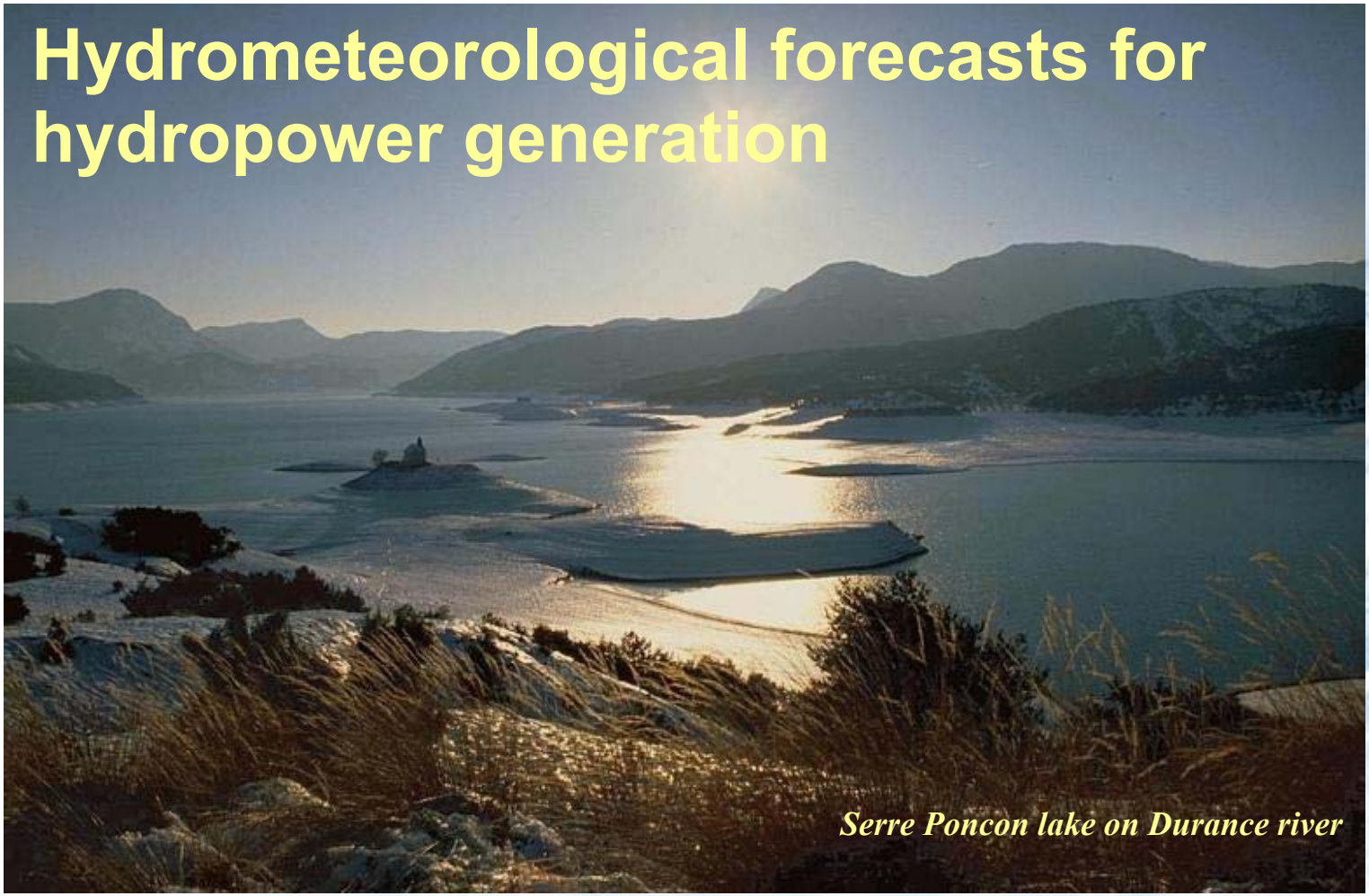
Hydrometeorological forecasts for hydropower generation



Serre Poncon lake on Durance river

Pierre BERNARD

EDF-DTG Water Ressources Departement

Email: pierre-2.bernard@edf.fr

Hepex Workshop – Reading – 8-10th March 2004

Water is for EDF:

-raw material for hydraulic power plants

=> Hydropower is 20% of EDF installed capacity and 15% of yearly average production

- cooling system mean for nuclear power plants

Water ressources particularities in France:

- High variability in space and time
- Sudden flow rate variations => flood

Illustrations…

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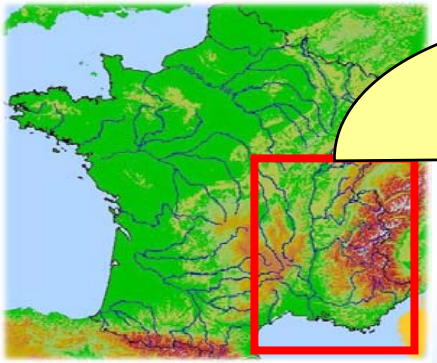
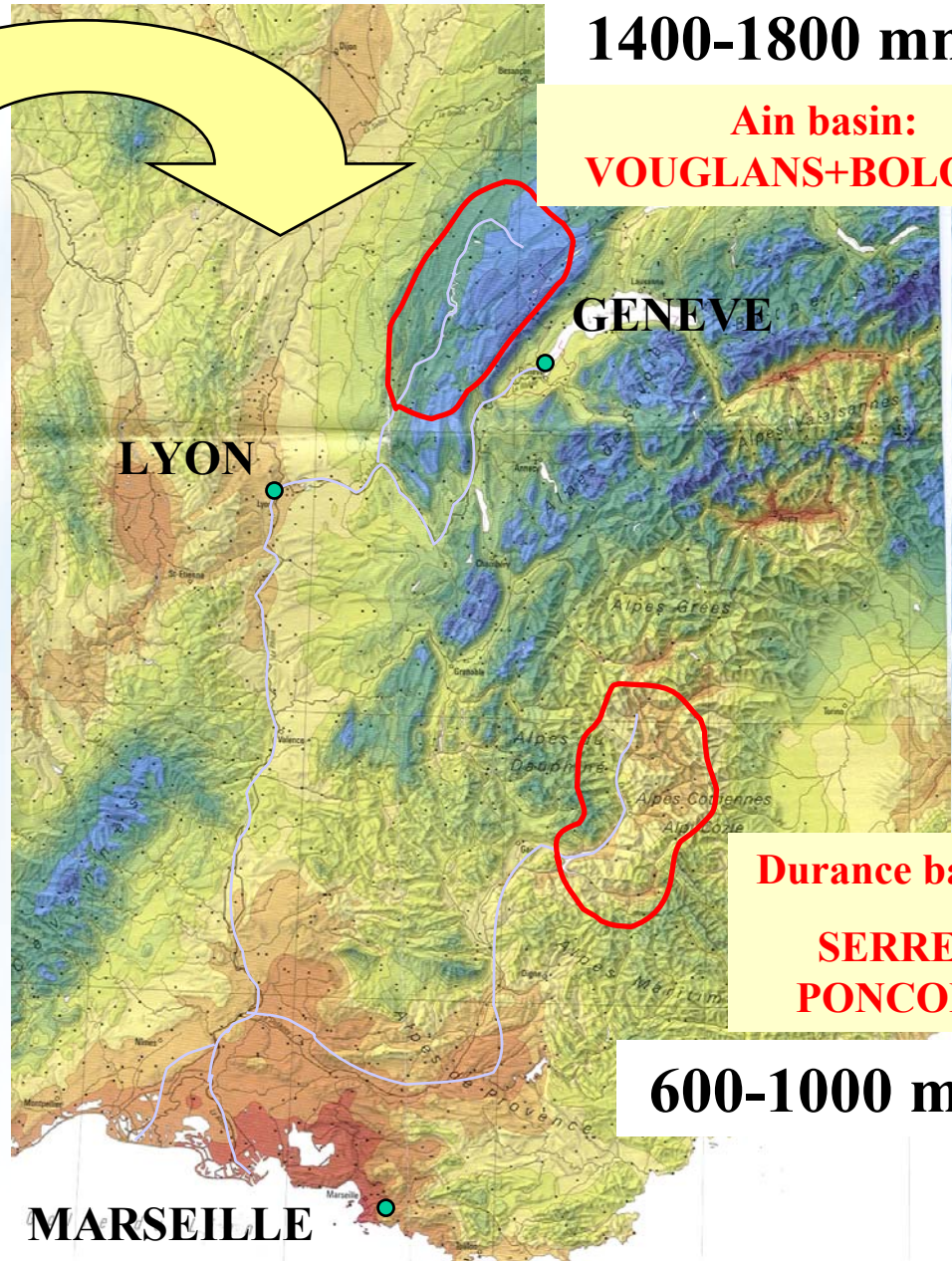
VARIABILITY IN SPACE





For example:

Average yearly rainfall

(in mm)

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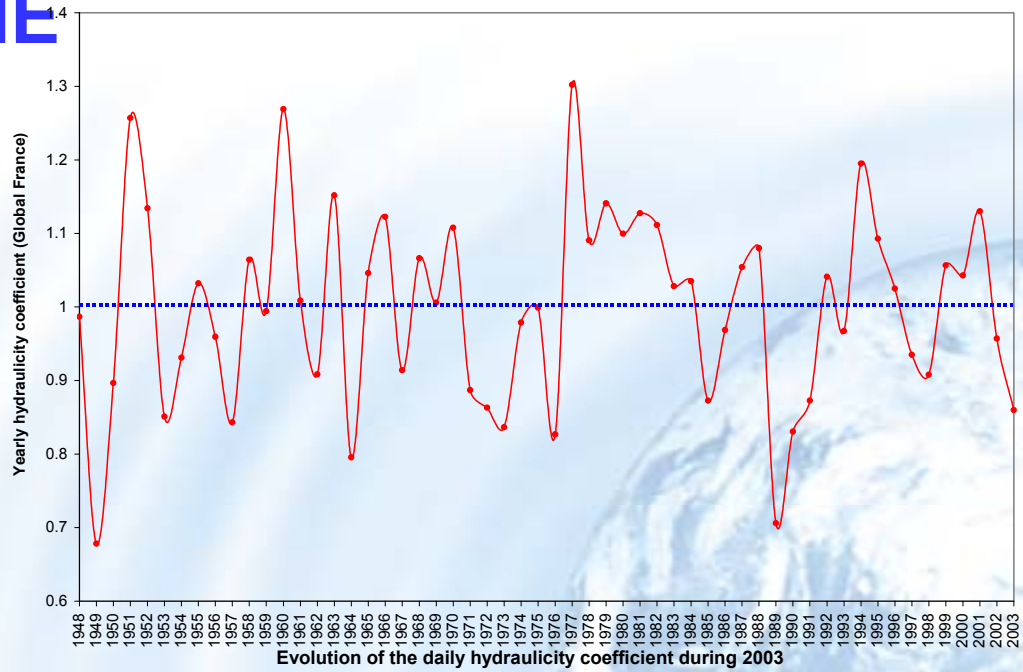
VARIABILITY IN TIME

Year to year

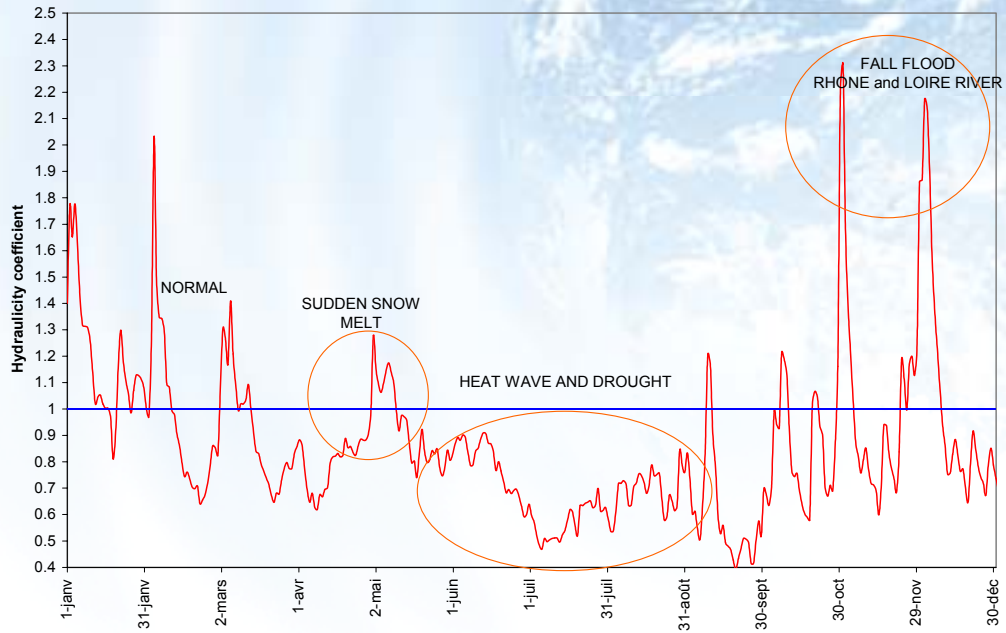
Inside a year

(as 2003…)

Evolution of the annual hydraulicity coefficient (on all EDF hydropowerplants)

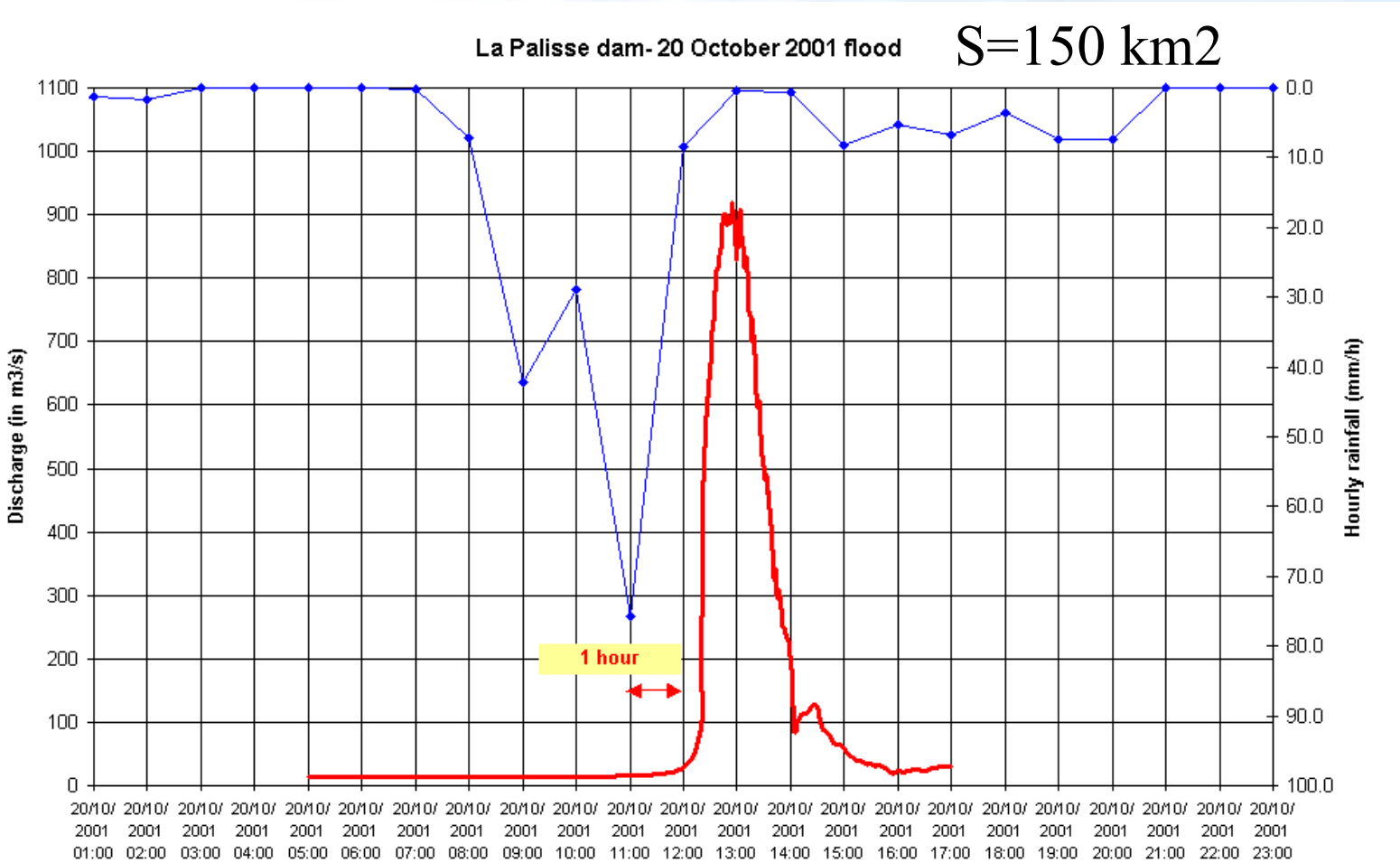


Evolution of the daily hydraulicity coefficient during 2003



FLOOD RISK => « Flash food »

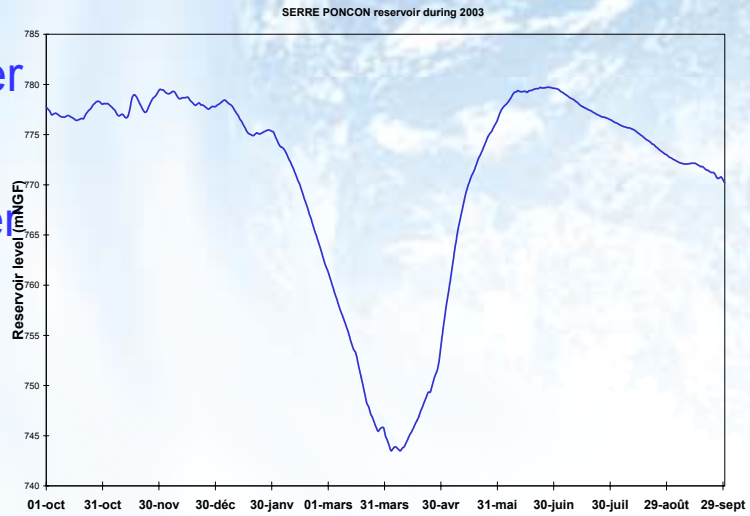
Upper Loire river during 20th October 2001 flood



- Electricity can't be directly stored: production has to be continuosly ajusted to consumers needs
- Demand depends partially on weather conditions
- EDF production depends on many factor, including hydrology
- 2 kinds of hydropower generation
  - Reservoirs in mountainous area
  - Along the river without storage capacity

For reservoir

- Management conditionned by snow cover conditions and long term inflow forecasts
- Water stored in reservoir is used in winter to produce peak power
- Filled in spring with snow melt
- Some of them have level constraint in summer for tourism or agriculture



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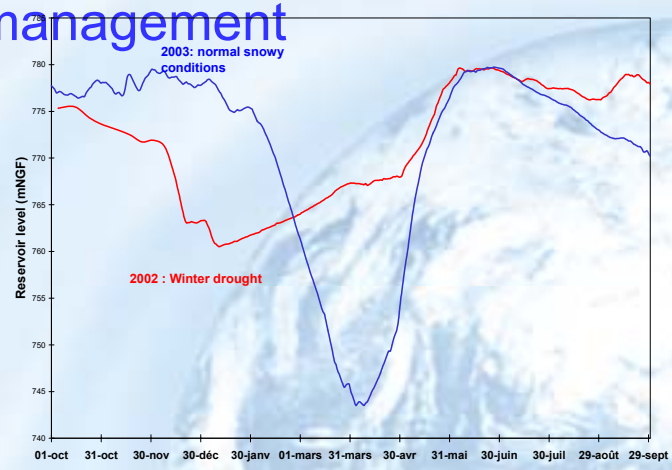
So, need for EDF to have hydrological forecasts:

-Long term forecast (few weeks) to optimize global production (nuclear and hydro) and decide reservoir management



-Short term (1-4 days): to optimize hydraulic ressource(avoiding spilling) and assure to produce energy sold to costumers

-Flood warning and real time survey: civil works and people safety

Forescasts made inside EDF by 2 Hydrometeorological centers : Toulouse and Grenoble

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TOOLS:

Observations

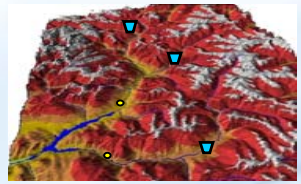
Real time monitoring survey, based on hydrological network operation

Precipitation

Air temperature

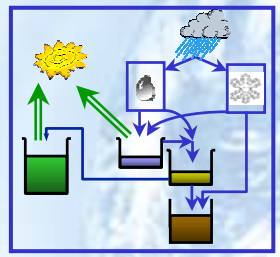
Snow cover

River discharge



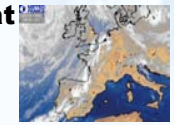
Hydrological modelling

rainfall-runoff DPFT and MORDOR-discharge routing PREDICE)

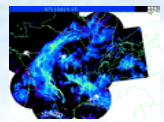


Meteorological forecasts

Satellite telemetry Meteosat

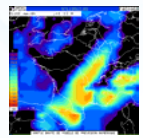


Radar Survey



METEO FRANCE

« Arpege-Aladin » modelling outputs (Meteotel and maps) + CEP



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Hydrological modelling : MORDOR

Lumped, continuous model

Daily time step

Watershed area from 40 to 4000 sq.mil

Adapted to mountainous areas (snowpack model)

Data input : rainfall (MAP), air temperature

Automatic calibration (genetic algorithm on historical data)

More than 30 in operational forecast use

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MORDOR model

mm

Evapotranspiration

IRRIGATION

TEMPERATURE

°C

t

RAINFALL +

mm

Observed data

Atmosphere

Surface

Sub-surface

Deep

S

1

Snowpack

Direct Runoff

U

2

Z

3

+

L

4

Surface Runoff

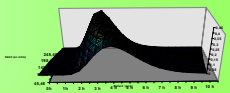
+

Groundwater

N

5

Base Flow



River discharge

m3/s

t

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METEOROLOGICAL FORECASTS

Products used:

- from METEO FRANCE

- EDF ANALOGUES model

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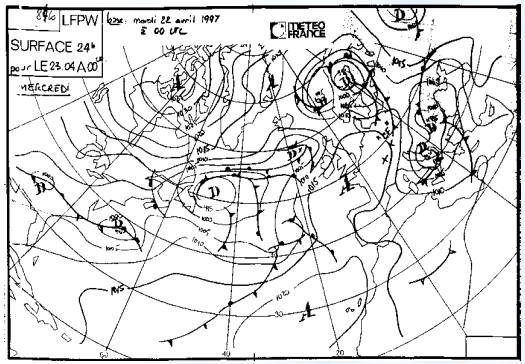
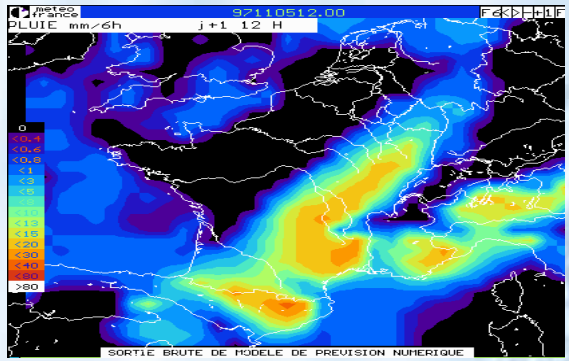
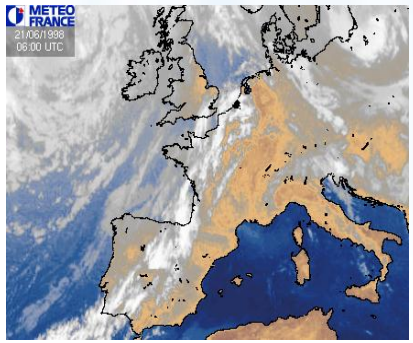
METEO FRANCE products:

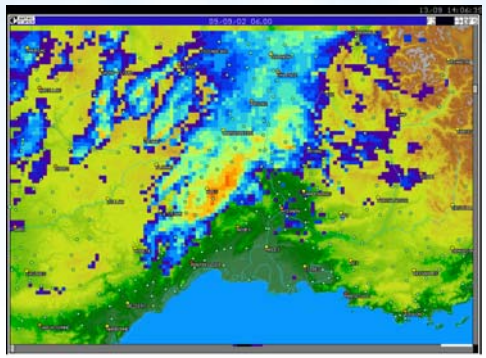
- Daily outputs of meteorological models (french ARPEGE ALADIN + european CEP) : maps and numerical grids





- real time : satellite telemetry METEOSAT – precipitation radar survey





ANALOGUES model

Aim: Daily rainfall probabilistic forecast (Day to Day+6) based on analogy of meteorological situation

Idea: « Same meteorological situations (pressure field) will lead to same consequences on rainfall phenomenon ».

Principle:

1- For each term (from D to D+6), research of the closest historical meteorological situations similar to the forecasted one (pressure field)

=> K situations

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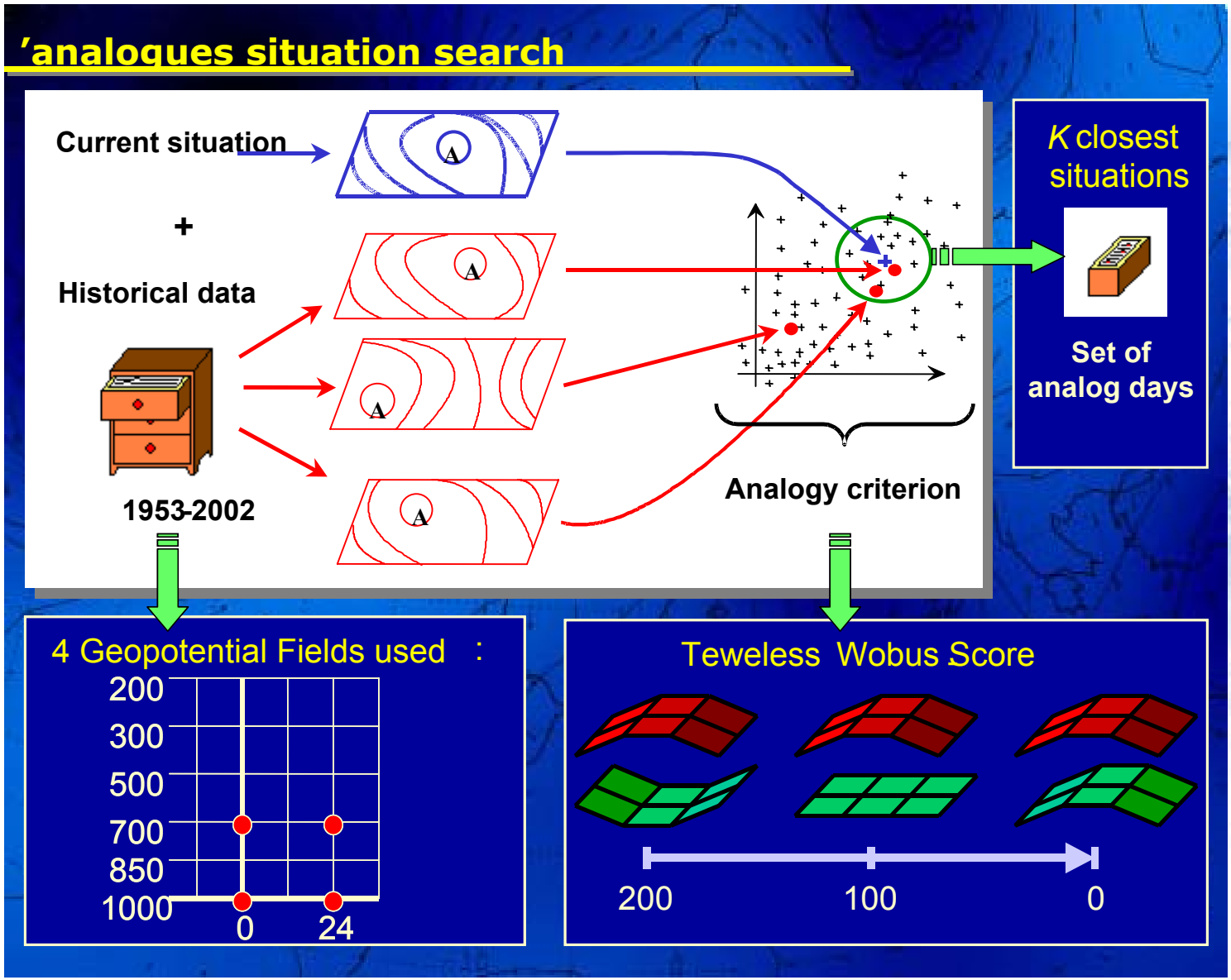
ANALOGUES model : principle



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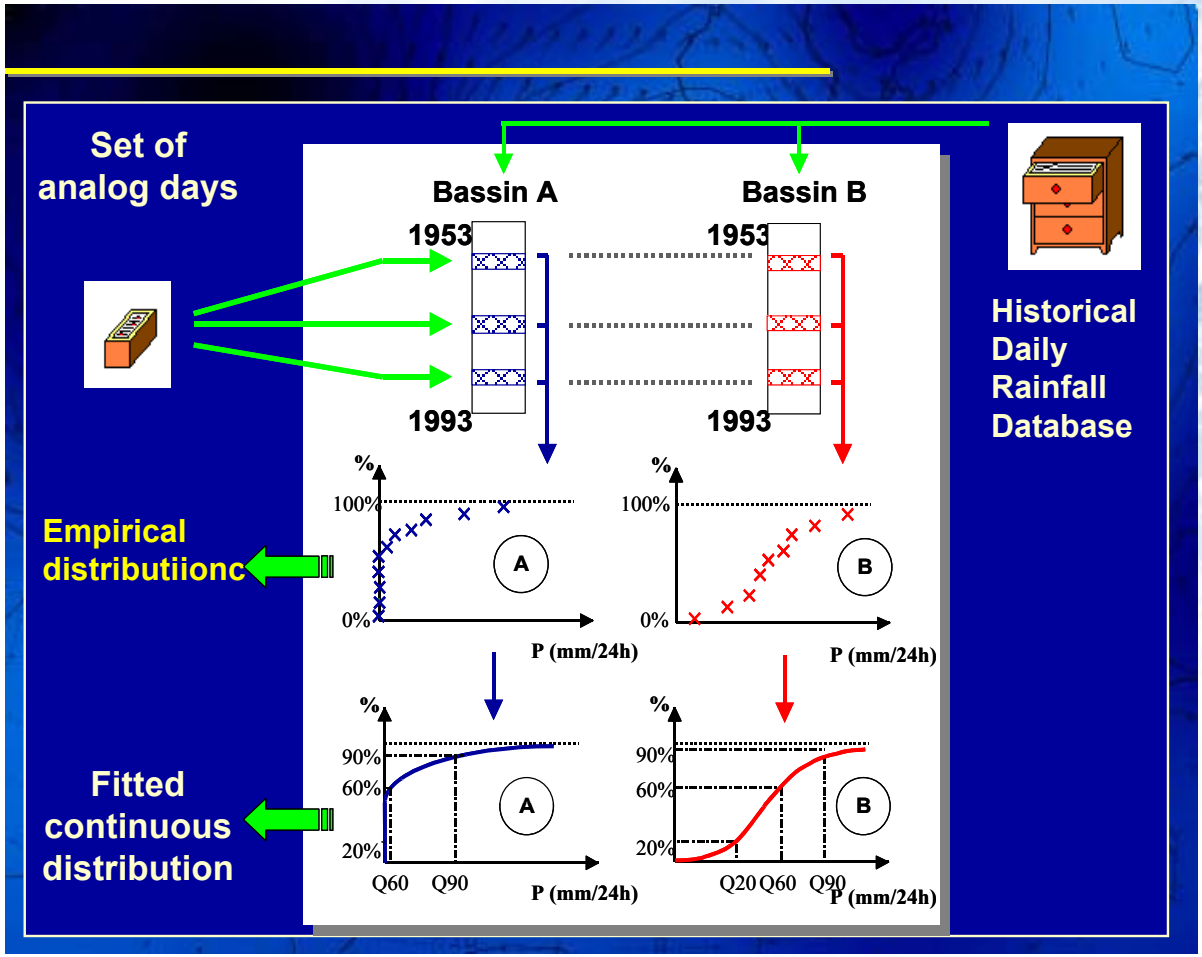
2-For the K analog days, retrieval of observed rainfall on every monitored watershed, in historical EDF data base.



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3-For each monitored watershed and for each day (D to D+6), quantitative and probabilized rainfall forecasts

-9999 1 7 8

GROUPEMENT NO	NOM	J+0 .20	J+0 .60	J+0 .90	J+0 MOY	J+0 MAX	J+1 .20	J+1 .60	J+1 .90	J+1 MOY	J+1 MAX
1	CURE	0	4	9	3	20	0	0	4	1	8
2	DOUBS	0	10	18	8	35	0	2	16	4	35
3	SAONE	0	3	12	4	30	0	0	7	1	12
4	AIN-VALSERINE	0	12	23	10	31	0	2	17	4	28
5	ARVE-GIFFRE	1	10	26	11	53	0	3	20	6	38
6	FIER	0	13	29	12	45	0	2	23	6	38
7	ARLY	0	9	25	10	48	0	4	23	7	29
8	HAUTE ISERE-DORON	0	5	15	5	34	0	2	15	4	24
9	PIEDMONT ITALIEN	0	8	26	9	60	0	3	19	6	45
10	HAUTE MAURIENNE	0	6	23	8	41	0	2	19	5	35
11	ROMANCHE-ARC INFERIEUR	0	6	20	7	43	0	1	14	4	26
12	ISERE MOYENNE	0	8	28	10	58	0	4	22	6	38
13	VERCORS-CHARTR-ND ISER	0	14	26	11	58	0	6	25	7	36
14	DROME	0	6	20	8	70	0	0	12	4	37
15	BUECH	0	7	22	8	41	0	1	10	3	27
16	DRAC	0	10	28	10	39	0	2	16	5	40
17	HAUTE DURANCE	0	6	19	7	27	0	2	13	3	28
18	GUIL-UBAYE	0	5	15	5	25	0	2	10	3	22
19	VERDON	0	5	16	5	20	0	3	12	4	33
20	BVI VERDON	0	3	13	4	19	0	1	9	3	30
21	DURANCE MOYENNE	0	5	14	4	17	0	2	9	3	21
22	VAR-TINEE-ROYA	0	5	17	5	25	0	2	12	4	44
23	DOUX-EYRIEUX	0	6	19	6	24	0	0	13	3	48
24	LOIRE SUPERIEURE	0	6	19	6	29	0	0	14	3	33
25	CHASSEZAC	0	6	23	8	63	0	0	10	3	41
26	GARD-CEZE	0	5	17	6	30	0	0	8	2	40
27	CORSE ORIENTALE	0	0	10	2	16	0	1	18	4	33
28	CORSE SUD	0	0	7	1	13	0	0	10	2	21
29	MORDOR DURANCE	0	6	17	6	22	0	2	12	3	27
30	MORDOR DRAC	0	10	28	10	39	0	2	16	5	39
31	MORDOR VERDON	0	7	21	7	25	0	2	10	3	34
32	VEZERE-VIENNE-DORDOGNE	0	2	12	4	24	0	0	5	1	13
33	CREUSE-CHER-SIOULE	0	3	10	4	13	0	1	5	1	8
34	CERE-MARONNE-RH-DORD	0	4	16	5	22	0	1	9	2	17
35	BROMME-BES-BORAL-TRUYE	0	5	13	5	21	0	1	11	2	21
36	HT TARN-HT LOT-HT ALLI	0	4	16	6	27	0	0	13	3	20
37	HT AGOUT-ARN-DOURDOU	0	3	20	5	32	0	1	11	3	24
38	AVEYR-TAR INF-GARO INF	0	4	13	5	27	0	1	10	3	15
39	PYR ATLANT HT BASSIN	0	3	14	5	25	0	1	8	3	29
40	PYR CENTR HT BASSIN	0	6	16	6	33	0	3	15	5	33
41	PYR ATLANT PIEDMONT	0	4	17	5	26	0	2	11	3	33
42	PYR CENTR PIEDMONT	1	6	17	7	39	0	3	17	5	25
43	PYR ARIEG HT BASSIN	0	7	20	7	35	0	5	14	5	25
44	PYR ARIEG PIEDMONT	0	6	18	7	40	0	4	11	4	21
45	TECH	0	7	13	6	34	0	2	13	3	19
46	AUDE-TET	0	5	14	5	33	0	3	12	4	18
47	BRETAGNE	0	0	5	1	7	0	0	3	1	15
48	DORA RIPARIA	0	5	17	999	25	0	1	14	999	33
49	ORCO	0	8	31	999	61	0	4	22	999	72
50	SESIA	0	12	41	999	138	0	5	31	999	104
51	TOCE GLOBALE	0	13	43	999	71	0	3	27	999	107
52	TOCE NORD	0	12	40	999	71	0	4	24	999	90

LES 10 MEILLEURES SITUATIONS ANALOGUES :

J+2	S1
19720518	232.34
19890531	242.92
19860524	244.77
19790607	246.18
19680512	246.32

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OPERATIONAL ORGANIZATION

-Analysis of meteorological and hydrological situation continously made each morning to adapt hydrometeorological information to watershed scale and to EDF end users

  -Bulletins and warning message, phone assistance

-Human investment is important :

  -Meteorological uncertainties

  -Monitoring différences between forecasts and field reality is useful for hydrologist: appreciates uncertainties, good recativity

- 2 aspects:

  - Real time and short time (< 4 days)
  - Long term

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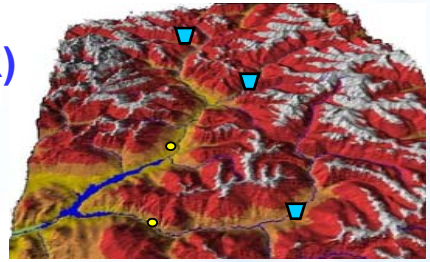
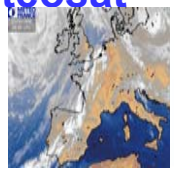
Short term

(1 hour to 4 days…)

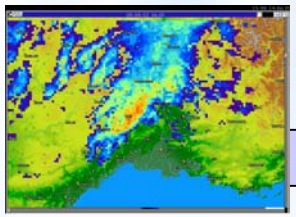
REAL TIME OBSERVED DATA
=> RAINFALL
=> AIR TEMPERATURE
=> DISCHARGE
=>(SNOW COVER)



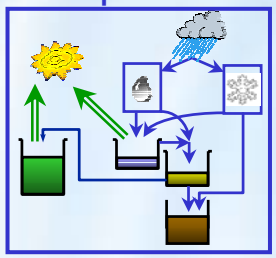
Satellite telemetry
Meteosat

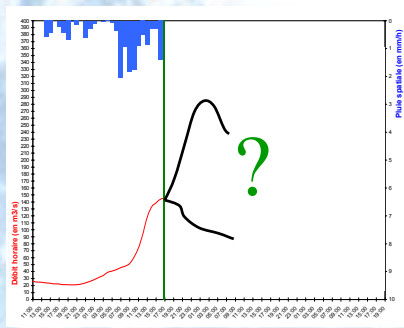


Radar
Survey

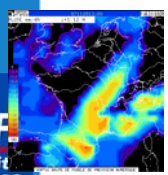


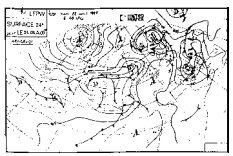
Hydrologic Model
Or expert evaluation

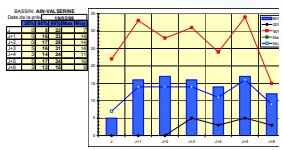




QUANTITATIVE FORECASTS
Precipitation and Air température
= > meteorological model ARPEGEALADIN (from MeteoFrance) 48h
=> ANALOGUES model: 6 days







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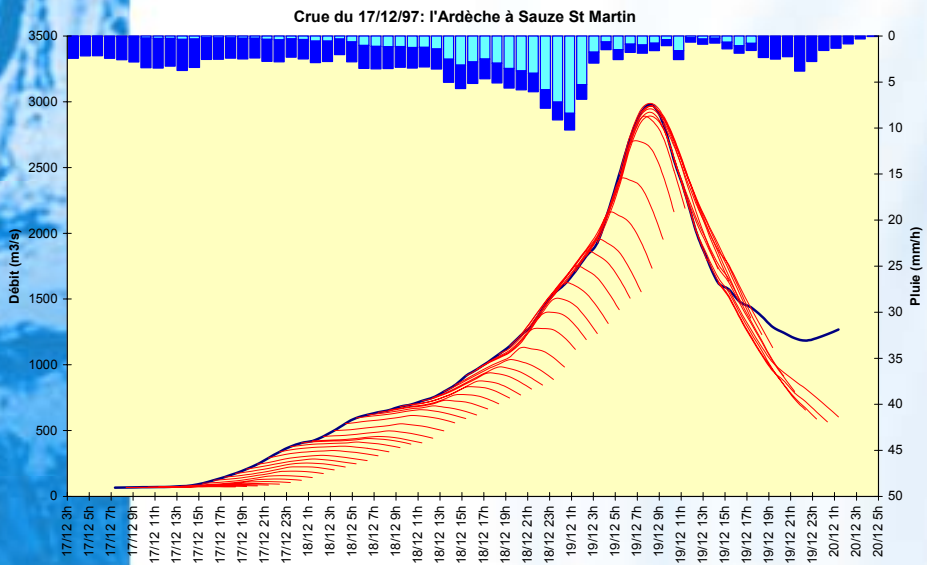
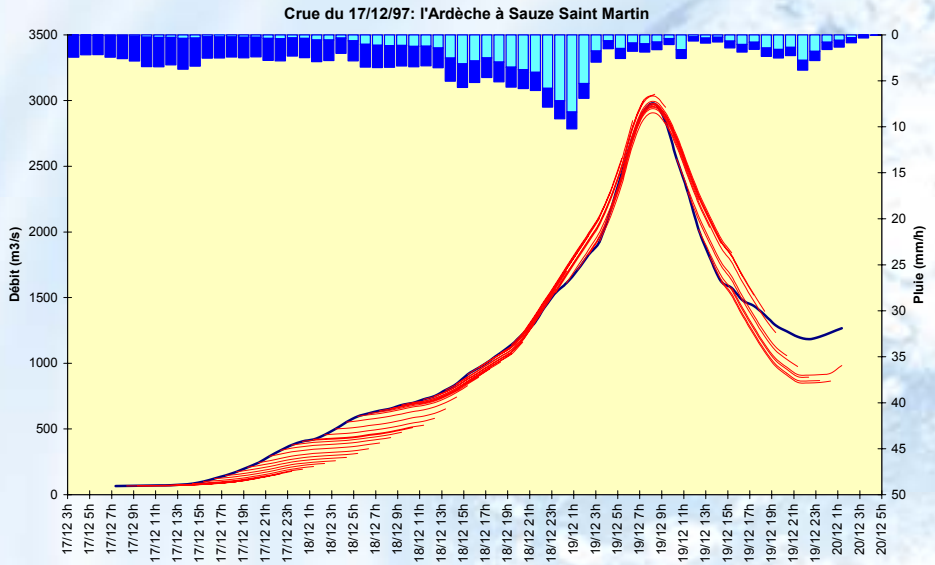
-Particularities and perspectives

- 1- Meteorology is determinant
- without future rain



with perfect future rain



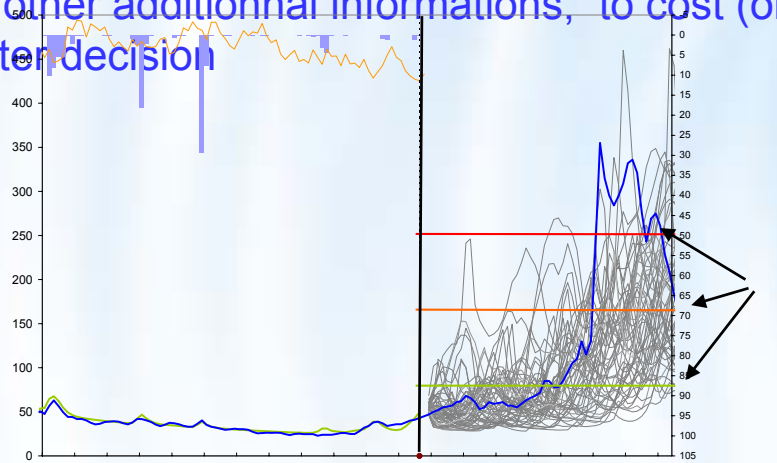
-In real time, hydrological modelling run automaticly with only two hypothesis on future meteorology: no rain- same rain during 1hour than last observed.

2-Meteorological forecast is manually taken into account

- Deterministic approach (Aladin output modelling)
- Manual analyse and human expertise
- Some probabilistic approach with Analogues model (manually made but automatic process would be used)
- Meteorological ensemble forecasts important for hydrologist because of no linear hydrologic phenomenon

3- Probabilistic approach and ensemble forecast is interesting for short term forecast

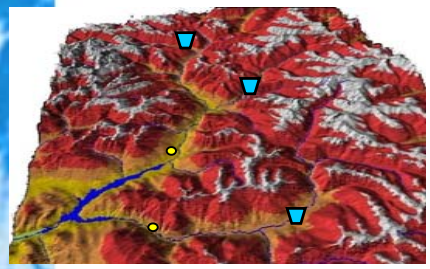
- probability to reach a critical discharge (spill,historical flood,...)
- improve, for the end users, the understanding of the forecast and its uncertainties
- provide to the end users graduated informations, that can be translated,with his own other additionnal informations, to cost (or benefices)curves in order to take better decision



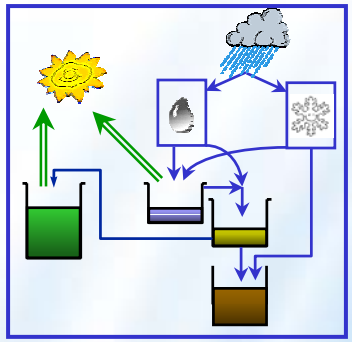
4-radar survey:

- actually only a qualitative way of use
- need to have a quantitative product (MAP improvement,anticipation

Long term (several weeks …)



Real time observed data precipitation,air temperature, snow cover, discharge)



MORDOR Model

Water balance for the present time
=>Water stored in snow and ground

And the future?

No meteorological forecasts

Representation of future alea with local climatology and historical data base (P,T)since 1948
Hypothesis of climate stationnarity

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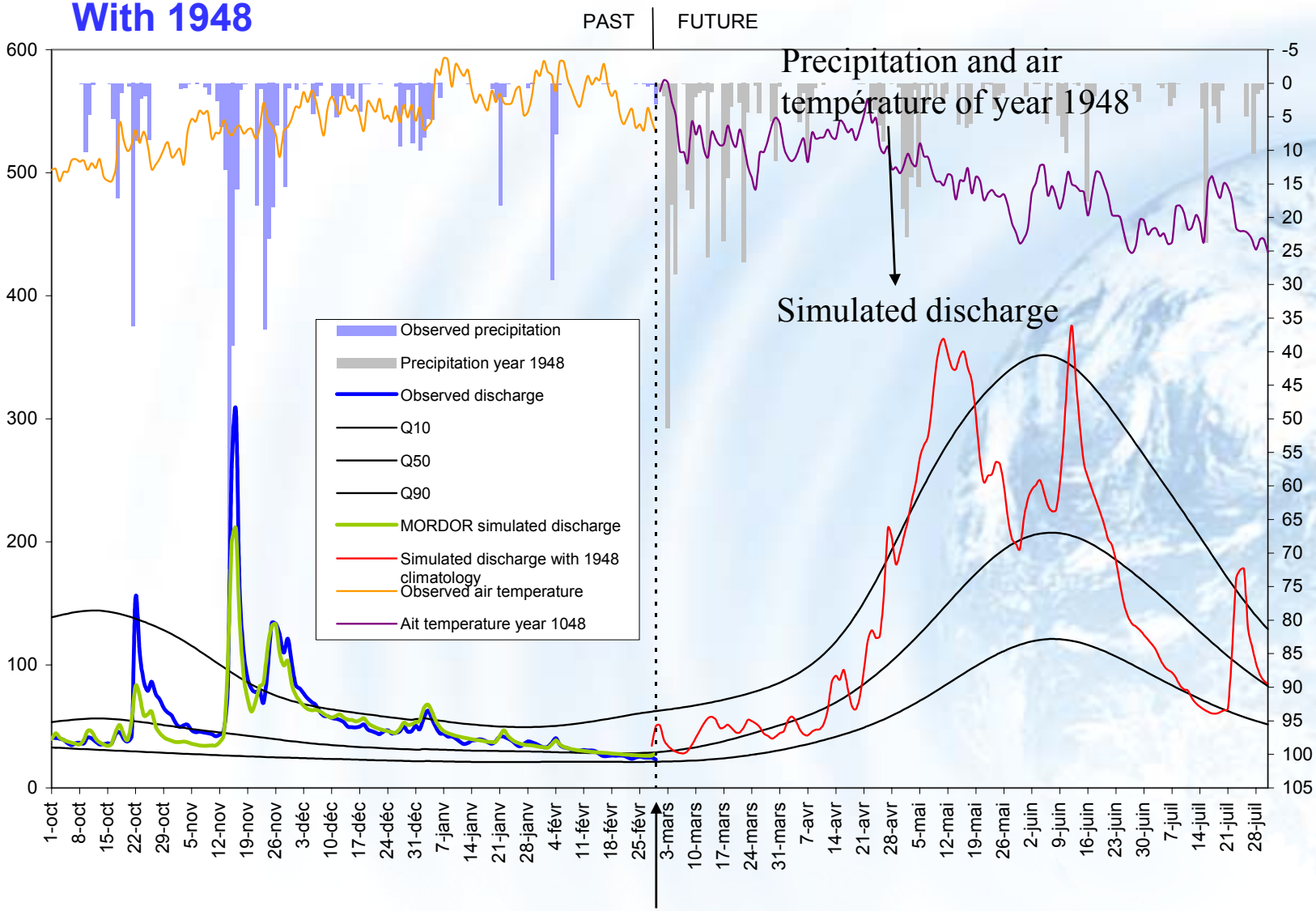
Ensemble forecasts with différent years of climatology

With 1948



Current hydrological situation

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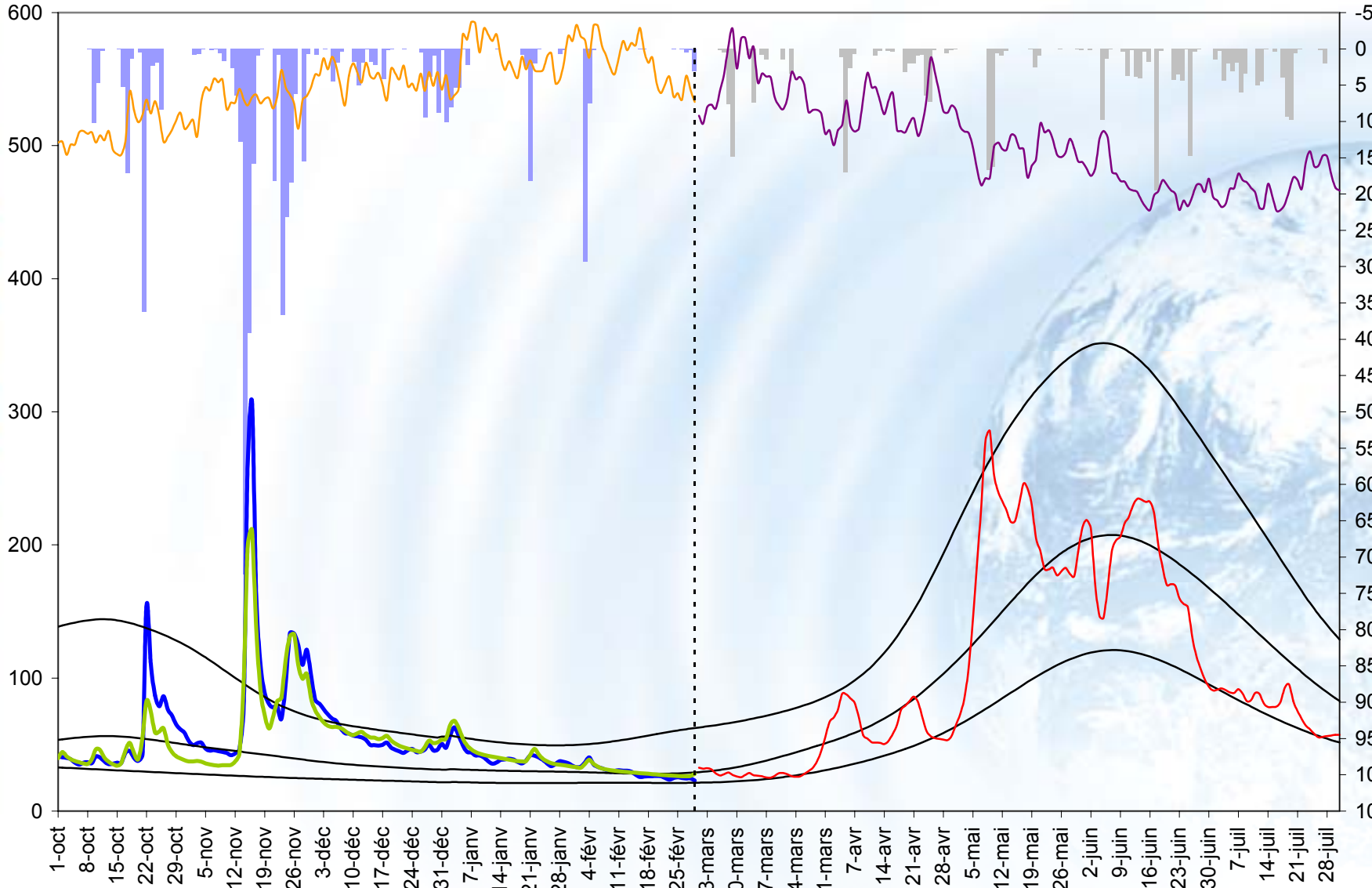
With 1949



And so on ..

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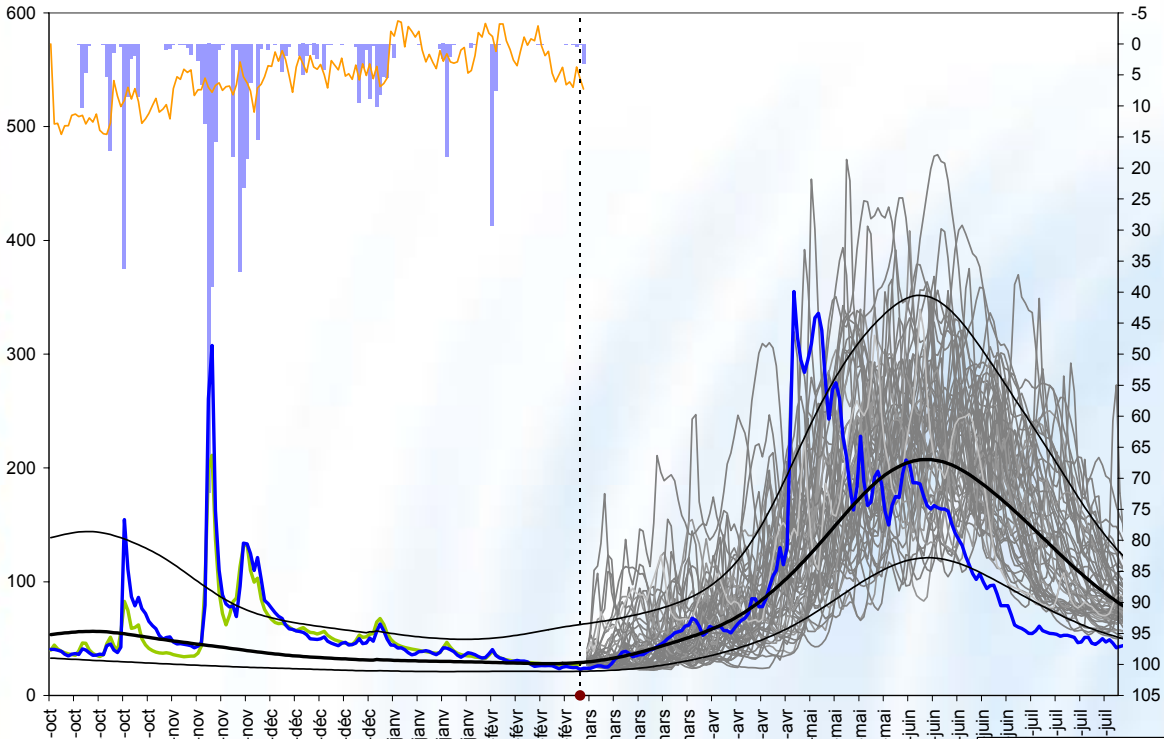

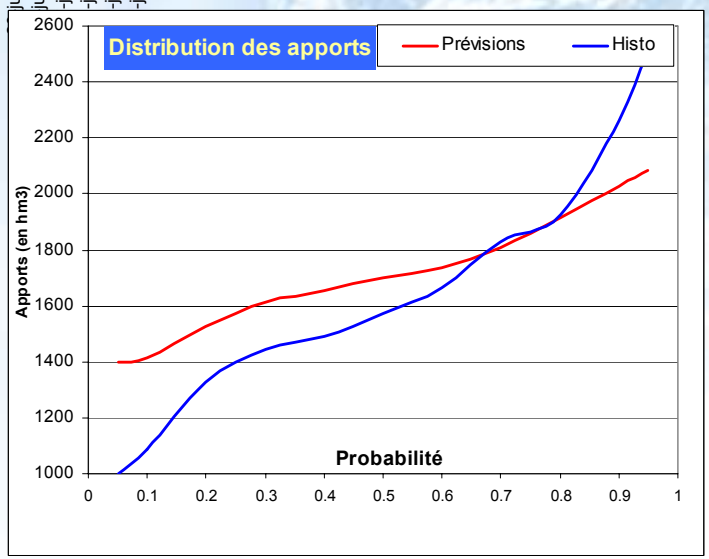

Probabilistic ditribution => probabilistic inflow forecast

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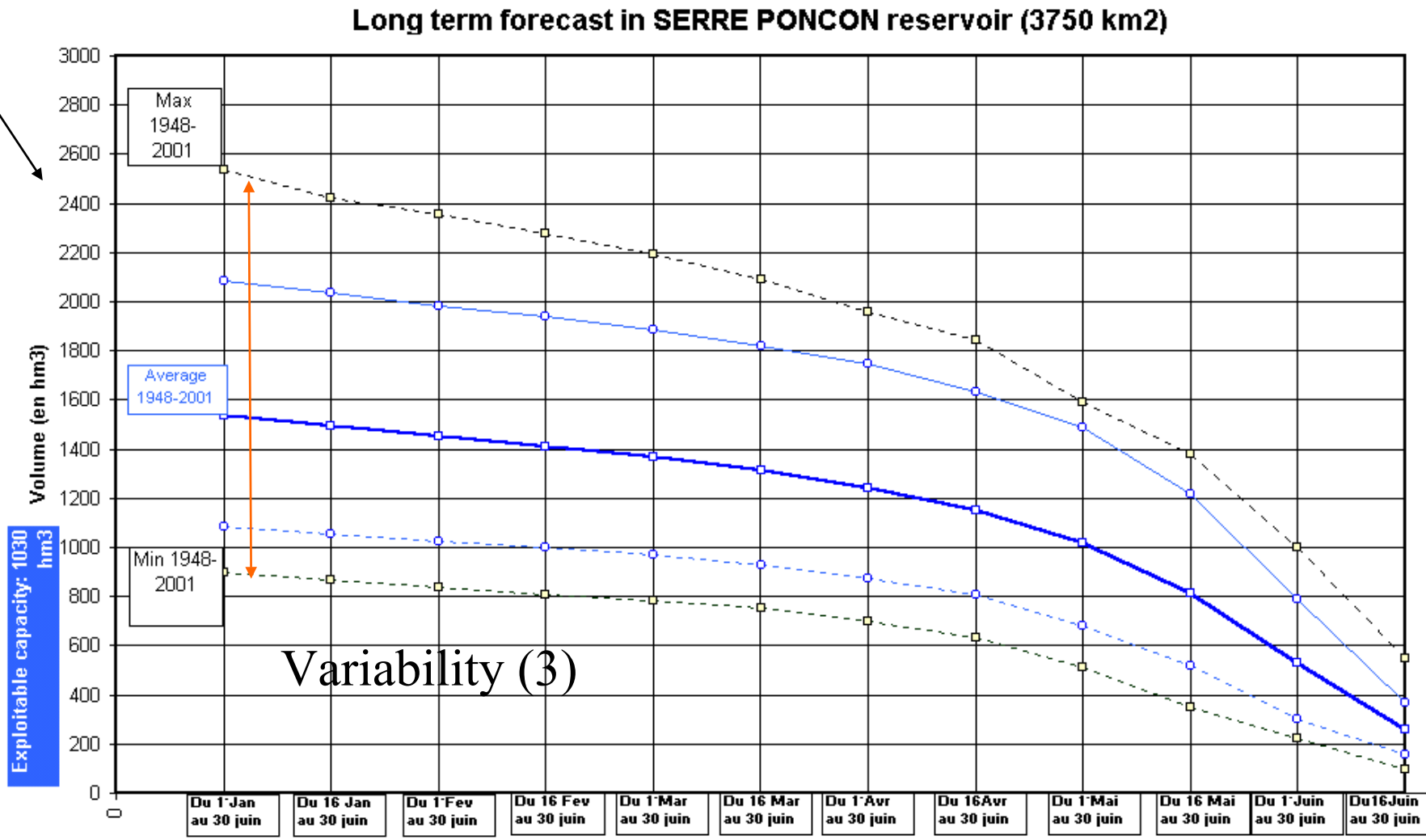
Without forecasts:historical data

Inflow during the period



Total Period

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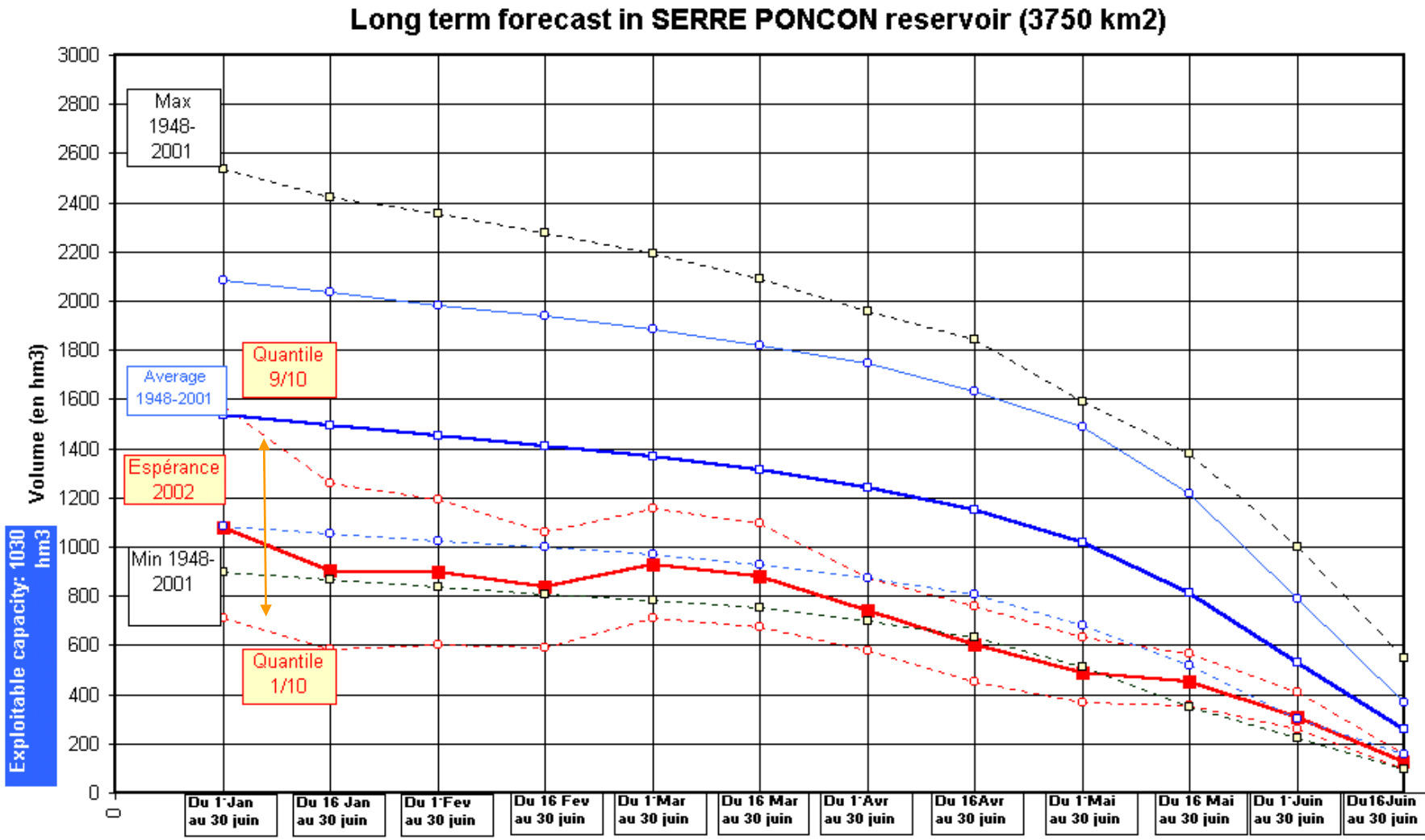
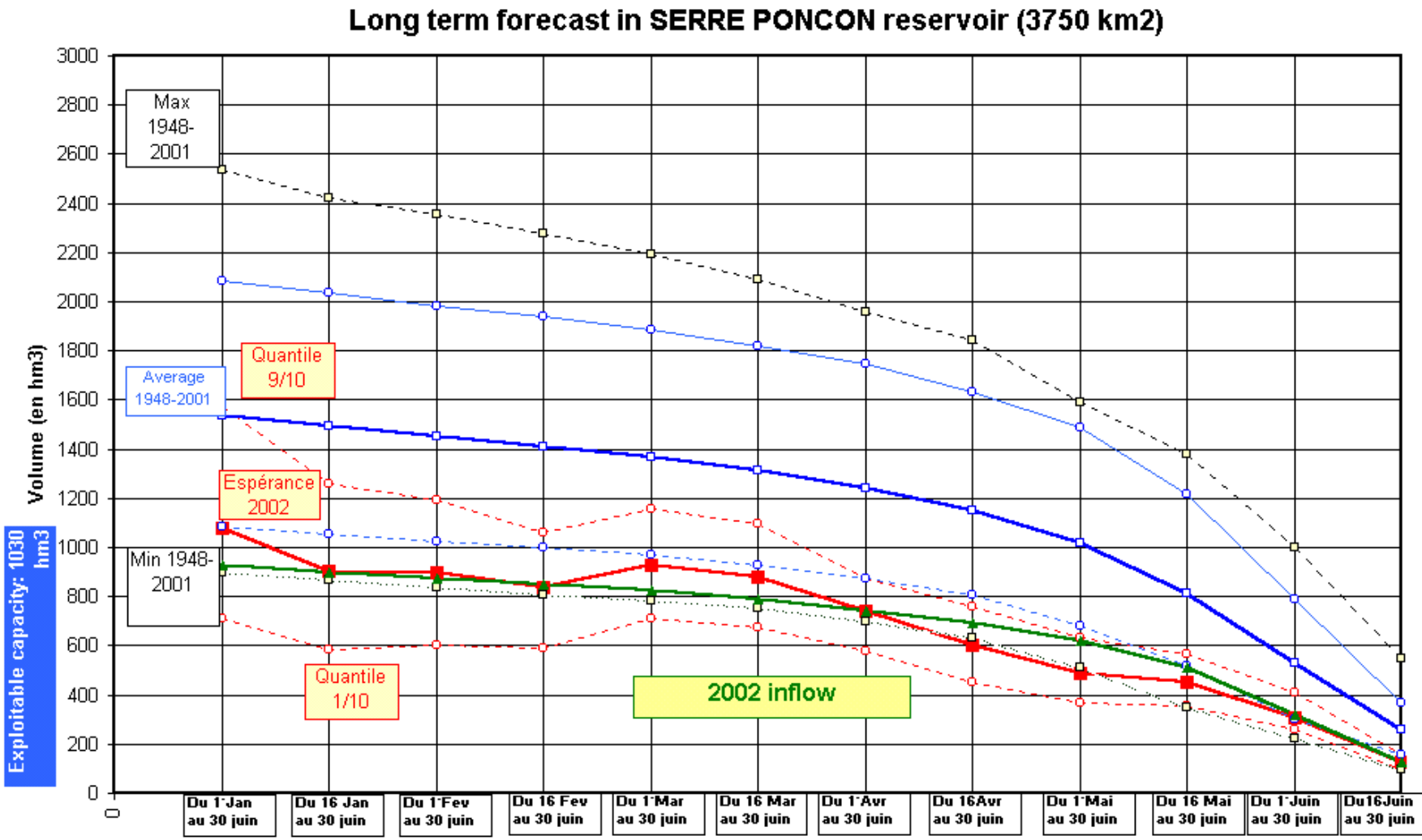
2002 forecasts



Compared to observed inflows

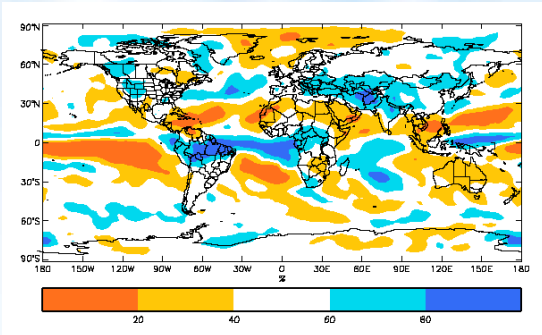


-Questions and Perspectives

1-Observation and hydrological modeling are determinant and reduces variability. Residual variability is due to future precipitation.

2- How to reduce meteo alea

- using monthly forecasts? seasonal prediction?



- Downscaling difficulty:

  study research project to use analogue model to downscale seasonal forecast (ensemble geoptentiel fields=> watershed precipitation and air temperature)

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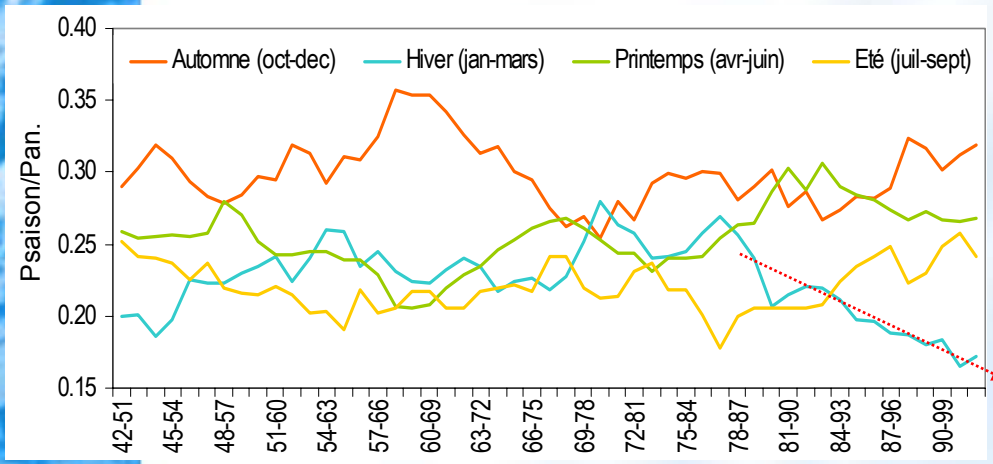
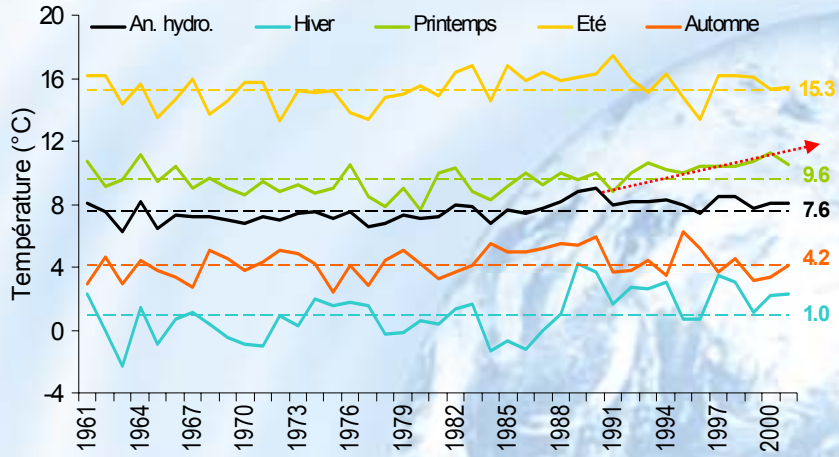
3-Is climatology of the past enough representative of future?

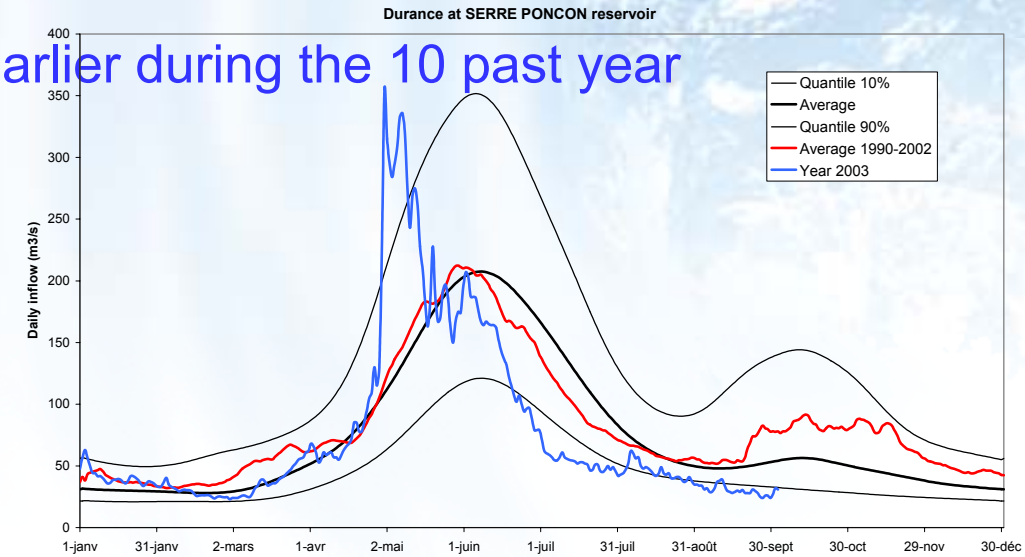
What we observed in the Alps:

- signal on precipitation and air temperature distribution inside the year





- snow melt is earlier during the 10 past year



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