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EOCENE AND OLIGOCENE VEGETATION IN THE ANTARCTIC REGION A REVIEW TO ASSIST GENERAL CIRCULATION MODEL EXPERIMENTS

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Introduction

With the advent of palaeoclimate earth system modelling, in conjunction with increased understanding of vegetation-climate feedbacks (e.g. albedo and the partitioning of sensible and latent heat flux between the land surface and the atmosphere), it has become important to characterise vegetation type and distribution during key geological periods because of their influence on climate model output.

Empirical data (including ice-rafted debris, a change in clay mineral composition and a significant d18O shift) suggest initiation of a substantial East Antarctic Ice sheet occurred around 34 Ma - the Eocene/Oligocene boundary. Recent coupled atmosphere-ice sheet modelling using the GENESIS (v2.1) GCM is investigating the initiation and persistence of Antarctic ice sheets from this time (Deconto and Pollard, 2003; DeConto and Pollard, in press). Results suggest that declining levels of atmospheric CO_2 set the scene for the initiation and subsequent behaviour of the East Antarctic Ice Sheet, triggered by specific orbital configurations.

In this study, empirical vegetation data from Antarctica, including fossil leaves, wood and terrestrial palynomorphs from glacial erratics, outcrop and near-offshore sediment cores, throughout the Eocene and Oligocene, are reviewed (Fig. 1, specific references available on request). Interpreted palaeotemperatures (normalised to mean annual temperature (MAT)) are compared to GCM model results, Dingle & Lavelle's (1998) relative palaeotemperature curve for the Antarctic Peninsula and selected ^{18}O derived bottom and surface ocean water temperature curves (Miller et al., 1987; Stott et al., 1990; Zachos et al., 1993).

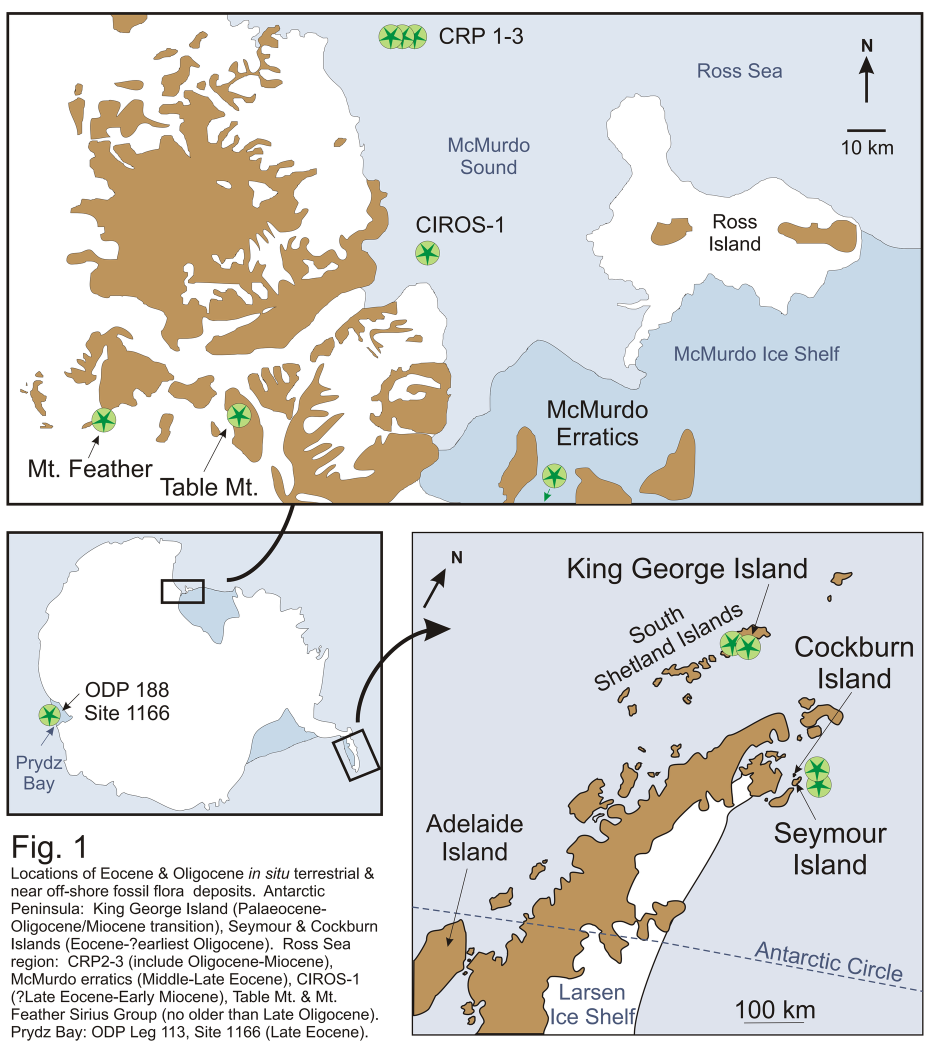


Fig. 1
Locations of Eocene & Oligocene *in situ* terrestrial & near off-shore fossil flora deposits. Antarctic Peninsula: King George Island (Palaeocene-Oligocene/Miocene transition), Seymour & Cockburn Islands (Eocene-?earliest Oligocene). Ross Sea region: CRP2-3 (include Oligocene-Miocene), McMurdo erratics (Middle-Late Eocene), CIROS-1 (?Late Eocene-Early Miocene), Table Mt. & Mt. Feather Sirius Group (no older than Late Oligocene). Prydz Bay: ODP Leg 113, Site 1166 (Late Eocene).

Key:

MWF Mount Wavel Formation
ACF Arctowski Cove Formation
PTF Point Thomas Formation
DIG Duyafel Island Group
FPG Fildes Peninsula Group
— King George Island, South Shetland Islands

LMF La Meseta Formation — Seymour & Cockburn Islands

Microphyllous fossil leaves (<8 cm long)
Notophyllous fossil leaves (8-12 cm long)
Terrestrial palynomorph flora
Fossil wood

Fossil Vegetation Review: Results

Continent-wide, the fossil flora can be divided into three zones representing a change from evergreen mixed broadleaf & needleleaf temperate forests (dominated by *Nothofagus* spp.) to tundra/low shrub vegetation from the Late Palaeocene to Early Miocene (Figs. 2 & 3). Through time, diversity decreases along with ocean water (and presumably terrestrial surface) temperatures and the canopy lowers and opens, thereby reducing albedo effects. The Eocene/Oligocene boundary at 34 Ma occurs within the transition zone from forest to tundra/low shrub.

Palaeotemperatures from the proxy vegetation records, summarised for each vegetation zone and region (Fig. 3), indicate a slightly warmer climate prevailed in the more oceanic Antarctic Peninsula (AP) region with MAT ranging from +5°C to +15°C from the Late Palaeocene to Early Miocene and throughout the Oligocene. In contrast, data from the continental margin Ross Sea & Prydz Bay (RSPB) regions suggest MAT ranges between -12°C and +13°C throughout the Eocene to Early Miocene.

Fig. 2

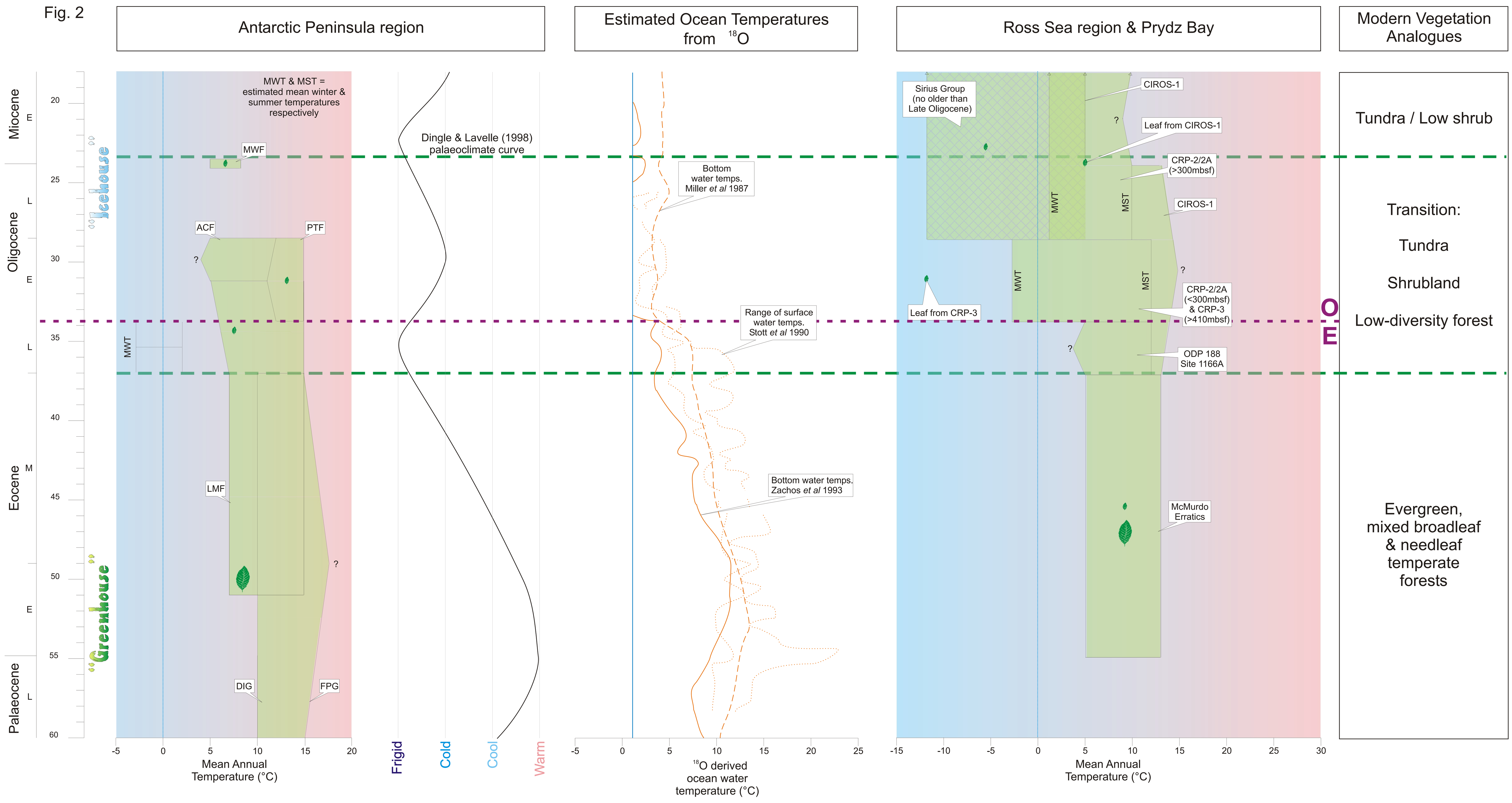
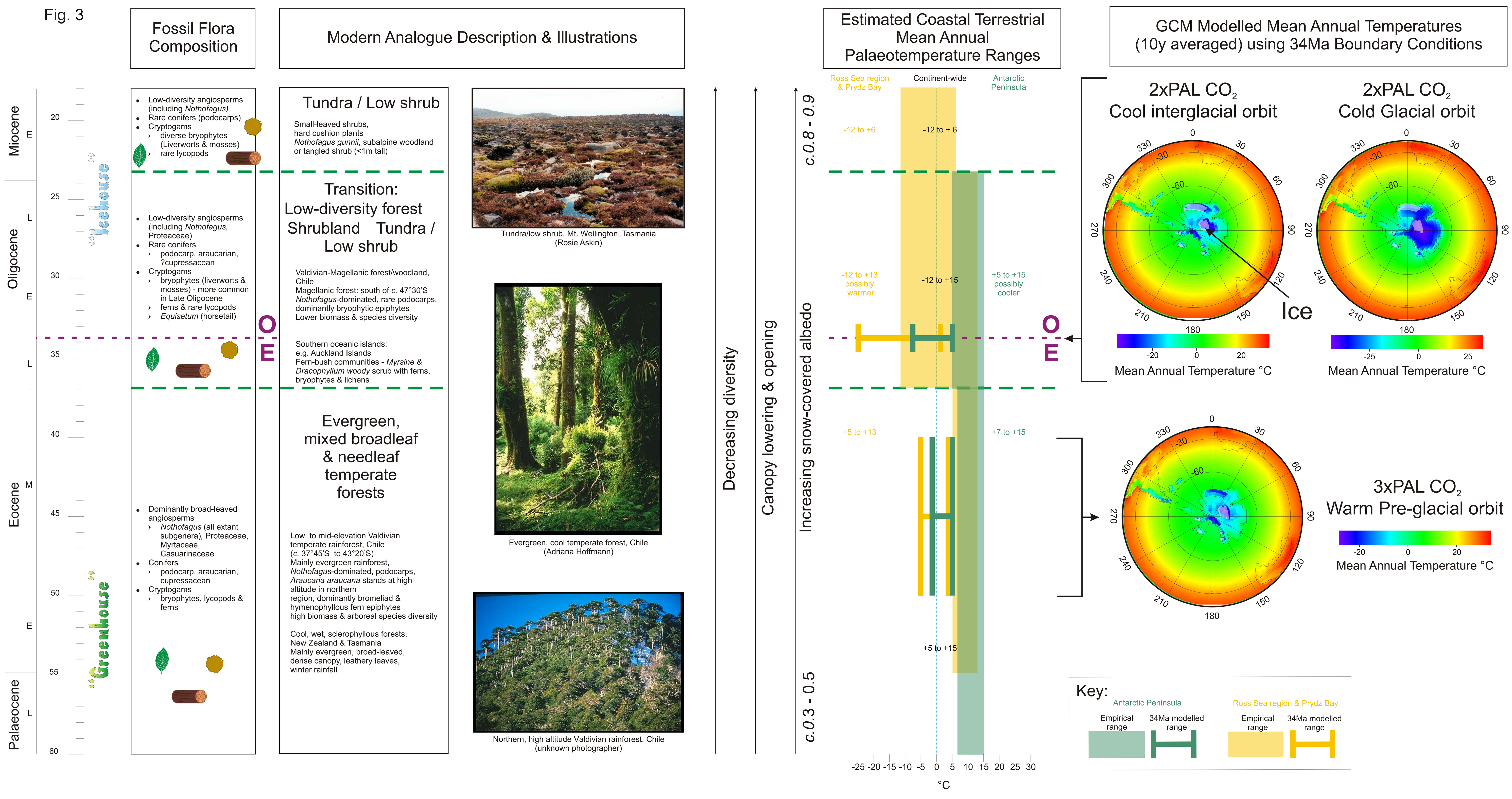


Fig. 3



Modelled MAT Results

Integrated models have been run using 34Ma boundary conditions including palaeogeography, topography, shorelines & a blanket tundra vegetation covering Antarctica and Greenland with mixed forest over the remainder of the terrestrial regions. Ice shelves are not included. Modelled 10y averaged MAT ranges for the AP and RSPB regions using 2x pre-industrial levels (PAL) of CO_2 have been extracted from polar stereographic GCM plots of snapshots at both a cool-interglacial (B) and cold-glacial (E) synthetic orbital configuration (Fig. 3). MAT ranges from both orbital configurations are combined to provide an overall modelled MAT range within each region at the Eocene/Oligocene boundary. Modelled MAT at 34Ma therefore ranges between -7.5°C and +5.0°C in the AP region and between -25.0°C and +1.0°C in the RSPB regions. Prydz Bay (-25.0°C to +1.0°C) is modelled cooler than the Ross Sea (-14.0°C to +1.0°C) perhaps due to the early initiation of a relatively thick ice sheet over the Gamburtsev Mountains.

A further snapshot of orbital configuration B, with the same boundary conditions as before, but run with 3x PAL CO_2 reflects a warm-preglacial scenario comparable to CO_2 levels reconstructed for 40, 45 and 50 Ma from proxy isotope data (Zachos et al 2001). Modelled 10yr averaged MAT ranges are therefore also plotted for both regions on Fig.3 ranging between 40 and 50Ma (AP -0.5°C to +5.0°C; RSPB -5.0°C to +4.0°C).

Conclusions

The upper limits of the modelled 10y averaged MAT ranges at 34 Ma for orbital configurations B and E at 2x PAL CO_2 appear to be relatively consistent with the lower limits of the proxy vegetation record with overlap present only in the RSPB regions. If ice shelves were included in the model, then modelled temperatures for the Antarctic Peninsula would presumably be even lower. Snow-covered albedo increases significantly from forest to tundra (Fig. 3), therefore replacement of the blanket tundra boundary condition with mixed tundra/low-diversity, mainly evergreen, broad-leaved forest vegetation would realistically model both vegetation types occurring continent-wide during the Eocene/Oligocene transition.

Selected References

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