Climate Induced Changes on the Hydrology of Mediterranean Basins

Lessons learned from the CLIMB project

Fourth Workshop on Water Resources in Developing Countries
15 June 2015, ICTP, Trieste

Ralf Ludwig and the CLIMB Consortium

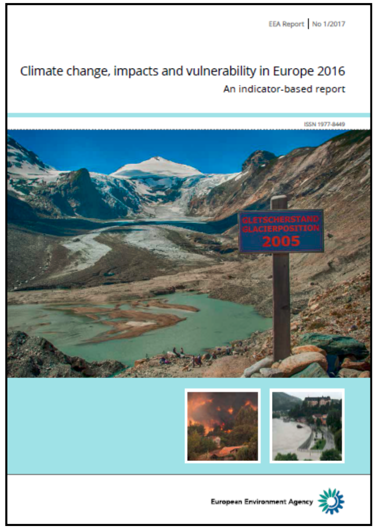
SEVENTH FRAMEWORK PROGRAMME
LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

A collaborative research project
under the 7th Framework Programme
Environment, incl. Climate Change (ENV)

CLIMB

Mediterranean region

Large increase in heat extremes
Decrease in precipitation and river flow
Increasing risk of droughts
Increasing risk of biodiversity loss
Increasing risk of forest fires
Increased competition between different water users
Increasing water demand for agriculture
Decrease in crop yields
Increasing risks for livestock production
Increase in mortality from heat waves
Expansion of habitats for southern disease vectors
Decreasing potential for energy production
Increase in energy demand for cooling
Decrease in summer tourism and potential increase in other seasons
Increase in multiple climatic hazards
Most economic sectors negatively affected
High vulnerability to spillover effects of climate change from outside Europe



Conclusion…

Measurements and projections indicate…

→ *severe impacts on water resources management & key strategic sectors of regional economies*

→ *a strong need for adaptation*

→ ***but is all this knowledge useful for the local stakeholder (water user, water manager)?***

→ ***modeling CC impacts on the local (catchment) scale!***

CLimate Induced Changes on the Hydrology of Mediterranean Basins –
Reducing Uncertainty and Quantifying Risk

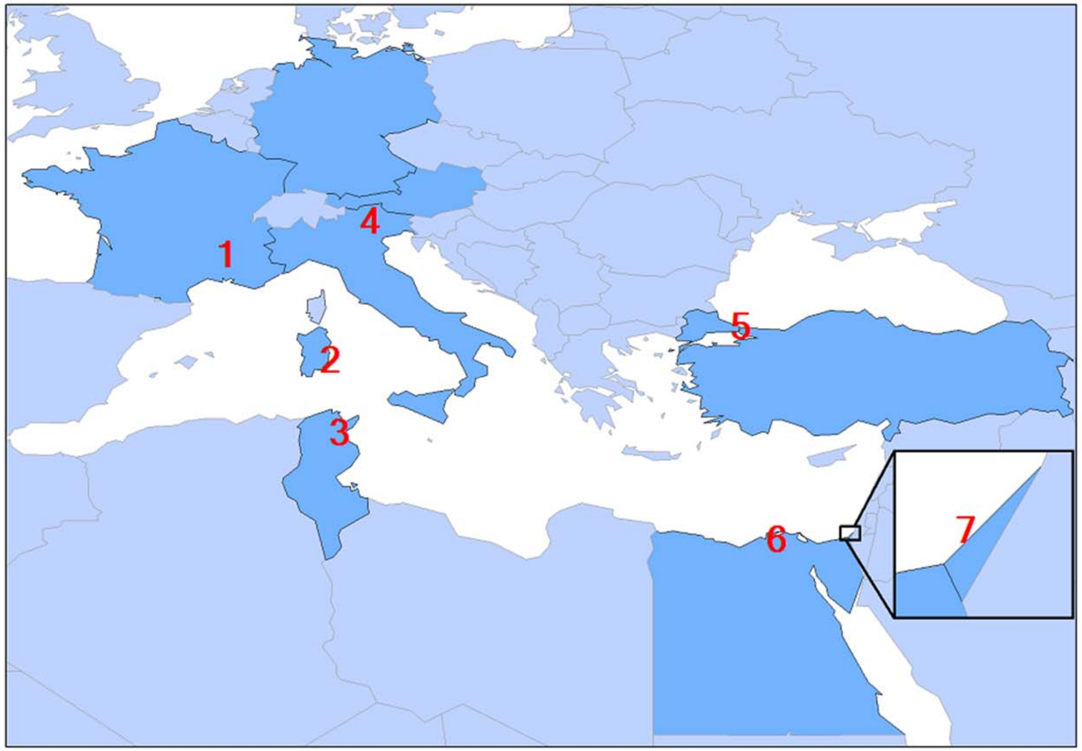
- funded under EU's FP7 Environment Theme (Theme: Climate, Water & Security, ENV.2009.1.1.5.2)
- funding period 50 months (2010 – 2015)
- 20 beneficiaries
- 9 countries:
  EU – Austria, France, Germany, Italy
  SICA – Egypt, Palest. Adm. Areas, Tunisia, Turkey
  Other – Canada

CLIMB – mission & objectives

→ analyse future climate induced changes in hydrological budgets and extremes

→ link the changes in hydrological quantities to vulnerability and associated risks

→ quantify uncertainties in climate change impact analysis



1) Thau – 280 km² - Coastal Lagoon - France
2) Rio Mannu – 473 km² - Sardinia, Italy
3) Chiba - 286 km² - Cap Bon – Tunisia
4) Noce - 1367 km² – Southern Alps – Italy
5) Izmit Bay – 673 km² - Kocaeli - Turkey
6) Nile Delta – 1000 km² - Nile - Egypt
7) Gaza Aquifer – 365 km² - Gaza – Palest.-admin. areas

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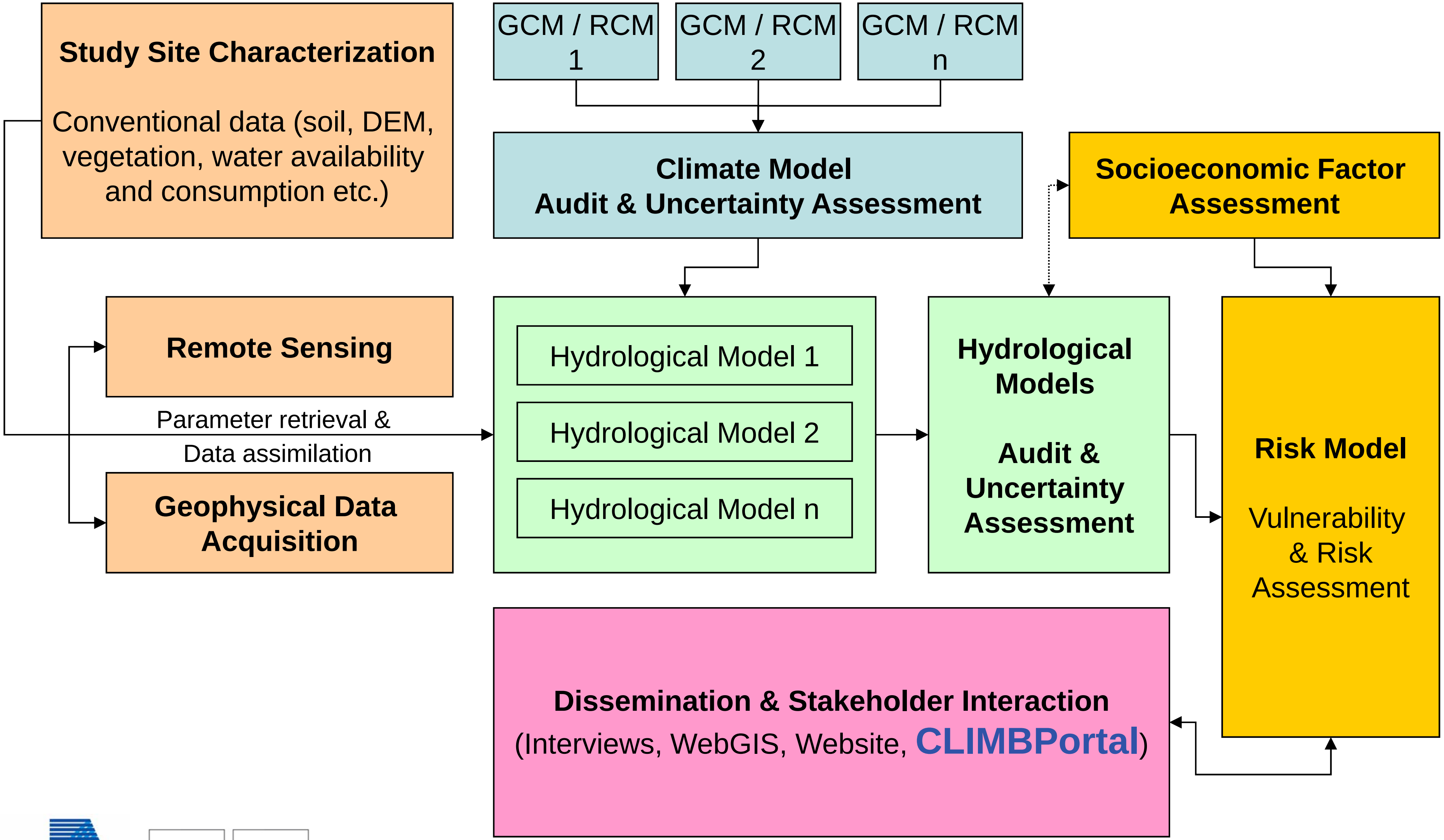
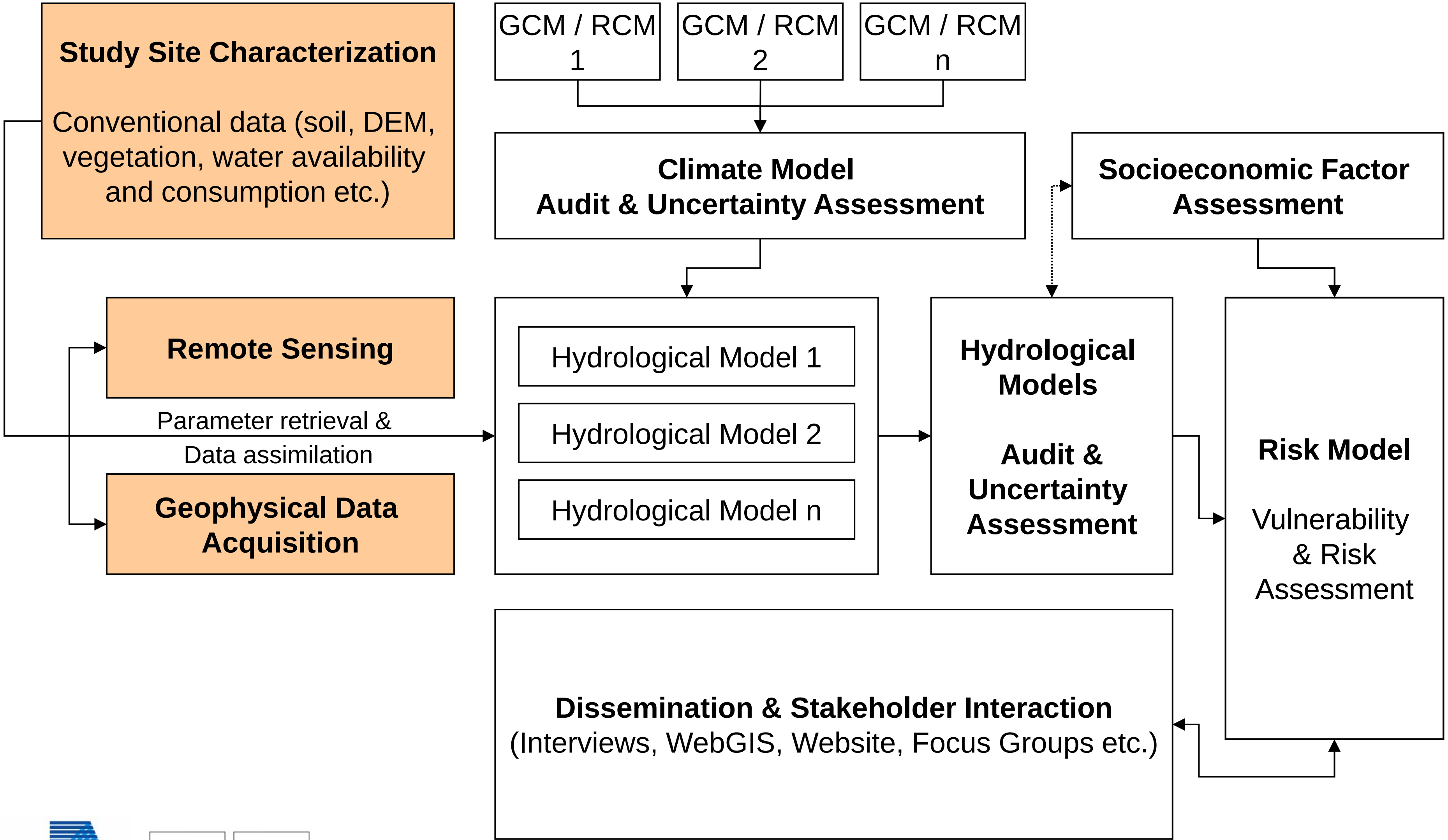
CLIMB – conceptual framework



CLIMB – Structure & Workflow



CLIMB – geophysical data acquisition

Study Site Characterization

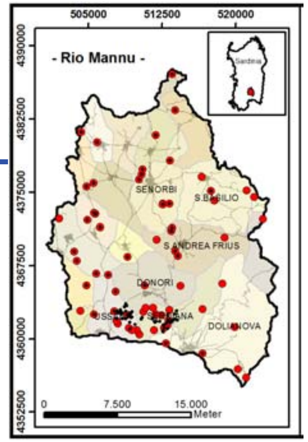
Conventional data (soil, DEM, vegetation, water availability and consumption etc.)

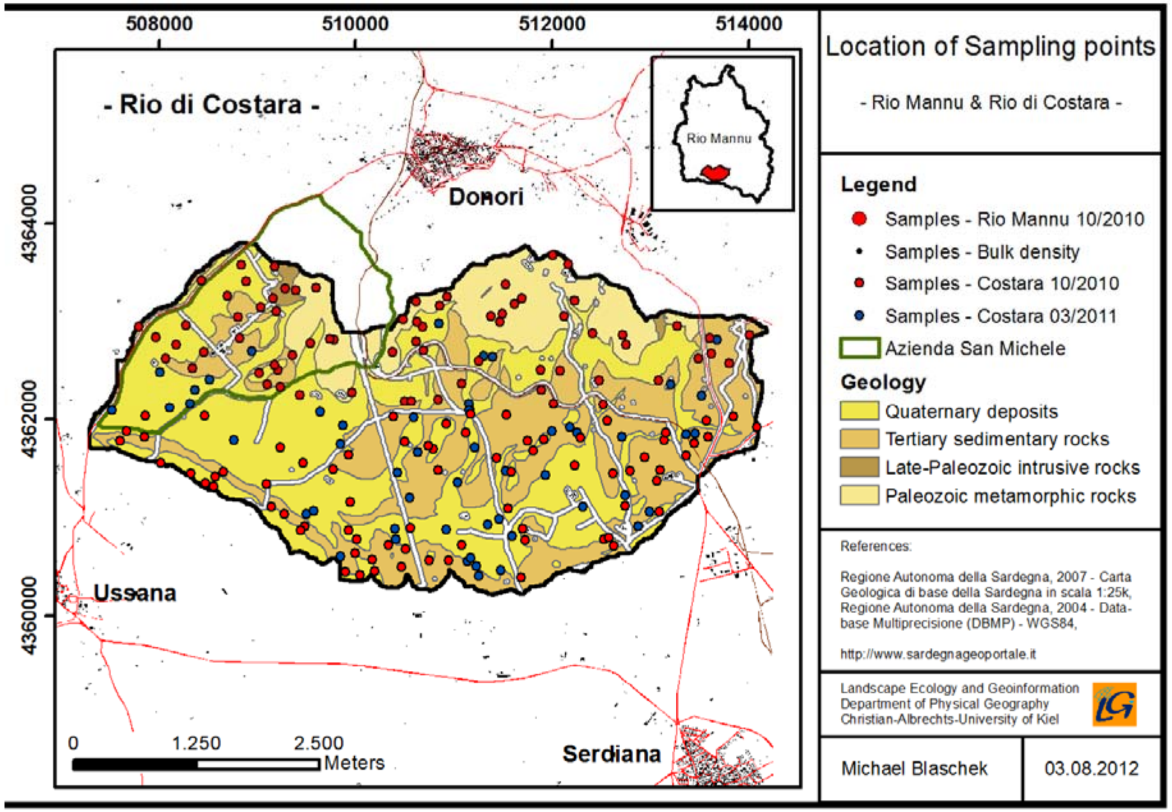
Remote Sensing

Parameter retrieval & Data assimilation

Geophysical Data Acquisition

e.g.
soil sampling and geostatistical analysis for soil texture regionalization





CLIMB – geophysical data acquisition

Study Site Characterization

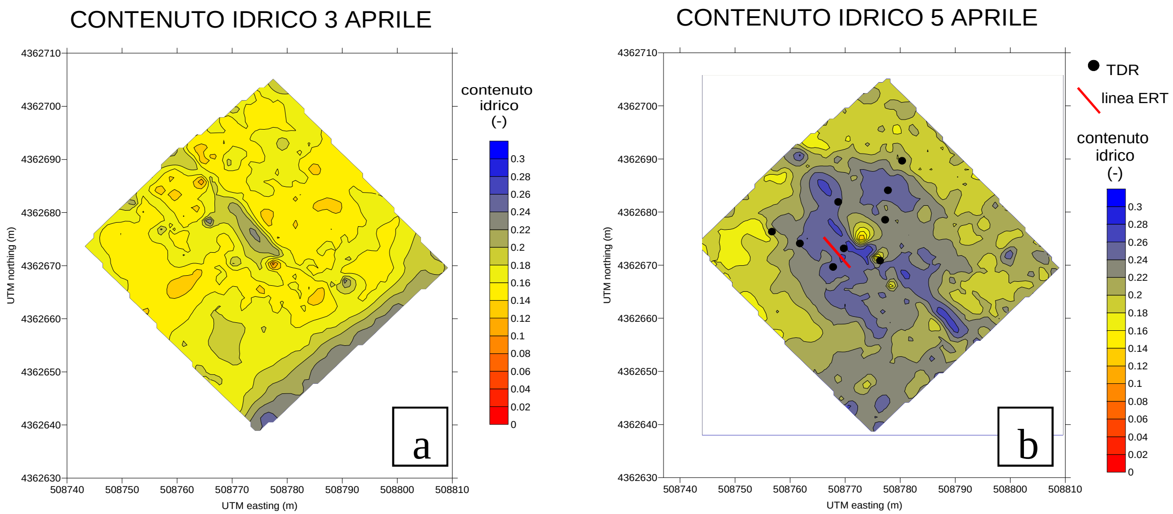
Conventional data (soil, DEM, vegetation, water availability and consumption etc.)

Remote Sensing

Parameter retrieval & Data assimilation

Geophysical Data Acquisition

e.g. hydrogeophysical measurements for the regionalization of soil hydraulic properties



CLIMB – remote sensing

Study Site Characterization

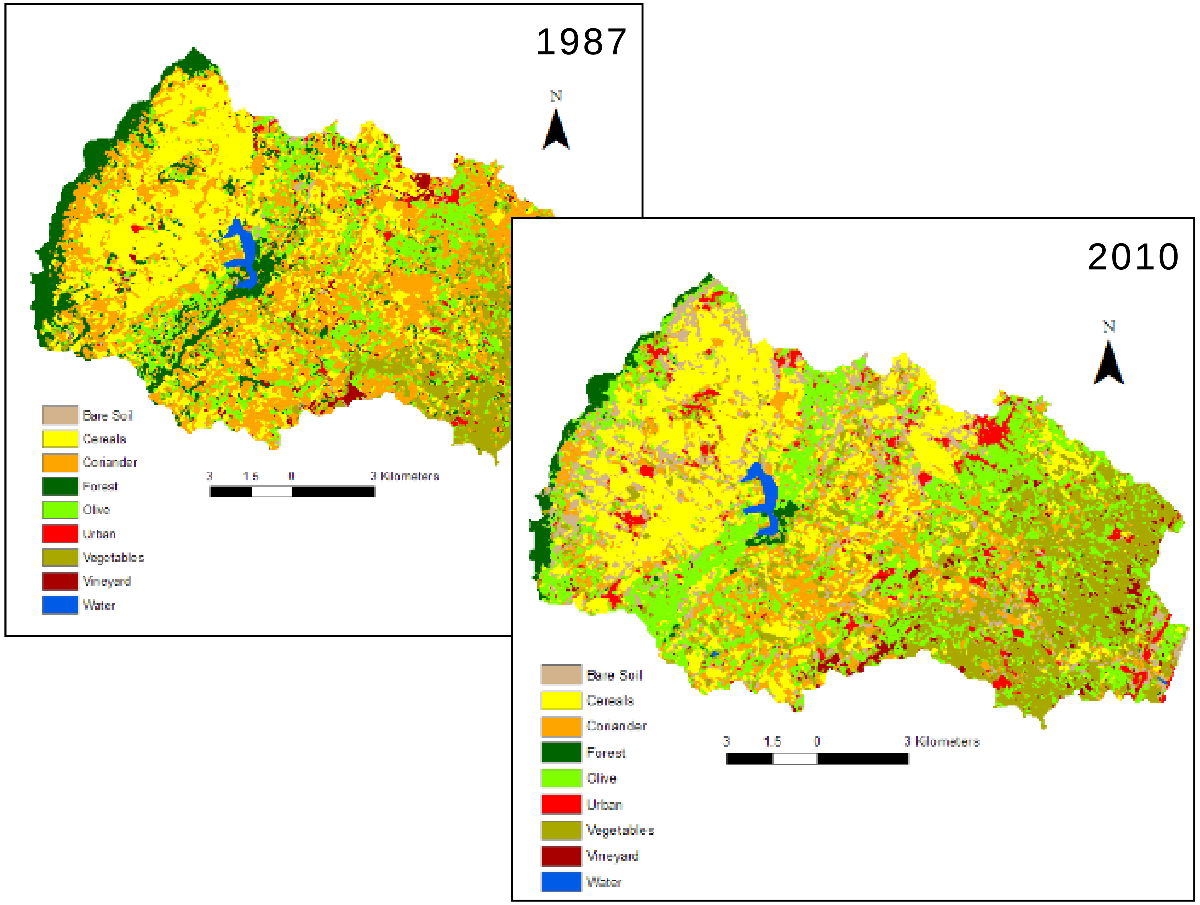
Conventional data (soil, DEM, vegetation, water availability and consumption etc.)

Remote Sensing

Parameter retrieval & Data assimilation

Geophysical Data Acquisition

e.g.
Multitemporal maps of land use for the study sites (e.g. Chiba, Tunisia)



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CLIMB – remote sensing

Study Site Characterization

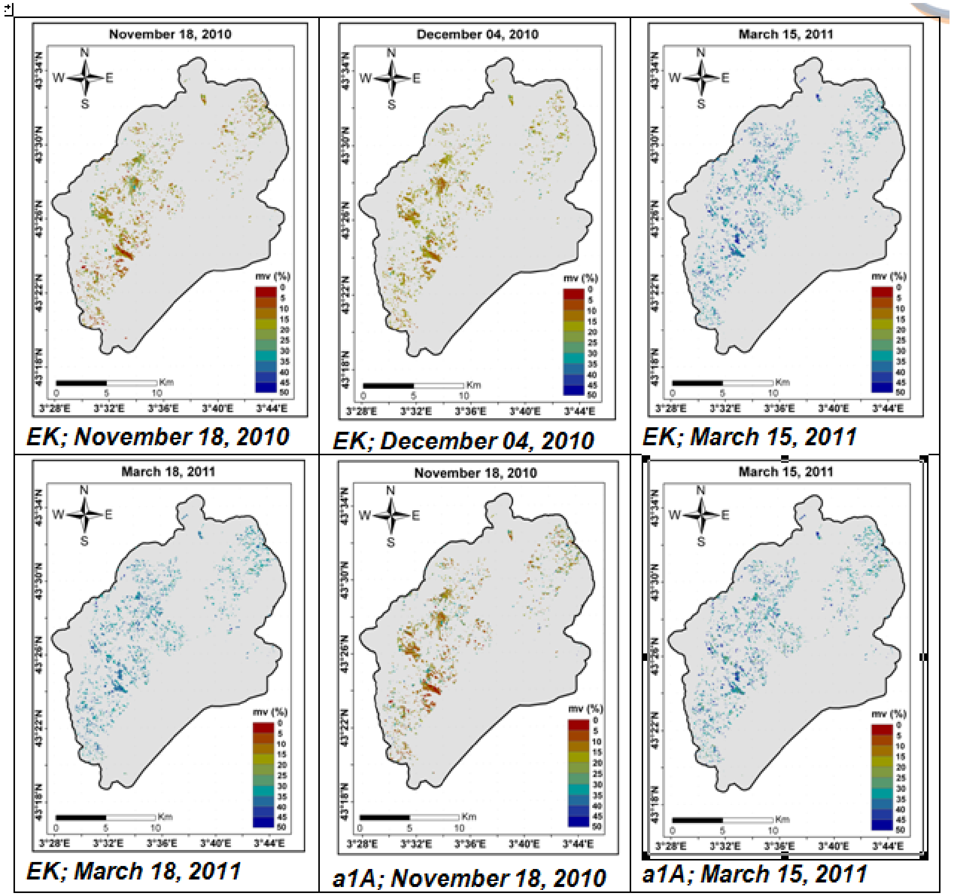
Conventional data (soil, DEM, vegetation, water availability and consumption etc.)

Remote Sensing

Parameter retrieval & Data assimilation

Geophysical Data Acquisition

e.g.
Multitemporal soil moisture from radar remote sensing (e.g. Thau, France)



CLIMB – remote sensing

Study Site Characterization

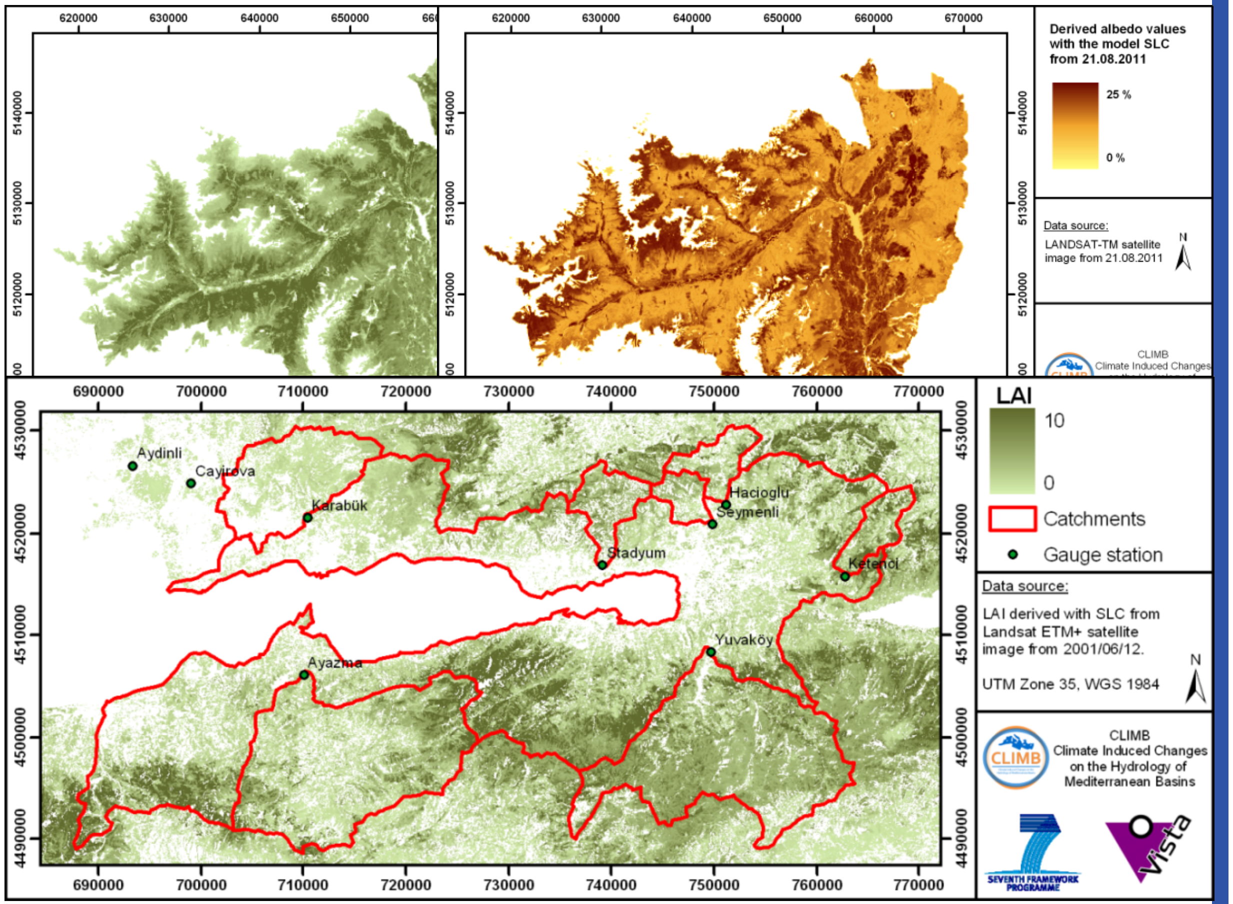
Conventional data (soil, DEM, vegetation, water availability and consumption etc.)

Remote Sensing

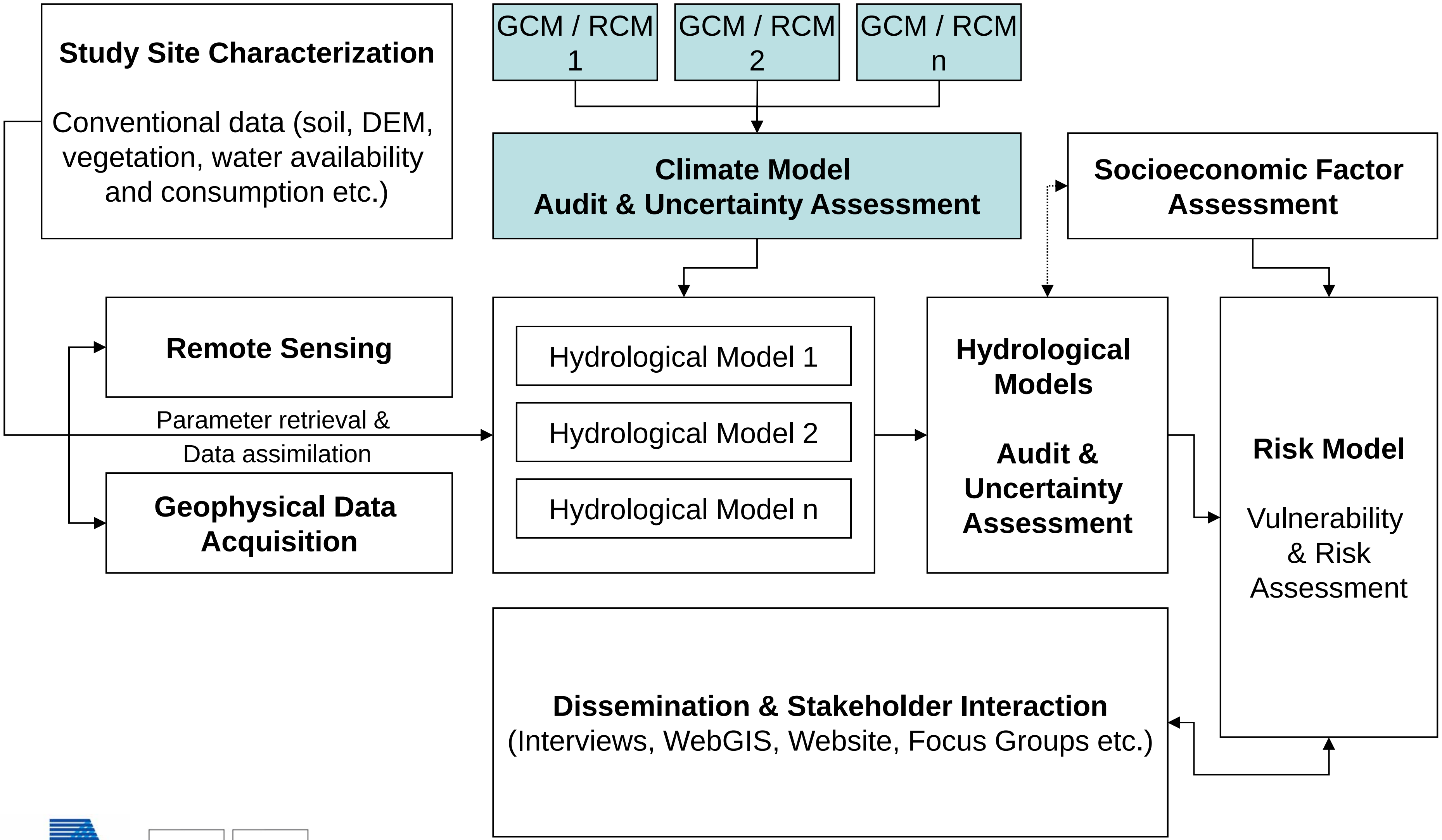
Parameter retrieval & Data assimilation

Geophysical Data Acquisition

e.g.
Retrieval of spatially distributed vegetation parameters (e.g. Noce, Italy & Kocaeli, Turkey)



CLIMB – Structure & Workflow

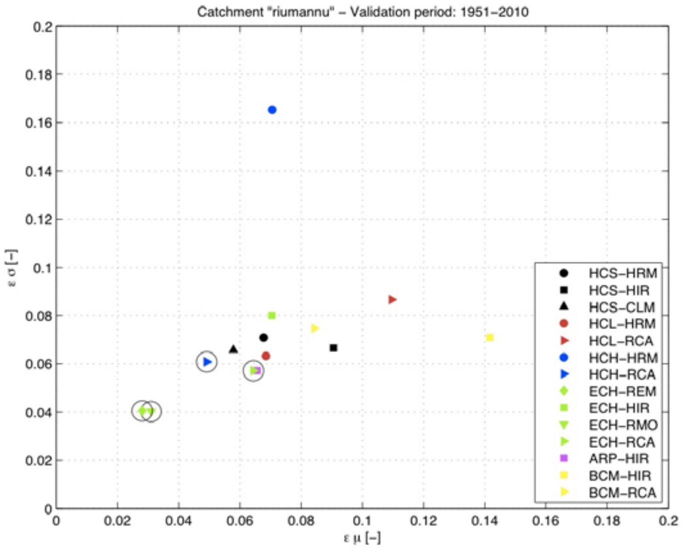


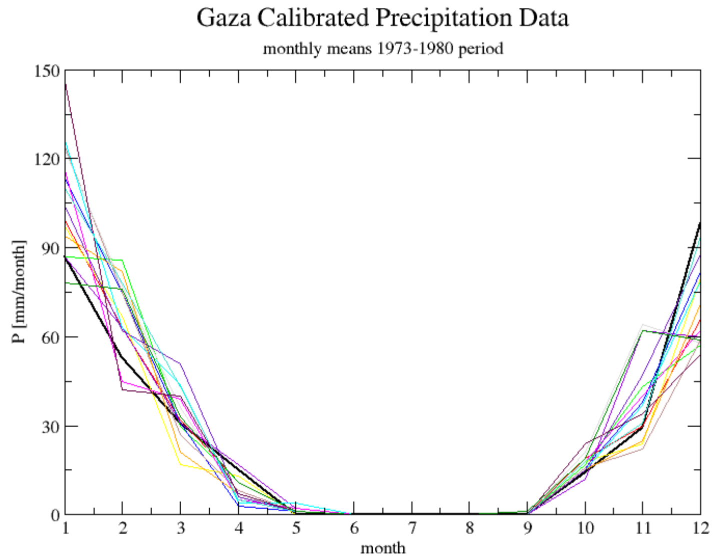
CMs Auditing & Downscaling – main steps

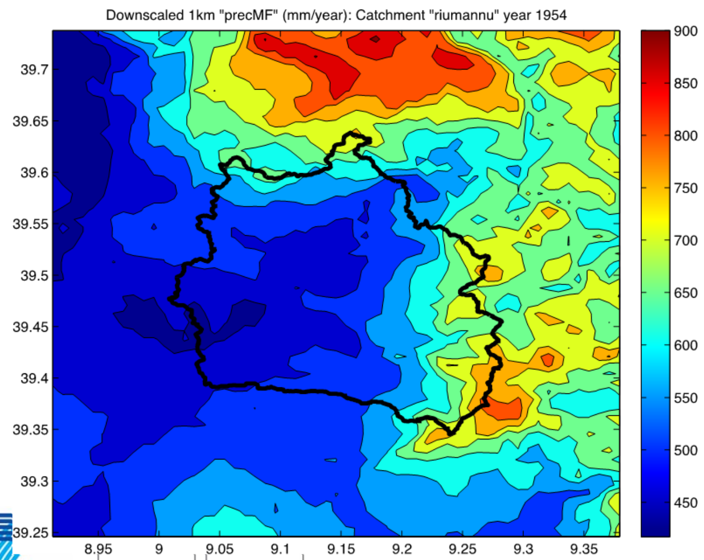
The objectives of "Climate Models (CMs) Auditing and Downscaling" were pursued in five (5) steps:

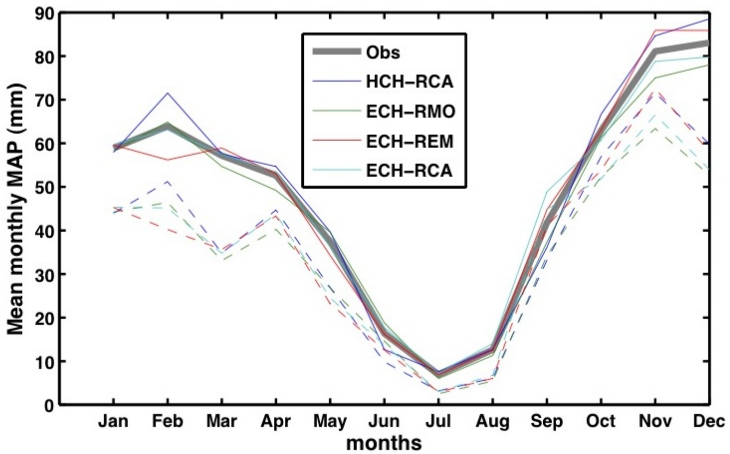
1. Climate Model selection (i.e. use a common subset of 4 regional climate models for hydrological simulations in all target basins)
2. Large-scale bias correction (RCM scales, ~ 25 km)
3. Catchment-scale bias correction (250-3500 km^2)
4. Small-scale interpolation and downscaling (i.e. provide high resolution input for hydrological models, about 1 km)
5. Overall uncertainty of climate forcing (i.e. evaluate the uncertainties related to the climatic component)

CMs Auditing & Downscaling – main steps









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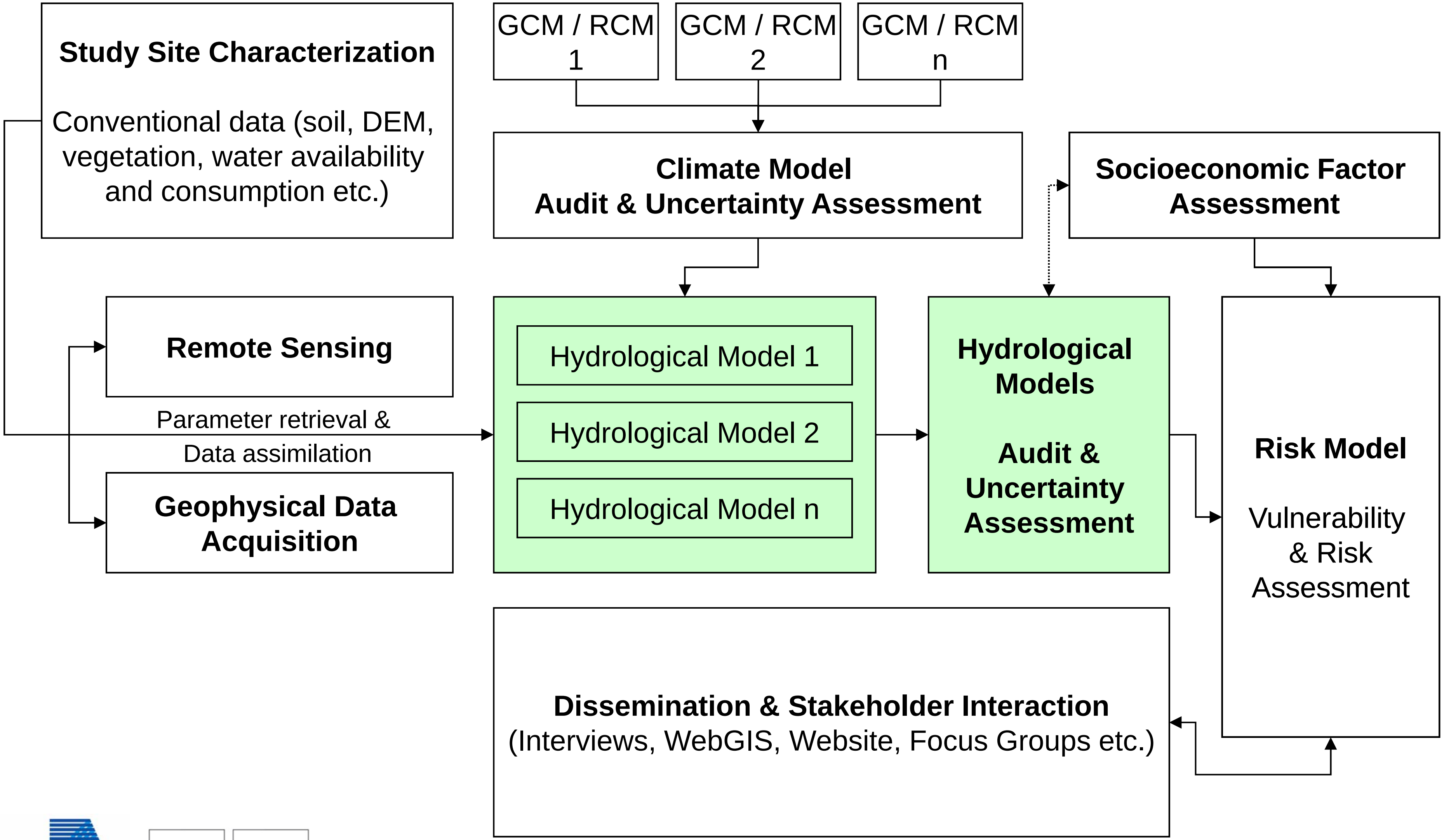
CLIMB – Structure & Workflow



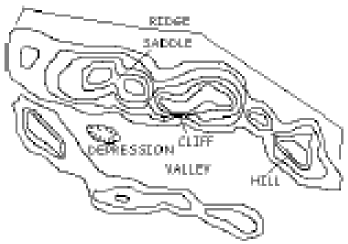
Hydrological modeling – a multi-model approach

(Perra et al. @EGU 2017)

CATHY model | SWAT model | TOPKAPI model | tRIBS model | WASIM model

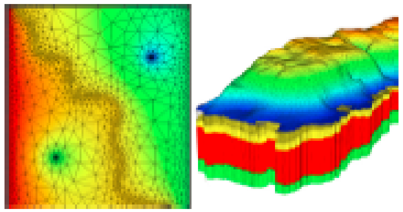
The 5 hydrologic models differ in their representation of

Terrain features



Physical processes

Numerical complexity

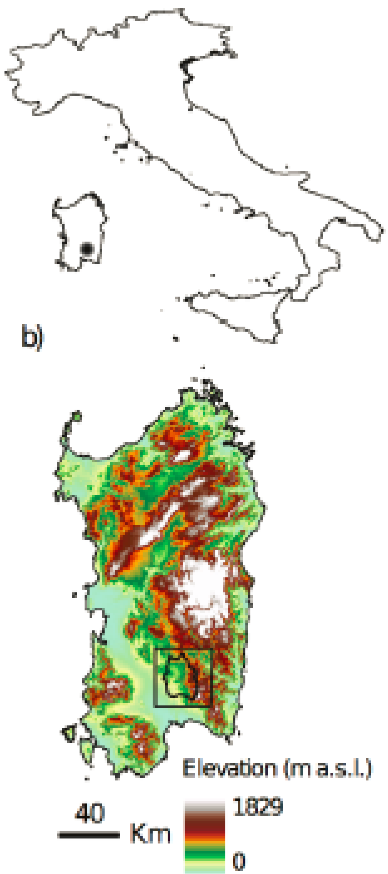


Hydrological modeling – a multi-model approach

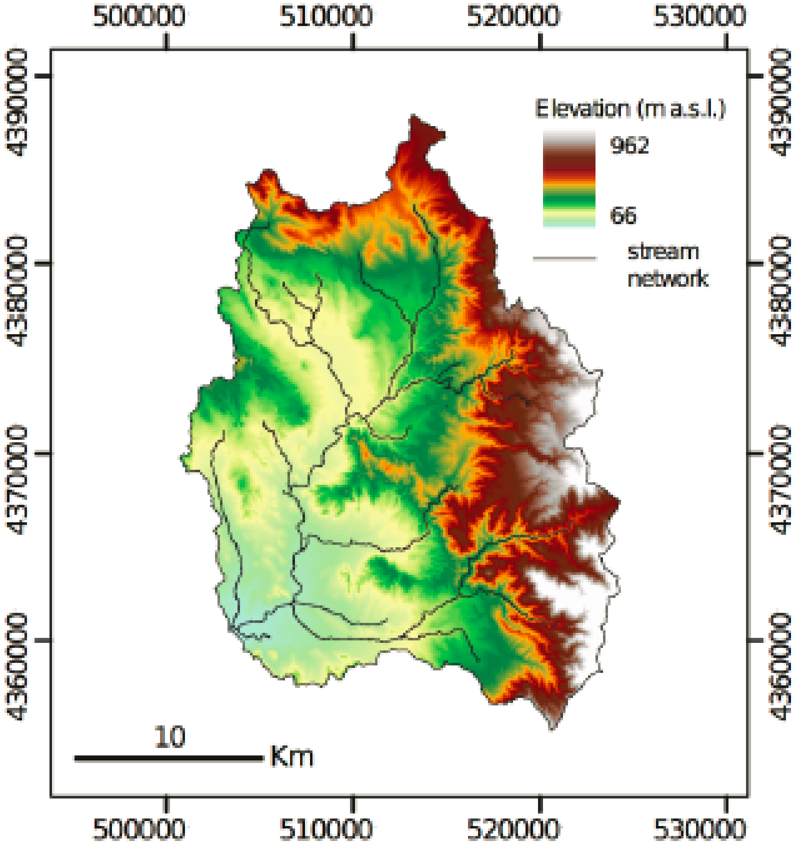
(Perra et al. @EGU 2017)

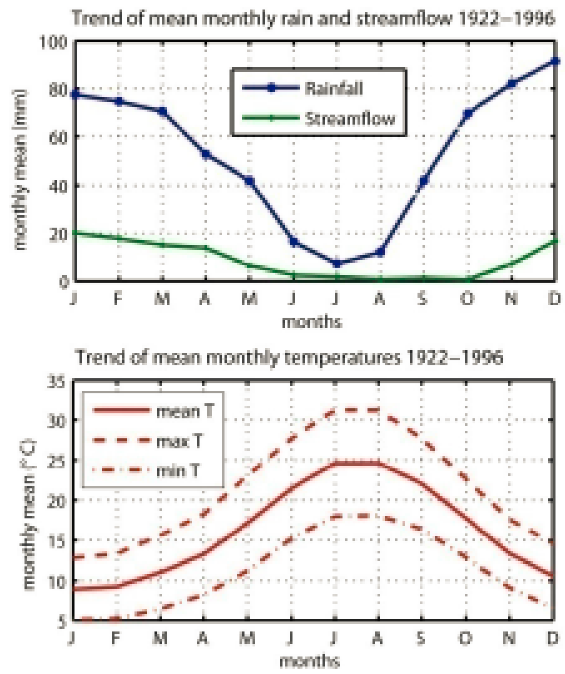
a)

b)



c)





Drainage Area [Km²]	Mean Slope [%]	Mean monthly Temperature [°C]	Mean annual Precipitation [mm]
473	17	9 (winter)- 25 (summer)	600

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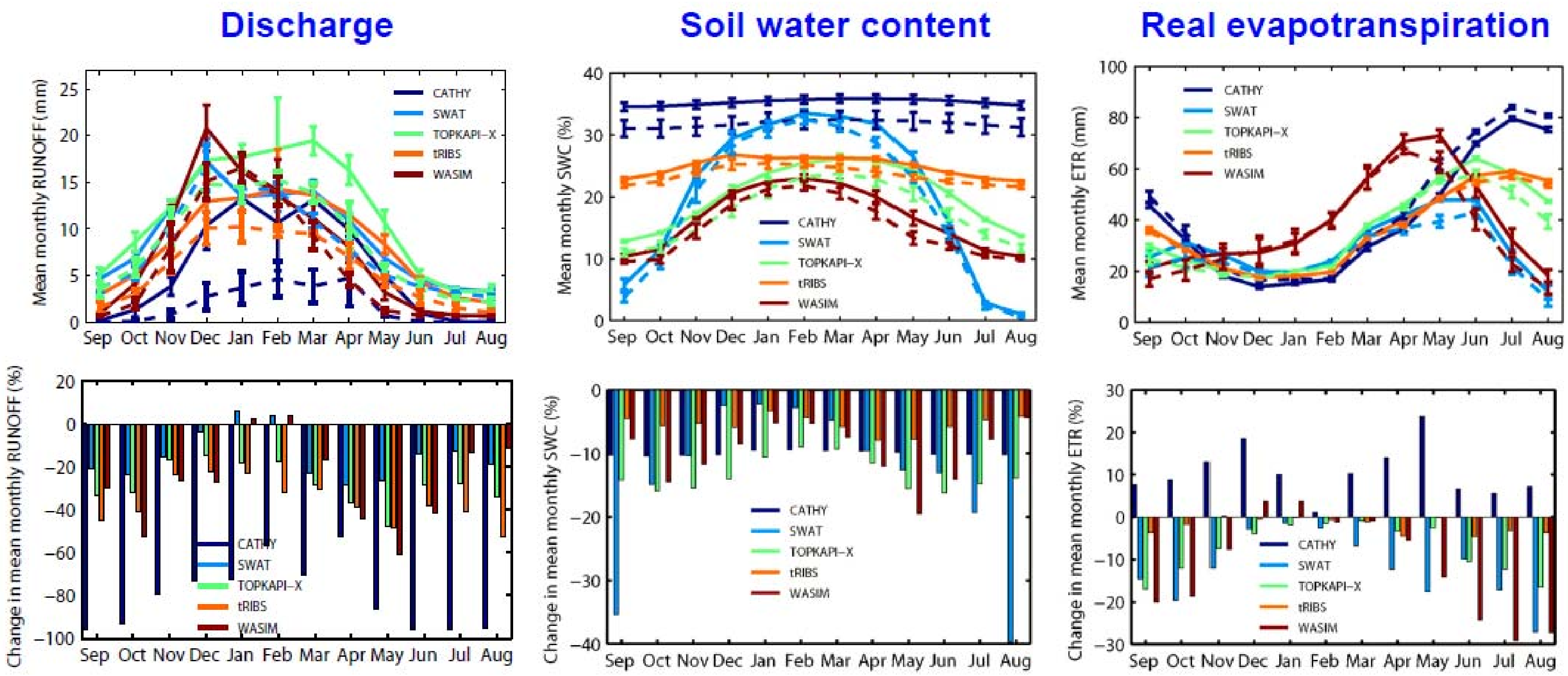
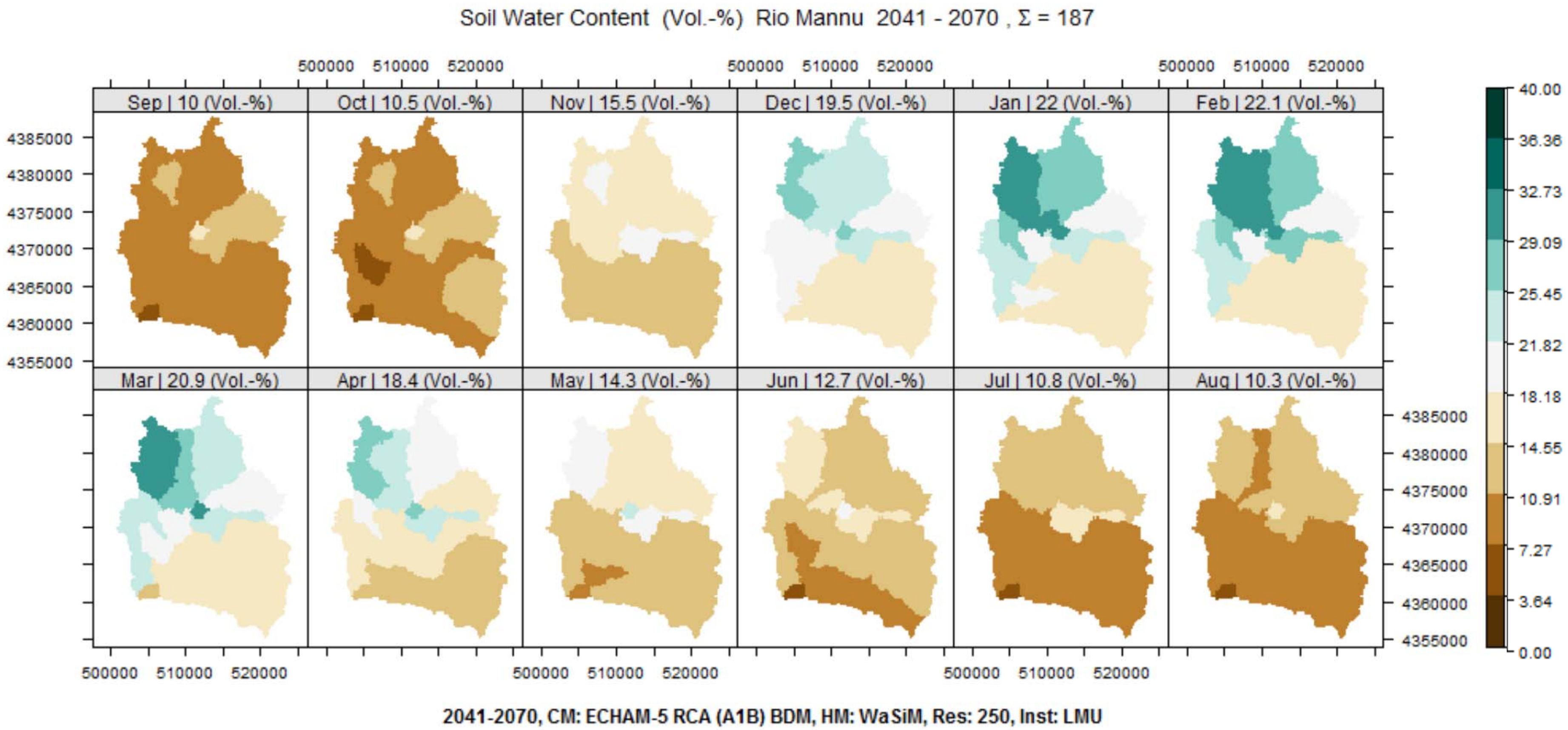
Hydrological modeling – a multi-model approach

(Perra et al. @EGU 2017)



The 5 hydrologic models present larger variations considering the monthly scale as compared to the annual scale.

Hydrological modeling – Rio Mannu: soil water content



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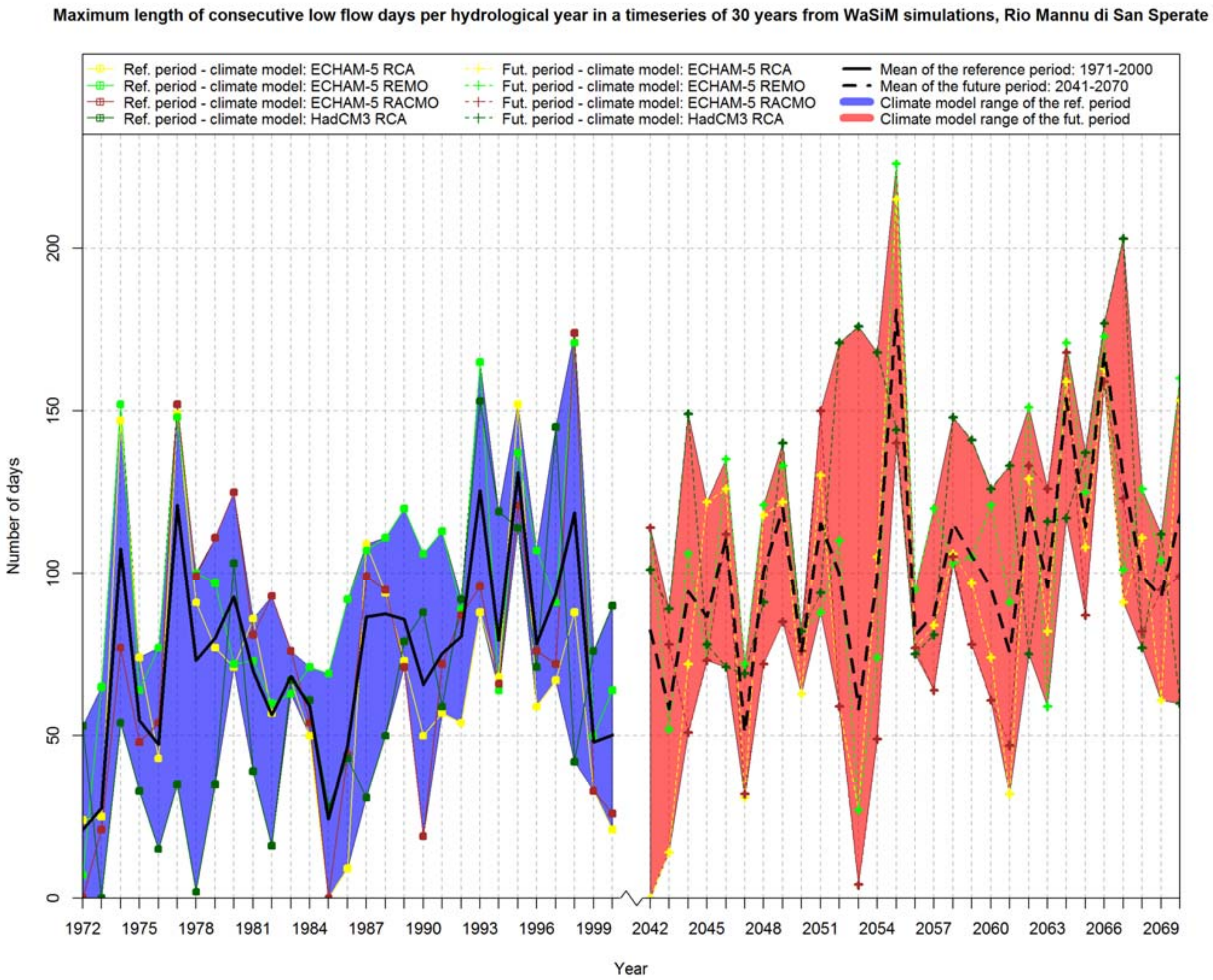
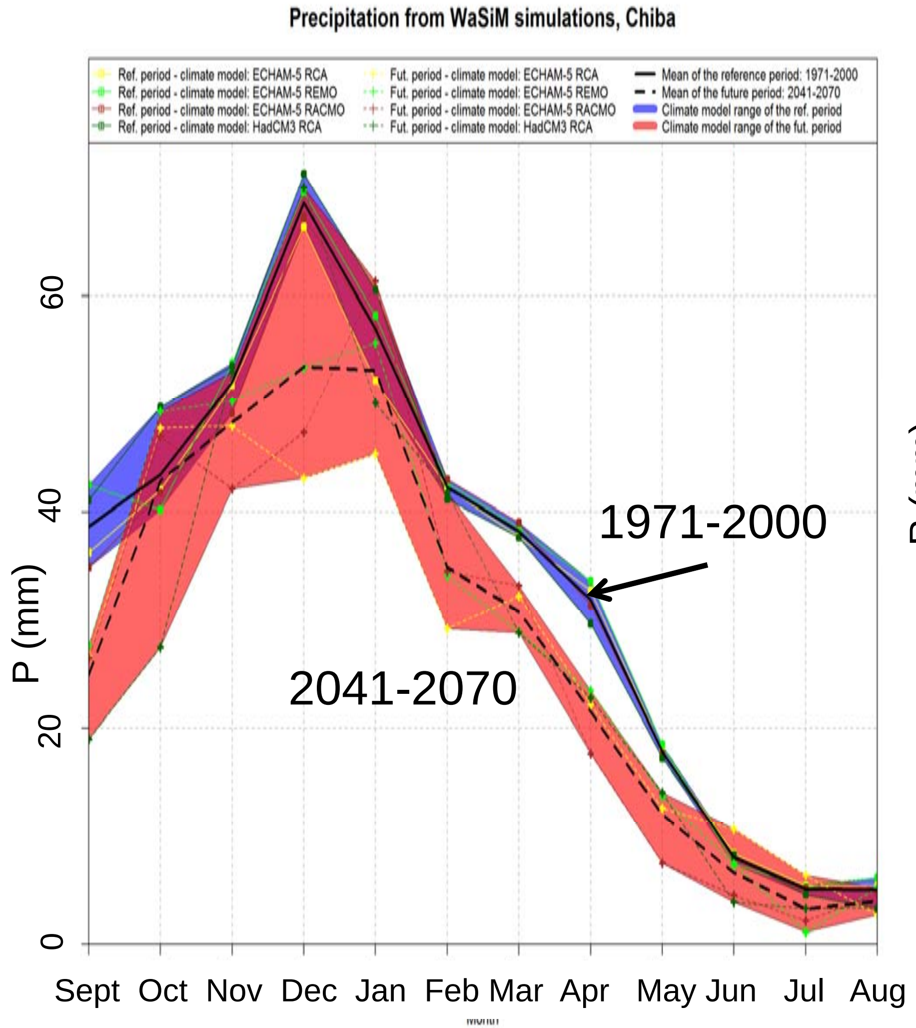
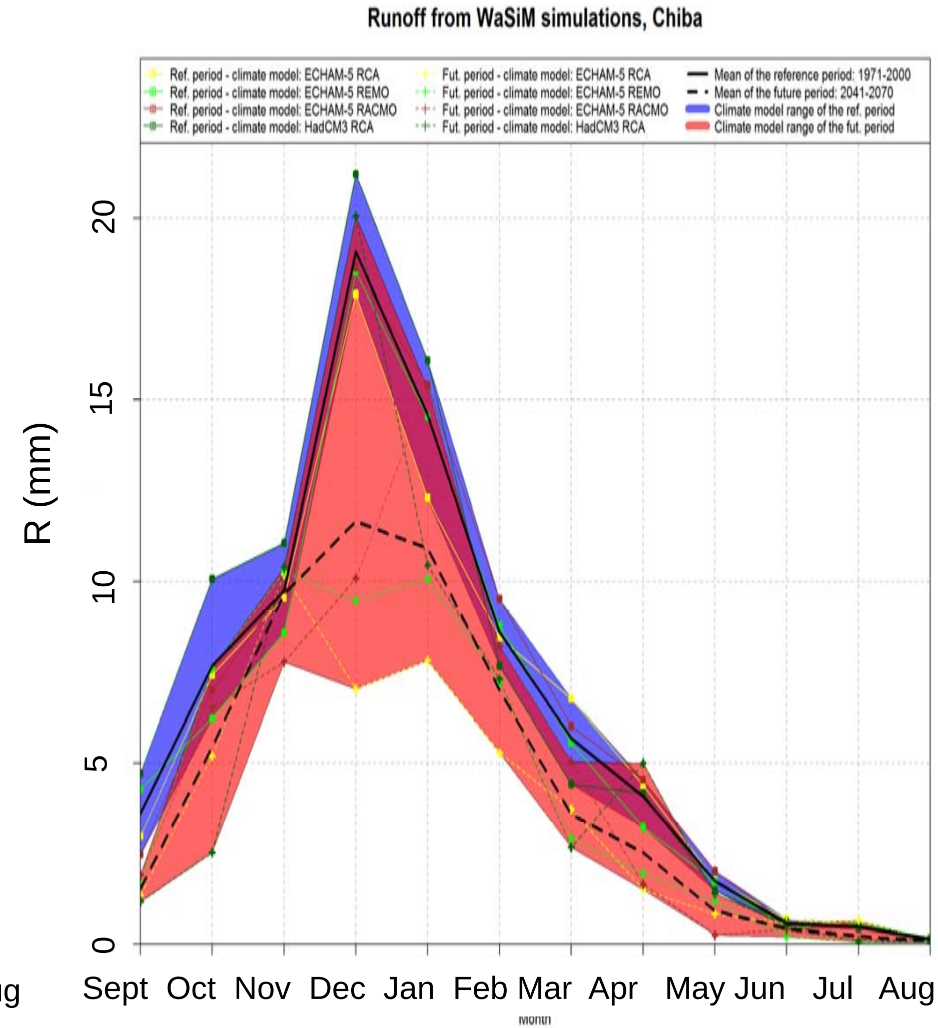
Hydrological modeling – Rio Mannu: Max number of consecutive low flow days

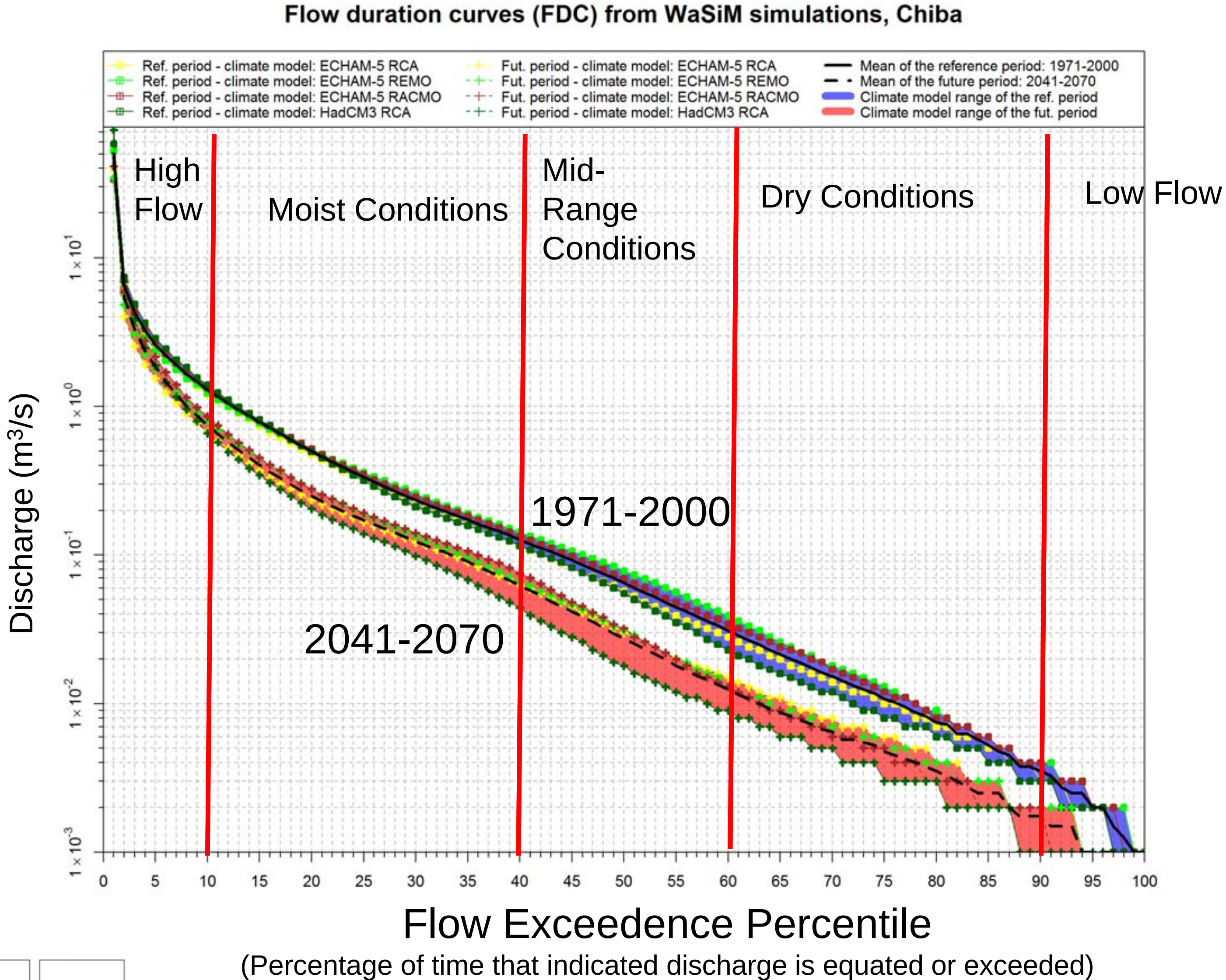


Hydrological modeling – Some examples: Chiba

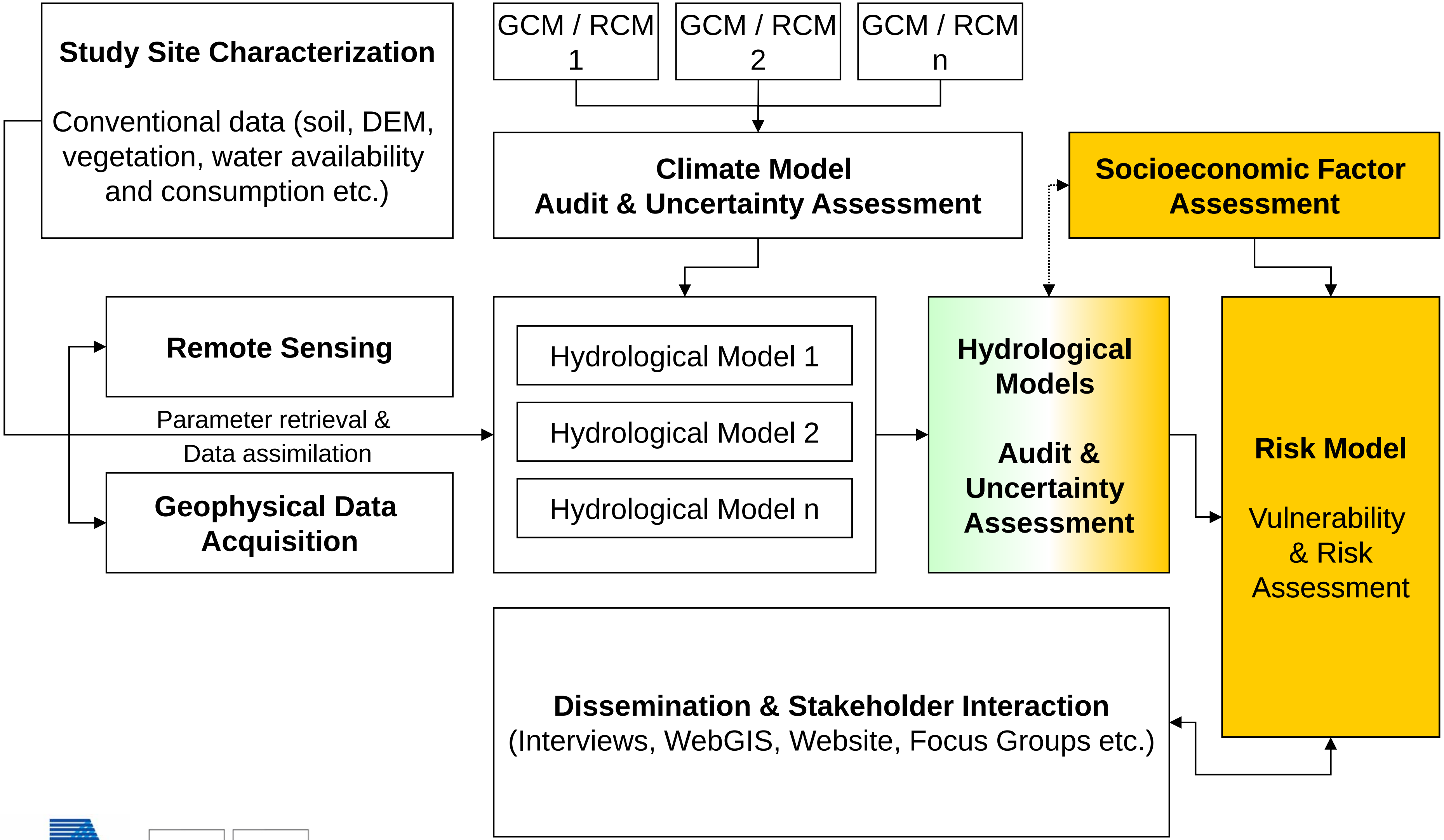




Hydrological modeling – Chiba: Flow duration curve

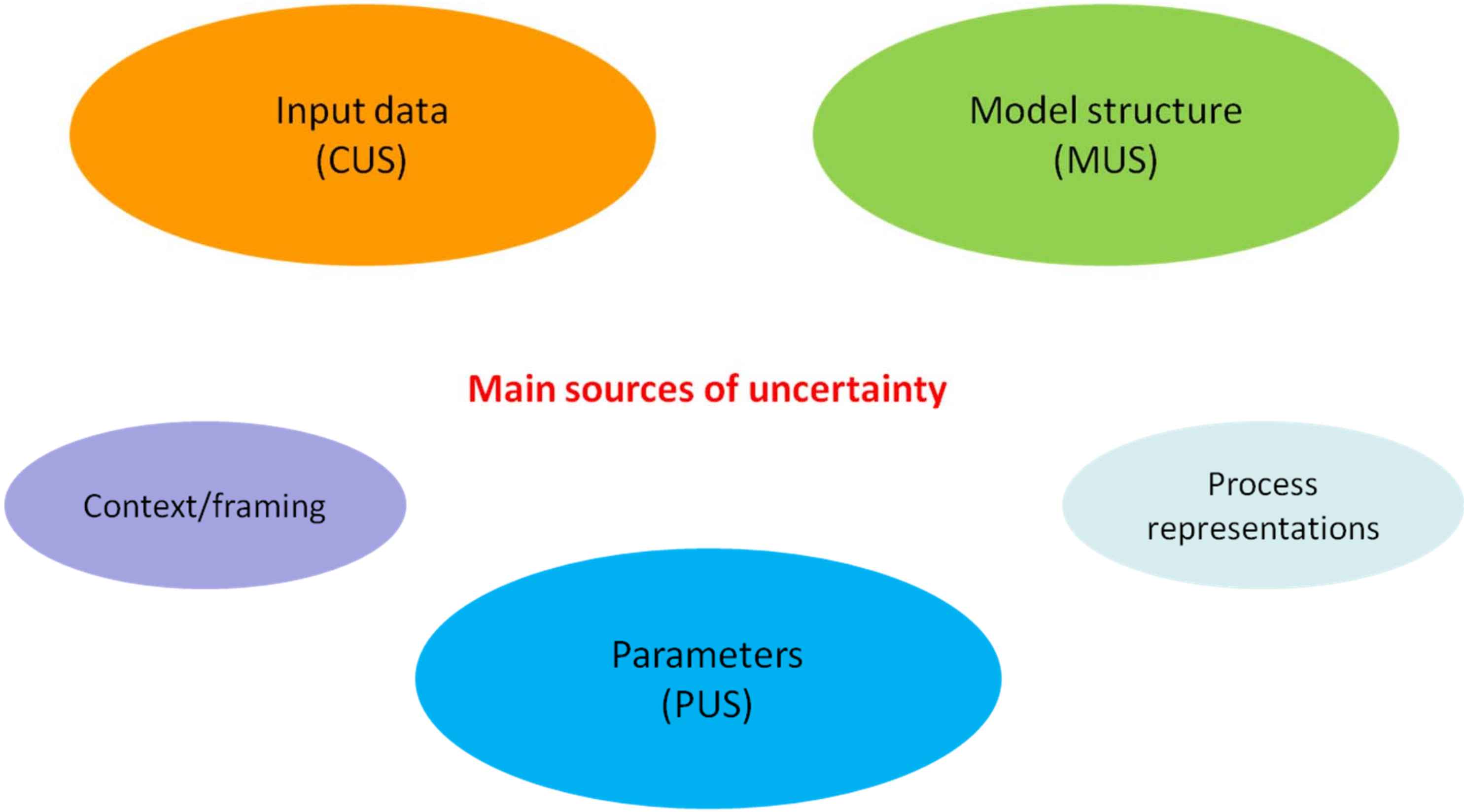


CLIMB – Structure & Workflow

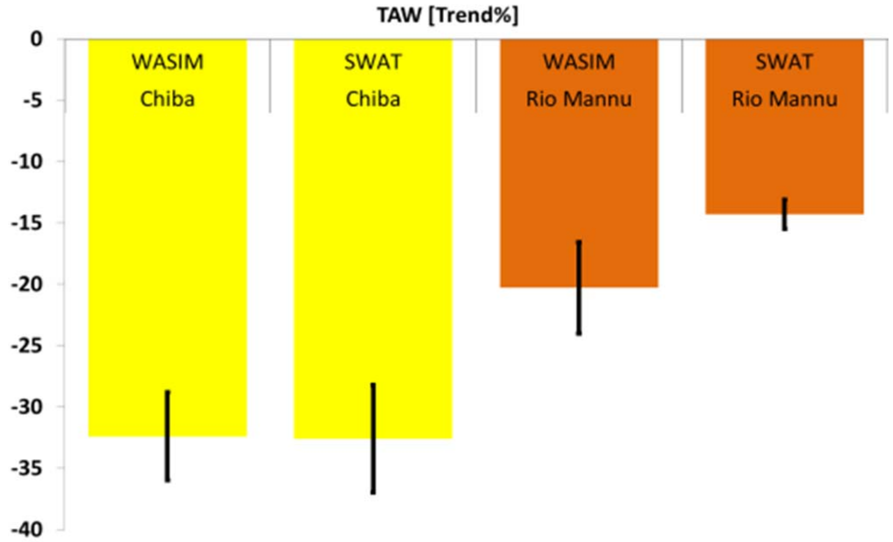


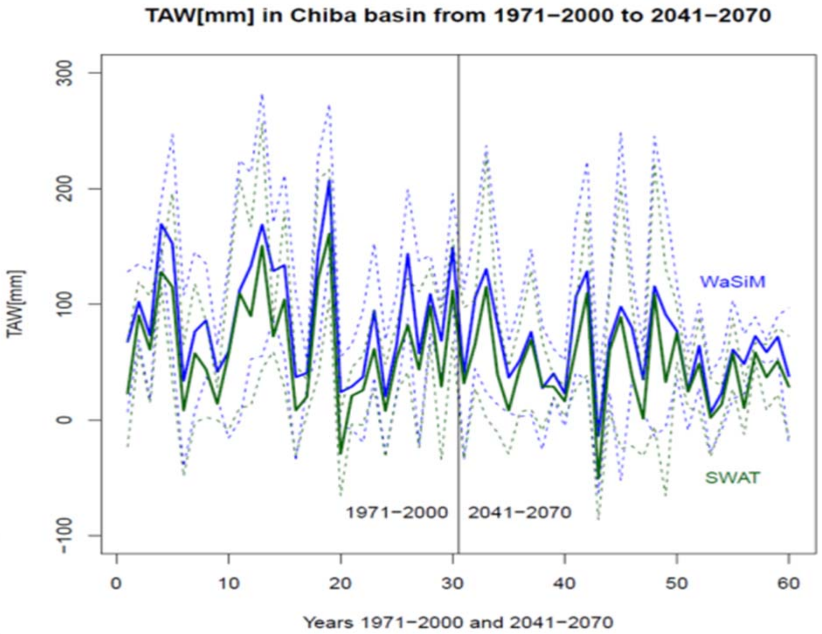
Uncertainty assessment

Handling of Uncertainty in science is central to its support of sound policy making” (Smith & Stern, 2011)



Uncertainty assessment - 1





FINDINGS AND IMPLICATION:

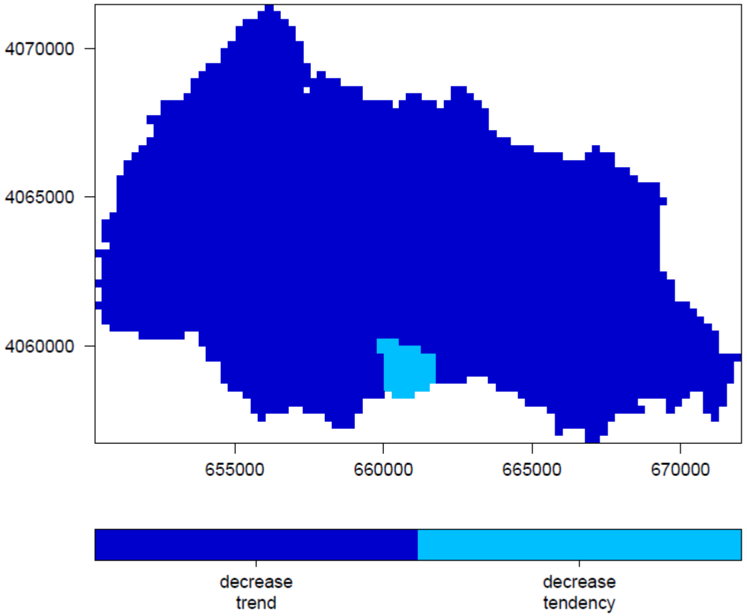
Both sites:

- TAW (-15 to -33%), reduces significantly in FUT
- CUS rated low (Chiba) to medium (Rio Mannu)
- Negative trend confirmed
- High confidence on trend

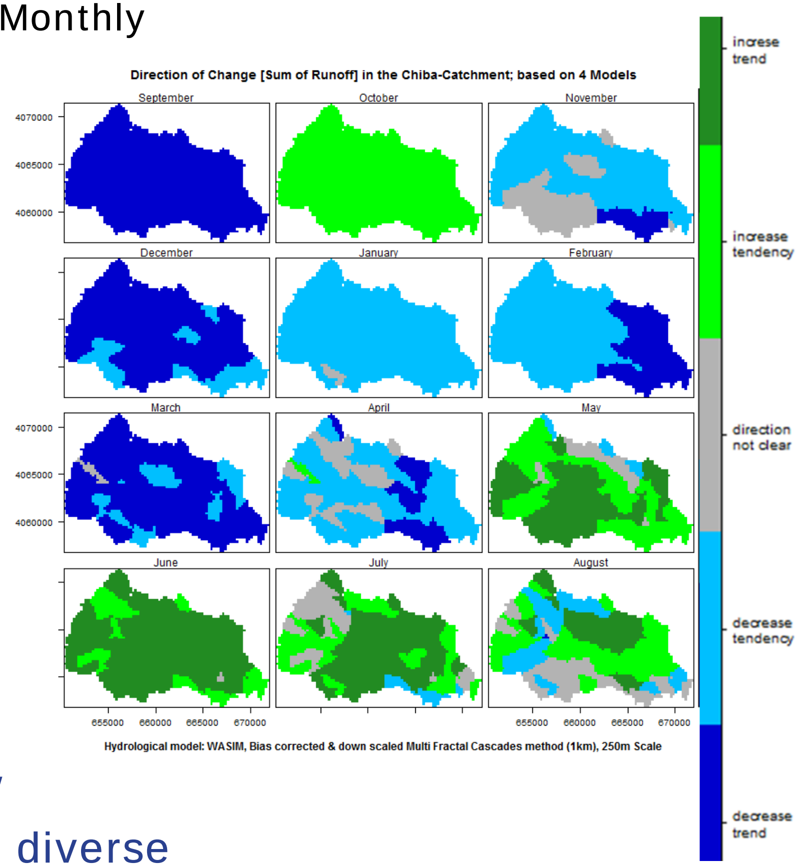
Uncertainty assessment - 2

Certainty Map of key indicators (here TAW)

Annual



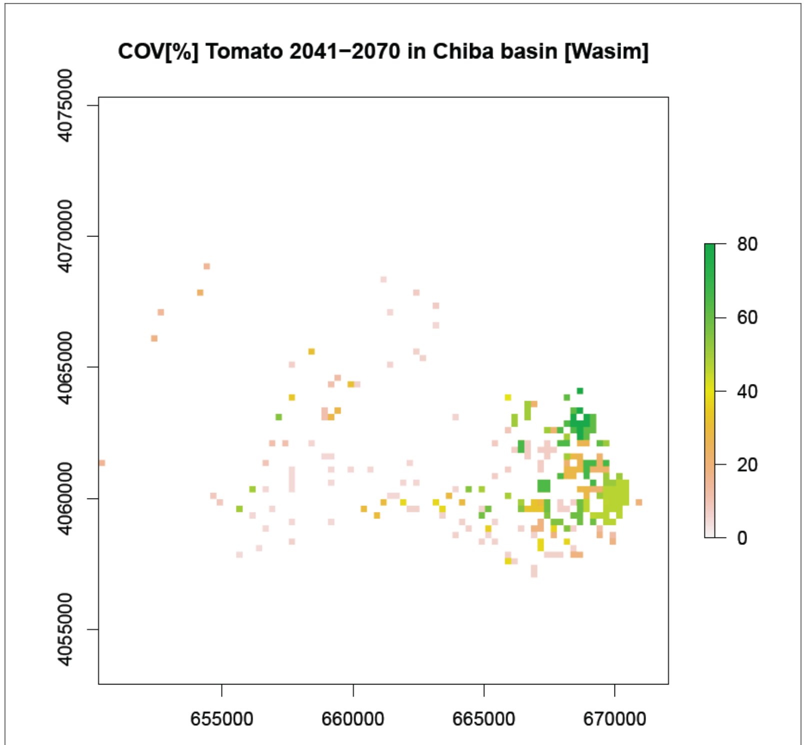
Monthly



- Decrease trend of long-term annual TAW
- Monthly-based degree of certainty, more diverse
- Hotspot areas can be clearly identified

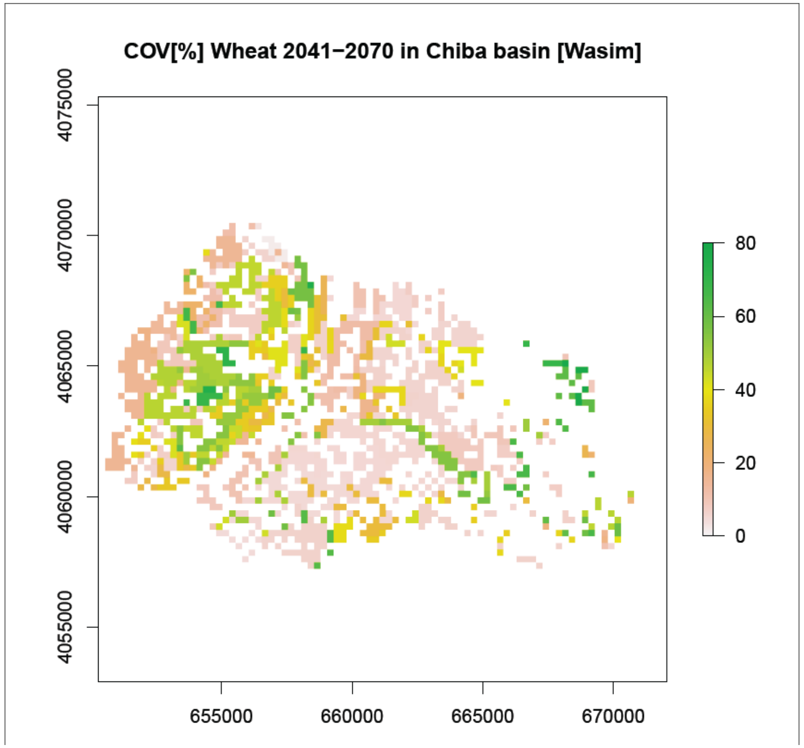
Uncertainty assessment - 3

Spatial representation of Uncertainty (COV in %): Chiba



COV[%] 1971-2000: 15.8 +/- 11.2

COV[%] 2041-2070: 32.5 +/- 24.2



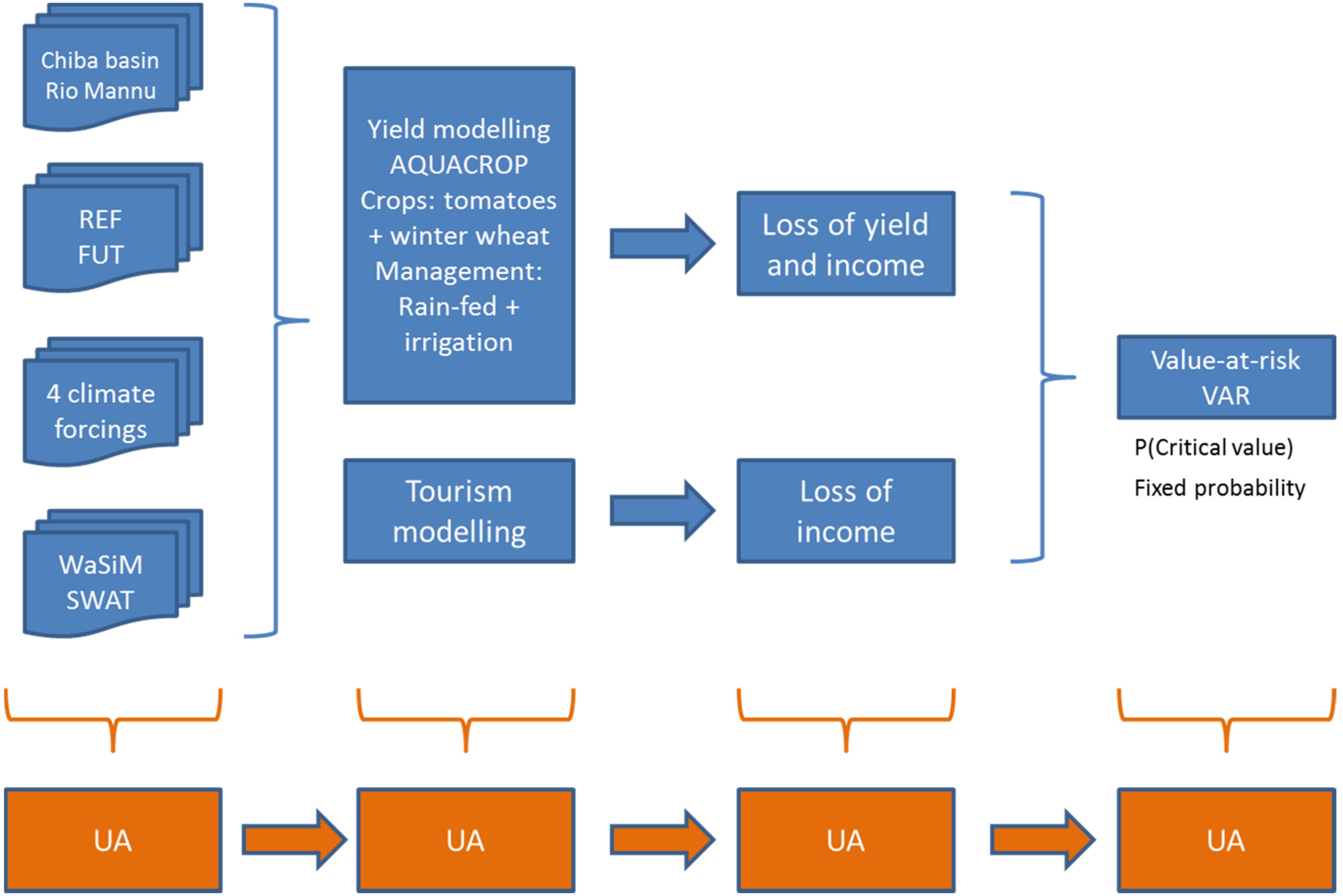
COV[%] 1971-2000: 13.4 +/- 11.2

COV[%] 2041-2070: 25.1 +/- 21.3

Spatial UA:

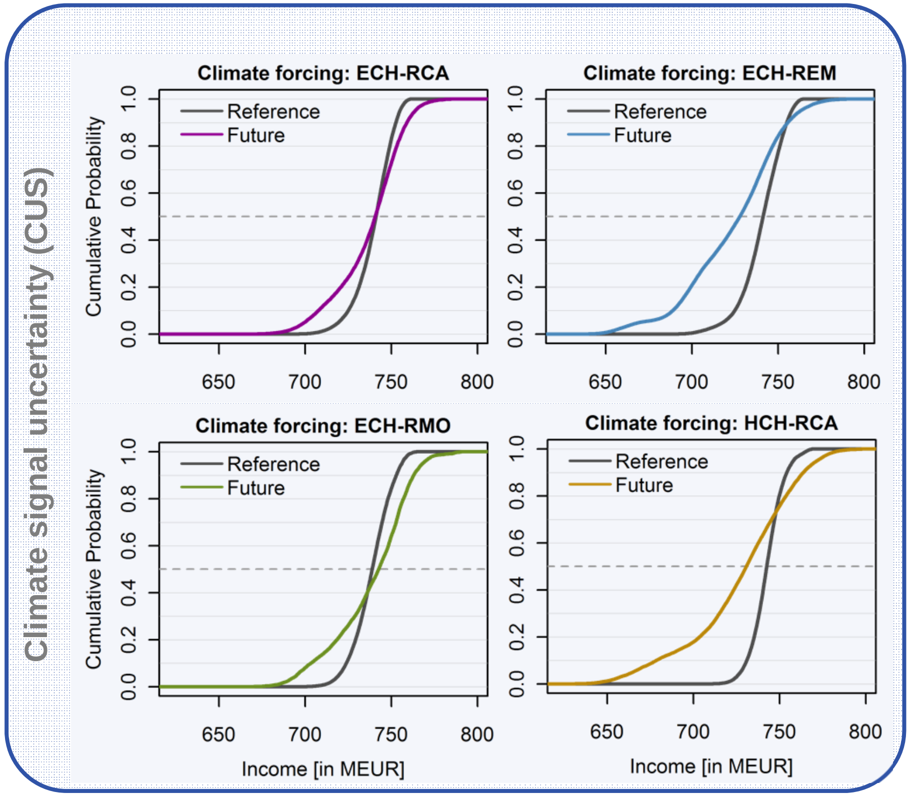
- COV doubles in FUT
- Clay loam soils with highest COV

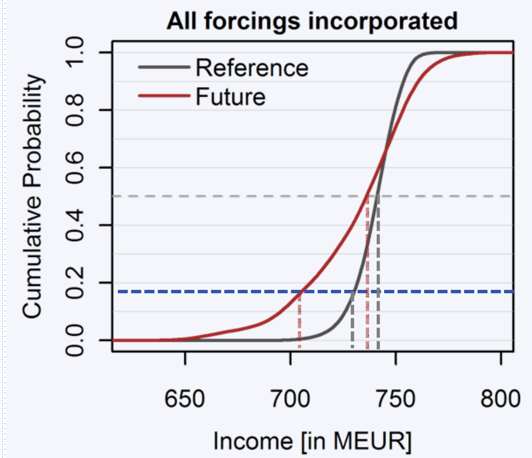
Integrating Uncertainty and Risk



Tourism – Value at Risk

Distribution of income generated by tourism in Sardinia (Jun.-Aug.) as a function of year-to-year weather variability





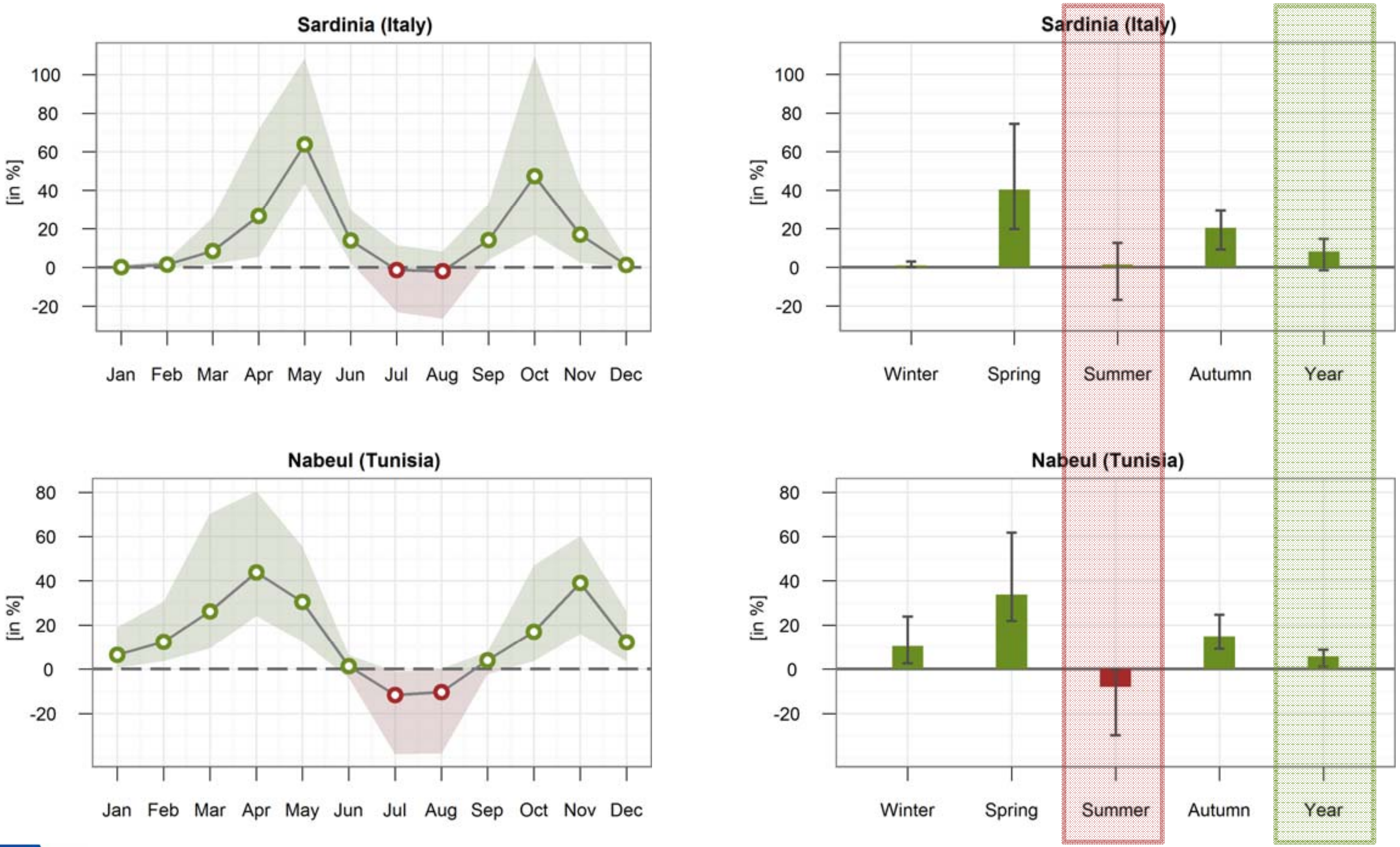
VaR(0.9):

	MEUR	%
REF	11.6	1.6
FUT	52.3	7.2
FUT (+Trend)	64.2	8.6

Income estimation: overnight stays * average expenditure per overnight stay

Tourism – potential CC-impacts

Expected change in overnight stays (in %) due to a change from reference (1971-2000) to future (2041-2070) climatic conditions



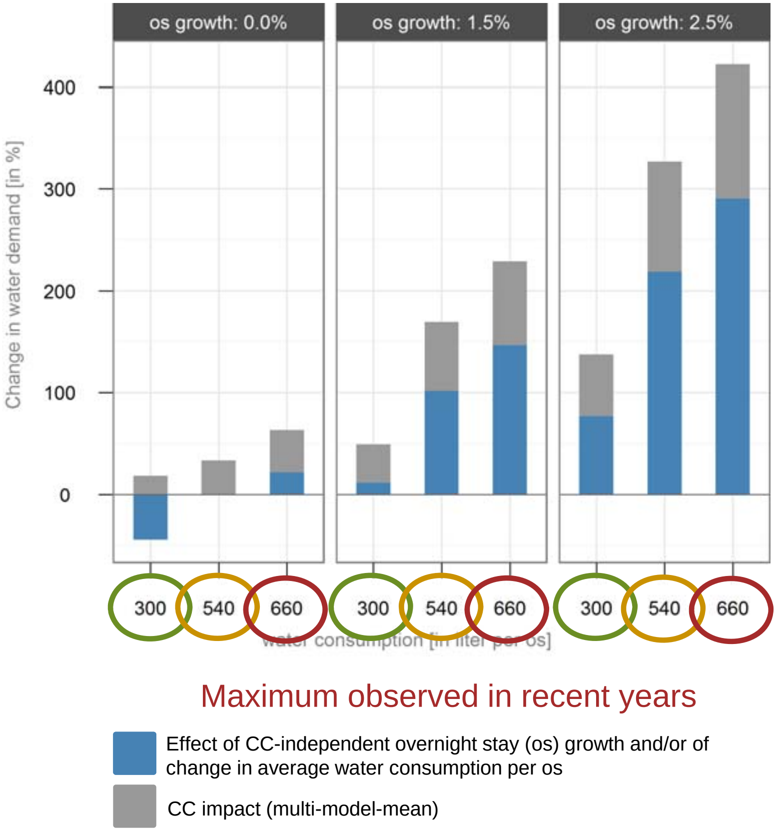
Potential losses in summer …

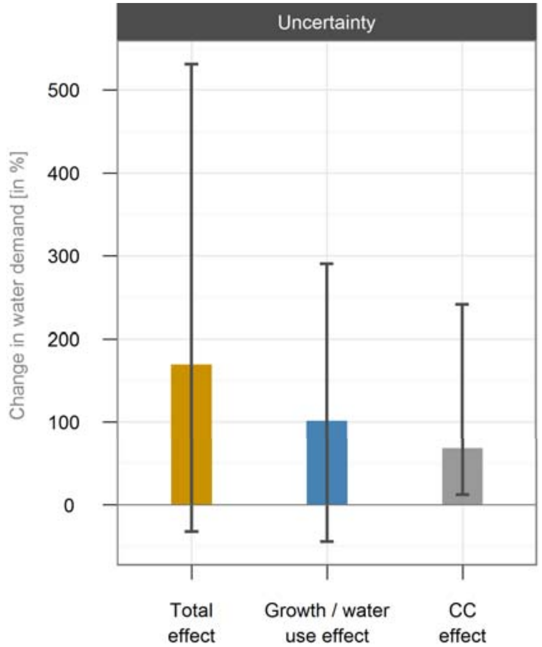
… BUT …

… tendentially positive annual net impacts.

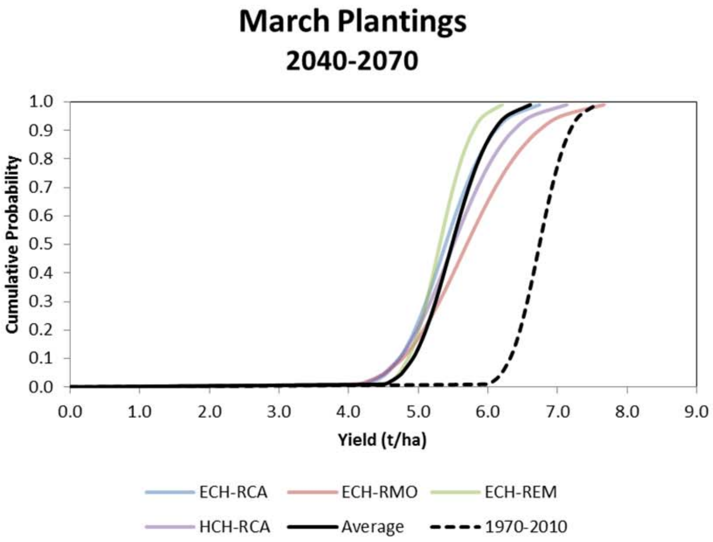
Tourism – future water demand scenarios

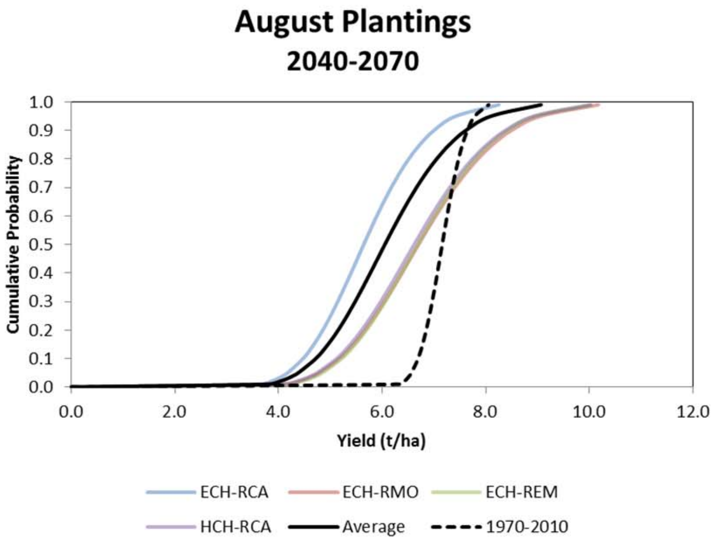
Change in future water demand (2041-2070) of tourism (Nabeul) during **spring** for different growth and water use scenarios

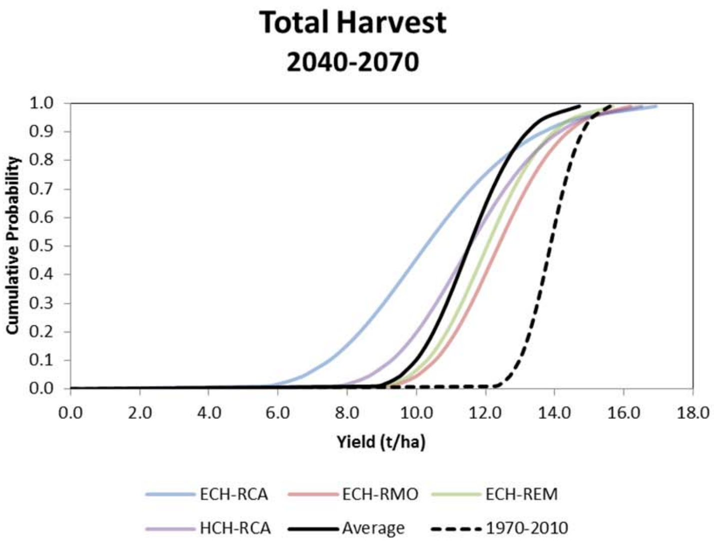




Agriculture - Tomatoes (same water usage as current)

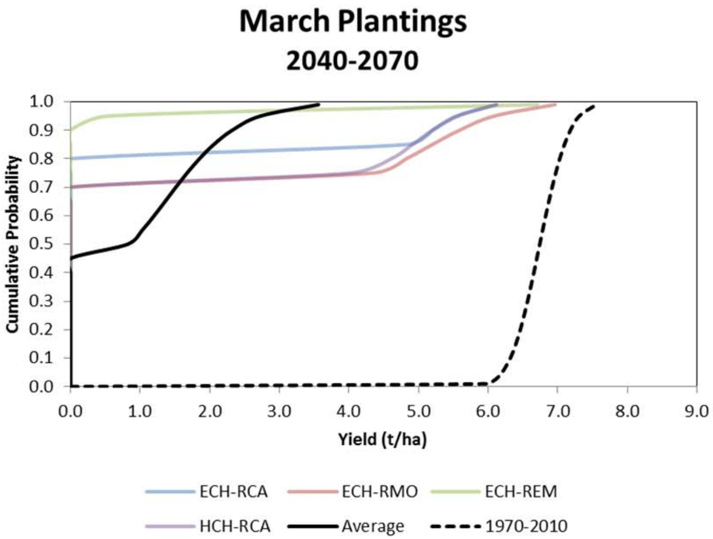


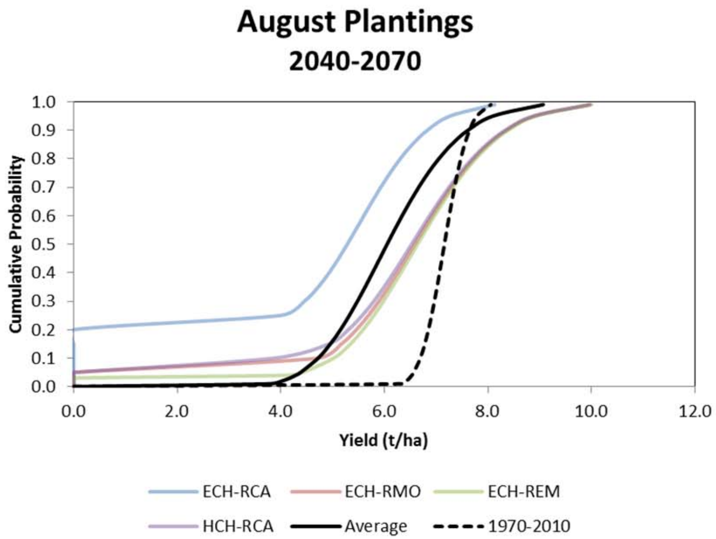


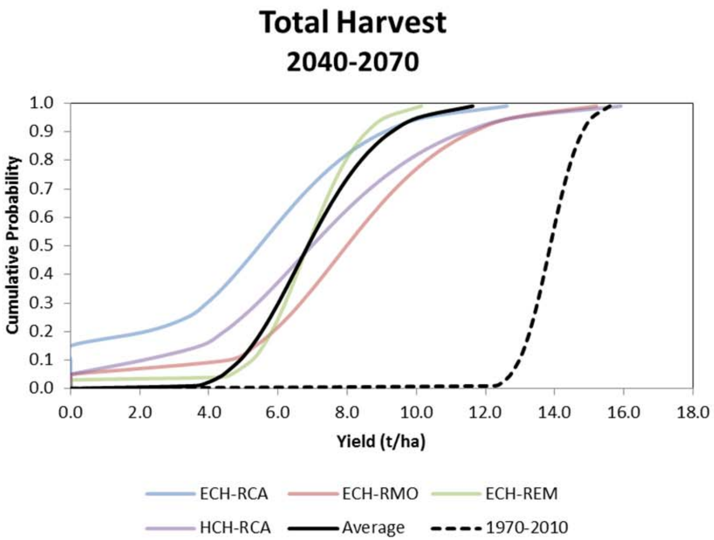


- March plantings
  - Yield ↓ 17%
- August planting
  - Yield ↓ 17%
- Results are soil dependent
  - Sandy clay loam strongly affected
  - Sandy loams least affected

Agriculture - Tomatoes (10% less water usage as current)







March plantings
- Yield ↓ 86%
- Crop failure 45%

August planting
- Yield ↓ 17%

Total harvest: 50% less yield

Agriculture – Adaptation recommendations

Agricultural risk can be minimised through adaptation

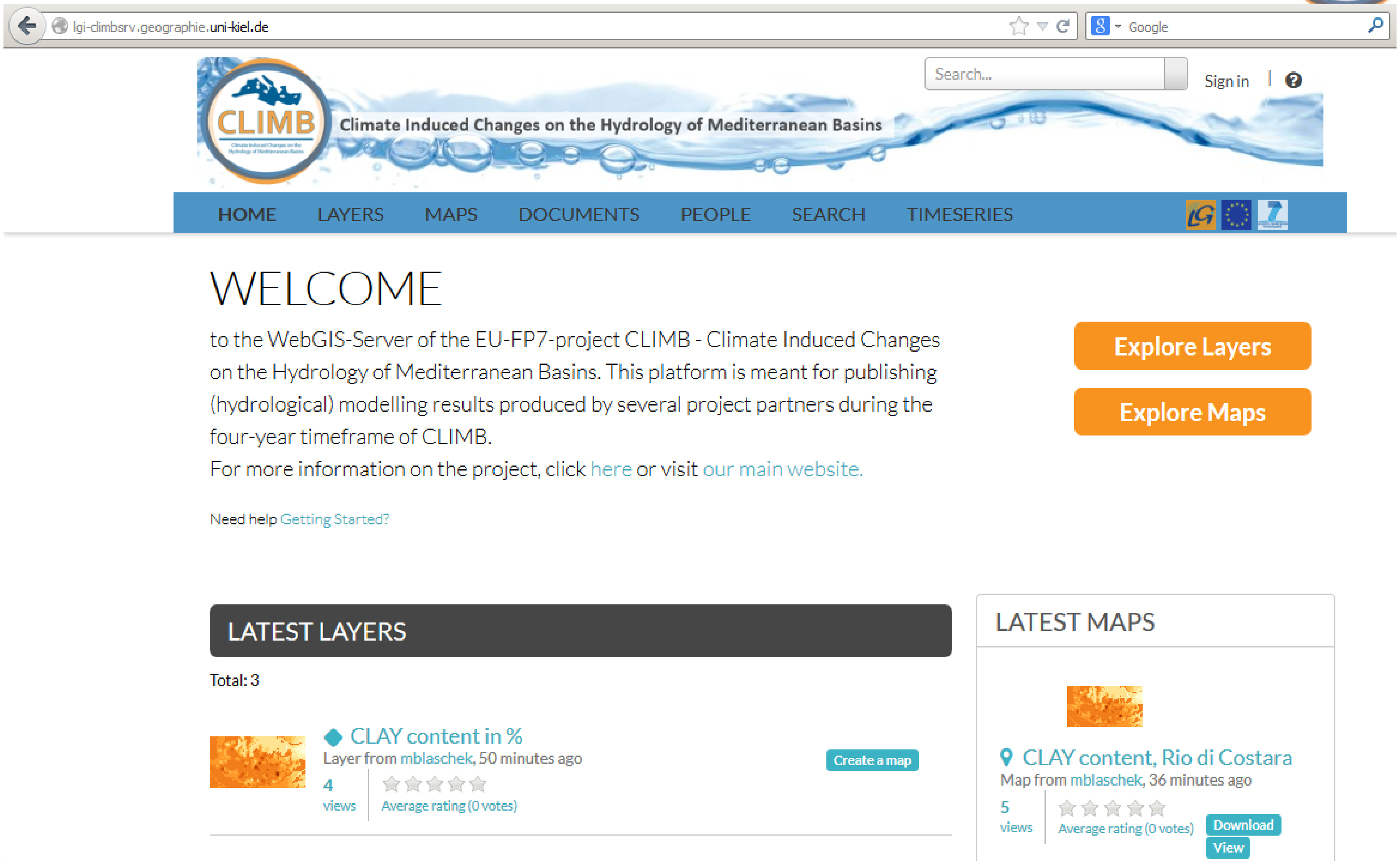
For crops / management systems at risk

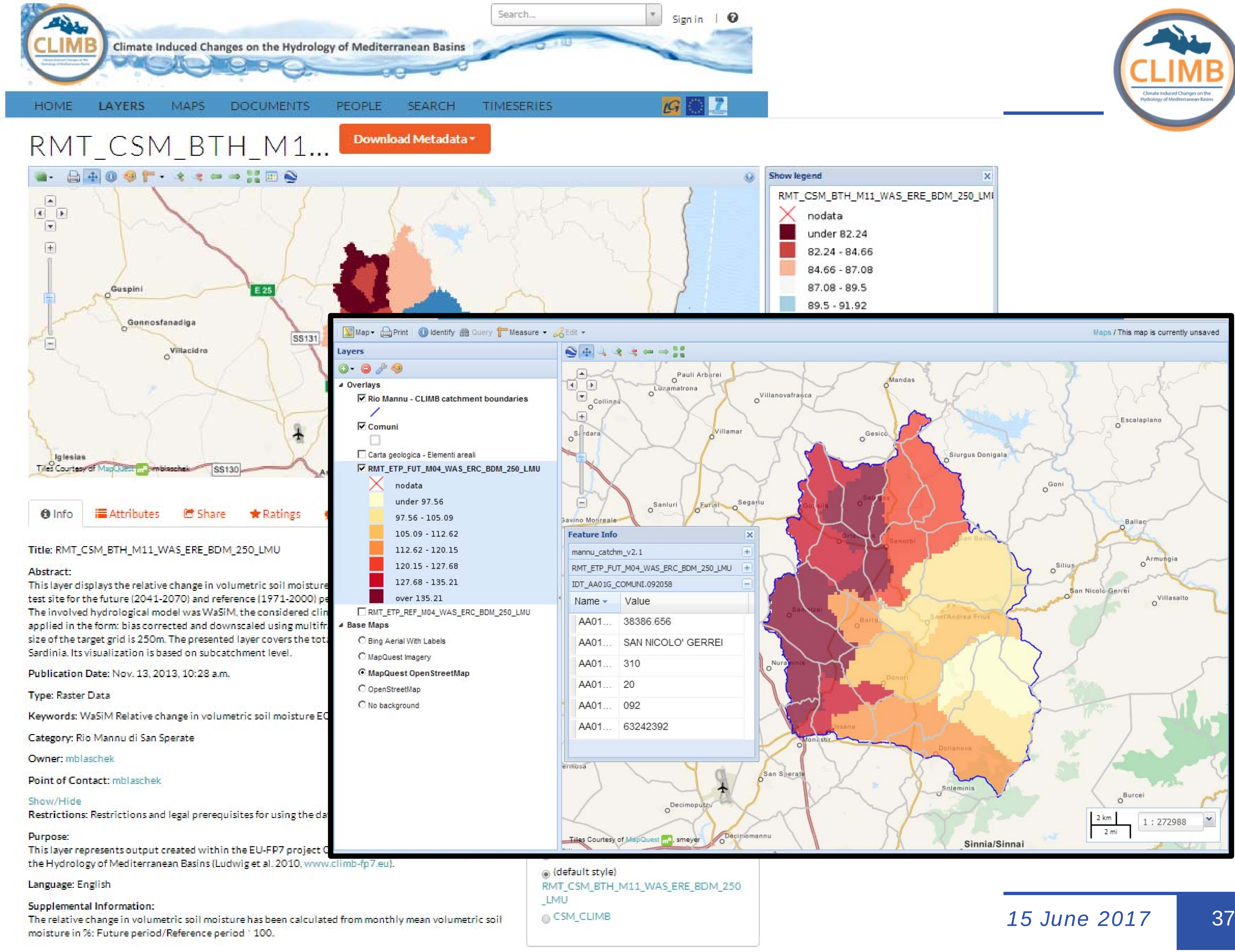
Severity

- Mulching
- Alter planting dates to follow seasonal changes
- Switch crops / management systems to lower risk systems that require less irrigation
- Discontinue high risk irrigation of crops / management systems on specific soils
- Discontinue high risk irrigation of crops / management systems completely

Use irrigation water saved on remaining crops or for other purposes (tourism)

CLIMBPortal – the window to the inside/outside





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89.5 - 91.92
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Abstract:
This layer displays the relative change in volumetric soil moisture
test site for the future (2041-2070) and reference (1971-2000) pe
The involved hydrological model was WaSiM, the considered clin
applied in the form: bias corrected and downscaled using multifr
size of the target grid is 250m. The presented layer covers the tot
Sardinia. Its visualization is based on subcatchment level.
Publication Date: Nov. 13, 2013, 10:28 a.m.
Type: Raster Data
Keywords: WaSiM Relative change in volumetric soil moisture EC
Category: Rio Mannu di San Sperate
Owner: mblaschek
Point of Contact: mblaschek
Show/Hide
Restrictions: Restrictions and legal prerequisites for using the da
Purpose:
This layer represents output created within the EU-FP7 project C
the Hydrology of Mediterranean Basins (Ludwig et al. 2010, www.climb-fp7.eu).
Language: English
Supplemental Information:
The relative change in volumetric soil moisture has been calculated from monthly mean volumetric soil moisture in %: Future period/Reference period * 100.
(default style)
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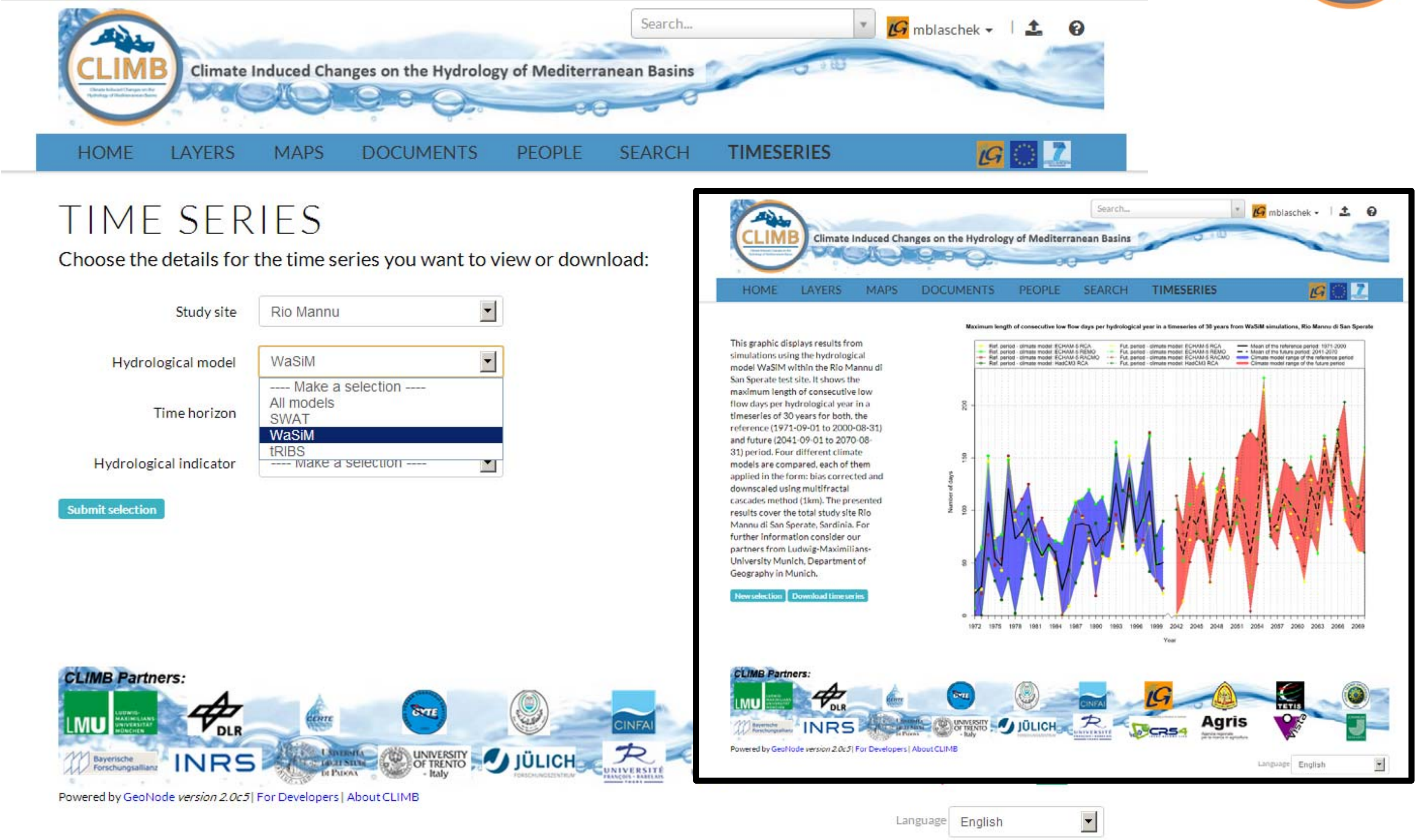
Measure
Edit
Maps / This map is currently unsaved
Layers
Overlays
Rio Mannu - CLIMB catchment boundaries
Comuni
Carta geologica - Elementi areali
RMT_ETP_FUT_M04_WAS_ERC_BDM_250_LMU
nodata
under 97.56
97.56 - 105.09
105.09 - 112.62
112.62 - 120.15
120.15 - 127.68
127.68 - 135.21
over 135.21
RMT_ETP_REF_M04_WAS_ERE_BDM_250_LMU
Base Maps
Bing Aerial With Labels
MapQuest Imagery
MapQuest OpenStreetMap
OpenStreetMap
No background
Feature Info
mannu_catchm_v2.1
RMT_ETP_FUT_M04_WAS_ERC_BDM_250_LMU
IDT_AA01G_COMUNI.092058
Name
Value
AA01... 38386.656
AA01... SAN NICOLO' GERREI
AA01... 310
AA01... 20
AA01... 092
AA01... 63242392
Pauli Arbarei
Lunamatrona
Villanovafranca
Mandas
Collinas
Sardara
Villamar
Gesico
Escalaplano
Siurgus Donigala
Goni
Sanluri
Furtei
Segariu
Ballao
Silius
Armungia
San Nicolo Gerrei
Villasalto
San Sperate
Decimoputzu
Decimomannu
Soleminis
Burcei
Dolianova
Monastir
Sinnia/Sinnai
1 : 272988
2 km
2 mi
Tiles Courtesy of MapQuest

CLIMBPortal – http://lfi-climbsrv.geographie.uni-kiel.de



Conclusion: CLIMB – mission & objectives (revisited)

This is what we announced:

→ to analyse ongoing and future climate induced changes in hydrological budgets and extremes

→ yes, but we had no means to look at all extremes

→ to link the changes in hydrological quantities to vulnerability and associated risk

→ yes, a very comprehensive framework was established, but could only be filled partially

→ to quantify (reduce?) uncertainties in climate change impact analysis

→ we managed to somewhat quantify (and even rank) uncertainties in some cases; but there was/is no way to effectively reduce it…

CLIMB – Some closing remarks

What needs to be done
(some personal thoughts for scientists and the EC):

→ monitoring, monitoring, monitoring…

→ uncertainty analyses!

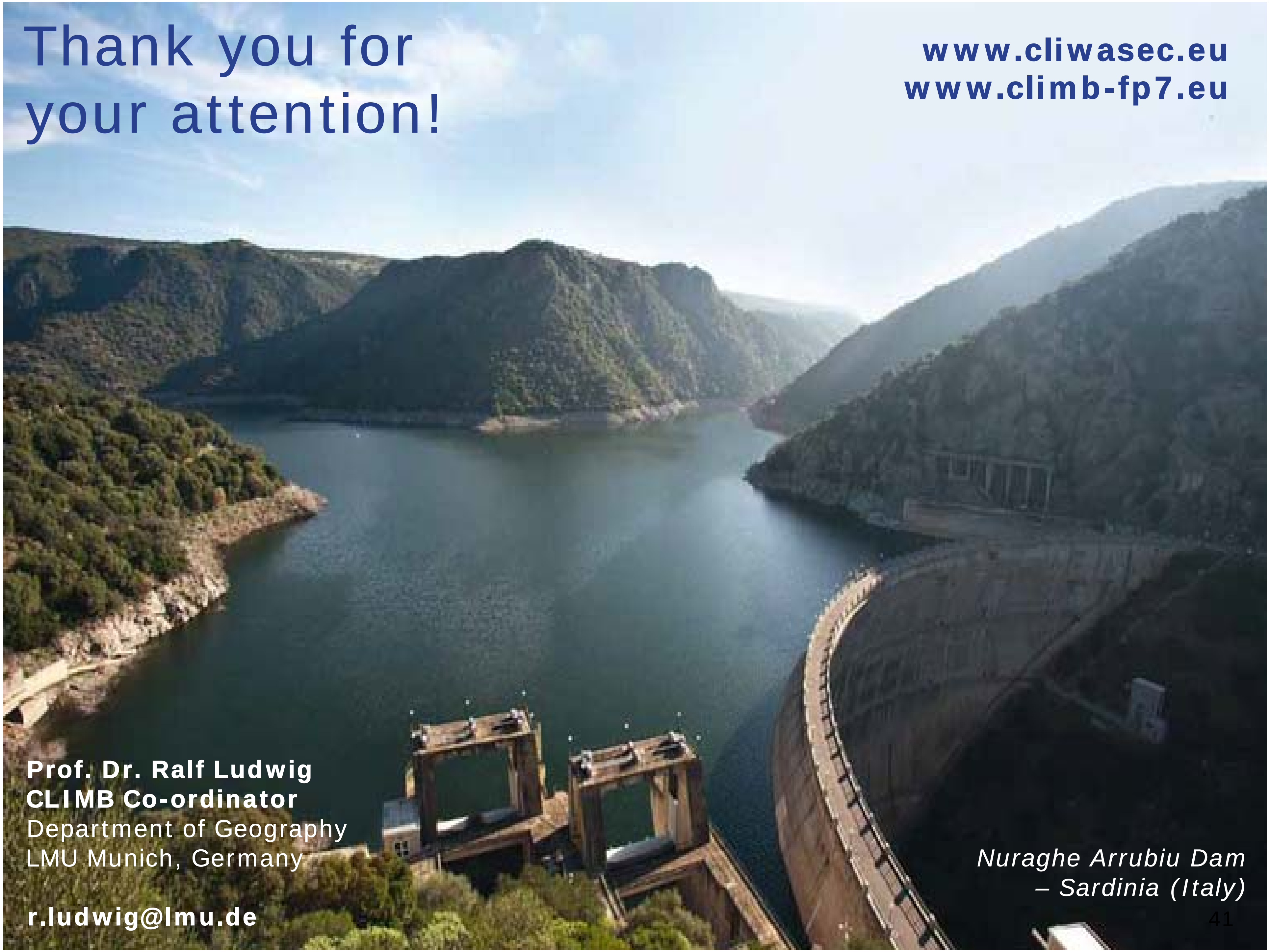
→ broaden the view (looking at 'climate induced changes…' alone imposes limits) and improve the networks among projects

→ continuity?

→ Dissemination activities
→ Portals
→ Project follow-ups…

Thank you for your attention!

www.cliwasec.eu
www.climb-fp7.eu



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Nuraghe Arrubiu Dam – Sardinia (Italy)


CLIMB
Climate Induced Changes on the Hydrology of Mediterranean Basins
WASSERMed
clico
Climate Change, Hydro-conflicts and Human Security

Developing the cluster

Quick facts

FP7-Topic:	SSH.2009.4.2.1
Funding period:	01/2010 – 12/2012
Coordinator:	Universitat Autònoma de Barcelona (UAB-ICTA, Spain
Partners:	14
Website:	www.clico.org
Contact:	Prof. Giorgos Kallis (project co-ordinator), giorgoskallis@gmail.com Dr. Christos Zografos (research co-ordinator), czografos@gmail.com

clico
Climate Change, Hydro-conflicts and Human Security

Quick facts

FP7-Topic:	ENV.2009.1.1.5.2
Funding period:	01/2010 – 03/2013
Coordinator:	Centro Euro-Mediterraneo per i Cambiamenti Climatici (CMCC, Italy)
Partners:	12
Website:	www.wassermed.eu
Contact:	Prof. Roberto Roson (project co-ordinator), roson@unive.it Simone Mereu (project manager), simonemereu@gmail.com

WASSERMed

Quick facts

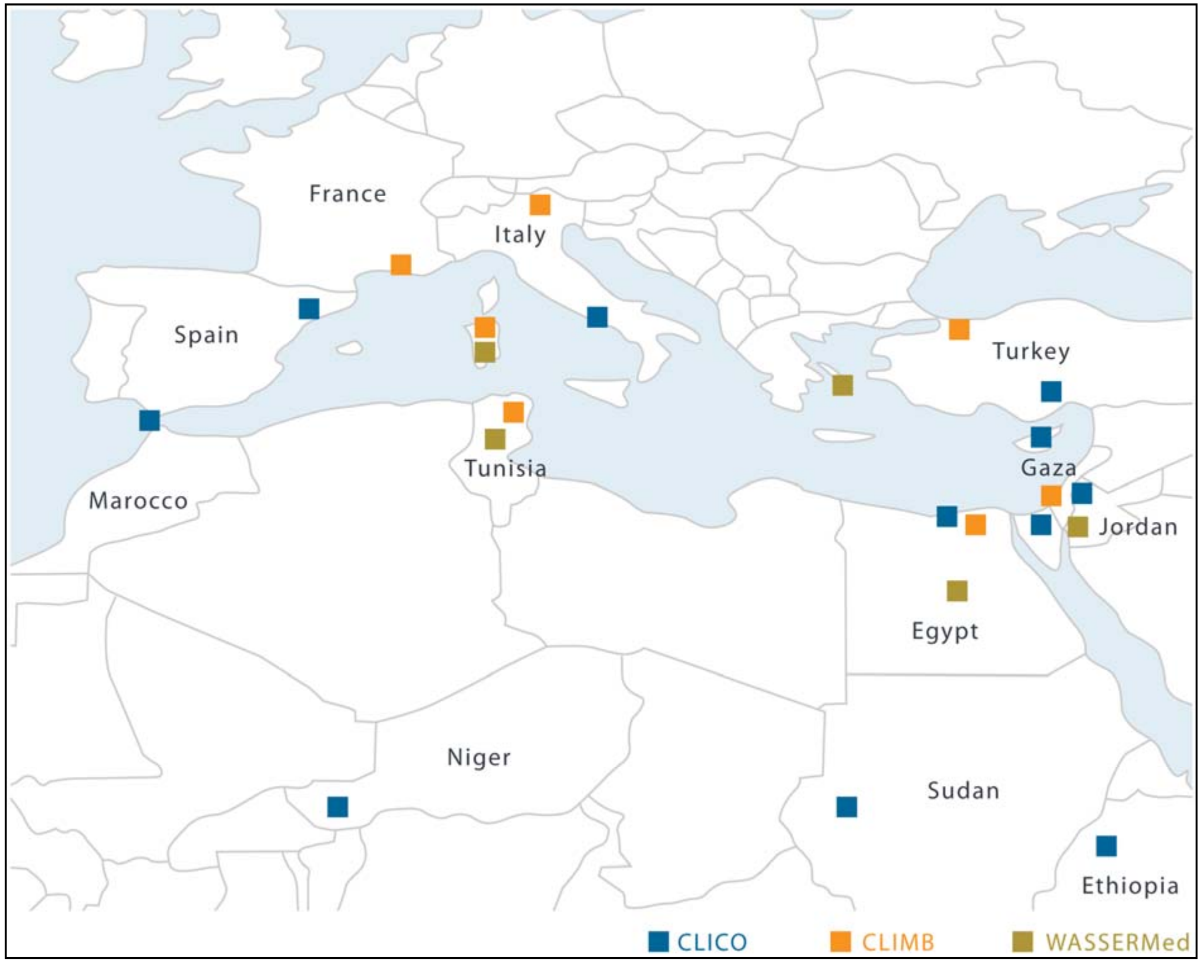
FP7-Topic:	ENV.2009.1.1.5.2
Funding period:	01/2010 – 12/2013
Coordinator:	Ludwig-Maximilians Universität München (LMU, Germany)
Partners:	20
Website:	www.climb-fp7.eu
Contact:	Prof. Dr. Ralf Ludwig (project co-ordinator), ludwig@lmu.de Dr. Thomas Ammerl (project manager), ammerl@bayfor.org

Critical mass of
46 Partners

Objectives of the CLUSTER

- **Scientific Synergy**

  Study Sites are comple-mentary in scope, region and scale



→ share information and data

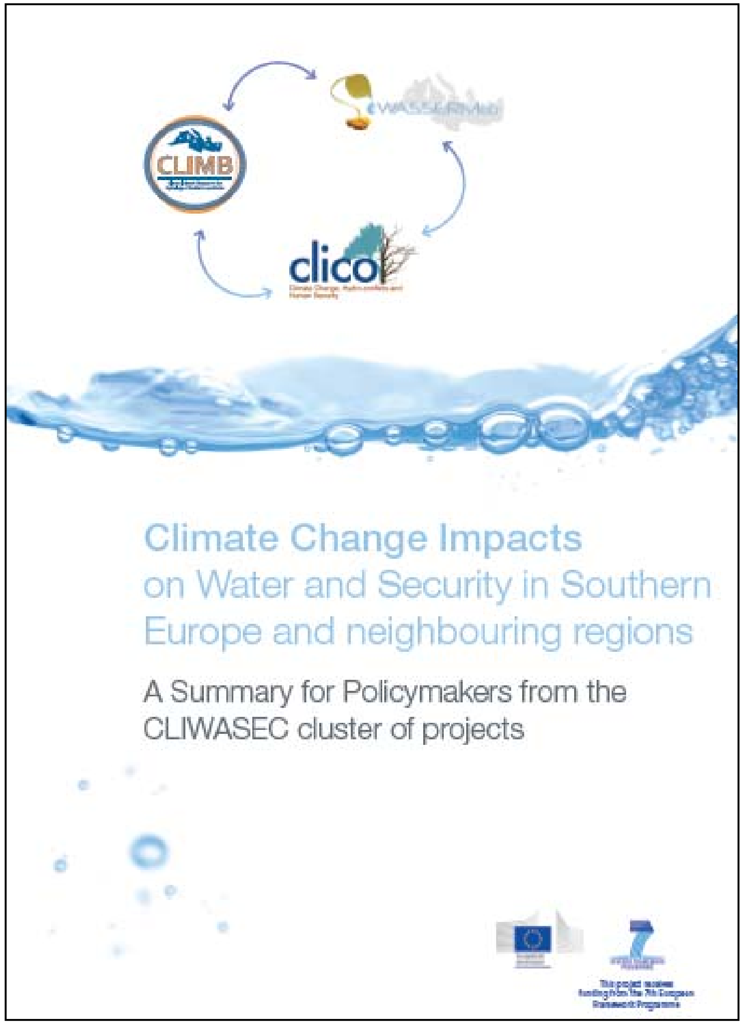
→ Identify common stake-holder groups

→ compare and integrate model results

→ joint publications

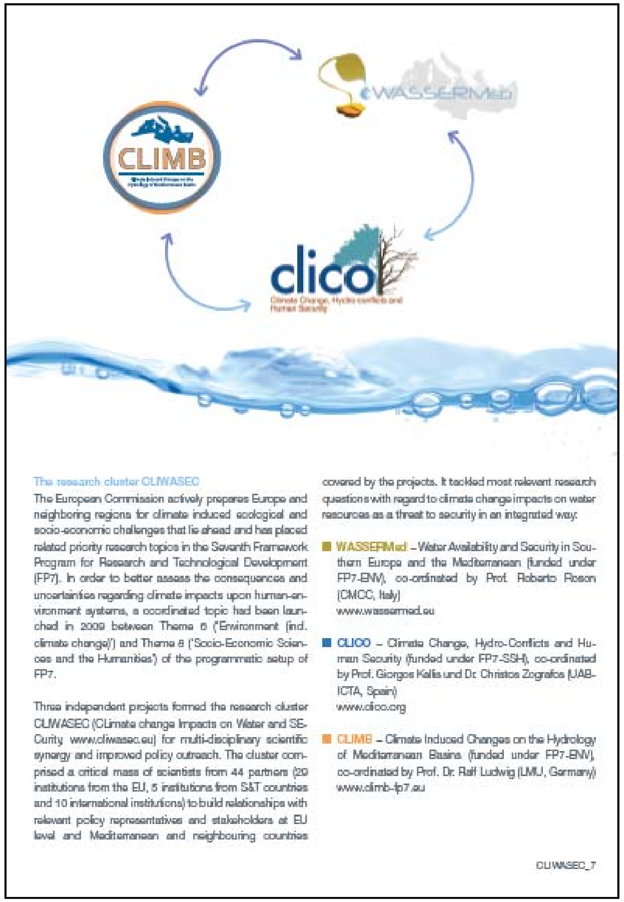
→ joint science-policy briefs

Summary for Policymakers



Climate Change Impacts
on Water and Security in Southern
Europe and neighbouring regions

A Summary for Policymakers from the
CLIWASEC cluster of projects



The research cluster CLIWASEC

The European Commission actively prepares Europe and neighboring regions for climate induced ecological and socio-economic challenges that lie ahead and has placed related priority research topics in the Seventh Framework Program for Research and Technological Development (FP7). In order to better assess the consequences and uncertainties regarding climate impacts upon human-environment systems, a coordinated topic had been launched in 2009 between Theme 6 ("Environment (incl. climate change)") and Theme 8 ("Socio-Economic Sciences and the Humanities") of the programmatic setup of FP7.

Three independent projects formed the research cluster CLIWASEC (CLimate change Impacts on Water and SECurity, www.cliwasec.eu) for multi-disciplinary scientific synergy and improved policy outreach. The cluster comprised a critical mass of scientists from 44 partners (29 institutions from the EU, 5 institutions from S&T countries and 10 international institutions) to build relationships with relevant policy representatives and stakeholders at EU level and Mediterranean and neighbouring countries covered by the projects. It tackled most relevant research questions with regard to climate change impacts on water resources as a threat to security in an integrated way:

- WASSERMed – Water Availability and Security in Southern Europe and the Mediterranean (funded under FP7-ENV), co-ordinated by Prof. Roberto Roson (CMCC, Italy)
  www.wassermed.eu
- CLICO – Climate Change, Hydro-Conflicts and Human Security (funded under FP7-SSH), co-ordinated by Prof. Giorgos Kallis und Dr. Christos Zografos (UAB-ICTA, Spain)
  www.clico.org
- CLIMB – Climate Induced Changes on the Hydrology of Mediterranean Basins (funded under FP7-ENV), co-ordinated by Prof. Dr. Ralf Ludwig (LMU, Germany)
  www.climb-fp7.eu

CLIWASEC_7

Summary for Policymakers

WASSERMed - Research Highlights

- The warming trend and changes in precipitation patterns could affect the composition and functioning of natural and managed ecosystems.
- Growing non-agricultural water needs will strongly affect agricultural water shortages in the Southern Mediterranean; Water resources for environmental preservation, are likely to decrease, especially in the MENA region.
- Intra-Mediterranean virtual water trade is likely to decline, with virtual imports from central and northern Europe increasing.
- Improved water efficiency appears to significantly mitigate the economic impacts of water scarcity, especially in the Northern areas.
- A seasonal change in tourism is probable due to improving climate conditions in spring and autumn and a slight deterioration in summer.
- Crop water requirements are very likely to increase in all case studies, requiring specifically adapted management practices.

Summary for Policymakers

CLICO - Research Highlights

- Climatic and hydrological factors seem to be less influential than political, economic and social factors for most water-related conflict situations.

- Democracies are likely to have more domestic water conflicts than autocracies, but autocracies are likely to have more violent water conflicts than democracies.

- Wars and violence increase the vulnerability of the population to hydro-climatic hazards.

- States can maladapt, that is they pursue adaptation policies that end up increasing, instead of decreasing, the vulnerability of parts of their population.

- Social security and civil security institutions – such as entitlement schemes, unemployment insurance, universal health care, or flood relief agencies – are central for reducing vulnerabilities and providing human security.

Summary for Policymakers

CLIMB - Research Highlights

- Climate change contributes, yet in strong regional variation, to water scarcity in the Mediterranean; other factors, e.g. pollution or poor management practices are regionally still dominant.

- Rain-fed agriculture needs to adapt to seasonal changes; stable or increasing productivity likely depends on additional irrigation.

- Tourism could benefit in shoulder seasons, but may expect income losses in the summer peak season due to increasing heat stress.

- Local & regional water managers and water users, lack, as yet, awareness of climate change induced risks; emerging focus areas are supplies of domestic drinking water, irrigation, hydro-power and livestock.

- Data and knowledge gaps in climate change impact and risk assessment are still wide-spread and ask for extended and coordinated monitoring programs.