Quaternary Science Reviews 92 (2014) 1–8

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Introduction

The dynamic Arctic

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ABSTRACT

Research campaigns over the last decade have yielded a growing stream of data that highlight the dynamic nature of Arctic cryosphere and climate change over a range of time scales. As a consequence, rather than seeing the Arctic as a near static environment in which large scale changes occur slowly, we now view the Arctic as a system that is typified by frequent, large and abrupt changes. The traditional focus on end members in the system – glacial versus interglacial periods – has been replaced by a new interest in understanding the patterns and causes of such dynamic change. Instead of interpreting changes almost exclusively as near linear responses to external forcing (e.g. orbitally-forced climate change), research is now concentrated on the importance of strong feedback mechanisms that in our palaeo-archives often border on chaotic behaviour. The last decade of research has revealed the importance of on-off switching of ice streams, strong feedbacks between sea level and ice sheets, spatial and temporal changes in ice shelves and perennial sea ice, as well as alterations in ice sheet dynamics caused by shifting centres of mass in multi-dome ice sheets. Recent advances in dating techniques and modelling have improved our understanding of leads and lags that exist in different Arctic systems, on their interactions and the driving mechanisms of change. Future Arctic research challenges include further emphases on rapid transitions and untangling the feedback mechanisms as well as the time scales they operate on.

1. Introduction

The Arctic has a prominent role in scientific debate on global change. This is a consequence from that the region is changing faster than almost anywhere on Earth and from that such dynamic change in the Arctic has been a characteristic of the entire Cenozoic Era. Thus, quantitative palaeoclimate reconstructions suggest that Arctic temperature changes have been three or four times the corresponding hemispheric or globally averaged changes over the past 4 Ma (Miller et al., 2010).

Globally, the general trend of increasing air surface temperature over the last 15 years has slowed in recent years, and is currently four times less than predicted by simulations within Phase 5 of the Coupled Model Intercomparison Project (CMIP5) (Fyfe et al., 2013). However, over the same interval, global atmospheric CO_2 level has continued to increase (Francey et al., 2013) and the Arctic Ocean has experienced a rapid decline in summer sea ice extent and thickness (Stroeve et al., 2012) (Fig. 1). The lack of a strong correlation between global average air temperature, atmospheric CO_2 and Arctic summer sea ice provides one example that shows that Arctic environmental changes are heavily influenced by complex interplays between different feedback mechanisms. These include changes in glacier/ice sheet extent, snow cover and sea ice distribution that affect surface albedo, and atmospheric and oceanic circulation patterns. The Arctic also influences environmental change at lower latitudes, primarily through the global thermohaline circulation and modulation of atmospheric CO_2 and CH_4 concentrations (Overpeck et al., 1997).

Environmental variability in the Arctic is increasingly viewed as the norm, and there is a growing recognition that today's Arctic cryosphere (glaciers, sea ice, permafrost, gas hydrates) and biosphere (terrestrial, lacustrine, and marine) are not in steady state; they have changed and will continue to change in response to climate and other perturbations. Recognition that the Arctic has likely never been in steady state is a challenge to those of interested in reconstructing past change. What, for example, is the purpose of

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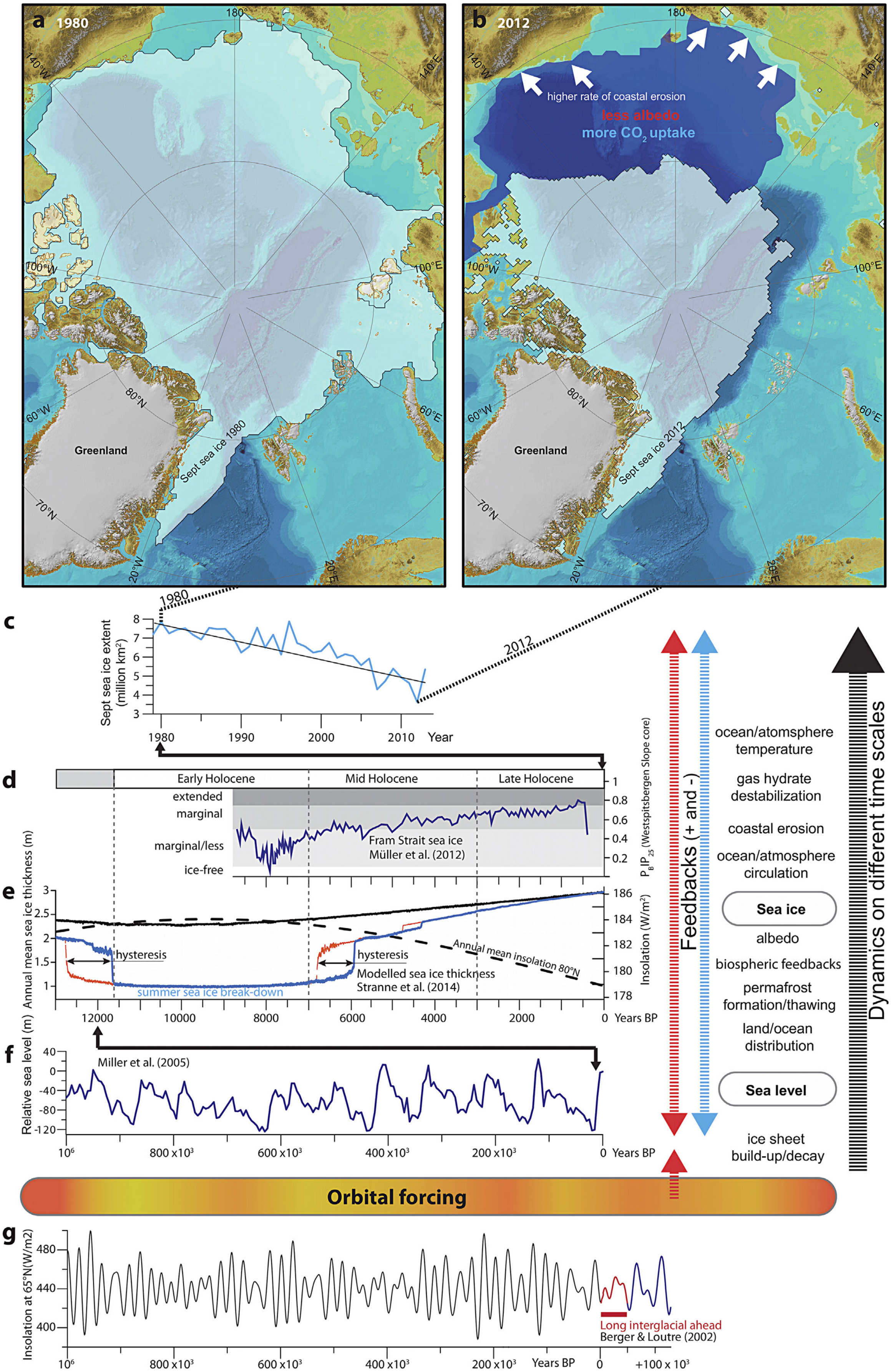
http://dx.doi.org/10.1016/j.quascirev.2014.03.022


a 1980
b 2012
180°
140°W
140°E
100°W
100°E
60°W
60°E
80°N
70°N
20°W
20°E
Greenland
Sept sea ice 1980
Sept sea ice 2012
higher rate of coastal erosion
less albedo
more CO2 uptake
c
Sept sea ice extent (million km²)
1980
2012
1990
2000
2010
Year
d
Early Holocene
Mid Holocene
Late Holocene
extended
marginal
marginal/less
ice-free
Fram Strait sea ice Müller et al. (2012)
PBIP25 (Westspitsbergen Slope core)
e
Annual mean sea ice thickness (m)
hysteresis
summer sea ice break-down
Modelled sea ice thickness Stranne et al. (2014)
Annual mean insolation 80°N
Insolation (W/m²)
Years BP
f
Relative sea level (m)
Miller et al. (2005)
Years BP
Orbital forcing
g
Insolation at 65°N(W/m2)
Long interglacial ahead
Berger & Loutre (2002)
Years BP
Feedbacks (+ and -)
ocean/atomsphere temperature
gas hydrate destabilization
coastal erosion
ocean/atmosphere circulation
Sea ice
albedo
biospheric feedbacks
permafrost formation/thawing
land/ocean distribution
Sea level
ice sheet build-up/decay
Dynamics on different time scales