Modeling Antarctic Sea Ice Halodynamics: From the Micro-Scale to the Climate-Scale

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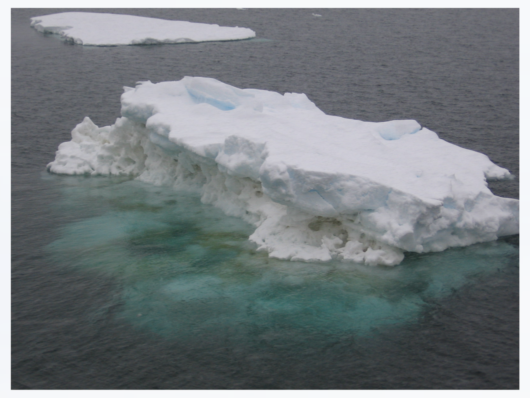
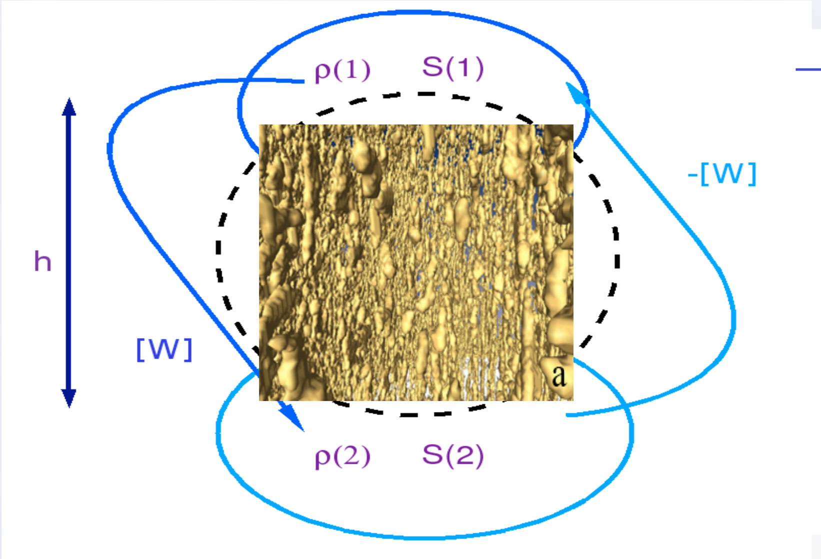
Observations From the Field: Sea ice is a biogeochemically active, multiphase medium

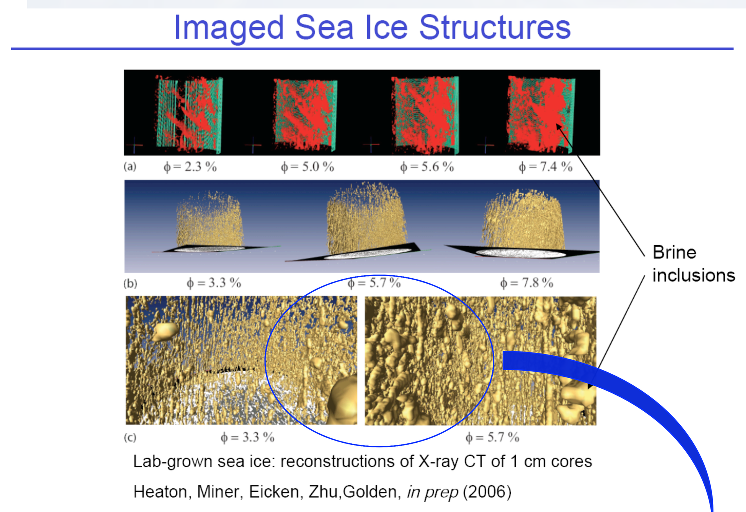
Sea ice flipped to reveal the ice algae growing in the bottom ice layers

Melting Antarctic sea ice: algae growing in the freeboard and near the sea surface



Parameterizing the Micro-scale Physics of Sea Ice





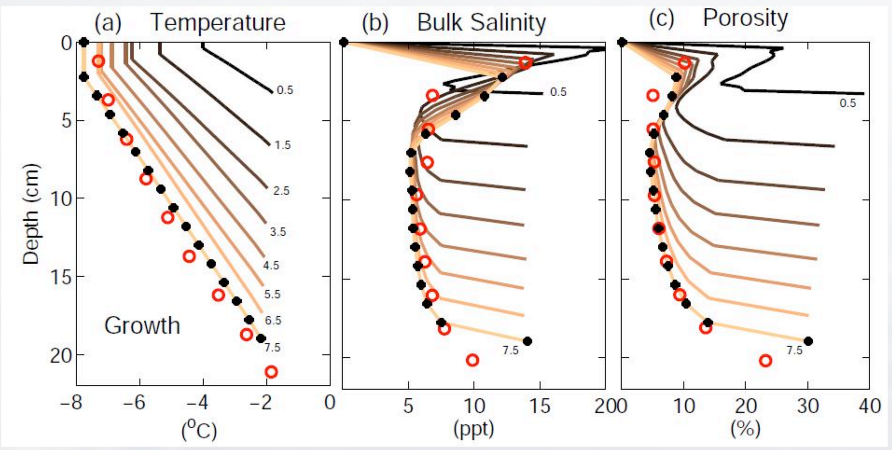
Test closure approximations

Mixing Length Diffusivity (MLD) $$D_{ml} = \begin{cases} \frac{g\Pi_o}{\mu}\phi^3\Delta\rho_b l & \text{if } \rho_b(z) \text{ is unstable} \\ 0 & \text{otherwise} \end{cases}$$

Enhanced Molecular Diffusivity (EMD) $$D_e = \begin{cases} \phi\mathcal{D}_e & \text{if } \frac{dh}{dt} > 0 \\ 0 & \text{otherwise} \end{cases}$$

Volume averaging fluid equations in a porous medium

Validation at the "Lab" Scale



- Model contour after 8 hours of growth
- Model 12 hr contours
- Measurement after 8 hours of growth

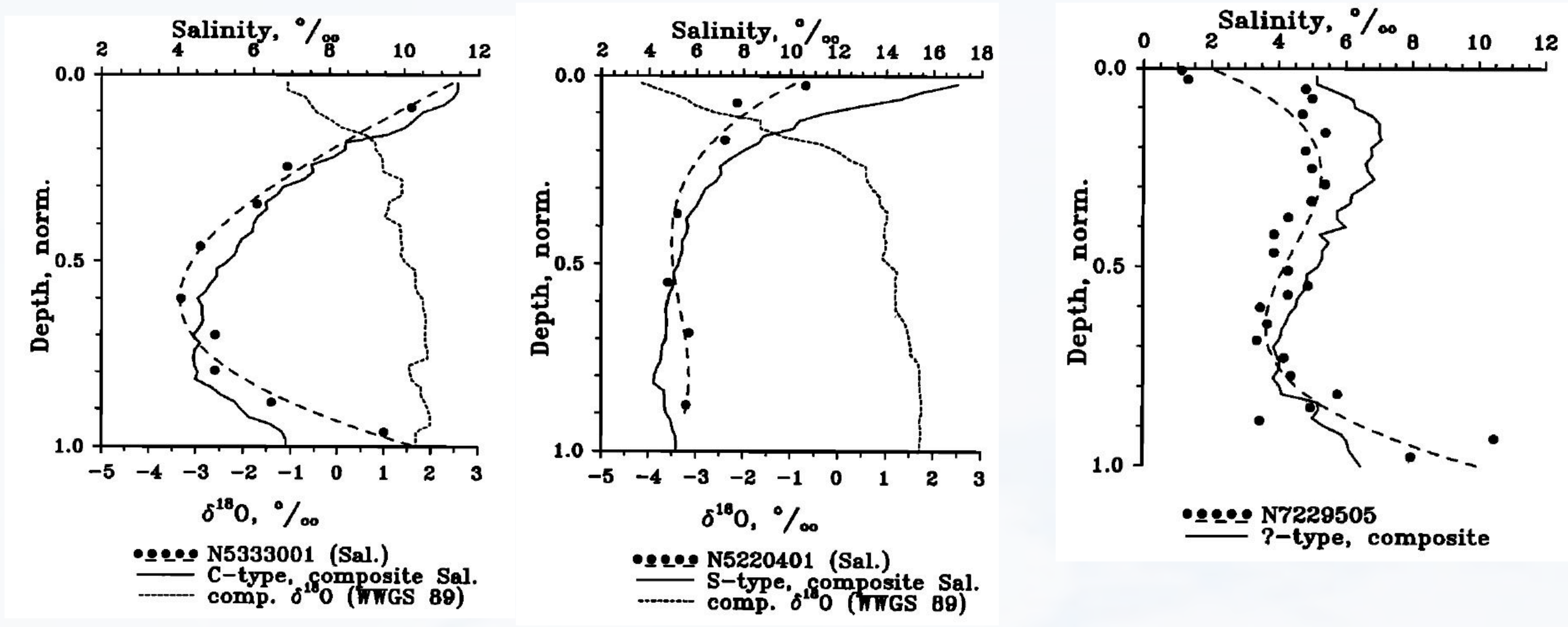
Comparison of modeled growing ice with lab study (Cottier et al. 1999, JGR)

The Trouble with Sea Ice (Snow and other messy complications)

A) C-Type (Young Ice Growth)

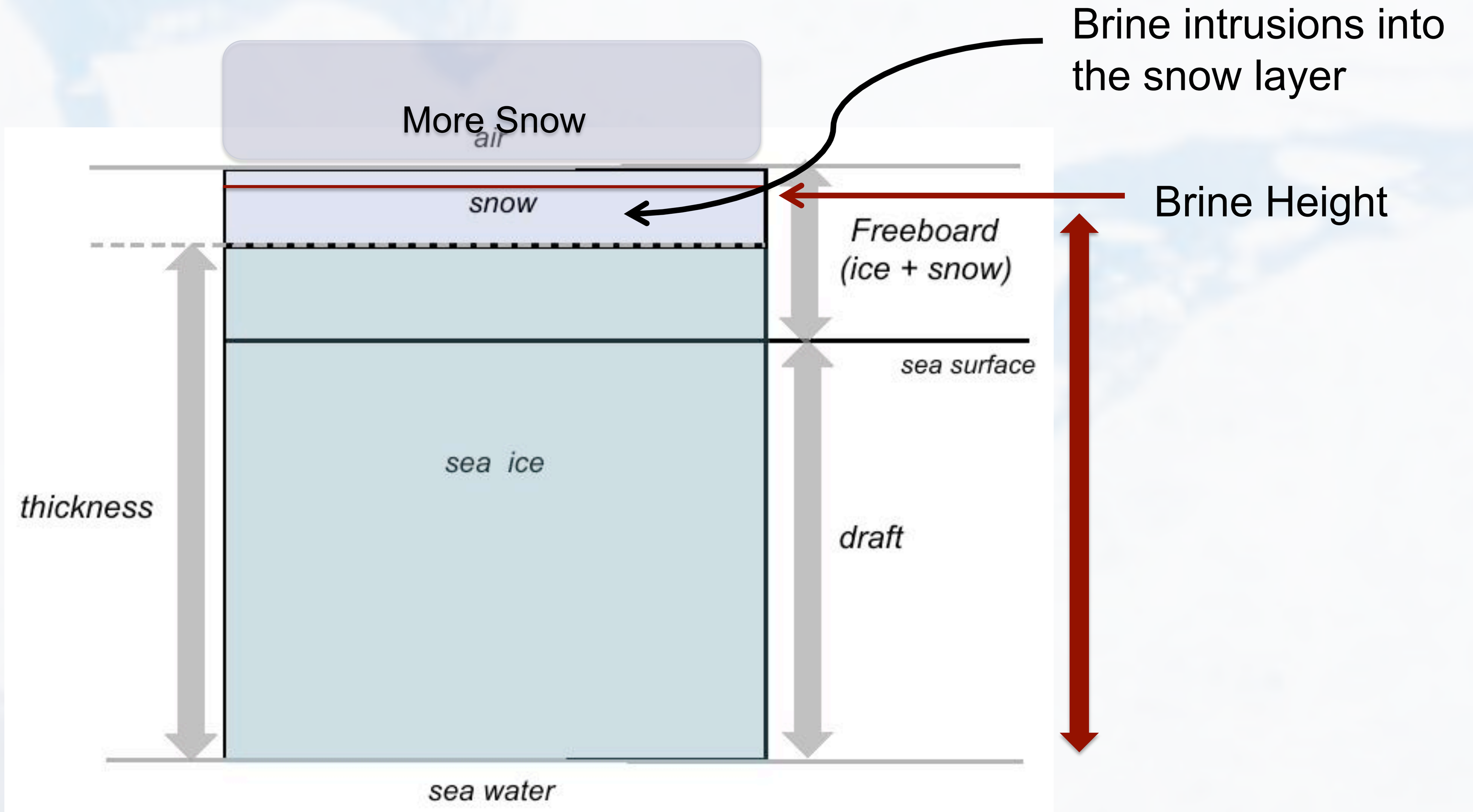
B) S-Type (Heavy Snow Accumulation)

C) ?-Type (Melt)



Characteristic salinity profiles and composites from 129 Weddell Sea ice cores (Eicken 1992, JGR). Vertical salinity profiles reflect physical processes during ice growth (C-type), snow loading (S-Type) and ice melt (?-Type)

Parameterization for the "Field" Scale



Heavy snow accumulation forces the ice further below sea level and drives brine into the snow layer. The higher snow porosities allow for greater brine accumulation per volume and, hence, greater salt accumulation.

Bibliography

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Jeffery, N., E. C. Hunke, and S. M. Elliott (2011), Modeling the transport of passive tracers in sea ice. *J. Geophys. Res., 116*, doi:10.1029/2010JC006527.
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Eicken, H. (1992). Salinity profiles of Antarctic sea ice: field data and model results. *J. Geophys. Res., 97*, 15,454-57.
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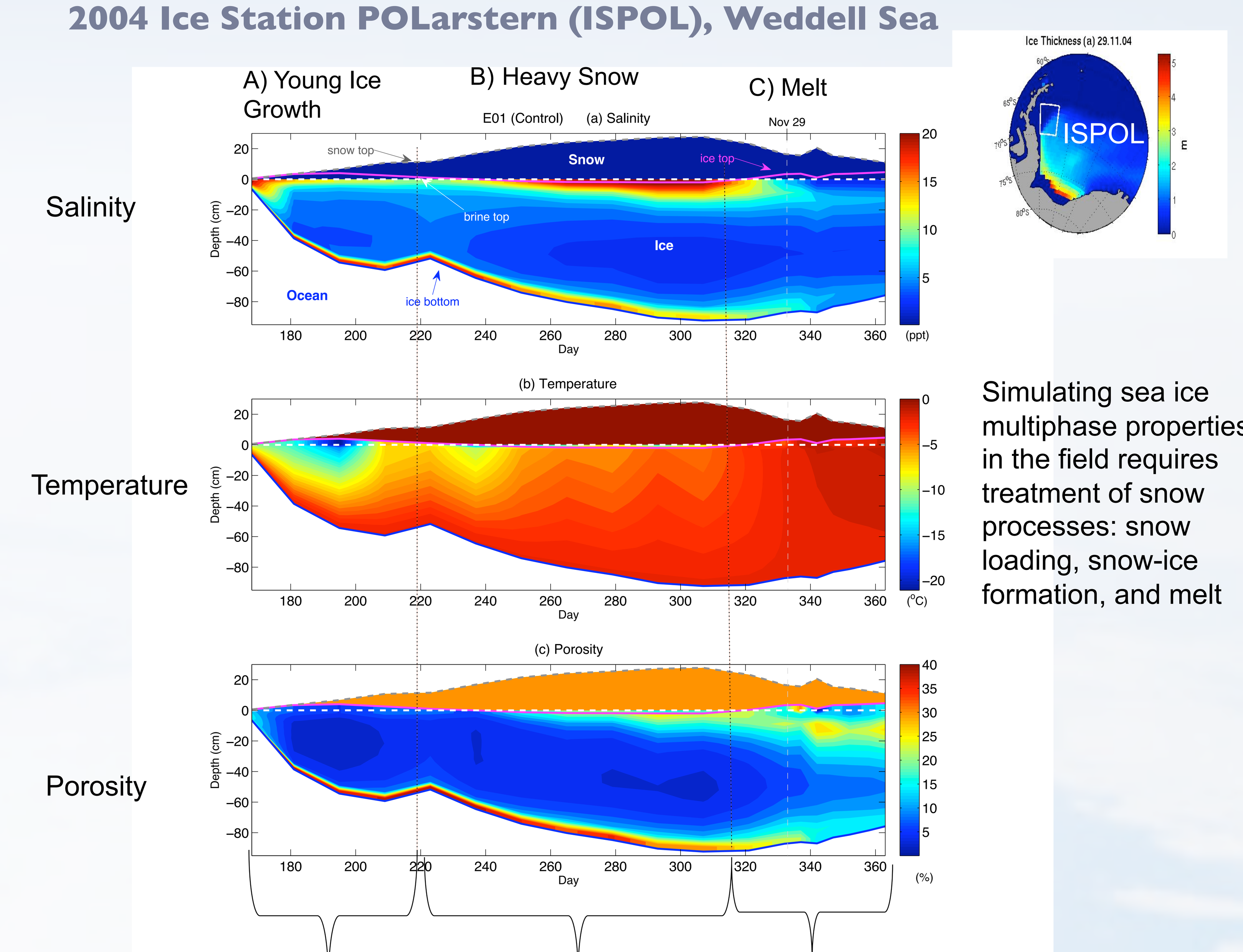
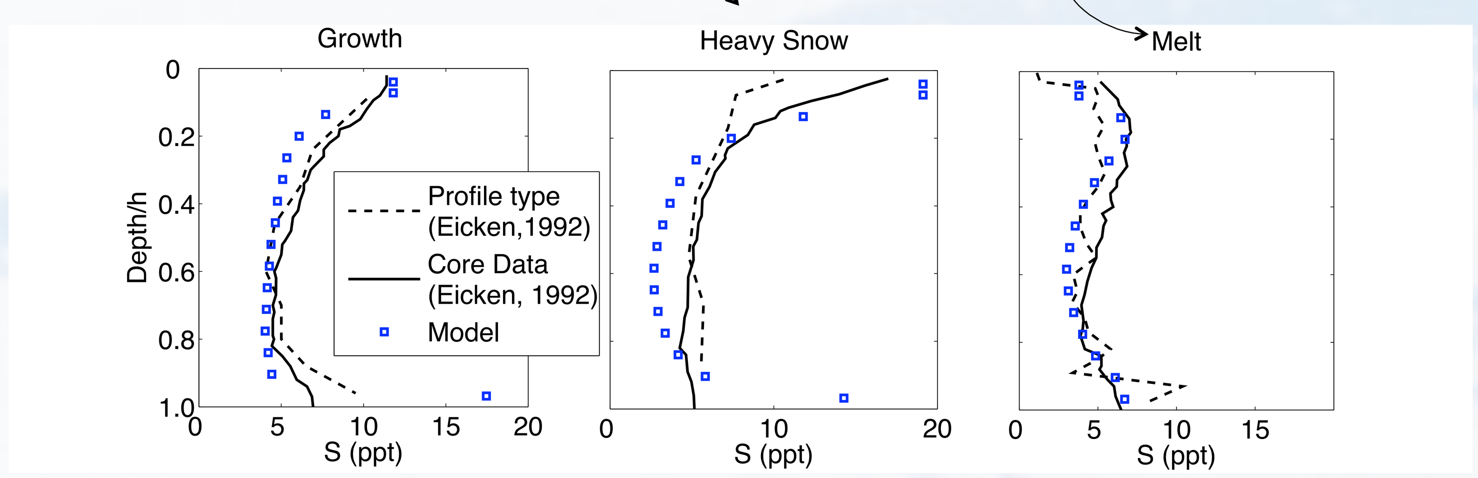
Modeling Sea Ice in the Field:

2004 Ice Station POLarstern (ISPOL), Weddell Sea



Simulating sea ice multiphase properties in the field requires treatment of snow processes: snow loading, snow-ice formation, and melt

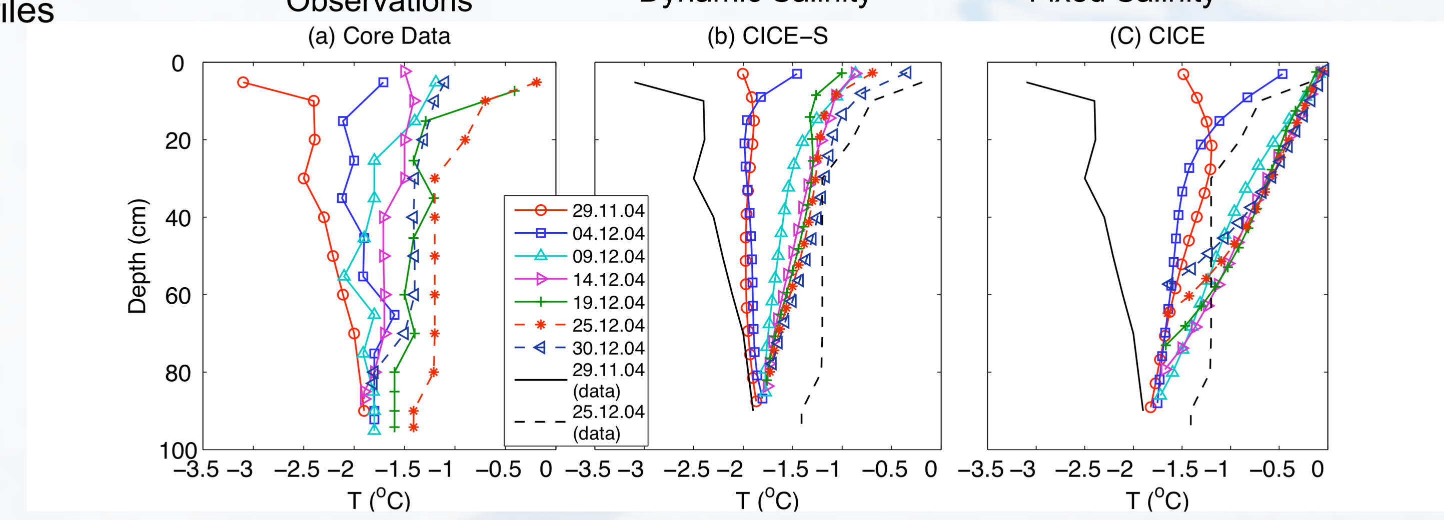


Temperature Profiles

A) ISPOL T Observations

B) Model with Dynamic Salinity

C) Model with Fixed Salinity



Conclusions

1) Observations of sea ice from the field motivate development of dynamical, multiphase ice models
2) Lab studies isolate processes and are essential for validation of micro-scale parameterizations
3) Geophysical models must account for coupled processes: example, snow/ice interactions complicate sea ice halodynamics
4) Good comparison with ice cores from the field over several thermodynamic regimes is essential for global applications