Sea level and vertical motion of continents from dynamic models since the Late Cretaceous

Sonja Spasojević[1] (sonja@gps.caltech.edu) and Michael Gurnis[1]

[1]Seismological Laboratory, California Institute of Technology, USA

Global sea level predictions

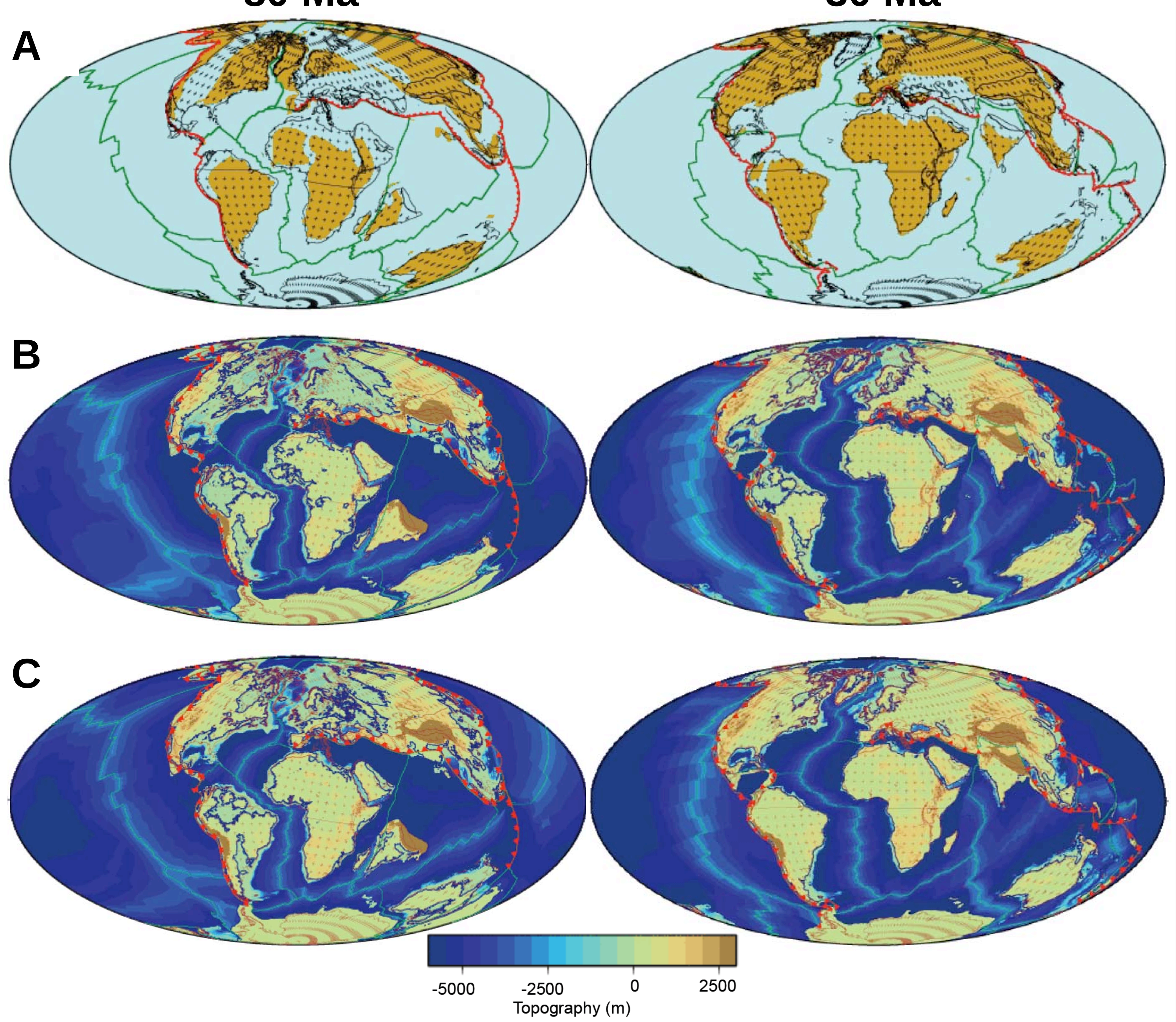


Fig 1. Comparison between paleogeographic reconstructions (A) [Smith et al,1994] and sea-level predictions accounting for: (B) dynamic topography, the geoid and changing ocean floor age (DYN-OFA models), and (C) changing ocean floor age (OFA models).

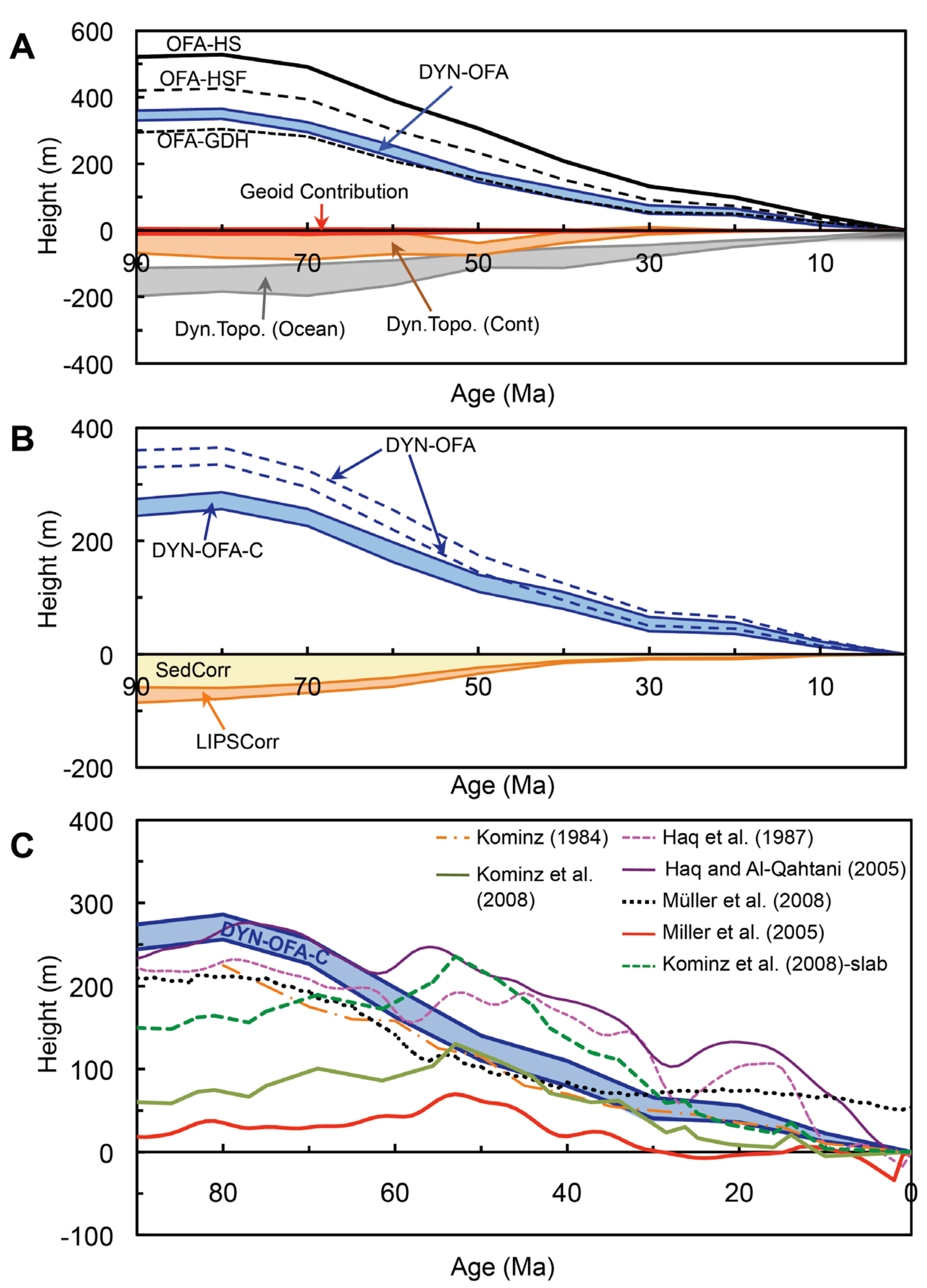


Fig 2. Global sea-level predictions. (A) Predictions accounting for changing sea floor age for half-space (OFA-HS), HS model with flattening (OFA-HSF), GDH-1 model (OFA-GDH), and DYN-OFA models, with the contribution of dynamic topography and geoid shown. (B) Final predictions of sea level from DYN-OFA models accounting for corrections (DYN-OFA-C) due to sedimentations. (C) Comparison between final prediction of sea level from DYN-OFA-C models and previously published sea-level curves.

Abstract

We develop hybrid dynamic earth models combining inverse and forward models of mantle convections in an effort to better understand the impact of mantle dynamics on vertical motion of continents and regional and global sea-level change since the Late Cretaceous. These models account for factors of long-term sea-level change: changing age of sea floor, dynamic topography in oceanic and continental regions, and the geoid. We infer the relative importance of dynamic vs. other factors of sea-level change, determine time-dependent patterns of dynamic subsidence and uplift of continents, and derive a sea-level curve.

We find that both dynamic factors and changing age of sea floor are important in controlling sea level (Fig.1). The dominant factor controlling global sea level is the changing age of sea floor, resulting in a large amplitude sea-level fall since the Late Cretaceous, with dynamic topography offsetting this fall. We find the maximum amplitude of sea level of 286 m to be reached at 80 Ma (Fig. 2). We track movement of continents over large-scale dynamic topography by consistently mapping between mantle and plate frames of reference, and we find that this movement results in continental dynamic subsidence and uplift (Fig. 3). Regional sea level is largely controlled by mantle dynamics in North and South America in the last 90 million years, Australia during Cenozoic, North Africa and Arabia in the last 40 million years, and southeast Asia in Oligocene-Miocene period (Fig. 3). Dynamic uplift affects East and South Africa in last 20-30 million years (Fig. 3). We also find models consistent with the evidence for Cenozoic tilting of Siberia (down to east) (Fig. 5) and Australia (down to NNE).

Model setup and predictions

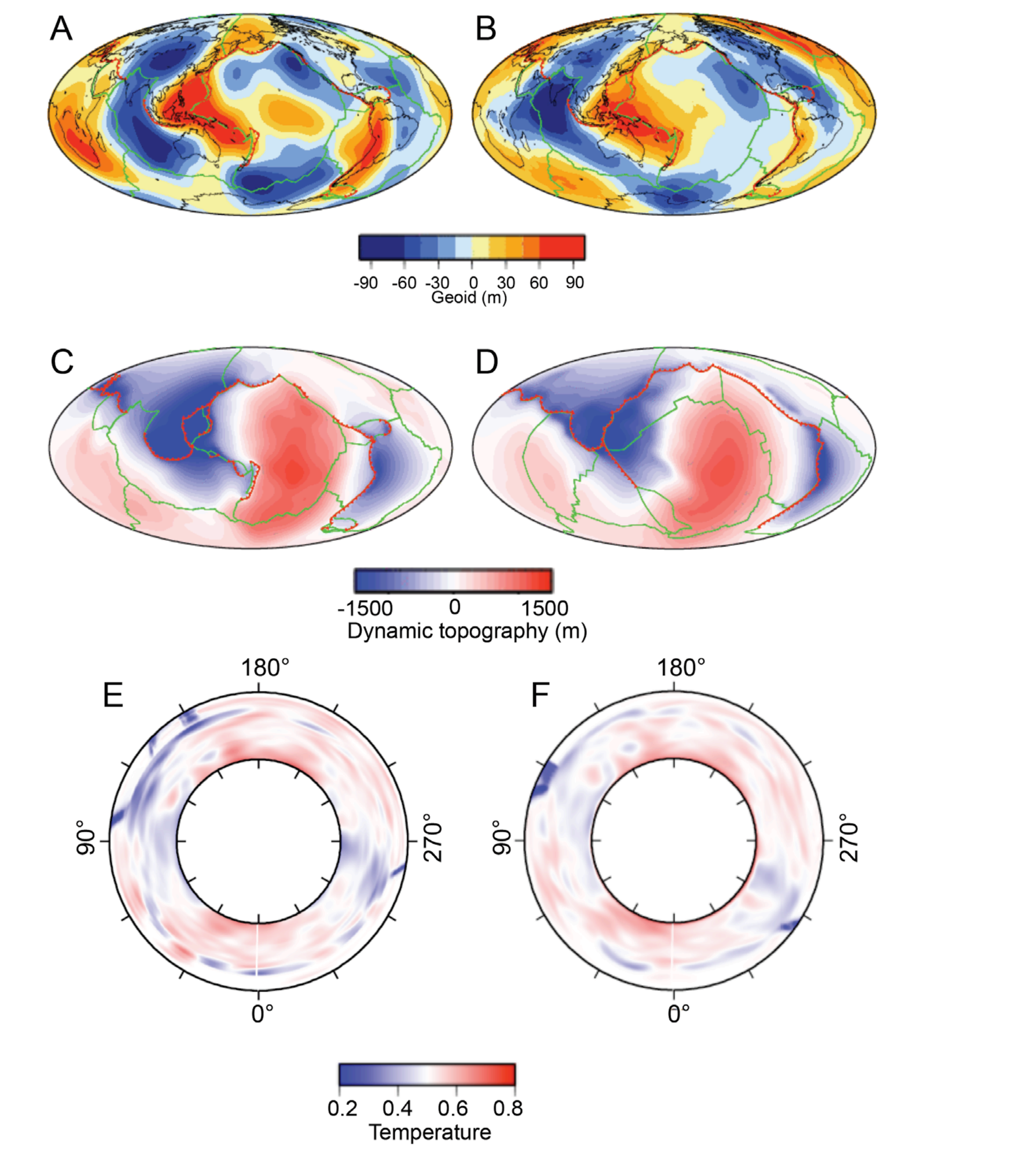
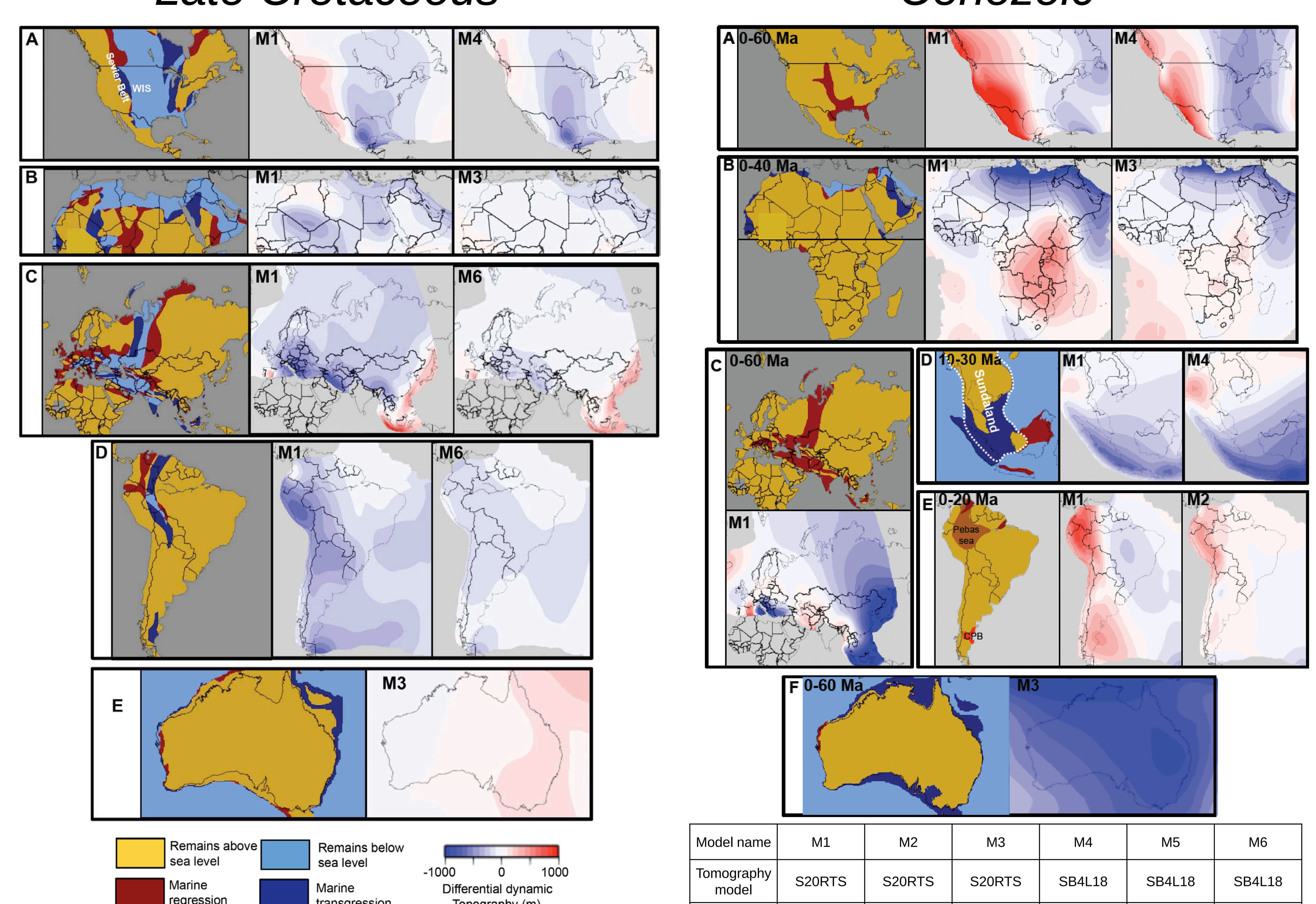


Fig 4. Predicted (A) and observed geoid (B), dynamic topography at 0 Ma (C) and 80 Ma (D), and cross-sections through thermal buoyancy field at 0 Ma (E) and 80 Ma (F)

Relative sea-level change and vertical motion of continents

Late Cretaceous / *Cenozoic*



Model name	M1	M2	M3	M4	M5	M6
Tomography model	S20RTS	S20RTS	S20RTS	SB4L18	SB4L18	SB4L18
UM:LM viscosity	1:20	1:60	1:100	1:20	1:60	1:100

Fig 3. Comparison between relative sea-level change inferred from paleogeography (first panel in each figure part) with differential dynamic topography for models M1-M6 (parameters shown in the table)

Cenozoic tilting of Siberia

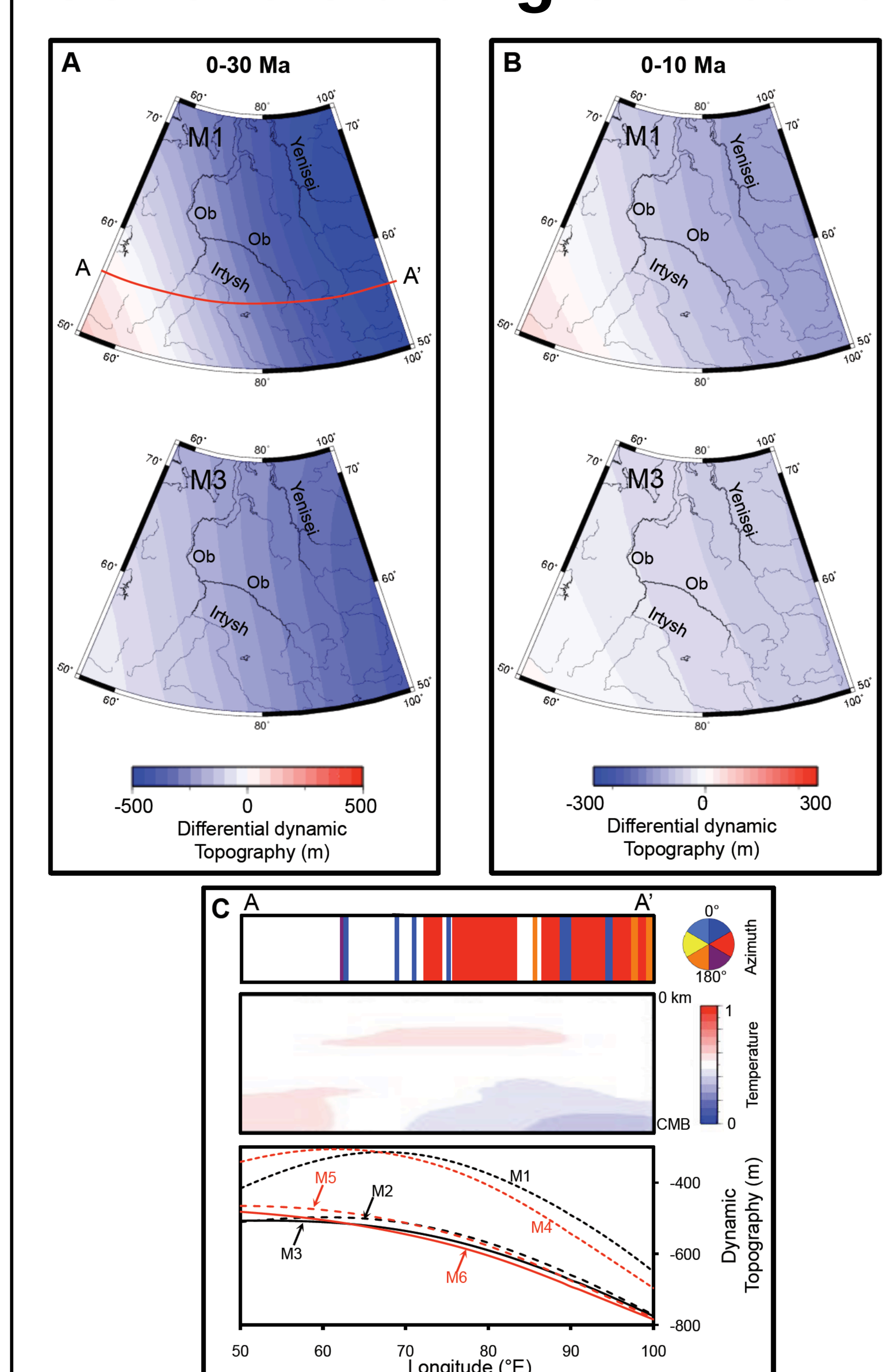


Fig 5. Inferred tilting of Western Siberia from dynamic models (A-B), compared with drainage shift directions (C) [Allen and Davies, 2007]