Thoughts on modeling for MOSAiC

Mikhail Ovchinnikov et al.

- Motivation, science questions
- Global, regional, small scales
- Planned and ongoing integrated activities
- ASR role

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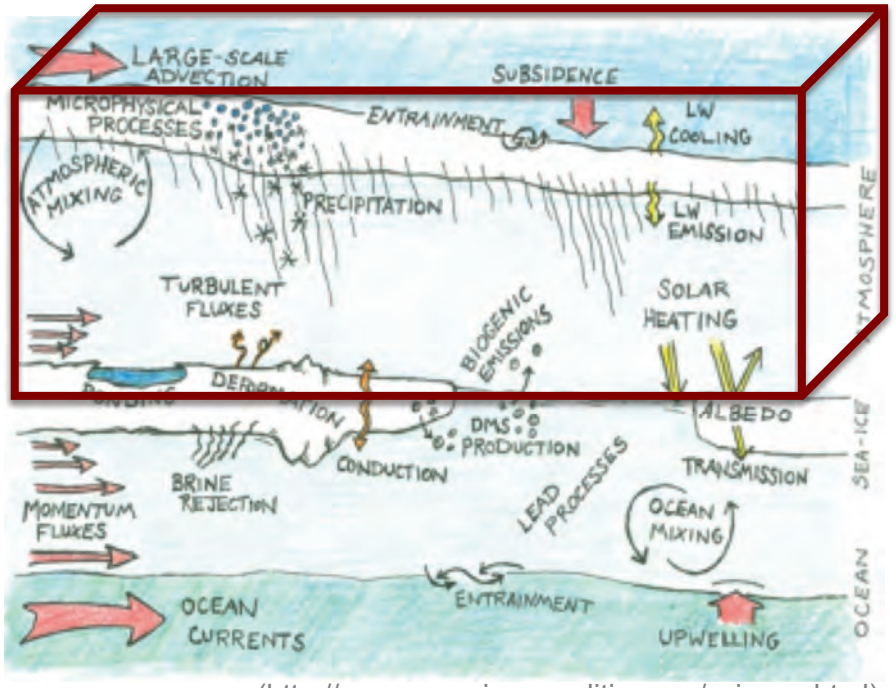
Small-scale processes are part of the big picture in MOSAiC but sub-grid for RCMs and GCMs

MOSAiC Science Questions

1. What are the seasonally-varying energy sources, mixing processes, and interfacial fluxes that affect the heat and momentum budgets of sea ice?
2. How does sea ice move and deform over its first year of existence?
3. What processes contribute to the formation, properties, precipitation, and maintenance of Arctic clouds and their interactions with aerosols and boundary-layer structure?
4. How do interfacial exchange rates, biology, and chemistry couple to regulate ecosystems and the major elemental cycles in the high Arctic sea ice?
5. How do ongoing change in the Arctic ice-ocean-atmosphere system impact larger-scale heat and mass transfers of importance to climate and ecosystems?



(http://www.mosaic-expedition.org/science.html)

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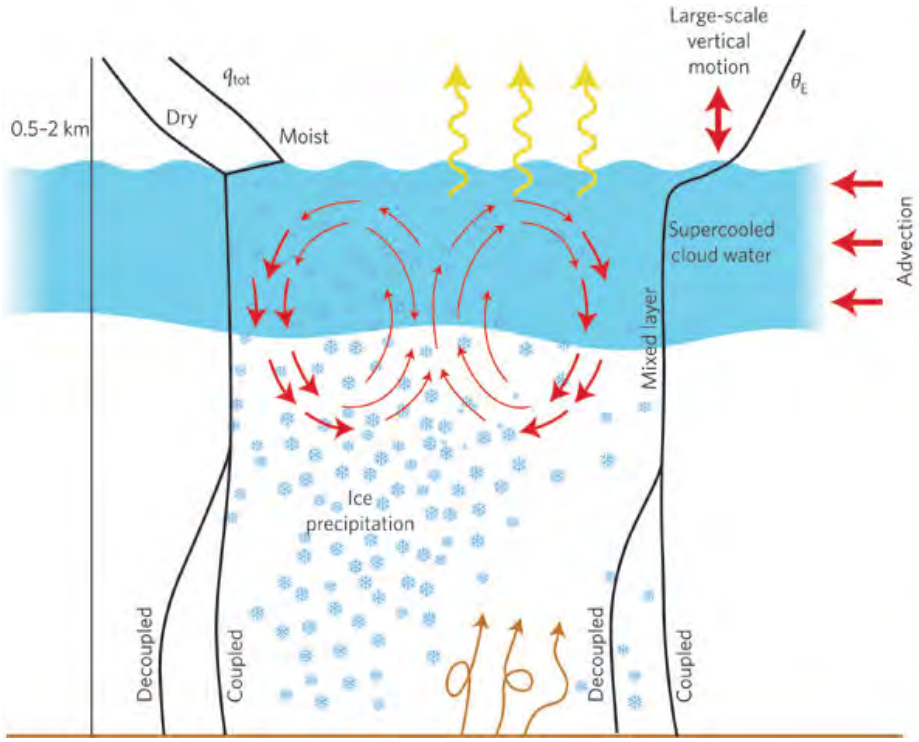
How is liquid maintained in mixed-phase clouds for hours/days?

Important dynamics – microphysics feedback:

- Vertical motions are critical for maintaining liquid phase
- Liquid layer is driving cloud circulation via cloud-top radiative cooling



Radiative Cooling
- Drives buoyant production of turbulence
- Forces direct condensation within inversion layer
- Requires minimum amount of cloud liquid water

Microphysics
- Liquid forms in updrafts and sometimes within the inversion layer
- Ice nucleates in cloud
- Rapid ice growth promotes sedimentation from cloud

Dynamics
- Cloud-forced turbulent mixed layer with strong narrow downdrafts, weak broad updrafts, and q_{tot} and θ_E nearly constant with height
- Small-scale, weak turbulence in cloudy inversion layer
- Large-scale advection of water vapour important

Surface Layer
- Turbulence and q contributions can be weak or strong
- Sink of atmospheric moisture due to ice precipitation
- Surface type (ocean, ice, land) influences interaction with cloud

(*Morrison et al., 2012*)

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Large-eddy simulations (LES) – a tool for small-scale process modeling

- **Resolve large eddies** (most energy and fluxes)

  explicit coupling of many processes;
  grid spacing: a few to 100's of meters;

grid points #:	10^6 to 10^9;	horizontal domain:	~1-100 km;
time step:	~ 1 s;	time period:	hours to days

- **Parameterized** (subgrid scale, SGS) **small eddies** (little energy and fluxes)
- Insensitive to SGS parameterization (ideally), but …

  

  near surface, very stable layers (inversions), in reactive flows, etc.
- Stand alone and nested configurations
- A dynamical framework coupled with various physics packages

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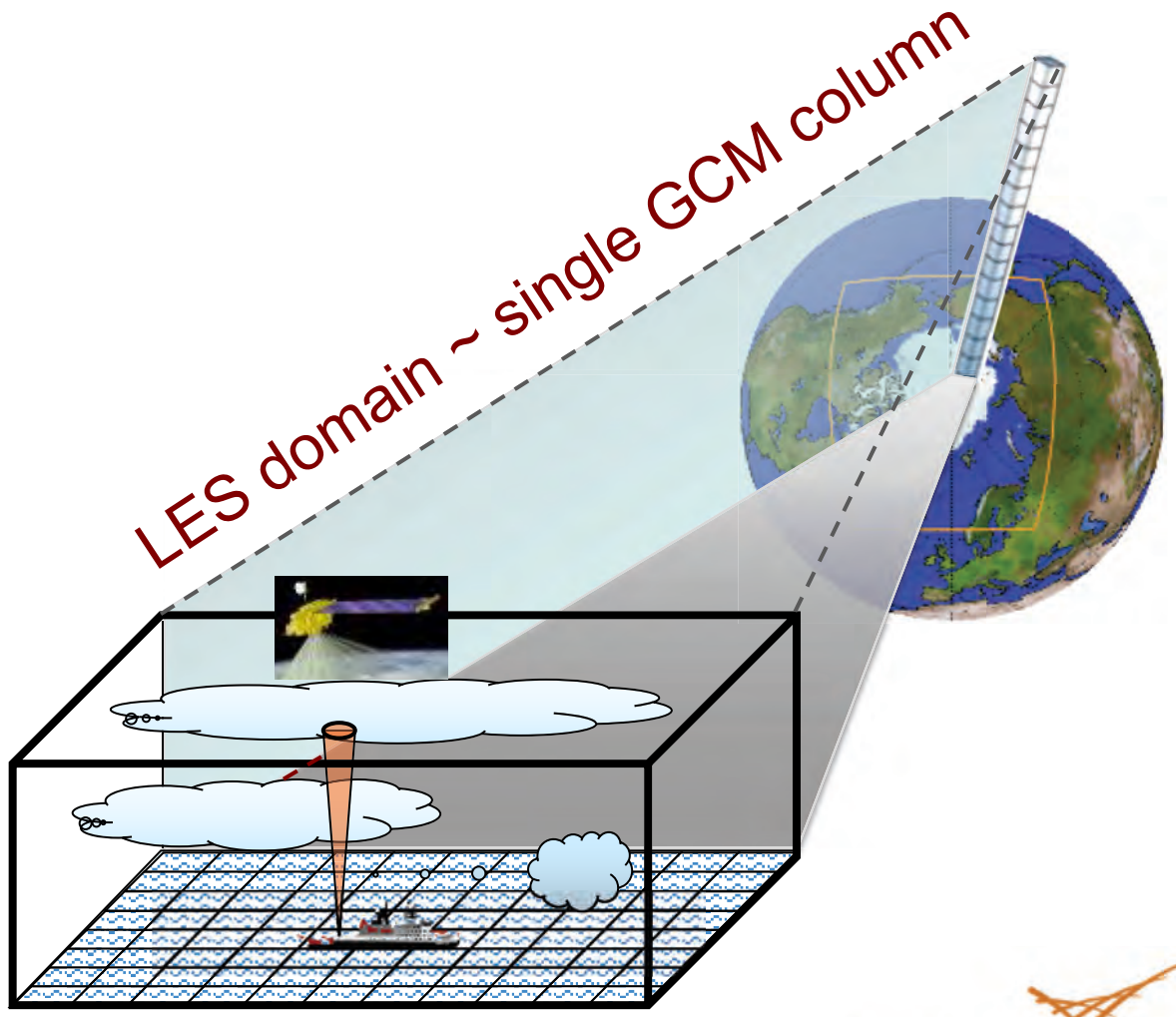
Goals of LES

- Test and improve understanding of relevant interacting processes
- Link observations at different scales
- Provide synthetic datasets for GCM parameterization development
- Guidance for GCMs to describe multi-scale interactions



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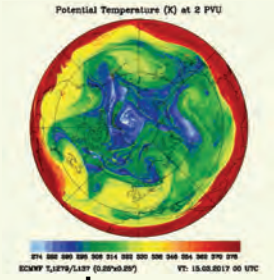
LES study setup

Input

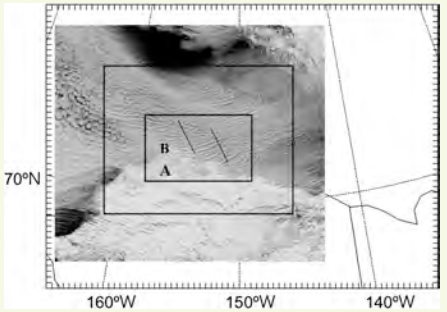


large-scale environment & forcing

initial & boundary conditions

LES

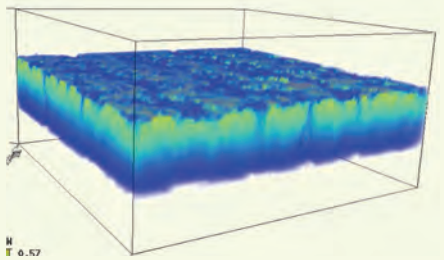
domain configuration



physics representations (cloud and aerosol microphysics, turbulence, radiation, surface)

Output

3D structure



instrument simulators

scalar & profile statistics

Evaluation

independent observations

Application

parameterization development & testing

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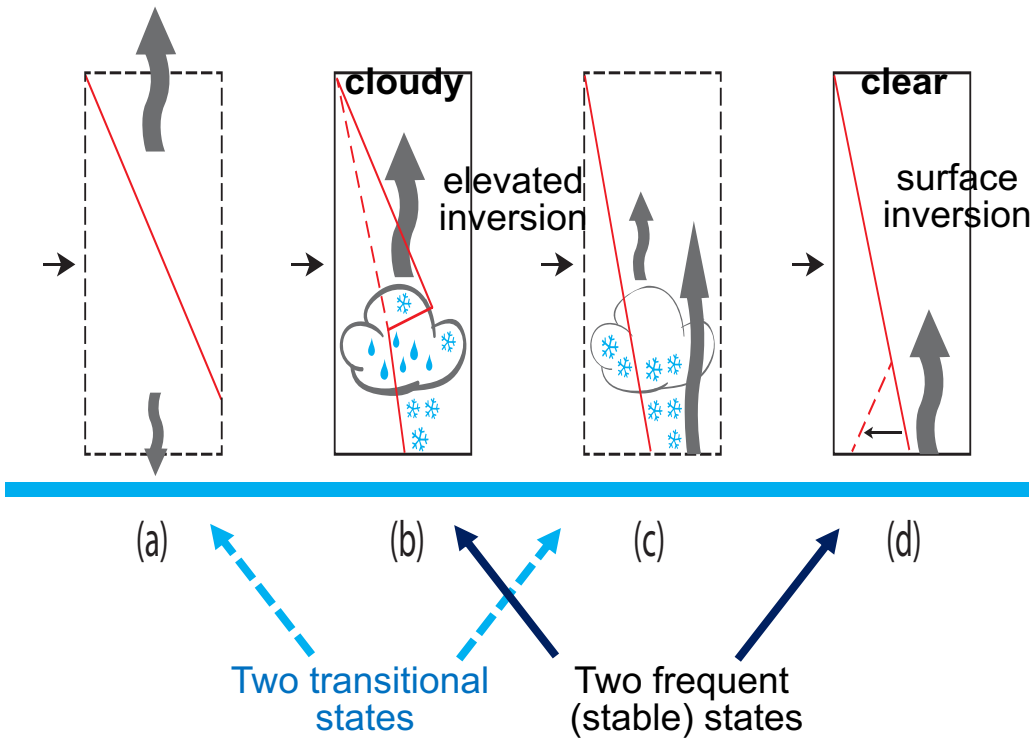
Cloud and aerosol issues and biases in GCMs

- CMIP5 models and single-column model have difficulties representing states of the Arctic boundary layer and transitions between them
- Transition from cloudy to clear is sensitive to representation of surface fluxes and microphysics of mixed-phase (liquid and ice) clouds
- Observations of air mass transformations including both boundary layer states are needed to constraint LES and SCM.

Arctic boundary layer states



(*Pithan et al., 2014 & 2016*)

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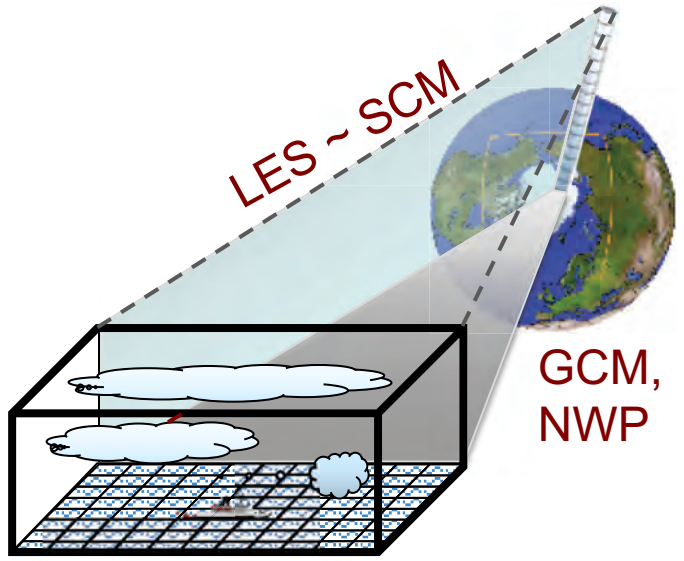
Challenges and opportunities

Extreme multi-scale nature of the Arctic climate/ecosystem is a key challenge

Coordination between modeling activities is essential:

- LES setup is analogous to Single-Column Model (SCM)
  Same cases and forcing datasets can be used
- Most LES studies have been based on idealized and steady-state cases, not suitable for modeling transitions between different regimes
- MOSAiC observation together with the **Year of Polar Prediction** coordinated activities will provide opportunities to develop time-variable forcing specifications and conduct Lagrangian (air-mass following) LES studies



Action item:
Advocate for LASSO support for MOSAiC

Routine LES, LASSO, and beyond (Breakout session)
Thursday, March 22, 10:45 am – 12:45 pm
Room: Great Falls

11:25–11:35: Open discussion for feedback on the LASSO implementation (Andrew Vogelmann)
11:35–11:40: Approaching the LASSO expansion decisions (James Mather)
11:40–12:25: Guided discussion of candidate scenarios (William Gustafson & Andrew Vogelmann)

- Arctic clouds on the North Slope of Alaska
- Arctic clouds in conjunction with the MOSAiC field campaign

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