CPS/WTK Seminar on October 6 (Tue) 2015

日本の衛星リモートセンシングと地球大気のエアロゾル研究

Satellite Remote Sensing in Japan and Study on Earth Aerosols

Hiroaki KUZE 久世宏明

President of the Remote Sensing Society of Japan

Professor, Center for Environmental Remote Sensing (CEReS), Chiba University

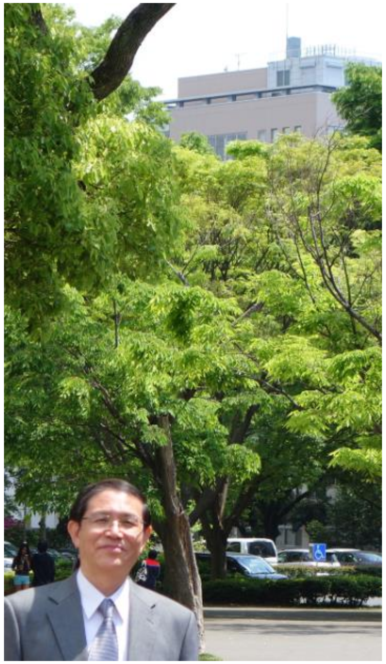
hkuze@faculty.chiba-u.jp

Center for Environmental Remote Sensing Chiba University

➢ Hiroaki Kuze finished the graduate school of the University of Tokyo in 1982, obtaining the Ph.D degree in physics in the field of quantum electronics.

・ After working as a post-doctoral researcher for the Institute of Physical and Chemical Research (RIKEN), in 1984 he became a research assistant and in 1986 an associate professor in the physics department, faculty of liberal arts, Shizuoka University.

・During 1987-1988, he stayed at the Institute for Quantum Optics, Max-Planck Institute in West Germany as a visiting scientist.



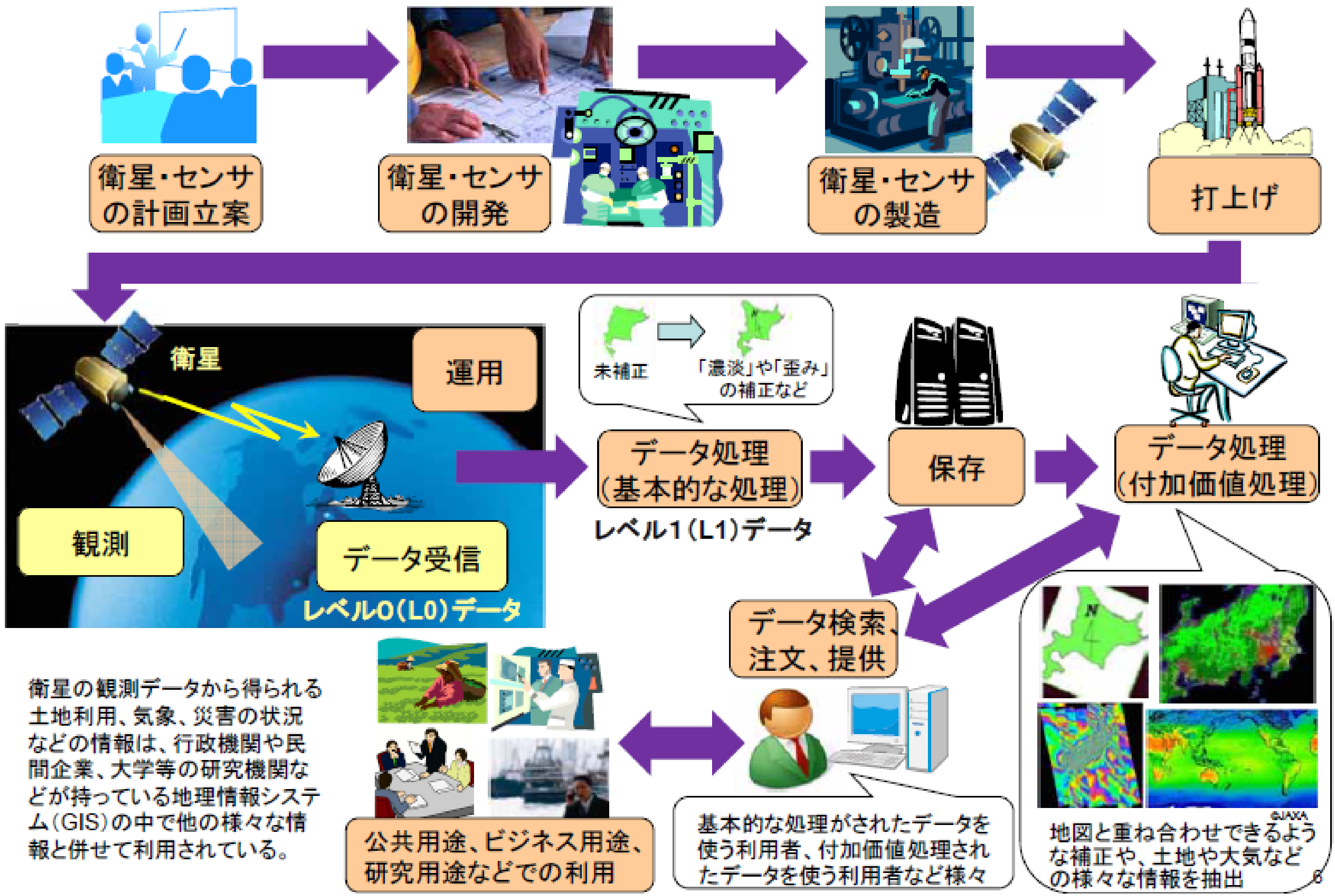
➢ From 1995 to 2004, he worked as an associate professor with the Center for Environmental Remote Sensing (CEReS), Chiba University, and in 2004 he became a professor.

・ Between 2010 and 2014, he served as the director of CEReS.

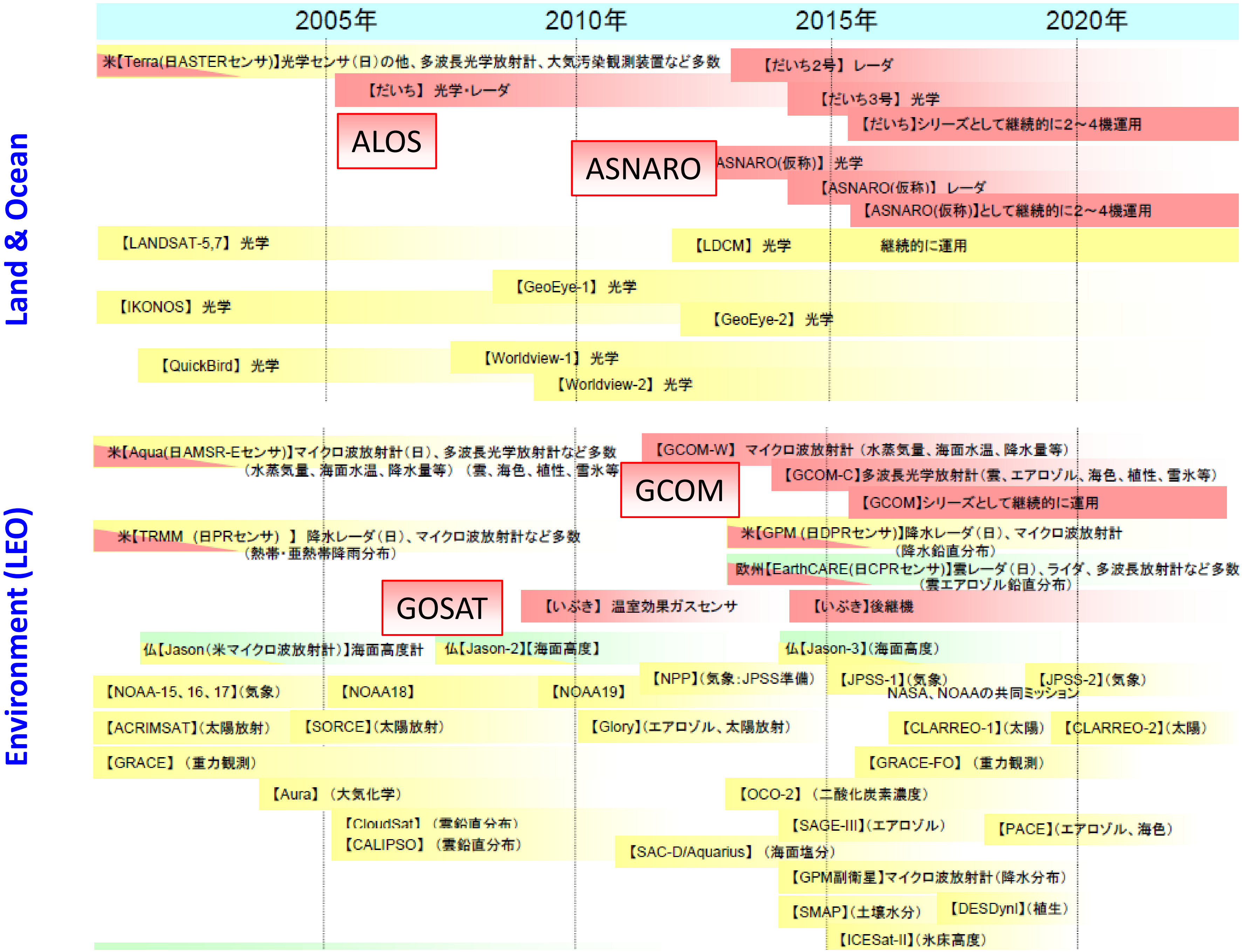
・ Since 2014, he is the president of the Remote Sensing Society of Japan (RSSJ).

・ His major research field is the optical remote sensing of the atmosphere.

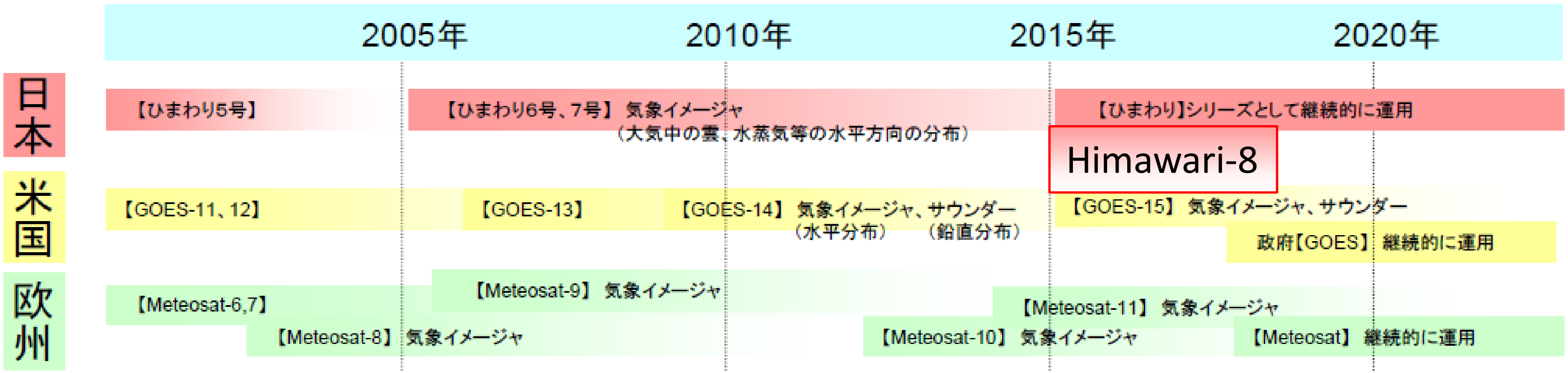
Development, Launch, Operation, and Data Use of Satellite Sensors



出典：内閣府 RSの現状と動向
http://www.kantei.go.jp/jp/singi/utyuu/RSSkentou/dai1/siryou2.pdf


2005年
2010年
2015年
2020年
Land & Ocean
米【Terra(日ASTERセンサ)】光学センサ(日)の他、多波長光学放射計、大気汚染観測装置など多数
【だいち2号】 レーダ
【だいち】 光学・レーダ
【だいち3号】 光学
【だいち】シリーズとして継続的に2～4機運用
ALOS
ASNARO
ASNARO(仮称)】 光学
【ASNARO(仮称)】 レーダ
【ASNARO(仮称)】として継続的に2～4機運用
【LANDSAT-5,7】 光学
【LDCM】 光学
継続的に運用
【GeoEye-1】 光学
【IKONOS】 光学
【GeoEye-2】 光学
【QuickBird】 光学
【Worldview-1】 光学
【Worldview-2】 光学
Environment (LEO)
米【Aqua(日AMSR-Eセンサ)】マイクロ波放射計(日)、多波長光学放射計など多数
(水蒸気量、海面水温、降水量等) (雲、海色、植性、雪氷等)
【GCOM-W】 マイクロ波放射計 (水蒸気量、海面水温、降水量等)
【GCOM-C】多波長光学放射計(雲、エアロゾル、海色、植性、雪氷等)
GCOM
【GCOM】シリーズとして継続的に運用
米【TRMM (日PRセンサ) 】 降水レーダ(日)、マイクロ波放射計など多数
(熱帯・亜熱帯降雨分布)
米【GPM (日DPRセンサ)】降水レーダ(日)、マイクロ波放射計
(降水鉛直分布)
欧州【EarthCARE(日CPRセンサ)】雲レーダ(日)、ライダ、多波長放射計など多数
(雲エアロゾル鉛直分布)
GOSAT
【いぶき】 温室効果ガスセンサ
【いぶき】後継機
仏【Jason(米マイクロ波放射計)】海面高度計
仏【Jason-2】【海面高度】
仏【Jason-3】(海面高度)
【NOAA-15、16、17】(気象)
【NOAA18】
【NOAA19】
【NPP】(気象:JPSS準備)
【JPSS-1】(気象)
NASA、NOAAの共同ミッション
【JPSS-2】(気象)
【ACRIMSAT】(太陽放射)
【SORCE】(太陽放射)
【Glory】(エアロゾル、太陽放射)
【CLARREO-1】(太陽)
【CLARREO-2】(太陽)
【GRACE】 (重力観測)
【GRACE-FO】 (重力観測)
【Aura】 (大気化学)
【OCO-2】 (二酸化炭素濃度)
【CloudSat】 (雲鉛直分布)
【SAGE-III】(エアロゾル)
【PACE】(エアロゾル、海色)
【CALIPSO】 (雲鉛直分布)
【SAC-D/Aquarius】 (海面塩分)
【GPM副衛星】マイクロ波放射計(降水分布)
【SMAP】(土壌水分)
【DESDynI】(植生)
【ICESat-II】(氷床高度)

Meteorological Satellites (Geostationary Orbit)



出典：内閣府 RSの現状と動向

【陸域・海域観測衛星】

➢ ALOS「だいち」: 光学センサ(パンクロマチックセンサ: 空間分解能2.5 m)、マルチスペクトルセンサ(空間分解能10 m)、レーダセンサ(空間分解能10 m)を搭載。

・ 地図作成、災害状況把握、資源調査などに活用。年間約30万シーンのデータ提供(2009年度: JAXA 共同研究目的および民間機関 商業目的)。

・後継機としてPALSAR2 (1×3 m)を搭載したALOS2が運用中。

➢ ASTER : 可視から熱赤外まで14バンドを有する米国衛星Terra搭載のマルチスペクトルセンサ(空間分解能15m)。石油資源探査や土地利用モニタリングに活用。

【地球環境観測・気象衛星】

➢ AMSR-E : 米国衛星Aqua搭載のマイクロ波放射計。降水量、水蒸気量、海面温度などを計測し、気象予報や地球科学研究、洪水予測などに活用。

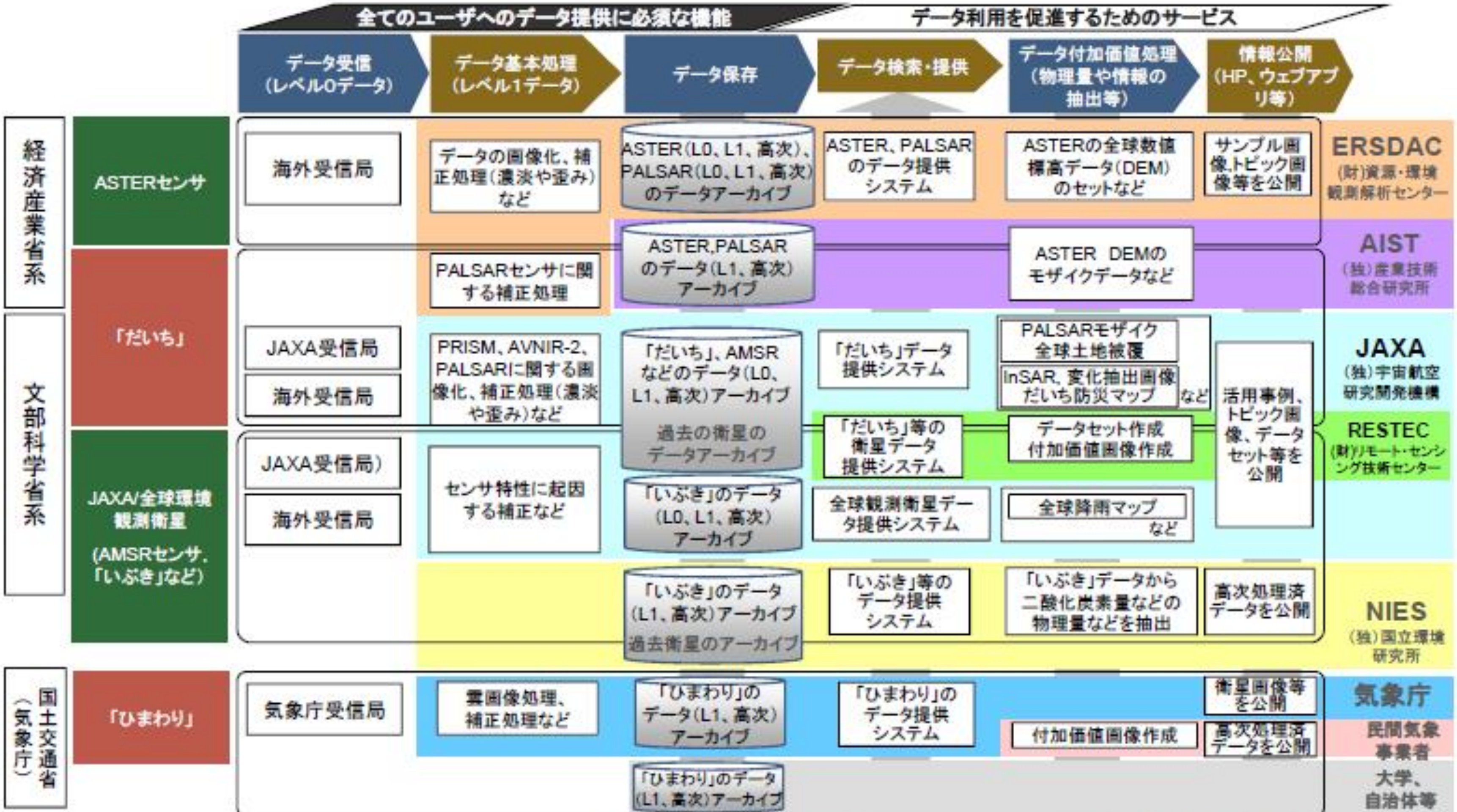
・後継機としてGCOM-W 衛星のマイクロ波放射計AMSR2が運用中。

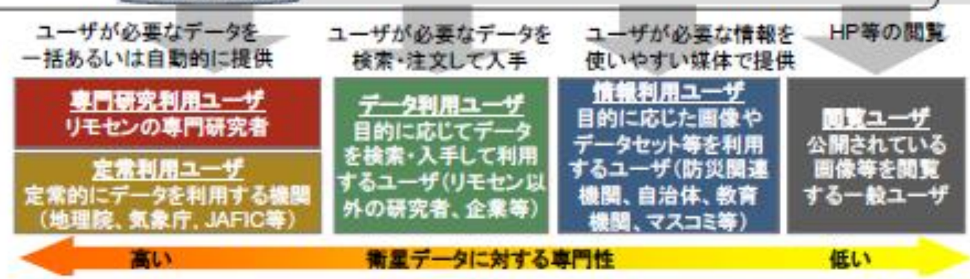
➢ TRMM-PR : 米国衛星TRMM搭載の降雨レーダ。熱帯・亜熱帯域の降雨分布を観測し、気象予報や気象科学研究などに活用。後継機GPMが運用中。

➢ GOSAT「いぶき」: 温室効果ガスの濃度分布計測、吸収排出量の把握に活用。

➢ Himawari「ひまわり」: 可視・赤外放射計を搭載。アジア・太平洋地域の雲、水蒸気、火山灰等の分布を24時間常時観測。台風や集中豪雨等の監視、数値予報、航空機の安全運航等に利用。

日本の衛星システムとその利用体系





- 我が国では、各機関ごとに衛星を保有、運用しており、衛星データについても、各機関ごと独自の処理・保存・配信システムにより運用。
- 現状は、専門性の高いユーザによる利用が中心となっている。

出典：内閣府 RSの現状と動向

Earth Observing Satellites in Japan

Name	Launch	Weight (kg)	Rokcet	Type
GMS	14-Jul-77	315	Delta 2914	The 1st Meteorologucal Geostationary Satellite
GMS-2	11-Aug-81	296	N-II-8	
GMS-3	3-Aug-84	303	N-II-13	
EGS or EGP	13-Aug-86	685	H-I-15	Mirror ball (2.15 m diameter) Experimental Geodetic Satellite
MOS-1	19-Feb-87	740	N-II-16	Marine Observation Satellite
GMS-4	6-Sep-89	325	H-I-20	
MOS-1b	7-Feb-90	740	H-I-21	
JERS-1	11-Feb-92	1340	H-I-24	L-band Synthetic Aperture Radar
GMS-5	18-Mar-95	345	H-II-3	
ADEOS	17-Aug-96	3500	H-II-4	Advanced Earth Observing Satellite (OCTS, AVNIR, POLDER, etc.)
TRMM	28-Nov-97	3500	H-II-6	Tropical Rainfall Measuring Mission
ASTER	18-Dec-99	450	Atlas-II	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ADEOS-II	14-Dec-02	3700	H-IIA-4	
MTSAT-1R	26-Feb-05	1600	H-IIA-7	Meteorologucal Geostationary Satellite with Aviation Controlling Capability
ALOS	24-Jan-06	3900	H-IIA-8	Advanced Land Observing Satellite (PRISM, AVNIR, PALSAR)
MTSAT-2	18-Feb-06	2400	H-IIA-9	
GOSAT	23-Jan-09	1750	H-IIA-15	Greenhouse gases observing satellite
GCOM-W	18-May-12	1991	H-IIA-21	Global Change Observation Mission
GPM	28-Feb-14	3750	H-IIA-23	Global Precipitation Measurement
HIMAWARI-8	7-Oct-14	1300	H-IIA-25	Third generation Meteorologucal Geostationary Satellite
ASNARO	6-Nov-14	450	Dnipro	Advanced Satellite with New system Architecture for Observation

➢ 各国は国際協力によるGEOSS（全球地球観測システム）の枠組みの中で、不必要な重複を避け、複数システム間の相互作用を促進。
➢ GEOSSは、地球環境問題等に対して持続可能な社会の実現を目指し、人工衛星観測および地上観測を統合した複数の観測システムからなる包括的なシステム。

The GEO is coordinating efforts to build a Global Earth Observation System of Systems (GEOSS). GEOSS is an international public infrastructure using land, sea, air and space-based Earth observation systems to provide comprehensive environmental data, information and analyses.

The GEOSS nine societal benefit areas：

- Natural and human-induced disasters.
- Environmental factors affecting human health and well-being.
- Management of energy resources.
- Understanding, mitigating and adapting to climate variability and change.
- Water resource management.
- Weather information, forecasting and warning.
- Protection of terrestrial, coastal and marine ecosystems.
- Sustainable agriculture and combating desertification.
- Understanding, monitoring and conserving biodiversity.

NASDA (National Space Development Agency

宇宙開発事業団 1969 - 2003

➢ The National Space Development Agency of Japan (NASDA) was established on October 1 , 1969, under the National Space Development Agency Law, to act as the nucleus for the development of space and promote the peaceful use of space.

➢ Being based on the Japanese Space Development Program enacted by the Minister of Education, Culture, Sports, Science and Technology (MEXT) NASDA was responsible for:

➢ Development of satellites (including space experiments and the space station) and launch vehicles, launching and tracking the craft.

➢ Development of methods, facilities and equipment required for the above.

http://global.jaxa.jp/about/history/nasda/index_e.html

First rocket / First satellite

The Pencil Rocket was developed by a prominent engineer, Prof. Hideo Itokawa of the University of Tokyo. The rocket was launched in March 1955. Length 23 cm, diameter 1.8 cm, and weight 200 g.

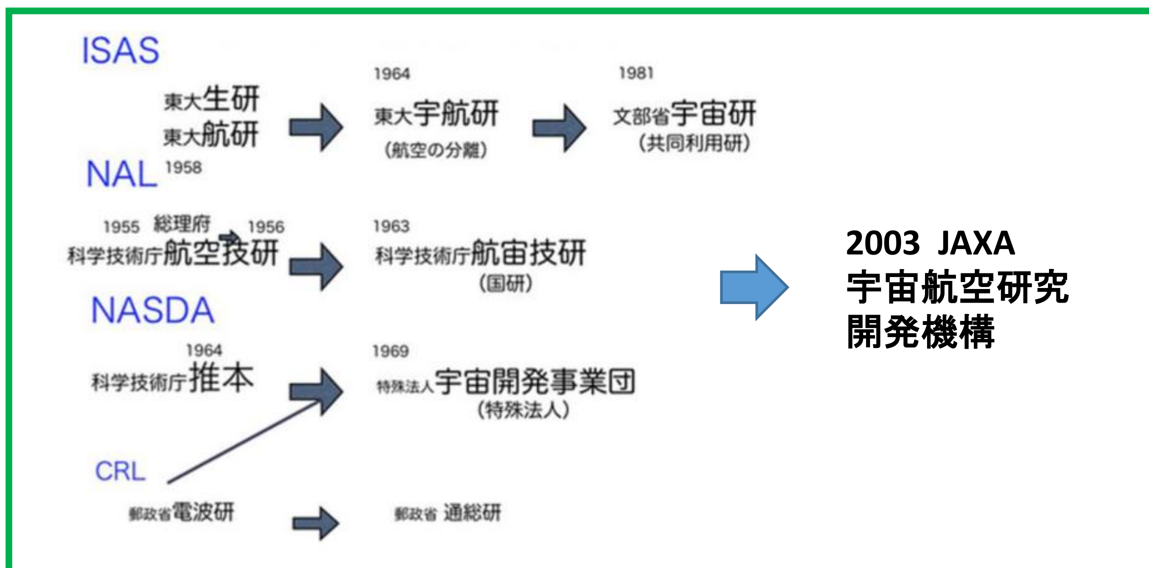
Ohsumi satellite : Launched on Feb. 11, 1970 with a Lambda-4S rocket. Weight 24 kg, power 10.3 W. Perigee 350 km, apogee 5140 km, Decay date Aug. 2, 2003.

JAXA (Japan Aerospace Exploration Agency)

宇宙航空研究開発機構 2003 - present

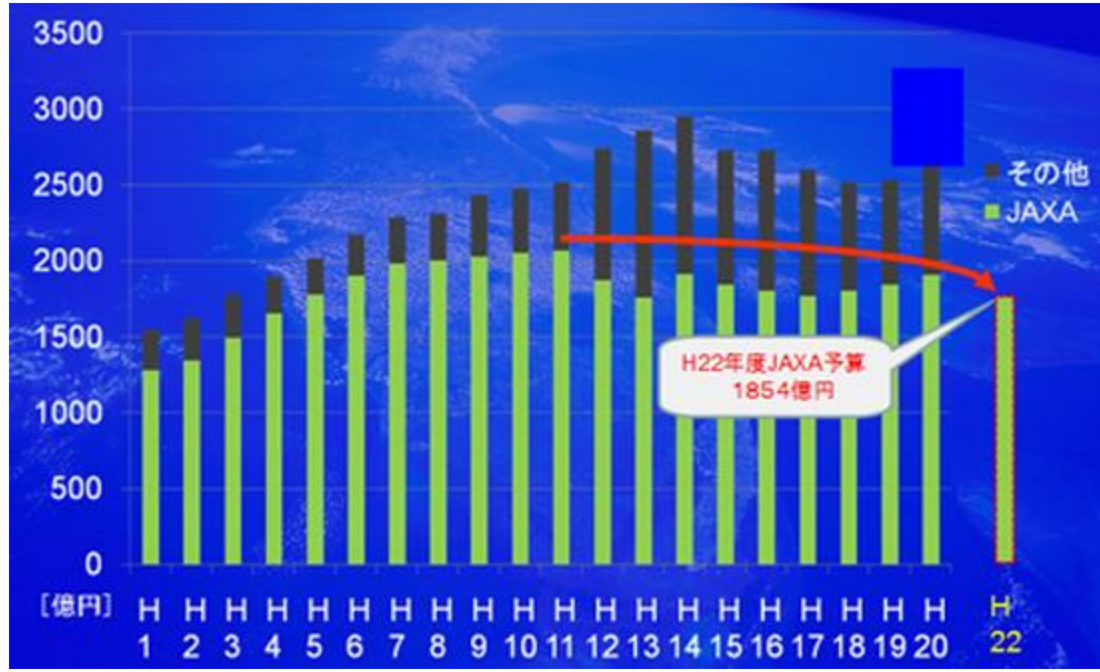
➢ In October 2003, Japan Aerospace Exploration Agency (JAXA) was established as an Independent Administrative Agency by merging three aerospace organizations:

- The Institute of Space and Astronautical Science (ISAS, 宇宙科学研究所)
- The National Aerospace Laboratory （NAL, 航空宇宙技術研究所）
- The National Space Development Agency of Japan （宇宙開発事業団）

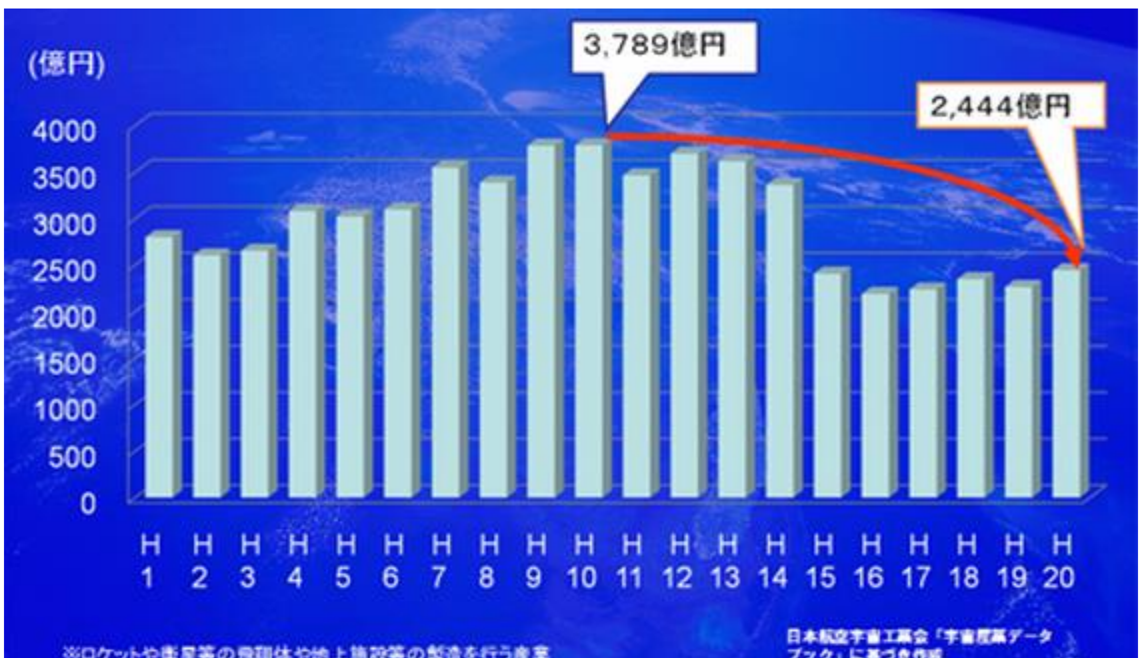


JAXA Budget

1b USD



1989 2000 2010



Space Industry (Rockets, Satellites, Ground Systems, ...)

http://www.cosmotec-hp.jp/column/future4.html

ALOS (Advanced Land Observing Satellite, 2006)

➢ The Advanced Land Observing Satellite "DAICHI" (ALOS) was developed to contribute to the fields of mapping, precise regional land coverage observation, disaster monitoring, and resource surveying.

➢ It enhances land observation technologies acquired through the development and operation of its predecessors, the Japanese Earth Resource Satellite-1 (JERS-1, or Fuyo) and the Advanced Earth Observing Satellite (ADEOS, or Midori).

➢ ALOS has three sensors:

- Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM), which is comprised of three sets of optical systems to measure precise land elevation
- Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2), which observes what covers land surfaces;
- Phased Array type L-band Synthetic Aperture Radar (PALSAR), which enables day-and-night and all-weather land observation.

http://global.jaxa.jp/projects/sat/alos/

ALOS (Advanced Land Observing Satellite, 2006)

➢ It was launched by the H-IIA launch vehicle No.8 from the Tanegashima Space Center (TNSC) in January 24, 2006.

➢ Since its launch in 2006, DAICHI's observation data were used in various areas including disaster mitigation through observing regions damaged by earthquakes, tsunami, or typhoons, as well as carrying out forest monitoring, natural environment maintenance, agriculture, and compiling a 1/25,000 topographical map.

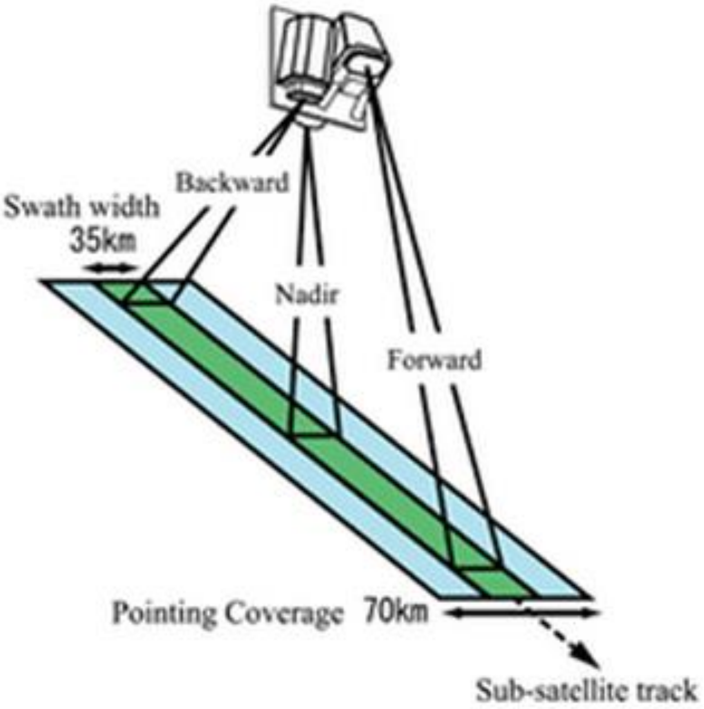
➢ When the Great East Japan Earthquake hit Japan in 2011, the DAICHI took some 400 images over disaster-stricken areas to provide information to all parties concerned.

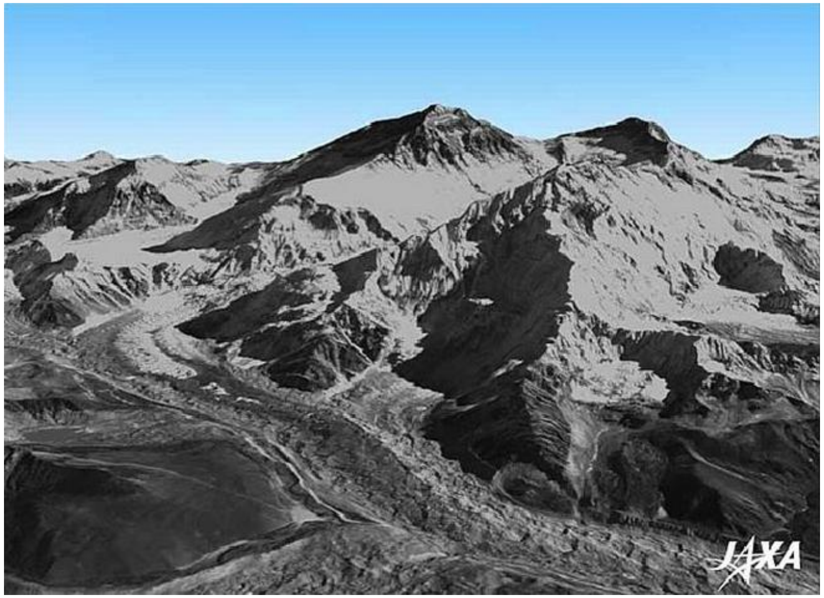
➢ On April 22, 2011, a power generation anomaly caused a communication loss. At 10:50 a.m. on May 12, 2011, JAXA sent a command to stop its operation.

ALOS PRISM (Panchromatic Remote-sensing Instrument for Stereo Mapping)

➢ PRISM has three independent optical systems for viewing nadir, forward and backward producing a stereoscopic image along the satellite's track.

➢ PRISM observes earth surface with 2.5 m spatial resolution. It is used for mapping, urban planning, monitoring designated area etc.



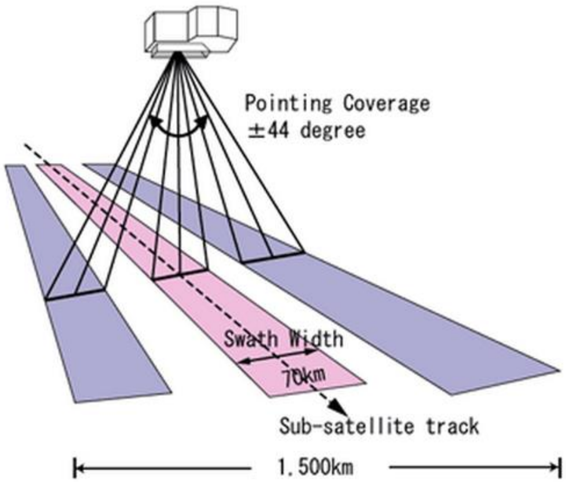


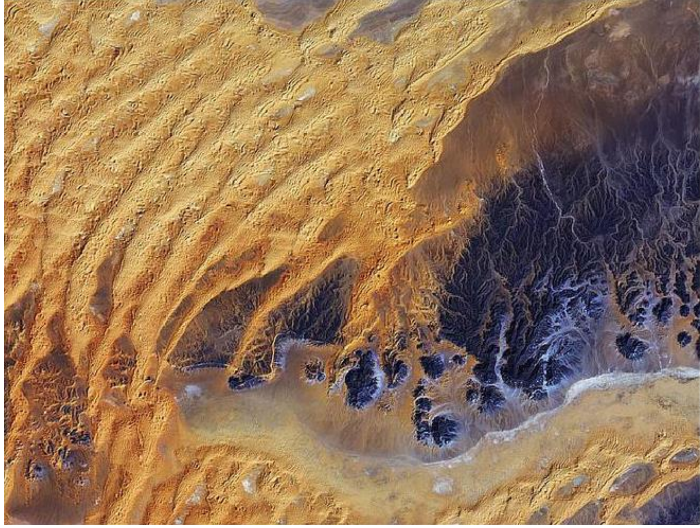
Digital 3D map image example of Mt. Everest (image credit: JAXA)

http://www.alos-restec.jp/en/staticpages/index.php/aboutalos-prism

ALOS AVNIR-2 (Advanced Visible and Near Infrared Radiometer type 2)

Band 1 : 0.42 to 0.50 μm
Band 2 : 0.52 to 0.60 μm
Band 3 : 0.61 to 0.69 μm
Band 4 : 0.76 to 0.89 μm
Spatial Resolution 10 m (at Nadir)
Swath Width 70 km (at Nadir)
Pointing Angle - 44 to + 44 degree





AVNIR-2 image of the Sahara desert in Algeria on January 28, 2011 (image credit: JAXA, ESA)

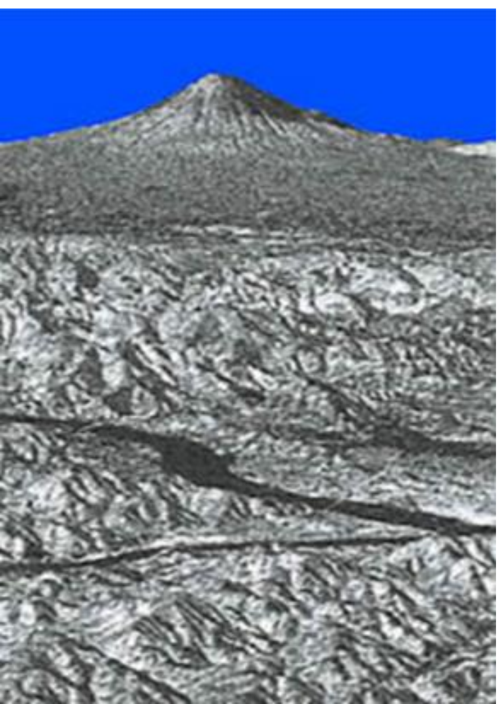
Mount Kenya, acquired with the AVNIR-2 instrument of ALOS on February 25, 2011 (image credit: JAXA, ESA)

http://www.alos-restec.jp/en/staticpages/index.php/aboutalos-avnir2
https://directory.eoportal.org/web/eoportal/satellite-missions/a/alos

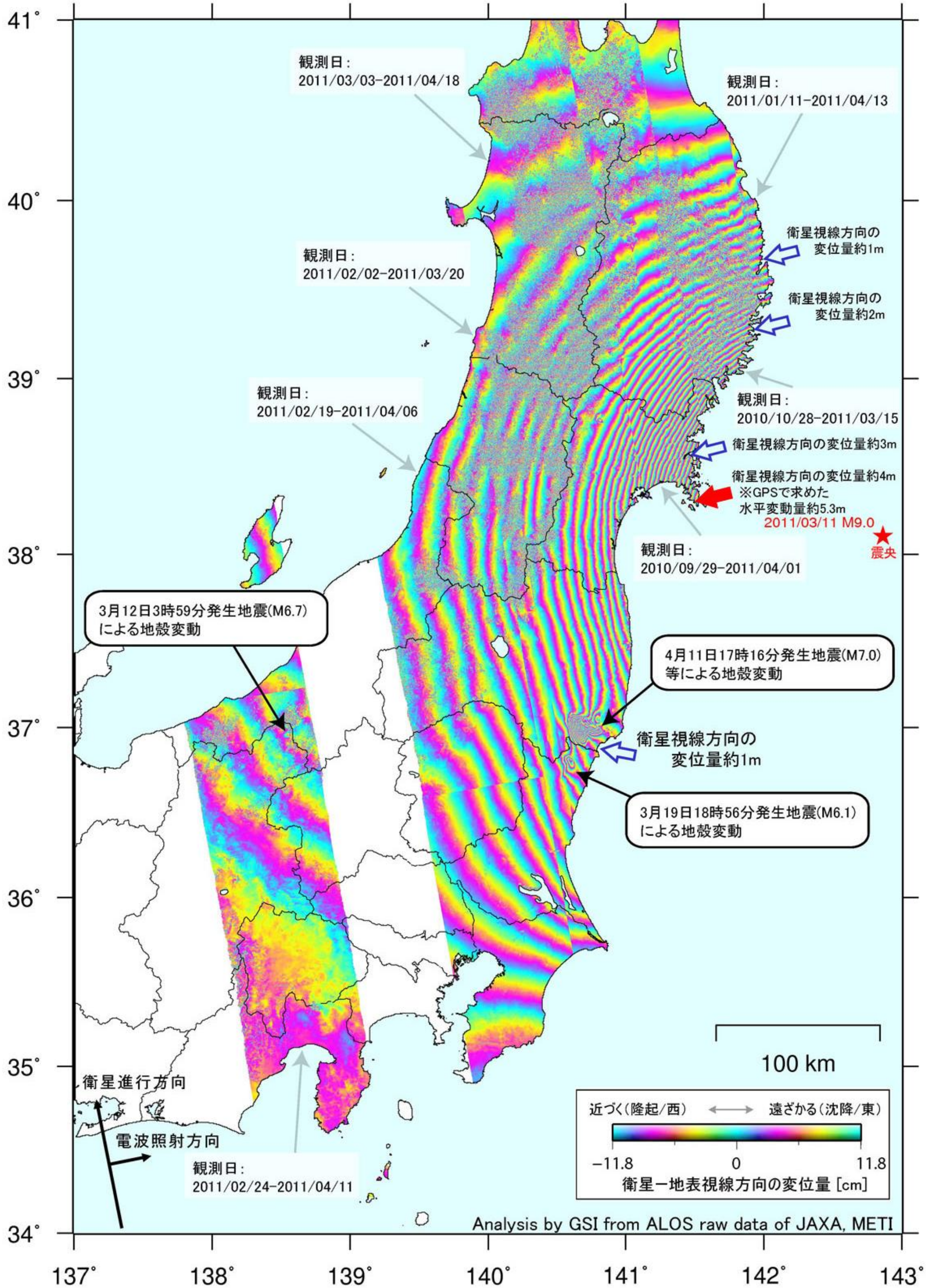
ALOS PALSAR (Phased Array type L-band Synthetic Aperture Radar)

➢ PALSAR is an active microwave sensor using L-band frequency, provides higher performance than the JERS-1's synthetic aperture radar (SAR). It enables to conduct cloud-free and day-and-night land observation.

➢ PALSAR has fine resolution in a conventional mode, plus Scan SAR mode that can extract a 250 to 350 km width of SAR images at the expense of spatial resolution. It is utilized to make digital elevation map (DEM) and to monitor designated area.

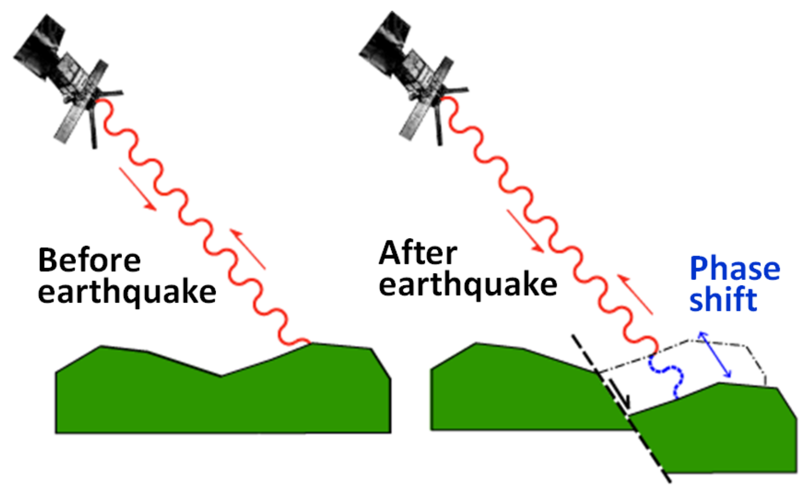


Mode	Fine	Scan	SAR
Center Frequency	1270 MHz(L-band)		
Chirp Bandwidth	28MHz	14MHz	14MHz,28MHz
Polarization	HH or VV	HH+HV or VV+VH	HH or VV
Incident angle	8 to 60 deg.	8 to 60 deg.	18 to 43 deg.
Range Resolution	7 to 44m	14 to 88 m	100m (multi look)
Observation Swath	40 to 70 km	40 to 70 km	250 to 350km



Synthetic aperture radar measurement of land displacement

The ALOS/PALSAR observation has revealed that there has been a movement toward the eastern direction by more than 4 m, an unprecedented value in previous earthquakes.



http://www.jaxa.jp/article/special/antidisaster/yamanaka_j.html

ASNARO (Launched in November 2014)

➢ Advanced Satellite with New system Architecture for Observation (ASNARO) is a research and development project for internationally competitive advanced small satellite system.

➢ It has been executed by NEC Corporation and Japan Space Systems under the contract of Ministry of Economy, Trade and Industry (METI).

➢ The goal of the project is to establish a new system architecture to realize a low-cost, high-performance and small-sized satellite with short delivery time.

➢ Though it is a 400 kg class satellite, its performance is equivalent to medium/large sized commercial satellites with ground res. of 0.5 m.

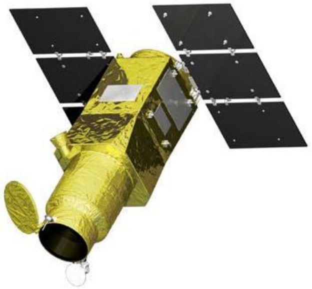
Item	System, Bus
Life Time	over 3 years (target 5 years)
Mass	Total 495kg ・Mission 200 kg ・Bus 295 kg (wet) <Maximum Propellant Mass 45 kg>
Power	Power Generation: 1300 W (after 3years) Mission Power Supply: 400 W
Pointing	Nadir ±45deg. Conical Area
Agility	90deg/90sec (Average 1deg/sec)
Item	**Mission**
Optical Sensor (Visible and Near-infrared) @504km Altitude	Panchromatic/Multi-spectrum(6ch) TDI CCD (TDI: Time Delay Integration) Ground Sampling Distance (GSD): <0.5m (Panchromatic), <2m (Multi) Swath: 10km

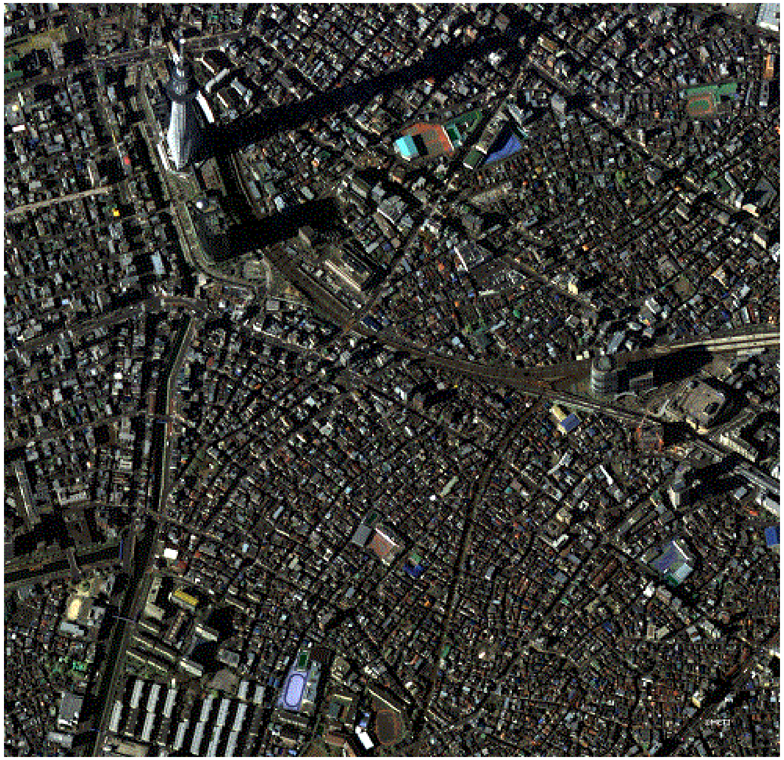
http://www.jspacesystems.or.jp/en_project_asnaro/

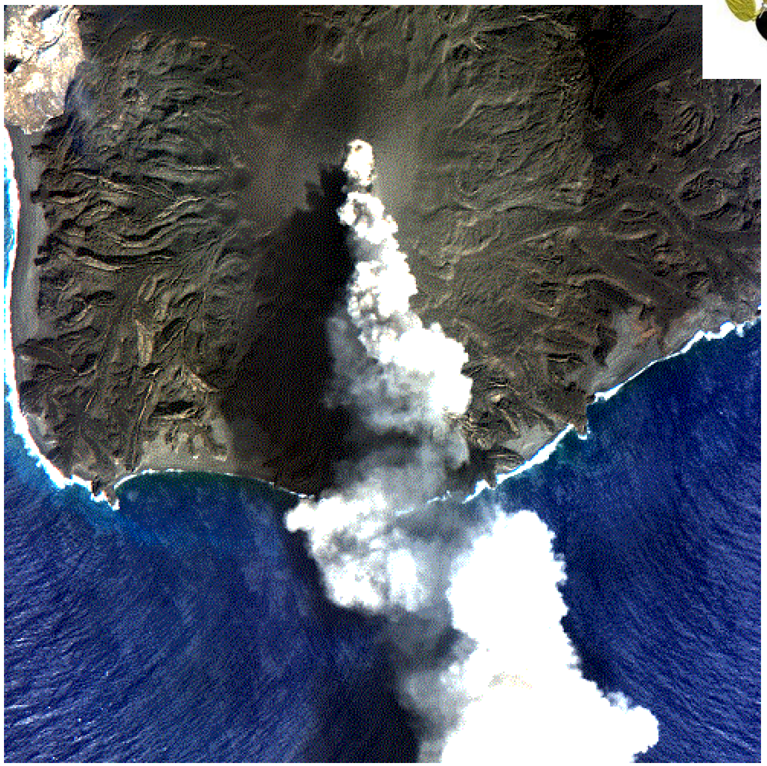
ASNARO-1
（Advanced Satellite with New system Architecture for Observation）

➢技術実証衛星「ASNARO-1」：経済産業省が我が国宇宙産業の国際競争力強化のため、高性能かつ小型で低コストな人工衛星の実現を目指し、研究開発を進めてきた。（観測幅 10 km、質量 450 kg、分解能 0.5 m）

➢ 2014年11月6日、ロシアのヤスニ射場からドニエプルロケットで打ち上げ(↓ スカイツリーと西ノ島の画像)







http://www.meti.go.jp/policy/mono_info_service/mono/space_industry/

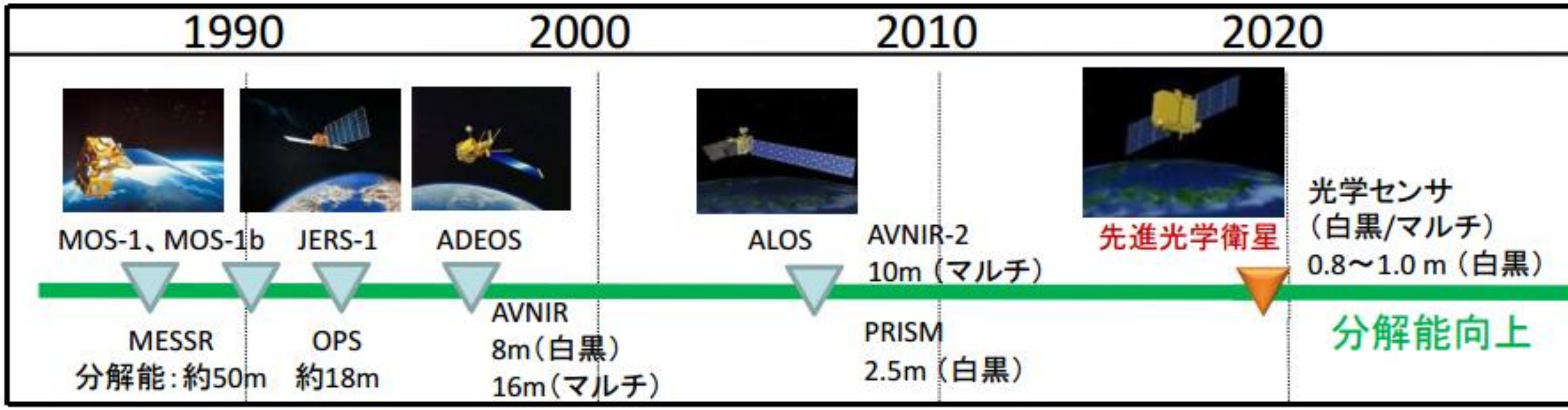
ほどよし1号機 Hodoyoshi-1

➢ 地球観測（リモートセンシング）を目的とした1辺約50cmの立方体形状をした質量60kgの超小型衛星。
➢ リアクションホイール、スターセンサ、MEMSジャイロ、GPS受信機などが搭載されており高度な3軸姿勢制御を行うほか、新規開発された過酸化水素水を推進剤とする推進装置による軌道制御の実証も行う。
➢ 地上分解能6.7m、観測幅約28 kmの画像を取得できる光学センサが搭載され、高度500kmの太陽同期軌道から地球を観測。

ナポリとヴェスヴィオ火山（撮影：2015-06-21 10:30UTC）

https://www.axelspace.com/solution/hodoyoshi1/
https://www.axelspace.com/special/20150731/

JAXA Advanced Optical Observation Satellites



MOS-1
（MESSR）

ALOS
（AVNIR-2）

Aiming at much higher performance

http://www.mext.go.jp/b_menu/shingi/gijyutu/gijyutu2/059/shiryo/__icsFiles/afieldfile/2014/10/01/1351678_4.pdf

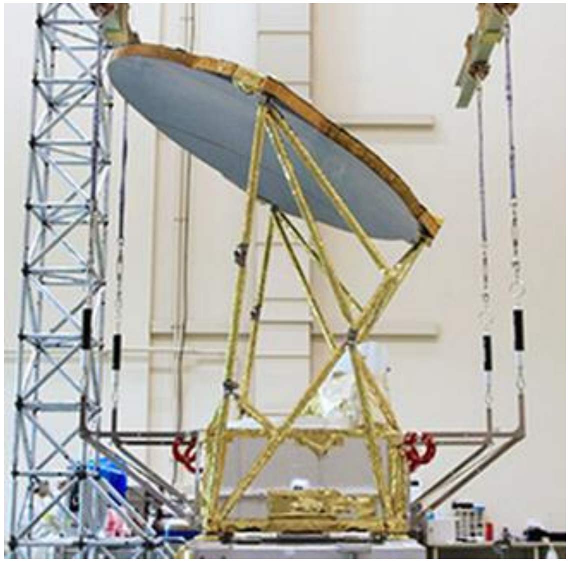
GCOM-W (Launched in May 2012)

➢ The "Global Change Observation Mission" (GCOM) aims to construct, use, and verify systems that enable continuous global-scale observations (for 10 to 15 years) of effective geophysical parameters for elucidating global climate change and water circulation mechanisms.

➢ The GCOM mission is a two series of satellites, GCOM-W for observing water circulation changes and GCOM-C for climate changes.

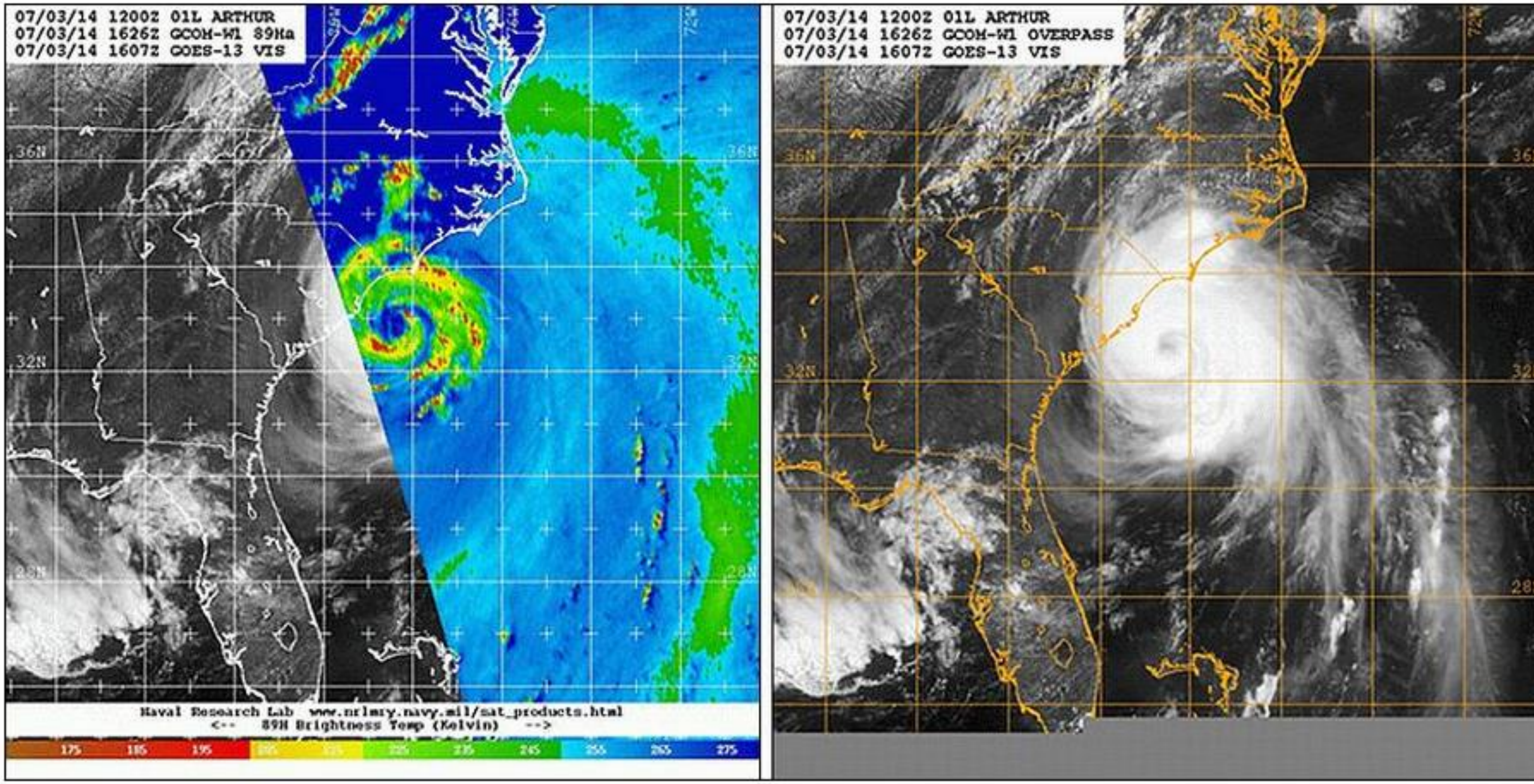
➢ The GCOM-W with a microwave radiometer onboard will observe precipitation, vapor amounts, wind velocity above the ocean, sea water temperature, water levels on land areas, and snow depths.

➢ The Advanced Microwave Scanning Radiometer 2 (AMSR2) is a sensor to observe radiometers, or microwaves emitted naturally from the ground, sea surface and atmosphere, using six different frequency bands ranging from 7 GHz to 89 GHz.



GCOM-W AMSR2

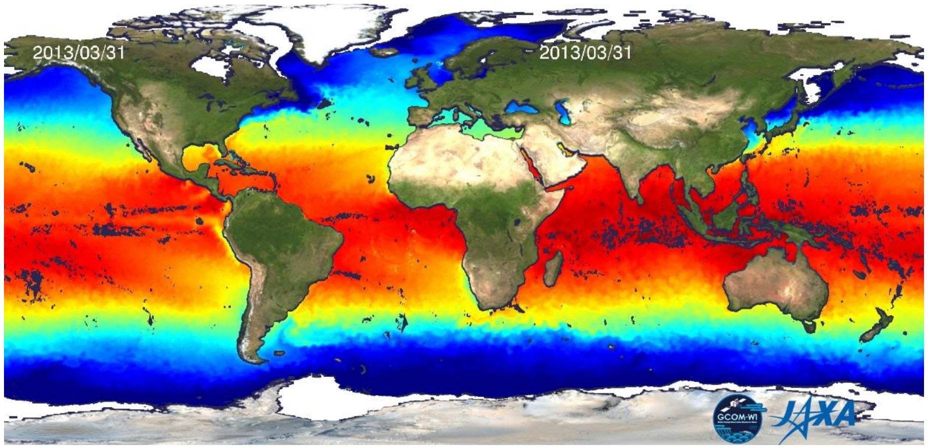
Images of Hurricane "Arthur" on July 3, 2014 acquired by MW observation of AMSR2 on GCOM-W1 (left) and by infrared observation (right) [Image credit: NOAA and NRL]



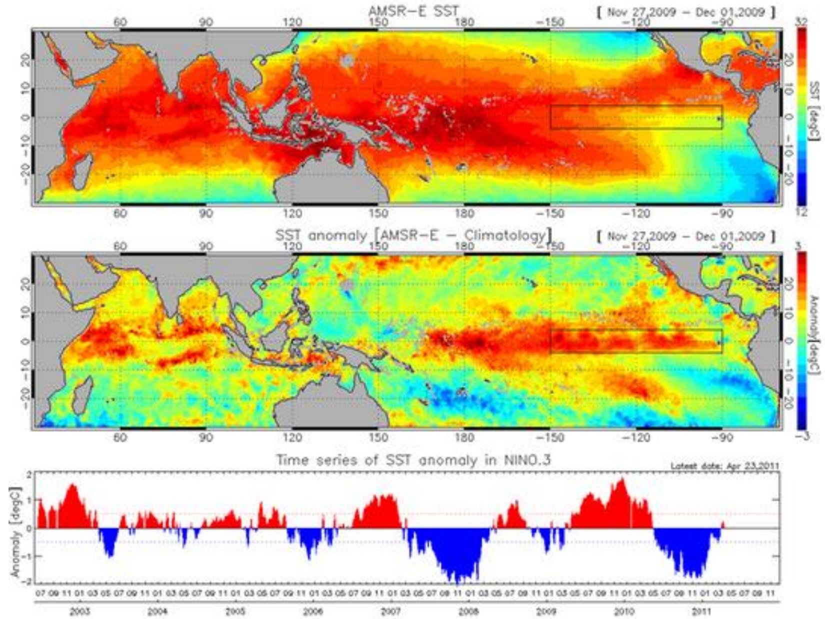
➢ **The cloud image captured through infrared observation (right) cannot clarify the internal structure of a typhoon or hurricane, but the MW observation (left) clearly shows the dual structure of the eye and surrounding rain bands of Hurricane Arthur off the U.S. East coast.**

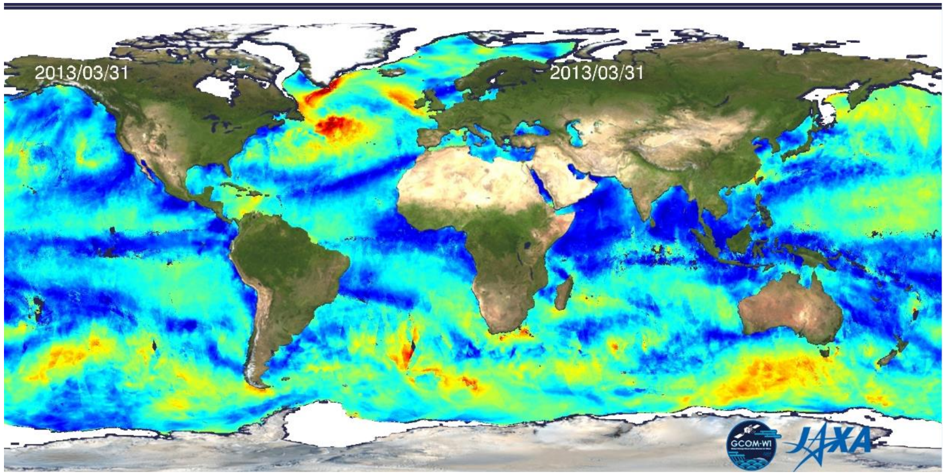
https://directory.eoportal.org/web/eoportal/satellite-missions/g/gcom

AMSR2 Archive（20121001-20130331）

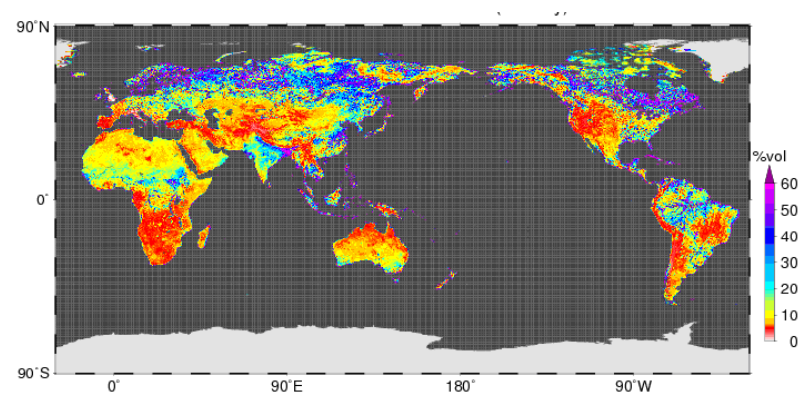


Sea Surface Temperature





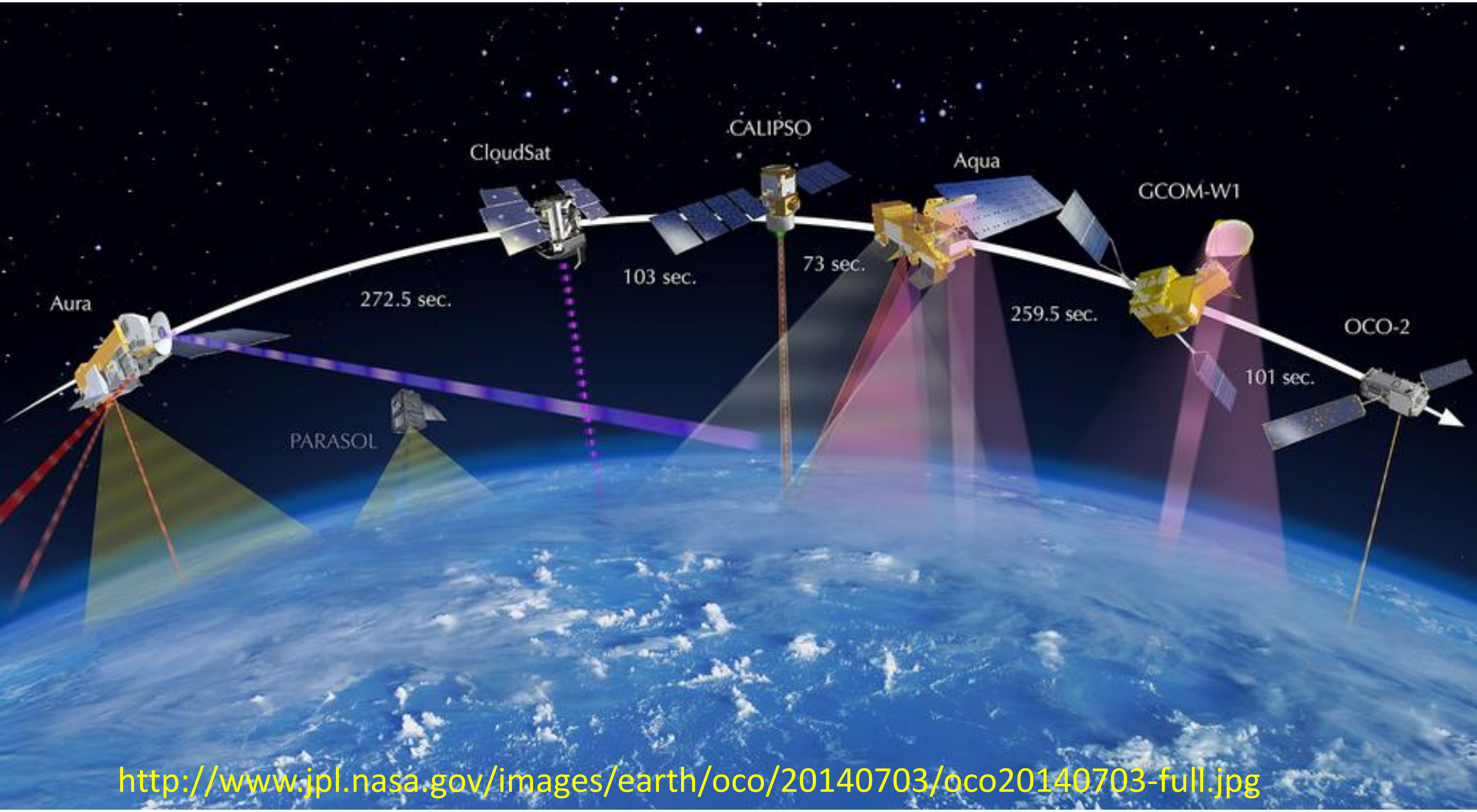
Sea Surface Wind



Soil Moisture

http://suzaku.eorc.jaxa.jp/GCOM_W/monitor/gallery_img/amsr2_archive_121001-130331_j.html

GCOM-W1 in A-Train



➢ **These five Earth-observing satellites carry more than 15 scientific instruments in total. Called the Afternoon Constellation, or A-Train, these satellites work as a united, powerful tool for advancing our understanding of Earth's surface and atmosphere.**

GCOM-C (to be launched in FY 2016)

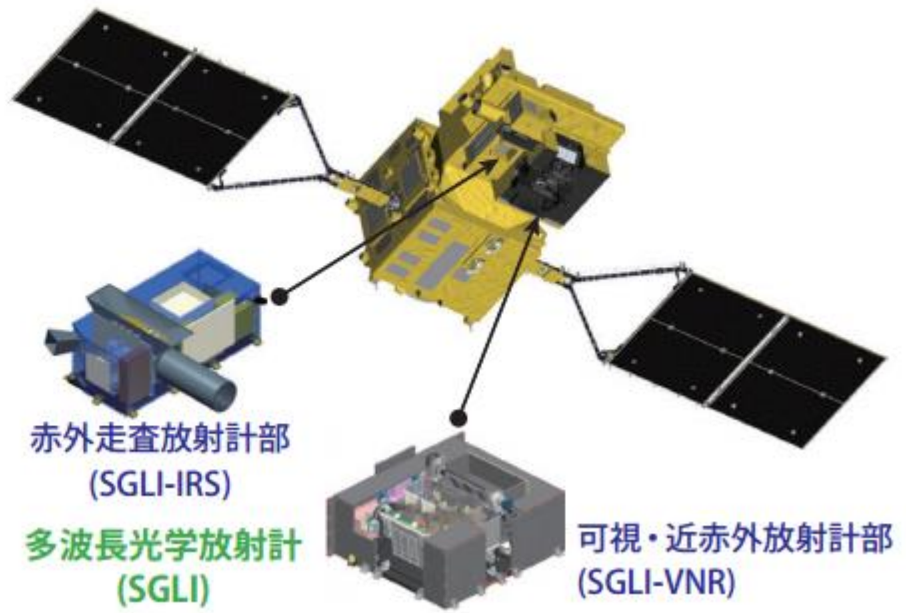
➢ The purpose of the GCOM（Global Change Observation Mission）project is the global, long-term observation of the Earth's environment.

➢ GCOM-C (climate) carries a SGLI（Second generation global imager）, which conducts surface and atmospheric measurements related to the carbon cycle and radiation budget.

➢ SGLI is an optical sensor observing at wavelengths from near-UV to thermal infrared wavelengths（380 nm to 12 μm）.

➢ Also, SGLI has polarimetry and forward / backward observation functions.

➢ Global data are obtained once every 2 or 3 days, with resolutions of 250 m to 1 km.



http://global.jaxa.jp/projects/sat/gcom_c/

GOSAT (Greenhouse gases observing satellite, 2009)

➢ The Greenhouse gases Observing SATellite (GOSAT) Project is a joint effort promoted by the Japan Aerospace Exploration Agency (JAXA), the National Institute for Environmental Studies (NIES) and the Ministry of the Environment (MOE).

➢ NIES organized the research team dedicated to the GOSAT project within its organization in April 2004, and since then has been working for the research and development with respect to GOSAT "IBUKI".

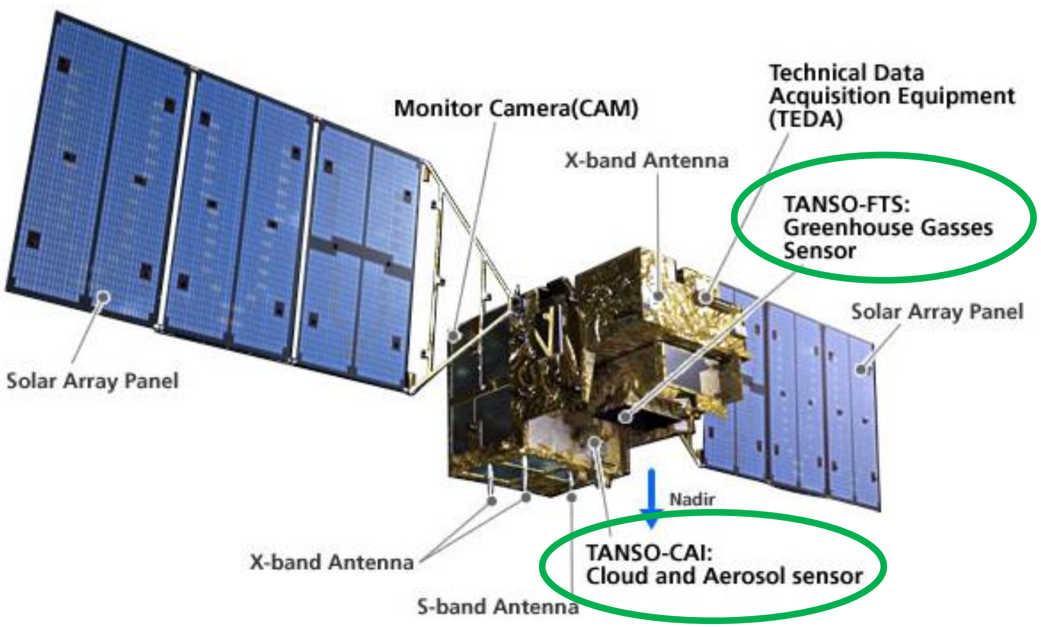
➢ GOSAT was launched using the H-IIA on January 23, 2009 from Tanegashima. The satellite flies at an altitude of approximately 666 km and completes one revolution in about 100 minutes. The satellite returns to the same point in space in three days.

http://www.gosat.nies.go.jp/index_e.html

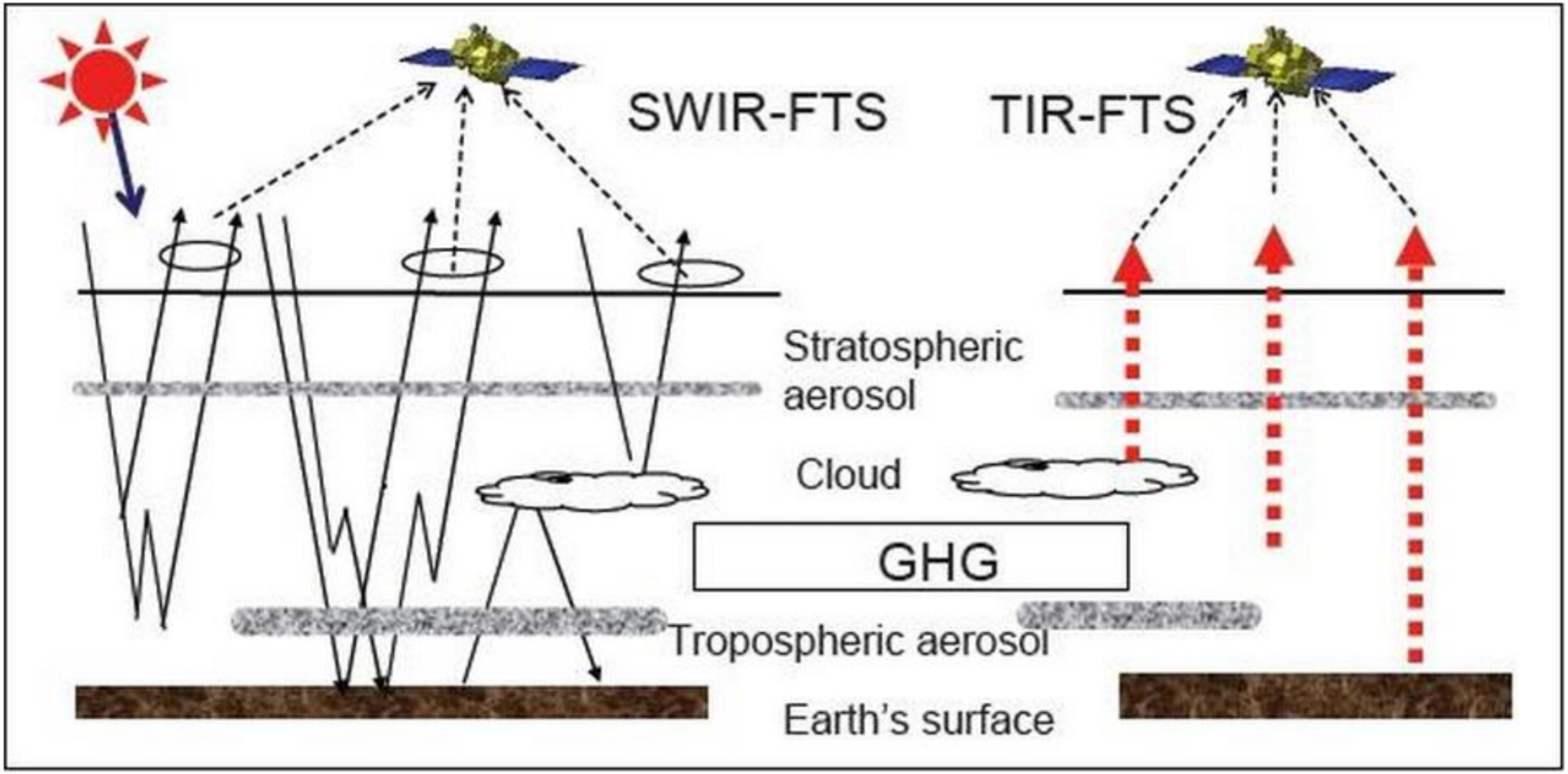
GOSAT TANSO-FTS & CAI

- The observation instrument onboard the satellite is the Thermal And Near-infrared Sensor for carbon Observation (TANSO). TANSO is composed of two subunits: the Fourier Transform Spectrometer (FTS) and the Cloud and Aerosol Imager (CAI). Tables 1 and 2 summarize the target gas species, spectral coverage, and other specifications of these two instruments.

- GOSAT observes infrared light reflected and emitted from the earth's surface and the atmosphere. Column abundances of CO_2 and CH_4 are calculated from the observational data. The column abundance of a gas species is expressed as the number of the gas molecules in a column above a unit surface area.



GOSAT SWIR vs. TIR

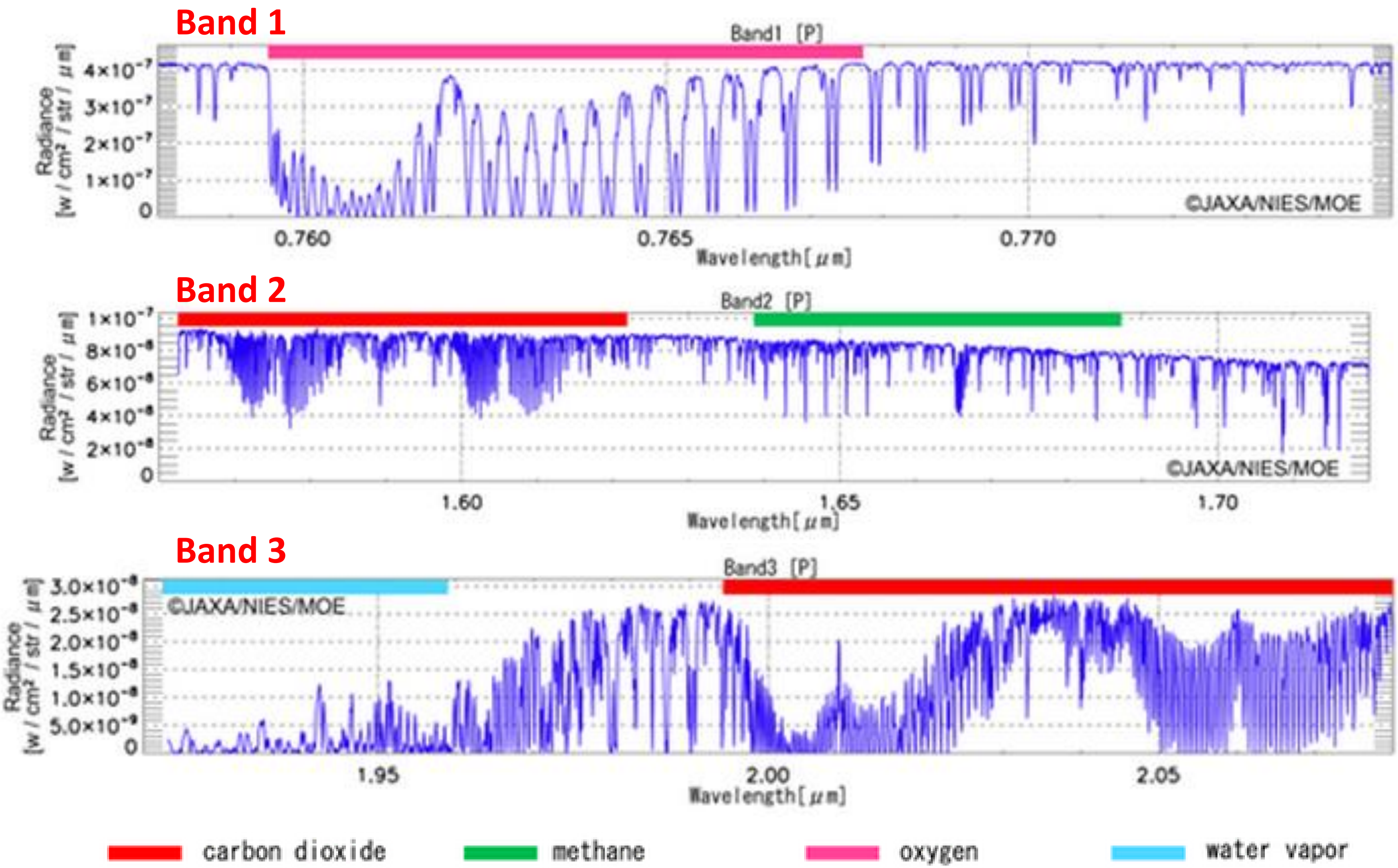


➢ **The reflective radiative energy is covered by the VIS and SWIR (Shortwave Infrared) ranges, while the emissive portion of radiation from Earth's surface and the atmosphere is covered by the TIR (Thermal Infrared) ranges.**

https://directory.eoportal.org/web/eoportal/satellite-missions/g/gosat

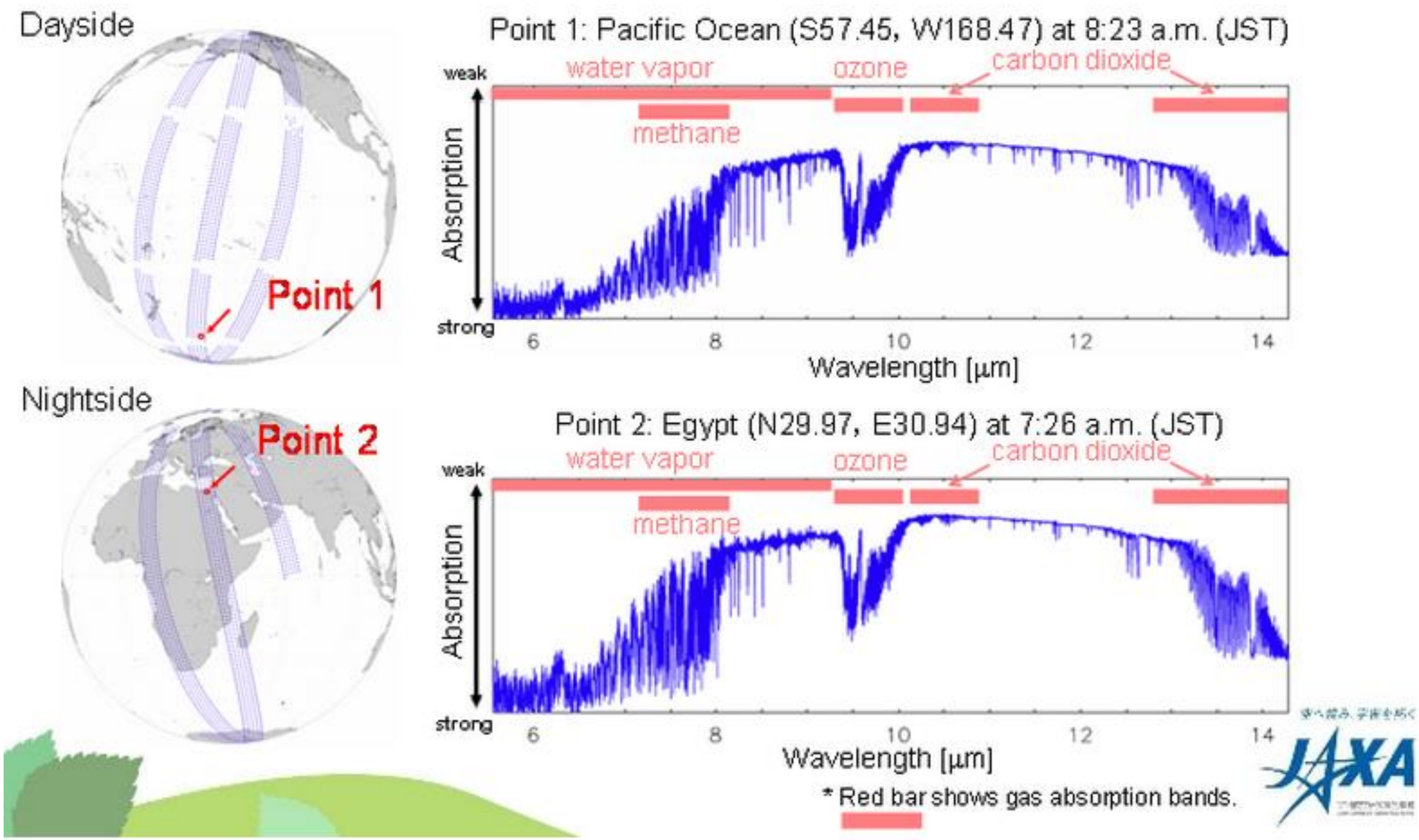
Band 1-4 radiance spectra of TANSO-FTS (SWIR)

observed on April 23, 2009, over Tsukuba, Japan



http://global.jaxa.jp/press/2009/10/20091030_ibuki_e.html

GOSAT TIR

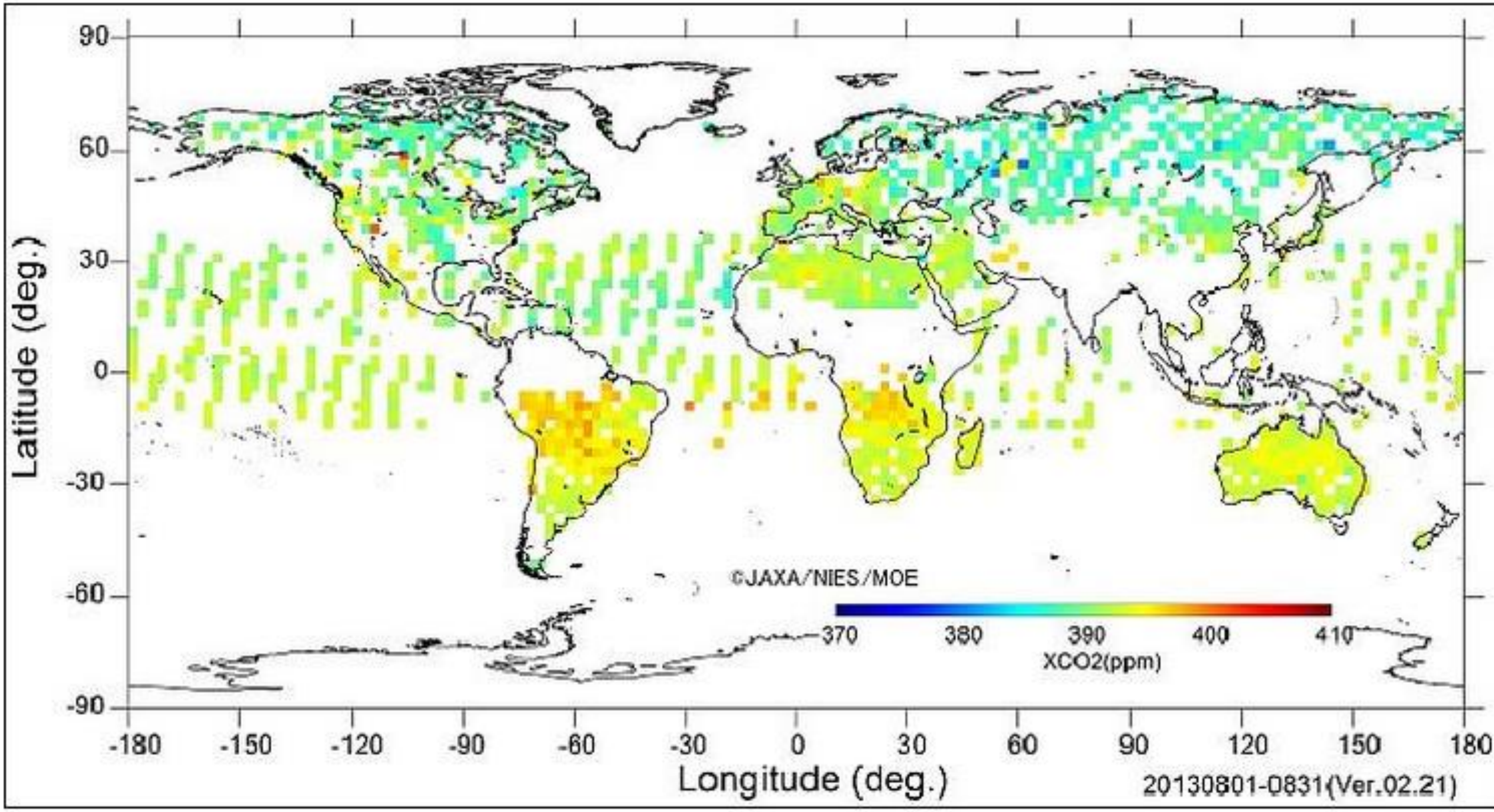


➢ **The SWIR bands mainly observe in the daytime because they measure the solar spectra reflected from the Earth's surface.**

➢ **TIR is able to observe both in the nighttime and daytime because it measures the spectra of Earth radiation. It has been confirmed that TIR could observe the absorption spectra of carbon dioxide and methane during both day and night.**

http://www.eorc.jaxa.jp/en/imgdata/topics/2009/tp090319.html

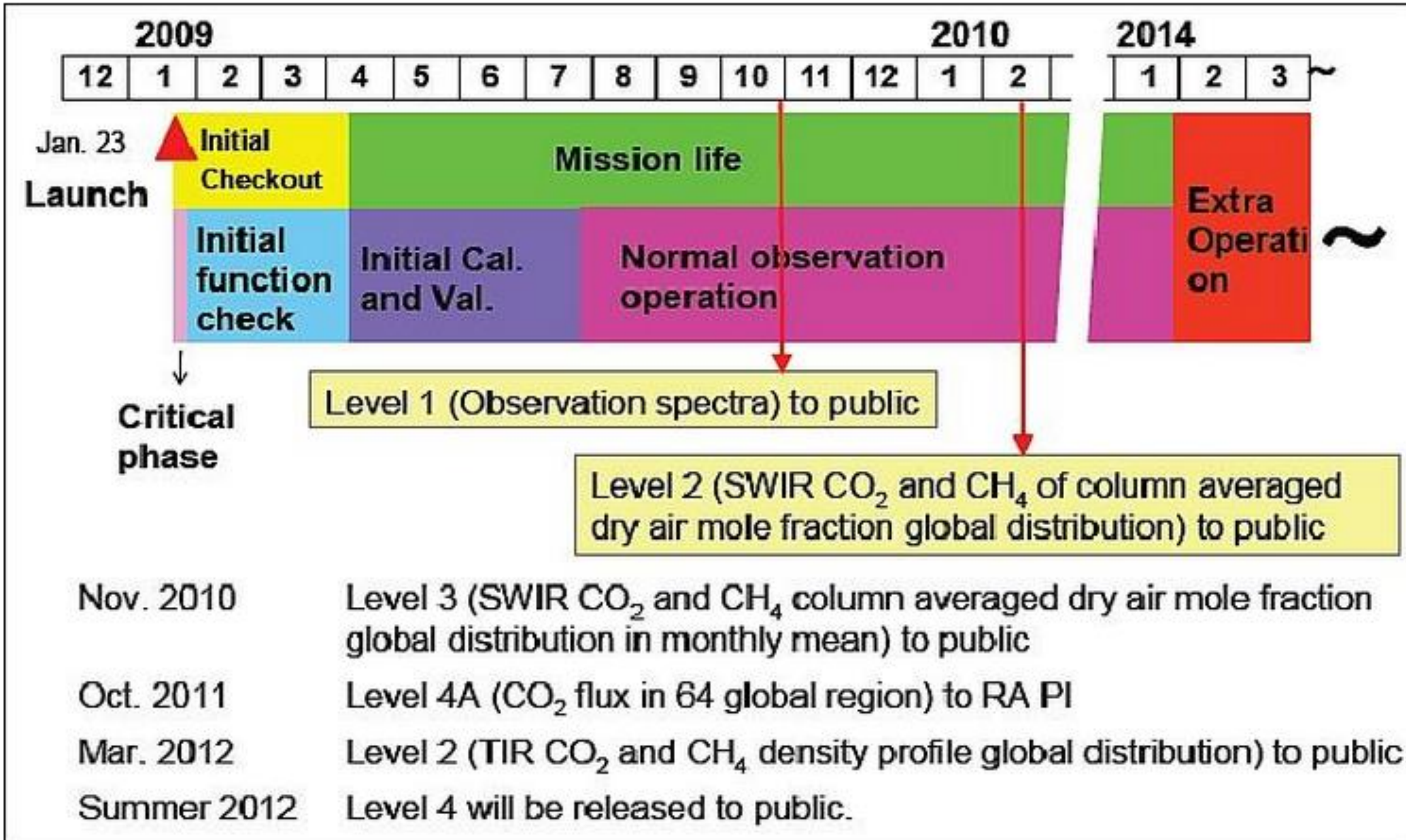
GOSAT CO_2 mixing ratio



- **Monthly Global Map of the CO_2 column-averaged volume mixing ratios in 2.5 deg by 2.5 deg mesh August 2013 Ver.02.21 (image credit: NIES)**

https://directory.eoportal.org/web/eoportal/satellite-missions/g/gosat

GOSAT mission schedule



https://directory.eoportal.org/web/eoportal/satellite-missions/g/gosat

NEC / Earth Observation Sensors

➢ **The sensors mounted on earth observation satellites for monitoring natural resources and the environment can be broadly classified as optical sensors or microwave driven radars.**

http://www.nec.com/en/global/solutions/space/earth_oservation/

Mitsubishi Electric / Earth Observation Satellites

➢ GOSAT-2: GOSAT-2 is the successor of IBUKI (also known as GOSAT). It is expected to play a major role in the international framework for space-based greenhouse-gas observation.

➢ ALOS-2: Advanced Land Observing Satellite-2 (ALOS-2) follows in the footsteps of ALOS, which monitored changes on Earth between 2006 and 2011. It's equipped with the PALSAR-2 panchromatic L-band synthetic aperture radar observation device.

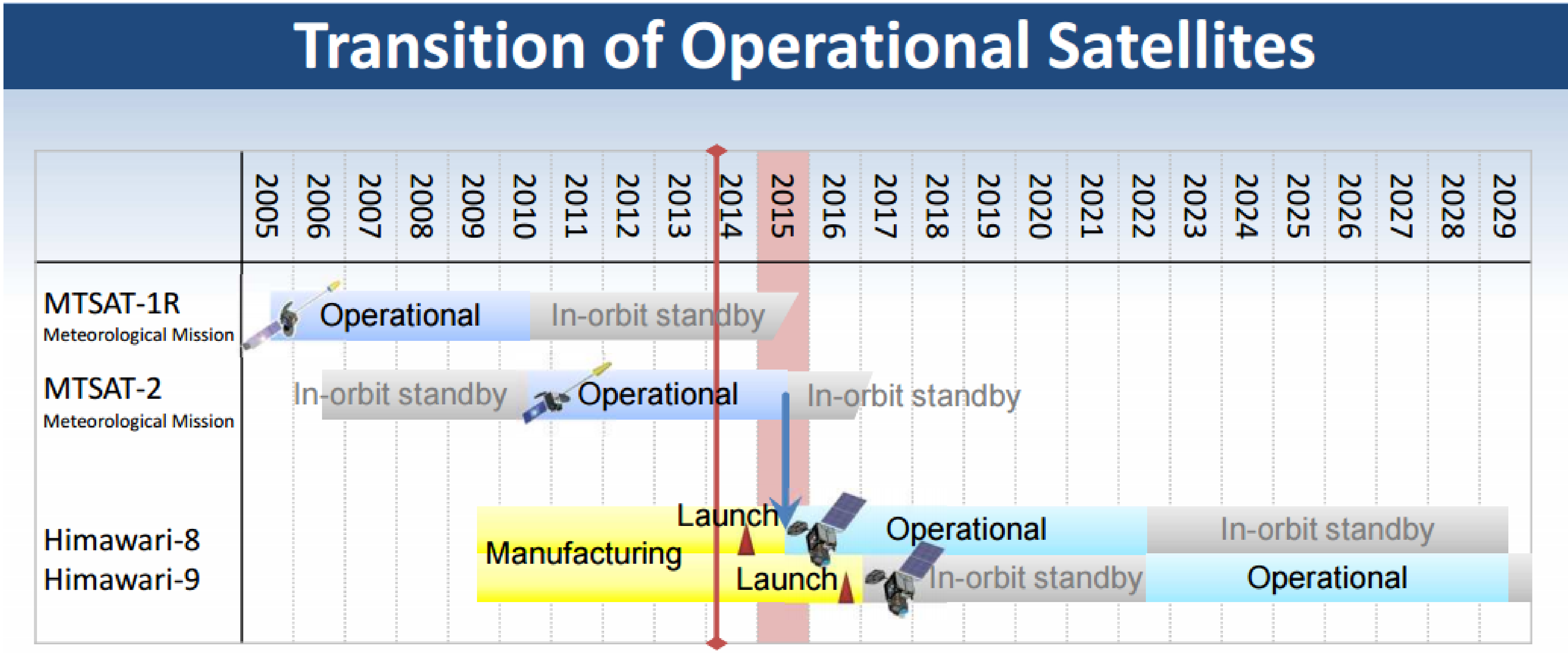
➢ Himawari-8, 9: Japanese meteorological satellite which are essential to the climate forecast of Japan. They will be the successors to MTSAT-2 (Himawari-7).

➢ MTSAT-2: MTSAT-2 carries out an aviation mission, such as successful air traffic control, as well as a meteorological mission.

➢ ADEOS-II: Advanced Earth Observing Satellite-II: ADEOS-II takes over ADEOS's mission of monitoring climate changes, expansion of the ozone holes, and global environmental changes, as well as investigating the causes of these phenomena.

http://www.mitsubishielectric.com/bu/space/satellite/observation/index.html

Third Generation Meteorological Satellites, Himawari -8 & 9



- Himawari-8 was launched on October 7, 2014.
- The launch of Himawari-9 for in-orbit standby is scheduled in 2016.
- Himawari-8/9 will be in operation around 140 degrees East covering the East Asia and Western Pacific regions for 15 years

http://severe.worldweather.wmo.int/TCFW/JMAworkshop/4-3.Himawari8-9_YIzumikawa.pdf

Himawari-8/9: Specification of Observation

Channel	Central Wavelength [µm]	Spatial Resolution
1	0.43 – 0.48	1 km
2	0.50 – 0.52	1 km
3	0.63 – 0.66	0.5 km
4	0.85 – 0.87	1 km
5	1.60 – 1.62	2 km
6	2.25 – 2.27	2 km
7	3.74 – 3.96	2 km
8	6.06 – 6.43	2 km
9	6.89 – 7.01	2 km
10	7.26 – 7.43	2 km
11	8.44 – 8.76	2 km
12	9.54 – 9.72	2 km
13	10.3 – 10.6	2 km
14	11.1 – 11.3	2 km
15	12.2 – 12.5	2 km
16	13.2 – 13.4	2 km

Channels 1–3: RGB Composite True Color Image

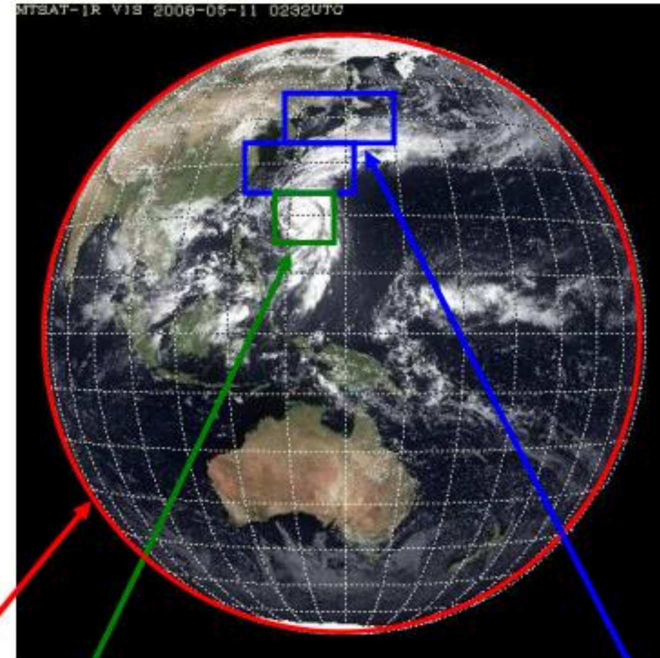
Channels 8–10: Water Vapor

Channel 11: SO_2

Channel 12: O_3

Channels 13–15: Atmospheric Windows

Channel 16: CO_2



Full disk
Interval: **10 minutes** (6 times per hour)

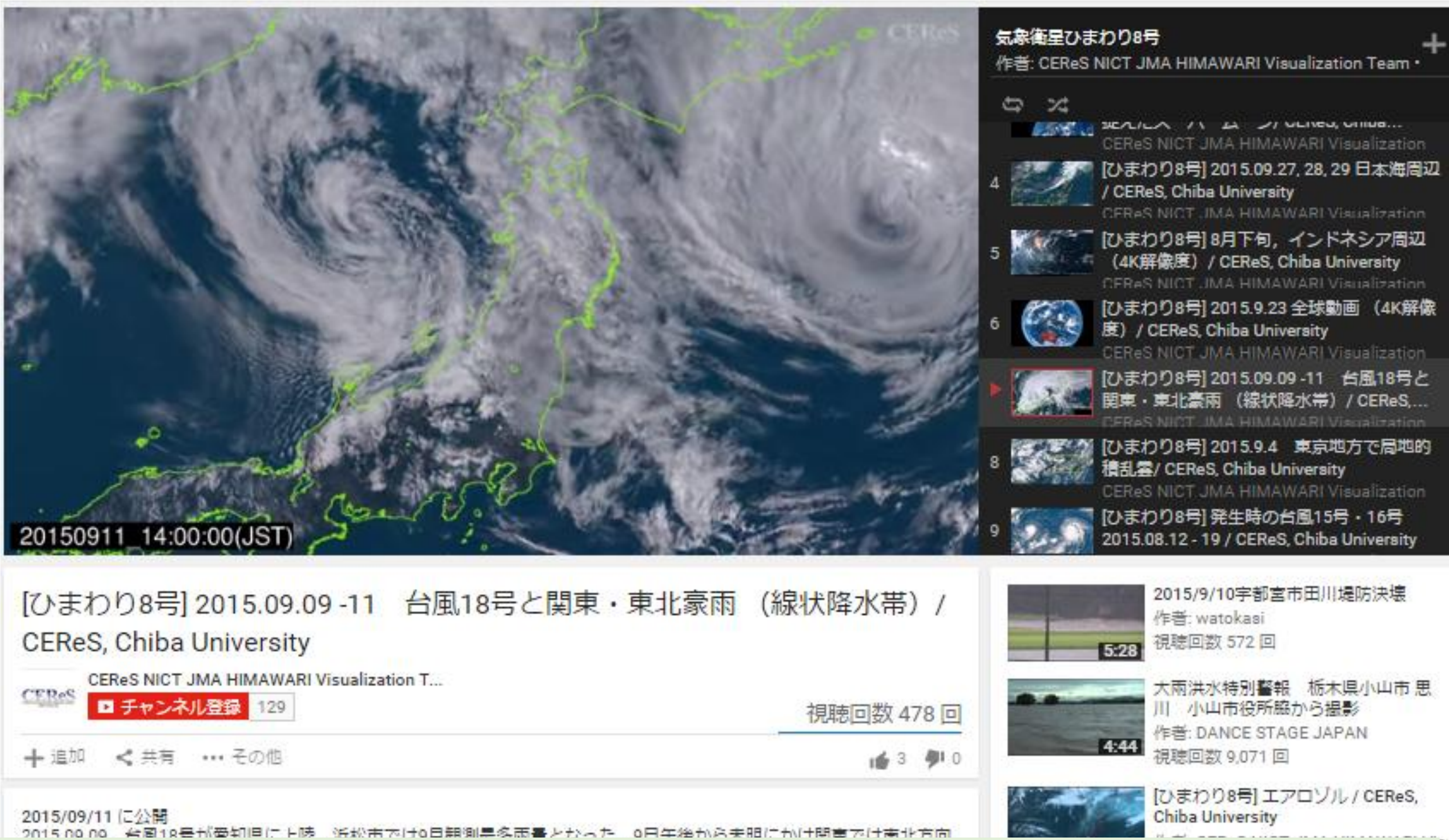
Japan area
Interval: **2.5 minutes** (4 times in 10 minutes)
Dimension: EW x NS: 2000 x 1000 km x 2

Target area
Interval: **2.5 minutes** (4 times in 10 minutes)
Dimension: EW x NS: 1000 x 1000 km

Number of Channels: 5 ⇨ 16

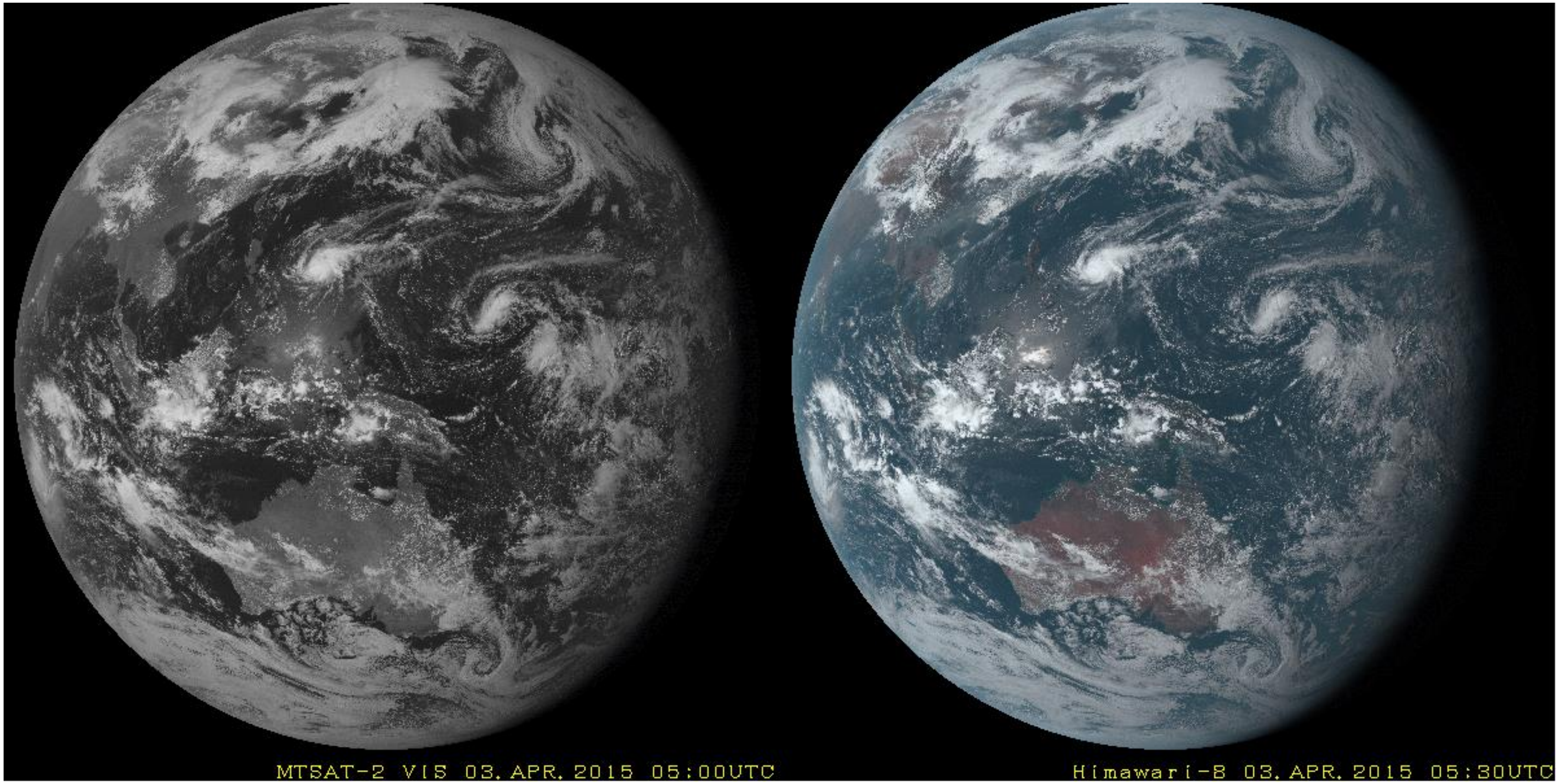
Interval: 30/60 min. ⇨ 10min.

CEReS NICT JMA Himawari-8 Official YouTube



※2005年7月7日の「ひまわり8号」正式運用後、MTSAT-2 データは、原則「ひまわり8号」データを HRITに変換した形で　気象庁業務支援センター -> ウェザーニュース社 -> 千葉大と送られてきている。そのため、データファイル名としてはクイックルック画像共に"MTSAT"となっているが、中身は「ひまわり8号」である。

MTSAT vs. Himawari-8



Himawari-7 (MTSAT) : every 1h **Himawari-8 : every 10 min**

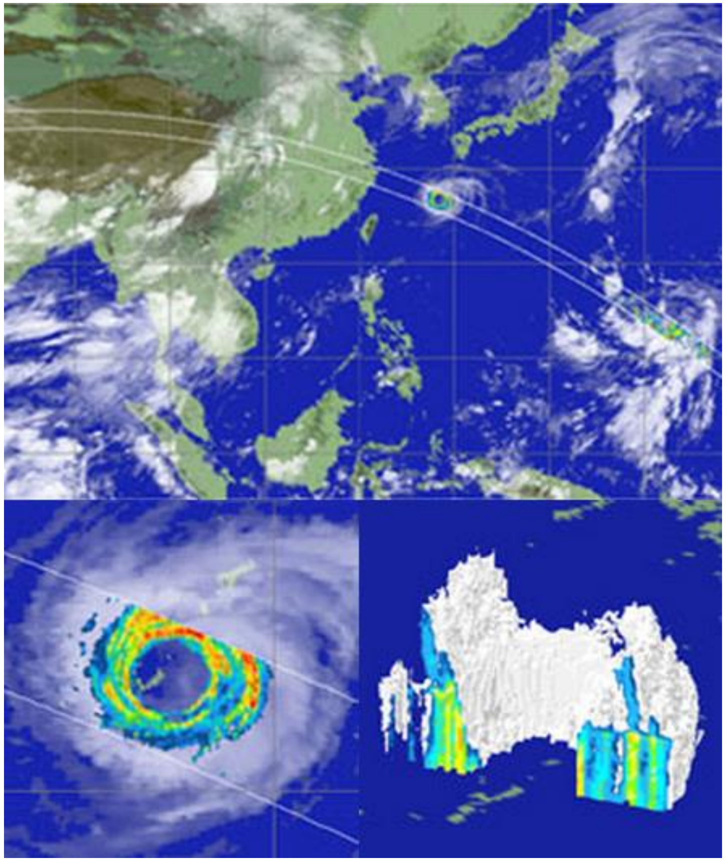
http://www.jma-net.go.jp/sat/data/web89/himawari8_sample_data.html

TRMM (Tropical Rainfall Measuring Mission,1997)

➢ Launched in November 1997, the TRMM (Tropical Rainfall Measuring Mission) was jointly developed by JAXA and NASA aiming at observing tropical precipitation.

➢ The PR (Precipitation Radar) was the world's first satellite onboard precipitation radar developed by Japan.

➢ The TRMM satellite completed its post-mission operation on October, 2014. The TRMM has been in its 17th year of operation, well exceeding its design life expectancy of three years and two months.



PR – 3-dimensional observation of rainfall is measured with a microwave radar operated at 13.796 and 13.802 GHz.
Swath: 220 km
Resolution 250 m (depth), 4.3 km (horizontal)

http://global.jaxa.jp/projects/sat/trmm/

http://www.eorc.jaxa.jp/TRMM/about/observation/images_j.htm

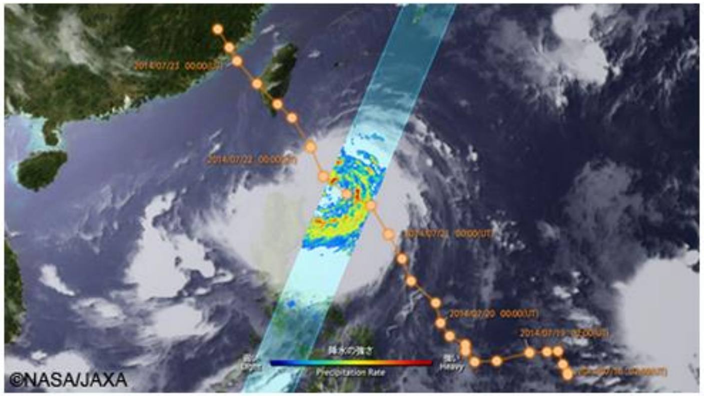
GPM (Global Precipitation Measurement)

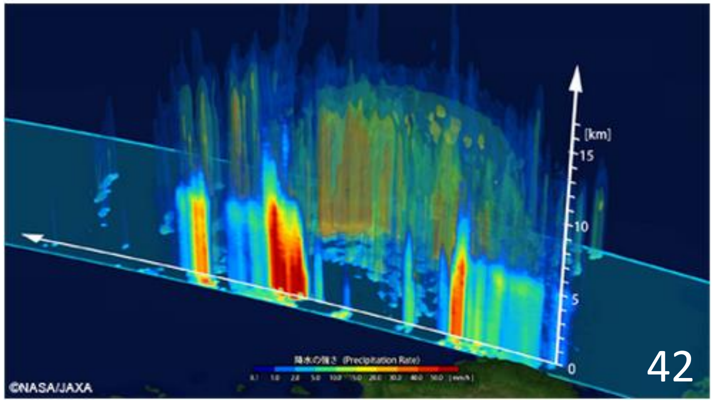
➢ **GPM is a joint mission between JAXA and NASA as well as other international space agencies to make frequent (every 2–3 hours) observations of Earth's precipitation.**

➢ **Dual-Frequency Precipitation Radar (DPR) - a radar providing 3-dimensional maps of storm structure. DPR has two frequencies: the Ku-band radar, similar to the PR on TRMM, covers a 245 km swath. Nested inside that, the Ka-band radar covers a 120 km swath.**

➢ **GPM Microwave Imager (GMI) - a passive sensor that observes the microwave energy emitted by the Earth and atmosphere at 13 different frequency/polarization channels. These data allow quantitative maps of precipitation across a swath that is 885 km wide.**

Launched in Feb. 2014





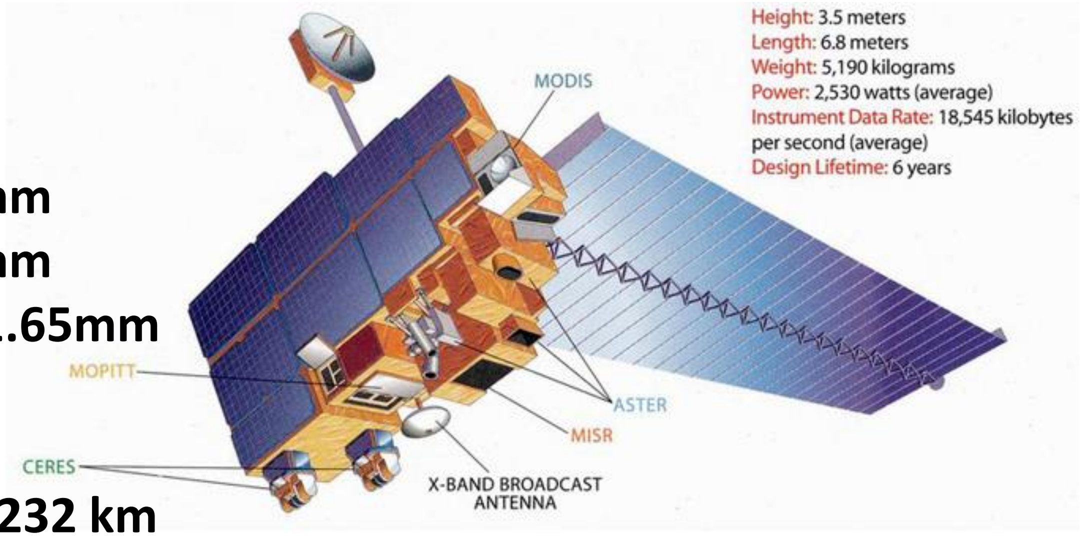
http://www.eorc.jaxa.jp/imgdata/topics/2014/tp140902.html

http://en.wikipedia.org/wiki/Global_Precipitation_Measurement

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer)

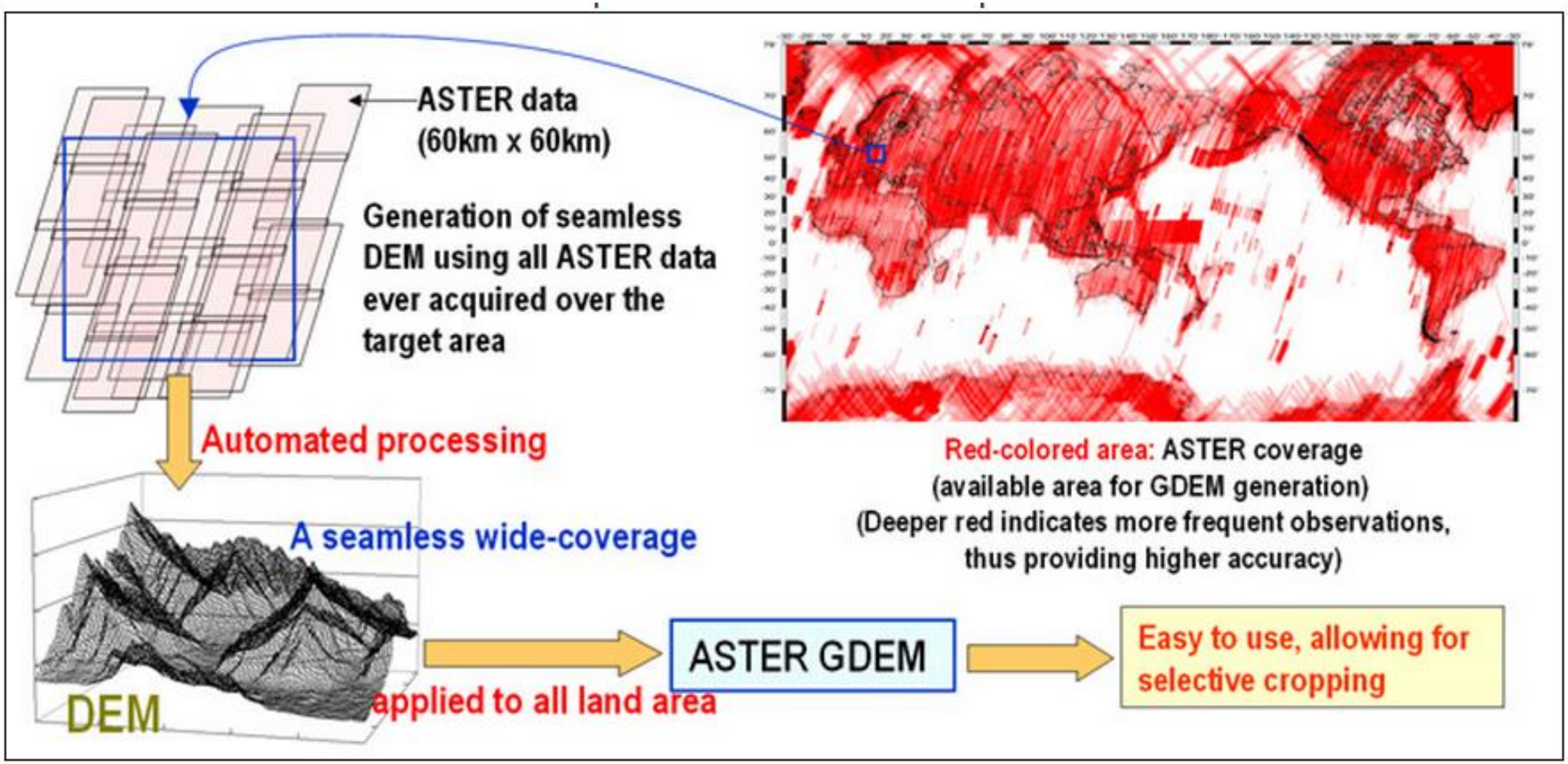
➢ ASTER is an imaging instrument onboard Terra, the flagship satellite of NASA's Earth Observing System (EOS) launched in December 1999.
➢ ASTER is a cooperative effort between NASA, Japan's Ministry of Economy, Trade and Industry (METI), and Japan Space Systems (J-spacesystems).
➢ ASTER data are used to create detailed maps of land surface temperature, reflectance, and elevation. The coordinated system of EOS satellites, including Terra, is a major component of NASA's Science Mission Directorate and the Earth Science Division.

➢ Spatial Resolution:
15 m (Bands 1〜3) 0.52 - 0.86mm
30 m (Bands 4〜9) 1.60 - 2.43mm
90 m (Bands 10〜14) 8.125 - 11.65mm
➢ Swath width: 60 km
➢ Total coverage in cross-track direction by pointing function: 232 km



https://asterweb.jpl.nasa.gov/

ASTER G-DEM (Digital Elevation Map)



- **Release: 2009 –**
- **Data: 2000 –**
- **Posting: 30 m**
- **DEM accuracy: 7-14m**

ASTER GDEM is an easy-to-use, highly accurate DEM covering all the land on earth. It can be used to display a bird's-eye-view map or run a flight simulation.

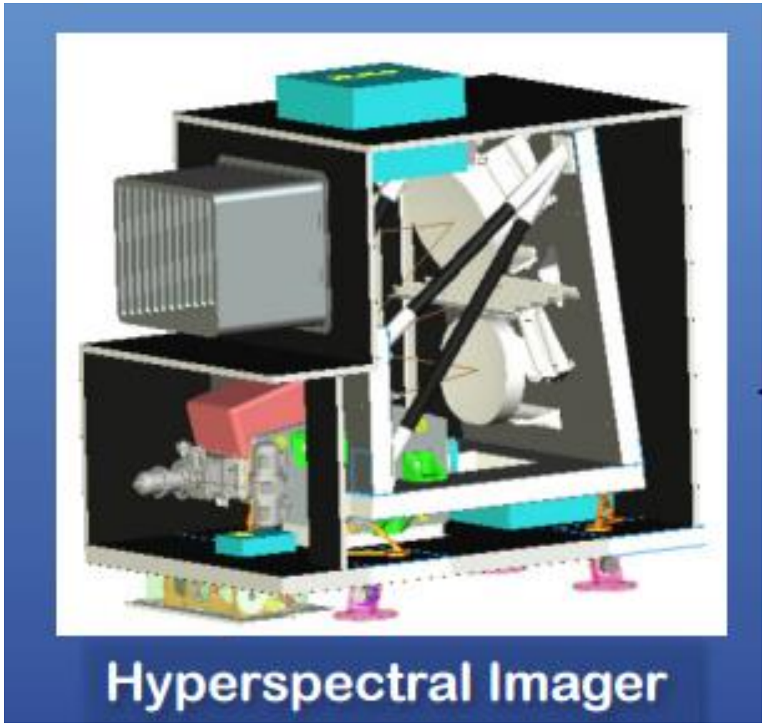
http://www.jspacesystems.or.jp/ersdac/GDEM/E/1.html

Hyperspectral Imager Suite (HISUI)

翡 翠

- ➢ Spatial Resolution: 30 m
- ➢ Swath Width: 30 km
- ➢ Spectral Bands: 185 (VNIR:57 SWIR:128)
- ➢ Range: 0.4 - 2.5 μm (VNIR: 0.4-0.97 μm, SWIR:0.9-2.5 μm)
- ➢ Resolution: 10 nm (VNIR), 12.5 nm (SWIR)
- ➢ Signal to Noise Ratio (30% albedo) ≥ 450 @620 nm, ≥ 300 @2100 nm
- ➢ Dynamic Range ≥ 10 bits (design=12bit)

Pointing Capability ≈ ±3° (±30 km)



➢ HISUI is being developed by Japanese Ministry of Economy, Trade, and Industry (METI) as its 4th spaceborne optical imager mission.

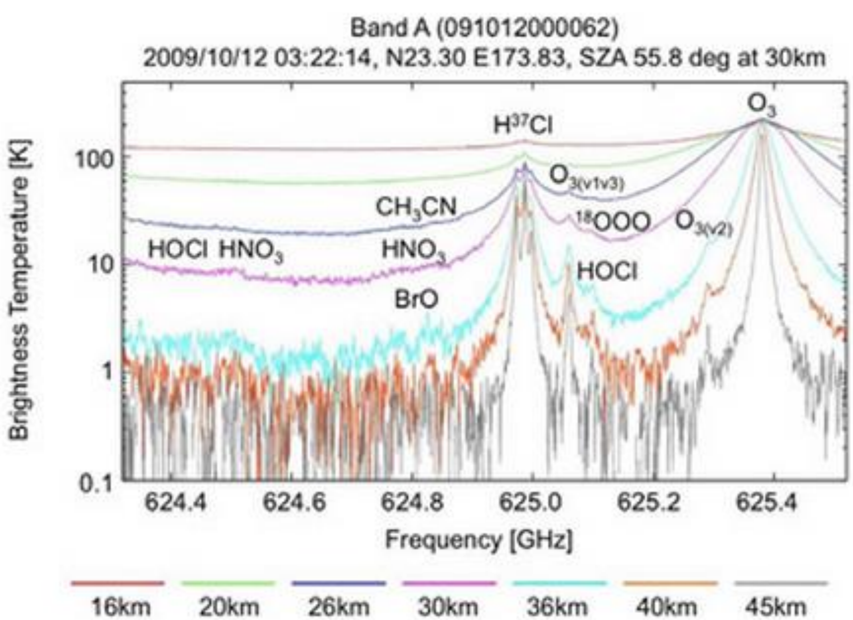
1) OPS onboard JERS-1 satellite (1992 – 1998)
2) ASTER onboard NASA's Terra satellite (1999 -)
3) ASNARO (2012-)

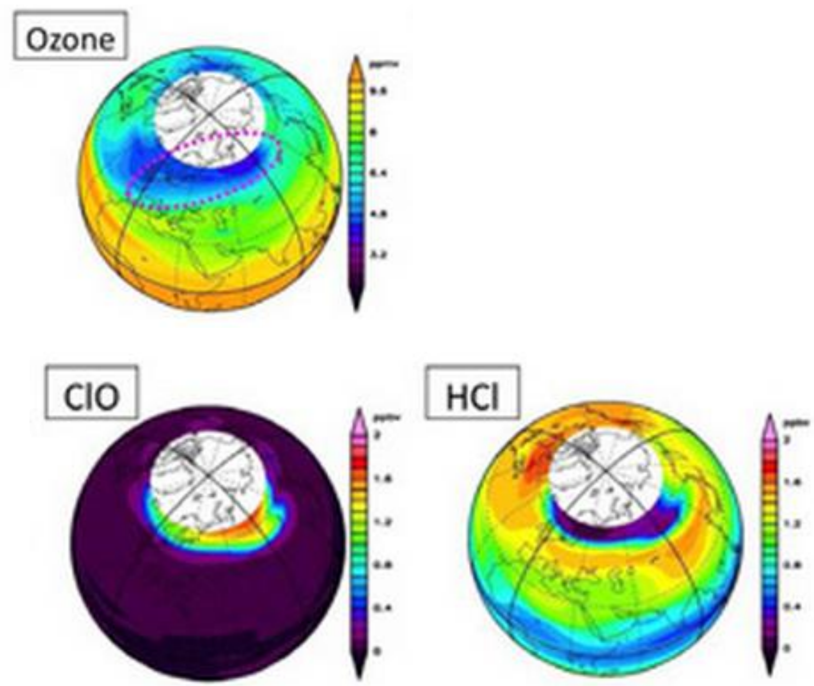
http://hyspiri.jpl.nasa.gov/downloads/2011_Workshop/day2/23.1108_HISUI_HyspIRIWS_06.pdf

Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES)

➢ **The SMILES investigation aims to globally map stratospheric trace gases by means of the most sensitive submillimeter receiver.**

➢ **Although SMILES stopped atmospheric observation due to instrumental failures since April 2010, highly sensitive data obtained for a half year provides accurate global datasets of atmospheric minor constituents related to ozone chemistry.**





http://www.nasa.gov/mission_pages/station/research/experiments/638.html

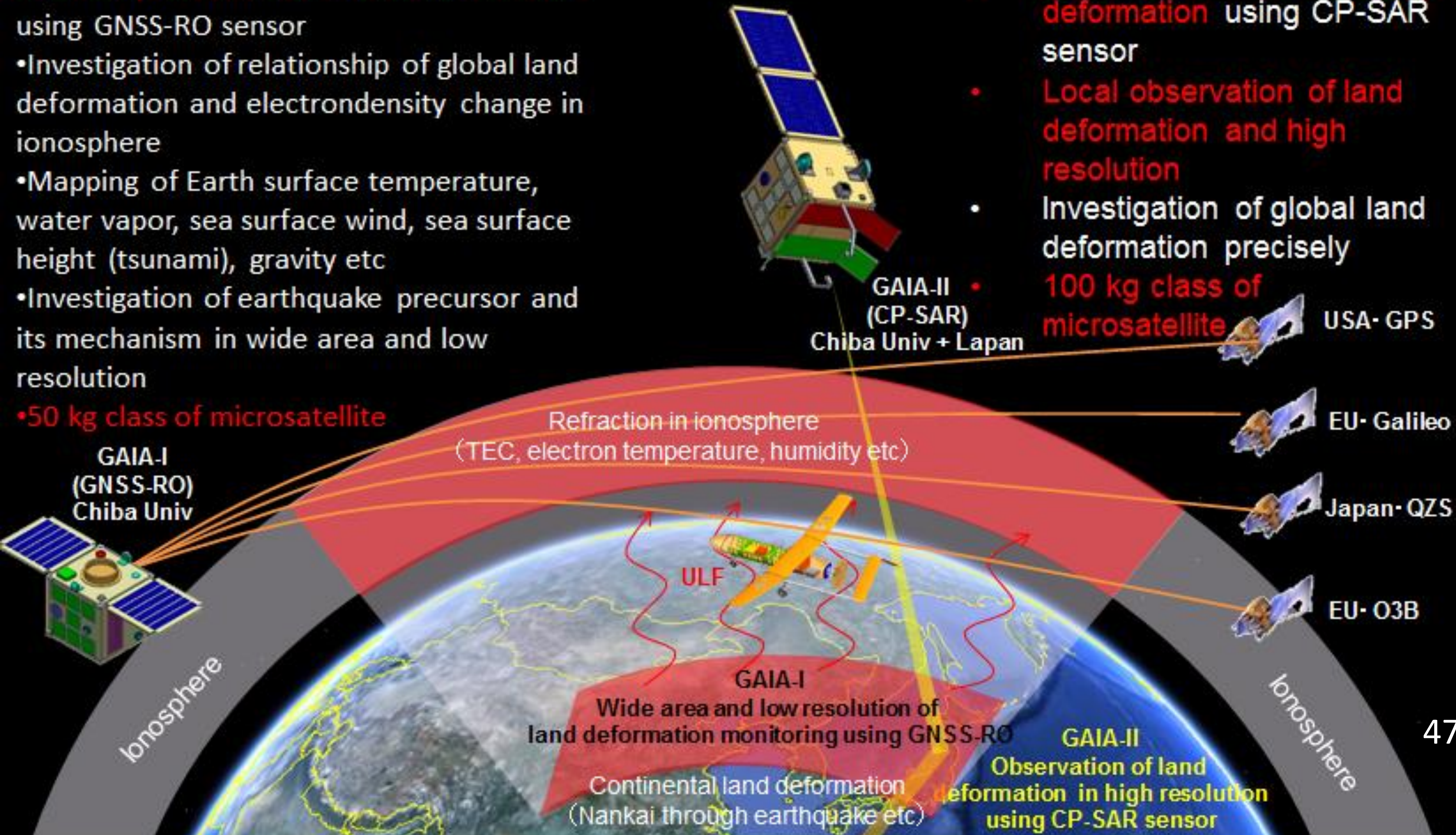
Earth Observation using the GAIA-I and GAIA-II

GNSS-RO onboard microsatellite （GAIA-I）:

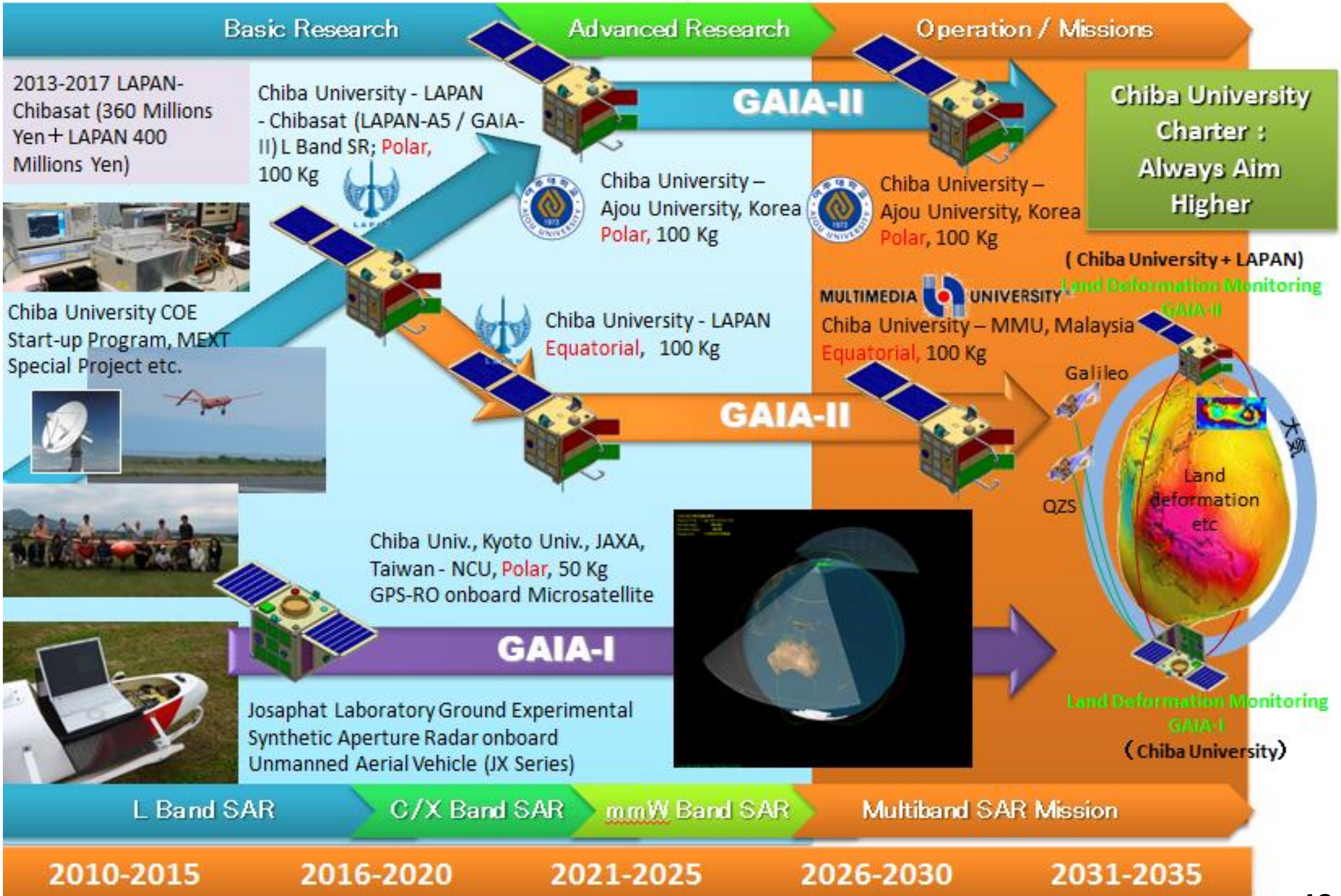
- Indirectly observation of land deformation using GNSS-RO sensor
- Investigation of relationship of global land deformation and electrondensity change in ionosphere
- Mapping of Earth surface temperature, water vapor, sea surface wind, sea surface height (tsunami), gravity etc
- Investigation of earthquake precursor and its mechanism in wide area and low resolution
- 50 kg class of microsatellite

CP-SAR onboard microsatellite （GAIA-II）:

- Directly observation of land deformation using CP-SAR sensor
- Local observation of land deformation and high resolution
- Investigation of global land deformation precisely
- 100 kg class of microsatellite



Roadmap of Chiba University Microsatellite Missions



科学技術から社会的活用へ

1956 科学技術庁 Science and Technology Agency (-2001)
1969 宇宙開発事業団 NASDA (-2003)
1970 おおすみ Ohsumi
1972 ERTS1 (-> Landsat)
1978 EOC (Earth Observation Center)/NASDA
" 1st PGSD (Policy Guideline for Space Development)
-> MOS satellite
1989 2nd PGSD -> ADEOS, ISS
1990 Japan-US Bilateral Agreement on Satellite Procurement
--- "FTA" for operational satellites
1995 EORC (Earth Obs. Res. Center)/NASDA
2003 宇宙航空研究開発機構 JAXA
2004 地球観測推進戦略 Strategy for Promotion of Earth Observation
2005 GEOSS (Global Earth Obs. System of Systems) 10 y project
2008 宇宙基本法 Basic Space Law
2009 宇宙基本計画 BPSP (Basic Plan for Space Policy)
2013 2nd BPSP (http://www8.cao.go.jp/space/english/index-e.html)

日本学術会議 地球惑星科学委員会 地球・惑星圏分科会
「我が国の地球衛星観測のあり方について」

2014年9月5日（記録）
SCJ第22期-260905-22641200-043

衛星による地球観測の科学的成果

【1．気象分野】
・静止衛星や低軌道衛星の観測により得られる可視・赤外・水蒸気画像は、地球の雲と雨に関する多くの発見をもたらしている。
・台風の発生、発達、経路に関する情報は、メカニズムの解明と予測に大きく貢献した。

・マイクロ波放射計は雲水量や降雨強度のほか、雲が存在する条件下でも気温、水蒸気、海面水温を観測することができる。特にマイクロ波サウンダによる気温の鉛直分布は、気象の数値予報の精度向上に大きく貢献している。
・日本が開発した衛星搭載降雨レーダは、宇宙からの降雨の立体観測を初めて可能にし、降雨の仕組みに関する多くの科学的発見をもたらした。
　気候モデルや雲解像モデルの降雨量の検証はもとより、マイクロ波イメージャでは困難な陸域での衛星観測による降雨量推定を可能にしたこと、降雨による大気加熱量の3次元分布を定量化したことも重要である。

【2. 海洋分野】

・可視・赤外放射計、マイクロ波放射計、マイクロ波散乱計、マイクロ波高度計、合成開口レーダなどを搭載した衛星が活躍している。

・海面水温、日射量、水蒸気量、降水量、海上風速・風向、海面塩分、海面高度、表層流速、波高・波向、植物プランクトン現存量、海氷分布などのパラメータが全球海洋上で観測され、海洋循環や大気海洋相互作用、エルニーニョ／南方振動、熱帯低気圧（台風）のメカニズム、極域環境変動、海洋生物環境、生物生産と炭素循環などの研究に活用されてきた。

・高分解能の衛星観測データにより中緯度の海流が雲・降水系や海上風に与える影響が特定された。

・最近は、海洋大循環数値モデル研究に、衛星観測による循環の駆動力の推定値が利用されるほか、海洋大循環モデルへのデータ同化やシミュレーション結果の検証用に衛星データが用いられている。

・このように衛星観測データは、海洋変動・気候変動のメカニズムの解明と予測、地球温暖化の影響評価と予測などに積極的に活用されている。

【３．大気化学分野】

・オゾン全量分光計による南極オゾンホールの発見以降、成層圏微量成分の衛星観測により、多角的にオゾン破壊過程の詳細が解明された。
・対流圏微量成分の衛星観測技術は、1990年代以降、地球環境問題への関心の高まりと共に飛躍的に進歩し、大気汚染物質である二酸化窒素（NO2）、二酸化硫黄（SO2）、ホルムアルデヒド（HCHO）など数多くの微量成分、およびエアロゾルの観測が実現した。
・これによって、アジア地域や半球規模での越境汚染、アフリカなどにおけるバイオマス燃焼が地球規模での環境に及ぼす影響などが明らかになった。さらに、欧州機関の短波長赤外での観測により、地上付近の微量成分、例えばメタンの全球分布が解明された。

・超伝導サブミリ波リム放射サウンダ（SMILES）は国際宇宙ステーション日本実験棟曝露部を利用して、成層圏から下部熱圏までのこれまでにない広範囲にわたる大気中の微量分子を高感度で測定し、オゾンを破壊するハロゲン系や水素系化学種の化学過程の反応を解明するなど、国際的に高い評価を得た。
・高分解能分光器の開発やリトリーバル手法の開発が進み、長い間技術的に困難とされてきた二酸化炭素の推定も可能となった。日本のGOSAT（いぶき）によって、世界で初めて本格的に二酸化炭素のグローバル観測が始まり、排出源や吸収源の特定を含む二酸化炭素のグローバルな収支の推定が行われている。

【4．地理・水文分野】

・40年に及ぶ可視・近赤外波長による地表面観測により、都市の拡大とヒートアイランドや大気汚染などの都市環境変化、耕地の拡大、森林伐採や砂漠化などによる植生変化の検知、積雪面積や氷河・氷床の消長等、劇的な変化を遂げつつある地球環境変化の様子が的確に記録されてきた。これらは地球環境の成り立ちや変化の要因の理解を進め、変化に対する対策の立案・実施に大きく貢献した。

・ALOSに搭載された可視波長センサ（PRISM）による立体視や、合成開口レーダ（PALSAR）によるインターフェロメトリ（干渉）などによって、グローバルな標高情報が、空間解像度5m程度にまで精緻化されて整備されようとしている。詳細な地形解析のみならず、可視・近赤外観測と組み合わせた地下の地質解析や、全球河道網、水面データセットの構築、巨大災害時の被害状況把握など、実用にも結びついた科学的成果が得られている。

・さらに、雲を透過しての地表観測が可能なマイクロ波放射計による観測が加わって、地表面土壌水分量や、積雪水量、植生量や水面面積割合などが準リアルタイムかつ高精度で推定可能となり、大気陸面相互作用や陸面変化への人間活動の影響等に関する科学研究が飛躍的に進捗しつつある。

【5．測地分野】

・全地球航法衛星システム（GNSS）は地殻変動観測の基盤技術の一つと位置付けられる。東日本大震災の際には、東北地方で水平5m、垂直1mの地殻変動が検出された。また、GNSSと音波で船と海底の点との距離を測る音響測距によって、31mの海底地殻変動が観測された。

・GNSSは、地殻変動だけでなく、水蒸気や電離層全電子数（TEC）など大気・電離層観測にも欠かせない存在となっている。

・干渉合成開口レーダ（InSAR）は地上機器の設置なしに面的な観測が可能であり、地震や火山に伴う地殻変動、地滑り、さらに、氷床変動、大陸氷河流動など広い分野で利用されている。波長の長いALOSのL-bandセンサは植生の影響を受けにくく、干渉SAR解析を通じて地殻変動の研究に貢献してきた。

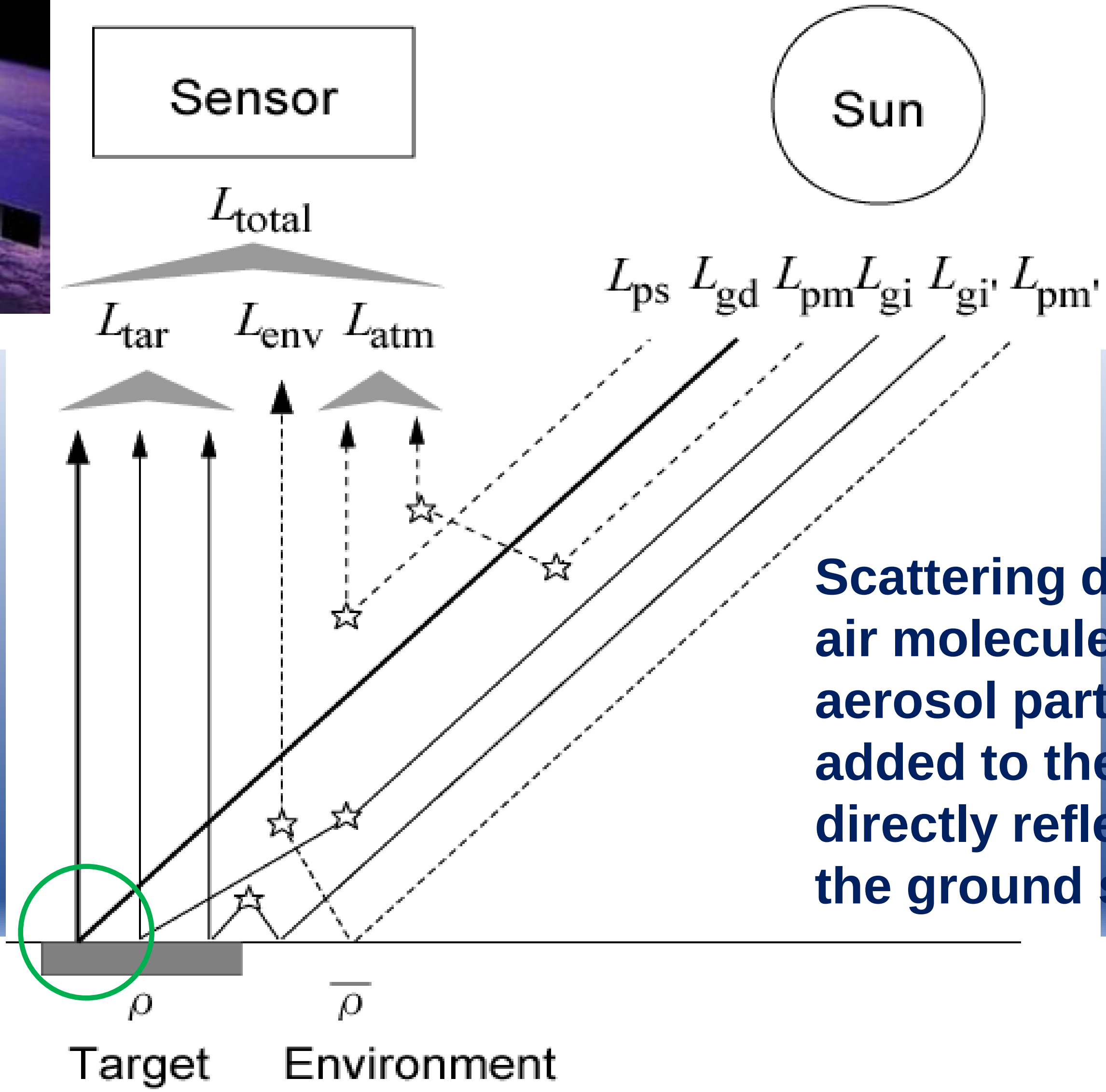
・衛星高度計による海面高測定は、海域の詳細な重力異常や海底地形を明らかにした。また、mmオーダーでの海面上昇も継続的に監視している。同じ地点に3日毎に戻るICEモードの観測は極域氷床変動の研究にも大きく寄与した。

・NASA衛星GRACEは、重力の時間変化を測定することで、陸水貯留量や極域氷床変動などを質量変化として捉えることができる。これによりグリーンランドでの氷床融解の加速や南極氷床変動、全球水循環の質量バランスなどが明らかになった。これらの基盤となっているのは高精度な測地座標系であり、その維持には1986年に打ち上げられた「あじさい」をはじめとする測地実験衛星が貢献している。

地球大気のエアロゾル研究
Study on atmospheric aerosols

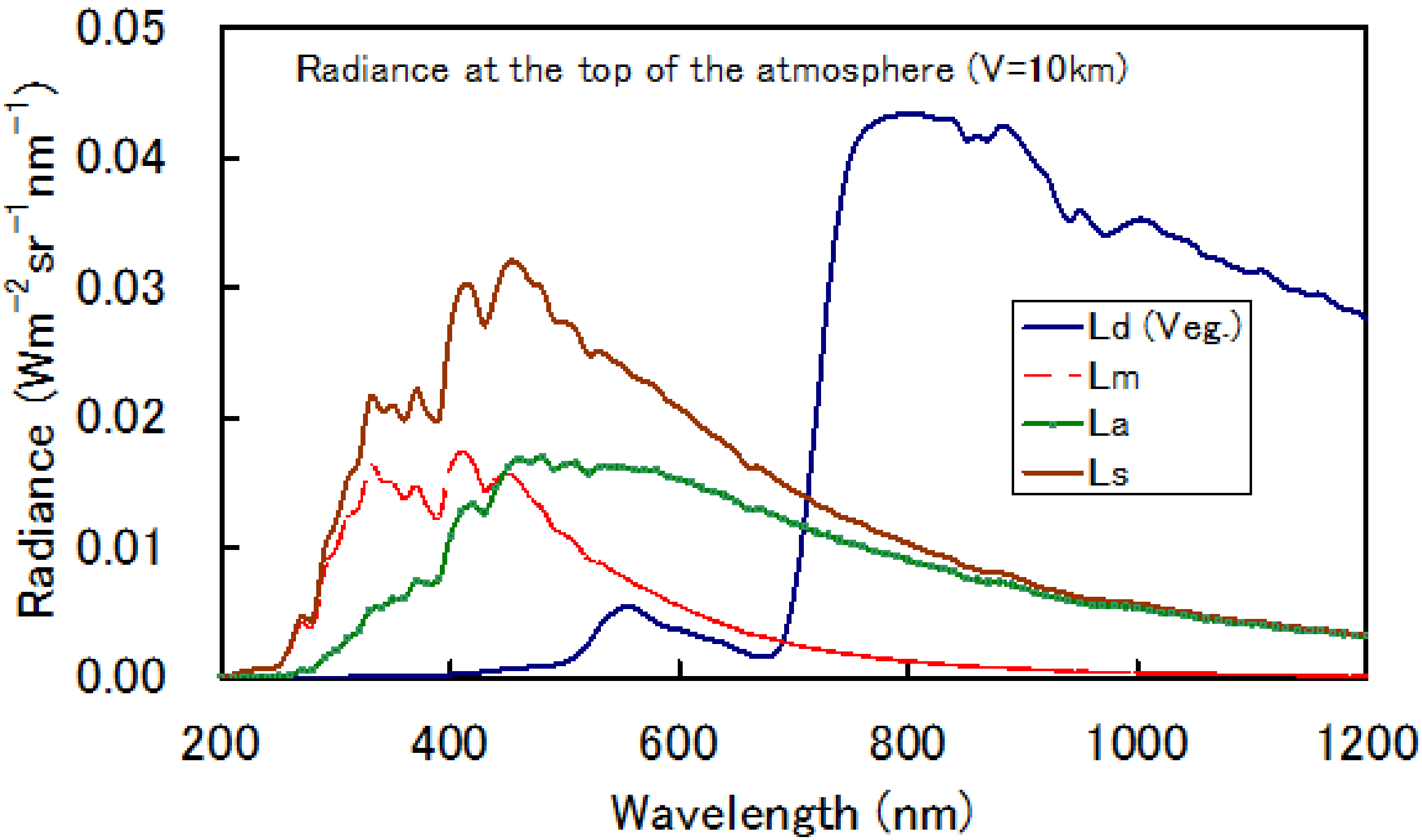


Radiance components observed by a satellite sensor



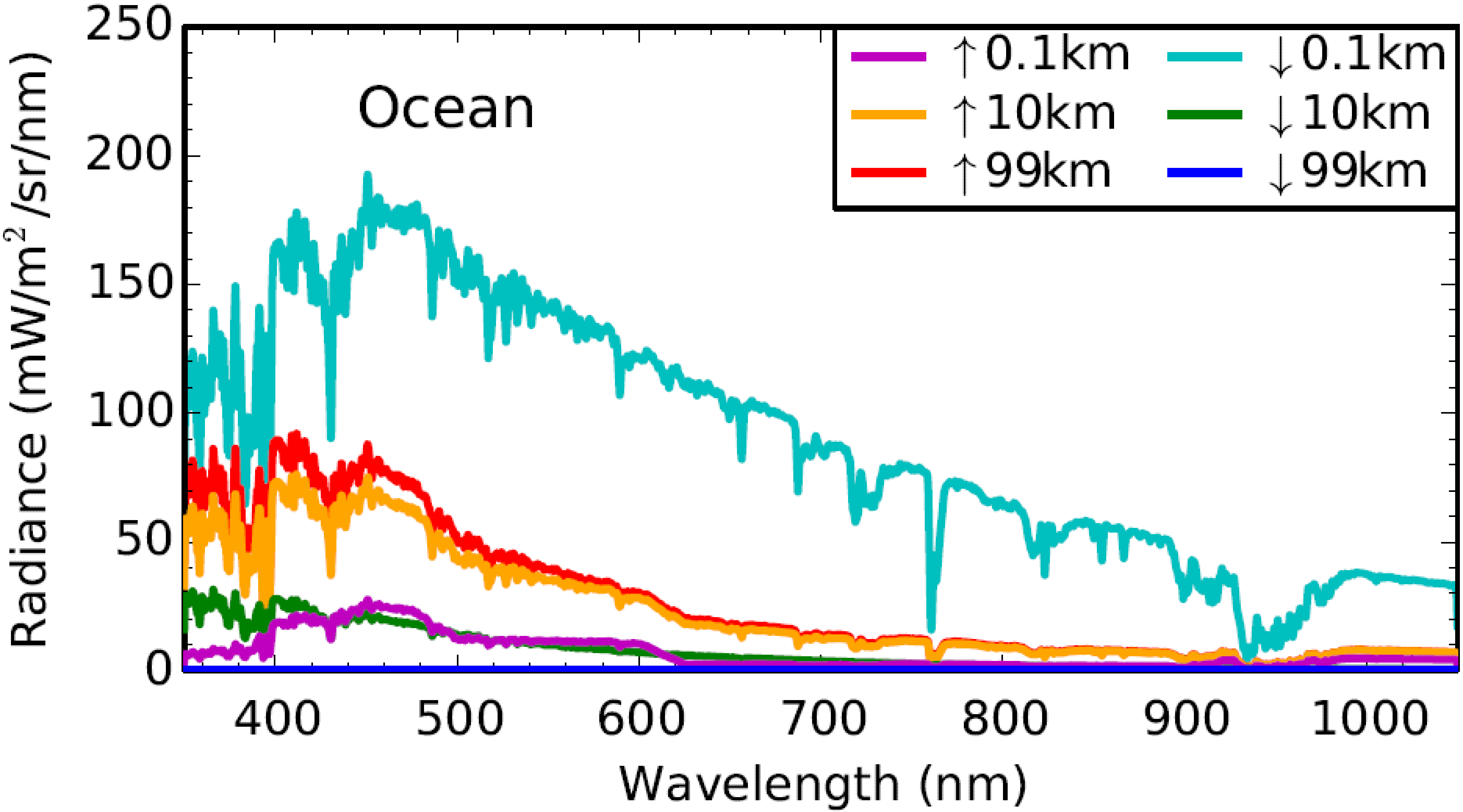
Scattering due to both air molecules and aerosol particles is added to the radiance directly reflected from the ground surface

Simulation of radiance at satellite sensor (reflection from vegetation covered surface)



➢ **Radiance due to** **atmospheric scattering** **tends to be dominant at wavelengths shorter than 700 nm, while the surface reflectance is much more important for longer wavelengths when the surface is covered with vegetation.**

Simulation of upward and downward radiance



Resolution 1nm, Mid-latitude summer, maritime aerosol, vis =20 km, SZA = 20 deg, S-E distance 1AU (April), TOA = 99 km, Ground = 0.1 km, Airplane = 10 km

放射伝達方程式
Radiative transfer equation (RTE)

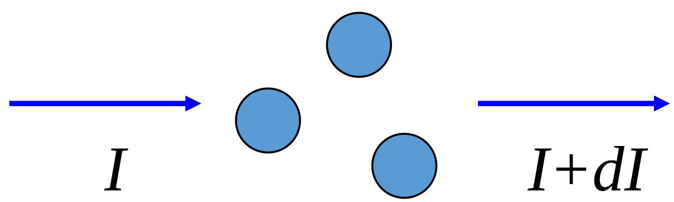
・散乱体の存在する空間での光の伝搬 radiation transfer in a volume with particulate/gas scatterers

$$\boxed{dI = -\alpha_{\mathrm{ext}} I ds = -n\sigma_{\mathrm{ext}} I ds}$$

α_{ext} [m^{-1}] 消散係数 extinction coefficient
n [m^{-3}]　散乱体の数密度 scatterer number density
σ_{ext}[m^2] 消散断面積 extinction cross-section

・放射伝達方程式 RTE

$$\boxed{\frac{1}{n\sigma_{\mathrm{ext}}}\frac{dI}{ds} = J - I}$$



J : 光源関数 source function

光学的厚さ Optical thickness τ

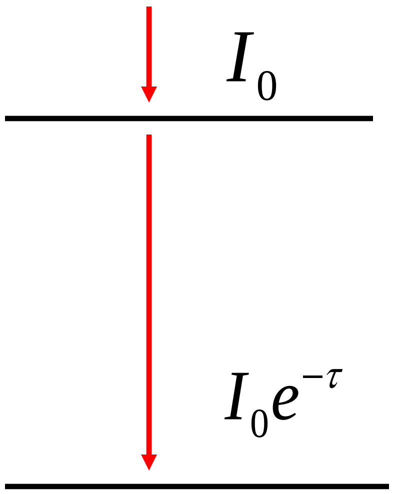
光源関数 *J*=0 のときの放射伝達方程式（鉛直方向）
Vertical radiation transfer when *J* = 0

$$\boxed{\frac{dI}{dz} = -\alpha I}$$

constant α

$$\boxed{\begin{aligned} I &= TI_0 \\ &= I_0 e^{-\alpha z} \\ &= I_0 e^{-\tau} \end{aligned}}$$

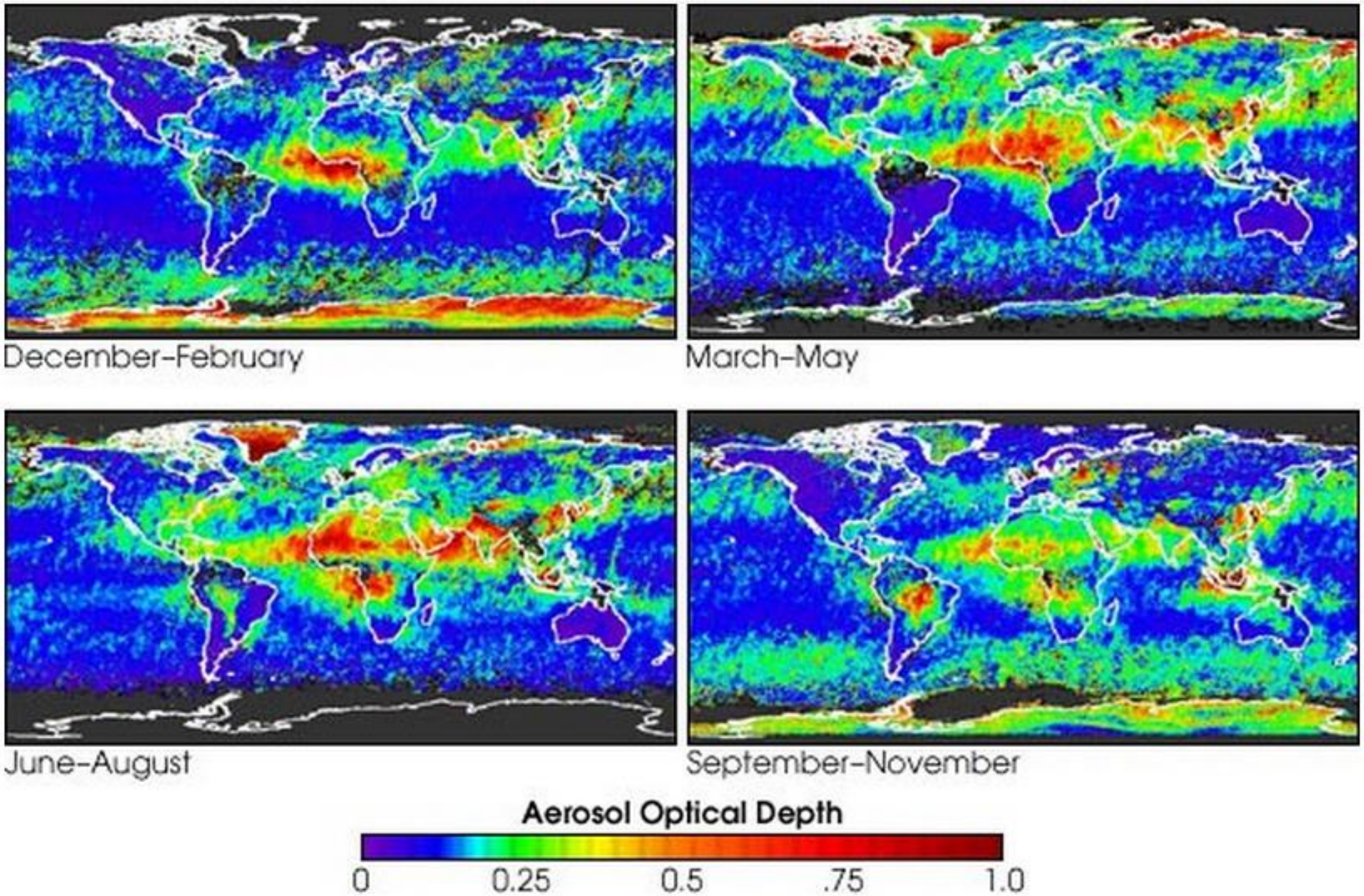
Lambert-Beer's law



$\tau = \alpha z = n\sigma z$：**光学的厚さ**
optical thickness

（$\tau = 1 \Rightarrow I = 0.37 I_0$）

Column Integrated AOT from December 2001 through November 2002



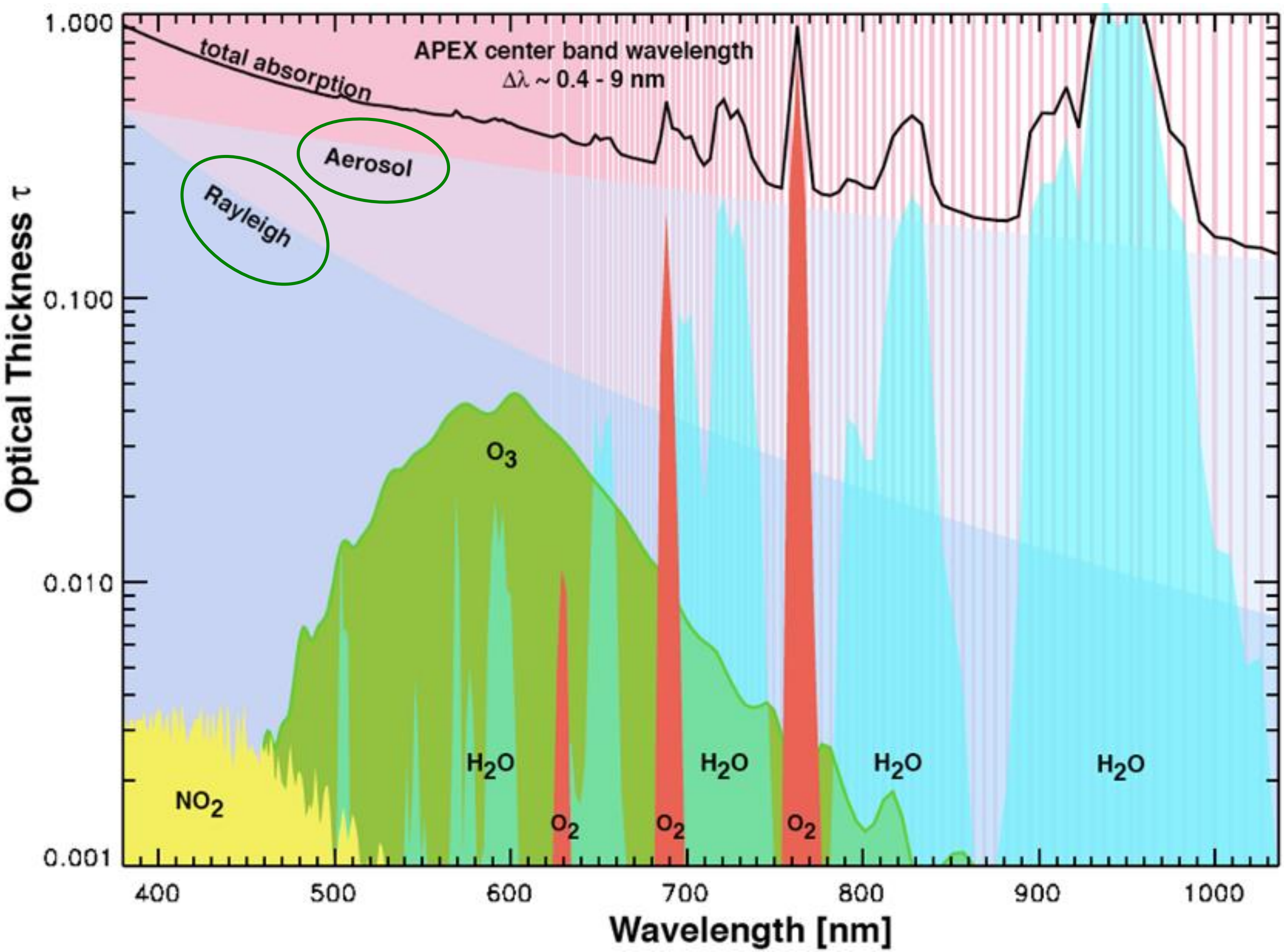
➢ **Global summaries of aerosol optical thickness at 558 nm from MISR (Multi-angle Imaging SpectroRadiometer)**

➢ **MISR algorithms retrieve aerosol amount from the variation in scene brightness over nine different view angles and four wavelengths.**

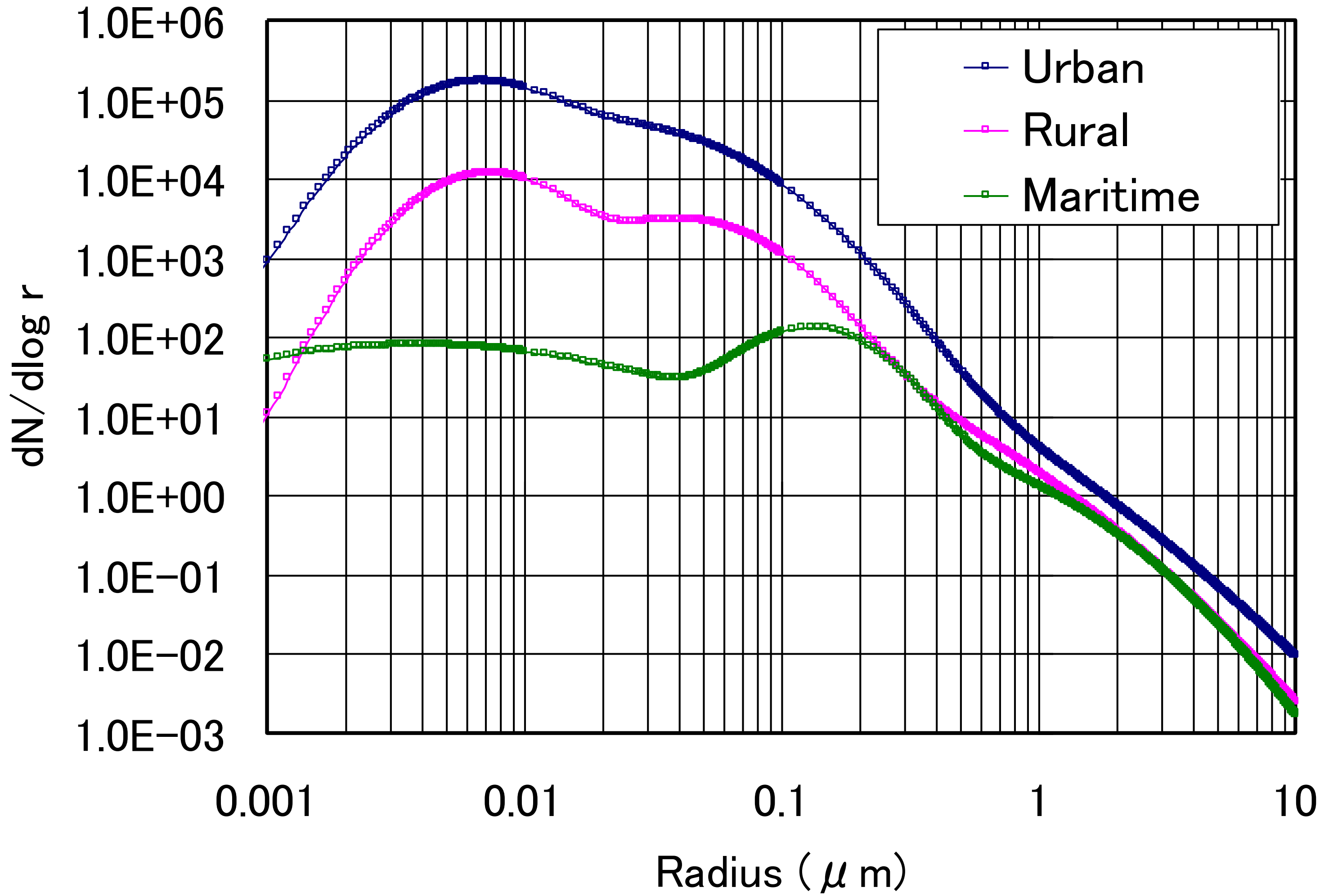
➢ **The maps include aerosol particles of various sizes and from multiple sources, including biomass burning, mineral dust, sea salt and regional industrial pollution.**

http://earthobservatory.nasa.gov/IOTD/view.php?id=3516

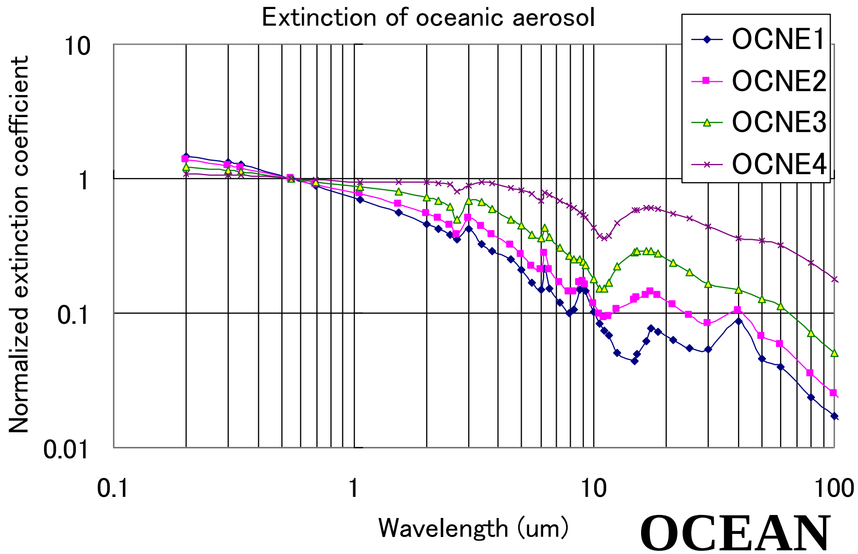
大気の鉛直透過における散乱と吸収の光学的厚さ
Vertical optical thickness due to scattring and absorption



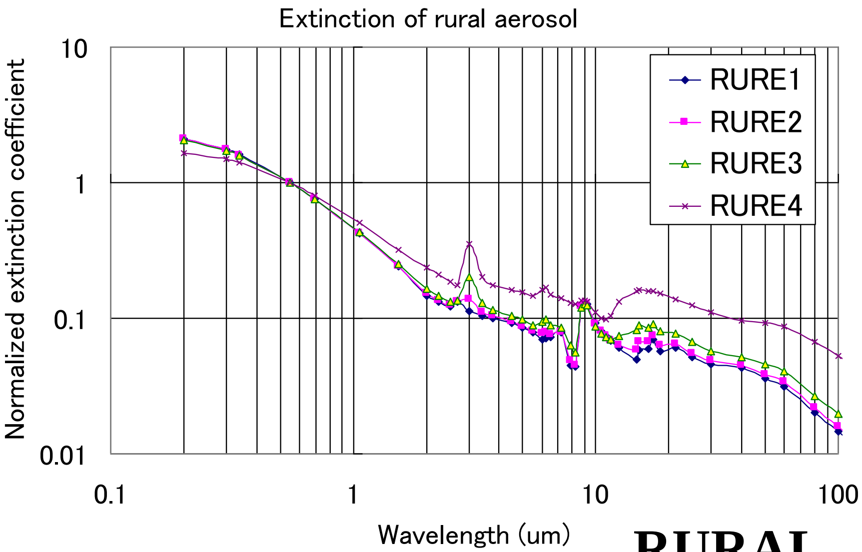
典型的なエアロゾルモデルの粒径分布
Aerosol size distributions



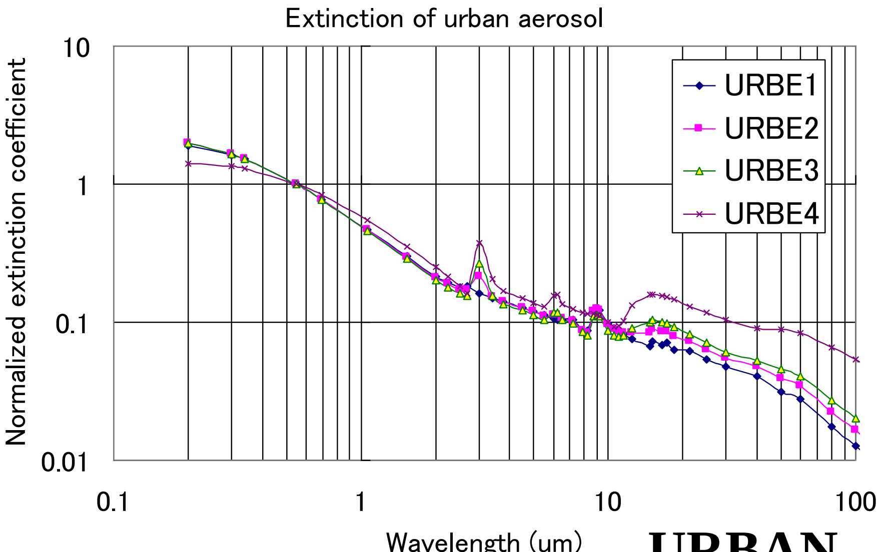
Wavelength dependence of aerosol extinction coefficients: effect of relative humidity



OCEAN



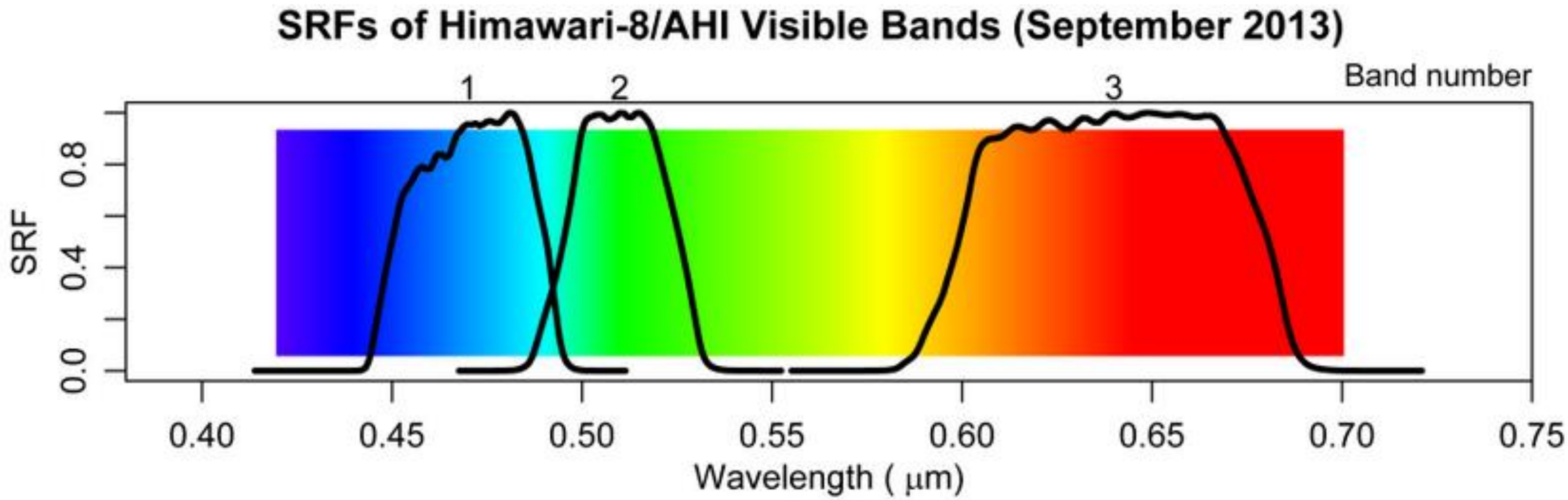
RURAL



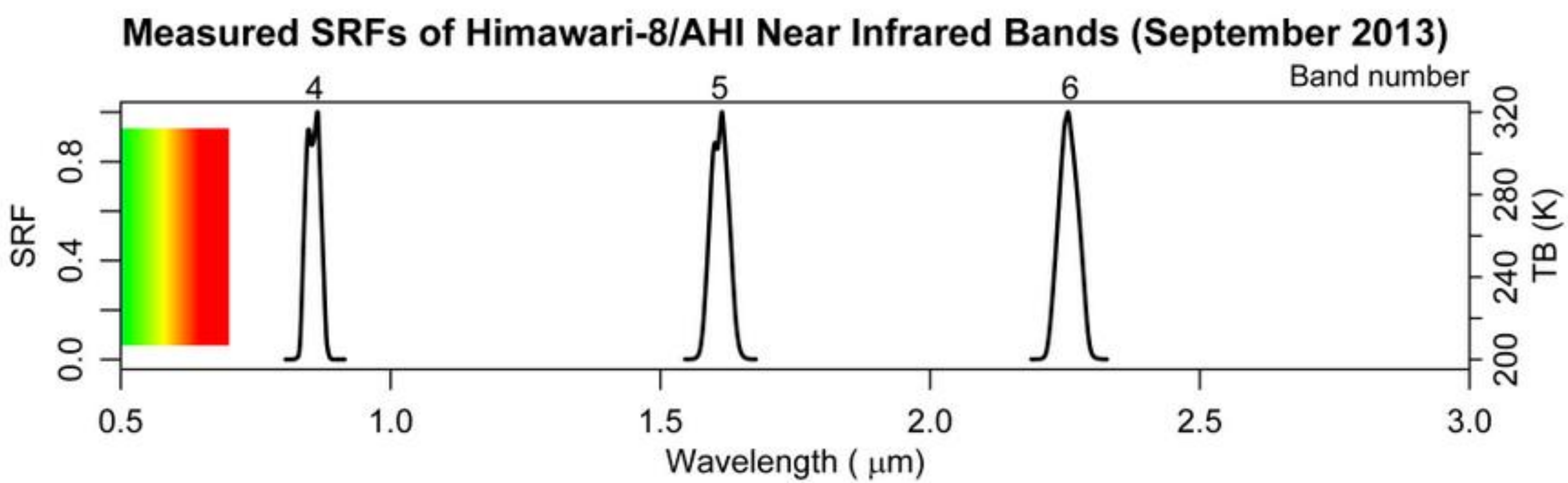
URBAN

OCNE1: RH = 0%
OCNE2: RH = 70%
OCNE3: RH = 80%
OCNE4: RH = 99%

Spectral response functions of a satellite sensor (Himawari-8)

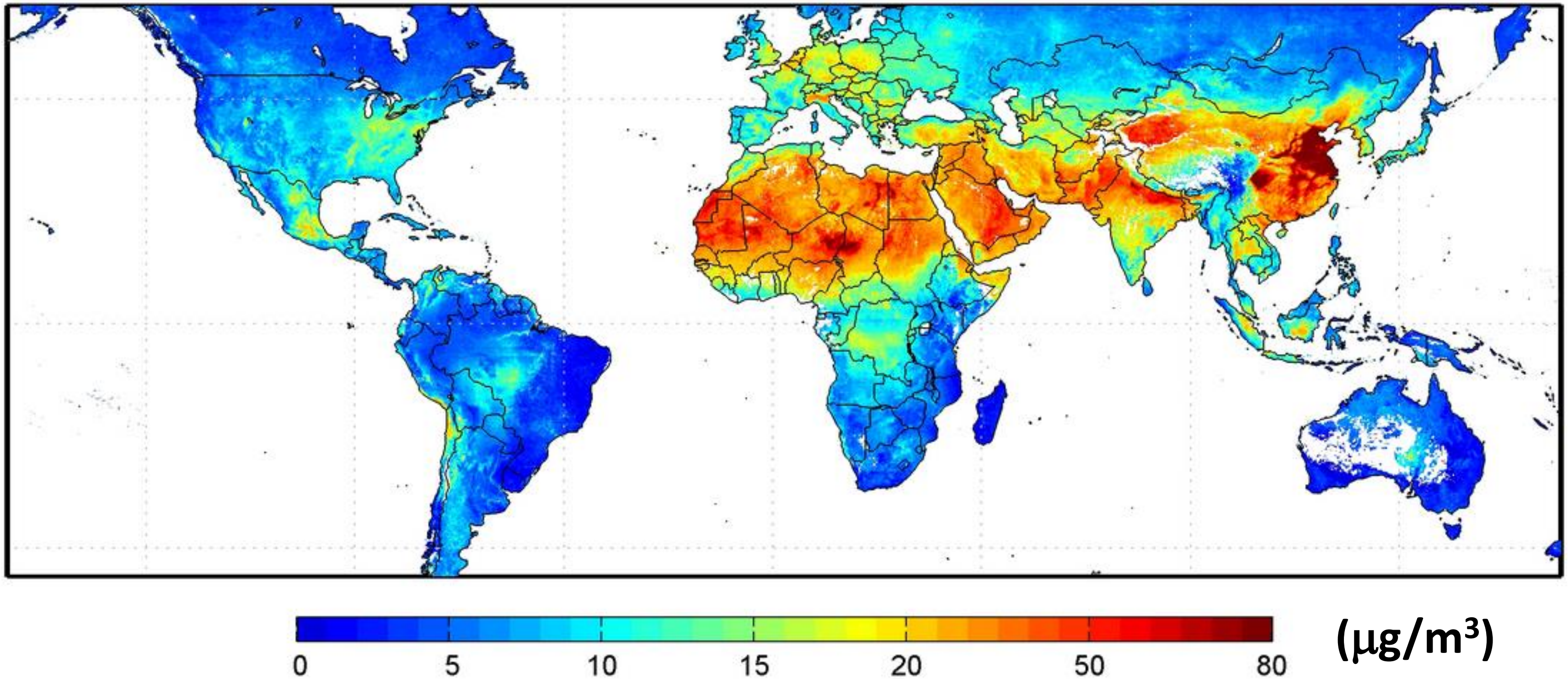


RGB VALUES FOR VISIBLE WAVELENGTHS by Dan Bruton (http://www.physics.sfasu.edu/astro/color/spectra.html)



http://www.data.jma.go.jp/mscweb/ja/himawari89/space_segment/spsg_ahi.html

Global distribution of PM2.5



➢The global ground-level PM2.5 concentrations are mapped using total column aerosol optical depth (AOD) from the MODIS and MISR satellite instruments and coincident aerosol vertical profiles from the GEOS-Chem global chemical transport model. Global estimates of long-term average (1 January 2001 to 31 December 2006) PM2.5 concentrations at approximately 10 km × 10 km resolution indicate a global population-weighted geometric mean PM2.5 concentration of 20 μg/m^3.

Donkelaar et al., http://ehp.niehs.nih.gov/0901623/

Estimations of global aerosol emissions

Species	AEROCOM		MIROC-SPRINTARS			
	Mean [Tg/yr]	Diversity [%]	Takemura [Tg/yr]	Standard [Tg/yr]	New [Tg/yr]	Error [%]
SO_2			149	145	219	78 (67)
carbons	109	26	106	83	136	78 (67)
dust	1,840	49	3,321	4,470	3,244	62 (62)
sea salt	16 600	199	3,529	3,145	9,073	18 (18)

➢ **AEROCOM**: Textor et al., Atmos. Chem. Phys. 2006.

➢ **Diversity** (standard deviation divided by mean) the same paper.

➢ **Takemura** et al., Geophys. Res. 2000 (older version of MIROC-SPRINTARS)

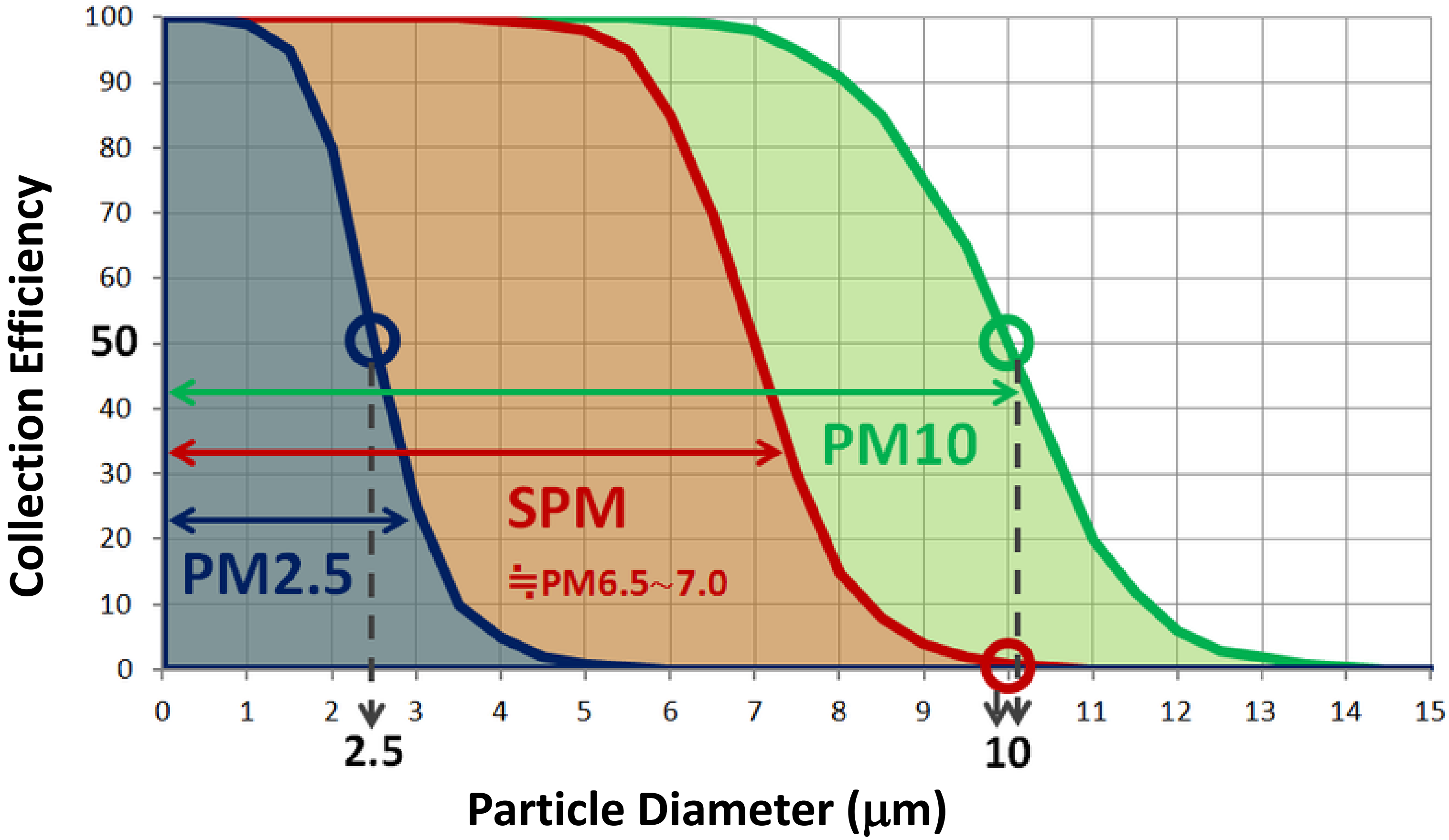
➢ **Standard and New**: the emissions used in N. Schutgens et al., Remote Sens., 2012. (Yearly emissions estimated from the values for January 2009).

➢ **Error:** estimates remaining in these emissions, as determined by the Kalman smoother. Values between brackets are global averages weighted by AOT.

N. Schutgens, M. Nakata, T. Nakajima, Remote Sens., 2012.

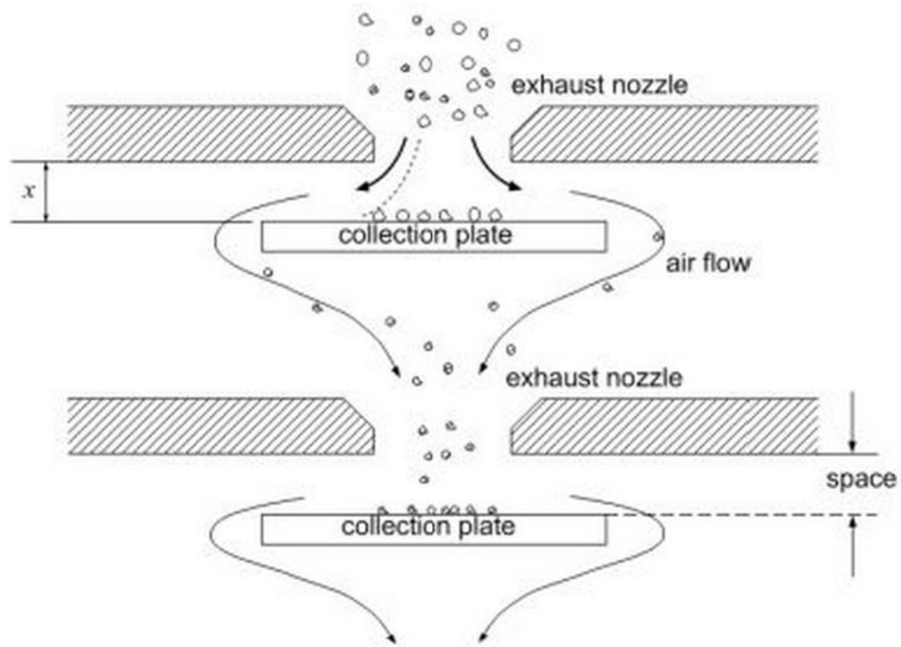
PM2.5, PM10 and SPM

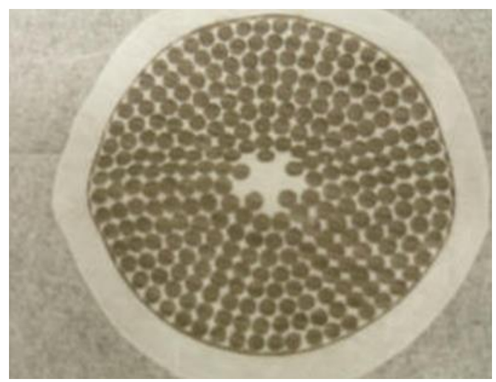
➢ In USA, a new environmental standard of PM2.5 was added in 1997 to the existing standard of PM10.
➢ In Japan, the standard for PM10 was established in 1972. The suspended particulate matter (SPM) was defined as particles with diameters less than 10 μm.



http://www.nies.go.jp/kanko/news/20/20-5/20-5-05.html

Andersen Sampler (Multi-stage cascade impactor)



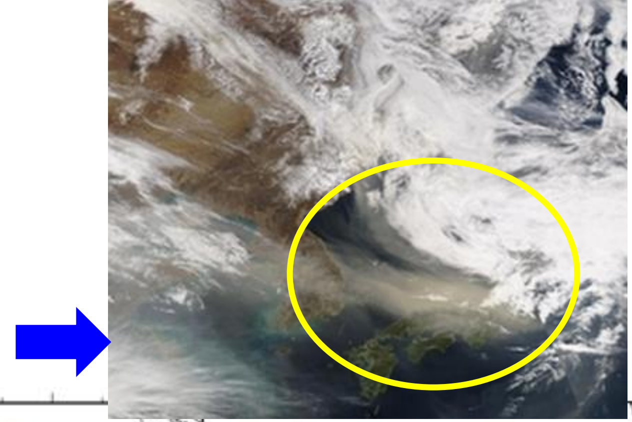


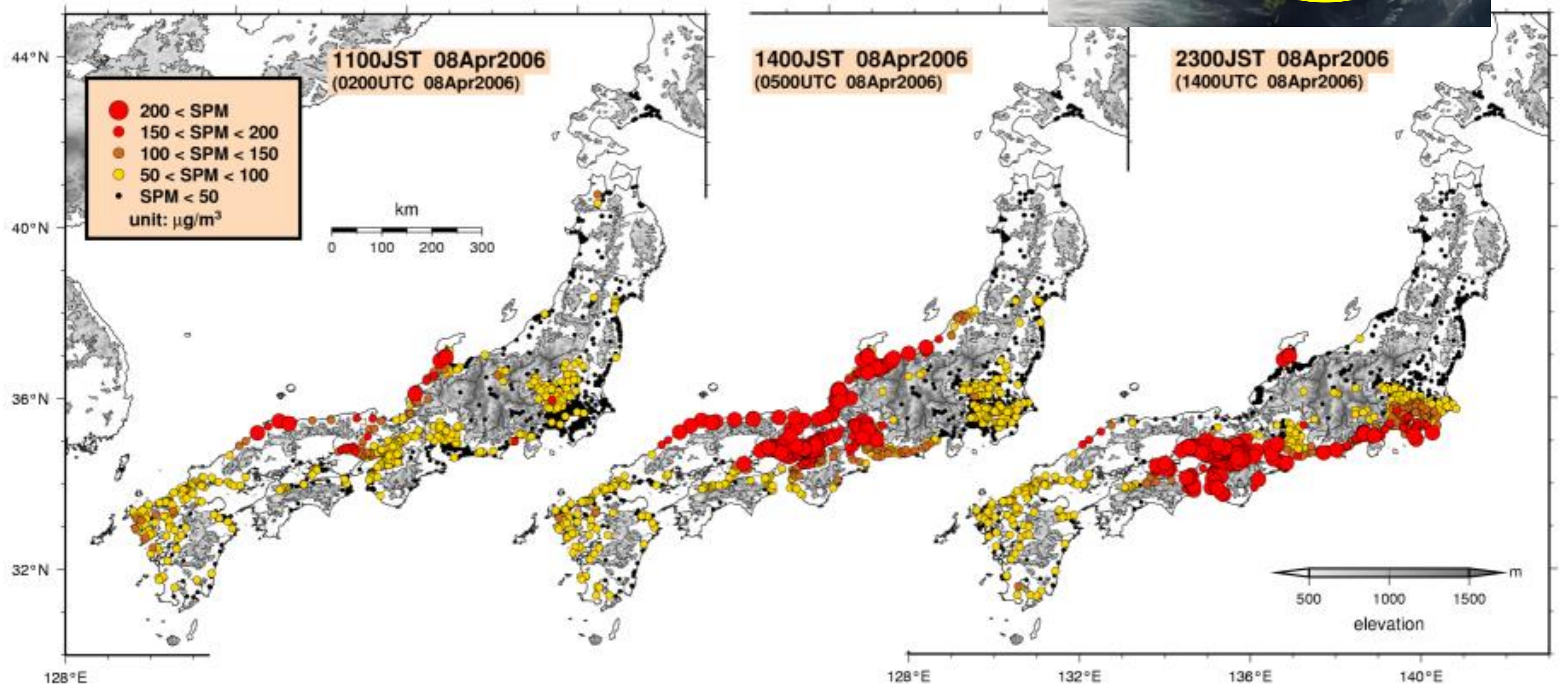
Aerosol particles accumulate on a filter paper.

http://www.h2.dion.ne.jp/~yokke/study/atmosphere/air_pm/air_pm.html

Asian dust event observed on April 8, 2006

Aqua/MODIS visible band (RGB)





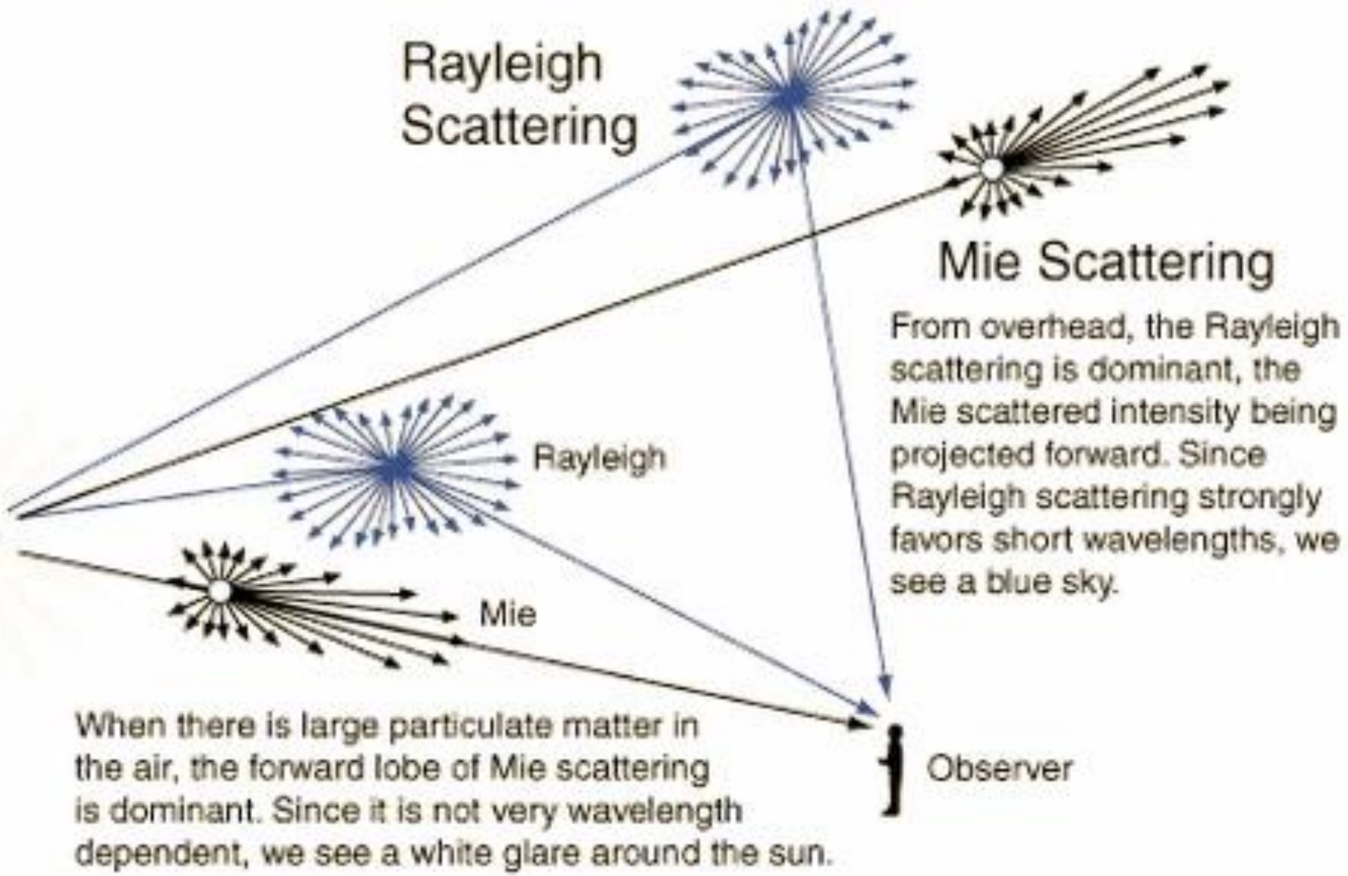
SPM distribution on the same day, (11:00, 14:00, and 23:00) observed at 1500 General (non-roadside) Stations.

http://fujin.geo.kyushu-u.ac.jp/~hayasaki/

ミー散乱 Mie scattering

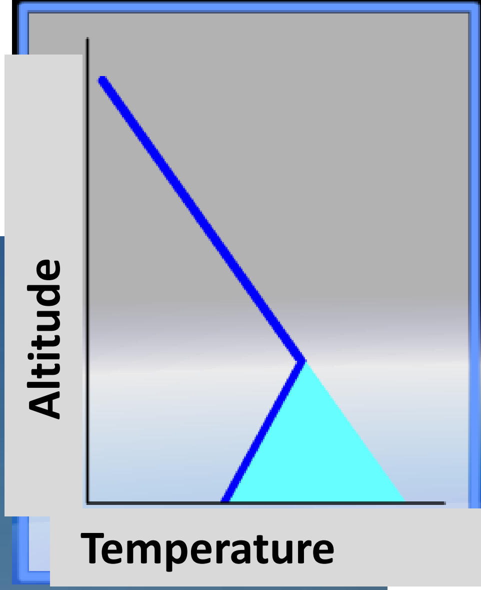
➢ **Clouds appear white, since wavelength dependence of Mie scattering is moderate.**

➢ **White haze is due to the presence of aerosol particles.**



Gustav Mie 1869-1957

冬季の接地逆転層
Inversion layer in winter morning



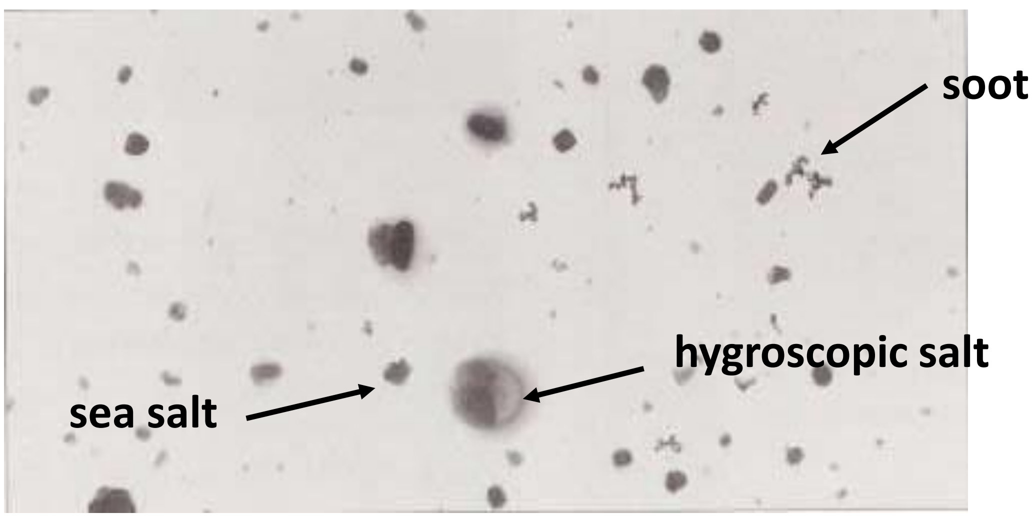
12:19 on 19 January 2010 at CEReS, Chiba University

エアロゾル粒子 Aerosol particles

- ➢ **Aerosol – liquid or solid particles floating in the atmosphere. The diameter varies from 10 nm to 10 μm.**
- ➢ **Cloud droplet – also, liquid or solid (ice) particles, but with larger diameters of 10-100 μm.**
- ➢ **Mie scattering occurs since the size of aerosol and cloud particles are similar to or larger than the optical wavelength.**

Aerosol (satellite image)

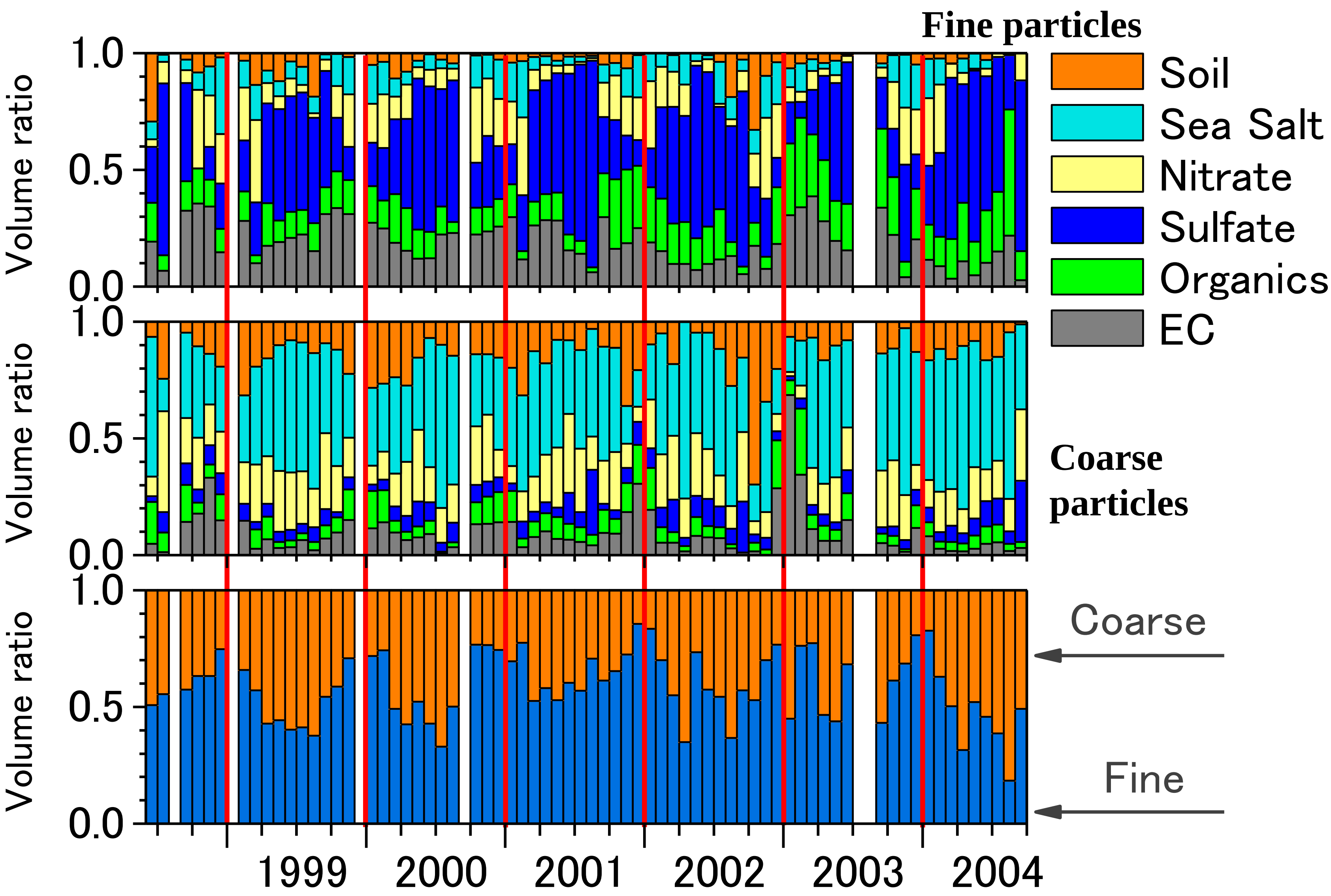
Cloud



1μm (Prof. Ohta, Hokkaido Univ.)

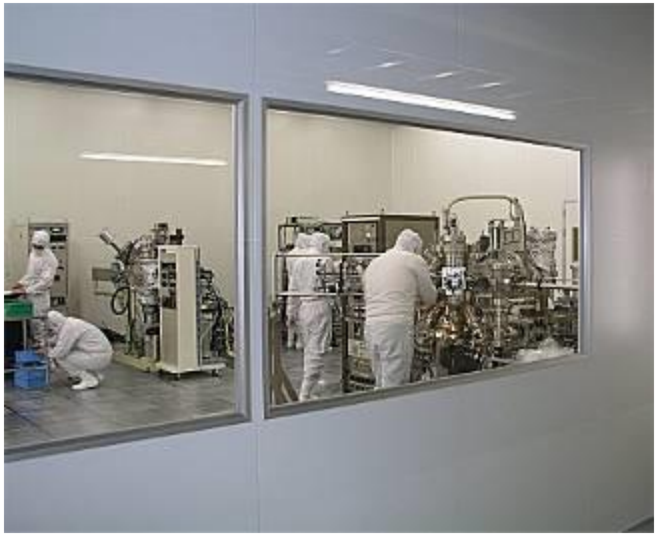
Indoor aerosol

Long-term aerosol analysis at Chiba University



S. Fukagawa et al., Atmos.Environ., 40, 2160-2168 (2006)

Clean room



➢ **Particles larger than 0.5 μm, including floating bacteria and fungi, should be removed for medical and food industry.**

➢ Particles larger than 0.5 – 1 μm must be removed in the case of semi-conductor manufacturing.

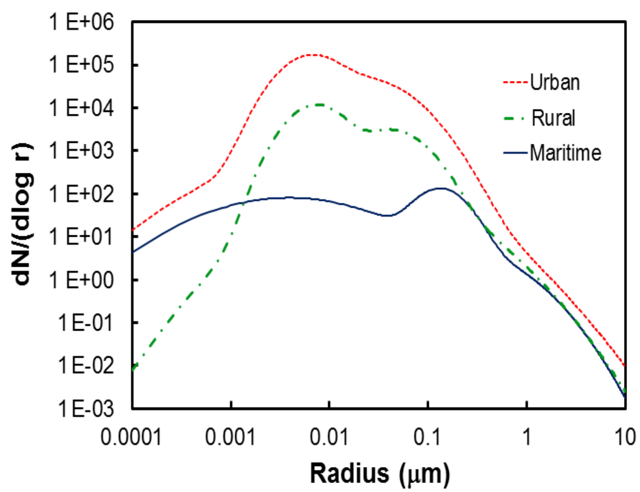
➢ **Ambient atmosphere corresponds to 1E+06 under clear sky. The number density drastically decreases under rainy conditions (600,000 – 200,000).**

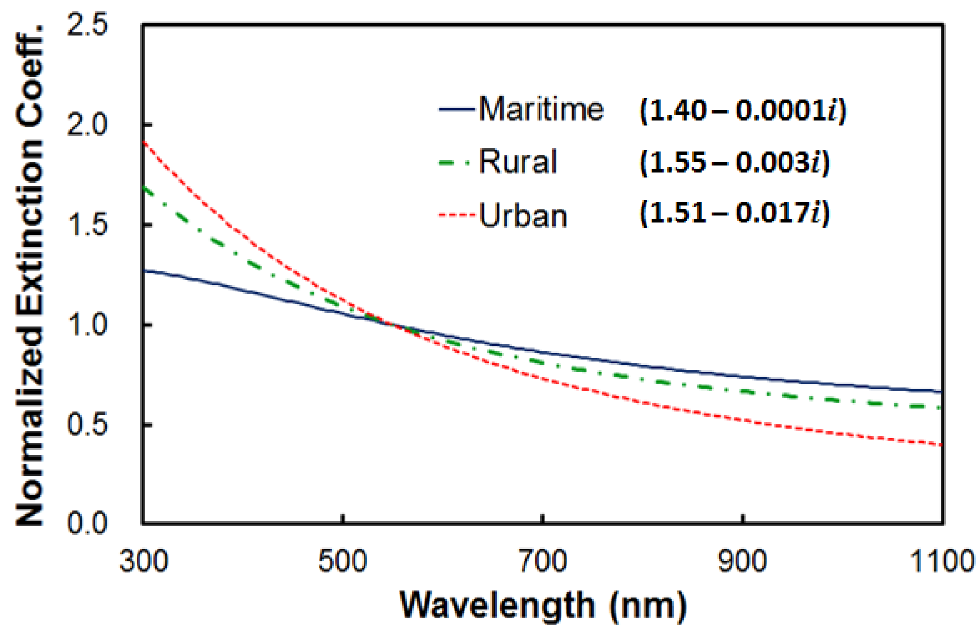
クラス	unit: particles/m^3						米国209E 基準相当値
	≥0.1 μm	≥0.2 μm	≥0.3 μm	≥0.5 μm	≥1 μm	≥5 μm	
ISO 6	1.0×10^6	237,000	102,000	35,200	8,320	293	クラス 1,000
ISO 7	1.0×10^7	2.37×10^6	1,020,000	352,000	83,200	2,930	クラス 10,000
ISO 8	1.0×10^8	2.37×10^7	1.02×10^7	3,520,000	832,000	29,300	クラス100,000
ISO 9	1.0×10^9	2.37×10^8	1.02×10^8	35,200,000	8,320,000	293,000	室内クラス

http://ja.wikipedia.org/wiki/

Calculation of wavelength dependence of extinction coefficient for typical aerosol models

典型的なエアロゾルモデルに対する消散係数の波長依存性の計算



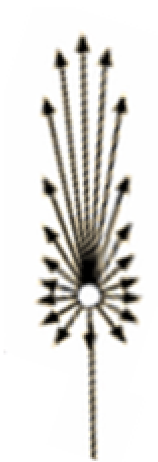


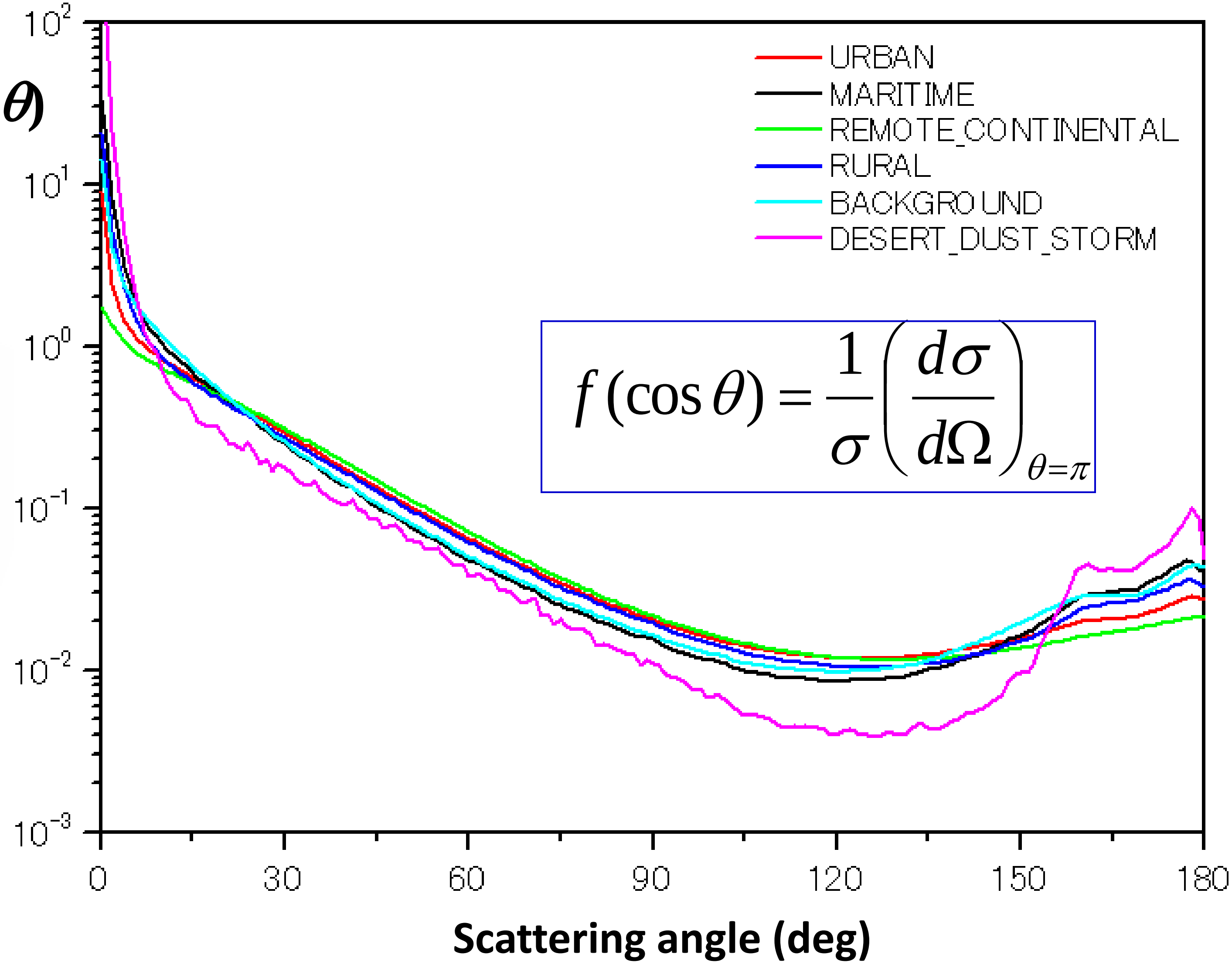
$$\frac{dN}{d(\log r)} = \sum_{n=1}^{3} \frac{N_{0n}}{\sqrt{2\pi}(\log \sigma_n)} \exp\left[-\frac{1}{2}\left(\frac{\log(r/\bar{r}_n)}{\log \sigma_n} \right)^2 \right]$$

$$\alpha_M = \int_{r_{\min}}^{r_{\max}} \pi r^2 Q_{ext}(r) \frac{dN}{d(\log r)} d(\log r), \qquad Q_{ext}(r) = \frac{\sigma_{ext}}{\pi r^2}$$

Scattering phase function of various aerosol models 散乱位相関数

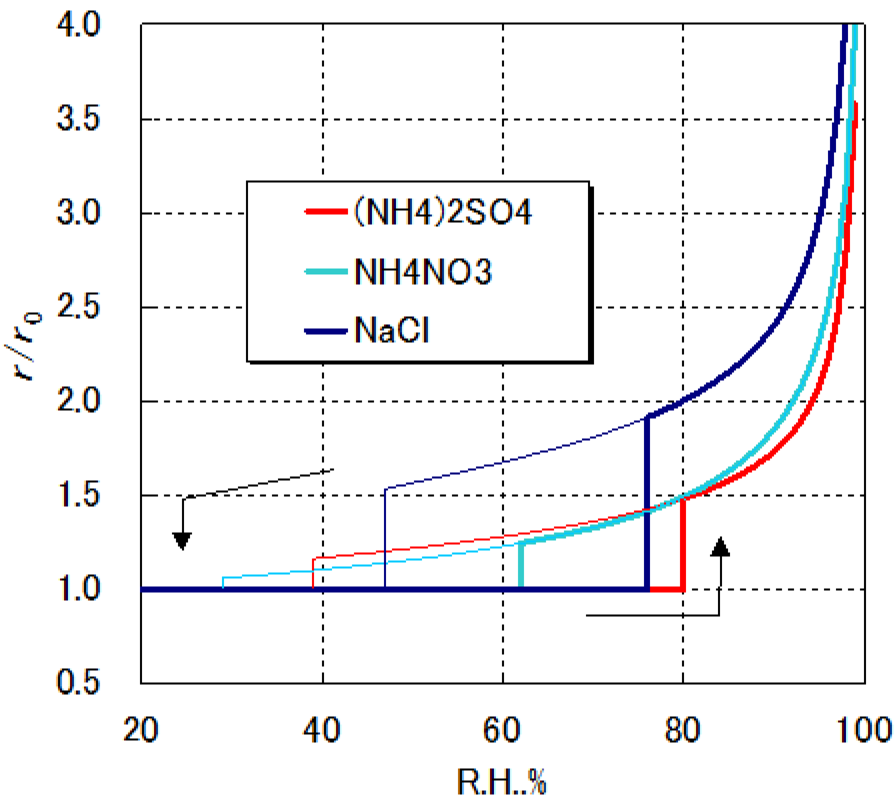
n'=1.50
k=0.001
λ=351 nm

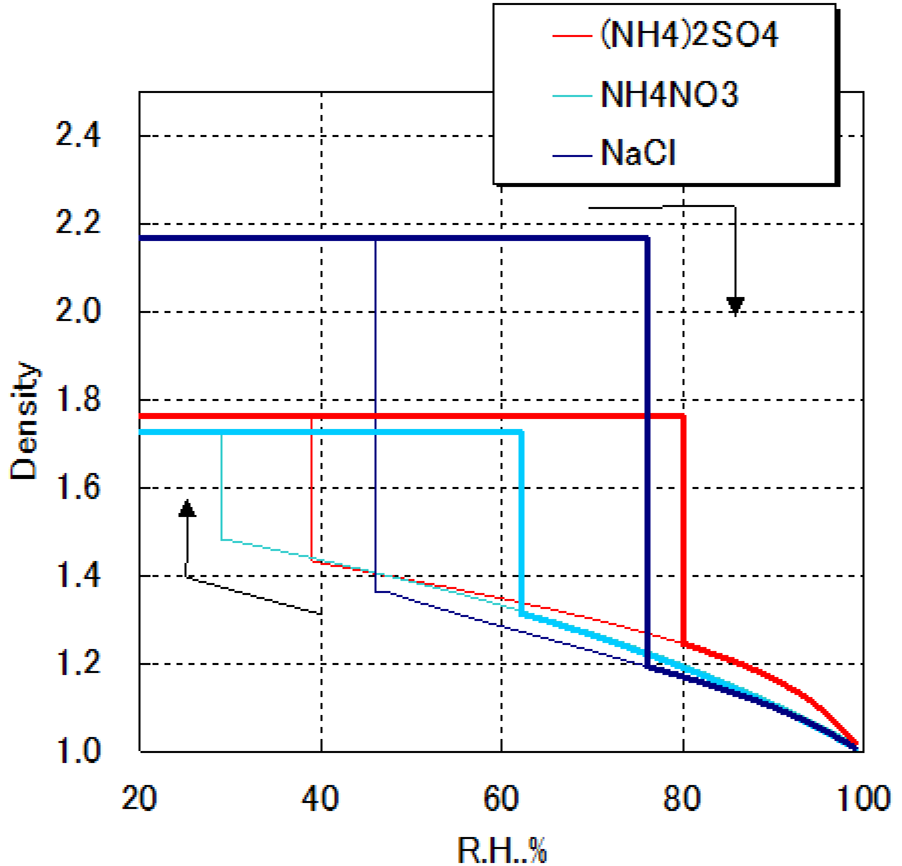




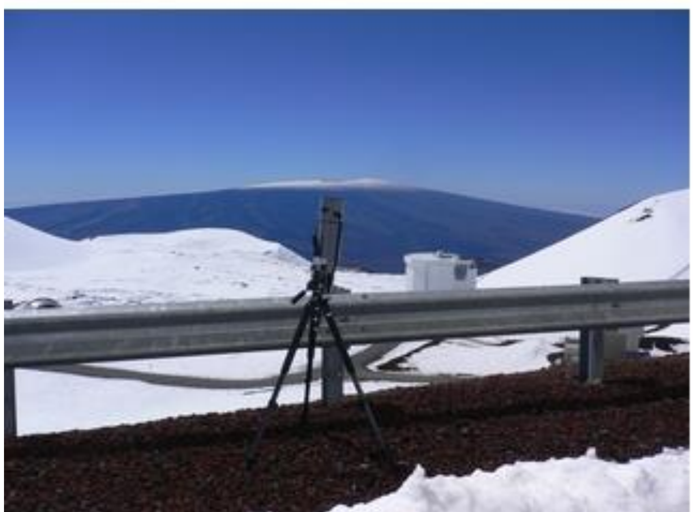
$$f(\cos\theta) = \frac{1}{\sigma}\left(\frac{d\sigma}{d\Omega}\right)_{\theta=\pi}$$

Effects of the Relative Humidity [*Tang, et al.*, 1996]



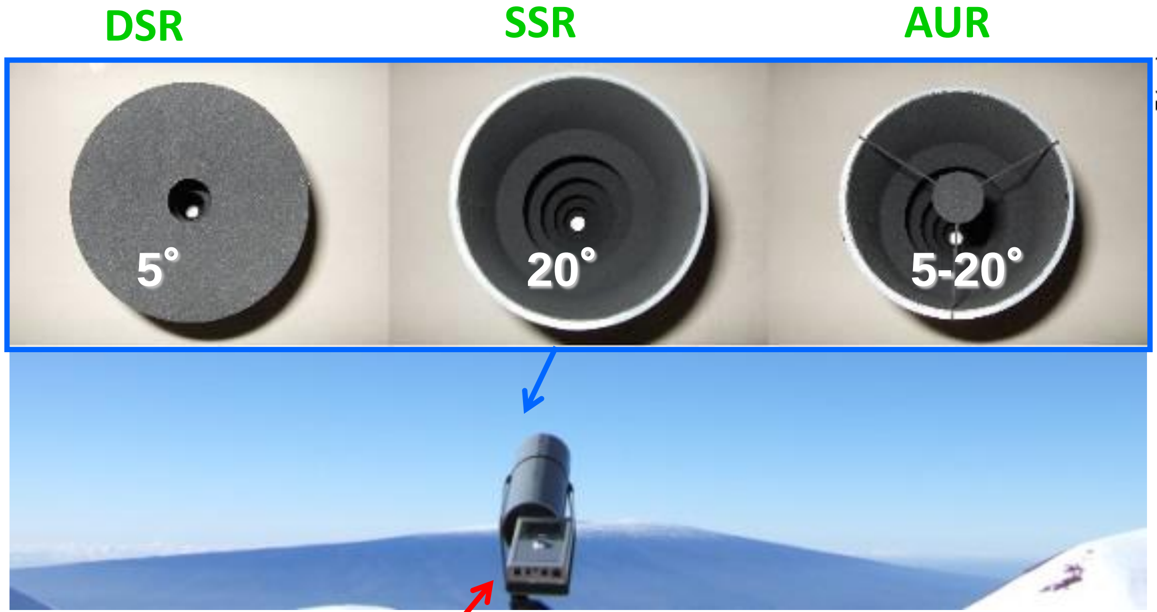


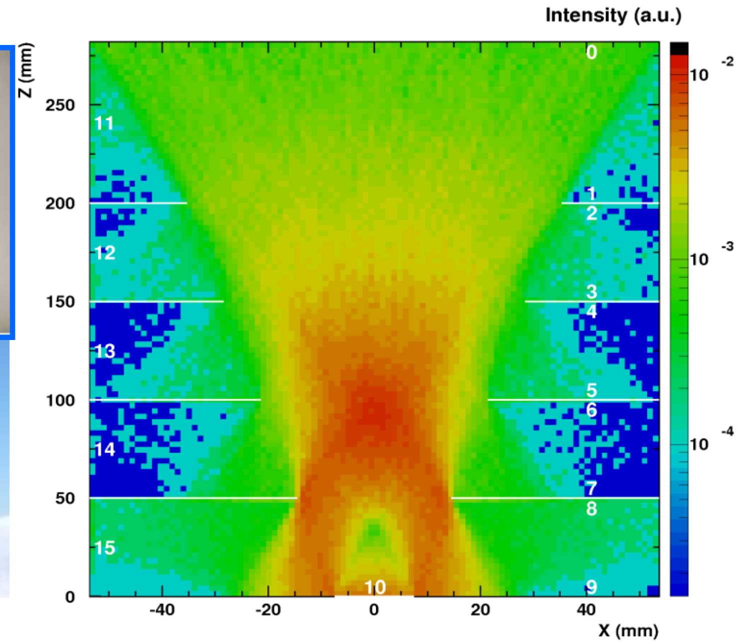
Calibration of MS-720 at the top of Mauna Kea Mountain (February 2008)



EKO MS-720 Spectroradiometer
- **350-1050 nm**
- **256 ch**
- **180/90 acceptance angle**
- **battery operated (>8h)**

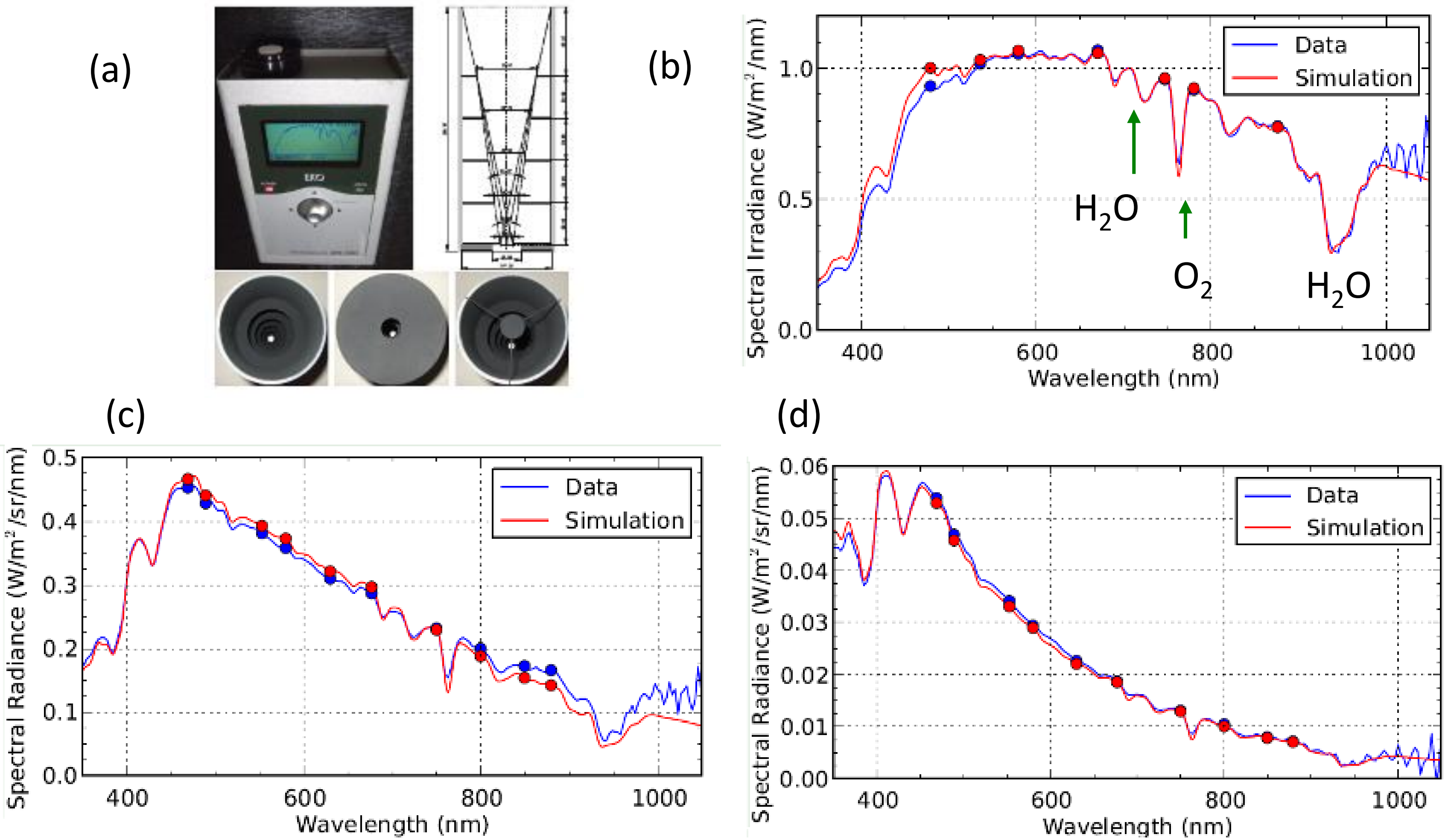
Spectrometer (MS-720) and adaptors





Dimension	100 x 165 x 60 mm^3
Practical wavelength range	350 – 1050 nm
Optical resolution (FWHM)	10 nm
Sampling interval	3 nm
Field of view (full angle)	180°
Typical battery life	18 hour (1000 spectra)

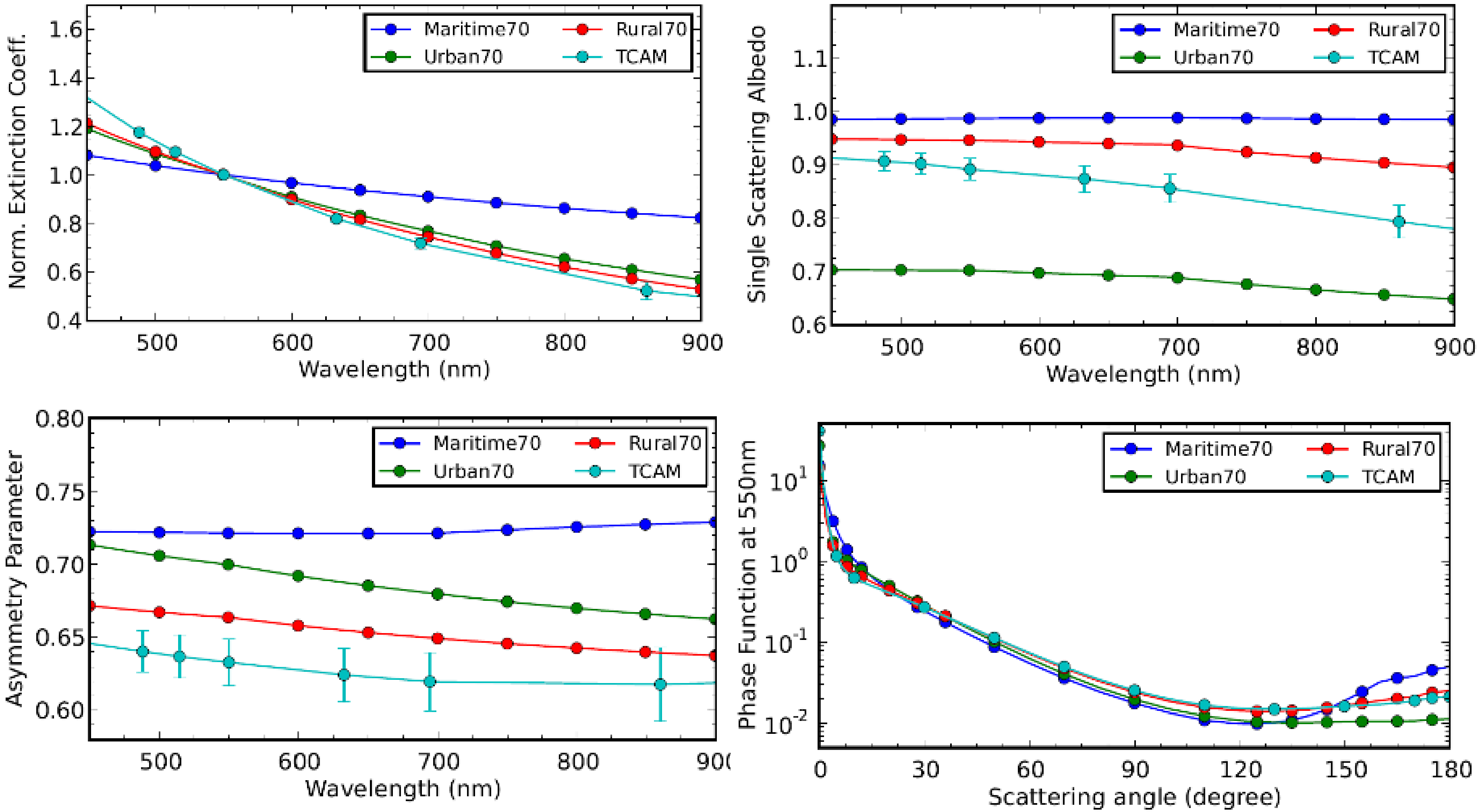
Irradiance and radiance measurement using a portable spectroradiometer



(a) MS720 and baffle tubes; (b) direct solar radiation; (b) aureole; (c) scattered solar radiation (zenith), measured around noon on 30 December 2008.

Aerosol optical properties derived from the spectral analysis

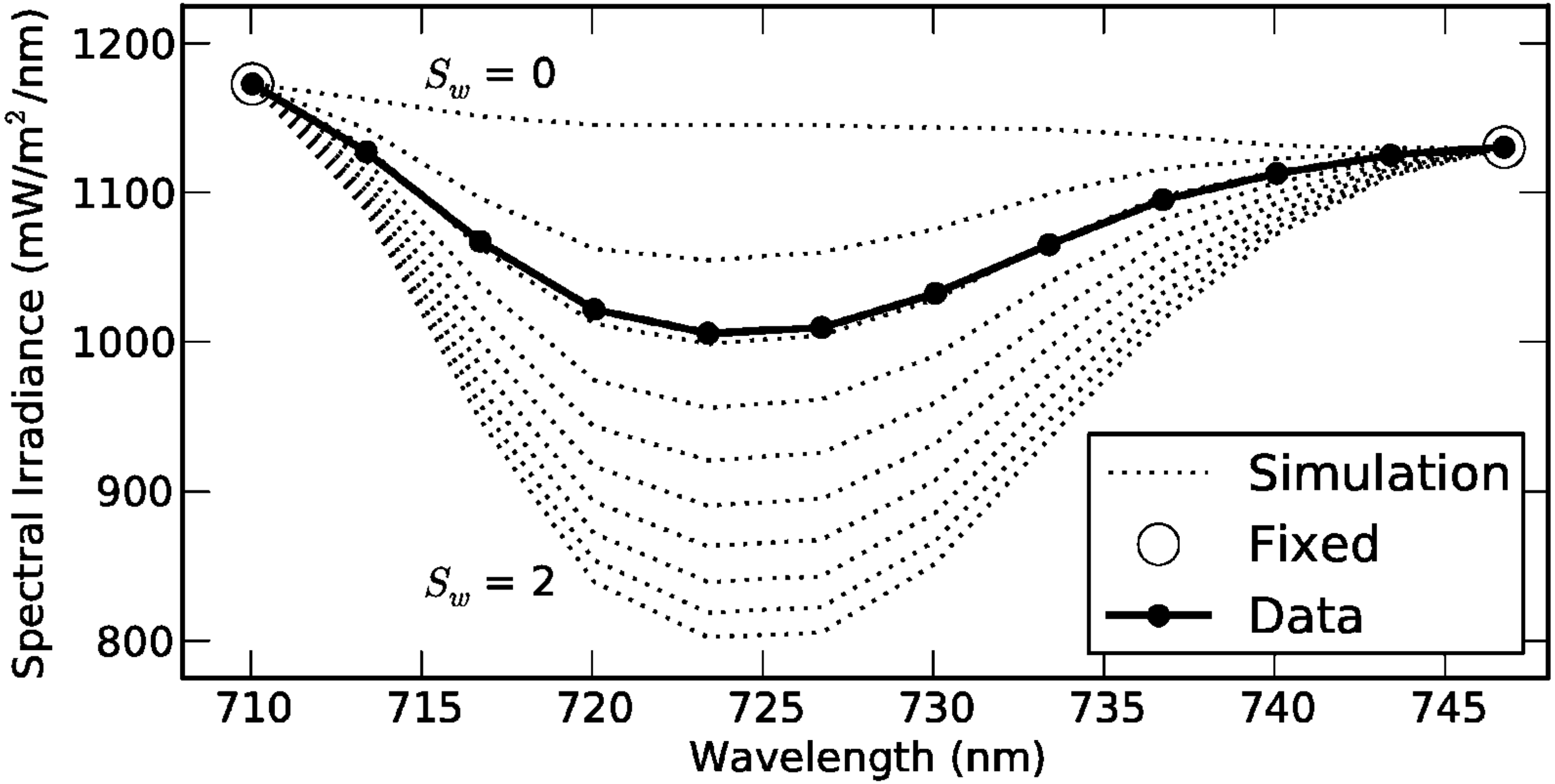
30 Dec. 2008; AOT(550 nm) = 0.190±0.001, H_2O 0.80±0.04 g/cm^2



Manago and Kuze, Applied Optics, 49(8), 1446 (2010)

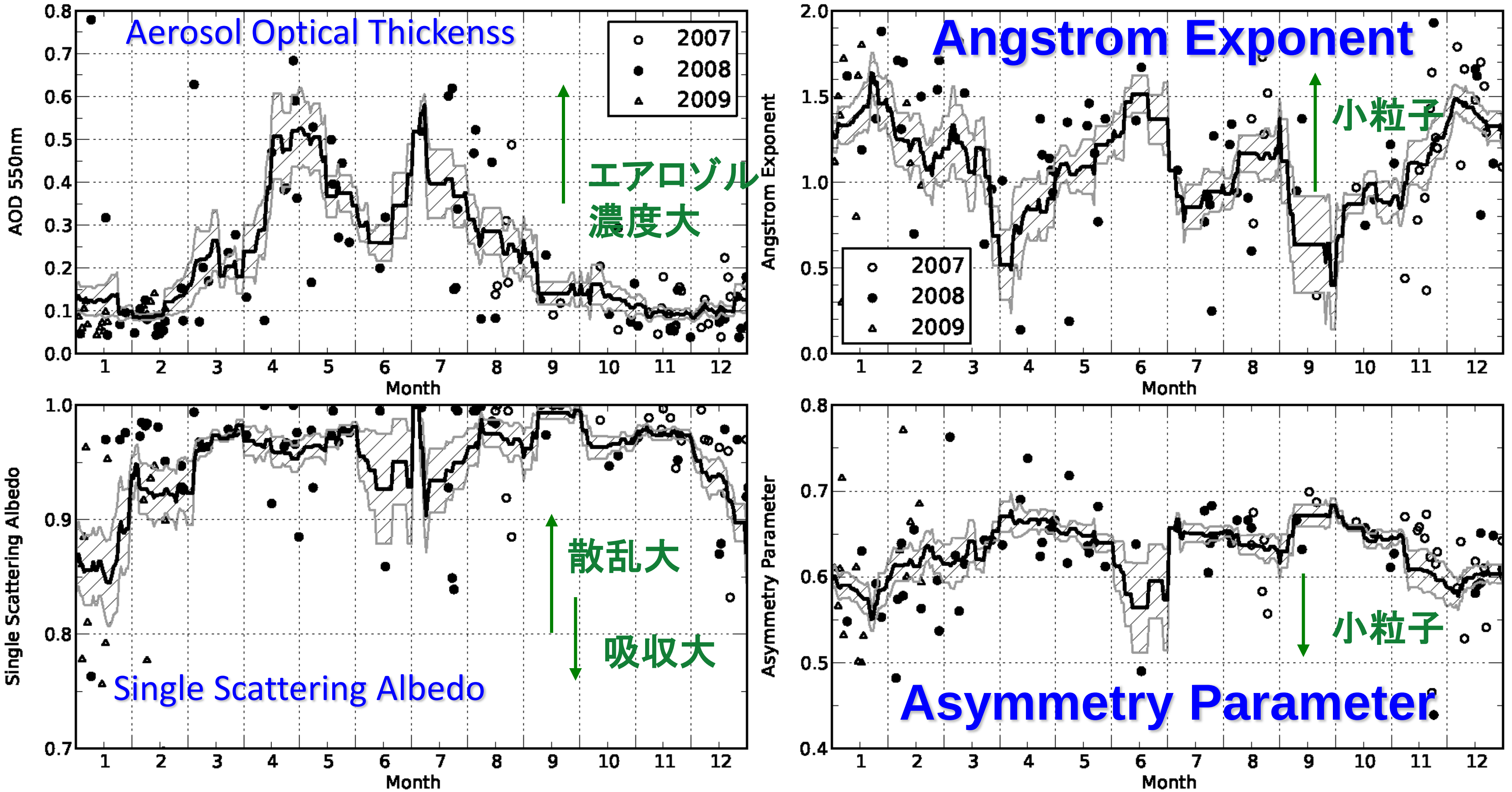
Water vapor column amount

- Simulated spectra are scaled to match with the observed spectrum at both ends of the absorption band.
- Optical resolution of the instrument must be incorporated.



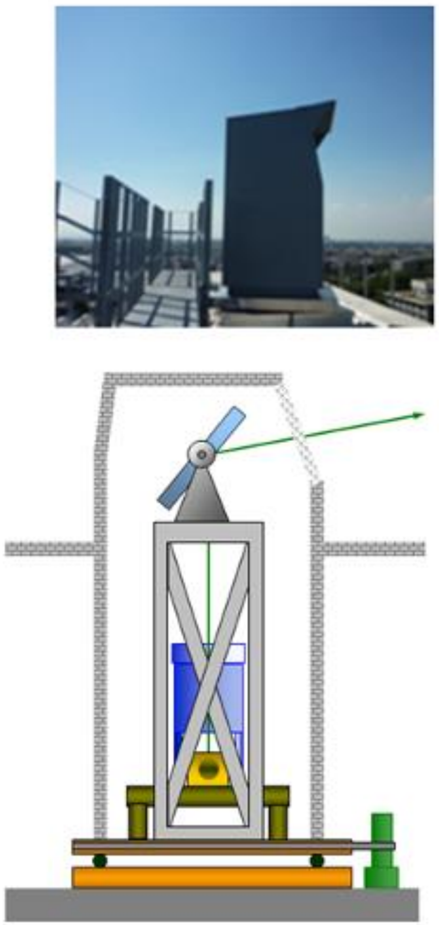
Seasonal variation of aerosol optical properties

Analysis of data observed on 130 days (during August 2007 and March 2009) under clear-sky conditions

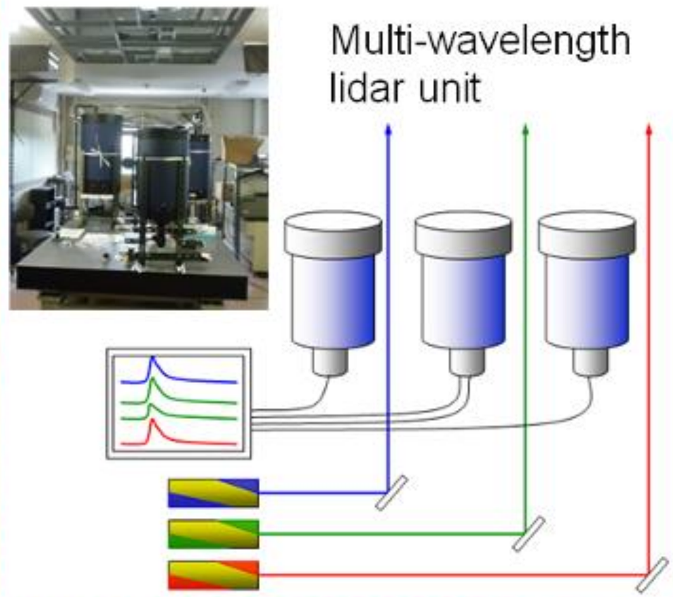


Manago, et al. JQSRT (2010)

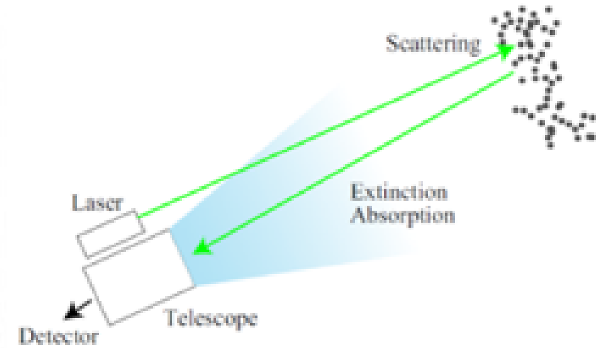
CEReS multi-wavelength lidar system



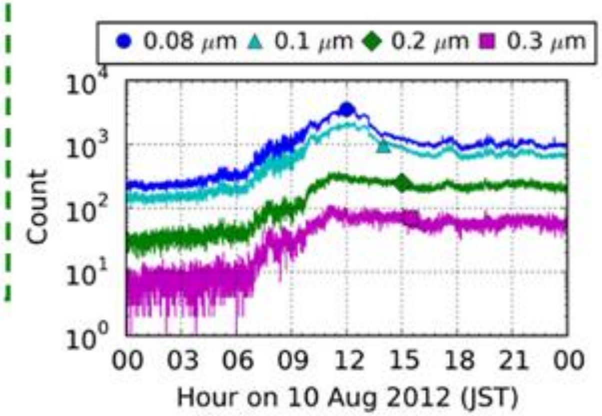
PPI unit



Aerosol measurement unit



Lidar principle

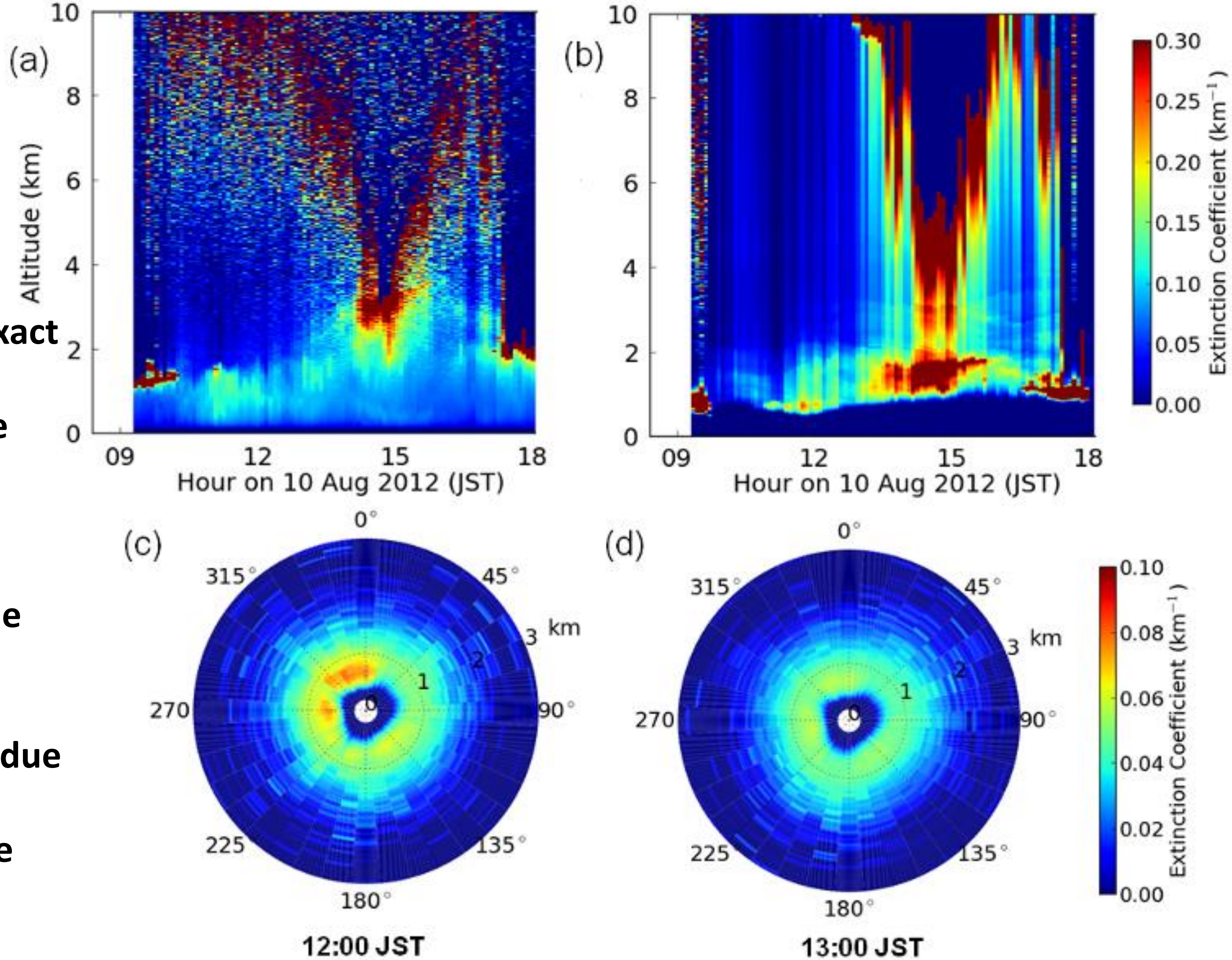


Kuze, 2012: http://spie.org/x91184.xml

Optical Particle Counter (OPC)

Lidar measurement of aerosols and clouds

- ➢ **Lidar can measure the exact location of a target from the time of flight meas. of laser pulses.**
- ➢ **Normally the horizontal distribution is homogeneous due to the layered structure of the atmosphere.**



SKYNET menu

Top

- **Outline**
  - Data transfer system
  - Observation instruments
  - Climate of SKYNET sites

- **Data**
  - Atmospheric parameters
  - Sky radiometer data
  - Data report

- Data transfer status
- Daily

Fukue , Hedo , Hefei , Miyako , Phi
Chiba , Mri , Osaka , Tokyo , Seoul
Bremen , Moshiri , Fujihoku , Send
Saga , Bologna , Rome

- Monthly & Daily

- Data list
  - Sky radiometer
  - Pyranometer/pyrgeometer

Welcome to SKYNET

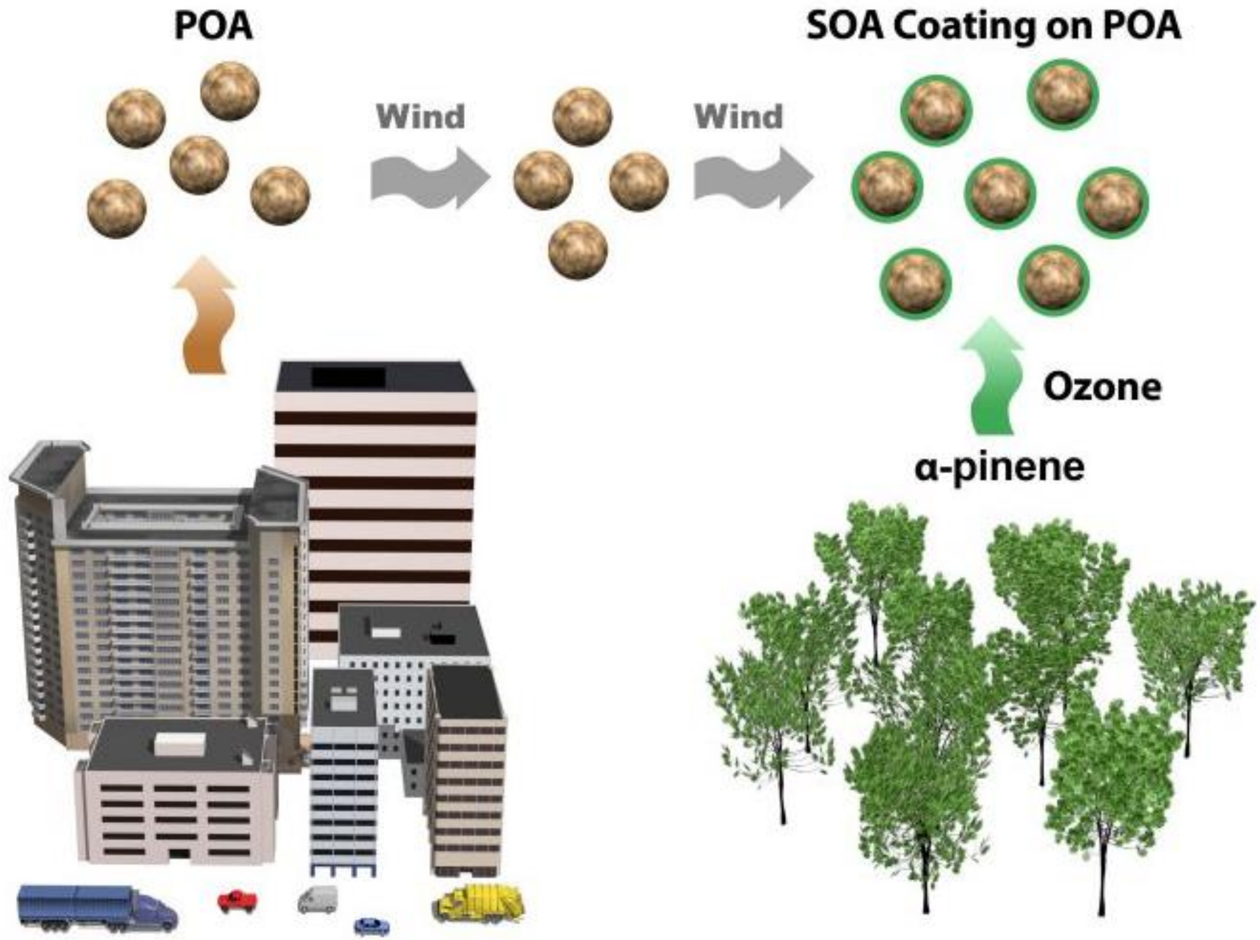
SKYNET is an observation network to understand **aerosol -cloud-radiation interaction** in the atmosphere. The main instruments consist of a sky radiometer and radiation instruments such as a pyranometer and pyrgeometer as a basic site, and a super site has more instruments extended for analyzing **atmospheric parameters** of aerosol , cloud and radiation.

The observation sites of SKYNET are located mainly in the Eastern Asia from Mongolia to Thailand as well as in Japan. The data observed at each site are collected into a site server and then transfered using an internet for super sites and sent by off-line transportation for other sites. These data arearchived into a SKYNET server in Chiba University and then open to the public.

The SKYNET is a voluntary-based activity, which is supported by **many researchers and collaborators** in the community.

CEReS Skynet

http://atmos.cr.chiba-u.ac.jp/



➢ α-pinene is a gaseous organic compound emitted by trees, which is known to react with ozone (oxidants) in the atmosphere to produce oxygenated organic vapors. These vapors condense onto POA particles to form SOA.

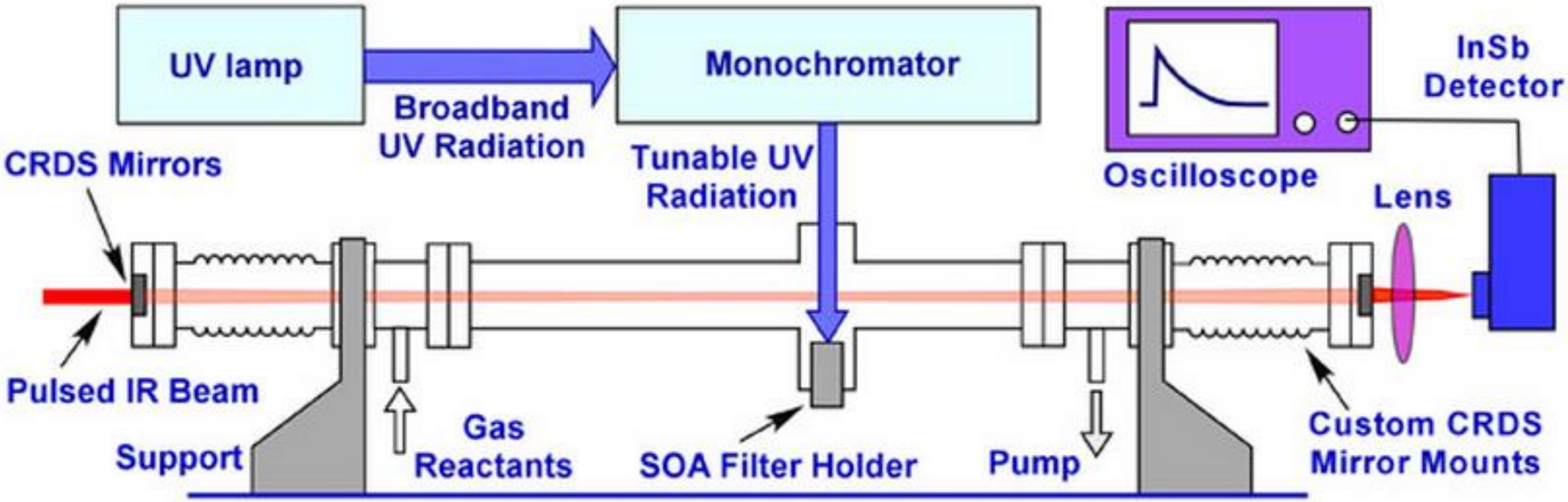
➢ Primary organic aerosols (POA) are directly emitted into the atmosphere through vehicle exhaust, biomass burning, etc.

➢ Secondary organic aerosols (SOA) are formed from gas-to-particle conversion of trace amounts of oxidized hydrocarbon vapors in the atmosphere.

➢ **POAs tend to be hydrophobic, whereas SOAs are generally water soluble (hydrophilic).**

http://www.pnnl.gov/science/highlights/highlight.asp?id=358

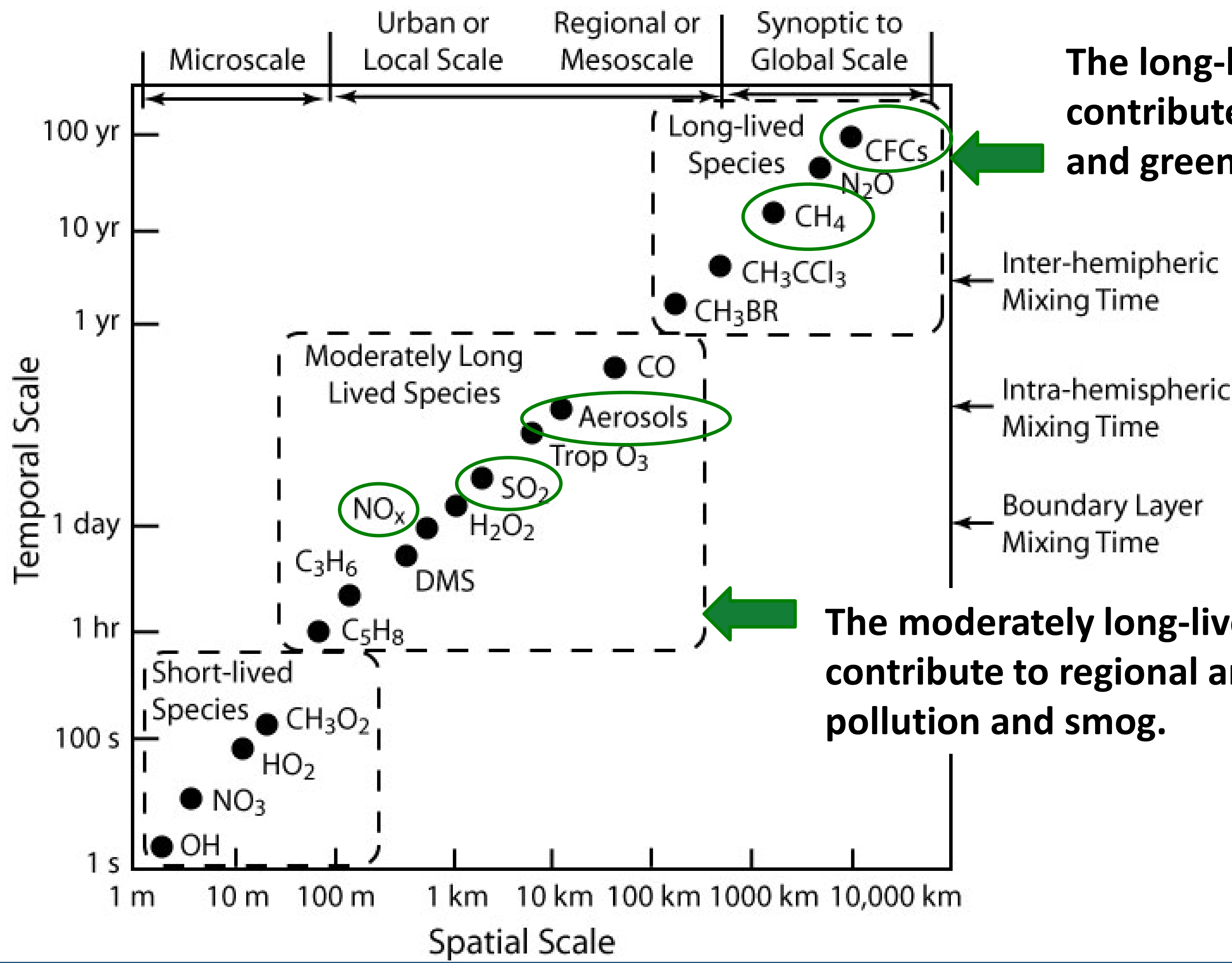
IR-CRDS (Infrared Cavity Ring-Down Spectroscopy)



- **Chemical processes that convert volatile organic compounds (VOC) into secondary organic aerosols (SOA) are generally quite fast. For example, terpenes rarely last longer than an hour after they are released by vegetation on a hot sunny day.**
- **CRDS is an ultrasensitive technique that quantifies optical absorption of molecules placed between two highly-reflective mirrors from the rate with which photons escape this cavity. This instrument is especially suitable for the detection of small molecular weight photolysis products such as CO, CO_2, H_2CO, and HCOOH via their highly-specific rotational-vibrational infrared absorptions.**

http://aerosol.chem.uci.edu/research/photochemistry.htm

Space and time scales of atmospheric trace gases
大気汚染物質の時空間スケール



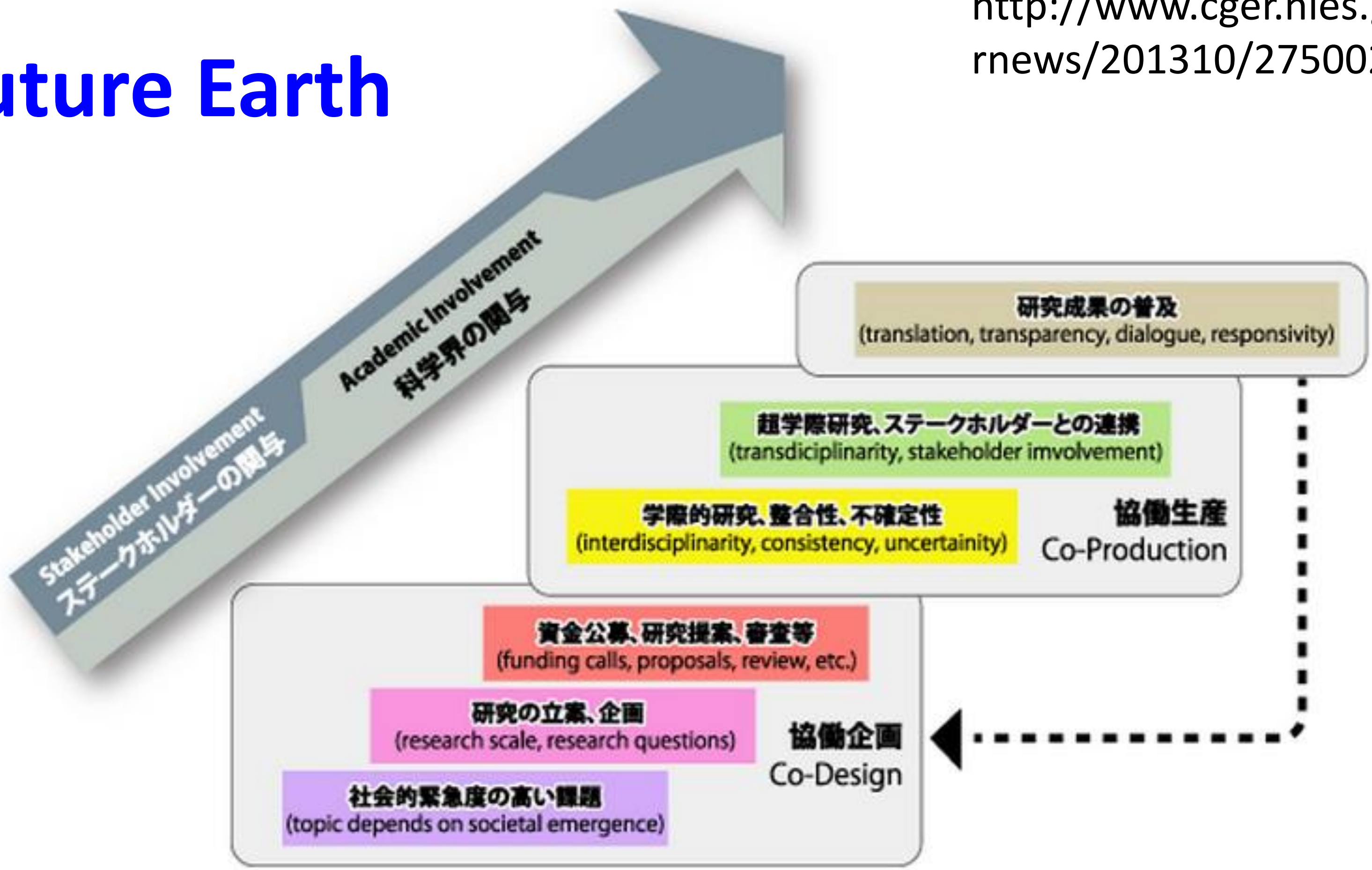
The long-lived species contribute to the ozone hole and greenhouse warming.

The moderately long-lived species contribute to regional and urban air pollution and smog.

http://oceanworld.tamu.edu/resources/oceanography-book/atmosphere.html

Future Earth

http://www.cger.nies.go.jp/cgernews/201310/275002.html



Dynamic Planet: 自然現象と人間活動による地球の変化の理解。
Global Development: 食料、水、生物多様性、エネルギー、物質及びその他の生態系の機能と恩恵についての持続可能で確実で正当な管理運用を含む、人類にとって最も喫緊のニーズに取り組む知識を提供すること。
Transformation towards Sustainability: 持続可能な未来に向けての転換のための知識を提供すること。グローバルな環境のガバナンスと管理の戦略を評価すること。

Summary

○ 陸域・海洋観測衛星としてはALOS、環境監視衛星としてはGOSAT、GCOM、静止軌道衛星としてはHimawari-8が運用されている。
○ 合成開口レーダSARは昼夜を通した観測ができる。マイクロ波放射計AMSR2や降雨レーダGPMは予報の精度向上にも貢献している。
○ 小型衛星（ASNARO、Hodoyoshiなど）や中型衛星のconstellationによる運用が盛んになっている。
○ 衛星データは気象、漁業などの現業用途や、陸域・海洋・大気情報の取得に、また、GEOSSやFuture Earthなどの社会的・国際的な枠組みにも活用されている。

○ 可視・近赤外の衛星データと放射伝達計算により、大気エアロゾルと地表面の情報が分離して抽出できる。
○ 対流圏エアロゾルには海洋、田園、都市型などがあるが、実際の化学組成の変動は大きい。
○ 地上ではサンプリングや分光放射計、サンフォトメータ、スカイラジオメータ、ライダーなど光学測器によるエアロゾル計測が継続して行われており、衛星データの検証にも有用である。
○ 個別エアロゾル粒子の散乱・吸収特性、地上サンプリングの質量情報を光学的特性に結び付けること、雲・エアロゾル相互作用の微物理を明らかにしていくことが求められている。