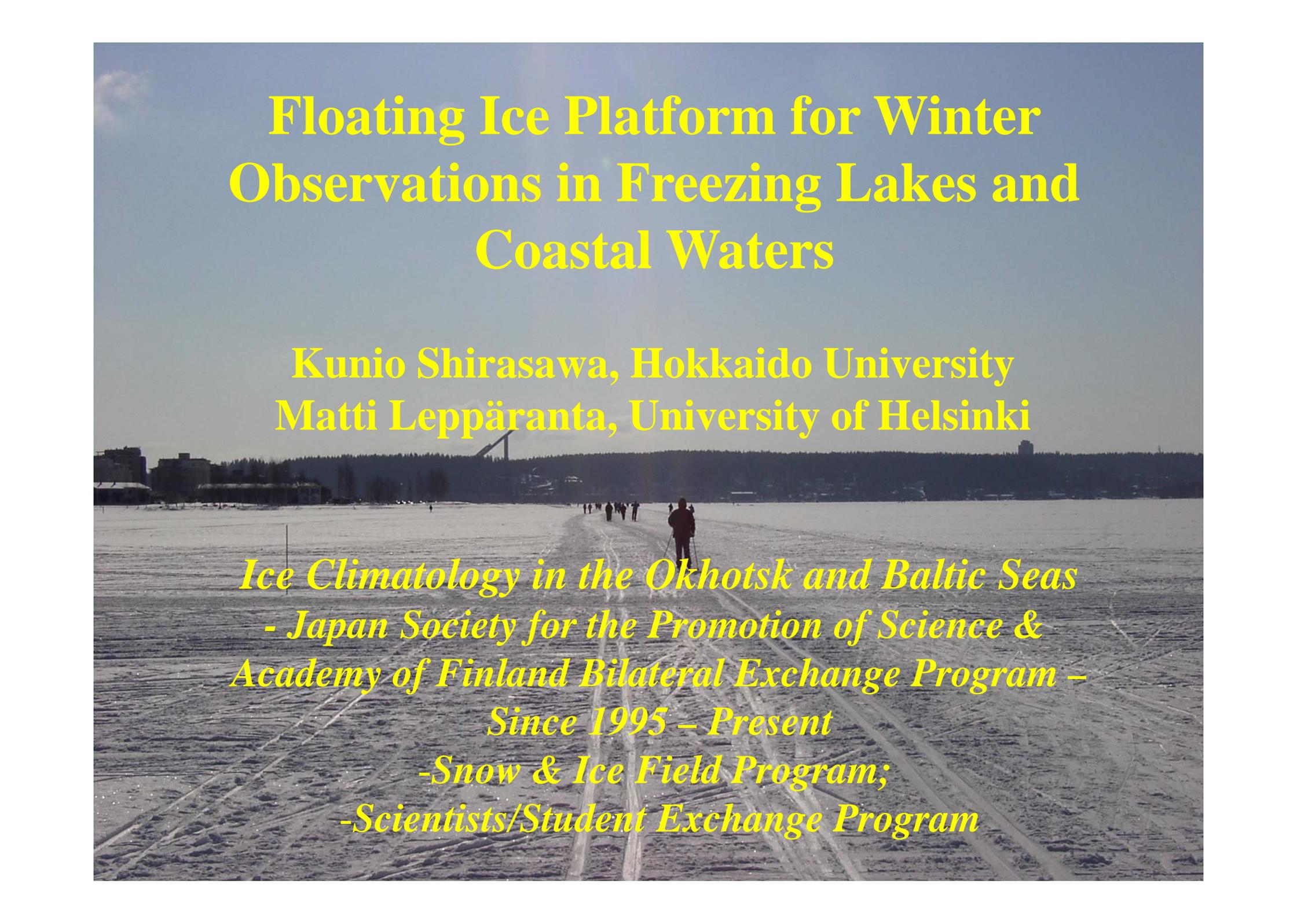




HOKKAIDO UNIVERSITY

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Floating Ice Platform for Winter Observations in Freezing Lakes and Coastal Waters

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Ice Climatology in the Okhotsk and Baltic Seas
- Japan Society for the Promotion of Science & Academy of Finland Bilateral Exchange Program –
Since 1995 – Present
-Snow & Ice Field Program;
-Scientists/Student Exchange Program

Contents

- (1) Lake ice & coastal fast ice problems
- (2) Structure of lake ice & brackish ice cover
- (3) Growth and melting of lake & coastal ice
- (4) Mathematical models
- (5) Lake ice and climate
- (6) Conclusions



Main Study Lakes & Coasts
Santala Bay
Pääjärvi
Vanajavesi
Kilpisjärvi

Field Programmes:

-Santala Bay, west Gulf of Finland

-Lake Pääjärvi & Vanajavesi,

southern Finland

-Lake Kilpisjärvi, northern Lapland

-Umea, Sweden

ラップランドの大自然

スカンジナビア半島北部からロシアにかけての北極圏の帯はラップランドと呼ばれ、フィンランドでもとりわけ大自然の美しさに恵まれた地域。秋から春にかけて、夜空に輝く幻想的なオーロラが現れます。また、夏至の頃には一晩中沈むことのないミッドナイト・サン「真夜中の太陽」が見られ、幻想的な白夜の大自然が広がります。

サンタクロースのふるさととして知られるロヴァニエミ。季節を問わずリゾートとして賑わうサーリセルカ、レヴィ、ユッラス。面積の半分以上が森林や湖沼に包まれた自然都市クーサモ。観光砕氷船サンボ号の発着地で「雪の城」でも有名なケミなどの観光地が点在しています。各地のリゾートでは、夏の森林ハイキングやカヌー、冬のオーロラ観測、トナカイぞり、犬ぞり、クロスカントリー・スキーなど、フィンランドならではのアクティビティが楽しめます。

森と湖の広がり——これこそフィンランド

フィンランド南東部からロシア国境にかけて、まさに「森と湖の国」が広がっています。民族叙事詩「カレワラ」が伝わるカレリア地方には、フィンランドの原風景があるといわれ、みごとな湖と森の景観を楽しむことができます。

北カレリア地方の中心地で、800年以上の歴史を持つギリシャ正教会のヴァラモ修道院で名高いヨエンスー。サイマー湖クルーズの発着地であり、初夏には北欧最大のダンス・フェスティバルが開かれるクオピオ。湖に浮かぶオラヴィ城で夏に開催されるオペラ・フェスティバルで有名なサヴォンリンナ。秋にクラシック・バレエの祭典が開かれるミッケリ。そして、サイマー湖南端にある南カレリア地方の中心地ラッペーンランタなど、フィンランドの心に触れられるカレリア地方は、見どころもいっぱいです。

また、湖水地方の中心部には、大学都市として知られ、建築家アルヴァ・アールト設計による都市づくりで知られるユヴァスキュラ。シルヴァーライン湖水クルーズの発着地で、中世の要塞ハメ城とシベリウスの生家で知られるハメーンリンナ。そして、ハメーンリンナからの湖水クルーズの中継地であり、ムーミン谷博物館も有名な、歴史ある工業都市タンペレがあります。

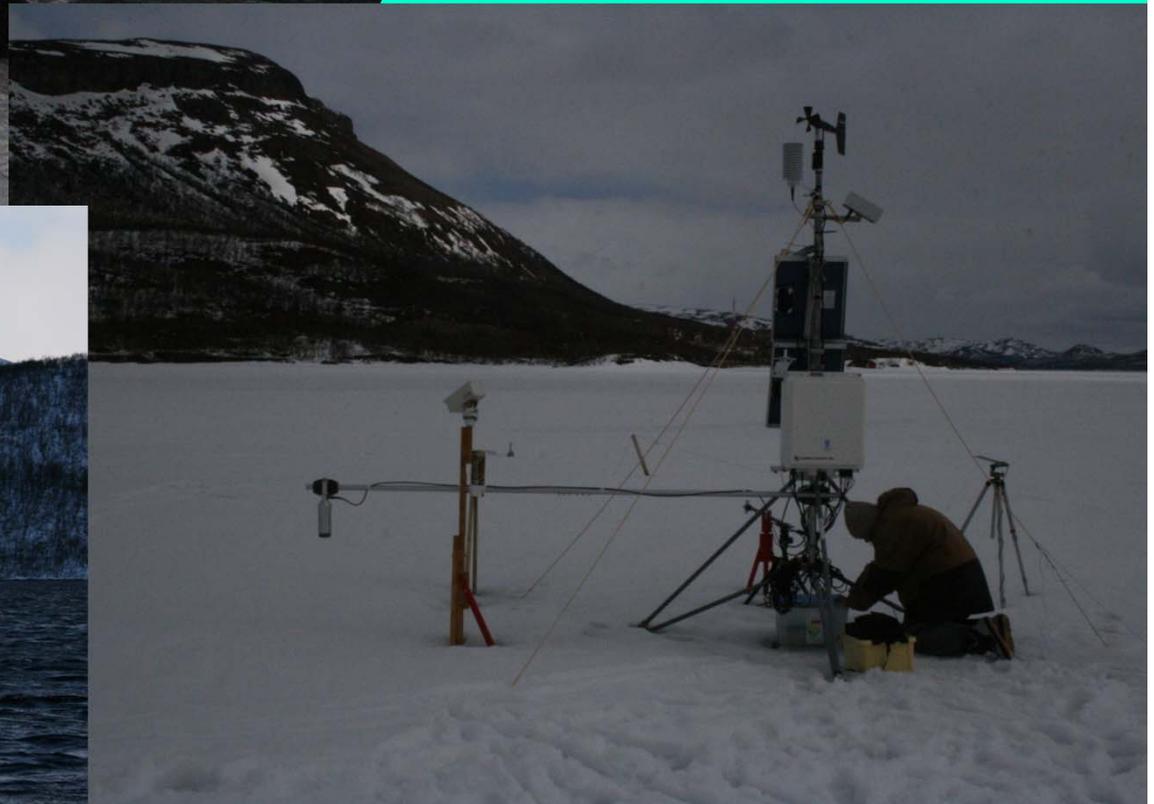
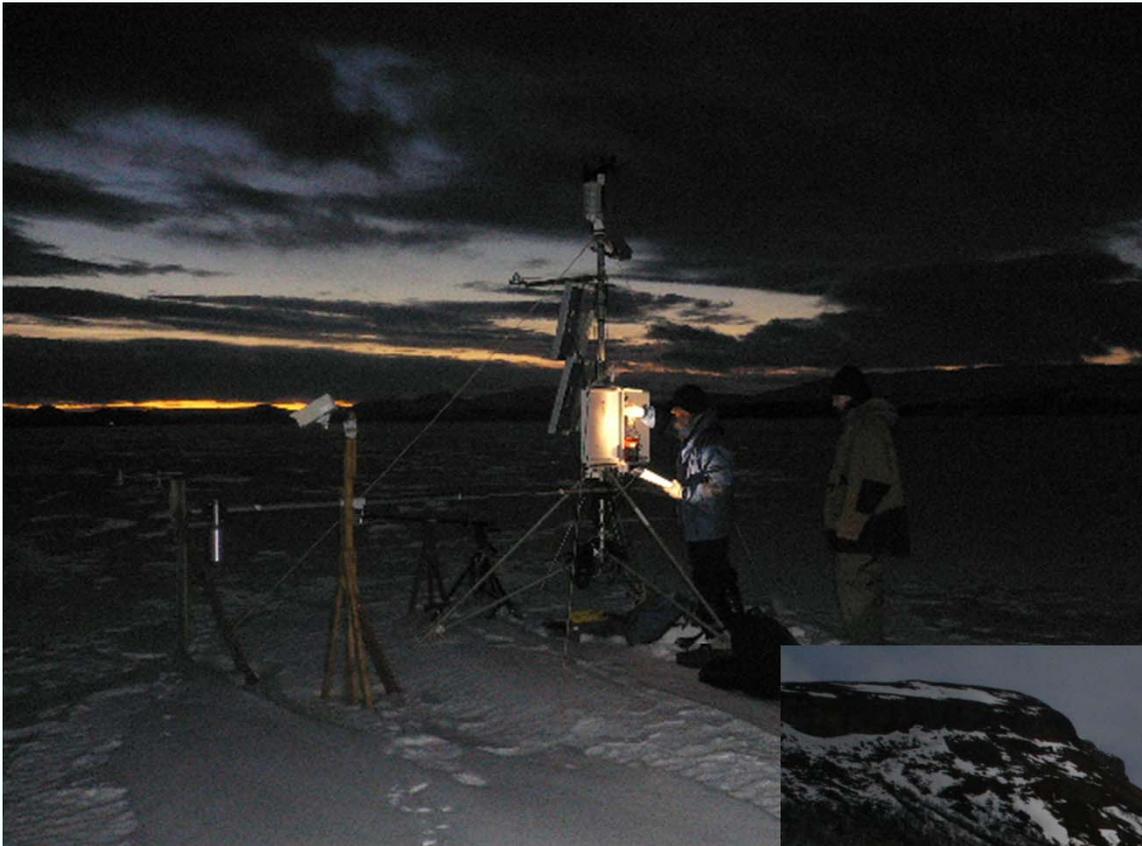
歴史あふれる街並み

ボスニア湾、バルト海を隔ててスウェーデンに面した地域には、歴史ある古都、近代的な都市、リゾート、国境海上の島々などがあり、多彩な顔を見せてくれます。

国立技術研究センターや大学、ノキアの研究機関などが集まるハイテク都市オウル。夏には国際



*Kilpisjärvi
Ice Station
2007 – 2009*



N61°03'09.6" E 25°04'44.8" 228°



Lake Pääjärvi Ice Station

*Area 13 km², Mean depth 14 m
Fresh water, Ice thickness 30–80 cm,
Significant portion snow ice,
Quiet water body in winter*



Winter Program

- *Ice and snow thickness*
- *Air – ice heat exchange*
- *Solar radiation transfer*
- *Under-ice boundary layer*
- *Heat flux from water to ice*

Santala Bay, Hanko Peninsula, Western Gulf of Finland

- *Ice cover:
Thermodynamics &
dynamics*
- *Ice structure &
properties*
- *Solar radiation transfer*
- *Ice growth & melting:*
- *Air - ice heat
exchange: Heat budget
& snow/ice thickness*
- *Under-ice boundary
layer:*
- *Heat flux from water to
ice*

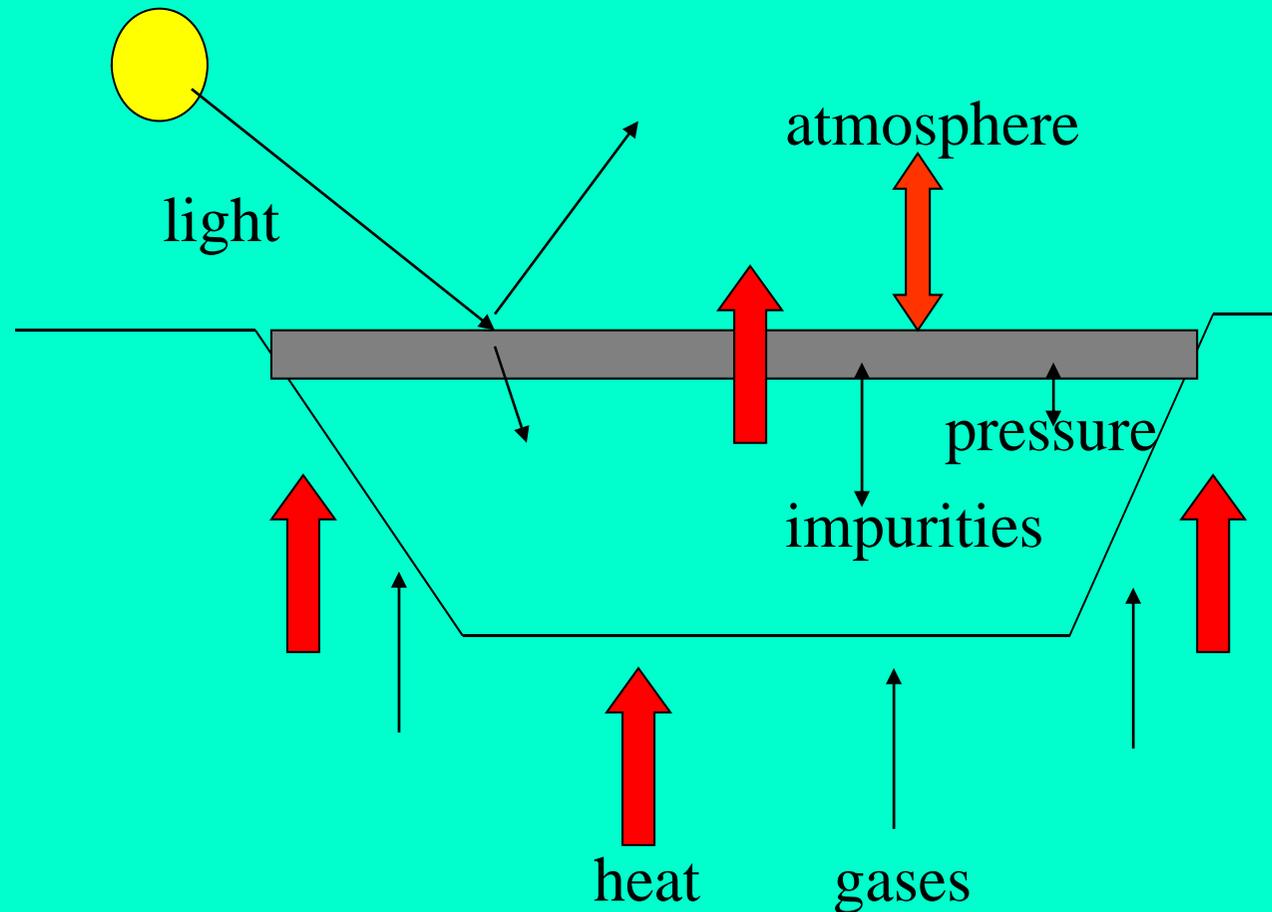


Motivation

- Northern and mountain lakes in Europe, and shallow coastal waters in Baltic Sea are ice-covered up to seven months per year; normally the ice is covered by a snow layer.
- The ice (and snow) produce a water body environment very different from open water period.
- An advanced treatment of ice has been necessary in research of freezing lakes and closed shallow coasts

Forcing in ice season

The role of ice cover :



- Stabilize the lake temperature field: the surface water is at 0°C, and only weak upward heat fluxes exist from bottom and out of the lake
- Weaken the light transfer
- Reject/reduce the momentum transfer from wind
- Capture impurities from lake water and lake bottom and atmospheric fallout

Mixing horizontal rather than vertical in the water body.

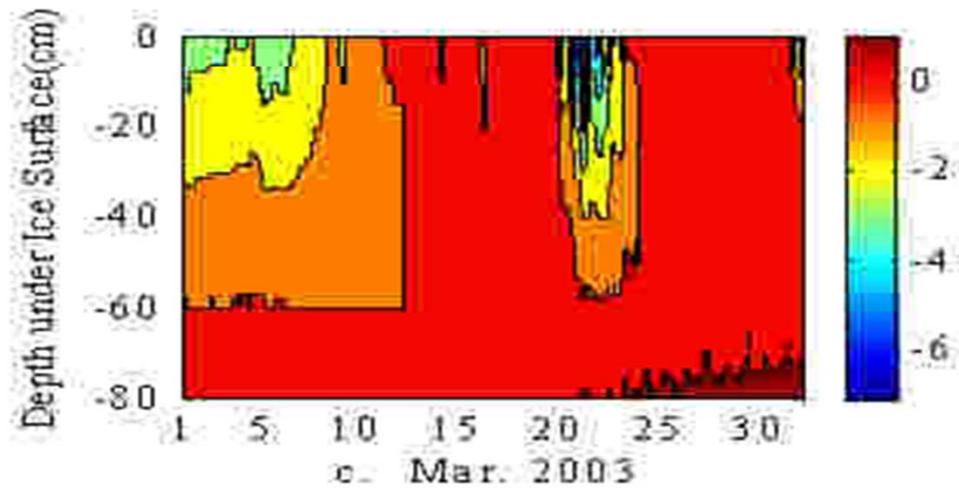
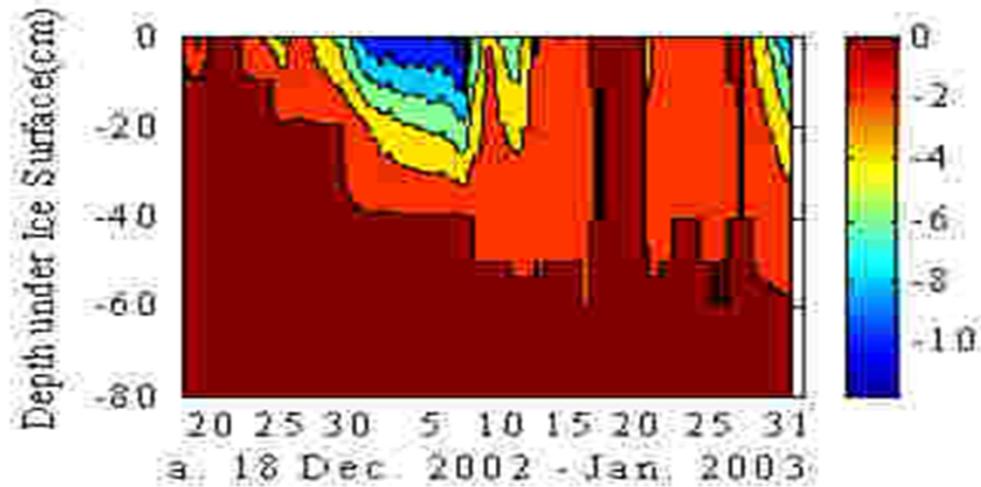
What is 'ice on lake'?

- Three principal layers
 - *snow*
 - *superimposed ice (snow-ice)*
 - *congelation ice*
 - Liquid water pockets inside
 - *internal melting*
 - *flooding*
 - *advection*
- habitats for biota



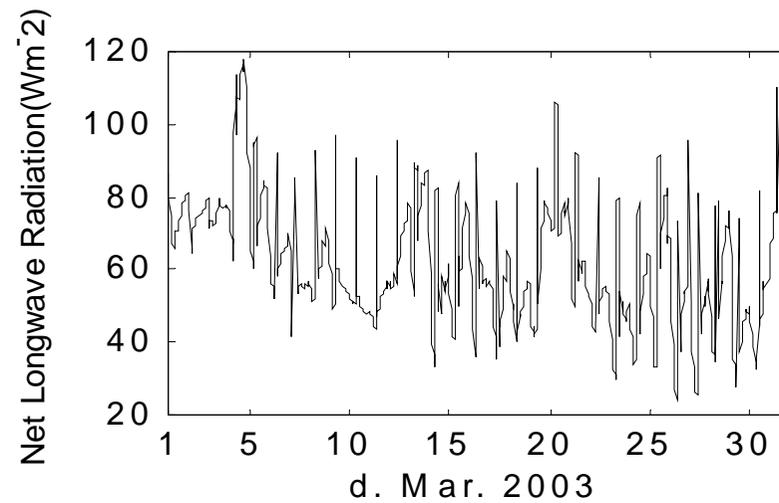
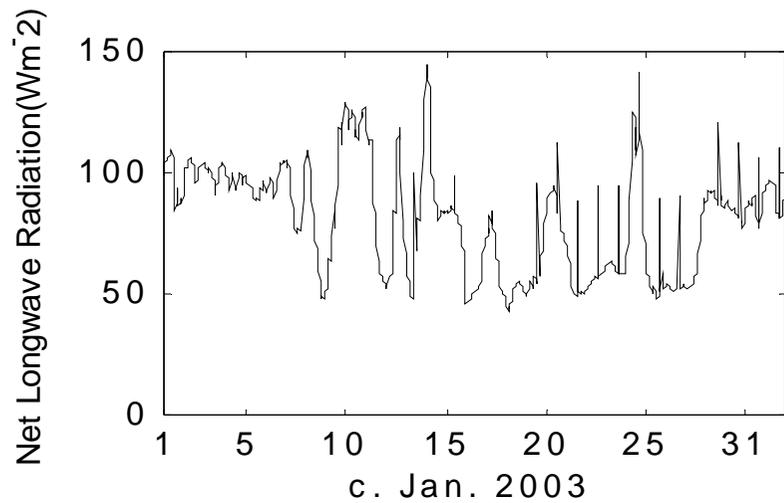
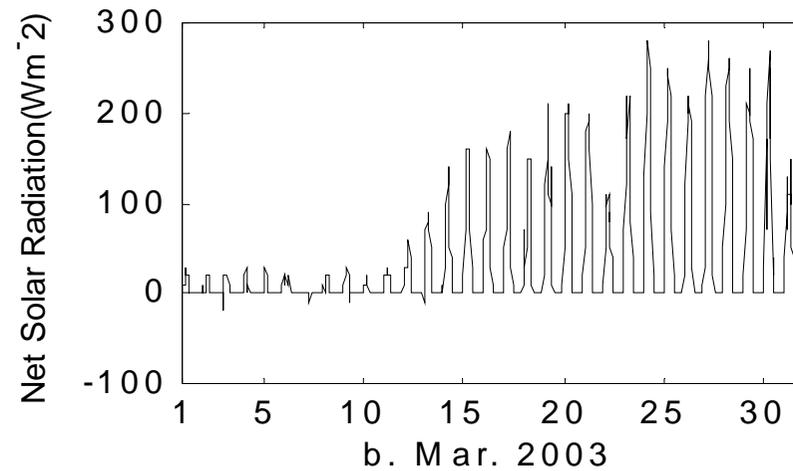
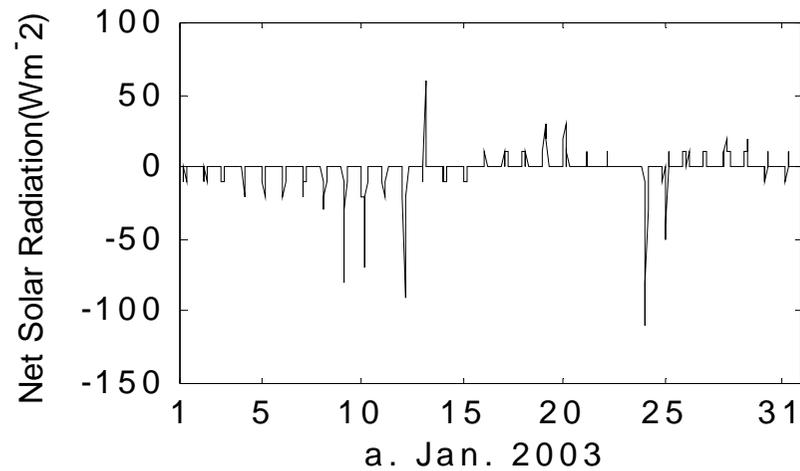
Lammi Ice Station

Temperature in ice 2003

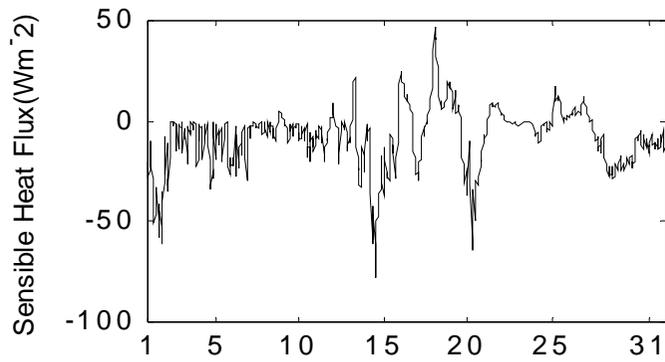


Lammi Ice Station

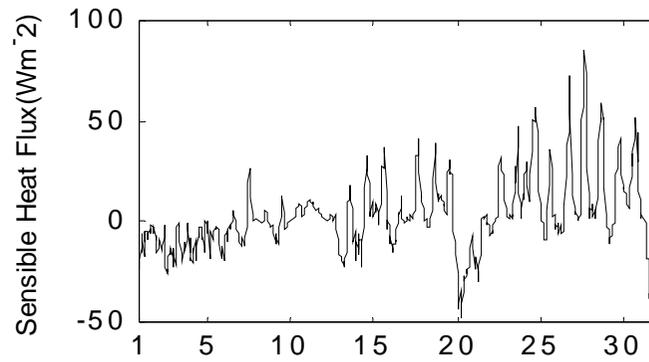
Radiation budget 2003



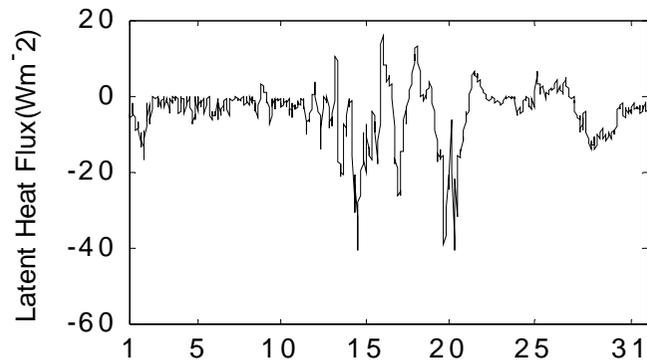
Turbulent heat fluxes 2003



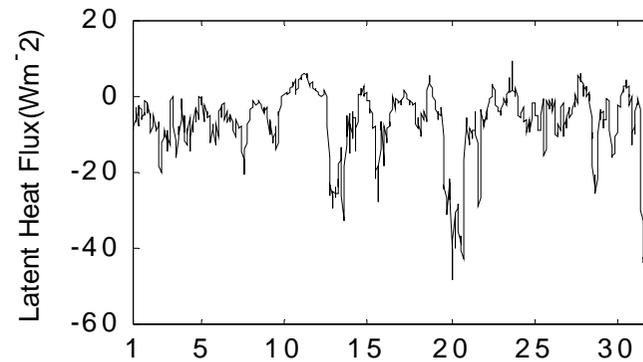
a. Jan. 2003



b. Mar. 2003



c. Jan. 2003

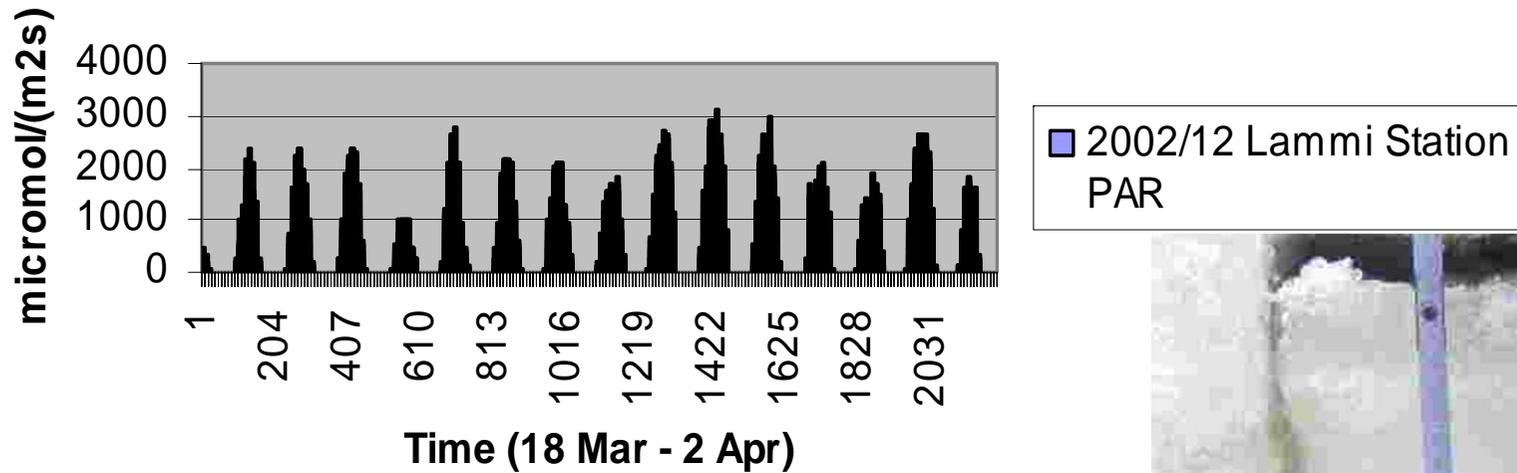


d. Mar. 2003

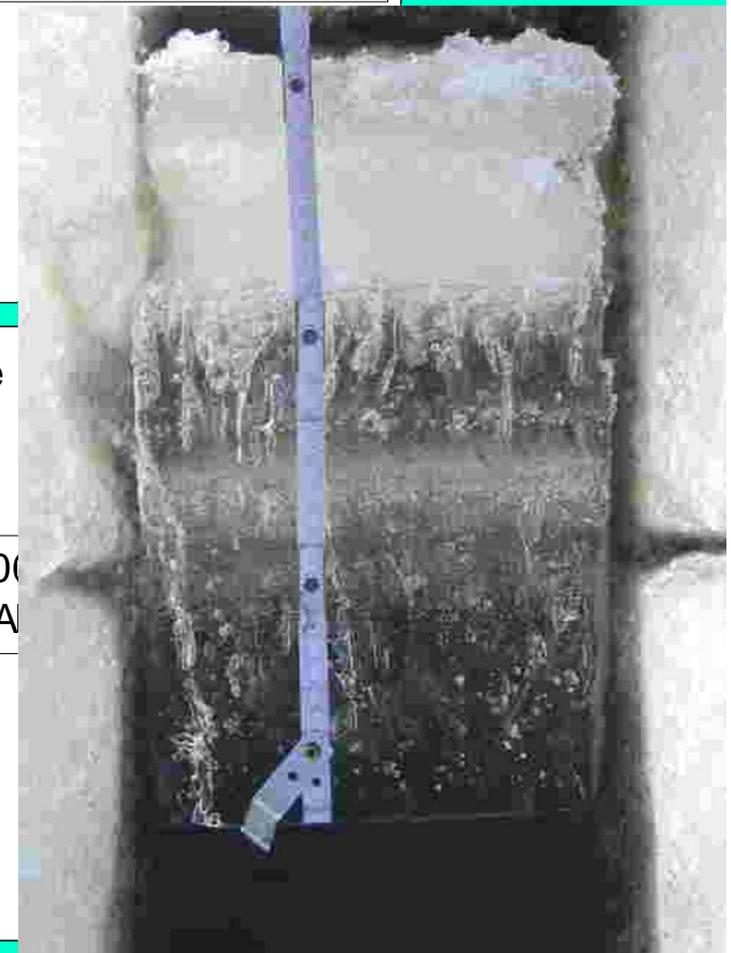
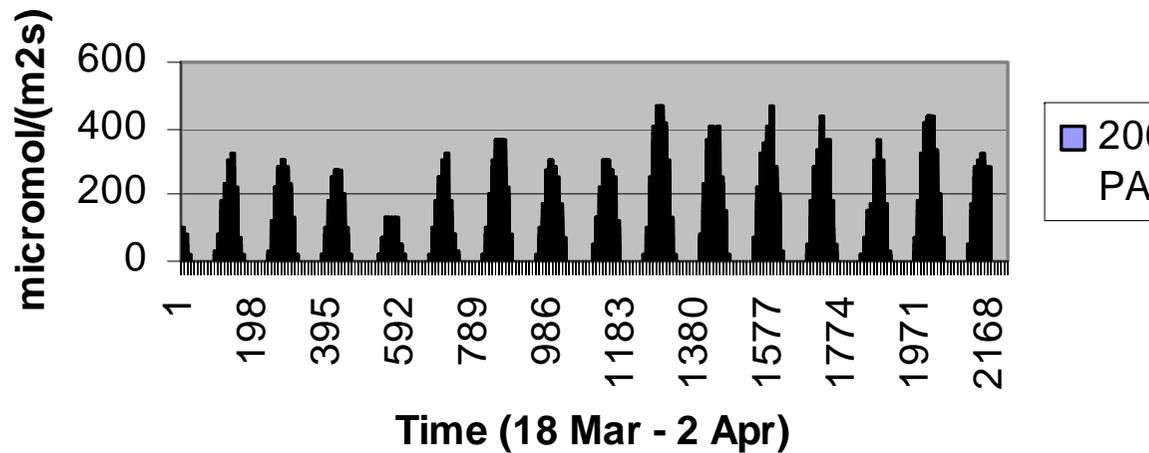
Lammi Ice Station

Solar radiation in ice: deployed 18 Mar 2003

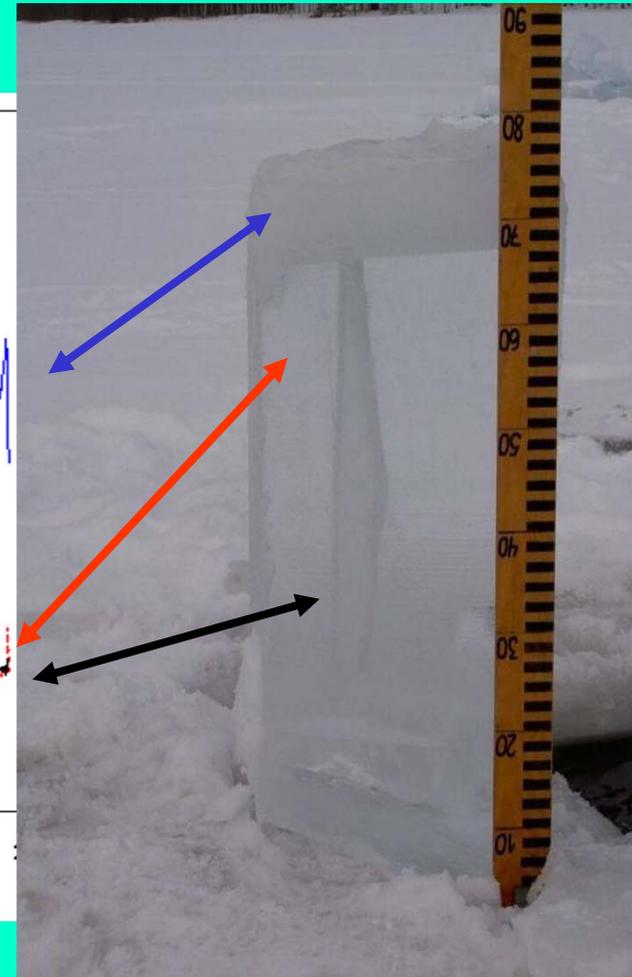
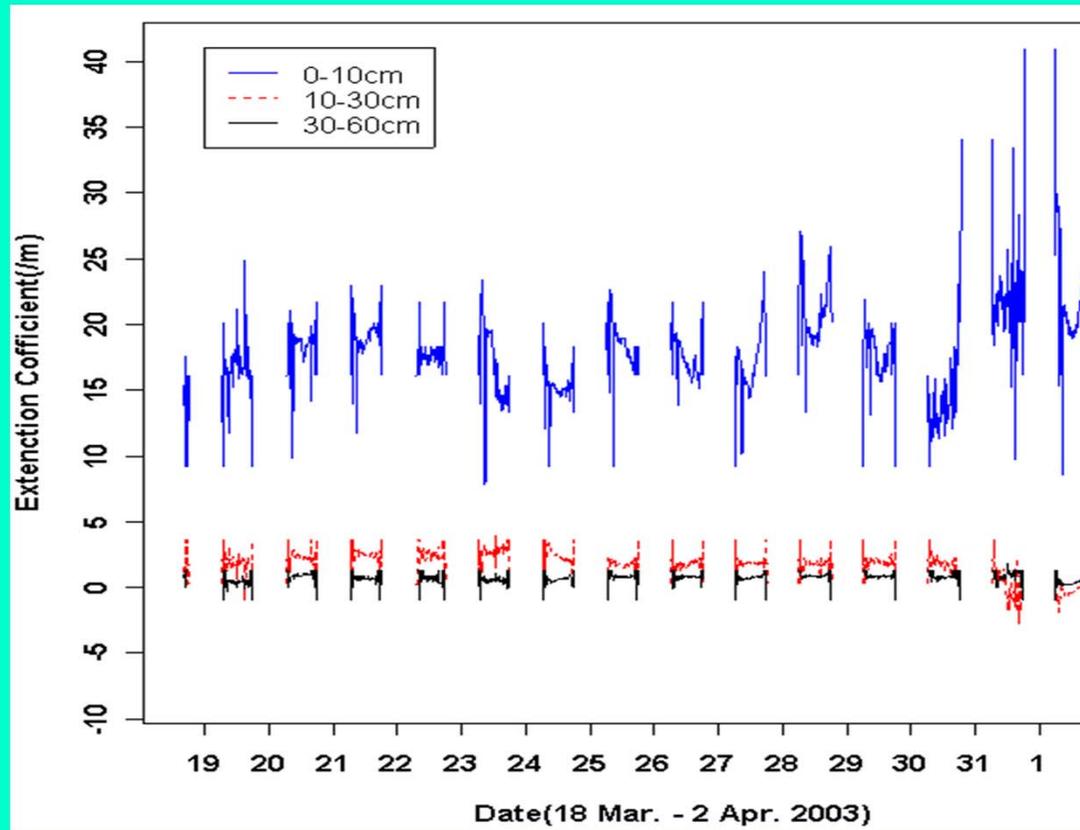
2002/12 Lammi Station PAR: surface



2002/12 Lammi Station PAR: 60 cm in ice



Light attenuation in ice

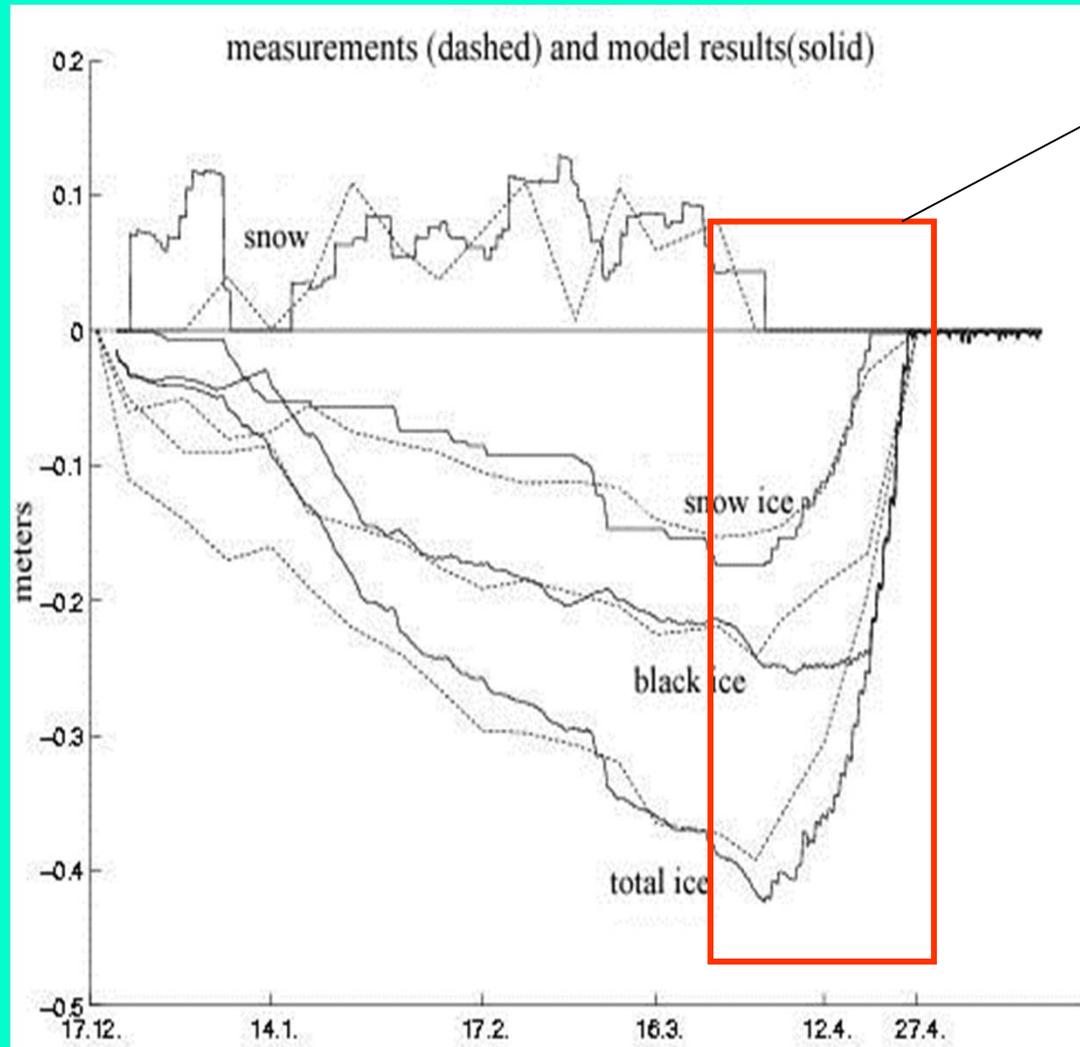


Lammi Ice Station

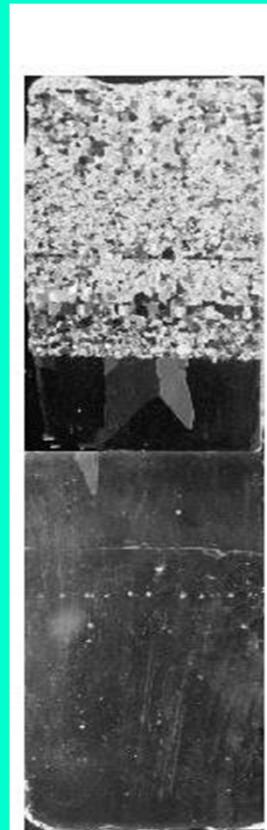
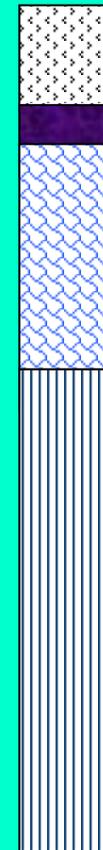
Model structure

- Three layers: snow, superimposed ice, congelation ice
- **Solid and liquid phases of water**
- Heat conduction with solar source term
- Snow model with snow metamorphosis
- Interactive surface heat balance
- Heat flux from lake water

Ice structure and full model



porosity important



Climate change influence

- **Freezing date:** delay $\Delta T/T_a' \sim 5 \text{ d}/^\circ\text{C}$,
 $\Delta T = \text{climate change}$, $T_a' = \text{fall cooling rate}$
- **Maximum annual ice thickness** \leftarrow air temperature, snow fall, $\Delta h \sim (0 - 10 \text{ cm}) \times \Delta T [^\circ\text{C}]$; internal layers may change
- **Ice break-up:** n days after radiation balance zero upcrossing, sooner by $(\frac{1}{2} - 1 \text{ day}) \times \Delta h [\text{cm}]$
- **Snow ?** \leftarrow ice season length, precipitation

Winter lake regimes move due to climate changes

Effeminate ice zone

Unstable ice zone

Stable ice zone



**Zone boundaries drift →
unexpected situations may come.**

Lake ice and society: climate warming impact

- Lake ecology is affected (+/- ?)
- Traffic on-ice: shorter season, more risks (change may be faster than learning)
- Recreation possibilities decrease: sport, fishing, ice-water bathing
- Local weather changes (←warmer surfaces)
- Open areas may persist → moisture fluxes, frazil ice

If the climate changes, not only the length of ice season and the thickness of ice, but the quality of physics, ecology and practical life will be different.

