JAXA Earth Observation Satellites and the Validation

Keiji Imaoka + many colleagues
Earth Observation Research Center (EORC)
Japan Aerospace Exploration Agency (JAXA)

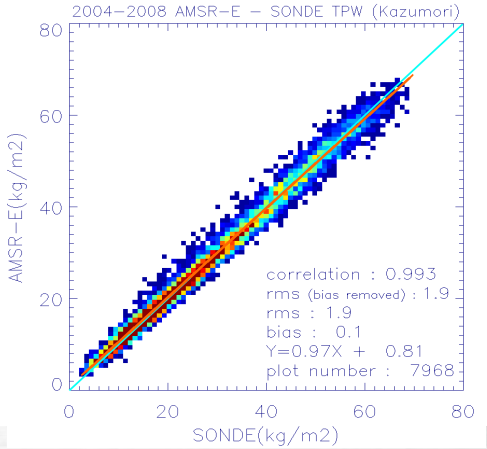
March 9, 2012
4th GRUAN ICM Meeting

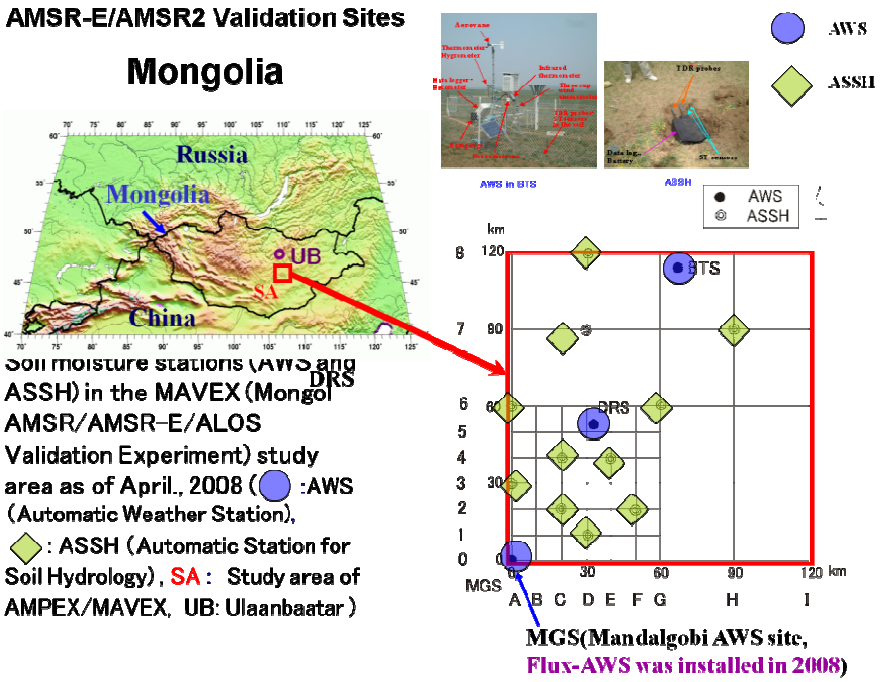
Ground-based and Satellite Measurements

- Satellite community needs “in-situ” data
  - Construction of atmosphere models for forward radiative transfer calculation and retrieval scheme.
  - Validation of satellite retrievals and refinement of retrieval algorithms (various time scales).
  - Synergistic use of in-situ and satellite data to understand various phenomena.
- Typical characteristics
  - In-situ data
    - Point measurement with vertical information, accurate, frequent, etc.
  - Satellite data
    - Wide swath (narrow swath) observation with column (vertical profile), intermittent, sometimes have calibration issues (sometimes...).

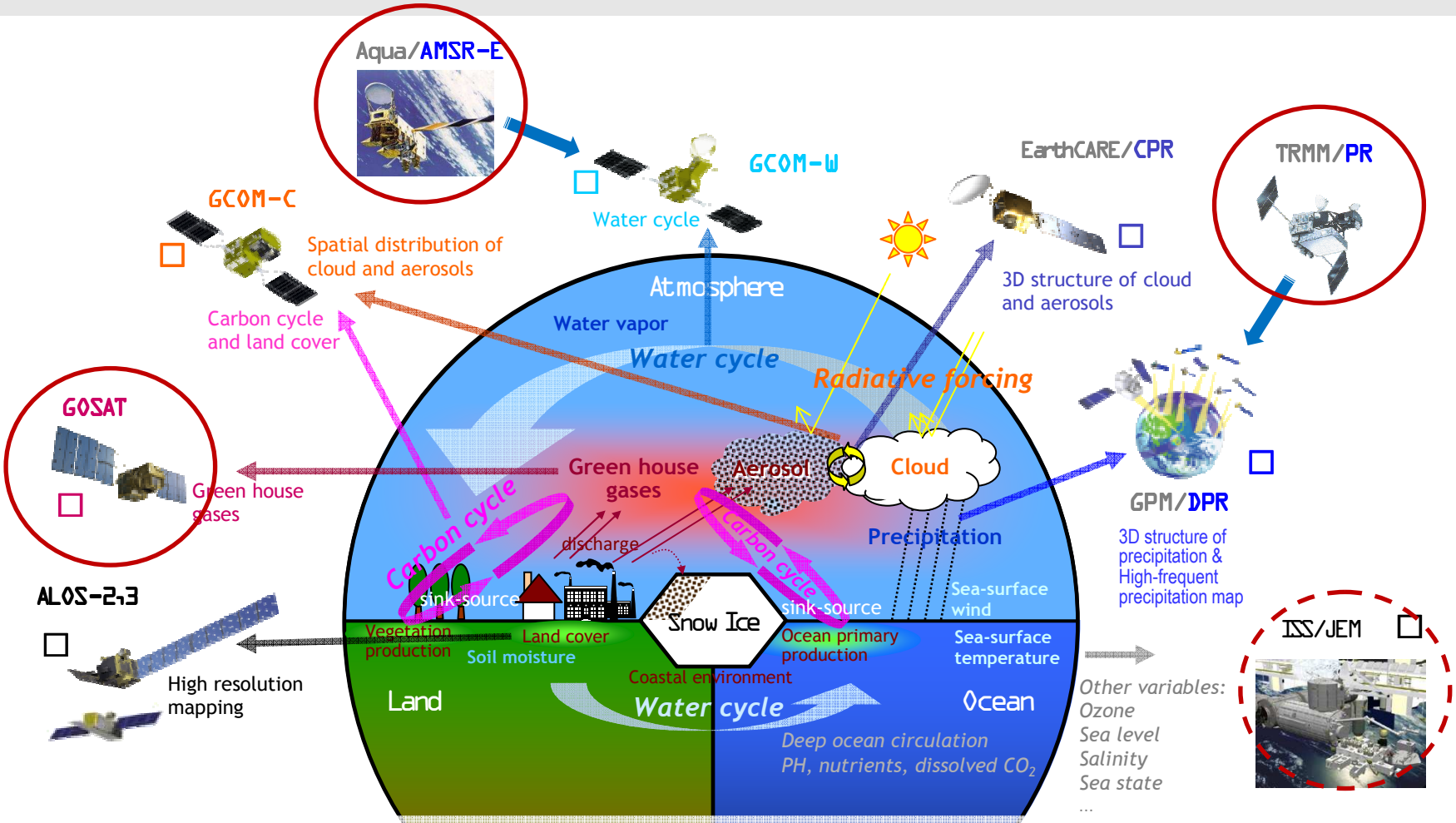
Satellite Validation Activities

- Validation by utilizing the existing observation networks:
  - Radiosondes and GPS networks, SST and sea surface wind speed from various buoy system, Ground-based precipitation radar networks, Snow depth and other surface measurements by meteorological agencies, etc.
- Specific field campaigns/monitorings
  - Specific field campaigns/monitorings for geophysical parameters for which continuous and global observations are not available.



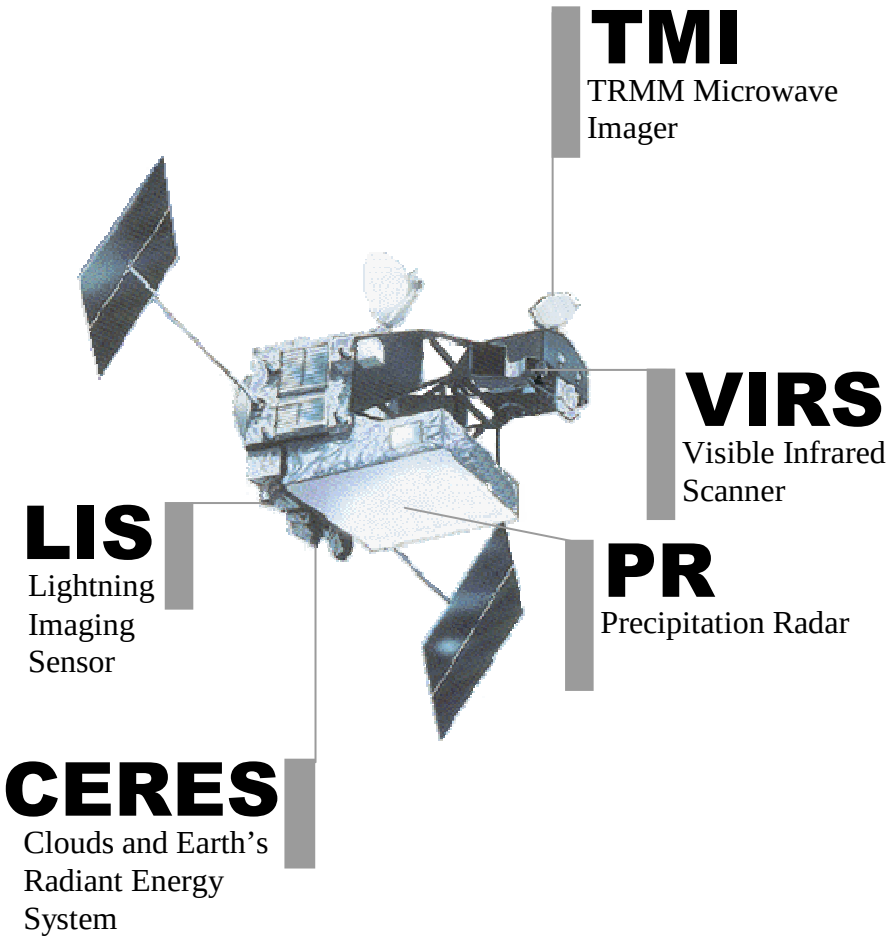


Current and Future JAXA EO Missions



GCOM-C:	Long-term observation of the horizontal distribution of aerosol, cloud, and ecosystem CO_2 absorption and discharge
GCOM-W:	Long-term observation of water-cycle such as the snow/ice coverage, water vapor, and SST
GOSAT:	Observation of distribution and flux of the atmospheric greenhouse gases, CO_2 and CH_4
EarthCARE/CPR:	Observation of vertical structure of clouds and aerosols
GPM/DPR:	Accurate and frequent observation of precipitation with active and passive sensors
ALOS-2,3:	Fine resolution mapping by optical and SAR instruments
ISS/JEM:	Demonstration of new missions (e.g., SMILES, GLISM, etc.)

Tropical Rainfall Measuring Mission (TRMM)



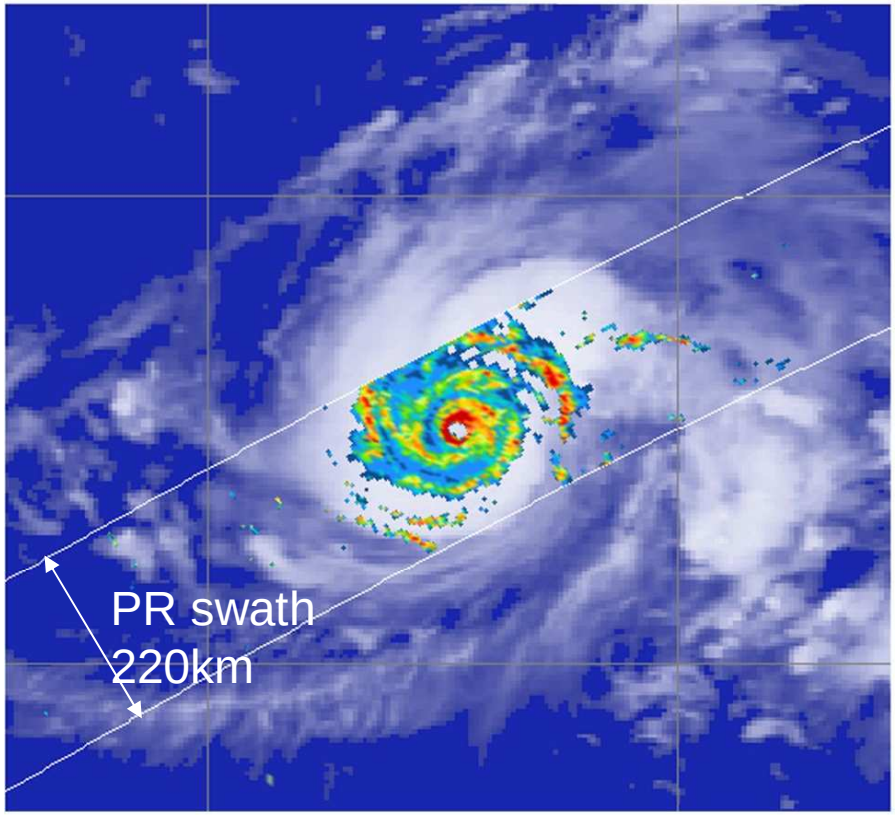
Orbit	Non-sun-synchronous circular orbit
Altitude	350 km □402.5 km after Aug 2001)
Inclination	35 deg
Instruments	Precipitation Radar (PR) TRMM Microwave Imager (TMI) Visible Infrared Scanner (VIRS) Clouds and the Earth's Radiant Energy System (CERES) Lightning Imaging Sensor (LIS)
Launch	28th Nov. 1997

Observation of 3-dimensional Structure by TRMM PR

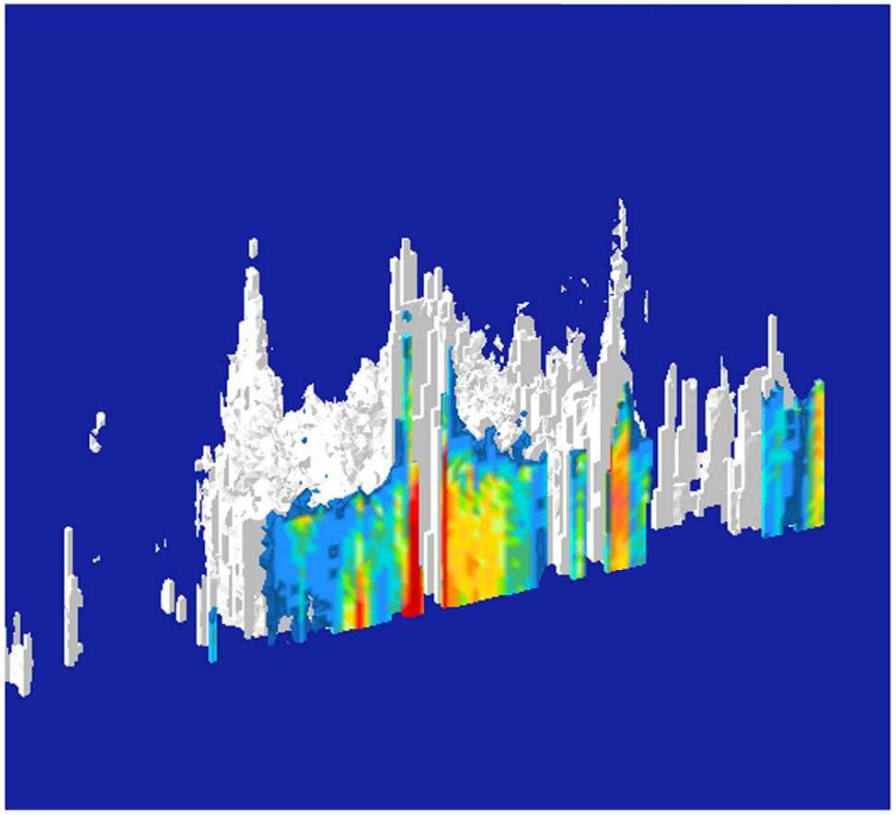
2 Aug.2000 11:49-11:53 (UTC)

Typhoon No.8 in 2000

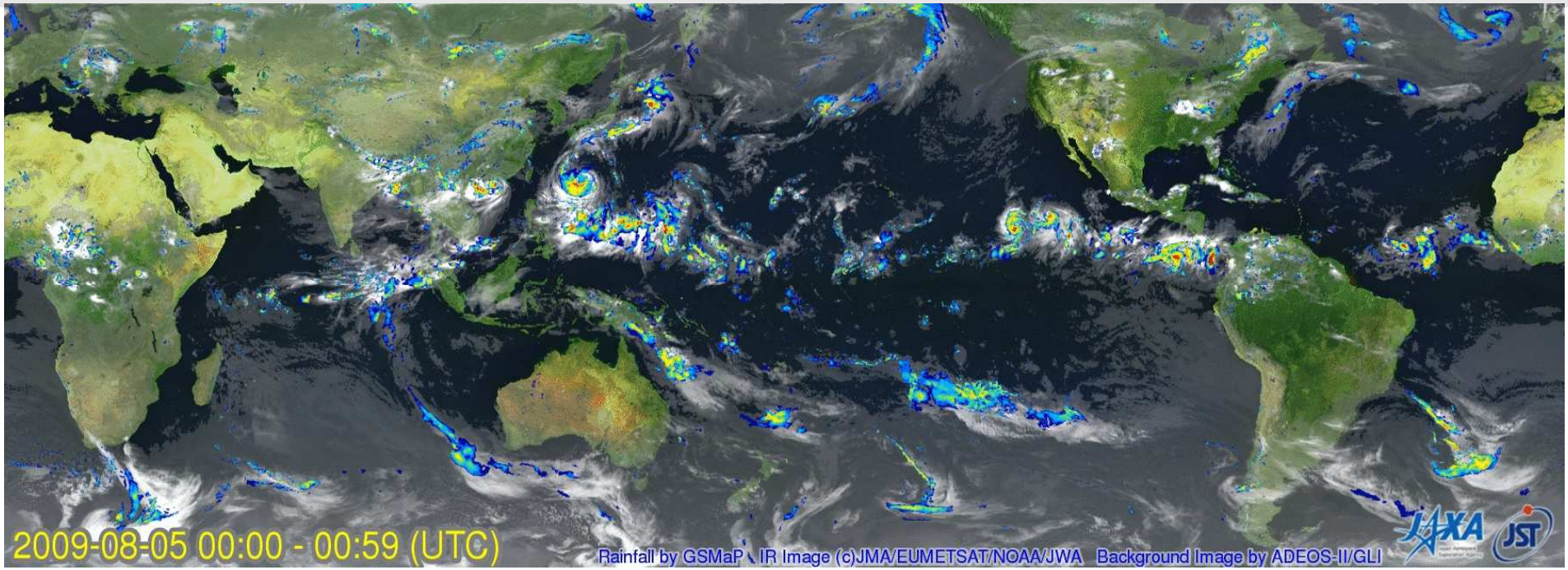
Horizontal Cross Section of Rain at 2.00km Height



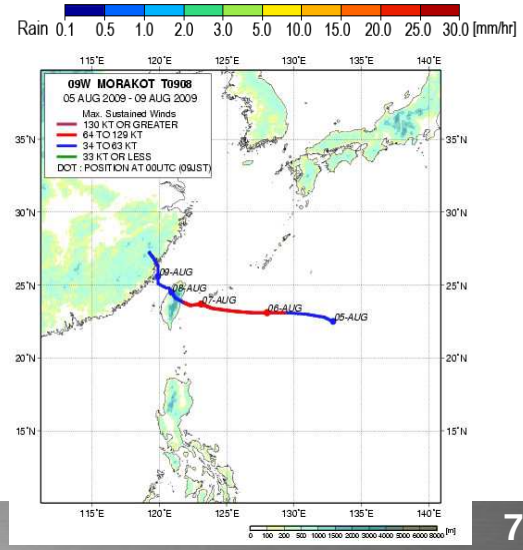
3D Rain Structure



Global Rainfall Map in Near Real Time



Typhoon MORAKOT (09W): Aug. 5 – 10, 2009 (Big impact in Chinese Taipei)



- Global rainfall map merging TRMM, Aqua/AMSR-E and other satellite information
- Available 4-hour after observation, hourly update
- 0.1-degree latitude/longitude grid

http://sharaku.eorc.jaxa.jp/GSMaP/

Advanced Microwave Scanning Radiometer for EOS (AMSR-E)

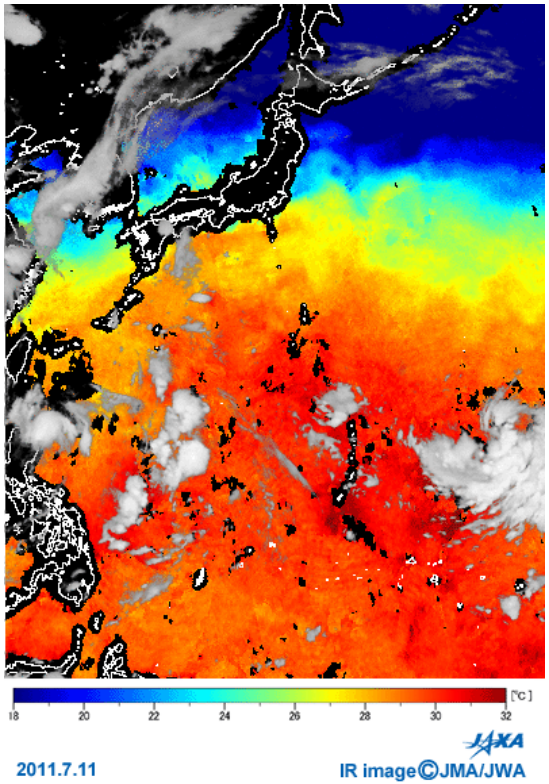
- **Mission status**
  - Operation was halted on October 4, 2011 due to the overrun of the antenna rotation torque, after the continuous observation over 9 years from EOS Aqua satellite. Investigations are underway.
  - AMSR-E data had been used in NWP and typhoon analyis in JMA.

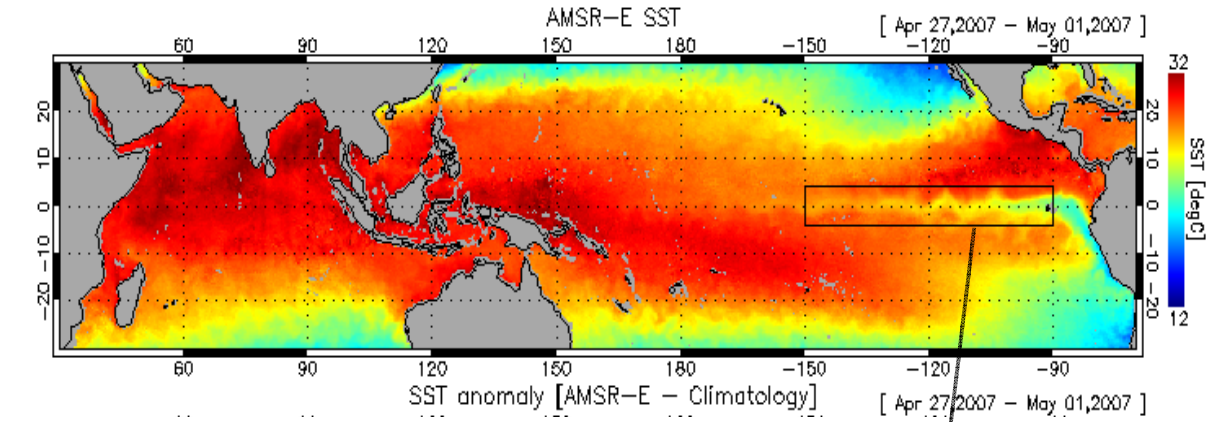
Aqua satellite

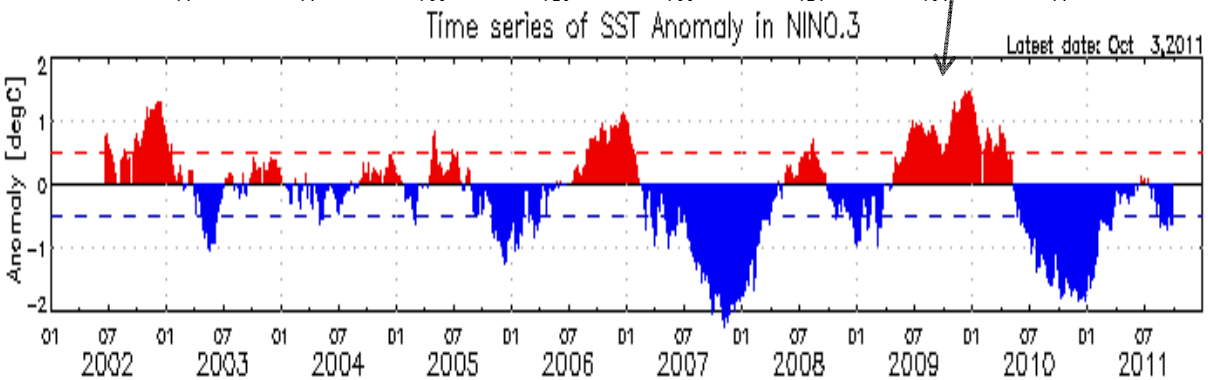
- **Instrument characteristics**
  - Multi-frequency microwave radiometer with dual polarization capability (developed by JAXA).
  - High-spatial resolution compared to existing instruments by large size antenna.
  - C-band (6.9GHz) channels for estimating SST and soil moisture.
  - Afternoon (1:30 pm) equatorial crossing time that is currently unique for microwave radiometers.

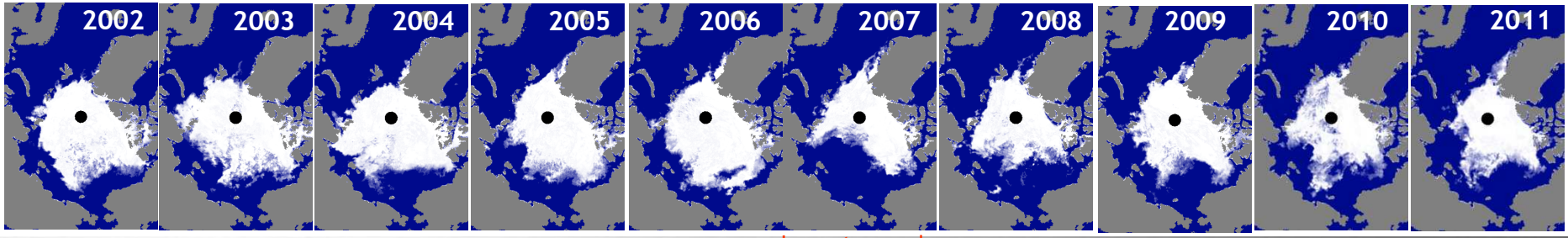
Pre-launch AMSR-E in Tsukuba Space Center

Observations by AMSR-E





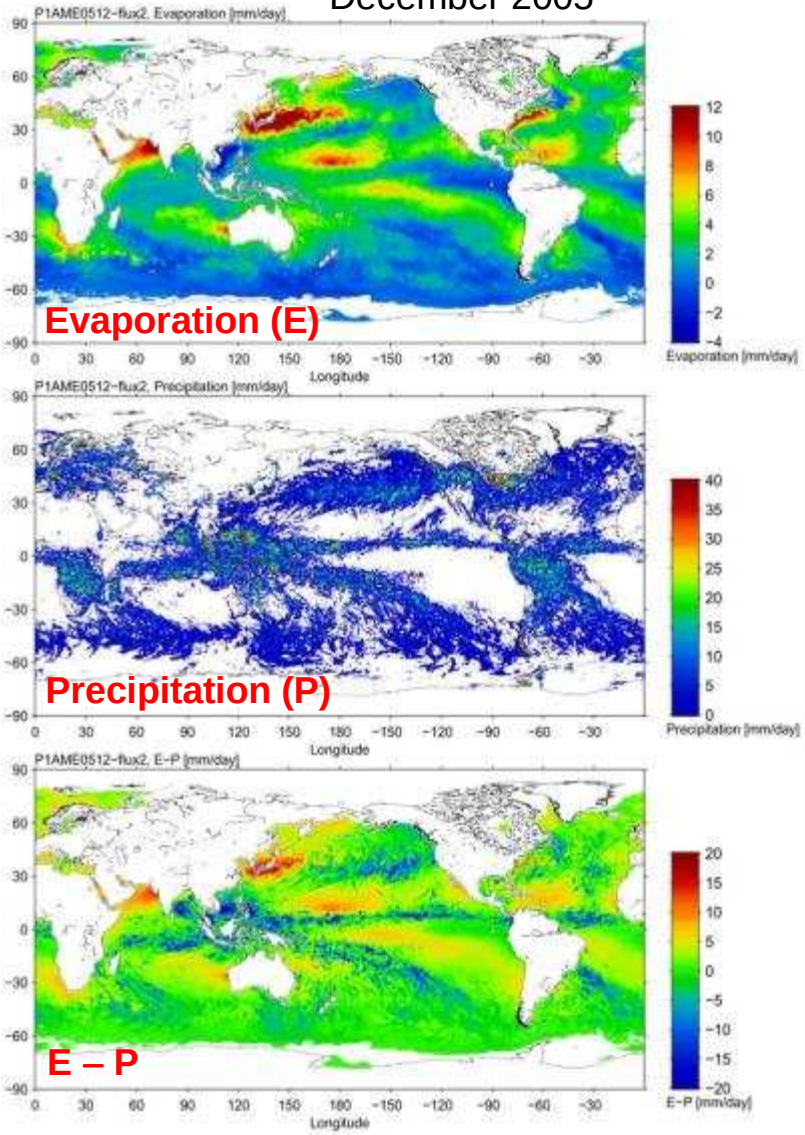




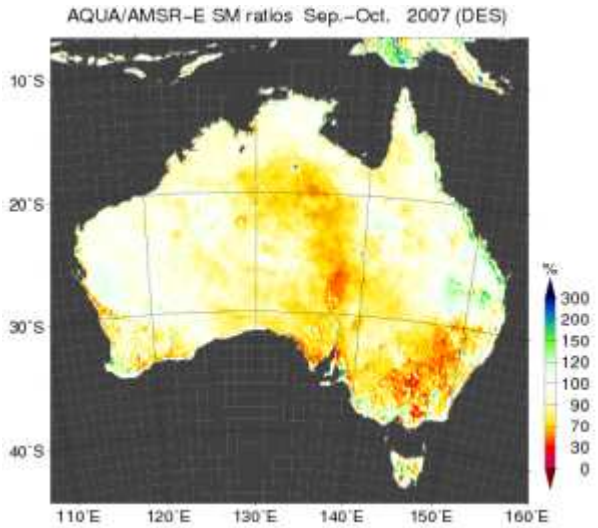
Lowest record

Observations by AMSR-E

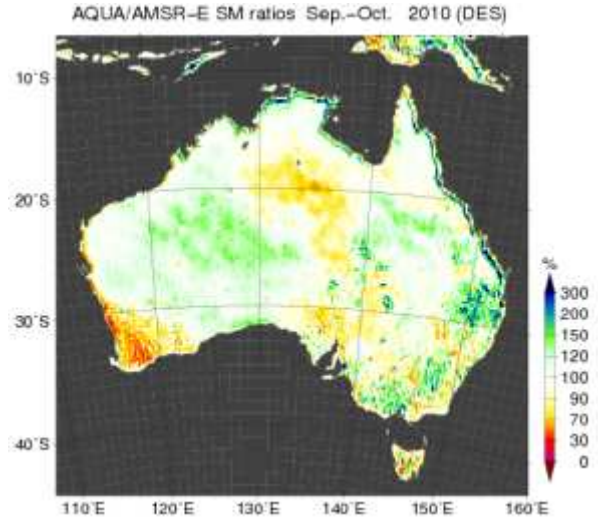
December 2005



Sea surface fresh water flux by AMSR-E

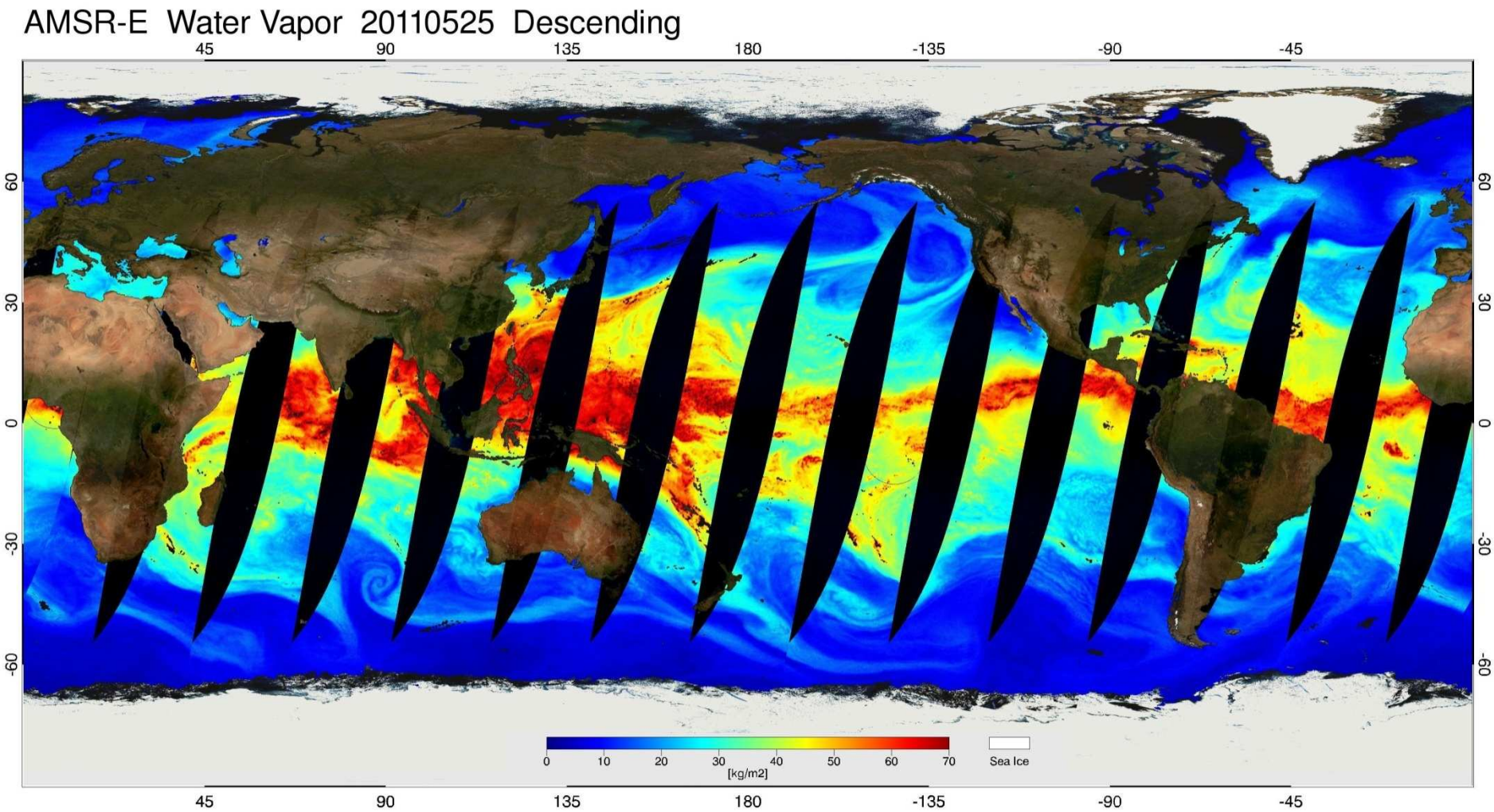


Soil moisture ratio of 2007 to 2005

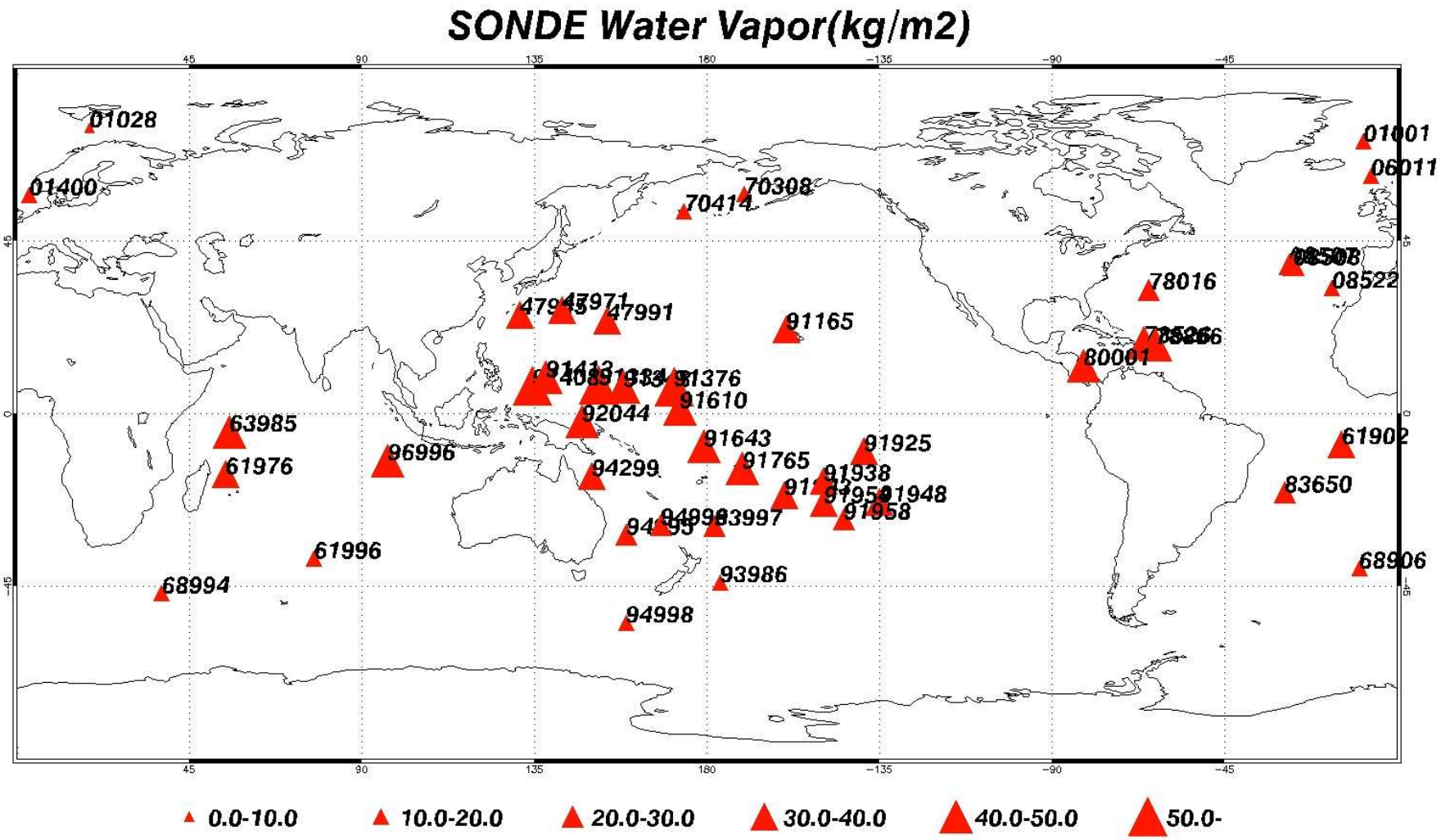


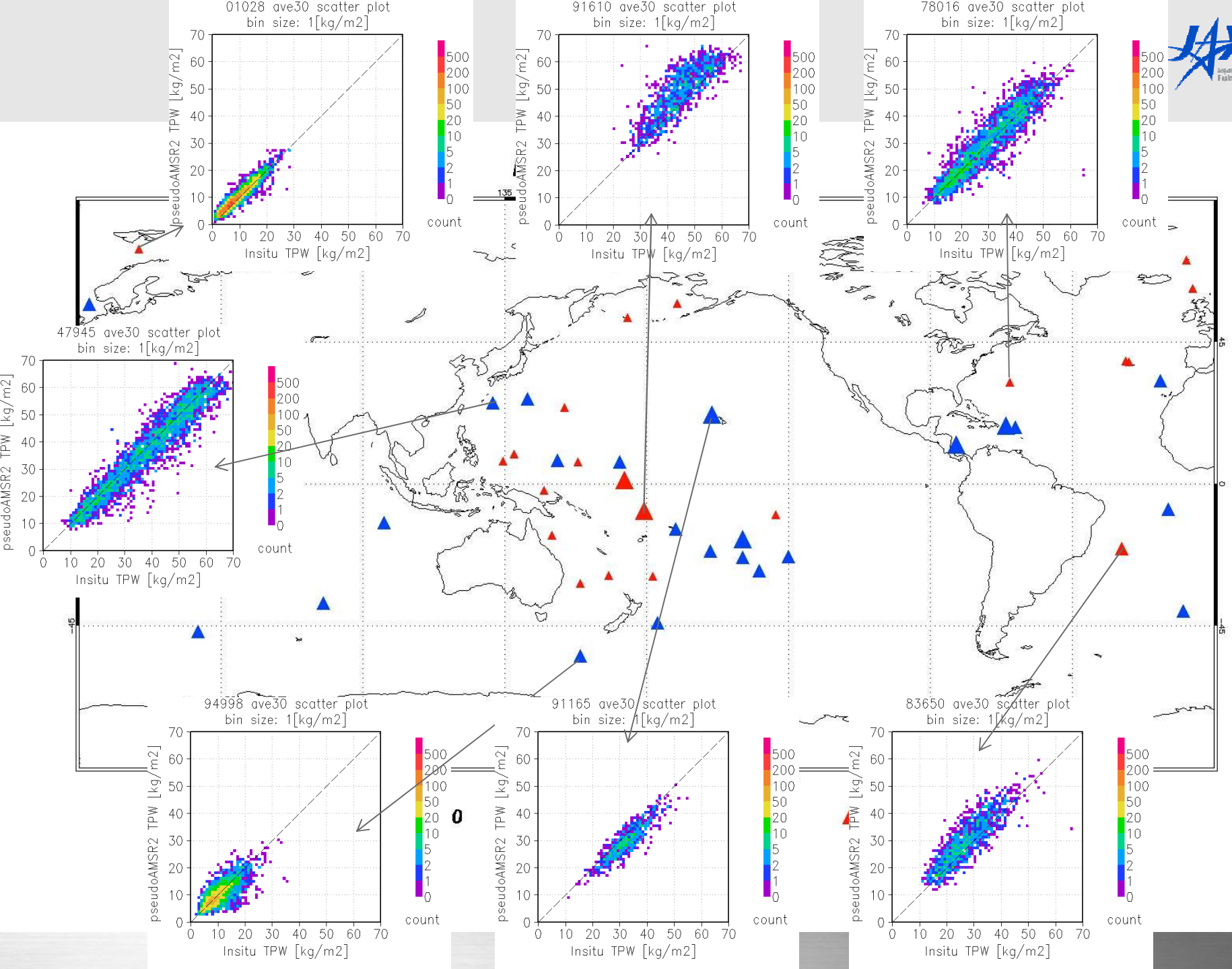
Soil moisture ratio of 2010 to 2005

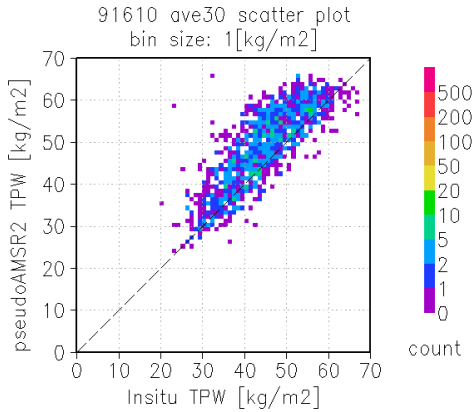
AMSR-E Integrated Water Vapor



Radiosondes used for Validation




01028 ave30 scatter plot
bin size: 1[kg/m2]
91610 ave30 scatter plot
bin size: 1[kg/m2]
78016 ave30 scatter plot
bin size: 1[kg/m2]
47945 ave30 scatter plot
bin size: 1[kg/m2]
94998 ave30 scatter plot
bin size: 1[kg/m2]
91165 ave30 scatter plot
bin size: 1[kg/m2]
83650 ave30 scatter plot
bin size: 1[kg/m2]
pseudoAMSR2 TPW [kg/m2]
Insitu TPW [kg/m2]
count
0 10 20 30 40 50 60 70
500 200 100 50 20 10 5 2 1 0
135
45
0
-45

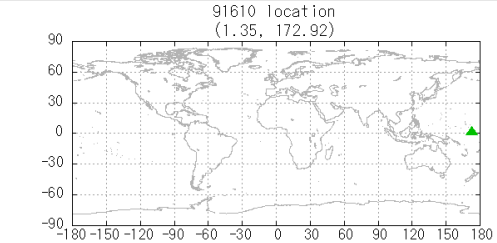


LAND 91610
ALTITUDE UNDER 200m

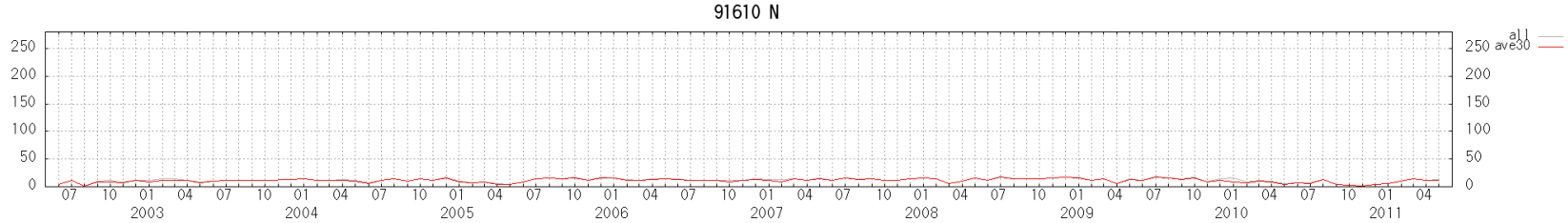
place: Tarawa

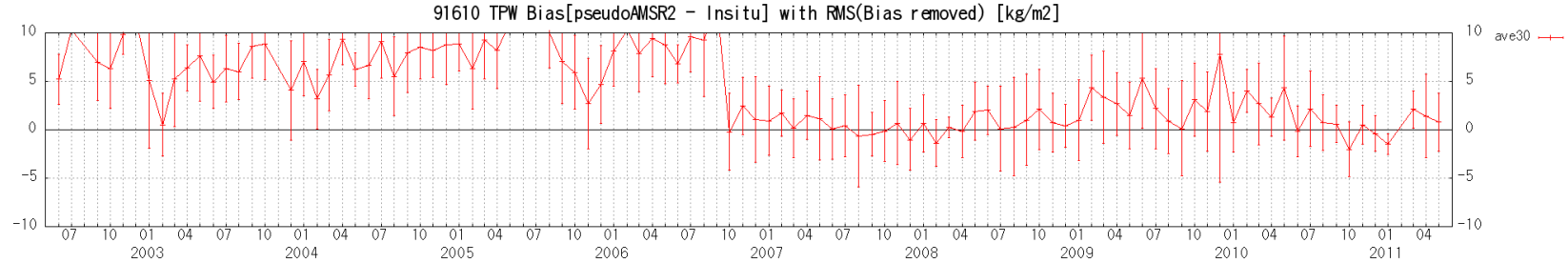
PERIOD: JUNE 2002 - MAY 2011
*** all N : 1255 ***
*** average30 ***

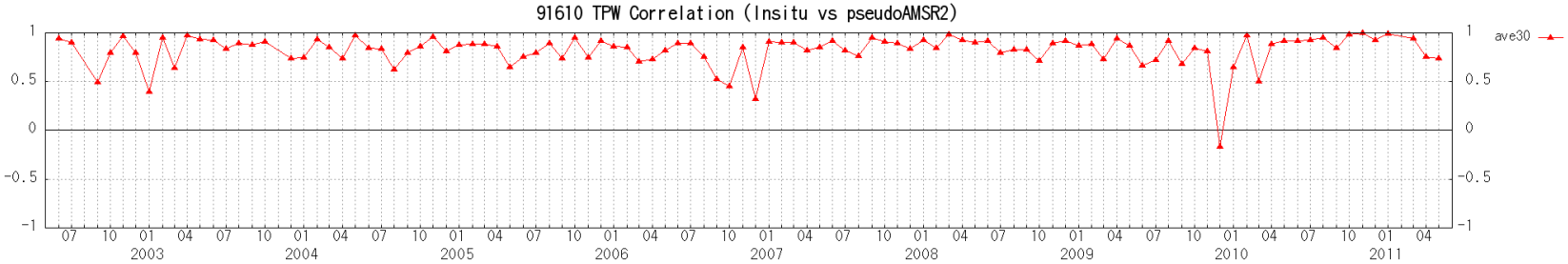
N	1185
Bias	4.222
RMS	6.757
RMS(Bias removed)	5.274
Correlation	0.816



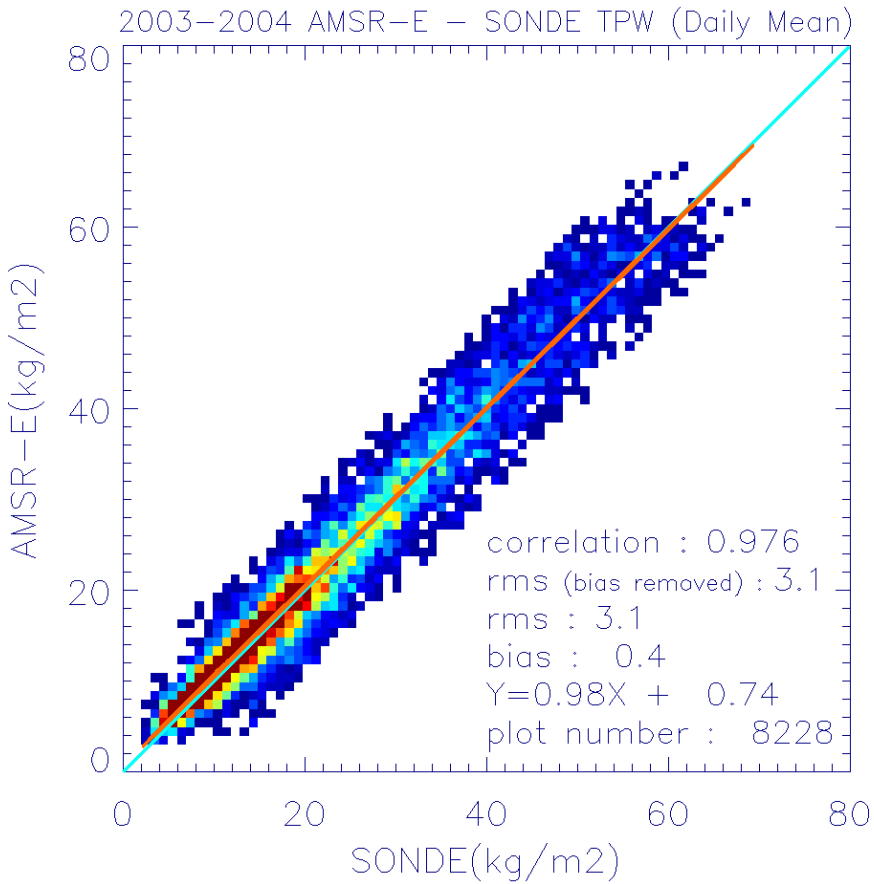
location transition
2002/06/11 23:00 - 2011/05/30 23:00 lat 1.35 lon 172.92 suf 4m



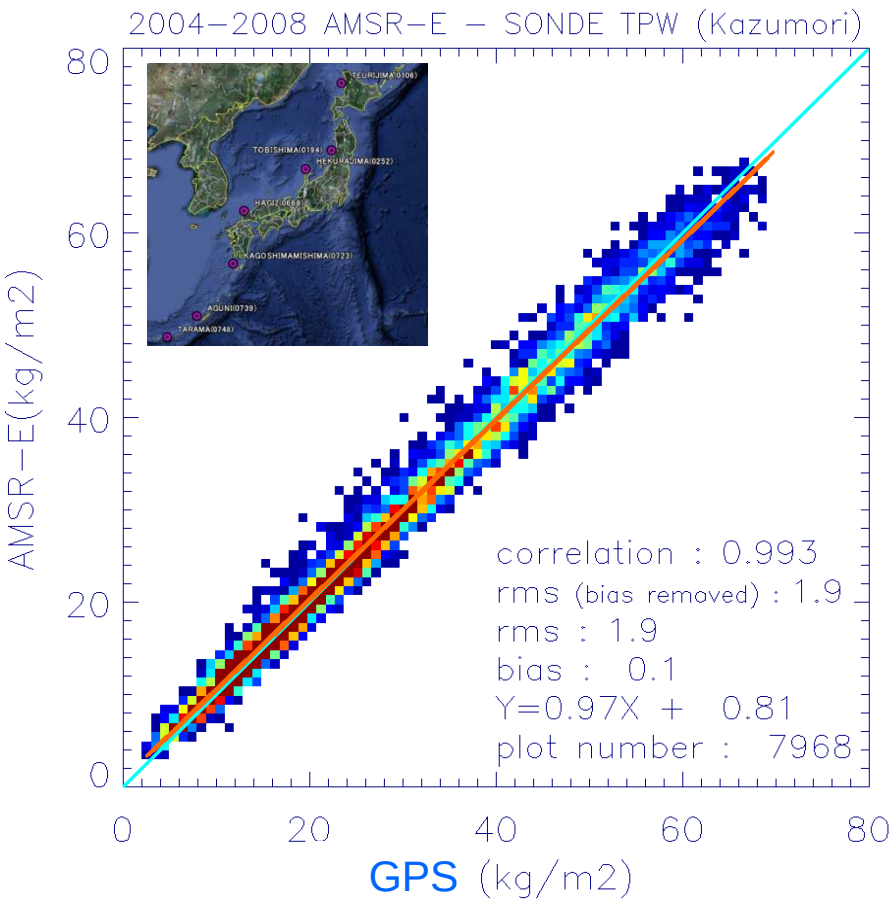




Radiosondes and GPS



TPW comparison between AMSR-E and radiosondes

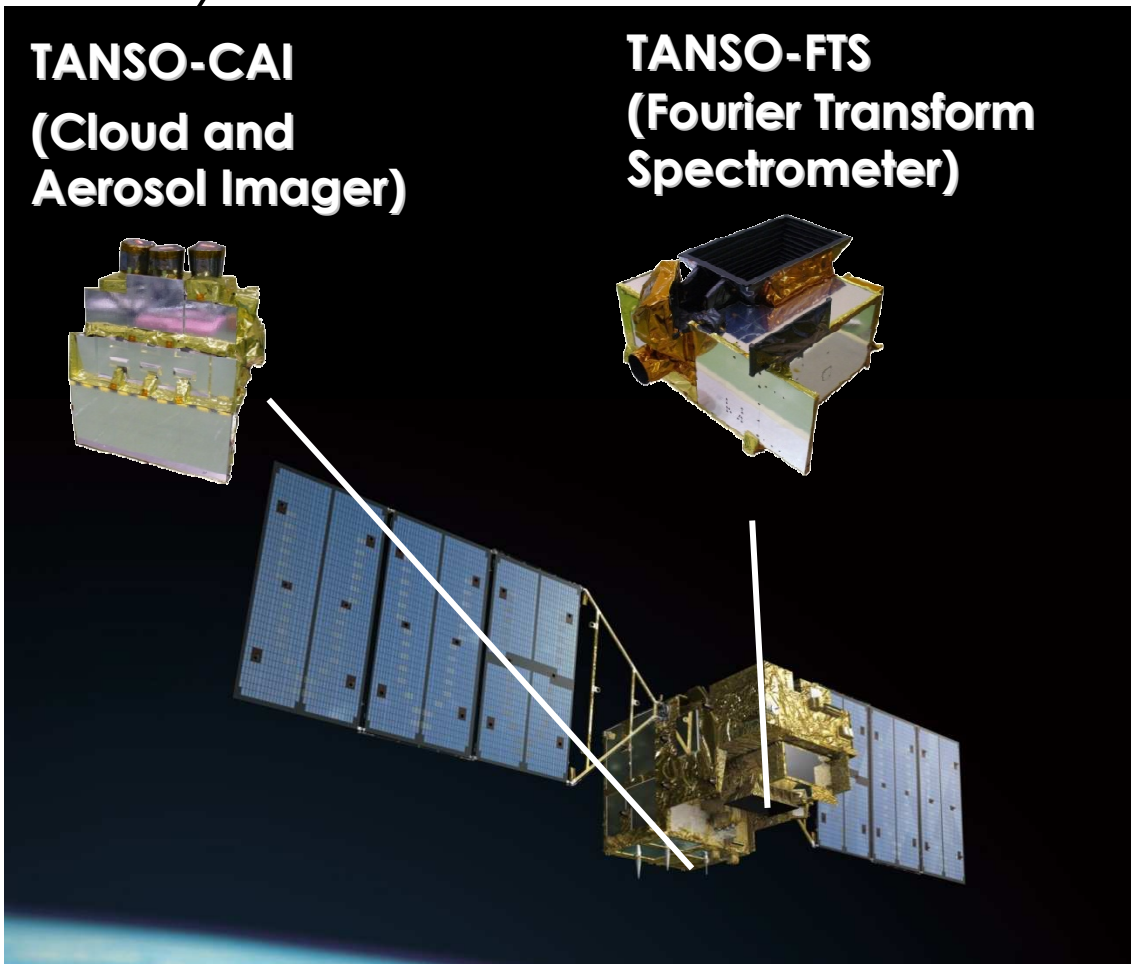


TPW comparison between AMSR-E and GPS

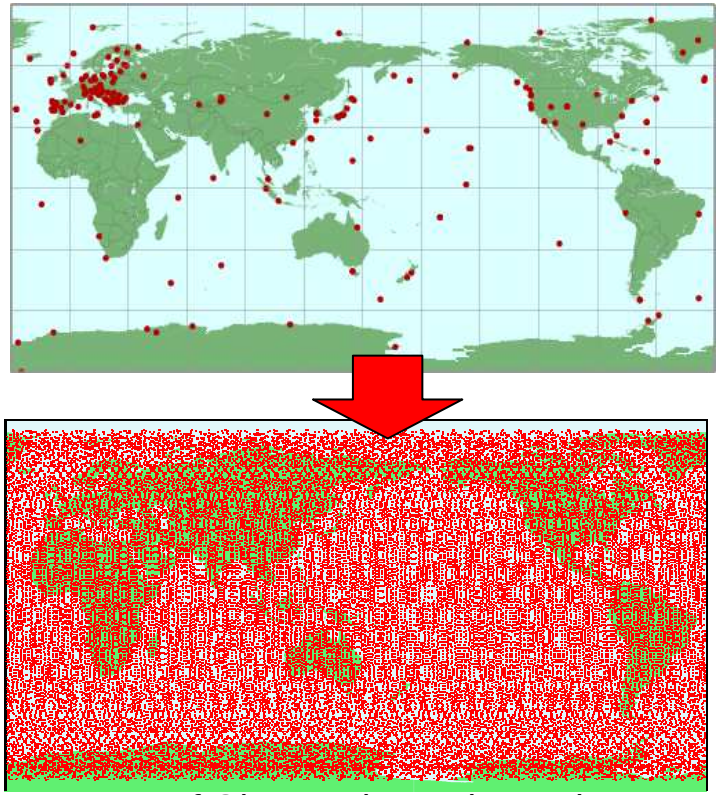
GPS total precipitable water was computed and provided by Dr. Shoji of MRI.

Greenhouse Gases Observing Satellite (GOSAT)

GOSAT enables global (with 56,000 points) and frequent (at every 3 days) monitoring CO2 and CH4 column density. (Launched in Jan 2009)

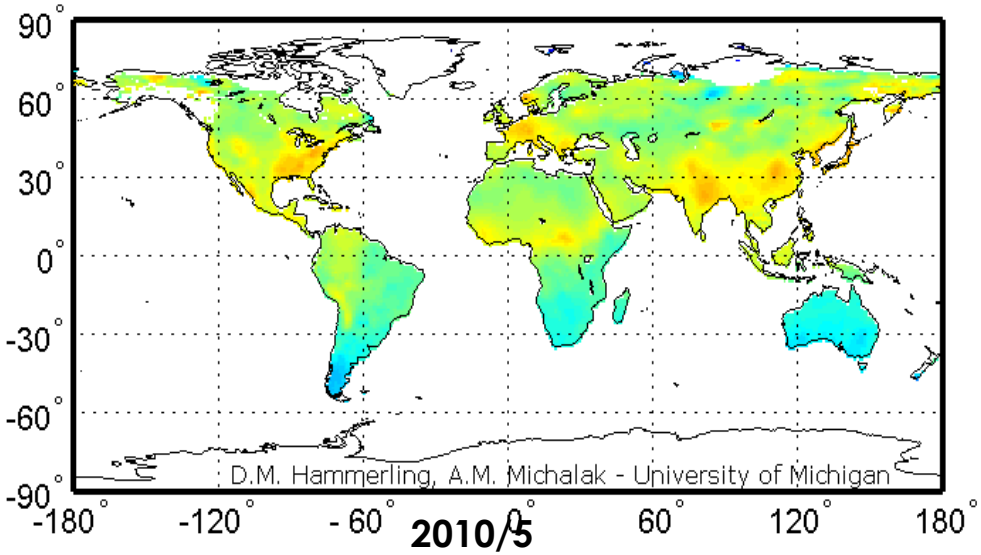


Current Ground-based Observation Points (320pts) *Provided by WMO WDCGG*



Increase of Observation Points using GOSAT (56,000pts)

GOSAT CO_2 global distributions

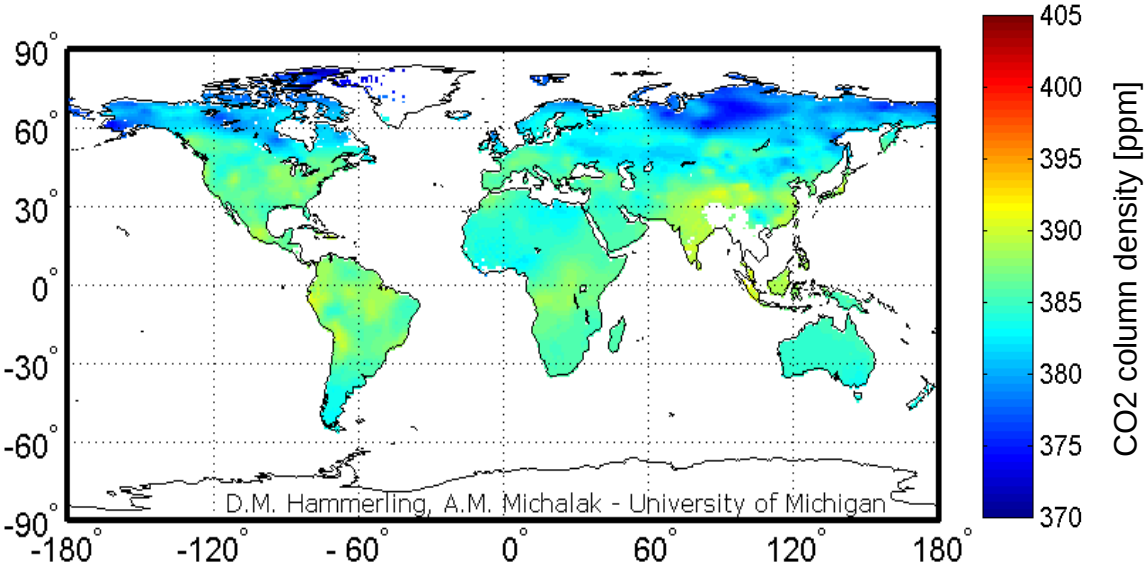


2010/5

CO2 column density decreases from May to August in the Northern Hemisphere because of photosynthesis.

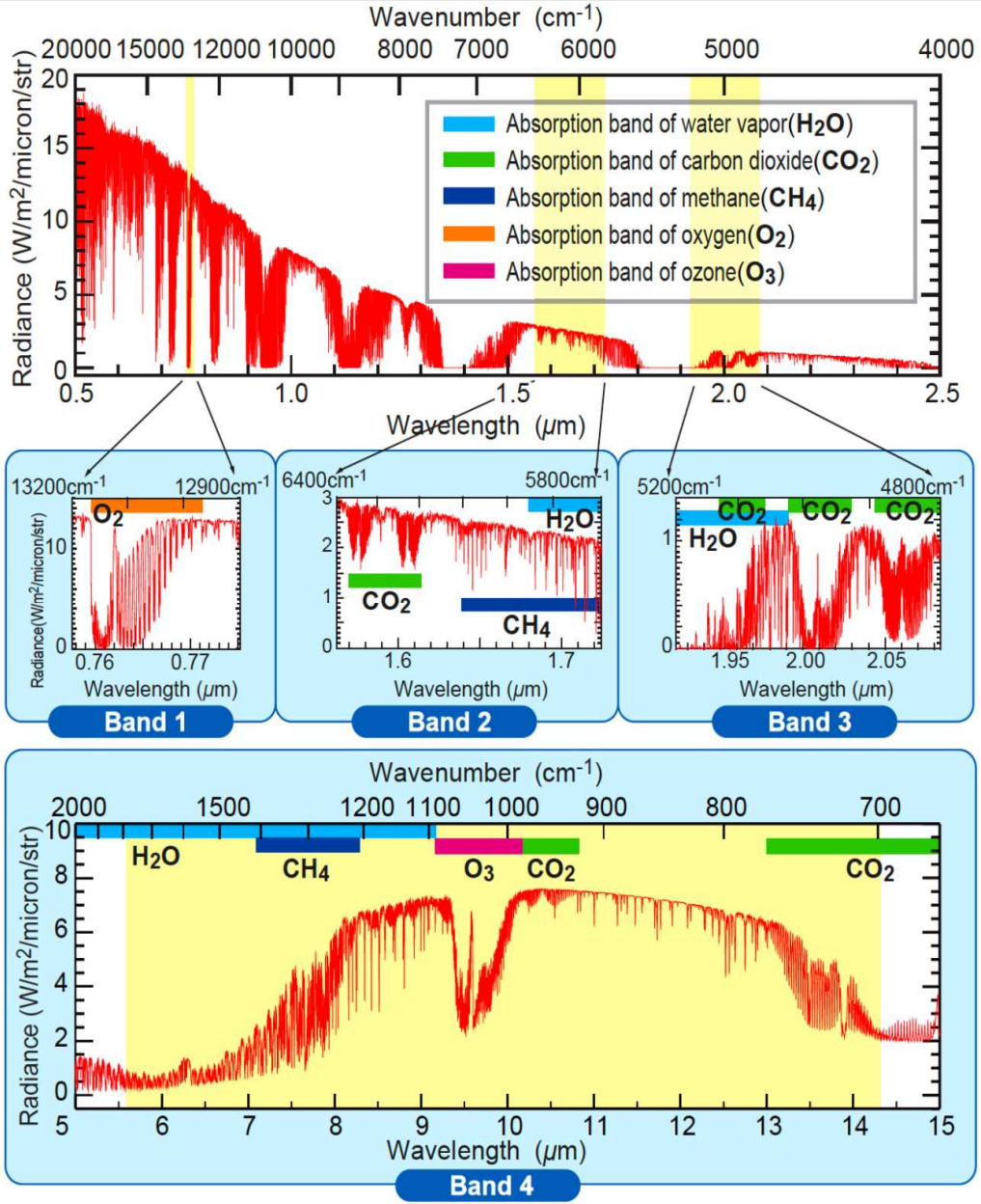
CO2 high density

CO2 low density



2010/8

Spectrum observed by GOSAT

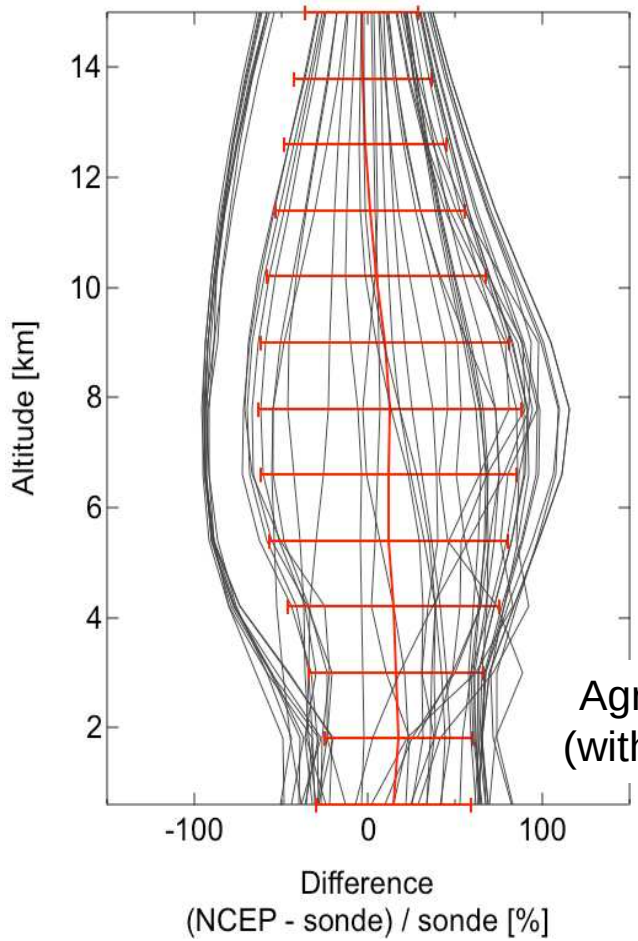


Source: NIES GOSAT pamphlet

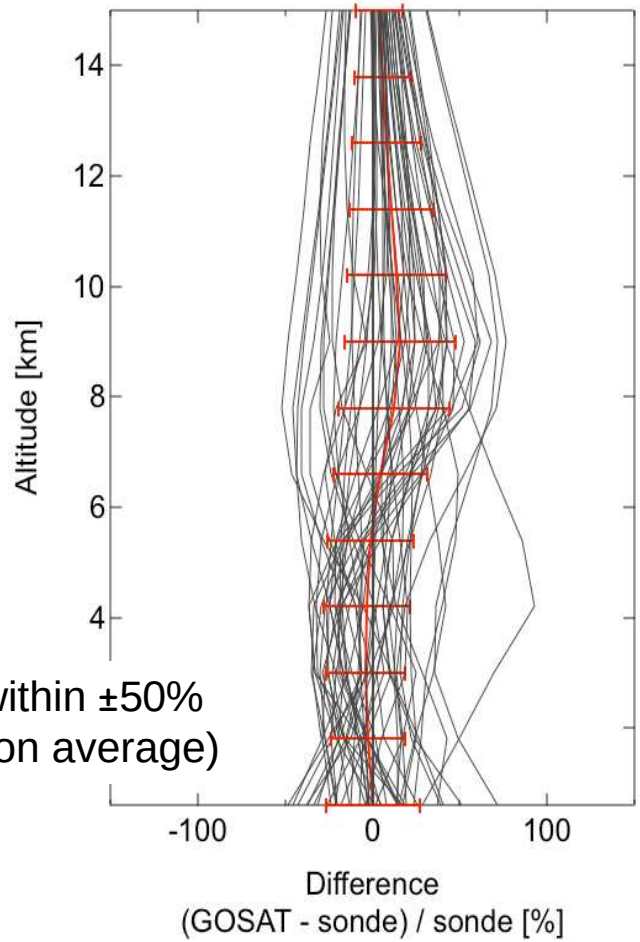
Comparison of H_2O profiles between GOSAT and Radiosonde

Computed H_2O concentration from radiosonde humidity profiles (Meisei RS-01G) obtained during the GOSAT validation campaign in Feb 2010, Jan-Feb 2011, and Jan 2012.

Initial value (NCEP) vs Radiosonde



GOSAT vs Radiosonde

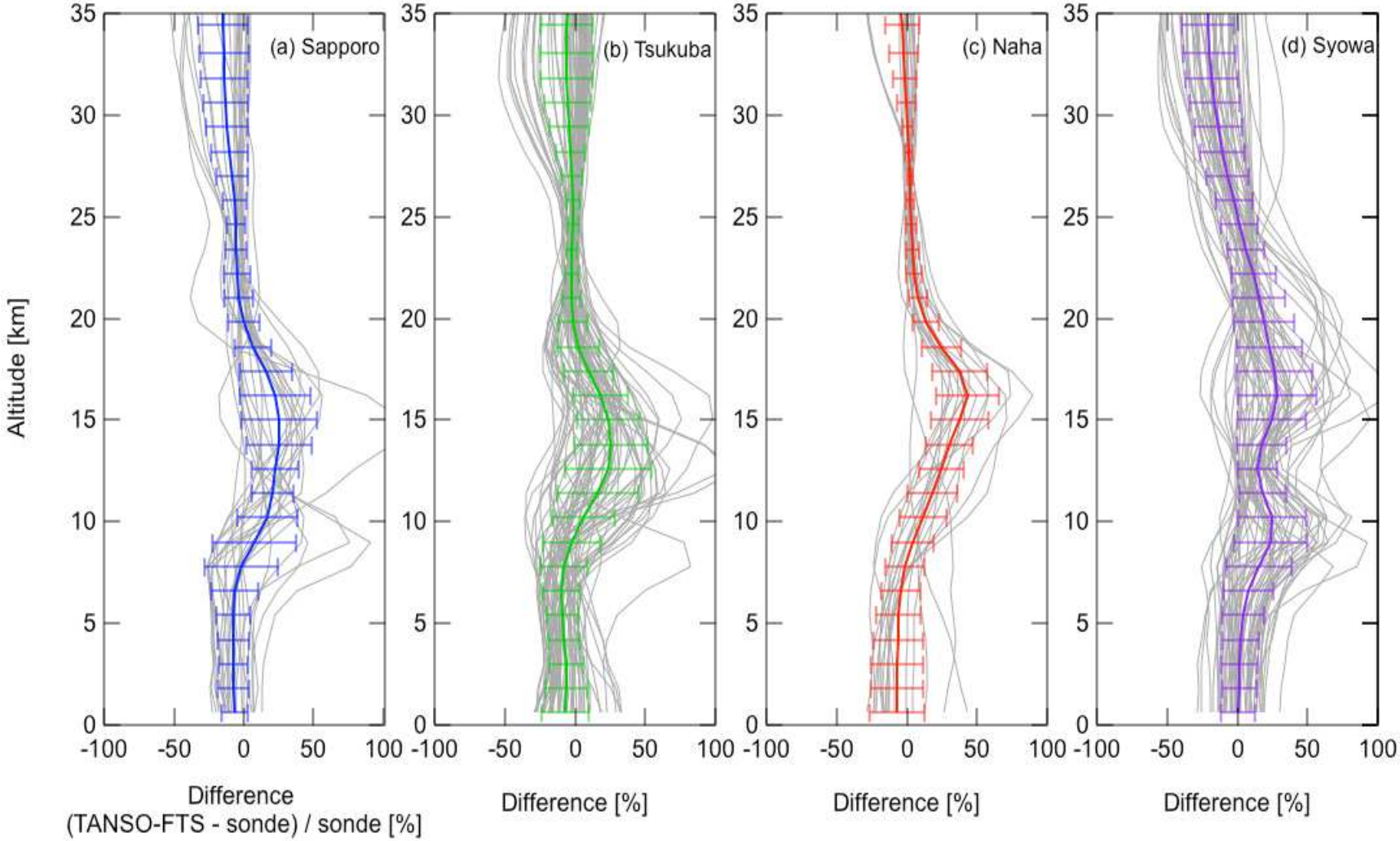


Agreement within ±50%
(within ±10% on average)

Results provided by Dr. Ohyama of JAXA/EORC. Radiosonde data were provided by Drs. Morino and Uchino of NIES.

Comparison of Ozone Profiles between GOSAT and Ozonesonde Observations

Match-up condition: 100km, 6h

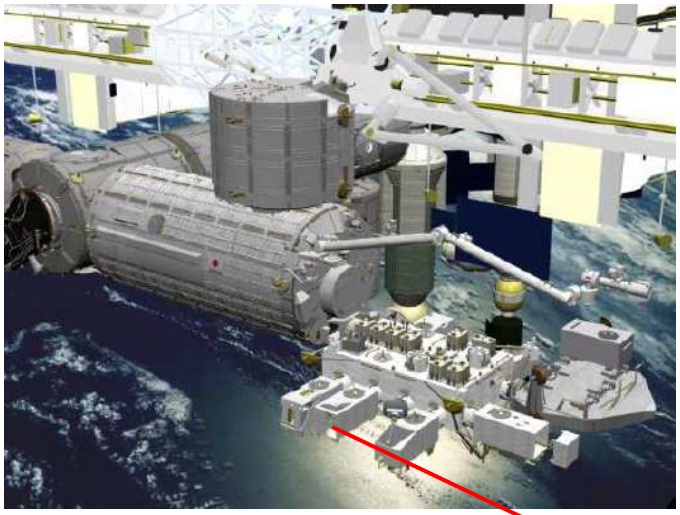


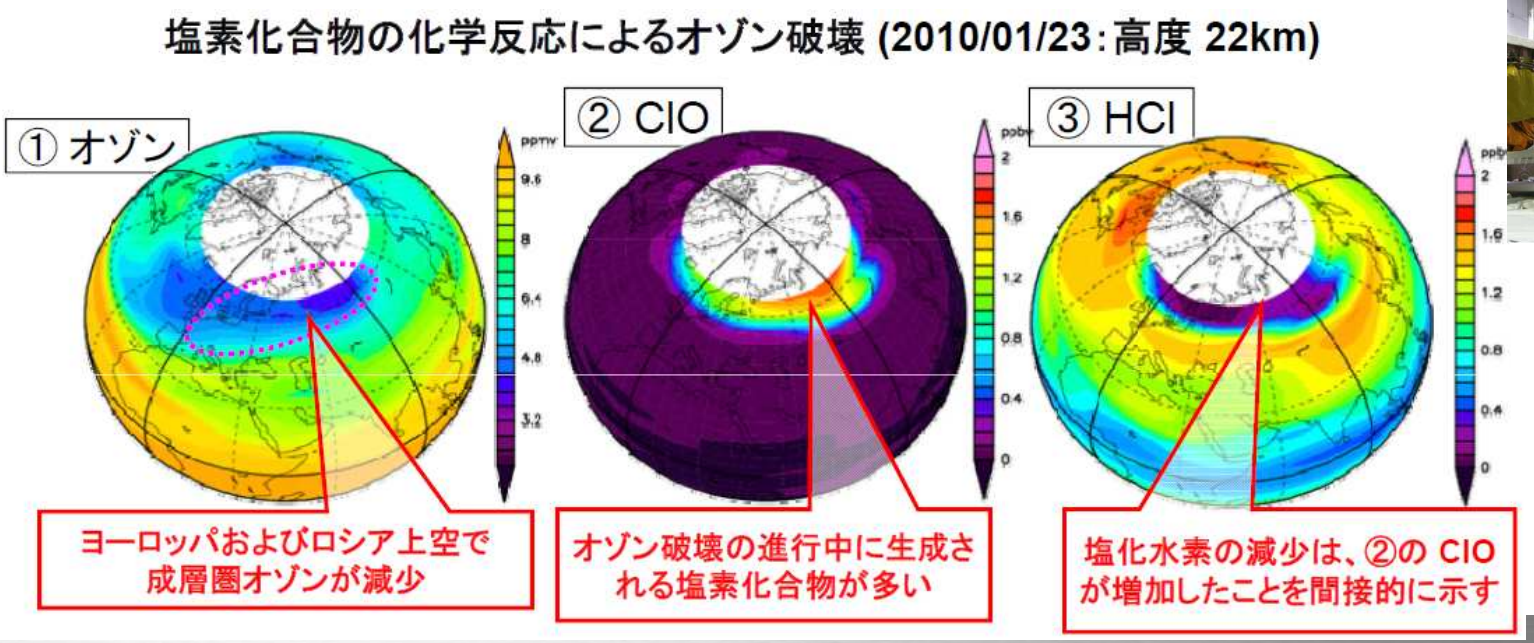
Positive bias near-tropopause

Results provided by Dr. Ohyama of JAXA/EORC. Ozonesonde data: http://www.woudc.org/

SMILES on ISS/JEM: 2009-2010

- High sensitivity in detecting atmospheric limb emission in the submillimeter wave range (624-650GHz).
- Vertical profiling (~3km) from JEM/ISS with latitudinal coverage from 65N to 38S.
- NICT and JAXA joint activity.



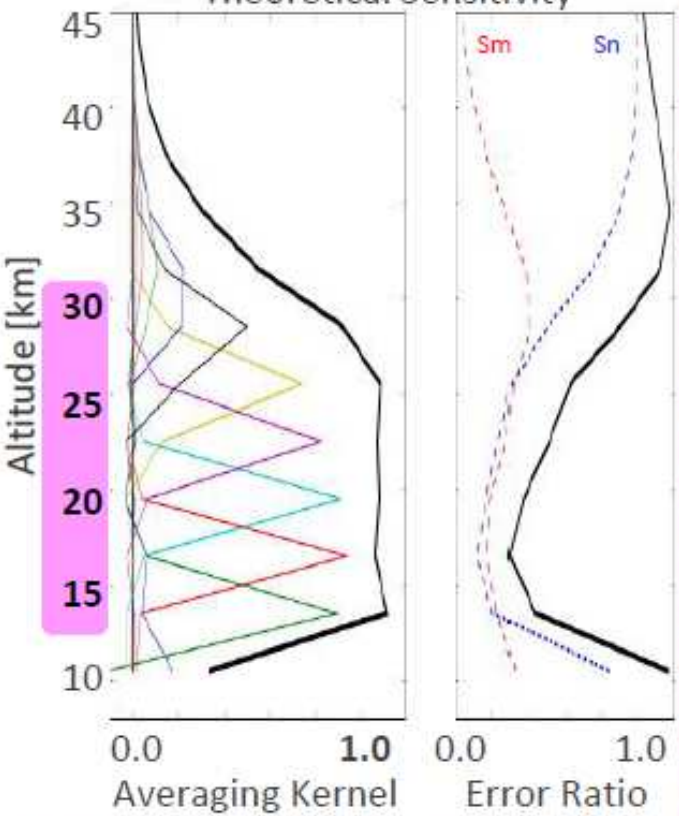


- SMILES sensitivity to H_2O

SMILES - A 625 GHz continuum

Full bandwidth is used for this calc.
Band B is almost same as Band A.
For Band C, the sensitivity range becomes narrower as 14 – 20 km.

Theoretical Sensitivity

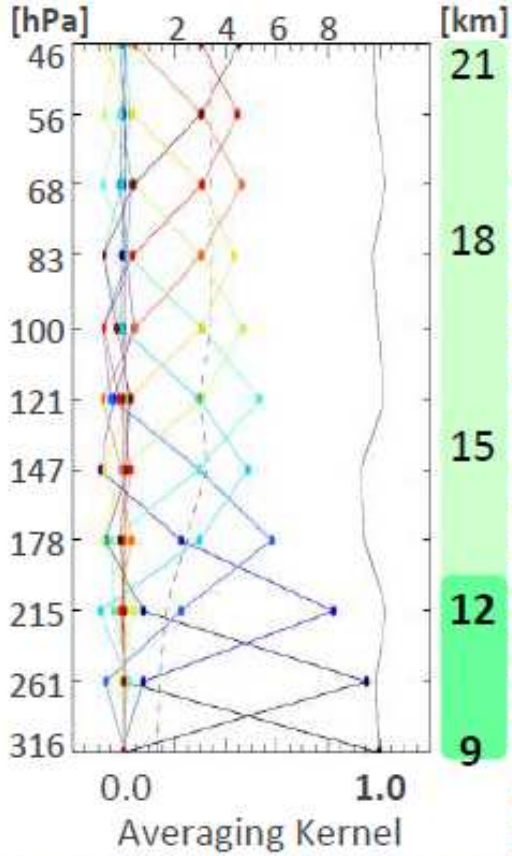


MLS 183 GHz H_2O line

Tropospheric altitudes are well covered.

Read et al. (2007, *JGR*)

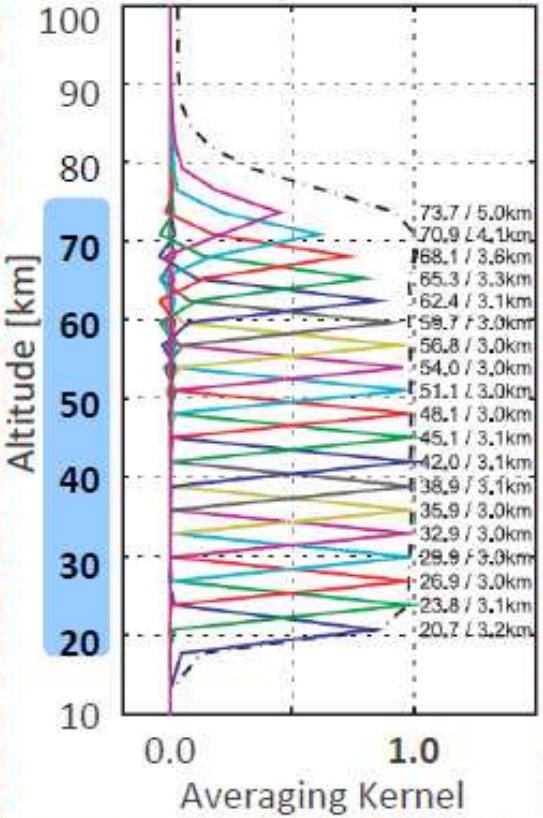
Vertical Resolution [km]



SMR 488 GHz H_2O line

Also observes 557 GHz transition. And, there is an UT/LS H2O product from the continuum opacity.

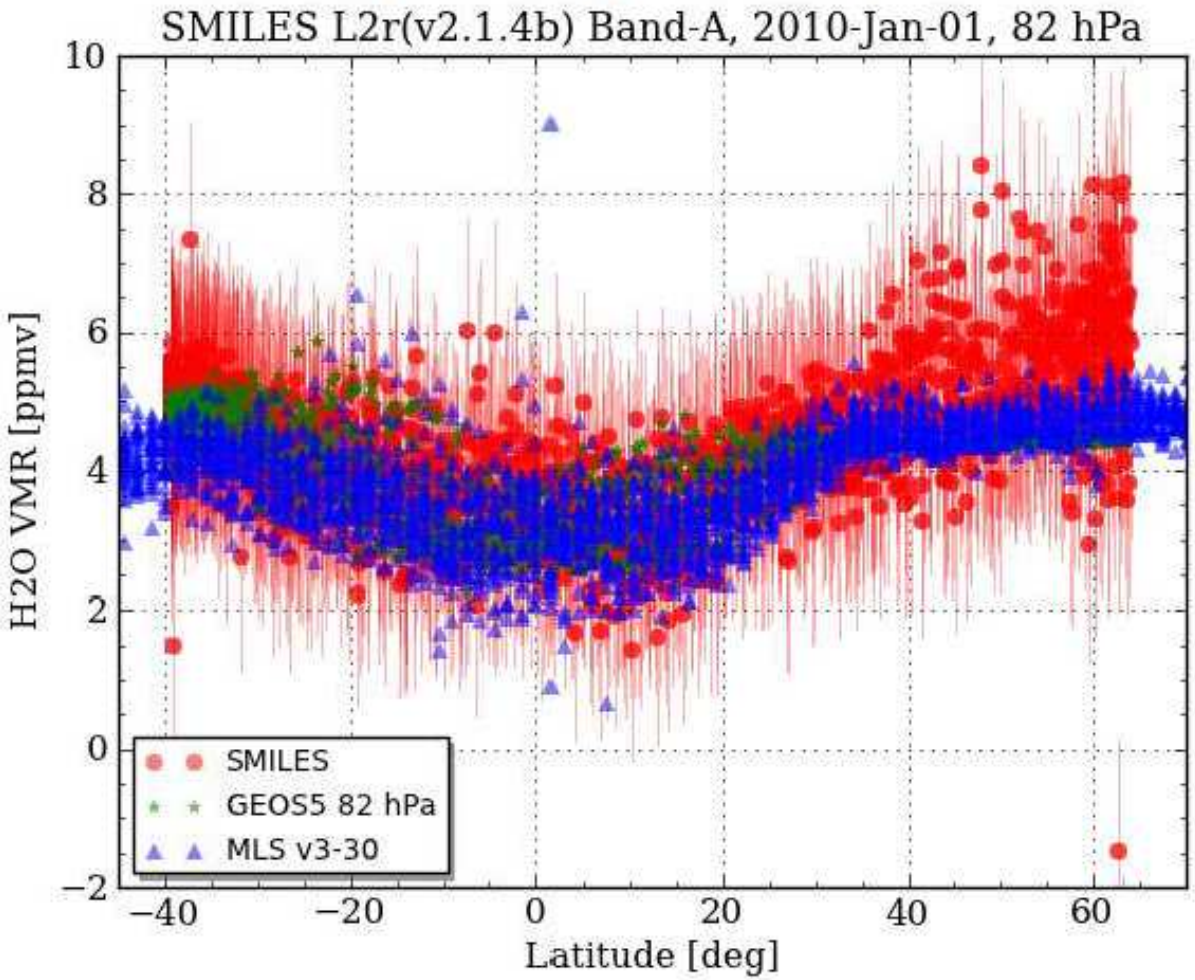
Urban et al. (2007, *PSS*)



Results provided by Dr. Sagawa of NICT.

- Latitudinal distribution, 82 hPa

01-Jan-2010, Band A (L1b v.007)

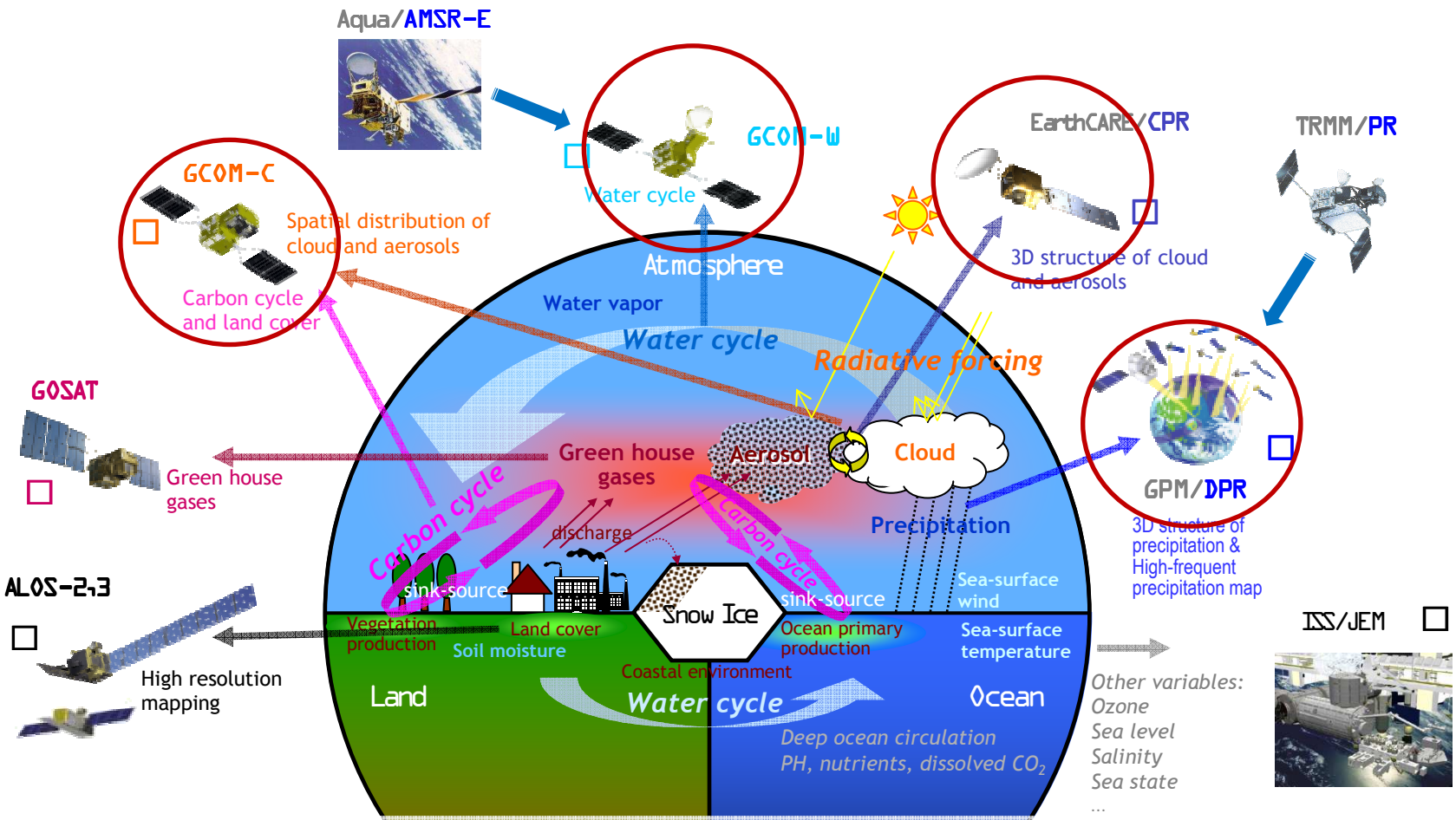


← Retrieved data which measurement response are larger than 0.85 are plotted. (vertical resolution of SMILES is 4 – 5 km)

Results of Tropics seems agree with GEOS5…

…or, just systematic & random errors?

Currently and Future JAXA EO Missions



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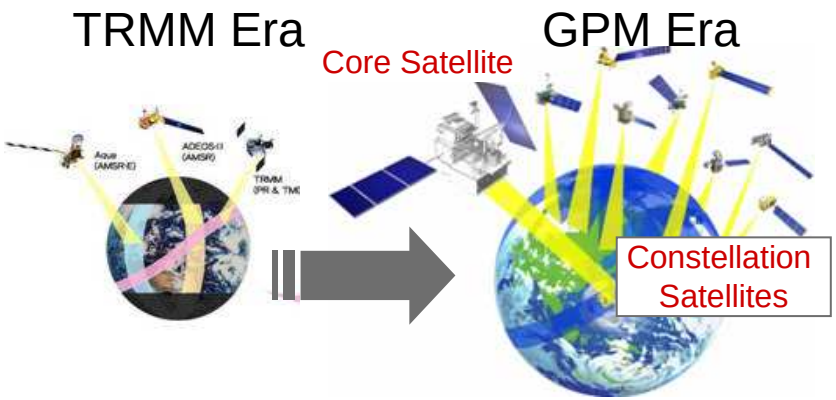
GCOM-W:	Long-term observation of water-cycle such as the snow/ice coverage, water vapor, and SST
GOSAT:	Observation of distribution and flux of the atmospheric greenhouse gases, CO_2 and CH_4
EarthCARE/CPR:	Observation of vertical structure of clouds and aerosols
GPM/DPR:	Accurate and frequent observation of precipitation with active and passive sensors
ALOS-2,3:	Fine resolution mapping by optical and SAR instruments
ISS/JEM:	Demonstration of new missions (e.g., SMILES, GLISM, etc.)

Global Precipitation Measurement (GPM)

- The Global Precipitation Measurement (GPM) is an expanded mission of the Tropical Rainfall Measuring Mission (TRMM)



Core Satellite (JAXA, NASA)

Dual-frequency precipitation radar (DPR)

GPM Microwave Imager (GMI)

- Precipitation with high precision
- Discrimination between rain and snow
- Adjustment of data from constellation satellites

(launch in FY2013)

Constellation Satellites (International Partners)

Microwave radiometers

Microwave sounders

- Global precipitation every 3 hours

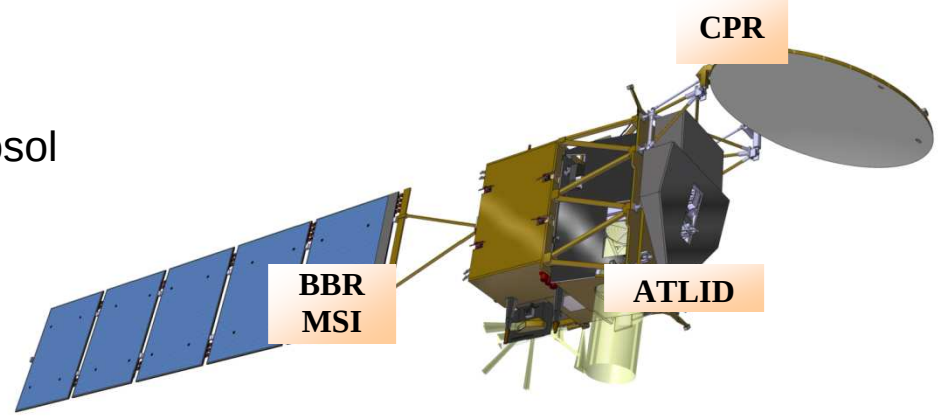
(launch around 2013)

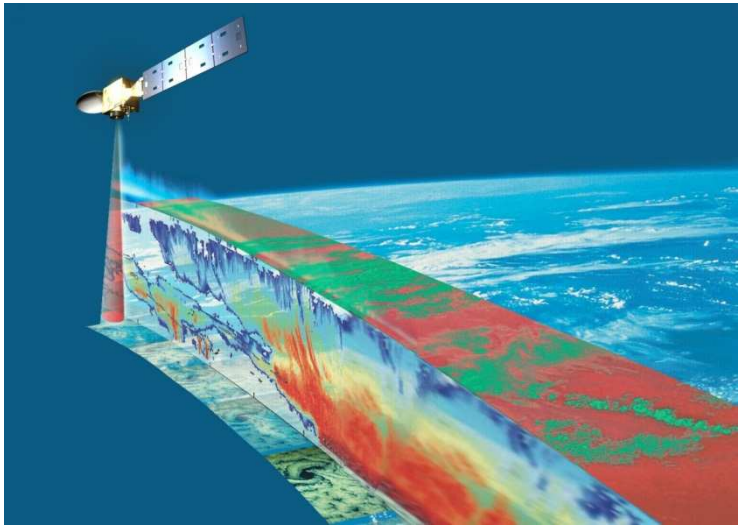
- Improve the accuracy of both long-term and short-term weather forecasts
- Improve water resource management in river control and irrigation systems for agriculture

EarthCARE/CPR

Climate monitoring of earth radiation, cloud and aerosol
Cooperation between ESA and Japan (JAXA/NICT)

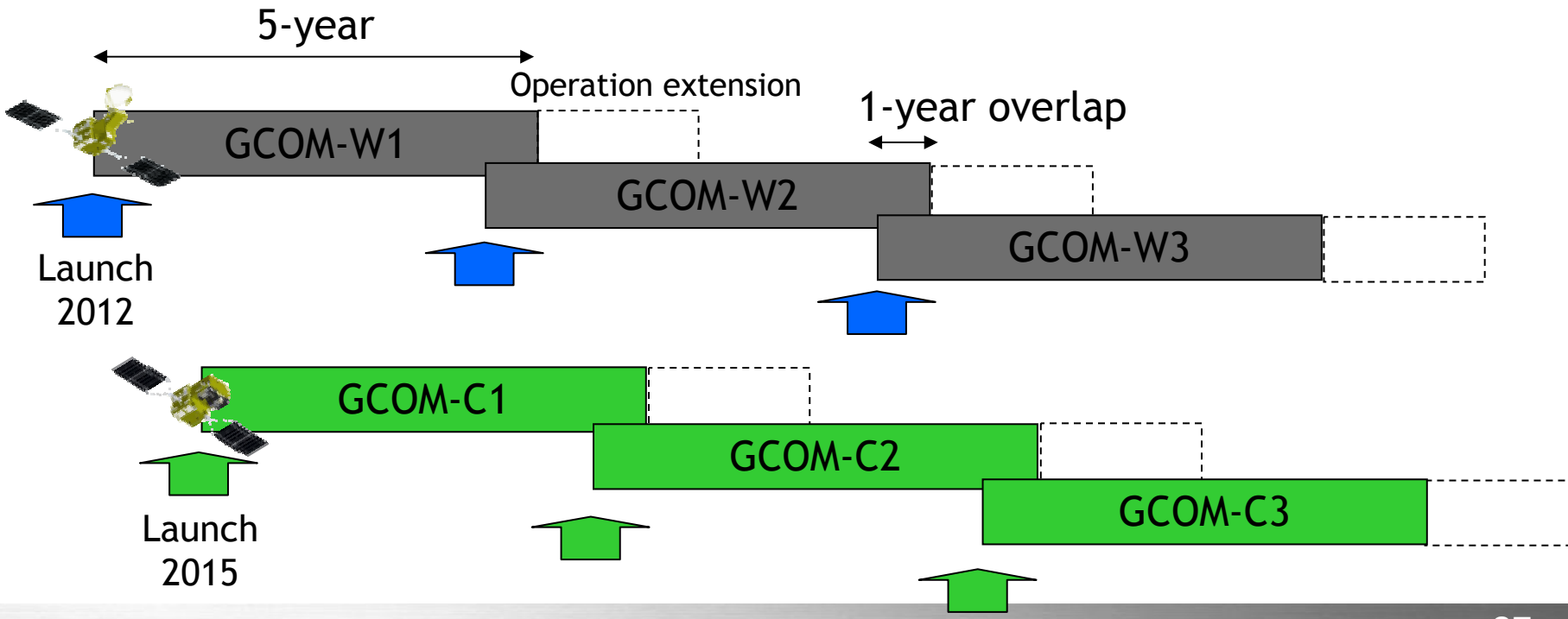
- **Mission**
  - Vertical profile of clouds, aerosol
  - Interaction between clouds and aerosol
  - Cloud stability and precipitation
- **Orbit**
  - Sun synchronous
  - Equator crossing time 13:45
  - Altitude 400km
- **Instrument**
  - CPR (Cloud Profile Radar)
  - ATLID (Atmospheric LIDAR)
  - MSI (Multi-Spectral Imager)
  - BBR (Broad Band Radiometer)
- **Task sharing**
  - JAXA/NICT□CPR□
  - ESA□LIDAR, MSI, BBR, Spacecraft)
- **Launch target**
  - JFY2013



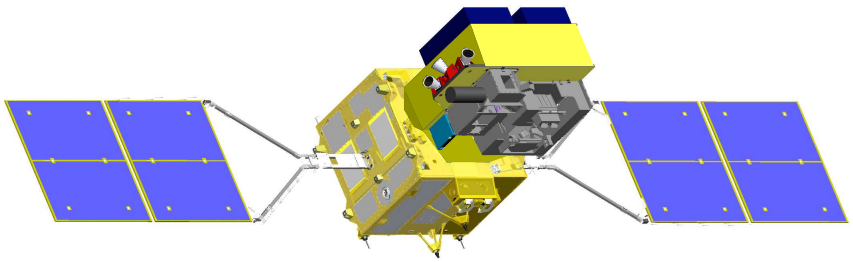


Global Change Observation Mission (GCOM)

- Demonstrate long-term global observation of various geophysical parameters for understanding climate variability and water cycle.
- Two medium-sized satellites, three generations with one year overlap to ensure 10-15 years stable data records.
- Cooperation with climate models and direct contribution to operational users.



GCOM 1st Generation Satellites



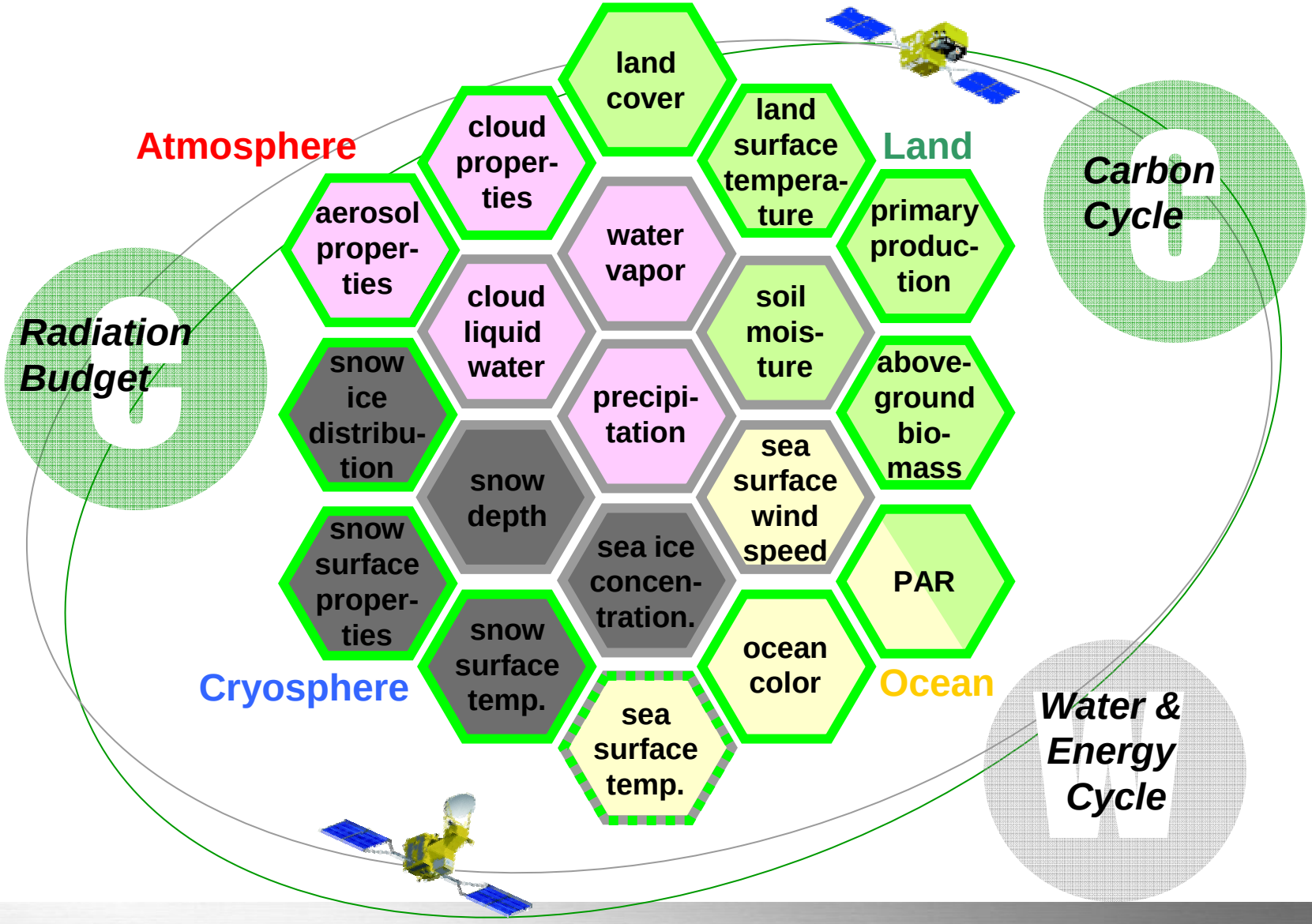
GCOM-W1 (Water)

Instrument	**Advanced Microwave Scanning Radiometer-2**
Orbit	Sun Synchronous orbit Altitude□699.6km (on Equator) Inclination: 98.2 degrees Local sun time: 13:30+/-15 min
Size	5.1m (X) * 17.5m (Y) * 3.4m (Z) (on-orbit)
Mass	1991kg
Power gen.	More than 3880W (EOL)
Launch	2012
Design Life	5-years

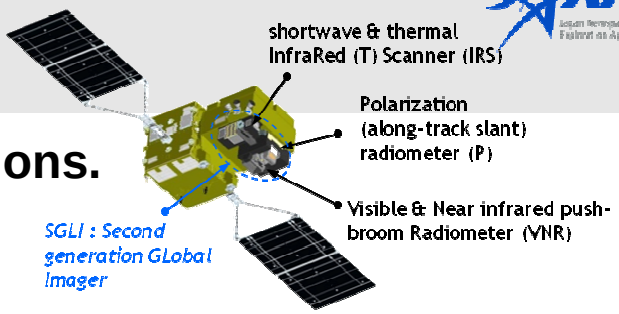
GCOM-C1 (Climate)

Instrument	**Second-generation Global Imager**
Orbit	Sun Synchronous orbit Altitude□798km (on Equator) Inclination: 98.6 deg. Local sun time: 10:30+/- 15min
Size	4.6m (X) * 16.3m (Y) * 2.8m (Z) (on orbit)
Mass	2093kg
Power gen.	More than 4000W (EOL)
Launch	JFY 2014 (TBD)
Design Life	5-years

Overview of GCOM Products



GCOM-C1/SGLI Instrument



SGLI improves land, coastal, and aerosol observations.

✓Finer spatial resolution: 250m (VNI) and 500m (T)

✓Polarization / along-track slant view channels (P)

GCOM-C SGLI characteristics	
Orbit	Sun-synchronous (descending local time: 10:30) Altitude 798km, Inclination 98.6deg
Mission Life	5 years (3 satellites; total 13 years)
Scan	Push-broom electric scan (VNR) Wisk-broom mechanical scan (IRS)
Scan width	1150km cross track (VNR: NP & PL) 1400km cross track (IRS: SWI & TIR)
Digitalization	12bit
Polarization	3 polarization angles for PL
Along track direction	Nadir for NP, SWI and TIR, +45 deg and -45 deg for PL
On-board calibration	VN: Solar diffuser, LED, Lunar cal maneuvers, and dark current by masked pixels and nighttime obs. SW: Solar diffuser, LED, Lamp, Lunar, and dark current by deep space window T: Black body and sensor back ground by deep space window

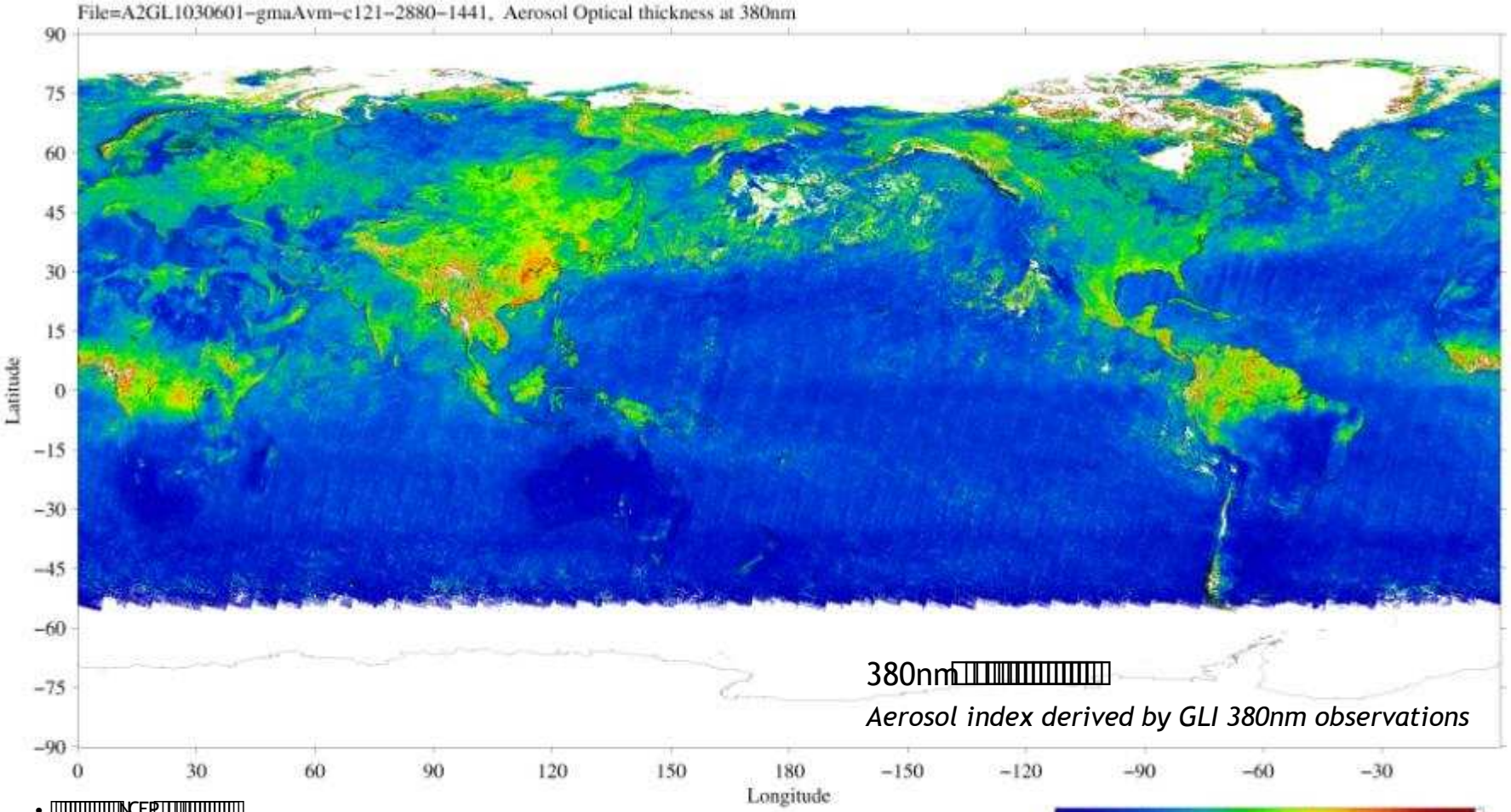
Multi-angle obs. for 674nm and 869nm

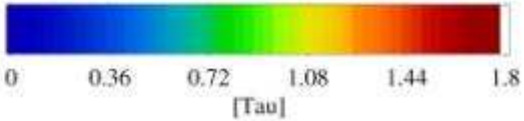
250m over the Land or coastal area, and 1km over offshore

SGLI channels						
CH	λ	$\Delta\lambda$	L_{std}	L_{max}	SNR at Lstd	IFOV
	VN, P, SW: nm T: µm		VNR, SWI: W/m²/sr/µm T: Kelvin		VNR, SWI: SNR T: NEΔT	m
VN1	380	10	60	210	250	250
VN2	412	10	75	250	400	250
VN3	443	10	64	400	300	250
VN4	490	10	53	120	400	250
VN5	530	20	41	350	250	250
VN6	565	20	33	90	400	250
VN7	*673.5*	*20*	23	62	400	250
VN8			25	210	250	250
VN9	763	12	40	350	1200	250/1000
VN10	*868.5*	20	8	30	400	250
VN11			30	300	200	250
PL1	*673.5*	20	25	250	250	1000
PL2	*868.5*	20	30	300	250	1000
SW1	1050	20	57	248	500	1000
SW2	1380	20	8	103	150	1000
SW3	*1630*	200	3	50	57	250
SW4	2210	50	1.9	20	211	1000
TIR1	10.8	0.74	300	340	0.2	250/500
TIR2	12.0	0.74	300	340	0.2	250/500

option

Over-Land Aerosol Estimation



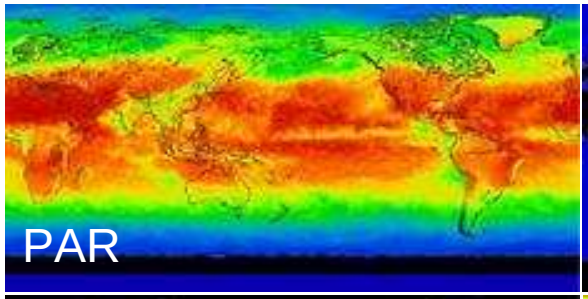


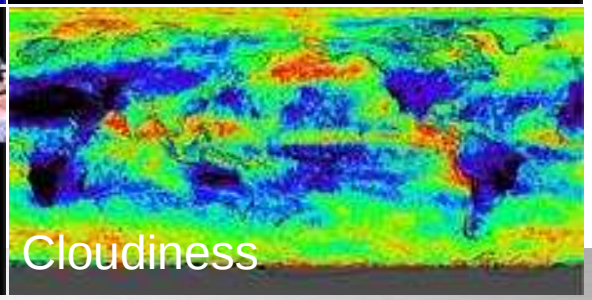
- NCEP
- 15°C 0.65K/100m
- Rural, sea spray 380nm Tau
- 380nm 380nm 380nm
- 10m/s

JASMES

JAXA Satellite Monitoring for Environmental Study

http://kuroshio.eorc.jaxa.jp/JASMES/index.html



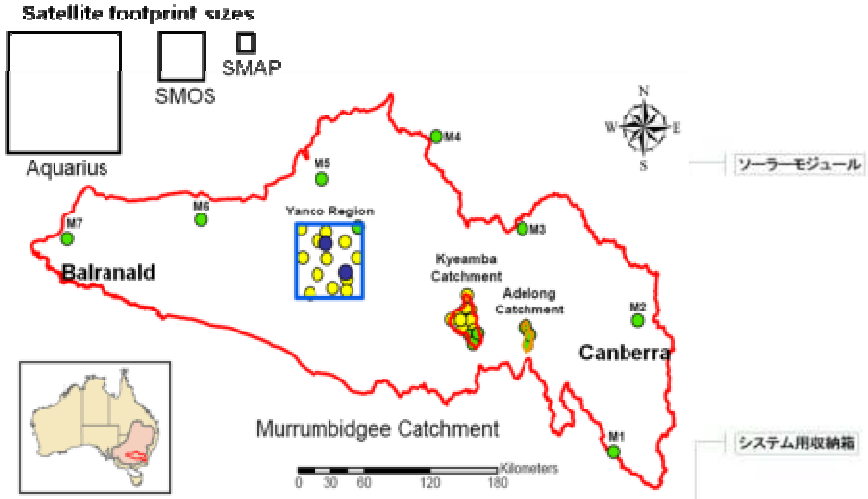


- ✓Satellite and Sensors
  - MODIS on Terra and Aqua
- ✓Temporal Resolution
  - Half-month composite
- ✓Spatial Resolution
  - Japan – 500m
  - Global – 5km
- ✓Geophysical Parameters
  - PAR
  - Snow Cover
  - Water Stress Trend
  - Forest Fire
  - Cloudiness

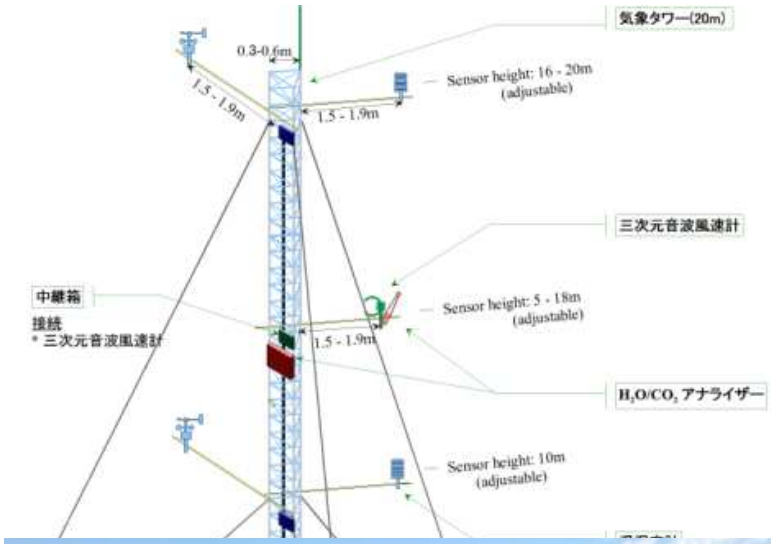
Validation of Aerosol and Cloud

- SKYNET
  - Observation network to understand aerosol/cloud/radiation interaction in the atmosphere. The main instruments consist of a sky radiometer and radiation instruments such as a pyranometer and pyrgeometer as a basic site, and a super site has more instruments extended for analyzing atmospheric parameters of aerosol , cloud and radiation.
  - http://atmos.cr.chiba-u.ac.jp/

Soil Moisture Validation



Smith, Walker et al. (In Review) WRR



Summary

- Satellite community needs upper air network observations for validation, model construction, and so forth.
- Many satellite missions are being planned worldwide and variety of geophysical parameters will be delivered.
- Extensive efforts are being made for calibration and validation of satellite products, resulting in increasing demands for accurate ground-based measurements.