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

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CORDEX and the RCM improvement « dilemma »

- Physics
- High resolution
- Large ensemble
- Complexity
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)
- Largely used nowadays (used in CORDEX FPS, statements and references in IPCC-AR6 Chap. 10)
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?

C. Caillaud, pers. comm., new AROME domain used at CNRM, Soto-Navarro et al. (in prep.)
Better forcings for the atmosphere-RCMs

Typical CPRCM domain at 2.5 km used in climate mode

SST pattern (°C, 1976-2005)

SST change (°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

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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

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

AOD local daily variability
(Lampedusa island, JJA 2012)

Nabat et al. 2015b, Nabat PhD 2014
Represent and study new feedback loops


Nabat et al. 2015
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

Peronnet et al. (in prep)
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)

Severity scale
- 70<= x <100
- 100<= x <200
- 200<= x <300
- 300<= x <500
- 500<= x <1000
- 1000<= x <= 1500

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

S. Somot, S. Damaraki, MHW tracker, Med-CORDEX simulations
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

Challenge #1. Definition
- RESMs are nothing more than RCMs. Figthing 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