How can seasonal to decadal forecasts be useful to the power sector ?

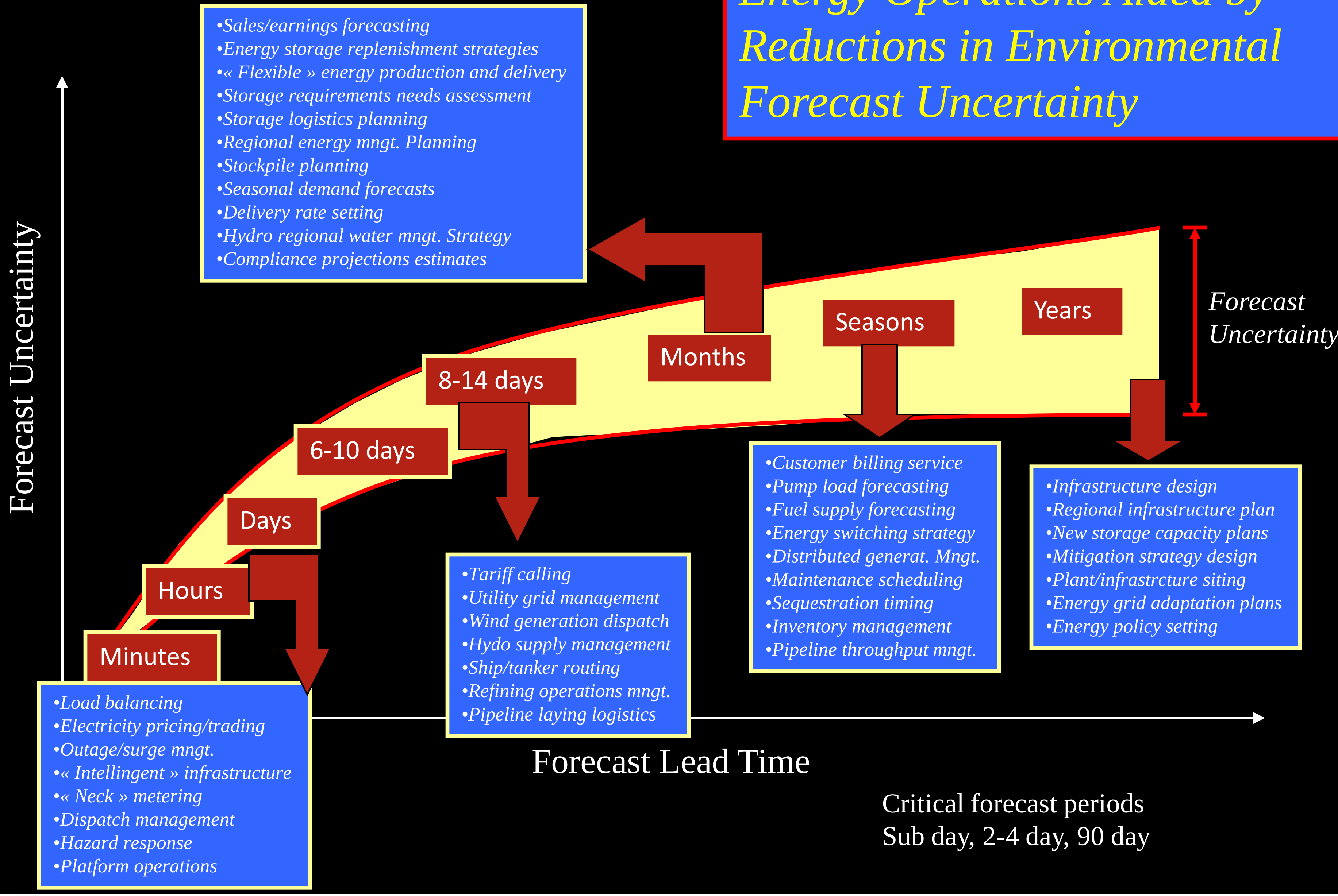
Laurent Dubus
Julien Najac
Sylvie Parey

EDF R&D
Applied Meteorology &
Atmospheric Environment Group

WCRP-WGSIP
International Workshop on seasonal to decadal prediction

Centre International de Conférence de Météo-France
Toulouse, France
13-16 May 2013

Energy Operations Aided by Reductions in Environmental Forecast Uncertainty



From GEOSS 10-Year Implementation Plan Reference Document
Courtesy of M.G. Altalo, Science Applications International Corp.

Outline

1. Power system management

2. Examples on monthly & seasonal time scales

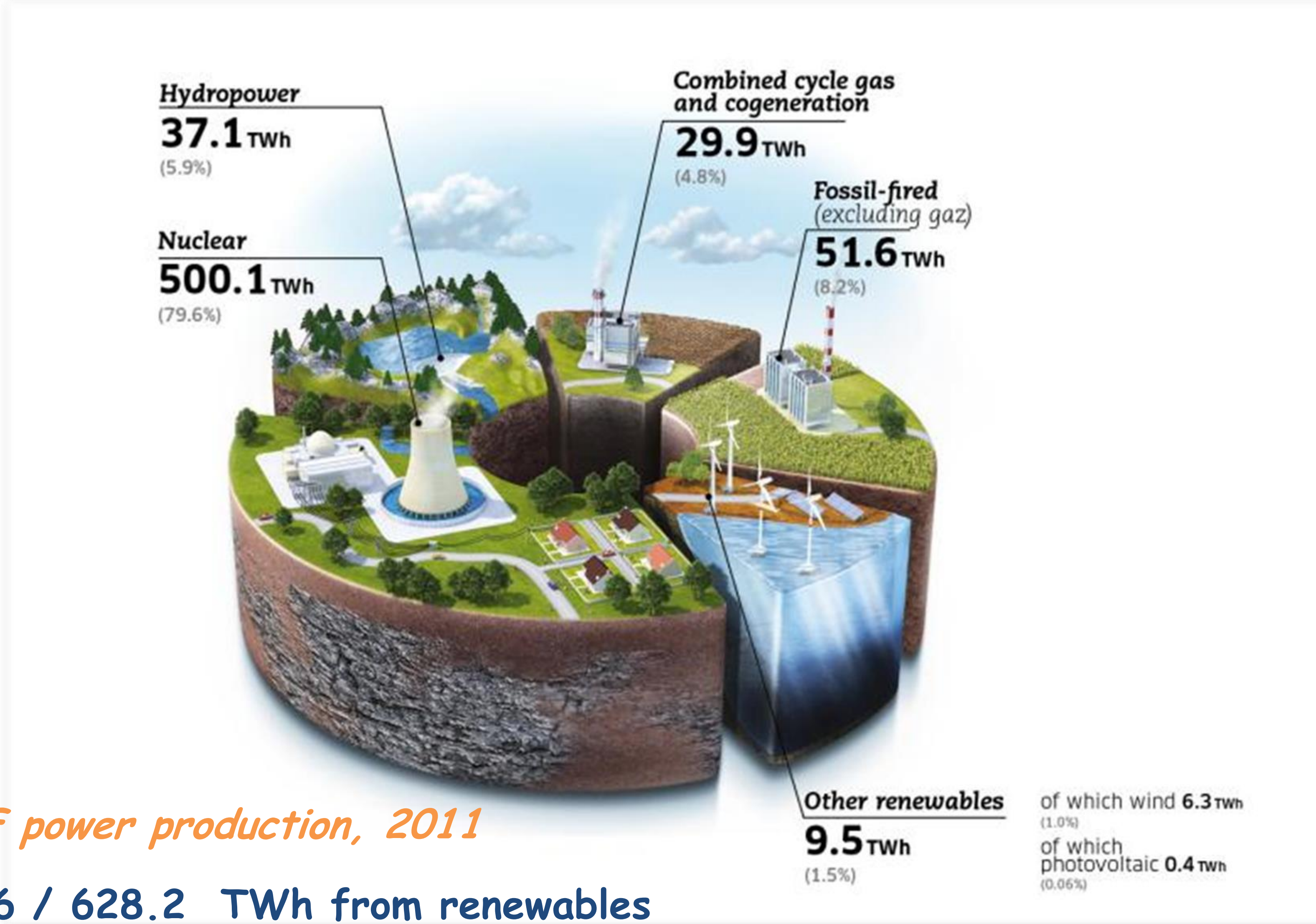
3. Examples on longer time scales

4. Some expectations & conclusions

Outline

1. **Power system management**
2. Examples on monthly & seasonal time scales
3. Examples on longer time scales
4. Some expectations & conclusions

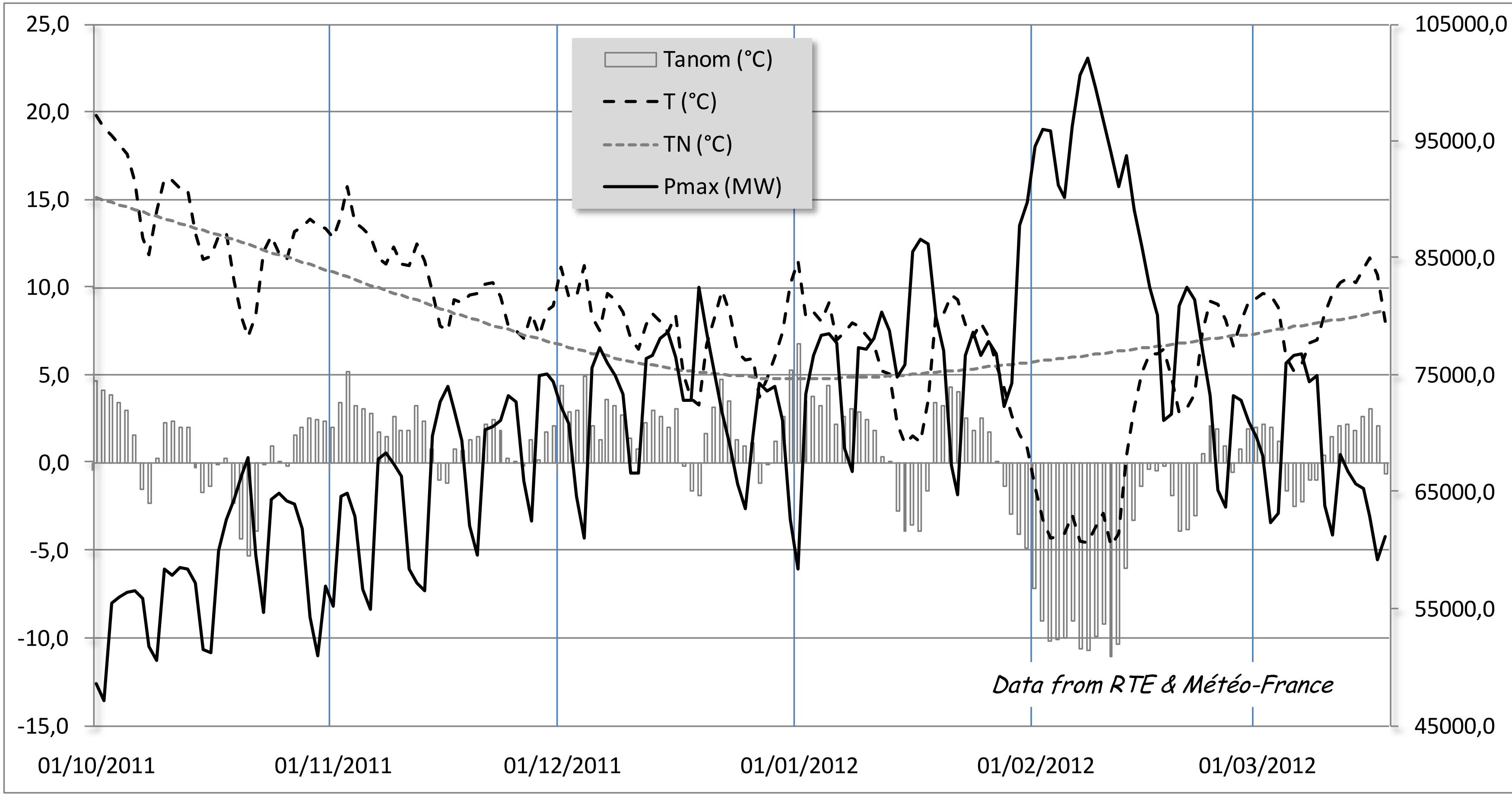
Power systems are more and more complex



EDF power production, 2011

46.6 / 628.2 TWh from renewables

Power demand depends on temperature

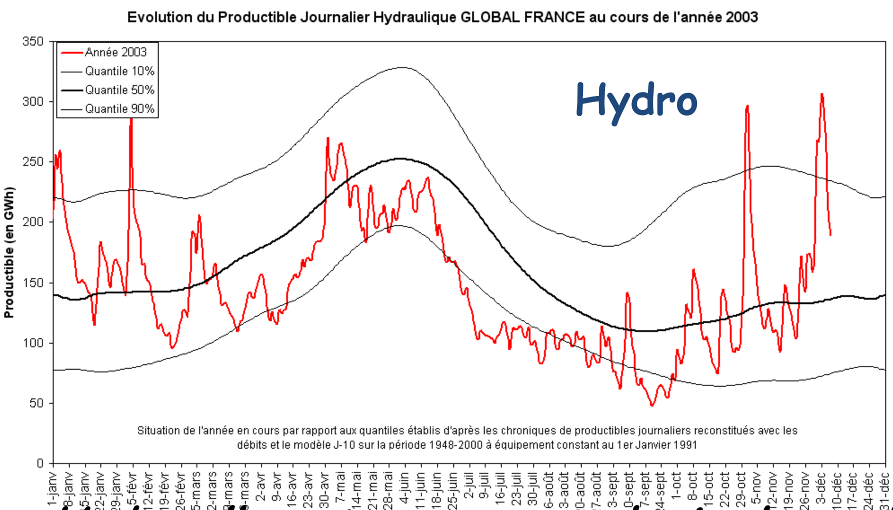


In France, power demand is highly dependent on temperature.

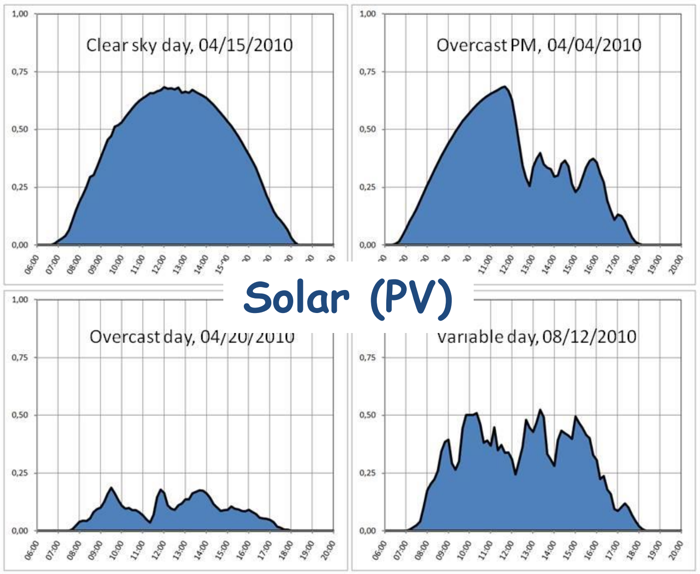
- in winter : -1°C dT ➔ +2 300 MW of extra production ~ 20 M€ hedging
- in summer : +1°C dT ➔ +400-500 MW of extra production

Increasing renewable energy production increases the dependance on weather, climate and water

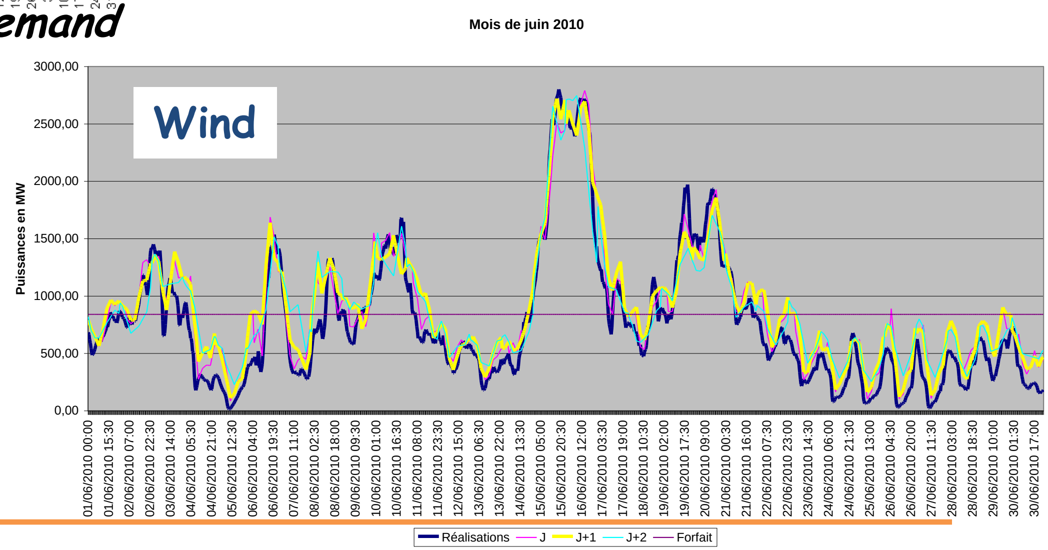
Daily variations of french hydro power production capacity in 2003



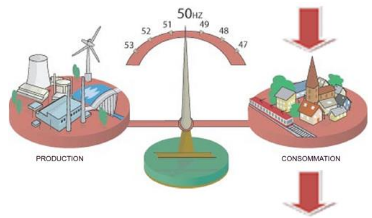
Hydro allows to answer peaks in demand



Renewables: highly fluctuating resources (especially wind and solar energy)



Power Offer/Demand balance: a complex problem

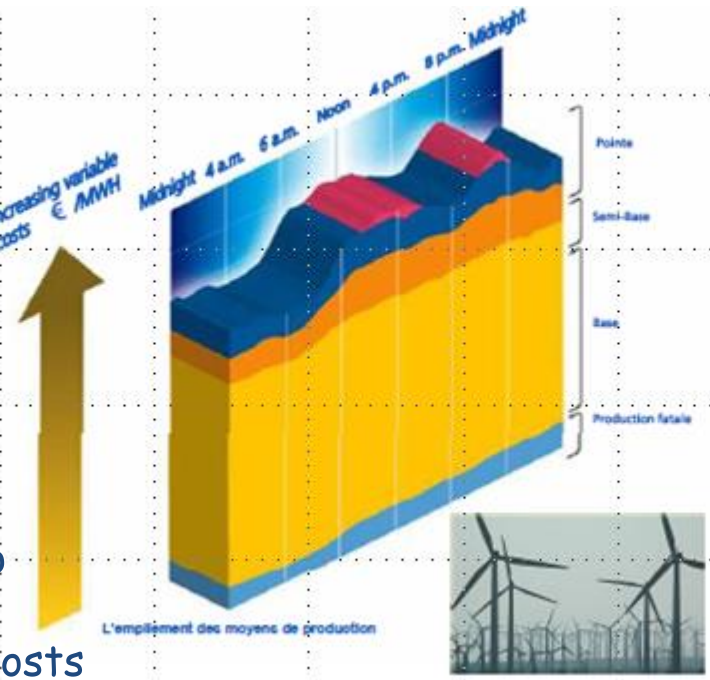


Production units' program:

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



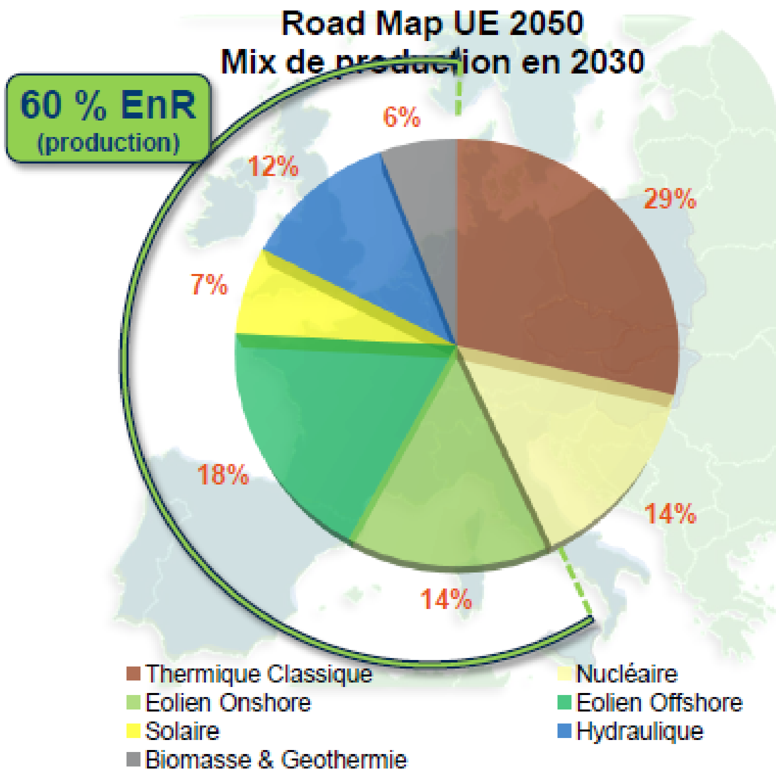
Huge optimization problem: 1 000 000 variables & 10 000 000 constraints for day+2 30 minutes forecasts

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)

Growing importance of Renewables

In the UE Road Map 2050 high RES scenario, wind and solar generation increase in share to 40 % of European generation in 2030.



	GW	Load factor (h/y)
P V	220	1100
On shore wind	280	1900
Off shore wind	205	3200
Hydro Power	120	3800

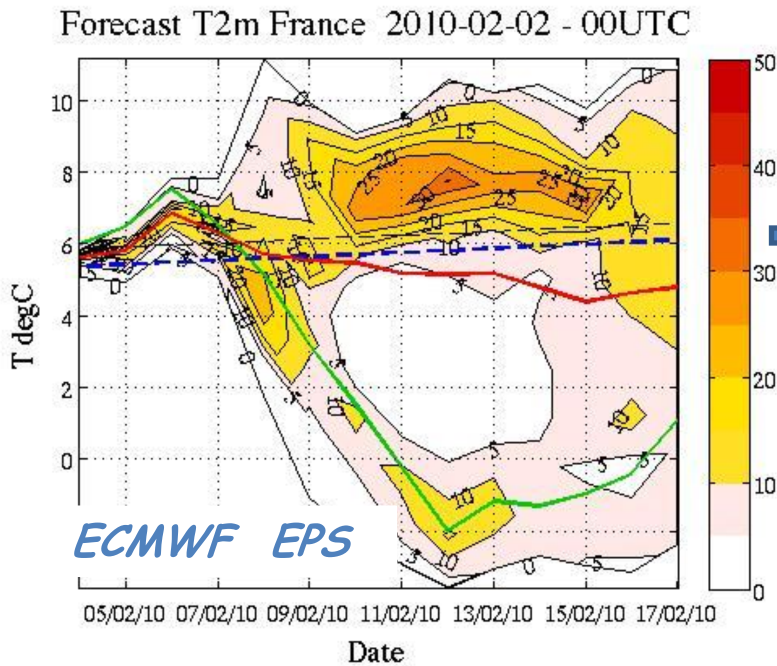
Could power systems adapt to the new sources of variability and uncertainty coming along with intermittent renewable generation ?

Outline

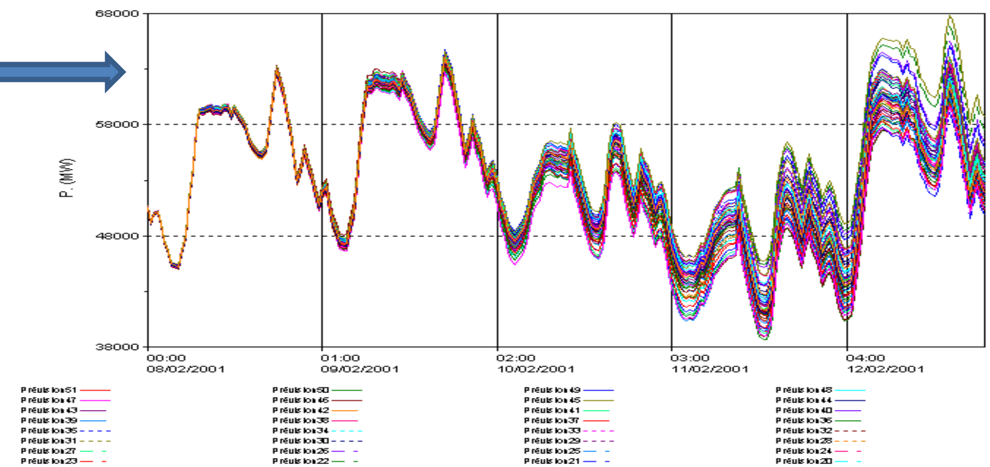
1. Power system management
2. **Examples on monthly & seasonal time scales**
3. Examples on longer time scales
4. Some expectations & conclusions

State of the art NWP models are used

Example: in-house products built from ECMWF & Météo-France VarEPS/monthly forecasts (temperature)

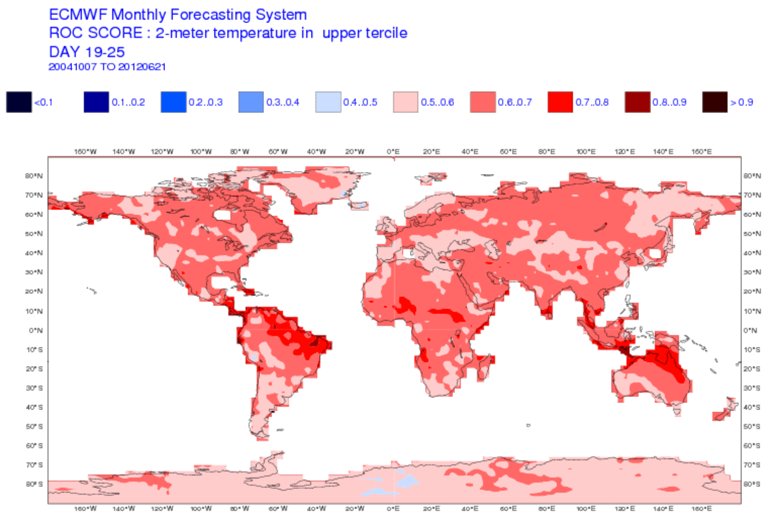


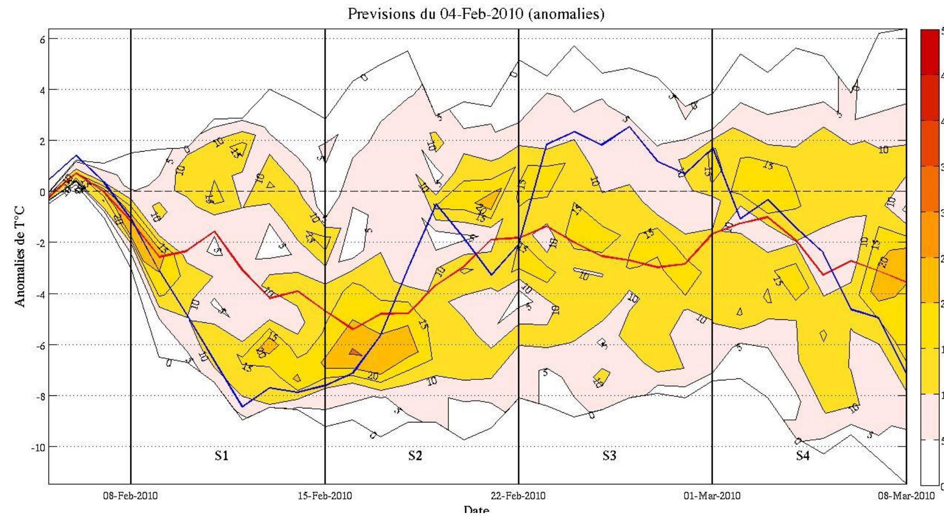
Load forecasts



Temperature + Cloud Cover ➔ Demand forecasts ➔ production units scheduling ➔ physical margins calculations ➔ hedging for residual financial risk (mandatory)

Monthly Forecasts: Feb. 2010 cold spell





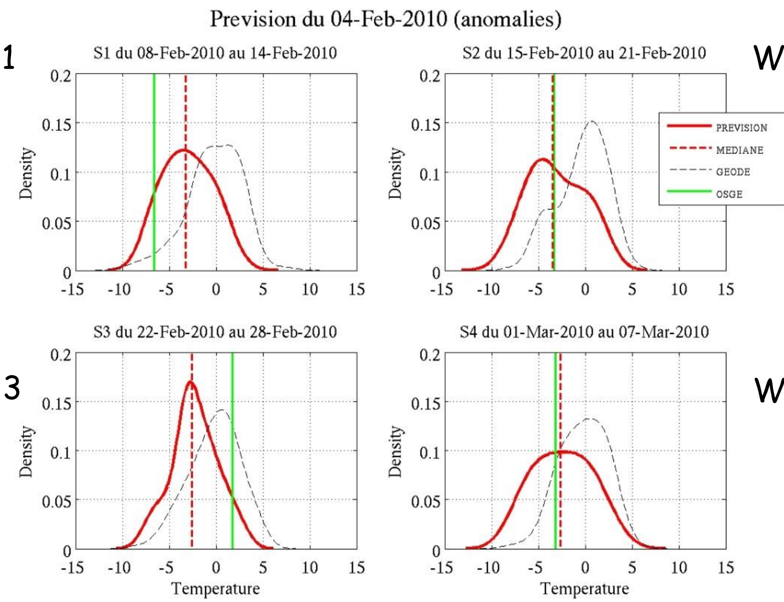
Week 1

Week 2

Climatology

Monthly fcst

Observation

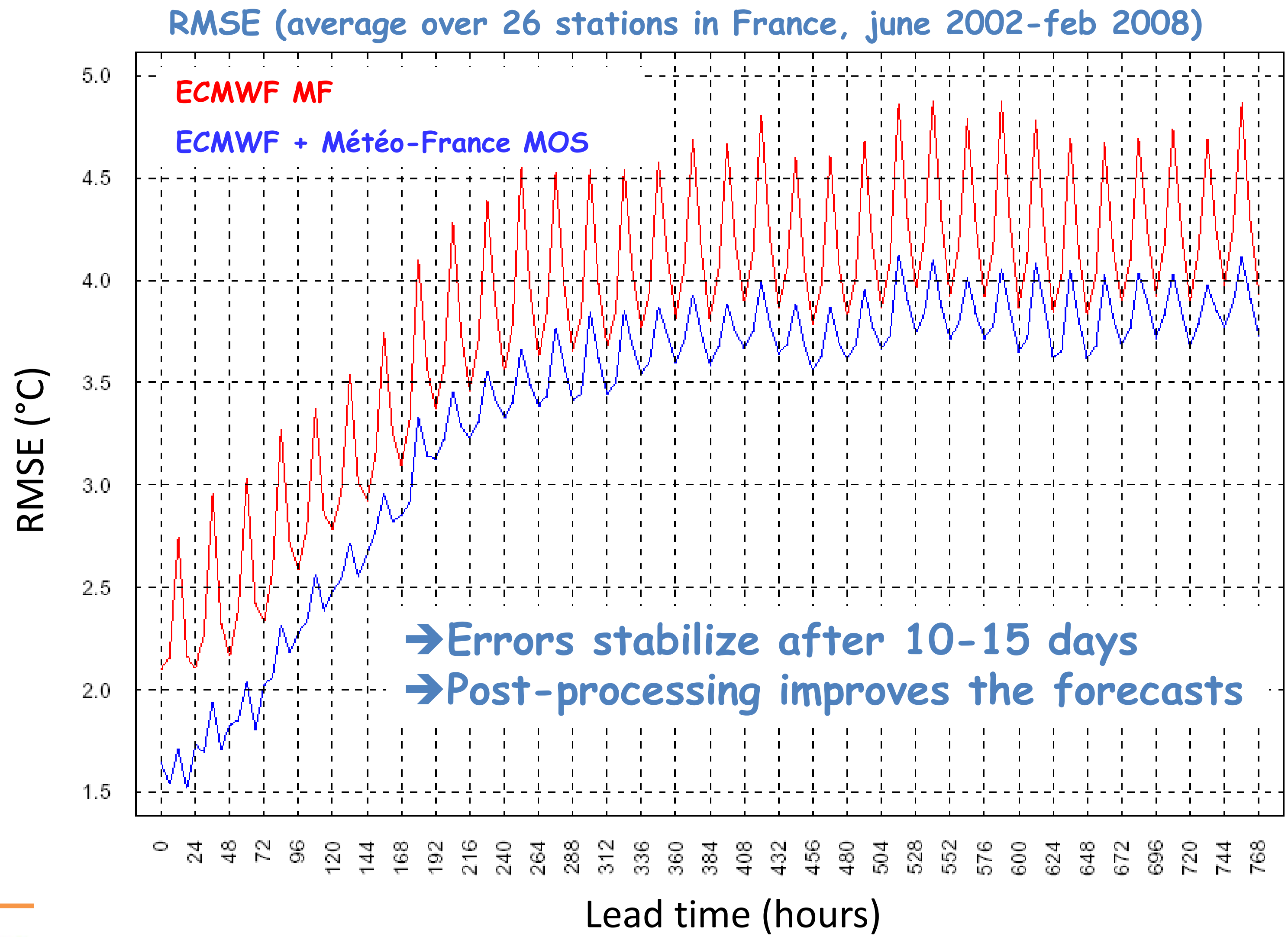


Week 3

Week 4

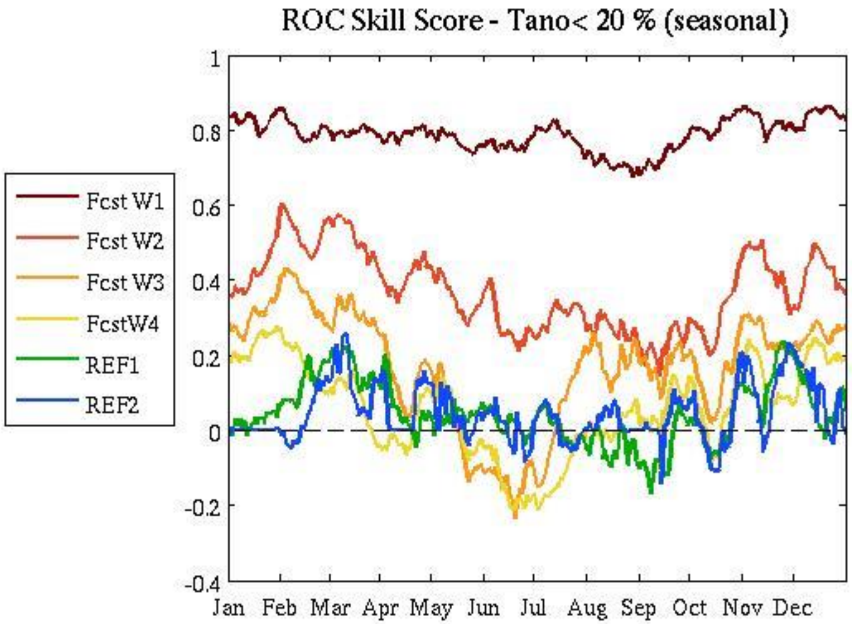
ECMWF Monthly Forecast
2010/02/04 - T2m over France

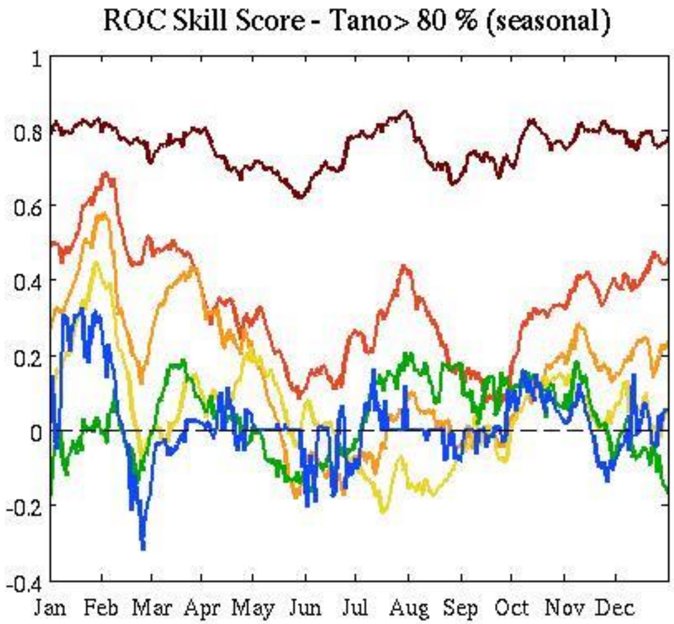
Monthly Forecasts: Statistical post-processing by Météo-France improves raw model outputs



Verification (10/2004 – 03/2012)

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





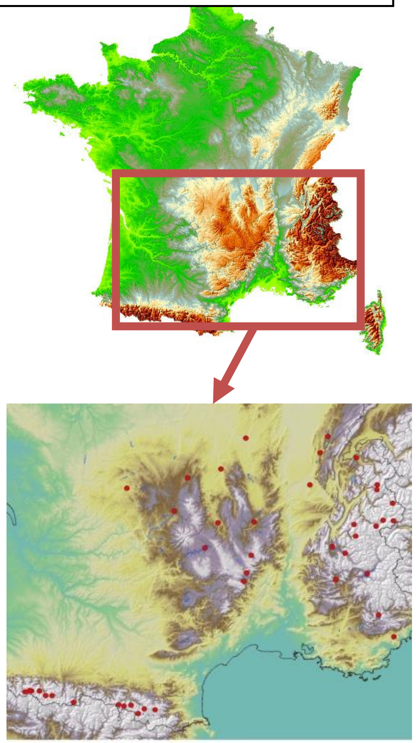
- There is information up to week 3 (4), in particular in winter and/or when the observed anomaly is strong

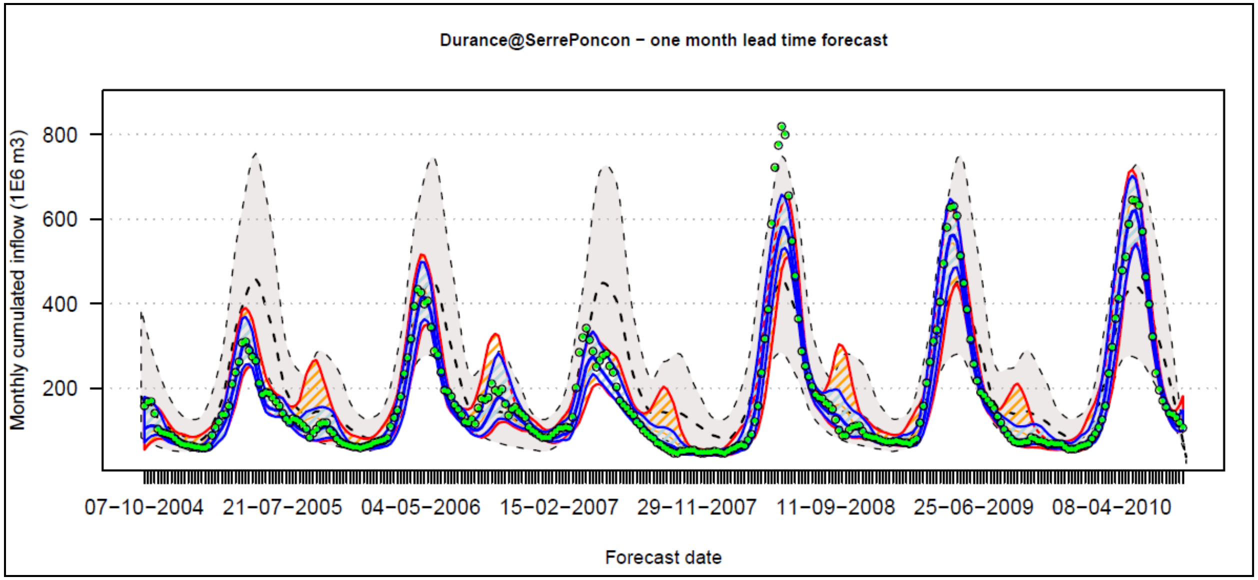
  → **MoF have been used routinely as support to decision making since 2006**

- but difficulties remain: users' understanding, distribution tails, integration into complex information systems…

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

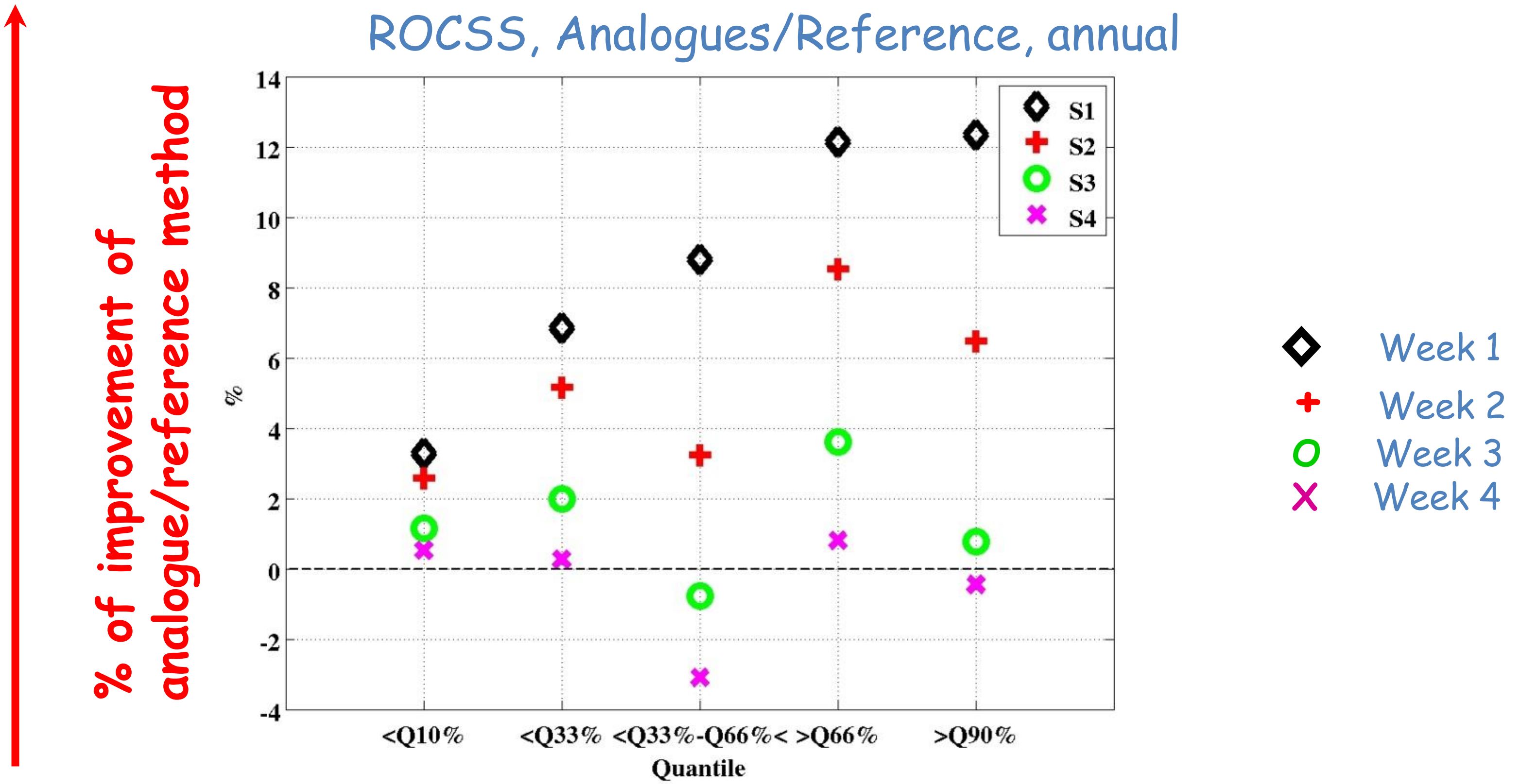




- *Streamflow climatology*
- *Hydro Model forced by T2m & Precip climatology (1969-2008)*
- *Hydro Model forced by Analog T2m & Precip*
- *Observation*

Monthly forecasts of river discharge using ECMWF products + in house post-processing methods

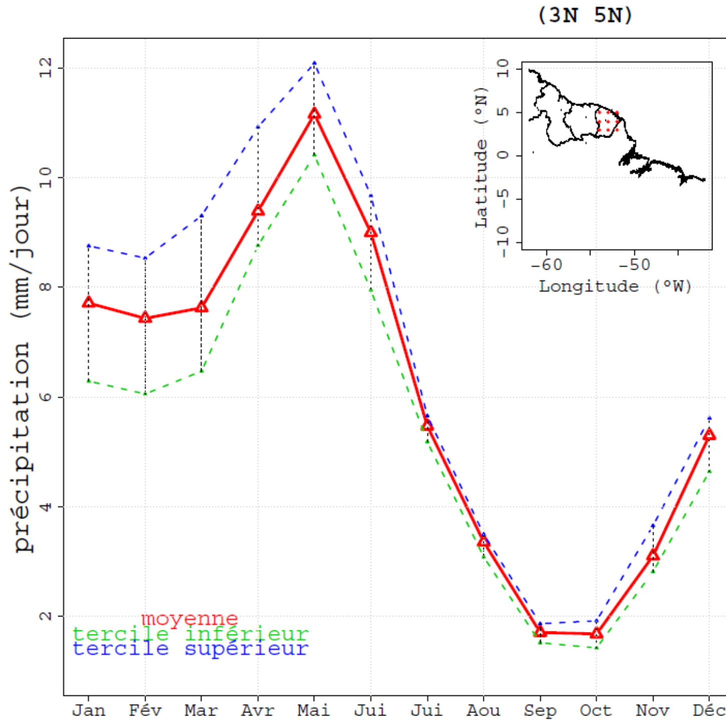
On average over 43 watersheds, annual

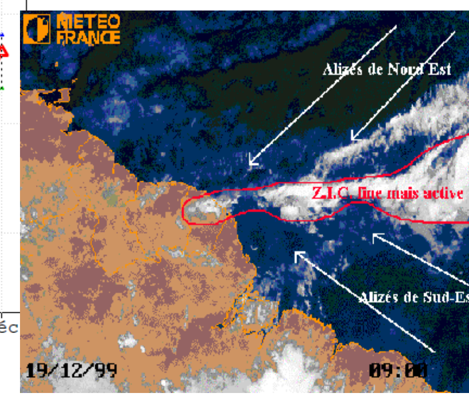


➔**New model is now operational,**
➔**an extension to seasonal forecasts is under consideration**

DUBUS, L. In Press. Weather & climate and the power sector: Needs, recent developments and challenges. In: TROCCOLI, A., AUDINET, P.,DUBUS, L. & HAUPT, S. (eds.) Weather matters for energy. Springer

Seasonal forecasts of river discharge in french Guiana



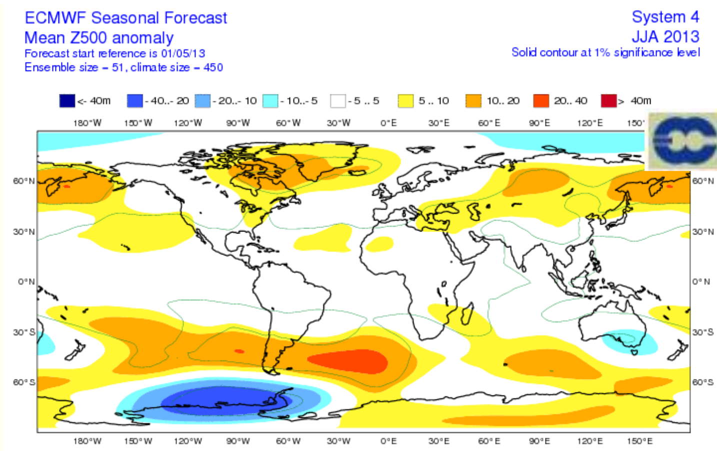


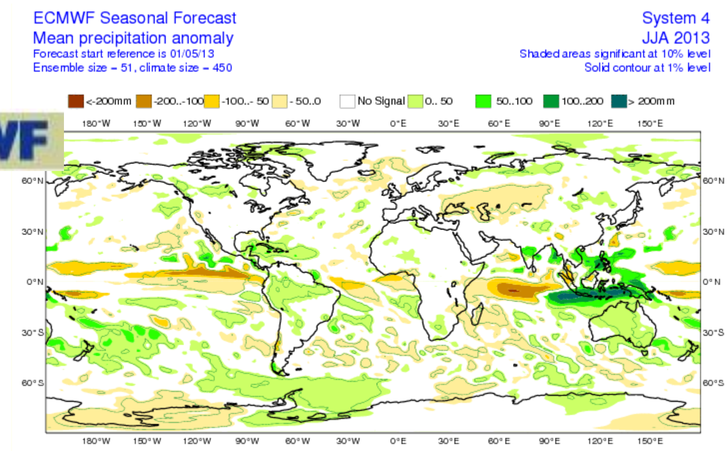
Petit-Saut reservoir & dam:

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

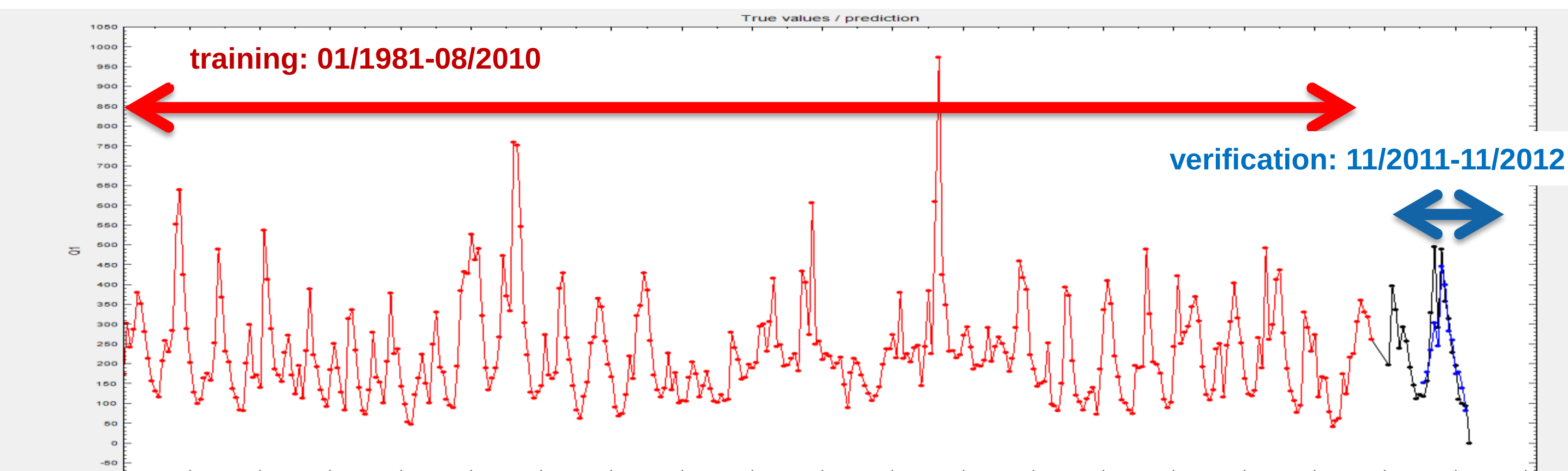
Goal : evaluate SF models to forecast the rainy season's (date of begining and intensity ?)

Seasonal forecasts of river discharge in french Guiana





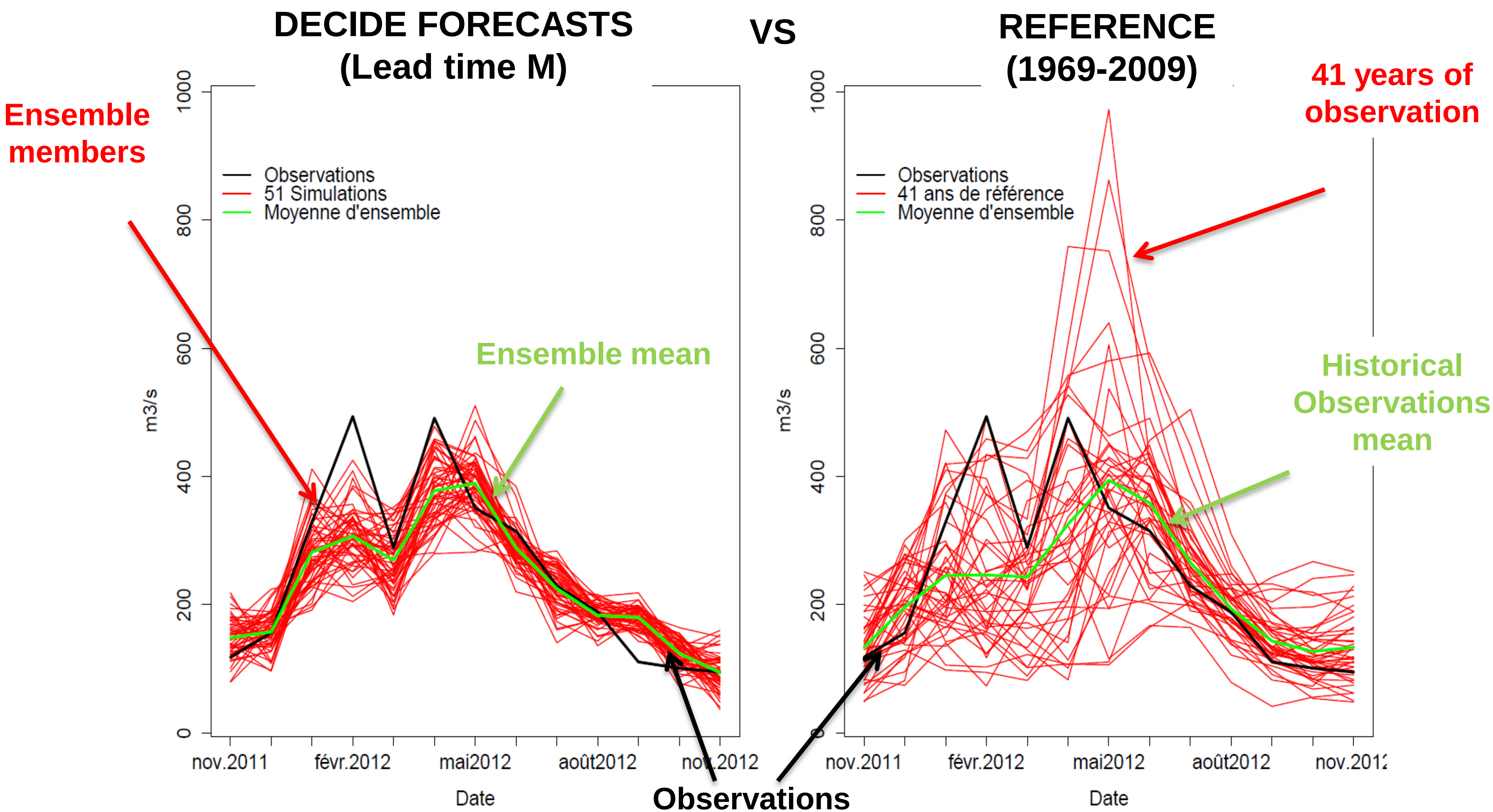
+ streamflow historical database (1969-2009)



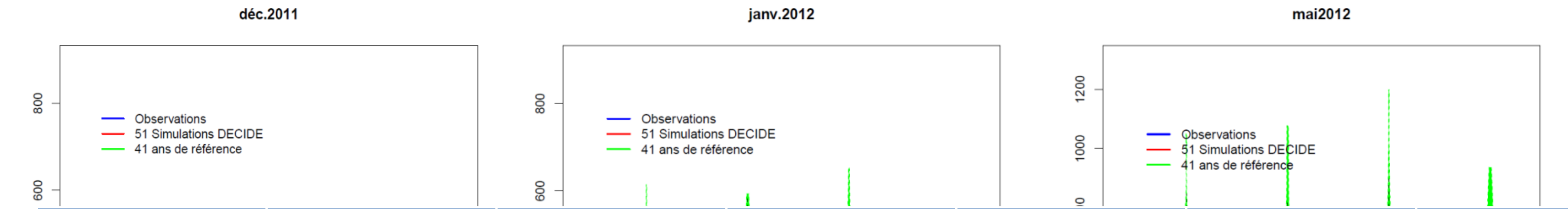
DECIDE: Metnext's statistical Model

Comparison with current method (streamflow climatology)

CL!MPACT metnext

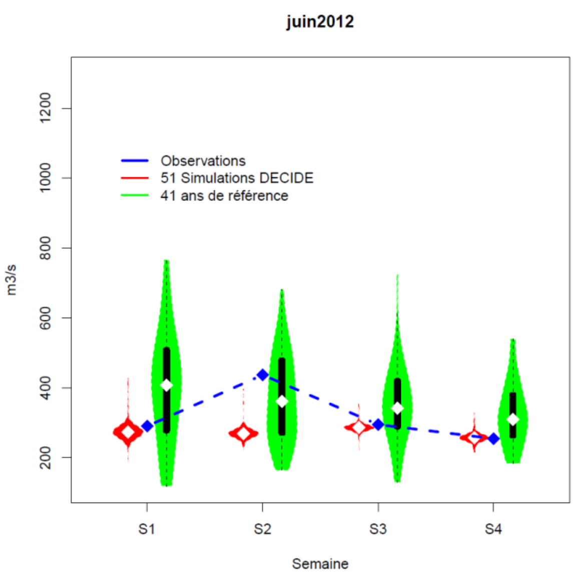


A few examples (lead time: 1 month)



Gain w.r.t reference)	Lead 1	Lead 2	Lead 3	Lead 4	Lead 5	Lead 6
Correlation	+19%	+8,7%	+16,1%	+16,9%	-5,6%	-5,2%
RMS	+26,1%	+11,0%	+23,7%	+26,4%	-14,7%	-17,3%
CRPS	+19,6%	+3,5%	+25,5%	+10%	-7,6%	-7,0%

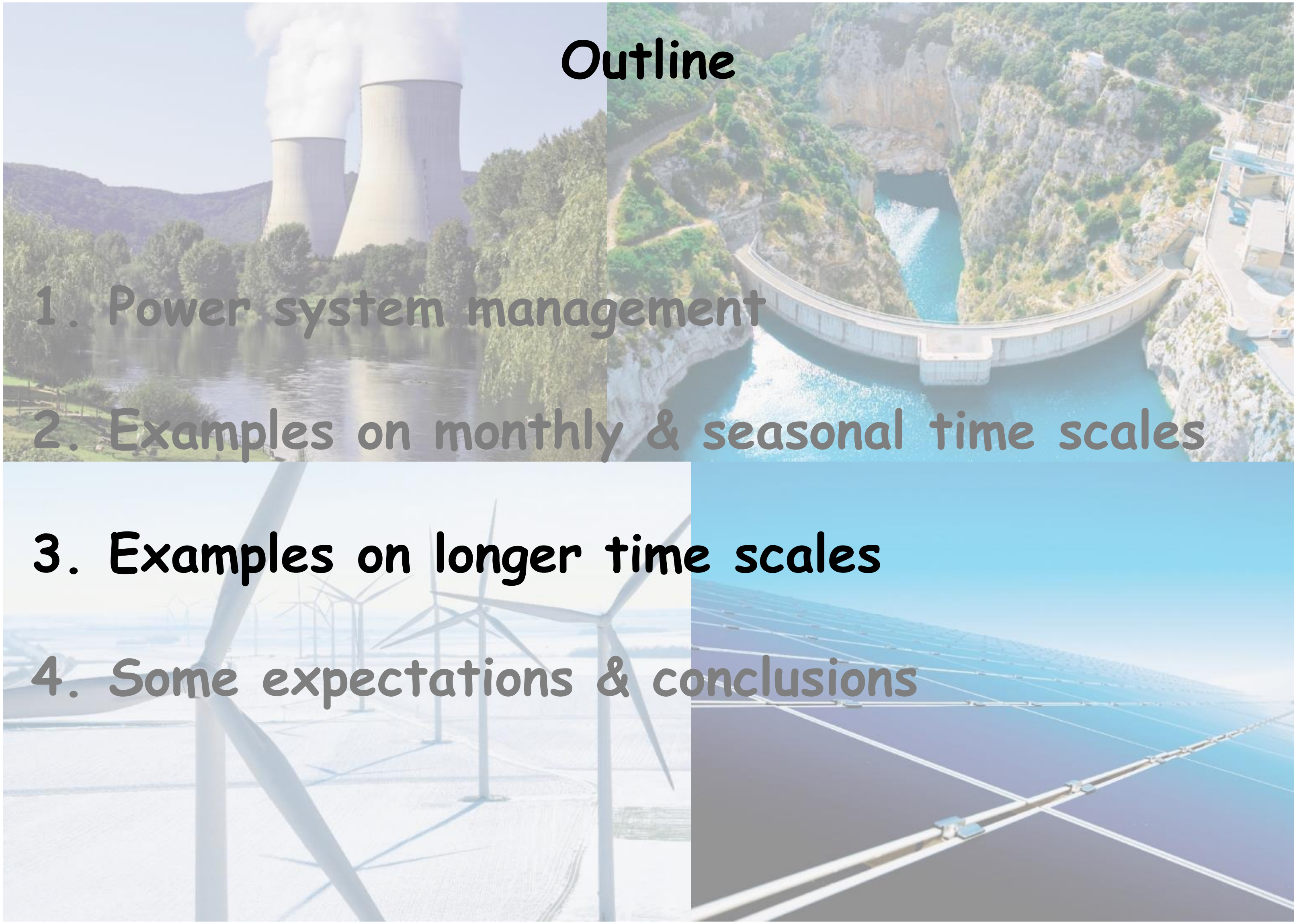
Semaine Semaine



!!! Only 13 months of verification !!!

But first results are encouraging

➔ Model should be soon implemented in a real-time experimental phase for 1 year



Outline

1. Power system management

2. Examples on monthly & seasonal time scales

3. **Examples on longer time scales**

4. Some expectations & conclusions

Stresses on supply/demand balance

Designing power systems at national/continental scales requires information on climate evolutions :

- stresses on power supply
  - hydroelectric power:
    -> water ressources: interannual variability, annual mean, seasonal cycle…
  - availability of thermoelectric power plants
    -> river flow, air and water temperature
  - solar and wind power ressources

ERA Interim						
Classe	Variable météo	Royaume-Uni	Allemagne	Nord de la France	Sud de la France	Espagne
RZ	Vent	+++	++	+	-	--
	Temp	+	+++	++	+	0
	Precipitations	+	0	0	--	--
AG	Vent	+	+	+++	++	++
	Temp	+	++	+++	++	+
	Precipitations	+	+	+	++	+
DA	Vent	+	+++	+	+	0
	Temp	-	0	0	0	+
	Precipitations	0	++	+	+	+
RB	Vent	--	--	--	-	-
	Temp	-	--	--	-	-
	Precipitations	-	--	--	--	-

- pc
- r… e.g.
  co

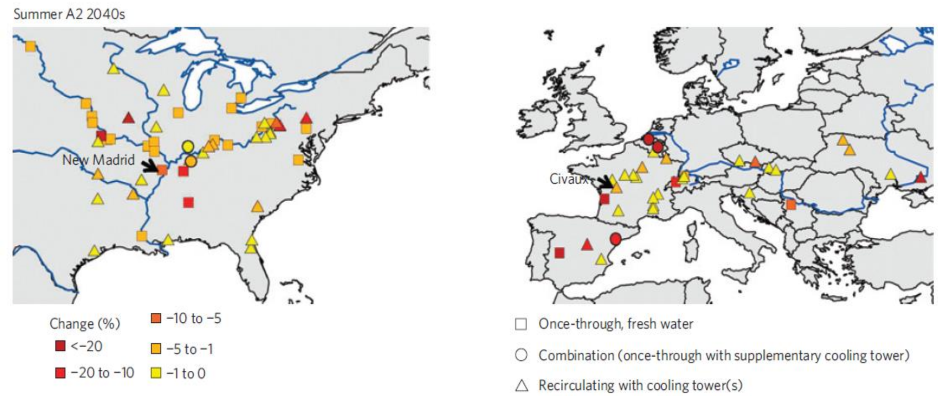
Unavailability of power plants

Power plants functioning:

- Needs water for cooling (thermal and nuclear)
- Strong relationship between temperature and energy loss :
  - Higher temperature => decrease in efficiency
  - Compliance with legal discharge temperature threshold => production losses
- Strong correlation between temperature and energy prices:
  - Increase in temperature => higher prices
- **The warmer it gets, the stronger are the economic losses**

Possible water stress:

- Example: Summer 2003 heatwave
- How will water-related parameters evolve with climate change?
  - Water temperature / flow



Changes in usable capacity of thermoelectric power plants (van Vliet et al. 2012)

Estimation of future extremes

Observed link between trends in mean and variance and trends in extremes for temperature (daily minimum Tn and maximum Tx)

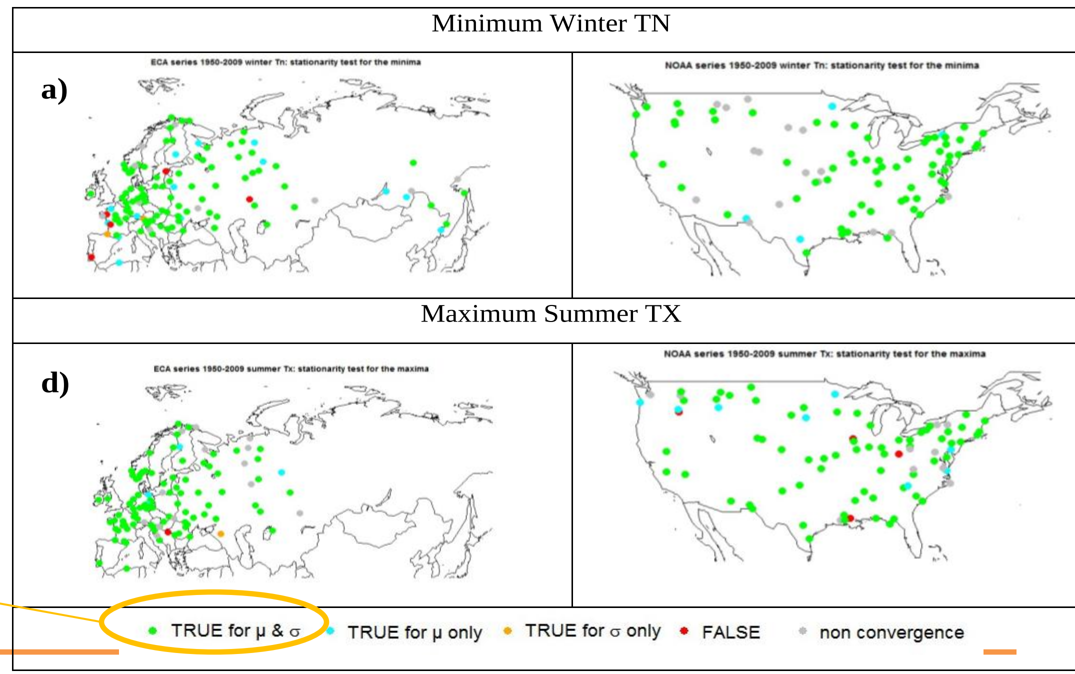
Design of a statistical test to check the stationarity of the extremes of the standardized residuals:

$$Y_t = \frac{X_t - m_t}{s_t}$$

where X_t is the observed temperature, and m_t and s_t non-parametric trends in mean and standard deviation

Hypothesis cannot be rejected - the extremes of Y(t) are stationary

Evolution of extremes significantly related to changes in mean and variance



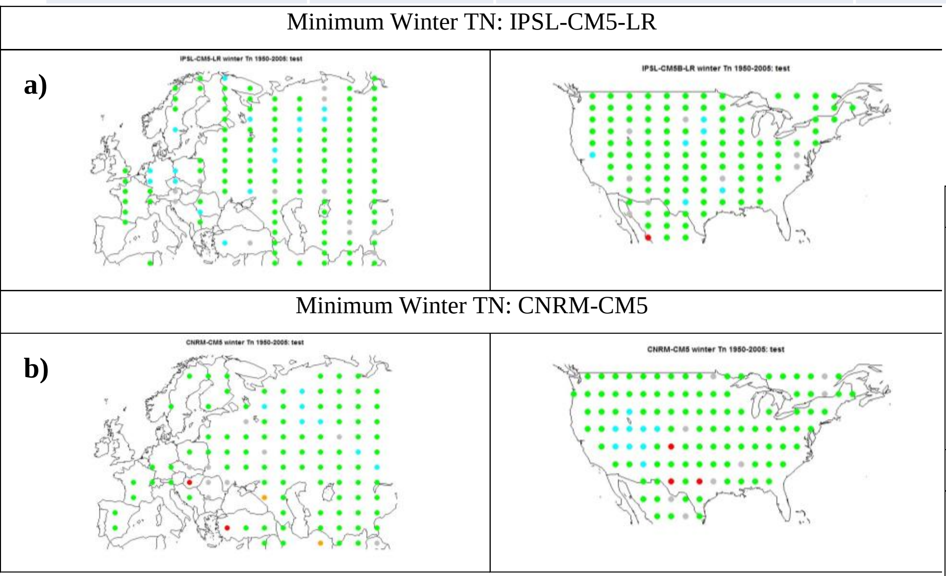
Verification for climate models

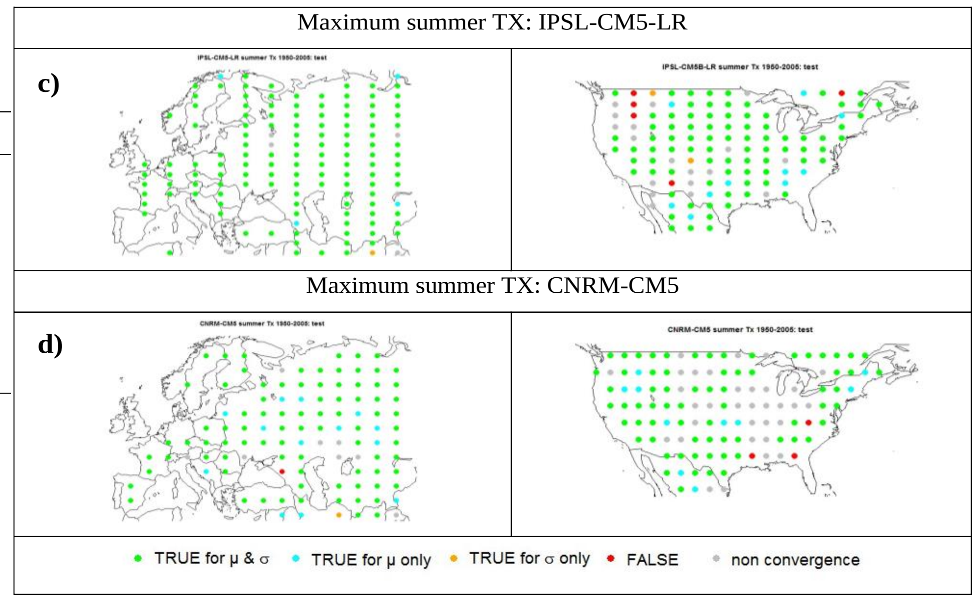
2 CMIP5 french models:

SIMULATIONS	Model	Variable / region	Grid points
CMIP5	IPSL-CM5B-LR	winter/*summer*, Tn / *Tx* Eurasia/US	All land grid po 1 / 2 [lon] in Eu
CMIP5	CNRM-CM5	winter/*summer*, Tn / *Tx* *Eurasia*/US	1 / 2 in US 1 / 2 [lon] in Eu

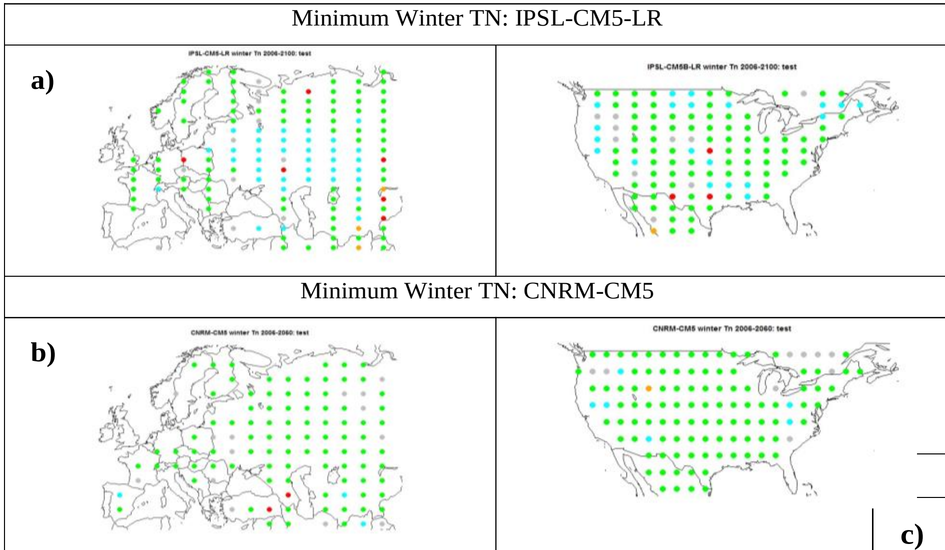
Hypothesis cannot be rejected – the extremes of Y(t) are stationary

Evolution of extremes significantly related to changes in mean and variance like in observations



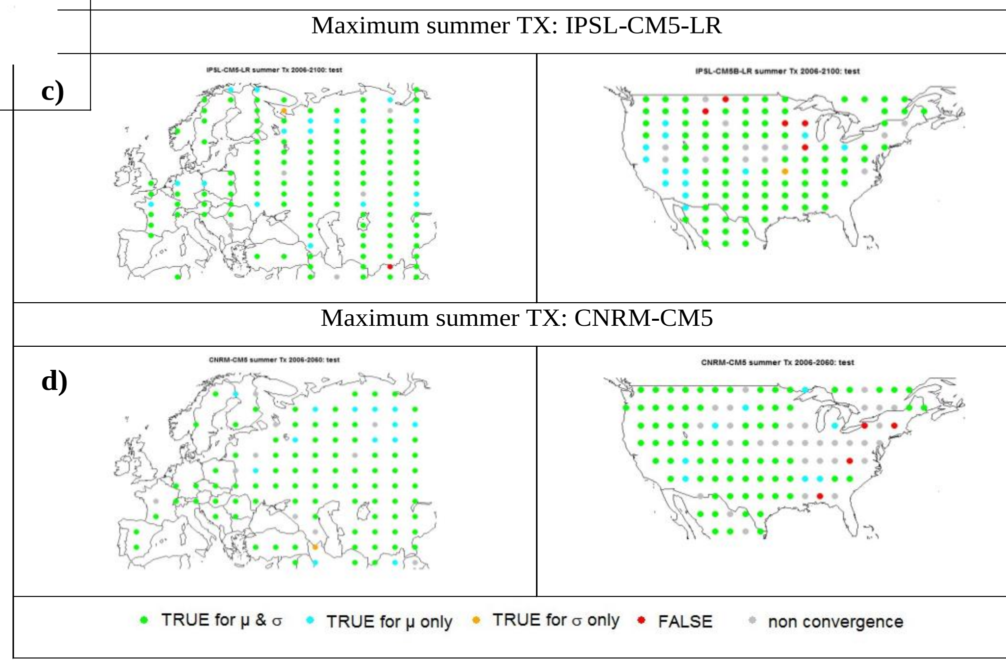


Is the link maintained in the future?



Yes, reasonably

Future extremes can be derived from extremes of Y(t) and future mean and standard deviation



Outline

1. Power system management

2. Examples on monthly & seasonal time scales

3. Examples on longer time scales

4. Some expectations & conclusions

Some barriers & gaps

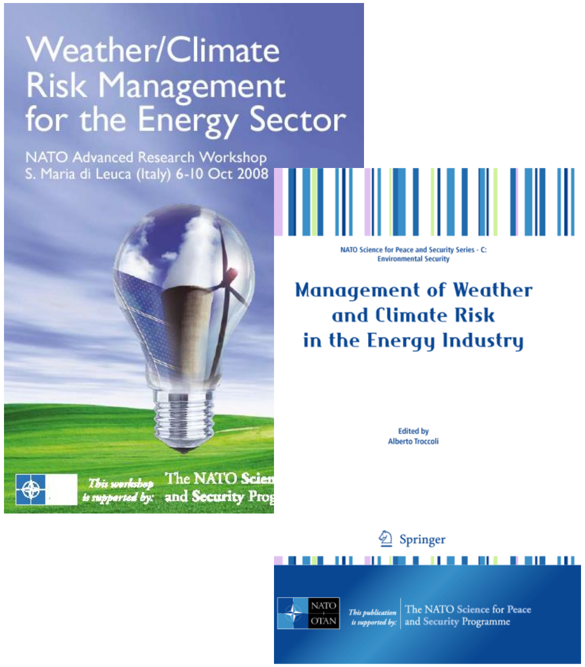
- ❑ Inadequacy of weather/climate info to feed application models (space & time scales, ensembles too small to look at distribution tails …)

- ❑ Users' understanding of probabilistic forecasts, and capacity to use them in operational tools

- ❑ Energy systems are evolving rapidly:
  - New uses (electric vehicule, air conditionning, time shift in hours of peak demand …)
  - Smart grids (local) & super grids (continental)

➔ evolutions will demand new products/information: local, high frequency forecasts for the various renewable energy sources (hydro, wind & solar)

Energy & Meteorology: developing collaborations



2008

EMS

Energy Meteorology session

2010 …

Energy & Meteorology
WEATHER & CLIMATE FOR THE ENERGY INDUSTRY
8-11 November 2011 Gold Coast, Australia

2011 / 2013 …

Book « Weather matters for energy » , A. Troccoli, P. Audinet, L. Dubus and S.E. Haupt, editors, in press (Springer)

CLIM-RUN
Climate Local Information in the Mediterranean region Responding to User Needs

EUPORIAS

Conclusions (1/2)

- Progress are needed in forecasts at all time scales, but also in observations
- Forecast skill is generally low in Europe at seasonal (and decadal ?) time scales…
- **But** several studies demonstrated the usefulness of SF in users' applications: particularly true when integrated impact variables are considered (see for instance following talks by JP Céron and others on hydrological applications).

➔ **Usefulness must be assessed w.r.t. the needs**

- Decadal forecasts seem promising for applications in the energy sector (and others !) in particular for long term planning

Conclusions (2/2)

- In the last 10 years, much **progress** was achieved in NMHSs and research centers: VarEPS/monthly forecasts @ ECMWF, Seasonal Forecasts
- Only a few energy companies **actively collaborate** with NMHSs & private weather companies to develop new tailored products
- **Dialog** between **Providers** & **Users** is essential to translate improvements in science into business improvements

➔ **Communication** towards & **training** of end-users is very important
➔ Upstream collaboration and partnership should be encouraged

Energy & Meteorology
WEATHER & CLIMATE FOR THE ENERGY INDUSTRY
2ND INTERNATIONAL CONFERENCE
25–28 June 2013, Météo-France International Conference Centre, Toulouse, France

www.icem2013.org

Thank you for your attention