Validation Plan
(of GOSAT TANSO Standard Products)

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Definition of validation

Validation

to evaluate uncertainties of GOSAT products with other data of less uncertainties acquired independently

Comparison

to evaluate GOSAT products with observation data with equivalent uncertainties or data estimated by simulation models

Calibration

to evaluate L1 product which is performed mainly by JAXA

$$\text{Uncertainty}=\{(\text{accuracy})^2 + (\text{precision}))^2\}^{1/2}$$

Basic Concept of GOSAT Validation

- The priorities of standard product validation and comparison have been set as follows:
  (1) L2 SWIR CO_2 and CH_4 column abundances
  (2) L2 TIR CO_2 vertical profile of concentration
  (3) Global distributions of L3 SWIR CO_2 and CH_4 column abundances
  (4) Global distribution of L4A CO_2 flux
  (5) Global distribution of L4B CO_2 concentration

Strategy for validation of GOSAT CO_2 and CH_4 column abundances

- **Requirement for observation equipments**
  - ✓ Well established observation technology
  - ✓ Small uncertainty; CO_2 less than 1%（0.3% preferable) , CH_4 less than 2%

- **Measurement technique to validate these products**
  - ✓ Absorption technique of solar direct radiation by ground-based high - resolution FTS (0.05-0.015 cm^{-1}) and mobile FTS (around 0.2 cm^{-1})
  - ✓ Aircraft in situ measurement（e.g. JAL project data）

To validate TIR products, vertical profiles of temperature, pressure, and water vapor obtained by Rawin Sonde are useful.

Methodology of validation of L2 products

- **Collect data at various conditions**
  - ✓ Albedo : grassland, forest, desert, snow surface, urban, sea surface
  - ✓ Terrain : flat or complex
  - ✓ Aerosol : sea salt, dust, artificial sulfuric acid, black carbon, organic carbon
  - ✓ Cirrus : thick or thin
  - ✓ Water vapor : high or low

  Continuously observing sites (ground-based high-resolution FTS: about 10 sites, JAL project: 10 airports) for validation (under consideration)

※Considering points: required quality level and cost effective

- **Set up necessary instruments at continuously observing sites (e.g. FTS, lidar and sky radiometer)**
- **Evaluation of spatial and temporal characteristics at each FTS site**

  → Identify the accuracy of GOSAT L2 products

  (It will take much time for evaluating the bias. 3 months for Lauder?)

  → Grouping (cirrus, aerosol, water vapor, albedo and etc.)

- **Other methods**

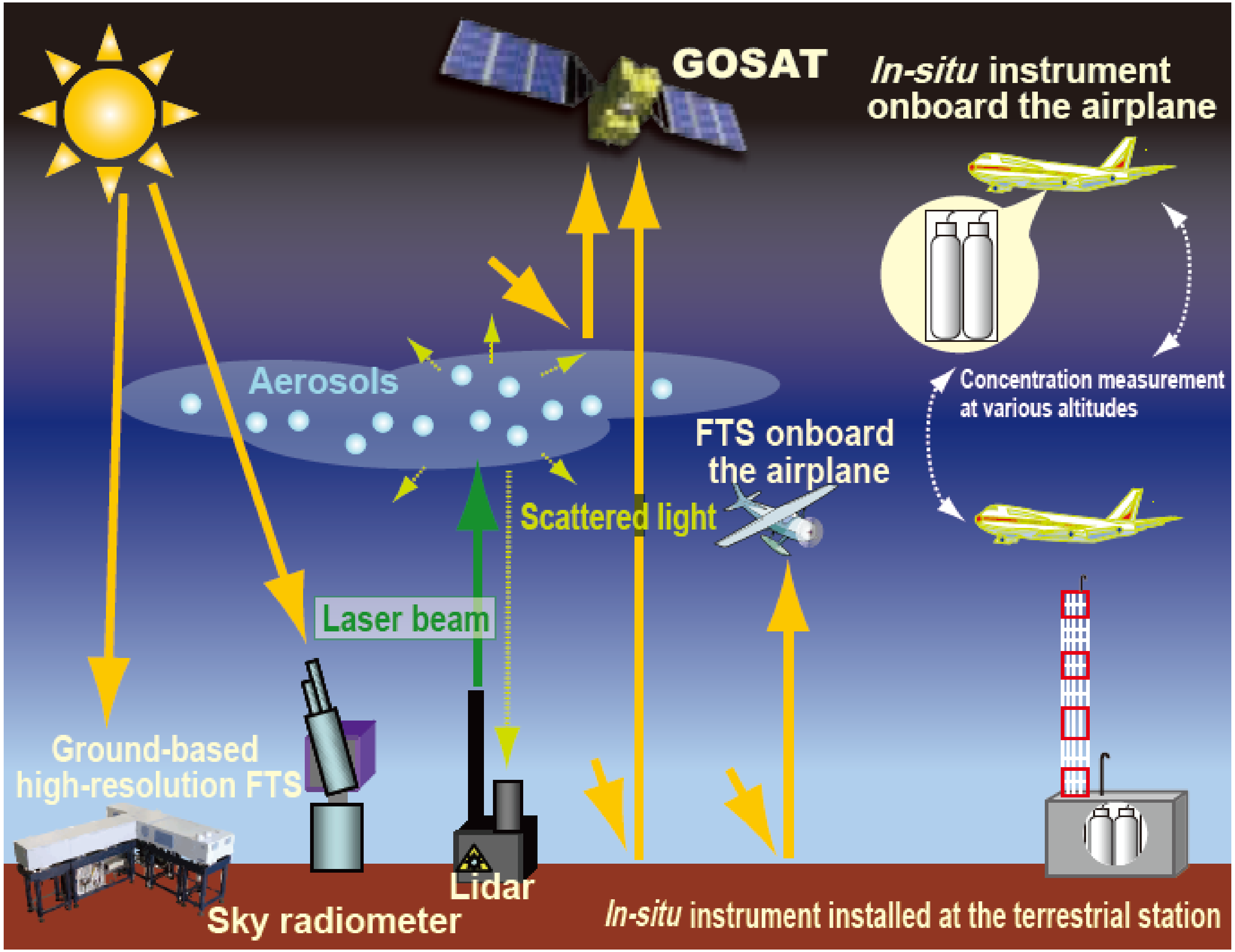
  e.g. Trajectory analysis, Regional CO_2 forward model

Error factors in deriving XCO_2 and XCH_4

Priority	Error factor	Methodology
**	Characteristics of TANSO FTS (e.g. SNR)	Calibration
**	Aerosol	Validation
*	Thin cirrus	Validation
*	Surface pressure (elevation)	Validation
*	Profiles of P, T and R.H.	Validation
*	Absorption line	Algorithm
*	Fraunhofer line	Algorithm
*	Surface albedo (sunglint reflectance)	Validation

**: the top priority, *: the second priority.

Schematic illustration of validation experiments



Source: GOSAT pamphlet

The uncertainty of the ground based high resolution FTS（Park Falls）

Washenfelder, R. A., et al. (2006), J. Geophys. Res., 111, D22305, doi:10.1029/2006JD007154.

- **The precision of FTS column CO_2**

  Clear day → about 0.1%

  Partly cloudy day → about 0.2%

- **The bias of FTS column CO_2 compared to integrated aircraft profiles**

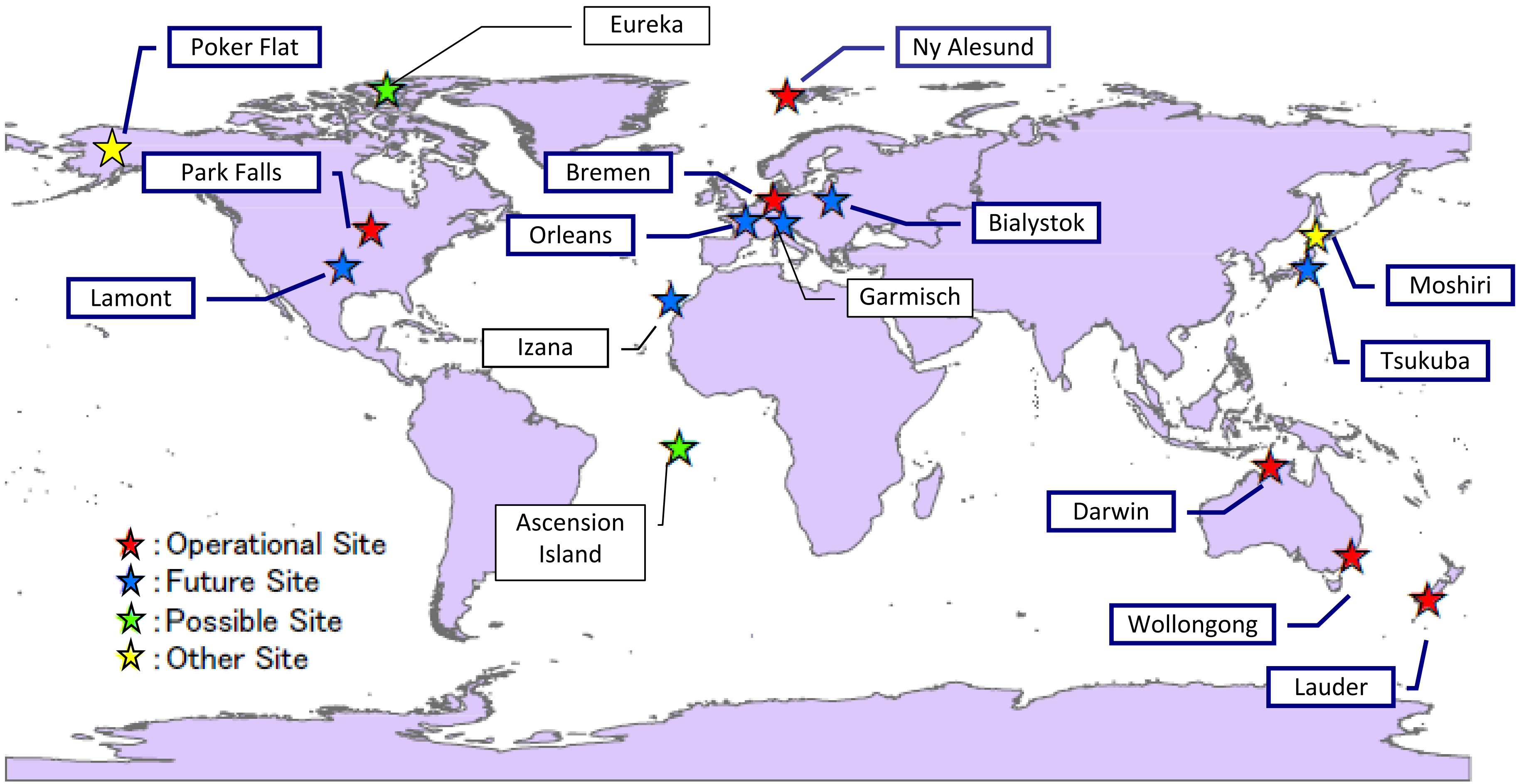
  less than 2%

- **The uncertainty of FTS column average CO_2 VMR after calibration**

  about 0.3% (±1.1 ppmv) at SZA less than 60 deg

The high resolution FTS is useful for GOSAT validation.
It is necessary to calibrate the FTS at validation sites.

TCCON is indispensable for GOSAT validation



▭ : will be used for initial validation

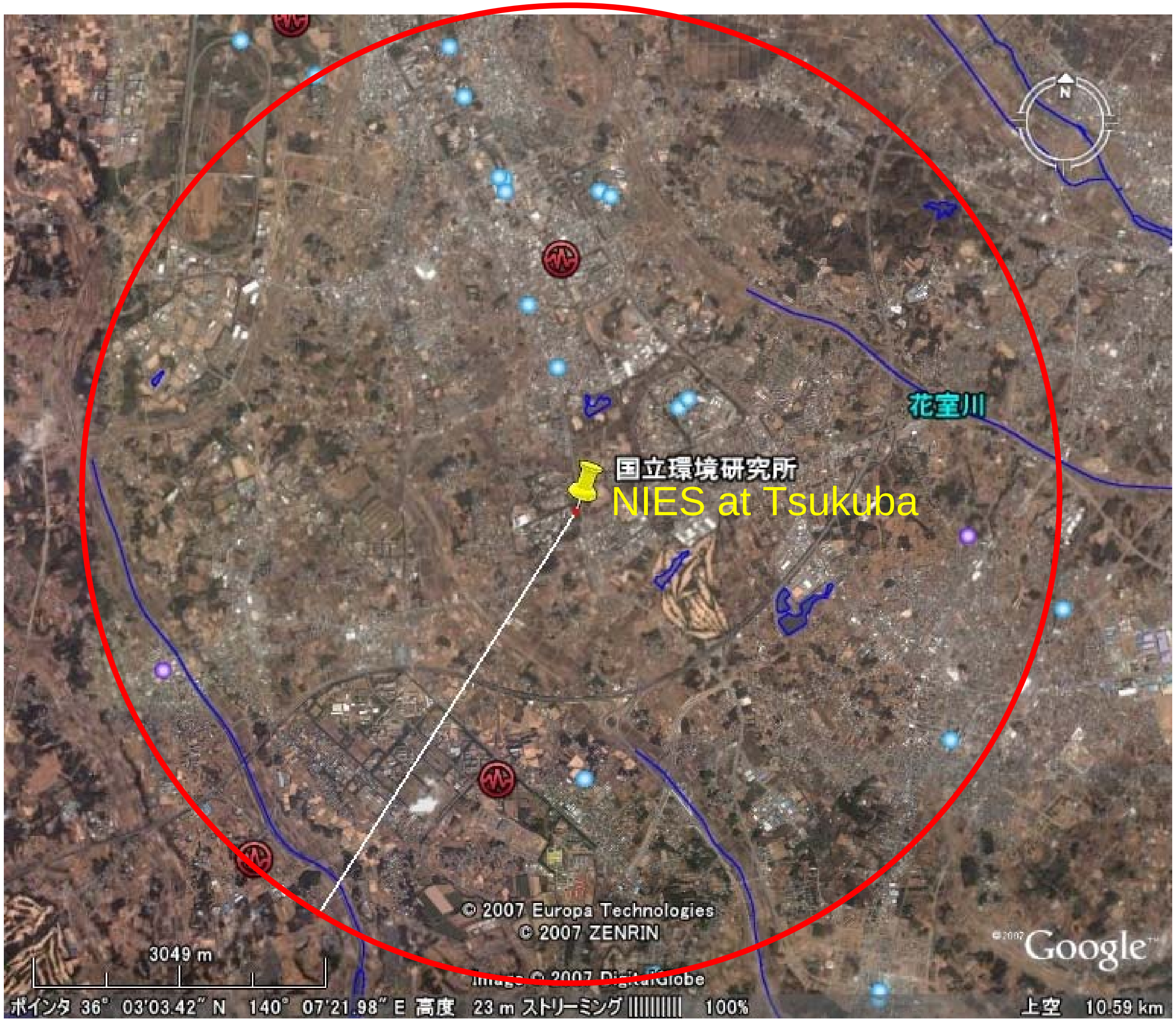
TCCON :Total Carbon Column Network
（http://www.tccon.caltech.edu/index.html）

Observation plan of cloud and aerosol parameters at some potential FTS sites for GOSAT validation

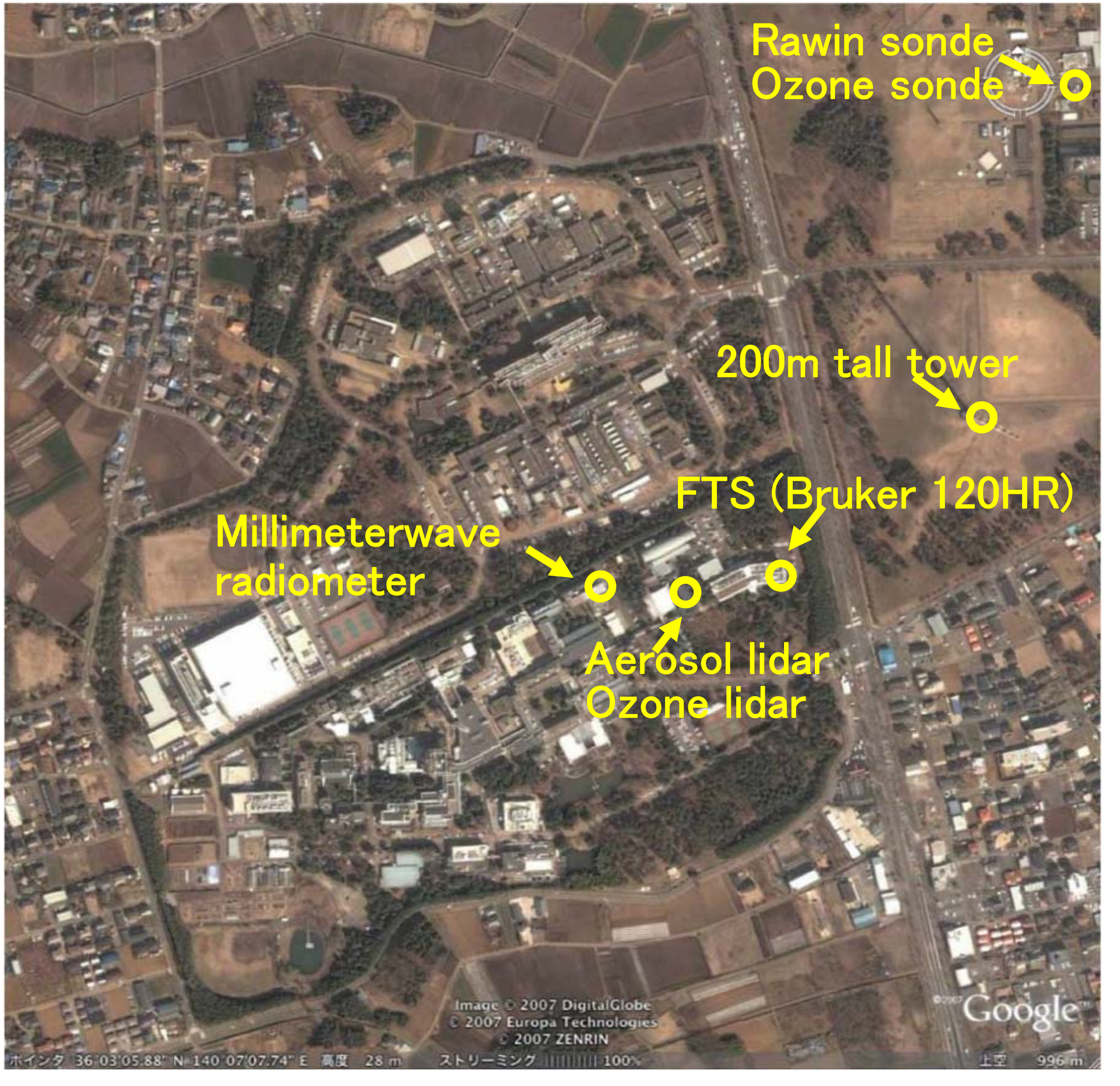
Site \ Instrum.	FTS	Lidar	Sky Radiometer	Sun Photometer
Tsukuba	Bruker 120HR (NIES)	Observed by NIES & MRI	Observed by MRI	None
Moshiri	Bruker 120HR (Nagoya U.)	***To be installed***	***To be installed (NIES's)***	None
Lauder	Bruker 120HR (NIWA)	***To be upgraded (MRI & NIES)***	None	CSD Middleton SP02 (ABM)
Bremen	Bruker 125 HR (U. Bremen)	***Seeking the fund to install***	***To be installed (NIES's)***	None
Darwin	Bruker 125 HR	Small power lidar (ARM site)	None	Cimel (ARM site)
etc.				

Lidar : two-wavelength polarization lidar

The site conditions of Tsukuba FTS



The site conditions of Tsukuba FTS



Ground-based NIR FTS at Tsukuba

- Observation site
  National Institute for Environmental Studies (NIES), Tsukuba, Japan
  (Latitude 36.1° N, Longitude 140.1° E, Altitude 31 m)

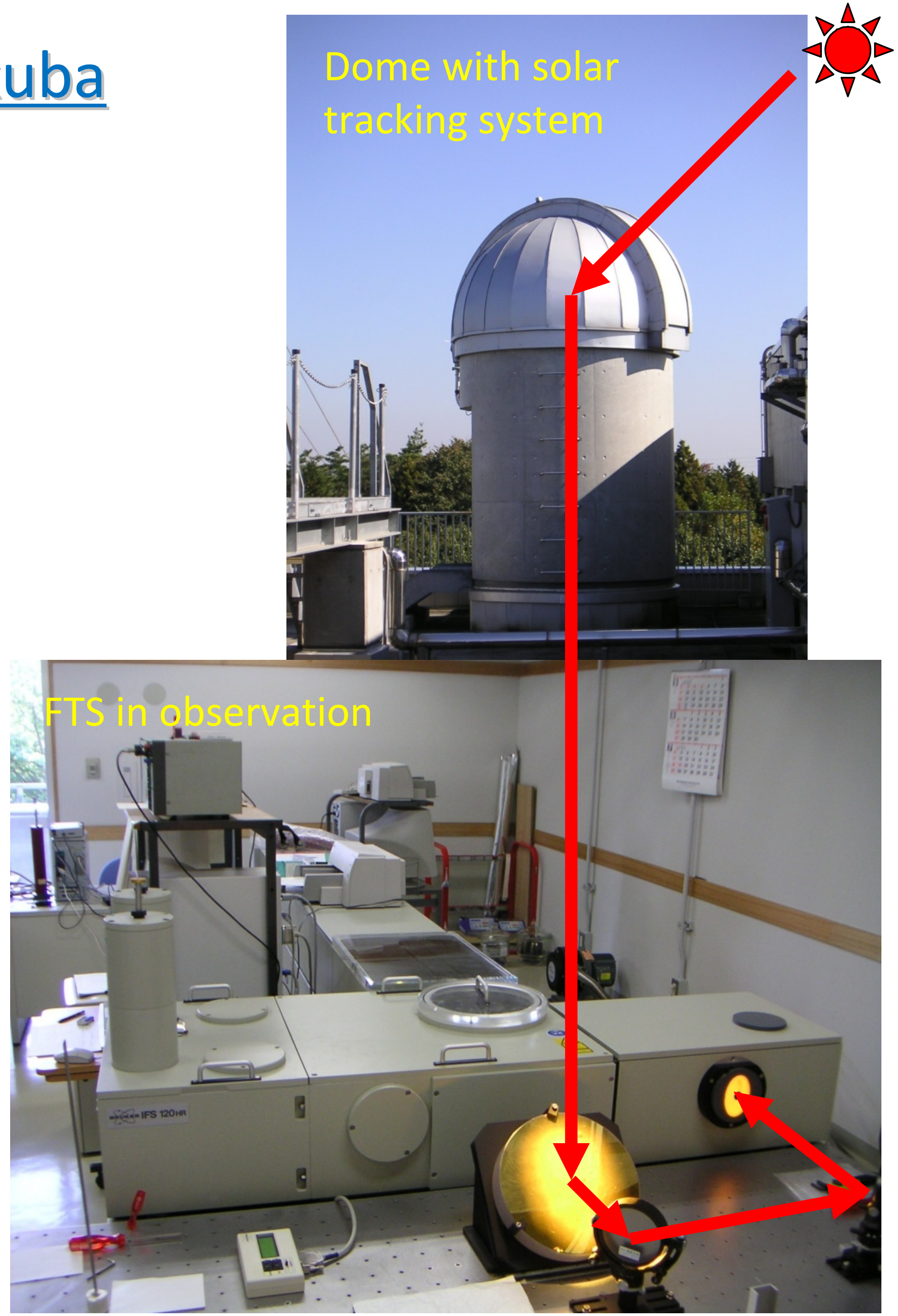
- FTS: Bruker IFS 120 HR
  Beam splitter: CaF_2
  Detector: InSb (1,800–10,500 cm^{-1})
  Si diode (9,200–14,000 cm^{-1})
  Instrument resolution: 0.05–0.0035 cm^{-1}
  Observation time: ~10 min

- In 2001, measurements of atmospheric constituents related with the destruction of the ozone layer were started in MIR region.

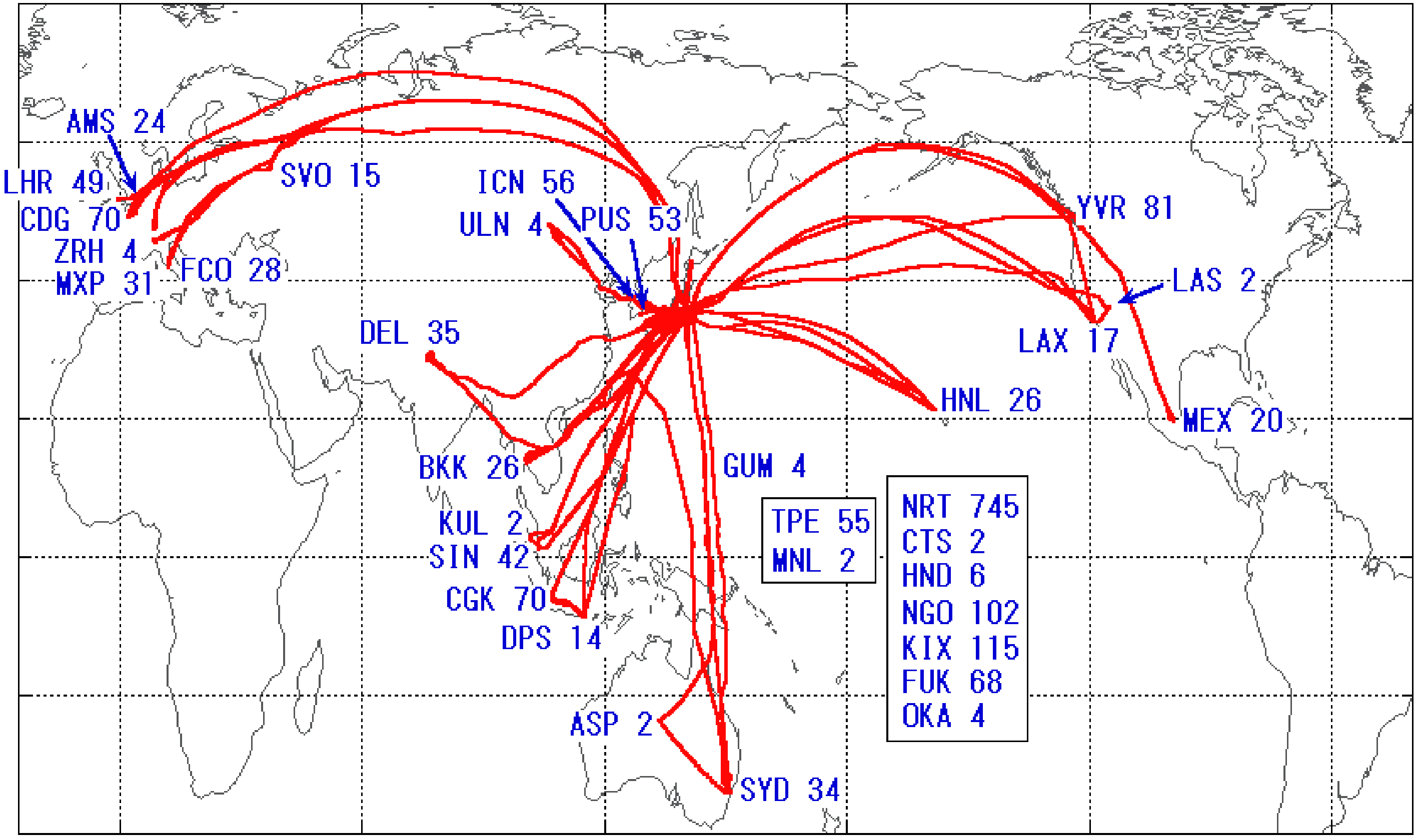
- In 2004, optical components of the FTS were replaced for measuring greenhouse gases such as CO_2 and CH_4 in NIR: optical filters, CaF_2 beam splitter, and InSb detector.

However, in the present, measurements with the NDSC #1, #2, and #3 optical filters are also in operation.

※NIES NIR FTS will be joined to TCCON



Airborne observation data is very useful for GOSAT validation

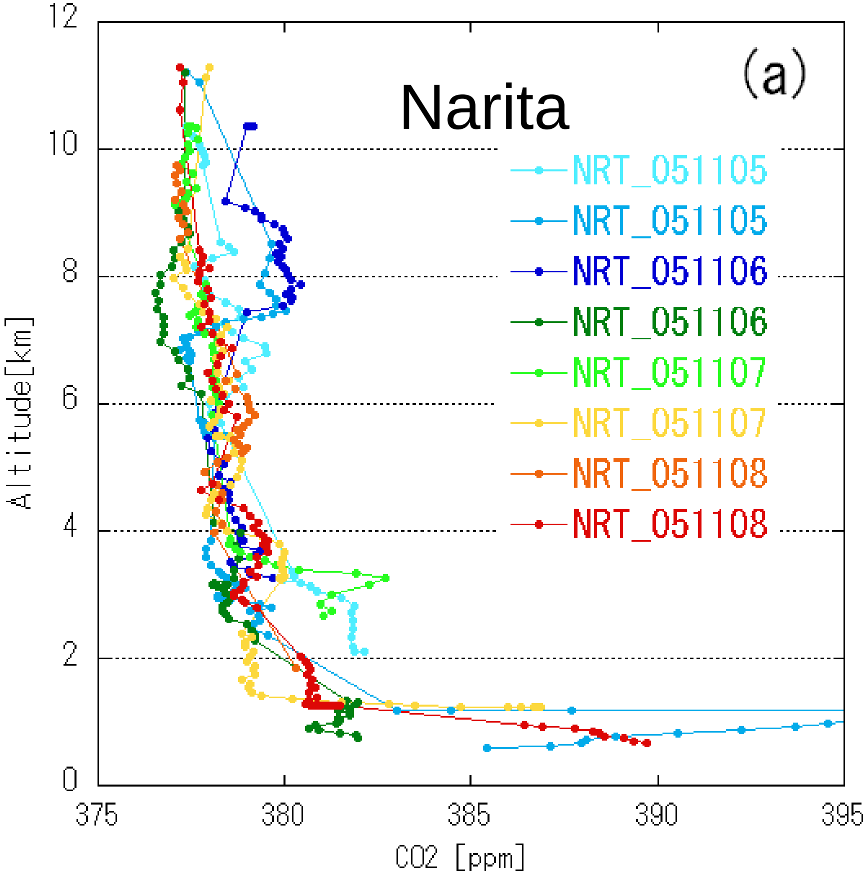


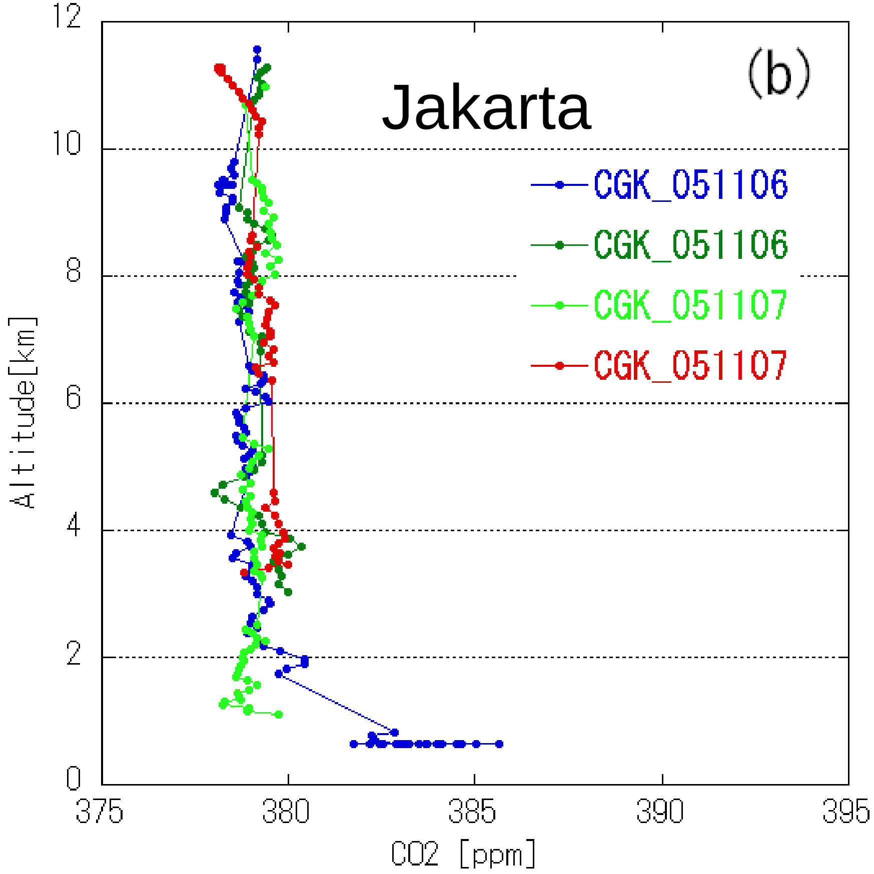
JAL flight routes of CO_2 observation and destination airport.
The numbers indicate the number of vertical profiles over each airport from November 2005 to April 2007.

Machida, Matsueda and Sawa, 2007(IGAC Newsletter)

Vertical CO_2 profiles obtained by CME on board aircraft (JAL)

around Narita and Jakarta airport



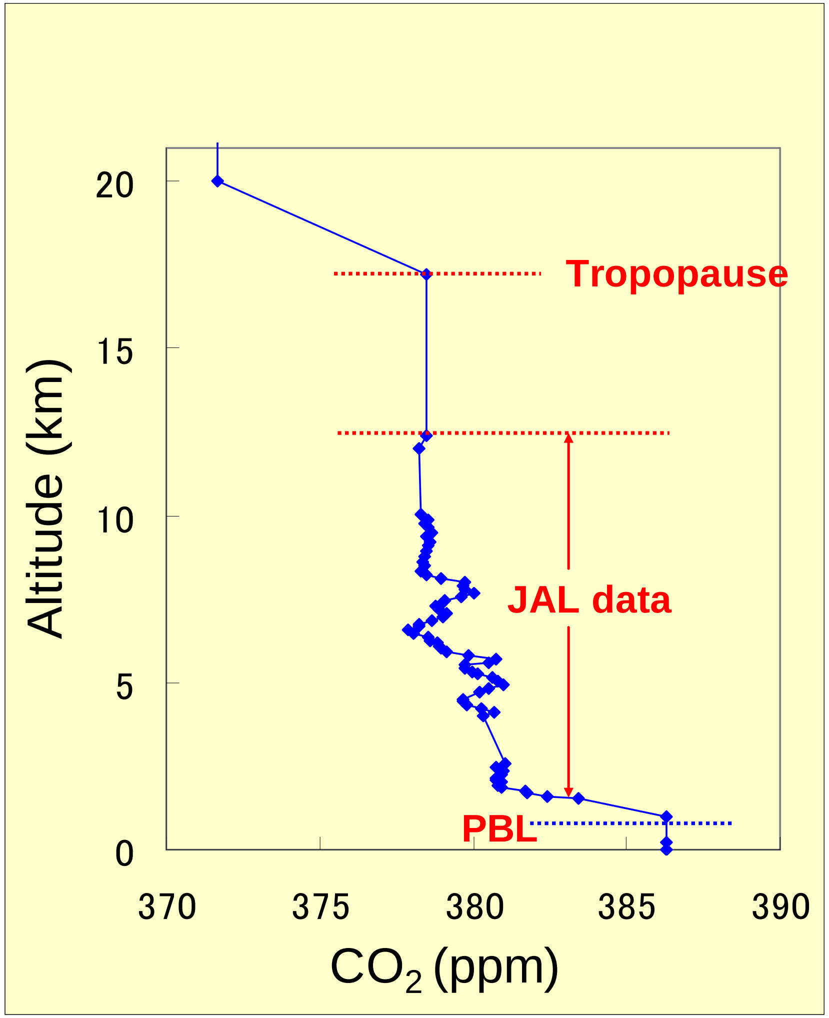


Similar profiles : Nagoya, Kansai

Similar profiles : Sydney, LA

Machida, Matsueda and Sawa, 2007 (IGAC Newsletter)

Data for estimation of XCO_2

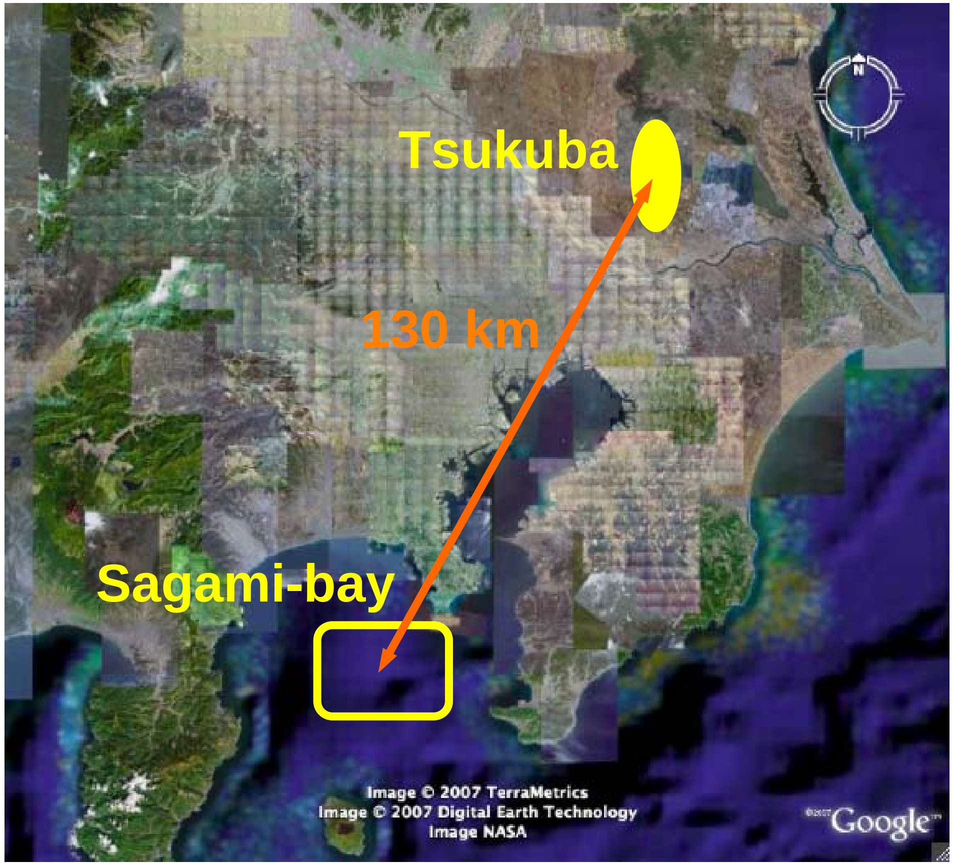


- in situ CO_2 data obtained by descending JAL aircraft (1,500~12,418 m)
  (Narita airport 2006/10/26)
- Tateno rawin sonde data
  PBL height : 1,000 m
  Tropopause height : 17,227 m
- CO_2 data from ground to PBL
  in situ data of MRI/JMA tower (200m)
  (by Machida)
- CO_2 data above 20km
  assumed nearly equal to the average value in troposphere 5 years ago
  (371.7 ppm)

X_{CO2}=380.079 ppm

Validation for GOSAT sunglint observation

Observation area: Sagami-bay (35.0-35.1ºN, 139.2-139.4ºE)
Sampling altitude: 0.5, 1, 1.5, 2, 3, 4, 5.5, 7 km
Sampling method: Flask sampling → Nadir
Observation schedule : every 2 weeks



Beechcraft 200T

[T. Machida, NIES]

Validation of aerosol and cirrus cloud

- **Error factors to the column abundance**
  - ✓ **Aerosol and thin cirrus cloud**
  - ✓ **It is necessary to observe these factors with CO_2 and CH_4 column abundances at the same time.**
- **Lidar**
- Derive the vertical distributions of aerosols and thin cirrus clouds with a range resolution of 15 m.
- Derive depolarization ratio with high accuracy, and discriminate liquid and solid particles.

- **Skyradiometer**
- Derive optical depth, particle size distribution and phase function with measurements of direct solar radiation and forward scattering.
- Derive Single-scattering albedo and phase function with these parameters.

To validate TANSO-CAI, measurements by lidar and skyradiometer are useful. SKYNET and AERONET data are also important for GOSAT validation.

Summary

- Ground-based high resolution FTS data are indispensable for validation of CO_2 and CH_4 column abundances retrieved from GOSAT data.
- Airborne in-situ measurement data are also important for validation of column abundances and vertical profiles of CO_2 and CH_4.
- Aerosol and thin cirrus cloud measurements at FTS sites are necessary to validate and improve GOSAT CO_2 and CH_4 column abundances.