GEOS 615 Sea Ice: Ice growth/salinity lab

General remarks:
The aim of this lab is to familiarize you with the processes of ice growth, ice microstructure and the ice salinity profile. While you can perform all the lab work at this point, some of the questions that need to be answered require a bit more knowledge of ice salinity evolution that will be discussed in class in early October. Hence, the lab reports for this class are not due until Friday, Oct 15, 5.00 pm (either in my mailbox as hardcopy or – preferably – as an electronic document via e-mail or in my incoming directory on the GI anonymous ftp server: ftp.gi.alaska.edu/pub/eicken/incoming).

For the work in the lab you will split up into three groups (one with four people in it). Patrick Cotter (GI Sea-ice lab manager, x1156, lab x5473) and Jeremy Miner will help in getting everybody started and introducing you to the techniques. The setting-up part of the experiments is straightforward and really only requires that one from each group come in at the same time (so the ice grows under comparable conditions) on Friday, Sept 24. Please arrange a time with Patrick for that.

The lab work for this exercise is a team effort, but in answering the specific questions that build on the lab work, I expect you to work independently. Lab reports that clearly contain sections culled from other people’s work or reports that indicate that you haven’t thought about this personally are not acceptable and may result in a C grade on this particular lab. This lab counts for one third of the total lab grade (i.e., 10 % of the final grade).

Required equipment (will be provided):
- Tubs with insulation (bags inside coolers)
- salt (table salt, enough to prepare up to 30 ‰ solutions in the containers)
- balance
- salinometer
- thermometer
- drill for temperature measurements
- handsaws
- glass slides, water etc. for thin section production
- camera

Day 1:

1.1. Prepare 3 coolers with solutions of approximate salinity 1, 15 and 30 ‰ (check with salinometer during preparation); each group is responsible for sampling and analysis of one of these coolers
1.2. Transfer vessels to cold room all at the same time
1.3. Set ambient cold room temperature to −5 to −10 °C and start experiment

2. Sample and thin-section processing
2.1. Salinity measurements: Cut samples (1-2 cm thick for salinity measurements) with band saw
2.2. Thin sections: Cut thick section (1 cm thick or thinner if possible) with band saw; freeze thick section onto glass plate; microtome surface of thick section; freeze glass plate onto microtomed surface; cut section in half; microtome new surface down to desired thickness
Day 2ff:

Executive summary:
1.1. End experiment; measure final ice thickness; extract samples for salinity and thin-section measurements; freeze samples so that they are at cold room temperature (<=10 °C)
1.2. Prepare one horizontal and one vertical thin section of each ice cover; measure grain size, qualitative assessment of interface morphology, brine inclusions etc. (this can be done at a later date as the ice will not spoil while in the freezer)
1.3. Cut sample into horizontal segments to determine vertical salinity profile (this can also be done independently at a later date)

Detailed description:

1.1. Cut samples (three slabs, ca. 10x10 cm in surface area, from each tank extending through the entire thickness of the ice cover; align samples with respect to tank and mark surface to indicate orientation of sample) from the three different ice tanks (one group per tank). Try to minimize disturbance of ice cover and underlying water.
1.2. Transfer one sample into aluminum foil and store in chest freezer until ready for salinity measurements (the warmer sections of the ice cover are easier to process at lower temperatures).
1.3. Transfer the two other samples into aluminum foil and store in cold lab near saw for processing.

2. Measure salinity and temperature of the water in the tank at 3 to 4 depth levels.

3. Remove another sample from the tank, drain water/brine from lowermost ice layers and investigate the nature of the lower ice interface. Measure and note conspicuous features (incl. approximate dimensions, orientation etc.; take digital photograph for documentation purposes).

4.1. Produce one vertical and one horizontal thin section (about one third of the thickness away from the bottom of the ice cover) from the slabs collected earlier. Measure ice thickness on vertical section.
4.2. Describe the grain morphology (between crossed polarizers) and measure grain cross-sections on about 1 to 2 dozen of the largest grains (on vertical sections: parallel and perpendicular to the direction of growth, with measurements perpendicular to direction of growth taken at 5 different depth levels; on horizontal sections measure maximum and minimum cross-section). Take digital photograph for documentation.
4.3. Determine whether crystals are displaying preferred c-axis alignment based visual inspection of horizontal and vertical section.
4.4. On the same thin sections describe the pore morphology (in ordinary transmitted light) and assess the width and spacing of regular arrays of brine layers (if present). Also note the presence and morphology of gas inclusions.

5.1. Cut the remaining ice sample into horizontal slices of approximately 2 to 3 cm thickness (or at least 5 if the ice cover is thinner).
5.2. Transfer slices into plastic sample bags, seal and immerse in hot water in order for the ice sample to melt.
5.3. Determine the salinity (or in the case of the freshwater ice, conductivity) of the melted samples.

6. Prepare a lab report, with a short summary of the set-up and course of the experiment and a more detailed results sections. In the results section, summarize findings and answer the following questions.
6.1. Discuss the variability in grain size with depth and explain the morphology of grains (length of major axes in three principal directions) in terms of the ice crystal structure.
6.2. Was any preferred alignment of crystal c-axes observed? If so, what type of alignment and what could be potential factors responsible for these patterns?
6.3. Discuss the presence/absence of brine inclusions in the ice cover and link their presence/absence to the morphology of the lower ice(-water) interface in terms of the build-up of solute at the interface and the crystal structure of ice.
6.4. Determine the salt segregation coefficient k (for details see lecture notes and Section 2.6 in Eicken, 2003) based on the measured ice salinity for the bottommost layer, the mid-depth layer and top layer of the ice cover.
6.5. Based on the estimated ice-growth rate, how do the measured k's compare with values published in the literature (cf. Cox and Weeks' data as referred to in lecture notes and in Eicken, 2003 – both graph and equations)?
6.6. Explain potential deviations from published estimates and discuss potential vertical gradients in k (and salinity) in terms of (1) the variability in growth conditions, (2) ice desalination processes and (3) sampling/measurement errors.
6.7. Based on the temperature data and measured salinities, derive the in-situ liquid volume fraction for the ice surface layer (based on the topmost sample salinity) as well as for the bottommost layer in the ice cover (bottom ice layer salinity). See the lecture notes, section 1.3, and the book chapter Eicken, 2003, section 2.4) on details of how to derive brine volume fraction. 
6.8. To what an extent have you observed correlations between the salinity, grain morphology and pore morphology in the samples analysed? How would one explain these?