Arctic Modelling and Observational Synthesis 'AMOS' within SCOR BEPSII Biogeochemical Exchange Processes at Sea-Ice Interfaces

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Activities, meetings and outreach activities are posted on SCOR's BEPSII website: http://www.scor-int.org/Working_Groups/wg140.htm

Overview SCOR WG 140 - Biogeochemical Exchange Processes at Sea-Ice Interfaces BEPSII:

Studies feedbacks between biogeochemical (bgc) and physical processes at the ocean–ice-snow -atmosphere interfaces and within the sea ice matrix and aims to improve sea ice biochemistry models from the micro to the global scale by bringing together experimentalist and modellers. The WG is closely linked to SOLAS (Surface Ocean Lower Atmospher Study) and OASIS (Ocean Atmosphere Sea-Ice Snowpack Interaction). BEPSII has 3 task groups:

TG1 on Methodologies and Intercomparisons: 1. Methodological review; 2. Dedicated intercomparisons and intercalibration projects; and 3. Guide of Best Practices (living web document).

TG2 on Data: 1. Produce new data inventories by collation of existing data; 2. Provide recommendations for standardized protocols and databases.

TG3 on Modeling (Focus of this poster):1. Recommendations from modelers to observationalists, 2. Review papers on major biogeochemical processes and their parameterization in models: a) DIC/Alk separation during the freezing process, b) release and transfer of iron and other minerals c) light transfer in sea ice, d) ice algal release into the water, e) link to atmospheric chemistry, f) turbulent mixing in Arctic Ocean models. 3. Intercomparison of 1D models a) General ice-phytoplankton models, b) DMS, c) Physical: convective mixing (EoS), ice thermodynamics, advection processes, 4. Application in regional models with links to global & regional climate modeling. Activities within 4 are strongly linked with FAMOS (Forum for Arctic Modelling and Observational Synthesis).

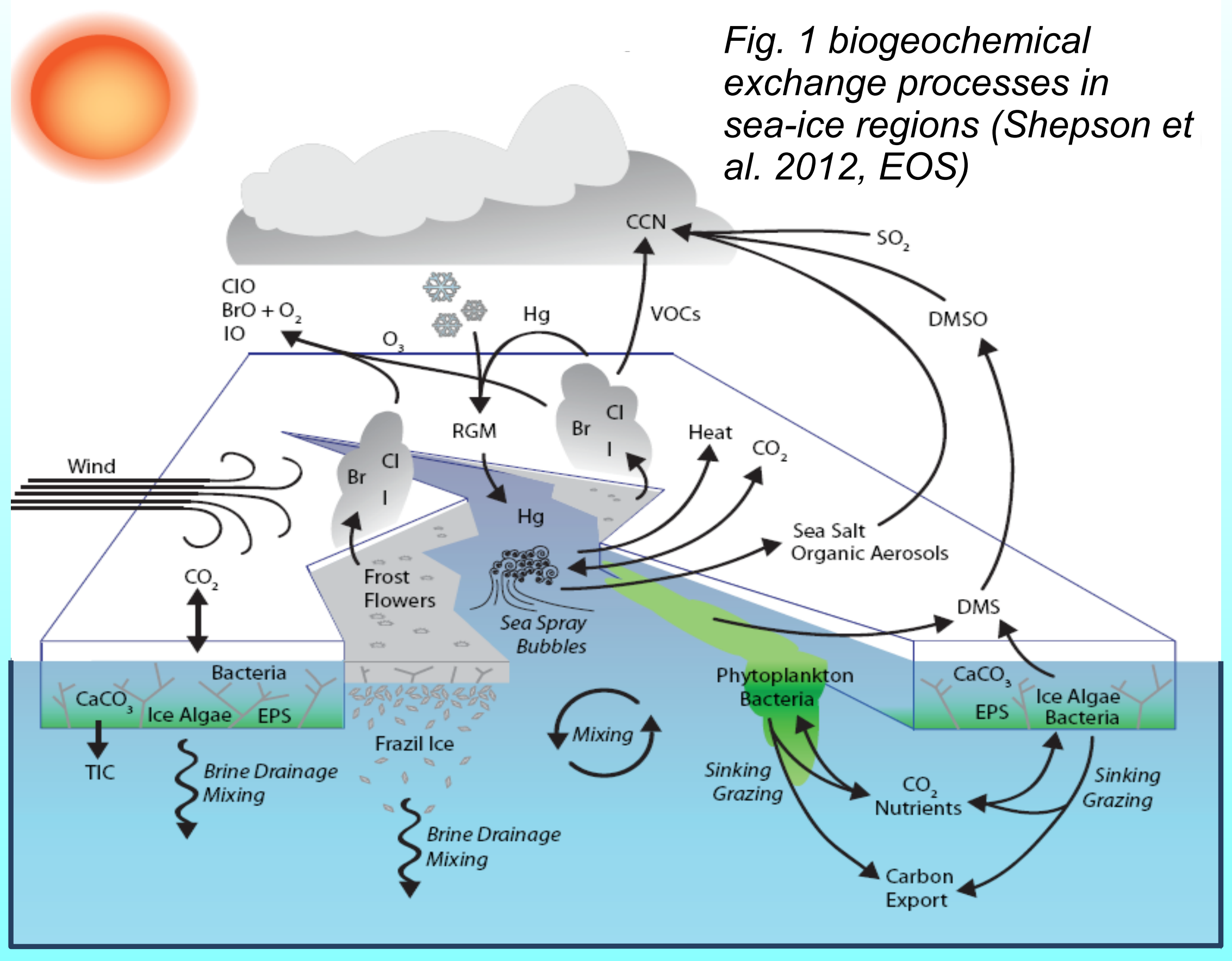


Fig. 1 biogeochemical exchange processes in sea-ice regions (Shepson et al. 2012, EOS)

BEPSII Foci:

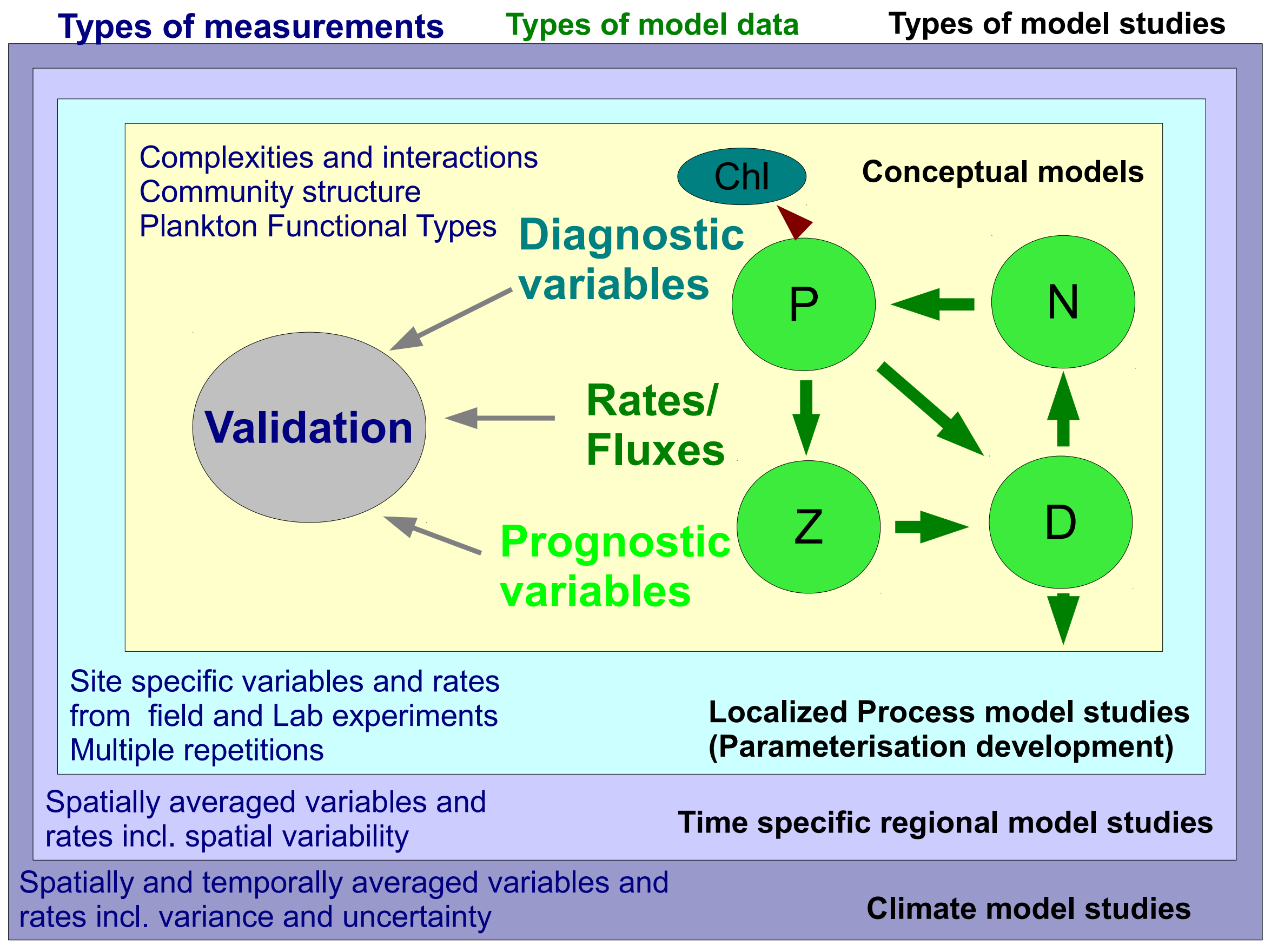
Physical forcings of biogeo-chemical processes in sea ice and at sea ice – snow -atmosphere interfaces

Role of biota in structuring ice chemistry and ice physical properties

Sea ice as a source of primary atmospheric aerosols and reactive halogens

Sea ice feedbacks to anthropogenic climate change

The global relevance of small-scale processes



Types of measurements | Types of model data | Types of model studies

Complexities and interactions
Community structure
Plankton Functional Types

Diagnostic variables

Rates/ Fluxes

Prognostic variables

Validation

Chl

P

N

Z

D

Conceptual models

Site specific variables and rates from field and Lab experiments
Multiple repetitions

Localized Process model studies (Parameterisation development)

Spatially averaged variables and rates incl. spatial variability

Time specific regional model studies

Spatially and temporally averaged variables and rates incl. variance and uncertainty

Climate model studies

Fig. 2 Schematic for Model Validation of biogeochemical models

The observational needs of a modeler:

To develop models and to test and understand model capabilities, rigorous model skill assessment is required which in turn requires observational data. An ideal dataset would cover all seasons and most of the model domain and be available as a gridded dataset.

However, observations in the Arctic are sparse and heterogeneous, so
 How can we make the measurements we can do most effecively?
 How can we use what we measure most effectively ?
 => Feedback from observationalists will allow modellers to better use observations.

Models produce three kinds of data to be validated (Fig. 2):
 prognostic model variables (model boxes)
 rates (model arrows), e.g. growth, mortality
 derived/secondary quantities => diagnostic variables
Different models require different validation data (Fig. 2):
 Conceptual models, process study models, regional models, global climate models.

Within BEPSII's TG3 the intention is to build on existing efforts (e.g. Kay et al. 2012) rather than duplicate. Focus is on the observational need for bgc model development in polar regions, but many general needs apply to physical and bgc variables. Vancoppenolle et al. 2013A's overview of the role of sea ice for bgc processes serves as an initial step.

Limitations:

1. Long term observations of Arctic biogeochemical variables are sparse and for many locations non existent. This significantly affects our ability to constrain models, which show large differences in bgc system variables.
2. Limited horizontal and vertical resolution affects basin exchange and mixing processes on shelves.
3. Sea ice retreat varies markedly between models, causing uncertainties e.g. in the timing and location bgc features.

Results - Primary Production, nutrients and Chl: A recent assessment of projected primary production, nutrient and sea ice concentrations in 11 CMIP5 ESMs shows that the mean model simulates Arctic-integrated primary production for 1998–2005 well, but that models neither agree on what limits primary production today, nor on the sign of future change. A balance of a decrease in available nutrients due to increased stratification and increased light availability due to reduced sea-ice cover operates in all models; however, it depends on the particular model as to whether the decrease in available nitrate is sufficient to overcome or not the benefits of the light increase (Fig. 3, Vancoppenolle et al. 2013b). A deep Chl maximum in the central Canada Basin is not consistently represented within 6 ESMs, but becomes more pronounced in the multimodel mean by the end of the century (Fig. 4).

Conclusions: Higher-resolution regional models of Arctic marine biogeochemistry are needed to identify, analyze and understand local changes and impacts. The lack of observational data is apparent; more consistent and expanded marine biogeochemistry observations are urgently needed to validate the models and reduce uncertainty in future projections.

Model Intercomparisons: Arctic biogeochemistry in Earth System Models (ESMs)

The purpose of coupled biological/physical models goes beyond synthesizing information and numerical experimentation. They are increasingly being used to assess ecosystem responses to climate change, allow cost analyses, predict outcomes of management choices, and eventually to support high-stakes decision making.

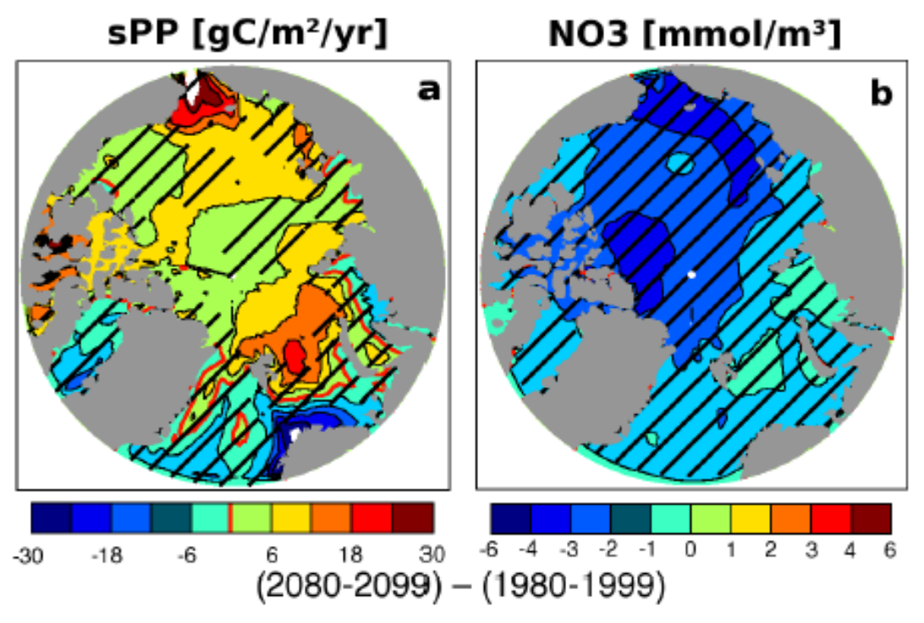


Fig.3: Mean model differences 2080-2100 minus 1980-2000 from 11 CMIP5 ESMs for a) annual specific primary production (sPP) and b) nitrate concentration. Hatching indicates where 80% of the models agree on the sign of change(Vancoppenolle et al. 2013b).

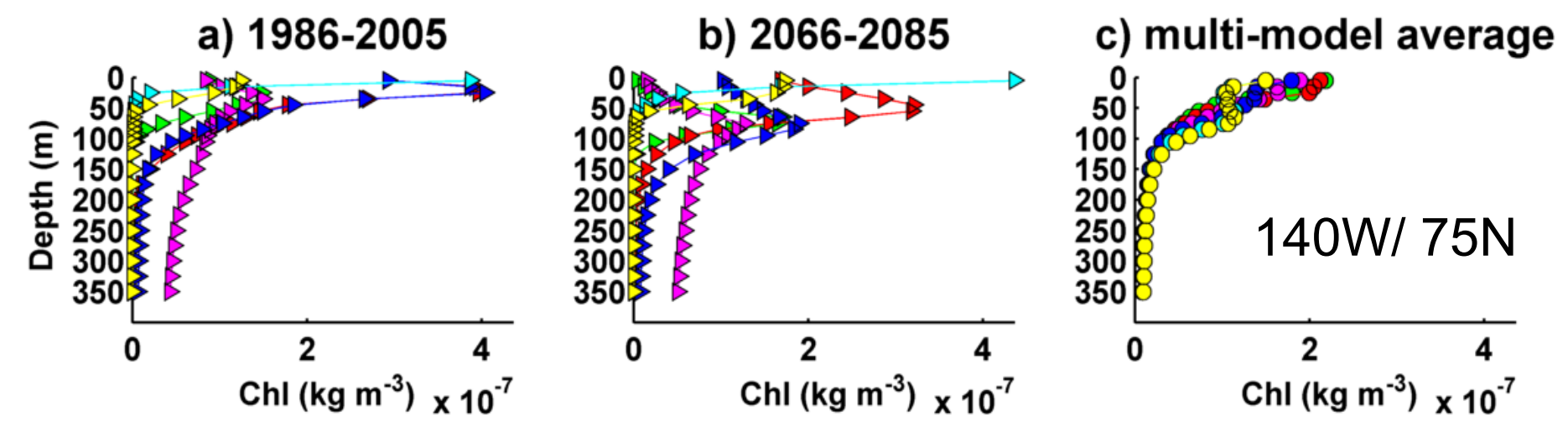


***Fig. 4** Modelled bidecadal annual mean profiles of Chlorophyll [kg m^3] .*

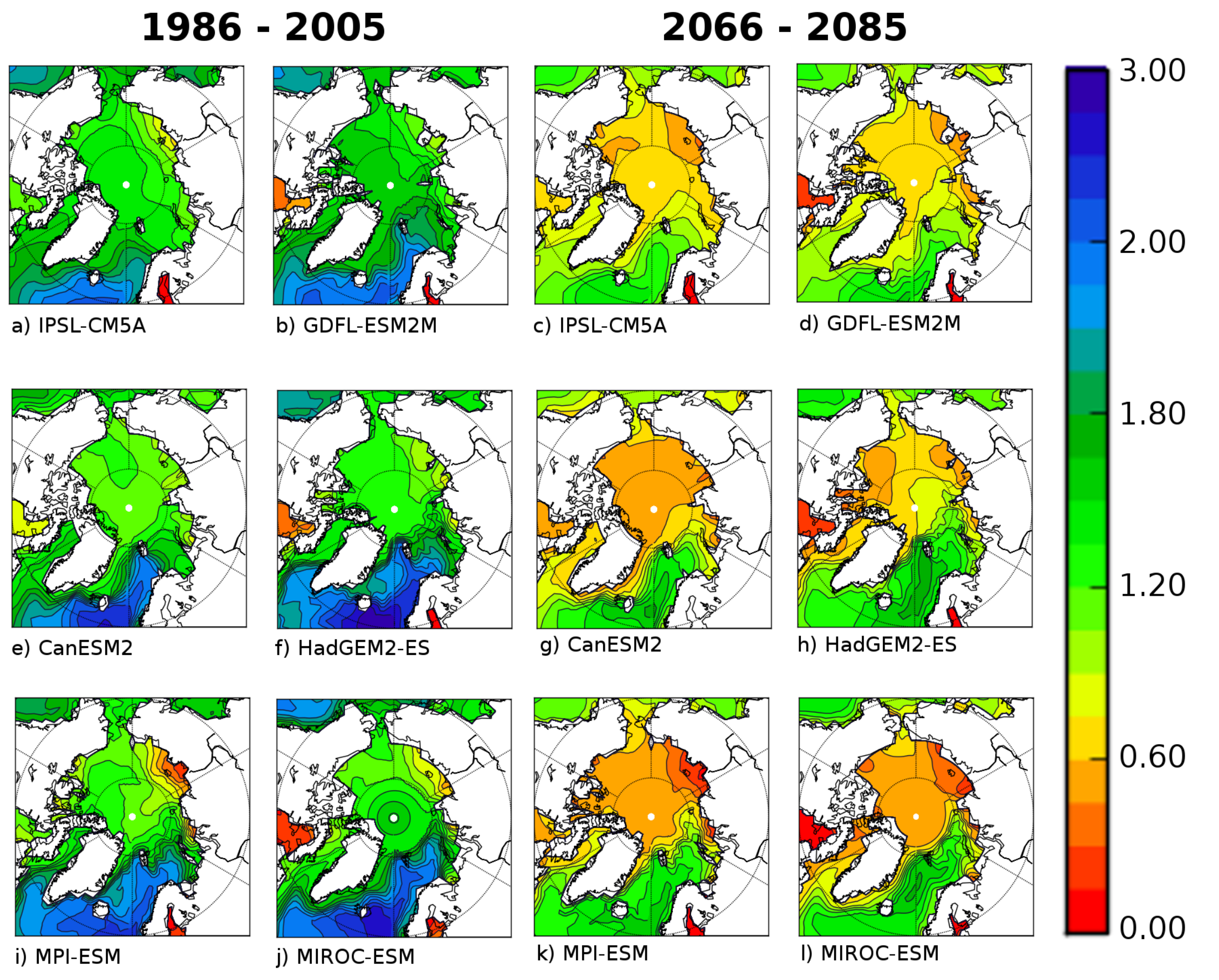


Fig. 5 Simulated annual mean aragonite saturation state (Steiner et al. 2013b).

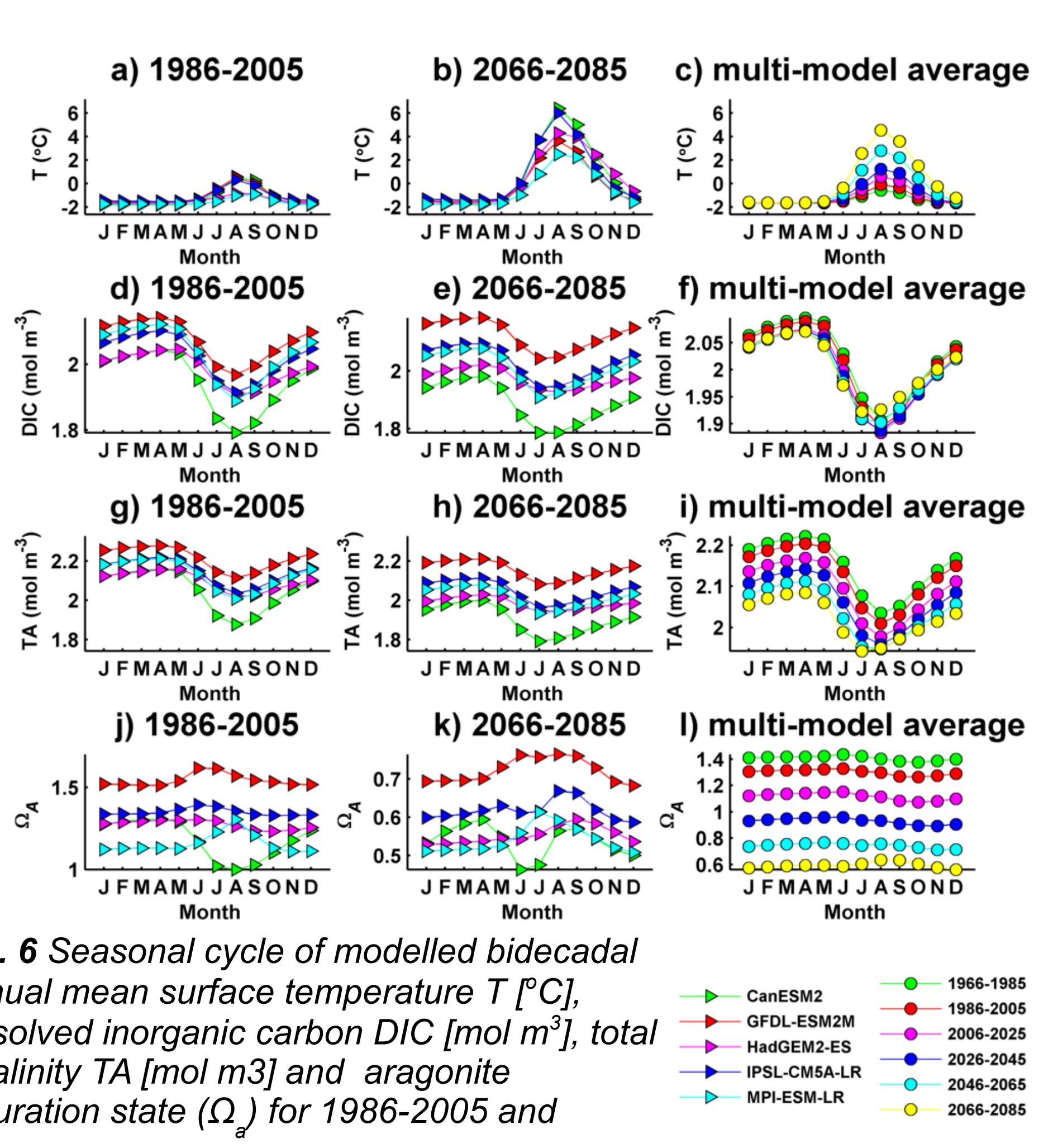


***Fig. 6** Seasonal cycle of modelled bidecadal annual mean surface temperature T [°C], dissolved inorganic carbon DIC [mol m^3], total alkalinity TA [mol m3] and aragonite saturation state (Ω_a) for 1986-2005 and 2066-2085 at 140W/75N. Right column: Projected temporal evolution of the multimodel mean from 1986-2005 to 2066-2085 (Steiner et al. 2013b).*

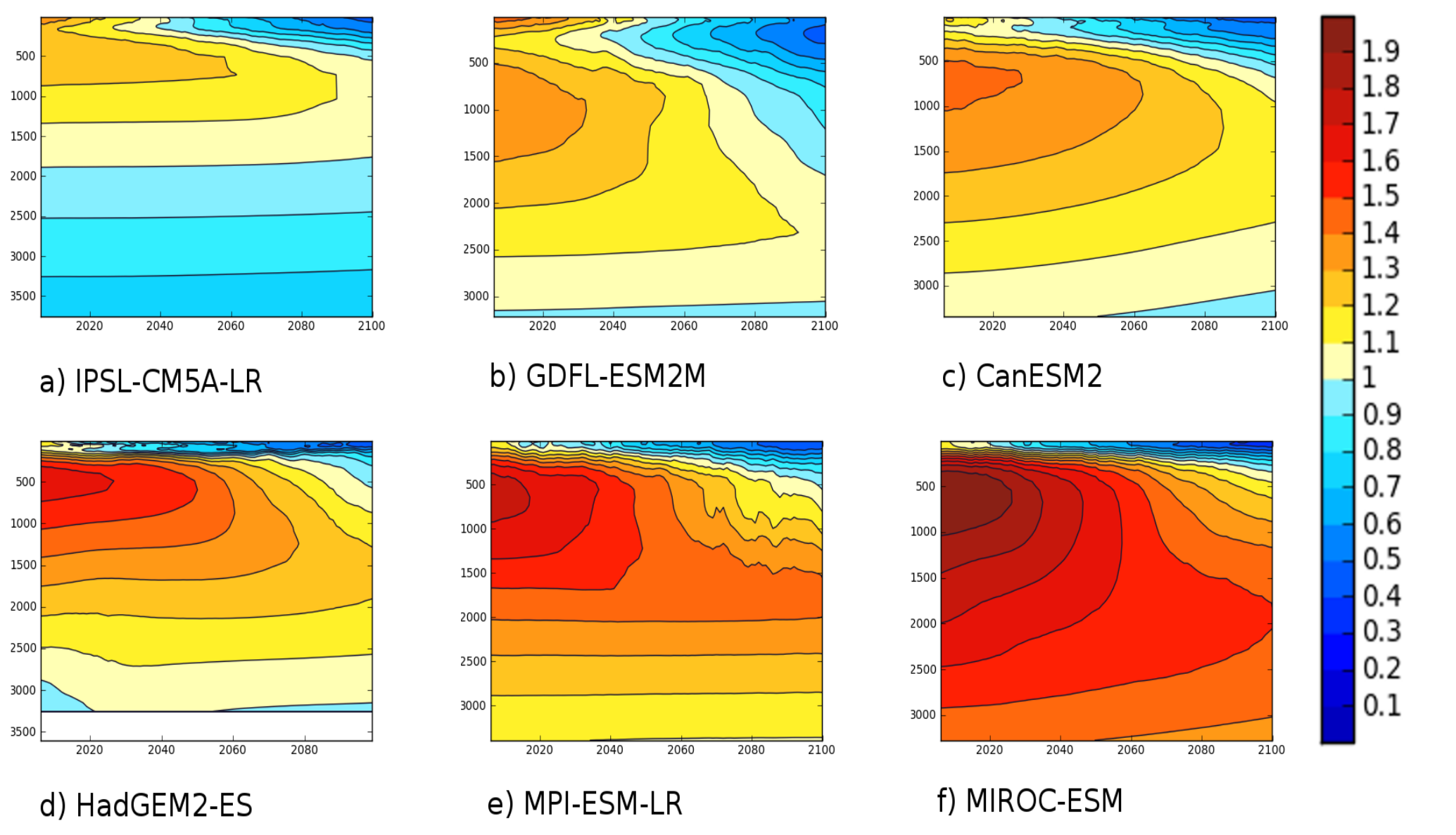


Fig 7. Timeseries of aragonite saturation state in the central Canada Basin (77.5N, 136W) as simulated for the RCP8.5 scenario (Steiner et al. 2013b).

Results - Acidification:

Based on 6 CMIP5 ESMs Steiner et al. 2013 a,b find: a) Continued acidification over the 21st century is a robust signal, despite the large model spread in summer sea ice cover: The pH in the Canada Basin decreases from ~8.1 in the recent past to ~7.7 by the end of the century and CaCO3 saturation states (Ω) reduce from ~1.2 (2.0) to ~0.6 (1.0) for aragonite (calcite) for RCP8.5 (Fig. 5). b) The projected seasonal amplitude in Ω shows little change, since the main drivers (dilution of DIC and TA) have opposite effects on the saturation state (Fig. 6). c) An emission scenario with mitigation (RCP4.5) reduces the progress of undersaturation (pH of 7.9 is reached about 25 years later in RCP4.5 than in RCP8.5). However, the emergence of undersaturated surface waters within the next decade differs little between scenarios. d) The Canada Basin shows a characteristic layering with respect to saturation states. Shallow undersaturated layers form at the surface and subsurface creating a shallow saturation horizon which expands from the surface downwards. This is in addition to the globally observed deep saturation horizon which is expanding upward with increasing CO2 uptake (Fig. 7). e) Models indicate a strong connection between simulated acidification and sea ice reduction as well as stratification.

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Shepson et al., 2012, Eos 93(11): Changing Polar Environments, Interdisciplinary Challenges 117-118
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