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Invited review article

Pacific decadal climate variability: Indices, patterns and tropical-extratropical interactions

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ABSTRACT

Pacific decadal variability (PDV) plays a critical role in the climate system. Here I present a review of indices and patterns of decadal climate variability in the Pacific from observations and palaeoclimate reconstructions. I examine the spatial characteristics of Pacific sea surface temperature variability and the metrics used to track observations of PDV. I find commonalities between the PDV patterns, the Interdecadal Pacific Oscillation (IPO) and its North and South Pacific counterparts, the Pacific Decadal and South Pacific Decadal Oscillations (PDO and SPDO). I present a tool to provide probabilistic quantification of the recent state of the IPO, and use the tool to provide reliable estimates of IPO state up to 2 years prior to the present. The tool indicates a probability of 80–90% that the IPO remained in its negative state until 2014–2015. I review palaeoclimate reconstructions of the IPO and PDO, and outline advances and challenges in our pre-instrumental understanding of PDV. I draw attention to a Pacific-wide tropical-extratropical mechanism that suggests that the cool and warm phases of PDV are not driven by tropical or extratropical variability alone, but are instead the result of continuous tropical-extratropical interactions on decadal timescales. I conclude by noting key sources of remaining uncertainty and emphasising the need to better understand decadal variability. This will occur through continual improvements in observations, an expansion of palaeoclimate exploration and data collection, and renewed efforts in model development.

1. Introduction

Variability on decadal timescales is critically important for planning. It is the intermediate timescale nestled between the better understood and more predictable interannual climate variability such as that associated with the El Niño Southern Oscillation (ENSO) and North Atlantic Oscillation (NAO) and the centennial and longer timescale changes due to external factors such as rising greenhouse gas emissions. Decadal-scale changes in the mean climate state are near enough to pose tangible risks to existing critical infrastructure, but long enough to be a significant challenge to climate prediction (Meehl et al., 2009). These challenges are due primarily to the limitations of an under-observed climate and its chaotic natural variability sensitive to initial conditions.

Decadal variations in the risk of extreme episodes such as floods, droughts and heatwaves have implications for risk assessment, with direct relevance to the insurance industry, the value of public and private assets and the safety of engineered materials and structures which have typically been designed under the assumption of risk stationarity. Agricultural and water supply systems are typically designed to withstand seasonal to interannual variability. But hydrological persistence on decadal timescales can pose additional unplanned threats to human and natural systems. Near term decadal prediction is now an intrinsic part of climate change projection and has a prominent chapter in the regular Assessment Reports (e.g. AR5) of the Intergovernmental Panel on Climate Change (IPCC, Kirtman et al., 2013).

Natural internal patterns of Pacific decadal variability (PDV), particularly the Interdecadal Pacific Oscillation (IPO, Folland et al., 1999; Power et al., 1999), the closely-related Pacific Decadal Oscillation (PDO, Mantua et al., 1997) and the Atlantic Multidecadal Oscillation (AMO, Knight et al., 2005) have been implicated in periods of acceleration and slowdown in the rate of global warming at the surface in the post-industrial period (England et al., 2014; Maher et al., 2014; Kosaka and Xie, 2013, 2016; Fyfe et al., 2016; Crowley et al., 2014). These patterns are also responsible for coherent and persistent hydroclimatic impacts globally. The uncertainty in the trajectory of global mean surface temperature in the coming 1–2 decades due to internal climate variability is higher than the uncertainty from emissions scenarios (Hawkins and Sutton, 2009). This places decadal variability and decadal prediction firmly in the spotlight.

The El Niño Southern Oscillation (ENSO) is at the heart of the

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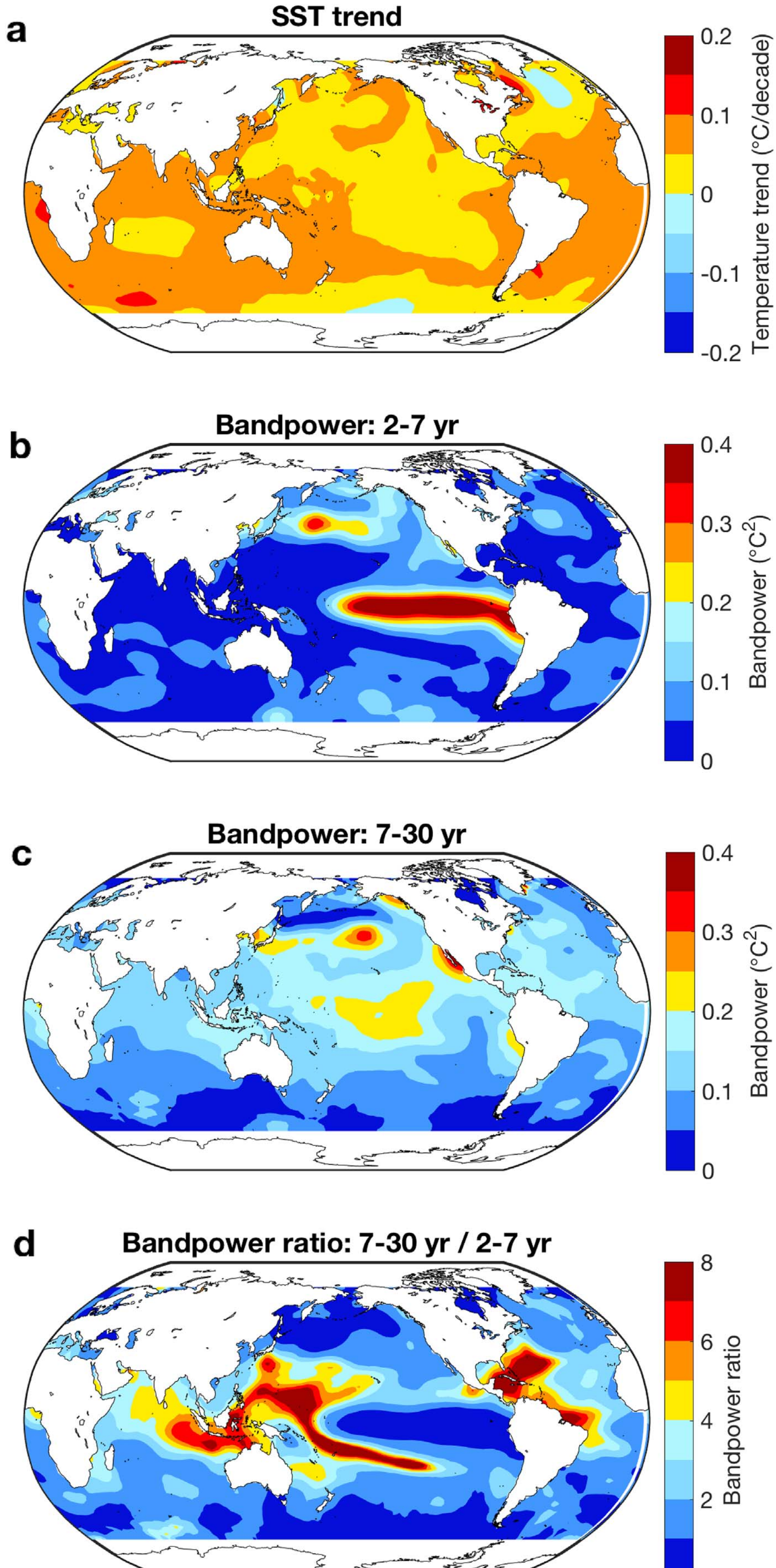

Fig. 1. Trend and persistence in global sea surface temperature for 1900–2016. a) Trend in global SST (linear regression coefficient), b) average bandpower in the 2–7 year and c) 7–30 year frequency bands and d) ratio of bandpower between the two bands.