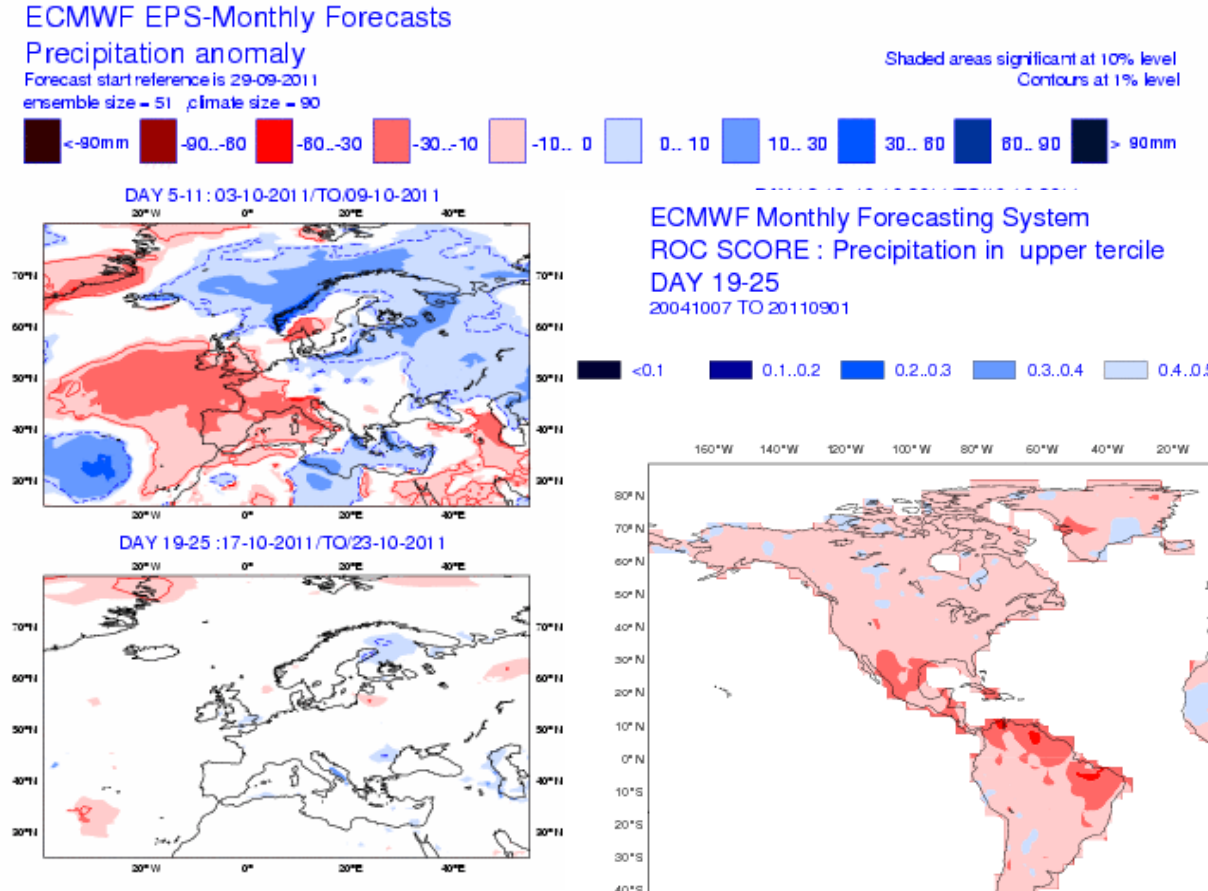
Hydropower used to answer peak demand ➔ high value

➔ Need of accurate precipitation forecasts from d+1 to 1 year !

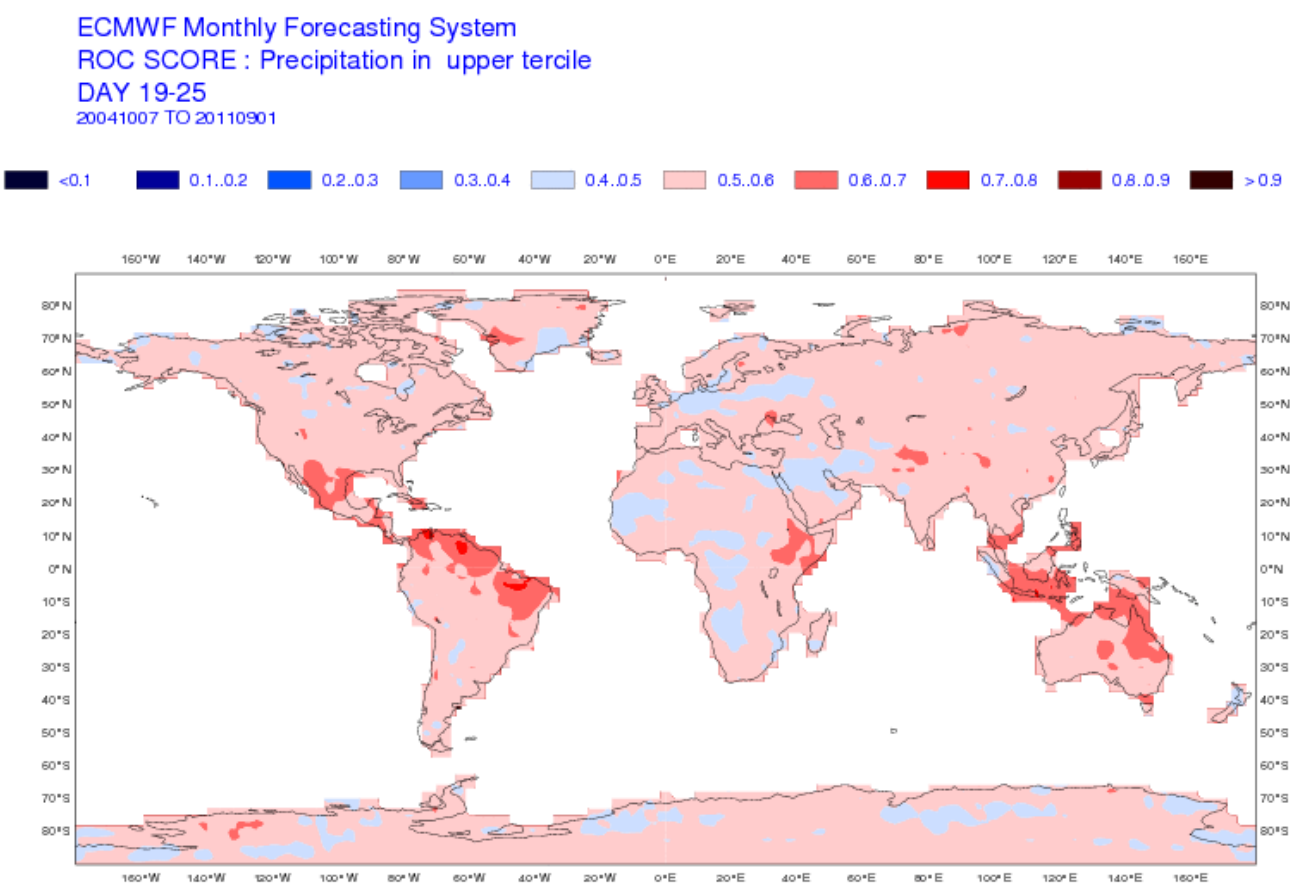


Source : Eco2Mix *http://www.rte-france.com*

Direct model outputs



Precip forecasts up to 32 days …



… but skill is weak

The analogs method

Analogs method

Weather Forecasts

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

Weather Archive

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

Analogs selection

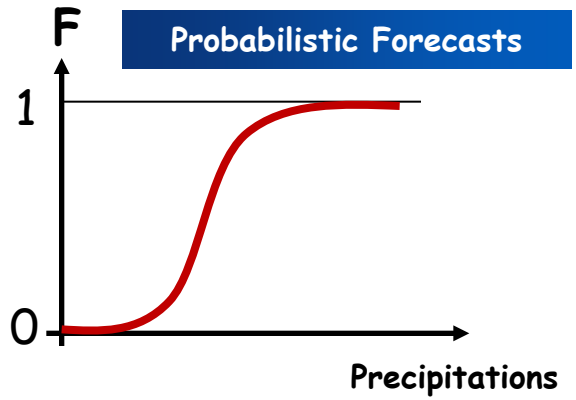
- Analogy criterion based on Euclidian distance between geopotential fields anomaly

Corresponding analog dates ensemble

Precipitation Archive

- Gauge data
- 1953 -> 2010

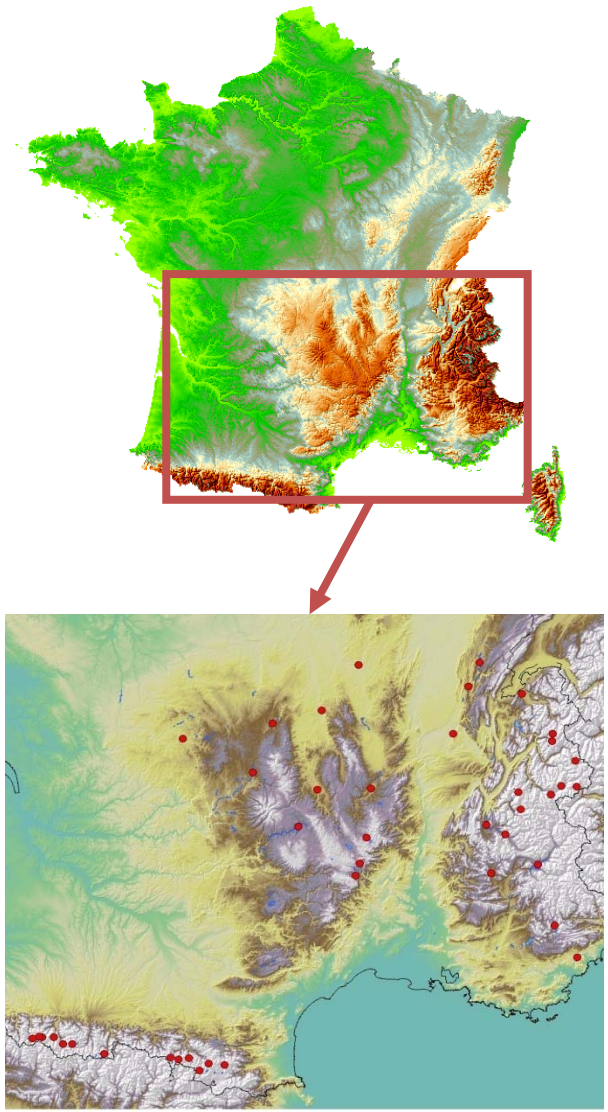
Conditionnal distributions



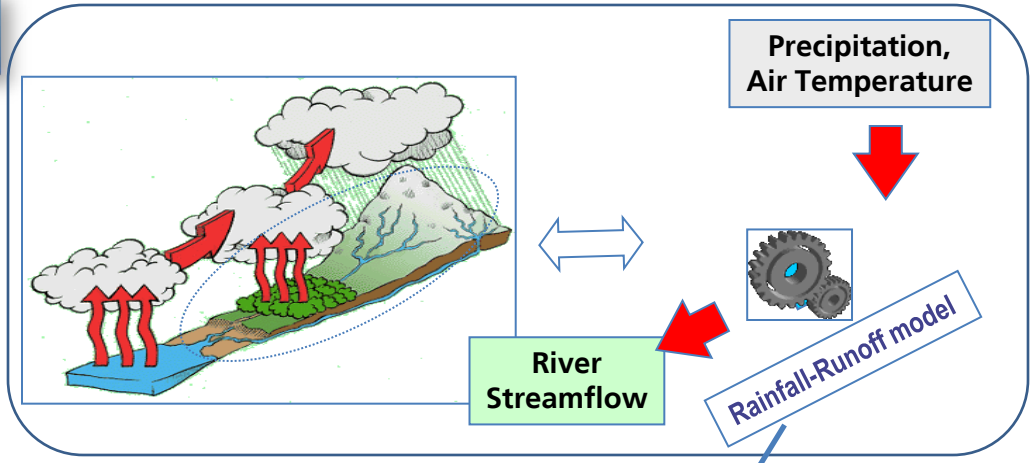
Probabilistic Forecasts

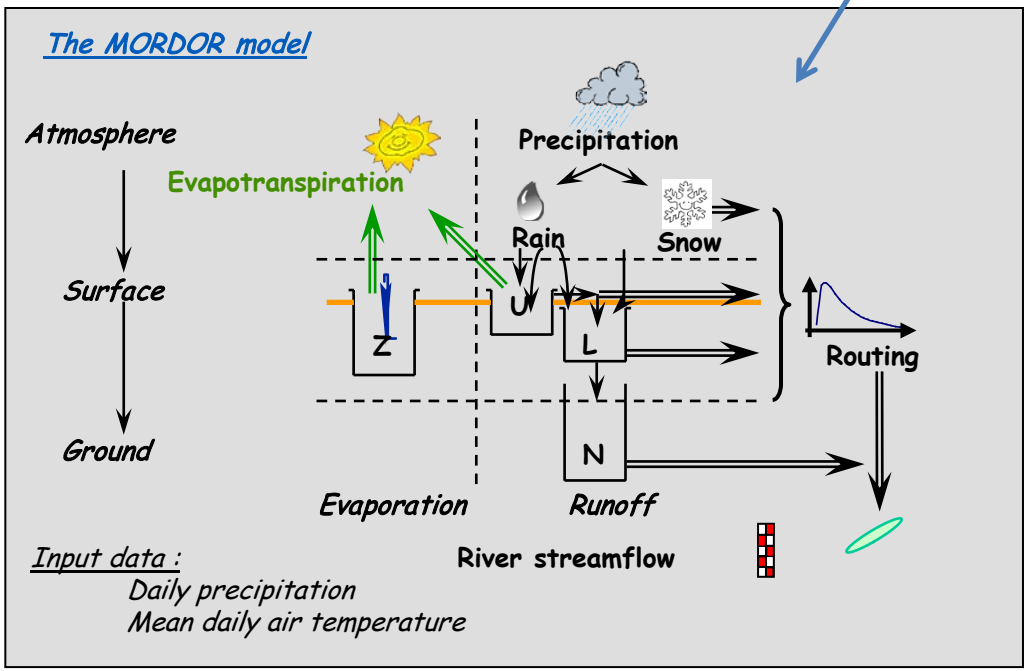
- **Output for each prediction: 50 selected analogs x 50 members -> 2500 monthly precipitation analogs forecasts (d+1 → d+32)**
- **Oct 2004 -> Oct 2010**

Domain and hydrological model



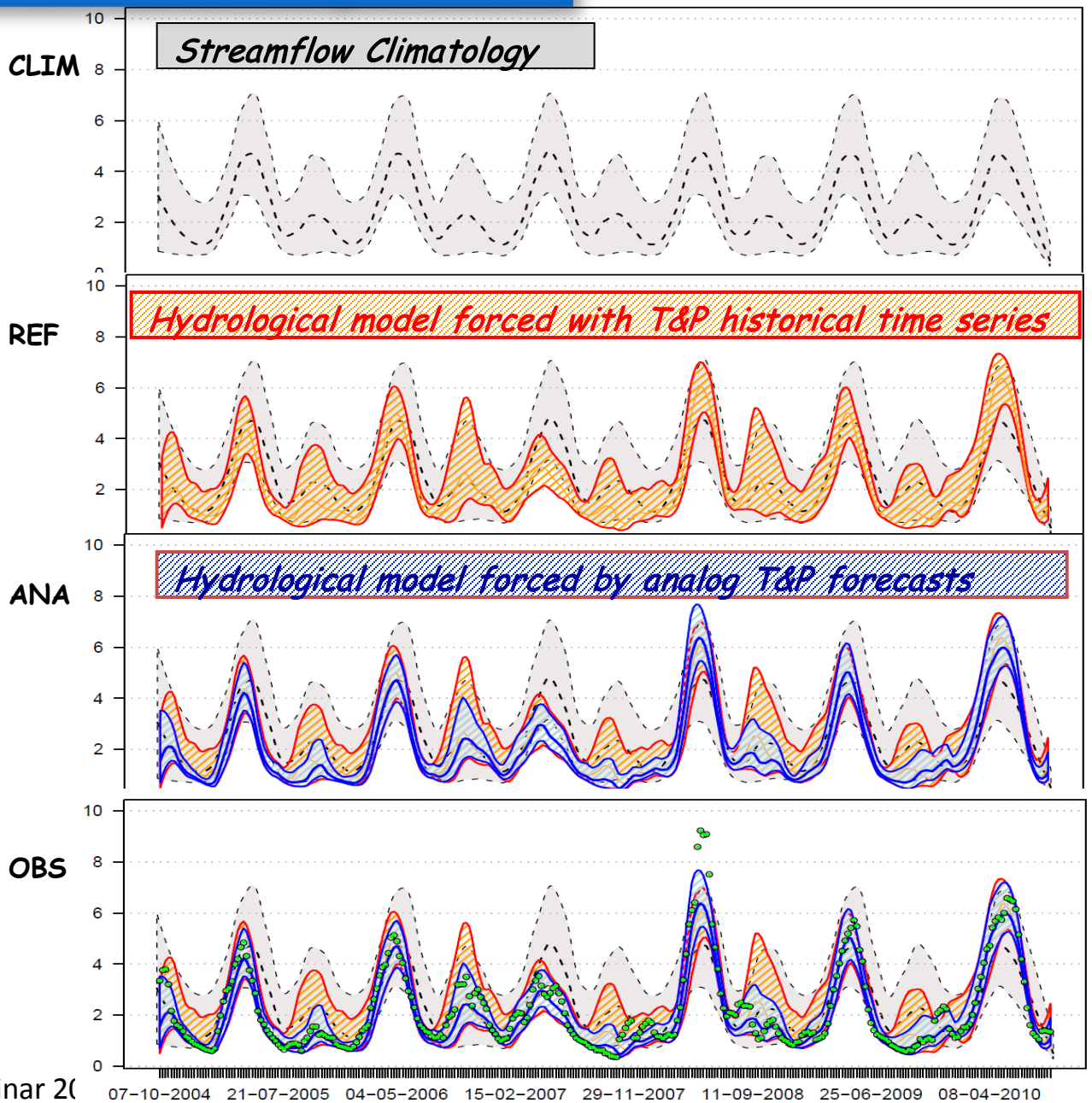
43 watersheds





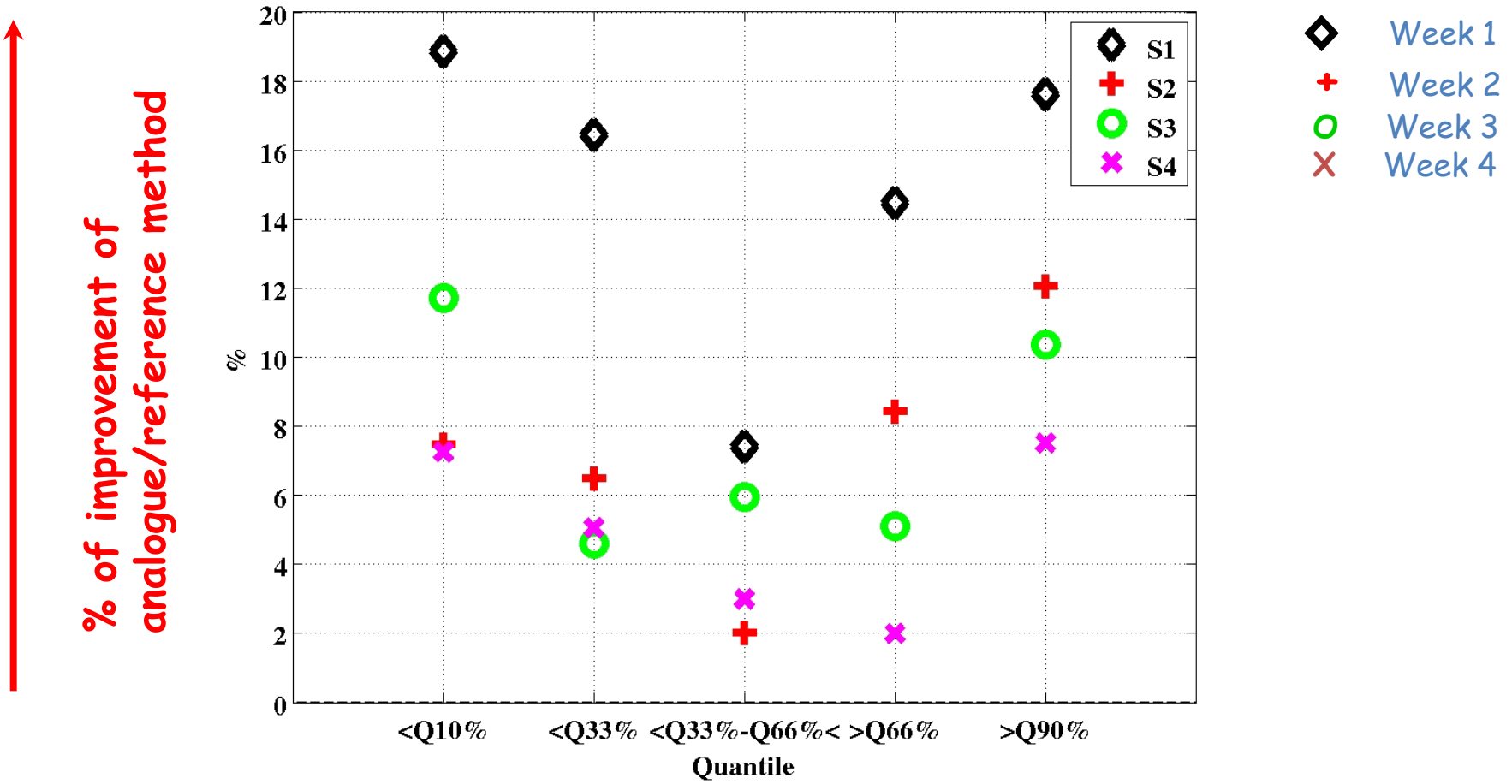
1 model for each watershed

3 different forecasting methods



Improvement in precipitation forecasts

On average over 43 watersheds, annual

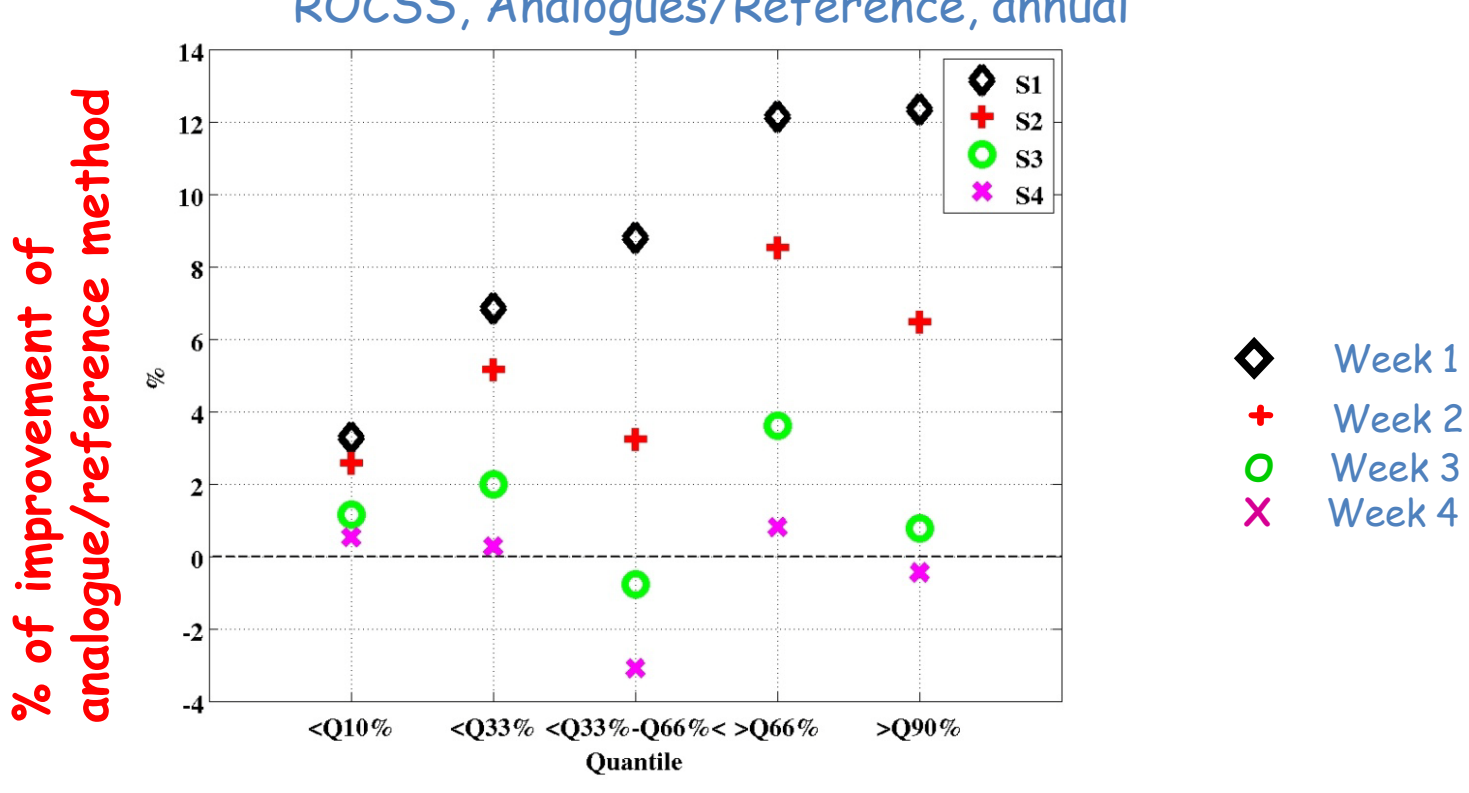


Precipitation: mean annual improvement (ROCSS analogue/raw forecasts)
Relative improvement: always positive on average over the 43 basins

Improvement in river flow forecasts

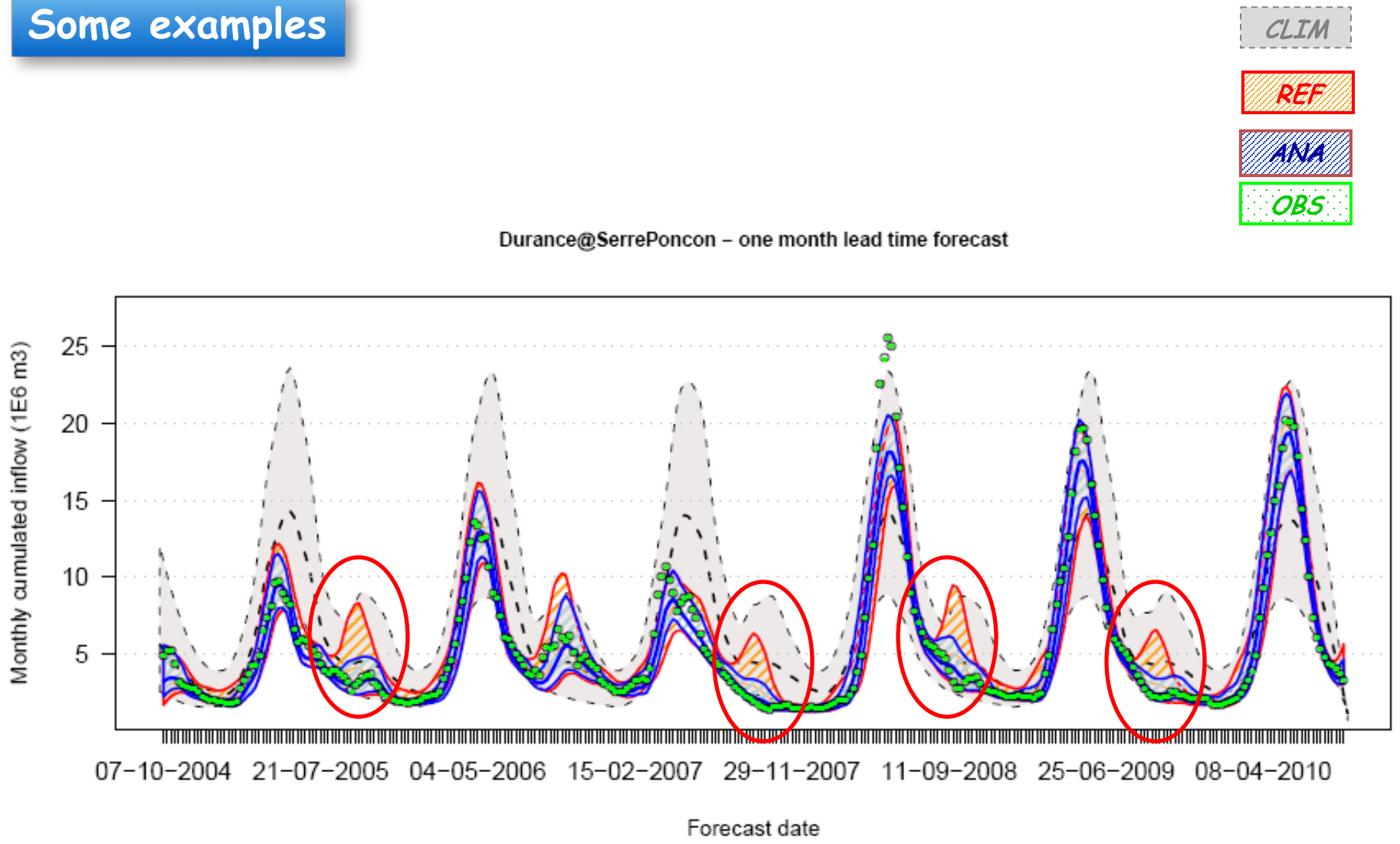
On average over 43 watersheds, annual

ROCSS, Analogues/Reference, annual



- Monthly forecasts + analogues ➔ improves results w.r.t. reference method in almost all cases
- Differences exist according to individual basins / season

Some examples



Target variable = monthly cumulated flow

Conclusions / River flow MF

- ECMWF Geopotential monthly forecasts are skillful over North Atlantic/Europe
- The analogue method can add value to this basic skill and improve precipitation (and temperature) forecasts
- The hydrological model is further improved with these dowscaled forecasts:
  - Low flows are well represented
  - Very high flows (floods) not well captured but better than reference method in general
- Work should go on to extend this to seasonal forecasts (3 to 6 months lead time)

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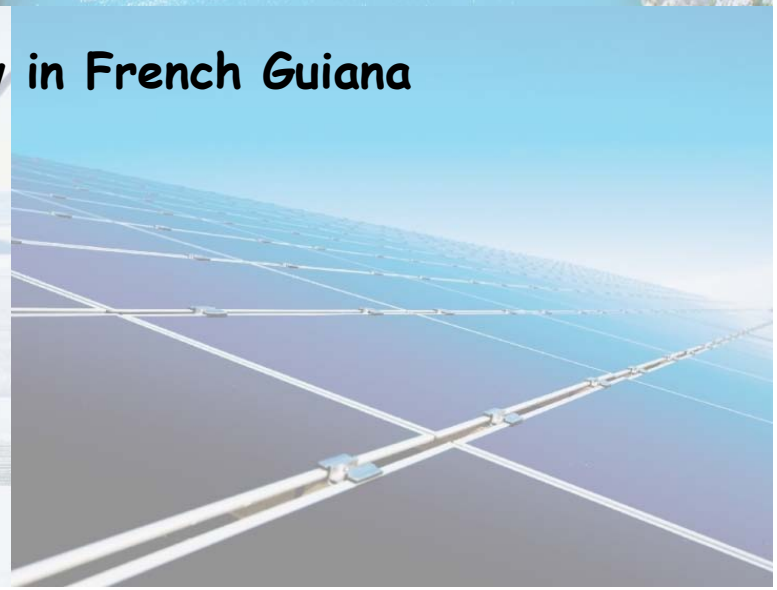
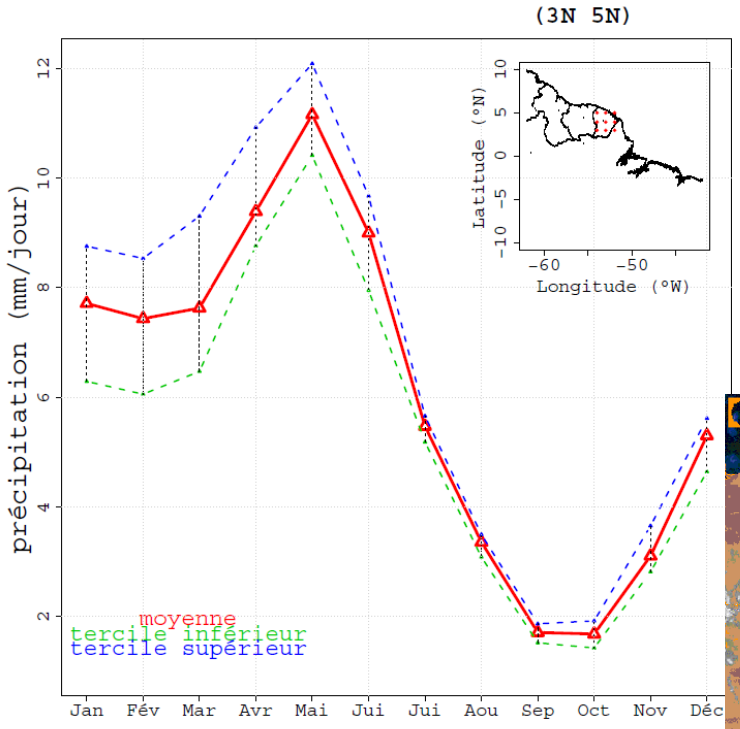
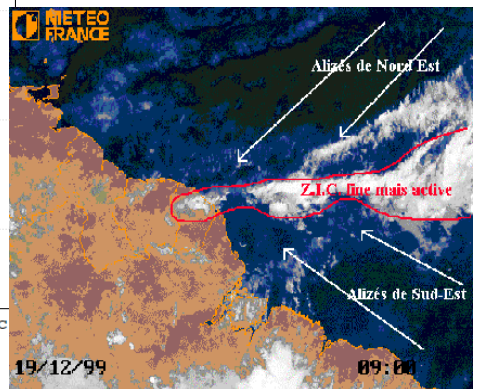


Petit-Saut: provides 2/3 of French Guiana's coastal area power





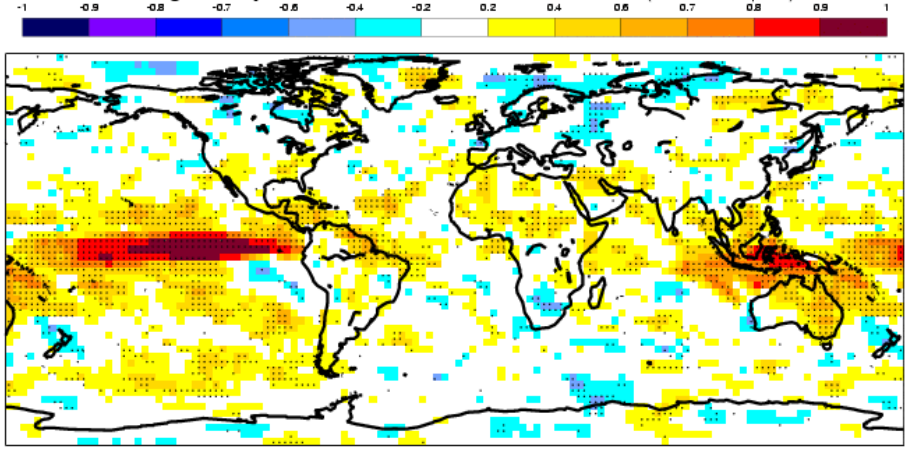
Petit-Saut reservoir & dam:

- ~70% of Guiana's power production
- Volume : 3.5 billion m^3
- Useful capacity 2.2 billion m^3

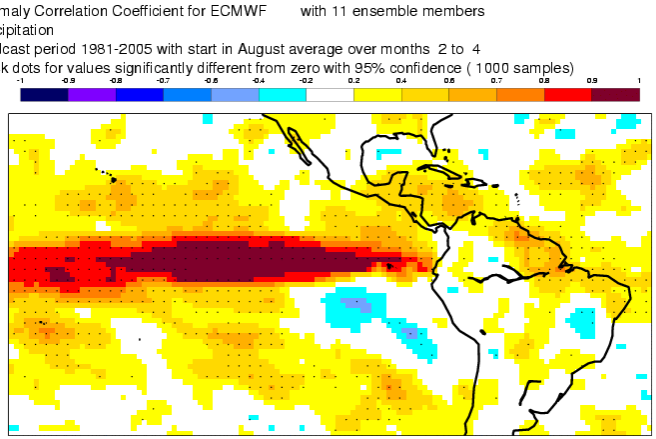
Goal : evaluate SF models to forecast the rainy season's (date of begining and intensity ?)

Precipitation: some skill over the Tropics !

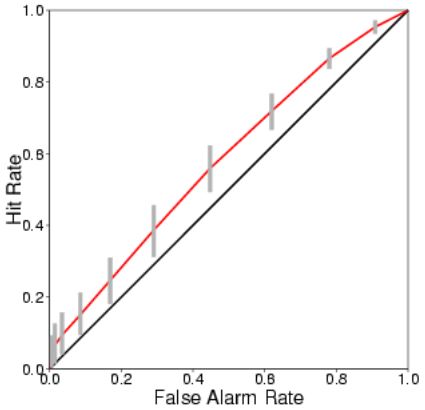
Anomaly Correlation Coefficient for ECMWF with 11 ensemble members
Precipitation
Hindcast period 1981-2005 with start in August average over months 2 to 4
Black dots for values significantly different from zero with 95% confidence (1000 samples)



ACC



ROC diagram for ECMWF with 11 ensemble members
Precipitation anomalies below the lower tercile
Accumulated over South America (land points only)
Hindcast period 1981-2005 with start in August average over months 2 to 4
Skill scores and 95% conf. intervals (1000 samples)
ROC score: 0.580 (0.530, 0.630)



ROC

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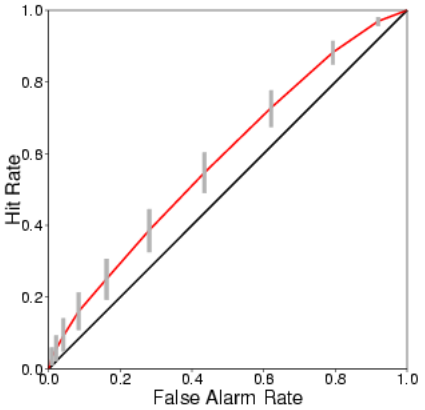
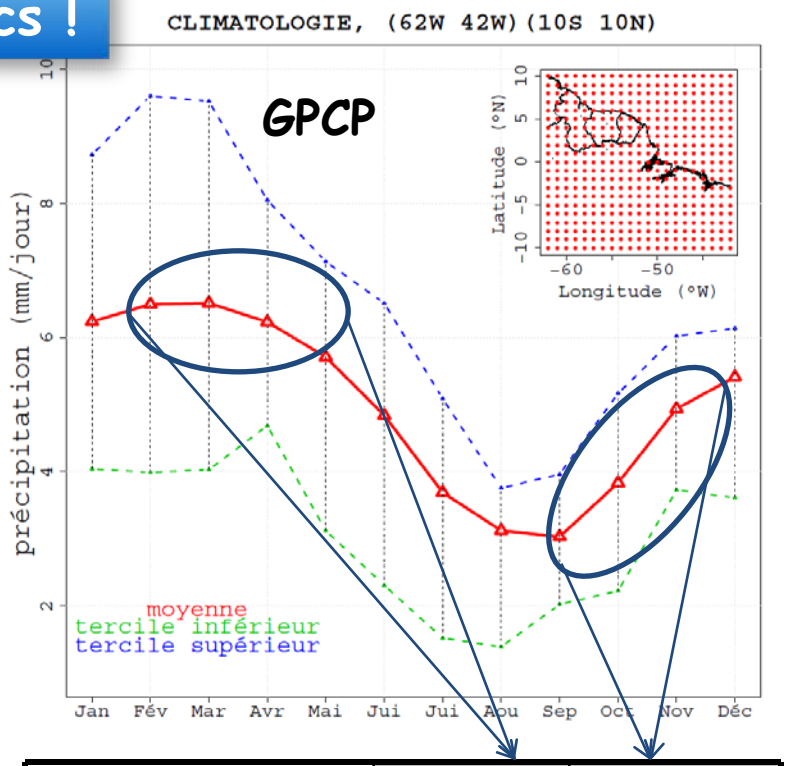


Precipitation: some skill over the Tropics !

- ECMWF S3 hindcasts (1980-2005)
- Verification against GPCP monthly Precip

➔ There is skill in precip / divergence@500hPa / Z500 / Humidity@500 …

➔ Can this be used to forecast river flow upstream the reservoir to allow a better management of the water stock ?



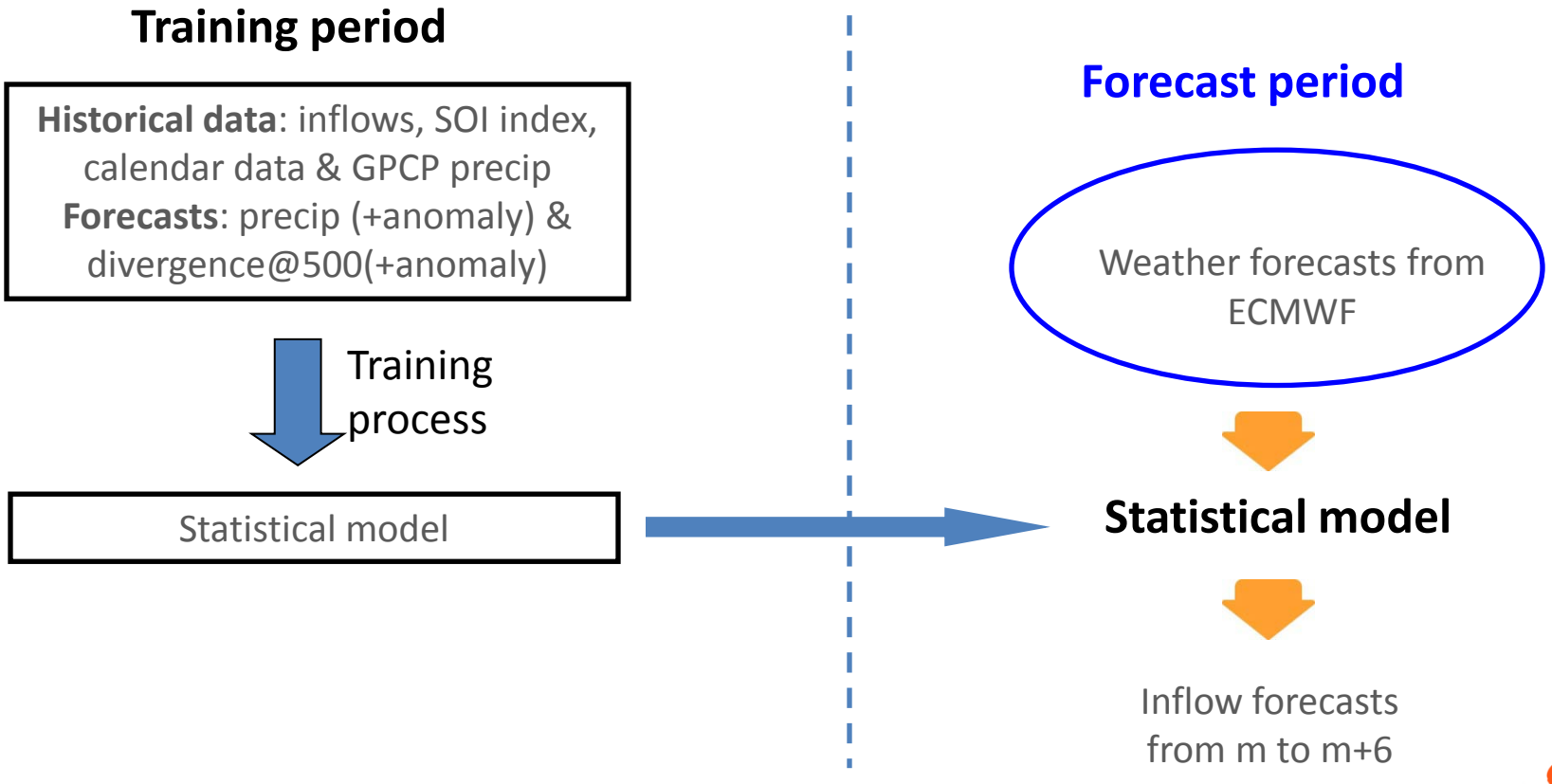
ECMWF		J→F/M/A	A→S/O/N
ACC		0,80	0,69
RMS SS		0,40	0,27
CRPSS		0,56	0,55
ROCA	Upper tercile	0,84	0,83
	Middle tercile	0,64	0.57
	Lower tercile	0,91	0.82

Precip scores (lead 2-4)

Streamflow forecasts ?

We use a commercial software / modelling suite to forecast inflows at Petit-Saut reservoir, from large scale forecasts

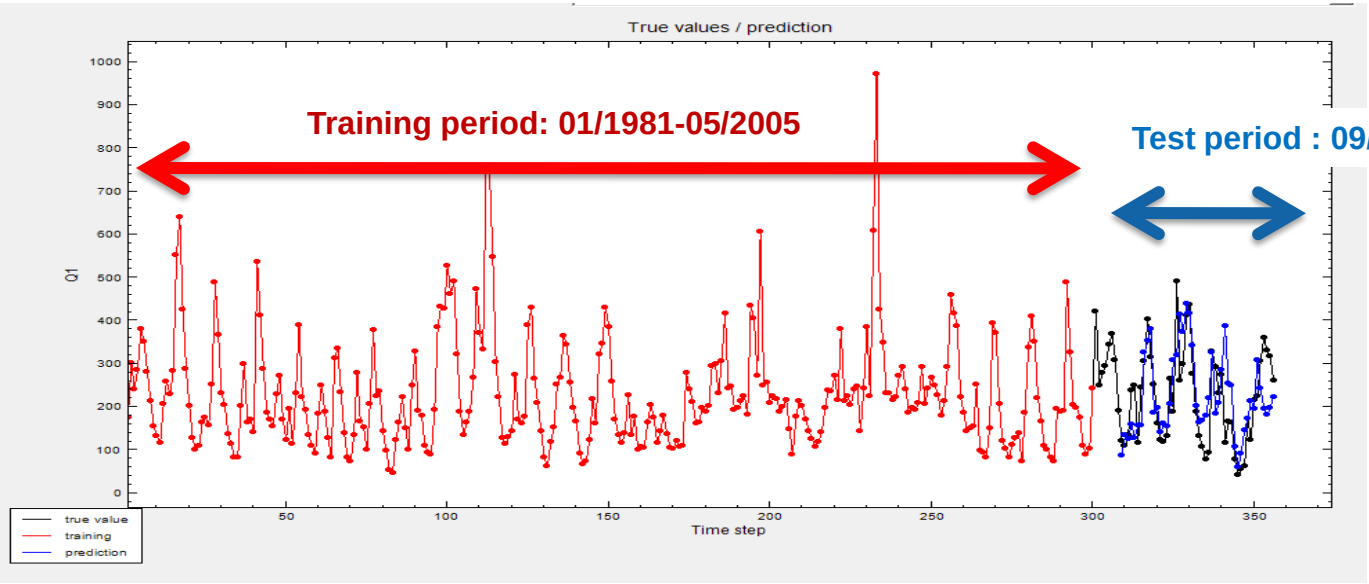
This model allows to use other predictors, like calendar data, dry/wet season index, SOI, climatology of target variable … and to pre-process the data (e.g. PCA …)



Variables used and model training

Input variables :

- SOI
- Historical flow (+anomaly)
- Forecasts:
  - ☑ Precipitation (+anomaly)
  - ☑ Divergence @500 (+anomaly)
  - ☒ Relative humidity @500
  - ☒ Z500



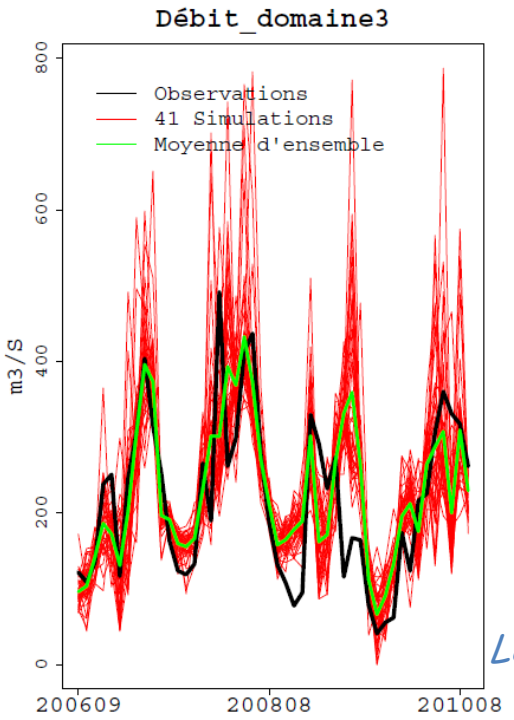
Some results

DECIDE vs REFERENCE

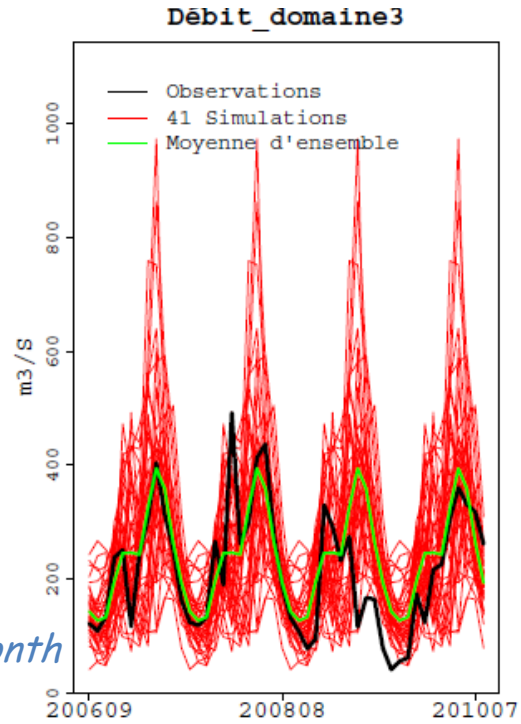
	Lead 3
Correlation	+ 5.2%
RMS	+ 7.3%
ROCA	+ 5.4%
BS	+ 14.4%
CRPS	+ 6.7%

Decide vs. Ref method

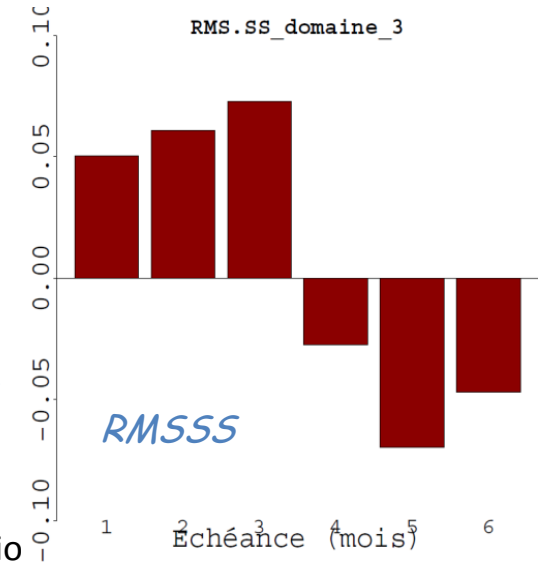
ECMWF SF/DECIDE



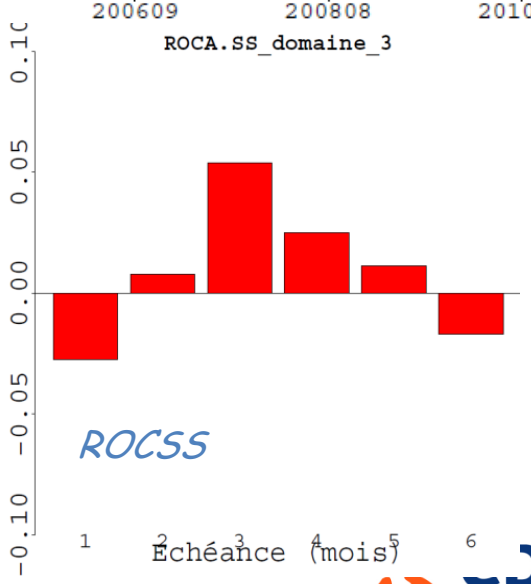
REFERENCE: streamflow climatology (41 years 1969-2009)



Lead: 1 month



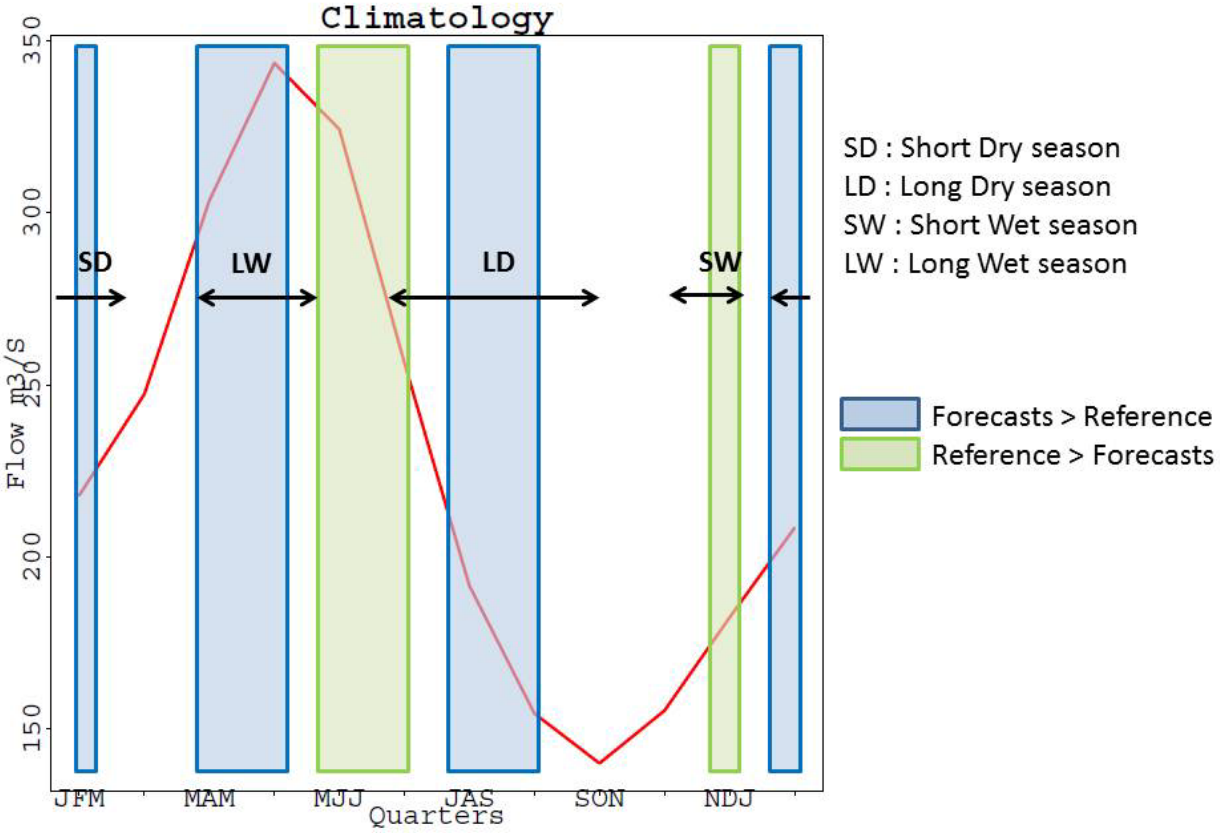
RMSSS



ROCSS

Schematic view: not that easy to use in operations !

Streamflow Climatology



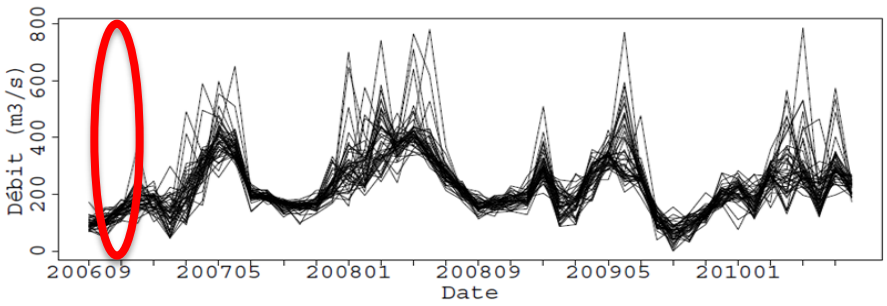
SD : Short Dry season
LD : Long Dry season
SW : Short Wet season
LW : Long Wet season

Forecasts > Reference
Reference > Forecasts

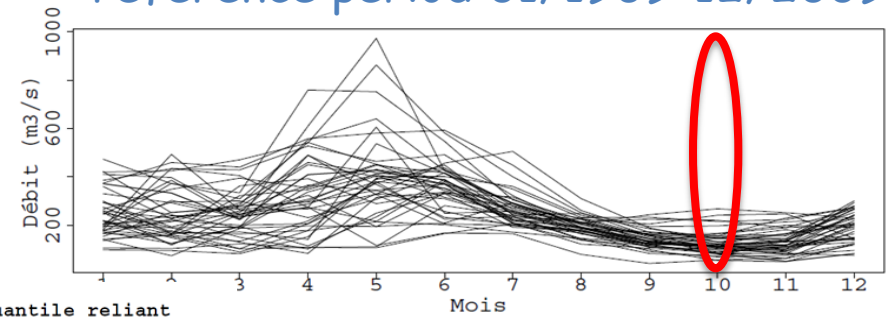
➔ Forecasts are sometimes good, but sometimes the Reference forecasts are better: how to arbitrate ?
End users want to get better or equal quality, but not worse !

Operations need (at least) weekly streamflow values !

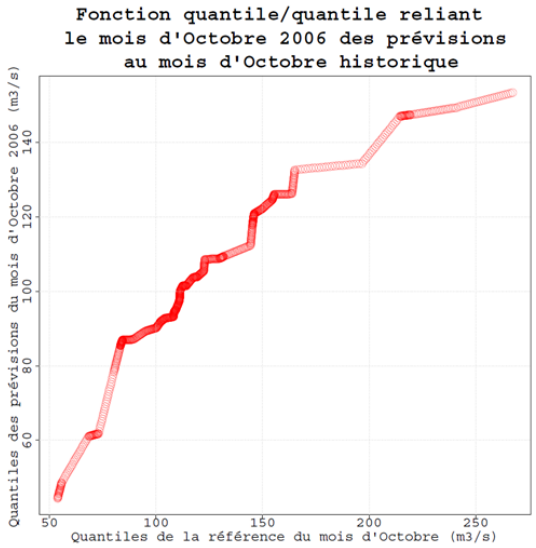
Monthly flow forecasts on test period 09/2006-08/2010



Climatological monthly flow on the reference period 01/1969-12/2009



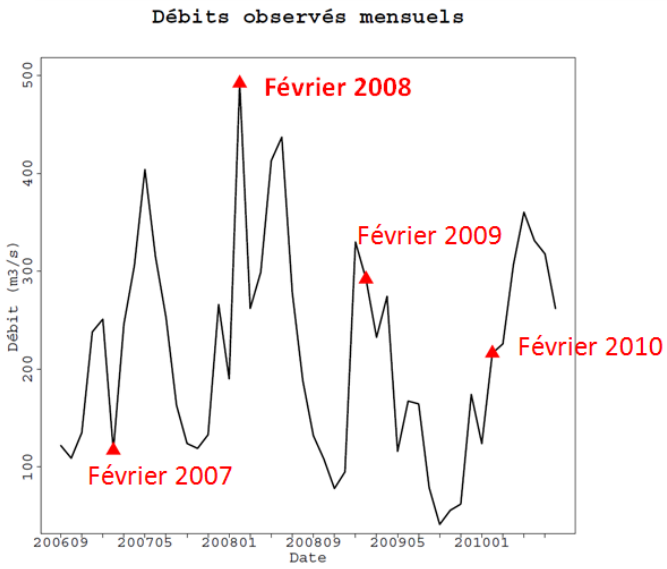
2006/10

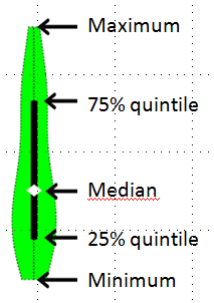


October (reference)

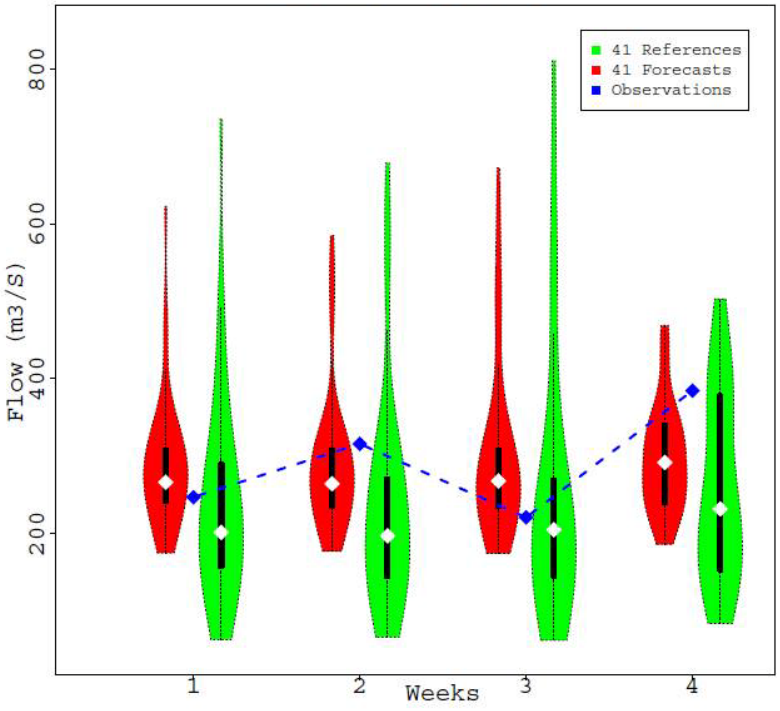
Regression parameters then applied to weekly flow values(ref) & forecasts (monthly) to get forecast weekly values

1 particular example … be optimistic !





Feb 2008, Weekly streamflow, lead=4 months



Feb. 2008 (very rainy/climatology):

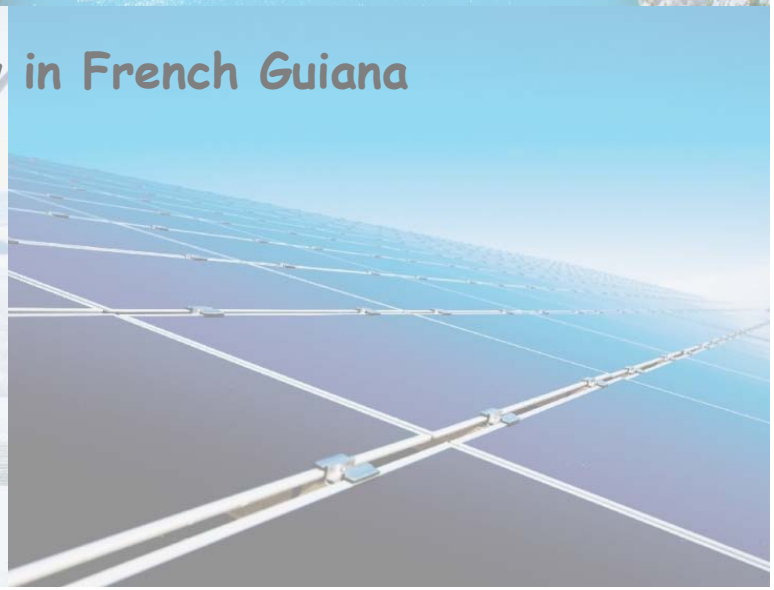
- Forecasts are much less dispersed than reference climatology
- Closer to the observations
- Better probabilities ?

Conclusions:

- New forecasts better than ref method until leads 3-4 months, in particular in rainy seasons
- Simple Q/Q regression allows to provide weekly values, with good results in the case of feb. 2008
- Re-entrain the model and compute scores with System 4 and extend to 2012: improvements ?

Outline

1. Power system optimization
2. Monthly forecasts: temperature in France
3. Monthly forecasts: precipitation and river flow in France
4. Seasonal forecasts: river flow in French Guiana
5. **Summary**



Summary

- Power demand and hydro power production are probably the (current) most weather dependant fields
- State of the art NWP determinitic models are used routinely for short-term forecasts
- Progress has been made in the use of probabilistic forecasts (incl. EPS)

- Monthly forecast now routinely used in decision making processes (but not included in tools/application models)

- Seasonal forecasts requested by end-users ☺, but not really used ☹

- Some difficulties remain:
  - users' understanding
  - interface with existing tools …
  - adequation to operational needs (distribution tails …)

➔ Users' training is essential

➔ Need of upstream provider/user collaboration to develop products & the use of probabilistic forecasts

Troccoli, A. *et al.*: Promoting New Links Between Energy and Meteorology. *BAMS*, doi: 10.1175/BAMS-D-12-00061.1

http://www.icem2011.org

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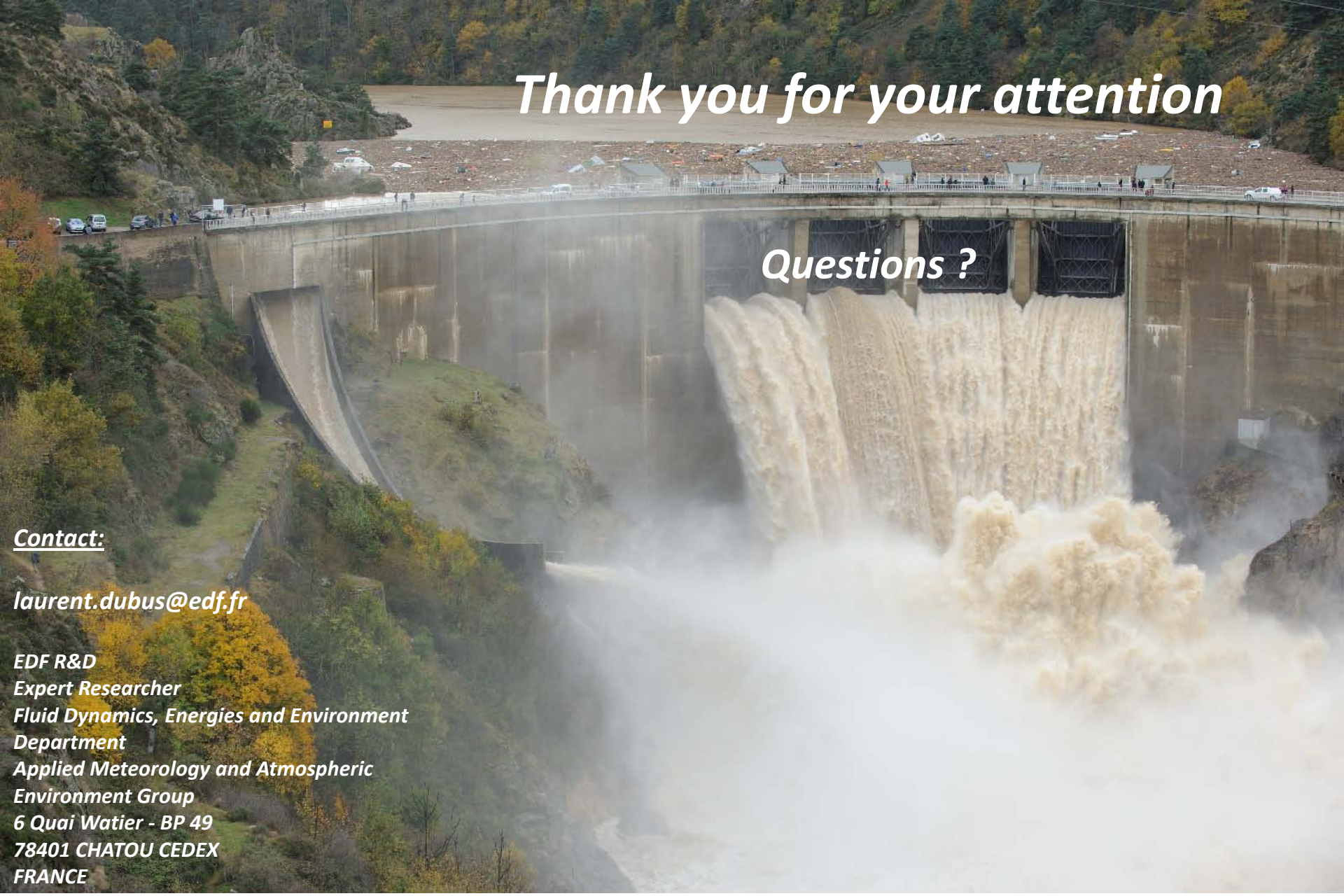

Thank you for your attention

Questions ?

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