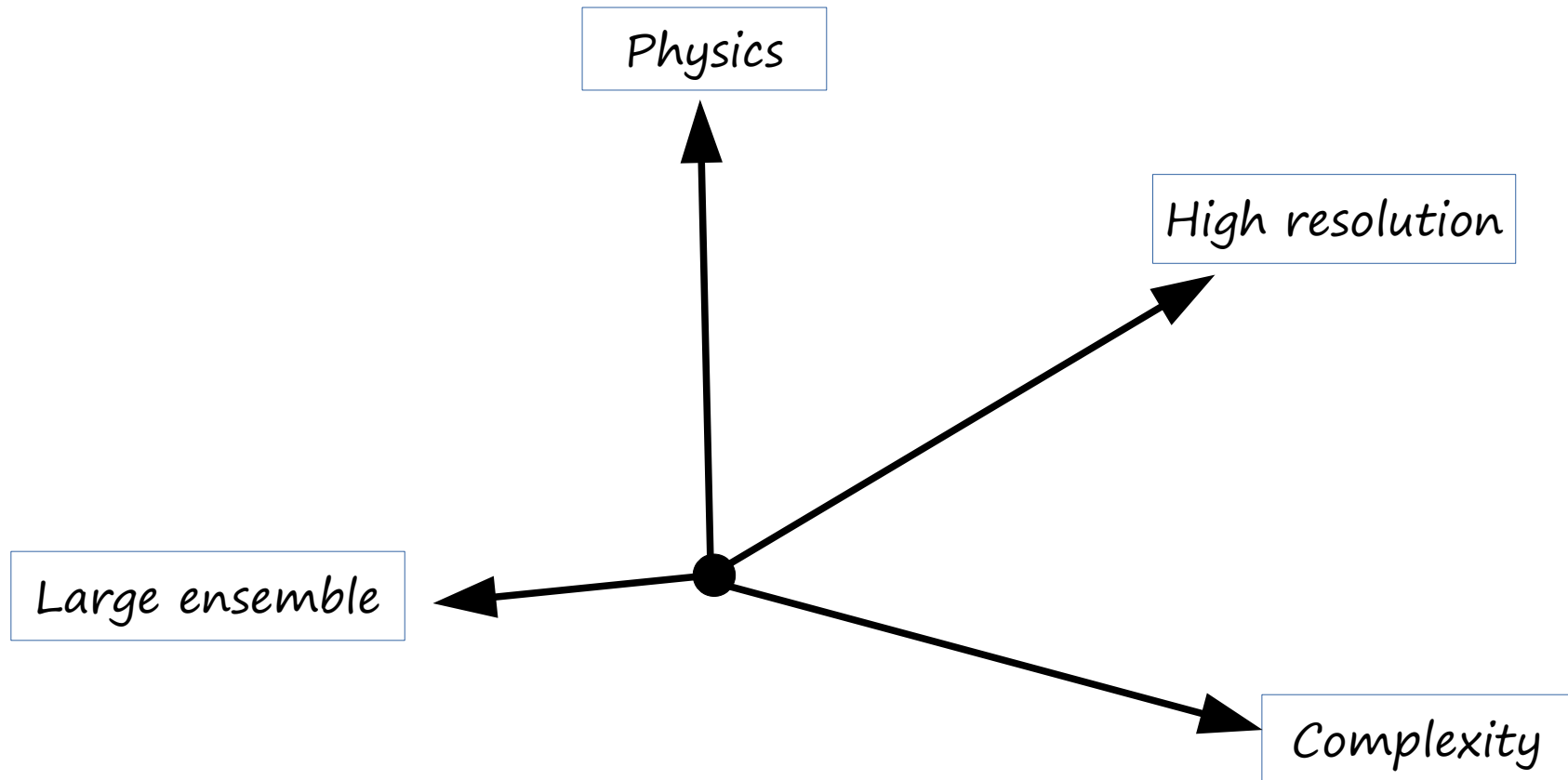




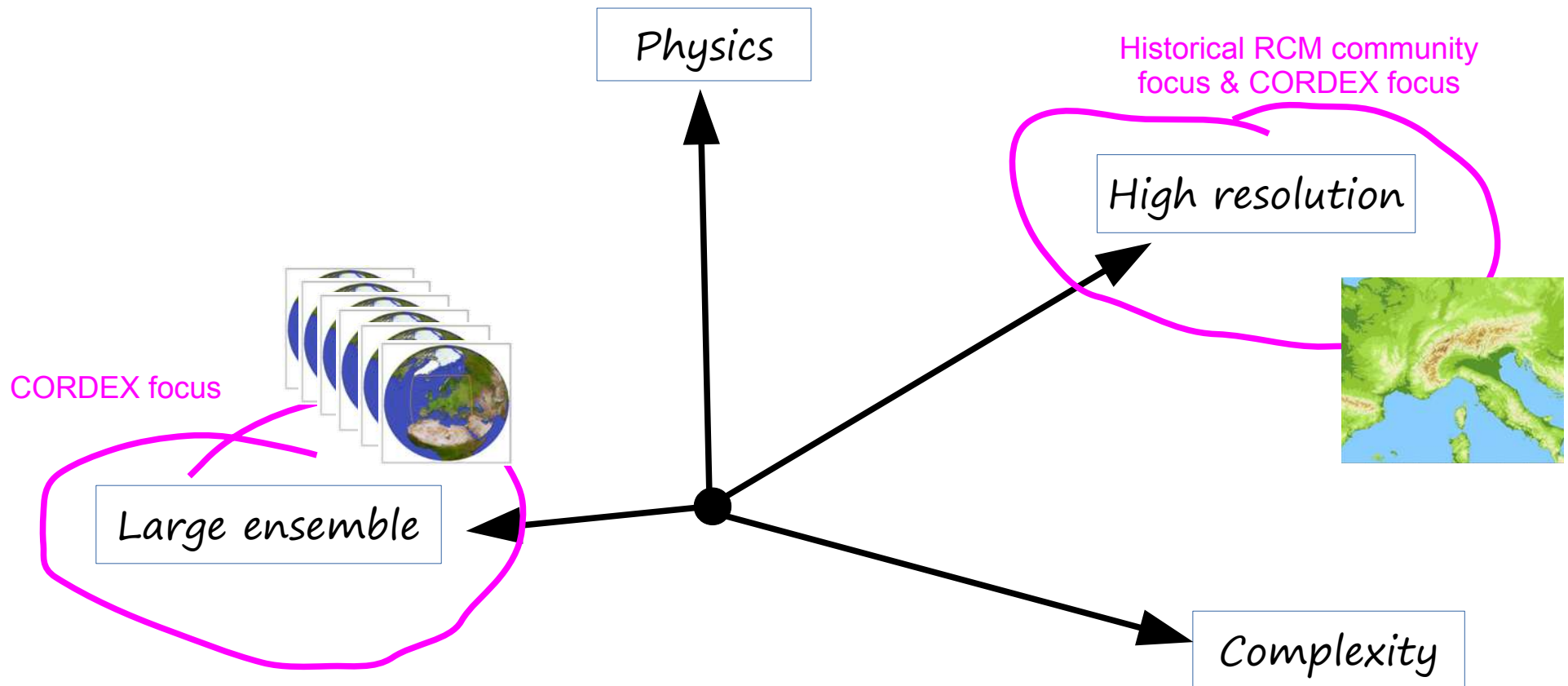
Regional Earth System Models : Uncertain Definition, Clear Benefits & Open Challenges

Samuel Somot, Météo-France / CNRM
samuel.somot@meteo.fr

CORDEX and the RCM improvement « dilemma »



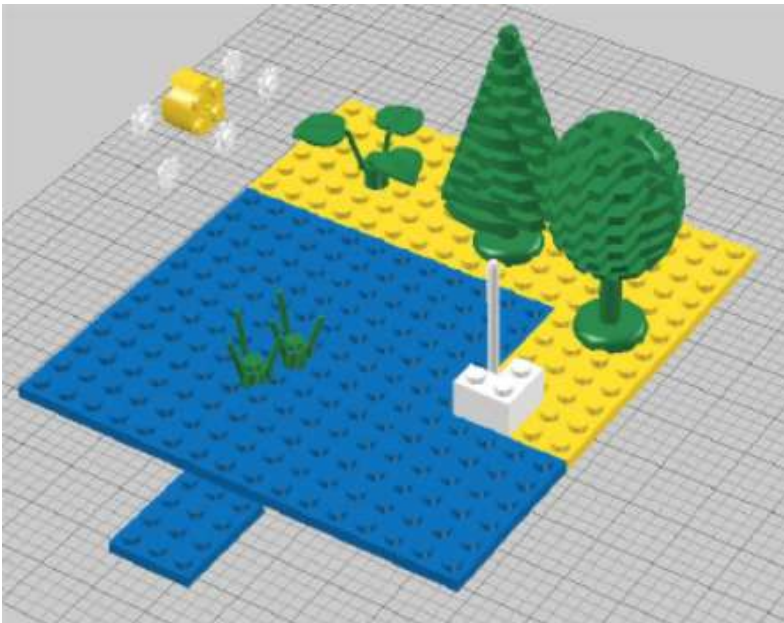
CORDEX and the RCM improvement « dilemma »



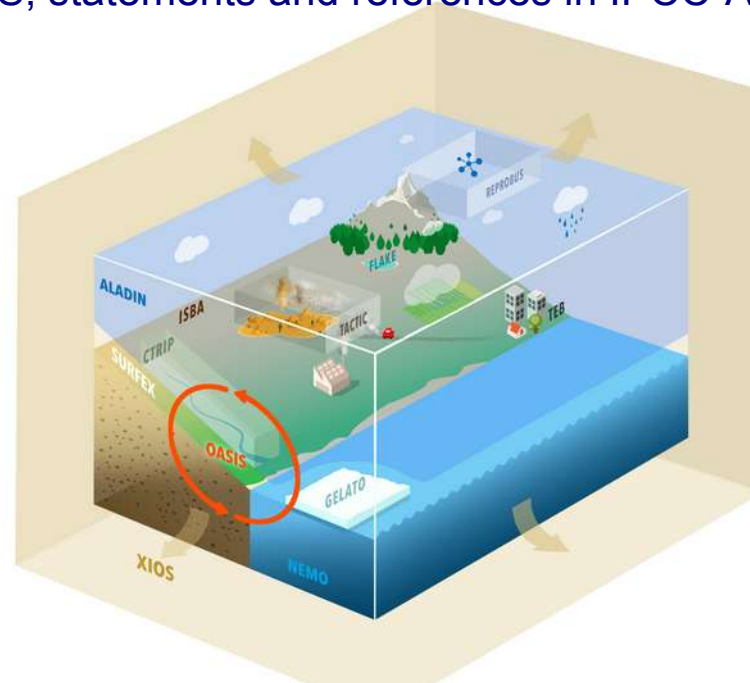
- CORDEX focus on increasing high-resolution and creating large ensembles
- Lead to RCMs including only atmosphere and (simple) land-surfaces
- The increase in complexity was largely out of the scope of the first phases

What are RESM : Regional Earth System Models ?

- No clear definition (not in IPCC glossary), no clear status in CORDEX, also called RCSM
- In theory : Holistic RCM coupling the regional climate system and the human society, therefore allowing to tackle Earth System Science questions
- In practice : Complex RCMs, including high-resolution representation and high-frequency coupling of various components of the climate system (ocean, continental hydrology, dynamical vegetation, carbon cycle, sea ice, glaciers, cities, natural or anthropogenic aerosols, chemistry, ocean biogeochemistry, human activities)
- Born in the 2000s with coupled Atmosphere-Ocean RCMs (*Döscher et al. 2002 for the Baltic, Rinke et al. 2003 for the Arctic, Aldrian et al. 2005 for the Maritime continent, Somot et al. 2008 for the Mediterranean*)
- Largely used nowadays (used in CORDEX FPS, statements and references in IPCC-AR6 Chap. 10)



P. Ruti, pers. comm.



Scheme of the CNRM-RCSM

Benefits of using RESM

Improve standard CORDEX regional climate information over land

- Improve the representation of key forcings of the regional climate (regional seas, aerosols, land-use-land-cover)
- Modify the regional climate by representing new feedback loops
- Test new « what-if » scenarios

Develop information for new components of the regional climate system

- Develop new knowledge
- Interact with new modelling communities
- Produce new regional climate datasets and regional climate information
- Propose climate services to serve new users

Better forcings for the atmosphere-RCMs

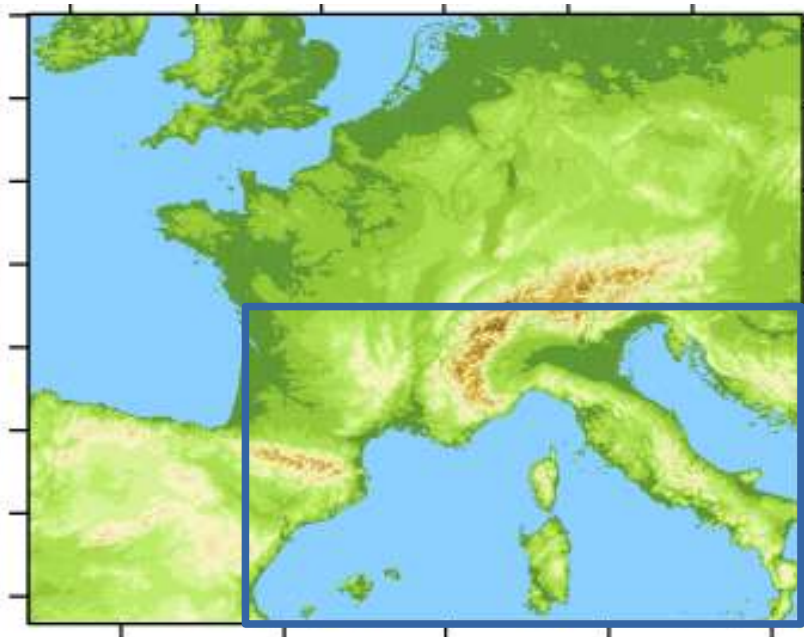
Typical CPRCM domain at 2.5 km
used in climate mode



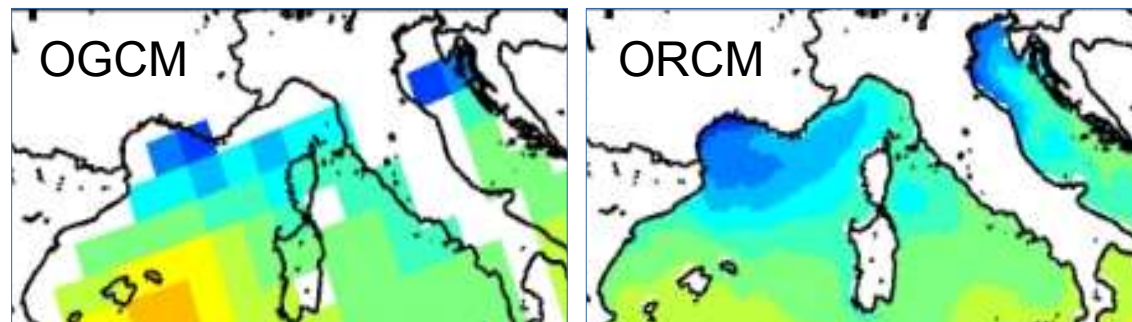
What is source of information for
the surface in such models ?
in evaluation/hindcast mode
and in scenario mode ?

Better forcings for the atmosphere-RCMs

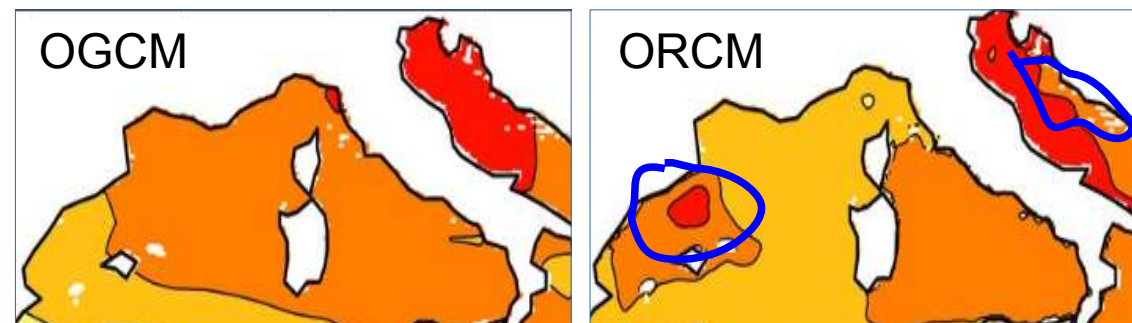
Typical CPRCM domain at 2.5 km
used in climate mode



SST pattern ($^{\circ}\text{C}$, 1976-2005)



SST change ($^{\circ}\text{C}$, 2071-2100 vs 1976-2005, SSP585)



What is source of information for
the surface in such models ?
in evaluation/hindcast mode
and in scenario mode ?

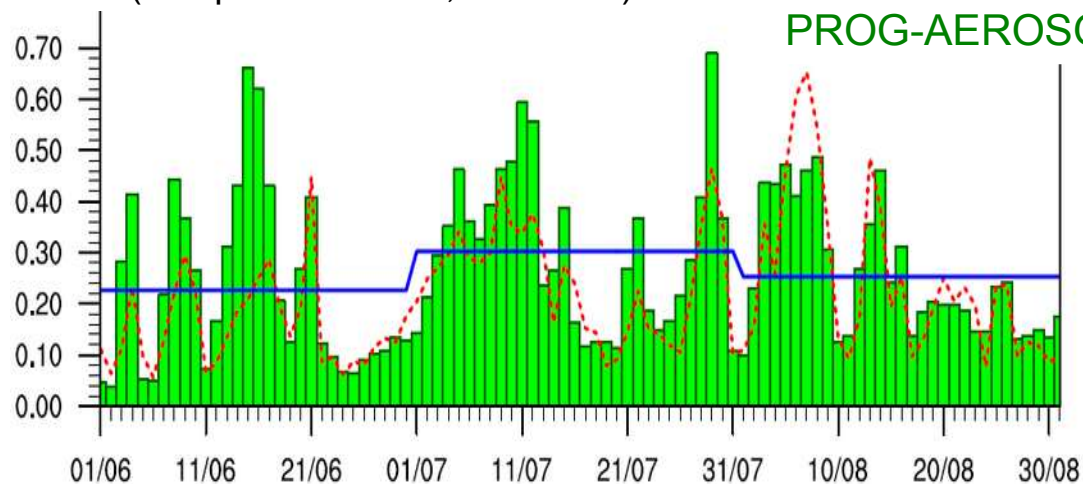
Expected impacts on island climate,
on coastal extreme precipitation events,
on Medicanes

Better forcings for the atmosphere-RCMs

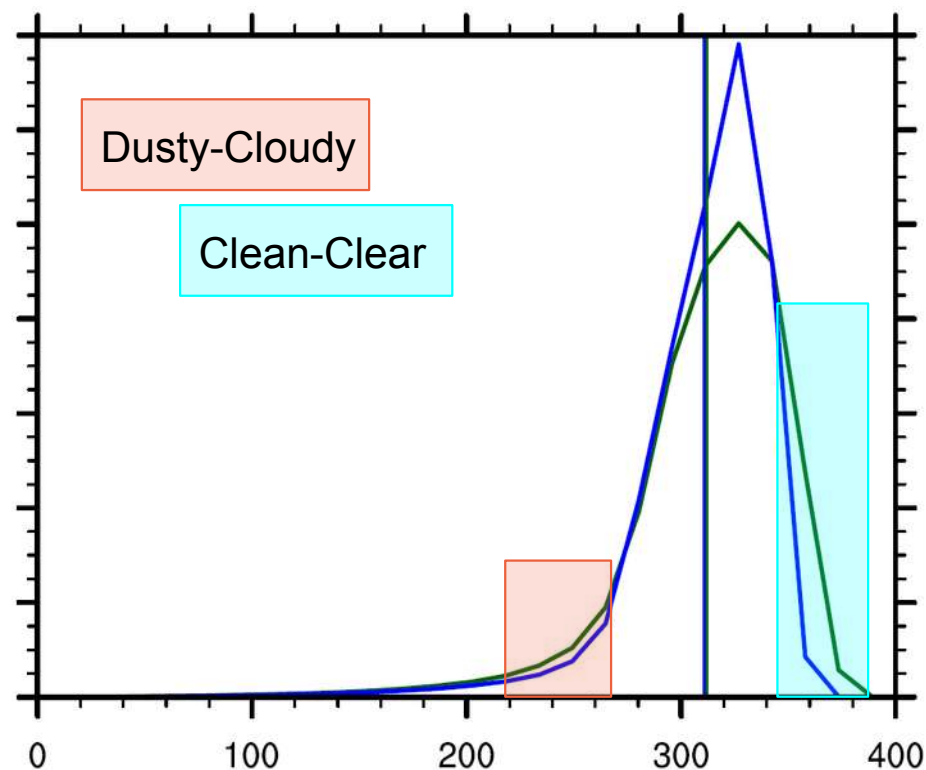
- Study impacts of aerosol representation in RCM in Summer in the Mediterranean area
- Using prognostic aerosols strongly increases the surface shortwave radiation daily variability
- Potential impacts on ecosystems and photovoltaic energy production

AOD local daily variability
(Lampedusa island, JJA 2012)

OBS
CLIM-AEROSOL
PROG-AEROSOL



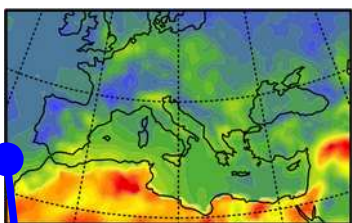
Daily PDF of surface solar radiation
(South Mediterranean domain, 1979-2013, JJA, W/m²)



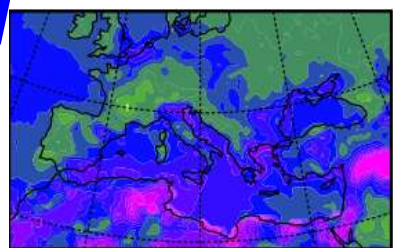
Represent and study new feedback loops

Sensitivity tests with and without aerosols in a coupled Atmosphere-Land-River-Ocean RCM (2003-2009, JJA)

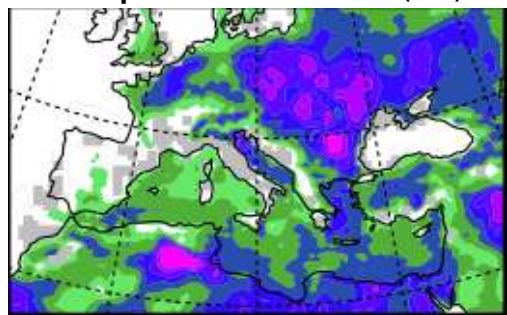
AOD (-)



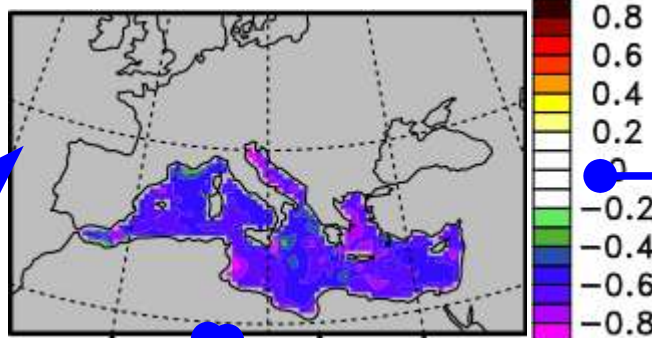
Direct aerosol SW radiative forcing (W/m²)



Impact on T2m (°C)

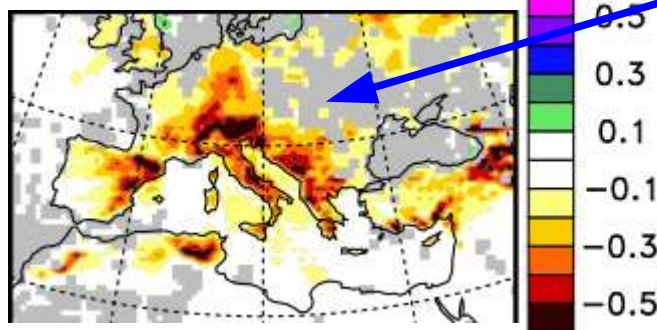


Impact on SST (°C)

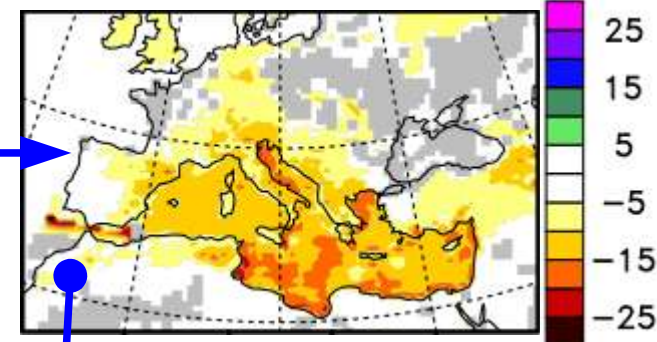


Advection of cold air

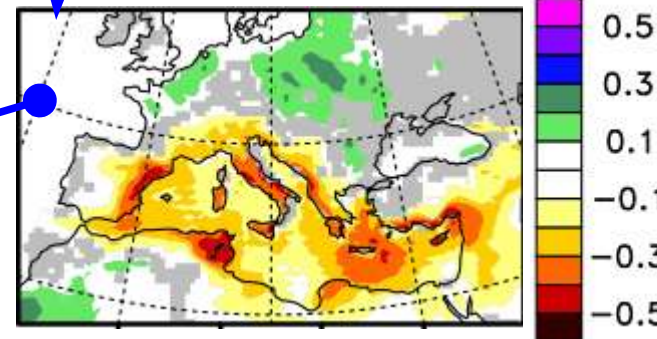
Impact on Precipitation (mm/d)



Impact of Latent heat loss (W/m²)

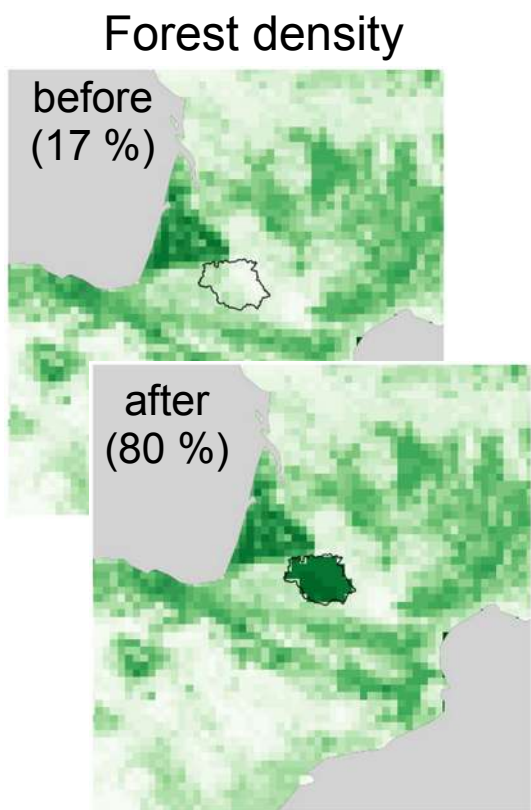


Impact on specific humidity (g/kg)

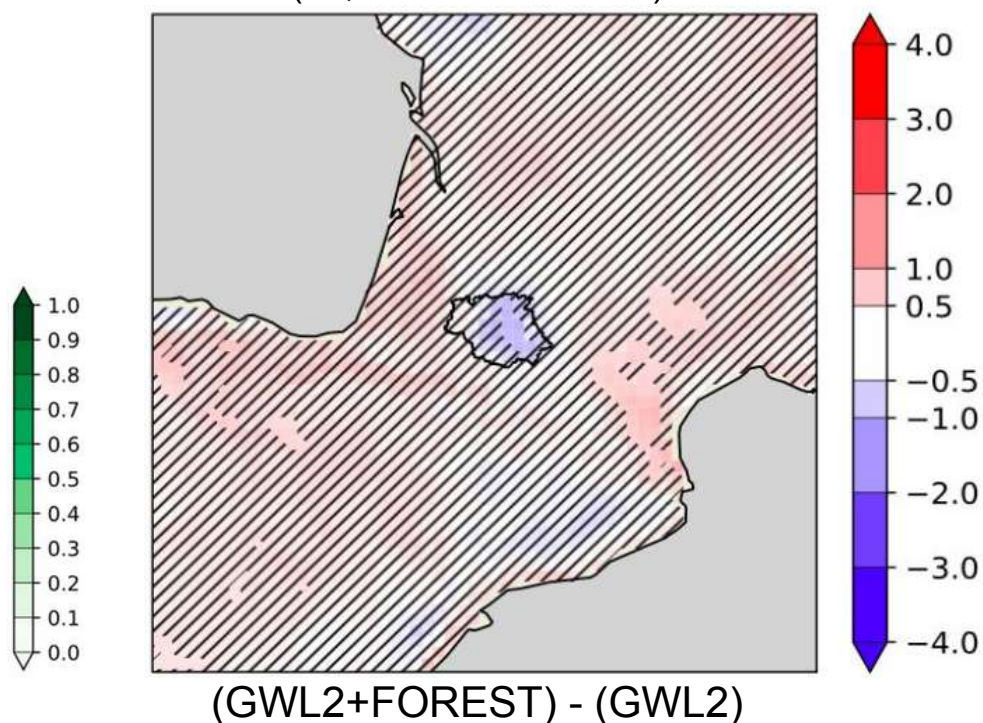


Test new « What-if » scenarios over land

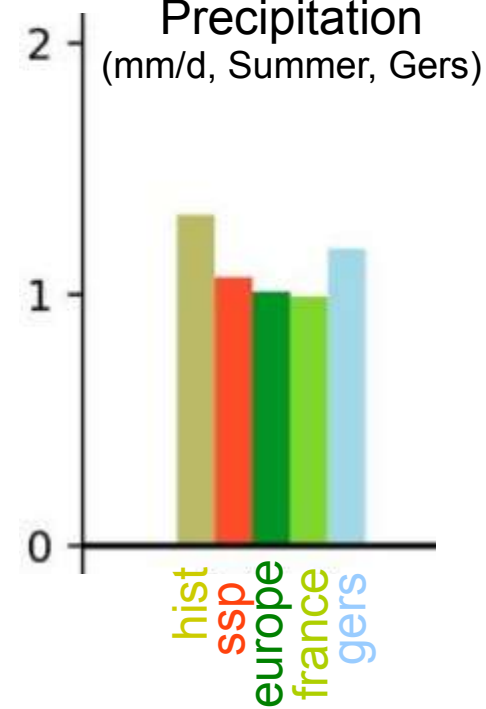
- User request for assessing local land-use change measure in the small « Gers » French region
- EURO-CORDEX-like runs (12 km) at a Global Warming Level = 2°C
- Drastic afforestation tests in RCM with complex land-surface module (interactive vegetation, hydrology)
- Local afforestation can mitigate local climate change
- Effects are complex: season, tree specy, afforestation spatial scale



Afforestation impact on
extreme temperature change
(°C, Annual maximum)



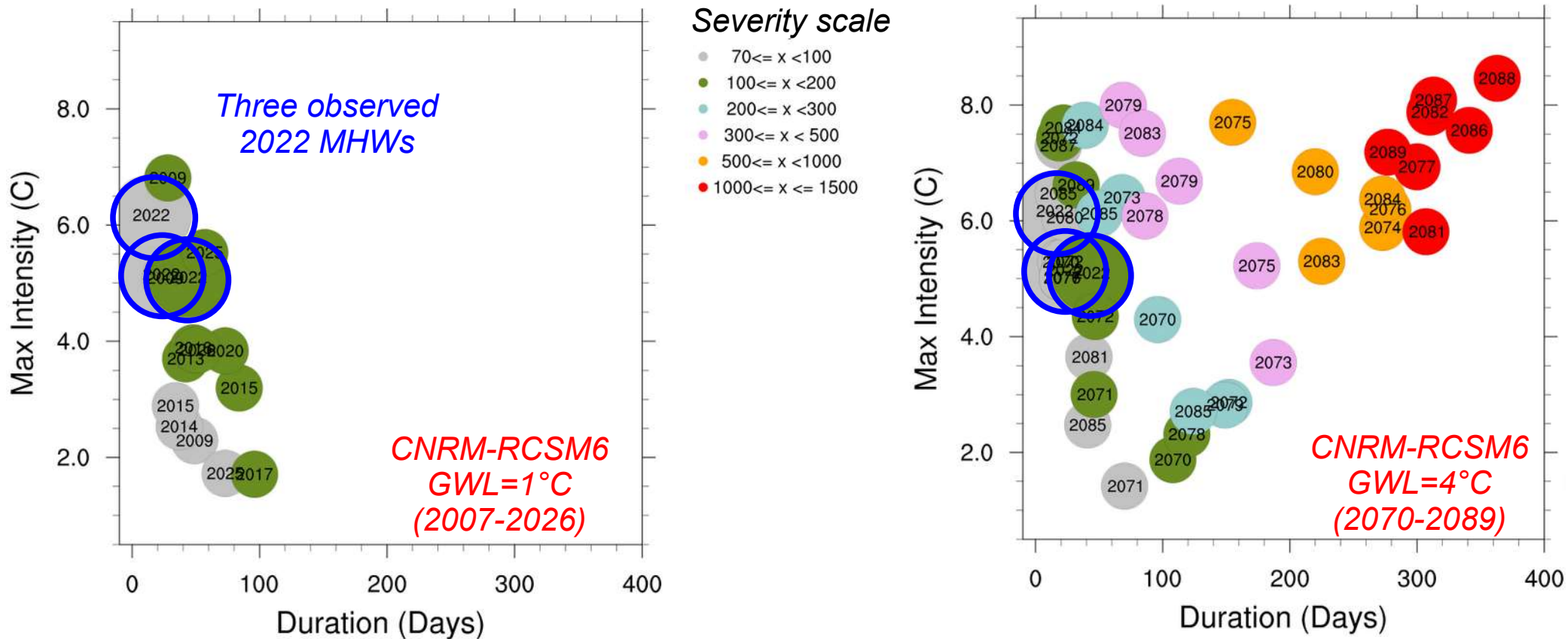
Precipitation
(mm/d, Summer, Gers)



New climate information for regional oceans

- Analysis of the sea component in scenario simulations performed with a complex RCM

Marine Heatwaves in front of the city of Marseille (5.375°E, 42.875°N)

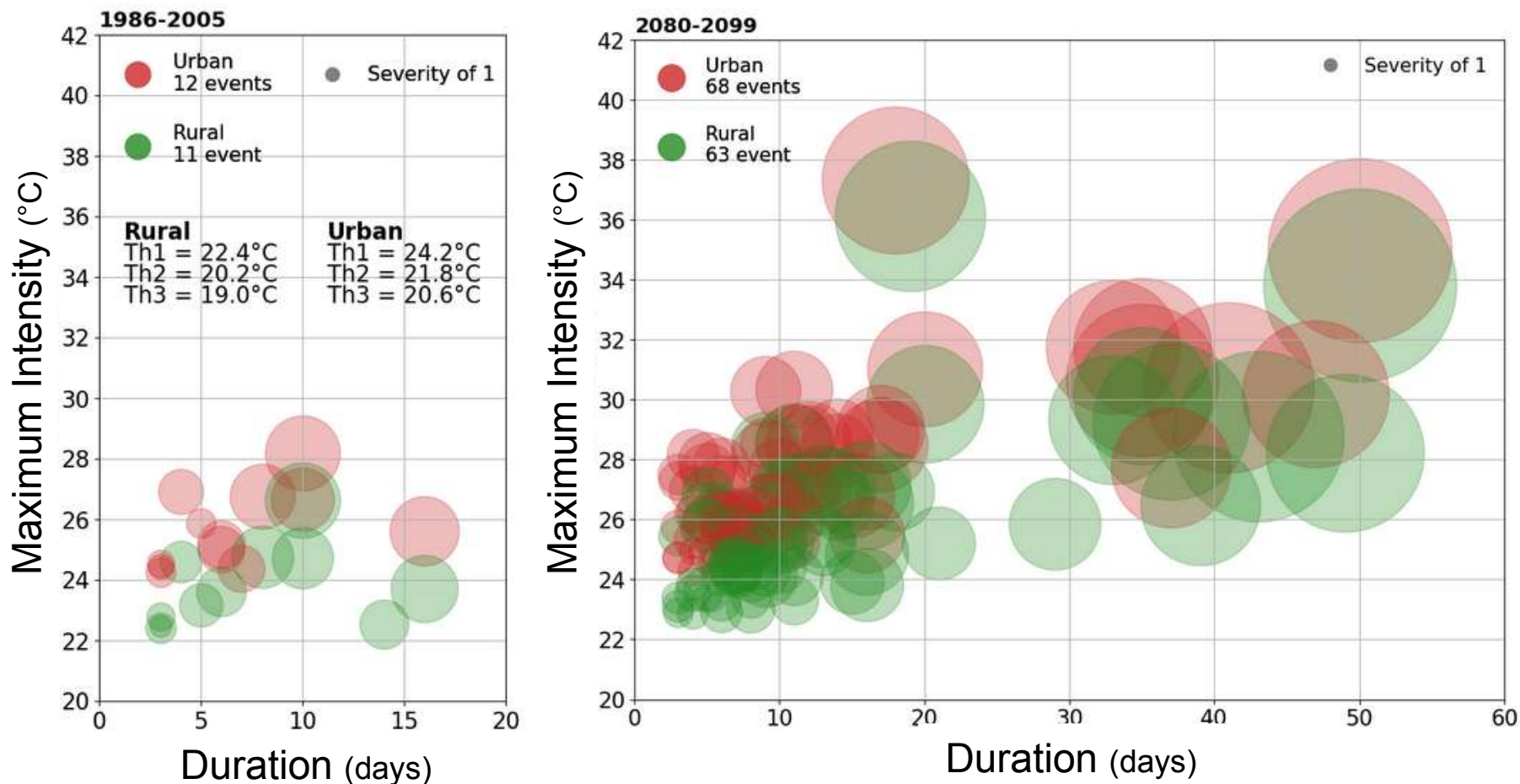


- Observed 2022 MHWs correspond to the strongest simulated MHWs at a GWL1
- Observed 2022 MHWs may become weak events at a GWL4

New climate information for cities

- SSP5-8.5 scenario run with a km-scale RCM including an advanced city module
- Heatwaves detection in the urban and surrounding rural area

Maximum-Intensity / Duration / Severity bubble graph (one bubble per detected event)



- Heatwaves are more intense in cities but not longer
- The urban-rural difference in the HW characteristics is attenuated at strong warming levels
- UHI decrease in the future

Current challenges and personal advice

*Warning :
this slide does not represent
the official CORDEX position
open to discussion*

Challenge #1. Definition

- RESMs are nothing more than RCMs. Fighting for a definition is useless and time consuming
- Mix RCMs with different levels of complexity in the same CORDEX ensembles (as in CMIP)
- Define what are the minimum required components for every CORDEX domain
- (If you don't follow my advice), clearly define the requirements to obtain the RESM label (good luck!)

Challenge #2. Capacity building

- Acknowledge the human, computation, financial, training resources needed
- Develop, maintain and share a diversity of relocatable complex RCMs
- Interact with already-existing and structured modelling communities, develop new reference datasets

Challenge #3. Standardization

- Prepare multi-model studies and data access: variable lists, file naming, specifications, ESGF
- Develop good practices : model documentation, simulation protocol, model evaluation

Challenge #4. New knowledge production

- Identify key scientific questions for your CORDEX domain that require coordination for complex RCMs
- Investigate the benefits/limitations of new coupled components with dedicated FPS
- Don't spend too much time on Added-Value study
- Use complex RCMs to tackle real-world scientific questions: feedbacks, what-if, robust assessments
- Derive new regional climate information, imagine new climate services and identify new users