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1 Editor summary:

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3 Small islands are particularly vulnerable to climate change. Here, the authors argue that
4 higher resolution projections are needed to capture the impacts global warming has on these
5 islands.

Higher resolution projections needed for small island climates

Jason P. Evans¹, Ali Belmadani², Christophe Menkes³, Tannecia Stephenson⁴, Marcus Thatcher⁵, Peter B. Gibson⁶ & Alexandre Peltier⁷

¹ Australian Research Council Centre of Excellence for Weather of the 21st Century and the Climate Change Research Centre, University of New South Wales, Australia

² Météo-France, École Nationale de la Météorologie, Toulouse, France & CNRM, Université de Toulouse, Météo-France, CNRS, Toulouse, France

³ ENTROPIE (IRD, Ifremer, Université de la Nouvelle Calédonie, CNRS, Université de la Réunion), Noumea, New Caledonia

⁴ Department of Physics, The University of the West Indies, Mona, Jamaica

⁵ Commonwealth Scientific and Industrial Research Organisation (CSIRO), Melbourne, Australia

⁶ National Institute of Water and Atmospheric Research (NIWA), Wellington, New Zealand

⁷ Météo-France, interregional office in New Caledonia and Wallis-and-Futuna, Noumea, New Caledonia

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 rise¹. 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

52 confidence. For the Small Islands chapter of Working Group II¹, ~90% of the climate
53 projections used came from global climate models (25 out of 28 studies with climate
54 projections). These global models use coarse horizontal resolution, generally 100 km or
55 larger, such that many small islands simply do not exist in these models (Figure 1). On the
56 ocean side, coastal and lagoon environments that provide essential ecosystem services and
57 food resources are also not resolved. This means that most of the climate change
58 projections used at the location of small islands are actually representative of the open and
59 deep ocean rather than an island and its shallow waters.

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

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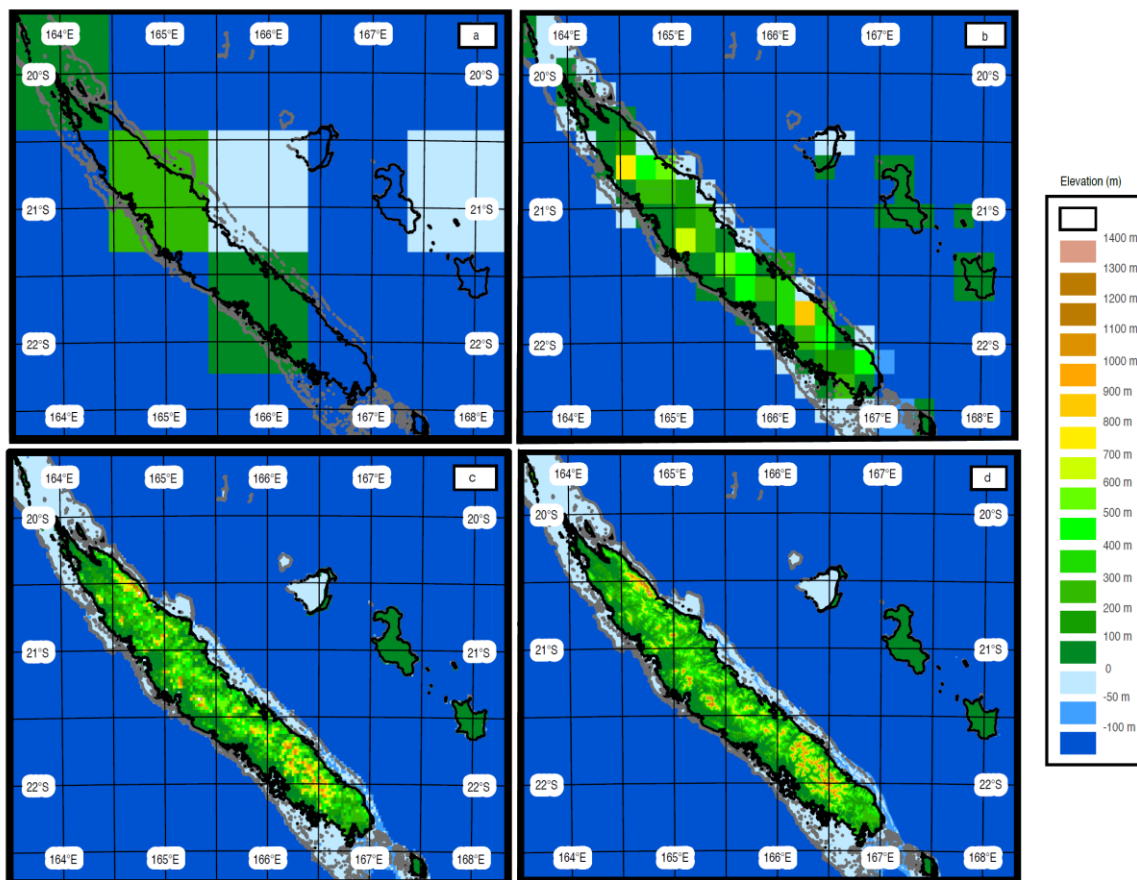


Figure 1: The topography and bathymetry of New Caledonia in the southwest Pacific at various resolutions. New-Caledonia's official topography (<https://georep.nc/actualites/service-imagerie-sur-le-mnt>) and bathymetry

(<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.

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73 Whether obtaining projections from global or regional climate models, these issues are
74 problematic as we know that the climate on islands differs from the open ocean around
75 them⁷. This is due to climatic processes such as the differential heating of land and ocean
76 that leads to local atmospheric circulations like sea-breezes, convection and the presence of
77 sometimes steep topography that typically leads to precipitation enhancement on the
78 windward side of mountains and formation of rain shadows on the leeward side, particularly
79 for tropical islands in stable trade-wind regime^{8,9}. Extreme events such as tropical cyclones
80 also lead to complex impacts when making landfall on islands due to topography and other
81 local effects¹⁰. In lagoons, where most coral reefs reside and are under increasing threat of
82 bleaching, shallow waters and complex geomorphology combine to produce specific
83 hydrodynamic processes¹¹. How these island climate processes will change with global
84 warming remains largely unknown but is key to understanding how climate change risks will
85 evolve over small island states and territories.

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88 **Future Steps: Enhancing Climate Projections for Small Island States**

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

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

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104 For most islands this will require projections at convection permitting (~1 km) resolution
105 nested within large domains simulated at resolutions in the 10-20km range, which are only
106 starting to become available^{9,12}. Islands surrounded with lagoons will require embedding
107 even higher resolution¹³. Ensuring adequate ensemble size will require the collaborative
108 work of many regional climate modeling groups around the world, as well as novel
109 approaches combining dynamical and statistical downscaling or artificial intelligence to
110 reduce computational costs¹⁴. Such an effort could be enabled through existing international
111 collaborative frameworks such as CORDEX.

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

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

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

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148 **Competing Interests**

149 The authors declare no competing interests.

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