Modeling "Landfast" Sea Ice

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Outline

I Landfast Observations

II Rheology Modifications

III Scale-Width

IV Simulations

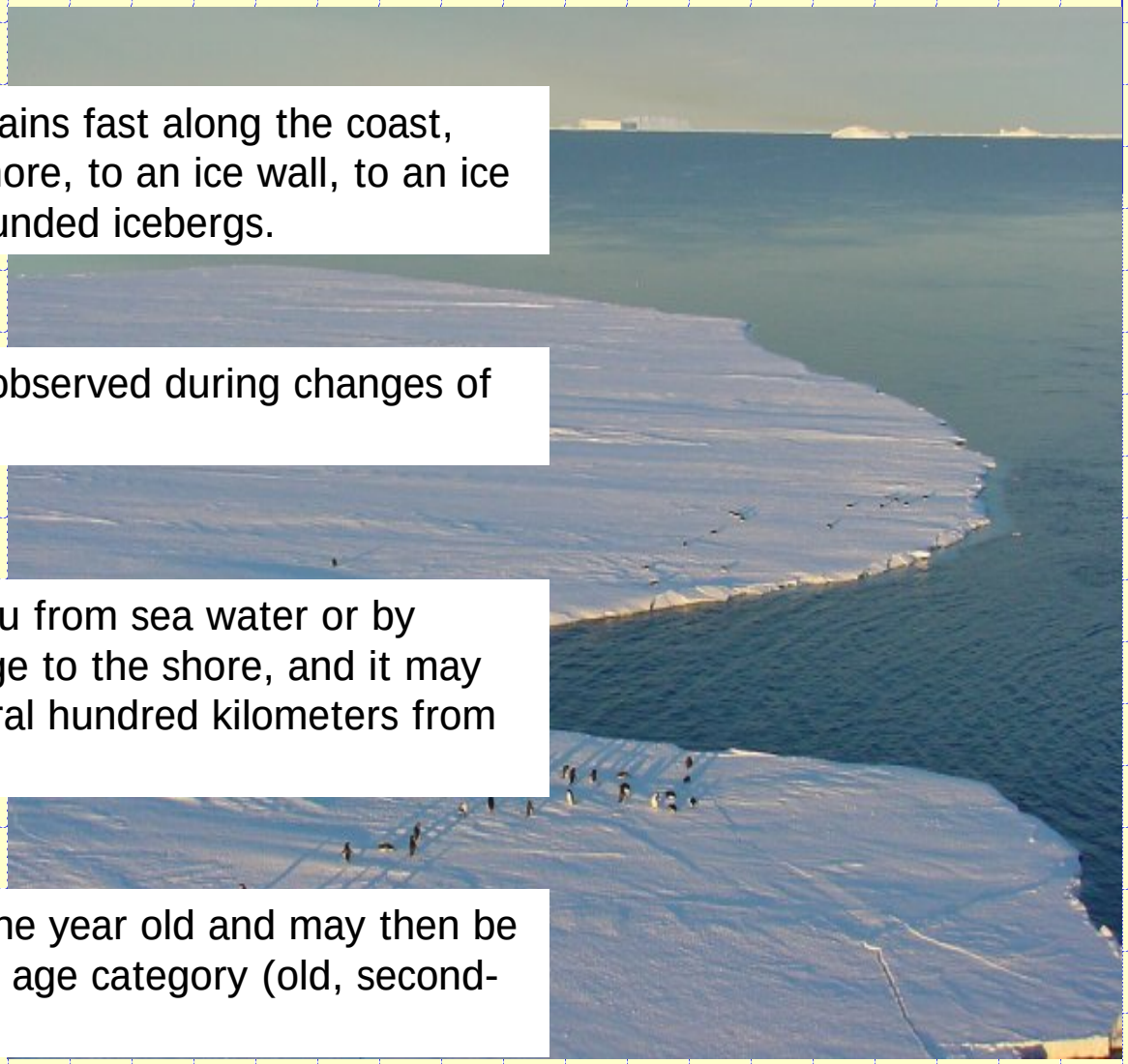
Fastice Definition

Sea ice which forms and remains fast along the coast, where it is attached to the shore, to an ice wall, to an ice front, between shoals or grounded icebergs.

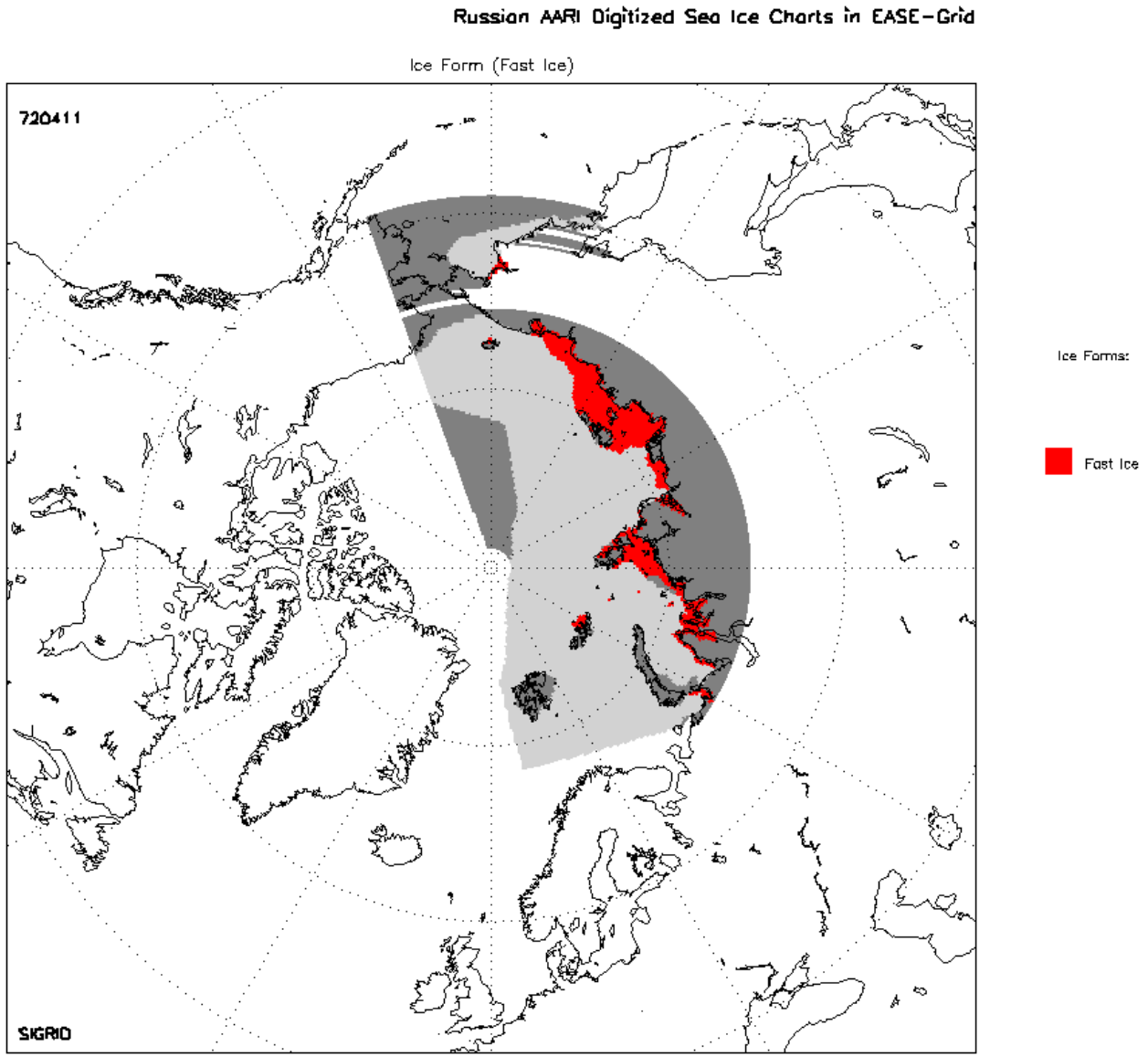
Vertical fluctuations may be observed during changes of sea-level.

Fast ice may be formed in situ from sea water or by freezing of pack ice of any age to the shore, and it may extend a few meters or several hundred kilometers from the coast.

Fast ice may be more than one year old and may then be prefixed with the appropriate age category (old, second-year, or multi-year).

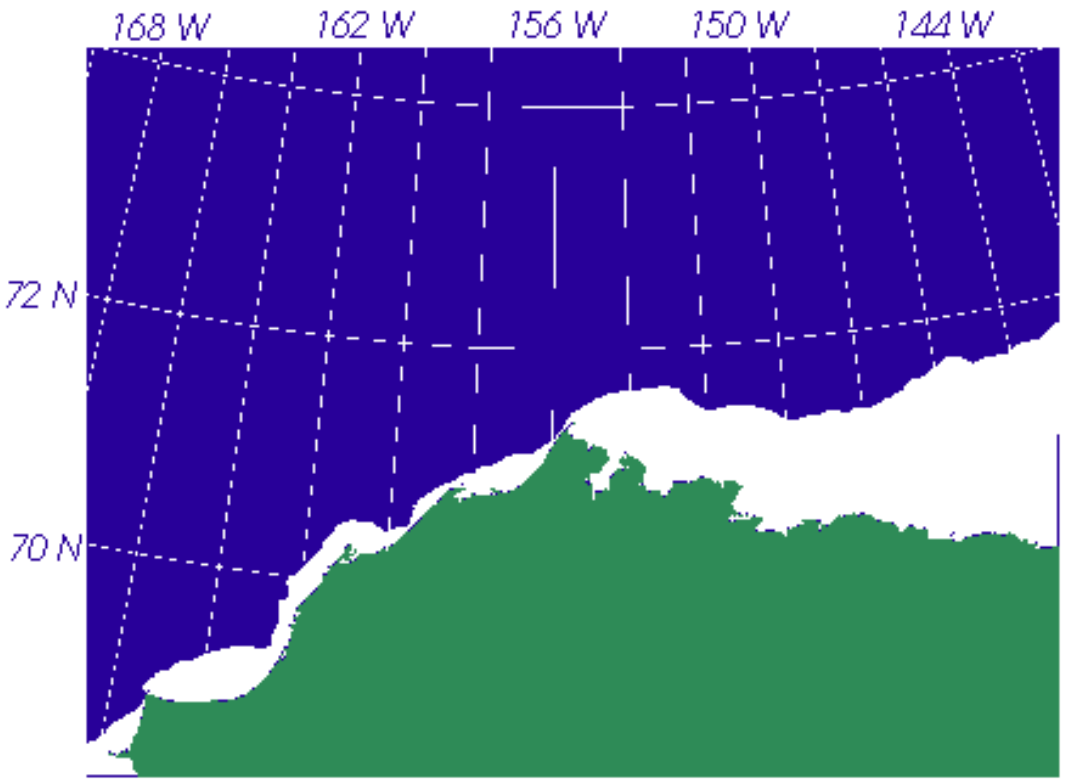


I Landfast Observations - Russian Arctic



National Snow and Ice Data Center

Landfast Observations - Alaskan Coast



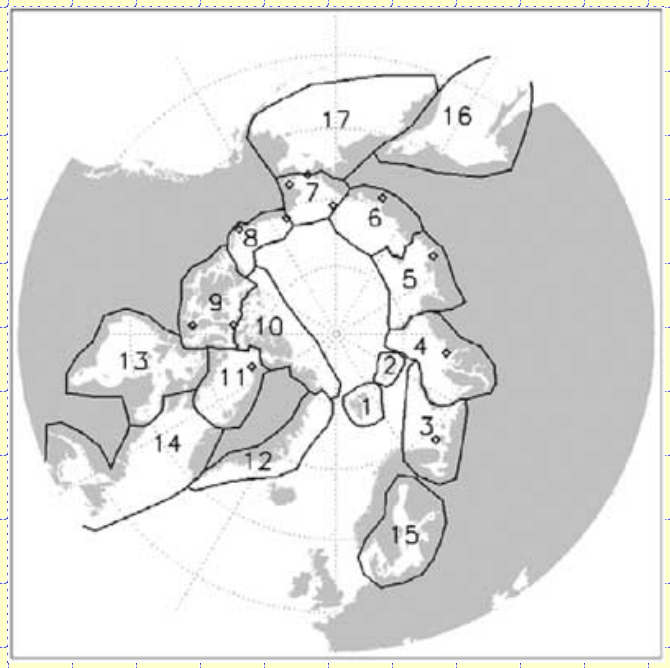
AVHRR

2000, Spring

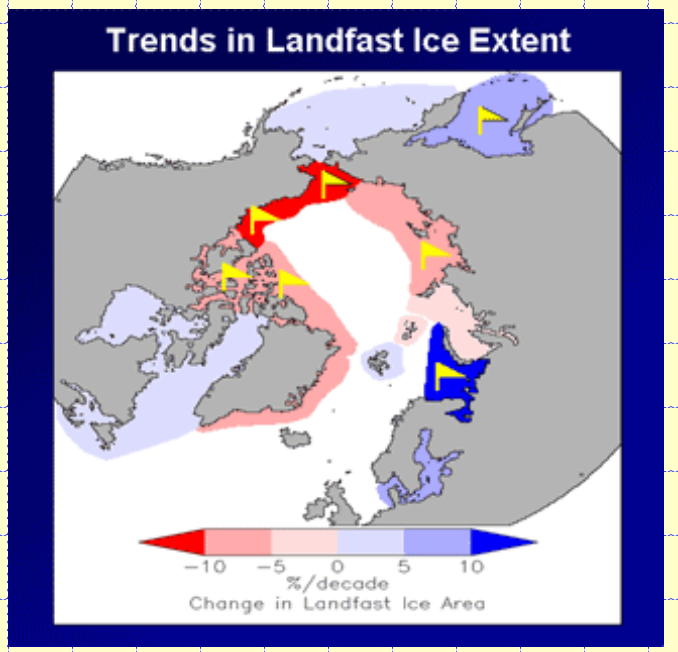
Andy Mahoney, GI/UAF

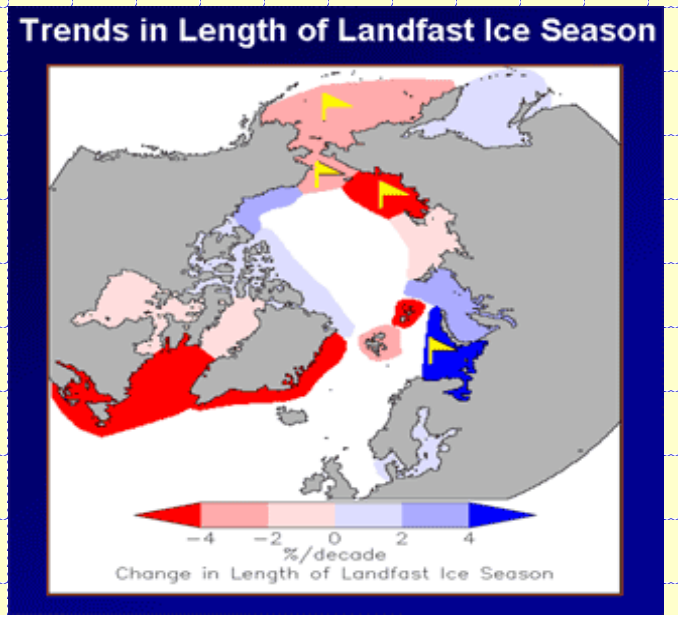
http://www.gi.alaska.edu/~mahoney/Research/FIDynam.html

Landfast Observations - Temporal Change



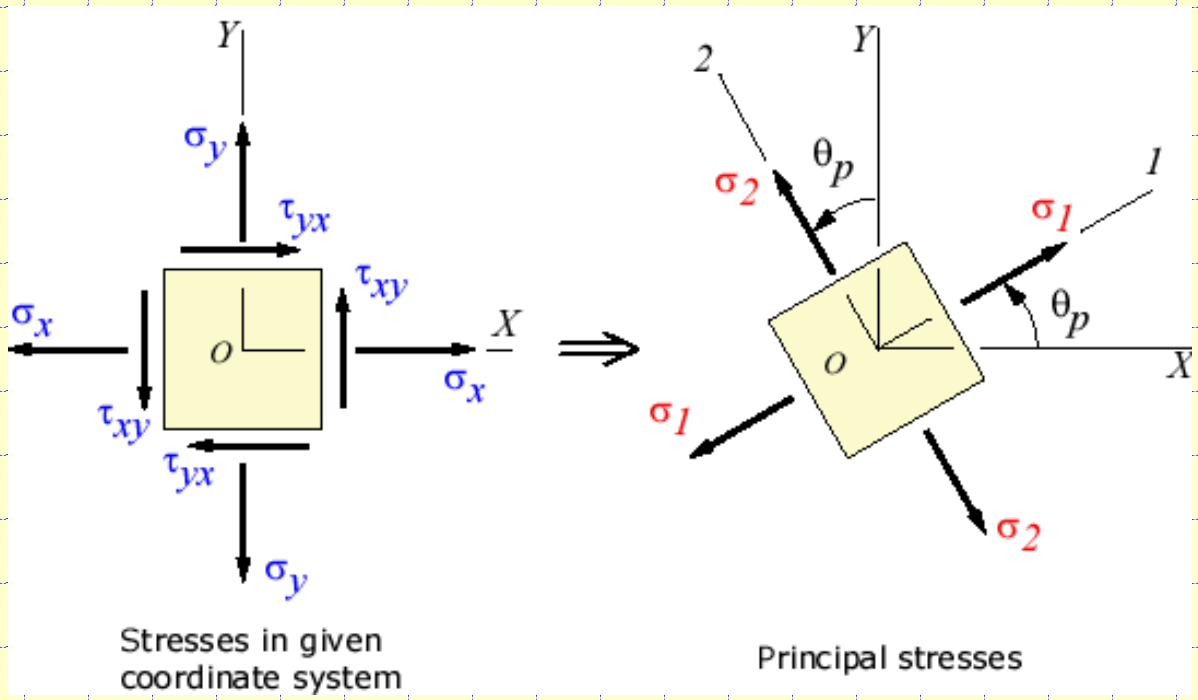
Yanling Yu, PSC/UW





http://psc.apl.washington.edu/search/activitiesNSF/YuDetails.html

II Rheology Modifications - Principal Stresses



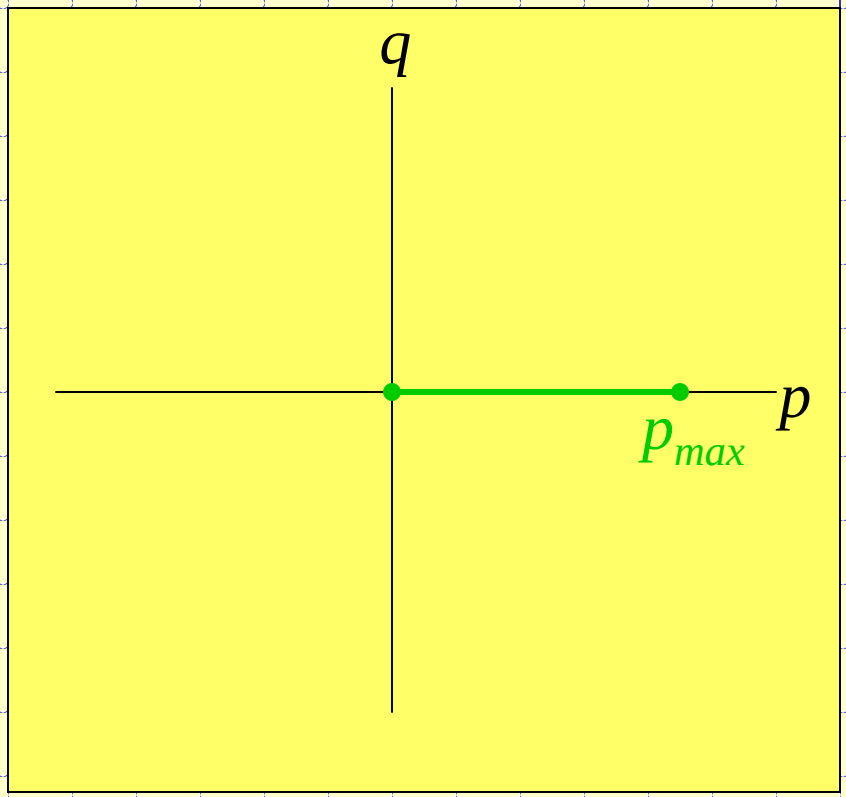
$$p = \frac{\sigma_1 + \sigma_2}{2}$$

$$q = \frac{\sigma_1 - \sigma_2}{2}$$

Cavitating-Fluid Rheology

$$q = 0$$

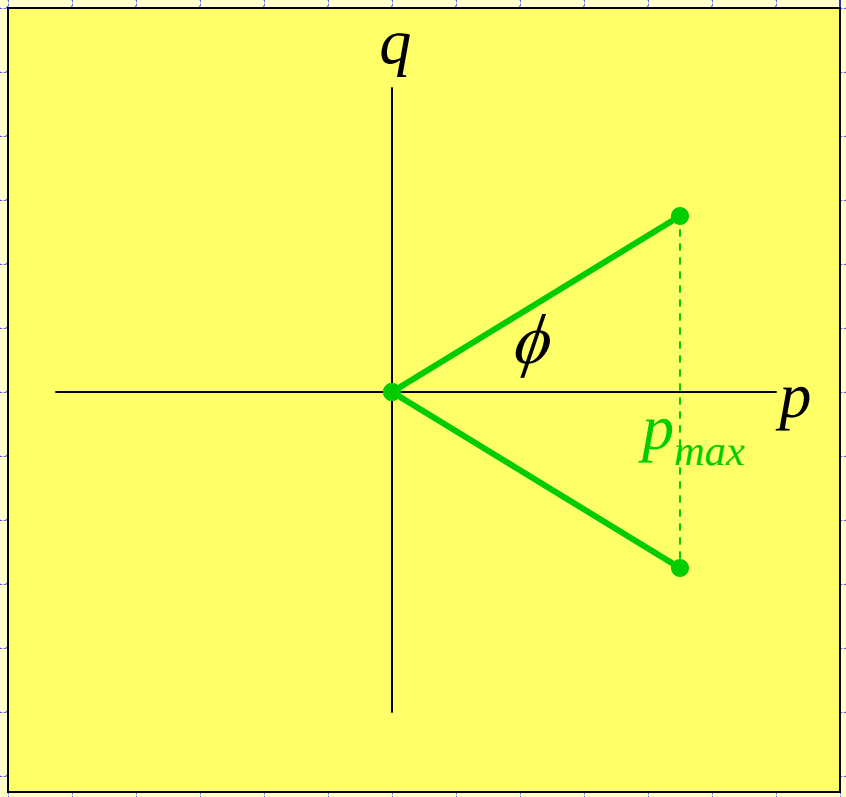
$$0 < p < p_{\max}$$



Mohr-Coulomb Rheology

$$q = p \tan \phi$$

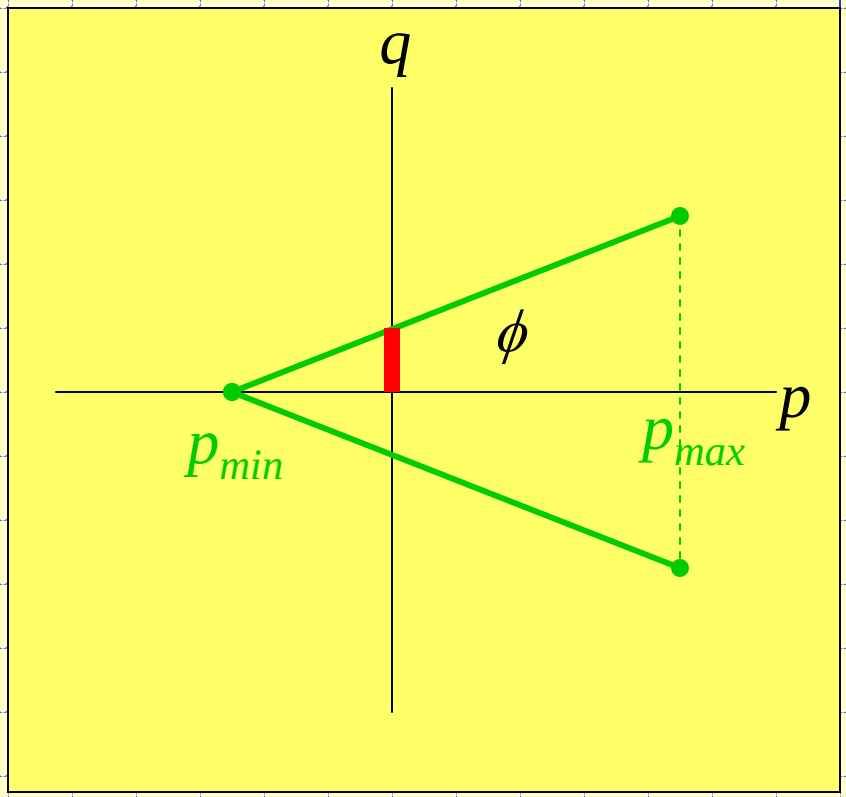
$$0 < p < p_{\max}$$



Tensile Stress Modification (p_{min})

$$q = q_{tensile} + p \tan \phi$$

$$p_{\min} < p < p_{\max}$$



Compressive Stress Formulation (p_{max})

$$p_{\max} = p^* ch e^{k(1-c)}$$

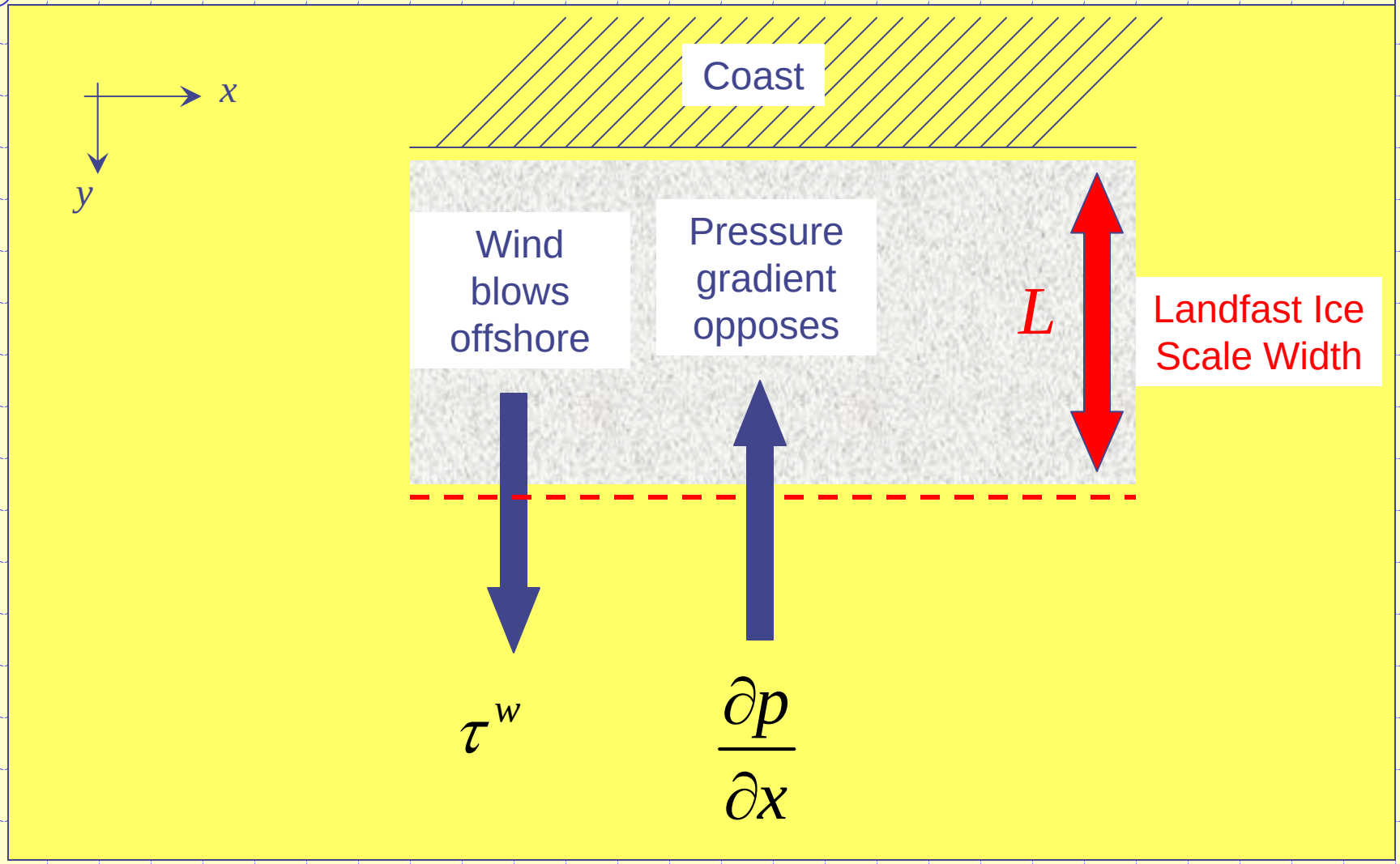
Tensile Stress Formulation (p_{min}) ?

Dependent upon:

- flow deformation
- memory ... settling time
- ice temperature/salinity
- ice compressive strength

- Code Modification

III Scale-Width of Landfast Ice



Scale-Width of Landfast Ice

Consider 1-D balance of offshore momentum

$$\rho\left[\frac{\partial v}{\partial t}+\vec{u}\cdot\nabla v+ fu\right]=-\frac{\partial p}{\partial y}+\tau^{w}+\tau^{o}$$

becomes the pressure gradient and wind stress relation

$$0=-\frac{\partial p}{\partial y}+\tau^{w}$$

Integrating from the coastline to offshore distance *L*

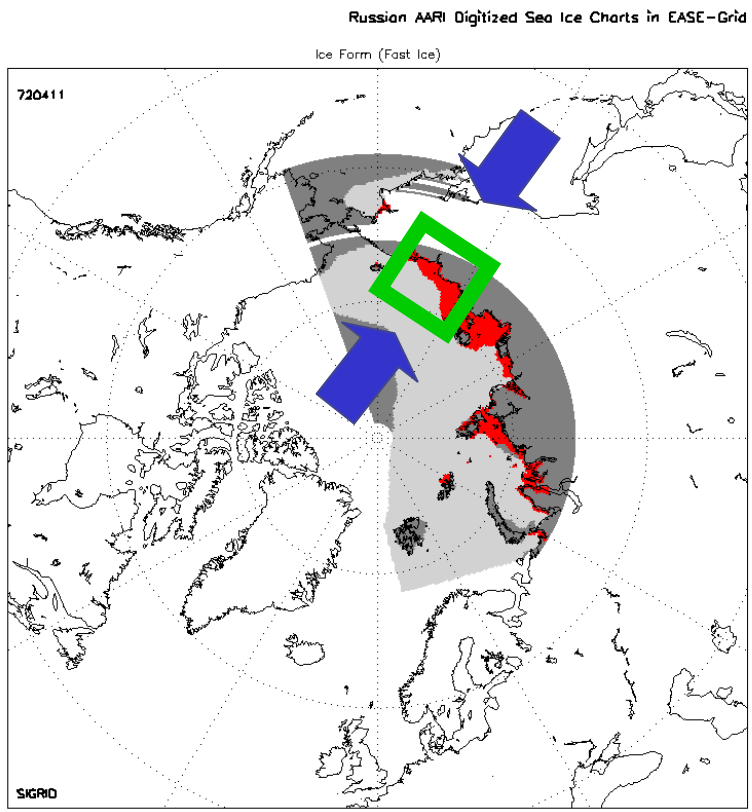
$$\int_0^L \frac{\partial p}{\partial y}dy=\int_0^L \tau^{w}dy \quad\Rightarrow\quad L=\frac{p(0)}{\tau^{w}}$$

For a strong windstress of 1.0 Pa and a strong coastal pressure of 200 kN/m

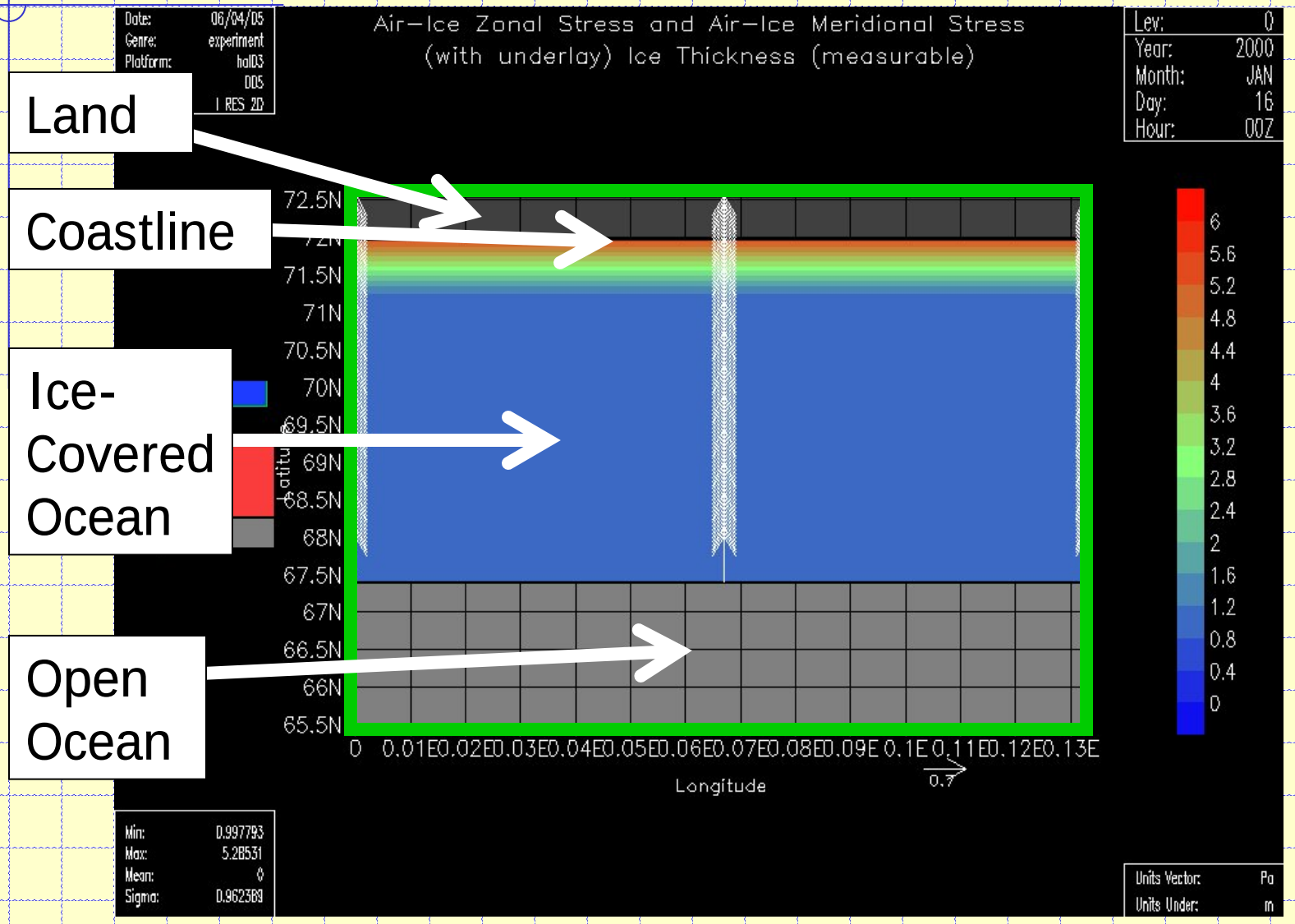
$$L=\frac{200\,kN/m}{1.0\,Pa}\sim 200\,km$$

IV Simulations

- Consider a small region of ocean near a coastline
- Ice model experiences dynamics, but no thermodynamics
- Atmosphere blows a periodic wind towards coast and away (one month a direction)
- Ocean is slab, no currents
- Simulation produces pictures once per day for one ‘year’

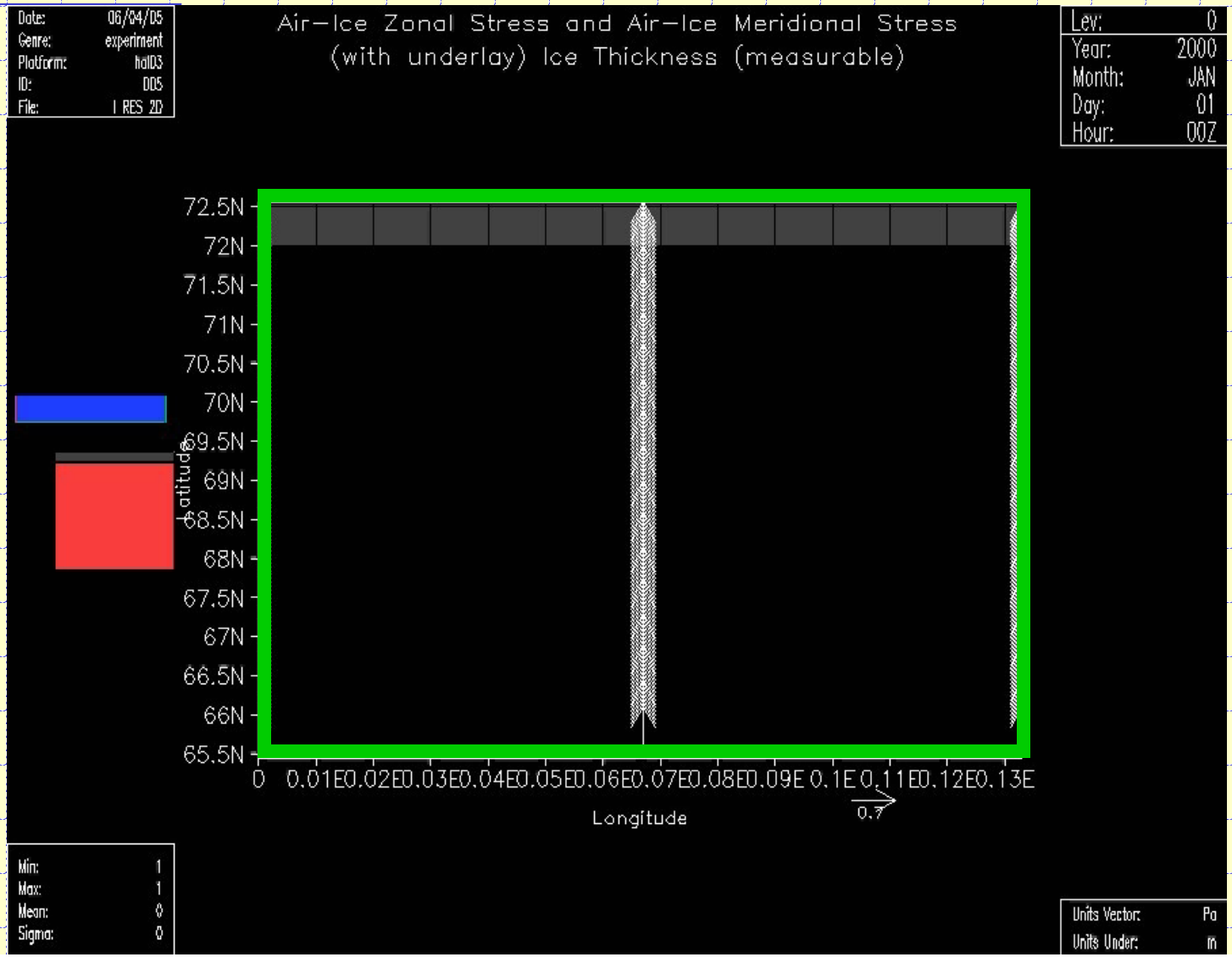


Domain Geometry



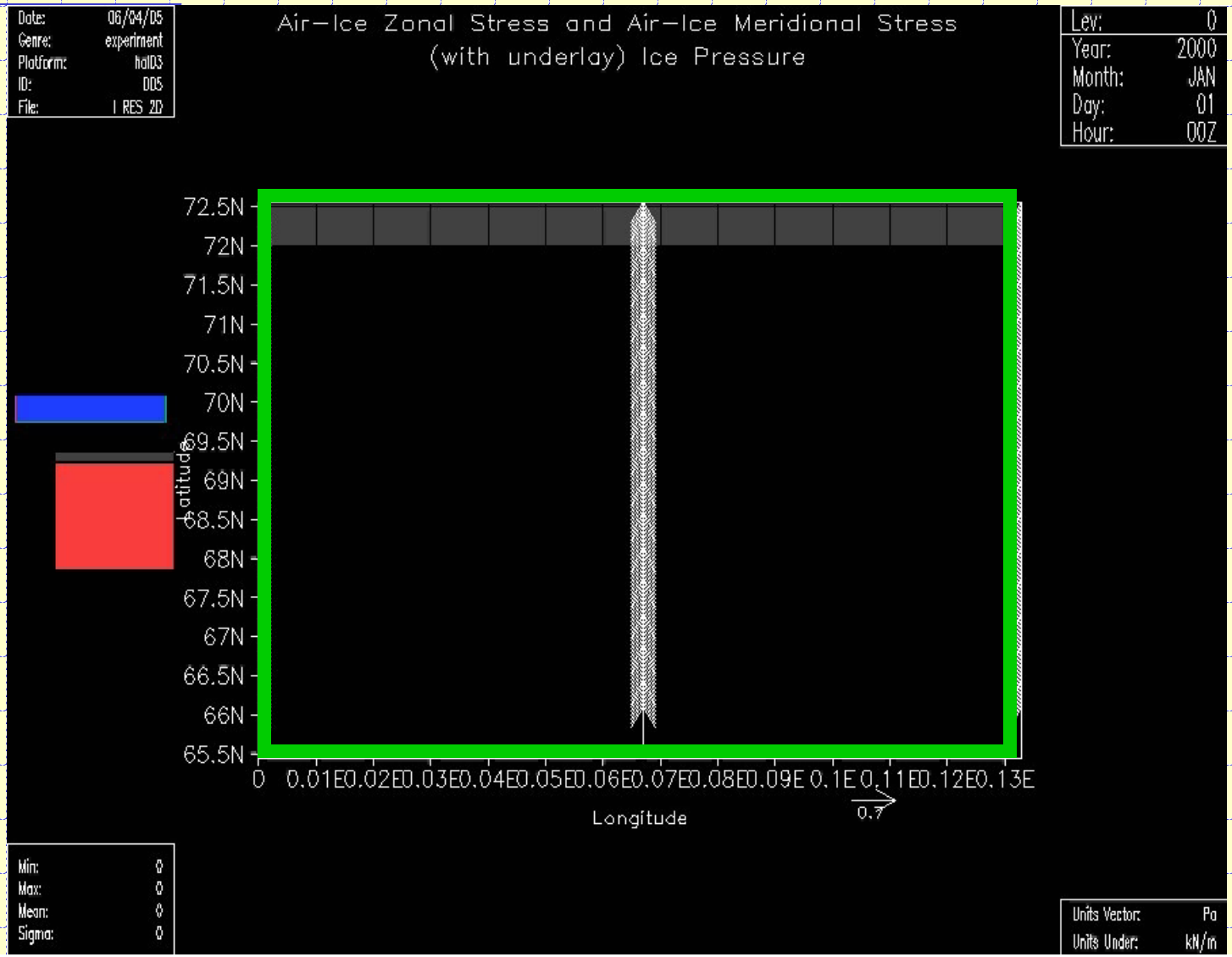
Experiment - Compressive Strength Only

Ice Thickness



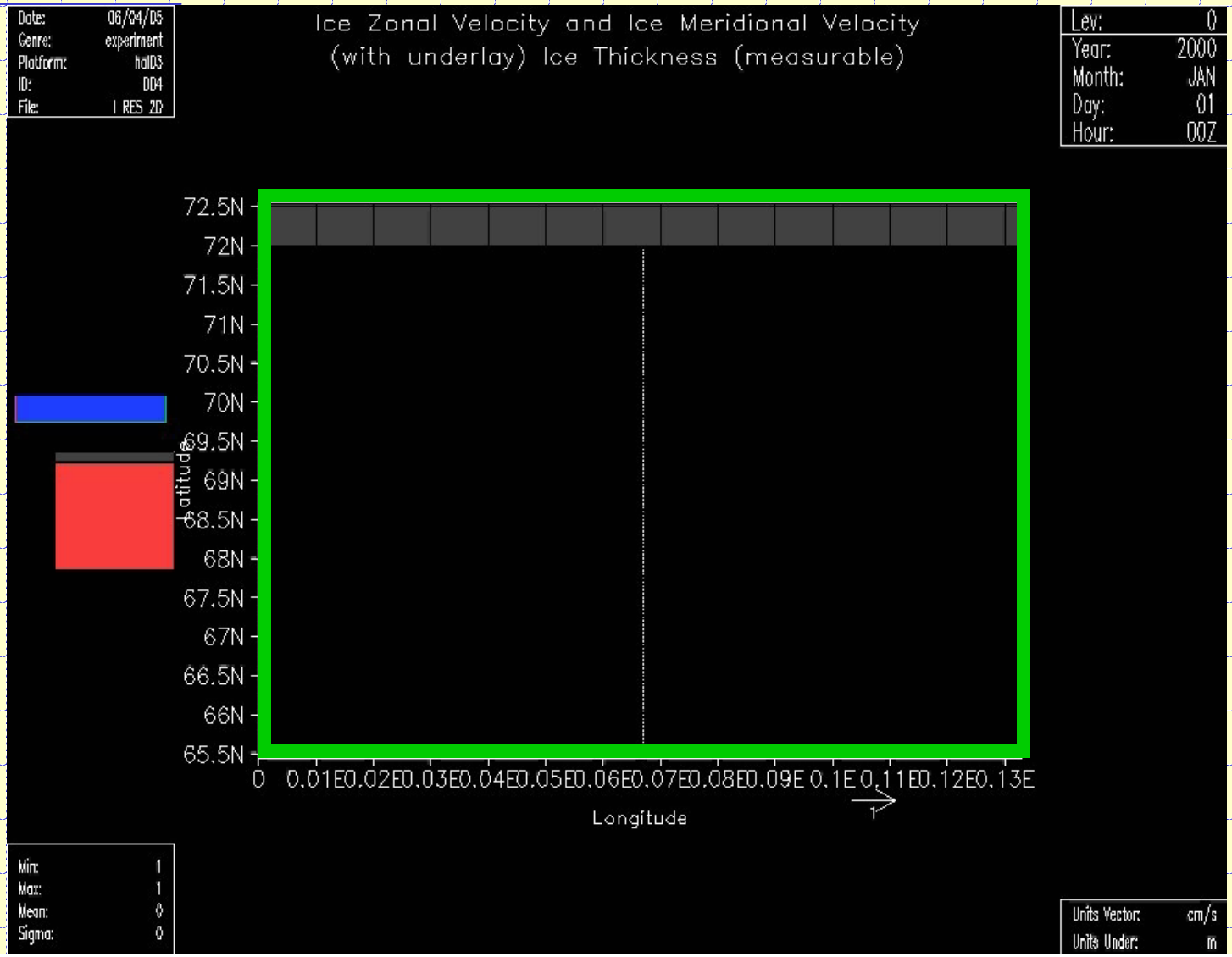
Experiment - Compressive Strength Only

Ice Pressure



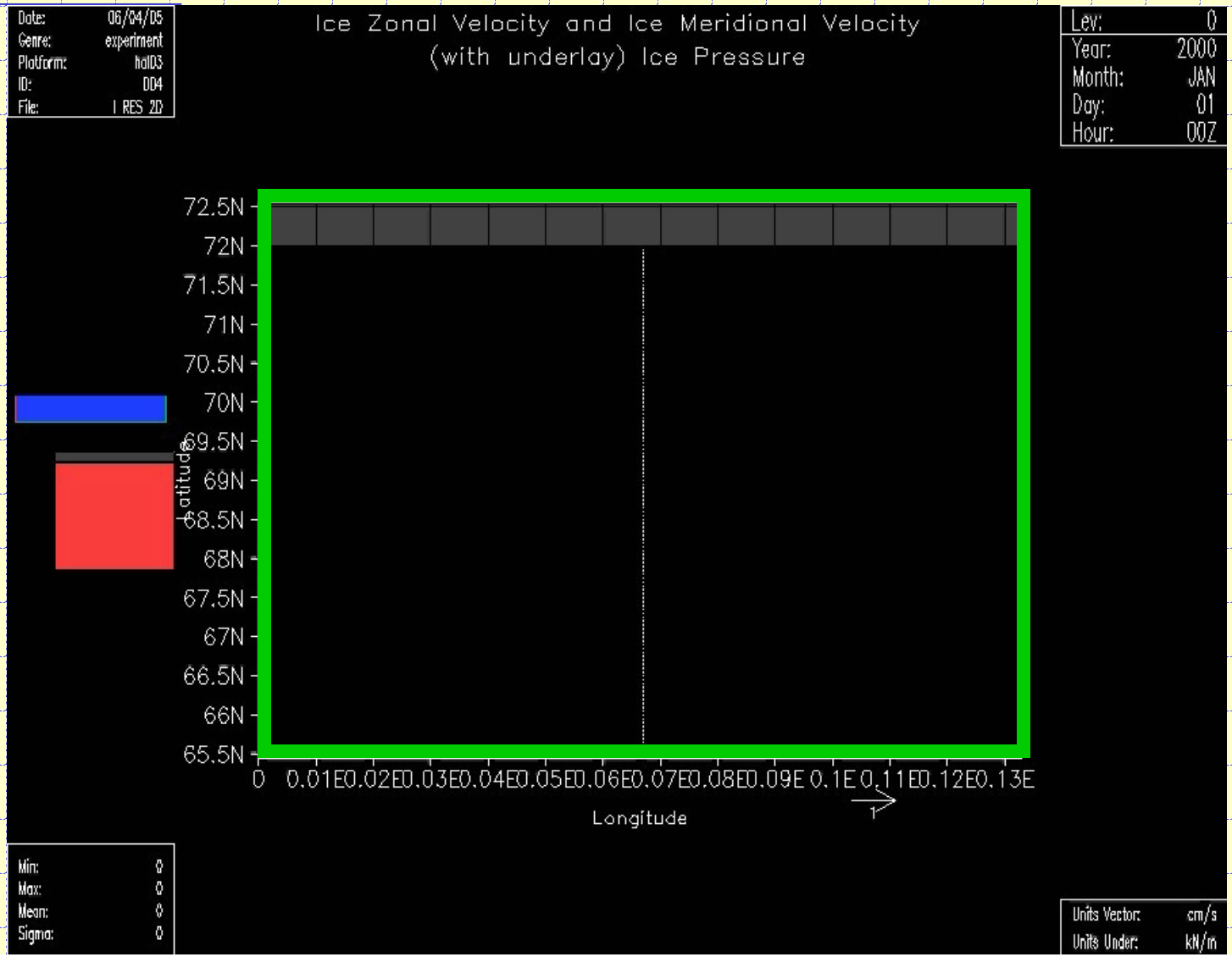
Experiment - Tensile & Compressive Strength

Ice Thickness



Experiment - Tensile & Compressive Strength

Ice Pressure



Conclusions

- Landfast ice pervasive in Arctic
- Plays role in water mass transformation
- Rheology needs modification