Characteristics and Trends of the Campbell Plateau Meander in the Southern Ocean: 1993-2020

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The Campbell Plateau meander has clear trends over the past 27 years:

- *Position*: relatively fixed, but downstream part moving northward.
- *Amplitude*: flattening upstream from the Plateau; flexing downstream from the Plateau.
- *Width & speed*: widening and accelerating, particularly downstream from the Plateau.
- *Similar* trends compared to the Agulhas-Kerguelen standing meander.

Introduction

- The Southern Ocean is warming & freshening [Punich et al. (2018); Cheng et al. (2020)].
- The westerly winds that drive the Antarctic Circumpolar Current are intensifying & shifting poleward [Swart & Fyfe, 2012].
- **Fronts**: boundaries between water masses of different properties [Orsi et al. 1995].
- **Meanders**: non-zonal fronts weaving horizontally and vertically [Hughes et al. 2005].
- Positions of fronts have **not** moved significantly meridionally over the past three decades [Chapman, 2017].
- **Characteristics** of meanders have changed [Thompson & Naveira Garabato, 2014].

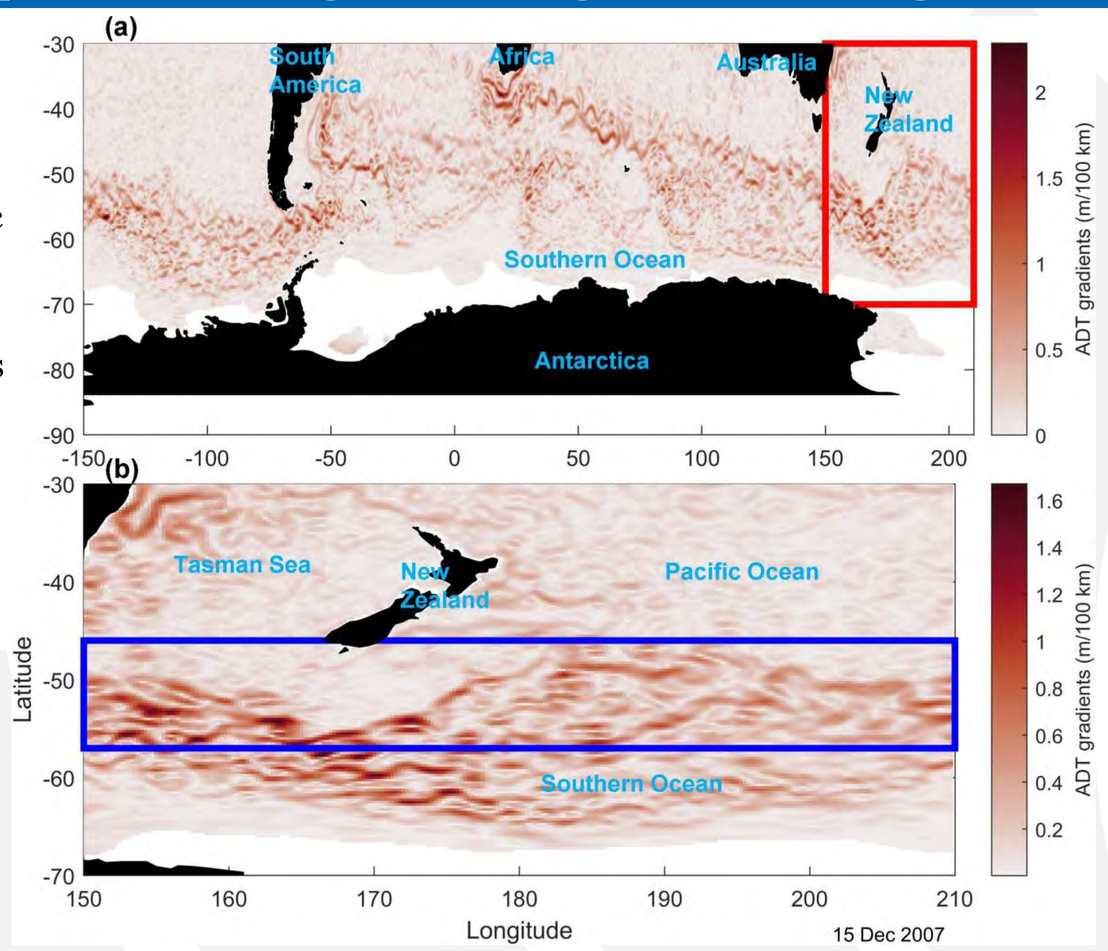

Figure 1: Snapshot of the absolute dynamic topography (ADT) gradients in m/100 km on 15 December 2007 in (a) the Southern Ocean and (b) the Campbell Plateau region. The red rectangle in (a) represents the Campbell Plateau region shown in (b), which is the study region. The blue rectangle in (b) indicates the smaller domain where the meander's latitude and longitude positions are identified. White areas are regions where no satellite altimetry data were available.

Data and Methods

- CMEMS AVISO altimetry data: absolute dynamic topography and surface geostrophic current velocities [1993-2020].
- A "**local gradient maxima**" method: based on Chapman (2017) & Meyer et al. (in prep):
  - I. Calculate the absolute dynamic topography gradients in the Campbell Plateau region.
  - II. Identify the Campbell Plateau meander's daily position.
  - III. Derive the meander's time-averaged positions.
  - IV. Identify the meander's key standing peaks and troughs.
  - V. Determine the meander's width and speed.

Motivation

- A lot has been done on the Southern Ocean fronts, their characteristics and response to climate change, but much *less* is known about meanders.
- The Southern Ocean standing meander regions are recognised as dynamical hotspots, where upwelling, subduction, cross-frontal exchanges, vertical momentum transport and eddy energy are enhanced.

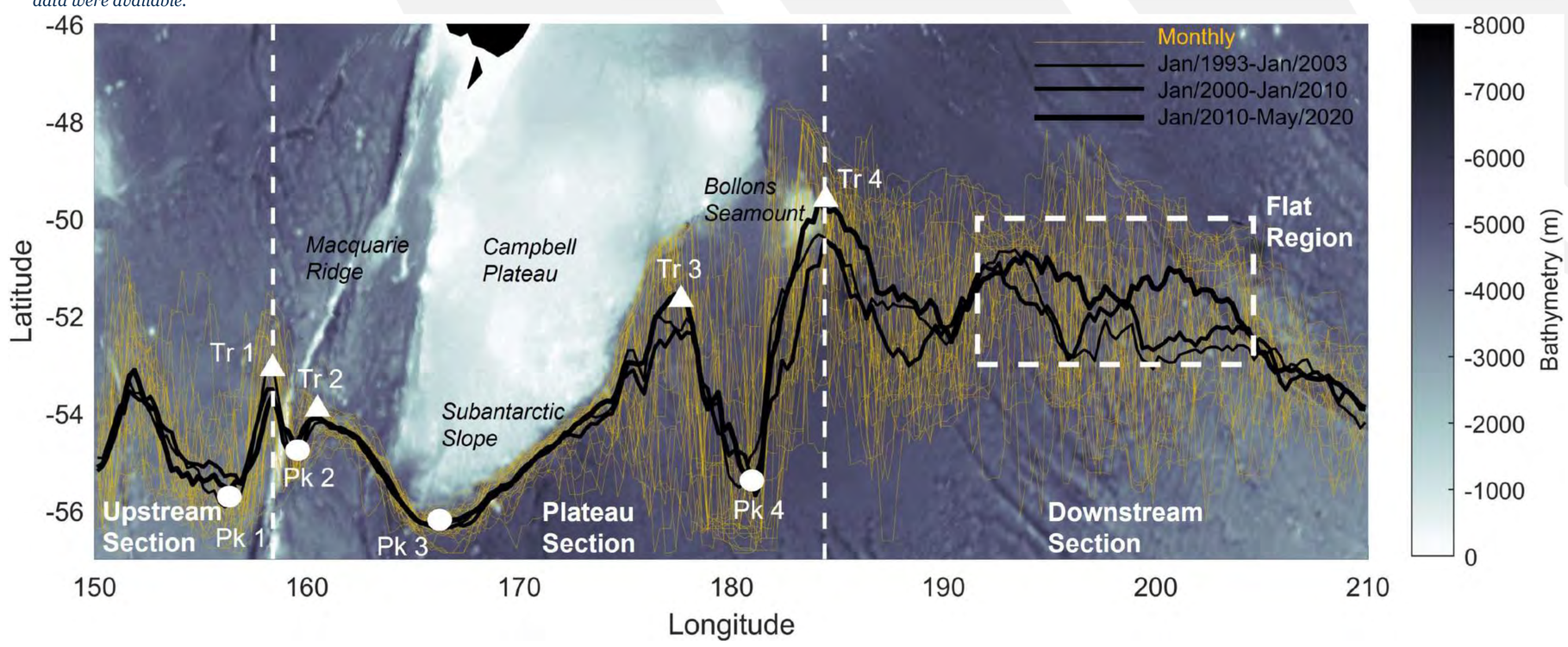

Figure 2: The Campbell Plateau meander's mean positions over three different decades (black lines) and monthly positions at the ten-month interval (yellow lines) between 1993 and 2020. Four peaks (white circles) and four troughs (white triangles) of the meander are marked along the meander's trajectory (Pk 1 to Pk 4 and Tr 1 to Tr 4). Also indicated are the three sections (Upstream, Plateau, and Downstream) of the meander separated by two white vertical dashed lines and the Flat Region (white dashed rectangle) is highlighted.

Results

- **Meander position**: Upstream & Plateau Sections not moving significantly in the meridional direction; Downstream Section significantly moving northward by 0.30° latitude per decade.
- **Meander amplitude**: decreasing by 0.31° latitude per decade (flattening) upstream from the Plateau; increasing by 0.25° latitude per decade (flexing) downstream from the Plateau.
- **Meander width**: mean value about 108km; whole meander significantly widening by 2.2 km per decade, mostly downstream (4.2 km per decade).
- **Meander speed**: whole meander significantly accelerating by 0.01 m s^{-1} per decade, mostly in the Flat Region downstream from the Plateau (0.02 m s^{-1} per decade).
- Comparing with the Agulhas-Kerguelen standing meander, the overall trends are **similar**: no southward displacements; similar mean widths and widening & accelerating trends.

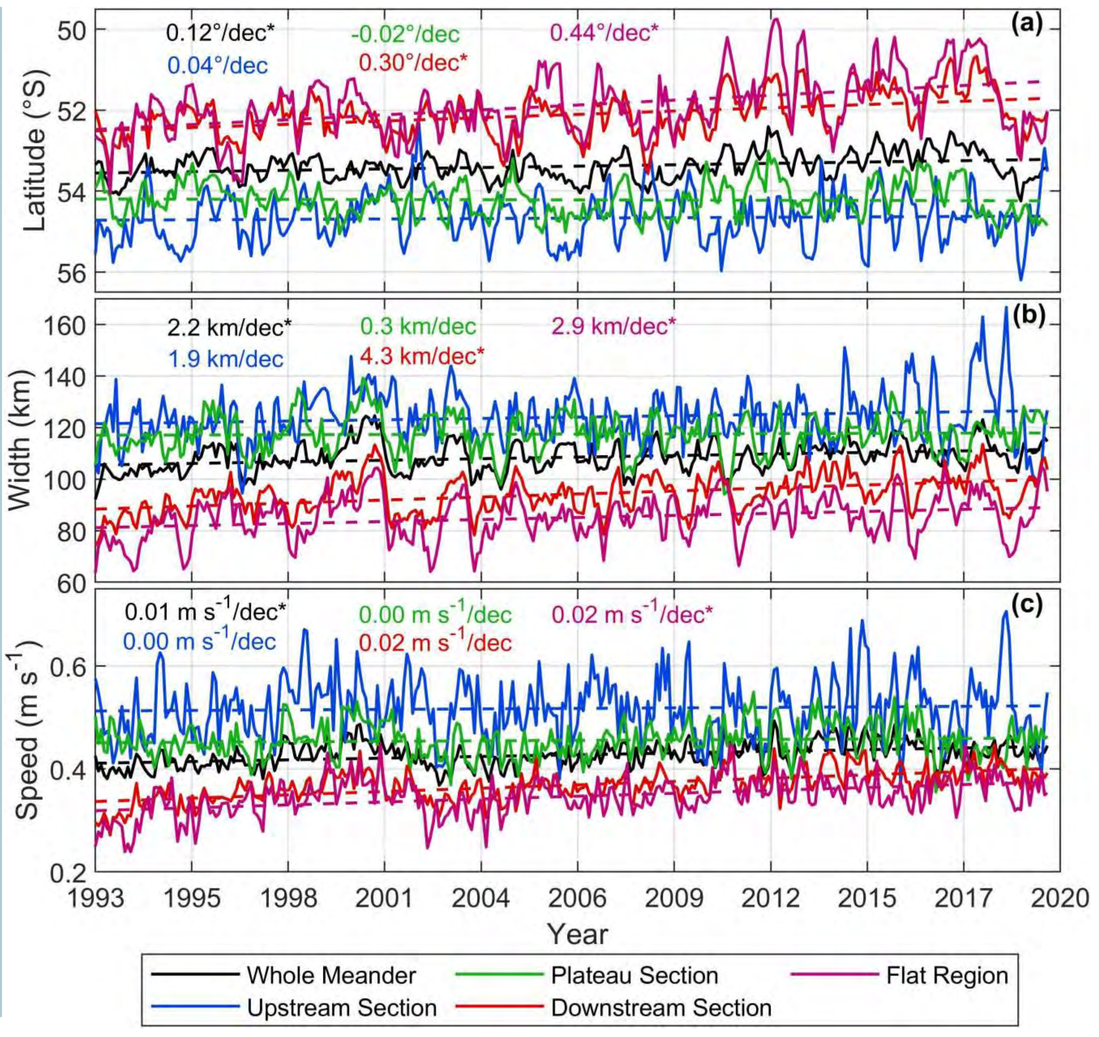

Figure 3: Monthly time series (solid lines) and corresponding linear trends (dashed lines) over the 1993-2020 period of the Campbell Plateau meander's (a) mean latitude position (degrees latitude per decade), (b) width (km per decade), and (c) geostrophic current speed (m s^{-1} per decade). Positive trend values in the mean latitude position, width, and geostrophic current speed represent the northward movement, widening, and accelerating of the meander; while negative trends indicate the southward movement, narrowing, and decelerating of the meander. Statistically significant trends are indicated with ''.*

Discussions

- ***Downstream Section significantly moving northward*:**
  - **Hypotheses: 1. Changes in the dynamic stability of the jet [Youngs et al. (2017); Barthel et al. (2022)]; 2. Interaction between the South Pacific gyre and Antarctic Circumpolar Current jets [Roemmich et al. 2007].**
- ***Increasing width*:**
  - **Consistent with Gille (1994); Hypothesis: Changes in the meander's volume transport.**
- ***Increasing speed*:**
  - **Consistent with recent Southern Ocean studies [e.g., Shi et al. (2021)].**
  - **Hypotheses: 1. Increased wind forcing; 2. Increased buoyancy forcing [Shi et al. (2021); Peng et al. [2022)].**