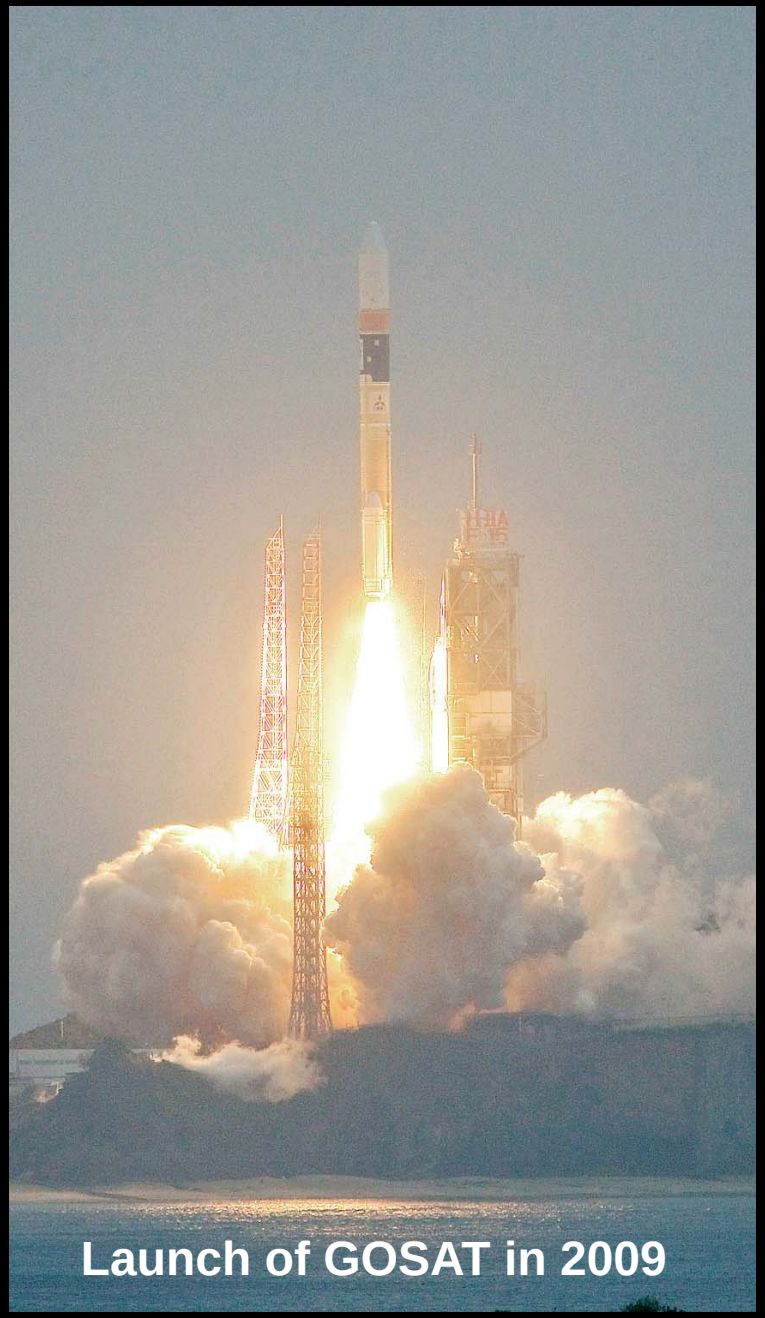
Atmospheric Pollution Monitoring Using GOSAT and GOSAT-2

Tsuneo Matsunaga
NIES GOSAT-2 Project Team
National Institute for Environmental Studies (NIES), Japan

Today's Topics

- Status of GOSAT and GOSAT-2
- GOSAT Air Pollution Watch
- Preparation of GOSAT-2 Validation
  - New TCCON site in Southeast Asia
  - Test of smaller FTS



Launch of GOSAT in 2009

GOSAT (Greenhouse gases Observing Satellite) is the world's first satellite dedicated to greenhouse gas monitoring from space.

GOSAT was successfully launched on January 23, 2009, and since then GOSAT has been monitoring the Earth's atmosphere continuously.

The successor, GOSAT-2, will be launched in FY2017. GOSAT-2 design reviews for spacecraft, instruments, and ground data system are ongoing.

Announcement (August 4, 2015)

- Around the noon of August 2nd, 2015 (Jananese Standard Time), the operation of Thermal Infrared (TIR) part of Fourier Transform Spectrometer (FTS) onboard GOSAT was terminated due to the sudden stop of its mechanical cooler to cool TIR detector to -200° C (≈ 70K).
- No impacts have been found in Shortwave Infrared (SWIR) part of FTS and Cloud and Aerosol Imager (CAI) so far. Carbon dioxide and methane observation by SWIR and aerosol/cloud observation by CAI are continued without termination.
- The root causes of the sudden stop of the cooler and treatments are under investigation.
- GOSAT has finished its nominal operation period (5 years) in January 2014, and is currently in its extended operation period.

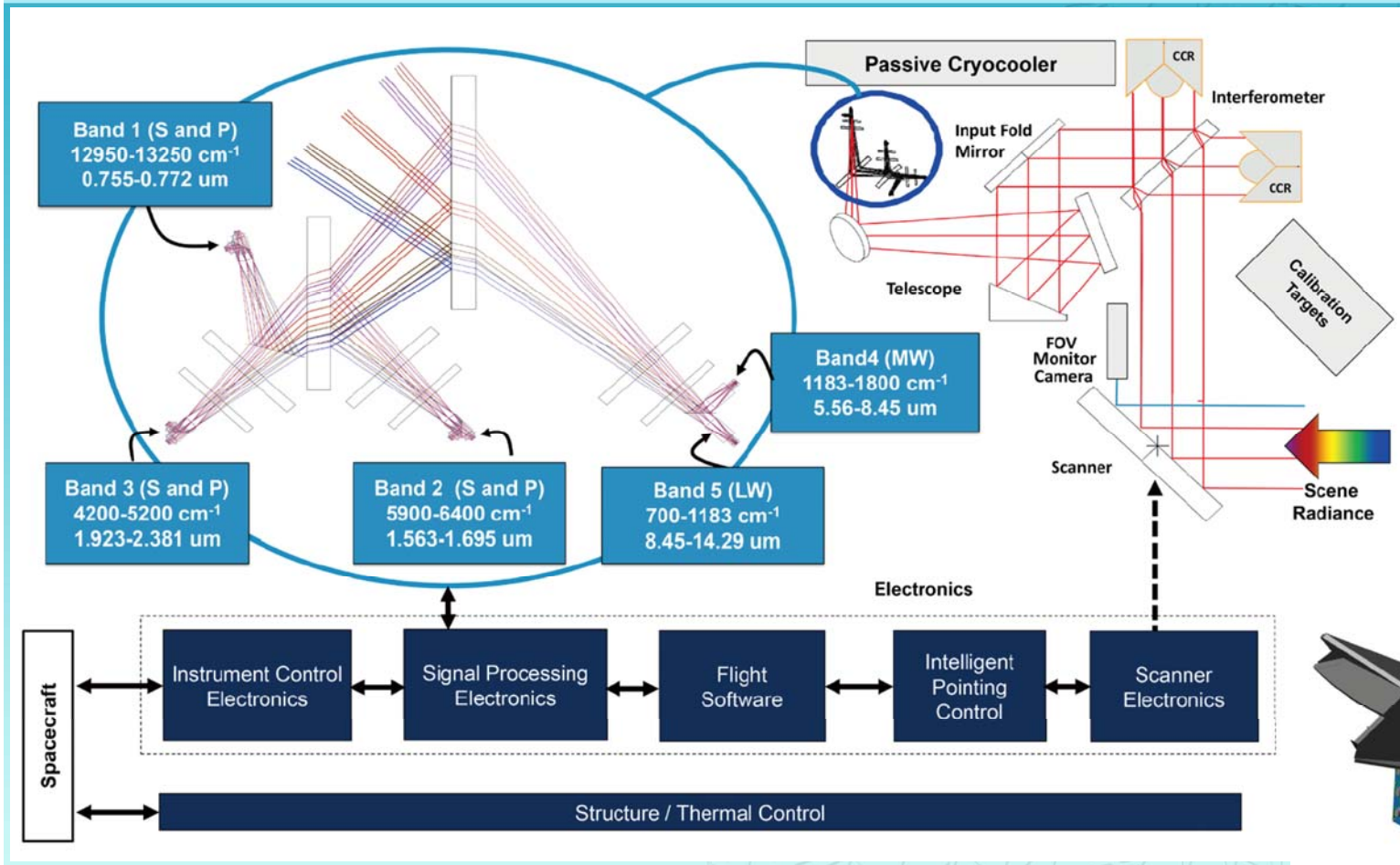
GOSAT-2 CG

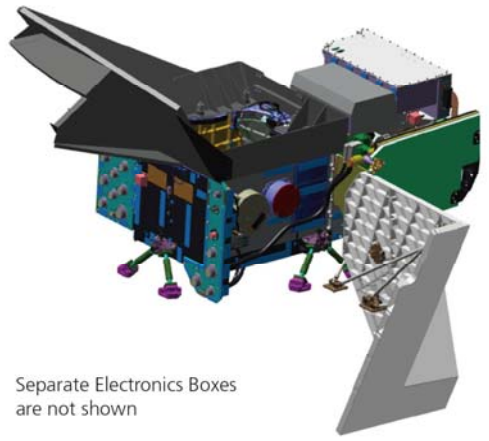
GOSAT-2 in Space

Quick Overview of GOSAT and GOSAT-2

	GOSAT Specifications	GOSAT-2 Requirements
Launch year and life time	Jan. 2009, 5 years	FY2017, 5 years
Satellite (Main body size, mass, power)	3.7 x 1.8 x 2.0 m, 1750kg, 3.8KW (EOL)	5.3 x 2.0 x 2.8 m, <2000kg, 5.0KW
Orbit (Type, altitude, repeat cycle, equator crossing time)	Sun synchronous, 666 km, 3 days, 13:00	Sun synchronous, 613 km, 6 days, 13:00±15 min
Target gases	CO_2, CH_4, O_2, O_3, H_2O	CO_2, CH_4, O_2, O_3, H_2O, CO
Fourier Transform Spectrometer (FTS and FTS-2)	Band 1 : 0.76 – 0.78 μm Band 2 : 1.56 – 1.72 μm Band 3 : 1.92 – 2.08 μm Band 4 : 5.6 – 14.3 μm IFOV = 10.5 kmϕ Pointing = ±20° (AT), ±35° (CT) Polarimetry = Band 1, 2, 3	Band 1 : 0.75 – 0.77 μm Band 2 : 1.56 – 1.69 μm Band 3 : 1.92 – 2.33 μm Band 4 : 5.5 – 8.4 μm Band 5 : 8.4 – 14.3 μm IFOV = 9.7 kmϕ Pointing = ±40° (AT), ±35° (CT) Polarimetry = Band 1, 2, 3
Cloud and Aerosol Imager (CAI and CAI-2)	Nadir B1 = 380 nm B2 = 674 nm B3 = 870 nm B4 = 1600 nm B1-B3 = 500 m / 1000 km, B4 = 1500 m / 750 km	B1-5: forward, B6-10:backward B1 = 343 nm B6 = 380 nm B2 = 443 nm B7 = 550 nm B3 = 674 nm B8 = 674 nm B4 = 869 nm B9 = 869 nm B5 = 1630 nm B10= 1630 nm B1-B4, B6-B9= 460 m / 920 km B5, B10 = 920 m / 920 km
Other new features of GOSAT-2 FTS-2	Intelligent pointing using FTS-2 FOV camera, fully programmable (target mode) observation, and improved SNR.	

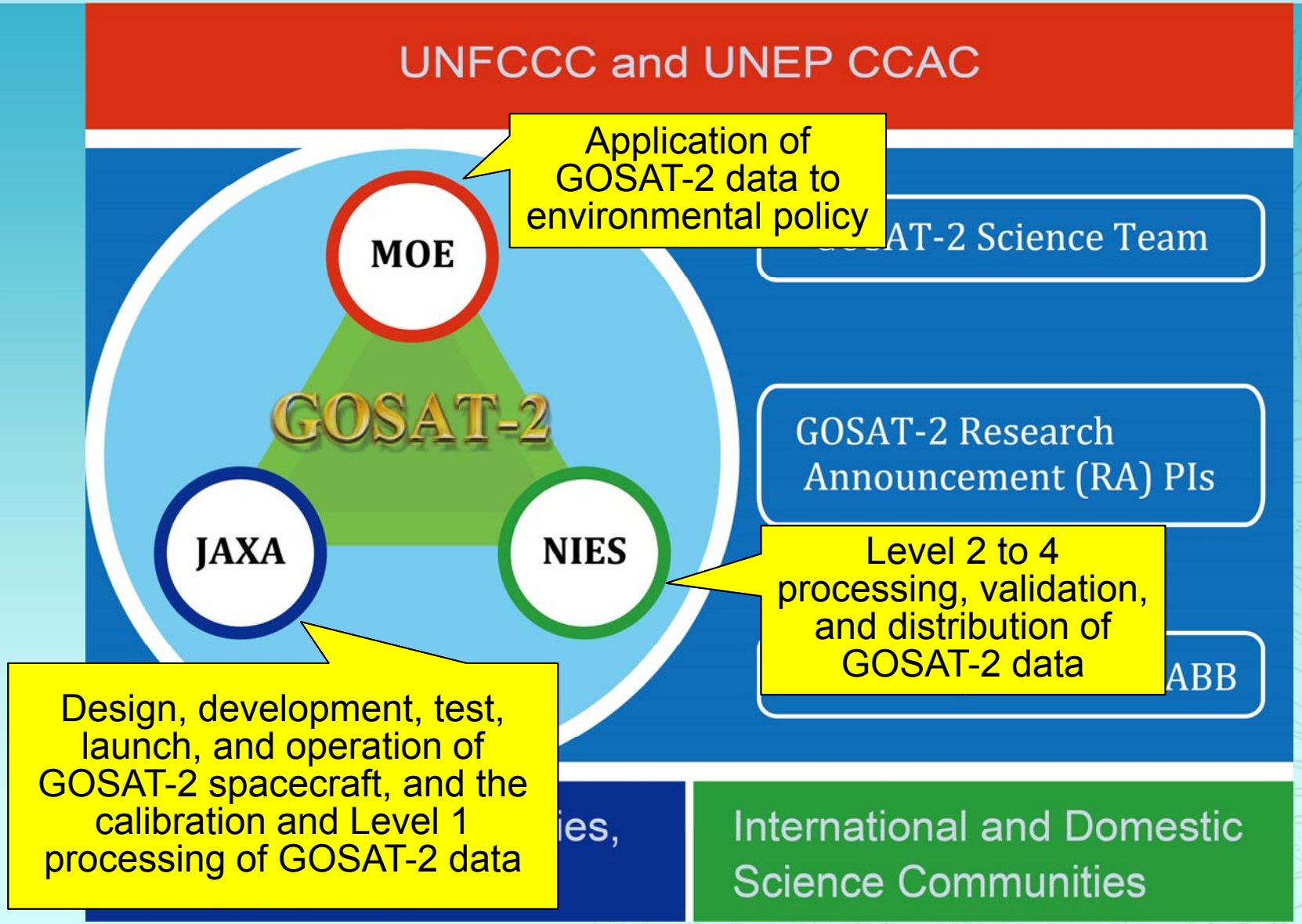
GOSAT-2 FTS-2
Optical Layout and External View





FTS-2 is designed based on CrIS(Cross-track Infrared Sounder) onboard NASA's Suomi NPP.

GOSAT-2 Joint Project



GOSAT Air Pollution Watch

- Japan has a satellite (GOSAT) and will have satelllites (GCOM-C and GOSAT-2) with sub km resolution UV imagers suitable for land aerosol / air pollution mapping (CAI, CAI-2, and SGLI).

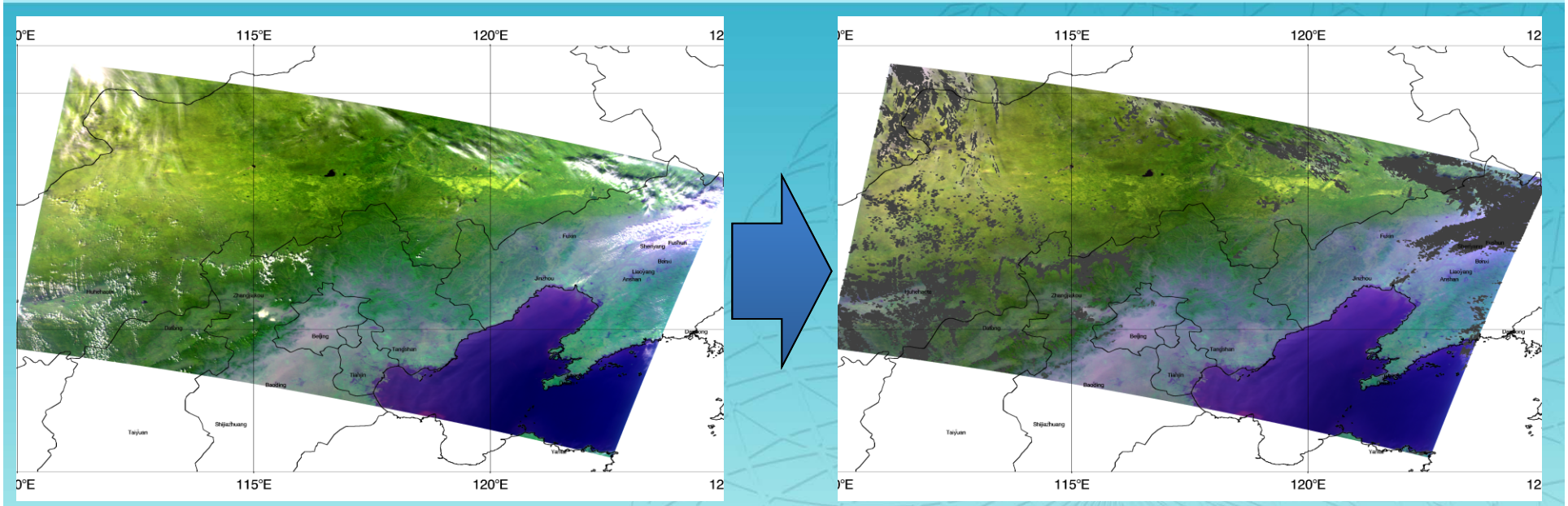
- Combined use of these satellites will enable us to monitor land air pollution frequently (daily) in quasi-realtime.

- ***GOSAT Air Pollution Watch*** is being designed for rapid processing / distribution of GOSAT CAI data for monitoring of air pollution caused mainly by particulate matters. Its testbed is already developed.

- Data processing algorithms in ***GOSAT Air Pollution Watch*** are based on but modified from GOSAT/GOSAT-2 algorithms for aerosol product generation to realize faster and timely data processing.

- Data from ***GOSAT Air Pollution Watch*** will be used to inform the current distribution of the polluted air. In addition, they will contribute to short term prediction of air pollution using atmospheric transport models.

GOSAT CAI Processing Flow
(1) Cloud Mask

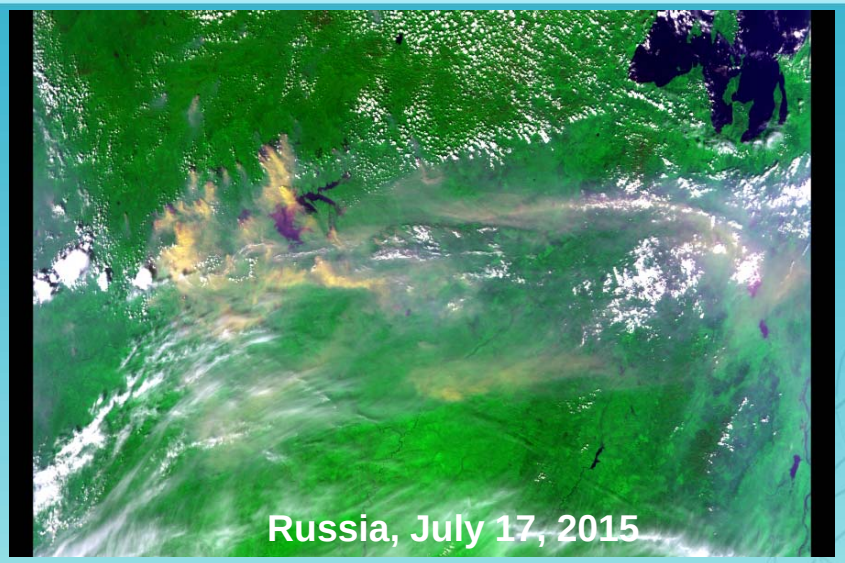


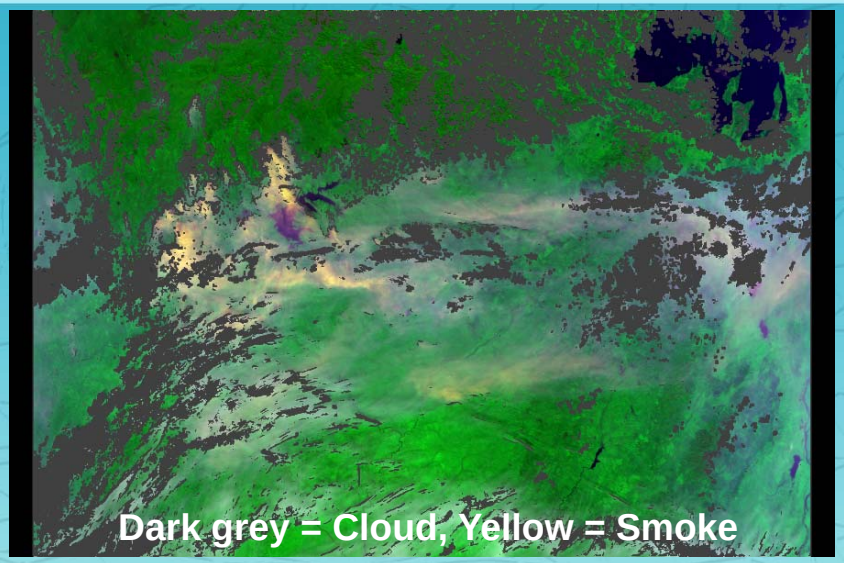
China, October 9, 2014

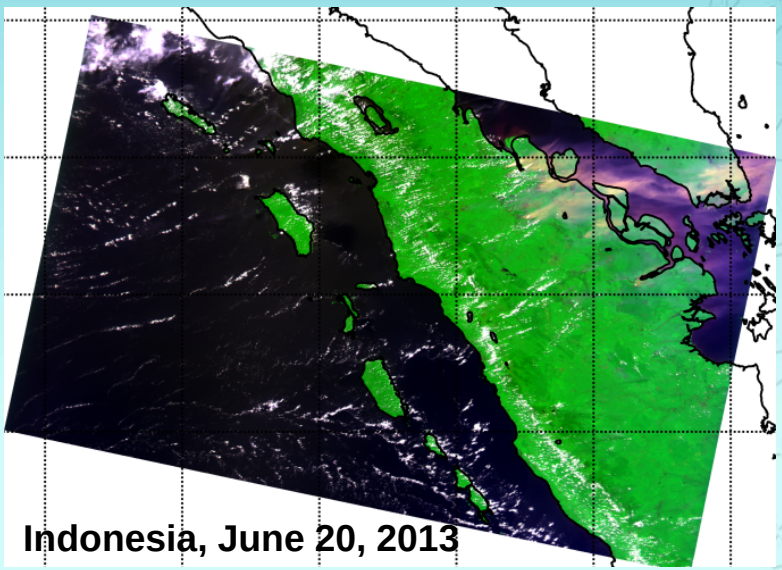
Dark grey pixels = Cloud
Pink pixels = Urban polluted air

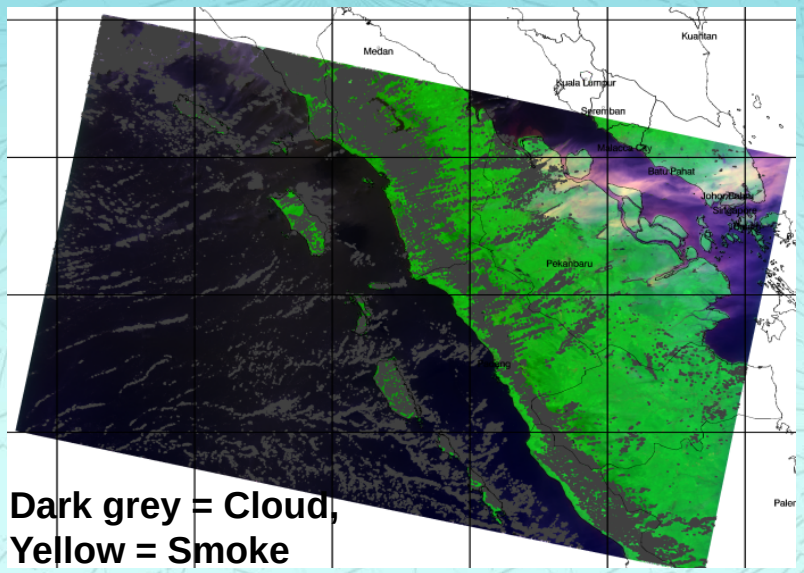
- Discriminate clouds from land, urban polluted air, dust, and smokes.
  - UV band brightness threshold (High UV reflectance => clouds)
  - UV band spatial smoothness (Smooth => other than clouds)
  - Current parameters are determined empirically using CAI images in Russia, China, and SE Asia.

GOSAT CAI Processing Flow
(1) Cloud Mask (Smoke case)

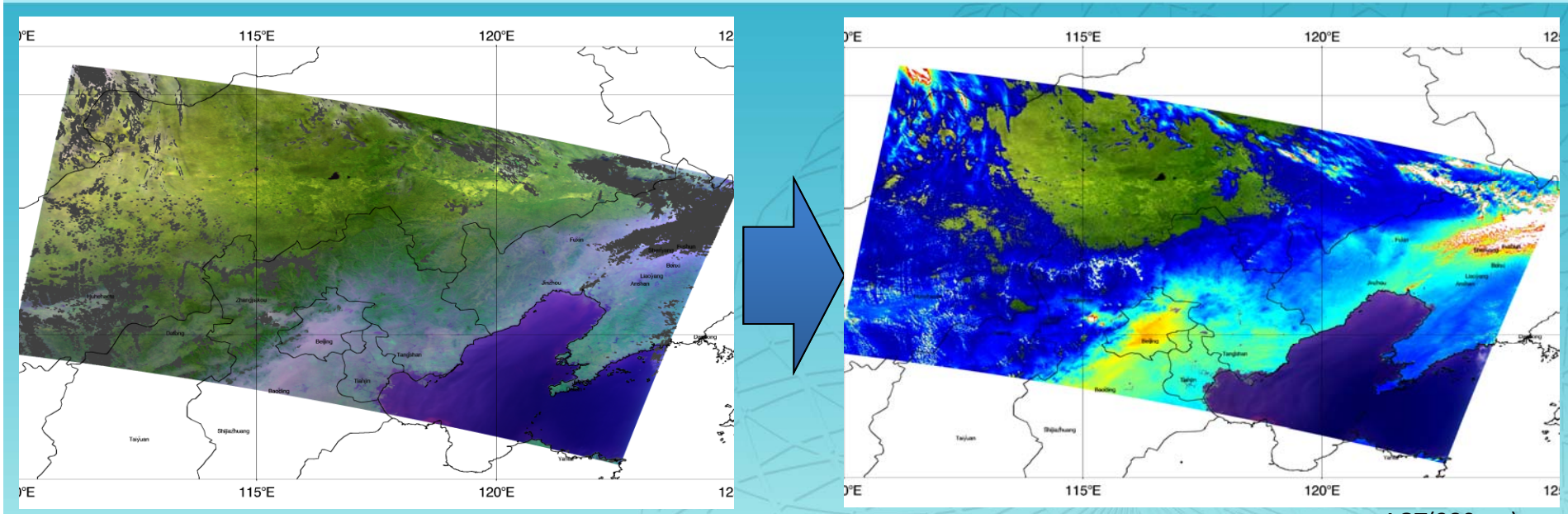








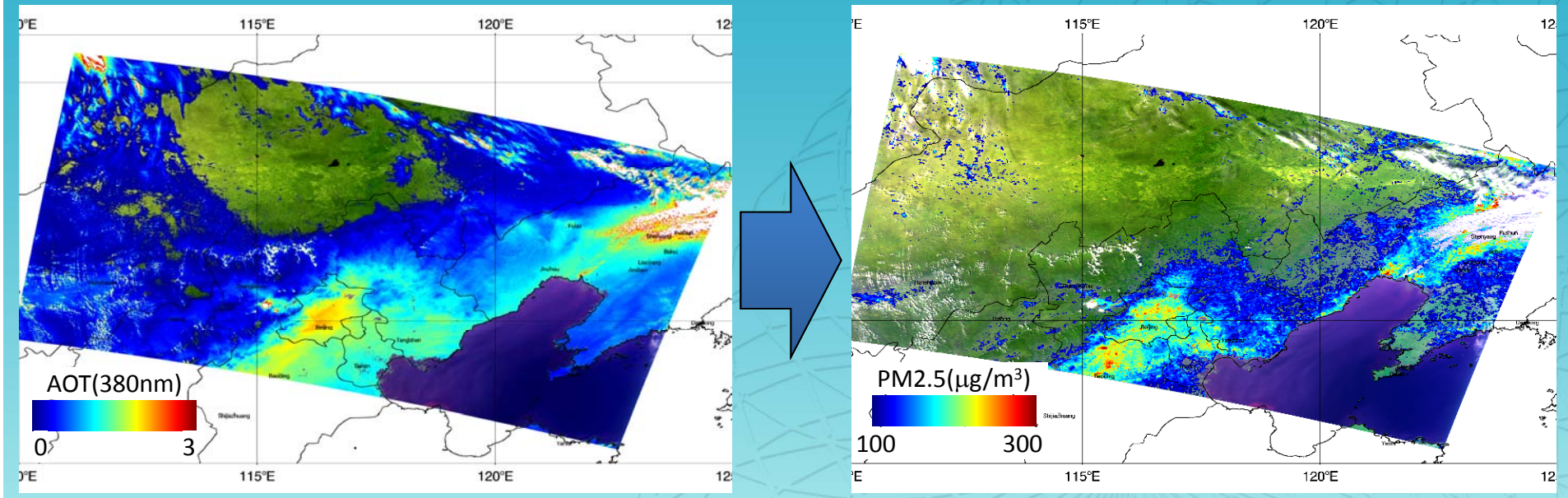
GOSAT CAI Processing Flow
(2) AOT(380nm) Estimation



China, October 9, 2014

- Estimate Aerosol Optical Thickness at 380 nm for non-cloud pixels.
  - Modified Kaufman Method (Fukuda et al., JGR, 2013) over land.
  - Use difference between observed and theoretical aerosol free surface reflectances in the UV region to estimate AOT (380).

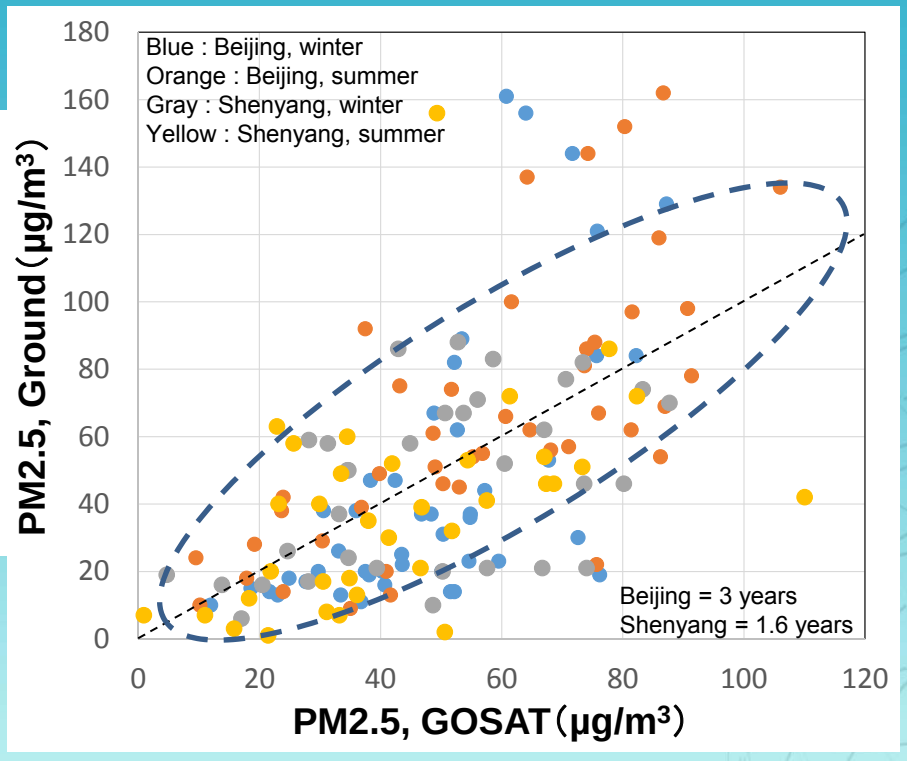
GOSAT CAI Processing Flow
(3) PM2.5 Estimation

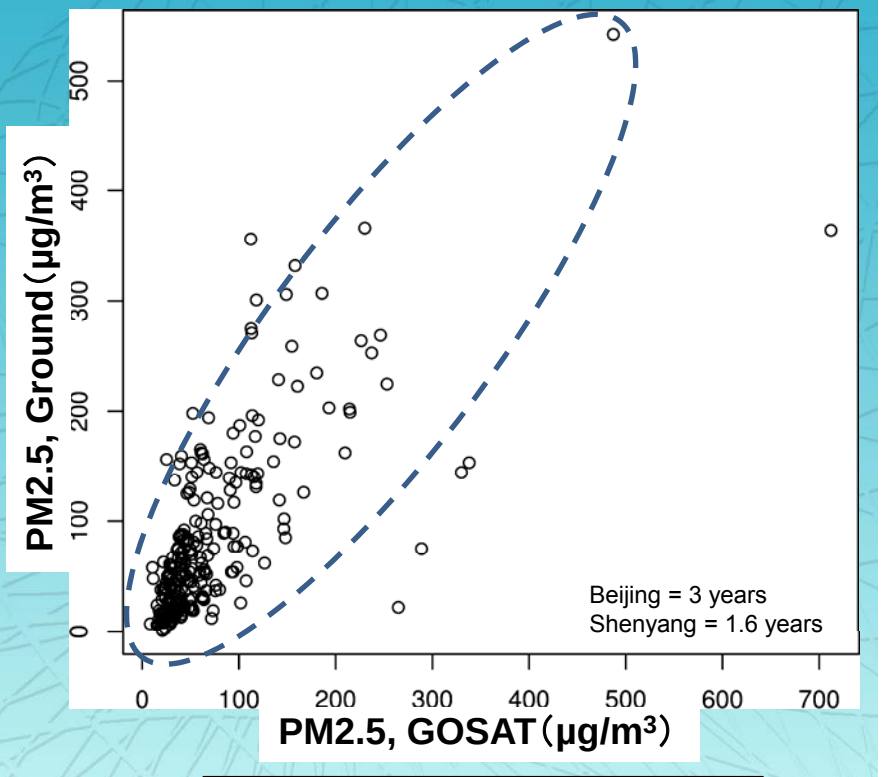


China, October 9, 2014

- Convert AOT(380nm) to PM2.5 concentration for non-cloud land pixels.
  - Empirical regression using AOT (380nm), observed spectral reflectances, PBL height, and humidity data is used in the conversion.
  - PM2.5 data measured in Beijing (3 years) and Shenyang (1.6 years), China, provided by US Embassy, are used in this study.

GOSAT CAI Processing Flow
(3) PM2.5 Estimation – Regression Residuals -



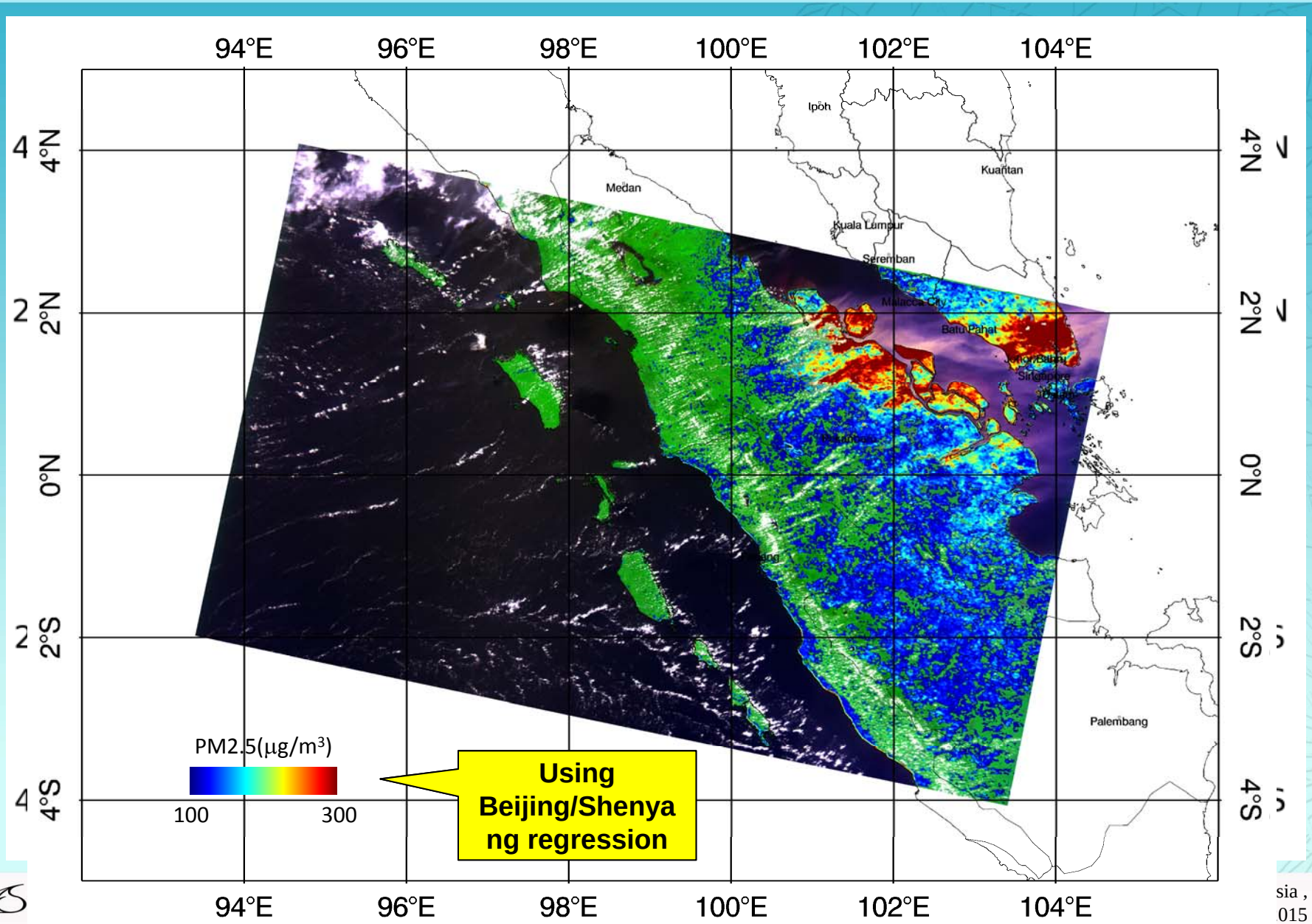


PM2.5 = 0 – 100 mg/m^3
RMSE = 21.4mg/m^3
N = 145

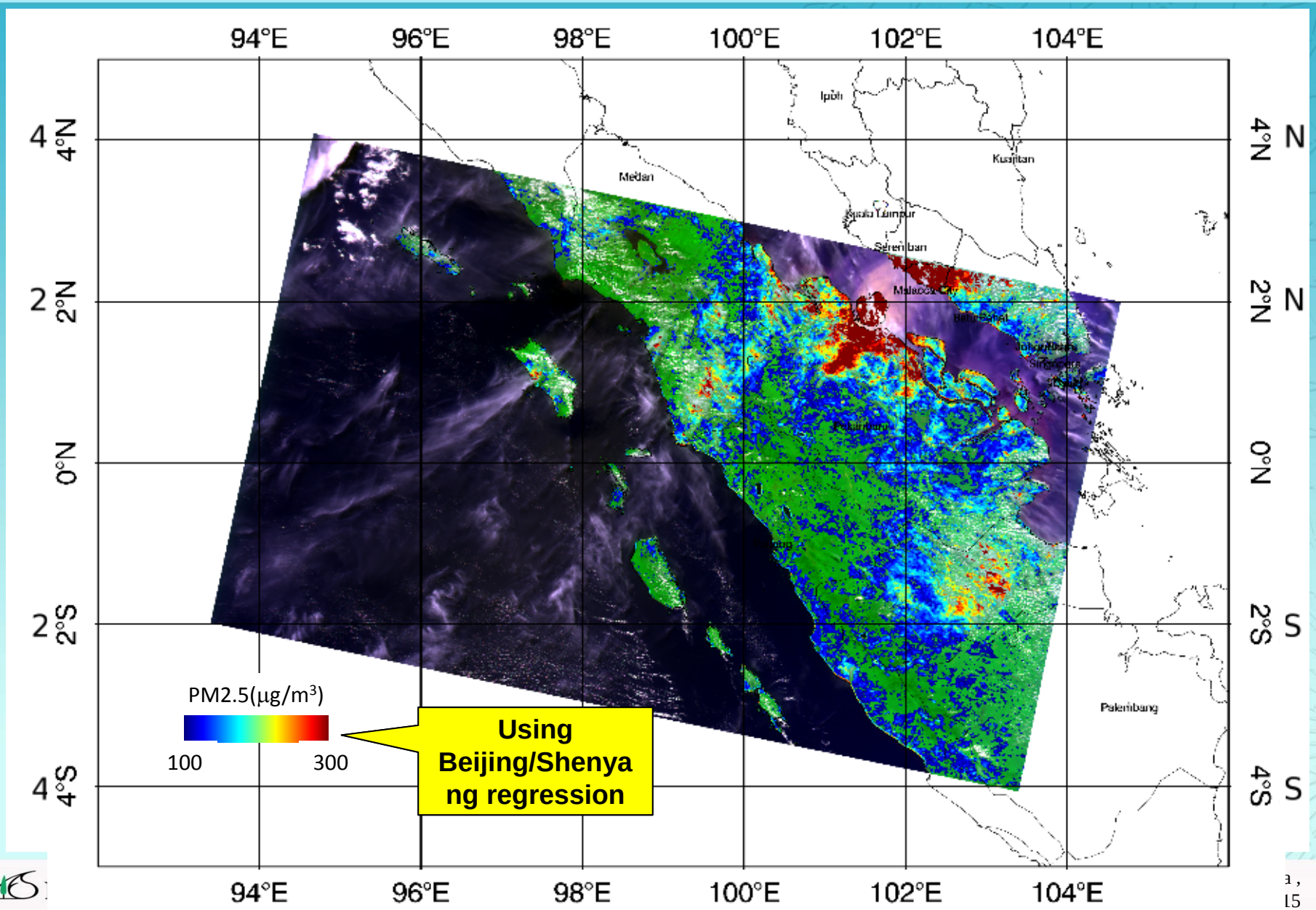
PM2.5 = 0 – 500 mg/m^3
RMSE = 67.8 mg/m^3
N = 256

- Regression residuals for Beijing / Shenyang data suggest PM2.5 estimation error is about 30 – 40 %.

GOSAT Air Pollution Watch
Sample 1: Indonesia June 20, 2013(P9F31)



GOSAT Air Pollution Watch
Sample 2: Indonesia June 23, 2013(P9F31)



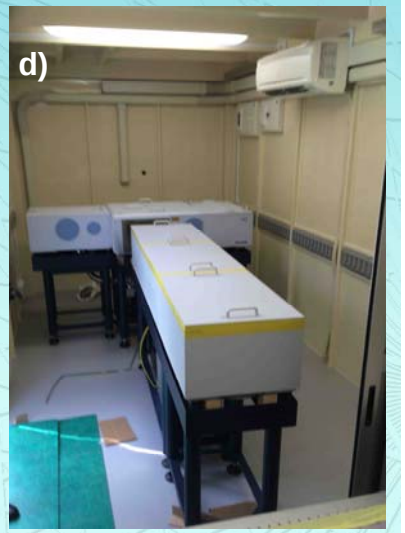
Call for ***GOSAT Air Pollution Watch*** Partners

GOSAT-2 PROJECT AT THE NATIONAL INSTITUTE FOR ENVIRONMENTAL STUDIES

- A testbed of ***GOSAT Air Pollution Watch*** was successfully developed using urban air pollution data from Beijing and Shenyang, China.
- NIES would like to issue “Call for new ***GOSAT Air Pollution Watch*** partners” to extend the coverage of the testbed to Southeastern and South Asian countries.
  - NIES will provide GOSAT raw and processed data (e.g.: air pollution maps) in quasi-real time.
  - Partners will provide local air pollution data (several years from 2009, hourly or higher sampling) such as BC and PM2.5 concentrations for regression analysis.
- The collaborative testbed will evolve into a multi-satellite system after GOSAT-2 and GCOM-C launches in coming years.
- These activities may have close relationships to JCM (Joint Crediting Mechanism) activities between Japan and asian countries.
- Contact : Tsuneo Matsunaga (matsunag@nies.go.jp)

A New TCCON Site in Southeast Asia
(Total Carbon Colunm Observing Network)

- **FY 2014**
  - Potential sites were identified and visited.
  - Bruker 125 HR FTS with solar tracker were installed in the container at NIES.
- **FY2015**
  - Decide the site considering scientific, logistical, and human resource aspects.
  - Negotiate with various stakeholders and conclude MOU.
  - Adjust and evaluate the newly procured FTS at NIES
- **FY2016**
  - Conclude all the contracts
  - Move FTS from Tsukuba to the site and start its operation



a) Locations oh three candidate sites in Philippines, b) Landscape at Burgos, c) Installation of a container for FTS at NIES, d) A high resolution FTS in the container.

Smaller (cheaper) FTS are being tested...

- Bruker 125 HR FTS is commonly used among TCCON stations. But it is so expensive and large to install many places.
- Currently, cheaper and smaller FTS such as Bruker EM27 are being tested to evaluate its observation performance as well as easiness of operation and maintenance.
- If smaller FTS work well, we may increase the number of validation sites especially in Southeast asia.

EM27 test at Caltech, CA

EM27 test in Railroad Valley, NV

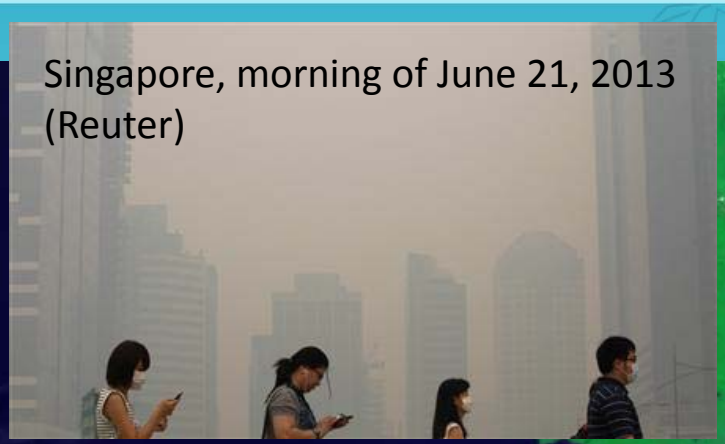
Thank you for your attention.

For more information, send e-mails to
gosat-2-info@nies.go.jp

or

Visit our website:
http://www.gosat-2.nies.go.jp

Forest Fires in Indonesia and Atmospheric Pollution in Singapore



Urban Atmospheric Pollution in China Observed by GOSAT CAI

GOSAT-2 PROJECT
AT THE NATIONAL INSTITUTE FOR ENVIRONMENTAL STUDIES