Science Challenges for MOSAiC

The Multidisciplinary drifting Observatory for the Study of Arctic Climate

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On Behalf of

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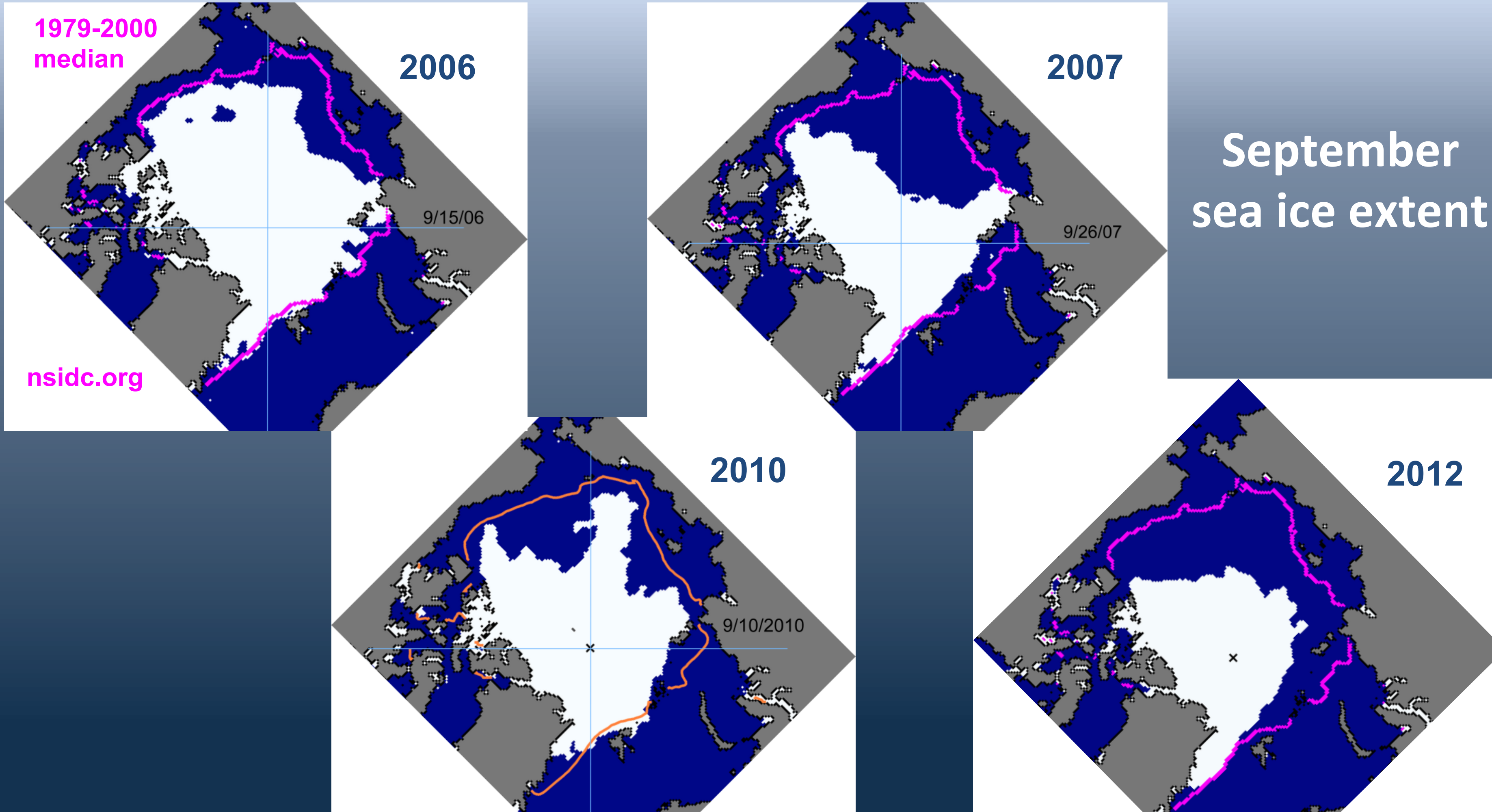
Arctic in Transition



One of the defining signatures of climate change.

A "grand challenge" for climate science (Kattsov et al. 2010)

Modeling the Arctic

Many elements of Arctic sea ice modeling can be tied directly to SHEBA (1997-1998, multi-year ice environment).

Two responses:

1) Highlights the value of inter-disciplinary, year-round measurements.
2) Yikes! SHEBA was 15 years ago in a sea-ice environment that barely exists anymore.

To manifest the next large advances in sea ice and Arctic system modeling, we need a modern-day, interdisciplinary perspective that represents current ice conditions and their interactions with the atmosphere, ocean, biogeochemical processes, etc.

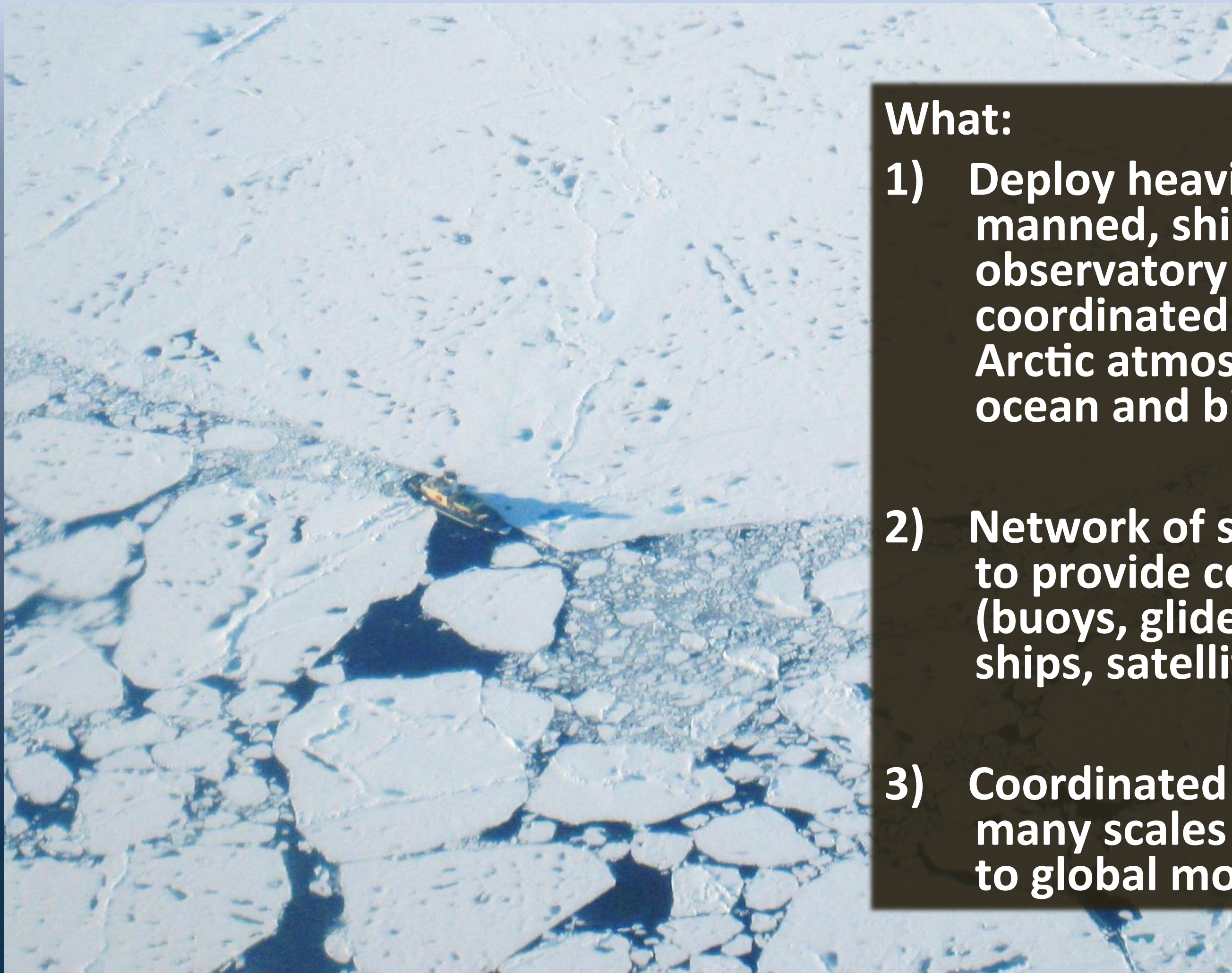
Critical Model Shortcomings
Inhibit our Understanding

"Further, understanding of the polar climate system is still incomplete due to its complex atmosphere-land-cryosphere-ocean-ecosystem interactions involving a variety of distinctive feedbacks.... A serious problem is the lack of observations against which to assess models, and for developing process knowledge......" (IPCC AR4, WG1, Section 11.8.1)

Among the primary causes of biases in simulated sea ice:

- High-latitude winds
- Vertical and horizontal mixing in the ocean
- Surface heat flux errors
- Atmospheric boundary layer
- High-latitude cloudiness

The MOSAiC Plan



What:

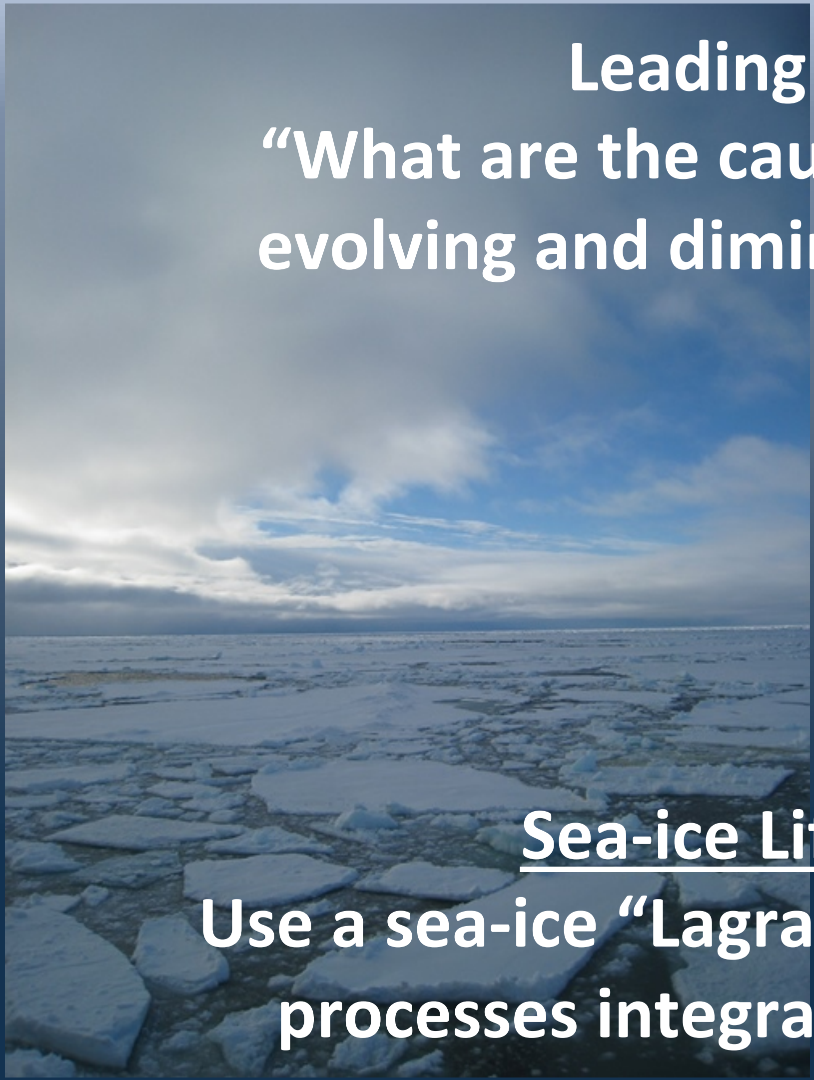
1) Deploy heavily instrumented, manned, ship-based, Arctic Ocean observatory for comprehensive, coordinated observations of the Arctic atmosphere, cryosphere, ocean and biosphere.

2) Network of spatial measurements to provide context and variability (buoys, gliders, UAVs, aircraft, ships, satellites, ice stations).

3) Coordinated modeling activities at many scales from process-studies to global models.

2018 to 2019, Transpolar drift, > 1 year, detailed process study

MOSAiC Science Drivers



Leading Science Question:
"What are the causes and consequences of an evolving and diminished Arctic sea ice cover?"

Sea-ice Lifecycle as a Theme.
Use a sea-ice "Lagrangian" perspective, where ice processes integrate forcings from atmos and ocean.

MOSAiC Science Drivers

Guiding Science Questions:
1. Energy budget of 1st year ice, stratification
2. 1st year ice movement & deformation
3. Cloud processes
4. Biological productivity
5. Elemental cycles
6. Large-scale linkages

Key Challenges

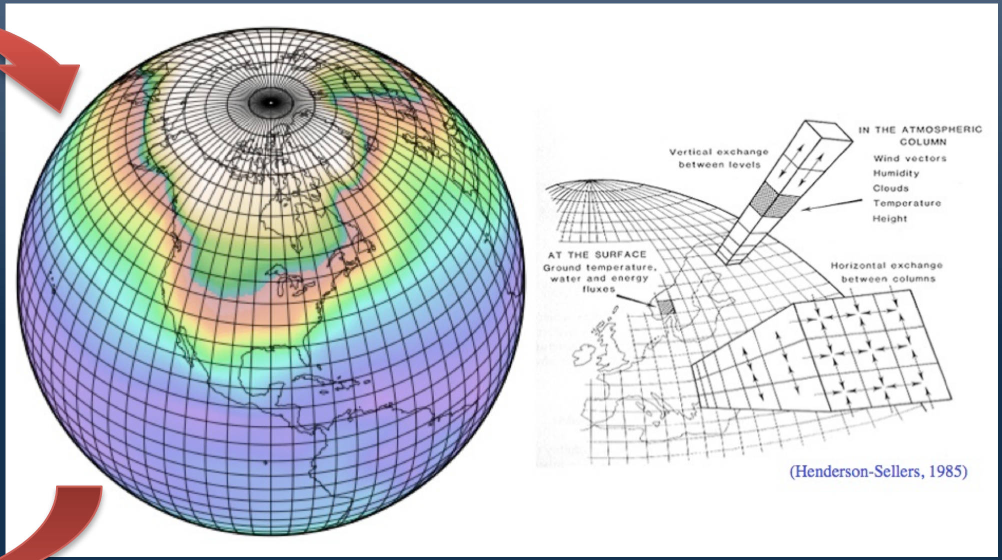
1. Efficiently impacting models
2. Being interdisciplinary
3. Characterizing heterogeneity
4. 1st year sea-ice environment

Key Challenges

<u>Direct, effective, and efficient impact on models</u>
<u>and process- and system-level understanding!</u>

- Integrating obs+model objectives from the beginning
- Using model needs to identify science questions
- Model needs as a metric for prioritization

The Challenges: Focusing objectives; Specifying measurements.



(Henderson-Sellers, 1985)

Key Challenges

1. Efficiently impacting models
2. **Being interdisciplinary**
3. Characterizing heterogeneity
4. 1st year sea-ice environment

Interdisciplinary

Persson et al. 2013

Multiple cloud events accompany warm moist advection aloft; Impacts BL structure.

Liquid water clouds increase LW_{down} by 40-70 W/m²

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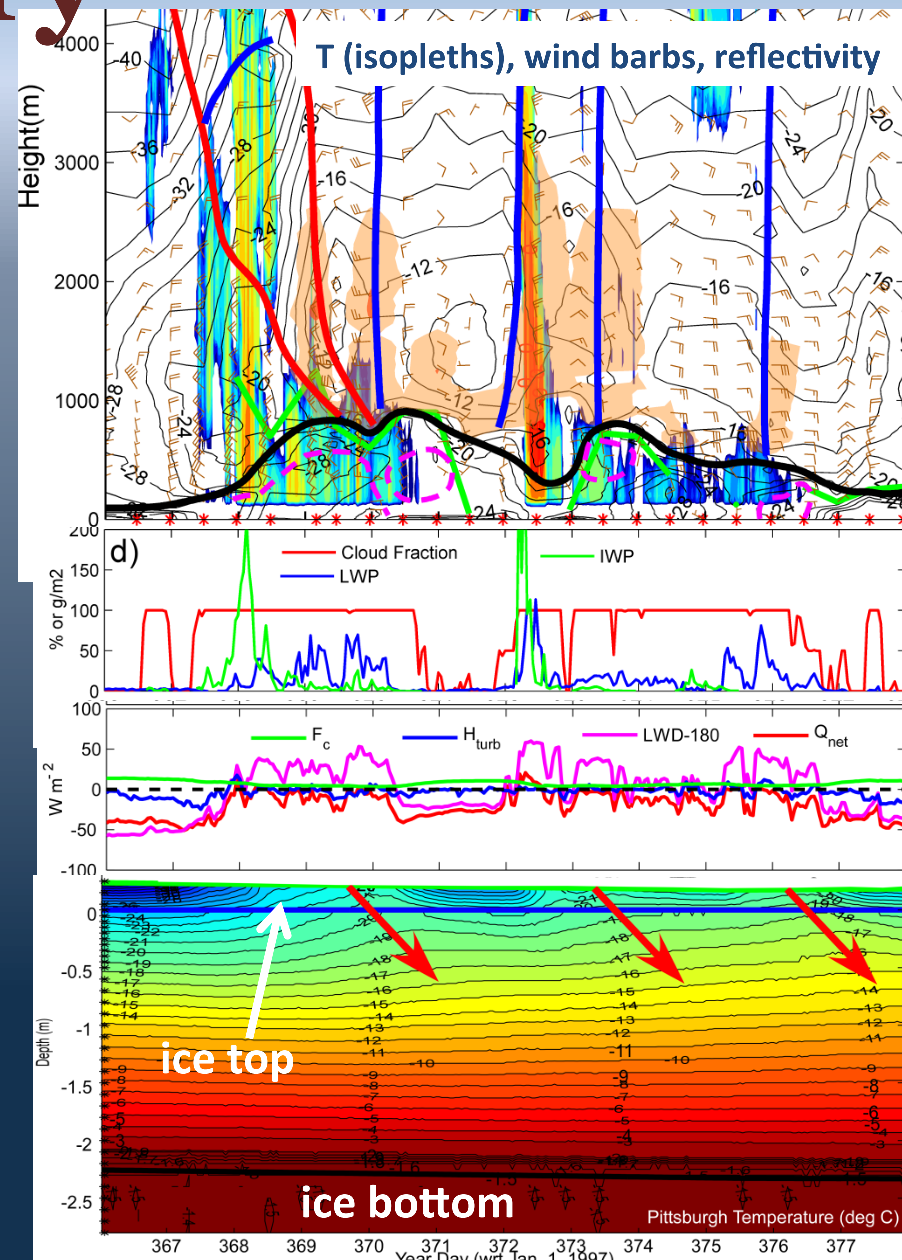
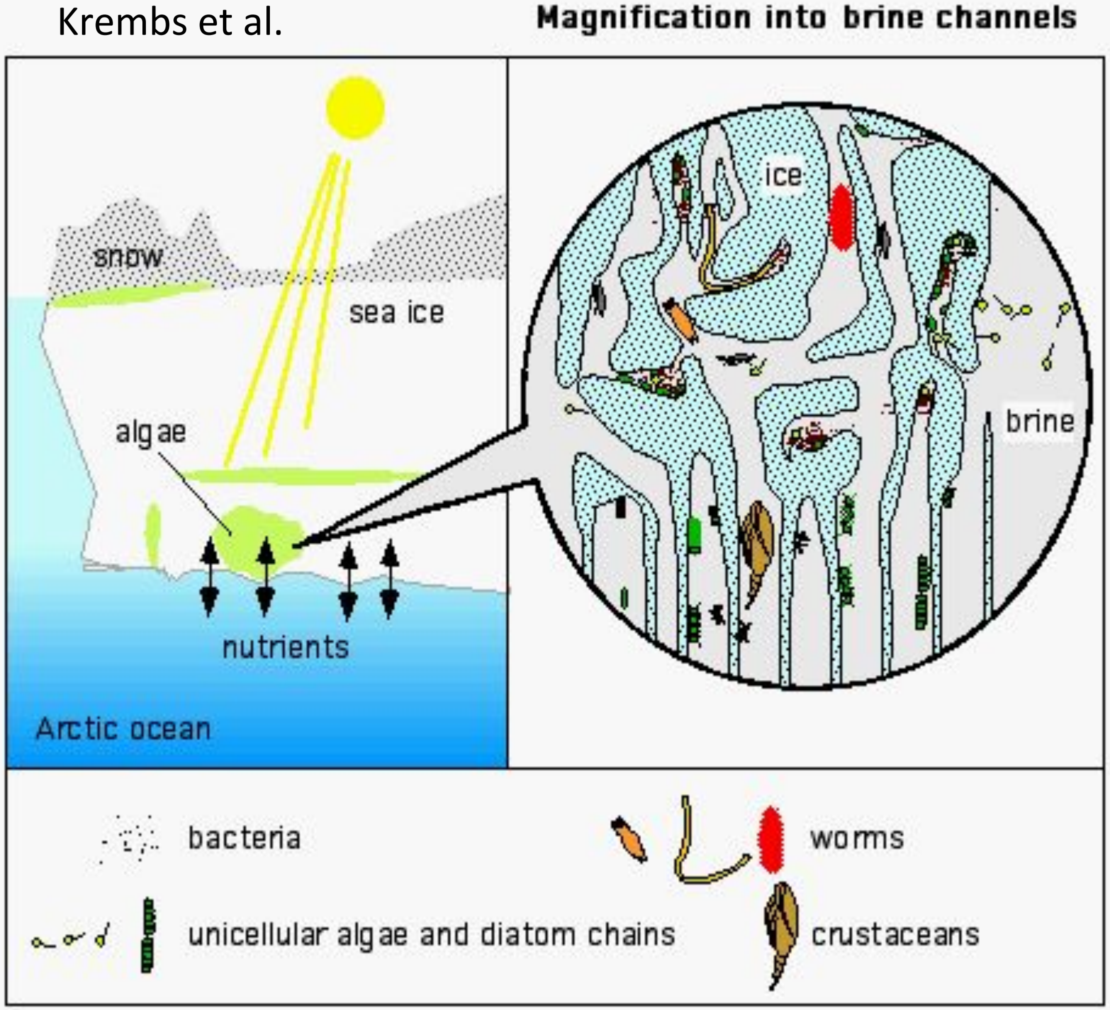
Significant change in surface energy budget.

Thermal structure of snow and ice responds strongly to these events



Interdisciplinary

Krembs et al.



Sea-ice Biology depends on….

Sea-ice processes:
Brine, temperature, opacity

Atmospheric processes:
Sun and radiation, snow cover

Ocean processes:
Nutrient exchange

Being Interdisciplinary

- Interdisciplinary processes represent climate system "coupling."
- "Coupling" is an important area of focus for model development.
  An example: Wieslaw Maslowski (ocean modeler) has become very interested in clouds
- Improved coupling =>> improved representation of <u>feedbacks</u> (which are largely beyond the reach of observations)

The Challenge:

Breaking down disciplinary barriers,

Designing appropriate cross-disciplinary studies,

(And eating Don's M&Ms)

Key Challenges

1. Efficiently impacting models

2. Being interdisciplinary

3. **Characterizing heterogeneity**

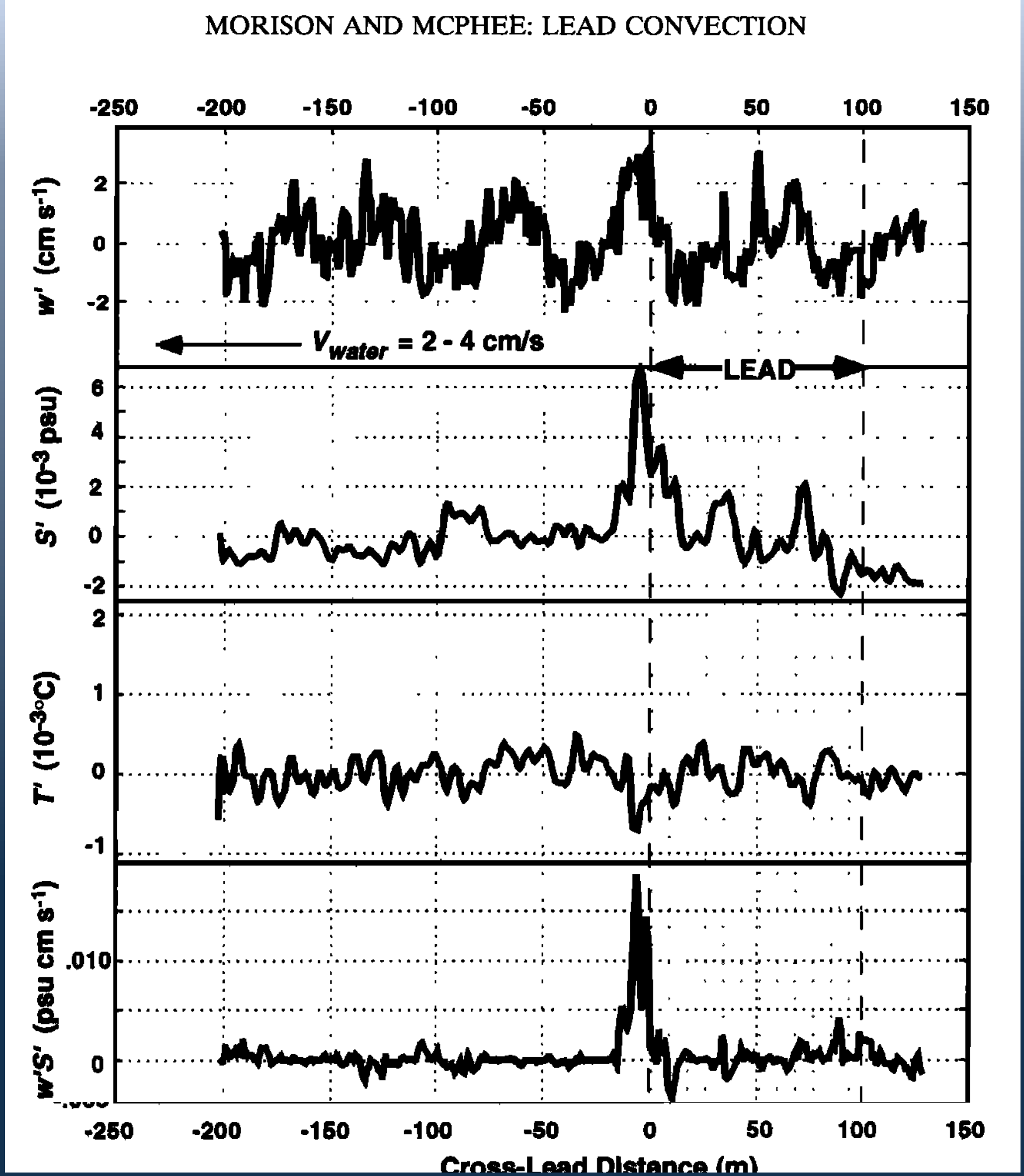
4. 1st year sea-ice environment

Heterogeneity in Space

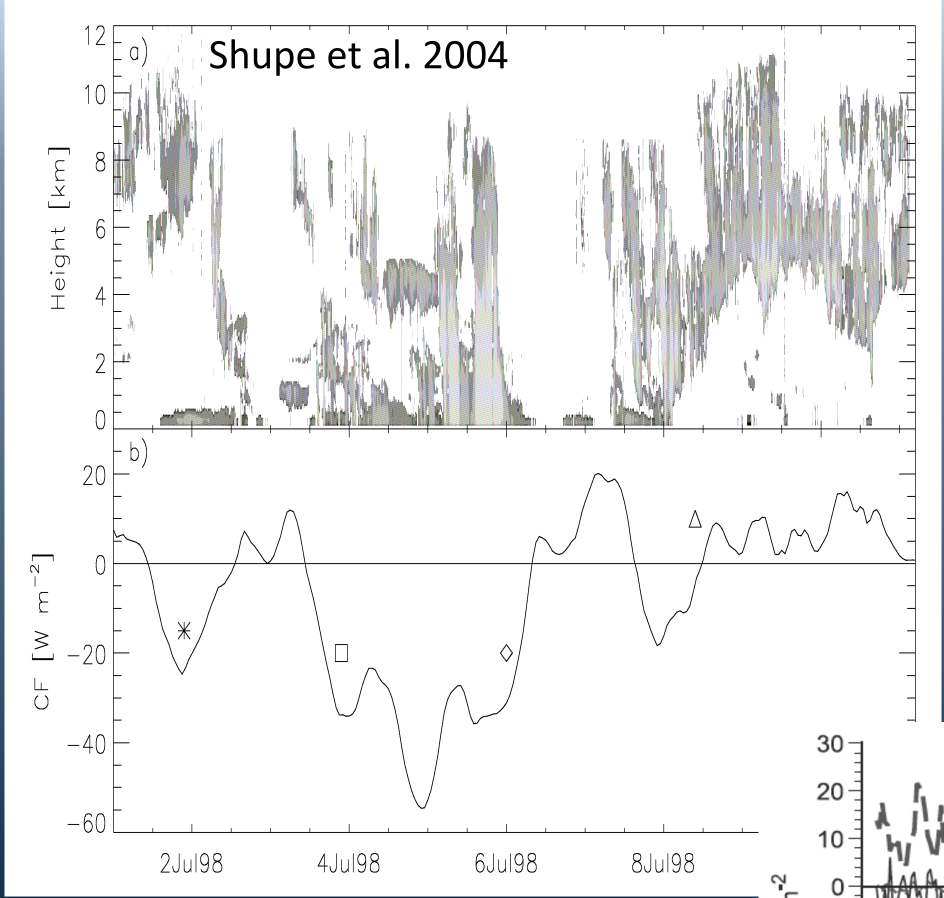
Example: Lead processes

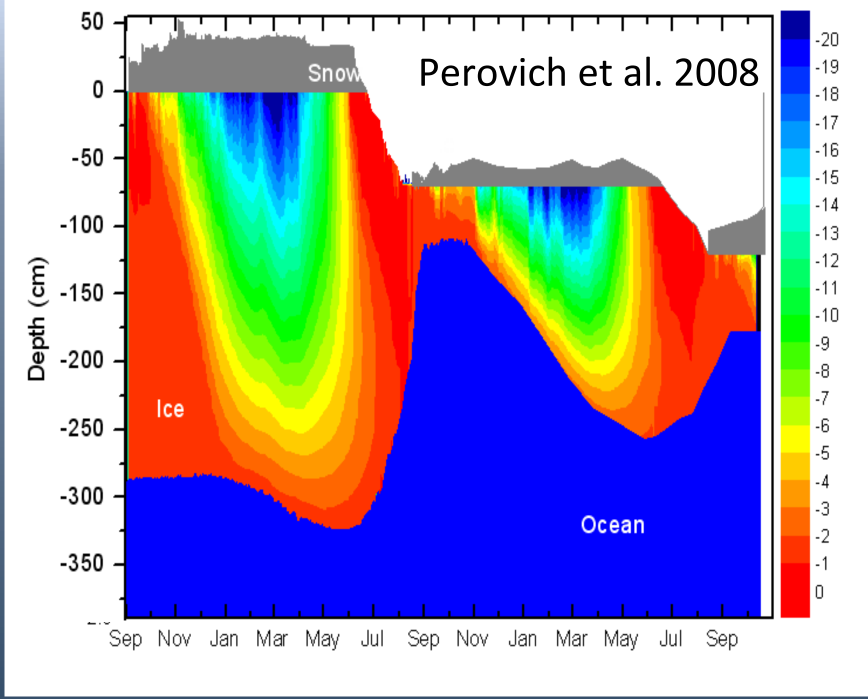
Assume horizontally uniform salt flux in leads
=>
Ocean mixed layer deepens and increases in salinity

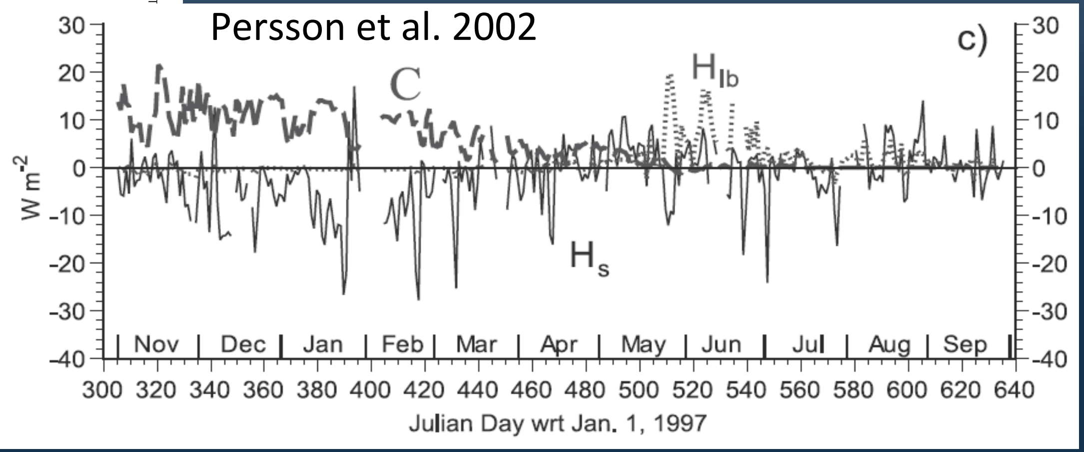
Downward salt flux actually occurs in plumes
=>
Mixed layer becomes shallower w/o salinity change



Heterogeneity in Time







< sec to > seasonal

Heterogeneity

- ***Spatial heterogeneity vs. temporal variability***. Both are important for building representative understanding and models.

- ***Spatial:*** Atmos., ice, ocean, biosphere all have distinct scales of heterogeneity that can vary seasonally and regionally. These impact and complicate the coupling in the system.
  >>> Important to design observations with an appropriate density to capture heterogeneity @ resolved and sub-grid scales

- ***Temporal:*** Processes can vary seasonally; It is insufficient to build models based on seasonally-limited observations.
  >>> Observations should be continuous, covering all seasons.

The Challenge: Defining appropriate measurement scales to best represent heterogeneity for effective upscalling?

Key Challenges

1. Efficiently impacting models
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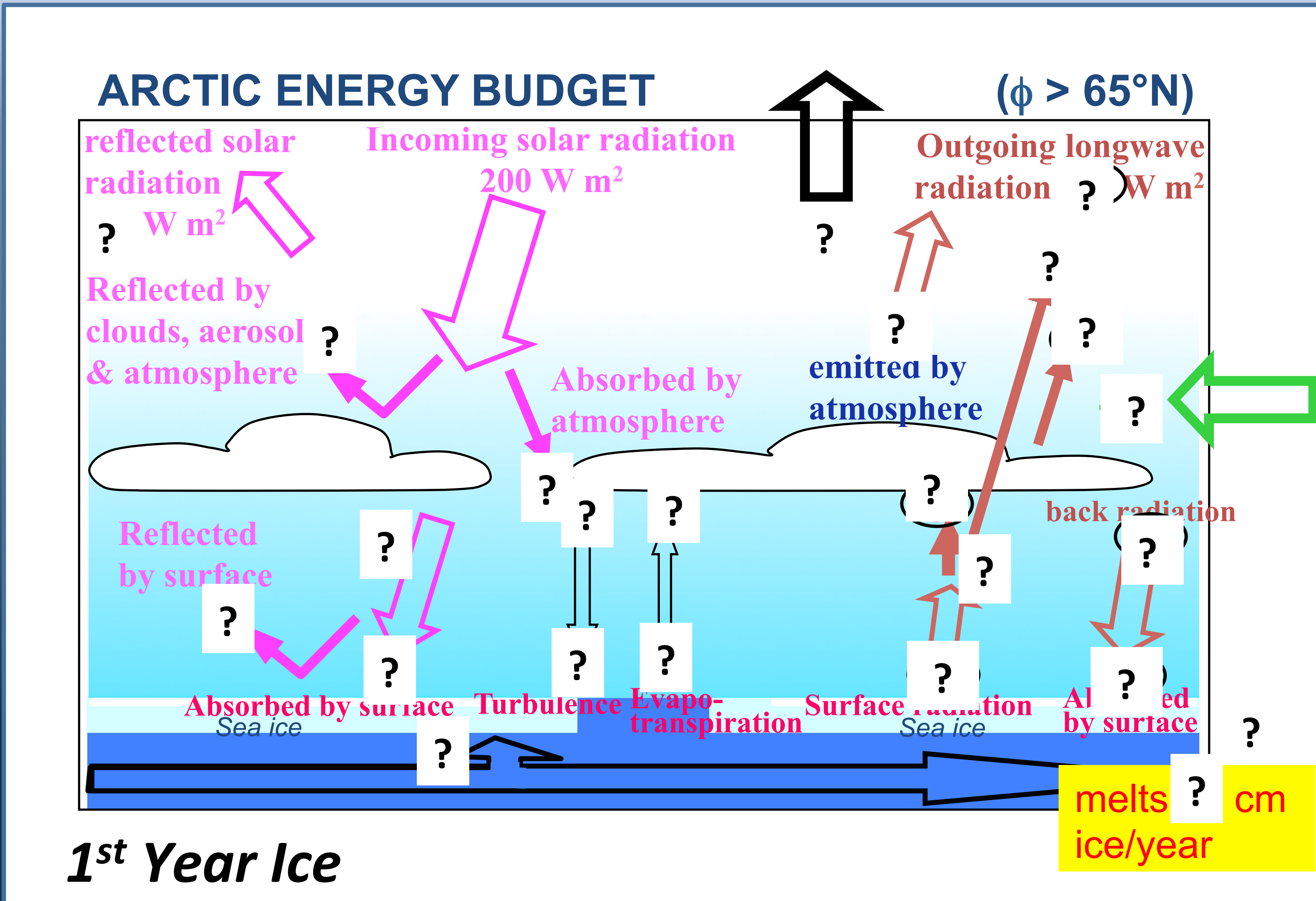
4. **1st year sea-ice environment**

Sea-Ice Energy Budget



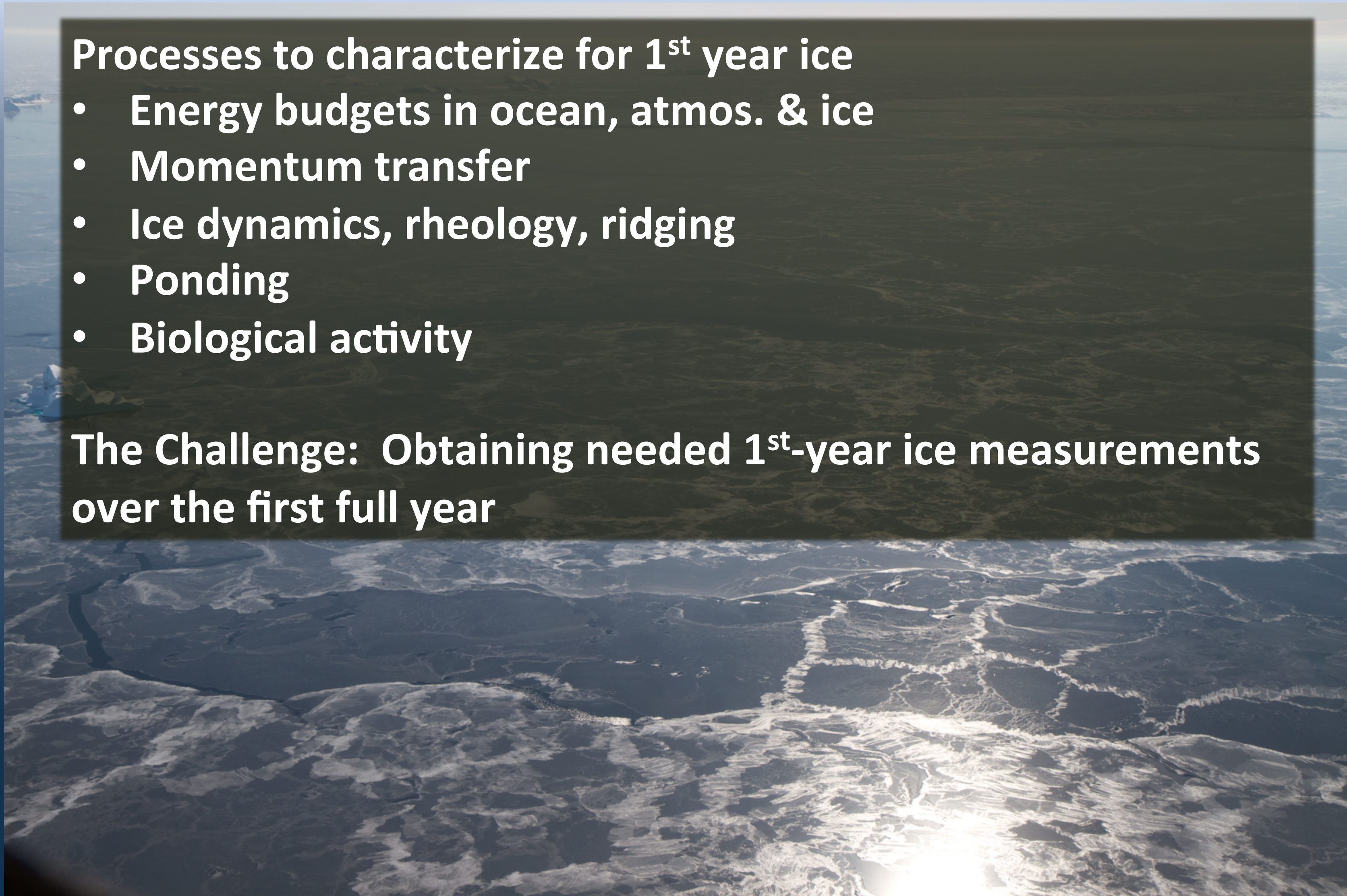
Persson et al. 2013

1st Year Ice

Processes to characterize for 1st year ice

- Energy budgets in ocean, atmos. & ice
- Momentum transfer
- Ice dynamics, rheology, ridging
- Ponding
- Biological activity

The Challenge: Obtaining needed 1st-year ice measurements over the first full year



MOSAiC into the Future

Important interactions with the [model] community:

- **Continued input on focus and prioritization of issues/processes/parameterizations**
- **Information to constrain/specify measurements: Frequency, spatial density, spatial scales, etc.**
- **Pre-field campaign model studies**
- **Operational model support for field activities**
- **Active use of the observations once available!**

MOSAiC needs broad community endorsement!

MOSAiC into the Future

Tentative MOSAiC Schedule

- Develop Science Plan – 2013
- Implementation Workshop and Plan – 2014
- MOSAiC Open Science Meeting – likely 2014
- Start serious funding discussions: 2013>
- Logistics planning 2013>
- Preparatory modeling & instrument development 2013>
- Field deployment September 2018 (estimate)

Thanks!

www.mosaicobservatory.org