Use of satellite Hyperspectral IR sounder* observation in JMA NWP systems and expectation for future NOAA IR sounding mission

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* hereafter, refer to as HSS
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1. JMA’s deterministic global NWP system

1. Coverage and Impacts of HSS data in JMA global NWP system

1. Usage status of HSS data in JMA global NWP system

1. Impact study of Geo HSS OSSE

1. Summary and expectation for future HSS observation
### JMA’s deterministic NWP model and DA system

<table>
<thead>
<tr>
<th></th>
<th>In Operation</th>
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<tbody>
<tr>
<td><strong>Global Spectral Model</strong> GSM</td>
<td><strong>Meso-Scale Model</strong> MSM</td>
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<tr>
<td><strong>Objectives</strong></td>
<td>Short- and Medium-range weather forecast</td>
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<tr>
<td><strong>Forecast domain</strong></td>
<td>Global</td>
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<tr>
<td><strong>Horizontal resolution</strong></td>
<td>TL959, approx. 20 km (0.1875 deg.)</td>
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<tr>
<td><strong>Vertical levels / Top</strong></td>
<td>128 0.01 hPa</td>
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<tr>
<td><strong>Forecast Hours (Initial time)</strong></td>
<td>264 hours (00, 12 UTC) 132 hours (06, 18 UTC)</td>
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<tr>
<td><strong>Initial Condition</strong></td>
<td>Global Analysis (Hybrid 4D-Var)</td>
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</table>

Satellite and conventional data are assimilated in data assimilation (DA) systems.

- **Global Analysis**
  - 6-hourly DA for delayed and early analysis
  - 6-hr data assimilation window
  - Data cut-off time 2hr 50min. (earliest case)

- **Meso-scale Analysis**
  - 3-hourly DA
  - 3-hr data assimilation window
  - Data cut-off time 50 min.

- **Local Analysis**
  - Hourly DA
  - 3-hr data assimilation window
  - Data cut-off time 30 min.
Dependency of JMA NWP systems and procedure of the data assimilation and NWP model forecasting

Global delayed analysis (Da) can use much observation data with its delayed cut-off time. First-guess from Da is used for early analysis (Ea). And Ea is used as initial condition for global forecast (Ef).

Global forecast (Ef) provides lateral boundary conditions for Meso-scale analysis (Ma). Ma is used as initial condition for Meso-scale forecast (Mf).

Meso-scale forecast (Mf) provides lateral boundary conditions for local analysis (La). La is used as initial condition for local forecast (Lf).

Three DA system use real time satellite data, e.g., MW observations.
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1. Summary and expectation for future HSS observation
Space-based and ground-based observations are assimilated to produce initial conditions in JMA global NWP system.

Hyper IR sounding data are key data set among operationally used observation data in JMA NWP system.

Aqua/AIRS
Metop-A,B/IASI
S-NPP,NOAA-20/CrIS

The used observation data coverage in 12UTC 28 June 2020 early analysis
Space-based and ground-based observations are assimilated to produce initial conditions in JMA global NWP system.

Hyper IR sounding data are key data set among operationally used observation data in JMA NWP system.

Aqua/AIRS
Metop-A,B/IASI
S-NPP,NOAA-20/CrIS

The used observation data coverage in 12UTC 28 June 2020 delayed analysis. Approx. 35% data increase in the delayed analysis.
Major events in HSS data use

2014.09:
Aqua/AIRS, Metop-A,B/IASI radiance data assimilation started.

2017.03:
Suomi-NPP/CrIS radiance data assimilation started.

2018.11:
Suomi-NPP/CrIS radiance data assimilation switched from NSR(Normal Spectral Resolution) to FSR(Full Spectral Resolution)

2019.03:
NOAA-20/CrIS radiance data assimilation started.

2020.12:
S-NPP,NOA-20/CrIS(FSR) Direct Broadcast radiance data assimilation started.

2021.06:
Metop-A,B/IASI radiance dataset assimilation switched from NESDIS(616ch) to EUMETSAT(500ch). Direct Broadcast radiance data(EUMETSAT 500ch) assimilation started.

2021.09:
Metop-A/IASI radiance data assimilation ended.

2021.11:

HSS data accounts for about half of all data.
IASI and CrIS radiance data have been operationally assimilated into JMA’s global Numerical Weather Prediction (NWP) system since September 2014. HSS data contribute to the accuracy of NWP forecasts.
CrIS Coverage by each assimilation slot

Equator crossing times between S-NPP and NOAA-20 is close.
By data assimilation slot, suitable to keep the satellite data coverage for 6-hour interval global data assimilation system.
Use of DBNet data

Global map of DBNet data coverage

The DBNet (Direct Broadcast Network) is an operational arrangement under the World Meteorological Organization to provide NWP centers with ATOVS data received at direct readout stations within 30 minutes of observation.

DBNet data is valuable for operational NWP system, especially for short data cut-off time system.

JMA Global early analysis (6 hourly) data cut-off 2 hr. 50min.

NOAA(0) KMA(17) CONAE(0) EUM(4668) NEA(0) CIMSS(0) JMA(261) BoM(357) INPE(0) CMA(0)
Normalized change of RMSE of Temperature Day 1 forecast

Control: JMA operational global NWP
Test: Data denial experiment
Period: Aug. 2018

Data denial experiment demonstrated Hyperspectral IR sounder has the impact of the forecast accuracy on the upper troposphere.

Warmer: degradation
Colder: improvement
Reference: ERA5
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Usage status of other NWP centers

ITSC-23 HSS NWP Survey
As of 2021.11.26 online

JMA assimilated the HSS radiance data from 15 microns (CO2 band).
Increase of channel for assimilation is our future work.
Used channels

Weighting Function of CrIS

15 microns CO₂  window + O₃  H₂O  Short Wave

<table>
<thead>
<tr>
<th>Pressure level (hPa)</th>
<th>LWIR</th>
<th>MWIR</th>
<th>SWIR</th>
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<tbody>
<tr>
<td>1000</td>
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<td>10</td>
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</table>

27 long-wave temperature sounding channels (around 15 μm)
The Side-2 LWIR Band Anomaly

• 2021.05.21- SNPP/CrIS Side-2 LW failure
• 2021.07.21- switch to Side 1

Side-2                          Side-1
• (no LW)+MW+SW -> LW+(no MW)+SW
• LWIR channels have higher impact than SWIR channels.

Global NWP system assimilates only long-wave bands of HSS. JMA have restarted the assimilation of S-NPP/CrIS on 22 July. When the sensor malfunctions for some reason, thank you for the decision to switch to Side-1 electronics to meet the needs of many numerical weather prediction centers.
Since there is bias in specific FOV, the used FOV number is limited. The original spatial resolution of the instrument cannot be fully utilized. In data assimilation, the data is thinned to eliminate the horizontal observation error correlation. Therefore, the spatial resolution may be acceptable even if it degradates from the current state.

Negative bias only for FOV5
Standard deviation is also larger than other FOVs
Channel Selection

Sensitivity analysis based on Jacobian calculation by RTTOV.

1. Use a channel in the CO2 absorption band with a wavelength of 15 microns (<wavenumber 780 [1 / cm]).

2. Excludes channels that are sensitive to water vapor and ozone.

3. If the channel numbers are adjacent, exclude one channel to reduce the effect of interchannel observation error.

4. check the O-B histogram.
Cloud QC

1. Split Window

- TBB11μm - TBB12μm

- remove cirrus cloud

2. CO2 Slicing  (Eyre and Menzel 1989)

\[
R_{obsi} = (1-N)R_{clr_i} + NR_{cldi}
\]

\[
R_k = (1-N)R_{clr_k} + NR_{cldk}
\]

For the paired IASI CH k,

\[
\left( \frac{R_{obsk} - R_k}{R_{obsk}} \right)^2
\]

By estimating cloud top altitude, assimilate channels in clear-sky or uncontaminated condition.

Snap shot of cloud QC

- PASS
- cloud check
- cirrus check
- Land or Sea check
- Gross Error check
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OSSE(Global) of hyperspectral IR sounder

- Hyper IR sounder is under considered for installation on Himawari follow-on.
- Several experiments were implemented with Okamoto et al. (2020)
  - Operational DA configuration (inc. use of AIRS/CrIS/IASI in global model)
  - Hypothetical IRS on GEO at 140.7 E, hourly full-disk obs w/ 30 km spatial resolution from ERA5
- Global DA (upper figure)
  - ~140 km improvement in typhoon position for 3-d forecast (time of landing)
- Regional DA (bottom figures)
  - Better location of the heaviest rain area which caused devastating floods
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Summary and expectation

- JMA operates global data assimilation system.
- In the global analysis, HSS data mainly are used the CO2 band (15μm), which is sensitive to temperature, and have impacts on the accuracy of NWP in the upper troposphere and stratosphere. Therefore, the continuity of the observation, timely and stable data delivery are highly desired.
- Current two orbit satellite configuration (i.e., morning(Metop), afternoon(JPSS) orbit) is a suitable to keep the satellite data coverage for 6-hour interval global data assimilation system.
- Thanks to the recent switch of S-NPP/CrIS to Side-2 electronics LW-Band (15μm), we continue the use of the HSS data in the assimilation.
- Since there is bias in specific FOV, the original spatial resolution of the instrument cannot be fully utilized. And also, the data is thinned to eliminate the horizontal observation error correlation. Therefore, the spatial resolution may be acceptable even if it degradates from the current spec.
- JMA is under considering the specifications of GEO equipped with HSS (JFY2028: Launch of Himawari 10). OSSE has confirmed that the HSS installed in GEO could contribute to the accuracy of global analysis and forecasts.
Thank you for your attention.