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15– 19 ноября 2010 г., Москва

Восстановление эффективного размера снежных зерен и загрязнений снега по спутниковым данным в полярных регионах

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DAMOCLES

Integrated Project

Developing Arctic Modelling and Observing Capabilities for Long-term Environment Studies

1 /12/ 2005 -1/06/2010

"Global Change and Ecosystems"

SNOW GRAIN SIZE MAPPING

Dozier and Marks, *1987*	**Landsat Thematic Mapper**
Nolin, *1995*	**AVIRIS, 1.03mkm**
Zege et all, *1997*	***ADEOS/GLI***
Aoki, Stammes *et al, 2003,2007*	***ADEOS/GLI, MODIS***
Zege at all, 2007,2010 (SGSP)	***MODIS***
Kokhanovsky, Tedesko , *2008*	***MODIS***
Lapustin, NASA, 2009	***MODIS***
Kokhanovsky, ESA, 2010	***MERIS***

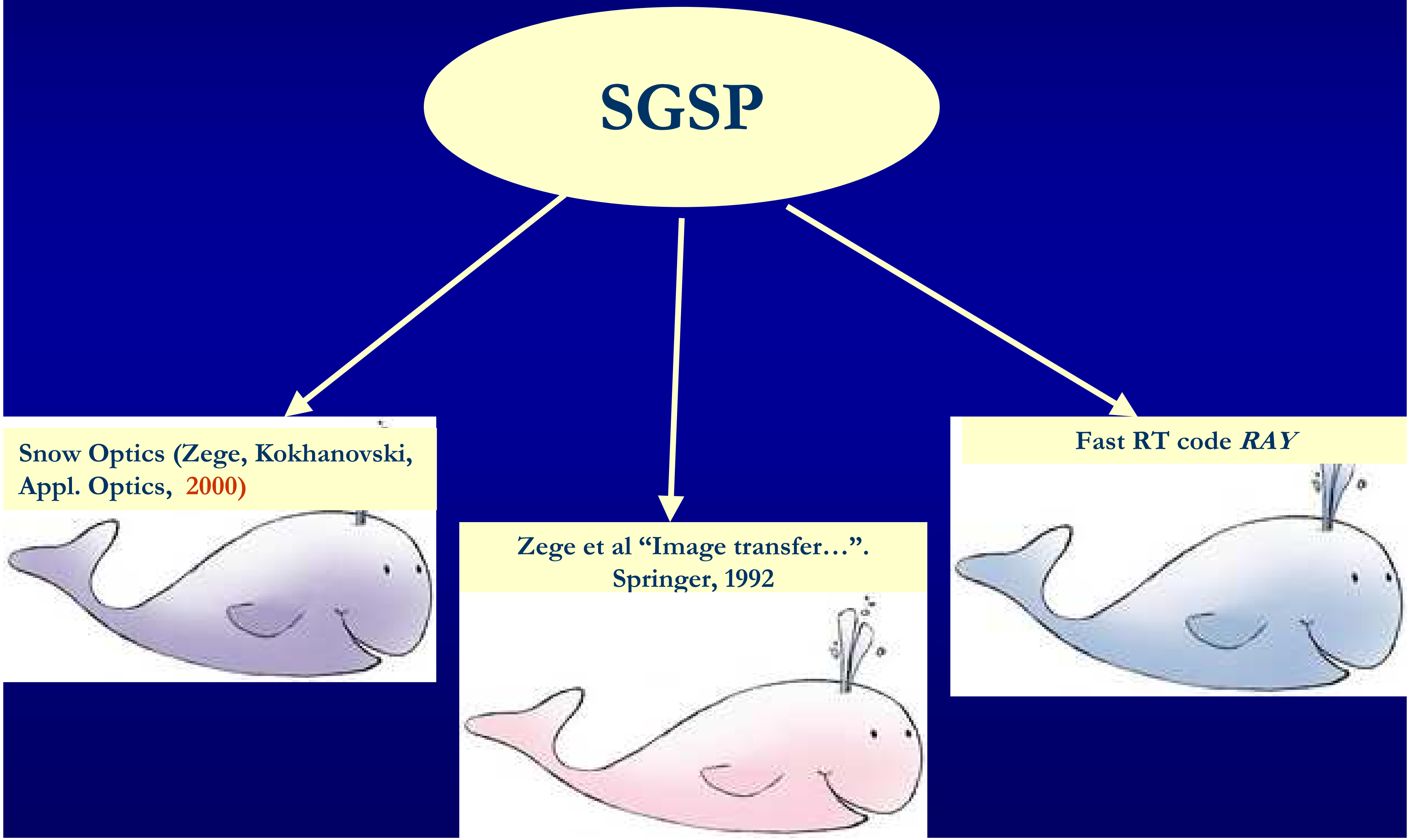
Algorithm to Retrieve Snow Grain Size and Pollutions (SGSP)

Zege E.P.,et all “Algorithm of the effective snow grain size and pollution amount retrieval from satellite measurements”, J. Remote Sensing, in print

Zege E.P., Katsev I.L., Malinka A.V., Prikhach A.S. New algorithm to retrieve the effective snow grain size and pollution amount from satellite data // Annals of Glaciology),2008

Zege E., A. Kokhanovsky, I.Katsev, I.Polonsky, and A. Prikhach. 1998*., M. I. Hovenier, eds._American Meteorological Society, Boston, Mass., 288–290.*

The base of our theory



Basic formulas of SGSP

Asymphthotic Solution */Zege.Katsev, Ivanov, Springer, 1993/*

$$R_i(\theta,\theta_0,\varphi) = R_0(\theta,\theta_0,\varphi)\exp\left[-y_i \frac{g(\theta)g(\theta_0)}{R_0(\theta,\theta_0,\varphi)}\right]$$

Do not depend on the absorption and grain size

$$y_i = A\sqrt{\frac{4\pi}{\lambda_i}\left(\chi_i + \kappa C_{st}^*\right)}\sqrt{a_{ef}}$$

Unknown values

effective size → a_{ef}

soot concentration → C_{st}^*

R_0

R_i reflection (BRDF) of snow layer at the wavelength λ_i

$A = 5.8$ varies within 10% dependently on grain shape

Basic formula of SGSP

Thus:

$$R_i = f\left(R_0, a_{ef}, C^*_{st}; \lambda_i\right)$$

THE IMAGYNARY PART OF THE SNOW REFRACTIVE INDEX IN THE SPECTRAL MODIS CHANNELS USED

MODIS channel	λ, [μm]	$\Delta\lambda$, [nm]	χ
3	0.469	20	$1.88\ 10^{-10}$
2	0.8585	35	$2.10\ 10^{-7}$
5	1.240	20	$1.22\ 10^{-5}$

Atmospheric correction

X={R_0, C_s, a_{eff}} is the solution of the equation:

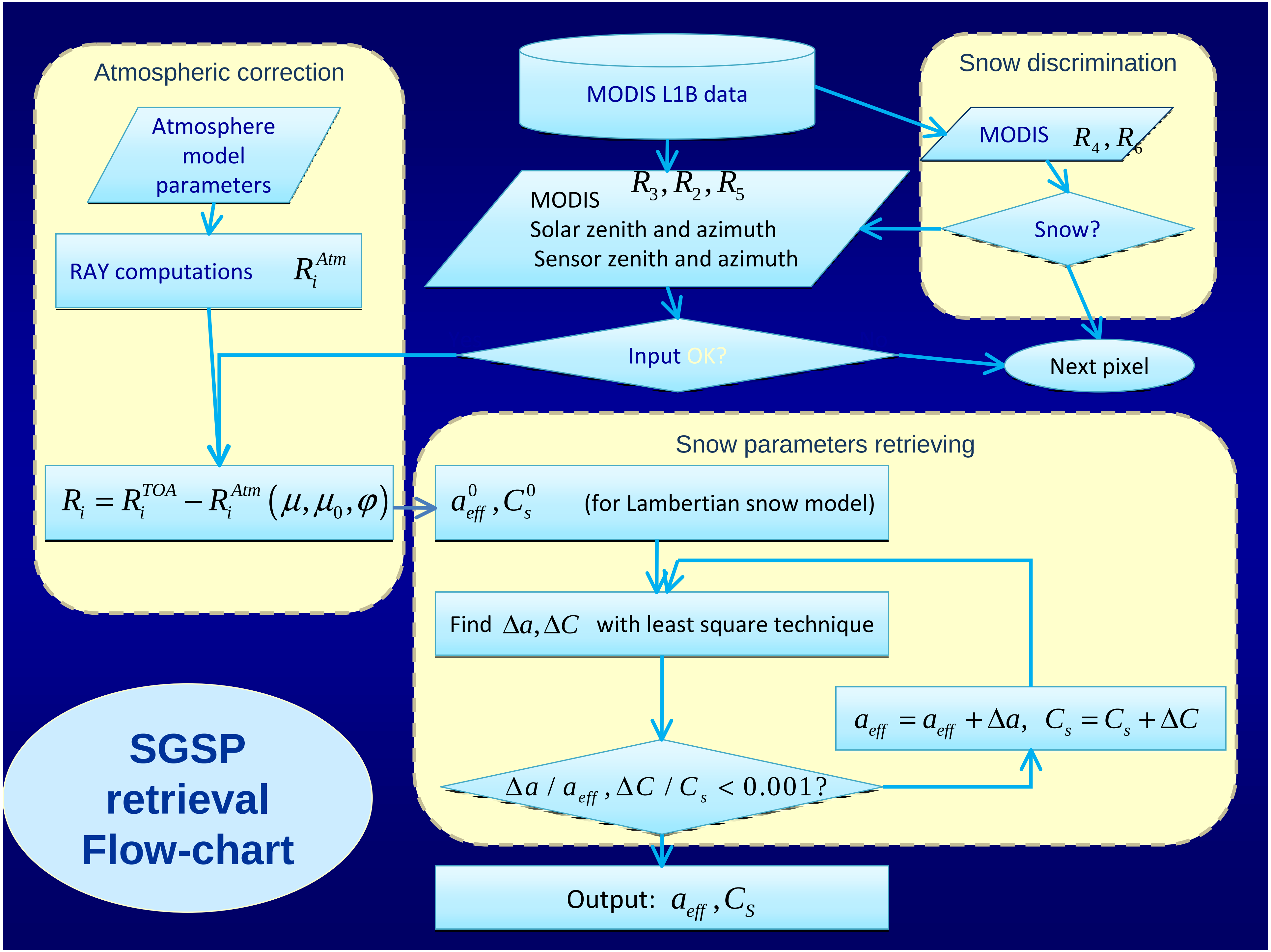
$$R_i^{TOA} = R_i^{Atm} + t_i^0(\mu)t_i^0(\mu_0)\left(R_0 e^{-y_i \frac{g(\mu)g(\mu_0)}{R_0}} - e^{-y_i} \right) + \frac{T_i(\mu)T_i(\mu_0)e^{-y_i}}{1 - r^{Atm}\, e^{-y_i}}$$

with $y_i = 5.8\sqrt{\frac{4\pi}{\lambda_i}(\chi_i + 0.2C_s)\, a_{eff}}$

The zero iteration of X – solution of the equation with the assumption that snow layer reflection is isotropic (Lambertian):

$$R_i^{TOA} = R_i^{Atm} + \frac{T_i(\mu)T_i(\mu_0)e^{-y_i}}{1 - r^{Atm}\, e^{-y_i}}$$

Iterations of X: $\Delta X = \left(\frac{\partial R_i^{TOA}}{\partial X_j} \right)^{-1} \Delta R_i^{TOA}$ until $\Delta X < 10^{-3}$ (usually, 5-6 iterations)


Atmospheric correction
Atmosphere model parameters
RAY computations R_i^{Atm}
$R_i = R_i^{TOA} - R_i^{Atm}(\mu, \mu_0, \varphi)$
MODIS L1B data
MODIS R_3, R_2, R_5
Solar zenith and azimuth
Sensor zenith and azimuth
Input OK?
Snow discrimination
MODIS R_4, R_6
Snow?
Next pixel
Snow parameters retrieving
a_{eff}^0, C_s^0 (for Lambertian snow model)
Find $\Delta a, \Delta C$ with least square technique
$a_{eff} = a_{eff} + \Delta a, \ C_s = C_s + \Delta C$
$\Delta a / a_{eff}, \Delta C / C_s < 0.001?$
Output: a_{eff}, C_S
SGSP retrieval Flow-chart

Verification of the SGSP with computer simulation

- Computation of the radiances in MODIS channels from snow or snow-atmosphere system with RAY code;
- Addition of random noise
- Inversion with SGSP algorithm

Snow reflectance simulator

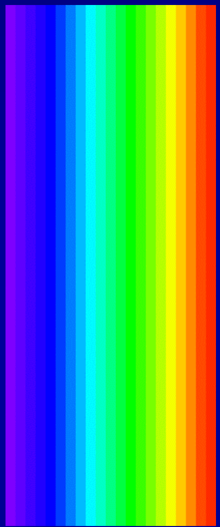
Simulates the response of atmosphere-snow system at satellite receiver channels with RT fast and accurate RAY-code,
includes data banks on

- *optical parameters of atmospheric aerosols,*
- *profiles of atmospheric pressure and temperature,*
- *profiles of ozone and water vapor in atmosphere*
- *optical models of snow (different shapes of particles)*

- *allows to user to build detail optical model of Arctic atmosphere, create optical model of stratified snow with layers of different microphysical and optical properties*

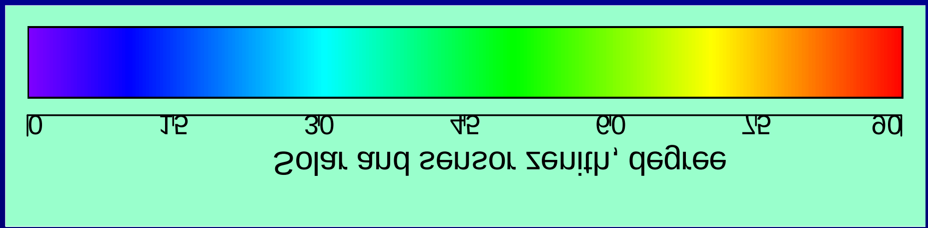
0.0, 2.5, 5.0, 7.5, 10.0, 15.0, 20.0, 25.0, 30.0, 35.0, 40.0, 45.0, 50.0, 55.0, 60.0, 65.0, 70.0, 75.0, 80.0, 85.0, 87.5

Solar zenith - 21 values



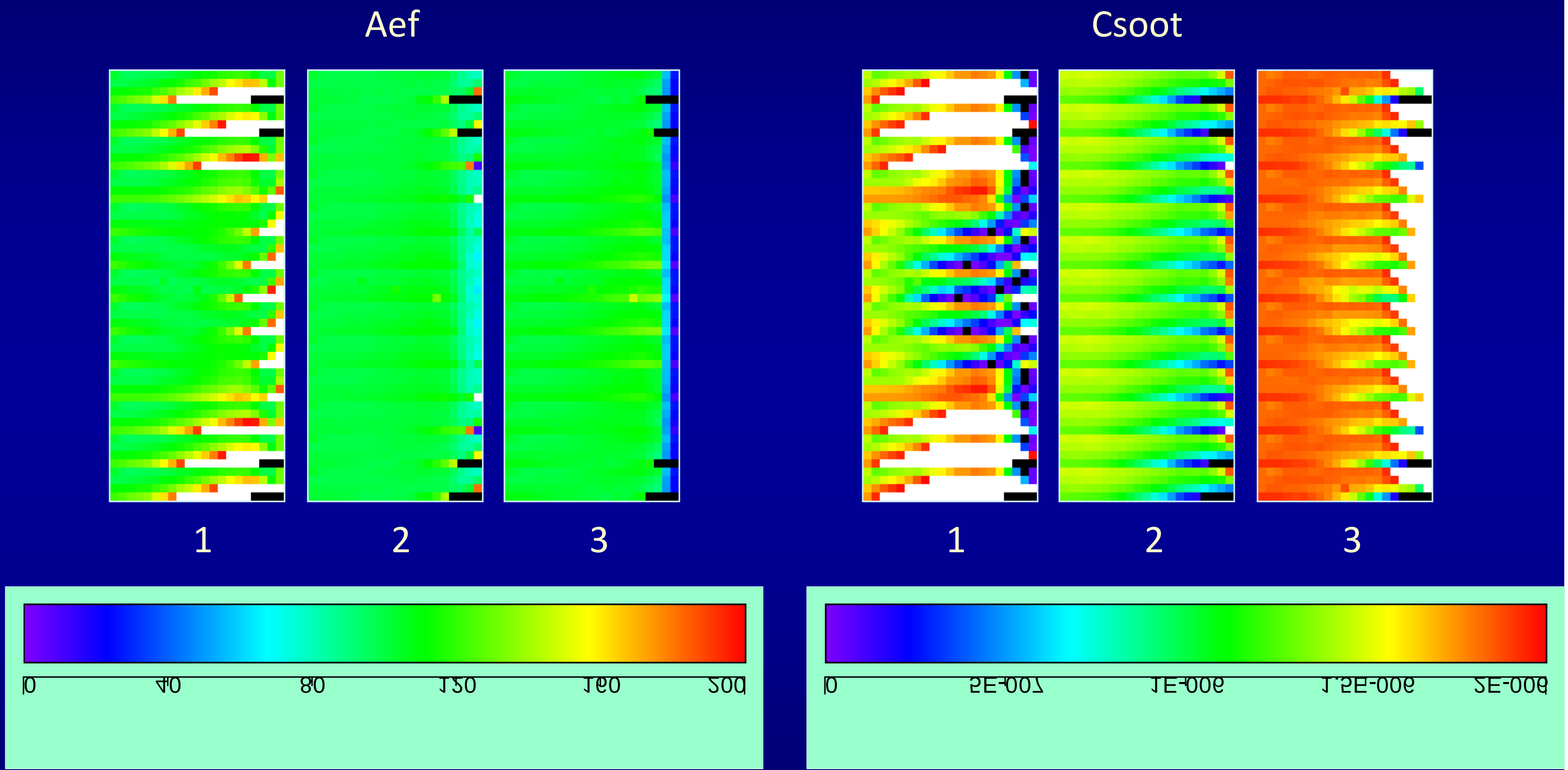
Sensor zenith – 4 values

0.0
20.0
40.0
65.0



Azimuth angles – 13 value: -180.0, -150.0, -120.0, -90.0, -60.0, -30.0, 0.0, 30.0, 60.0, 90.0, 120.0, 50.0, 180.0

mix_100_s-6_aHaze

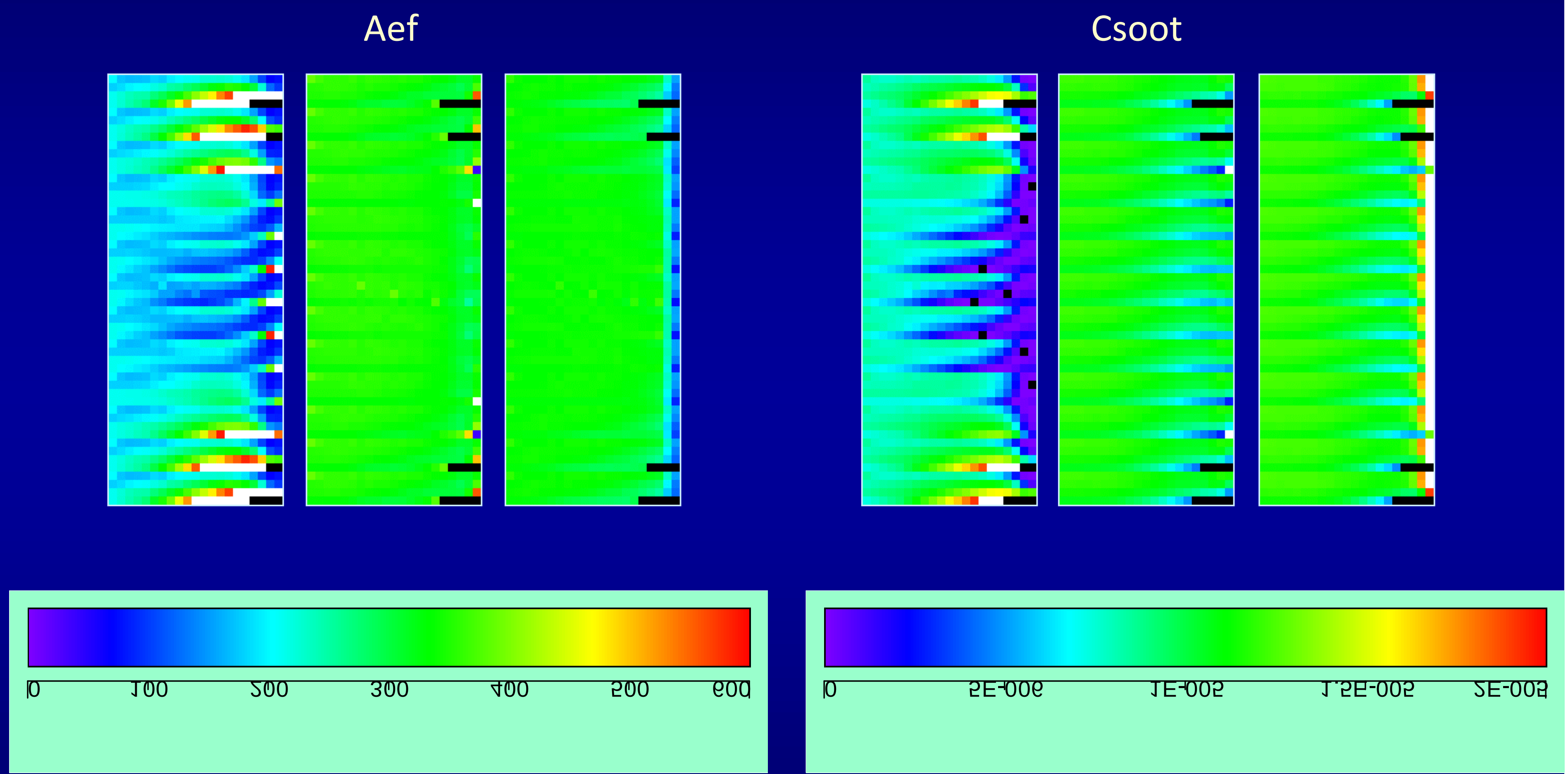


1 – without correction

2 – correction with “real” atmosphere model

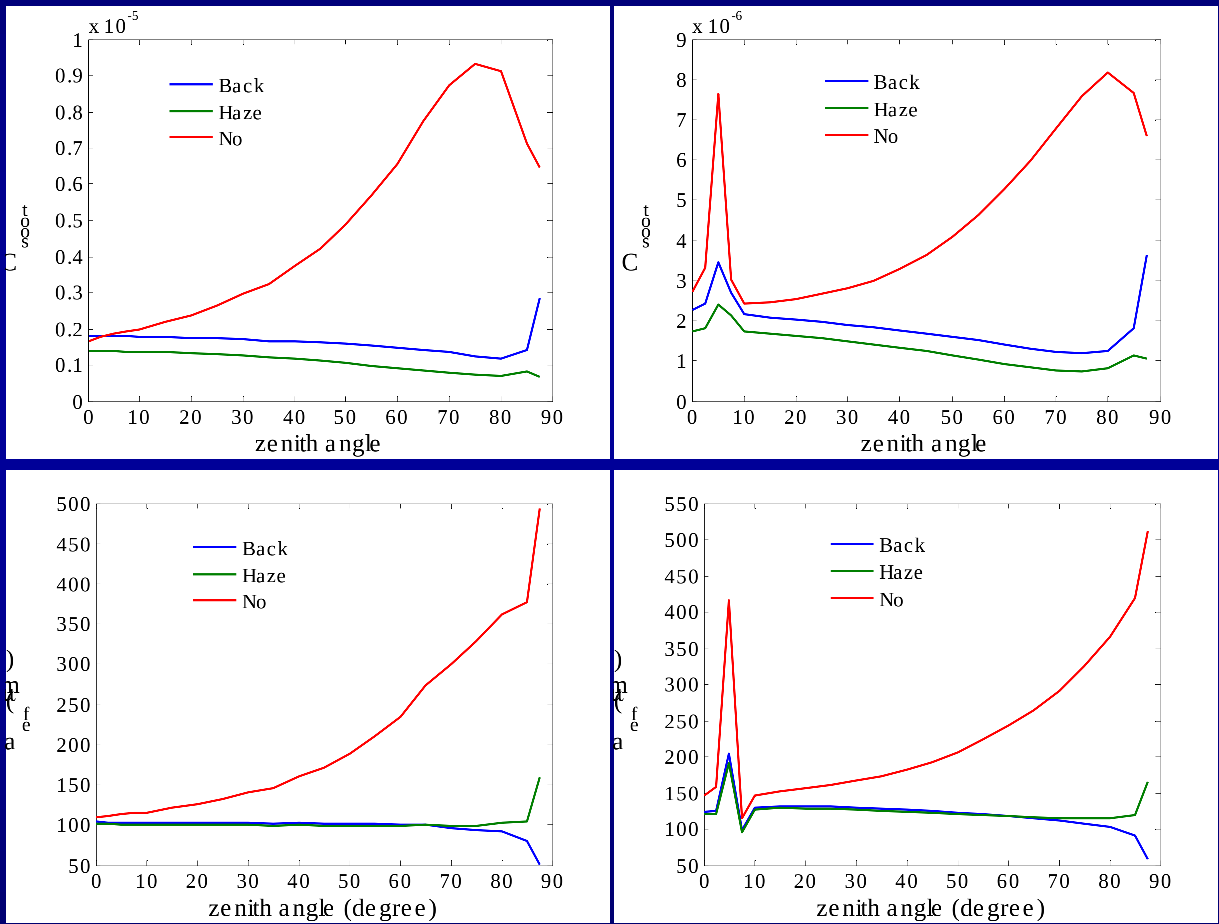
3 – correction with no aerosol model

mix_300_s-5_aHaze



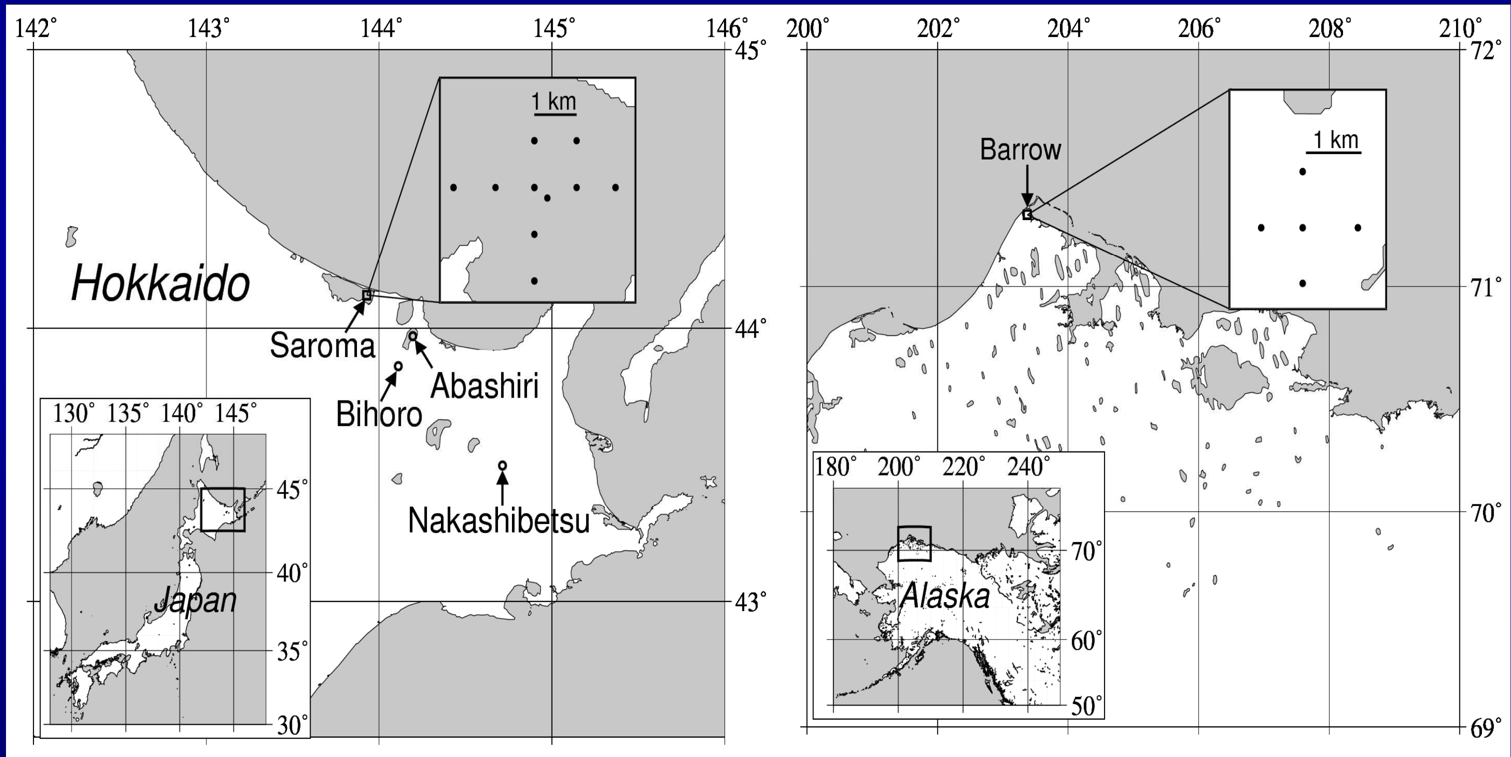
1 – without correction
2 – correction with “real” atmosphere model
3 – correction with no aerosol model

Soot concentration (upper) and the grain size retrieval (lower)

- 

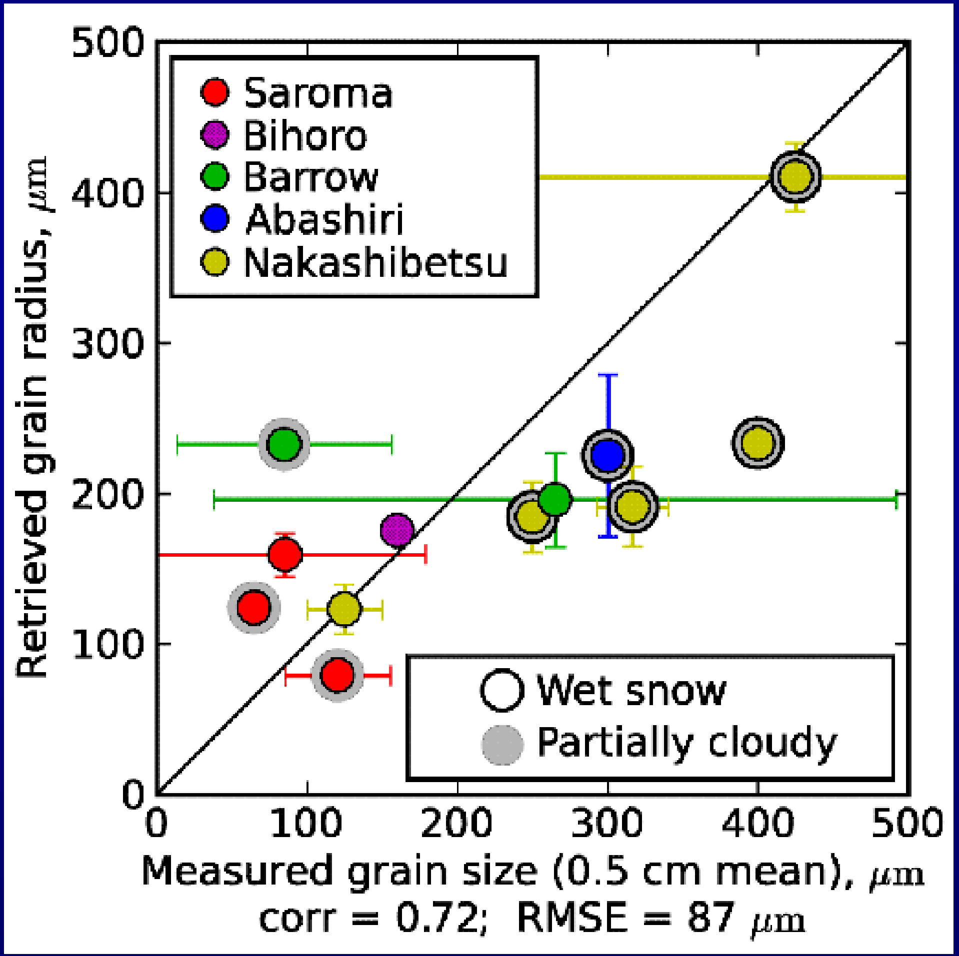
exact atmospheric model (green),
Arctic Background aerosol model (blue),
no atmospheric correction (red)

Map of the in-situ measurement sites by Aoki et al.



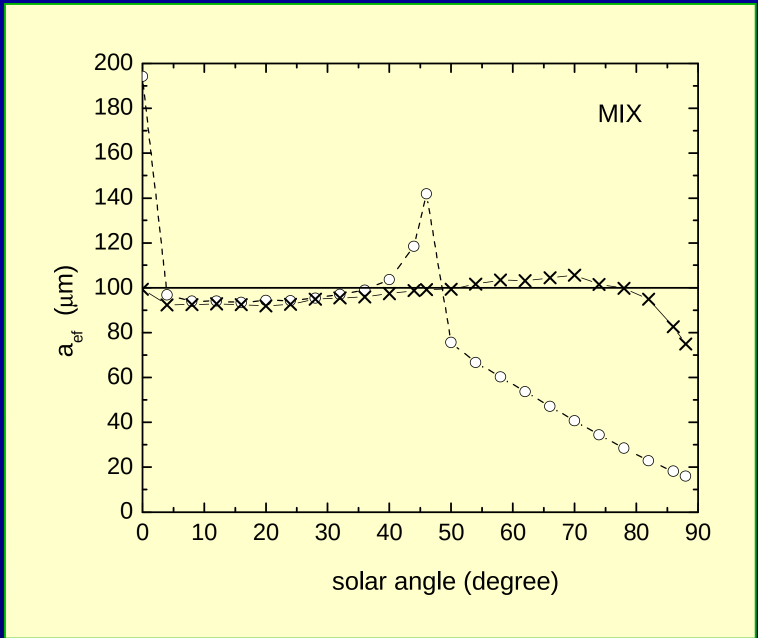
Сравнение с данными наземных измерений

(Aoki et al, 2001–2005)

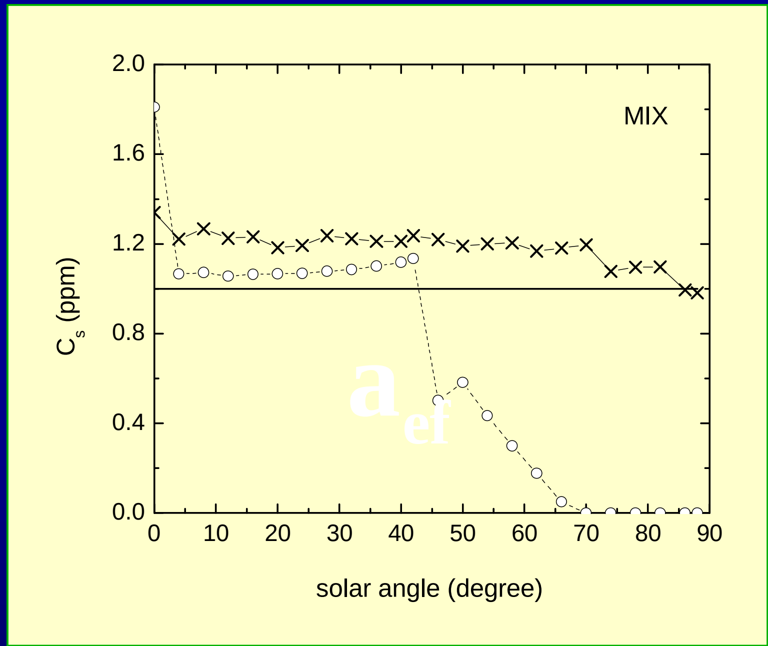


Retrieval of effective snow grain size and soot concentration (SGSP vs LUT)

a_{ef}, *nm*



C (ppm)



X – **SGSP**, o - LUT (Mie + RT calculation)

SGSP code is available now as Win32 and LINUX console applications

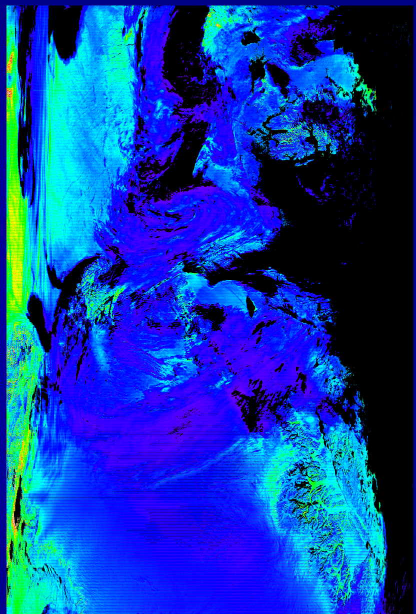
.

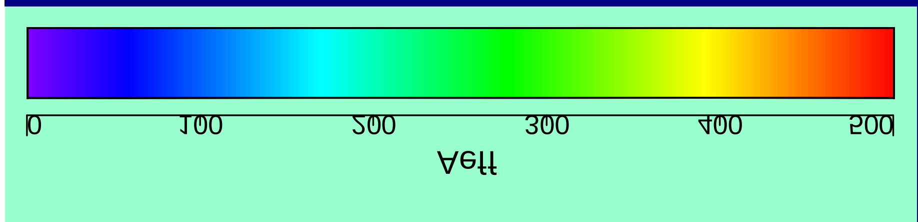
- The developed algorithm was implemented in a near-real time MODIS processing chain at the University of Bremen (see ***http://www.iup.uni-bremen.de:8084/amsr/modis.html***)

- It works operationally and provides the retrieval of the snow characteristics on the regular base that are available in the online archive ***http://www.iup.uni-bremen.de:8084/amsredata/modis/*** **.**

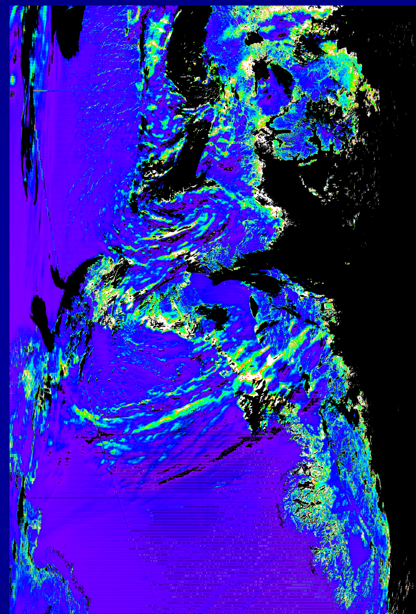
d:\Modis_work\SGSPRinp_MOD021KM.A2007111.1500.005.2007312045801.h5 (correction – back atm)

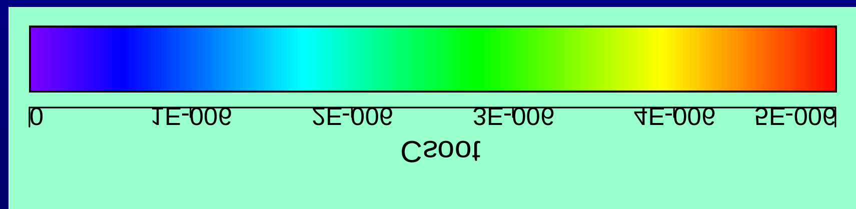
a_{ef}



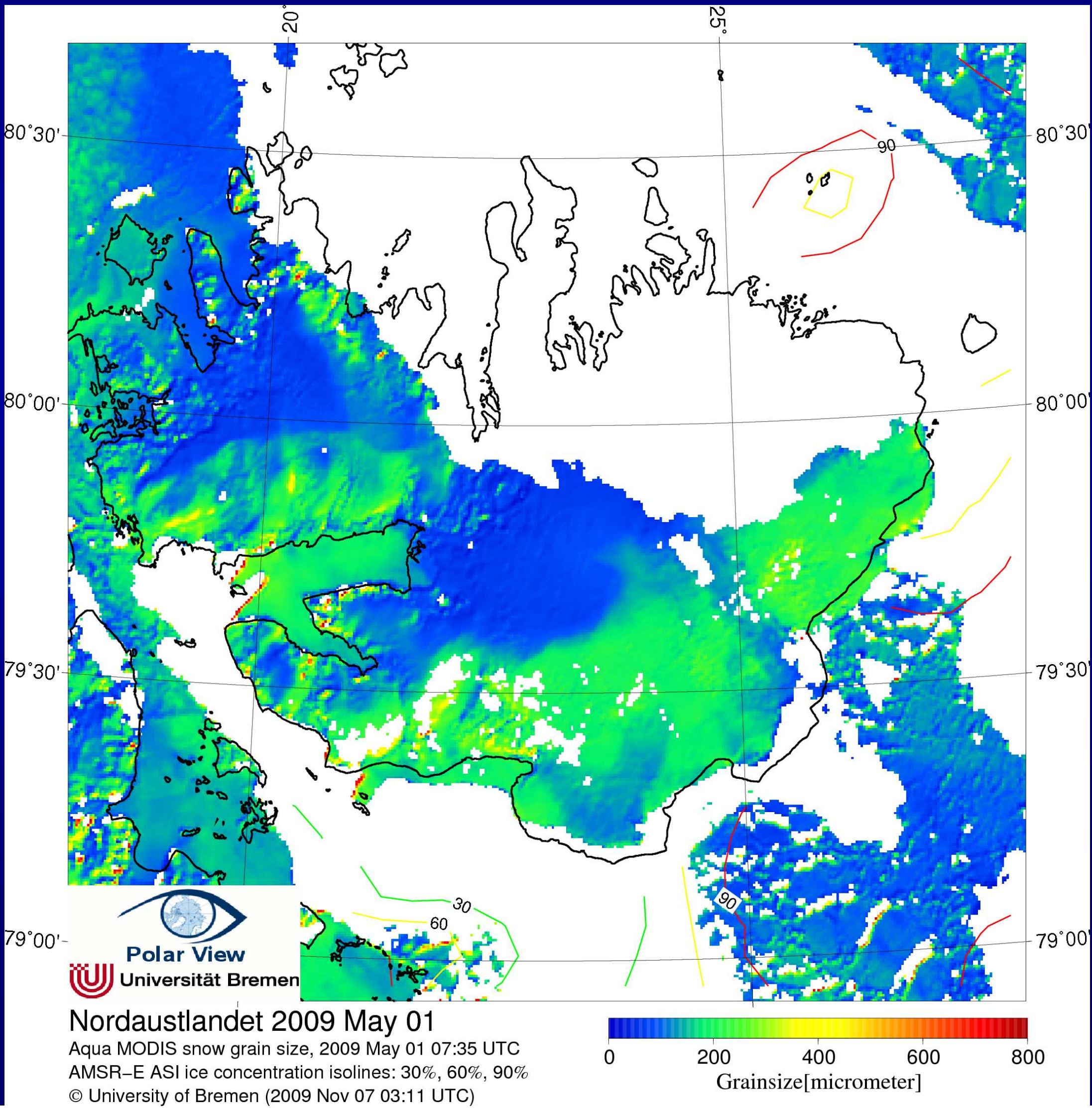


C (soot concentration)





One more example of retrieval



CONCLUSION

We presented here a new sufficiently mature SGSP retrieval algorithm.

It is currently used for the near-real time MODIS data processing (website of Bremen university).

The main advantages of the proposed algorithm over currently used ones are :

- the rejection of any a priory snow model used rather than the use of any model of snow particles;

-the reasonable accuracy of the retrieval for very low Sun that is typical for Polar regions;

-the high-speed data processing.

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