Training 4-3: Operational Application at JMA

IPWG7 training course

Session 4. Application of Precipitation Retrievals

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18 Nov. 2014

Contents

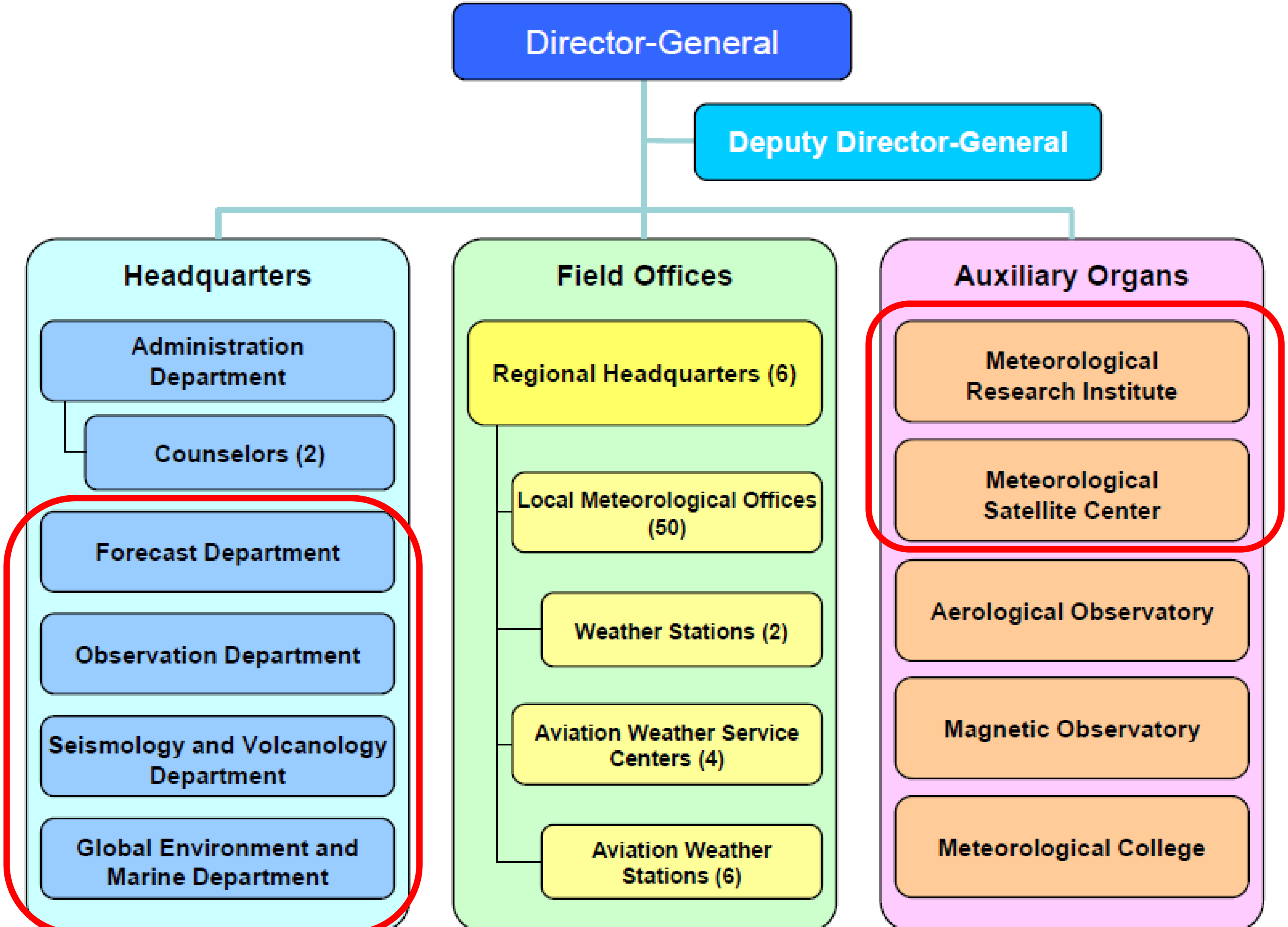
1-1. JMA : What we are?

JMA

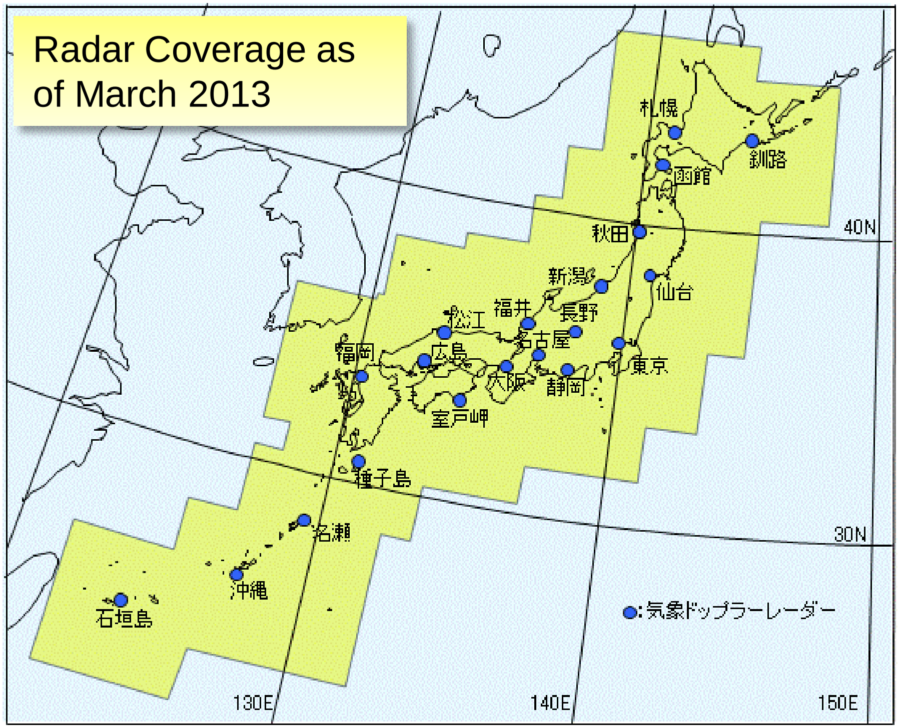
- Mission
  - Monitor the earth's environment and forecast natural phenomena related to the atmosphere, the oceans and the earth
  - Ultimate goal : prevent and mitigate natural disasters, enhance safety of transportation, develop and prosper industry and improve public welfare
- Particular emphasis on the prevention and mitigation of natural disasters
  - Typhoons, heavy rains and earthquakes
  - Responsible for issuing weather/tsunami warnings and advisories

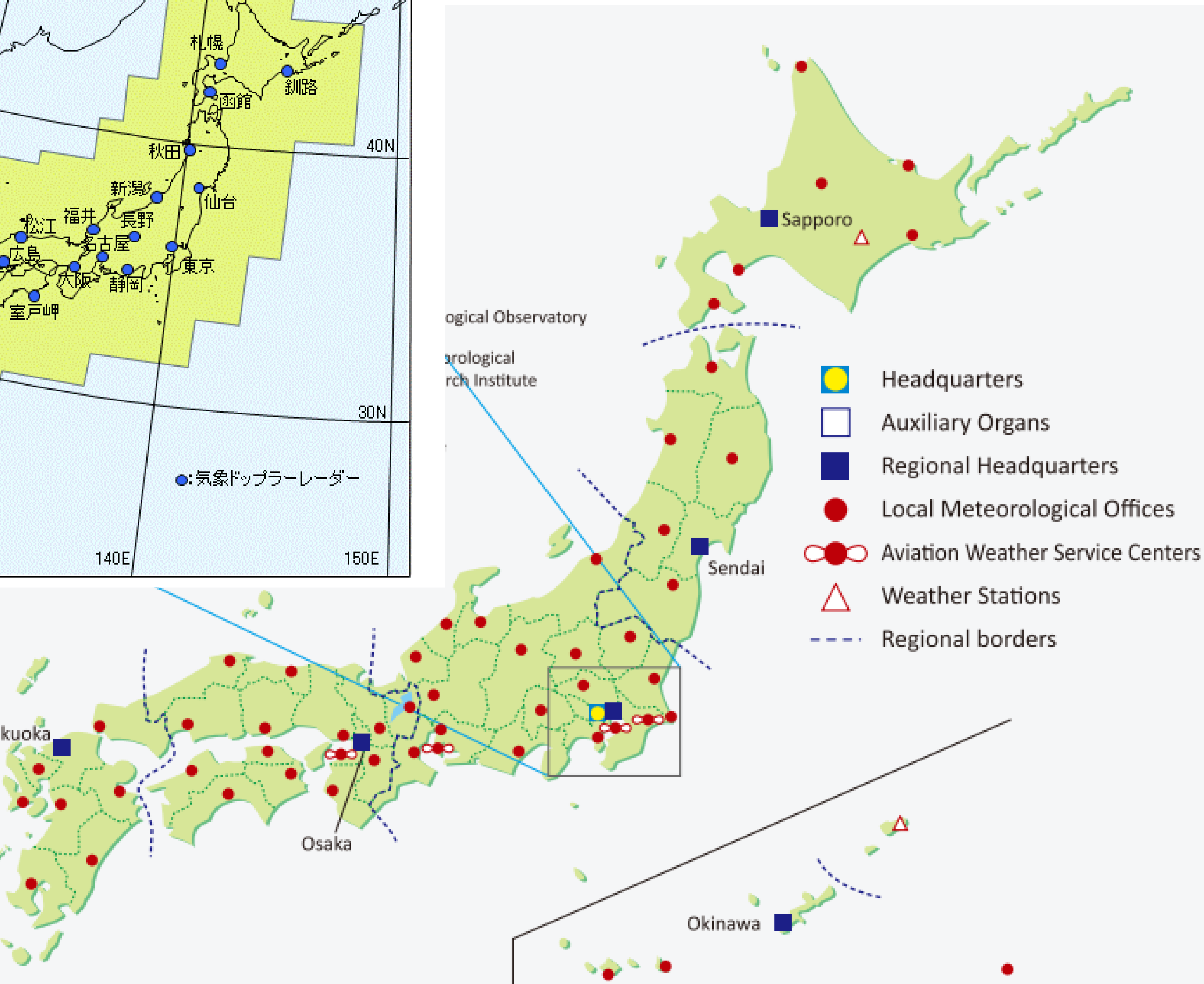
http://www.jma.go.jp/jma/en/Background/mission.html

Organizational structure of JMA



JMA main offices and radar sites





http://www.jma.go.jp/jma/en/Background/organization.html

Geo-stationary satellites

JMA

GMS (Geostationary Meteorological Satellite)

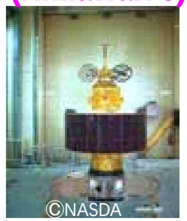
GMS **(Himawari)**

Jul 1977

GMS-2 **(Himawari-2)**

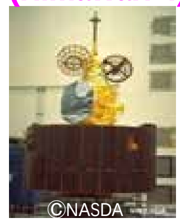
Aug 1981

GMS-3 **(Himawari-3)**



Aug 1984

GMS-4 **(Himawari-4)**



Sep 1989

GMS-5 **(Himawari-5)**

Mar 1995

(GOES-9)

Back-up operation of GMS-5 with GOES-9 by NOAA/NESDIS from May 2003 to June 2005

MTSAT (Multi-functional Transport SATellite)

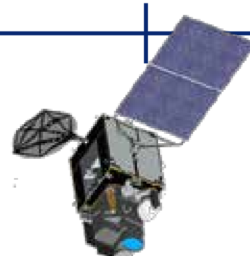
MTSAT-1R **(Himawari-6)**

Feb 2005

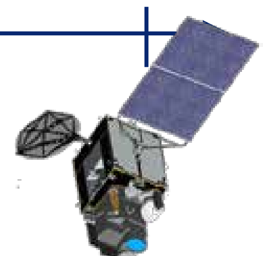
MTSAT-2 **(Himawari-7)**

Feb 2006

Himawari-8
Oct 2014



Himawari-9
2016



Himawari

Satellite	Observation period
GMS	1978 – 1981
GMS-2	1981 – 1984
GMS-3	1984 – 1989
GMS-4	1989 – 1995
GMS-5	1995 – 2003
GOES-9	2003 – 2005
MTSAT-1R	2005 – 2010
MTSAT-2	2010 – 2015
Himawari-8	**2015 – 2022**
Himawari-9	**2022 – 2029**

New function of Himawari-8 imager (AHI)

JMA

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 Composited True Color Image**

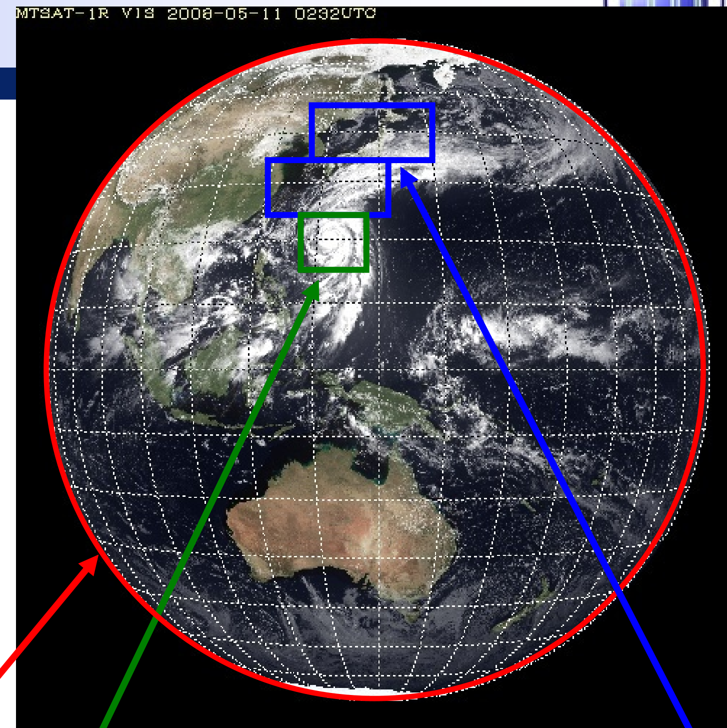
Channels 8–10: **Water Vapor**

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)

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

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

Number of Bands: 5 à 16
H.Resolution : 1,4km à 0.5/1,2km

Interval: 30/60 min. à 10 min.

1-2. JMA operations using satellite data

- Weather service
  - Weather warning/advisories, marine warning, tropical cyclone information
- Numerical Weather Prediction (NWP)
  - Data assimilation for initial conditions, model validation, boundary/climate conditions
- Climate and global environment
  - Dust, ozone, CO_2
  - Reanalysis
  - Climate system monitoring, snow depth analysis
- Marine diagnosis
  - Sea surface temperature, sea ice, ocean current, ocean wave
- Earthquake and volcanoes
  - Earthquake, volcano eruption, volcanic ash

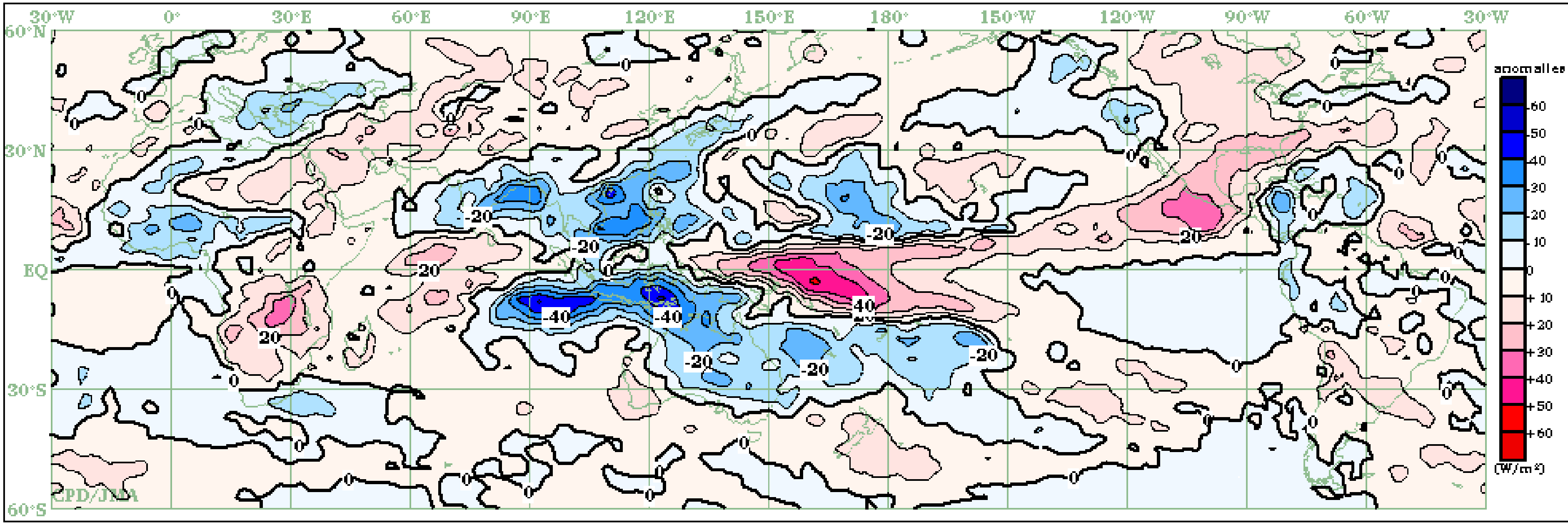
2. JMA operations using satellite precipitation estimates

- Climate system monitoring
- NWP (data assimilation and global model validation)

2-1. Climate system monitoring

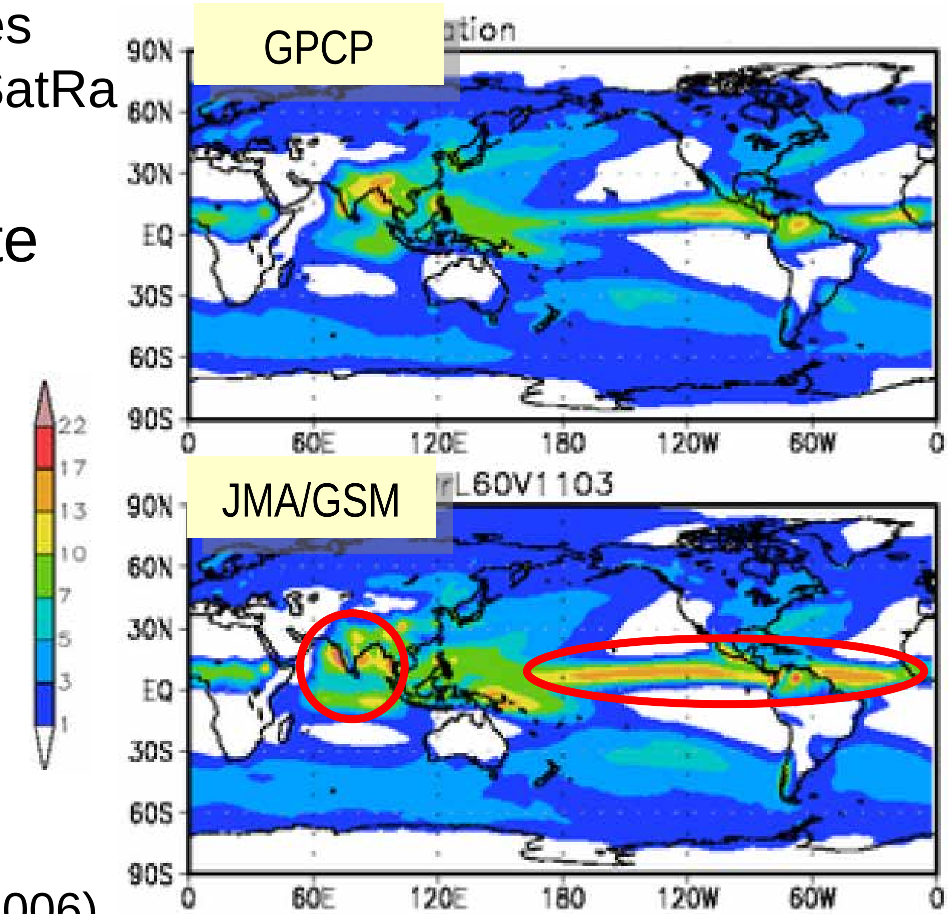
- Need long-tem and consistent dataset
- CPC merged analysis of precipitation (CMAP) used for climate system monitoring

Anomaly of monthly OLR
From Monthly report on climate system monitoring in Oct. 2010



2-2. Numerical Weather Prediction (NWP)

- Model validation
  - Global validation against GPCP, GSMaP,,,
  - IPWG support intercomparison of model outputs as well as satellite precipitation estimates http://cawcr.gov.au/projects/SatRain/validation-intercomparison.html
- Data assimilation to generate initial conditions



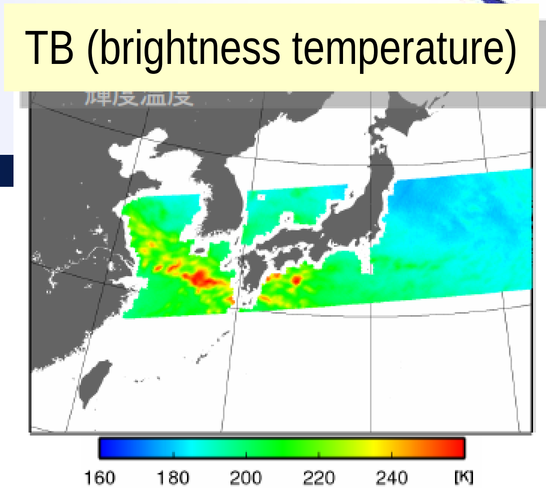
Monthly precipitation average in July [mm/day]

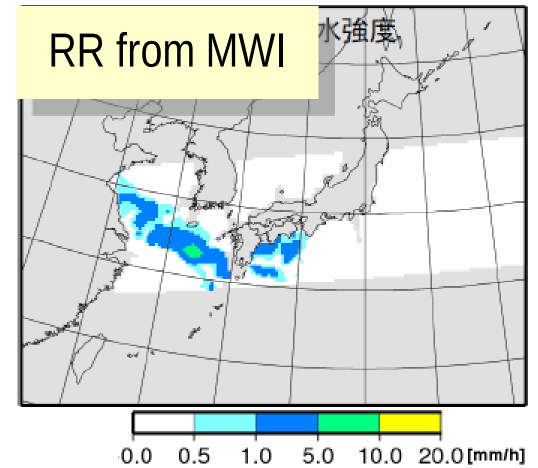
Takaya (2006)

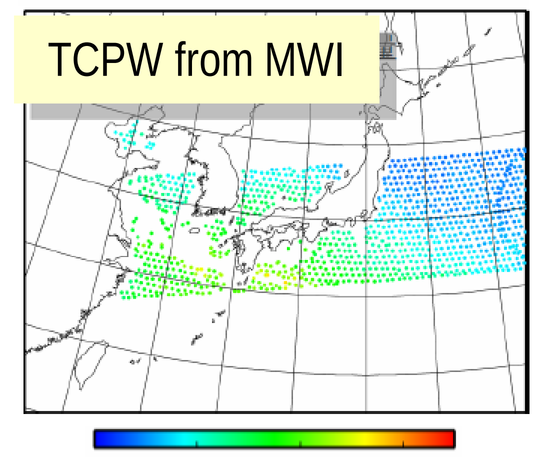
Assimilation

- Assimilation of MW imagers
  - Clear-sky radiances in global analysis
  - Clear-sky radiances and surface rain-rate (RR) in meso-scale analysis
    - Formerly total column precipitable water (TCPW)
  - Improve moisture and precipitation forecasts

- Procedures of assimilating RR
  1. Retrieve RR
     - JAXA standard algorithm for AMSR-E/AMSR2 (Takeuchi 1999)
  2. Bias-correction to remove inconsistency between different satellites
  3. Assume equivalence to one-hour accumulated RR à inflate observation errors
  4. Assimilate RR and radiances (TCPW) in clear-sky areas

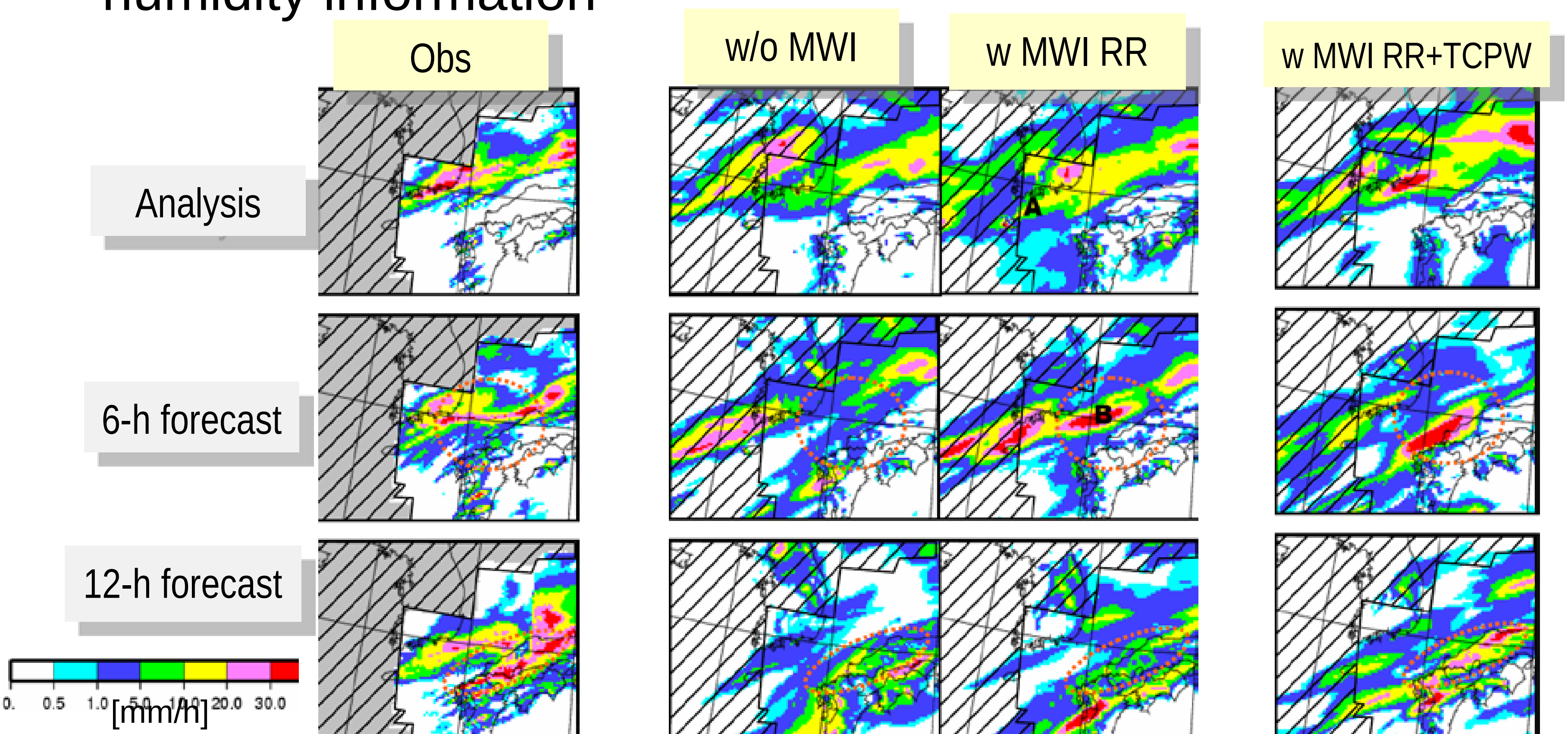






Assimilation of MWI

- Assimilating surface rain-rate (RR) improves forecasts but its impact does not last long enough
- Adding TCWV (radiance) assimilation, even in clear-sky area only, keeps impacts because of its wider coverage of humidity information



3. JMA operations using other MW observations from satellite

- Tropical cyclone (TC) analysis
- Sea surface temperature (SST) and sea-ice concentration (SIC) analysis
- Data assimilation in NWP

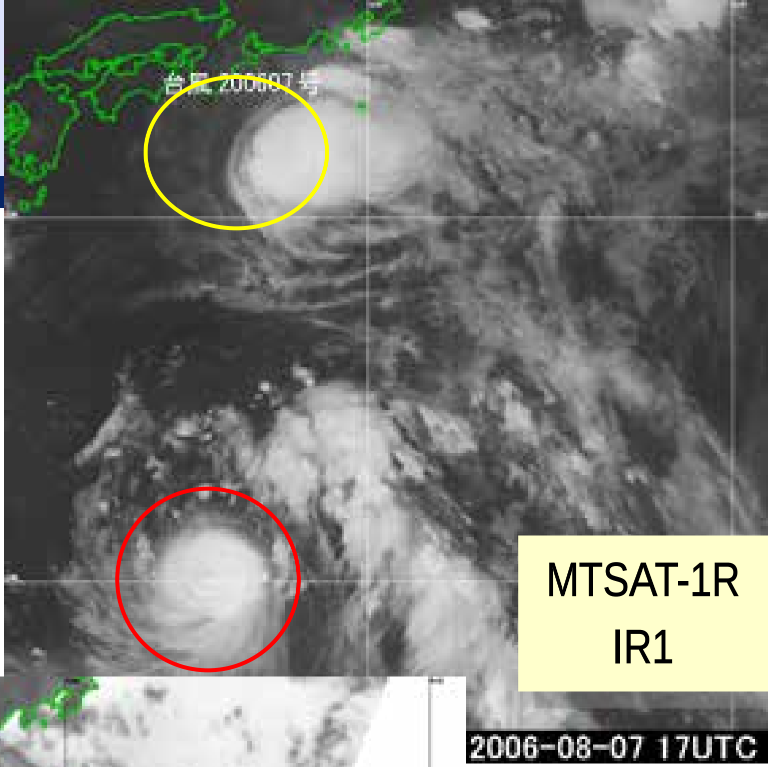
3-1. Tropical Cyclone (TC) analysis

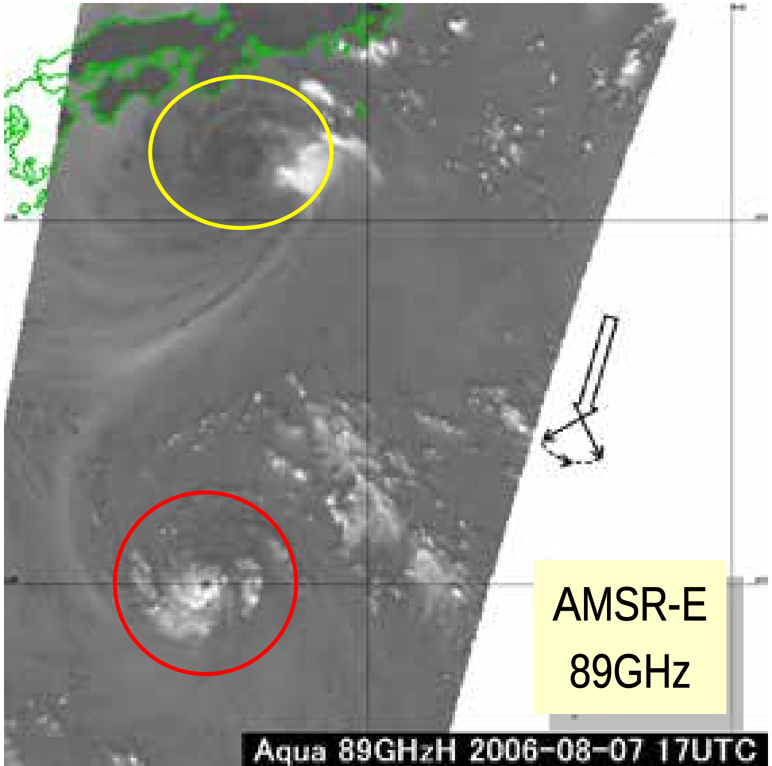
JMA

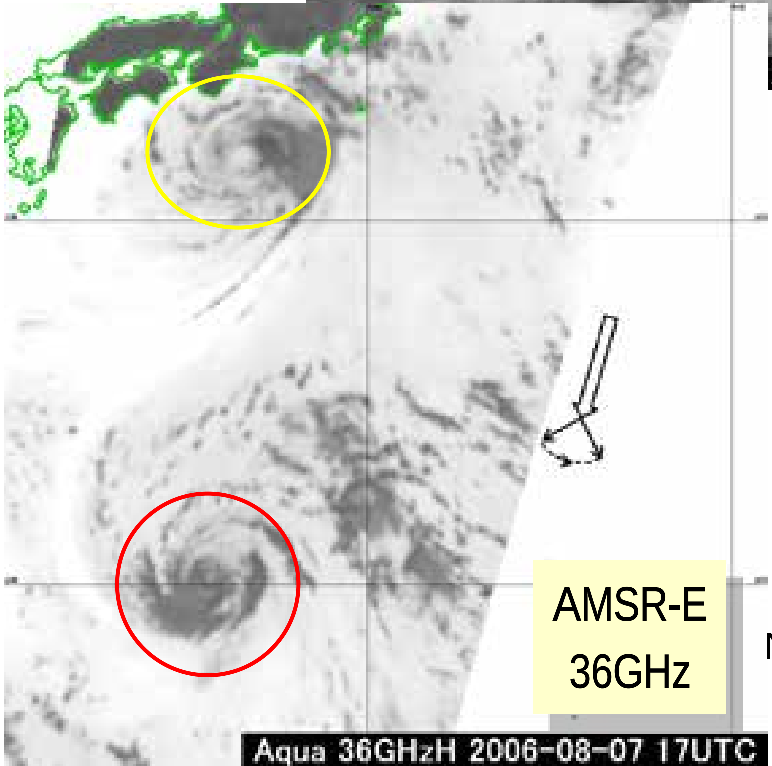
- Position of the center, maximum wind speed (MWS), minimum sea level pressure (MSLP)
- Traditional Dovorak technique widely employed
  - Based on IR images from geostationary satellites
  - High clouds hinders the information below
- MW imagers and sounders complement geostationary IR observations
  - Penetrate high thin clouds
  - MWS extracted from sea surface emissivity variation induced by winds
  - MSLP extracted from upper tropospheric temperature anomaly (in warm core regions)
- MW imagery and retrievals are used in the operational TC analysis as an ancillary information

Position and structure of TC

- Geo IR imagers : frequently taken (every 30/10 min), but not see below high clouds
- MW imagers helps TC analysis







Nishimura 2007

Max. wind speed (MWS) retrieval from TMI

1. Calculate TB parameters (max, average, min etc). in the predefined domains

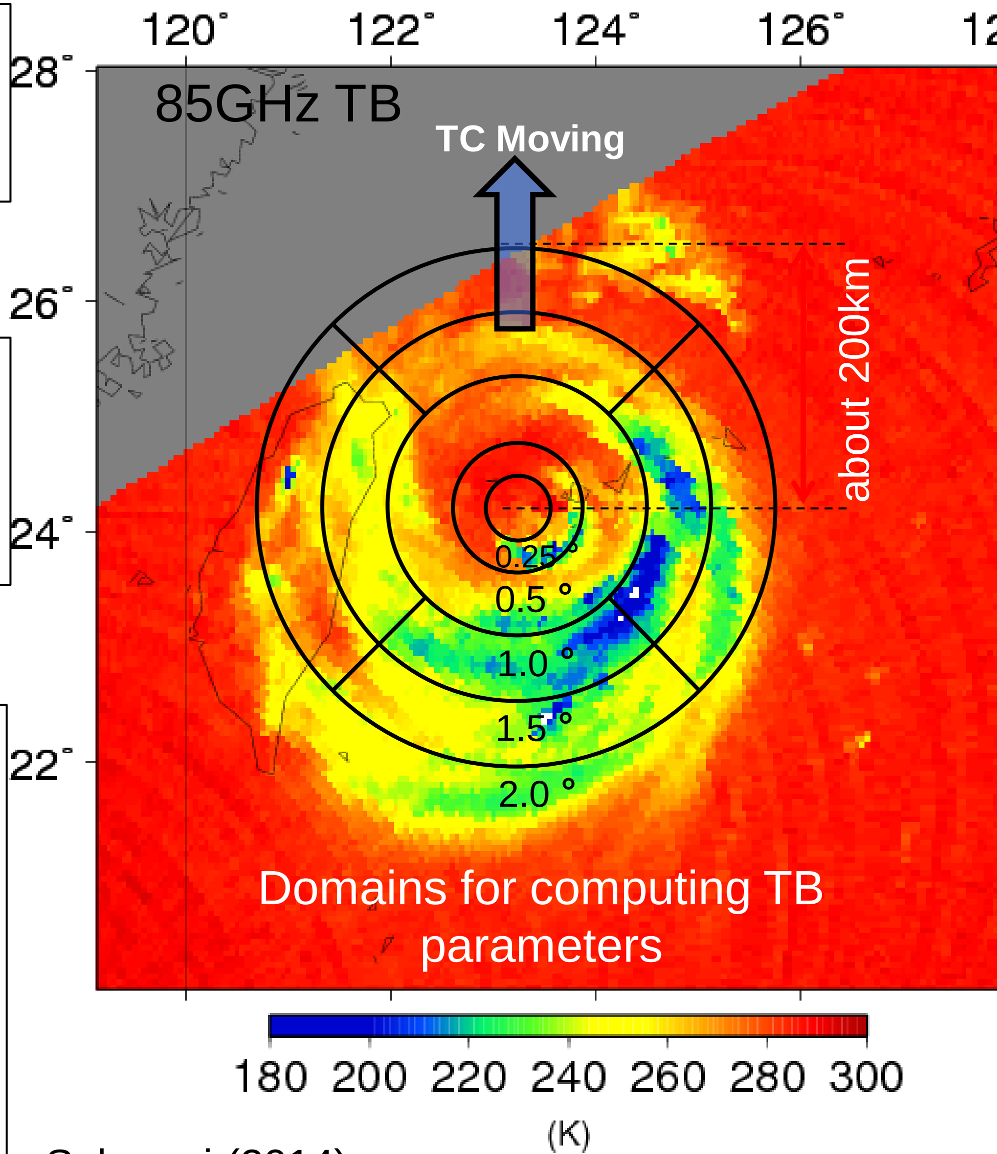
2. Categorize TB image pattern of TC inner core (out of 10 patterns) using TB parameters to treat with TC asymmetric structure

3. Estimate MWS with a multiple-regression equation for each TB image pattern.

MWS = A0 + Σ {A(n) x TBp (n)}

TBp (n): TB parameters highly correlated to MWS

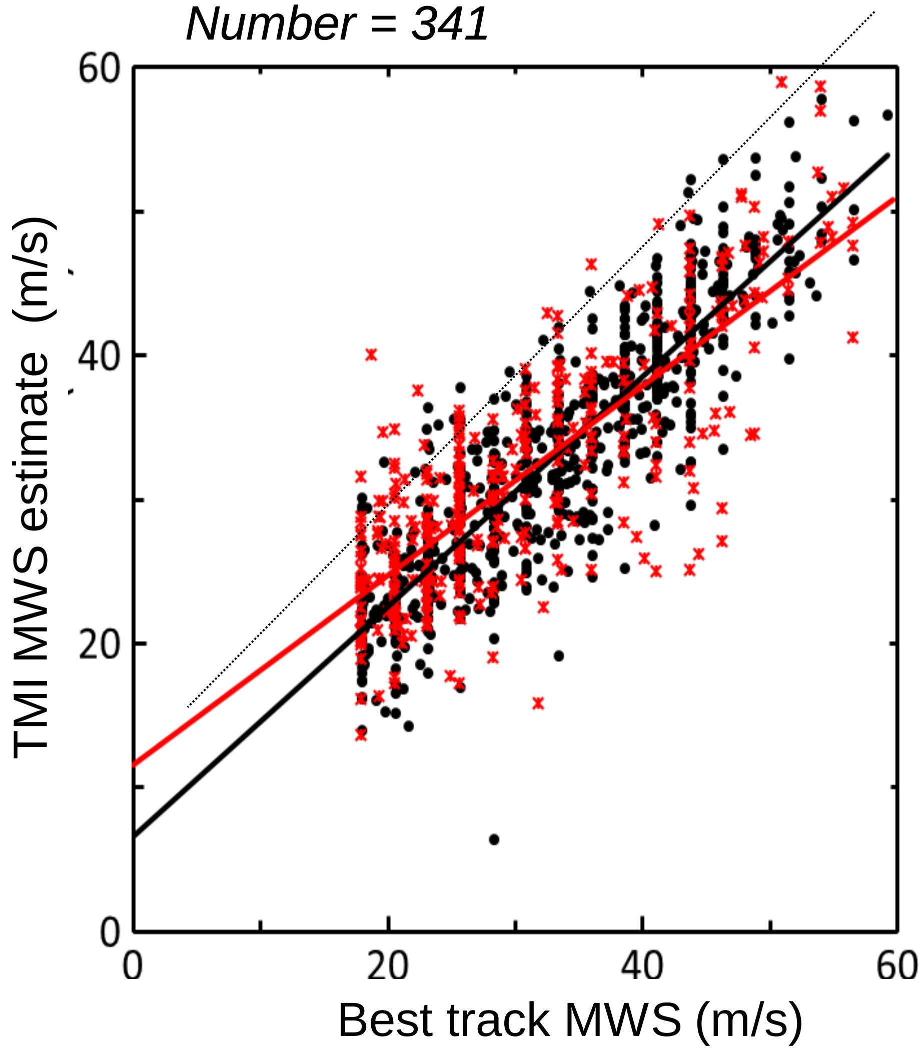
n = 1 to 7



Sakuragi (2014)

Validation of MWS from TMI

Black : dependent dataset
Red : independent dataset
Number = 341

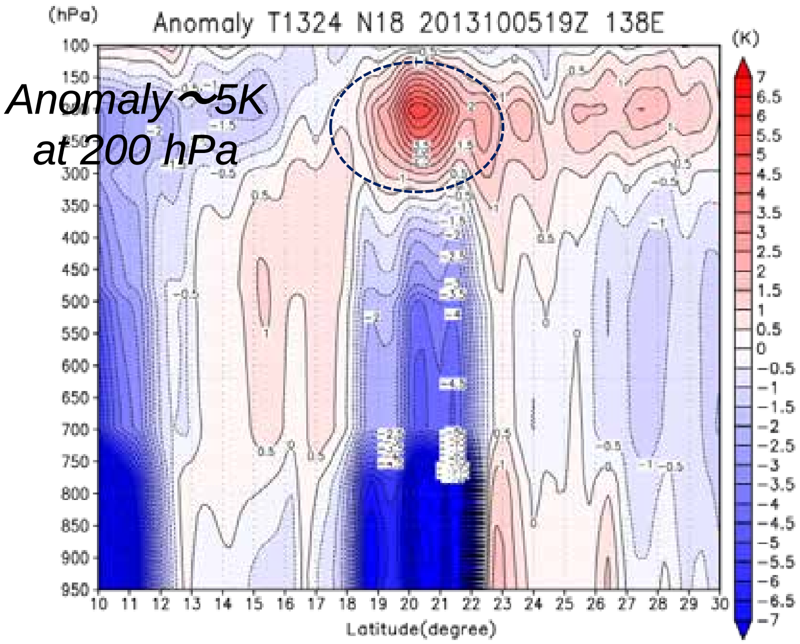


- Comparable performance with Dovorak technique
  - 6.26 m/s in RMSE
- Possible error sources :
  - Inadequate input TB parameters at the TC formation stage
  - Determination error of TC center position

Min. Sea Level Pressure (MSLP) retrievals from AMSU-A

Oyama (2014)

Temperature anomaly retrieved by AMSU-A for TC Danas (1324)



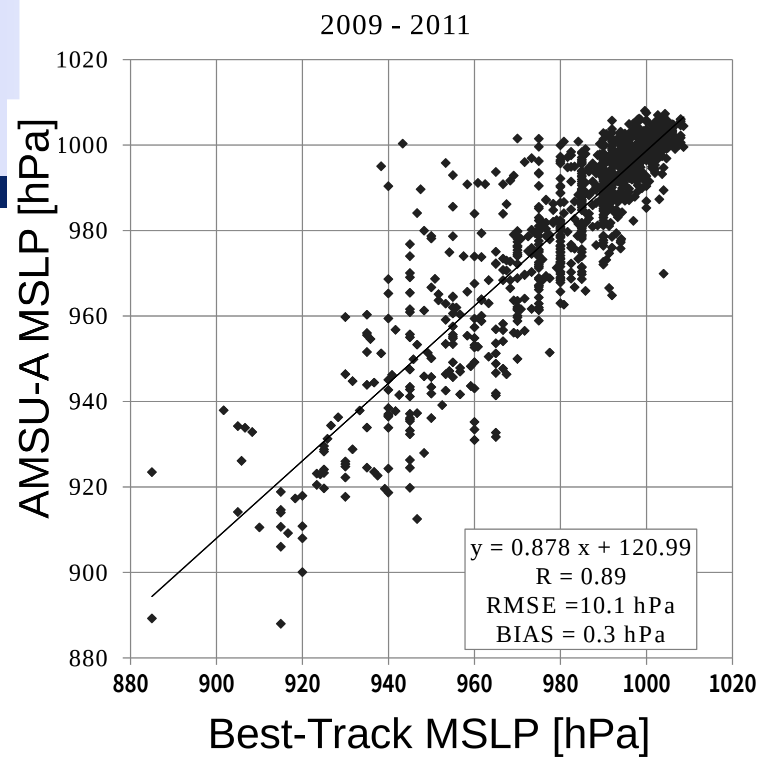
1. Estimate "warm core intensity" (WCI) by TB anomaly from environment of AMSU-A ch 6, 7 or 8
2. Correct WCI to reduce errors caused by low resolution, scan-dependency and ice scattering
3. Estimate MSLP with a regression method

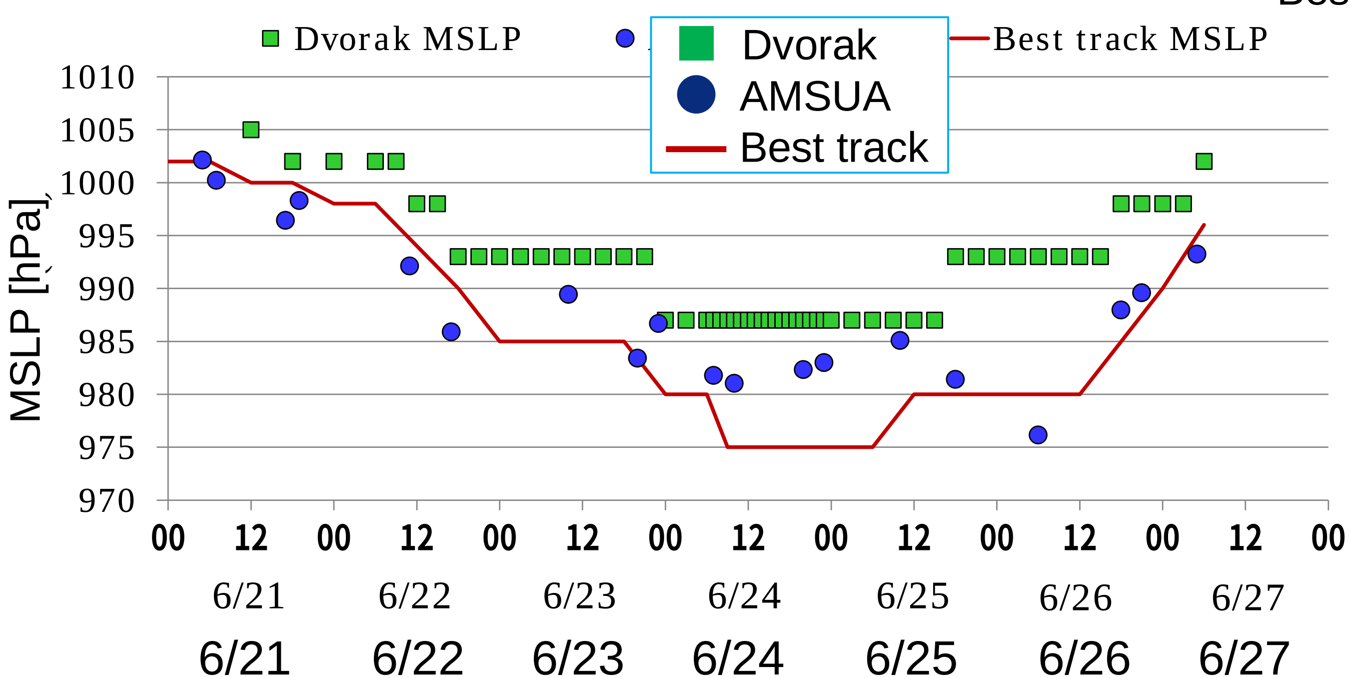
   MSLP = a*WCI+b

Warm air	⟷	*Low surface pressure*
Large (small) warm core	⟷	*Large (small) TC size*

Validation of MSLP from AMSU-A

- Better quality for large TCs than compact TCs
    - n à AMSU algorithm outperforms Dvorak for large TCs





TC Meari (T1105)

3-2. Analysis of SST and SIC

- Sea Surface Temperature (SST)
  - Merged satellite and insitu data Global Daily SST(MGDSST)
  - Data used: AVHRR, AMSR2, and insitu-observation
  - Scale-dependent Optimum Interpolation (OI)
  - Used for NWP models

- Global Sea Ice Concentration (SIC)
  - Data used : SSMIS
  - NASA-team algorithm
  - Used for COBE-SST, reanalysis, NWP, MGDSST
- Regional SIC in the Sea of Okhotsk
  - Data used : AMSR2, MTSAT, AVHRR, MODIS, RADARSAT, SSMIS, aircraft, ship, visual images
  - Subjective analysis
  - Used for SST analysis and NWP, wave model, fax chart

Satellite data processing for MGDSST

NOAA/DDS

GAC Level 1B
NOAA/AVHRR

JAXA

Level 2
GCOM-W/AMSR2

JMA/MSC

HRPT
NOAA/AVHRR

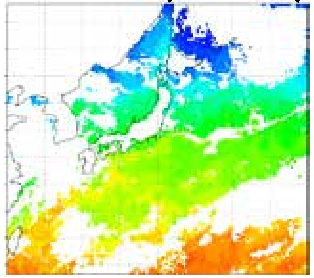
JMA/Office of Marine Prediction

- Clear-sky selection
- Retrieve MCSST
- QC, bias correction
- Daily average in 0.25° grid

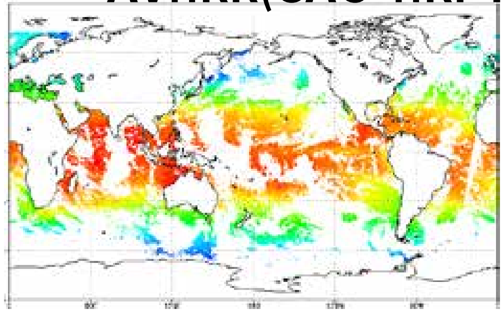
- QC (Shibata, 2004)
- daily average in 0.25° grid
- Bias correction to match in-situ observations

MCSST
0.1 ° x0.1 °

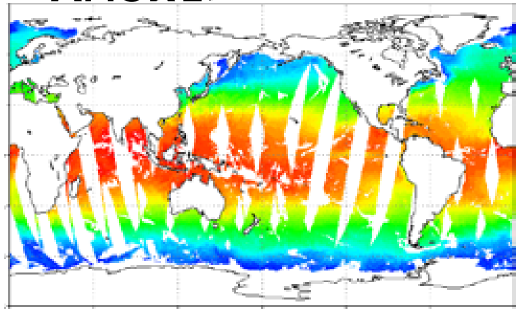
AVHRR(HRPT)



AVHRR(GAC+HRPT)



AMSR2



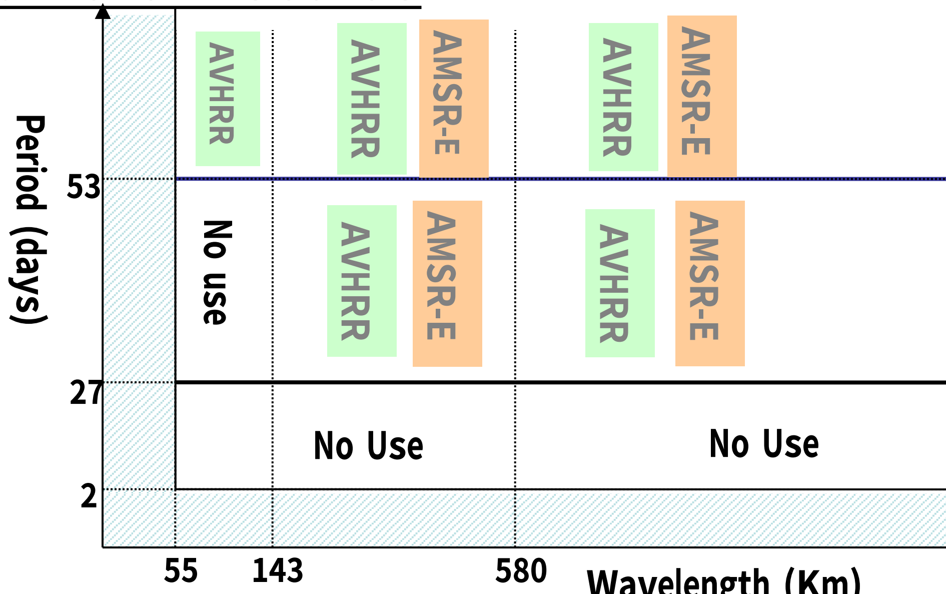
MCSST algorithm

Strong & McClain (1984)

$$T_{SST} = aT_{11} + b(T_{11}-T_{12}) + c(T_{11}-T_{12})(\sec\theta-1) + d$$

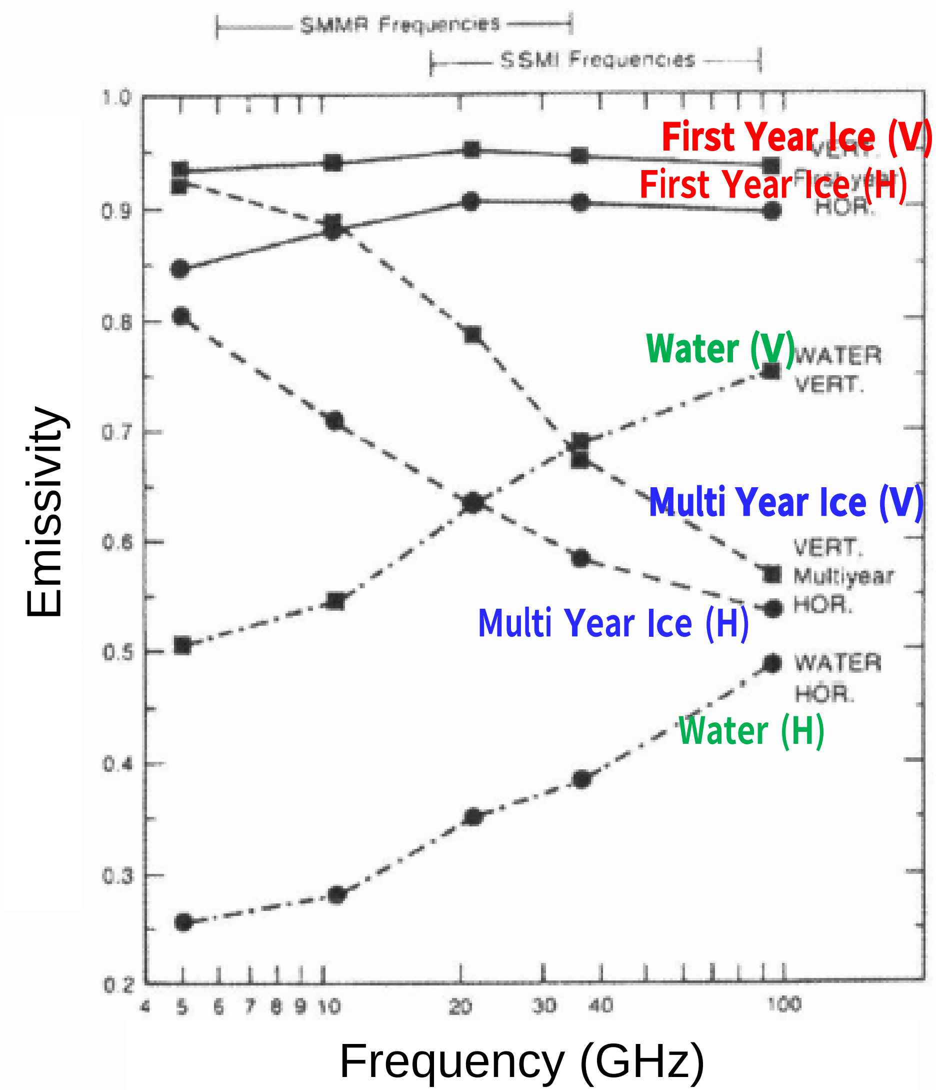
MGDSST processing

1. Make spatial/temporal separation of satellite SST estimates with a Gaussian-filter
   - 56/145/590 km, 2/27/53 days
2. Reduce systematic inconsistency between satellite SST and in-situ SST
   - 2-D Poisson eq. under constraint of in-situ obs boundaries
3. Implement Optimal Interpolation (OI) analyses for AVHRR, AMSR2 and in-situ SSTs <u>at different scales</u>
4. Merge the scale-dependent analysis results



Sea-ice concentration (SIC)

- Used for global SST (MGDSST, NWP) and historical SST analysis (COBE SST; Ishii et al. 2005)
- NASA-team algorithm (Cavarieli et al. 1984, 1991)
  - $SIC = C_f + C_m$
    - $C_x = a_{x0} + a_{x1}P + a_{x2}R + a_{x3}P*R$ x=f (fist year ice) and m (multi-year ice)
    - $P = (T_{19V} - T_{19H})/(T_{19V} + T_{19H})$
    - $R = (T_{37V} - T_{19v})/(T_{37V} + T_{19V})$

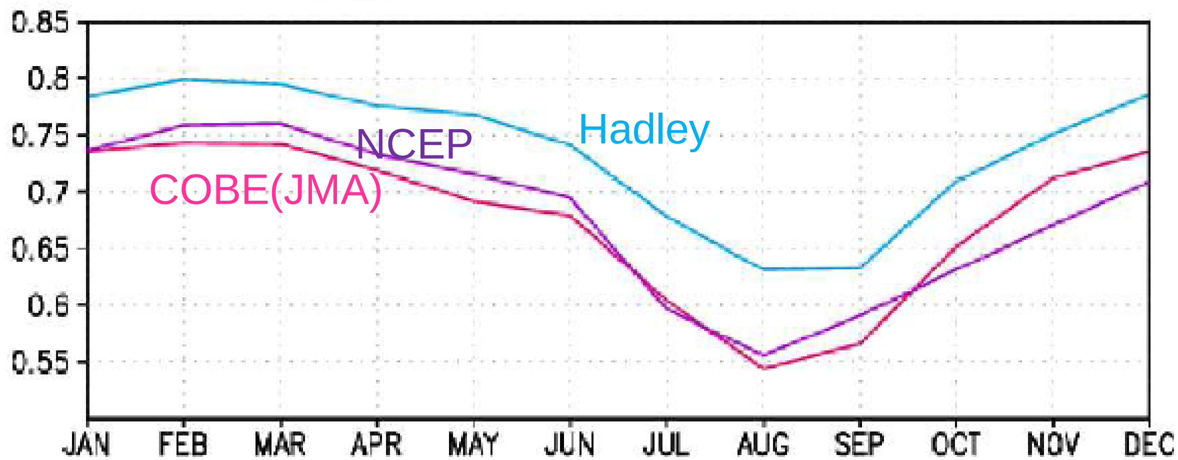


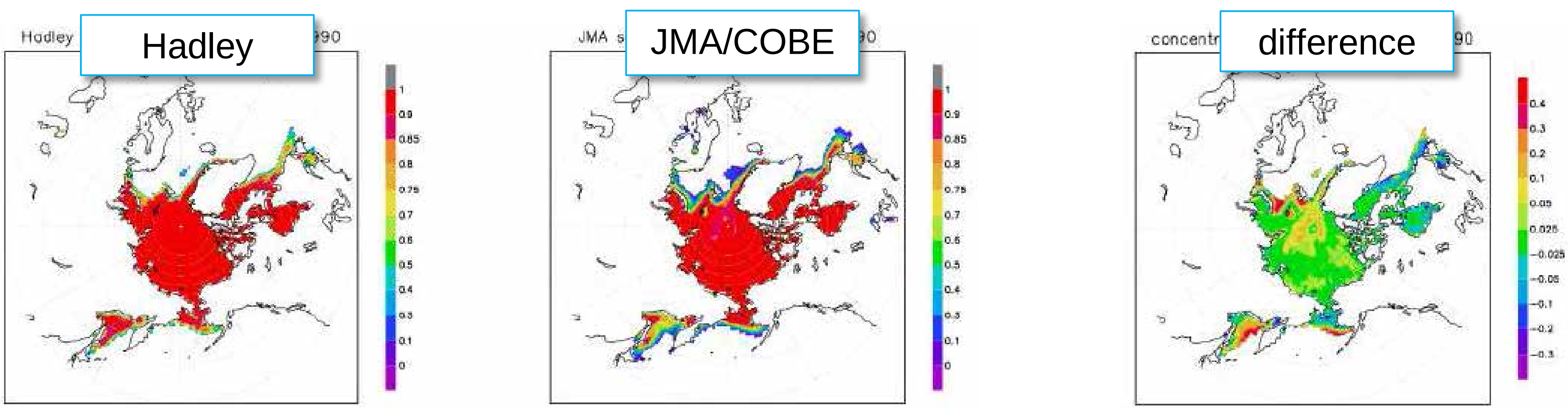
Svendsen et al. (1983)

SIC validation

- SIC in COBE-SST compared with other SIC products
  - Nimbus7/SMMR , DMSP/SSMI
- Lower than Hadley products (Rayner et al. 1984)

Seasonal change of SIC

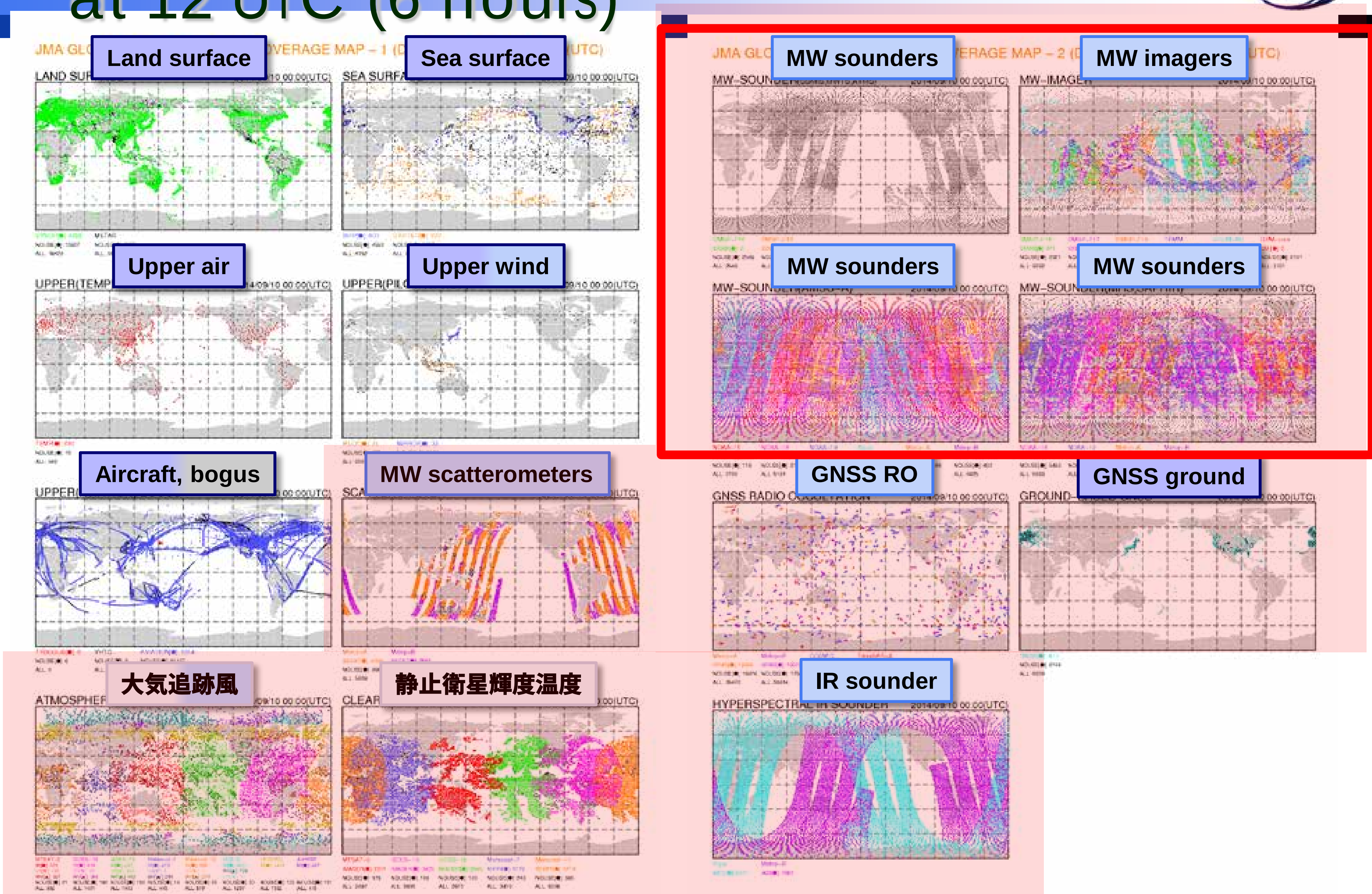




3-3. Data assimilation in NWP

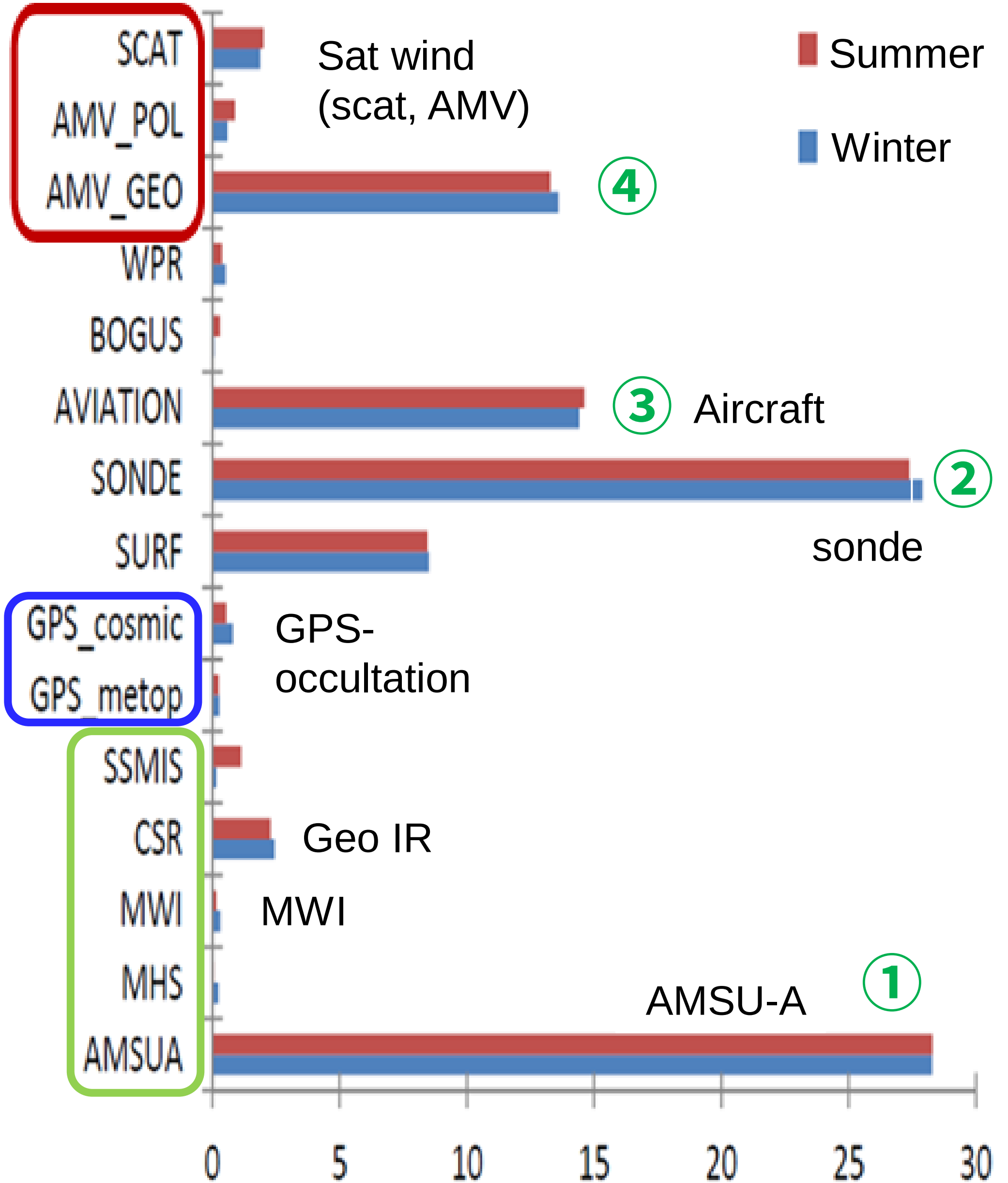
- Assimilate radiance data from MW imagers and sounders in clear-sky conditions
  - Meso-scale analysis assimilates surface rain-rate too
- Radiance of MW sounders bring the biggest impact on NWP forecast skills in terms of synoptic scale field among all observations
  - Accurate T/Q information and wide horizontal and vertical coverage
- Assimilation procedures involves
  - QC, bias correction, radiative transfer calculation, observation error assignment,,,
    - Apply simple cloud/rain retrieval algorithms to detect cloud/rain in QC
    - Note that only a small amount of cloud/rain-affected radiances is assimilated in most NWP centers

Data distribution for global analysis at 12 UTC (6 hours)



Impact of each data type at JMA

- Relative contribution to forecast error reduction in JMA global NWP system
- Greatest impact from MW sounders
- 2nd largest impact from radiosondes
- 3rd aircraft, 4th AMV



Isihbasi (2007)

4. Summary

- Satellite precipitation dataset is used in JMA operations of climate system monitoring and Numerical Weather Prediction (NWP)
  - Meteorological operations requires high accuracy, high frequency, short latency of data delivery, especially for weather information for warning/advisories

- MW imagers and sounders are widely used in the JMA operations
  - Tropical cyclone (TC) analysis, marine forecast (SST and sea ice), land surface forecast (snow), climate analysis (reanalysis) and NWP
- Biggest impact on forecast skills is brought by MW sounders in the global data assimilation system
  - However, current DA system underuses satellite data especially in cloudy/rainy conditions

End

- Thank you for your attention

Backup

Instrument type and its application at JMA

- MW imagers：NWP, reanalysis, TC analysis, SST, sea-ice
- MW sounders：NWP, reanalysis, TC analysis
- IR/VIS imagers : NWP, reanalysis, SST, sea-ice, dust,,,
- IR sounders : NWP, reanalysis, CO2 monitoring
- UV : ozone
- GNSS radio occultation : NWP, reanalysis
- Scatterometers: NWP, reanalysis, wave, ocean, marine information
- SAR：earthquake, sea-ice
- Altimeters : ocean

Comments on operational use of precipitation estimate

- Conditions on operational use
  - Highly accurate
  - Frequently available
  - Short latency of data delivery or long record
- E.g. weather service
  - Currently employs radar-rain gauge composite analysis
  - Hard to satisfy with current satellite observation capability
- Satellite obs can enhance the data coverage especially over the sea
  - If they are available in timely manners