Grand Challenge Food for the Food Baskets of the world

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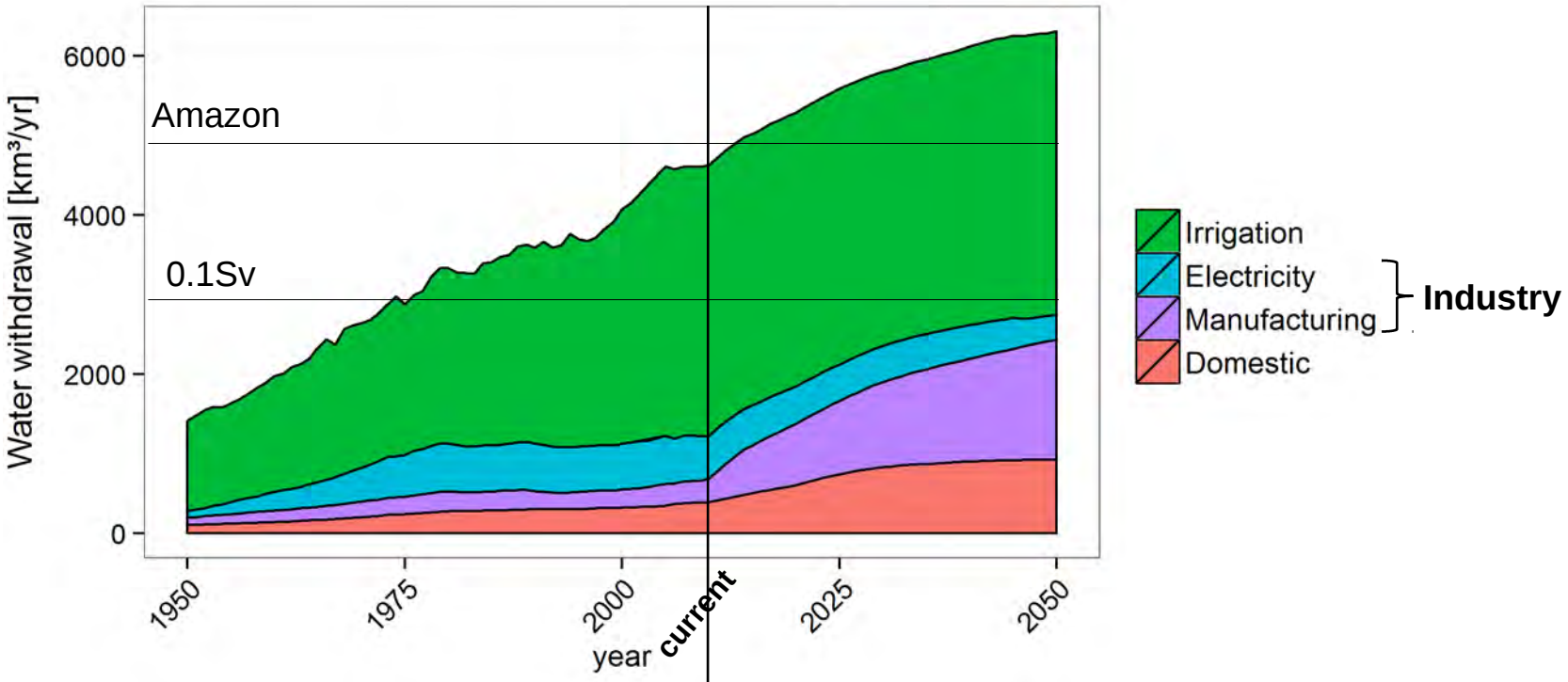
Motivation

- The first large scale intervention on the landscape go back to the Roman empire.
- The industrial revolution accelerate population growth and thus needs to produce food.
- It is only after the second world war that human intervention in the landscape reached a global scale.
- Now the human usage of the natural resources is directly affected by climate change.

Global Water Use: *Where we are*

Climate
Socio-economic drivers → Water use model → Sectoral water uses



hindcast ↔ forecast

Main drivers

- Population
- GDP, GVA
- Thermal electricity production
- Irrigated land
- Technological change rate

Flörke et al. (2013)
Wada et al. (2016)

The challenge for the community

- Our knowledge on the water cycle is essentially of the natural system.
- How well do we know the processes governing slower reservoirs (groundwater, snow, glaciers, …) ?
- Climate change will perturb the real system but how relevant is our knowledge of the natural cycle ?
- Practices for water resource management are based on past experience. Have they evolved with our knowledge on climate change ?
- Is our science relevant for the practitioner … what do we need to make the transfer of knowledge effective ?

Proposed Structure for GC questions

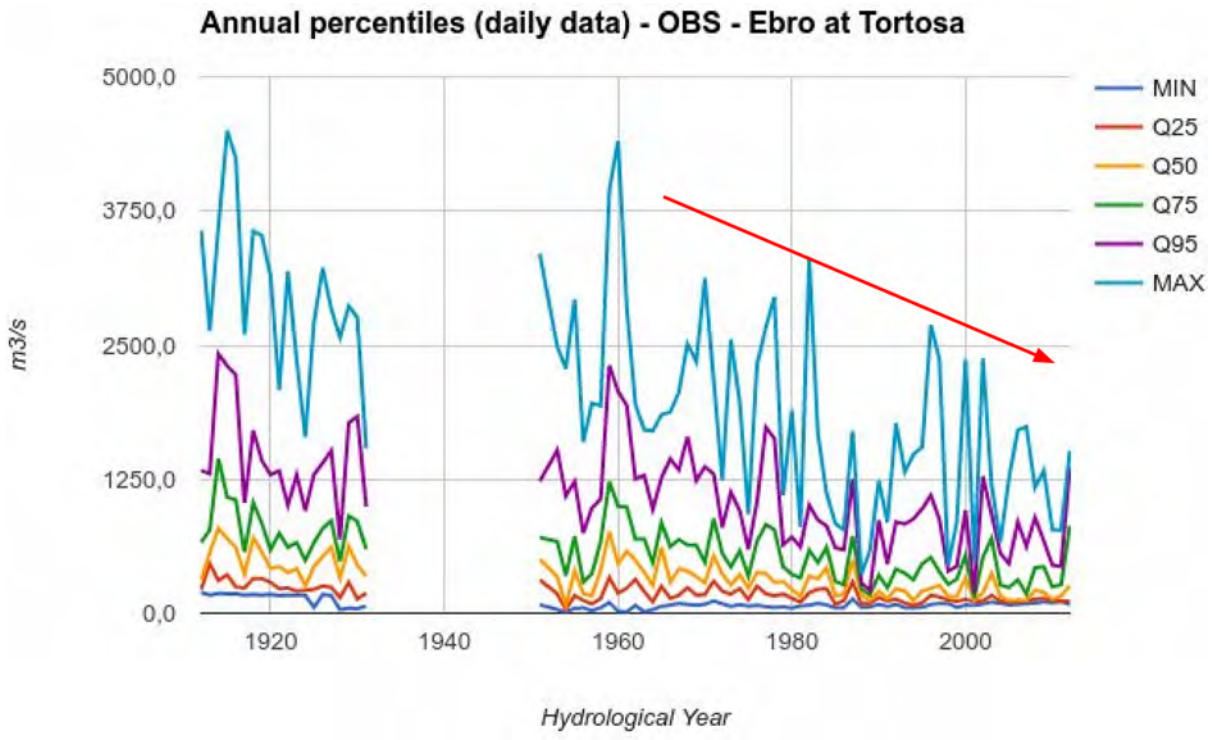
1)Quantification of human intervention on the landscape and management of water flows.
2)Feedback between human intervention and climate.
3)Interactions of climate change and a human controlled land surface.
4)Combined effect land & water use and climate change on air and water quality.

Quantifying human intervention

We need a long term perspective and detailed process knowledge on :

- Land use impact on evaporation, irrigation, cold processes and groundwater recharge.
- Impact of field drainage on soil moisture and hydrology.
- Irrigation technique and their impact on the surface energy balance and water demand and management.
- Groundwater pumping … how much do we know?
- Contribution of high mountain (& cold) hydrology to water resources.
- Usage of fertilizers and their impact on atmospheric chemistry.

An example from the HyMeX RHP



- Spain has become the vegetable garden of Europe.
- The changes are visible in the landscape and the water cycle.

- Humans have reorganized the water cycle to optimise agronomic productions.
- The process has been very rational, even if with some unintended consequences.

The Ebro valley

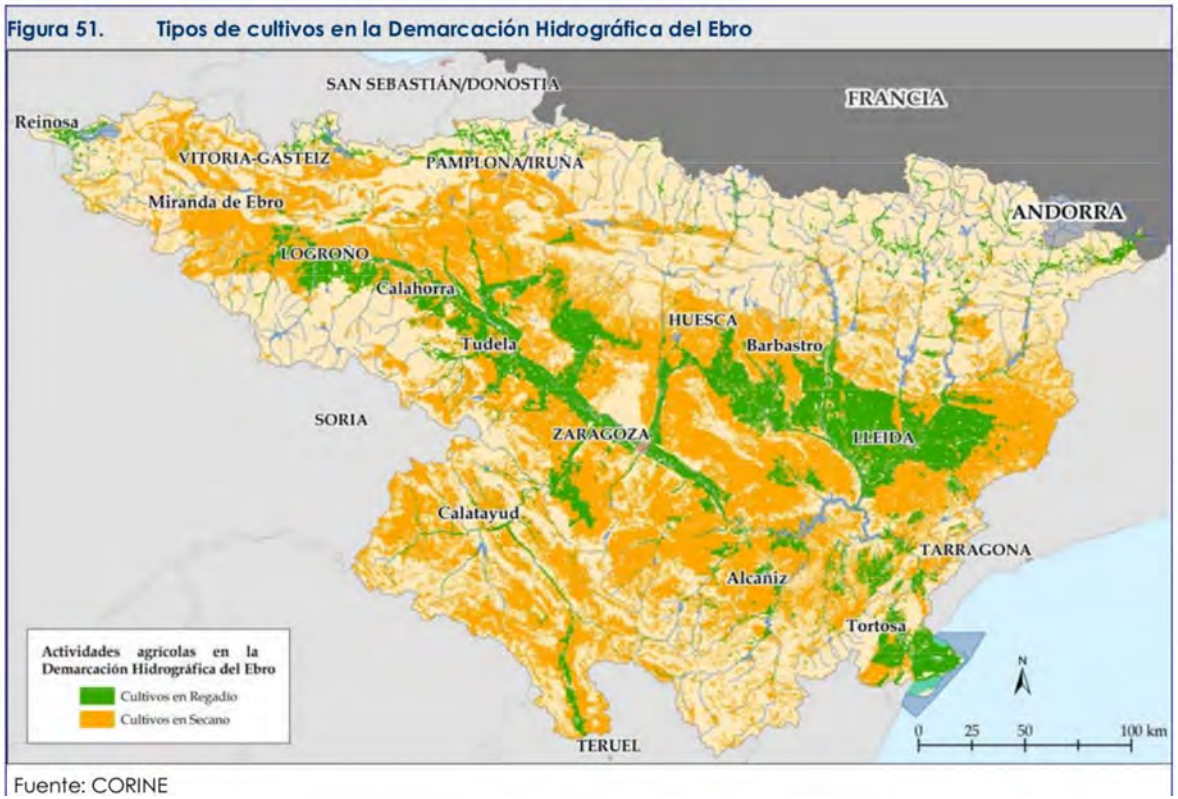
Agriculture

Agriculture is concentrated in the valleys.

Diversity of crops.

Water is needed mainly in spring and summer.

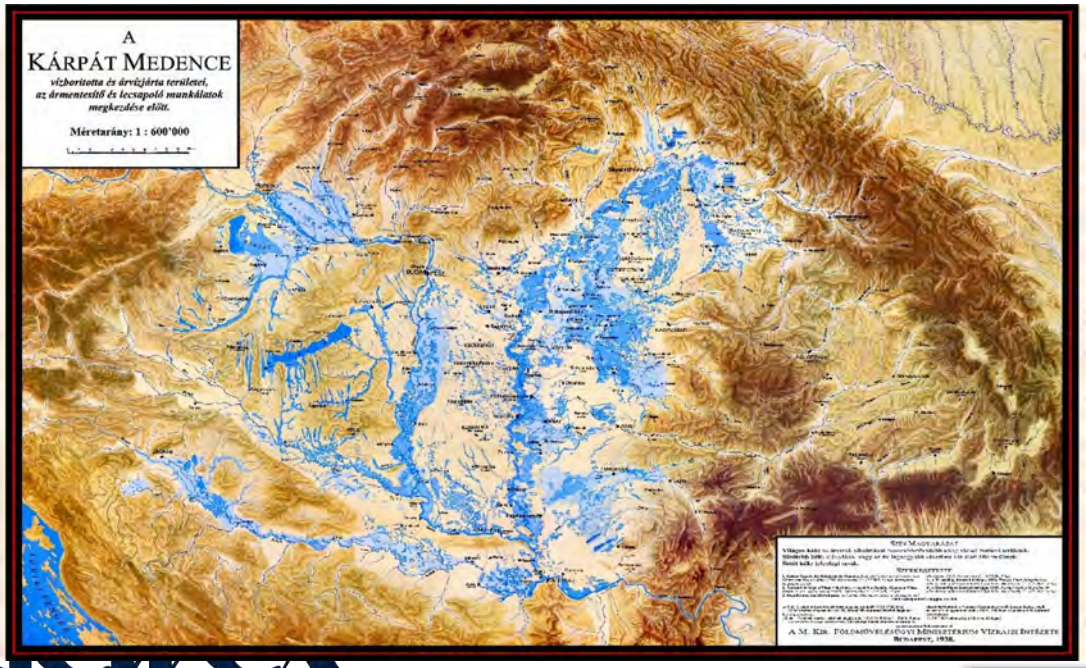
Water is stocked in dams and transported through the river and canal networks.



Only an understanding of the processes (Natural and socio-economic) should allow to represent this in our models.

The Pannonian basin

- Since the 19th century flood control measures were introduced along the Danube and its tributaries
- Fields were drained to make them arable.
- The Danube was developed as a waterway (Tiza river was shortened by 453km between 1846 and 1880).



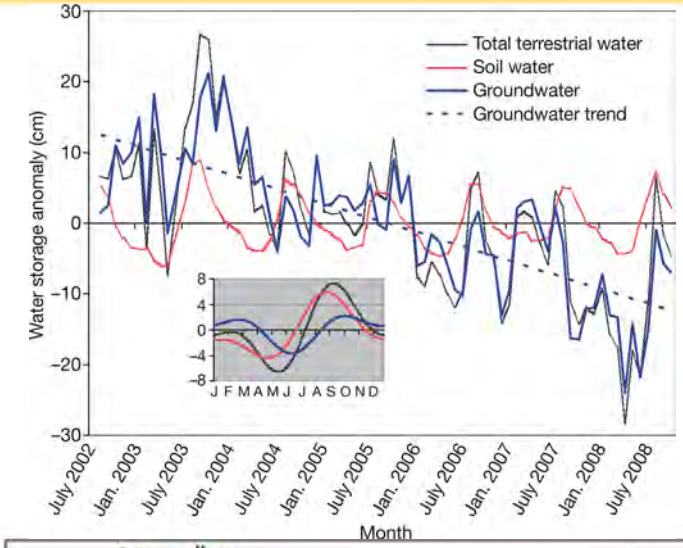
Blue regions used to be floodplains !

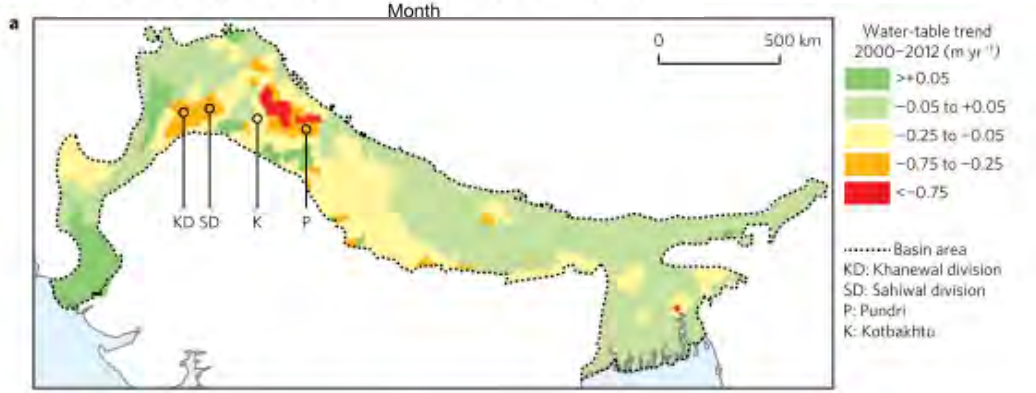
Impact and land & water use on climate

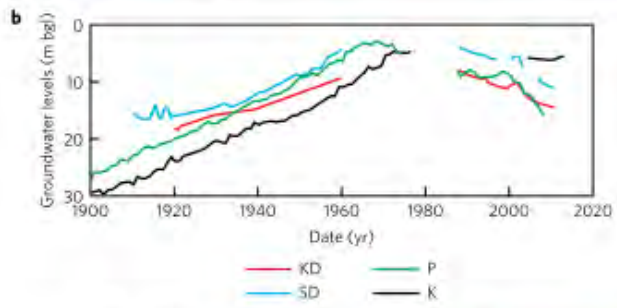
The human intervention in the system is now on such a scale that it has probably affected climate in various aspects.

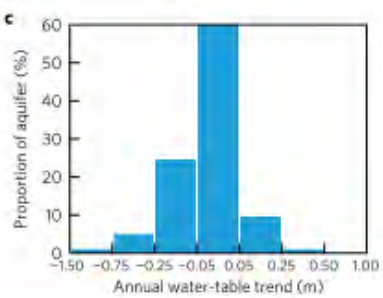
- How has the reduction of water flow to the oceans affected coastal processes ; physics and biochemistry ?
- Has the response of the surface to extreme meteorology been affected by the human management ?
- How has the land & water use changed ground water recharge as a whole ?

Ground water in the Ganges plain









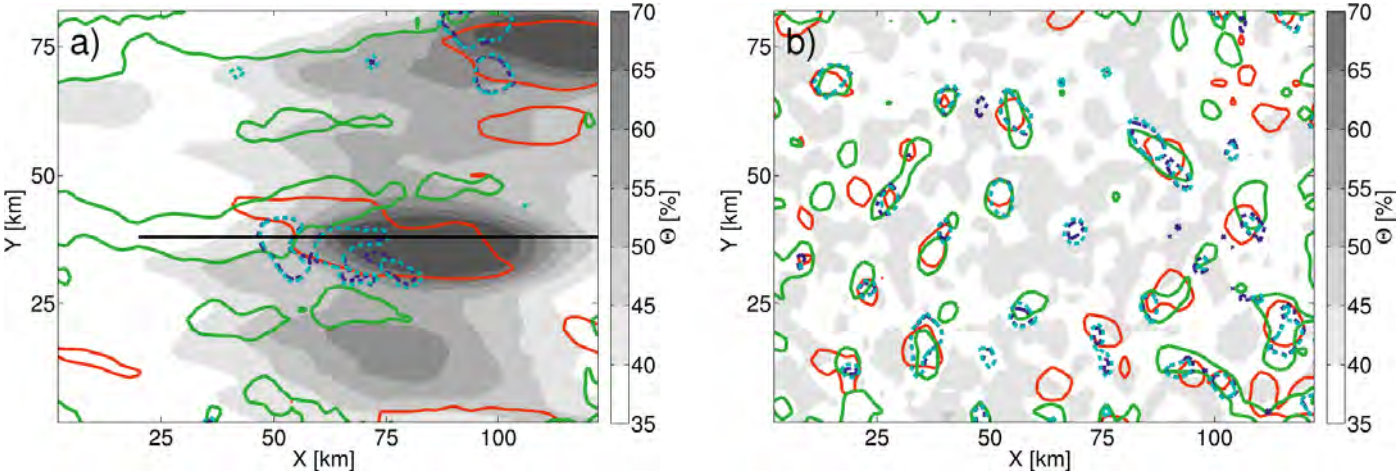
- GRACE data has given the impression of a dramatic decline of ground water levels in Northern India (Rodell et al. 2009).
- But longer term observations show that the picture is more complex and human have modified ground water levels for much longer (MacDonald et al. 2016).

Impact of land & water use on climate

- The land surface and water usage changes have modified the planetary boundary layer :
  - In its diurnal development,
  - Its water and aerosol content,
  - Its chemistry !
- When humans cut trees, plant, irrigate build reservoirs, … they create gradients at the surface. In the last years observations have shown that small scale gradients are key in the surface atmosphere interactions. Is it time to read again some old papers (Avissar et al.) ?

New intellectual tools

Froideveaux et al. (2014) propose some solid physics to understand surface atmosphere interactions.



- Grey : soil moisture
- Red : afternoon rain
- Green : morning PBL ascent
- Blue : afternoon convection

CTL **U00**

- This mental model confirms that initiation occurs over the dry patches, up-wind of wet areas.
- Advection of the precipitating system leads to afternoon rainfall which can propagate over wet patches.

→ These results are in agreement with observations

→ The surface/atmosphere interactions are tightly coupled to the diurnal cycle

Climate change : modification of the resources and resilience of the surface.

How has the human intervention changed the sensitivity of the system to climate change ?

- Many characteristics of precipitation will change (intensity, frequency, duration, phase) : how does that affect crop yields, infrastructures, domestic water use, industrial water use ?
- How will snow and glacier melt evolve and affect water resources ?
- Increasing temperature will change the biology of water reservoirs.
- How will evaporative demand of the atmosphere change ?

Are today's management tools transferable ?

- Water managers and agronomist use empirical formulations for potential evaporation for they day to day job (Priestley and Taylor, Rohwer, Thornthwaite, …).
- Climate change will modify :
  - Radiation at the surface
  - Atmospheric turbulence
  - Diurnal temperature amplitude.
- None of the formulations take all these effects into account !
- There is a wide variety of drought indicators. How many consider changes in rainfall characteristics and is the way they are considered relevant for climate change ?

Combined impact on air and water quality

- Modification of infiltration and runoff as well as usage of agricultural inputs change water quality.
- Temperature increase amplifies the consequences of these changes and impacts the ecology of water bodies (lakes or closed seas).
- Agriculture (VOC) and usage of fertilizers (N) interact with modifications of the PBL structure to impact air quality in urban and peri-urban areas.

Implementation

- There is a wide scope of processes which link water & land use in food baskets and the climate system !
- Not all of these processes are relevant in all regions of the world.
- Neither are all these processes yielding interesting scientific questions.

Thus the Grand Challenge needs to help the community to prioritize the questions and identify opportunities.

Implementation

- Already achieved :
  - GEWEX Convection-Permitting Climate Modeling Workshop (Boulder, Sep. 2016).
  - Workshop on including human processes in land surface models (Gif-sur-Yvette, Sep. 2016).
  - Meeting with WMO hydrological forecasting unit and WMO Agronomic application unit.
- Planned for the near future :
  - Raise the visibility of these issues in the community through publications in the literature
  - Identify RHPs or activities within RHPs which contribute to these objectives and promote them.

Contribution of GEWEX activities

- **GLASS** : make land surface models more relevant to simulating the real land surfaces and slow components (ground water, glaciers, …).
- **GASS/GABLS** : build process knowledge on the surface atmosphere interactions which allows to qualify climate simulations.
- **GDAP** : retrieval algorithm which take into account the full complexity of the surface. High resolution GRACE for groundwater monitoring.
- **GHP** : analyze the full complexity of interactions at the socio-economic scales :
  - PANNEX : an excellent case to place future changes in a historical context.
  - Wester US RHP : Intense water usage in a region with important high evelevation resources.
  - All other RHPs as well !

Conclusion

- This GC raises a lot of important questions :
  - Some are fundamental science questions,
  - Others are more knowledge transfer problems.
- The time scale to be studied is the full 20th century. So we need to resort to non-conventional observations.
- GEWEX rightfully leads this GC but we need to involve the other core projects :
  - CliC : snow and glaciers
  - SPARC : atmospheric processes and air quality
  - CLIVAR : ocean water cycle and coastal processes
- With the help of other WMO departments we should reach out to the agronomic science and water management and hydro-economists.