



Institute of Remote Sensing and Digital Earth
Chinese Academy of Sciences

Aerosol Optical Depth Retrieval from Satellite Data in China

Professor Dr. Yong Xue



Research Report Outline



- Multi-scale quantitative retrieval of Aerosol optical depth (AOD) over land
 - Spatial resolution: 10km, 1km, 100m
 - for researches of global AOD variation, especially the spatial and temporal AOD evolution and air pollution researches in urban regions over China
 - Temporal resolution: polar-orbit satellites
V.S. geostationary satellites
 - for studies on extreme weather cases e.g. dust storms

Time Series Retrieval



Time Series (TS) technique makes use of the two visible bands at 0.6 μm and 0.8 μm (with support of 1.6 μm) in three orderly scan.

Land-Atmosphere (Mei et al., 2011)

$$\rho = \frac{[a+c(\Gamma-\rho_{TOA})]e^{k\tau} + [b+c(\rho_{TOA}\Gamma-1)]\Gamma e^{-k\tau} + (\Gamma^2-1)G^+ e^{-\frac{\tau}{\mu_0}}}{[a+c(\Gamma-\rho_{TOA})]\Gamma e^{k\tau} + [b+c(\rho_{TOA}\Gamma-1)]e^{-k\tau} + (\Gamma^2-1)G^- e^{-\frac{\tau}{\mu_0}}}$$

A prior knowledge (Multi-Channel)

$$\tau(\lambda) = \beta\lambda^{-\alpha} \quad (\text{Angstrom et al., 1961})$$

Land model (Multi-Temporal)

$$\frac{\rho_1(\lambda)}{\rho_2(\lambda)} \approx k(\lambda) \quad (\text{Flowerdew et al., 1995})$$

Inputs: 3 scans/2 bands

10 Equations = 10 Un-knows

Other constrains:

Aerosol Type (Govarert et al., 2010)

Single Scattering Albedo

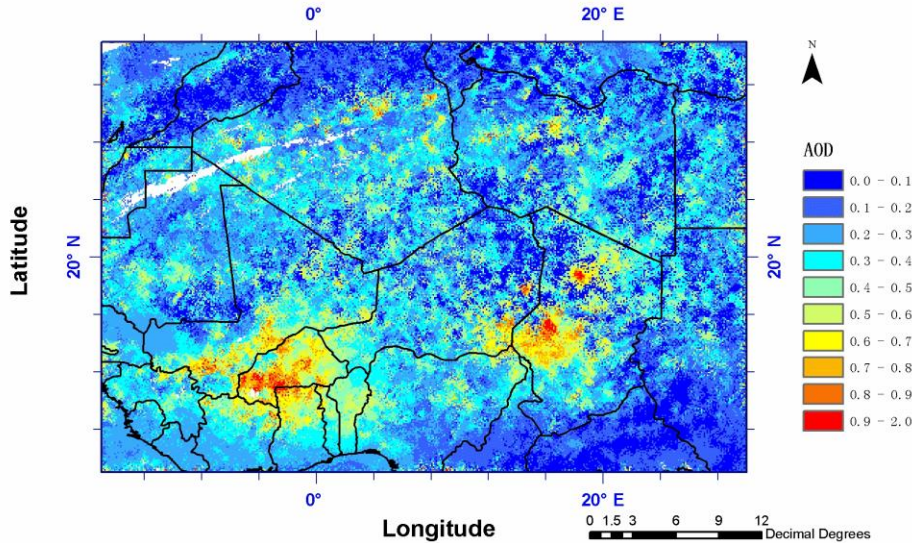
Asymmetry factor

Reflectance (Kim et al., 2008)

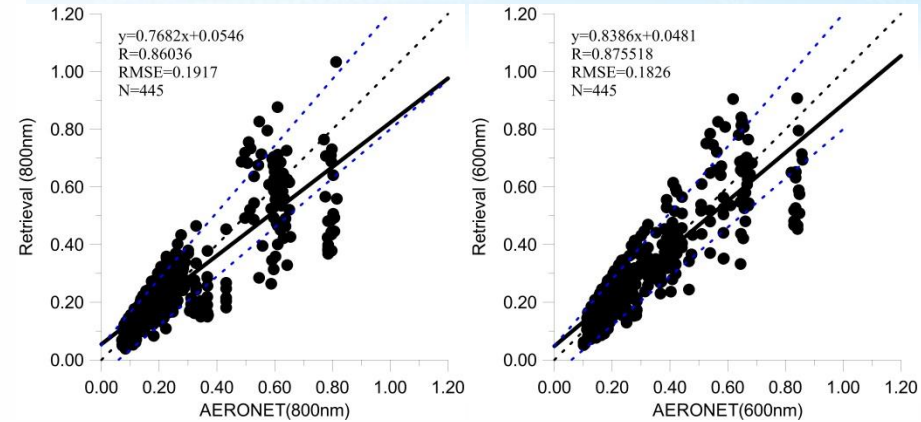
$$\varepsilon = \min \left\{ \sum_t \sum_{j=1}^n (A_{\lambda_{t,j}}^k - A_{\lambda_{t+1,j}}^k)^2 \right\}$$

Hourly AOD from MSG/SEVIRI Data

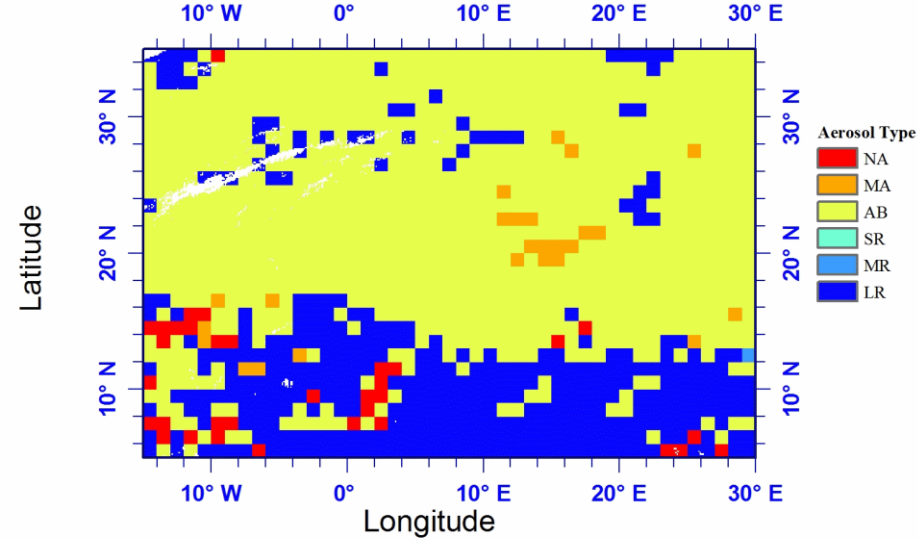
AOD_10KM_TS(0.8μm) SEVIRI_MSG_2010_04_14_08:45



NA: Spherical Non Absorbing
 MA: Spherical Moderately Absorbing
 AB: Spherical Absorbing
 SR: Non Spherical Small
 MR: Non Spherical Medium
 LR: Non Spherical Large



Aerosol Type SEVIRI_MSG_2010_04_14_08:45

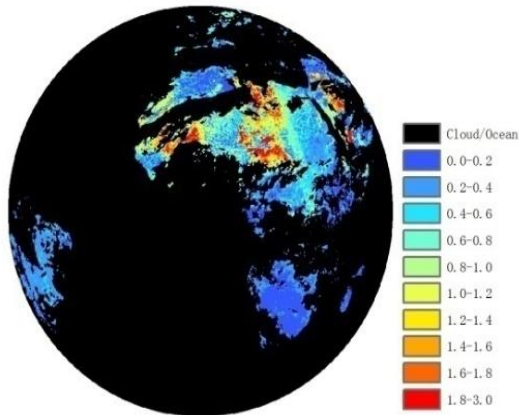


Mei, L., Xue, Y., et al.: Retrieval of aerosol optical depth over land based on a time series technique using MSG/SEVIRI data, *Atmos. Chem. Phys.*, 12, pp9167-9185, 2012.

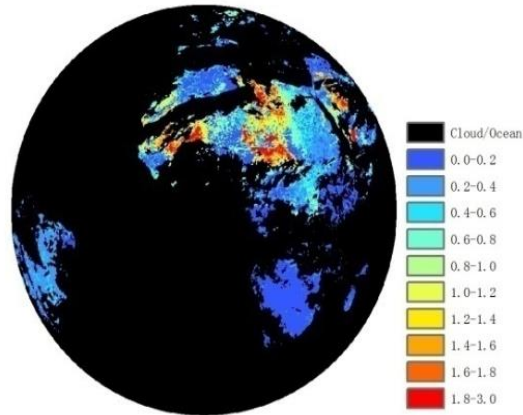
Hourly AOD from Geostationary Satellite Data



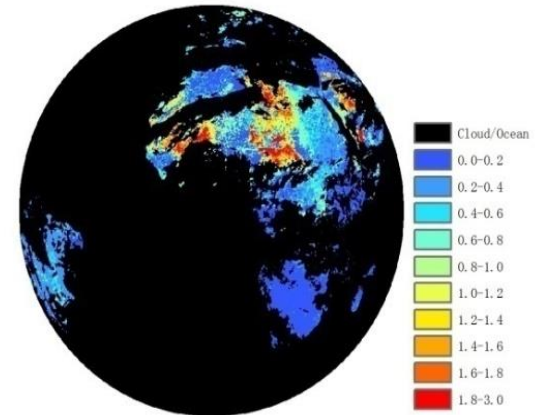
MSG/SEVIRI_AOD_12KM(0.6 μ m)
2010_04_14_10:30



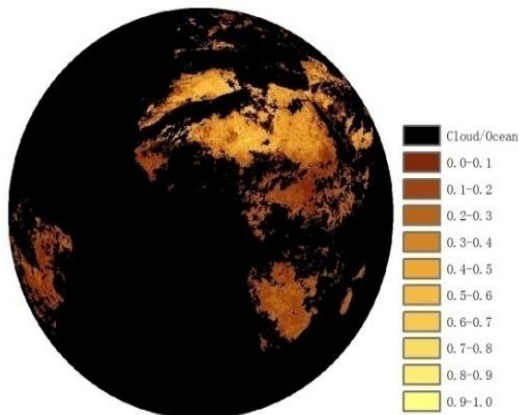
MSG/SEVIRI_AOD_12KM(0.6 μ m)
2010_04_14_10:45



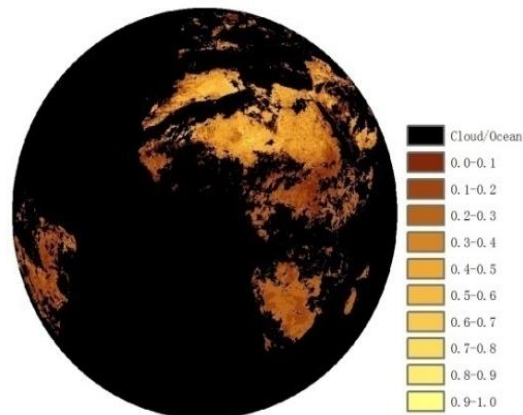
MSG/SEVIRI_AOD_12KM(0.6 μ m)
2010_04_14_11:00



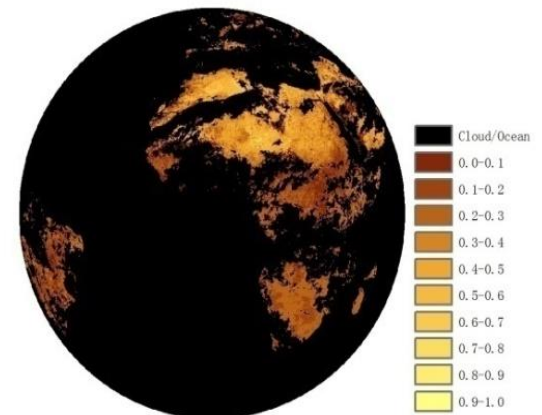
MSG/SEVIRI_REF_12KM(0.6 μ m)
2010_04_14_10:30



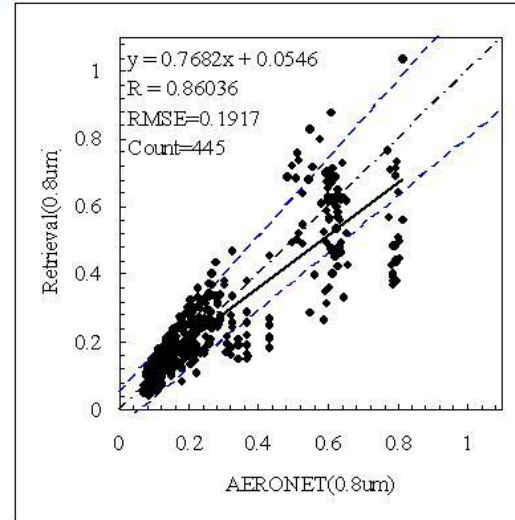
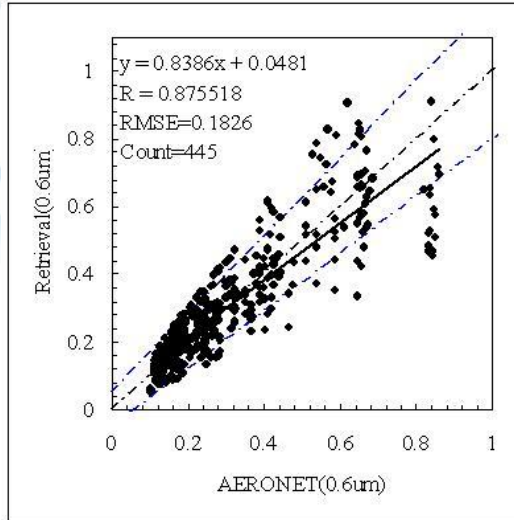
MSG/SEVIRI_REF_12KM(0.6 μ m)
2010_04_14_10:45



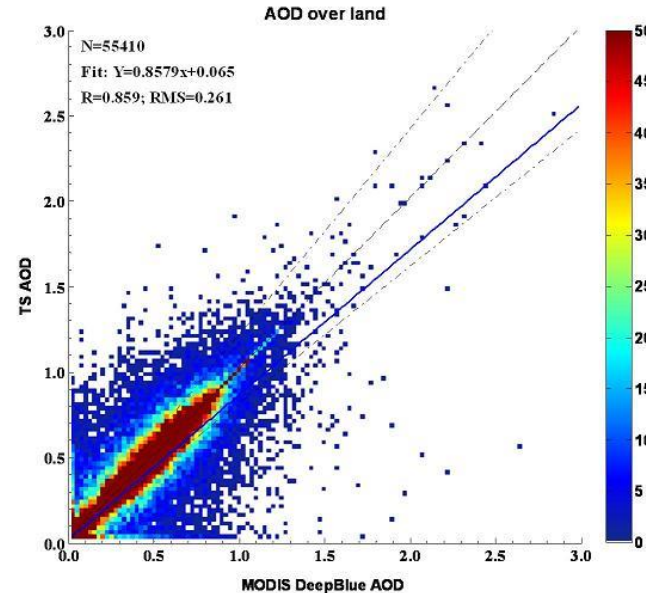
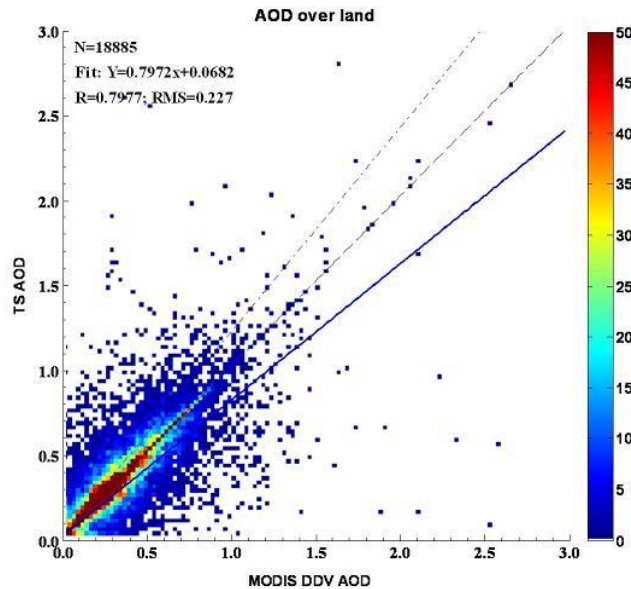
MSG/SEVIRI_REF_12KM(0.6 μ m)
2010_04_14_11:00



Validations



MSG vs AERONET



MSG vs MODIS

Land Aerosol property and Bidirectional reflectance Inversion by Time Series technique

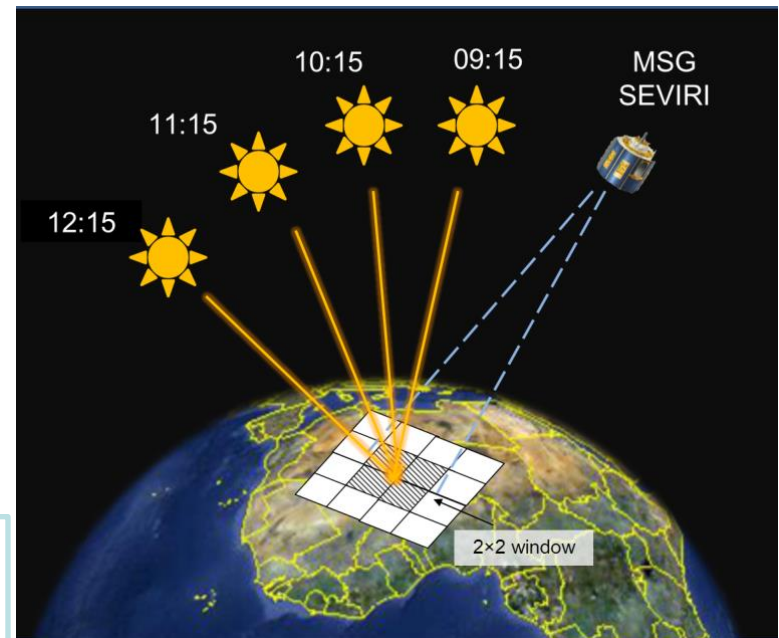


(LABITS)

Basic Assumptions :

1. Surface reflectance (R) changes quickly with location but remain the same in short time interval. Thus, during observations in a row, for single visible band we can assume that R is invariant in each pixel.
2. Aerosol optical depth (AOD) has a high temporal variation but is consistent spatially in a small area.

Area with the size of N , multi-observations number as K , for single visible band, there are KN^2 measurements and $K + 3N^2$ unknowns. If $KN^2 \geq K + 3N^2$, we can retrieval AOD and BRDF parameters simultaneously. Here, we set $K = 4$ and $N = 2$.



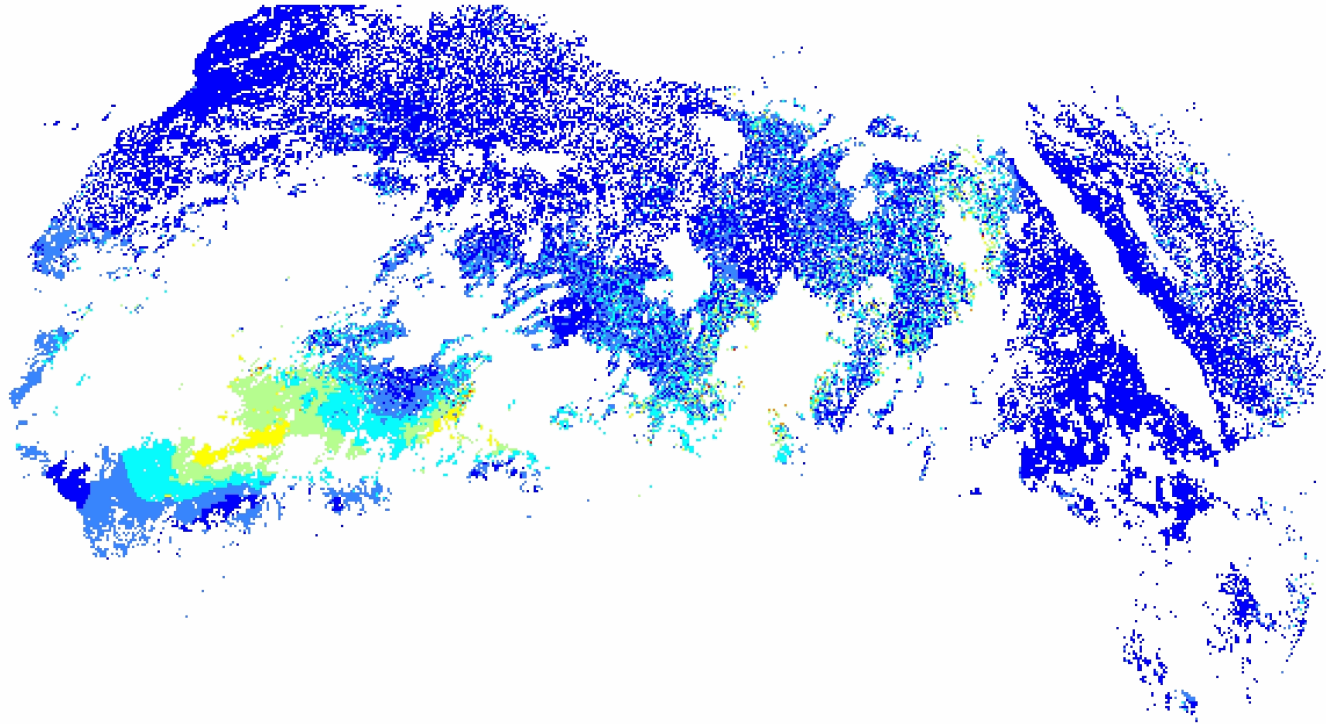
Yingjie Li, Yong Xue, Gerrit de Leeuw, et al. (2013), Retrieval of aerosol optical depth and surface reflectance over land from NOAA AVHRR data, *Remote Sensing of Environment*, 133, 1-20.

Hourly Time-Series AOD Results from MSG/SEVIRI Data

2006_03_08 08:00 GMT



MSG-AOD



AOD Results from MSG/SEVIRI Data



MSG-AOD

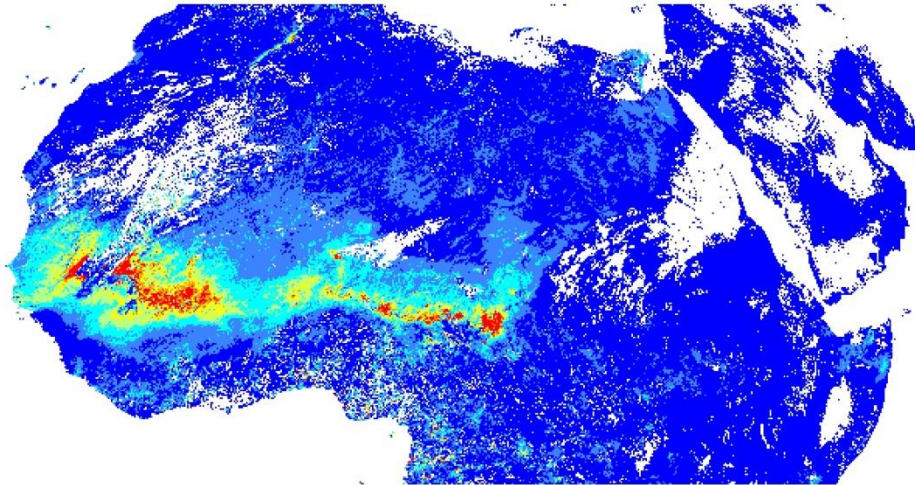
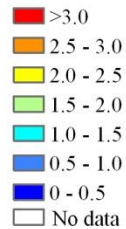


Figure 1. Spatial distribution of MSG AOD by the operational MSG aerosol inversion algorithm on 8 March 2006 over North Africa

MSG-AOD

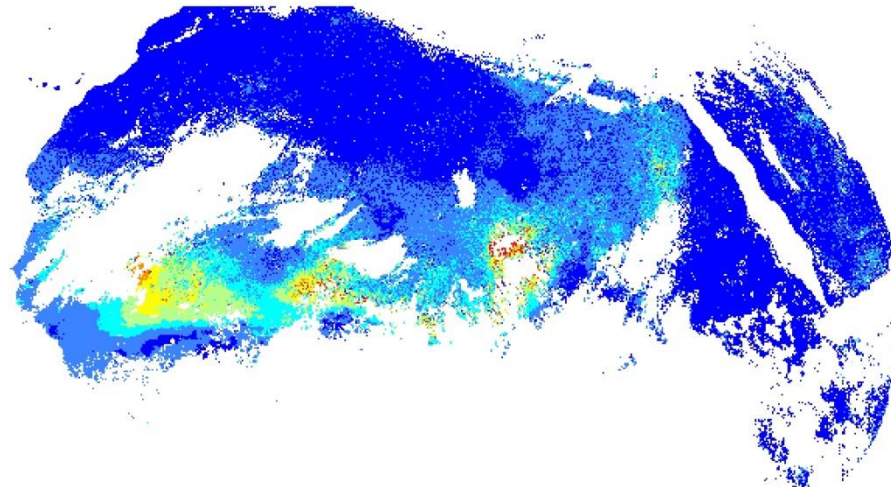
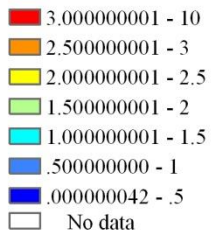
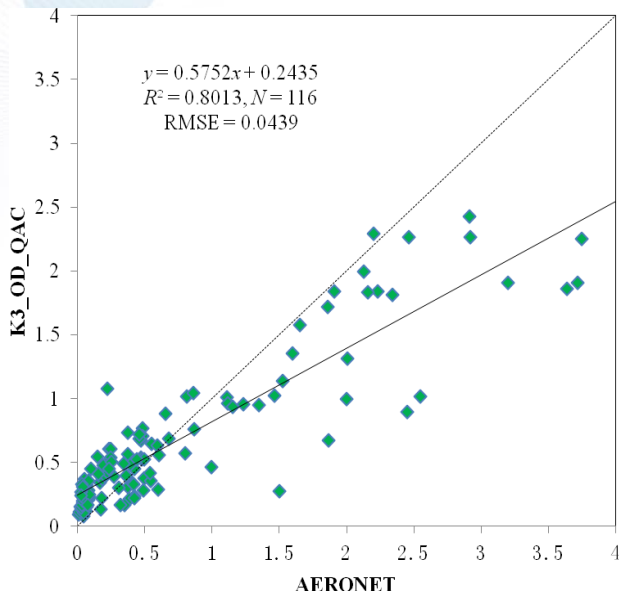
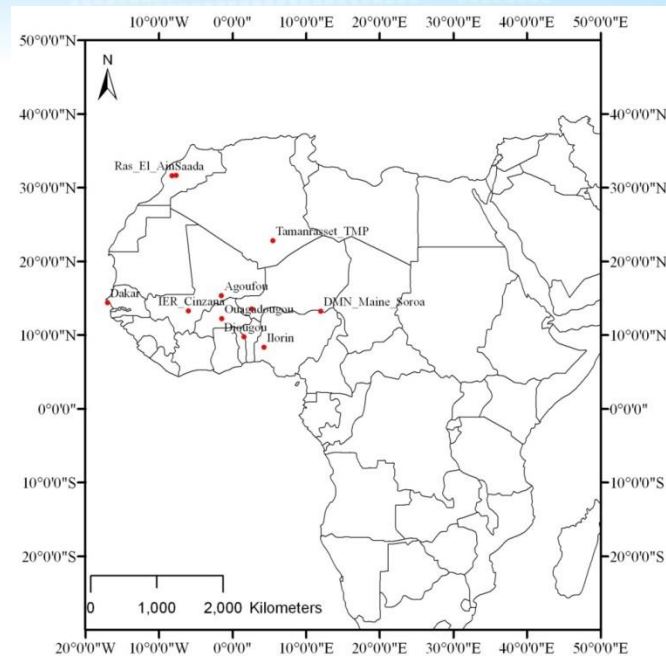


Figure 2. Spatial distribution of daily means MSG AOD by LABITS algorithm on 8 March 2006 over North Africa

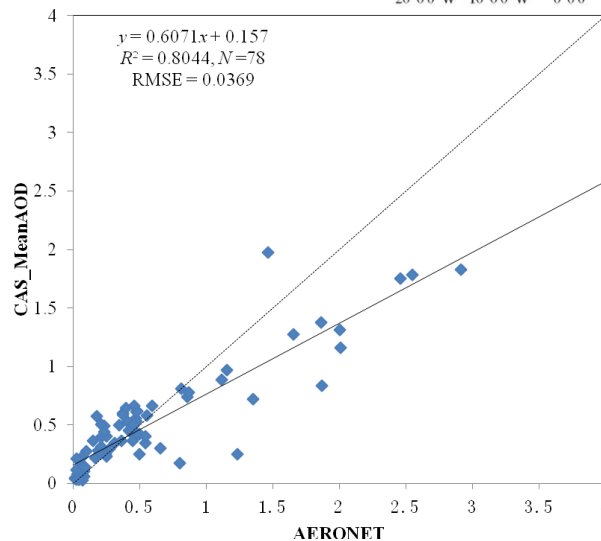
Preliminary validation



Scatterplots between daily average AERONET and MSG AOD estimates by the operational MSG aerosol inversion algorithm during 1 March 2006 to 15 March 2006

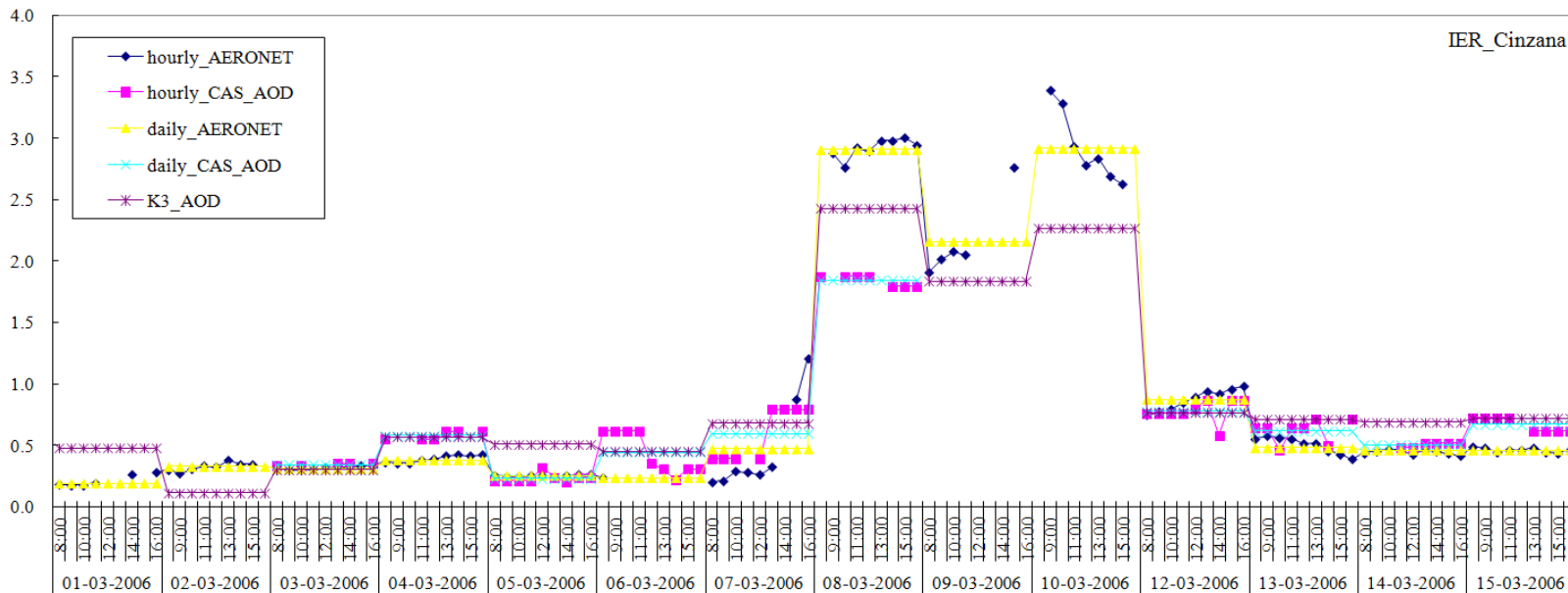
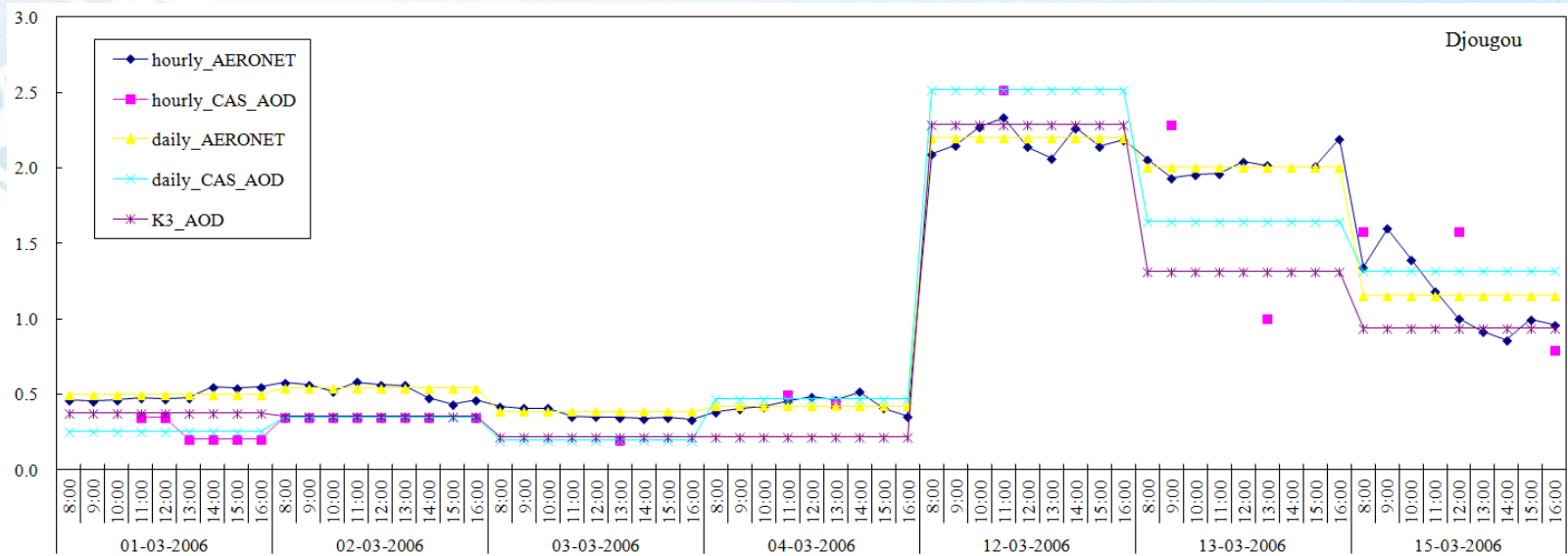


Location of the AERONET stations investigated in the present study



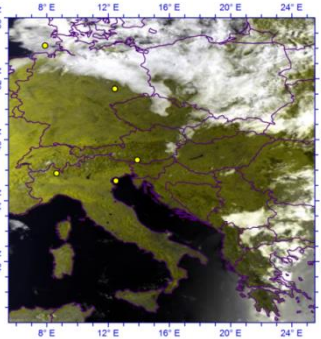
Scatterplots between daily average AERONET and Mean MSG AOD estimates by LABITS algorithm during 1 March 2006 to 15 March 2006

Preliminary validation

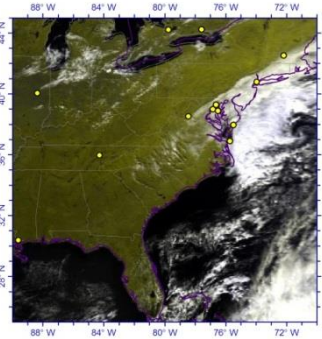


Long-term (30 yrs) AOD data from AVHRR Data

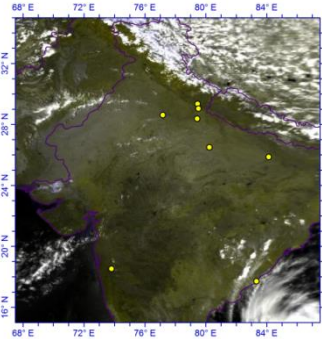
NOAA-15 AVHRR RGB Image over EUR on 08/14/2001



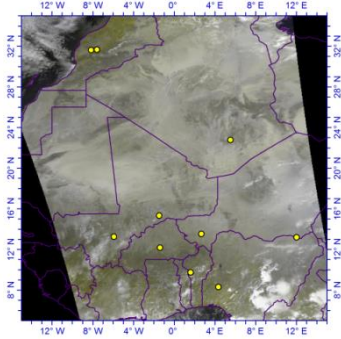
NOAA-16 AVHRR RGB Image over AME on 10/01/2001



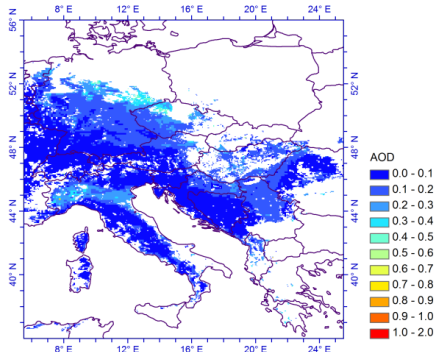
NOAA-18 AVHRR RGB Image over IND on 04/29/2008



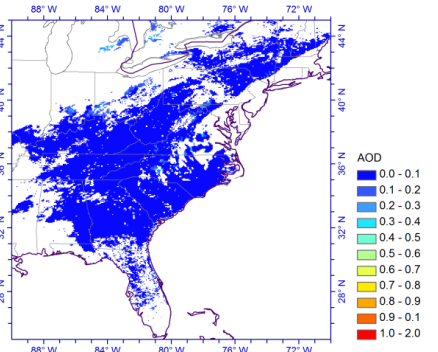
NOAA-18 AVHRR RGB Image over SAH on 04/29/2006



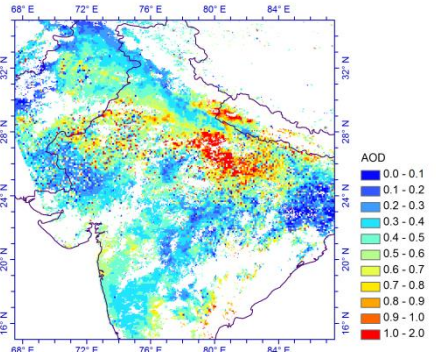
NOAA-15 AVHRR AOD at 0.63 um over EUR on 08/14/2001



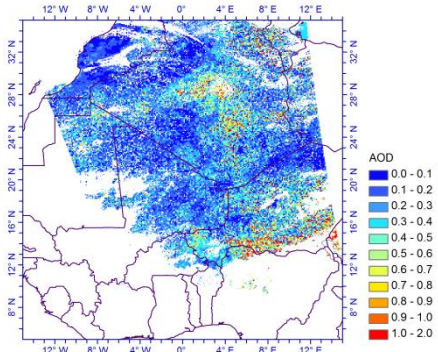
NOAA-16 AVHRR AOD at 0.63 um over AME on 10/01/2001



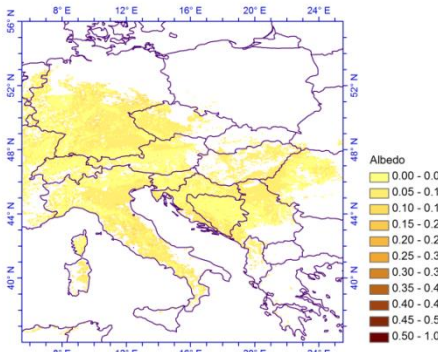
NOAA-18 AVHRR AOD at 0.63 um over IND on 04/29/2008



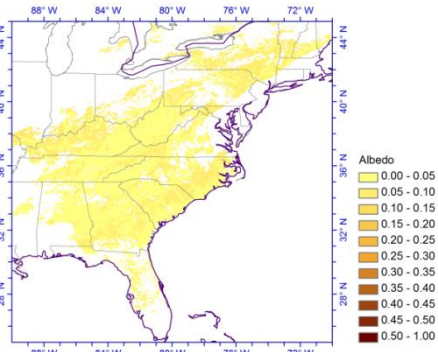
NOAA-18 AVHRR AOD at 0.63 um over SAH on 04/29/2006



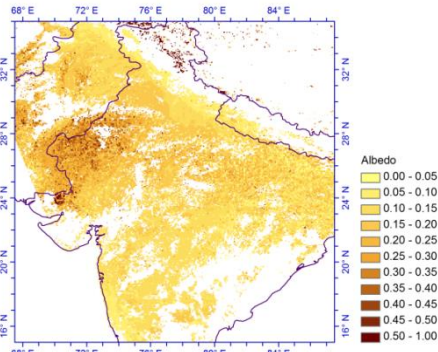
NOAA-16 AVHRR Albedo at 0.63 um over EUR 08/14/2001 - 08/15/2001



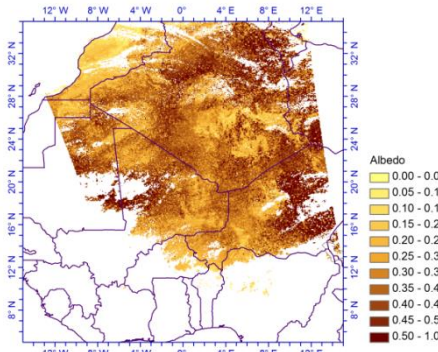
NOAA-16 AVHRR Albedo at 0.63 um over AME 10/01/2001 - 10/04/2001



NOAA-18 AVHRR Albedo at 0.63 um over IND 04/29/2008 - 05/02/2008



NOAA-18 AVHRR Albedo at 0.63 um over SAH 04/29/2006 - 04/30/2006



Improved Aerosol Optical Depth and Ångström Exponent Retrieval over Land from MODIS Based on the Non-Lambertian Forward Model

Non-Lambertian Forward Model

$$\rho^* = \rho_a + \frac{\bar{T}(\mu_s) \bar{R} \bar{T}(\mu_v) - e^{-\tau/\mu_s} |\bar{R}| e^{-\tau/\mu_v} \cdot S}{1 - \rho_{BHR} S}$$

$$\bar{R} = \begin{bmatrix} \rho & \rho_{DHR} \\ \rho_{HDR} & \rho_{BHR} \end{bmatrix}$$

denotes the reflectance matrix, while ρ_{DHR} is the directional-hemispherical reflectance (DHR), ρ_{HDR} is the hemispherical-directional reflectance (HDR), ρ_{BHR} is the bi-hemispherical reflectance (BHR) equal to the surface albedo.

$$|\bar{R}| = \rho \cdot \rho_{BHR} - \rho_{HDR} \cdot \rho_{DHR}$$

The determinant of the reflectance matrix \bar{R}

$$\bar{T}(\mu_s) = [e^{-\tau/\mu_s} \quad t_d(\mu_s)]$$

$$\bar{T}(\mu_v) = [e^{-\tau/\mu_v} \quad t_d(\mu_v)]$$

Transmission matrices.

Lambertian Forward Model (NASA MODIS DT)

$$\rho^*(\mu_s, \mu_v, \phi) = \rho_a + \frac{T(\mu_s) \rho_t T(\mu_v)}{1 - \rho_t S}$$

VISvs2.12

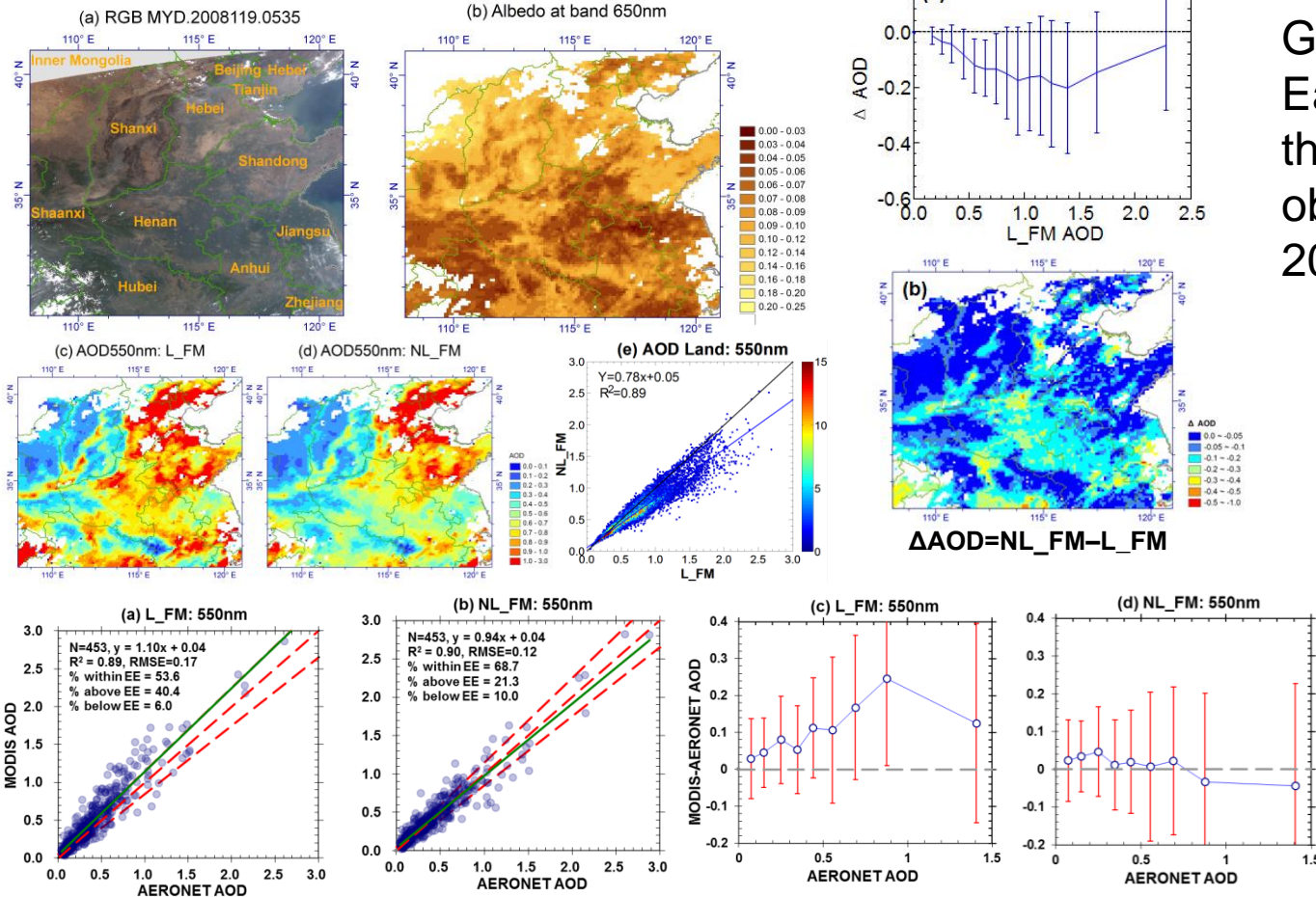
$$\begin{bmatrix} \rho & \rho_{DHR} \\ \rho_{HDR} & \rho_{BHR} \end{bmatrix}$$

MCD43: BRDF/Albedo product

MCD43



Improved Aerosol Optical Depth and Ångstrom Exponent Retrieval over Land from MODIS Based on the Non-Lambertian Forward Model



Granule retrieved over Eastern China from the MODIS-Aqua obtained on April 28, 2008 at 05:35 UTC.

AOD:
 68.7% vs. 53.6%
 $EE = \pm 0.05 \pm 0.1\tau$

Systematic overestimation:
 40.4% vs. 21.3%

over the study area of Eastern China

Leiku Yang, Yong Xue, Jie Guang, Hassan Kazemian, Chi Li, and Tingkai Wang, 2013, IEEE Geoscience and Remote Sensing Letter, (Revised).



www.radi.cas.cn

Aerosol Properties Retrieval over Snow (APRS)

The main concept of the most frequently used approximate radiative transfer equations consists of substituting the exact integrodifferential equation for radiant intensity by common differential equations for the upward and incident radiation fluxes (Kondratyev et al., 1969).

Two-Stream approximation

$$\frac{dF^{(1)}}{d\tau} = -m^{(1)}(\tau) [k + \sigma\Gamma^{(1)}(\tau)] F^{(1)}(\tau) + m^{(2)}(\tau) \sigma\Gamma^{(2)}(\tau) F^{(2)}(\tau)$$

$$-\frac{dF^{(2)}}{d\tau} = m^{(2)}(\tau) k\Gamma^{(2)}(\tau) F^{(2)}(\tau) - m^{(2)}(\tau) [k + \sigma\Gamma^{(2)}(\tau)] F^{(2)}(\tau)$$

$$R = \frac{(1 - R'M_1)e^{\rho_1\tau_A} + (R'M_2 - 1)e^{\rho_2\tau_A}}{(R'M_2 - 1)M_1e^{\rho_2\tau_A} + (1 - R'M_1)M_2e^{\rho_1\tau_A}}$$

$$M_2 = \frac{m^{(1)}(1 - \omega) + m^{(1)}\omega\Gamma + \rho_2}{m^{(2)}\omega\Gamma}$$

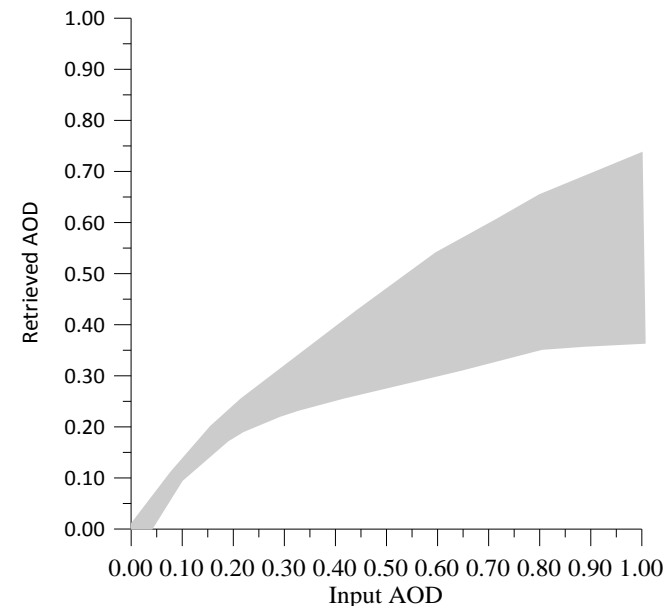
$$M_1 = \frac{m^{(1)}(1 - \omega) + m^{(1)}\omega\Gamma + \rho_1}{m^{(2)}\omega\Gamma}$$

$$\rho_2 = \frac{(m^{(2)} - m^{(1)})(1 - \omega + \omega\Gamma) - \sqrt{(m^{(1)} - m^{(2)})^2(1 - \omega + \omega\Gamma)^2 + 4m^{(1)}m^{(2)}(1 - \omega)(1 - \omega + 2\omega\Gamma)}}{2} \quad m^{(1)} = 2$$

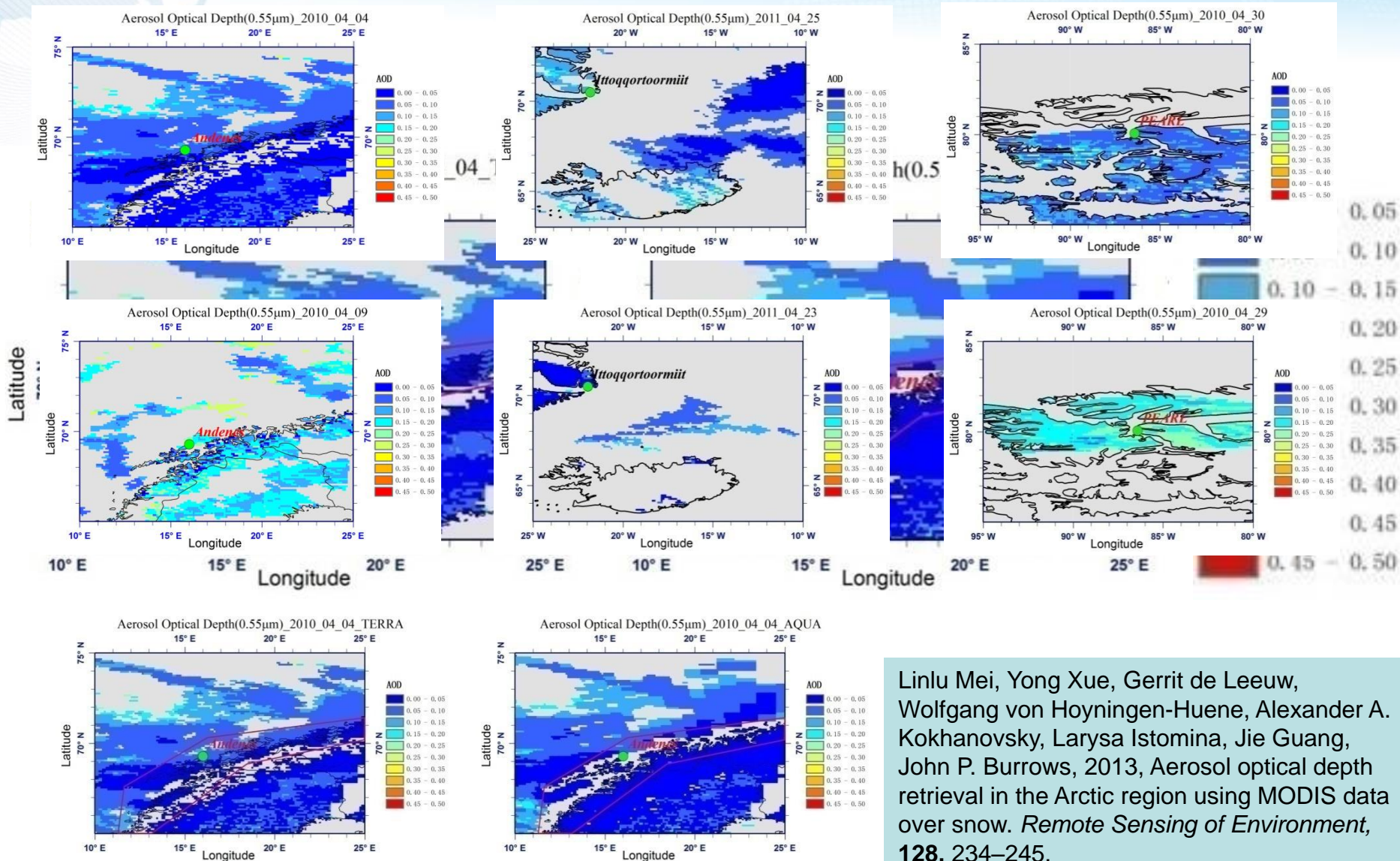
$$\rho_1 = \frac{(m^{(2)} - m^{(1)})(1 - \omega + \omega\Gamma) + \sqrt{(m^{(1)} - m^{(2)})^2(1 - \omega + \omega\Gamma)^2 + 4m^{(1)}m^{(2)}(1 - \omega)(1 - \omega + 2\omega\Gamma)}}{2} \quad m^{(2)} = \sec \theta$$

$$\sum_{i=1}^j \left(\frac{R^{\text{RTE}}_{Terra, \lambda_i}}{R^{\text{RTE}}_{Aqua, \lambda_i}} - \frac{R^{\text{BRDF}}_{Terra, \lambda_i}}{R^{\text{BRDF}}_{Aqua, \lambda_i}} \right)^2 < \chi$$

9 Equations = 9 Un-knows

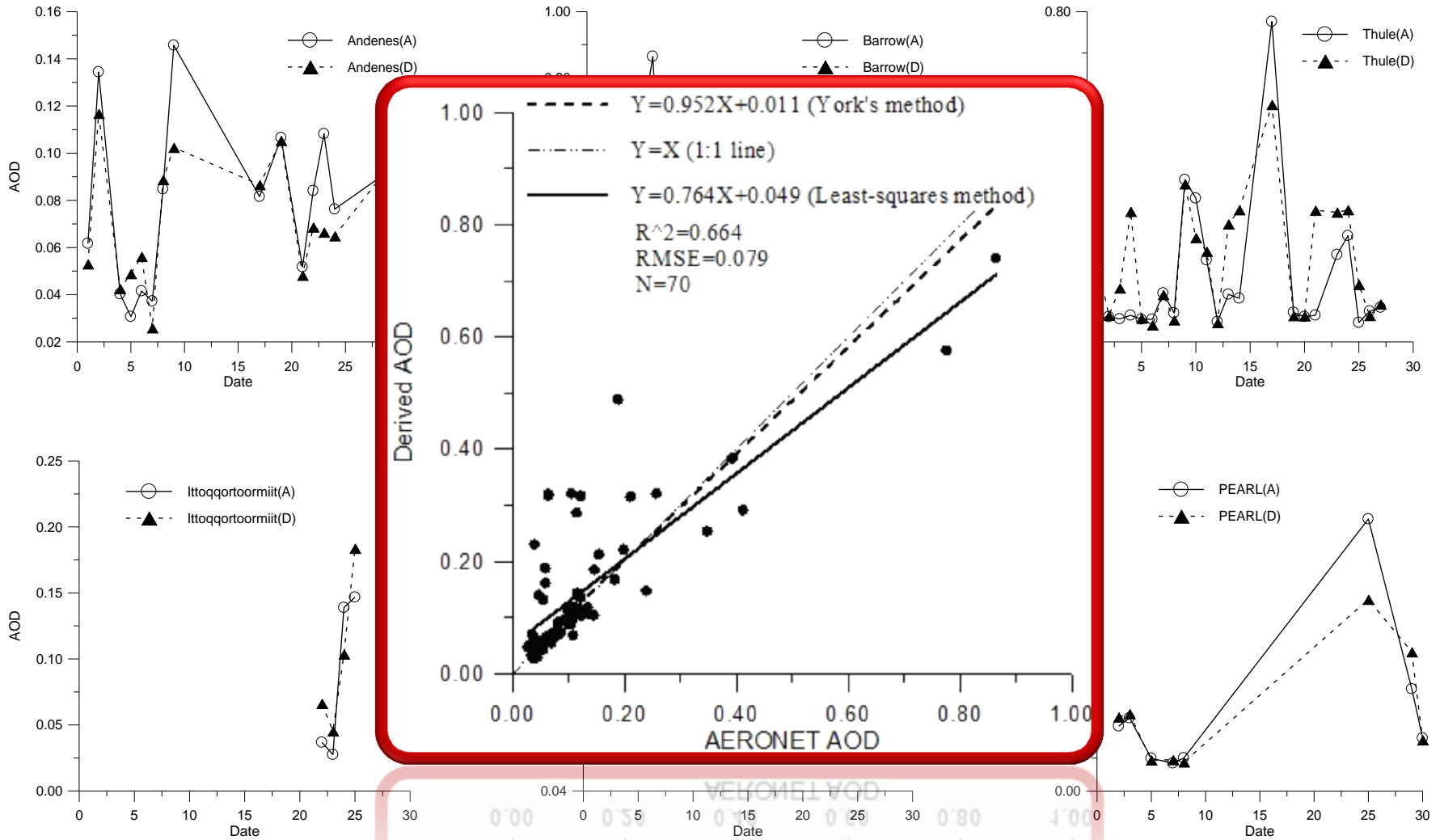


Retrieval Results



Linlu Mei, Yong Xue, Gerrit de Leeuw, Wolfgang von Hoyningen-Huene, Alexander A. Kokhanovsky, Larysa Istomina, Jie Guang, John P. Burrows, 2013, Aerosol optical depth retrieval in the Arctic region using MODIS data over snow. *Remote Sensing of Environment*, 128, 234–245.

Validations



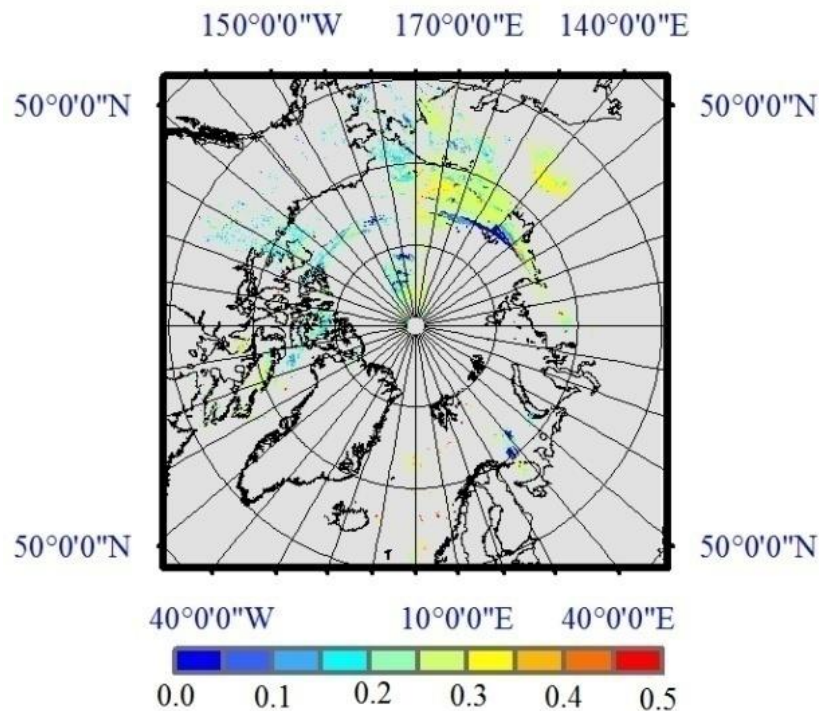
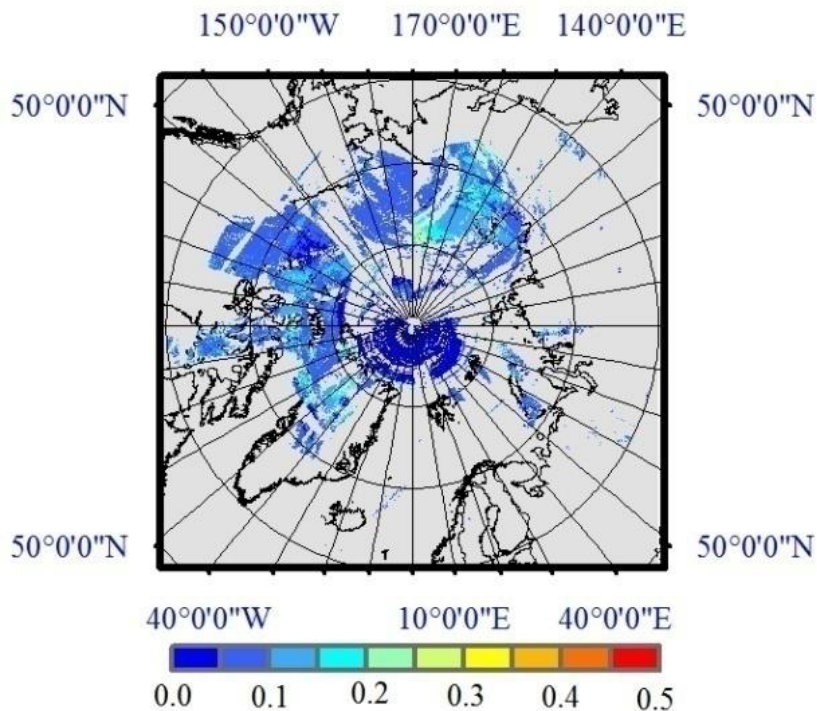
AOD of Arctic Region



Stohl et al., 2007

MODIS/TERRA AOD [550nm] 2006-03-29

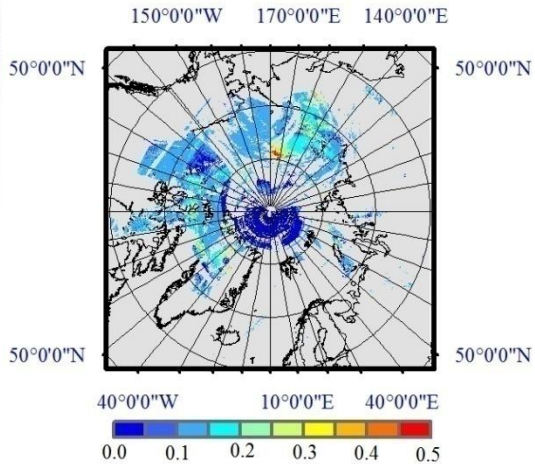
MODIS/TERRA AOD [550nm] 2006-05-03



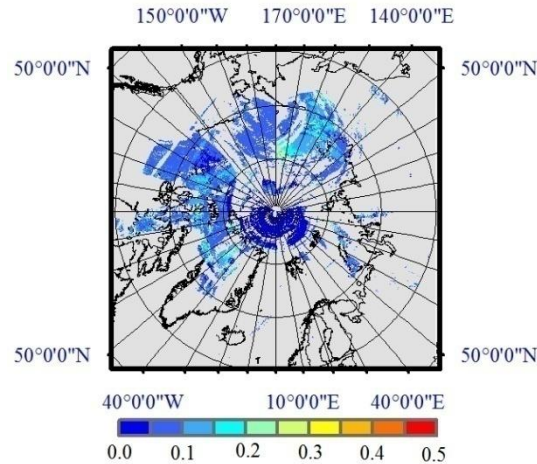
AOD of Arctic Region-Terra



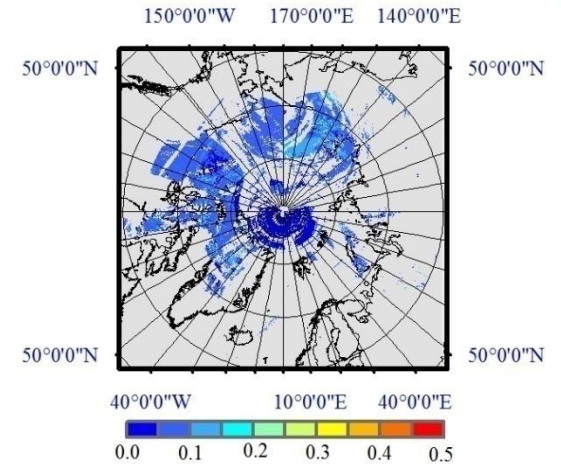
MODIS/TERRA AOD [470nm] 2006-03-29



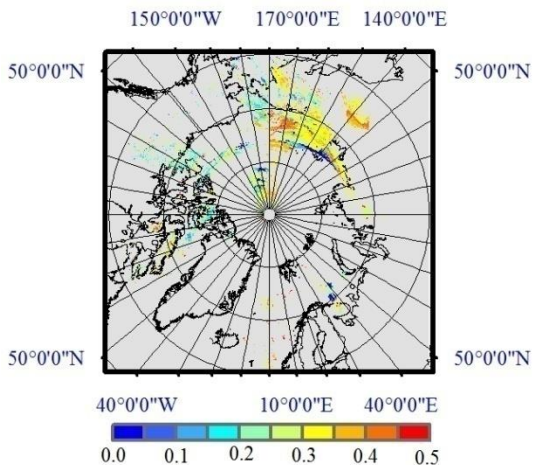
MODIS/TERRA AOD [550nm] 2006-03-29



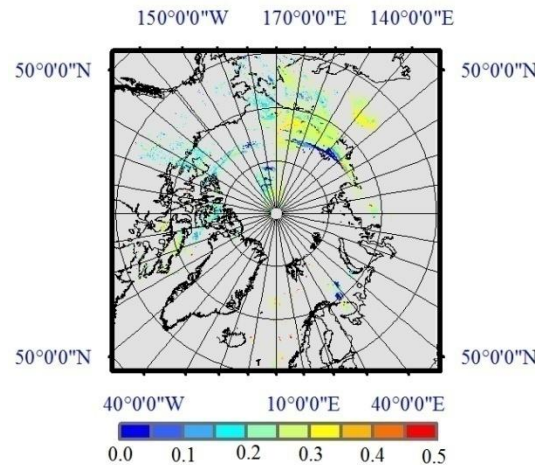
MODIS/TERRA AOD [660nm] 2006-03-29



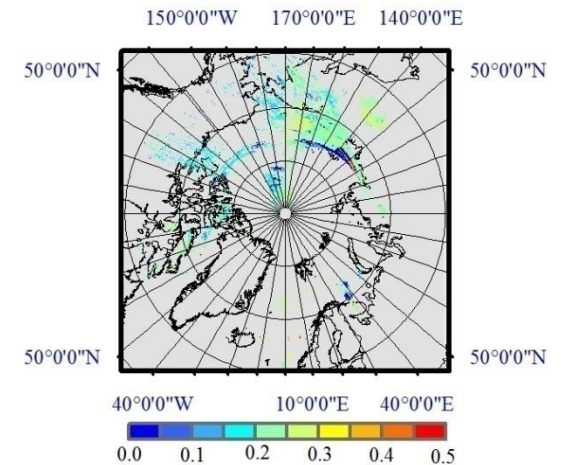
MODIS/TERRA AOD [470nm] 2006-05-03



MODIS/TERRA AOD [550nm] 2006-05-03



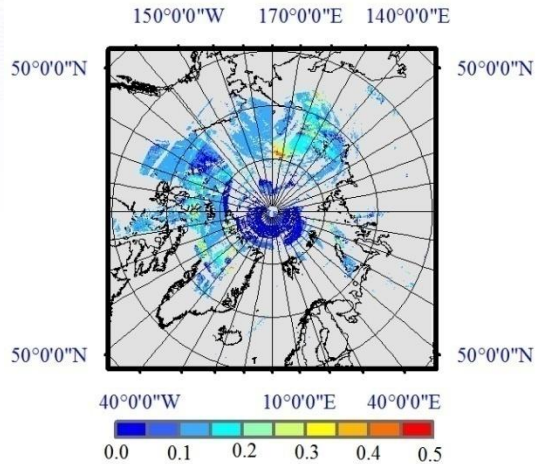
MODIS/TERRA AOD [660nm] 2006-05-03



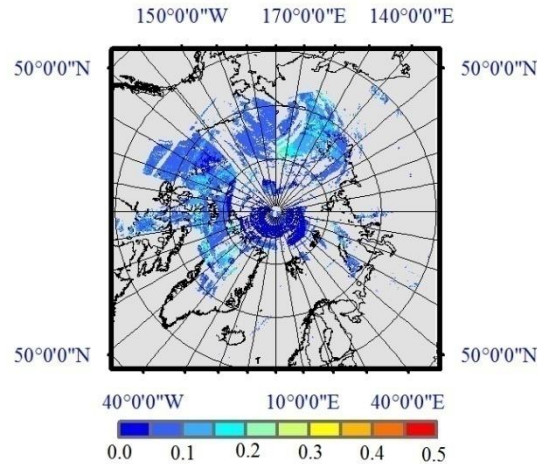
AOD of Arctic Region-Aqua



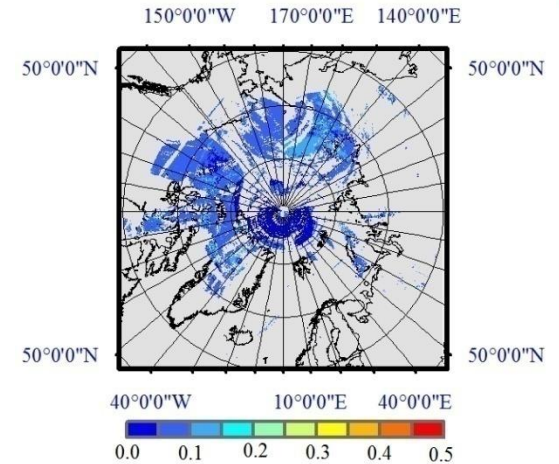
MODIS/AQUA AOD [470nm] 2006-03-29



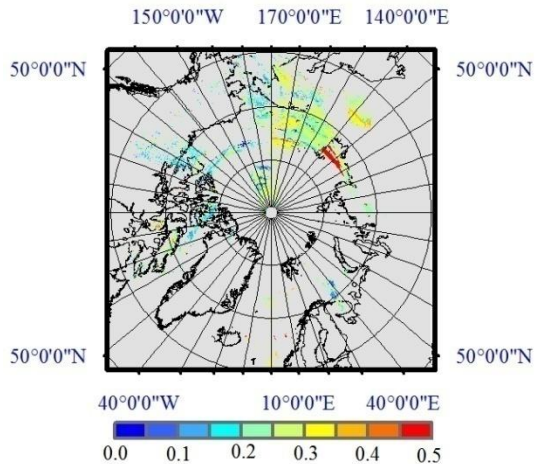
MODIS/AQUA AOD [550nm] 2006-03-29



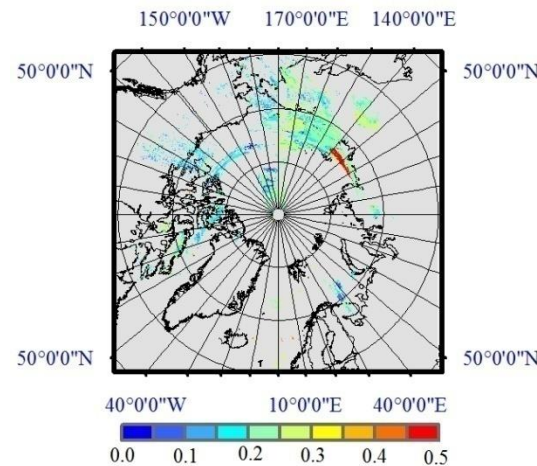
MODIS/AQUA AOD [660nm] 2006-03-29



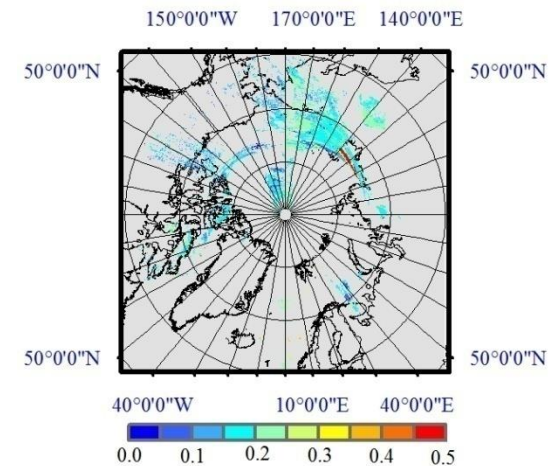
MODIS/AQUA AOD [470nm] 2006-05-03



MODIS/AQUA AOD [550nm] 2006-05-03

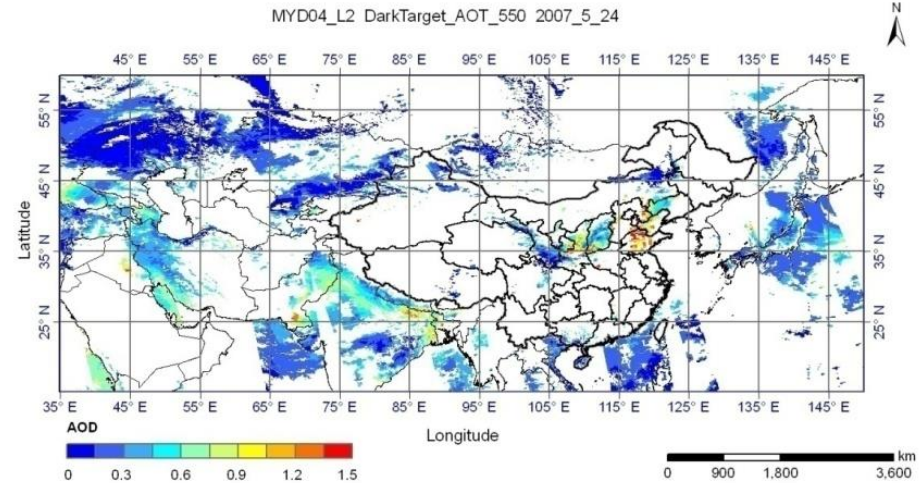
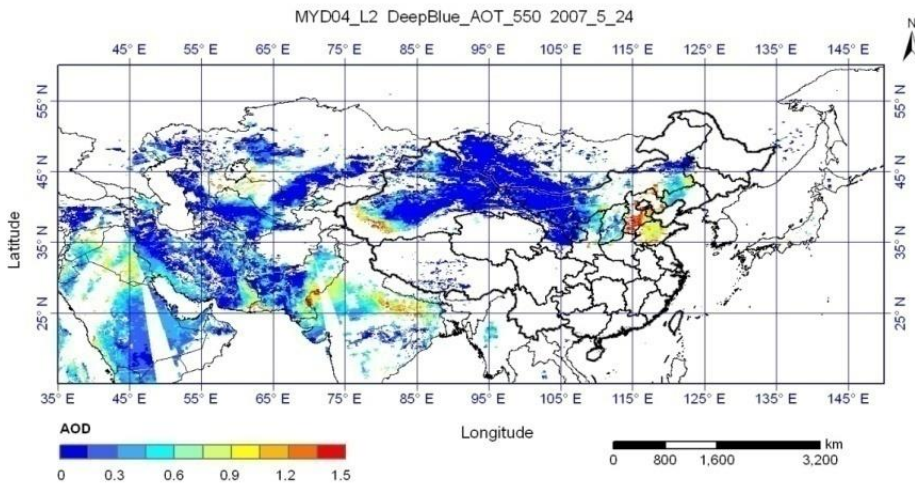
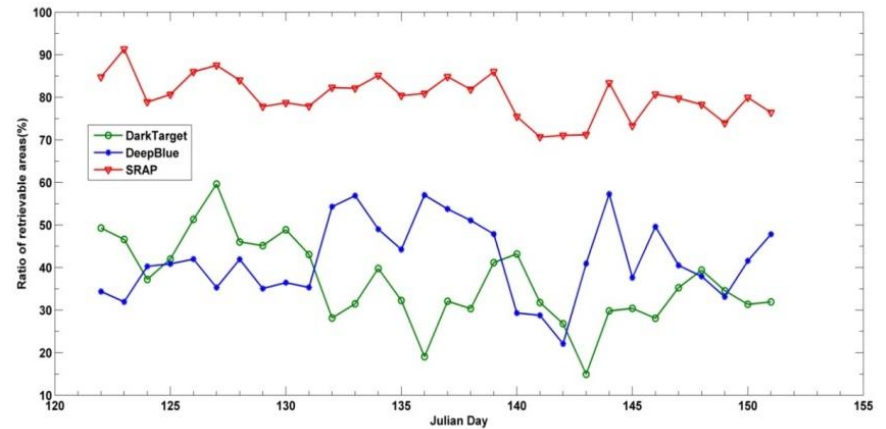
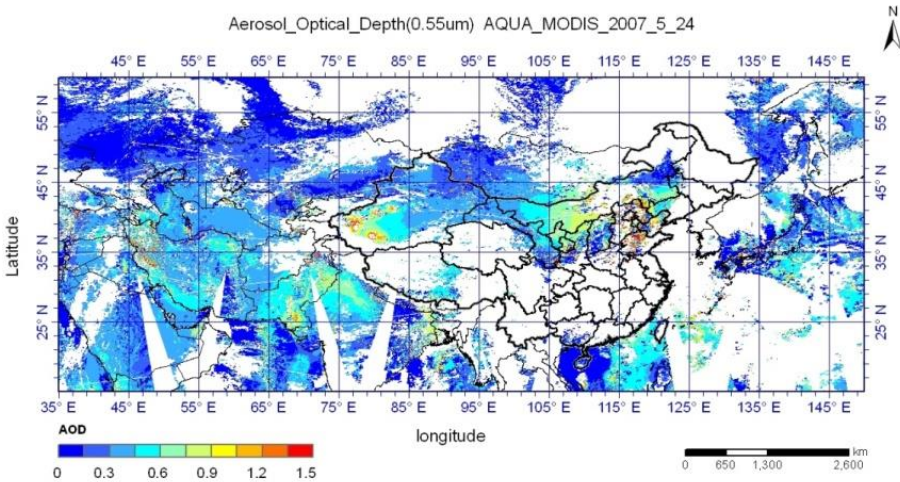


MODIS/AQUA AOD [660nm] 2006-05-03

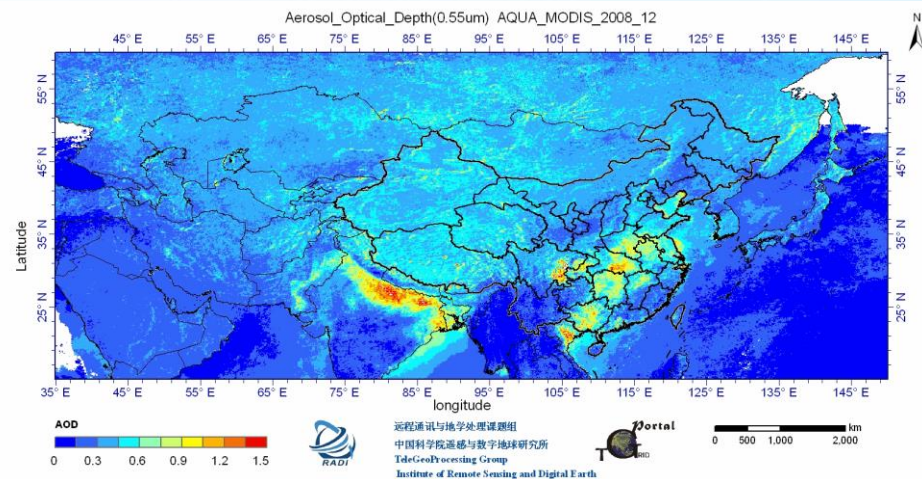
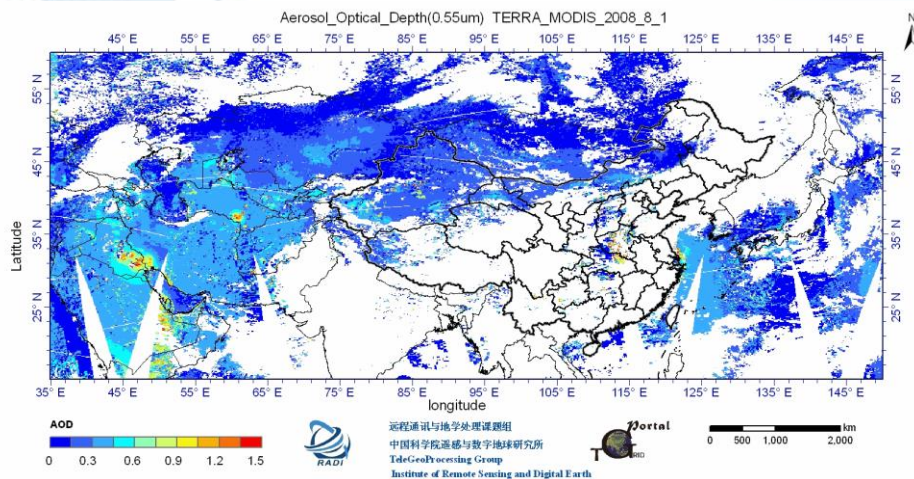


China Collection 2.0

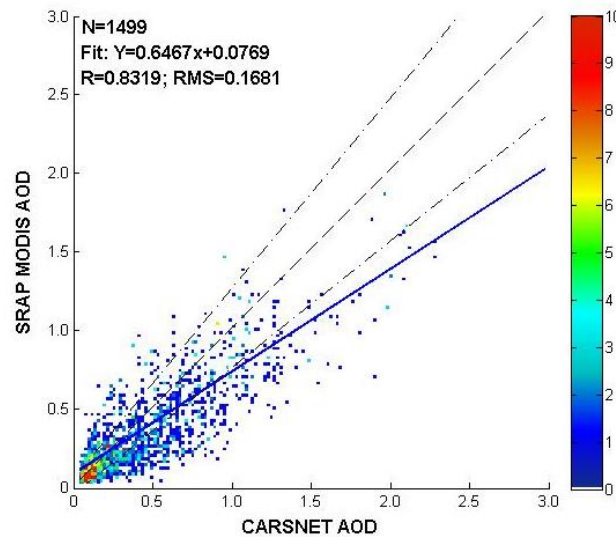
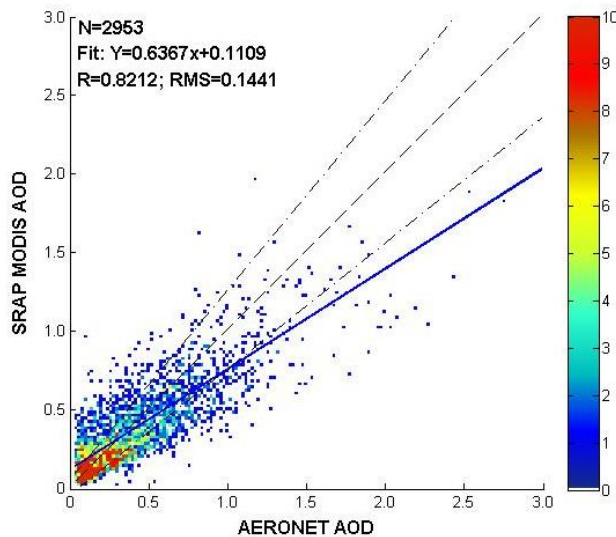
Coverage comparison among TGP/SRAP, NASA/DB and NASA/DT



Validation



2008 Mainland China and East Asia



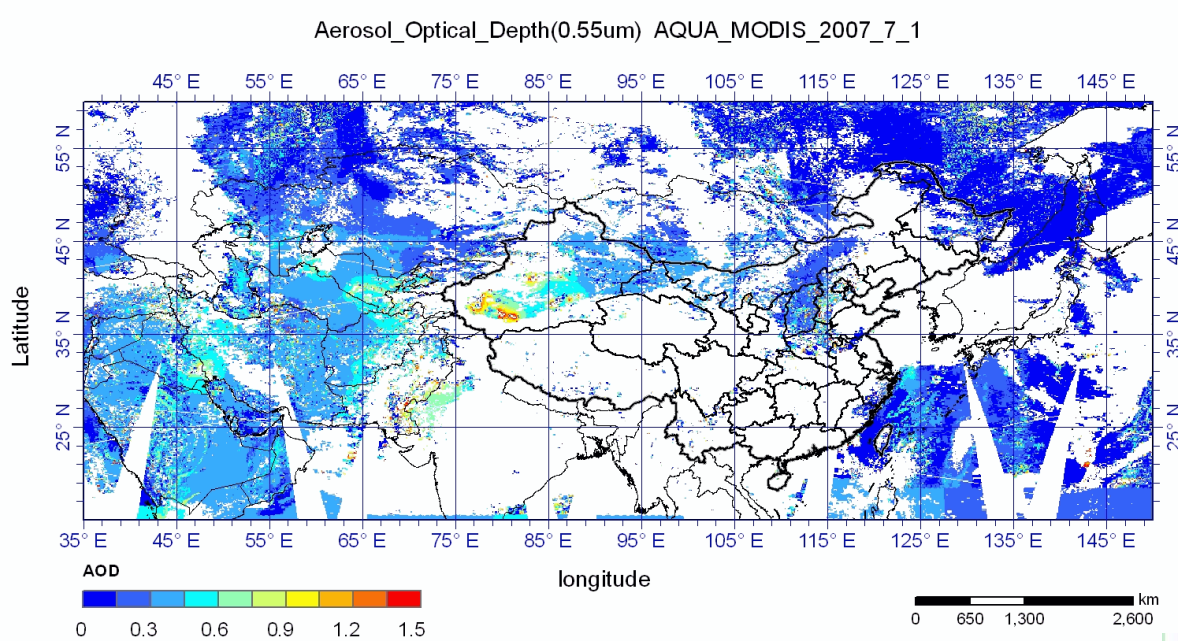
CARSNET



AOD data collection over Mainland China

China Collection 2.0 & 2.1

Aerosol_Optical_Depth(0.55um) AQUA_MODIS_2007_7_1



Spatial Resolution: 10km, 1km
Temporal Scale: from August 2002

(AOD at 1 km resolution)



Tel: (010) 64889540
 Mobile: 13910535998
 website: www.tgp.ac.cn
 Email: yxue@irsa.ac.cn

Professor Dr. Yong Xue

ENGLISH(联系我们)

遥感信息服务网格节点
 Remote Sensing Information Service Grid Node

首页 数据服务 网格 workflow 论文发表 科研成果 科研队伍

数据说明

本节点可提供TERRA和AQUA卫星MODIS数据提供的10km的AOD产品China Collection 1.0, 时间范围从2002年8月至2011年, 覆盖亚洲区域, 并将提供进一步细分的China Collection 2.0产品在其它传感器, 如AVHRR的AOD产品.

相关链接

- 中国科学院
- 中国科学院遥感应用研究所
- Grid
- HPCtech

数据结果显示与下载

数据源	卫星	传感器	波段	产品	时间	下载数据
TGP	TERRA	MODIS	1	AOD	2010-12-01	下载
TGP	TERRA	MODIS	1	AOD	2010-12-02	下载
TGP	TERRA	MODIS	1	AOD	2010-12-03	下载
TGP	TERRA	MODIS	1	AOD	2010-12-04	下载
TGP	TERRA	MODIS	1	AOD	2010-12-05	下载
TGP	TERRA	MODIS	1	AOD	2010-12-06	下载
TGP	TERRA	MODIS	1	AOD	2010-12-07	下载
TGP	TERRA	MODIS	1	AOD	2010-12-08	下载
TGP	TERRA	MODIS	1	AOD	2010-12-09	下载
TGP	TERRA	MODIS	1	AOD	2010-12-10	下载
TGP	TERRA	MODIS	1	AOD	2010-12-11	下载
TGP	TERRA	MODIS	1	AOD	2010-12-12	下载
TGP	TERRA	MODIS	1	AOD	2010-12-13	下载
TGP	TERRA	MODIS	1	AOD	2010-12-14	下载
TGP	TERRA	MODIS	1	AOD	2010-12-15	下载
TGP	TERRA	MODIS	1	AOD	2010-12-16	下载
TGP	TERRA	MODIS	1	AOD	2010-12-17	下载
TGP	TERRA	MODIS	1	AOD	2010-12-18	下载
TGP	TERRA	MODIS	1	AOD	2010-12-19	下载
TGP	TERRA	MODIS	1	AOD	2010-12-20	下载
TGP	TERRA	MODIS	1	AOD	2010-12-21	下载
TGP	TERRA	MODIS	1	AOD	2010-12-22	下载