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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

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**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<sup>1</sup>. 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<sup>2,3</sup>. 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<sup>4,5</sup> 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 II<sup>1</sup>, ~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)<sup>6</sup>. 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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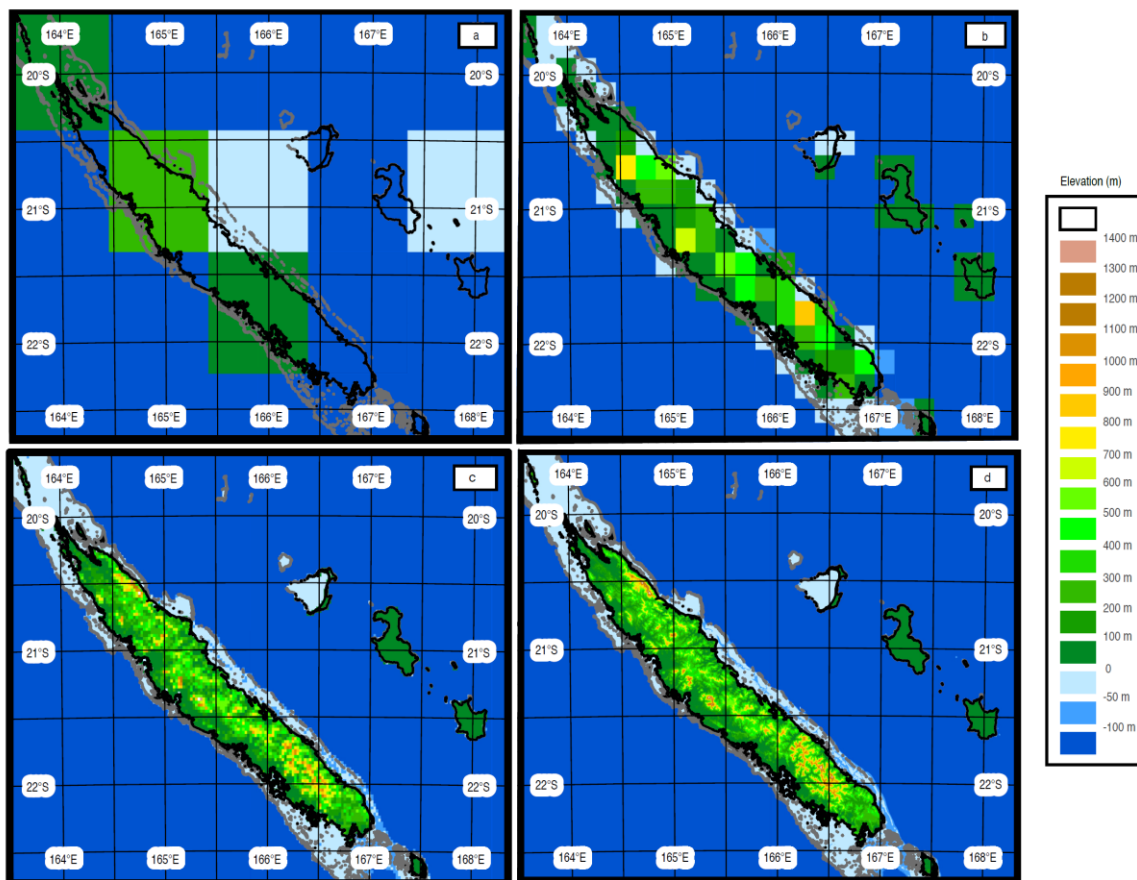


Figure 1: The topography and bathymetry of New Caledonia in the southwest Pacific at various resolutions. New-Caledonia's official topography (<https://georep.nc/actualites/service-imagerie-sur-le-mnt>) and bathymetry

(<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 them<sup>7</sup>. 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<sup>8,9</sup>. Extreme events such as tropical cyclones  
80 also lead to complex impacts when making landfall on islands due to topography and other  
81 local effects<sup>10</sup>. 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 processes<sup>11</sup>. 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<sup>9,12</sup>. Islands surrounded with lagoons will require embedding  
107 even higher resolution<sup>13</sup>. 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 costs<sup>14</sup>. 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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