OSM 2008 – Session 003

Ocean Acidification in the Arctic over the 21st Century

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Thanks to:

Fortunat Joos
Thomas Frölicher
Gian-Kasper Plattner

NCAR CSM1.4-carbon model

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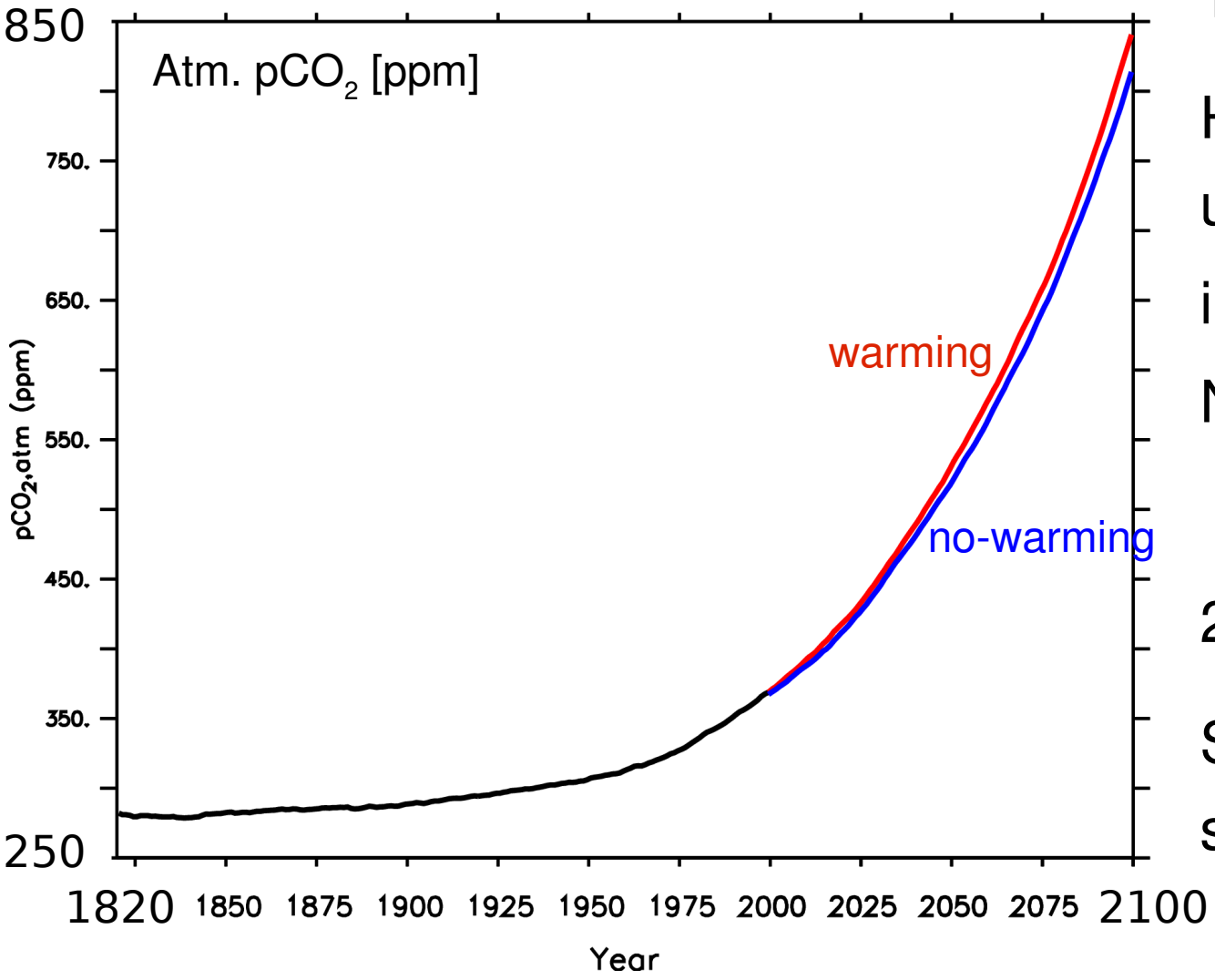
- Fully coupled 3-D climate model with atmosphere, ocean, land, and sea-ice components (Doney et al. 2006)
- Ocean model resolution: T31x3 grid
  3.6° x (0.8-1.8)° x 25 vertical layers
- Ocean carbon-cycle model is a derivative of the OCMIP-2 biotic carbon model (modified from restoring to prognostic formulation)

Experiments



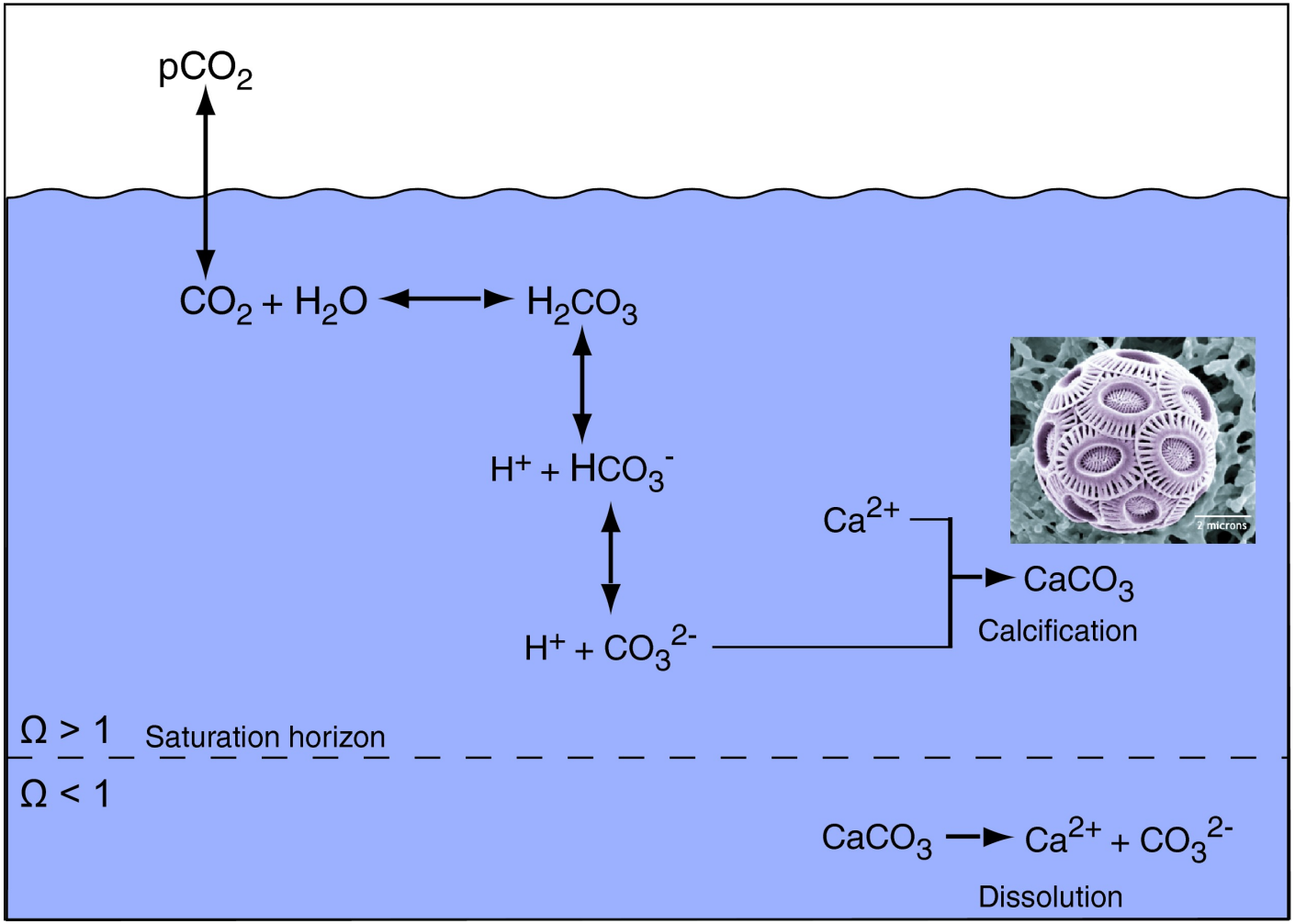
1820-2000:

Historic fossil fuel & land use CO_2 emissions, solar irradiance, volcanism, CH_4, N_2O, CFCs, aerosols

2000-2100:

SRES A2 emission scenario

Ocean Acidification



$\Omega=[Ca^{2+}][CO_3^{2-}]/K_{sp}$

Ω_A: Calcium carbonate saturation state of aragonite

Annual mean surface Ω_A

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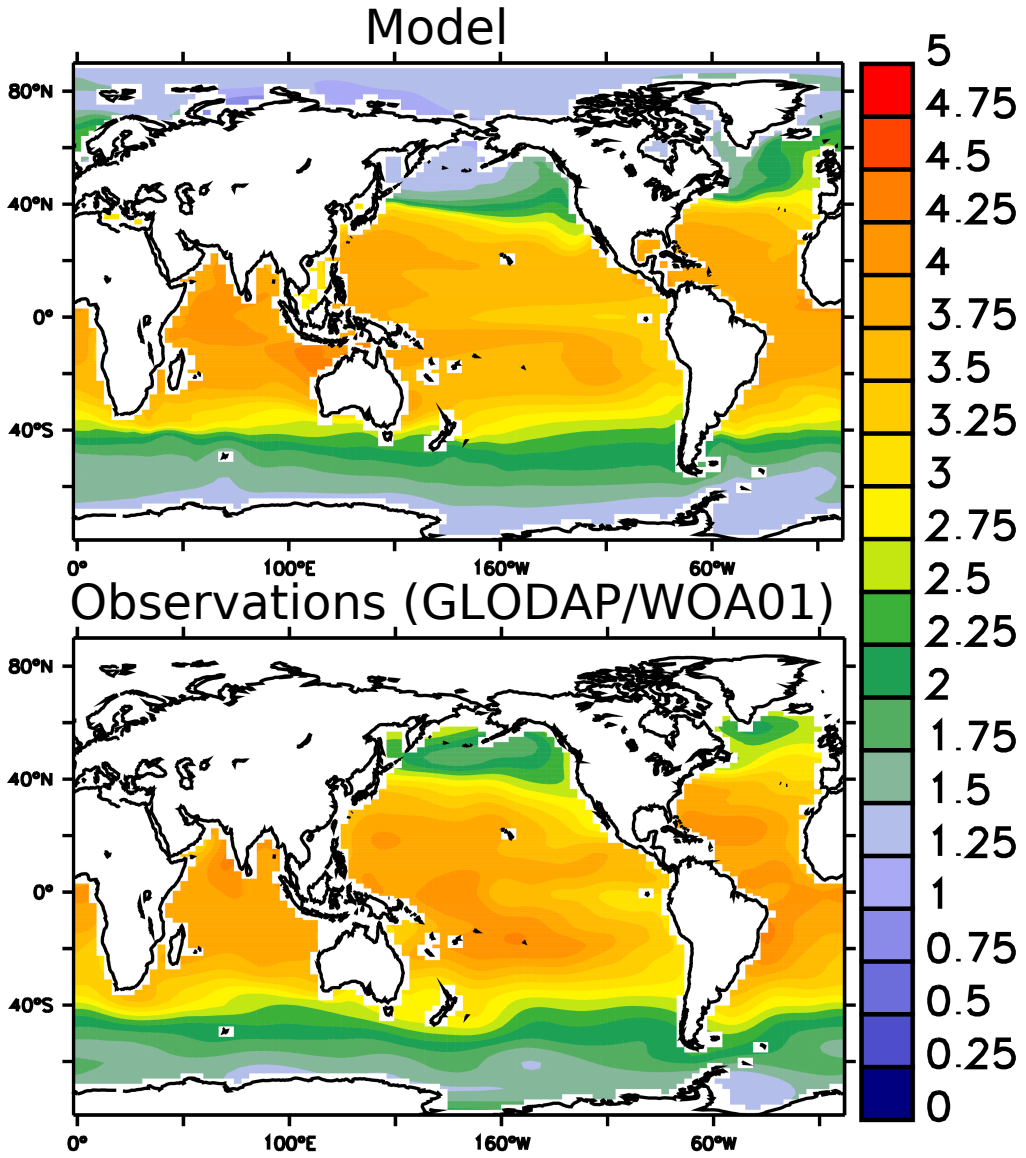

Comparison with observation-based data from GLODAP/WOA01:

- Generally good agreement.
- The model tends to underestimate surface Ω_A, while values are somewhat too high in Intermediate waters.

Arctic sections: Ω_A

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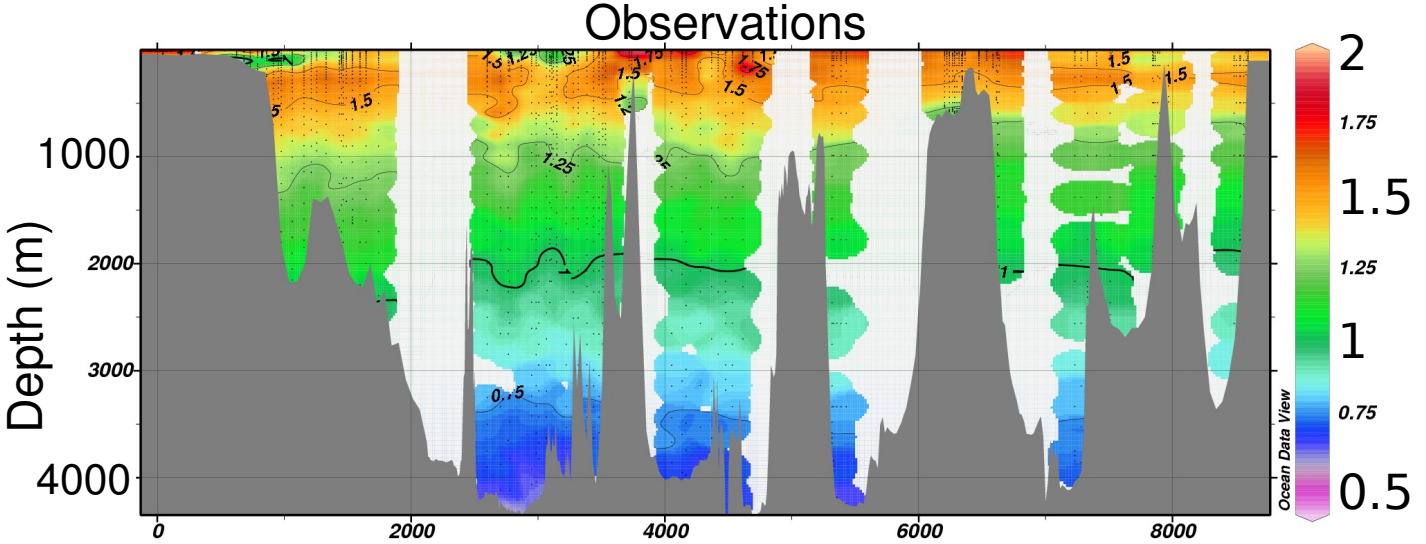
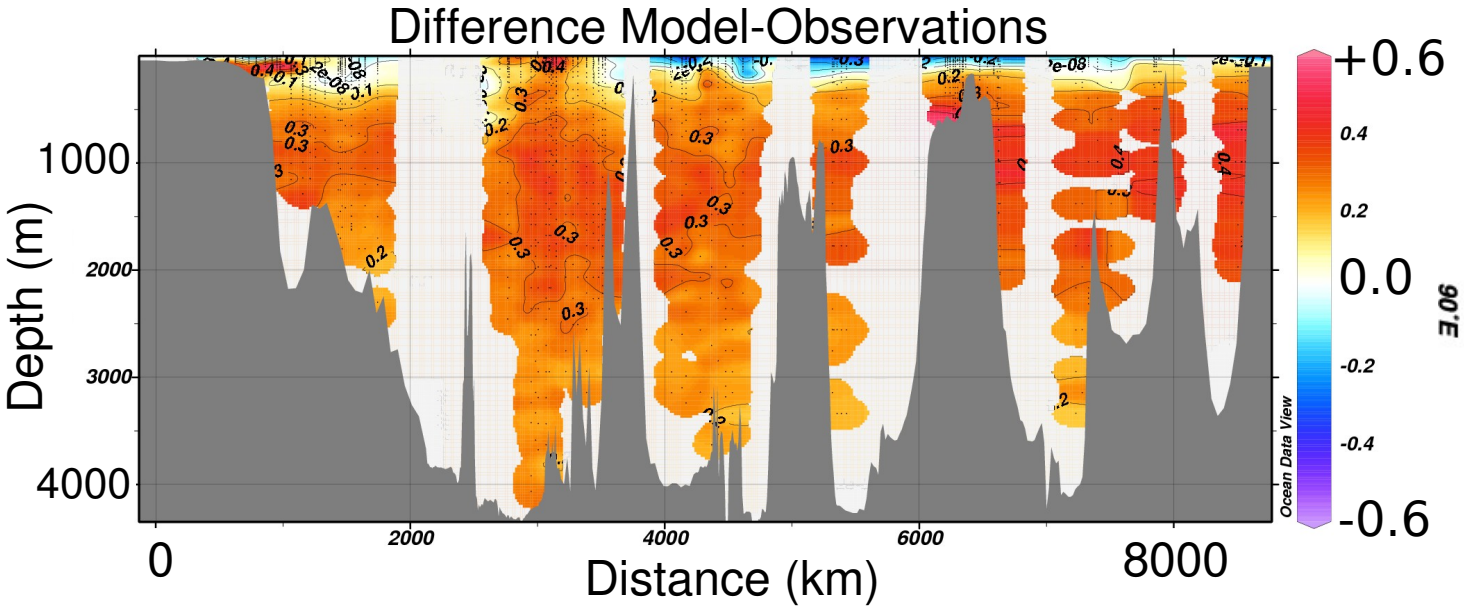
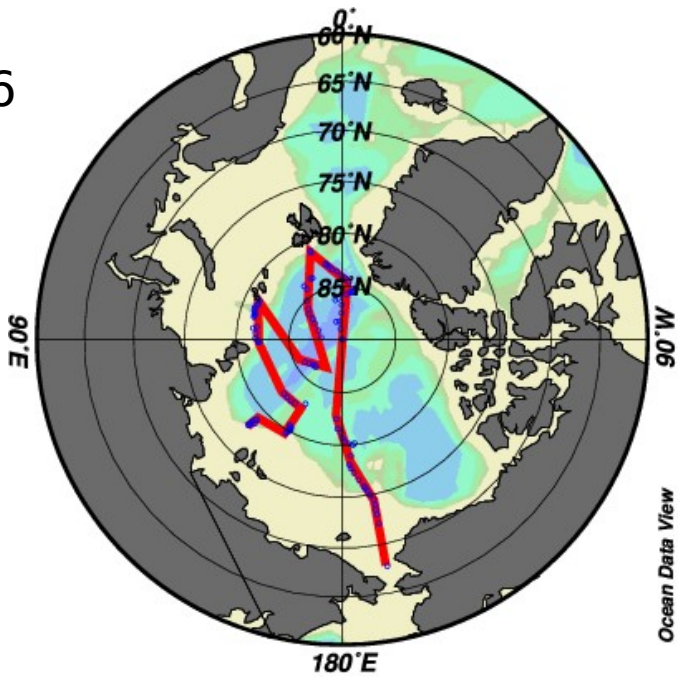




Observation-based estimates from:

- ODEN-91
- AOS-94
- ARCSYS-96



Seasonal variability of surface Ω_A

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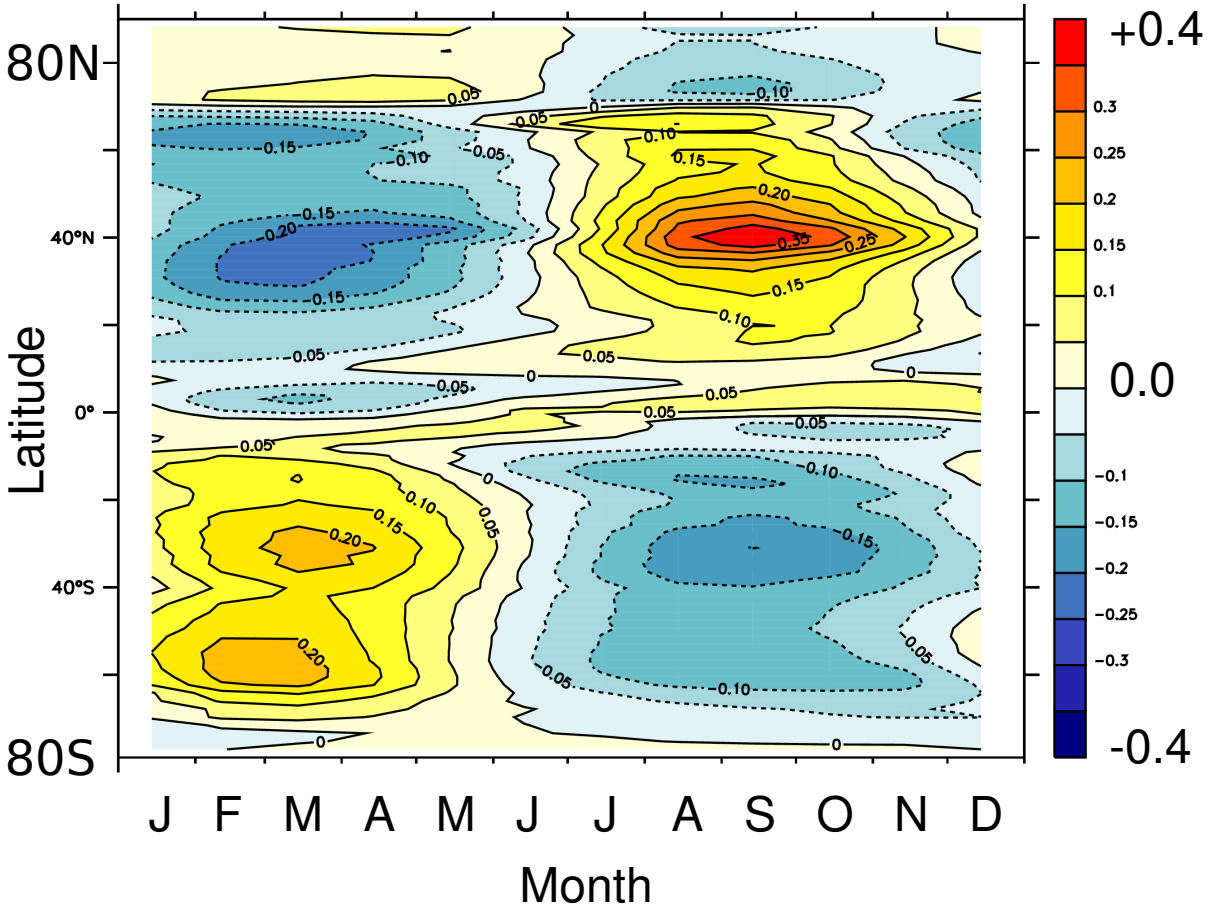
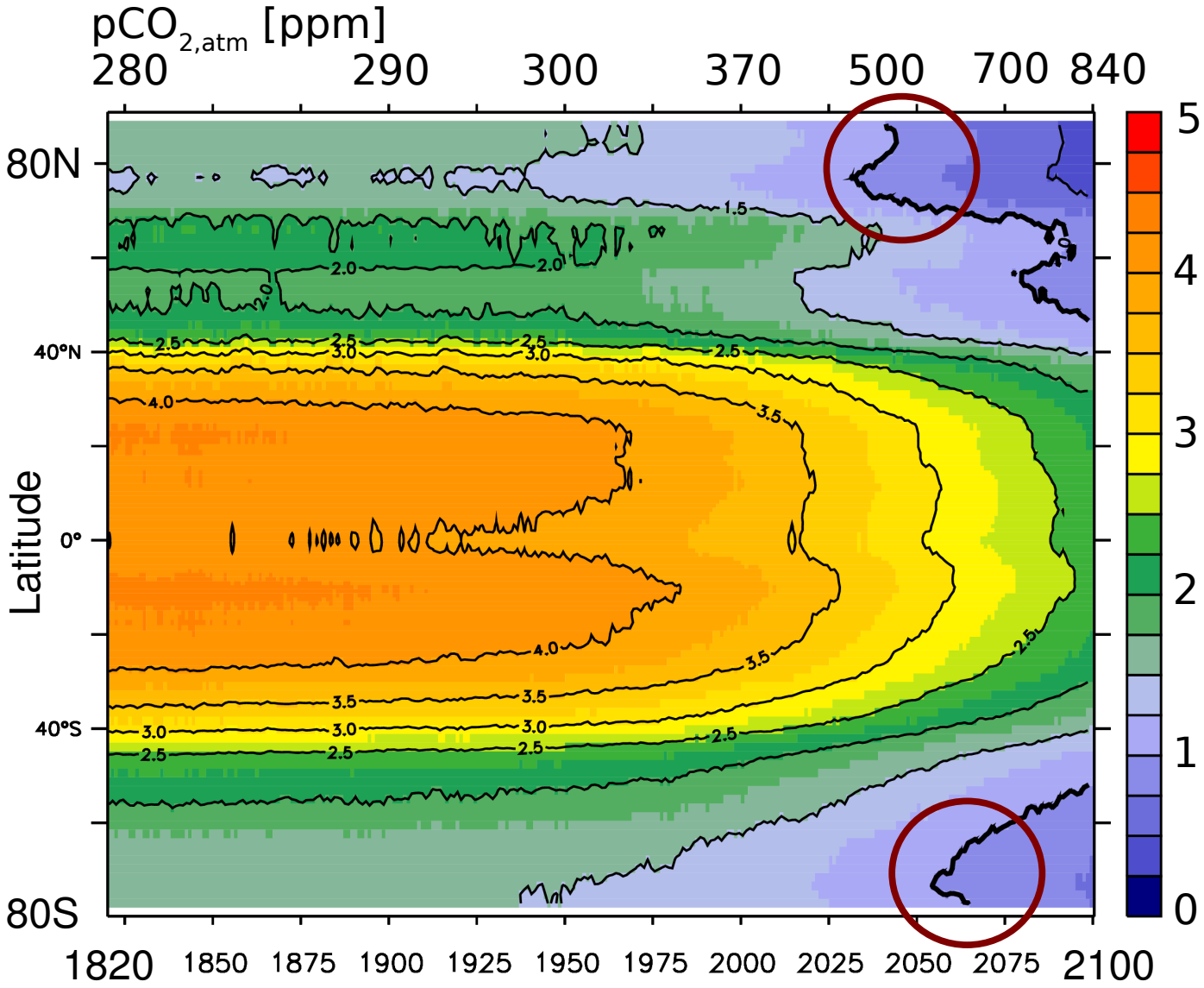


- Low in high latitude and tropical surface ocean (<5%).
- Up to 15-20 % in Northern Hemisphere mid-latitudes.

The inter-annual variability is low.

Projected surface Ω_A



Model results (A2) of annual mean surface Ω_A

Undersaturation of Arctic surface waters by 2040 (475 ppm)

Undersaturation in Southern Ocean by 2060 (575 ppm)

Largest changes in surface pH can be found in the Arctic (ΔpH=-0.50).

Impact of Climate Change on Ω_A

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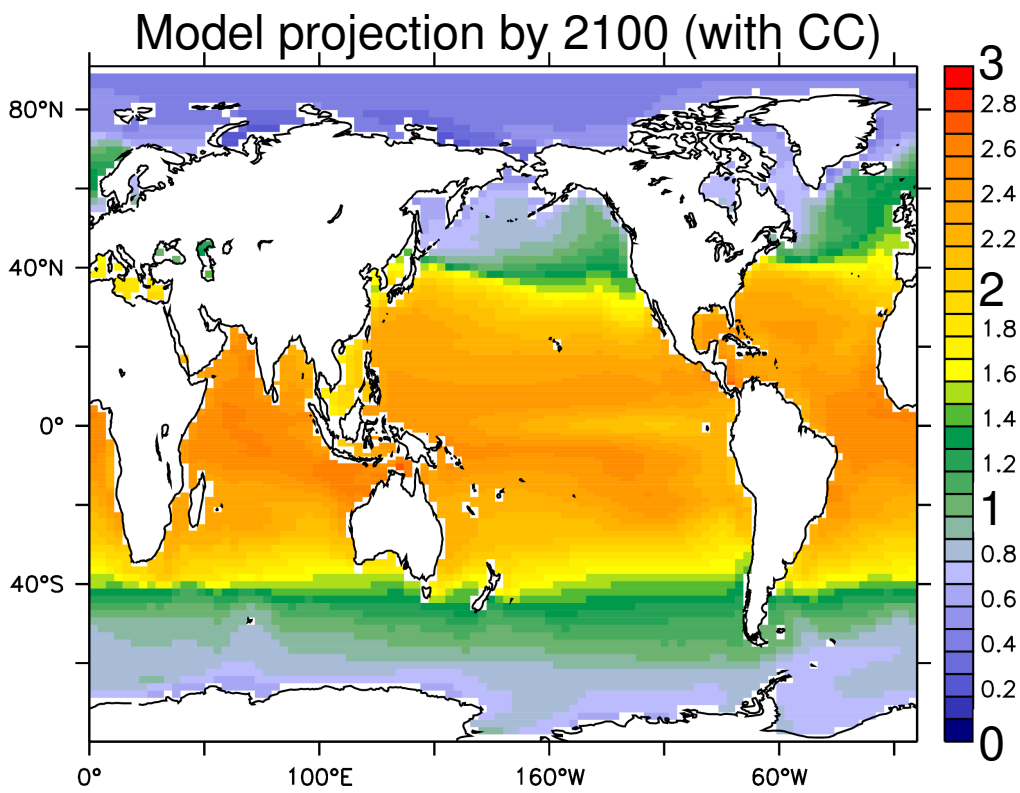
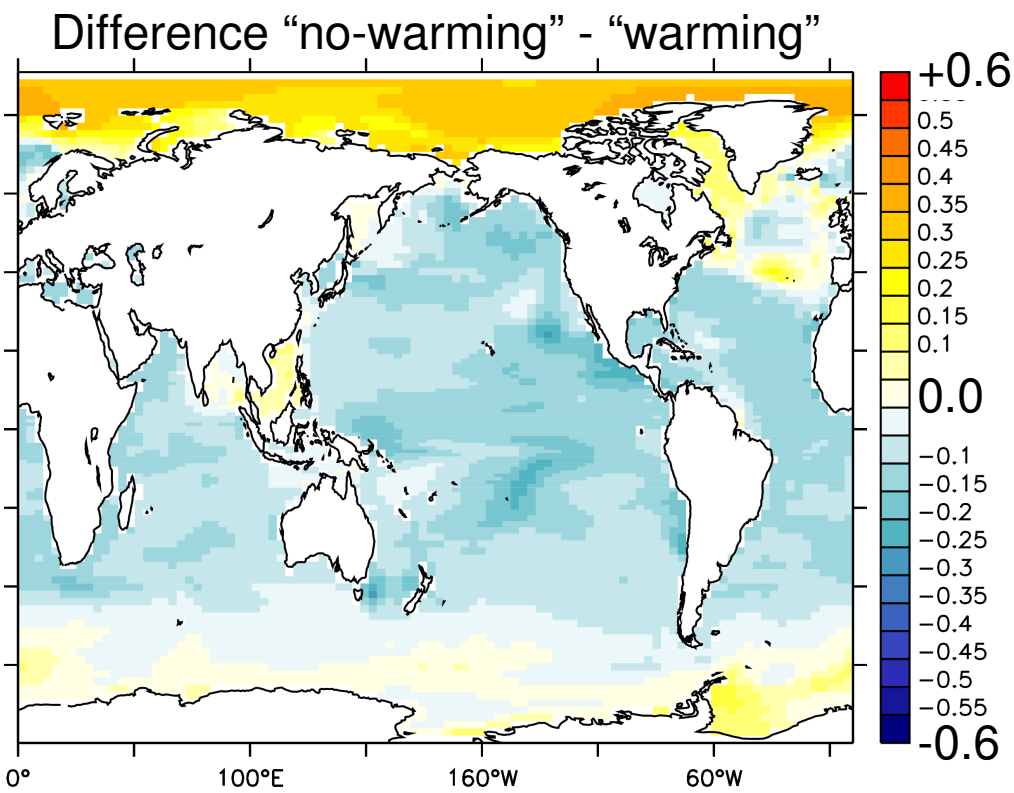
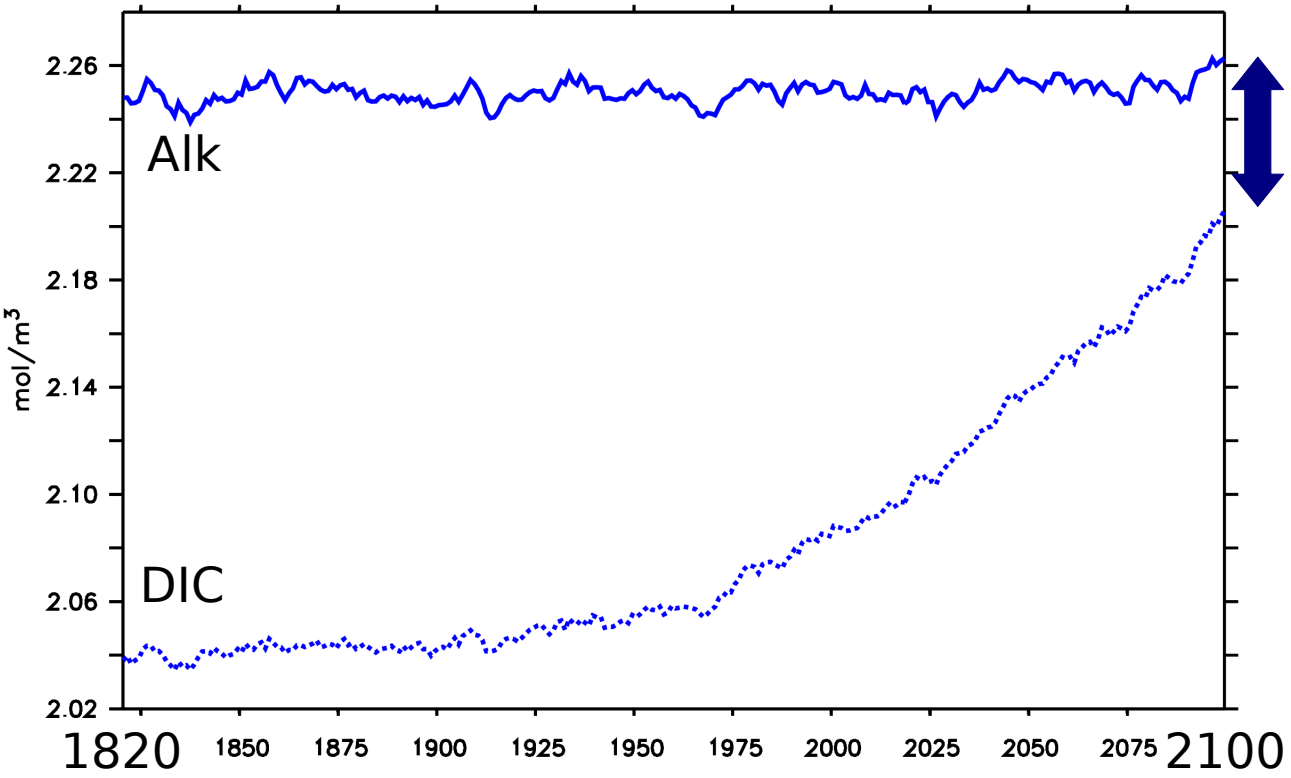




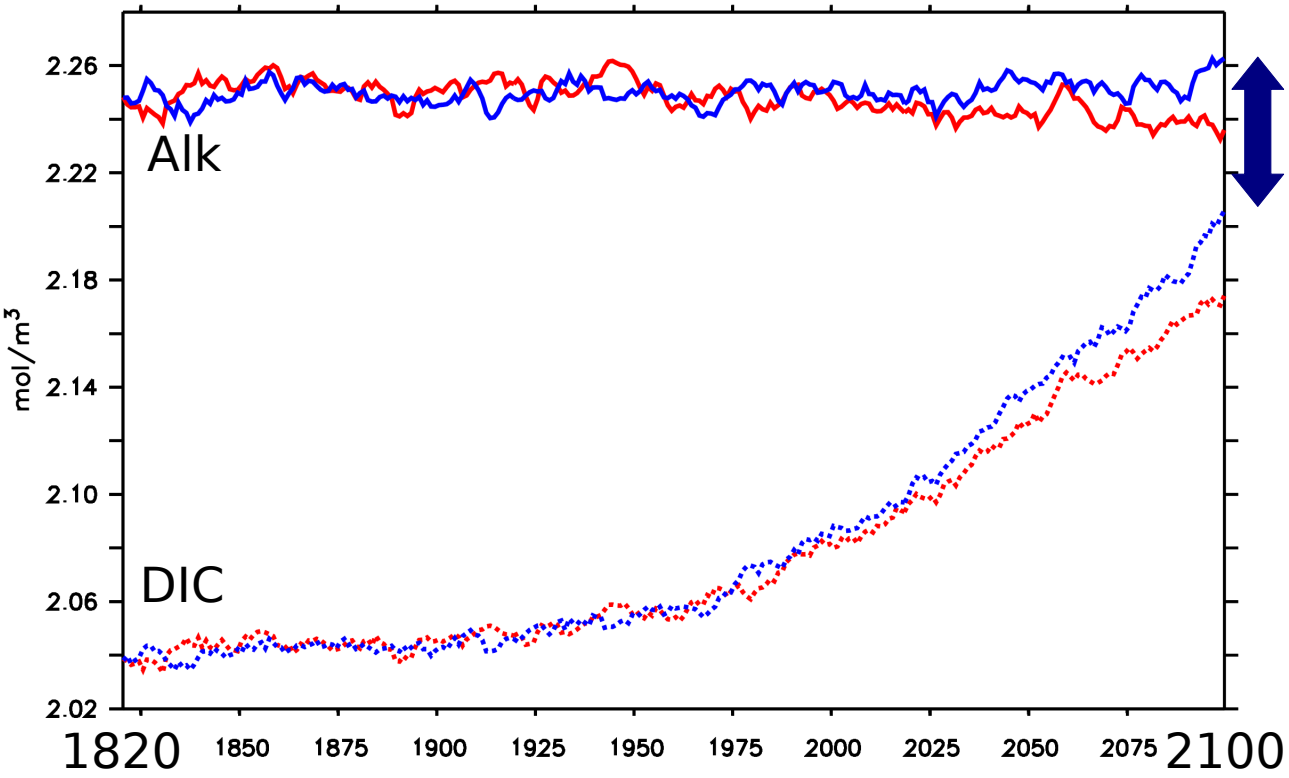
- Impact of Climate Change is relatively low in most regions.
- Ocean acidification is slightly reduced in low- and mid-latitudes ($\Delta\Omega_A$ around -0.15).
- Ocean acidification is enhanced in the Arctic Ocean ($\Delta\Omega_A$ up to 0.4)

Impact of Climate Change on Ω_A



$[CO_3^{2-}] \approx$ Alk – DIC
(without warming)

Impact of Climate Change on Ω_A



$[CO_3^{2-}] \approx$ Alk – DIC (without warming)

$[CO_3^{2-}]$ with warming

Impact of Climate Change on Ω_A

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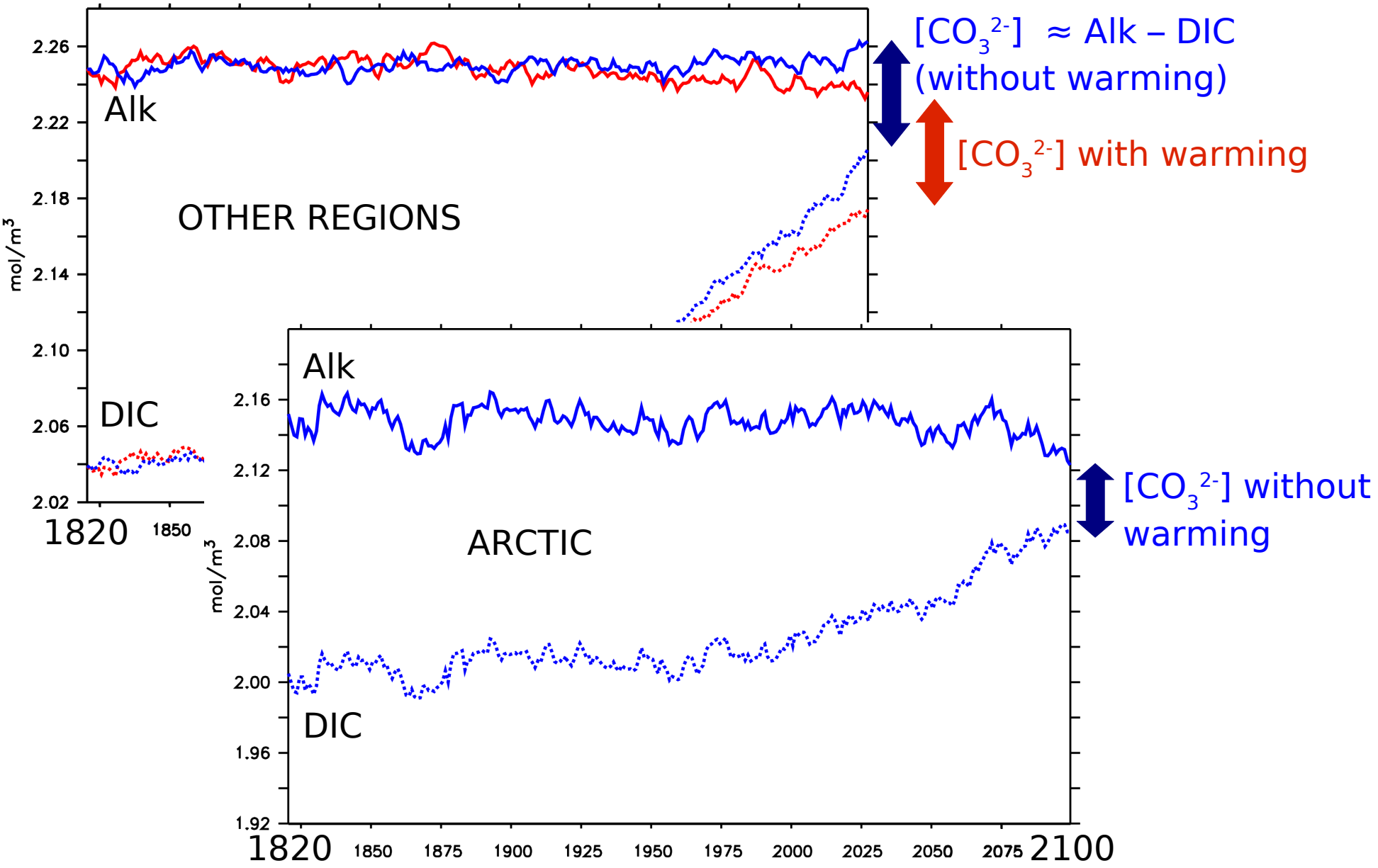

Impact of Climate Change on Ω_A

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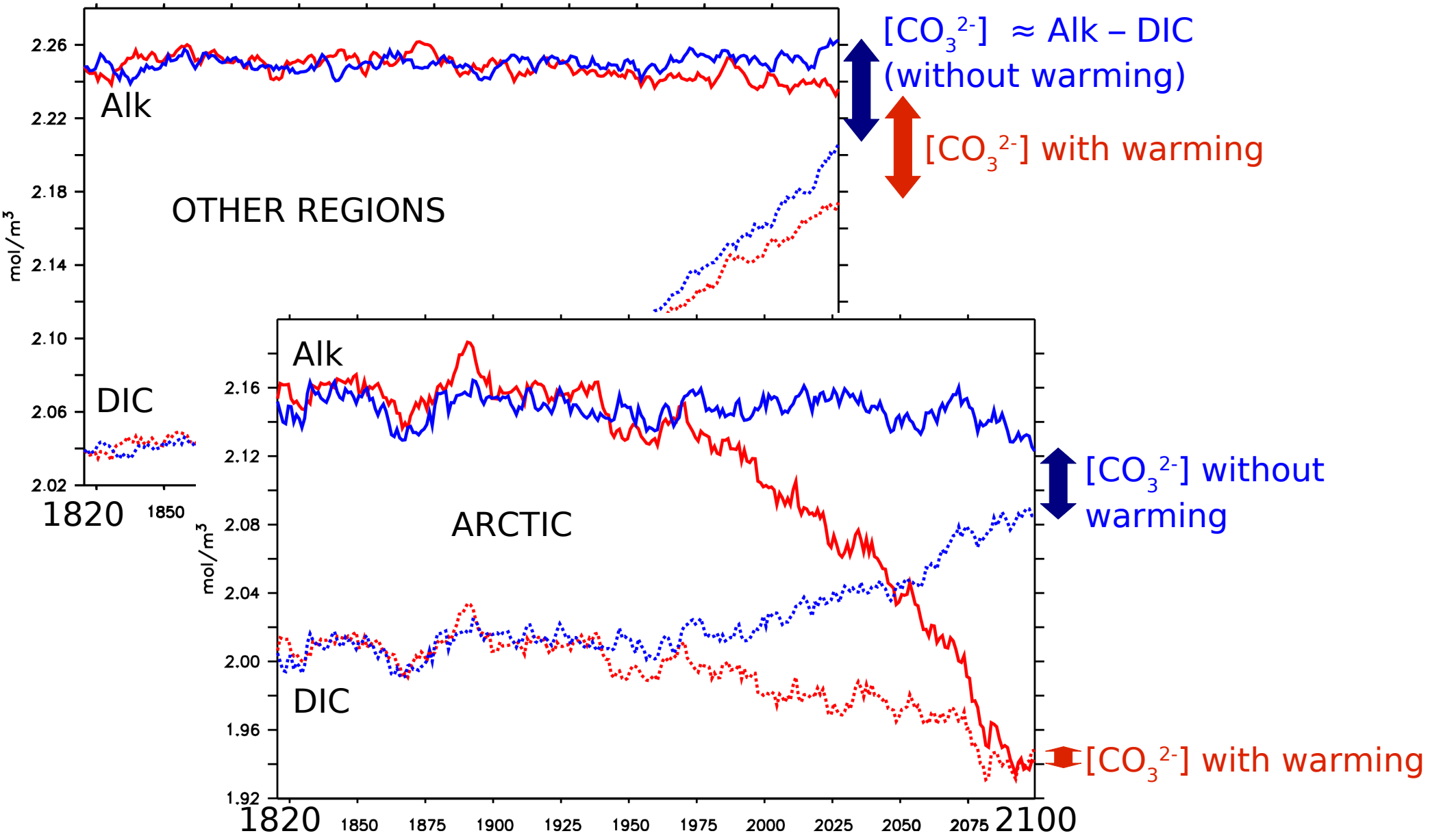

Impact of Climate Change on Ω_A

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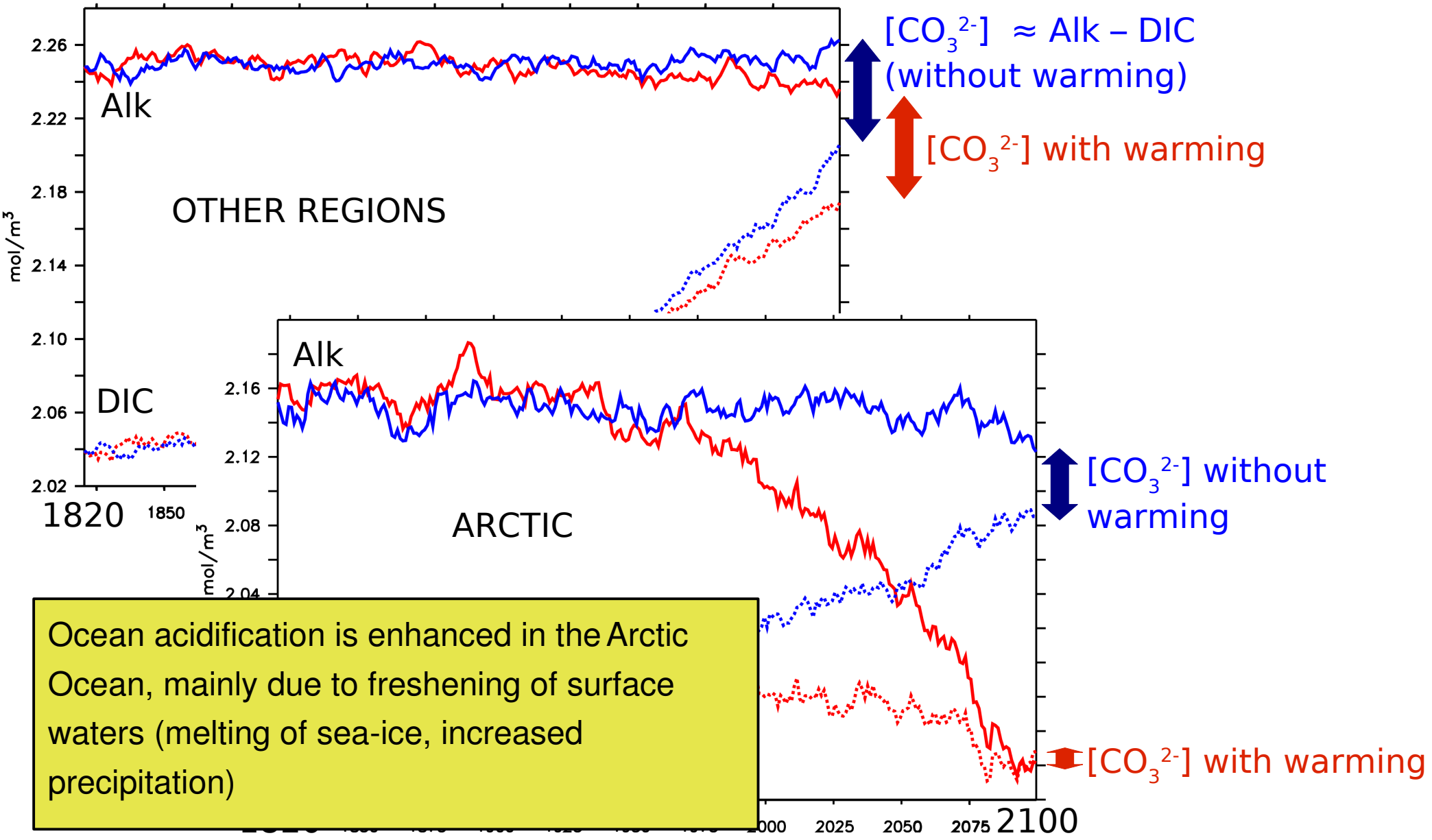

Ocean acidification is enhanced in the Arctic Ocean, mainly due to freshening of surface waters (melting of sea-ice, increased precipitation)

Summary

- Generally good agreement with observation-based estimates
- Maximum seasonal variability in mid-latitudes of Northern Hemisphere (15-20%)
- Arctic surface waters undersaturated by 2040 ($pCO_{2,atm}$=475 ppm); largest changes in pH (-0.5)
- Climate change enhances acidification in Arctic, mainly due to freshening of surface waters

Arctic sections: Projected Ω_A

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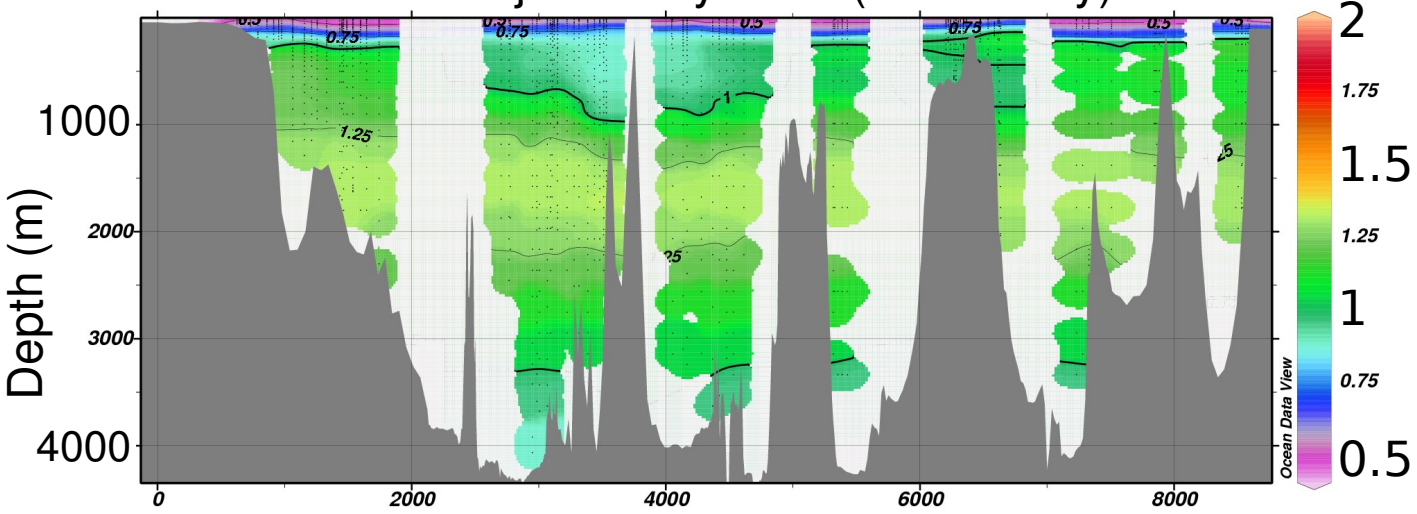
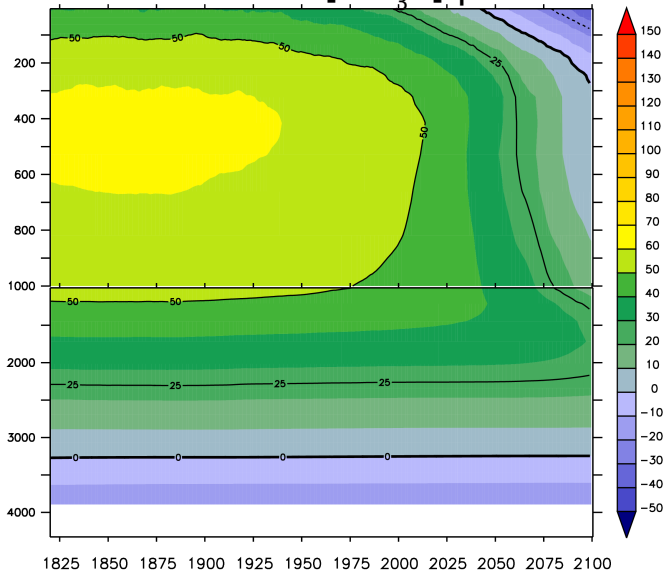
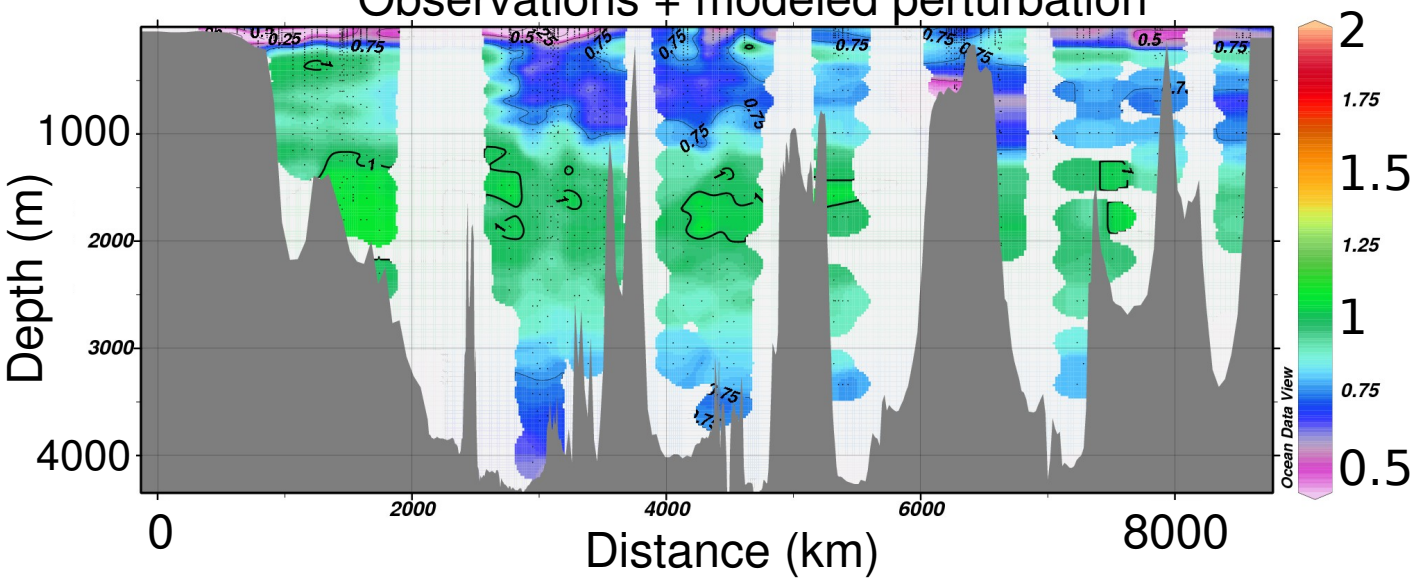
Projection by 2100 (model only)

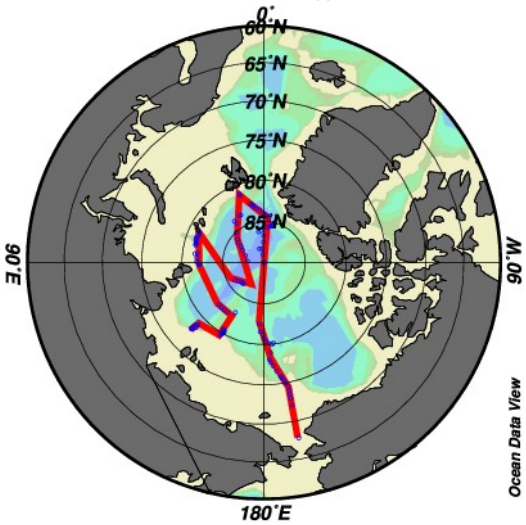


Arctic mean $\Delta[CO_3^{2-}]$ profile



Observations + modeled perturbation





Observation-based estimates from: ODEN-91, AOS-94, ARCSYS-96

$\Delta[CO_3^{2-}]$: Atlantic & Pacific sections

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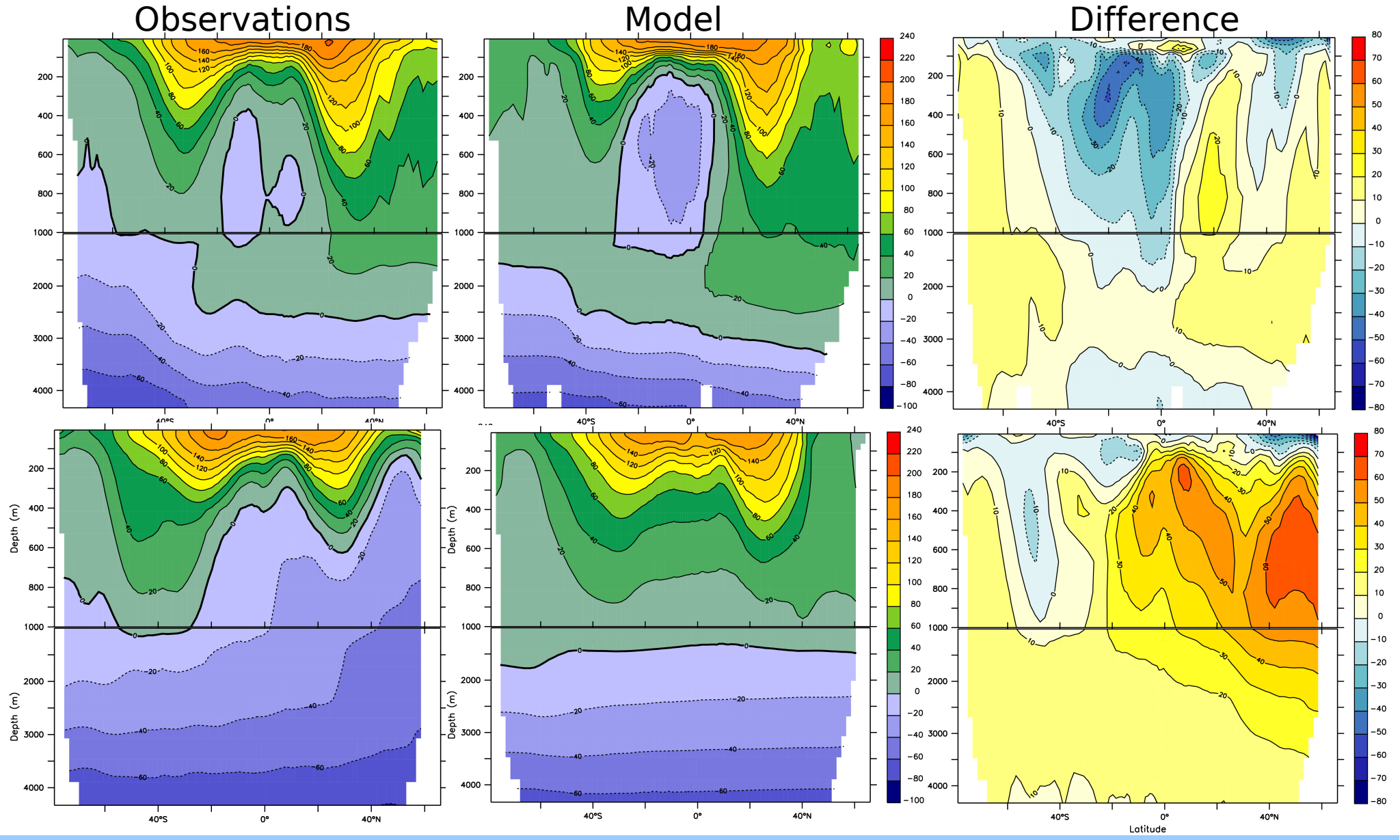

Changes in volume distribution

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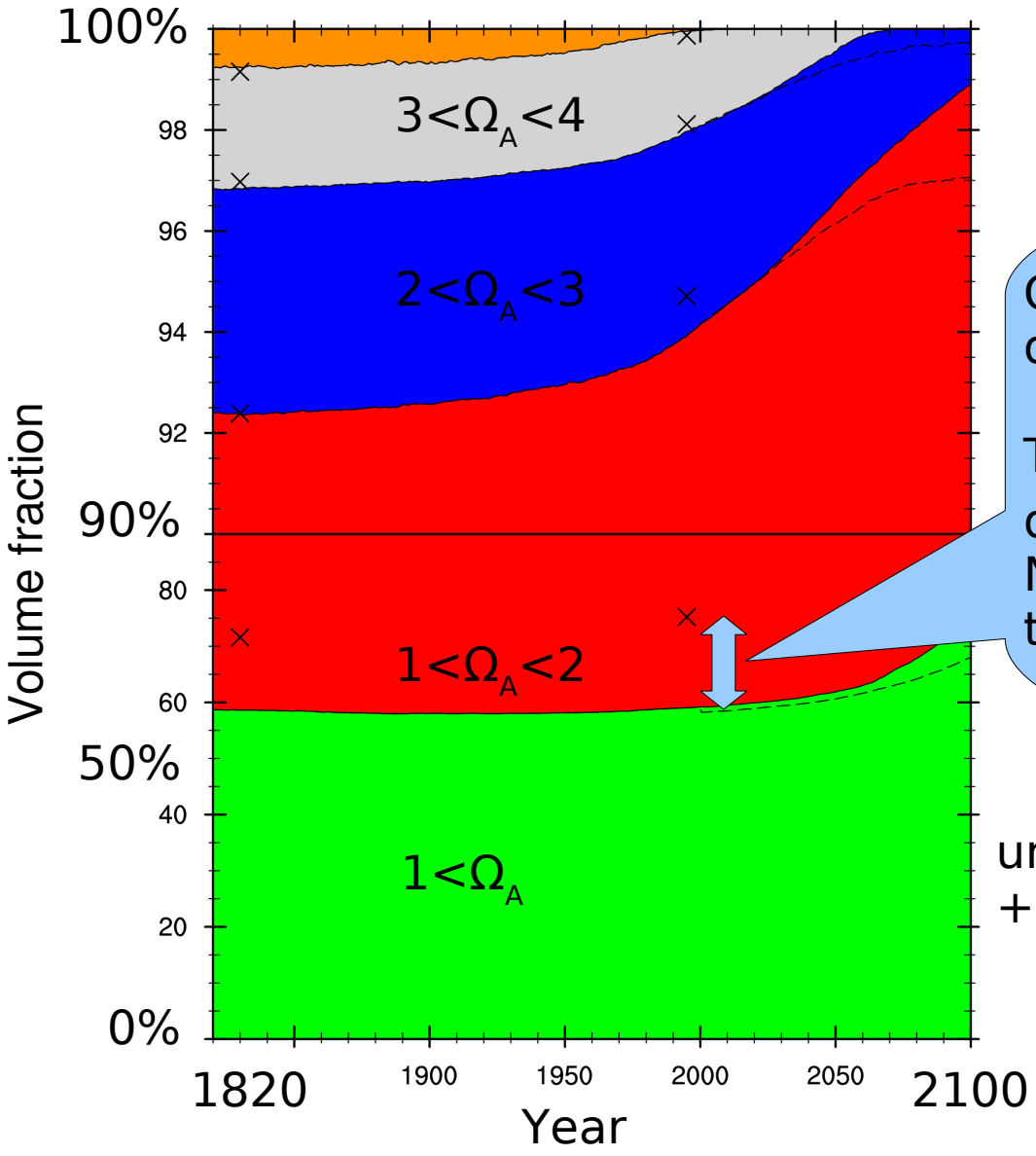

Comparision with observation based data from GLODAP/WOA01:

The model tends to overestimate Ω_A at depths of 500 – 1500 m, most notably in North Pacific => Saturation horizon is too deep.

undersaturated waters:
+ 30% (+17% of total ocean volume)

Changes in volume distribution

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