Journée de la Chaire
Prospective pour les enjeux Énergie-Climat
Mercredi 17 Novembre 2010

Modéliser la gestion de l'eau face au changement climatique : les leçons d'un essai sur le bassin méditerranéen

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Chaire Modélisation prospective
au service du développement durable

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Mediterranean region, climate change and water resources

- 7% of world’s population
- 3% of water resources
- Major driver: socioeconomic changes
- Also reduction of precipitation and ETP increase

→ Optimal dimensioning of hydraulic infrastructure under CC
→ Quantification of changes and influence of operating rules adaptation

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Some specifics on economics of water resources systems

- Supply side
  - **Site specific** potential resources at the basin level
  - **Costly and « constrained » trans-basin transportation**
  - Hydraulic infrastructures increases the reliable available water.
    - **High** investment costs
    - Moderate costs of management and maintenance

- Demand side
  - **Consumptive** and **non-consumptive** uses: hydroelectricity, power plant cooling, agriculture, industry, domestic, sanitation, recreation, landscape, navigation
  - Swamped effect of price signals
  - Economic structure, demography are the main drivers

Tensions on water in a Climate change context

- Increasing episodes of droughts
- Model of water management under large uncertainty in view of a coupling with
  - GCM/RCM
  - Activity models (agriculture, electricity, industry)
  - Hybrid macroeconomic model

- Problem of scale **integration**
- Site specific nature of water management
- Large scale determinants and impacts , GCM and economic models coarse resolution

Modeling adaptation of water management to droughts under climate change; step by step approach

- Changes of future water demand at constant economic activity levels to represent vulnerability (*Regional level*)

- Adaptation of water supply through changes in reservoirs management only (*Regional level*)

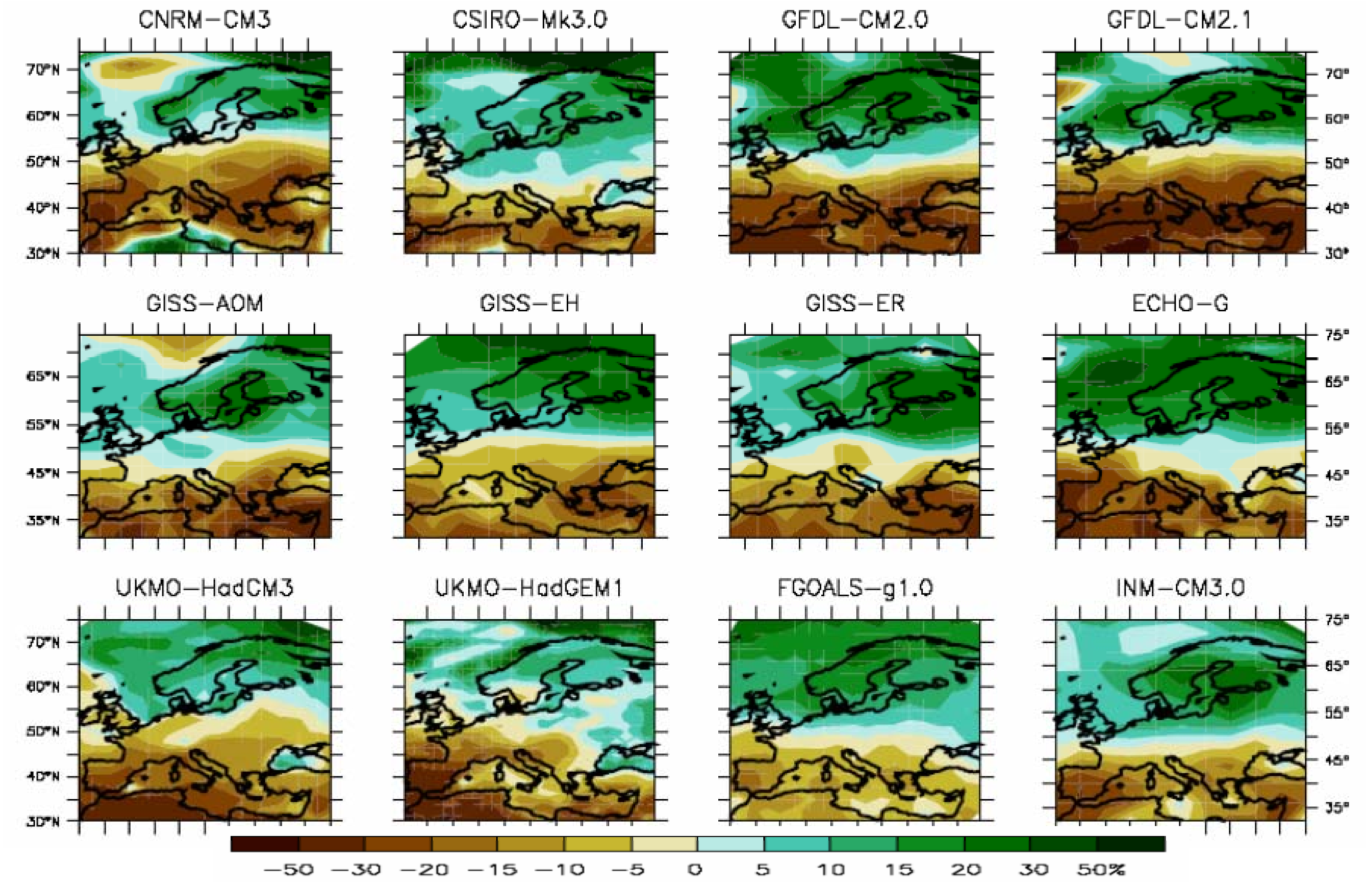
- Modification of dimensions of dams and reservoirs => assessment of the risk of sunk costs (*generic model* tested on a *case study*)

- Coupling demand projection with partial equilibrium (activity) models

- Introduction of the “nexus” into a hybrid general equilibrium model to study the propagation effects

Part I: Dam dimensioning under climate change

Dam dimensioning under climate change and climatic model uncertainty



- Several climatic models, coarse resolution of GCMs, downscaling problem
- Uncertainty due to climate models diversity

Assessment of optimal dam dimensioning under climate change

- How does uncertainty affect hydraulic infrastructure dimensioning?
- Generic model applied to a catchment with one reservoir
- Cost- Benefit Analysis (NPV maximization) as criterion for dimensioning and robust decision making
- Climate Change modeled as a succession of stationary climates
- Demands adapts to available supply

What is the change in optimal volume storage of reservoirs?

19 climatic models

Reservoir length	4km			10km			20km			Runoff
Pure time preference	0%	3%	6%	0%	3%	6%	0%	3%	6%	change
BCCRBCM20	-10	-6	-3	-12	-7	-7	-8	-8	-2	-8
CCCMACGCM31	-9	-4	-3	-15	-5	-6	-16	-10	-1	-12
CNRMCM3	-23	-12	-12	-23	-14	-10	-23	-13	-7	-20
CSIROMK30	-14	-9	-5	-16	-10	-8	-11	-10	-3	-11
CSIROMK35	-10	-6	-3	-12	-6	-7	-9	-9	-1	-9
GFDLCM20	-10	-3	-3	-14	-6	-4	-25	-9	-1	-15
GFDLCM21	-17	-7	-6	-21	-10	-8	-34	-12	-3	-21
GISSMODELER	-15	-9	-6	-21	-10	-8	-25	-11	-3	-19
INGVECHAM4	-17	-10	-8	-22	-11	-9	-17	-12	-4	-18
INMCM30	-4	-2	-1	-4	-2	-3	-5	-4	-1	-4
IPSLCM4	-17	-10	-7	-20	-11	-8	-17	-11	-4	-17
MIROC32MEDRES	-5	-2	-1	-6	-2	-3	-8	-7	-1	-6
MIUBECHOG	-17	-10	-7	-18	-10	-9	-14	-10	-4	-13
MPIECHAM5	-17	-10	-7	-22	-11	-8	-26	-12	-4	-20
MRICGCM232A	-6	-3	-1	-7	-2	-4	-9	-8	-1	-7
NCARCCSM30	-8	-4	-2	-12	-4	-5	-11	-9	-1	-9
NCARPCM1	2	2	0	1	1	1	-9	-1	1	-1
UKMOHADCM3	-6	-3	-2	-10	-3	-4	-13	-9	-1	-9
UKMOHADGEM1	0	0	0	0	0	0	0	0	0	-0

Table 3: Change in optimal volume storage relative to a case with no climate change, for three valley lengths, three rates of pure time preference, and 19 IPCC models.

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Investment under uncertainty, risk of sunk costs and maladaptation: How to make robust decision?

Valley length	10km		
« Pure Time Preference »	0%	3%	6%
Max NPV loss	-23%	-18%	-14%
Min NPV loss	0%	0%	0%

- Low total cost of dimensioning mistakes (0.26-2.83%)
- But potentially substantial and very uncertain welfare loses
- Robust choice by minimizing the error cost but adaptation efforts do not help a lot in case of large changes in precipitation

Part II: Prospective of water availability in the Mediterranean region

Analysis of Supply and Demand imbalances: could reservoirs operating rule adaptation reduce climate change impacts?

- Spatial and temporal heterogeneity
- ➔ generic model, multiple scale integration
- High anthropization ➔ operating rules adaptation

Methodology:

- Demands location
- Demands projection
- Reservoirs network, sub-basins, inflows
- Reservoir-demand links
- Operating rules

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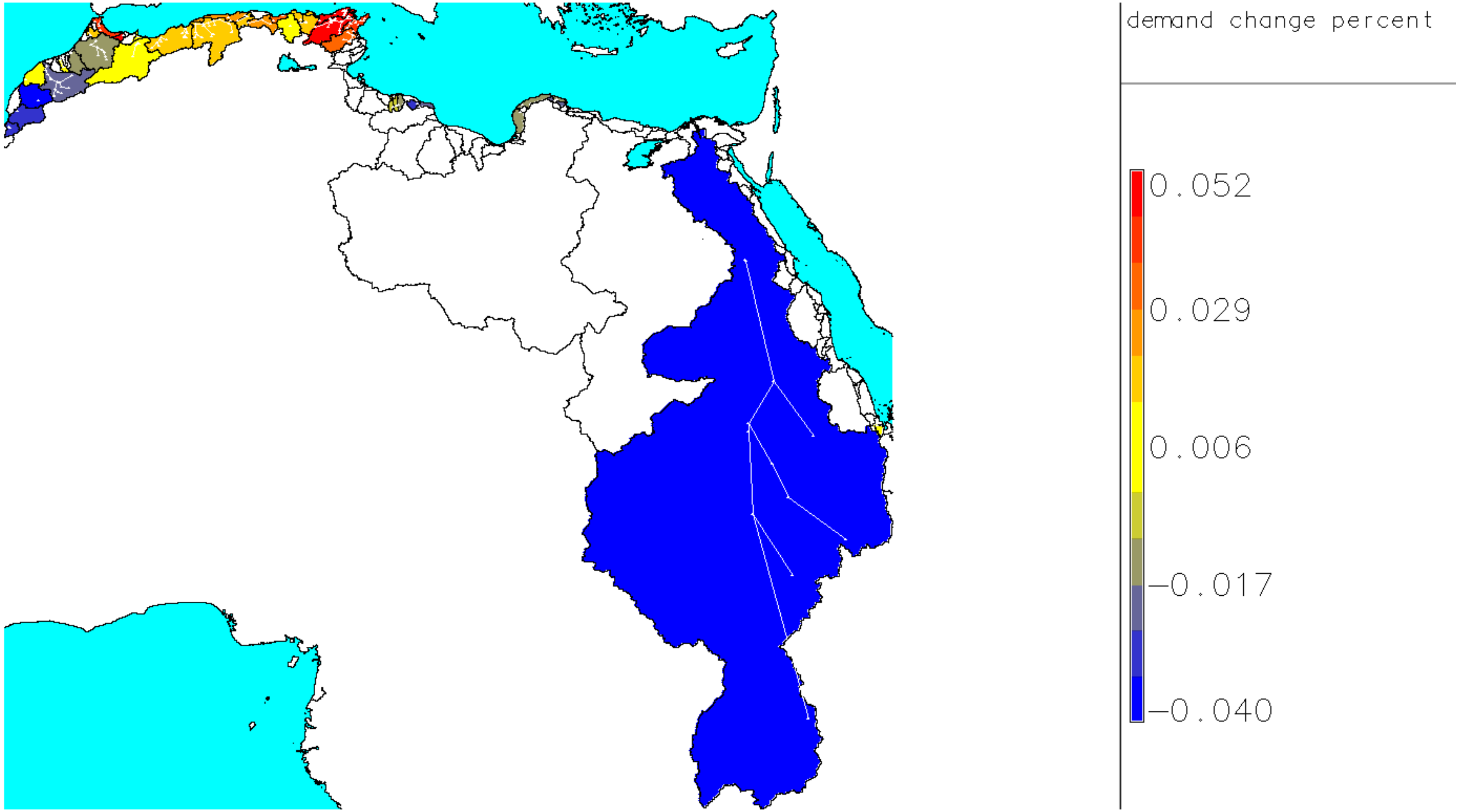
Demands

- Demands location
  - Population (CIESIN), power plants (CARMA) , Global Map of Irrigated Areas (Aquastat)
- Exogenous drivers (based on WATERGAP) :Domestic, power plants cooling, Industry
  - GDP, population (IMF), past consumption (Eurostat, Plan Bleu), electricity production (IEA),, water use intensity, Added value (Enerdata, GTAP, World Bank), past intensity (Eurostat, Plan Bleu)
- Irrigation : Present surfaces, climate change
  - Land use (FAO Agromap, Faostat)
  - Phenology: Growing degree days
  - Evapotranspiration : Heargrave (FAO Irrigation and Drainage paper N°56)
  - Irrigation fills the deficit between evapotranspiration and effective precipitation

Change of satisfied demand under CC: North Africa irrigation



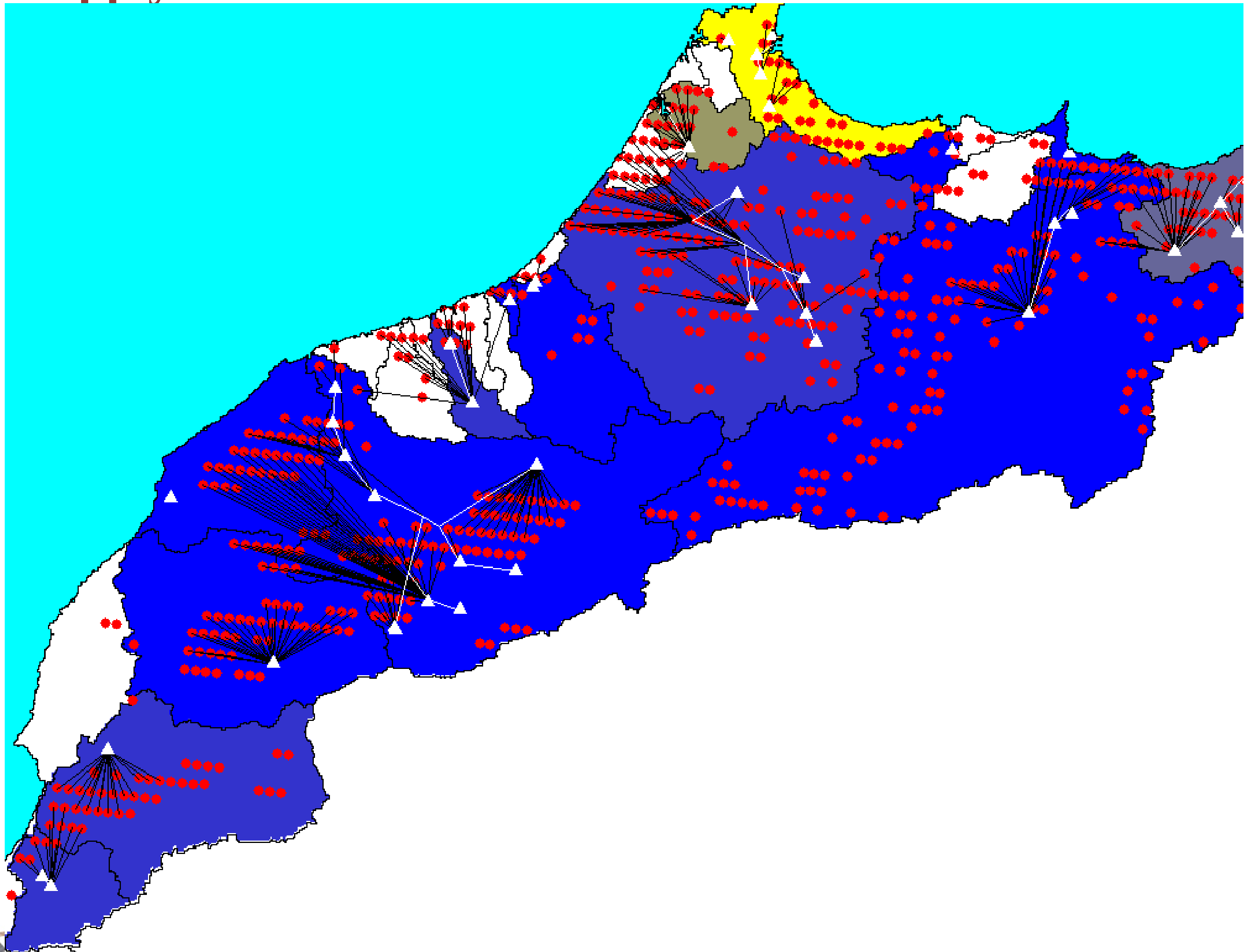
$$\frac{Dproj\_cc - Dproj\_no\_cc}{Dproj\_no\_cc}$$

Reconstructing reservoir network and associating reservoirs and demands

- **27000 Demand nodes (3500 in North Africa) , 525 Supply nodes (140 in North Africa)**

- No detailed network information, reconstruction based on dams and demands data
- Reservoirs network, sub-basins, inflows (hydro1k, ICOLD, CIRCE climatic models)
- Reservoirs Demands (cost function, penalizing distance and altitude difference)
- Only one reservoir is selected for each demand (cost minimization, mean inflow =mean demand)
- In the African region, the share of demands associated to a reservoir are:
  - 89% of power plants
  - 81% of irrigated surfaces
  - 87% of population

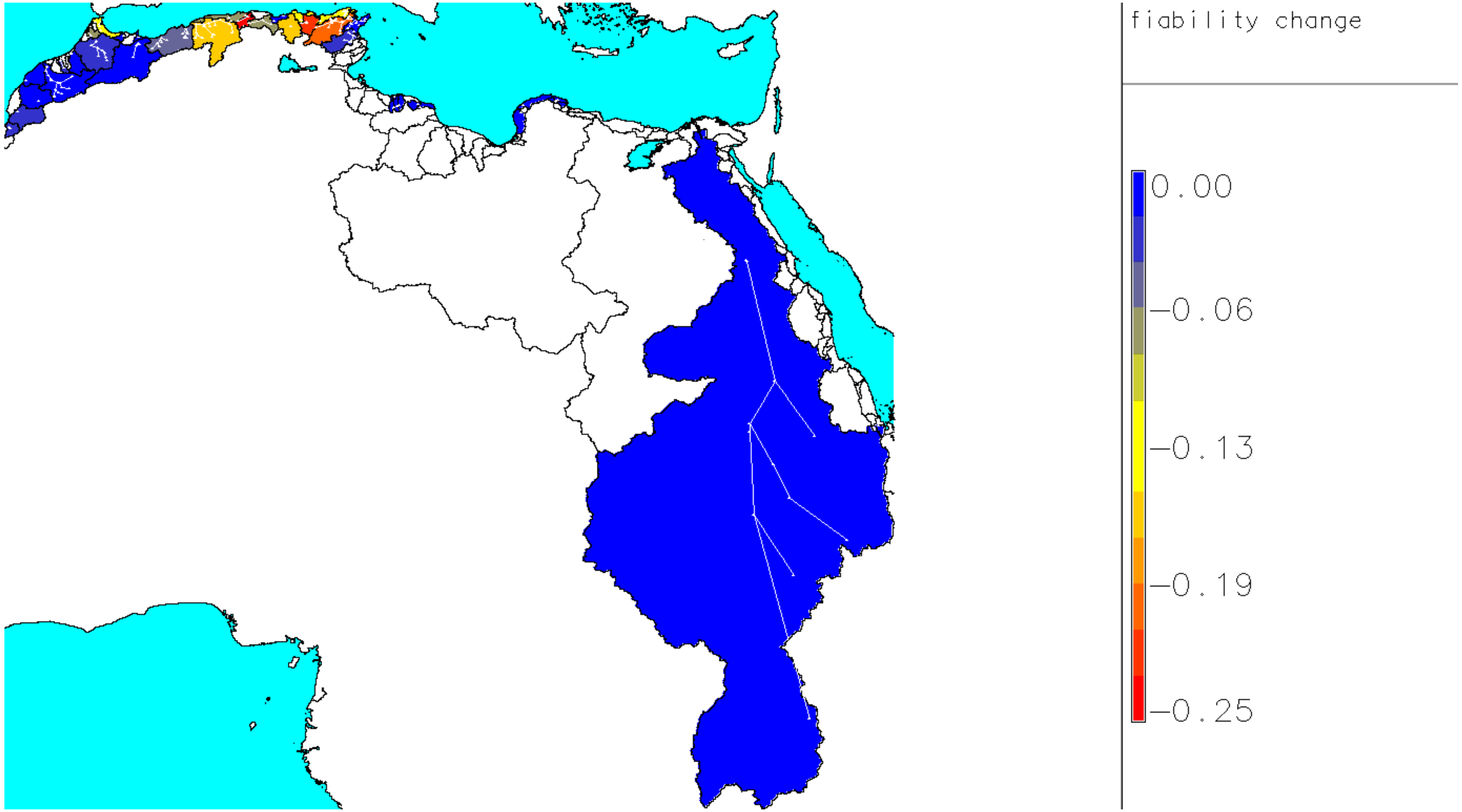
Supply and Demand Network: illustration on Morocco



Modeling Operating rules

- Determined at the river basin scale
- No priorities among demands
- Objective: Reliability maximization
- Optimization of the parameters of empty space allocation among reservoirs in parallel

Change of reliability under CC: North Africa case



$$\Delta \mathrm{Re}liability = \mathrm{Re}liability_{cc} - \mathrm{Re}liability_{no\_cc}$$

Perspectives

- Representation of non consumptive water uses
- Groundwater representation
- Coupling with Agricultural model using water extraction costs and irrigation benefits
- Adaptation of demand (capital, activities) according to available supply
- Link investments in the electricity sector and intra-annual water demand for hydroelectricity and power plant cooling to water supply
- Floods integration
- Optimal dimensioning of reservoirs, under uncertainty

THANK YOU!