GLI Cryosphere Products and Findings from the Validation Experiments

Teruo Aoki (MRI)
Masahiro Hori (JAXA/EORC)
Hiroki Motoyoshi (Space Service Co., Ltd.)
Tomonori Tanikawa and Akihiro Hachikubo (Kitami Institute of Technology)
Konosuke Sugiura (JAMSTEC/IORGC)
Teppei J. Yasunari (Hokkaido University)
Yasuko Iizuka (Graduate Univ. of Advances Studies)
Yukinori Nakajima and Fumihoro Takahashi (RESTEC)
Knut Stamnes, Wei Li and Hans Eide (Stevens Institute of Technology)
Rune Storvold (NORUT Information Technology Ltd.)
and
Jens Nieke (University of Zurich)

Goal

✓Development of remote sensing technique to detect qualitative change of cryosphere, the most sensitive area for global warming.

✓To investigate the radiative properties of snow/ice surface.

✓Improvement of land-surface model (LSM) in cryosphere of GCM.

GLI Cryosphere products

✓Cloud detection over snow/ice

✓Snow/Ice extent

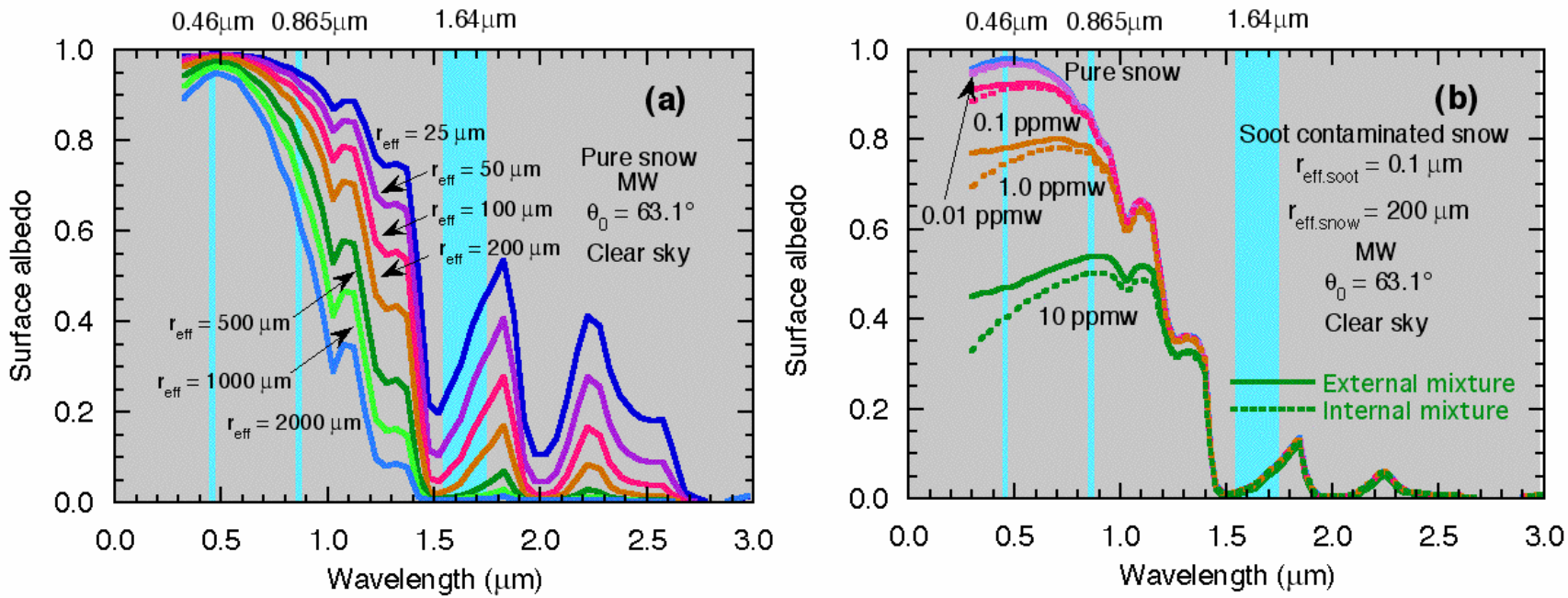
✓Snow surface temperature

✓Two types of snow grain sizes

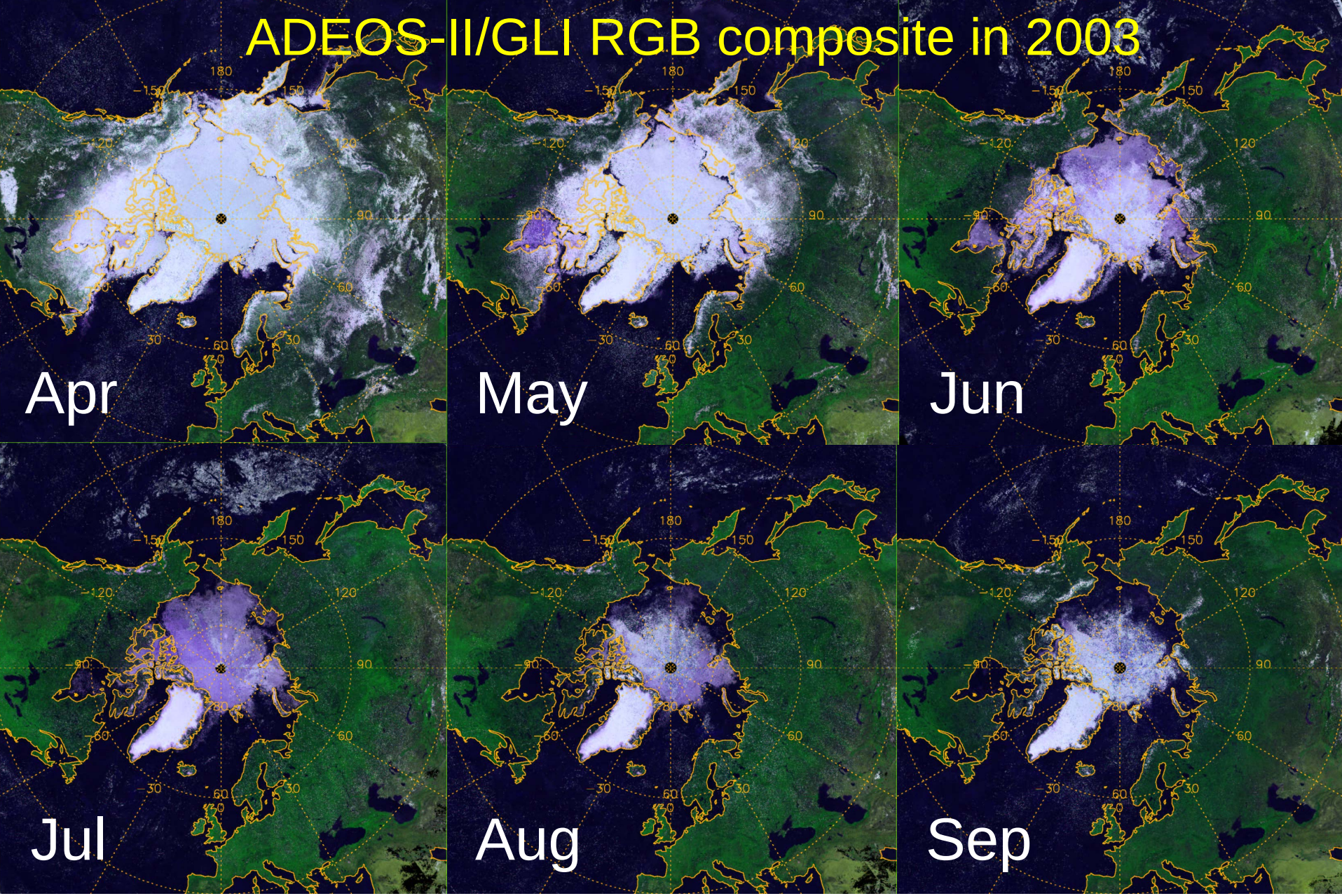
✓Mass concentration of snow impurities (water-insoluble solid particles (soot-equivalence))

Principles to retrieve snow grain size and impurities

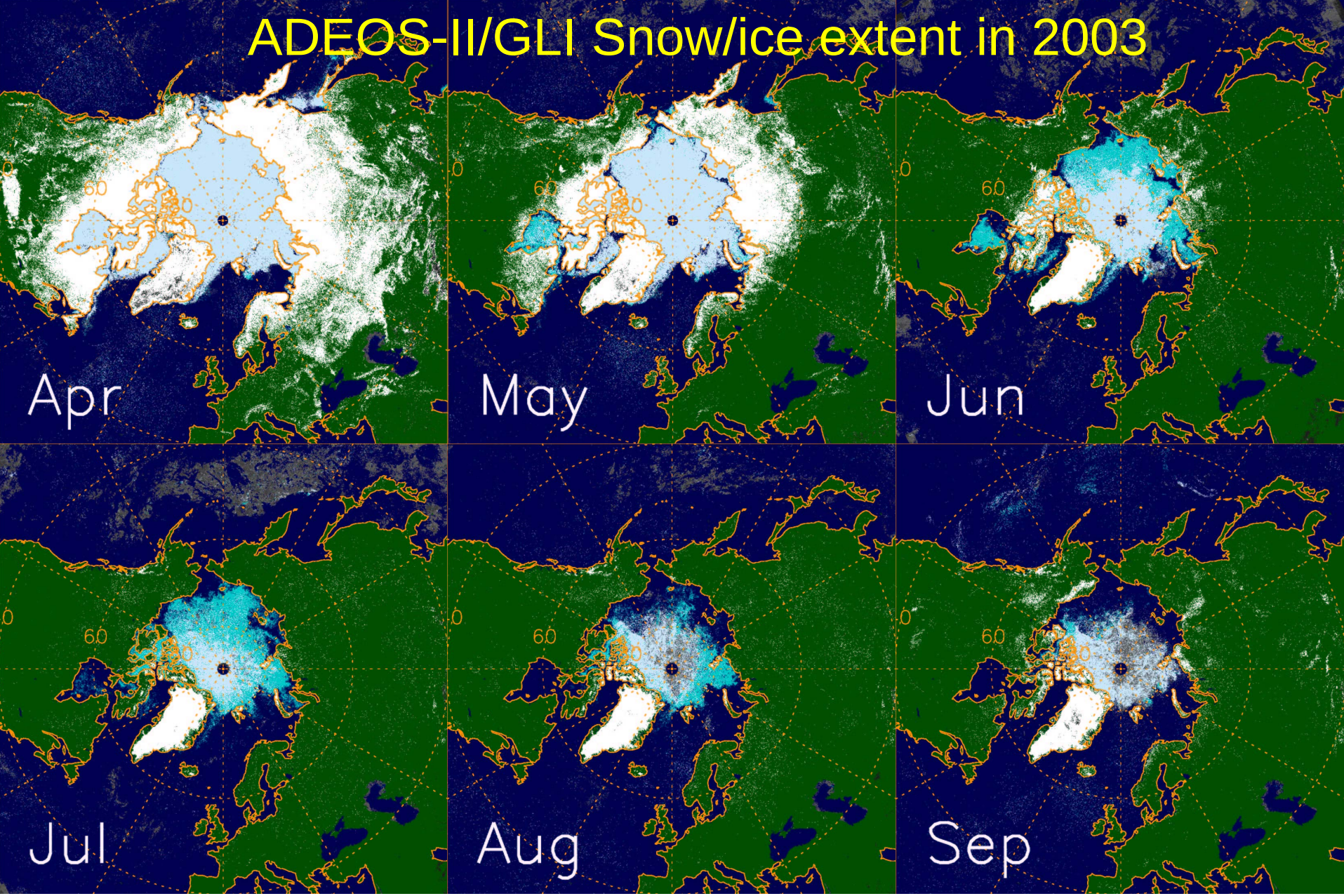
✓Near infrared albedo depends on snow grain size
✓Visible albedo depends on mass concentration of impurities



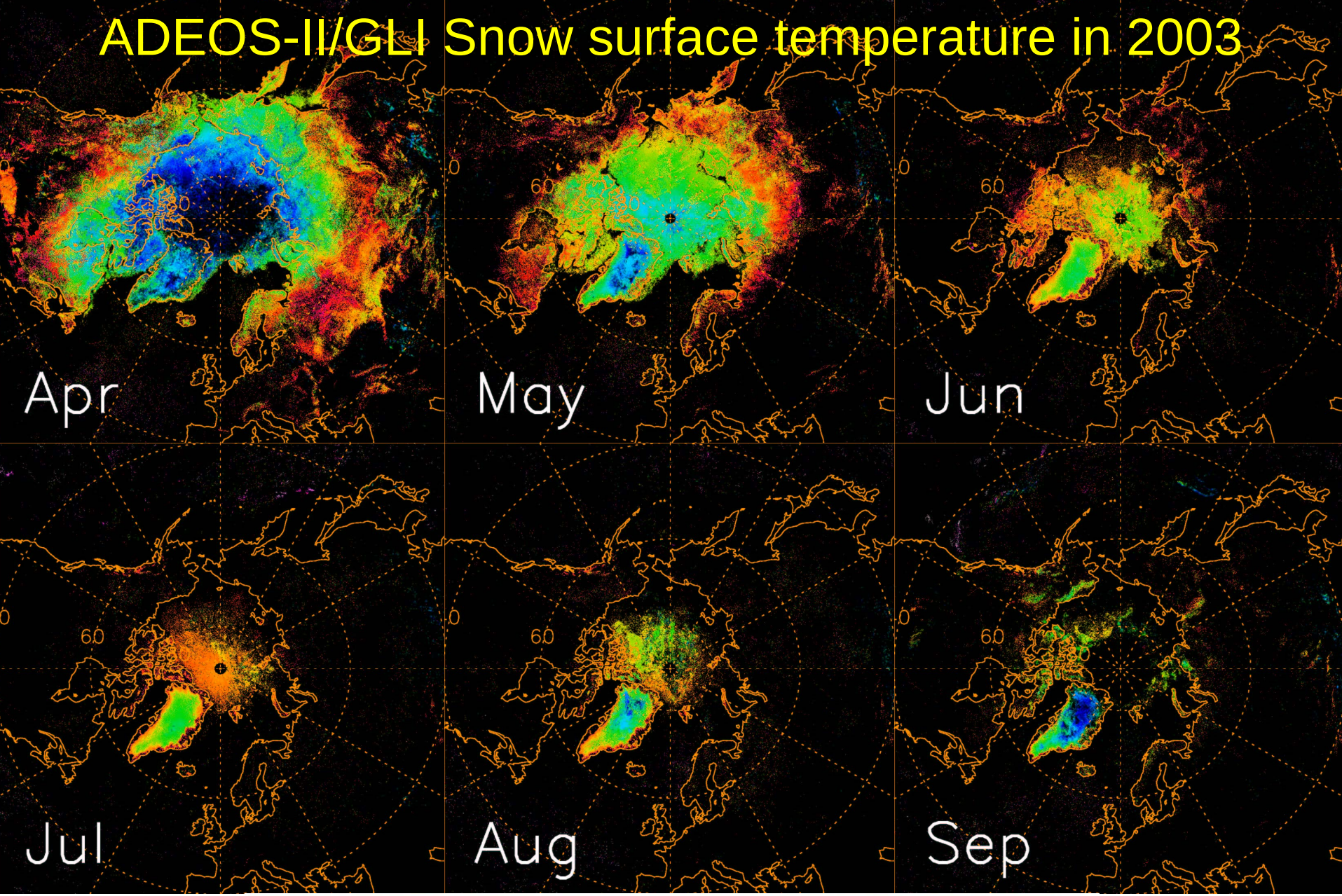
Spectral albedos depending on (a) snow grain size and (b) impurities, where spherical ice particles are assumed for snow grains and soot for impurities.


ADEOS-II/GLI RGB composite in 2003
Apr
May
Jun
Jul
Aug
Sep
R: 0.678 μm G: 0.865 μm B: 0.460 μm

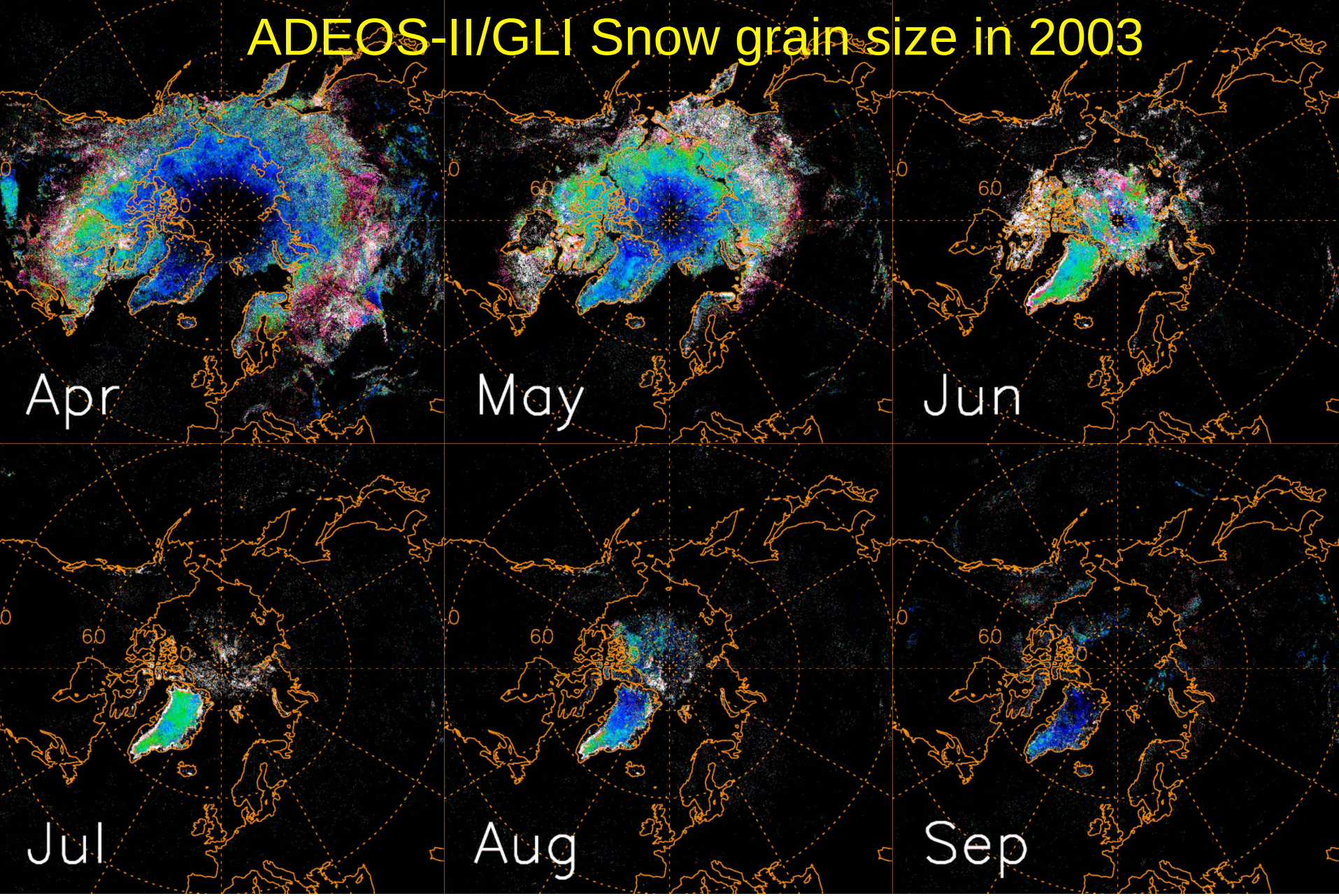
ADEOS-II/GLI Snow/ice extent in 2003



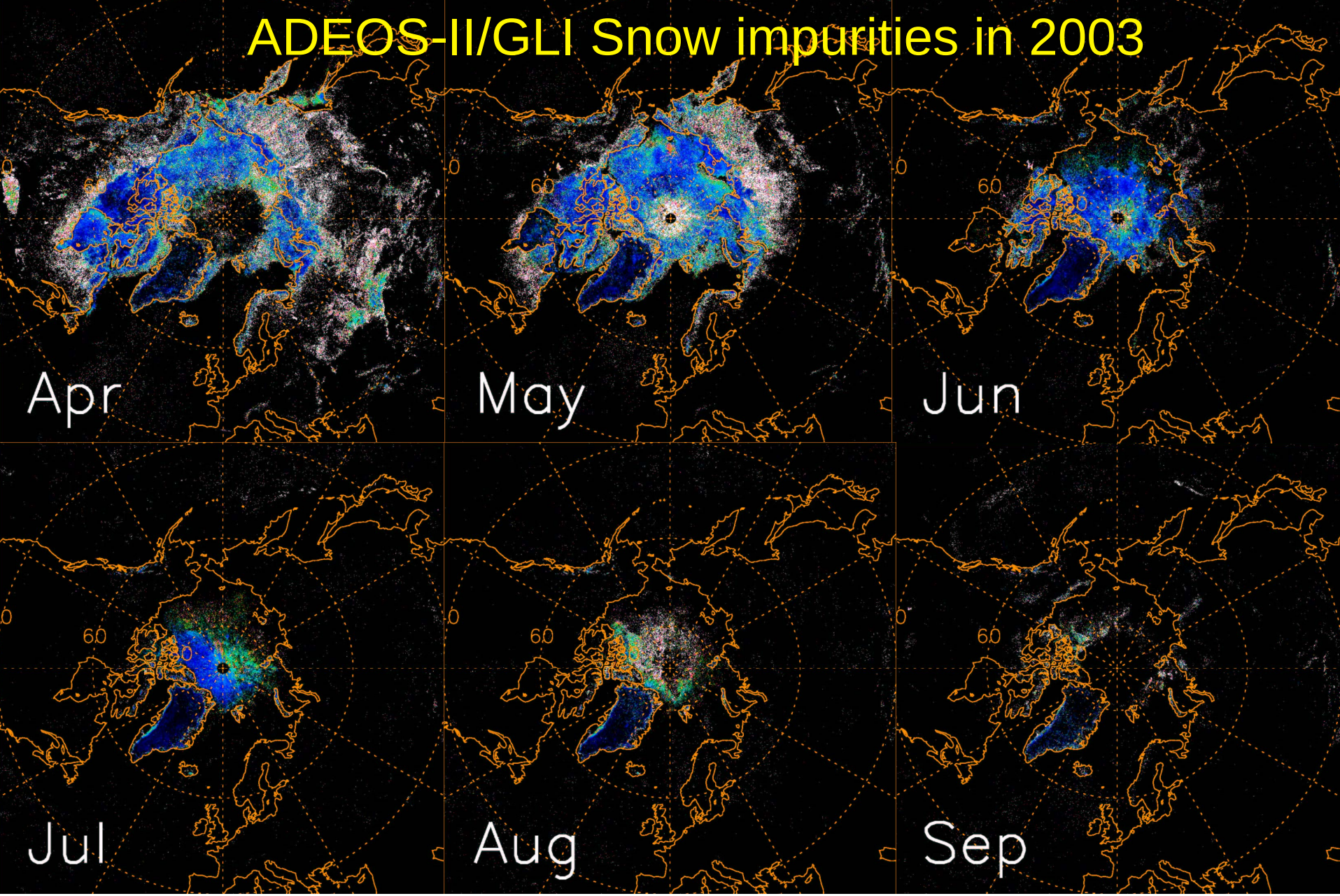
ADEOS-II/GLI Snow surface temperature in 2003



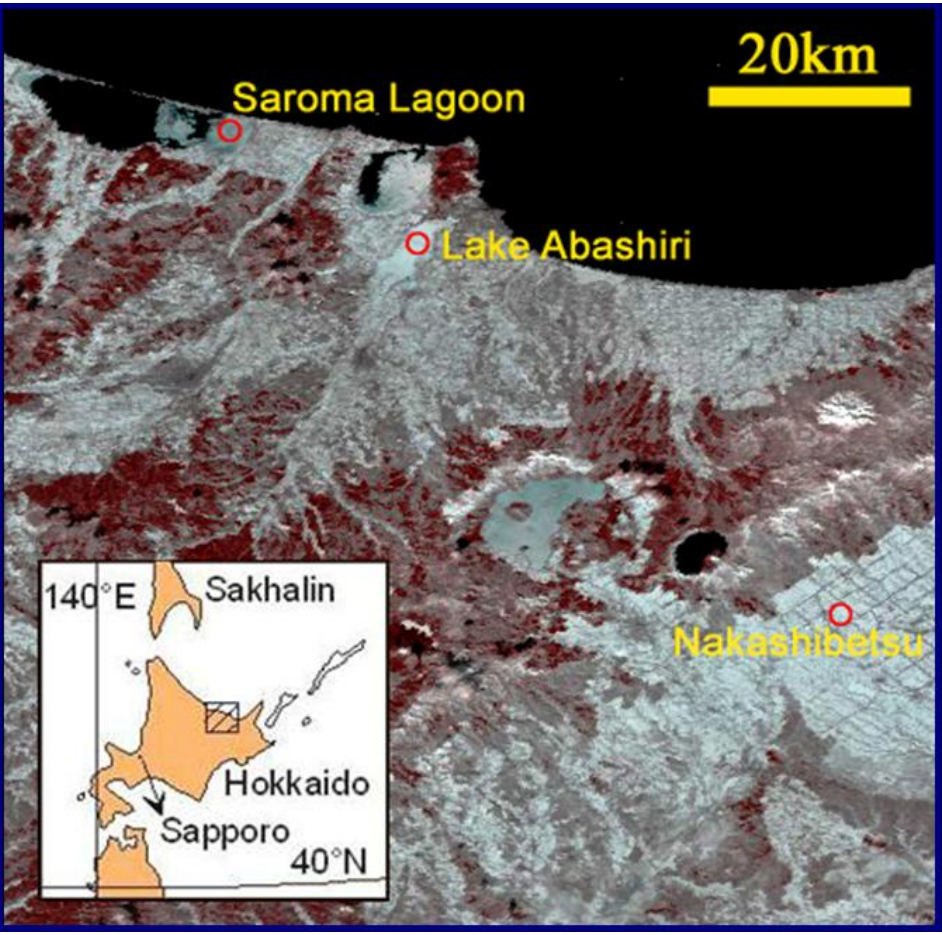
ADEOS-II/GLI Snow grain size in 2003

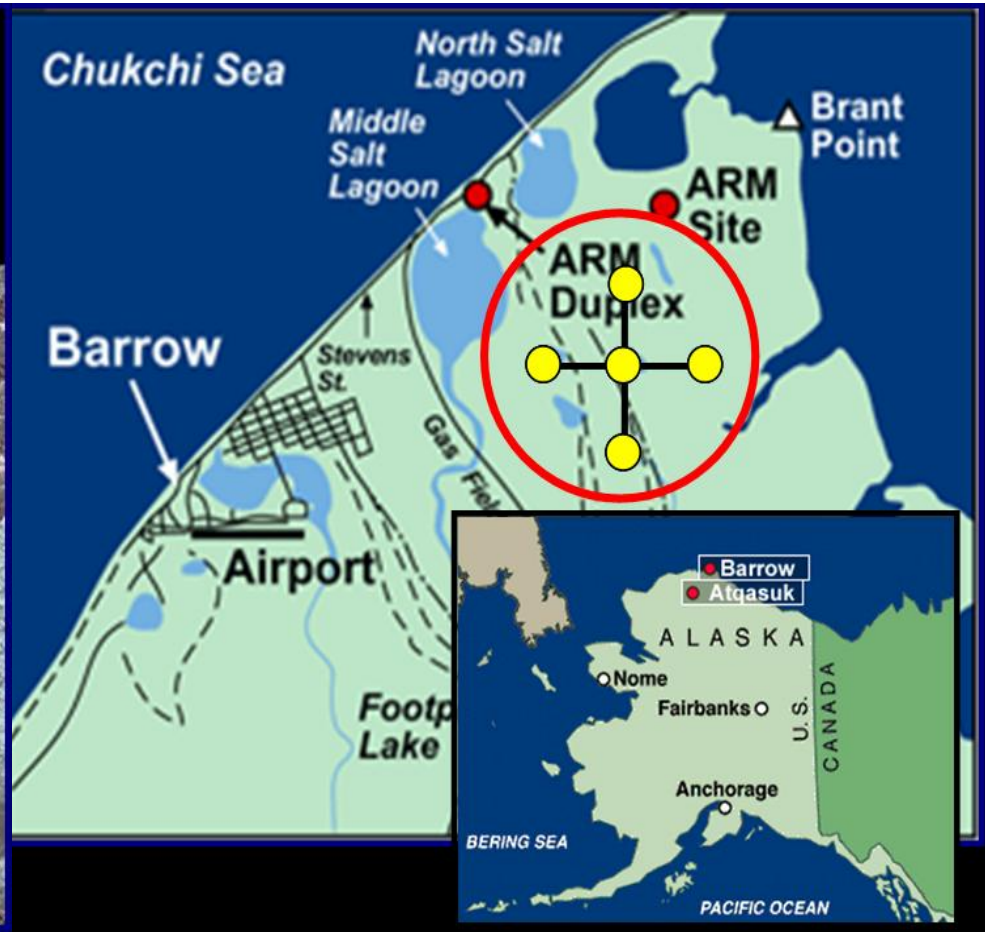


ADEOS-II/GLI Snow impurities in 2003



Validation Experiments





Eastern Hokkaido, Japan:
Feb. or Mar. in 2001-2005
for MODIS

Barrow, Alaska:
Apr. in 2003
for GLI & MODIS


Spectral BRDF

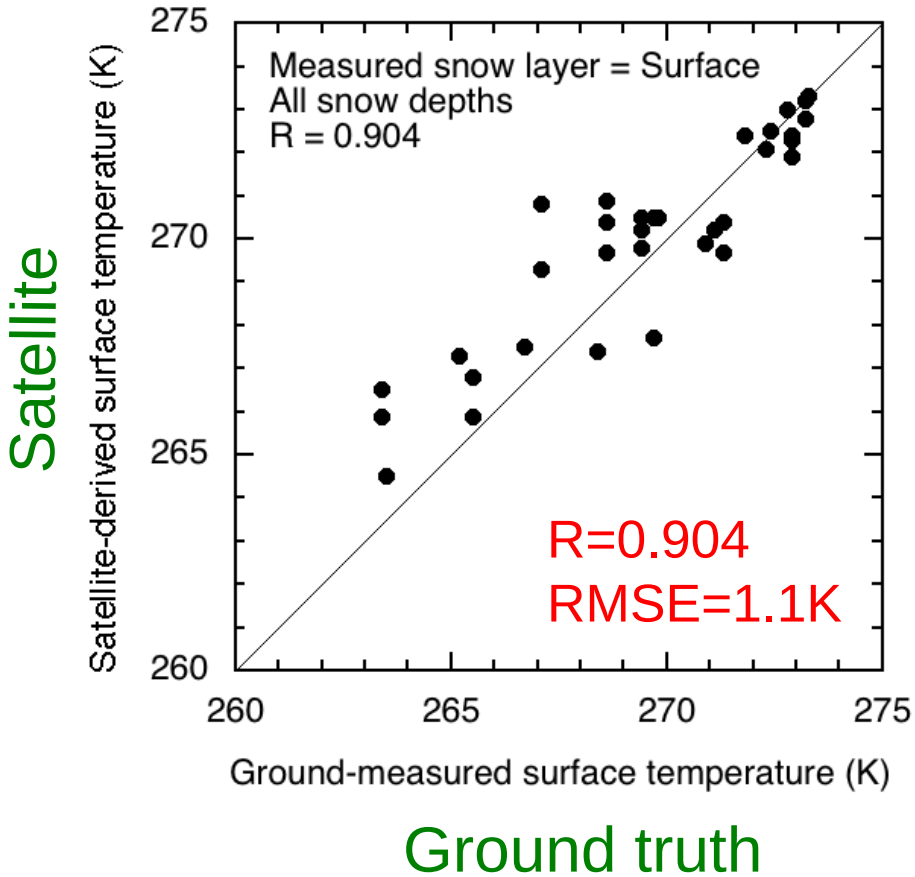

Spectral albedo


FTIR


Snow pit work

Validation of snow surface temperature

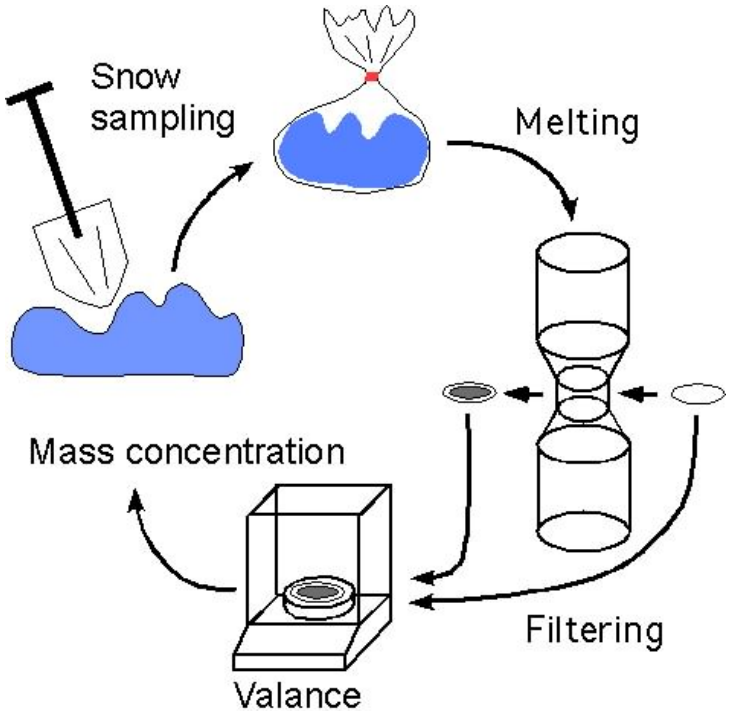
Snow pit work for snow surface temperature in Barrow, Alaska



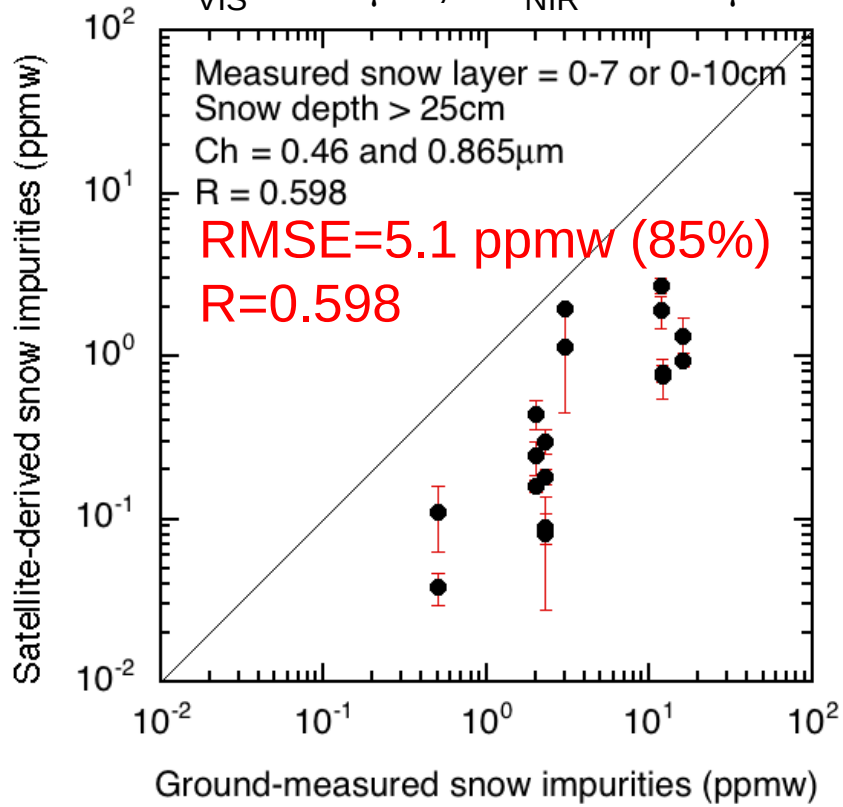
✓Satellite-derived snow surface temperature well agreed with the ground-based measurements with RMSE= 1.1K.

Validation of snow impurities

Ground truth for mass concentration of snow impurities

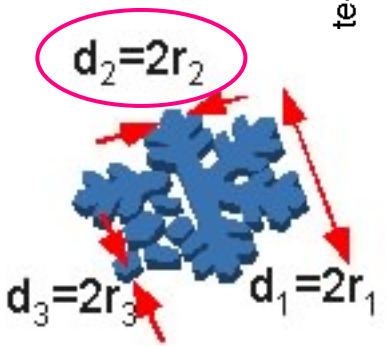


Ch_{VIS}=0.46μm, Ch_{NIR}=0.865μm



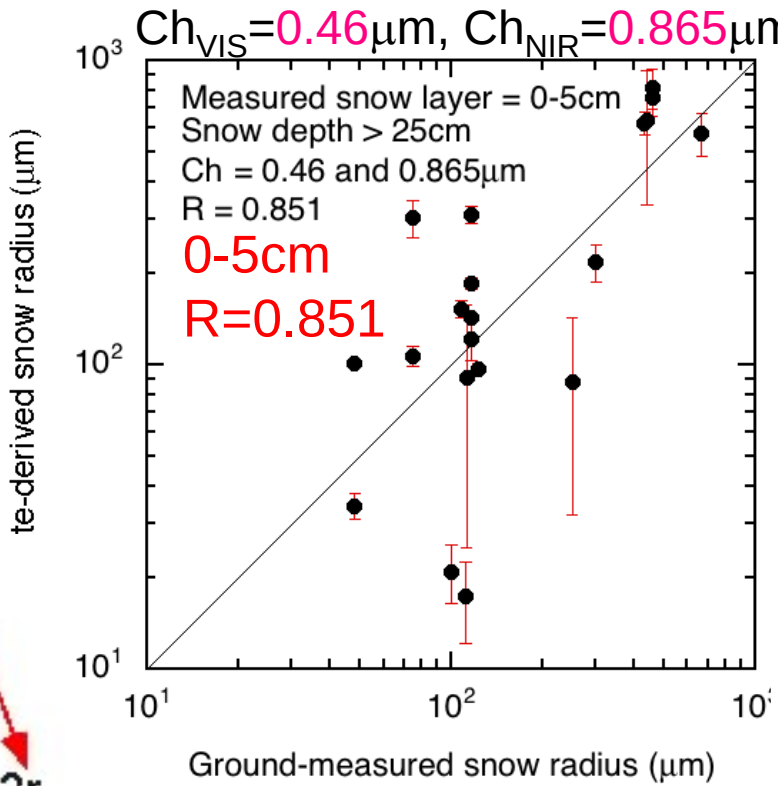
✓Satellite-derived mass concentrations of snow impurities were lower than the ground-based measurements. This is because the snow impurities assumed in the algorithm was soot, whereas the main composition of in situ measured impurities was mineral dust in our sites.

Validation of snow grain sizes

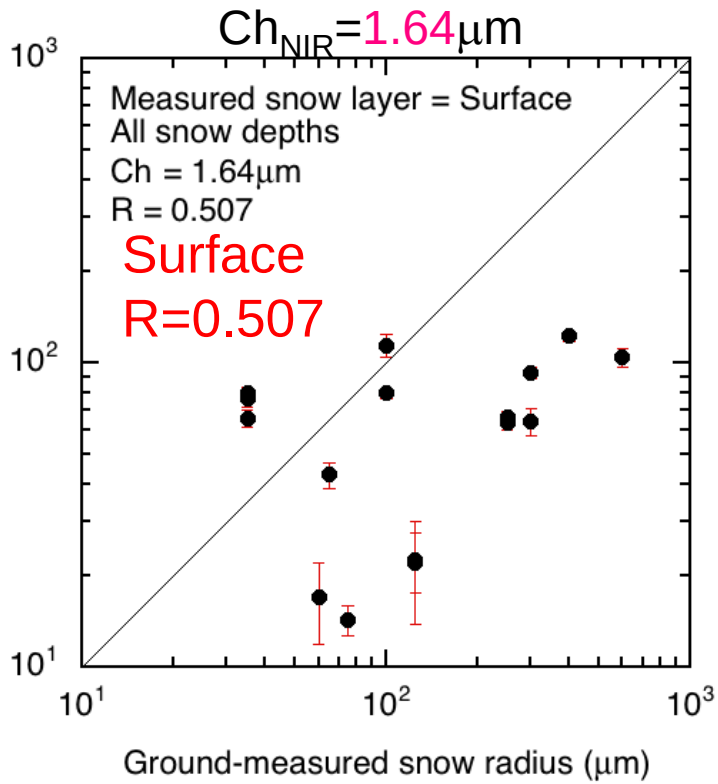


Satellite

Ch_{VIS}=0.46μm, Ch_{NIR}=0.865μm



Ch_{NIR}=1.64μm



Ground truth (r_2=branch width)

✓Retrieved grain size from Ch_{VIS}= 0.46μm and Ch_{NIR}= 0.865μm comparatively agreed with ground truth data.

✓Grain size from Ch_{NIR}=1.64μm was smaller than those from snow pit work, which means measured reflectance at λ=1.64μm is higher than theoretically assumed one in the algorithm.

Sun glitter from sun crust

and some possibilities at λ=1.64μm

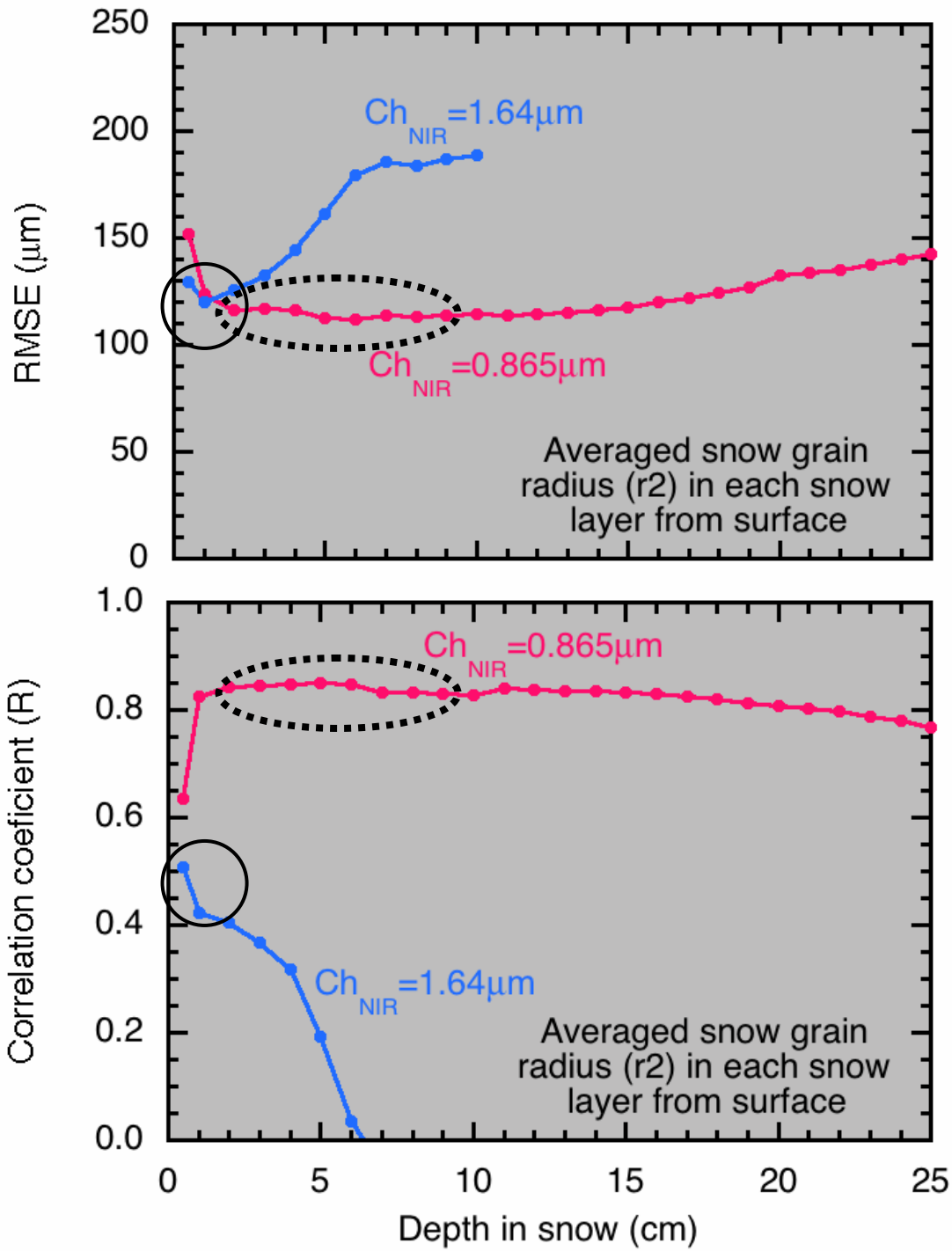
- ✓BRDF
- ✓Sensor calibration
- ✓Validation method

P_V

P_H

Retrieved vertical information of snow grain size

It was confirmed that retrieved snow grain size using 1.64μm-ch. contains the information of shallower snow layer than 0.865μm-ch., where the minimum RMSEs and the highest correlations are observed at surface for 1.64μm and 0-5cm layer for 0.865μm-ch.



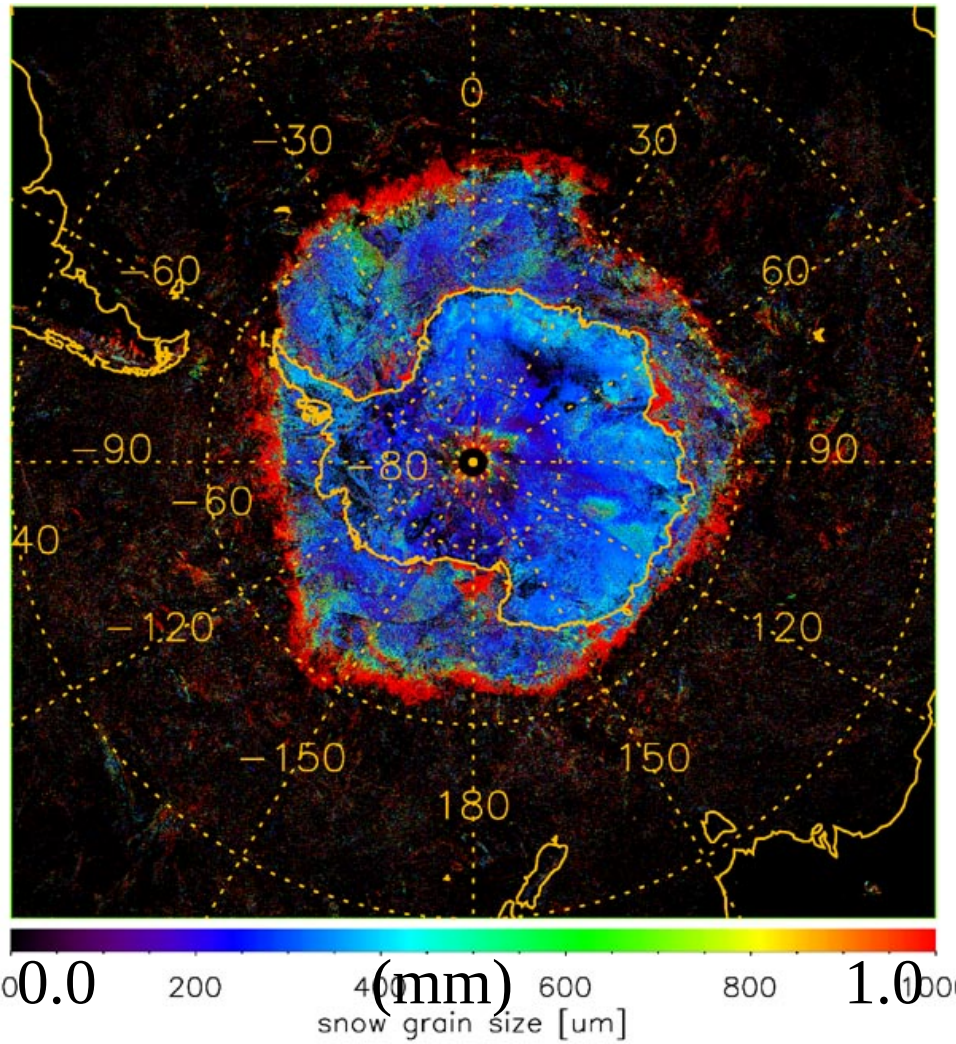
Summary (1)

✓Comparatively good agreements were obtained for satellite derived snow surface temperature and snow grain size using 0.865μm-ch. with in situ measurements.

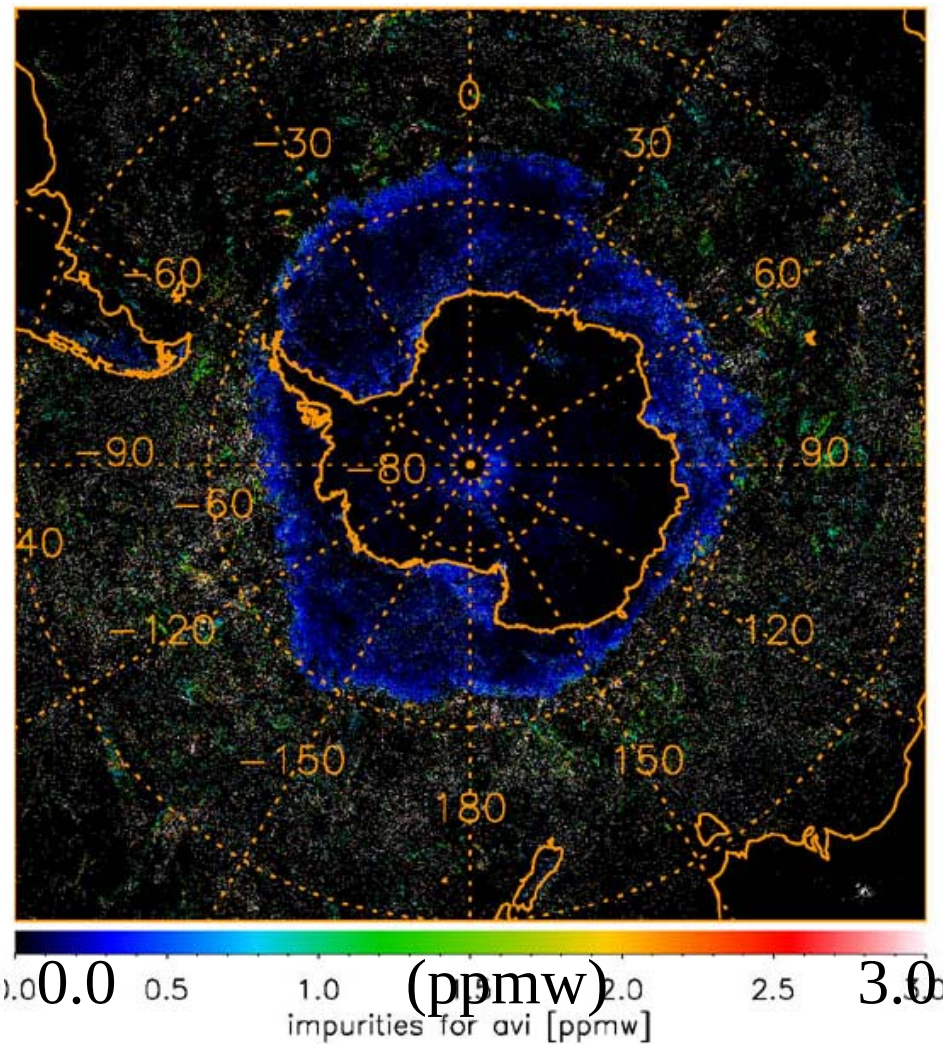
✓Accuracy of mass concentrations of snow impurities and snow grain size from 1.64μm-ch. was insufficient. However, their essential information were successfully retrieved.
-> Need algorithm improvements.

✓Validations are still insufficient for all cryosphere products.
✓-> Need more validations.

Snow grain size and impurities from two-week-data (TERRA/MODIS, Sep.27–Oct.11, 2000)



Snow grain size

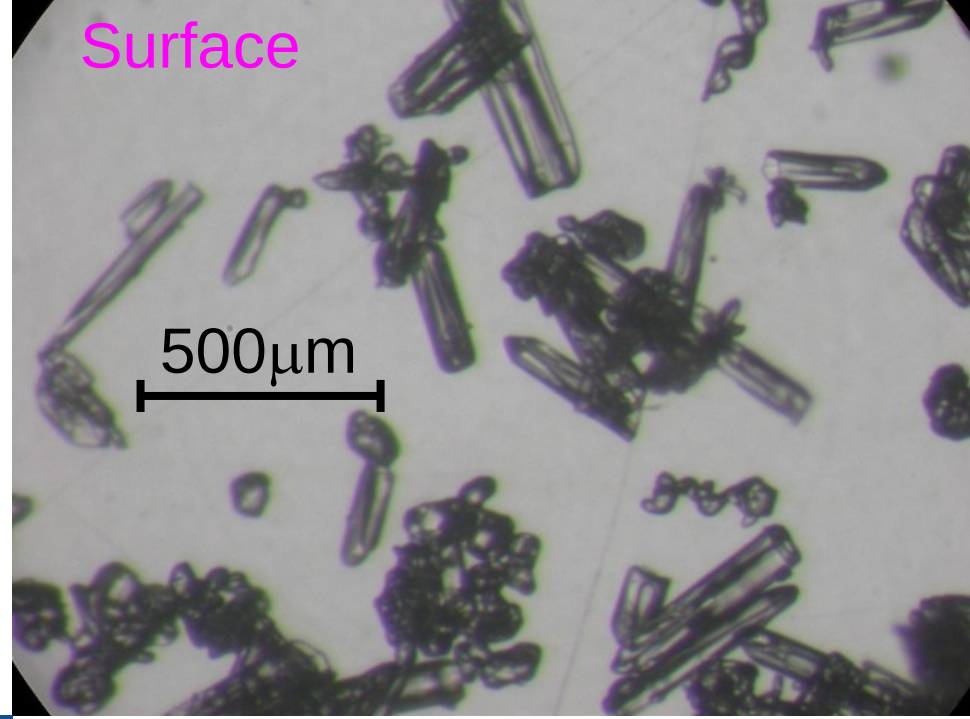


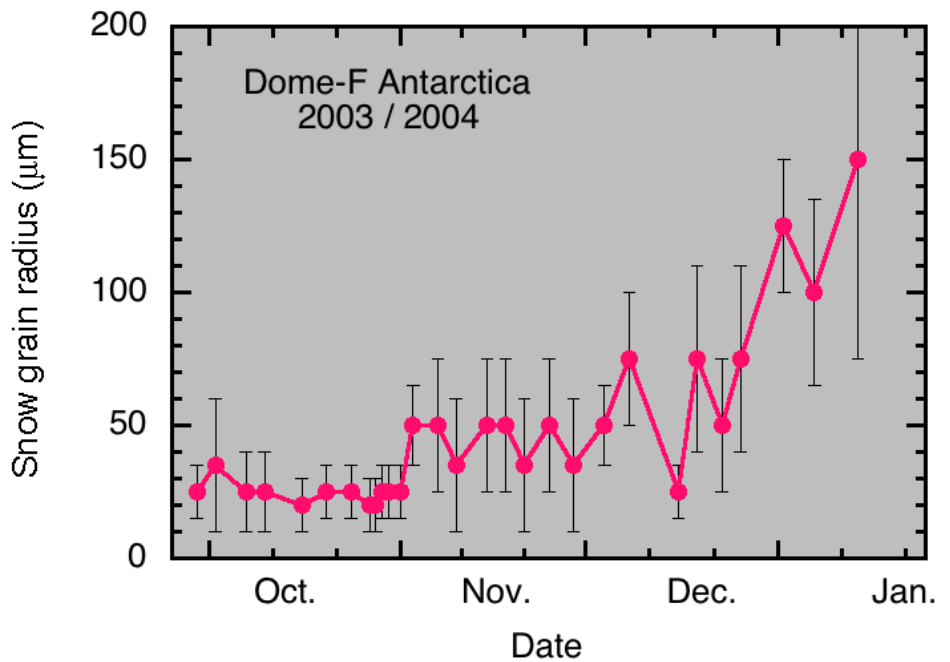
Mass concentration of snow impurities

Snow crystals at Dome-Fuji (77° 19'S, 39° 42'E, 3810m) in Antarctica

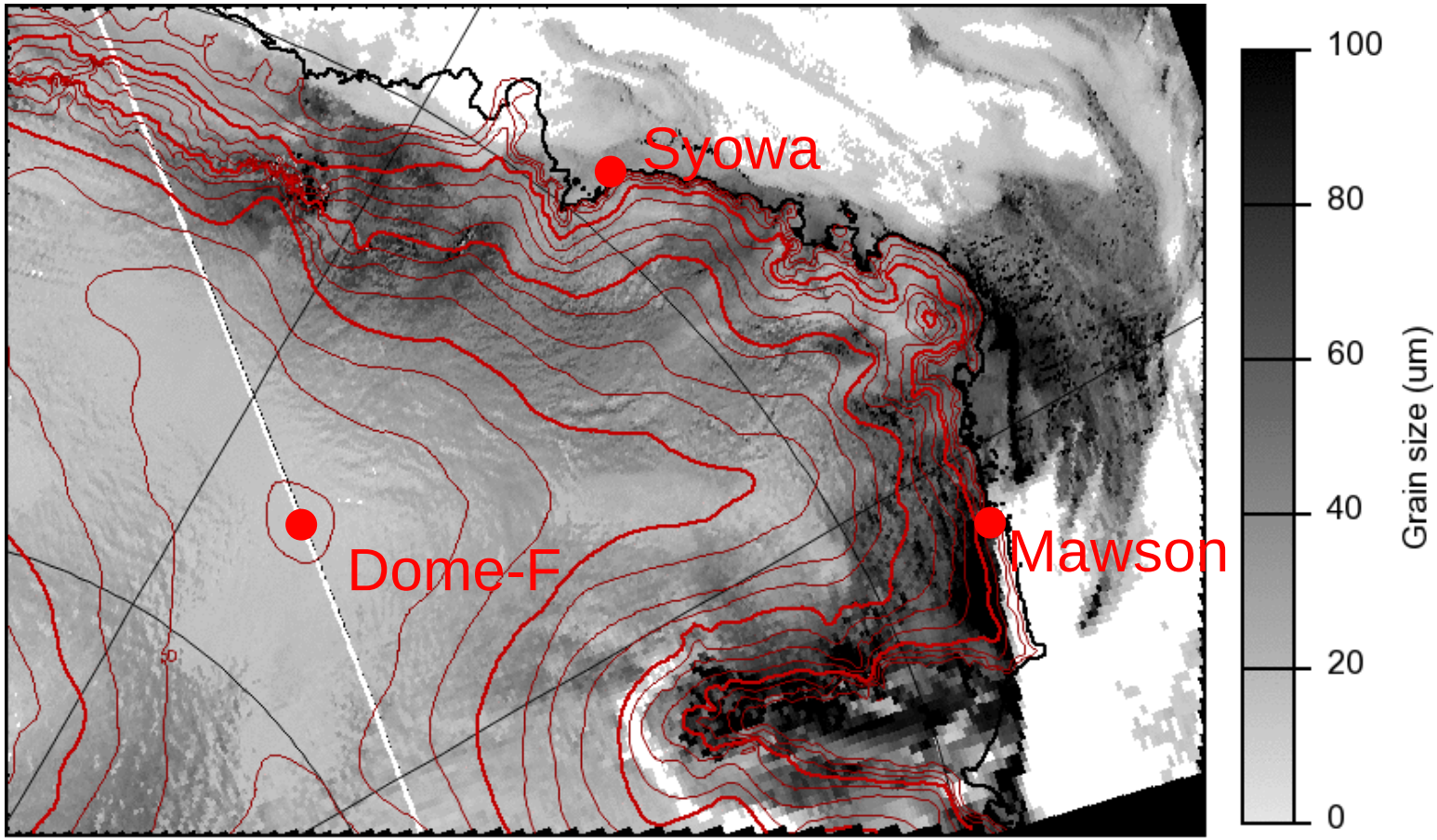
✓Snow pit works with 2-3 times a week from Oct., '03 - Jan., '04.

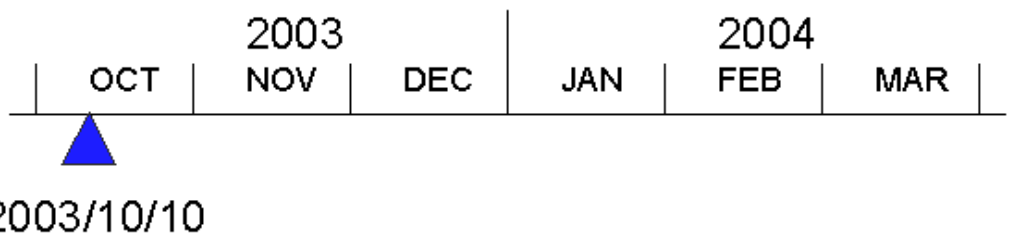
✓Surface snow were covered with diamond dust and the grain size increased in summer.





Satellite retrieved snow grain radius using 1.64μm channel





(Motoyoshi et al. 2006, to be submitted)

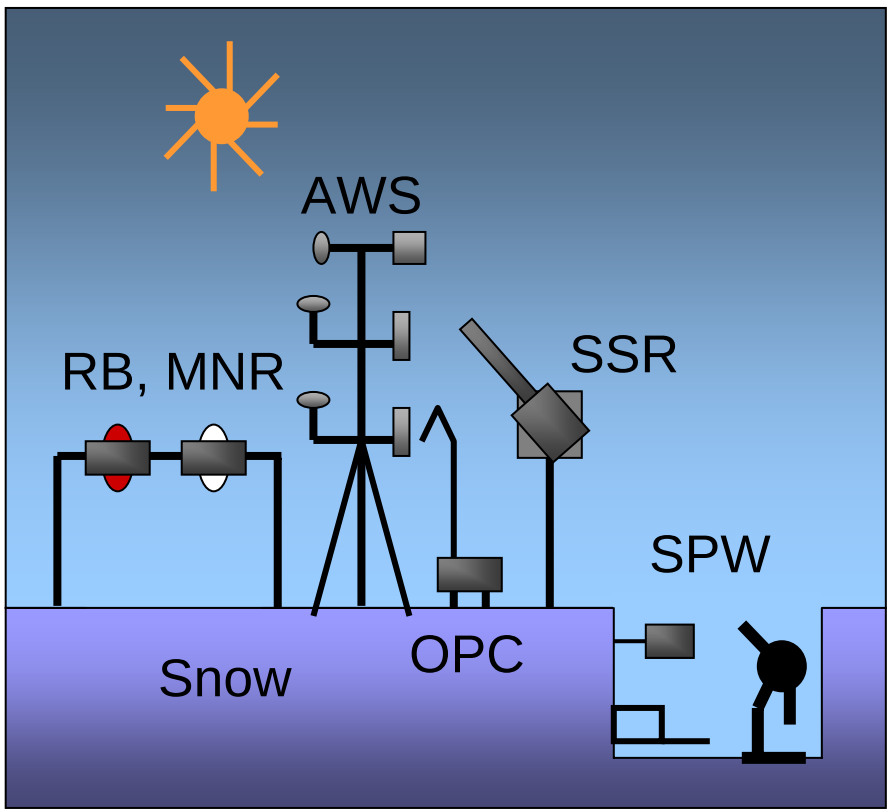
✓Snow grain size was large in summer and over plateau.

➢It would be very sensitive to global warming.

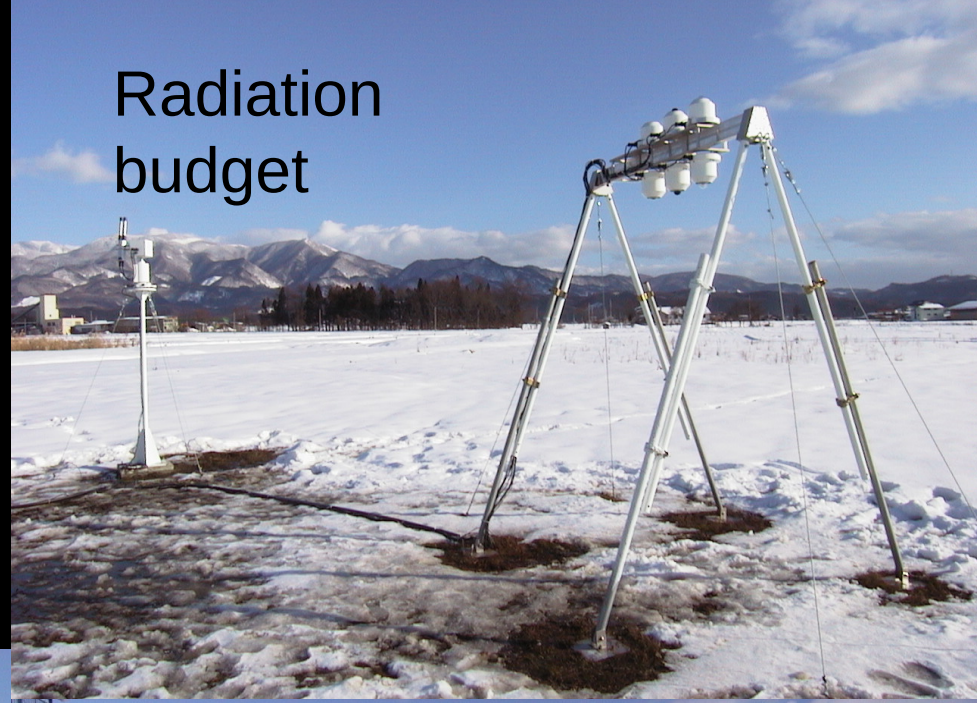
Observations for radiation budget, snow, and aerosols

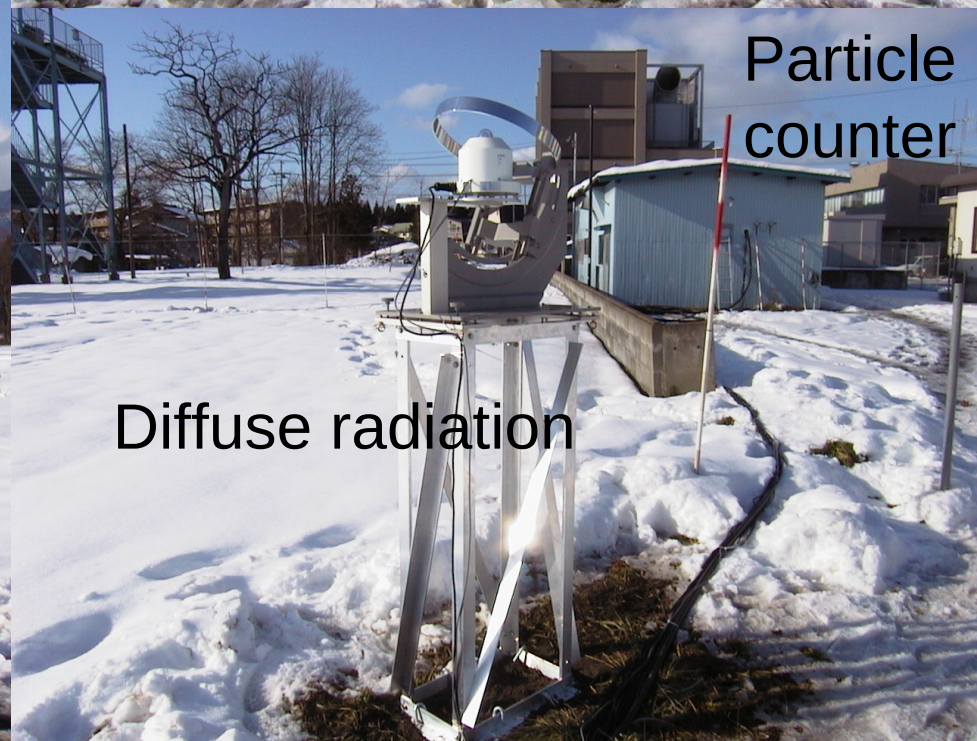
- 1999-2001 at Kitami, Hokkaido
- 2001-2003 at Shinjyo, Yamagata
- 2004-2006 at Sapporo, Hokkaido

RB: Radiation Budget
SPW: Snow Pit Work
MNR: Multi-channel Radiometer
OPC: Optical Particle Counter
SSR: Snow-Sky Radiometer
AWS: Automatic Weather Station

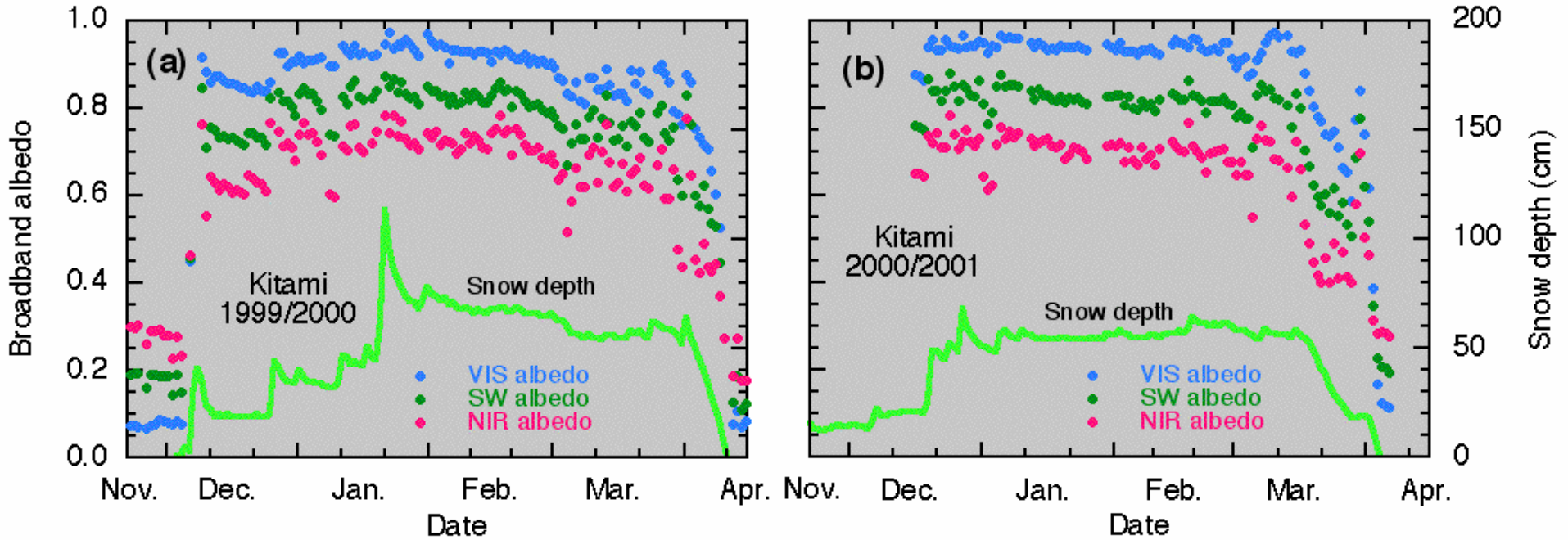


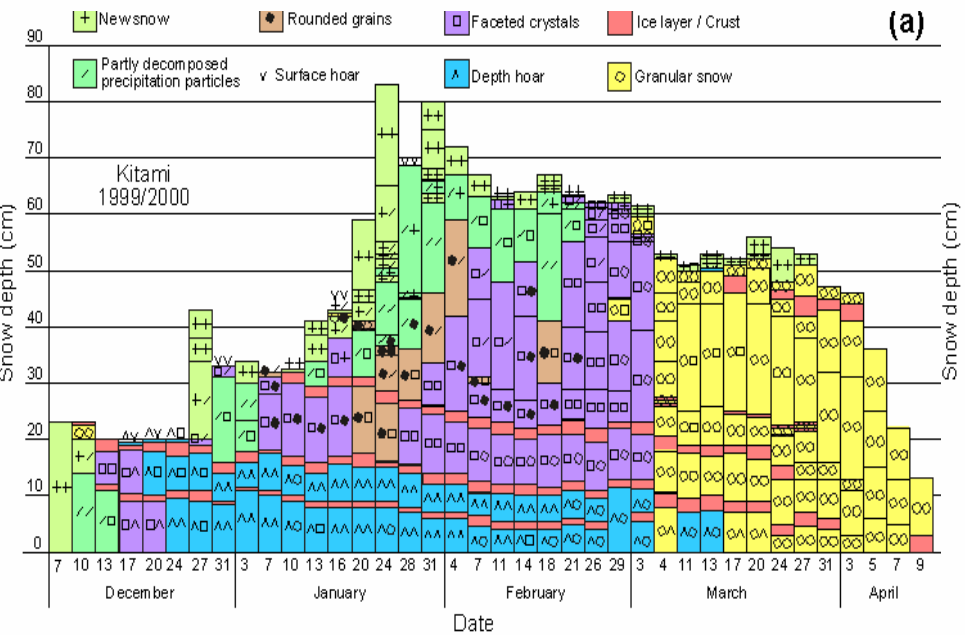
Observations for radiation budget, snow, and aerosols

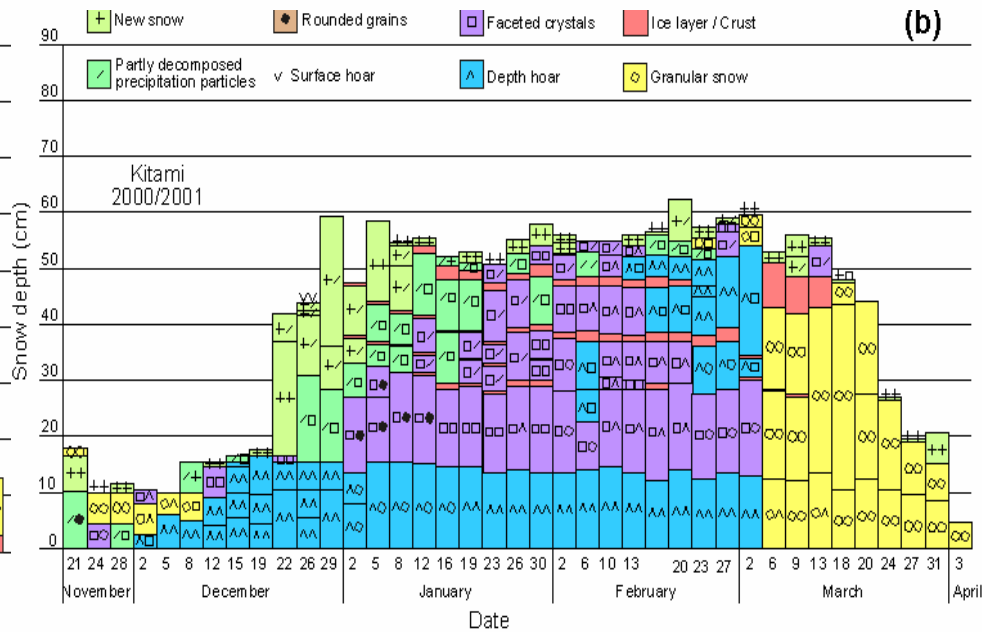




Snow pit work and radiation budget





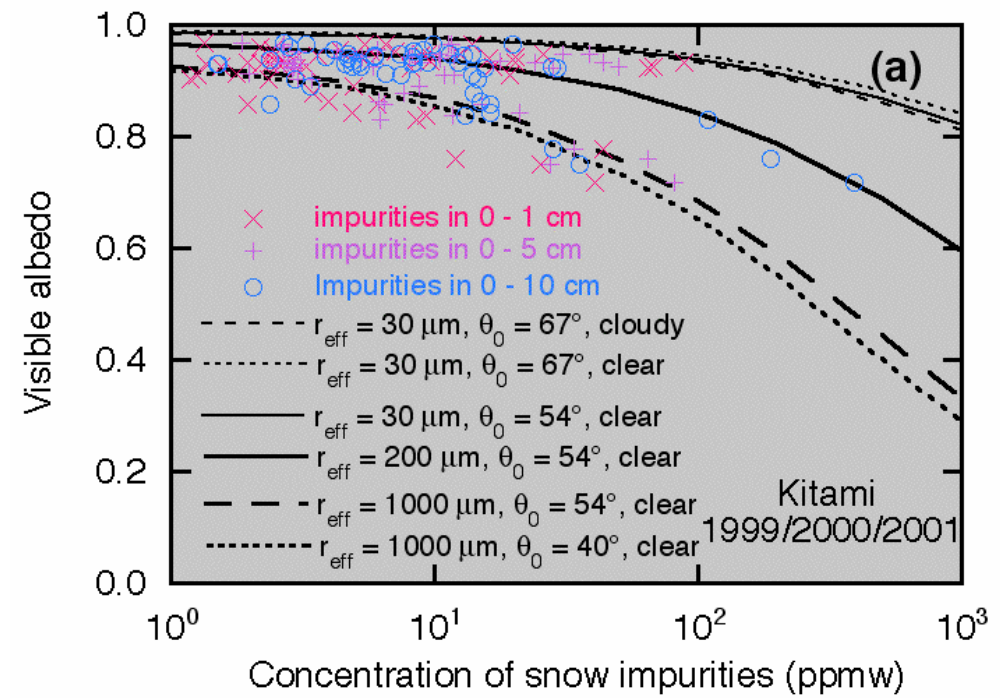


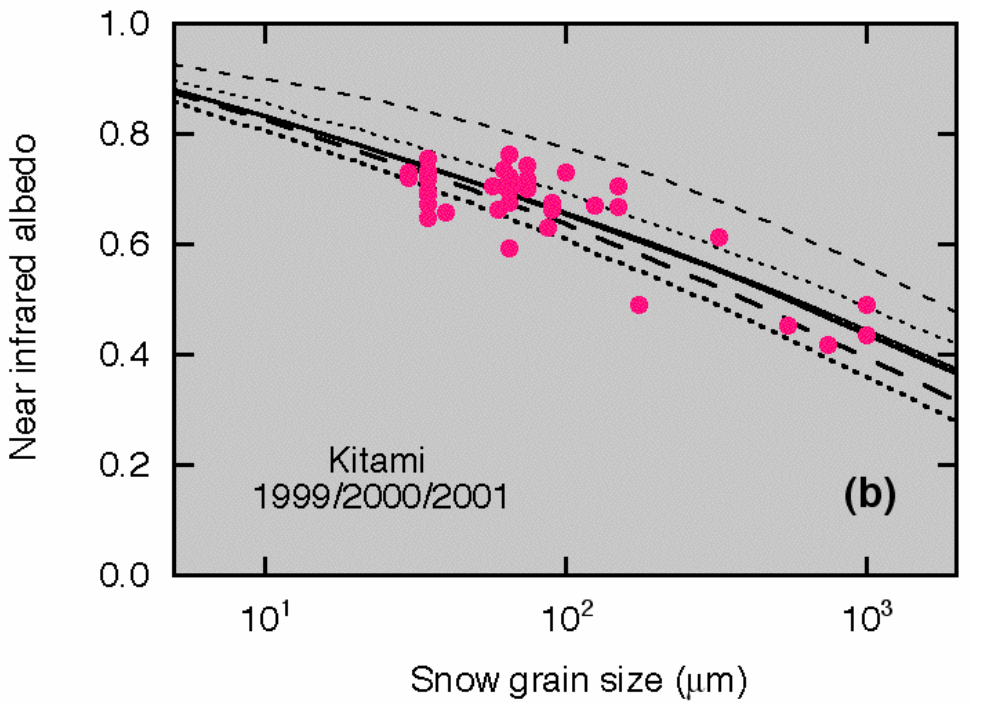
Effects of snow physical parameters on albedo

✓Measured visible and near-infrared albedos fall within theoretically inferred ranges from snow grain size and snow impurities with RTM.

-> These data could be used for validations of empirical snow albedo model of LSM in GCM and/or development of physically-based snow albedo model.

(Aoki et al. 2003, JGR, doi:10.1029/2003JD003506)

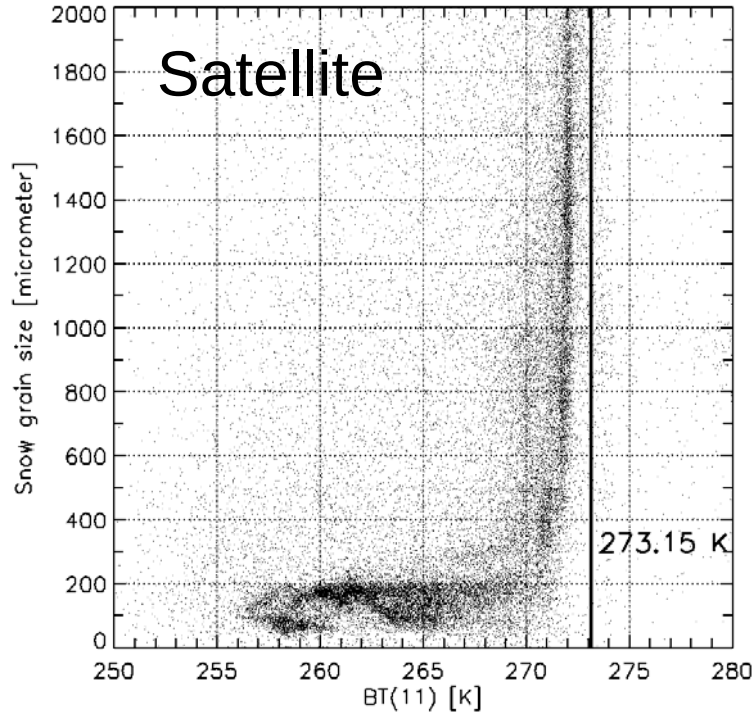


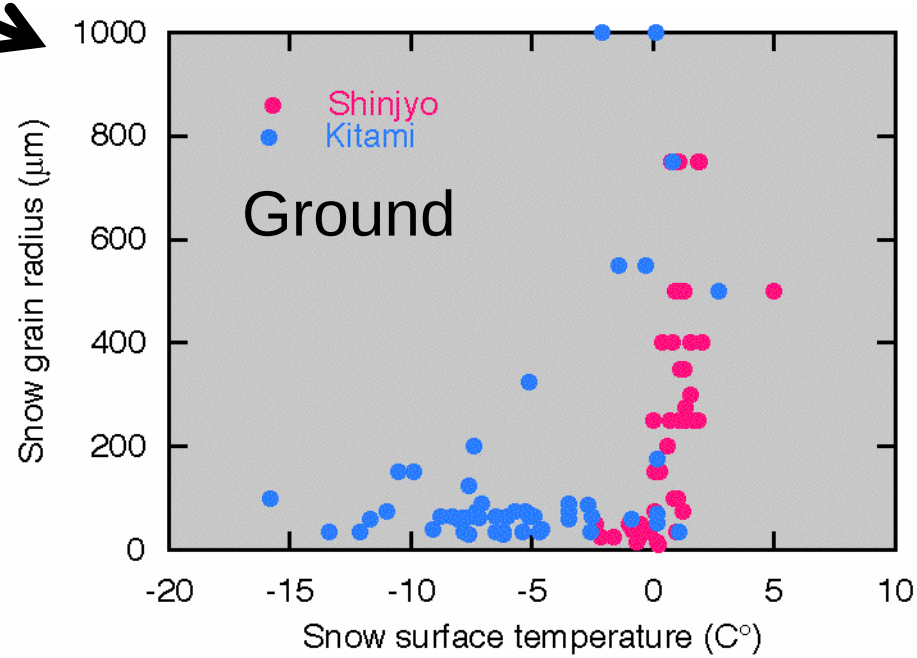


Satellite-retrieved snow parameters and validation data on the ground

- ✓T_s and r_{eff}
- ✓T_s and c_s
- ✓r_{eff} and c_s
- ✓Albedo and r_{eff}
- ✓Albedo and c_s

-> These data also could be used for validations of snow albedo models of LSM in GCM.



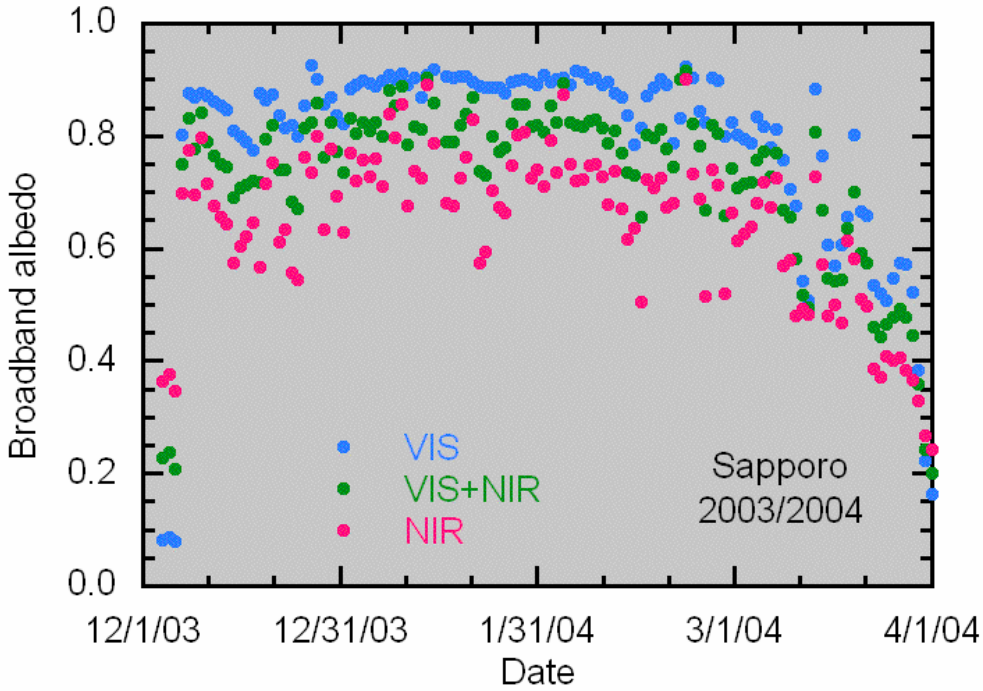


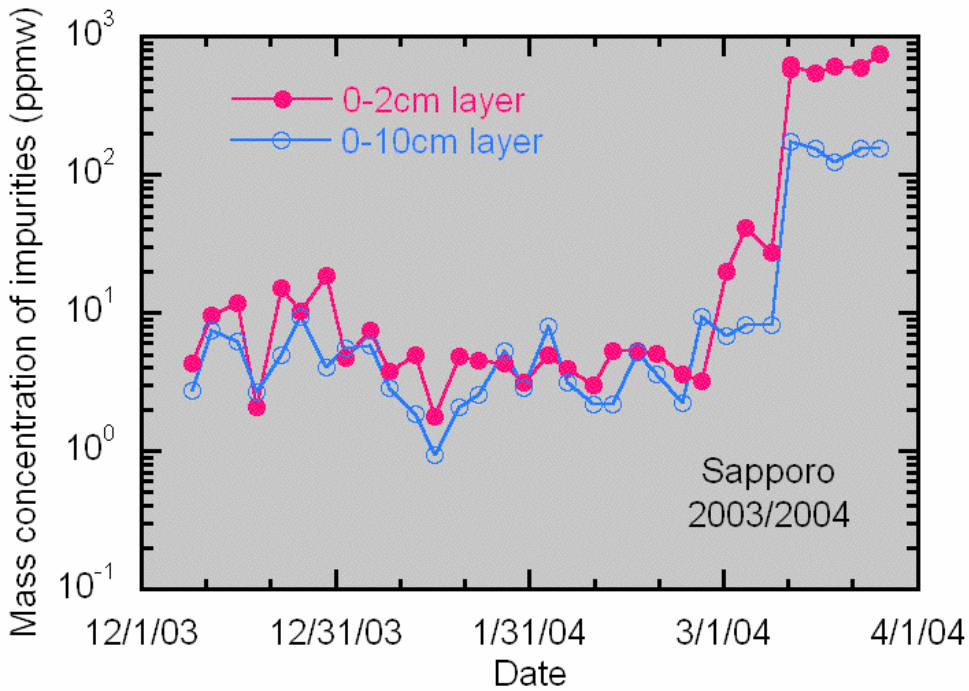
Daily variations of snow impurities and albedo

✓Mass concentration was low in accumulation season and high in melting season.

✓Remarkable albedo reduction was observed at heavy dust event on 11-12 March 2004.

(Aoki et al. 2006, SOLA in press)





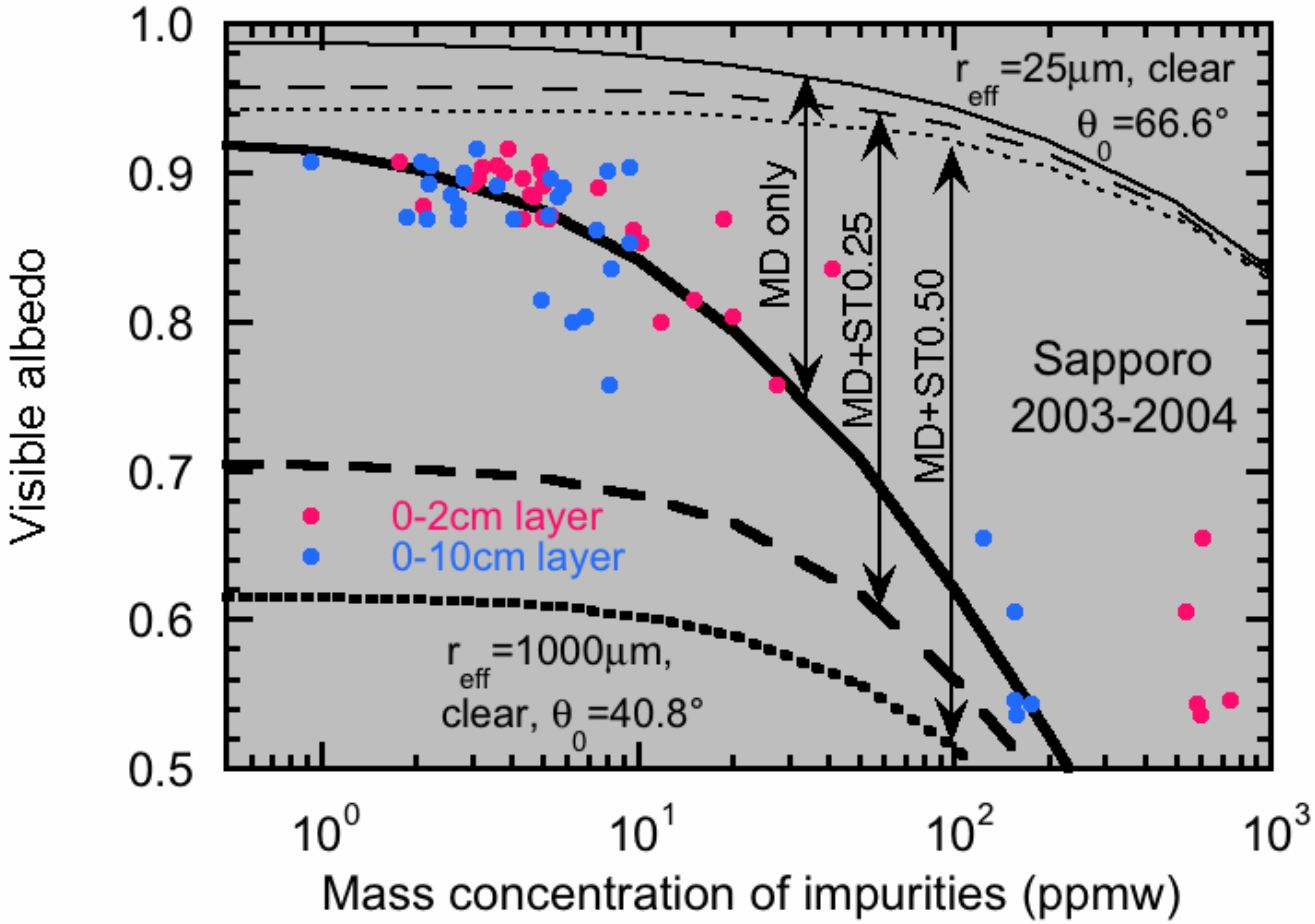
Relationship between snow impurities and visible albedo

Snow RTM model:

✓One snow layer

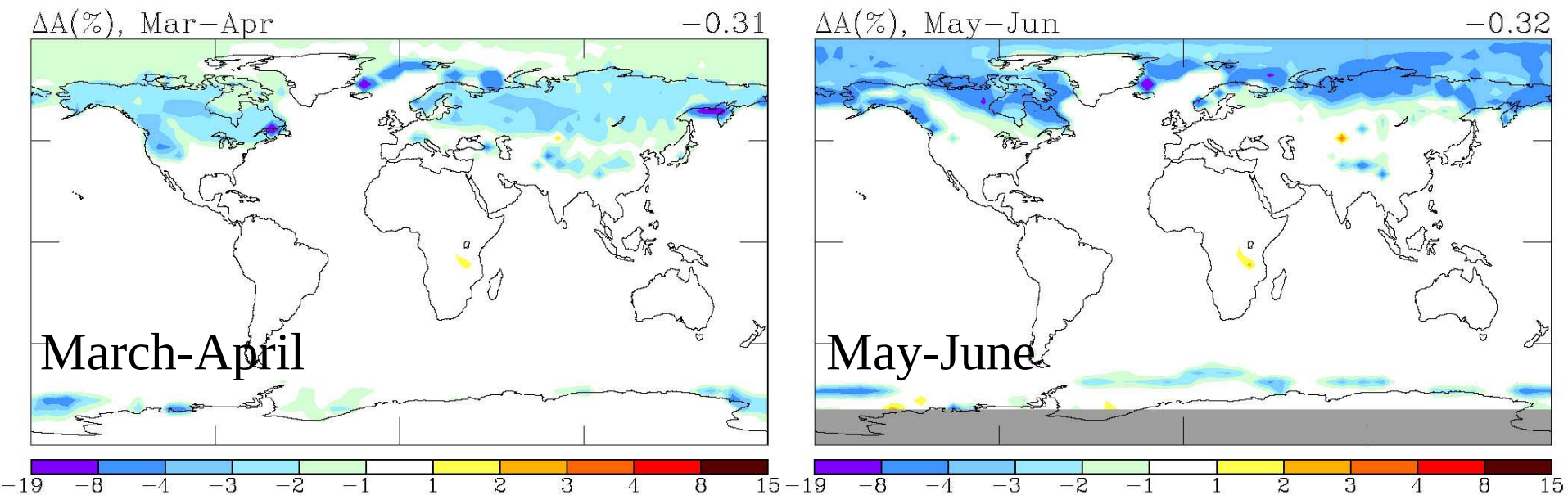
✓Mineral dust mode as snow impurities

✓Several snow grai sizes

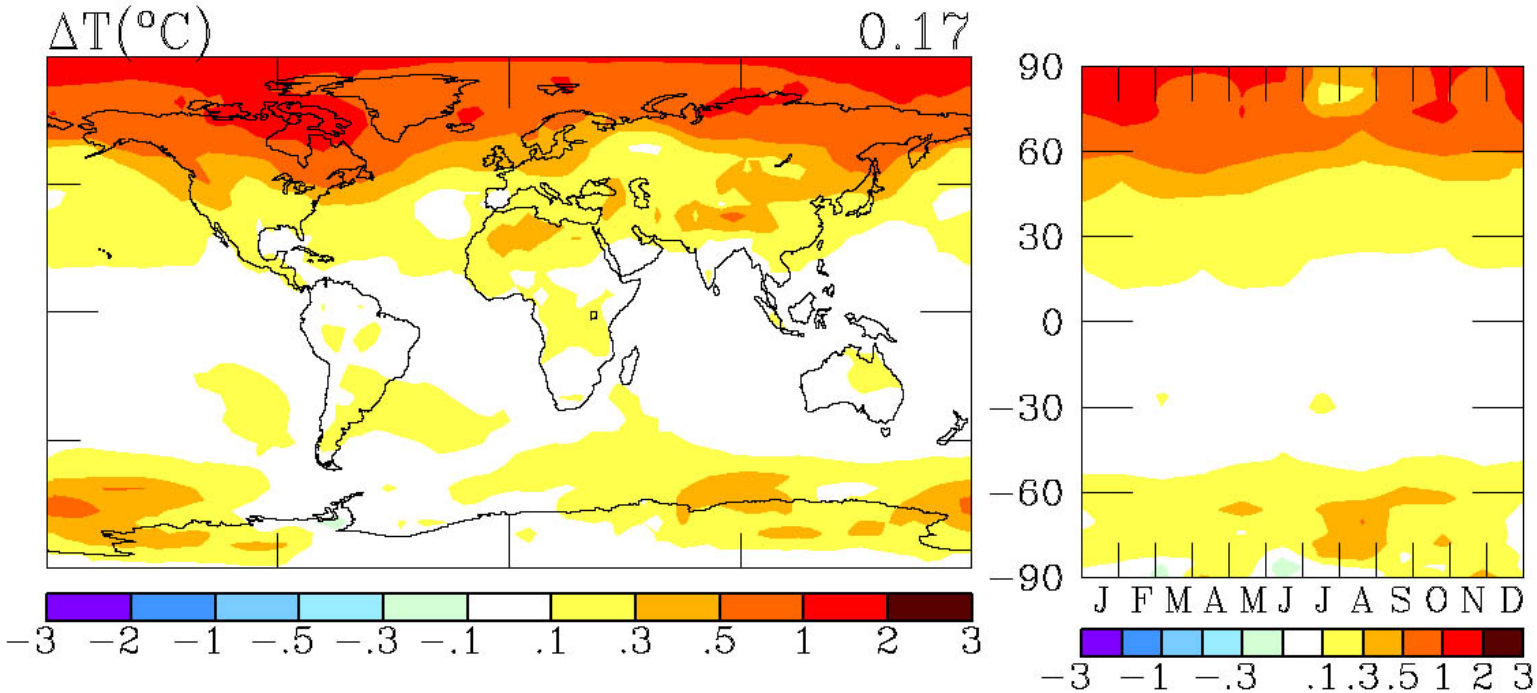


✓Even in accumulation season (high albedo period), measured snow albedos were lower than theoretically calculated one with 'mineral dust (MD) only' model and fall in the range of theoretically calculated one for 'MD+soot (ST) 0.50 ppmw' model.

-> This suggests the snow would be polluted with the absorptive aerosols such as black carbon (soot).



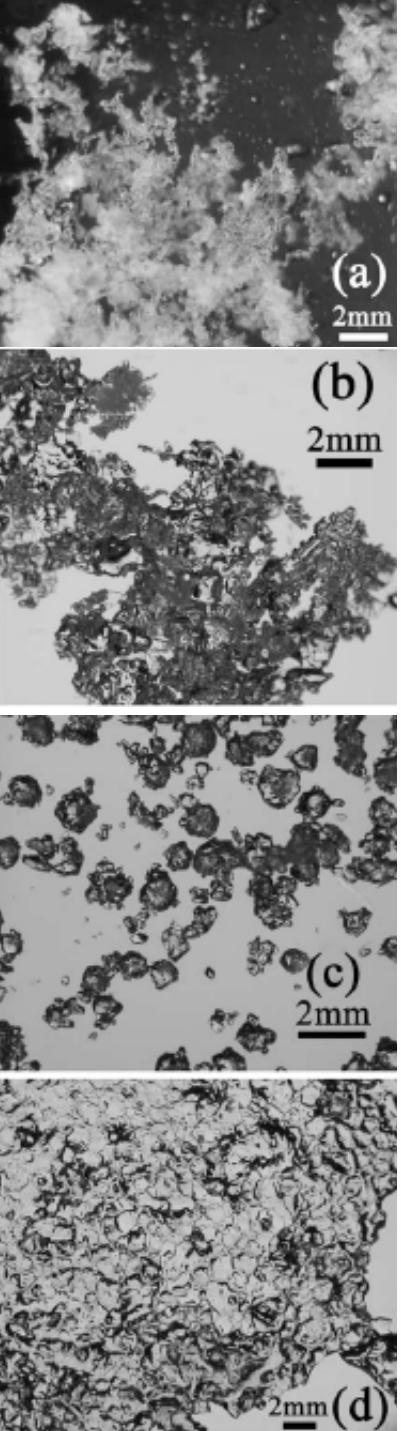
Simulated 1880-2002 snow albedo change due to BC.

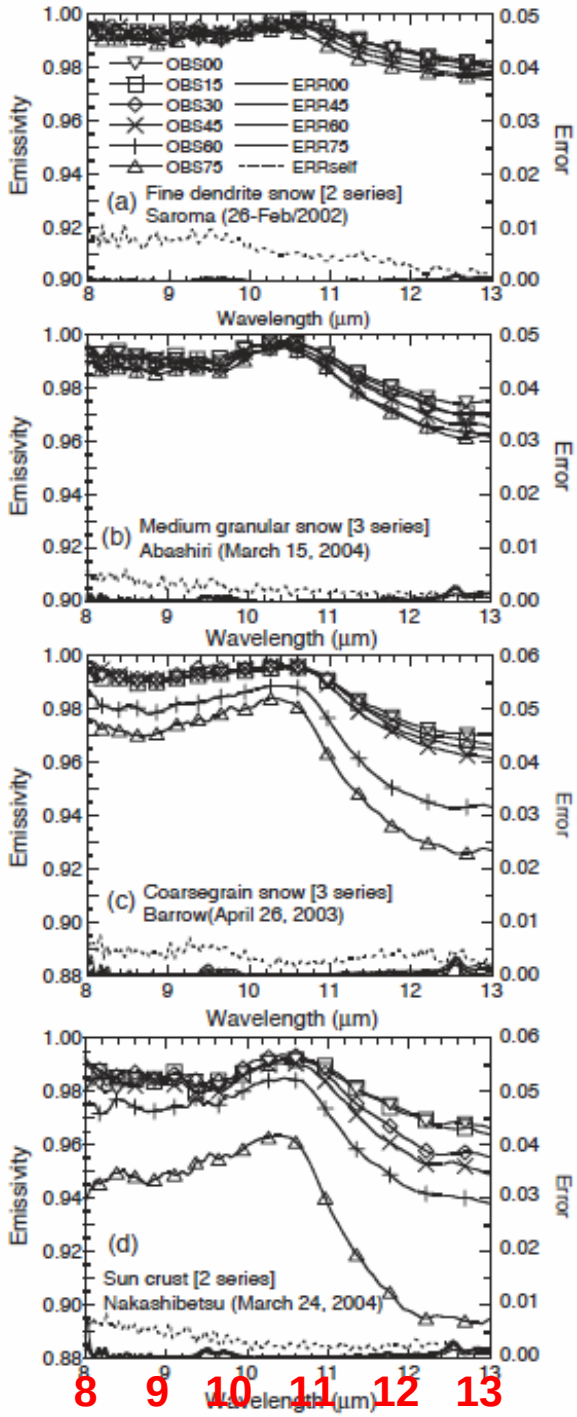


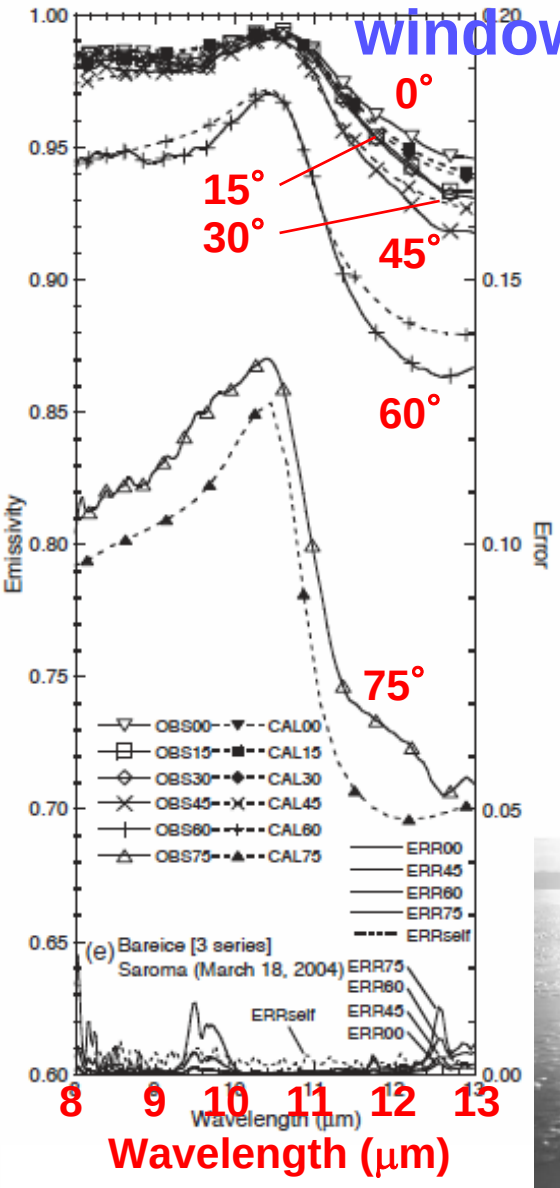
(After Hansen and Nazarenko, 2003)

Simulated 1880-2002 T_s change for the transient BC snow/ice albedo forcing

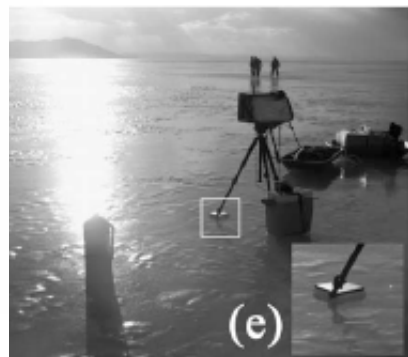
In-situ measured spectral directional emissivity of snow/ice in the atmospheric window







(Hori et al. 2006, RSE in press)



Summary (2)

✓Radiation properties of snow/ice were clarified with validation experiments using radiometers, spectrometers and FTIR.

✓Spatial-time variations of snow grain size in the Antarctic were obtained.

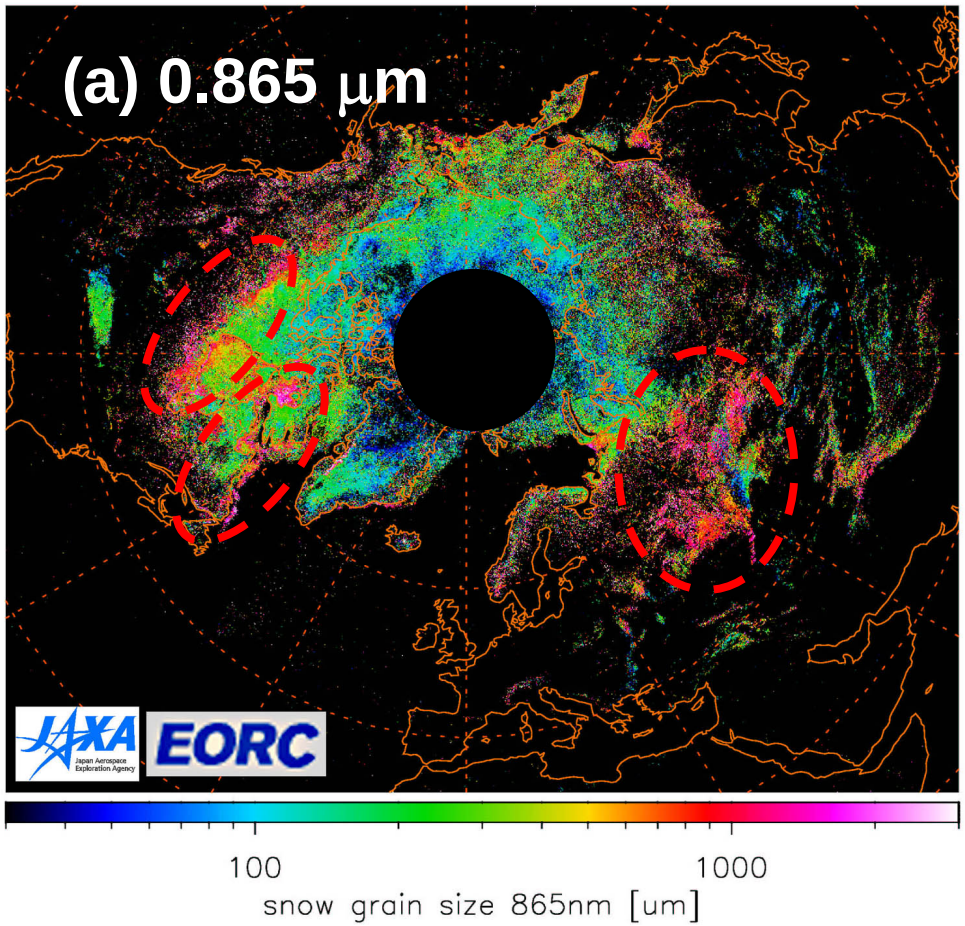
✓Snow contamination with soot was confirmed in Japan.
- > For the northern hemisphere?

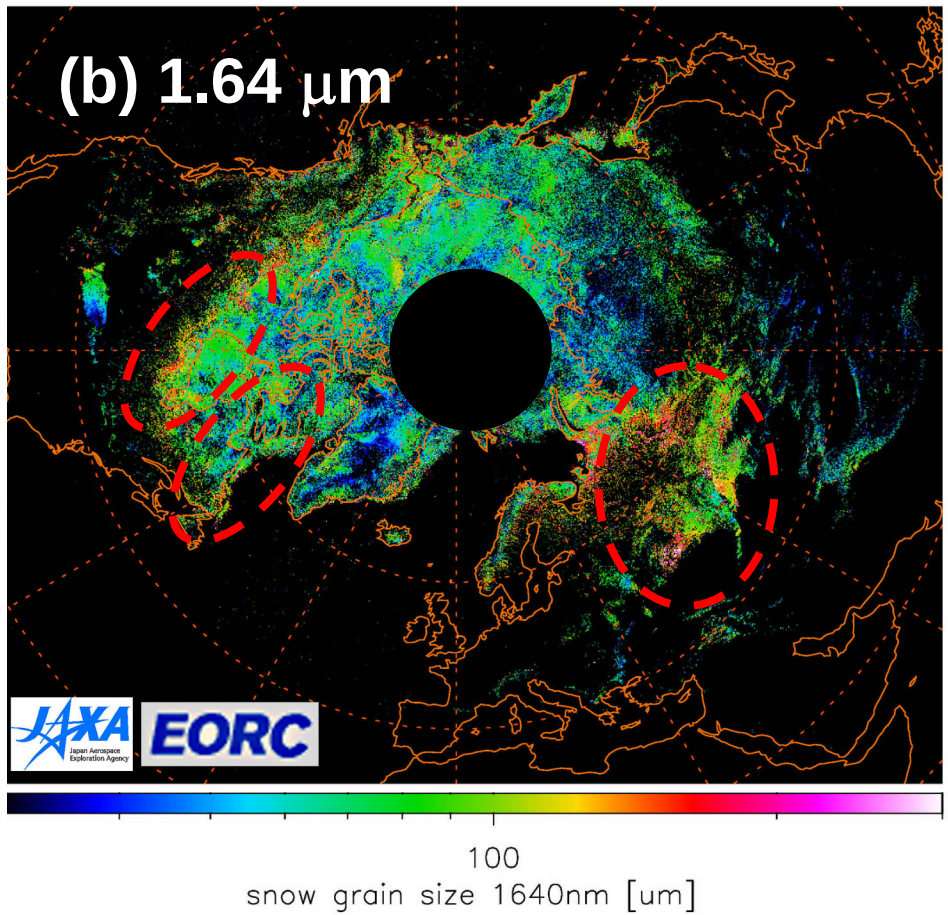
✓Those data could be used for validations of empirical snow albedo model of LSM in GCM and/or development of physically-based snow albedo model.

Snow grain sizes using 0.865- and 1.64μm-channels

✓In melting (wet) snow areas, retrieved snow grain size from 1.64μm is expected to be the same as that by 0.865μm.

✓However, snow grain size by 1.64μm is smaller than 0.865μm.





Snow grain size retrieved ADEOS-II/GLI data in April, 2003 using (a) 0.87μm-channel and (b) 1.64μm-channel.