High-Resolution Sea-Ice Prediction: Coupled Processes and Prediction System Development
by Patrick Hogan & Cecilia Bitz
Consists of **floes** that are ~0.1-10 km wide and ~0.1-5 m thick; separated by cracks or **leads**. Floes may freeze together (healing) to form **floe aggregates**. Ice area concentration typically 20-99%.
Pressure ridges form when floes collide. The ice sheet breaks up into blocks that are pushed into sails and keels. Pressure ridges can be many kilometres in length.
Complex Variability

- When & where do leads form?
- What is the distribution of snow?
- When does melt start?
- When do ponds form?
Timing is everything: Impact of leads

Spring

Early summer

Late summer

Need to adjust for the incident sunlight
Timing is everything: Impact of leads

Spring

Early summer

Late summer

Incident sunlight

Extra absorbed

Albedo
Changing ice, changing light – FY vs. MY

First year ice transmits much more sunlight to ocean

slide from D. Perovich
As light transmission increases:

- Not enough light
- Ice algae bloom
- Phytoplankton bloom

Snow, thick MY ice → Less snow, thinner FY ice → No snow, no ice algae, FY ice

slide from D. Perovich
Bottom vs. lateral melt

Total melt

Volume loss

July – pre event

August – post event

Water Depth (cm)

Horizontal position (cm)

Total melt (m)

Very little data
Anisotropy is present at all scales in sea ice.

- Kwok [2001], RADARSAT RGPS
- Schulson [2004], LAB EXPERIMENT

Slide from D. Feltham
Anisotropy is present at all scales in sea ice

Kwok [2001], RADARSAT RGPS

Schulson [2004], LAB EXPERIMENT

Linear Kinematic Features

slide from D. Feltham
Anisotropy is present at all scales in sea ice.
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Kwok [2001], RADARSAT RGPS
Schulson [2004], LAB EXPERIMENT

slide from D. Feltham
Anisotropy and continuity

Ice cover is anisotropic (though not in ice models until recently). Has implications for ice stresses and so affects the momentum balance and thus every aspect of sea ice simulations.

If failure physics (cracking) is truly scale invariant and this physics is included in models then one might expect to recover the anisotropy by increasing the resolution. But there are floes ...

With isotropic physics, simulations at high spatial resolutions do not capture the observed failure patterns. Testing on anisotropic models in progress now.
Sea ice models at high resolution should simulate
• sea ice thickness distribution
• melt ponds
• floes size distribution
• anisotropy

Initialization for prediction: Under what conditions do properties that affect these items need to be initialized?
Sea ice models – autocorrelation timescales
• sea ice thickness distribution – year or so
• melt ponds – a few months
• floes size distribution – a month? (my guess)
• anisotropy – a week

Subseasonal forecast (2-3 weeks):

Initialized with the current thickness, concentration, and floe & melt pond size statistics. The key external conditions that will determine the fast evolution is wind anomalies, and to a lesser extent SST anomalies. Forecast is primarily a coupled atmosphere-ice problem (with correct SST ICs).
Sea ice models – autocorrelation timescales
• sea ice thickness distribution – year or so
• melt ponds – a few months
• floes size distribution – a month? (my guess)
• anisotropy – a week

Subseasonal-seasonal forecast (3-50 weeks):

Initialized with the current thickness, concentration, and floe & melt pond size statistics. The key external initial condition is ocean temperature. Forecast is a coupled atmosphere-ocean-ice problem.
Current state of sea ice initialization in subseasonal to decadal prediction

Climatology of last X years

Sea ice “along for ride” = ocean state estimate - ocean DA and prescribed atm

Sea ice DA coupled with ocean DA (atm prescribed or ideally coupled)
   Sea ice DA is usually just sea ice concentration, though sea ice thickness/freeboard probably would have a bigger impact.

Resolution of available observations for ICs

AMSR products horizontal ~6 km (I think)

Ice thickness (long story)

Ice ponds and floe size – nothing available beyond a few surveys