What do climate change models tell us? Spain

L. Garrote

UNIVERSIDAD POLITÉCNICA DE MADRID
• **Projections of runoff**
  – Studies made by Cedex

• **Projections of water availability**
  – WAAPA model, global for Europe and specific for Spain
  – Analysis of factors determining water availability

• **Role of adaptation**
  – Effect of policy on water availability
Studies of Cedex (2010, 2017) Methodology

**Climate forcing**

**Study of 2010**
- 6 projections SRES A2
- 6 projections SRES B2

**Study of 2017**
- 6 projections RCP4.5
- 6 projections RCP8.5

**Hydrologic model**

**Results by basin**

**Hydrologic projections**

- Runoff
- Recharge
- Actual ET
**Comparison of studies by Cedex (2010-2017)**

**Tabla 27. Rango y media de Δ en las variables hidroclimáticas en España en cada PI y escenario de emisiones según el presente estudio y comparación con el de CEDEX 2010.**

<table>
<thead>
<tr>
<th>ESPAÑA</th>
<th>Presente Estudio</th>
<th>CEDEX 2010</th>
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<tbody>
<tr>
<td></td>
<td>RCP 4.5</td>
<td>RCP 8.5</td>
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<tr>
<td></td>
<td>Mx</td>
<td>Med</td>
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<td>ETP (%)</td>
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<td>ETR (%)</td>
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<tr>
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**Similar results, slightly less reduction in runoff**
Results of Cedex 2017

Projected reduction of runoff (%)

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<tr>
<th>ESC</th>
<th>Δ Anual (%)</th>
<th>RCP 4.5</th>
<th>RCP 8.5</th>
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<td>2070-2100</td>
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<td>-16</td>
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</table>

Large variability, strong reduction of runoff
Results of Cedex 2010-2017

Projected reduction of runoff (%)

Large variability, strong reduction of runoff (10% for RCP4-5)
• Runoff is a proxy for changes in water availability

• But there are other factors…
  – Changes in variability
  – Water management: reliability, environmental flows, storage

• Simple model to estimate water availability
  – Streamflow, storage, demands and environmental flows
  – Analysis under climate change scenarios
WAAPA Model

WAAPA: Water Availability and Adaptation Policy Analysis

GEOGRAPHICAL DATA
- Reservoirs and demands distributed in subbasin

WAAPA MODEL ALGORITHM
- One reservoir and one demand per subbasin

Reservoirs are operated jointly to supply a set of demands

Supply

WAAPA MODEL DATA
Potential Water Availability analysis

Performance (Volume Reliability)

Desired performance

\( p^\alpha_{\text{req}} \)

Maximum acceptable demand in the system

\( d^\alpha_{\beta\text{max}} \)

Demand component \( d_\alpha \)

DEMAND-RELIABILITY CURVE

CONTROL SCENARIO

Reservoirs are operated jointly to supply a set of demands

Supply

Urban demand

Irrigation demand

\( p^\alpha_\alpha: \text{Performance for } d_\alpha \)
PWA analysis under climate change

DEMAND-RELIABILITY CURVE
Climate scenarios

- Climate scenarios were taken from regional models in different projects: PRUDENCE, ENSEMBLES and CORDEX
  - 8 A2, 4 B2, 3 A1B, 5 RCP2, 5 RCP4, 5 RCP6, 5 RCP8
  - Time slices CTL: 1960-2000 FUTURE: 2070-2100

Validation with GRDC data

Effect of Climate change

- Streamflow data were corrected for bias

- Significant reduction in most basins
Analysis of European basins

Scenario RCP4.5

Loop over 5 models
Analysis of Uncertainty

Runoff: Model uncertainty larger than emission scenario uncertainty
Availability: same level of uncertainty (storage)
Specific study of Mediterranean basins

Storage $V$ (km$^3$) / Mean Annual Flow $F$ (km$^3$/yr) / Area $S$ (km$^2$)

[Graph showing scatter plot with dots representing different basins.]

[Map inset showing Mediterranean region with color-coded basins.]
Climate projections

Change in Mean Annual Flow

ΔMAF = \frac{MAF_{\text{proj}} - MAF_{\text{hist}}}{MAF_{\text{hist}}}

Change in Coefficient of Variation of Annual Flow

ΔCV = \frac{CV_{\text{proj}} - CV_{\text{hist}}}{CV_{\text{hist}}}

Ebro : V/F=0.33

ΔCV = \frac{CV_{\text{proj}} - CV_{\text{hist}}}{CV_{\text{hist}}}

ΔMAF = \frac{MAF_{\text{proj}} - MAF_{\text{hist}}}{MAF_{\text{hist}}}

A2
B2
A1B
RCP-2
RCP-4
RCP-6
RCP-8
Reduction in MAF and larger increase in CV
Stronger forcing in areas already exposed to water scarcity
Reduction in MAF and larger increase in CV
Stronger forcing in areas already exposed to water scarcity
Potential Water Availability

Ebro: $V/F = 0.33$

Probability of Non-Exceedance vs. Potential Water Availability (km$^3$/yr)

Legend:
- A2
- B2
- A1B
- RCP-2
- RCP-4
- RCP-6
- RCP-8
- CTL
Large uncertainty and significant reduction of PWA
Model uncertainty larger than emission scenario uncertainty
Large uncertainty and significant reduction of PWA
Model uncertainty larger than emission scenario uncertainty
Projected changes of MAF vs. PWA

Ebro: V/F = 0.33

Change in Potential Water Availability

\[ \Delta PWA = \frac{PWA_{PROJ} - PWA_{HIST}}{PWA_{HIST}} \]

Change in Mean Annual Flow

\[ \Delta MAF = \frac{MAF_{PROJ} - MAF_{HIST}}{MAF_{HIST}} \]
Projected changes of MAF vs. PWA

Changes in MAF are a good proxy for changes in PWA
We found stronger dispersion in areas with high variability
Changes in MAF are a good proxy for changes in PWA
We found stronger dispersion in areas with high variability
Changes in MAF vs PWA

Ebro: V/F=0.33

Change in Mean Annual Flow and Potential Water Availability

\[ \Delta MAF = \frac{MAF_{PROJ} - MAF_{HIST}}{MAF_{HIST}} \]

\[ \Delta PWA = \frac{PWA_{PROJ} - PWA_{HIST}}{PWA_{HIST}} \]
We found a range of behaviors:

1. similar reduction;
2. less reduction PWA;
3. cross;
4. more reduction PWA.
We found a range of behaviors:
1 similar reduction; 2 less reduction PWA; 3 cross; 4 more reduction PWA
The role of adaptation

• **Strong reductions of runoff and water availability**

• **Policy and management may modify availability**
  – Water allocation to environmental flows
  – Investment in infrastructure or improved management
  – Governance: social arrangements to accept less reliability

• **What is the impact of policy on water availability?**
  – Simple analysis based on modelling framework
Adaptation options

Reference Management

Every reservoir supplies local demands only

Improved Management

All reservoirs contribute to supply all demands

POLICY: densification of water transport and distribution networks; enhancement of management capacity

Reference Governance

99%

Water users do not share resources

Improved Governance

95%

Water users cooperate and share resources

POLICY: enhancement of legal framework for water sharing; capacity building to improve education of water users
Adequate management and governance may compensate the reduction of availability.
• **Policy target**
  – Maintain acceptable reliability under climate change scenarios

• **Main policy action**
  – Demand reduction to maintain reliability under climate change

• **Additional policy actions**
  – Supply enhancement through increased reservoir storage
  – Increase water efficiency in urban use
  – Modify environmental flow conditions
The range and effectivity of measures vary strongly across basins.
• Modeling tools
  – Model performance is very poor while describing the currently observed features of hydrologic regime relevant for water availability
  – Model uncertainty is very wide, equal or greater than emission scenario uncertainty. Is this of any use?

• Water availability projections
  – Climate change impacts on water availability are uncertain and heterogeneous, but are expected to be strongly negative in Spain
  – Impacts are stronger in areas already affected by water scarcity

• Role of adaptation policy
  – Improved water management and water governance may compensate adverse effects of climate on water availability
  – Effectiveness varies across basins, requiring local analyses
What do climate change models tell us?
Spain

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