Nature Climate Change
July 2024, Volume 14 Issue 7 Pages 668-670
https://doi.org/10.1038/s41558-024-02028-9
https://archimer.ifremer.fr/doc/00899/101059/

Comment. Higher-resolution projections needed for small island climates

Evans Jason P. [1,*], Belmadani Ali [2,3], Menkes Christophe [4], Stephenson Tannecia [5], Thatcher Marcus [6], Gibson Peter B. [7], Peltier Alexandre [8]

[1] Australian Research Council Centre of Excellence for Weather of the 21st Century and the Climate Change Research Centre, University of New South Wales, Sydney, New South Wales, Australia
[2] Météo-France, École Nationale de la Météorologie, Toulouse, France
[3] CNRM, Université de Toulouse, Météo-France, CNRS, Toulouse, France
[4] ENTROPIE (IRD, Ifremer, Université de la Nouvelle Calédonie, CNRS, Université de la Réunion), Noumea, New Caledonia
[5] Department of Physics, The University of the West Indies, Mona, Jamaica
[6] Commonwealth Scientific and Industrial Research Organisation (CSIRO), Melbourne, Victoria, Australia
[7] National Institute of Water and Atmospheric Research (NIWA), Wellington, New Zealand
[8] Météo-France, interregional office in New Caledonia and Wallis-and-Futuna, Noumea, New Caledonia

* Corresponding author : Jason P. Evans, email address : jason.evans@unsw.edu.au

Abstract :

Projections of the future climate of small island states and territories are currently limited by the coarse resolution of models. We call for rapid global and regional cooperation to develop projections compatible with small island scales, providing relevant local information and decision-making tools.

Small island states and territories are amongst the most vulnerable to climate change impacts, particularly sea level rise[1]. Indeed, sea level rise poses an existential threat to some low-lying atolls, while questioning the long-term livability of the usually densely populated coastal areas of taller islands. While sea level rise is an important impact of climate change on small islands, it is not the only one. The populations of small islands are impacted by a variety of climatic hazards including marine and atmospheric heatwaves (that increasingly threaten fragile ecosystems such as coral reefs), extreme ocean wave events, heavy precipitation and floods, storms, landslides, drought, severe winds and wildfire, among others. Furthermore, the concentration of strategic assets, such as airports, harbors, hospitals and emergency services, as well as endemic ecosystems and historical or cultural sites over a limited area (especially for mountainous islands with limited flat terrain), often associated with high population density and with remoteness, makes island populations particularly vulnerable to such hazards[2,3]. In order to better grasp the future risk to small islands posed by climate change, we need to understand how it will impact this wide variety of oceanic and atmospheric hazards, beyond large scale sea level rise.

The latest Intergovernmental Panel on Climate Change (IPCC) assessment reports[4,5] provide evidence of sea level rise and increasing hot extremes on islands that are projected to continue increasing with high confidence. Yet, future projections of other climate hazards (*e.g.*, floods, landslides, drought, severe winds, fire weather) have only low confidence. An examination of the studies assessed by the IPCC reveals a likely reason for such low confidence. For the Small Islands chapter of Working Group II[1], ~90% of the climate projections used came from global climate models (25 out of 28 studies with climate projections). These global models use coarse horizontal resolution, generally 100 km or larger, such that many small islands simply do not exist in these models (Figure 1). On the ocean side, coastal and lagoon environments that provide essential ecosystem services and food resources are also not resolved. This means that most of the climate change projections used at the location of small islands are actually representative of the open and deep ocean rather than an island and its shallow waters.

Higher resolution regional projections have also been produced, mostly through the Coordinated Climate Downscaling Experiment (CORDEX)[6]. They rely on regional climate models with resolutions ranging from 50 km down to 12.5 km, which is enough to represent the larger islands but are still unable to represent small islands and lagoons (Figure 1). We also note that the CORDEX projections mostly use domains centered over continental regions, excluding vast fractions of the world ocean and the embedded islands, particularly in the Pacific Ocean. This means that the CORDEX projections are also not ideal for simulating island climates as the islands are often found near the boundaries, where the projections are less reliable, or the islands may not be included at all.

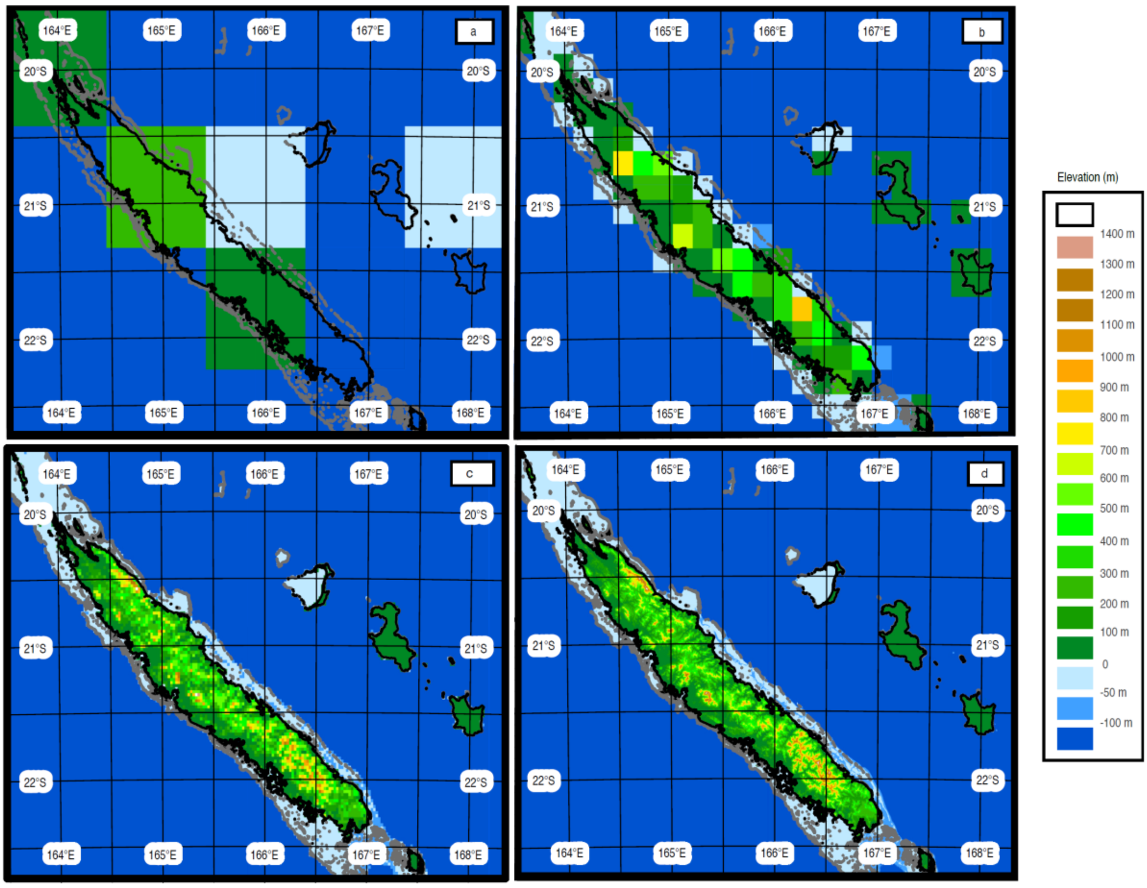

Figure 1: The topography and bathymetry of New Caledonia in the southwest Pacific at various resolutions. New-Caledonia's official topography (https://georep.nc/actualites/service-imagerie-sur-le-mnt) and bathymetry

(https://georep.nc/actualites/bathymetrie-du-parc-naturel-de-la-mer-de-corail) regridded at a) 100km resolution, b) 25 km, c) 2.5 km and d) 100m. The original horizontal resolution of the topography is 10m and the bathymetry is 100m. The colours show the elevation above (or below) the mean sea level at Nouméa. The land border is shown in black. The lagoon and reef limits are shown in gray.

Whether obtaining projections from global or regional climate models, these issues are problematic as we know that the climate on islands differs from the open ocean around them[7]. This is due to climatic processes such as the differential heating of land and ocean that leads to local atmospheric circulations like sea-breezes, convection and the presence of sometimes steep topography that typically leads to precipitation enhancement on the windward side of mountains and formation of rain shadows on the leeward side, particularly for tropical islands in stable trade-wind regime[8,9]. Extreme events such as tropical cyclones also lead to complex impacts when making landfall on islands due to topography and other local effects[10]. In lagoons, where most coral reefs reside and are under increasing threat of bleaching, shallow waters and complex geomorphology combine to produce specific hydrodynamic processes[11]. How these island climate processes will change with global warming remains largely unknown but is key to understanding how climate change risks will evolve over small island states and territories.

Future Steps: Enhancing Climate Projections for Small Island States

Clearly, small island states and territories need more reliable, higher-confidence projections of changes in all relevant climate hazards in order to understand and adapt to the risks they pose to human societies and ecosystems. The characteristics of the required projections would include:

- Model resolution high enough to accurately capture the island topography, shallow water lagoons, local circulations, ocean/atmosphere/land coupling and precipitation mechanisms.
- Computational domains large enough to adequately capture important regional features such as the Inter-tropical Convergence Zone, South Pacific Convergence zone, tropical cyclones and mid-latitude storm tracks, among others.
- Ensembles designed to span plausible climate futures, including emission scenarios aligned with the Paris agreement and higher emission scenarios in-line with current emissions trajectories.

For most islands this will require projections at convection permitting (~1 km) resolution nested within large domains simulated at resolutions in the 10-20km range, which are only starting to become available[9,12]. Islands surrounded with lagoons will require embedding even higher resolution[13]. Ensuring adequate ensemble size will require the collaborative work of many regional climate modeling groups around the world, as well as novel approaches combining dynamical and statistical downscaling or artificial intelligence to reduce computational costs[14]. Such an effort could be enabled through existing international collaborative frameworks such as CORDEX.

To enable the creation of these required projections we need to:

- Invest in the development of very high resolution regional climate models to better represent physical processes at the local scale, on land and its coastal surroundings. This requires models capable of long simulations with resolutions of a kilometer or better for atmospheric processes and even higher resolution to represent their often complex coastal environments.
- Explore the use of artificial intelligence/machine learning techniques as a complementary method to simulate local climates, quantify internal climate variability and better sample the full range of climate uncertainty. Such methods may provide a very cost-effective way to produce the large simulation ensembles needed to increase the robustness of, and confidence in, local climate projections.
- Enhance the collection, sharing, and analysis of climate-related observational and model data through regional cooperation and partnerships between island states and territories, research institutions, and international organizations. This could expand the role of the World Meteorological Organisation Regional Climate Centres and requires capabilities similar to those available through EU Copernicus.
- Empower local research communities, regional organizations, and governments with the knowledge and tools to participate in and contribute to the climate modeling and communication process, ensuring that projections are relevant and utilized in decision-making on the islands.
- Secure increased international funding and support for climate research in small islands including targeted efforts within international initiatives such as CORDEX, recognizing their limited resources and heightened vulnerability.

Small island states and territories are at the forefront of climate change impacts. There is a critical need for more accurate and comprehensive climate change projections for the islands. We call for rapid global and regional cooperation to develop high-resolution projections compatible with small island scales. It will require a funded, coordinated, international collaborative effort to ensure that small island states and territories can move beyond sea level rise impacts and understand their full spectrum of climate change related risks.

Competing Interests

The authors declare no competing interests.

1. Mycoo, M. *et al.* in *Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (eds. Portner, H.-O. et al.) 2043–2122 (Cambridge University

Press, Cambridge, 2023). doi:10.1017/9781009325844.017.

2. Monioudi, I. N. *et al. Reg Environ Change* **18**, 2211–2225 (2018).
3. Barnett, J. & Waters, E. in *The Palgrave Handbook of International Development* (eds. Grugel, J. & Hammett, D.) 731–748 (Palgrave Macmillan UK, London, 2016). doi:10.1057/978-1-137-42724-3_40.
4. IPCC. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2021). doi:10.1017/9781009157896.
5. IPCC. *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2022). doi:10.1017/9781009325844.
6. Giorgi, F., Jones, C. & Asrar, G. R. *WMO Bulletin* **58**, 175–183 (2009).
7. Cantet, P., Déqué, M., Palany, P. & Maridet, J.-L. *Tellus A: Dynamic Meteorology and Oceanography* **66**, 24065 (2014).
8. Lefèvre, J., Marchesiello, P., Jourdain, N. C., Menkes, C. & Leroy, A. *Marine Pollution Bulletin* **61**, 413–431 (2010).
9. Dutheil, C. *et al. Clim Dyn* **56**, 87–108 (2021).
10. Cécé, R. *et al. Natural Hazards and Earth System Sciences* **21**, 129–145 (2021).
11. Monismith, S. G. Hydrodynamics of Coral Reefs. *Annual Review of Fluid Mechanics* **39**, 37–55 (2007).
12. Fandrich, K. M., Timm, O. E., Zhang, C. & Giambelluca, T. W. *Journal of Geophysical Research: Atmospheres* **127**, e2021JD035684 (2022).
13. Martins, K. *et al. Ocean Modelling* **179**, 102110 (2022).
14. Rampal, N. *et al. Artificial Intelligence for the Earth Systems* **3**, 230066 (2024).