Dynamics of a Snowball Earth Ocean

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- Nature
- Size of evidence set:
  - 2 6-panel figures, 1 3-panel figures showing model results
  - No legit magic numbers (hypothetical numbers in model results)

Fig 1

Presenting “argued” data here as what would have occurred under model parameters

Panels e and f showing a relationship(?)

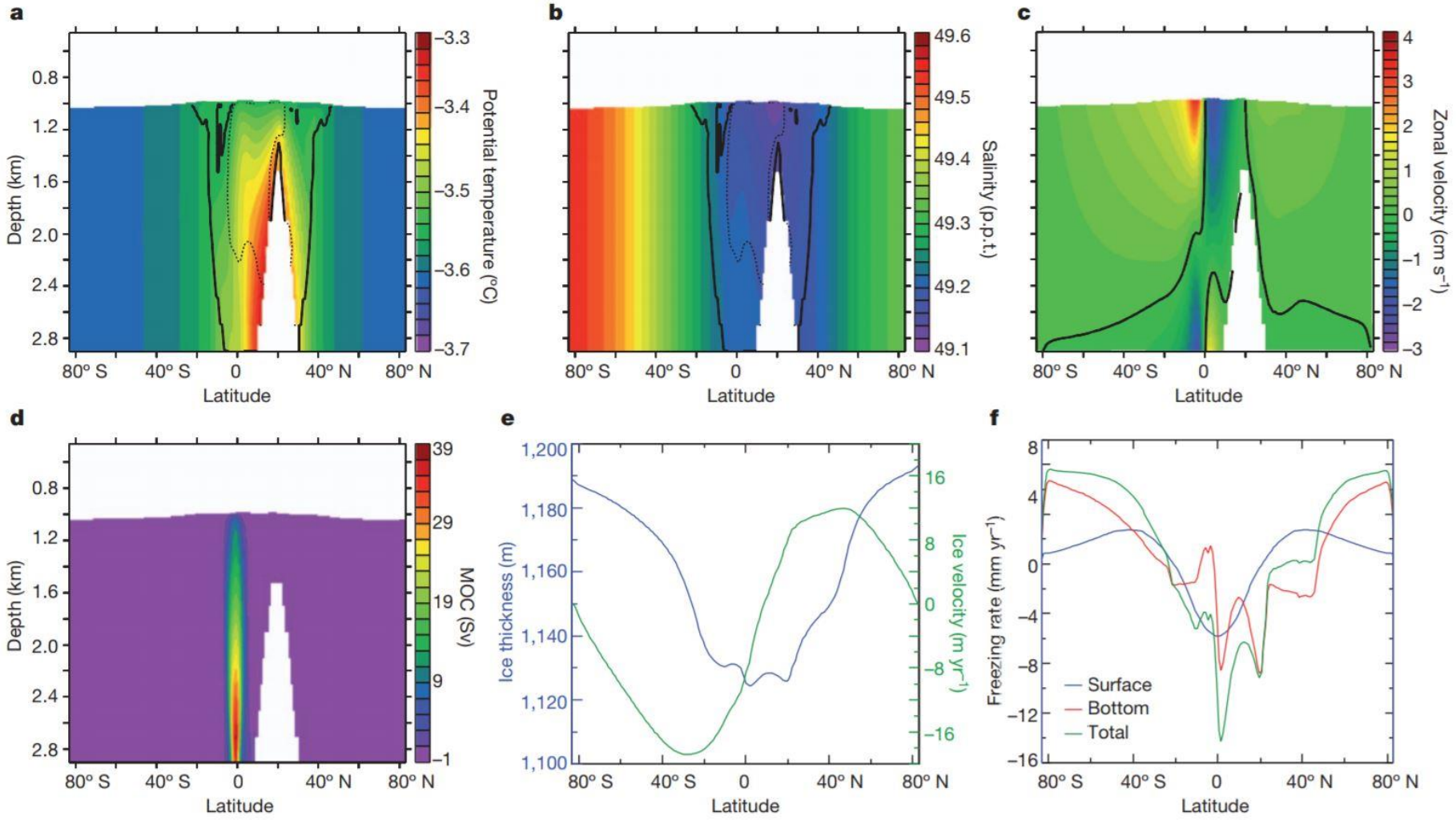


Fig 2

Presenting "argued" data here as what would have occurred under model parameters

Panel f showing a relationship(?)

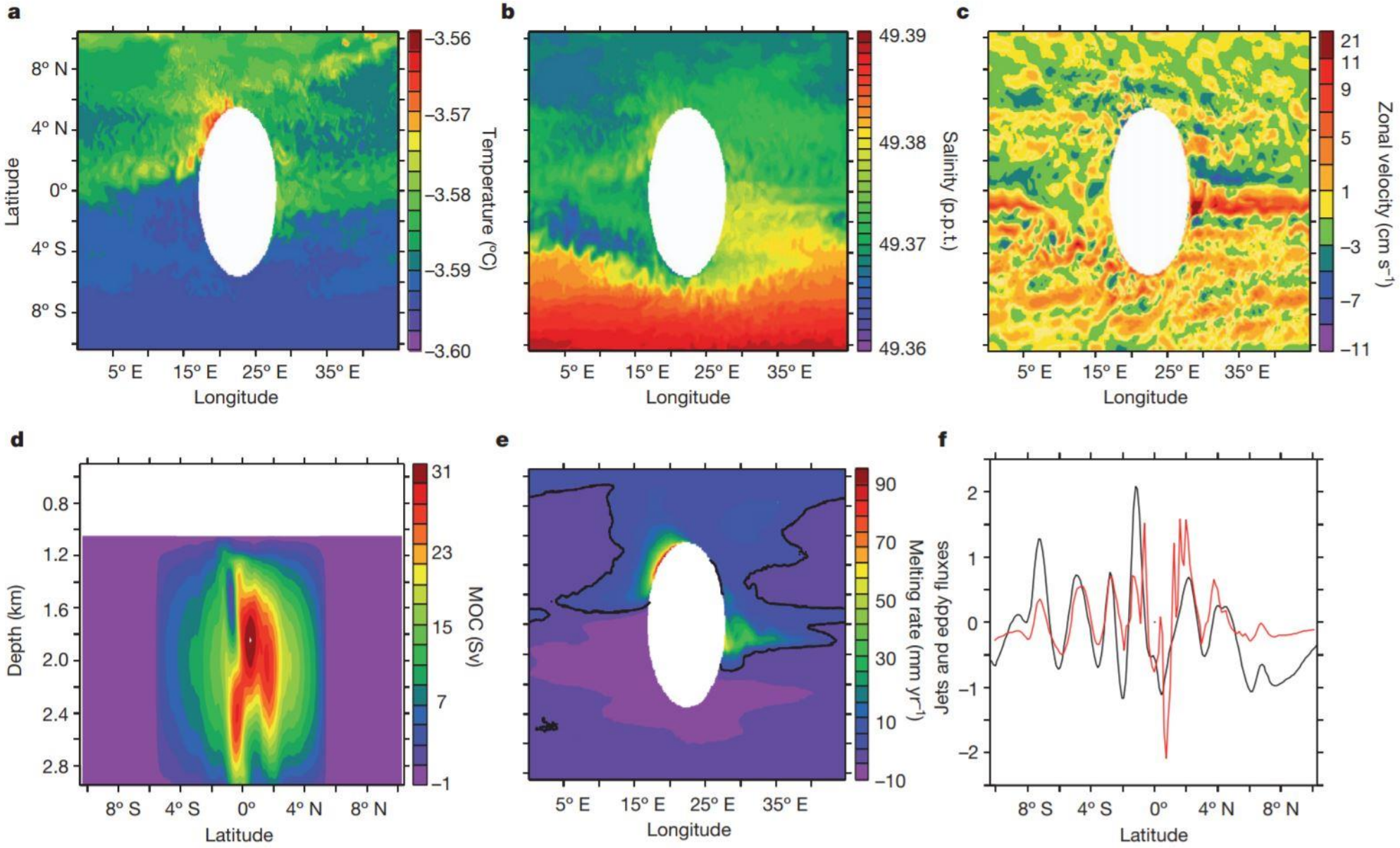
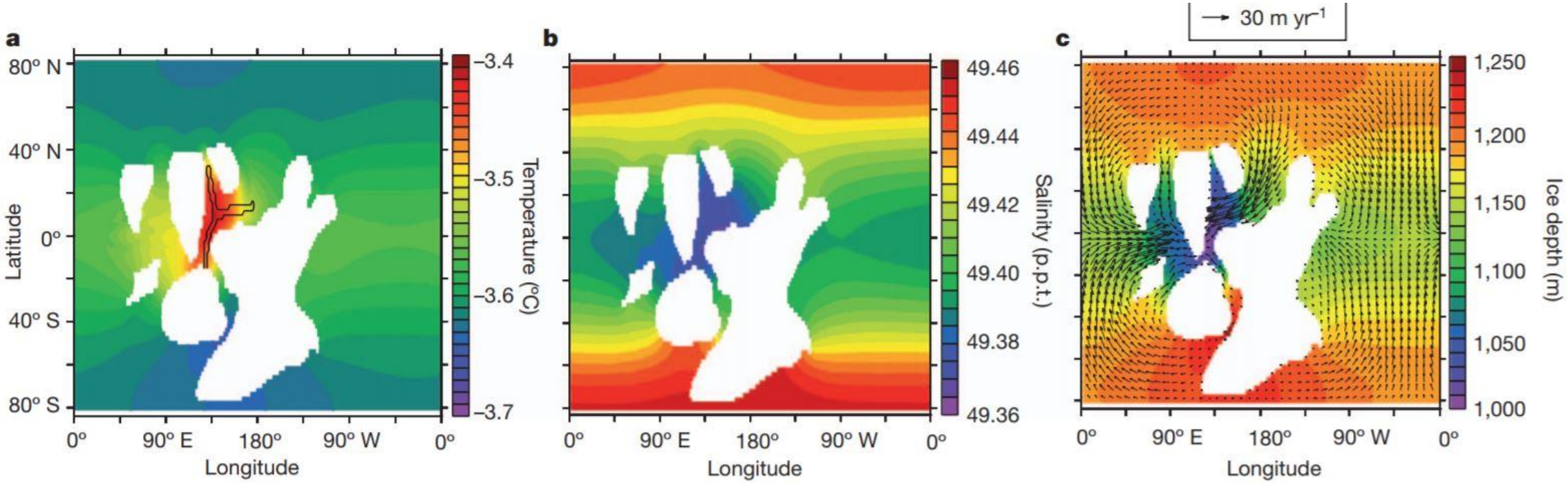


Fig 3



Presenting “argued” data here as what would have occurred under model parameters

30 m yr-1 showing a magic number?

Geological evidence suggests that marine ice extended to the Equator at least twice during the Neoproterozoic era (about 750 to 635 million years ago)1,2, inspiring the Snowball Earth hypothesis that the Earth was globally ice-covered3,4. In a possible Snowball Earth climate, ocean circulation and mixing processes would have set the melting and freezing rates that determine ice thickness5,6, would have influenced the survival of photosynthetic life4,5,7–9, and may provide important constraints for the interpretation of geochemical and sedimentological observations4,10. Here we show that in a Snowball Earth, the ocean would have been well mixed and characterized by a dynamic circulation11, with vigorous equatorial meridional overturning circulation, zonal equatorial jets, a well developed eddy field, strong coastal upwelling and convective mixing. This is in contrast to the sluggish ocean often expected in a Snowball Earth scenario3 owing to the insulation of the ocean from atmospheric forcing by the thick ice cover. As a result of vigorous convective mixing, the ocean temperature, salinity and density were either uniform in the vertical direction or weakly stratified in a few locations. Our results are based on a model that couples ice flow and ocean circulation, and is driven by a weak geothermal heat flux under a global ice cover about a kilometre thick. Compared with the modern ocean, the Snowball Earth ocean had far larger vertical mixing rates, and comparable horizontal mixing by ocean eddies. The strong circulation and coastal upwelling resulted in melting rates near continents as much as ten times larger than previously estimated6,7. Although we cannot resolve the debate over the existence of global ice cover10,12,13, we discuss the implications for the nutrient supply of photosynthetic activity and for banded iron formations. Our insights and constraints on ocean dynamics may help resolve the Snowball Earth controversy when combined with future geochemical and geological observations.

Fig. 1 and 2 a/b

Fig. 1 and 2 d

Fig. 1c and 2f

Fig. 2 c/fv

Fig. 2 d