Highlights from the 14th International Workshop on Greenhouse Gas Measurements from Space

Ray Nassar (Environment and Climate Change Canada)

CEOS Chair Priority Workshop on GHGs
European Commission, Joint Research Centre, Ispra, Italy, June 18, 2018

IWGGMS Objective & History

Exchange information on the state of the art in remote sensing of CO_2, CH_4, and other greenhouse gases, and foster international collaboration, focusing on:

- Existing and on-going missions
- Retrievals and validation
- Use of the data for flux/source estimation
- Future missions

186 Registered Participants,

51 Talks, 90 Posters in 2018

1 – Tokyo, Japan, April 2004

2 – Pasadena, USA, March 2005

3 – Tsukuba, Japan, May 2006

4 – Paris, France, June 2007

5 – Pasadena, USA, June 2008

6 – Kyoto, Japan, January 2010

7 – Edinburgh, UK, May 2011

8 – Pasadena, USA, June 2012

9 – Yokohama, Japan, June 2013

10 – Noordwijk, The Netherlands, May 2014

11 – Pasadena, USA, June 2015

12 – Kyoto, Japan, June 2016

13 – Helsinki, Finland, June 2017

14 – Toronto, Canada, May 2018

https://iwggms14.physics.utoronto.ca/presentation-archive/

Precision, Accuracy, Resolution, and Coverage: A few insights from GOSAT and OCO-2

David Crisp, Annmarie Eldering, Christopher W. O'Dell

- GOSAT and OCO-2 have met their precision and accuracy requirements and helped us to understand what we need for the next generation of missions.

Fast Forward to 2015: COP21

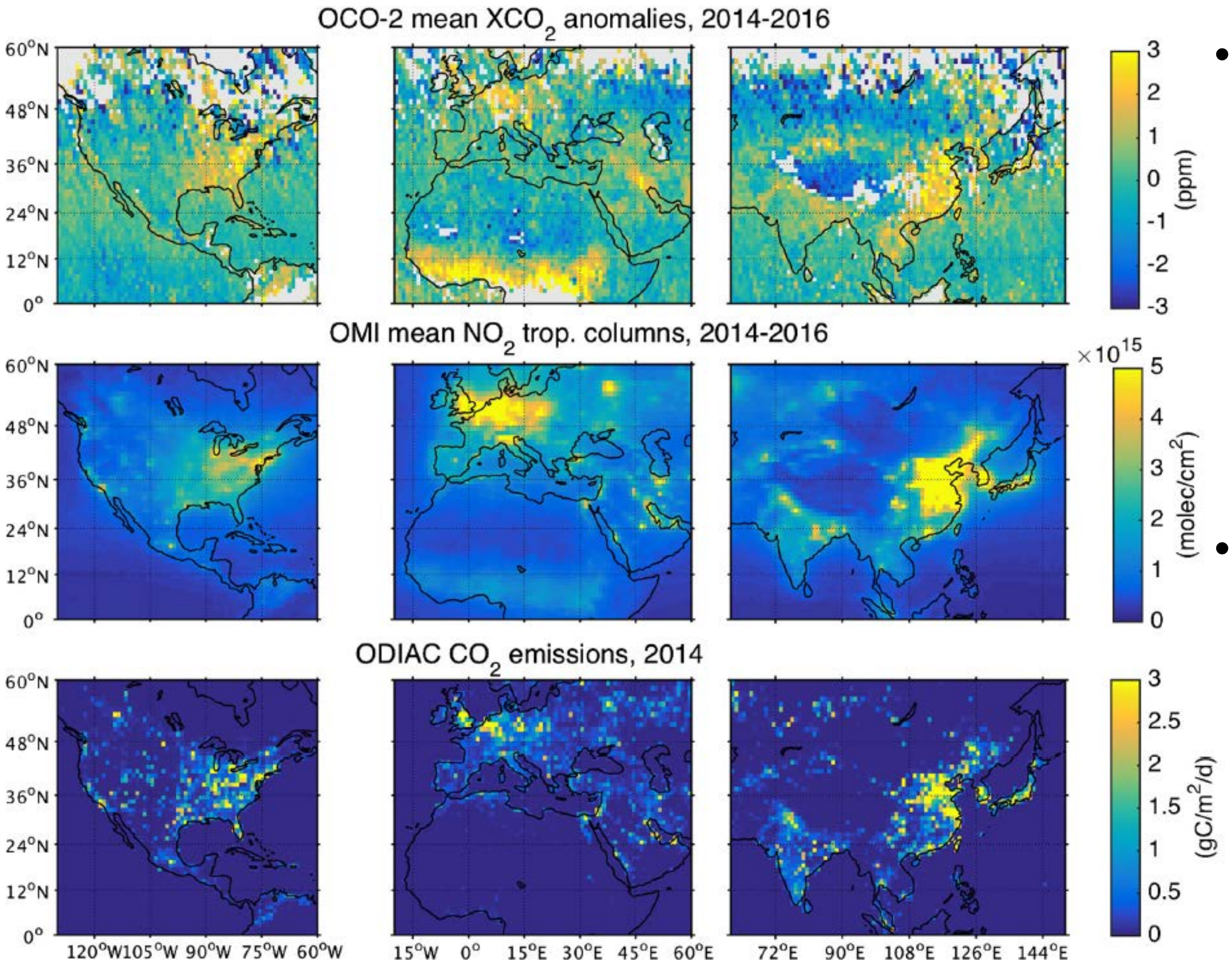
LABEL
PARIS2015
COP21·CMP11

To support the Paris Agreement:

- The overall goal is to develop a sound, scientific, measurement-based approach that:
  - reduces uncertainty of national emission inventory reporting,
  - identifies large and additional emission reduction opportunities
  - provides nations with timely and quantified guidance on progress towards their emission reduction strategies and pledges (Nationally Determined Contributions, NDCs)
- In support of these efforts, atmospheric measurements of greenhouse gases from satellites could
  - Improve the frequency and accuracy of inventory updates for nations not well equipped for producing reliable inventories, and
  - help to “close the budget” by measurement over ocean and over areas with poor data coverage
- We now have strong support, but new marching orders

Global XCO_2 anomalies as seen by OCO-2

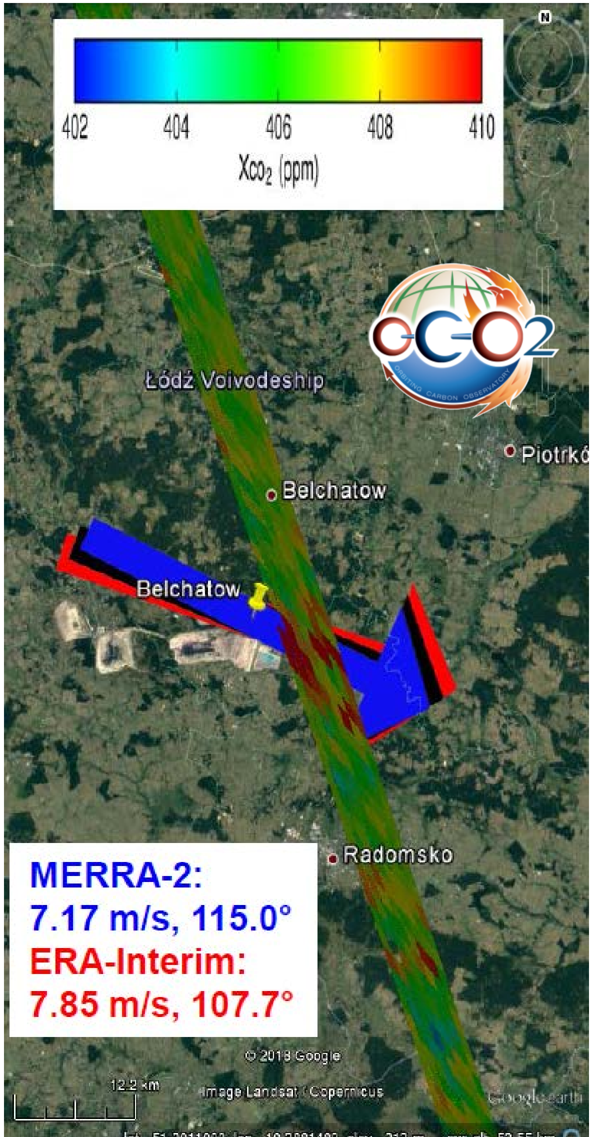
Janne Hakkarainen, Iolanda Ialongo, Shamil Maksyutov and David Crisp



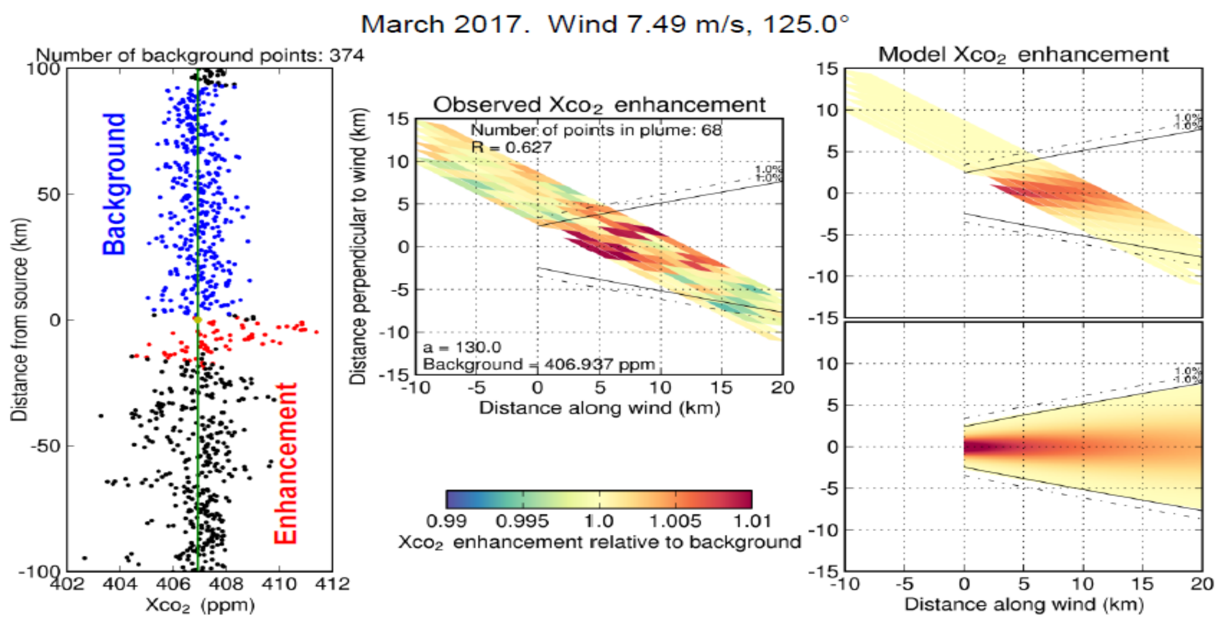
- Hakkarainen et al. (2016, GRL) demonstrated that XCO_2 enhancements in OCO-2 data could be traced to either fossil fuel use or biomass burning
- More recently extending their method to look at finer time scales

Advances in Quantifying Power Plant CO_2 Emissions from Space

Ray Nassar, Cameron MacDonald, Tim G. Hill, Chris McLinden, Debra Wunch, Dylan B.A. Jones, and David Crisp



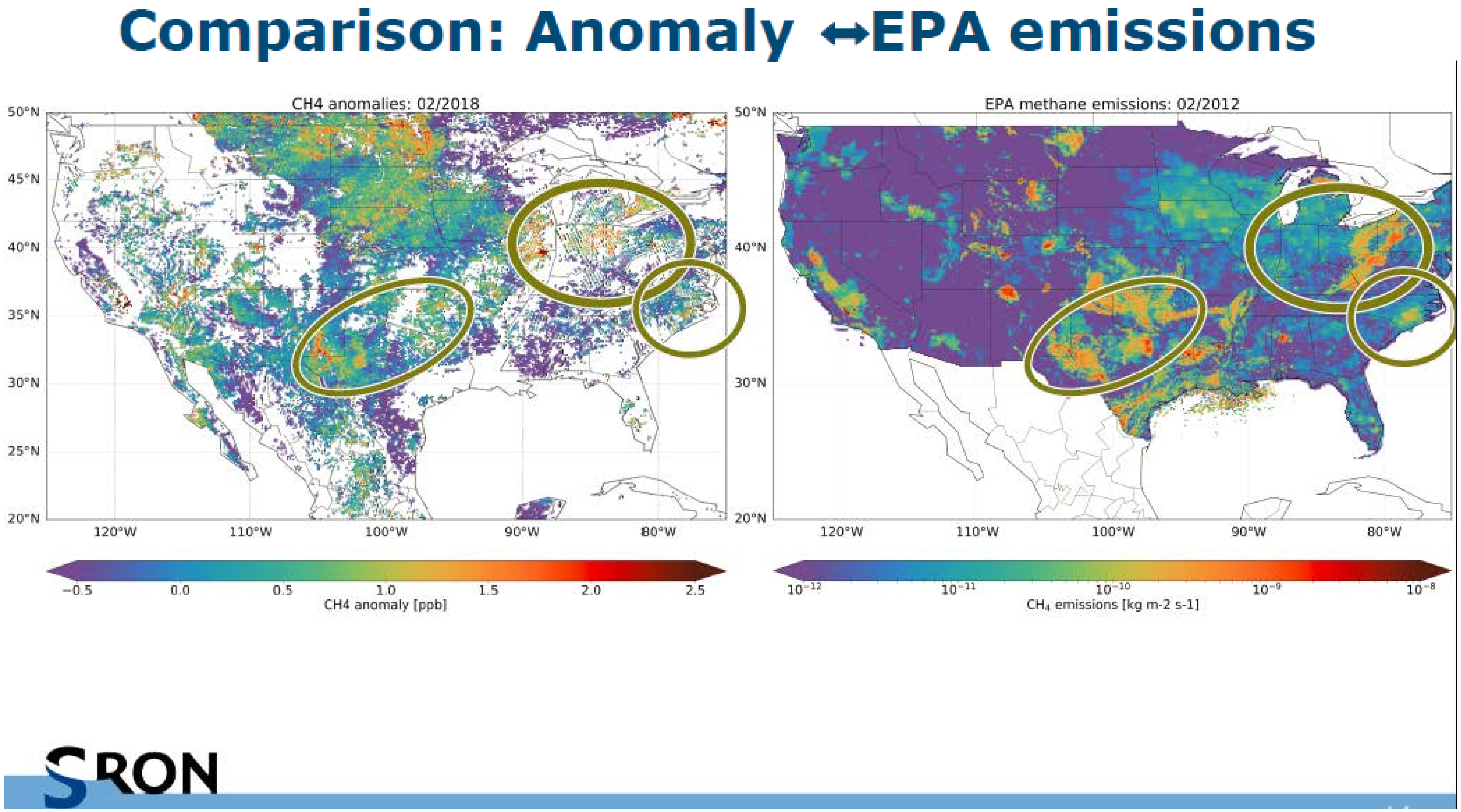
- Nassar et al. (2017, GRL) was first quantification of CO_2 emissions from individual power plants from space
- OCO-2 versions 7 & 8 show good consistency, but small improvements with use of v8
- New OCO-2 close flyby of Europe's largest power plant is promising, but likely has topography-related bias requiring a correction during processing (v9)
- Also described new statistical studies on US EPA data to try to quantify number of overpasses needed for accurate *annual* emission quantification



First methane retrievals and hotspot identification with TROPOMI

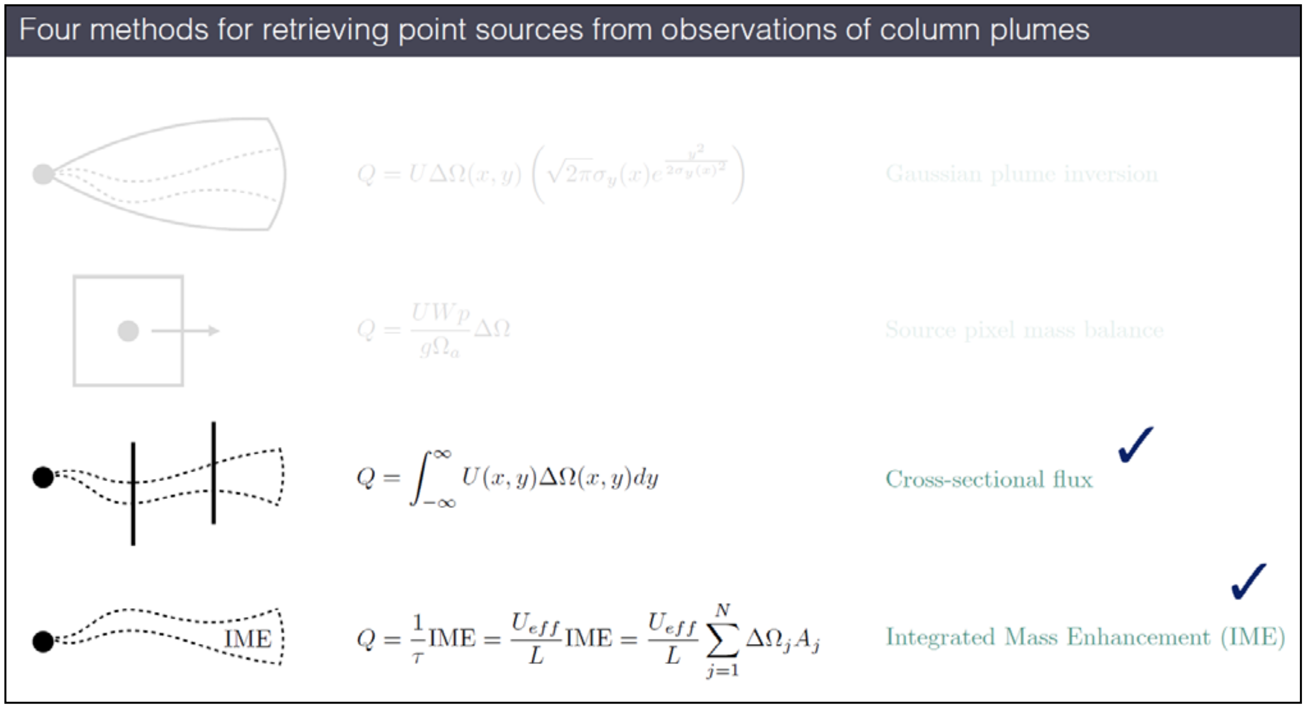
Haili Hu, Jochen Landgraf, Sudhanshu Pandey, Rob Detmers, Tobias Borsdorff, Joost aan de Brugh, Andre Butz, Ilse Aben, Sander Houweling, Coleen Roehl, Laura Iraci, Paul Wennberg, Otto Hasekamp

- TROPOMI-GOSAT CH_4 comparisons suggest similar quality data
- XCH_4 anomaly over the US shows clear evidence for CH_4 enhancement due to anthropogenic and wetland emissions



Quantifying methane point sources from fine-scale (GHGSat) satellite observation of atmospheric plumes

Daniel Varon, Daniel J. Jacob, Jason McKeever, Dylan Jervis, Berke O. A. Durak, Yan Xia, Yi Huang



- Comparison of methods for retrieving point source emissions from column observations of plumes reveals the strengths and weaknesses of different methods
- CO_2 and CH_4 may require different approaches due to typical scales: Power plant (CO_2) vs. leaks in infrastructure (CH_4)

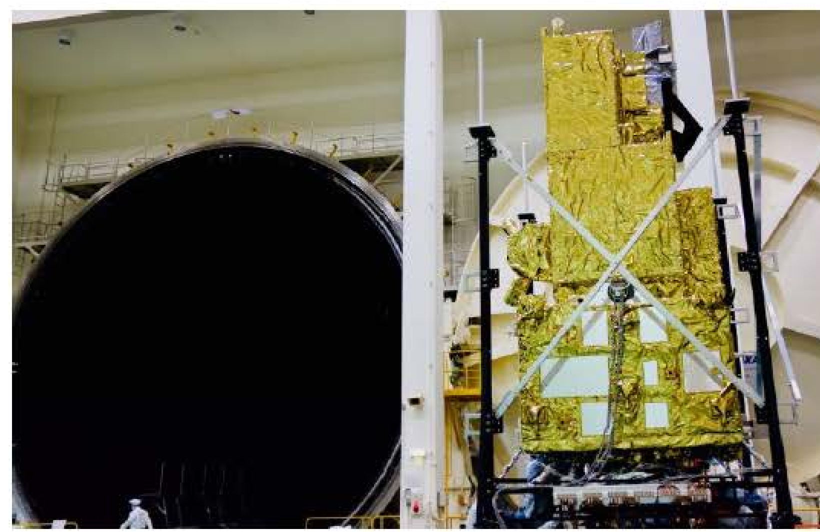
- GHGSat Inc. is a commercial Canadian entity that launched a 15 kg satellite with a Fabry-Perot Spectrometer in 2016 and plan to launch follow-on missions to establish a constellation. GHGSat-D images CH_4 and CO_2 columns at ~30x30 m^2, but precision is ~7.5% for CH_4 and ~30% for CO_2 (Durak et al. 2017, IWGGMS talk)

- Bluefield is a US company with similar (although more ambitious plans) for a constellation of ~20 microsatellites using gas correlation spectrometers for high spatial resolution CH_4 observations

Recent Progress of GOSAT Project and Preparation for GOSAT-2

Tsuneo Matsunaga, Akihide Kamei, Shamil Maksyutov, Isamu Morino, Makaoto Saito,
Hibiki Noda, Hirofumi Oyama, Fumie Kawazoe, Yukio Terao, and Osamu Uchino

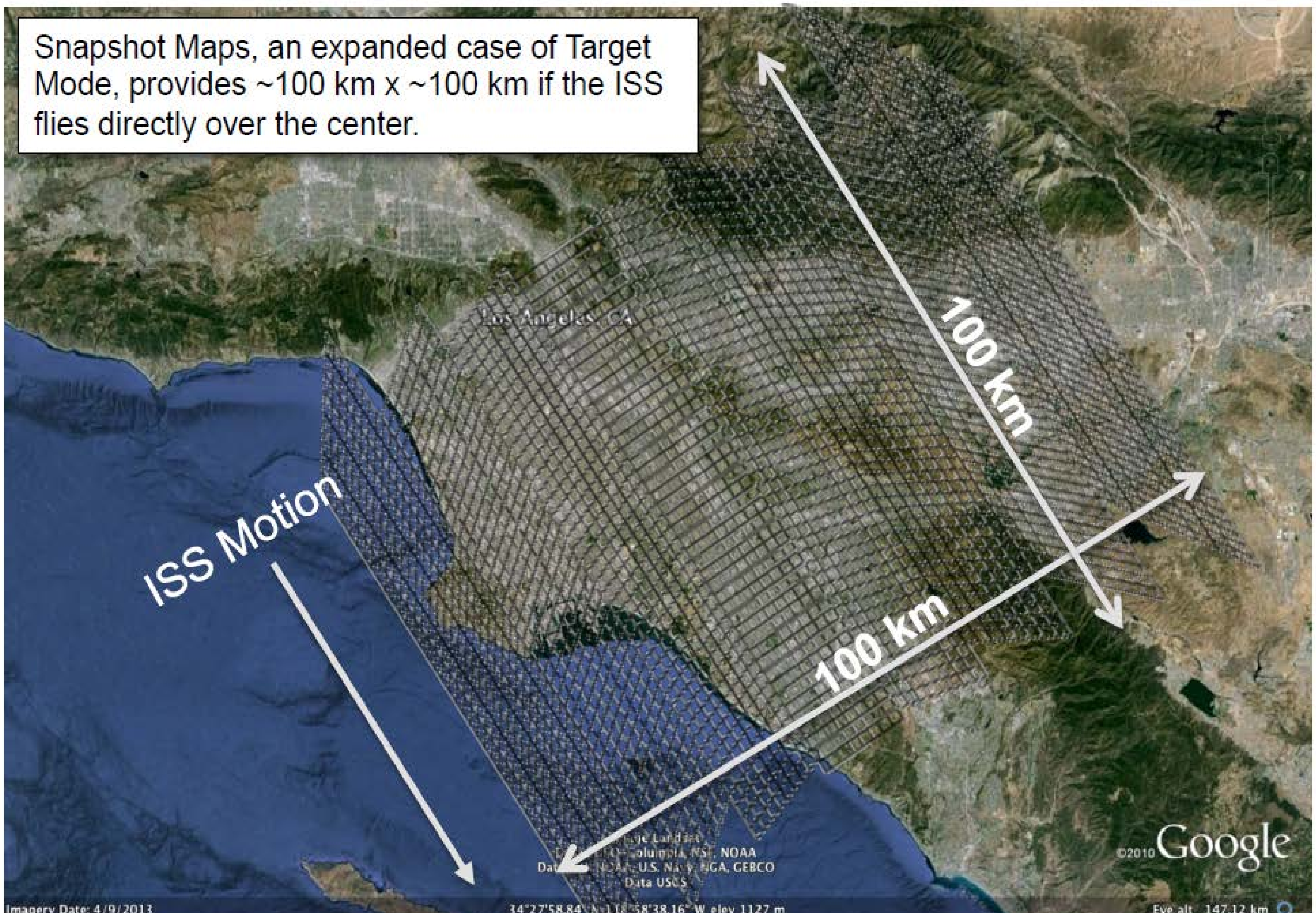
- GOSAT-2 is now being assembled and tested at JAXA Tsukuba Space Center.
- Ground data systems for GOSAT-2 at JAXA and NIES are being developed and tested.
- Japanese version of “GOSAT Data Policy” was simplified / modified to cover GOSAT-2. English version is almost completed.
- GOSAT-2 will be launched by H-IIA rocket from JAXA Tanegashima Space Center in FY2018.



https://twitter.com/ibuki2_jaxa

OCO-3: Science Objectives and Instrument Performance

Annmarie Eldering and the OCO-3 team including: Chris O'Dell, Tommy Taylor, Ryan Pavlick, Thomas Kurosu, Greg Osterman, Brendan Fisher, Rob Rosenberg, Richard Lee, Peter Lawson, Lars Chapsky, Shanshan Yu, Matt Bennett, Muthu Jengenathan, Gary Spiers, Ralph Basilio

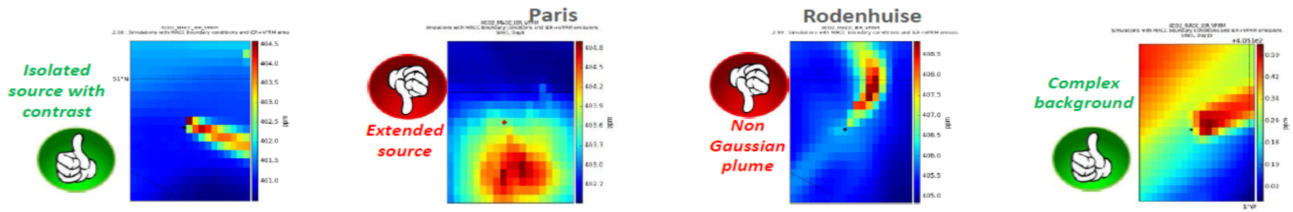


- Launch to ISS planned for Feb 2019 - SpaceX
- More focus on anthropogenic using target and snapshot capabilities

Plume detection and characterization from XCO_2 imagery: methodology and expected uncertainties on derived point source fluxes

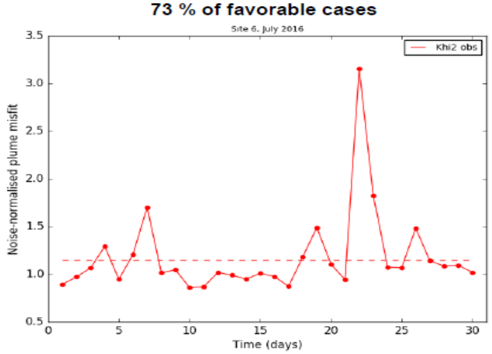
Claude Camy-Peret, Pascal Prunet, François-Marie Bréon, Grégoire Broquet, Diego Santaren

- Validation with MicroCarb City Mode simulations: Processing of 180 noisy images (6 sites x 30 days). How does Gaussian model fit realistic observations ?

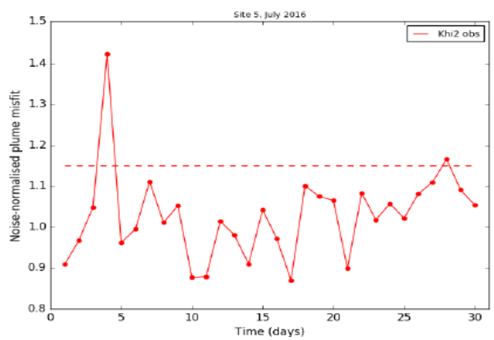


Identify cases well-fitted with our Gaussian retrieval : $\chi^2_{y\,(red)} = \frac{(y_{obs}-y_{OEM})^T S_y^{-1} (y_{obs}-y_{OEM})}{N_{obs}}$ *close to 1 (threshold: 1.15)*

Weisweiler (strong source: ~19 MT CO_2/year)
73 % of favorable cases



Rodenhuise (weaker source: ~2 MT CO_2/year)
50 % of favorable cases



Over the 6 sites and 30 days, 60 % of cases are identified as favorable
- Well fitted
- Detectable (good SNR)
- Retrieval convergence and stability with noise

(1 ppm noise, no clouds)

10

- Studies to inform decisions for MicroCarb city mode
- Gaussian plume assumption can be reasonable for isolated sources but not for emissions from an urban area

also: **An updated status of MicroCarb Project**

Francois Buisson, Didier Pradines, Arnaud Varinois, Véronique Pascal, Pascal Prieur, Denis Jouglet

Anthropogenic CO_2 Monitoring Mission

European Commission

opernicus

esa

State of play of the European Anthropogenic CO_2 Monitoring Mission

Yasjka Meijer, M.R. Drinkwater, J.-L. Bezy, A. Loescher, B. Sierk, B. Pinty, H. Zunker with contributions from many experts

The European Anthropogenic CO_2 Monitoring Mission: Instrument spectral sizing and the supporting aerosol instrument

Jochen Landgraf, Joost aan de Brugh, Lianghai Wu, Stephanie Rusli, Hein van Heck, Rob Detmers, Haili Hu, Otto Hasekamp, Andre Butz, Michael Buchwitz, Heinrich Bovensmann, Hartmut Bösch, Yasjka Meijer, Armin Löscher, Bernd Sierk

The European Anthropogenic CO_2 Monitoring Mission: Instrument requirements for space-borne measurement of greenhouse gas point sources *(poster)*

Bernd Sierk, Jochen Landgraf, Joost aan de Brugh, Michael Buchwitz, André Butz, Hartmut Bösch, Yasjka Meijer, Armin Löscher, Jean-Loup Bézy

The next generation of Chinese greenhouse gas monitoring satellite mission: TanSat-2

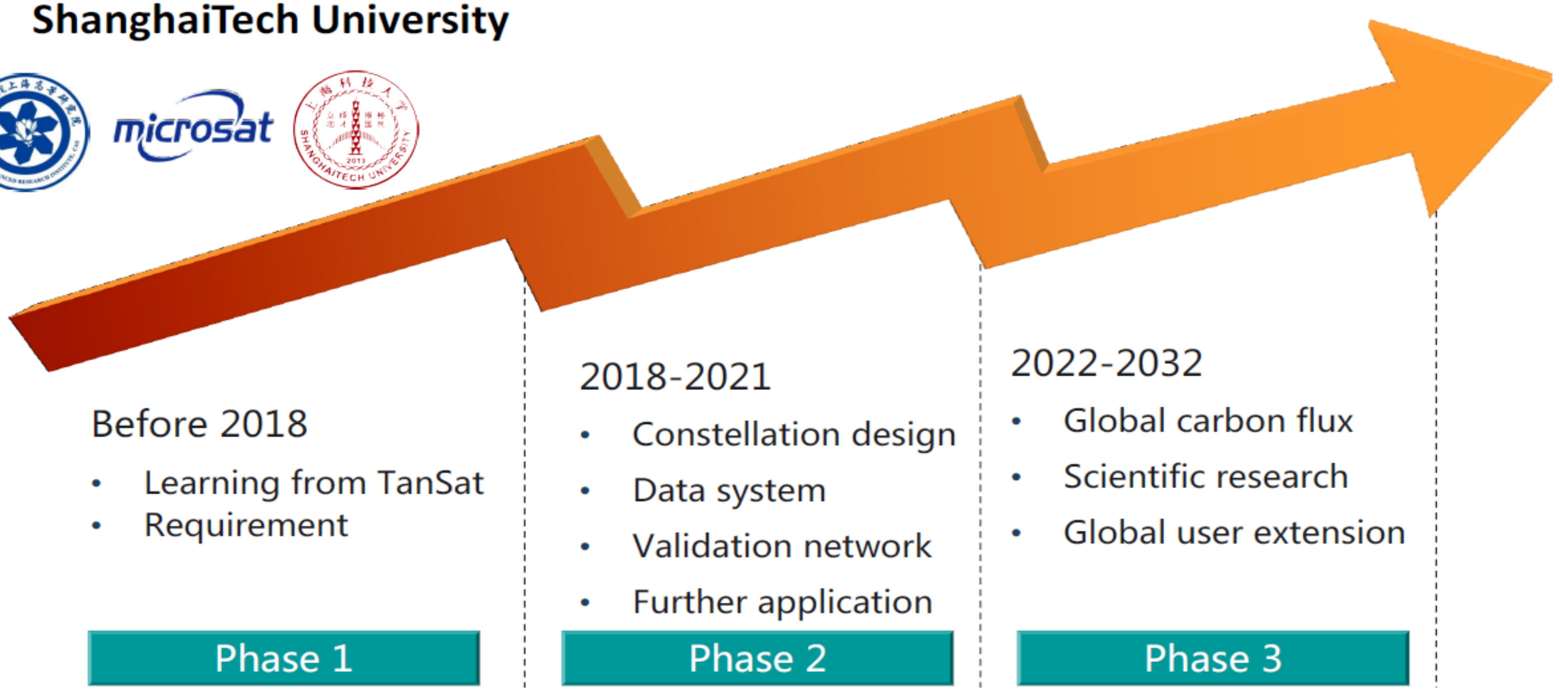
Dongxu Yang, Yi Liu, Maohua Wang, Zengshan Yin, Zhaonan Cai, Lin Qiu, Longfei Tian and the TanSat-2 team

Mission overview

- 4-6 LEO satellites
- > 100 km swaths
- CO_2, CH_4, CO, O_3, NO_2, SO_2 at ~2x2 km^2
- Cloud & aerosol < 0.5 km

TanSat-2 mission is initiated by

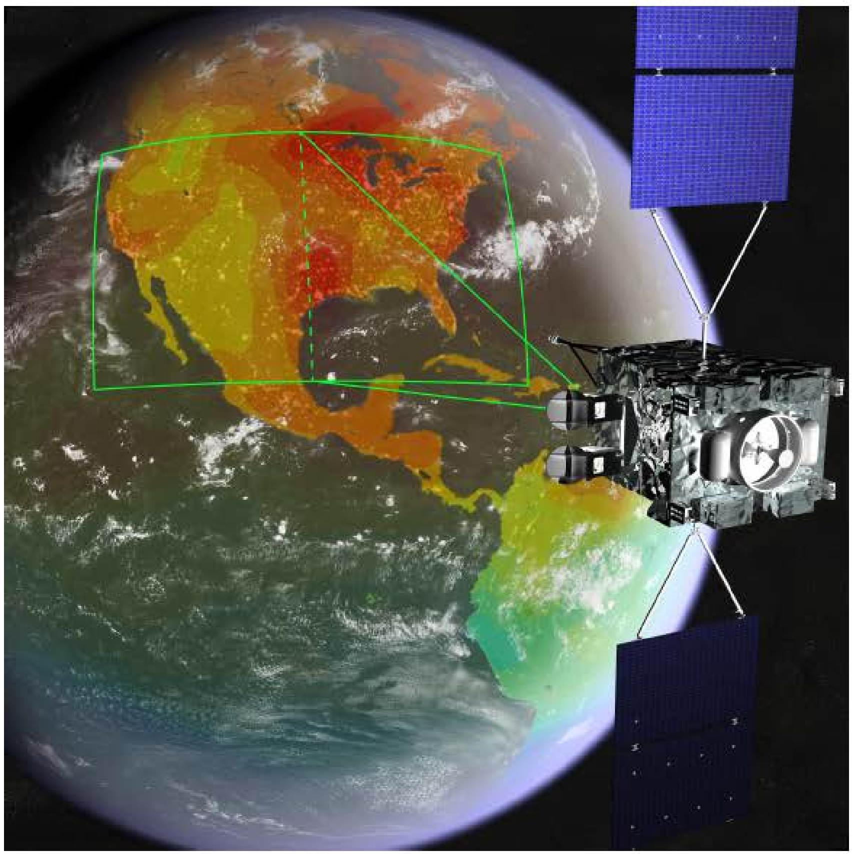
- **Shanghai Advanced Research Institute, CAS**
- **Innovation Research Institute of Micro-Satellite, CAS**
- **ShanghaiTech University**



GeoCarb: Mission Status Update

Berrien Moore, Sean Crowell, Eric Burgh, Chris O'Dell, Greg McGarragh, Susan Kulawik, Cathy Chou, Brett Allard, Steve Merrihew, Dean Read, Shelly Finley, David Crisp, Annmarie Eldering, James Lemen, David Schimel and many others

Launch and Orbit Raising Jun 2022 - Mar 2023



Principal Investigator	Berrien Moore, University of Oklahoma
Technology Development	Lockheed Martin Advanced Technology Center
Host Spacecraft & Mission Ops	SES Government Solutions

Instrument	Single slit, 4-Channel IR Scanning Littrow Spectrometer
Bands	0.76μm, 1.61μm, 2.06μm and 2.32μm
Measurements	O_2, CO_2, CO, CH_4 & Solar Induced Fluorescence
Mass	158 kg (CBE)
Dimensions	1.3 m x 1.14 m x 1.3 m
Power	128W (CBE)
Data Rate	10-100 Mbps
Daily Soundings	~10,000,000 soundings per day

ARRHENIUS

A. Butz, P. Palmer, H. Bösch, Phillipe Bousquet, H. Bovensmann, D. Brunner, L. Bugliaro, D. Crisp, S. Crowell, J. Cuesta, B. Dils, E. Gloor, S. Houweling, J. Landgraf, J. Marshall, C. Miller, R. Nassar, J. Orphal, G. van der Werf

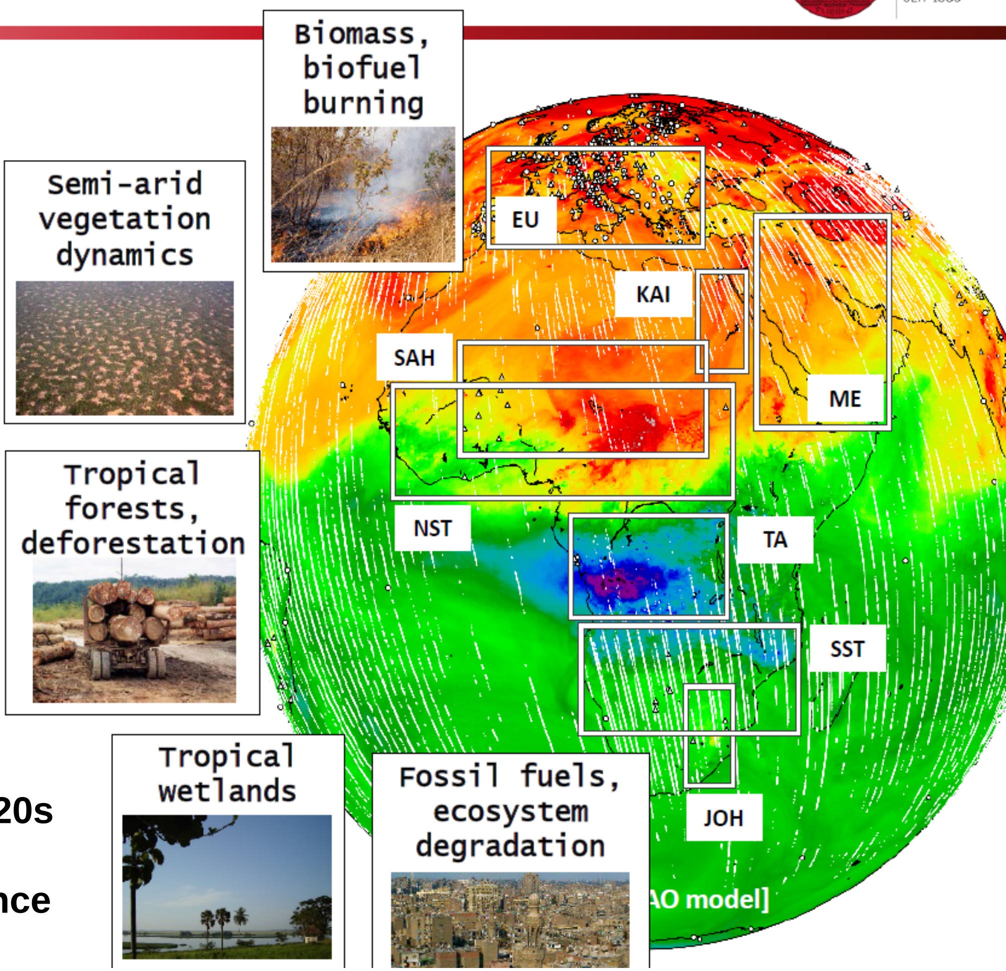
ARRHENIUS: a Geostationary Carbon Process Explorer

UNIVERSITÄT HEIDELBERG
ZUKUNFT
SEIT 1386

for Africa, Europe and the Middle East

WHAT FOR?

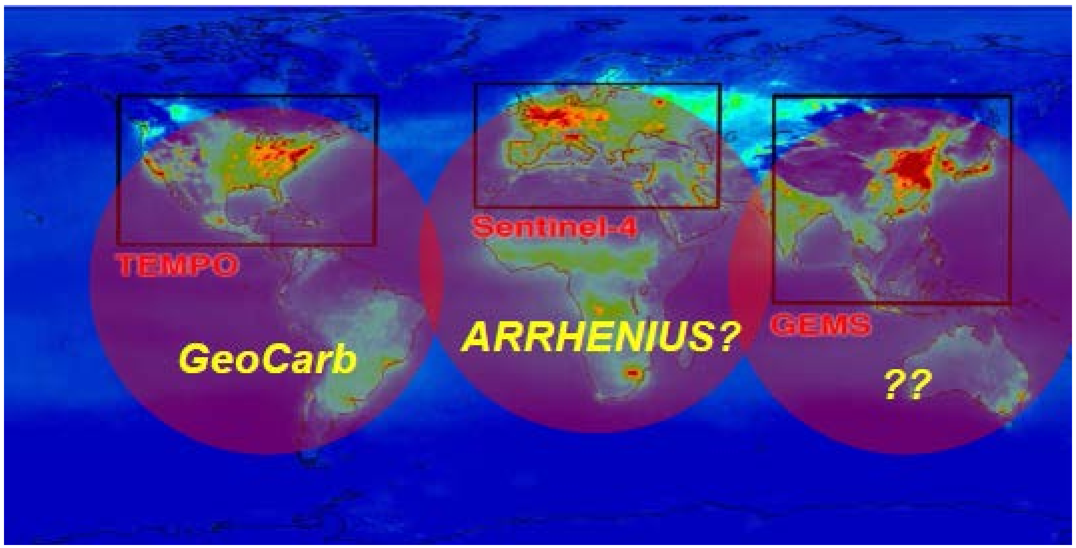
- Understand **terrestrial carbon cycle processes** that determine the **global carbon sink**.
- **Quantify carbon-feedbacks** in response to **climatic, meteorological, and human forcing**.
- Ultimately, improve the **carbon cycle representation** in Earth System Models to estimate **climate sensitivity**.

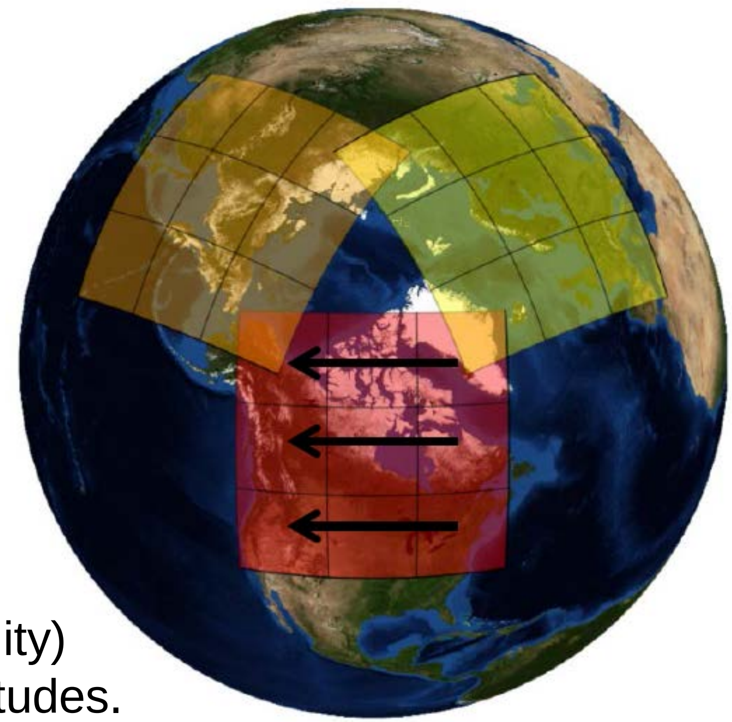


Candidate for ESA's EE-10, target launch late 2020s
Process-emphasis, diurnal cycle coverage with flexible and intelligent pointing for cloud avoidance

AIM-North: The Atmospheric Imaging Mission for Northern Regions

R. Nassar, C. McLinden, C. Sioris, J. Mendonca, L. Garand, S. Polavarapu, Y. Rochon, F. Kolonjari, A. Trichtchenko, C. Boisvenue, M. Johnson, C. Adams, G. Drolet, K. Walker, T. McElroy, D. Wunch, K. Strong, N. O'Neill, D.B.A Jones, R.V. Martin, Z. Vaziri, G. Singh, C. MacDonald, F. Grandmont, L. Moreau, J. Tamminen, C. Miller, W. Simpson

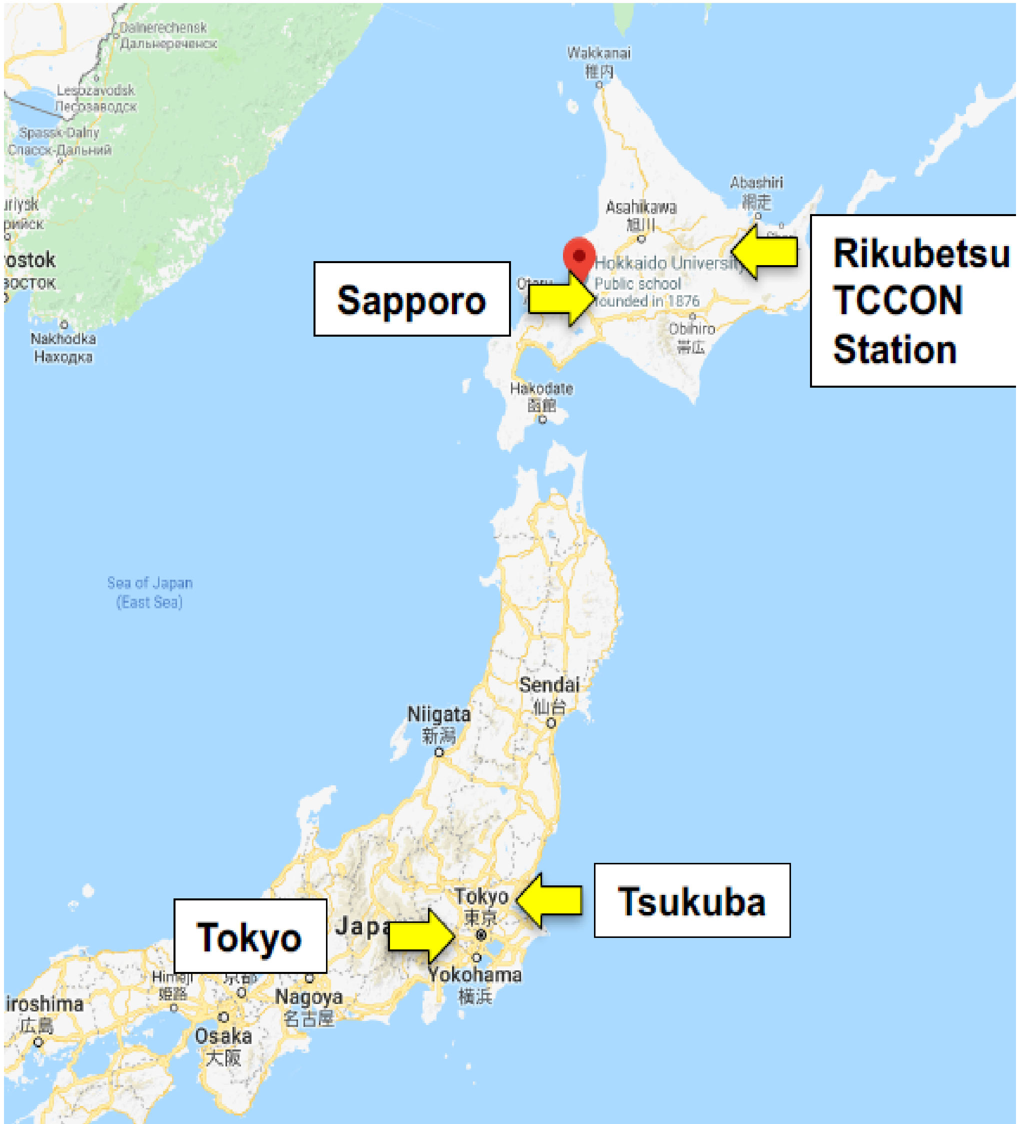




- A LEO & GEO constellation for GHGs (or air quality) would leave a gap in diurnal sampling of high latitudes.
- A highly elliptical orbit (HEO) mission could fill this gap and overlap with GEO coverage for intercalibration.
- CO_2, CH_4, CO, SIF, O_3, NO_2, BrO, HCHO, SO_2 …
- 3x3 km^2 every ~90 minutes of daylight over land
- Now in Phase 0, with potential launch in late 2020s

Canada

IWGGMS-15



- Shortly after launch of GOSAT-2
- Hokkaido University, Sapporo, Hokkaido, Japan
- 3 days during the week of June 3-7, 2019
- Expect > 200 participants