

Introduction and
motivation

Atmosphere

Biosphere

Ocean and the
cryosphere

References

Climate: A whirlwind tour

Open Seminar Series, Department of Physics

Aditya Narayanan ¹

Department of Ocean Engineering
IIT Madras

October, 2018

¹adityarn@gmail.com, <https://github.com/adityarn/presentations> ↗ ↘ ↙

Climate change

Climate: A
whirlwind tour

Aditya Narayanan

Introduction and
motivation

Atmosphere

Biosphere

Ocean and the
cryosphere

References

Regional warming in the decade 2006-2015 relative to preindustrial

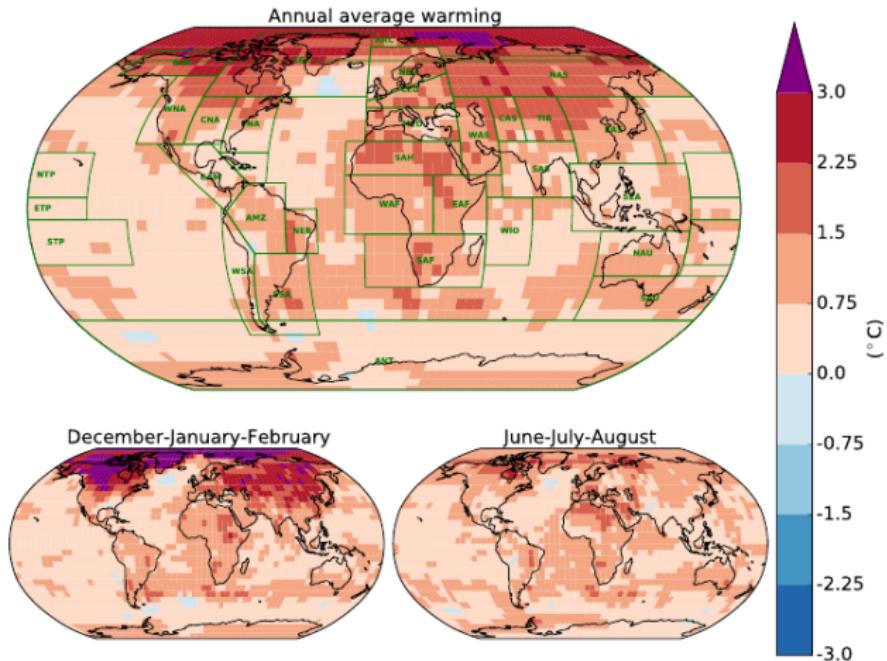


Figure 1 : Temperature change (2005 - 2015) with respect to pre-industrial (1850-1900). Source: *IPCC SR15, 2018*.

Historical CO₂ levels

Climate: A whirlwind tour

Aditya Narayanan

Introduction and motivation

Latest CO₂ reading
October 25, 2018
Ice-core data before 1958. Mauna Loa data after 1958.

406.53 ppm

CO₂ Concentration (ppm)

Thousands of Years Ago

Figure 2 : Historical CO₂ levels. Source: *Scripps, UCSD*

Introduction and
motivation

Atmosphere

Biosphere

Ocean and the
cryosphere

References

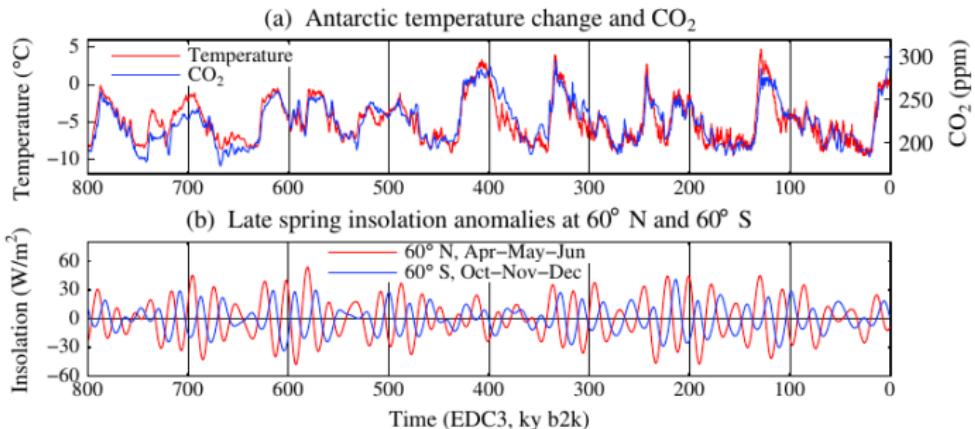


Figure 3 : (a) Antarctic (Dome C) temperature anomaly relative to 10kyr, CO₂ levels (Lüthi et al., 2008); (b) Insolation anomalies.

Source: (Hansen et al., 2016)

Radiative forcing

Climate: A whirlwind tour

Aditya Narayanan

Introduction and motivation

Atmosphere

Biosphere

Ocean and the cryosphere

References

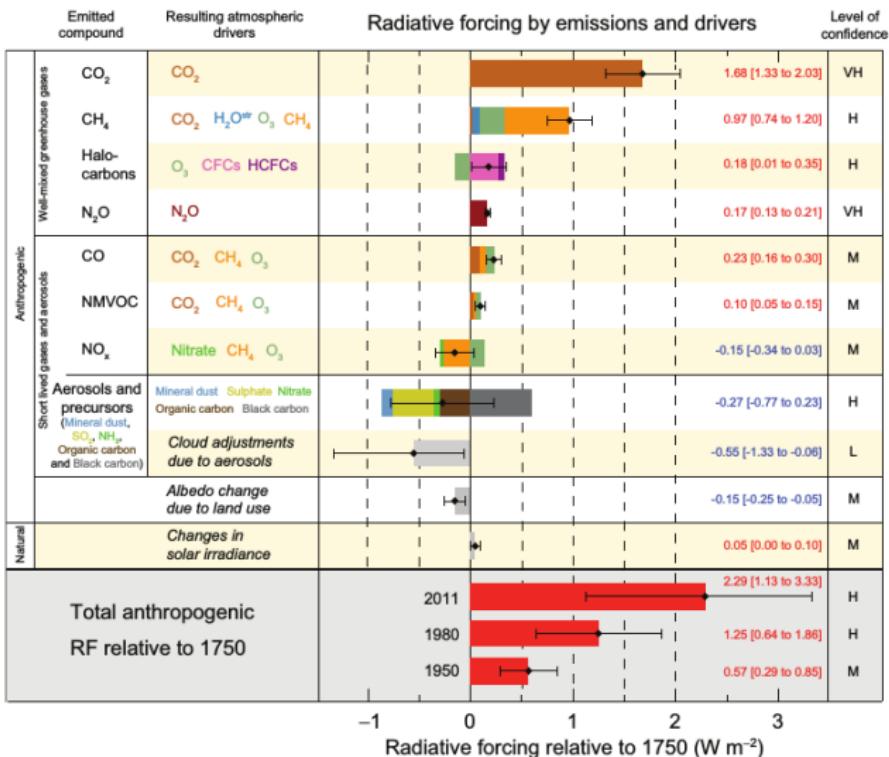


Figure 4 : Radiative forcing. Source: IPCC-WG1, 2013

Earth's energy budget

Climate: A
whirlwind tour

Aditya Narayanan

Introduction and
motivation

Atmosphere

Biosphere

Ocean and the
cryosphere

References

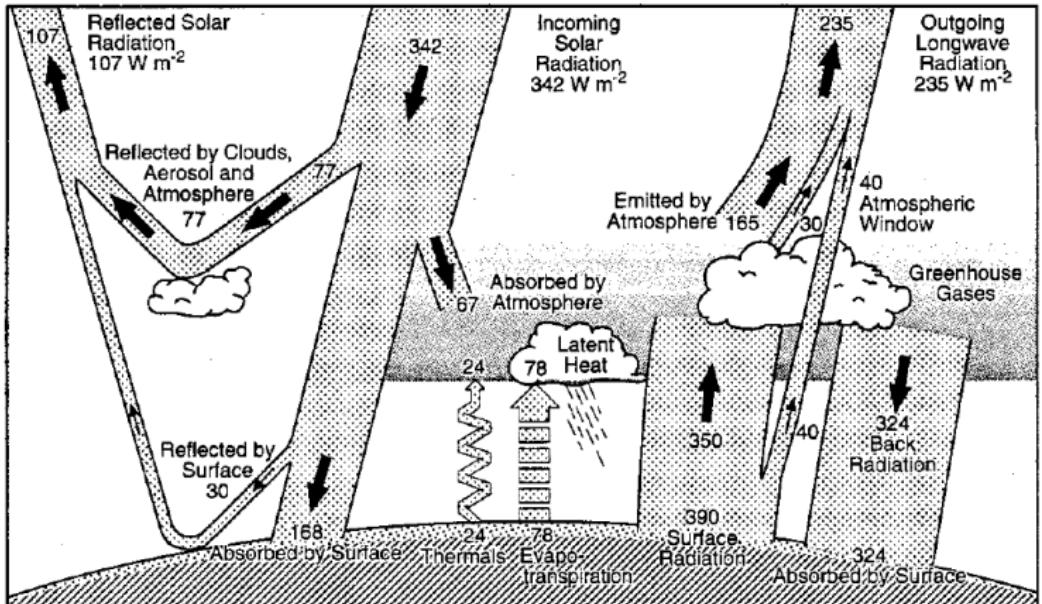


Figure 5 : (Kiehl and Trenberth, 1997)

Aerosols

Climate: A
whirlwind tour

Aditya Narayanan

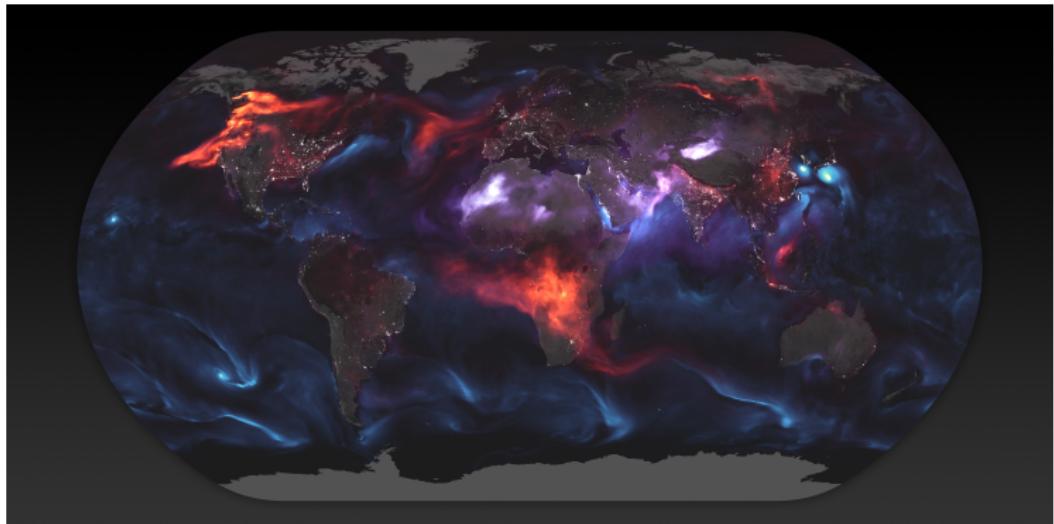


Figure 6 : Wildfires, dust, and sea salt - August 23rd, 2018. Source:

NASA GEOS-FP

Introduction and
motivation

Atmosphere

Biosphere

Ocean and the
cryosphere

References

Biosphere

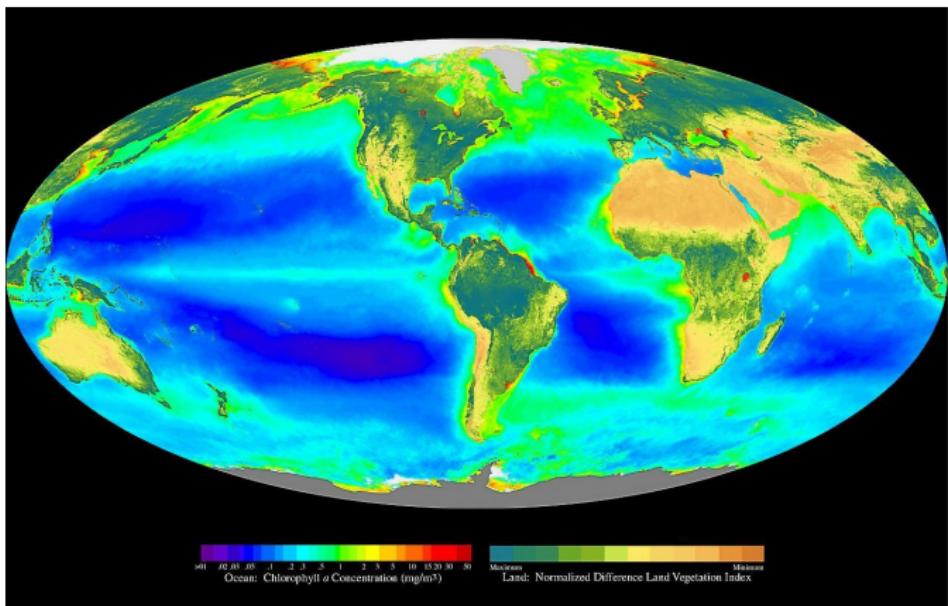


Figure 7 : Abundance of photosynthesizing organisms. Source: NASA, GSFC (SeaWiFS)

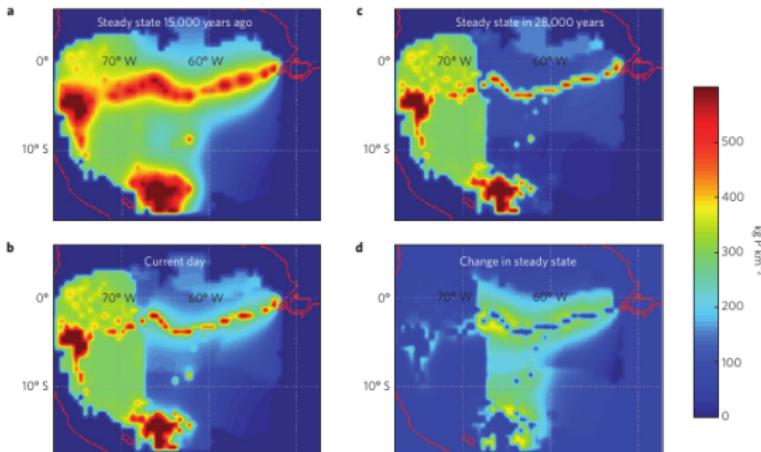


Figure 3 | Map showing changing ecosystem P concentrations in South America due to megafauna extinctions. **a**, The steady-state estimate of P concentrations in the Amazon basin before the megafaunal extinctions with a lateral diffusivity Φ_{excreta} value of $4.4 \text{ km}^2 \text{ yr}^{-1}$. **b**, The current-day estimate of P concentrations 12,000 years after the extinctions with current animals and a Φ_{excreta} value of $0.027 \text{ km}^2 \text{ yr}^{-1}$. **c**, Estimated P concentrations in the Amazon basin 28,000 years in the future. **d**, The difference between the pre- and post-extinction equilibrium (**a** and **c**).

Table 1 | Average $\Phi_{\text{excreta}} * \alpha B$ ($\text{km}^2 \text{ yr}^{-1}$) for each continent calculated for modern species and modern plus extinct species.

	North America	South America	Australia	Eurasia	Africa
Number of species extinct	65	64	45	9	13
Mean weight of extinct animals (kg)	846	1,156	188	2,430	970
Modern $\Phi_{\text{excreta}} * \alpha B$	13,876	12,934	21,804	21,779	265,621
Modern + extinct fauna $\Phi_{\text{excreta}} * \alpha B$	140,716 ($\pm 38,000$)	283,854 ($\pm 81,000$)	48,250 ($\pm 8,000$)	118,349 ($\pm 29,000$)	324,848 ($\pm 18,000$)
Percentage of original	10% ($\pm 2\%$)	5% ($\pm 1\%$)	45% ($\pm 6\%$)	18% ($\pm 4\%$)	82% ($\pm 4\%$)

Bottom row is the percentage of the original $\Phi_{\text{excreta}} * \alpha B$ remaining. The error represents an uncertainty in extinct species distribution of 30%.

Figure 8 : Source: (Doughty et al., 2013)

Introduction and
motivation

Atmosphere

Biosphere

Ocean and the
cryosphere

References

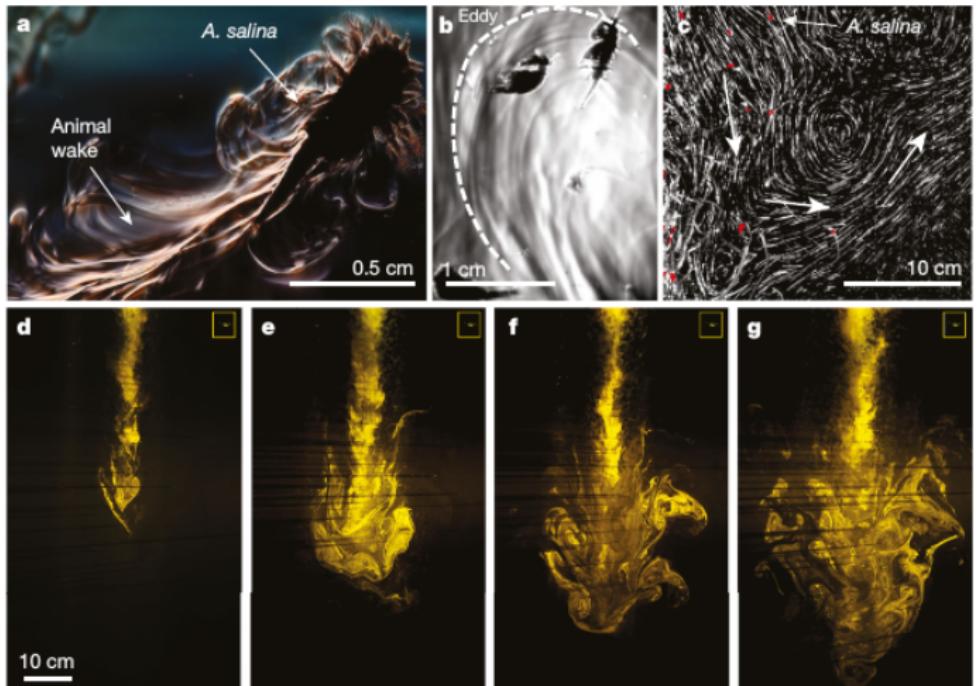


Figure 9 : Flow visualization of diffusion caused by the vertical migration of *A. Salina* (brine shrimp). $\kappa_{\text{eff}}/\kappa_{\text{mol}} \approx 10^3$ Source:
(Houghton et al., 2018)

Introduction and
motivation

Atmosphere

Biosphere

Ocean and the
cryosphere

References

Thermohaline circulation

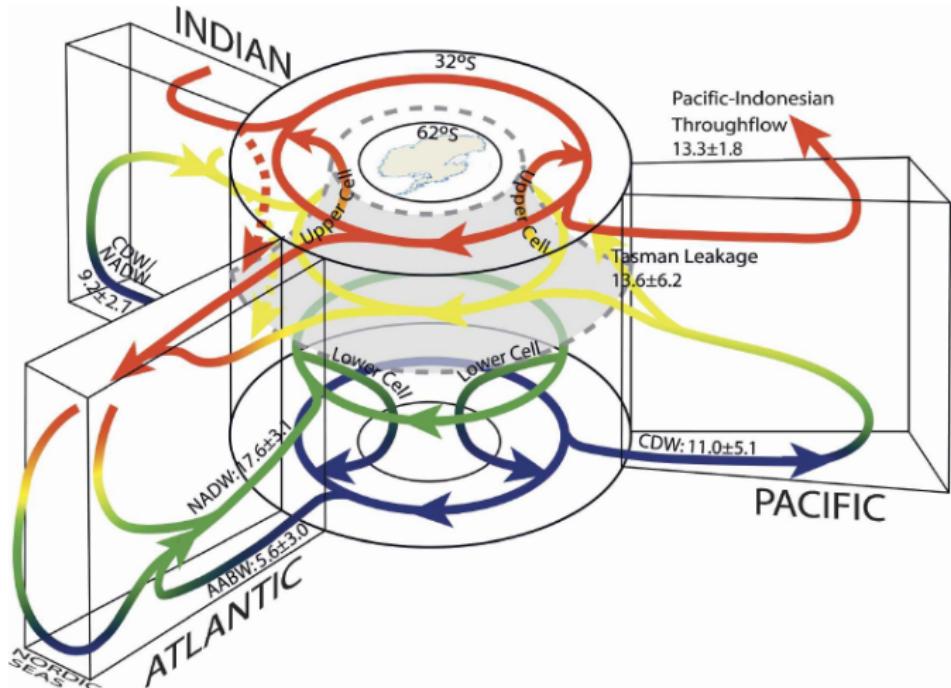


Figure 10 : Global thermohaline circulation source: Lumpkin and Speer, 2007
(Lumpkin and Speer, 2007)

Ocean and the cryosphere

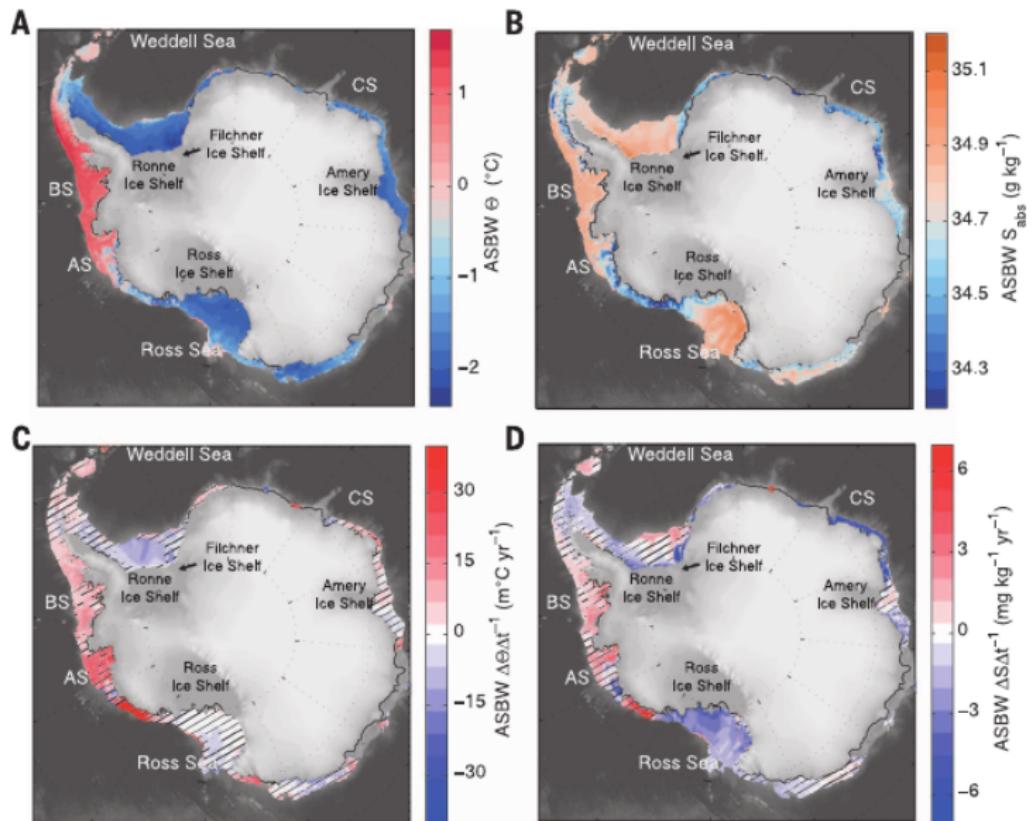


Figure 11 : Antarctic shelf sea bottom water properties and trends. Source: (Schmidtko et al., 2014)

Introduction and motivation

Atmosphere

Biosphere

Ocean and the cryosphere

References

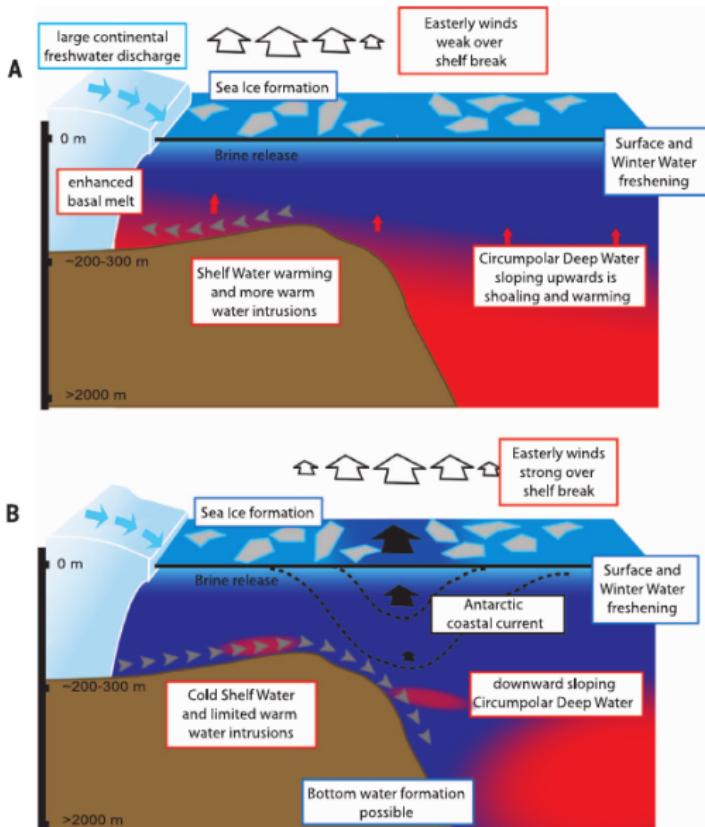


Figure 12 : Mechanisms of ocean currents warming the continental ice shelves of the Antarctic. Source: (Schmidtko et al., 2014)

Introduction and
motivation

Atmosphere

Biosphere

Ocean and the
cryosphere

References

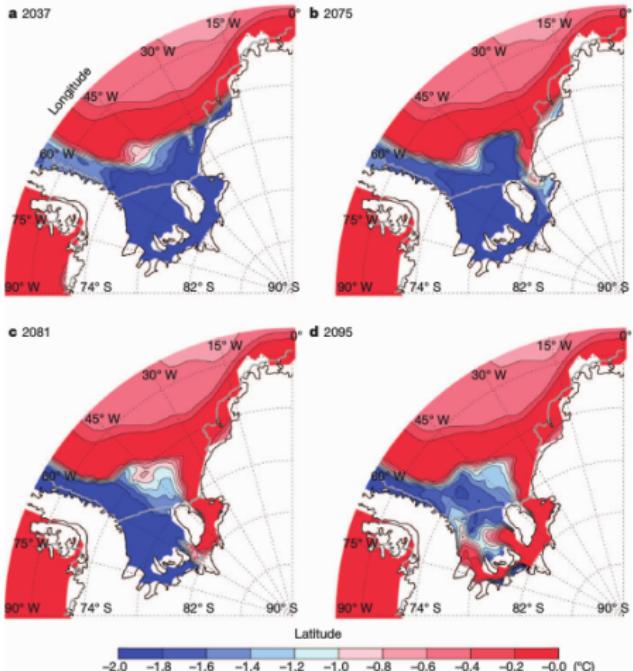


Figure 13 : Modelling the future shelf bed of the Weddell Sea.

Source: (Hellmer et al., 2012)

Introduction and
motivation

Atmosphere

Biosphere

Ocean and the
cryosphere

References

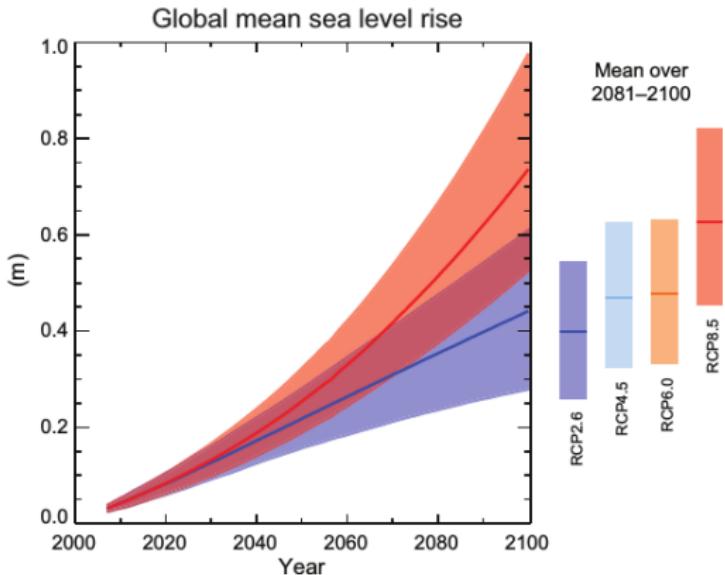


Figure 14 : IPCC 2013, sea level rise projections. Source: IPCC 2013,

AR5-WG1

Introduction and
motivation

Atmosphere

Biosphere

Ocean and the
cryosphere

References

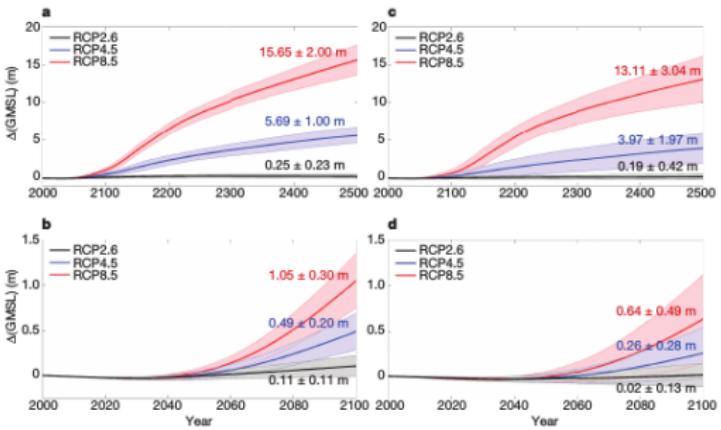


Figure 15 : Model analyses of future Antarctic contribution to sea level rise. Source: (DeConto and Pollard, 2016)

Reference I

Climate: A
whirlwind tour

Aditya Narayanan

DeConto, R. M. and Pollard, D. (2016). Contribution of antarctica to past and future sea-level rise. *Nature*, 531(7596):591.

Doughty, C. E., Wolf, A., and Malhi, Y. (2013). The legacy of the pleistocene megafauna extinctions on nutrient availability in amazonia. *Nature Geoscience*, 6(9):761.

Hansen, J., Sato, M., Hearty, P., Ruedy, R., Kelley, M., Masson-Delmotte, V., Russell, G., Tselioudis, G., Cao, J., Rignot, E., et al. (2016). Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 c global warming could be dangerous. *Atmospheric Chemistry and Physics*, 16(6):3761–3812.

Hellmer, H. H., Kauker, F., Timmermann, R., Determann, J., and Rae, J. (2012). Twenty-first-century warming of a large antarctic ice-shelf cavity by a redirected coastal current. *Nature*, 485(7397):225–228.

Houghton, I. A., Koseff, J. R., Monismith, S. G., and Dabiri, J. O. (2018). Vertically migrating swimmers generate aggregation-scale eddies in a stratified column. *Nature*, 556(7702):497.

Kiehl, J. T. and Trenberth, K. E. (1997). Earth's annual global mean energy budget. *Bulletin of the American Meteorological Society*, 78(2):197–208.

Lumpkin, R. and Speer, K. (2007). Global ocean meridional overturning. *Journal of Physical Oceanography*, 37(10):2550–2562.

Lüthi, D., Le Floch, M., Bereiter, B., Blunier, T., Barnola, J.-M., Siegenthaler, U., Raynaud, D., Jouzel, J., Fischer, H., Kawamura, K., et al. (2008). High-resolution carbon dioxide concentration record 650,000–800,000 years before present. *Nature*, 453(7193):379.

Schmidtko, S., Heywood, K. J., Thompson, A. F., and Aoki, S. (2014). Multidecadal warming of antarctic waters. *Science*, 346(6214):1227–1231.

Introduction and motivation

Atmosphere

Biosphere

Ocean and the cryosphere

References