GOSAT and GOSAT-2:
Achievements and Future Plan

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With Tatsuya Yokota, Masakatsu Nakajima, Gen Inoue, Teruyuki Nakajima, and Ryoichi Imasu
GOSAT
Greenhouse Gas Observing Satellite
(January 2009 - )

Image Courtesy: JAXA
GOSAT is a Japanese earth observation satellite, launched in January 2009, for CO2 and CH4 measurement from space.

GOSAT successfully demonstrated the power of CO2 and CH4 measurement from space.
- 4-year global observation of CO2 and CH4
- Precision of “single shot” CO2 retrieval $\approx 2$ ppm
- Significant error reduction in global CO2 flux estimation by adding GOSAT CO2 data
- New science topics such as chlorophyll fluorescence.

GOSAT experienced several difficulties:
- Data scarcity
data scarcity cloud, hazy atmosphere, nighttime, winter in high latitude, ...
- Remaining uncertainty / instability in flux estimation
GOSAT “Seasonal” XCO2 2.5 Degree Maps
July 2012 – April 2013

GOSAT XCO2 Monthly Regional Averages
US and Australia
June 2009 – April 2013
Global (64 regions) Monthly Flux Map from GLOVALVIEW and GOSAT data (Maksyutov et al., ACP, 2013)

Time series of monthly fluxes (g C/m²/day) for June 2009 to May 2010. The graphs show a prior fluxes (green lines), fluxes estimated from GV data alone (red lines), and fluxes estimated from GV and GOSAT retrievals (blue lines). The error bars show flux uncertainties. The gray vertical bars represent percent reduction in the uncertainty by adding GOSAT data.
Timeline of XCO2 Observation Satellites

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Yellow: Designed life time
Green: Extended operation
Pink: End of mission

We are here.
In 2011, Ministry of the Environment (MOE), Japan Aerospace Exploration Agency (JAXA), and National Institute for Environmental Studies (NIES) agreed to start development of the GOSAT’s successor, GOSAT-2, to be launched in early 2018.

- GOSAT designed mission lifetime is 5 years and will end in January 2014.

It is expected that GOSAT-2 will contribute to:

- Continuation and enhancement of GOSAT observation
- Carbon cycle science
- Early detection of changes of carbon cycle
- Verification of national GHG emission inventories
- Carbon emission reduction policies such as REDD+ and JCM (Joint Crediting Mechanism)

Planned improvements of GOSAT-2

- Enhanced (land) aerosol mapping capability (CAI-2)
- Carbon monoxide retrieval (FTS-2)
- More capable pointing mechanism (FTS-2)
- Various engineering improvements.
GOSAT-2 Observation and Carbon Cycle Science

Continue and enhance GOSAT observation
- Long-term global monitoring of GHGs from space

New scientific topics
- Improvement of terrestrial ecosystem models
- Monitoring and modelling of emission from forest/peat fire
- Monitoring of oceanic flux
- Monitoring of large (point) sources
- Detection of carbon cycle change in subcontinental scale
- Others (e.g. Chlorophyll fluorescence)

Contribute to carbon cycle related climate science

Monitor carbon cycle changes due to climate change and human activities

Reduce uncertainty in future climate prediction

Policies on emission reduction targets

Policies on emission reduction efforts (e.g. REDD+ and JCM) and adaptation to climate change

International collaboration

Climate Change Policies
GOSAT-2 Requirements
XCO2 precision and accuracy

- GOSAT achieves “single shot” precision of ≈2 ppm.

- **GOSAT-2 XCO2 precision**: enough to reveal regional XCO2 behaviour around tropical rain forests.

- Simple case studies suggest 0.5 ppm precision of monthly XCO2 for 5 degree mesh.
  - Better “single shot” precision
    - improvements on instrument and algorithm
  - More data for averaging

- **GOSAT-2 XCO2 absolute accuracy**: Global and regional bias errors should not affect the flux estimates significantly.
  - We need more studies to quantify this requirement.
Carbon tracker data is the average CO2 concentration in the free troposphere (1.2 – 5.5 km altitude. To calculate column CO2 gradient, the CO2 concentrations below 1.2 km and above 5.5 km are assumed to be constant.

http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/
GOSAT-2 Requirements
CO2 Flux Estimation

• Requirements on region or grid size:
  - Urban area and project-level REDD+ $\approx 10^{1-2}$ km
  - Current global grid $\approx 10^{2-3}$ km
  - Current global land 42 region $\approx 10^{3}$ km
  - How do we reconcile this mismatch? (e.g. Role sharing with other satellites)

• Requirement on flux uncertainty:
  - To facilitate discussion on regional carbon balance, each region should be classified into, at least, three categories (Source / Sink / Neutral) considering flux uncertainty.
  - Current NIES L4A product : 42 land regions x 12 months = 504 data
    Neutral : $\text{abs(flux)} < 0.2 \text{ GtC/region/year}$,
    Source : $\text{flux} > \text{uncertainty}$, Sink : $\text{flux} < -\text{uncertainty}$
    Neutral = 28 %, Source = 25 %, Sink = 14 %, Unclassified = 33%
  - GOSAT-2 : The percentage of “Unclassified” should be significantly reduced (e.g. Unclassified < 3%).
### Specifications for the FTS-2

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<td><strong>Spectral coverage (μm)</strong></td>
<td>0.749 ~ 0.775</td>
<td>1.56 ~ 1.69</td>
<td>1.92 ~ 2.08</td>
<td>2.32 ~ 2.38</td>
<td>5.5 ~ 14.3</td>
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<td><strong>Spectral resolution (cm⁻¹)</strong></td>
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<td>0.27</td>
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<td><strong>Polarized light observation</strong></td>
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<td><strong>Field of view at nadir (km)</strong></td>
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<td>Corresponds to less than 10.5</td>
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### Specifications for the CAI-2

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For more details, see Shiomi’s poster
GOSAT-2 will inherit from GOSAT

- Organizational structure: MOE, JAXA, and NIES
- Instruments: FTS-2 and CAI-2
  - Spectral data quality has a higher priority than sampling density.
- Algorithms for GOSAT Standard Products (Level 2 and Level 4)
- Validation including international efforts such as TCCON
- GOSAT-2 data policy and Research Announcement (RA) will be discussed.

• JAXA and NIES will contribute GOSAT/GOSAT-2 exhibition materials to “Japan GEO” booth.

• JAXA has submitted “Request for Side Event” to GEO Secretary.
  • Title: “Greenhouse Gases Observation from Space”
  • Proposed Date and Time: 15:00 – 16:30, January 16, 2014
Policy-relevant Recommendations and Potential Users

Please close your PPT with one final slide containing one or more policy-relevant recommendations (to be conveyed to decision makers) needed to establish a global carbon cycle observing and analysis system.

Please try to identify potential users of the carbon data products, and discuss on how to involve them.

**Coordinations among satellite and validation projects**
- To avoid data gaps between satellites
- To maintain long-term consistency among satellite data sets
  - validation
  - common quality control

**Potential Users**
- GHG inventory editors?
- REDD+/JCM Project Managers?
Thank you