Vegetation lidar WS, Chiba University, May 26, 2017

Role of the active sensing in the satellite earth observation

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Active sensors

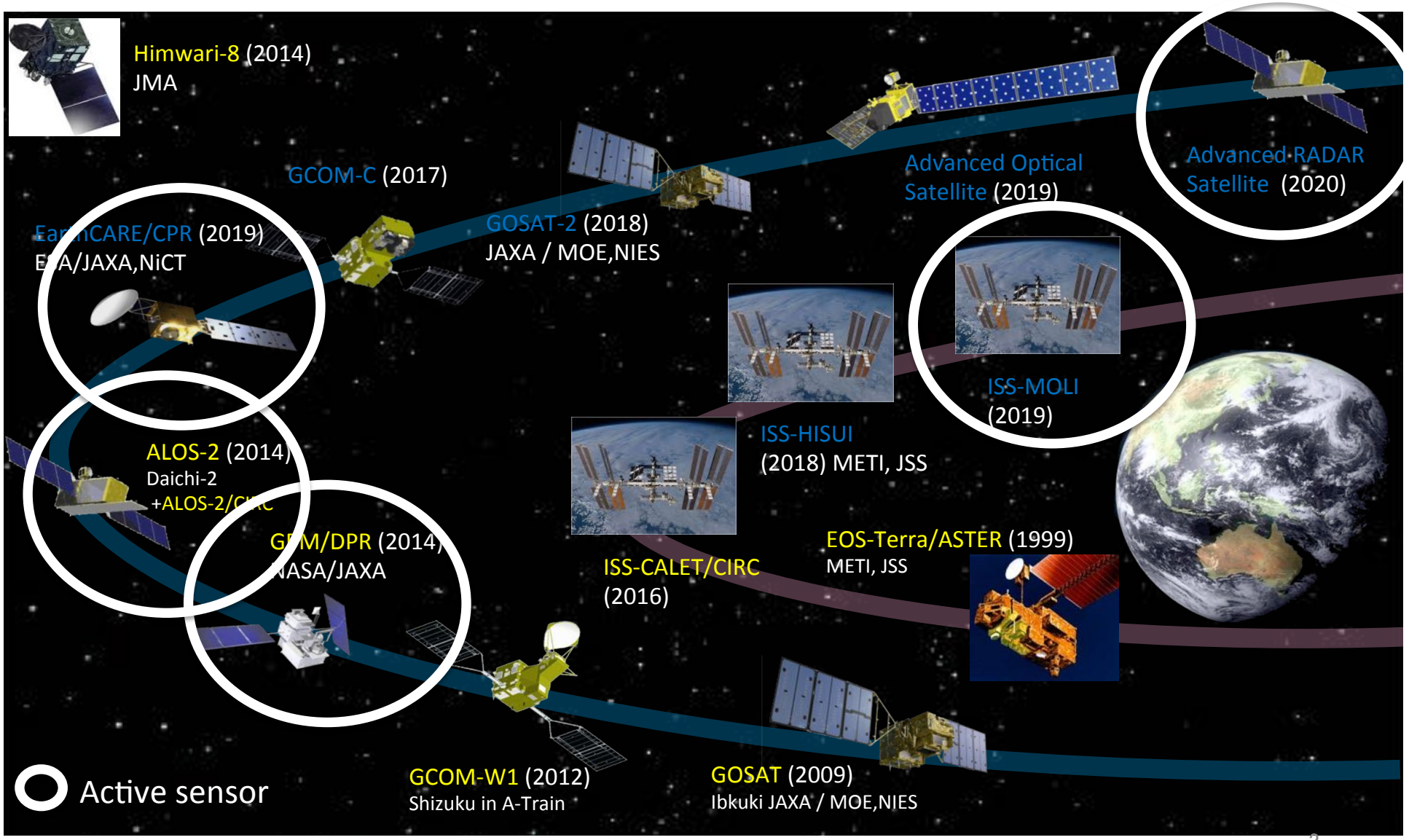
- Atmospheric aerosols and clouds (CALIPSO, EarthCARE)
- Wind vectors, hydrometers fall velocity by Doppler (ADM, EarthCARE)
- Water vapor and other gaseous compositions, DIAL, multi-wavelengths
- Hydrosols: NUV, VIS for surface 100m
- Biomass, Ice volume, muti-beams (ICEsat,GEDI, MOLI etc)

All weather

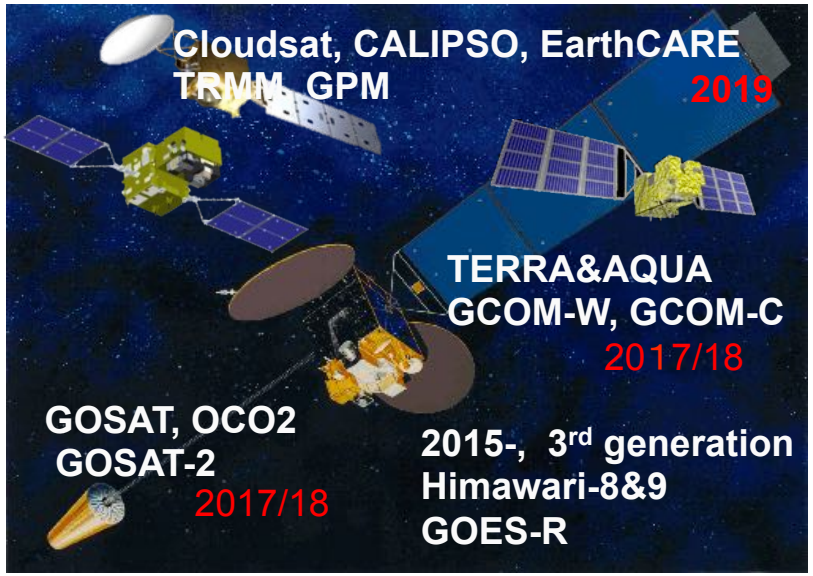
- Hydrometeor. radar: GPM/DPR (Ku, Ka), CLOUDSAT, EarthCARE (W-band)
- Ocean altimeter: all weather (TOPEX/Poseidon, Jason-1,2 etc, C, Ku, Ka...)
- SAR: TerraSAR-X (X), PALSAR-2 (L)

- High spectral resolution, Raman
- Doppler, interferograms
- Scanning

Major Japanese E/O satellites, instruments

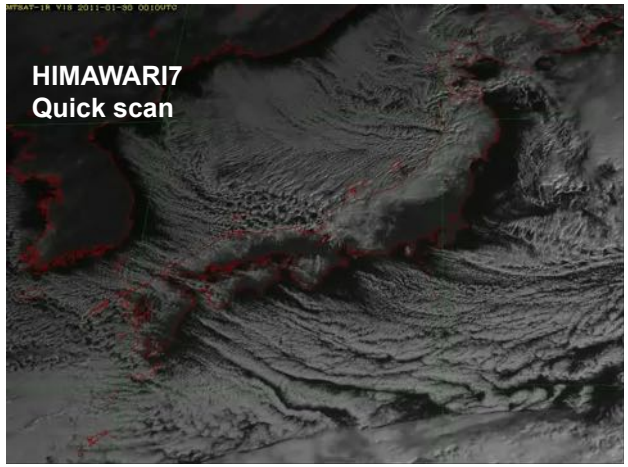


Next generation EO satellites



AHI, HIMAWARI-8/9

16 bands (1km, 2km)
Full disk scan every 10min
Rapid scan every 2.5 min



Weather, environ. monitoring

GCOM-W/AMSR2

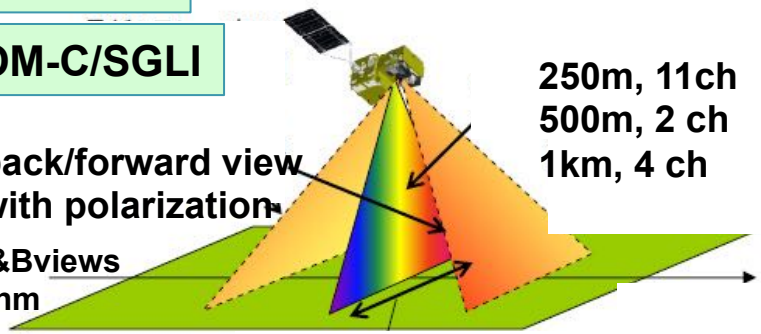
GCOM-C/SGLI

imager

back/forward view with polarization

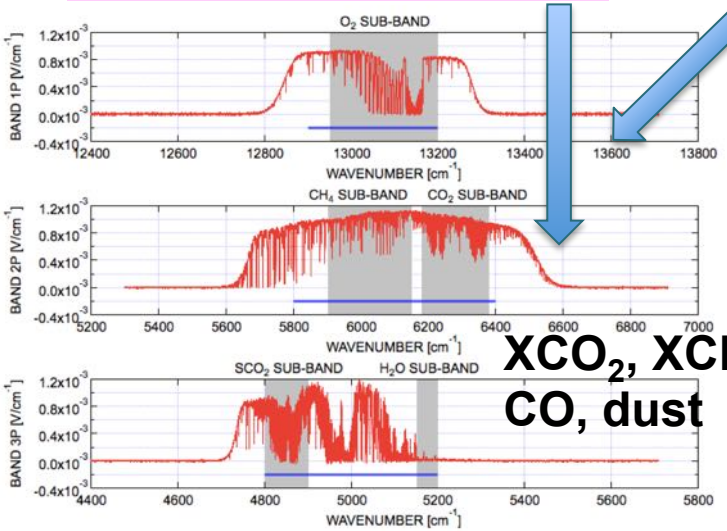
250m, 11ch
500m, 2 ch
1km, 4 ch

500m, F&Bviews
340, 380nm



GOSAT2/FTS-SWIR **FTS-TIR** **CAI2**

Greenhouse gas monitoring



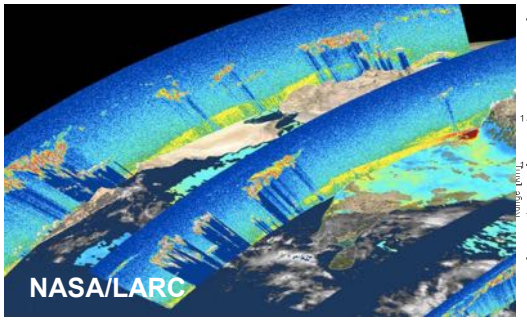
XCO_2, XCH_4
CO, dust

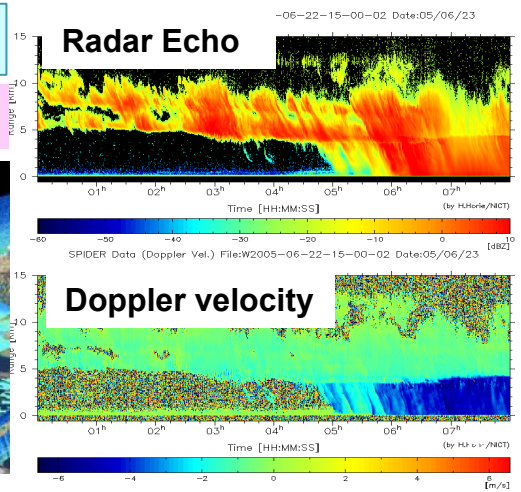
Radar&lidar

Dynamics, radiation& particles

TRMM, GPM, EarthCARE

Precip, cloud **Aerosol effect**



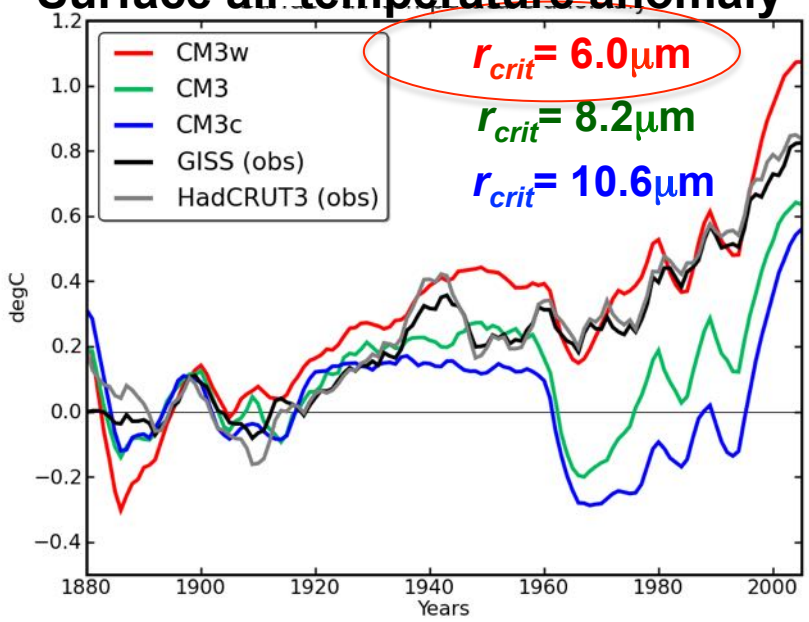


Uncertainties in cloud modeling

- Climate models are still at tuning stage
- Combined passive and active remote sensing effective to solve this problem: e.g. CFODD (*K. Suzuki et al., JAS' 10*)

GFDL CM3

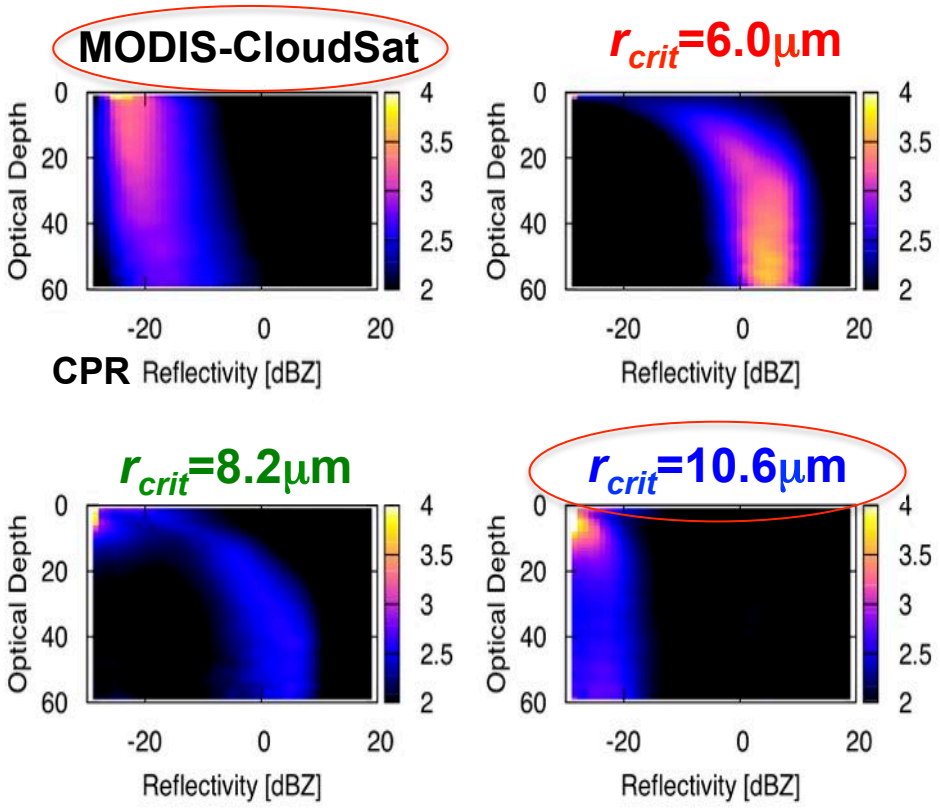
Surface air temperature anomaly



r_{crit}: threshold radius for rain to occ
precipitation

Golaz et al. (GRL'13)

"incipient stage": R_e=6-10μm



Suzuki, Golaz, Stephens (GRL '13)

Different response of the climate system

- Concept of Efficacy (Hansen et al., 2005)
- Model difference large

Atmospheric heating > stability >
cloud response > temperature

BC, tropo O3

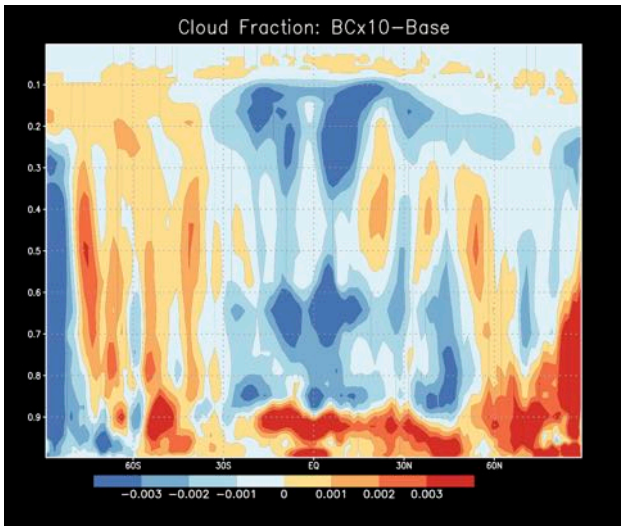
CO2, CH4,
Sulfate, Solar

Surface forcing

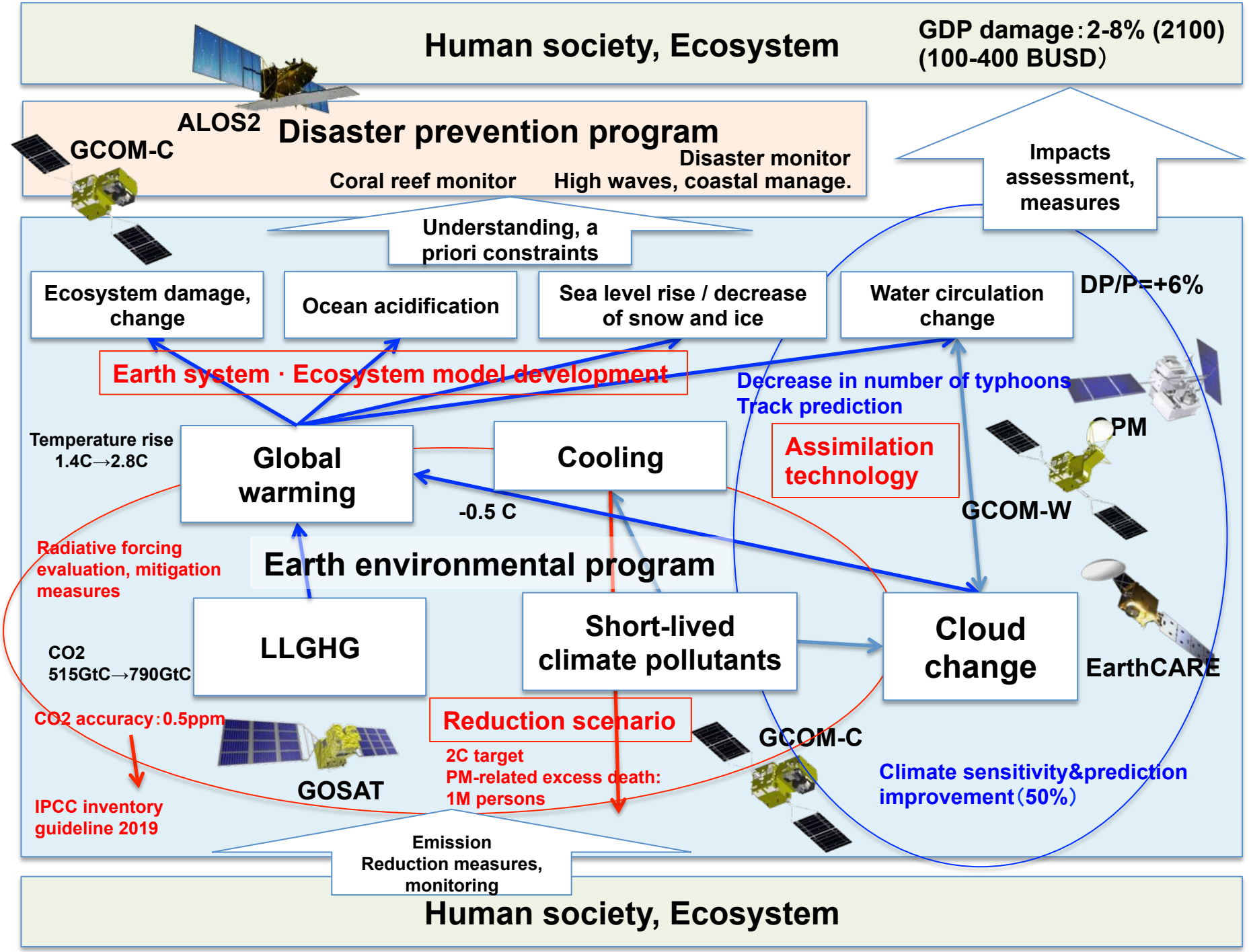
to be appeared after publication

Cloudiness change by 10xBC
MIROC SST prescribed

(MOEJ-S-12)



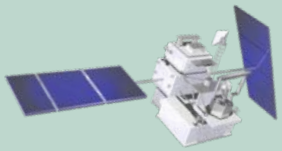
Suzuki, Takemura, Goto (MOEJ S12 workshop'17)


Human society, Ecosystem
GDP damage：2-8% (2100)
(100-400 BUSD)
ALOS2
Disaster prevention program
GCOM-C
Disaster monitor
Coral reef monitor
High waves, coastal manage.
Impacts assessment, measures
Understanding, a priori constraints
Ecosystem damage, change
Ocean acidification
Sea level rise / decrease of snow and ice
Water circulation change
DP/P=+6%
Earth system · Ecosystem model development
Decrease in number of typhoons
Track prediction
Assimilation technology
CPM
GCOM-W
Temperature rise
1.4C→2.8C
Global warming
Cooling
-0.5 C
Radiative forcing evaluation, mitigation measures
Earth environmental program
LLGHG
CO2
515GtC→790GtC
Short-lived climate pollutants
Cloud change
EarthCARE
CO2 accuracy：0.5ppm
GOSAT
Reduction scenario
2C target
PM-related excess death:
1M persons
GCOM-C
Climate sensitivity&prediction improvement（50%）
IPCC inventory guideline 2019
Emission Reduction measures, monitoring
Human society, Ecosystem

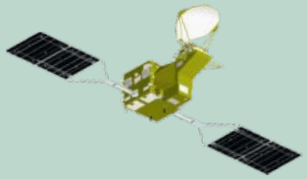
GSMaP: Global Satellite Mapping of Precipitation

Active / Passive sensor merge

❖ **Satellite-based global hourly precip**



TRMM PR/TMI
GPM DPR/GMI



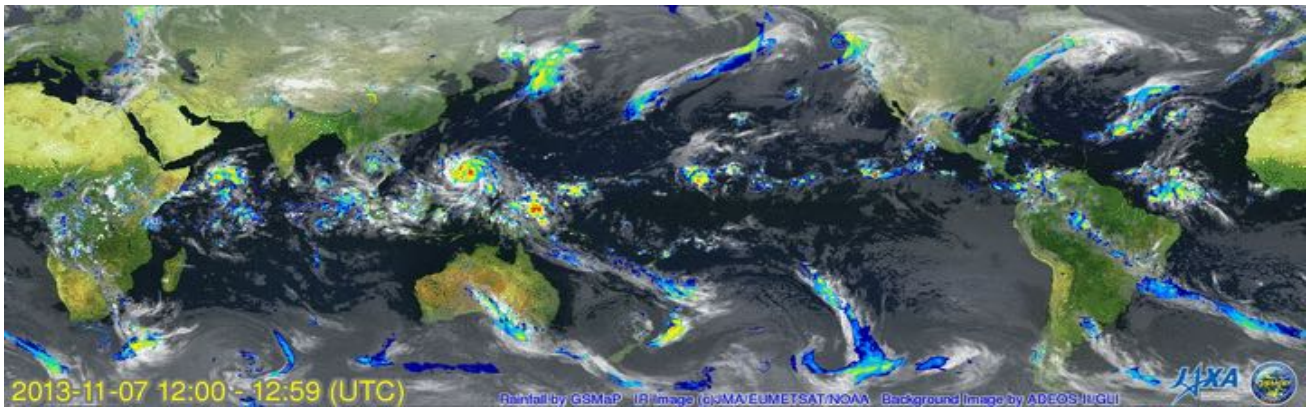
Aqua AMSR-E
GCOM-W
AMSR2

DMSP
SSM/I, SSMIS

NOAA&MetOp
AMSU-A/MHS

Geostationary Satellite (Himawari)

Calculate cloud moving vectors



GSMaP rainfall in 0.1-deg grid and hourly

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

GPM/DPR Data Assimilation in the JMA NWP

The Japan Meteorological Agency (JMA) started the DPR assimilation in the meso-NWP system and the GMI assimilation in the meso- and global-NWP system on March 24 2016. → Word's first "operational" assimilation of spaceborne radar data in the NWP system of meteorological agencies!

a) 33-hour prediction without the DPR | **b) 33-hour prediction with the DPR** | **c) Observation**

to be appeared after publication

Provided by JMA

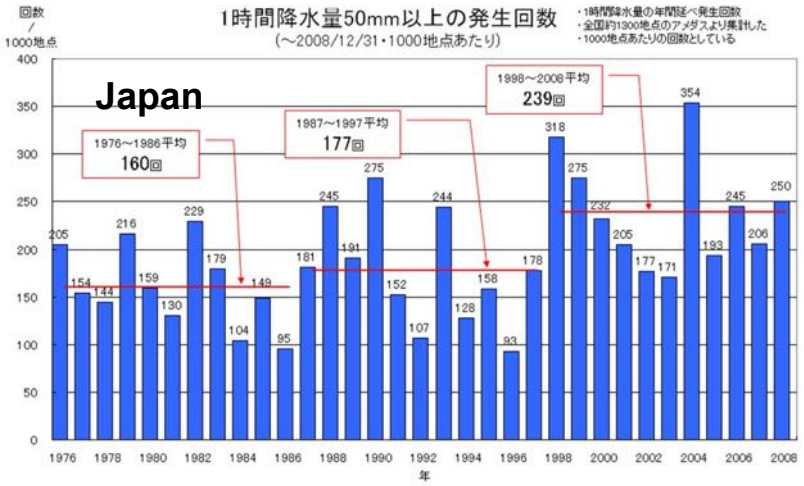
- **Example of Kanto-Tohoku Heavy Rainfall in 2015**
- **Improvements in water vapor analysis accuracy over the ocean**
- **Improvements in rainfall forecast accuracy**

Extreme weather increase and disaster monitoring

Flood caused by KANTO/TOHOKU heavy rain in Joso-city, Ibaraki-Pref. in September 2015. ）

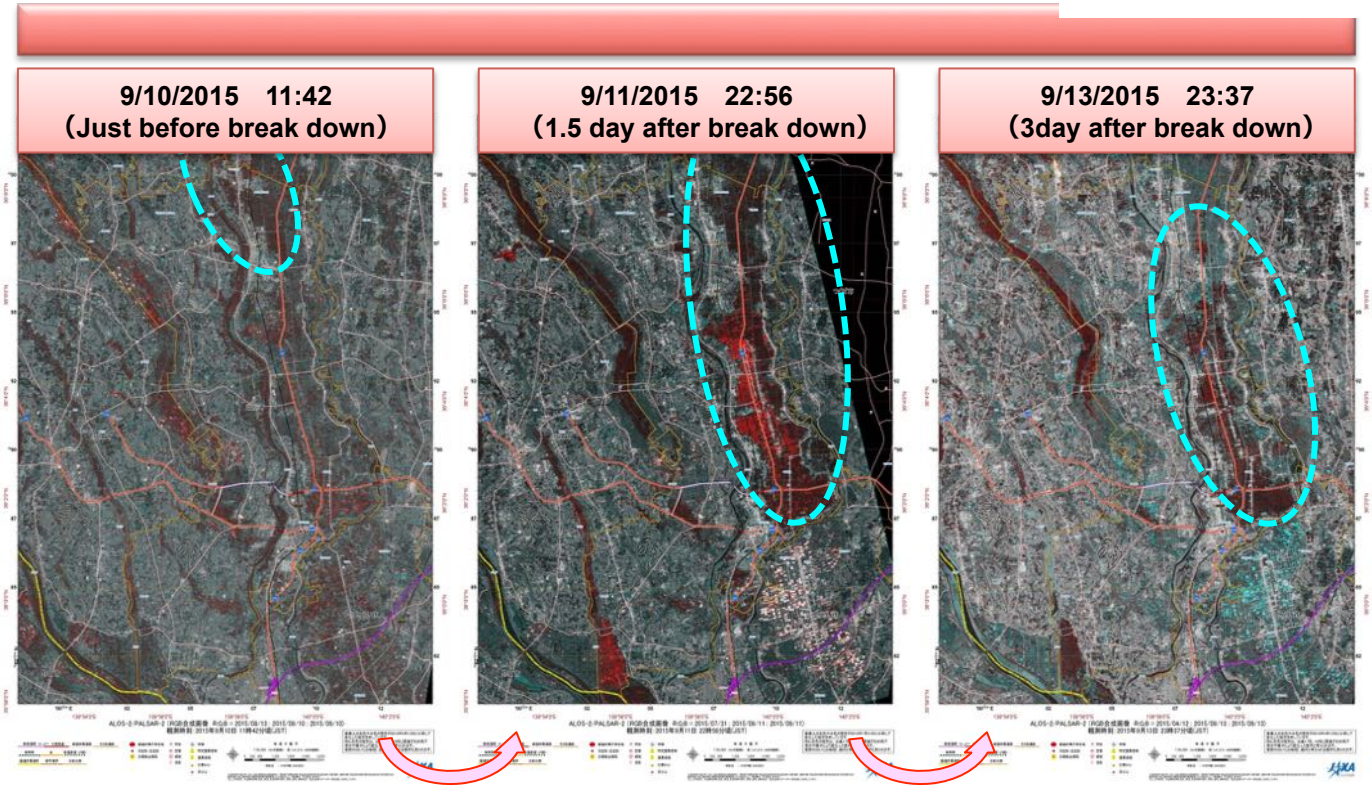
Increasing extreme weather events

# of Precip events more than 50mm/hr



JMA Report

Flooded area detection by ALOS-2



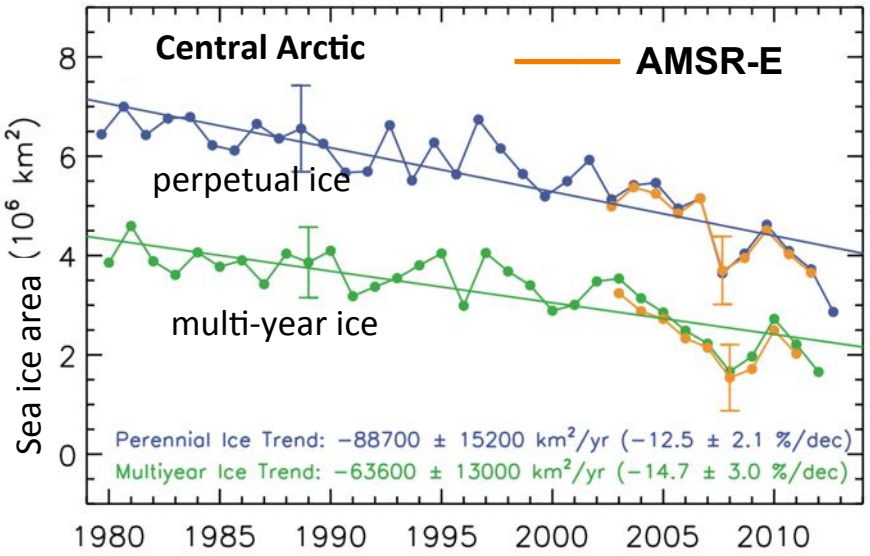
Flooded area expanding

Flooded area reducing but moving to south direction

Kinu-river flooding and Observation by ALOS-2

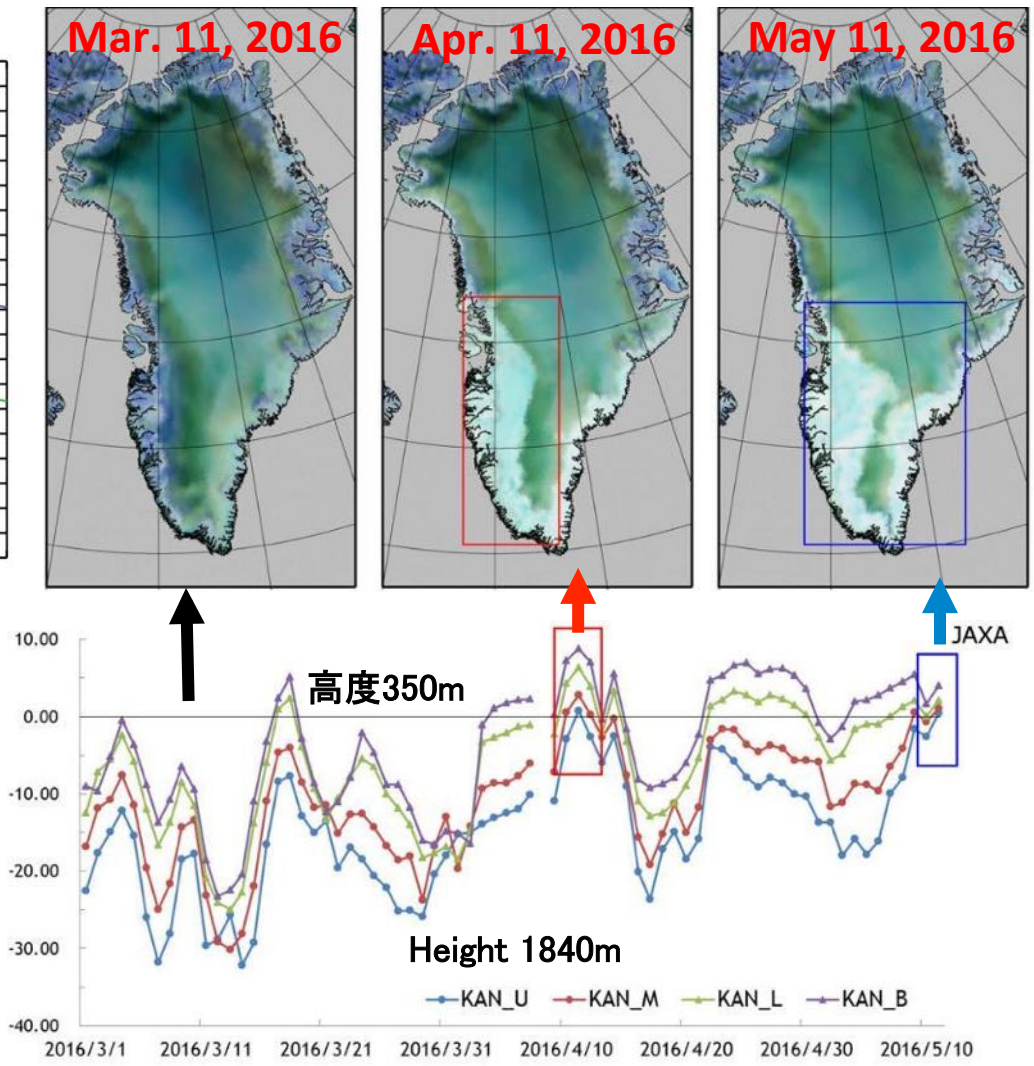
Global warming problem: Change in cryosphere

Sea ice change in central arctic area



IPCC-AR5 (2011)

AMSR-2 TB (18V/36V/36H) data, Greenland ice in melting (white) and non-melting (black, blue)



Melting usually starts in late May to early June

Data provided by Greenland Analogue Project (GAP)

Global anthropogenic CO_2 budget

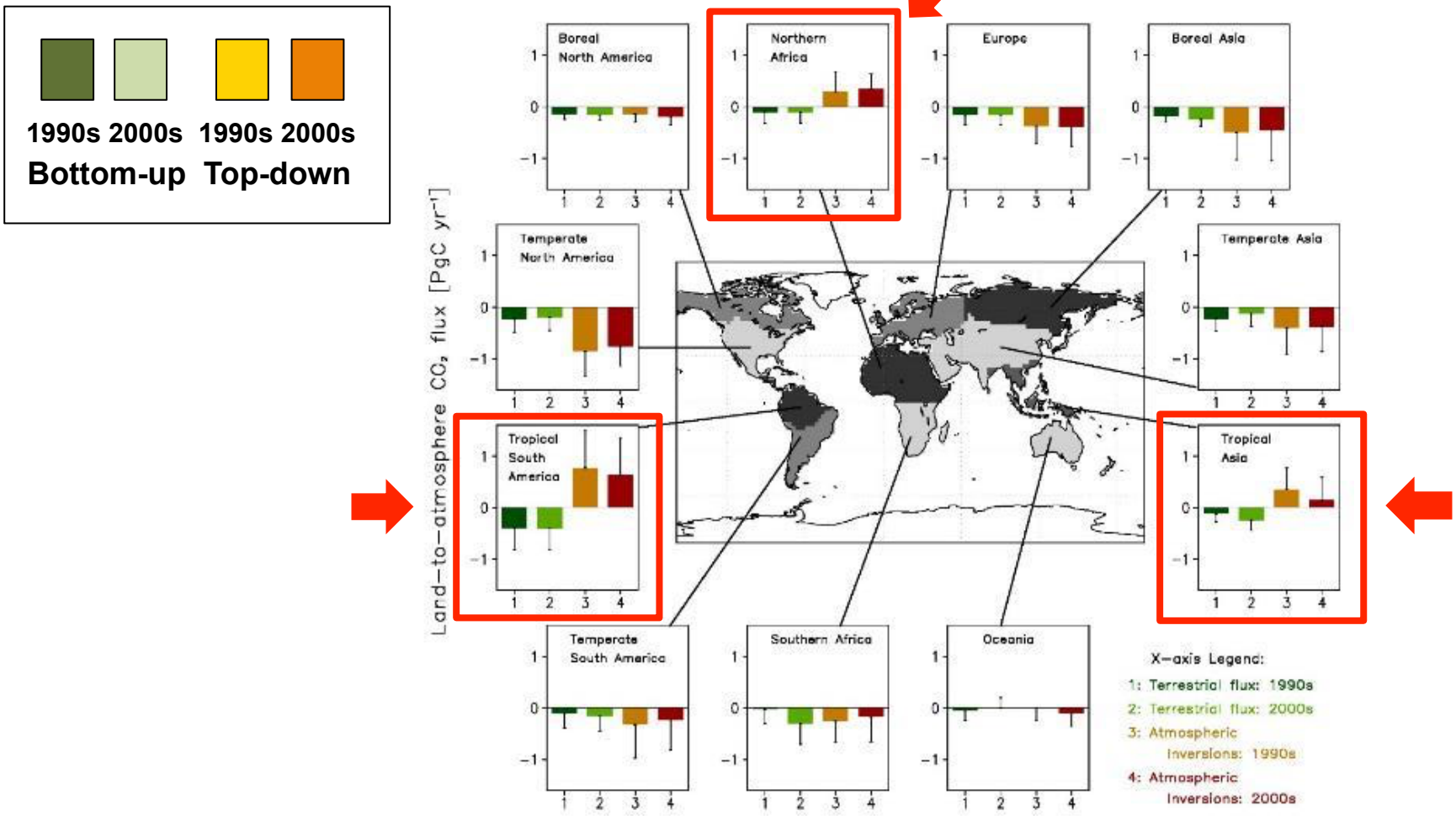
- **Needs precise evaluation of "BIOMASS" and its change**

(IPCC AR5)

	1750–2011 Cumulative PgC	1980–1989 PgC yr^{-1}	1990–1999 PgC yr^{-1}	2000–2009 PgC yr^{-1}	2002–2011 PgC yr^{-1}
Atmospheric increase[a]	240 ± 10[f]	3.4 ± 0.2	3.1 ± 0.2	4.0 ± 0.2	4.3 ± 0.2
Fossil fuel combustion and cement production[b]	375 ± 30[f]	5.5 ± 0.4	6.4 ± 0.5	7.8 ± 0.6	8.3 ± 0.7
Ocean-to-atmosphere flux[c]	−155 ± 30[f]	−2.0 ± 0.7	−2.2 ± 0.7	−2.3 ± 0.7	−2.4 ± 0.7
Land-to-atmosphere flux	30 ± 45[f]	−0.1 ± 0.8	−1.1 ± 0.9	−1.5 ± 0.9	−1.6 ± 1.0
Partitioned as follows					
Net land use change[d]	180 ± 80[f,g]	1.4 ± 0.8	1.5 ± 0.8	1.1 ± 0.8	0.9 ± 0.8
Residual land sink[e]	−160 ± 90[f]	−1.5 ± 1.1	−2.6 ± 1.2	−2.6 ± 1.2	−2.5 ± 1.3

- **Cumulative result shows contribution of *"Land to atmosphere flux"* is enough large, comparing with *"Fossil fuel combustion (Anthropogenic)"***
- **Recent result shows the uncertainty of *"Land to atmosphere flux"* is much worse.**

Differences of CO_2 land flux estimation from Top-down and Bottom-up approaches



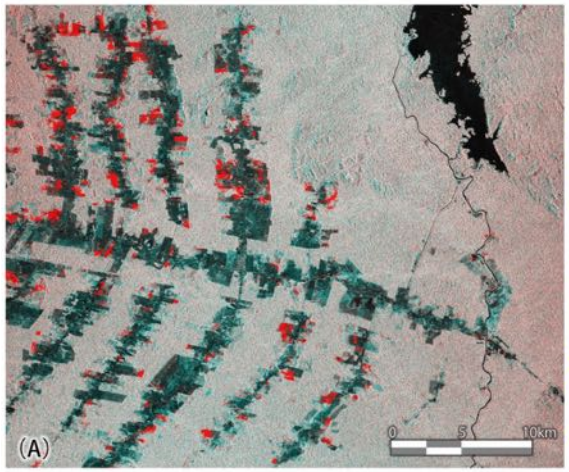
Ciais et al., (2013)

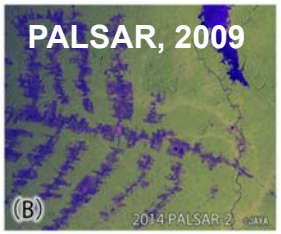
Active / Passive Synergy technique is the key

	Passive Horizontal Distribution		Active Vertical Distribution		Synergy Global 3D Recognition
Precip.	Microwave Radiometer	×	Precipitation Radar	=	GSMaP Achieved
Cloud & Aerosol	Multiband Imager	×	Cloud Radar Atmos. LIDAR	=	Cloud 3D estimation Will be Achieved
Forest	(L-band SAR) SGLI	×	(L-band SAR) + LIDAR	=	Biomass map Expectation to be Achieved

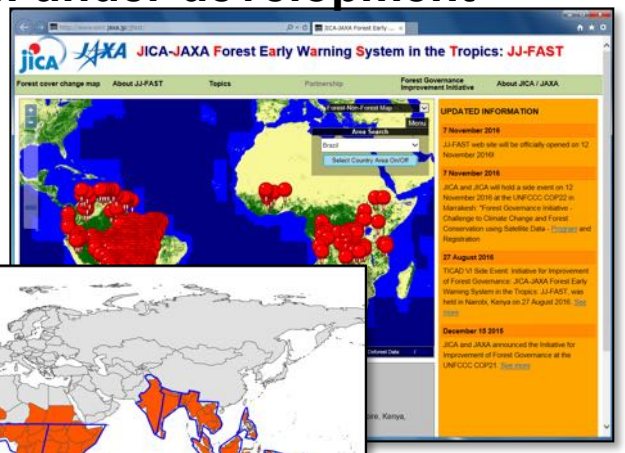
JICA-JAXA Forest Early Warning System in the Tropics (*JJ-FAST*)

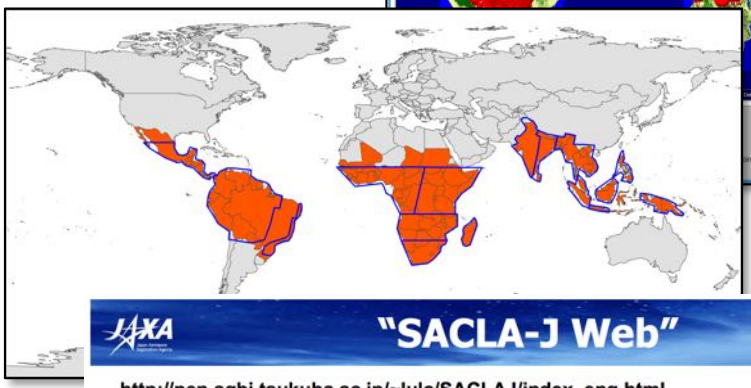
- A new JICA&JAXA deforestation monitoring system under development
- ALOS-2/PALSAR-2 ScanSAR mode HV image.
- Coverage: 79 countries
- Update: Every 1.5 months
- iPhone

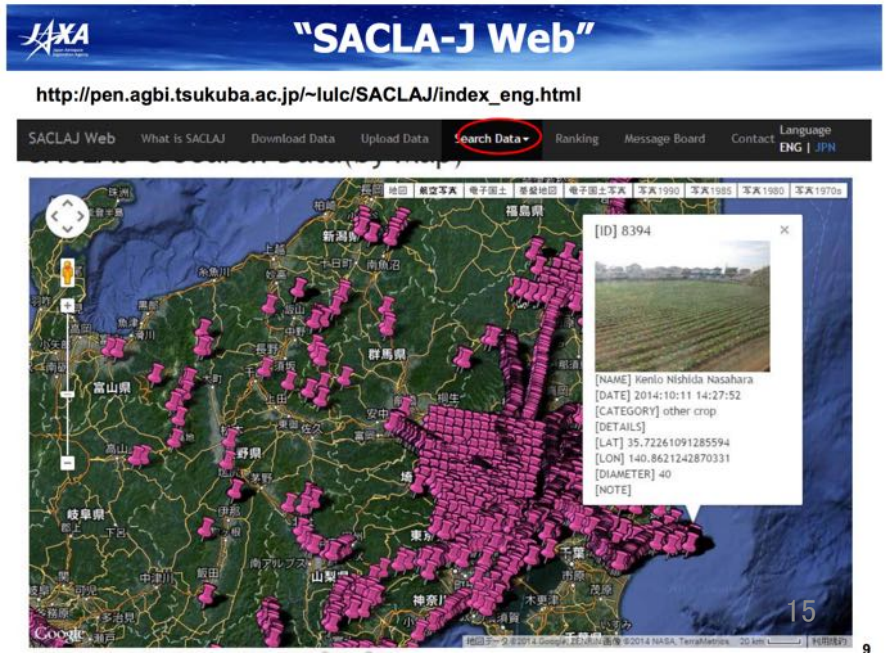




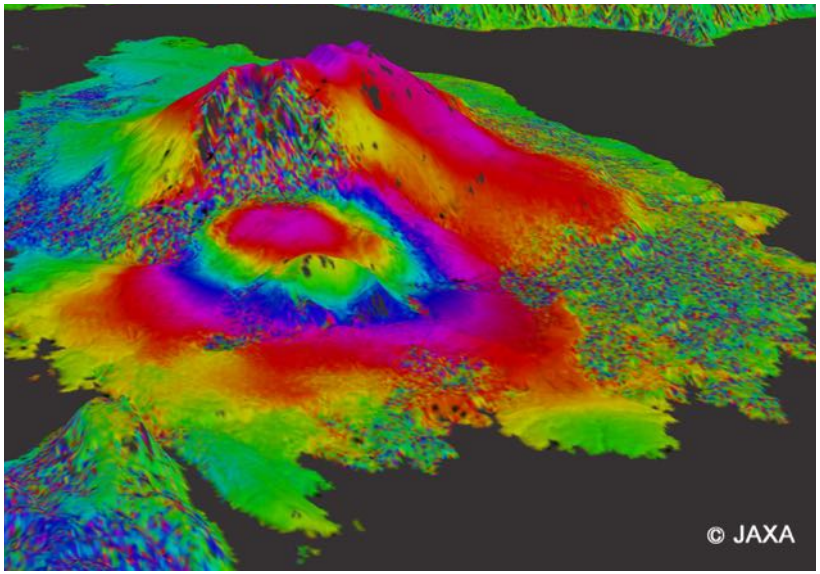
Wide swath of 2,320km;
High resolutions of 1-3m





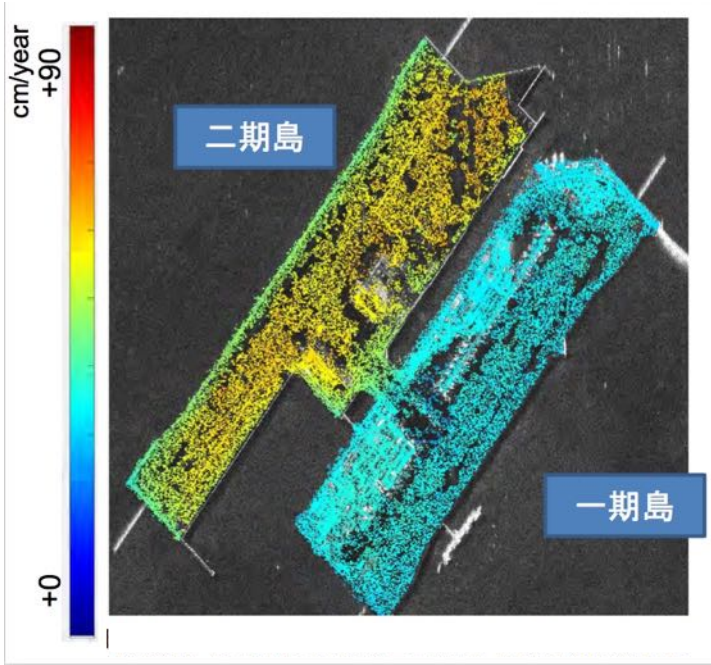


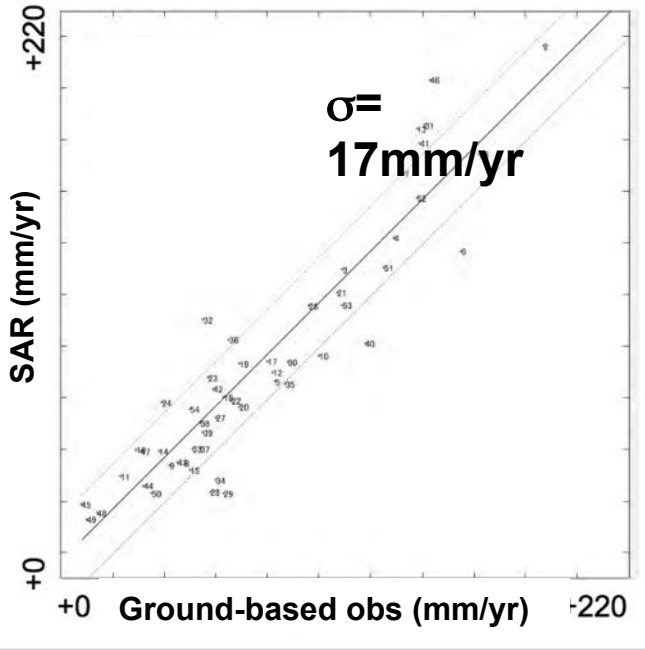
Surface/infrastructure deformation monitoring



ALOS-2 PALSAR-2 imageries & interferogram analyses

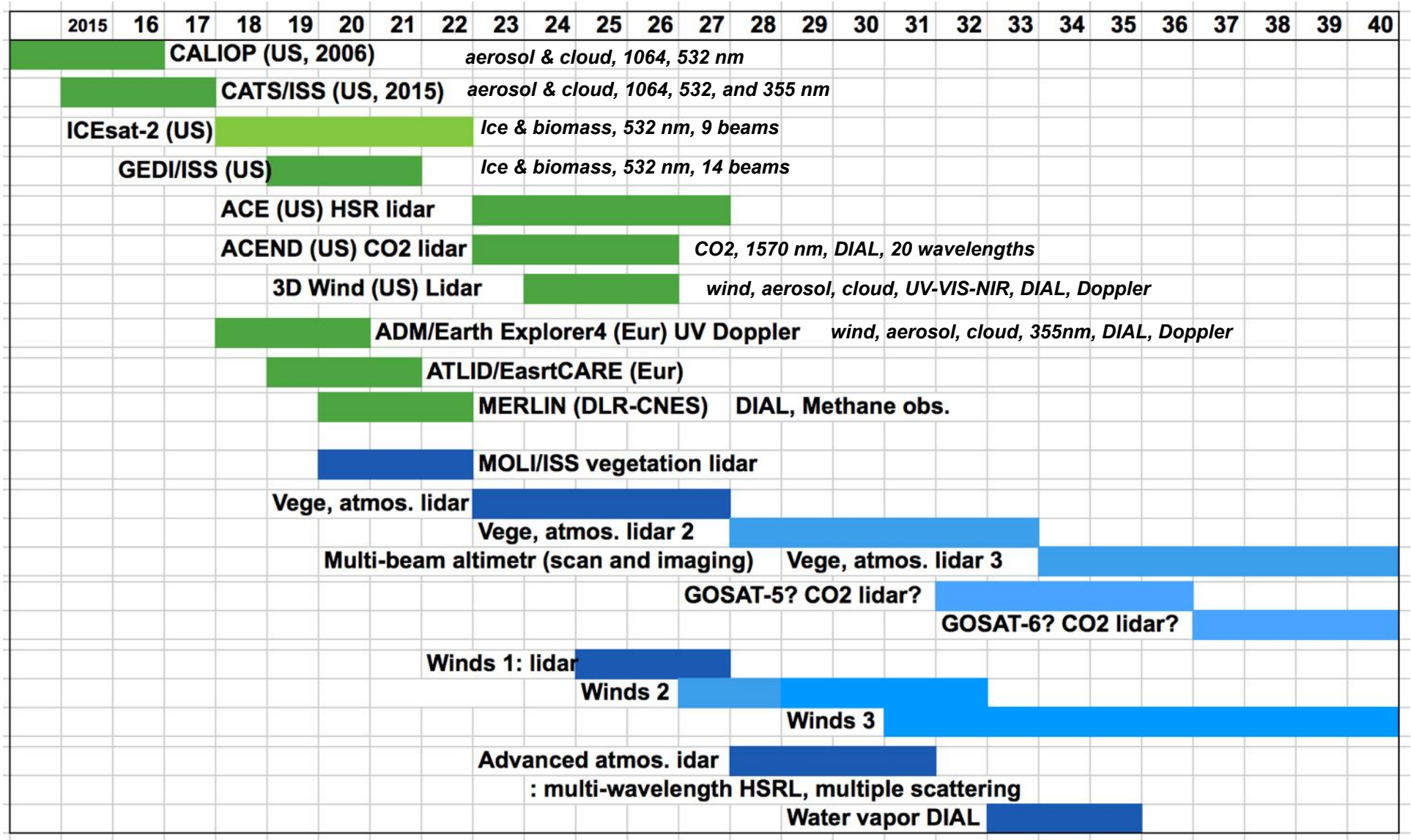
Surface deformation of M t. Sakurajima
Jan 14, 2015 – Aug 8, 2015
Max 16 cm surface rise was monitored.





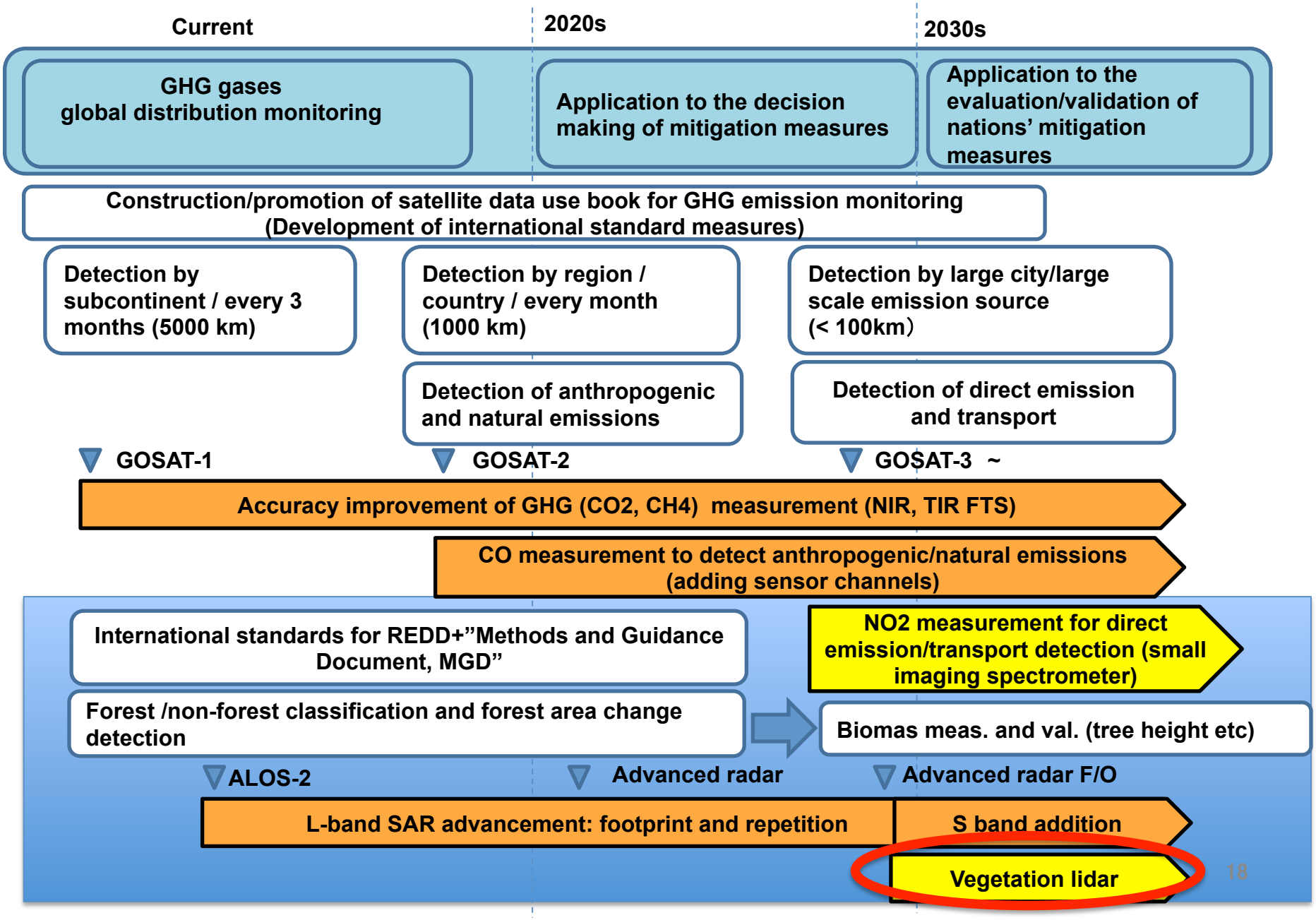
World satellite plans: Lidar

【NO Japanese Earth Observation Lidar (Active Optical) yet】



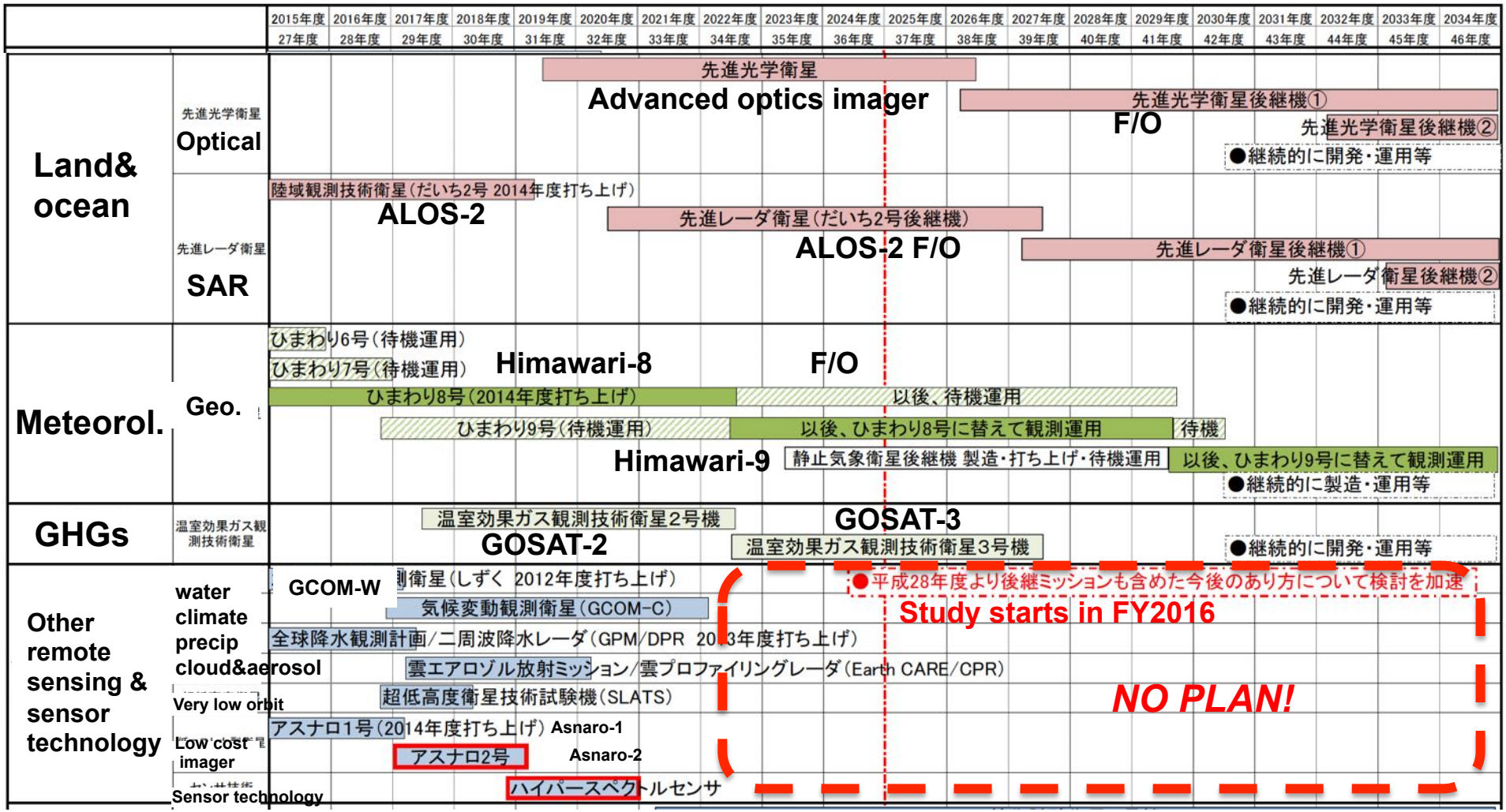
World trend analysis of the earth observation plans, Meteorol. Note 2017, TF Earth Science Study WG

JAXA's engineering plan: Climate change mitigation



New Basic Plan on Space Policy & work plan(Jan. '15)

- Governance by Cabinet Office; No GEO subcommittee
- No plan for other remote sensing satellites after 2020
- Active EO sat. planning (2020-40) in the world (US, Euro, China etc)

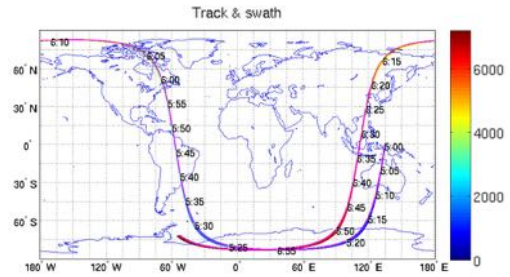


Shared Tools

Satellite users
Modellers
(MIROC,NICAM,
WRF etc)

Assimilation/
inversion/
forecasting of non-
met parameters

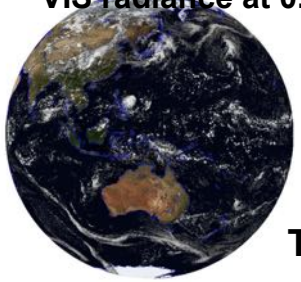
Joint Simulator for Satellite Sensors
Joint-Simulator



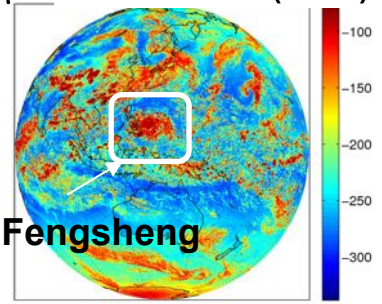
Visible-IR-Microwve-BBR-CPR-Lidar simulator

Himawari simulation with NICAM

VIS radiance at 0.62 μm



TOA LW flux (Wm^{-2})



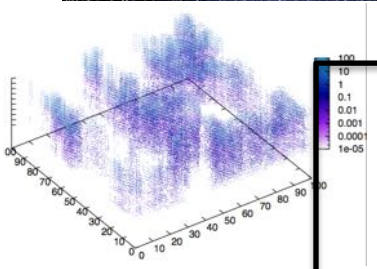
TC Fengsheng

JAXA JS2
Super

NIES Super

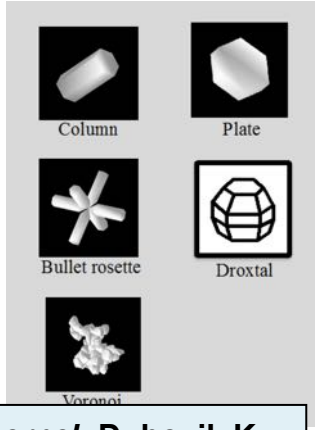
RIKEN
HPCI-K

STAR codes



3D scene
generator

STAR
Rstar, Pstar, Fstar,
MCstar, Mstrn



Nonspherical scattering kernel: Dubovik K (LOA), Pin-Yang K1&2(Texas A&M);TY. Nakajima, Ishimoto (MRI)

L2 algorithms

BRDF, (Neighbour Effects under work)

Coupled Ocean

Summary

- Climate & environmental change program
  - Forcing: LLGHG, SLCP; emission estimate
  - Climate sensitivity, mechanisms: Cloud, precipitation
  - Impacts: water, ecosystem, cryosphere
- Disaster prevention program
- Horizontal and vertical information needed
- Imager, lidar, radar technologies in progress