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Update on the Geostationary Extended Observations Sounder radiance proxy datasets

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1. Background

- Geostationary Extended Observations (GeoXO) satellite system scheduled for launch in the 2030s
- Part of WMO GEO ring: GeoXO (US), MTG (Europe), FY4 (China), and Himawari-10 (Japan)
- An unprecedented level of sounding information (T/Q/U/V) for weather forecasting and nowcasting capabilities
- BAE Systems has been selected as the vendor to manufacture the GeoXO Sounder (GXS), the first GEO hyperspectral resolution infrared sounder in USA
- Version 2 (V2) proxy datasets have been generated based on vendor's information and ready for community use

2. V2 Proxy data simulation

- Version 1 proxy datasets assume a Fourier Transform spectroscopy (FTS): spectral response function (SRF) and noise equivalent delta radiance (NEdN) from Performance Operational Requirement Document (PORD)
- Version 2 proxy datasets use a grating system based on vendor's prototype GXS SRF and best estimate NEdN

2.1 SRF

- BAE GXS has much more channels than FTS (1563)
- BAE GXS has much smaller spacing than FTS (0.625 cm^{-1})
- BAE GXS likely has more information content than FTS

Spectroscopy type	Grating
Spectral Range	Longwave: 680-1095 cm^{-1} Midwave: 1689-2250 cm^{-1}
Spectral Resolution	0.54 to 0.61 cm^{-1}
Spacing	0.15 to 0.59 cm^{-1}
# of spectral detectors binned	1-9
# of channels	2402
GSD	4 km
Refresh Rate	60 min for Sounding Disk

Table 1. Key spectral information of GXS

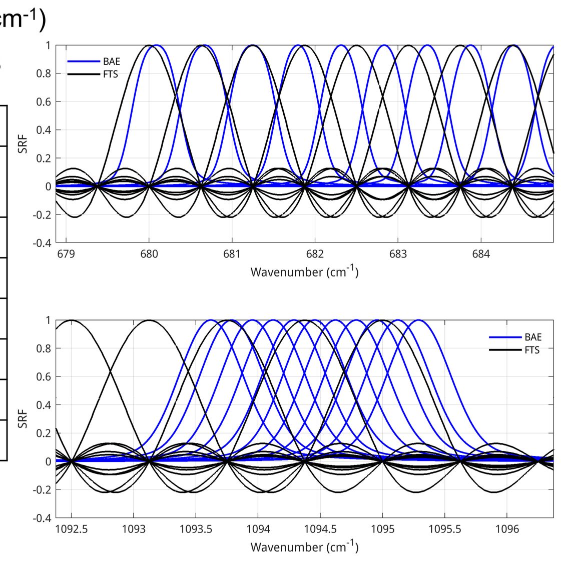

Fig. 1. SRF for an FTS with a spectral resolution of 0.625 cm^{-1} and BAE GXS

2.2 NEdN

- BAE GXS is expected to have less noise than FTS based on PORD, but more noise than CrIS
- BAE GXS likely has more information content than FTS based on PORD

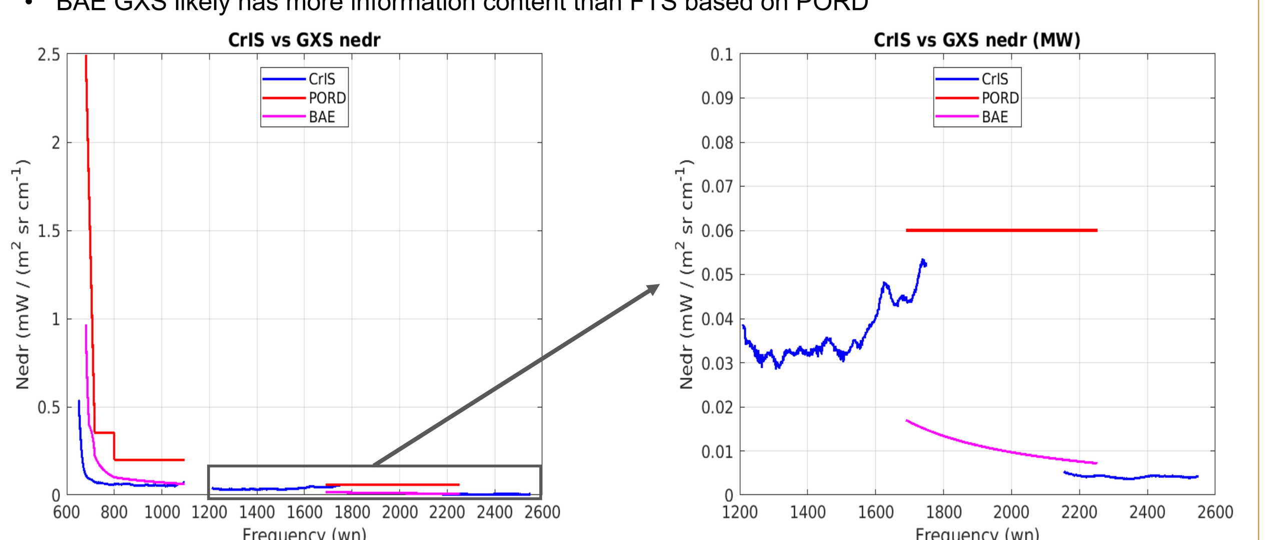

Fig. 2. NEdN from CrIS (blue), FTS GXS based on PORD, and BAE best estimate

2.3 Radiative Transfer Model (RTM)

- Using different RTMs for radiance simulation and applications (i.e. retrievals and assimilations) avoids perfect RTM assumption in simulation studies
- CIMSS/SSEC/UW-Madison in-house RTM model used
  - Pressure layer Fast Algorithm for AtmoSpheric Transmittances (PFAAST)
  - All sky capability, coupled with the Texas A&M cloudy model
- Coefficients generated based on BAE SRF
- Comparison with CRTM shows very small standard deviation of differences.
- Relatively large biases are seen especially for absorption channels, due to the different versions of LBLRTM used.

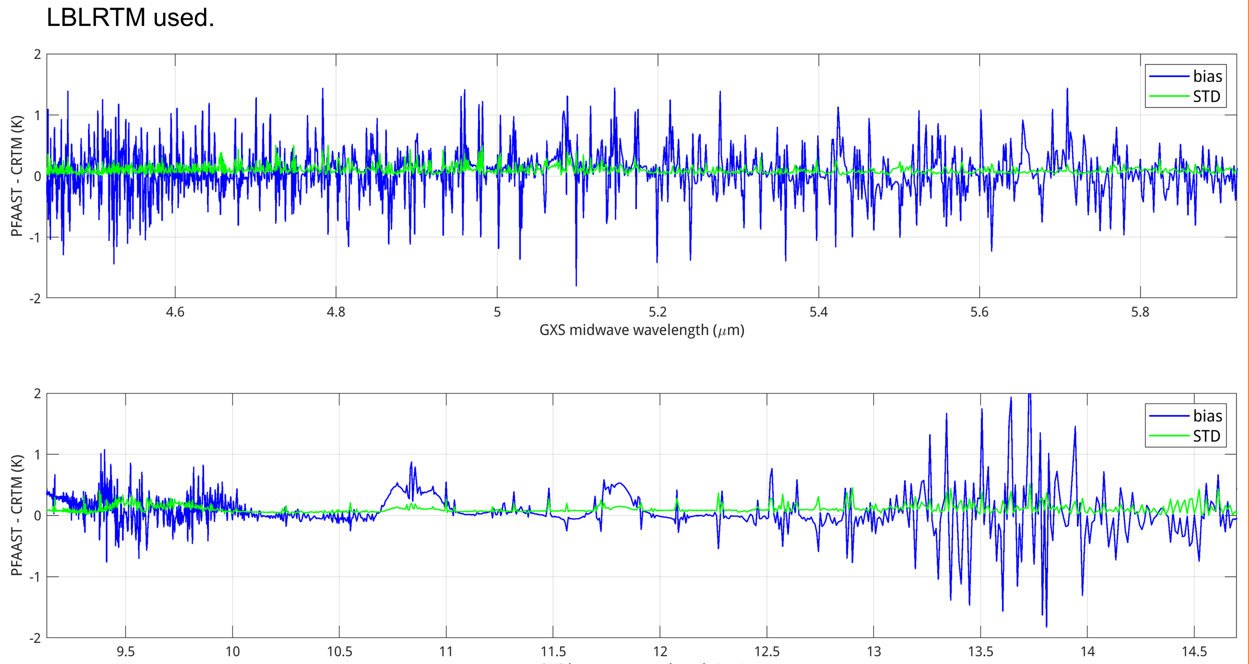

Fig. 3. Biases (blue) and standard deviations (green) of the differences (CRTM – PFAAST) for 6 typical atmospheric profiles

2.4 Numerical Weather Prediction (NWP) field

- ECMWF Experimental nature run at global 1-km resolution (XNR1K) from Oak Ridge Leadership Computing Facility (OLCF) at Oak Ridge National Laboratory
- 15-minute interval
- 3 local severe storm cases over CONUS from August/September 2019
  - Limited to Continental US (CONUS) to reduce data volume
  - 36-72 hours for each case (total 158 hours)
- 1 full disk case (18 hours)
- Information of atmosphere, surface and clouds as inputs for RTM
- Spatially interpolated to GXS 4-km field of views with angle and footprint size considered
- Same data used for V1 proxy datasets

2.5 GXS Proxy datasets

- Output in NetCDF format, variables include
  - T, Q, U, V, skin temperature, emissivity, and surface pressure
  - Latitude, longitude, satellite zenith and azimuth angles, solar zenith and azimuth angles
  - Brightness temperature and random observation noise (based on BAE NEdN)
  - Cloud top pressure, cloud optical thickness, cloud particle size, phase, and cloud fraction
  - Ready for community use. See summary section on how to access the data

3. Simulated brightness temperature

3.1 CONUS

- Brightness temperature imagery of a window channel of 909.23 cm^{-1} (Fig. 4)
- Nice cloud patterns, such as convections and a tropical cyclone
- High clouds have colder brightness temperatures
- High clouds are ice clouds and low clouds are water clouds

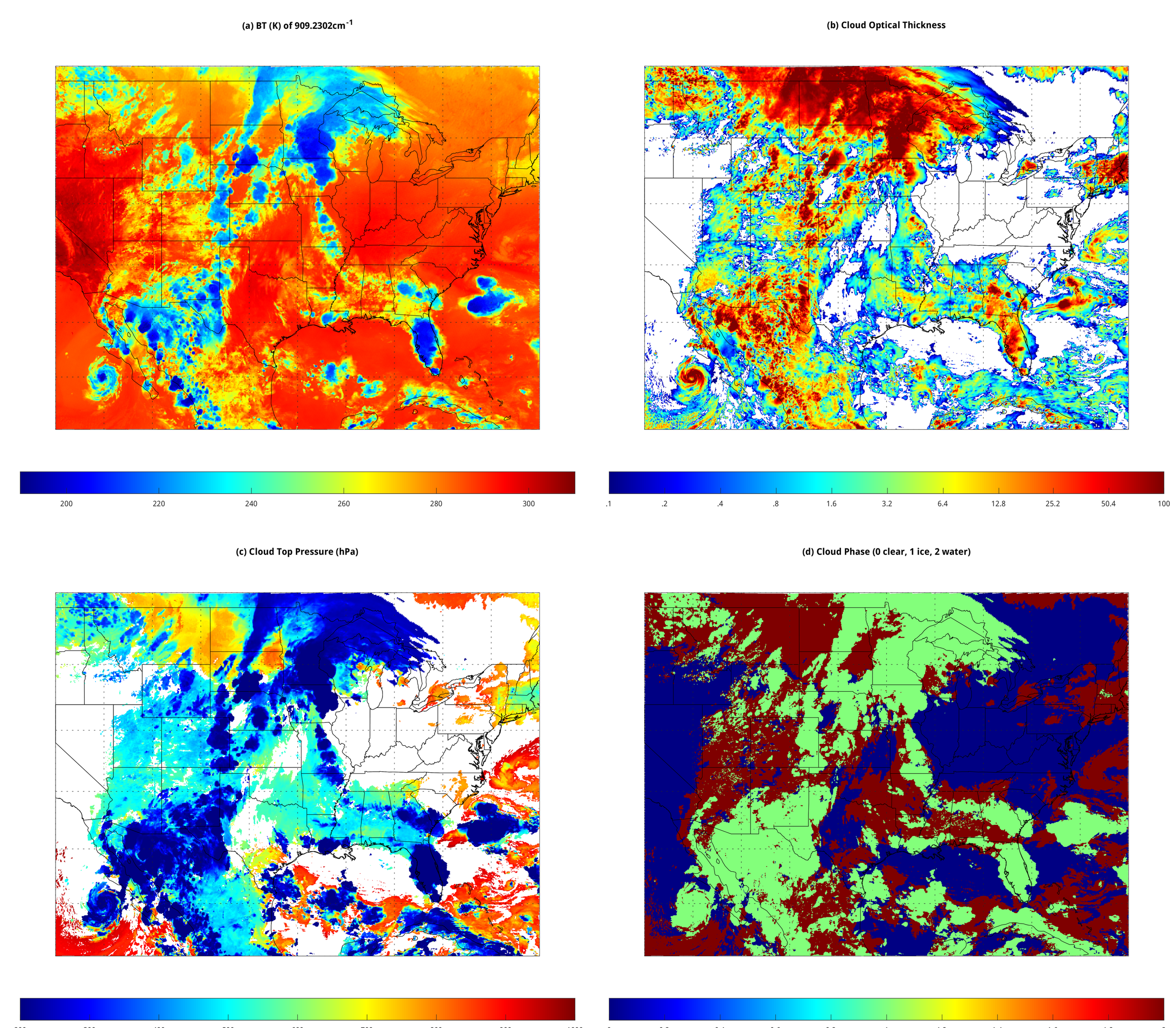

Fig. 4. Simulated GXS CONUS (a) all sky brightness temperature (K) of 909.2302 cm^{-1}, (b) the cloud optical thickness, (c) cloud top pressure (hPa), and (d) the cloud phase at 00:15 UTC on September 6 2019.

3.2 Sounding disk

- ITCZ clearly seen
- Noise is random and consistent with NEdN
- More noise in cold scene like cloudy region

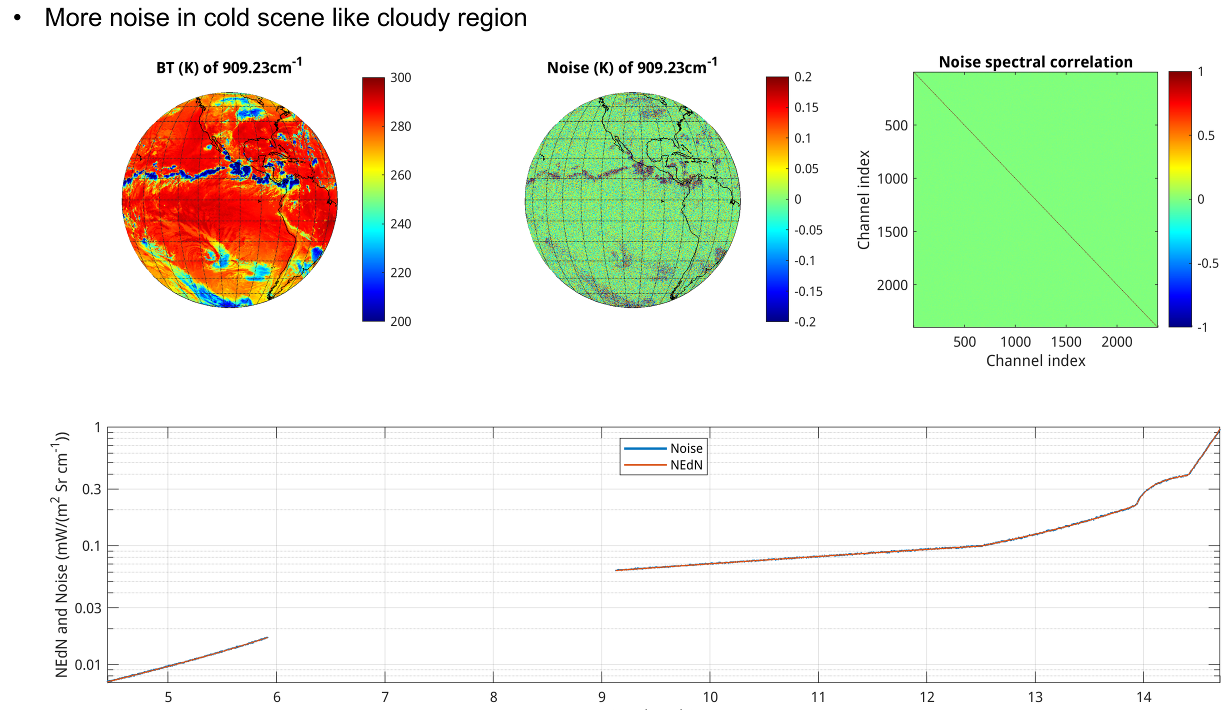

Fig. 5. Simulated GXS sounding disk all sky brightness temperature (K) of 909.2302 cm^{-1} (top left), the observation noise (in BT unit, top middle), noise spectral correlation (top right), as well as the NEdN and noise (in radiance unit) (lower).

4. Potential applications of proxy datasets

4.1 Demo of GXS scan pattern

- While the GXS scan pattern has not been determined, the potential options include
  - Zone 1 to 5 repeatedly, approximately 30 min to scan the disk
  - Zone 1/2/3, followed by zone 1/2/4 and 1/2/5. More frequent observations over northern hemisphere are beneficial for quality 3D winds, which is critically important for NWP applications
  - The regional and CONUS scan can be planned as well
- Slit is oriented N/S and projected onto the field of regard
- One slit image samples 3.48 deg of N/S field of view
- Scan mirror slews slit image from West to East over the scan swath
- Swaths are scanned roughly 3.7 deg per minute

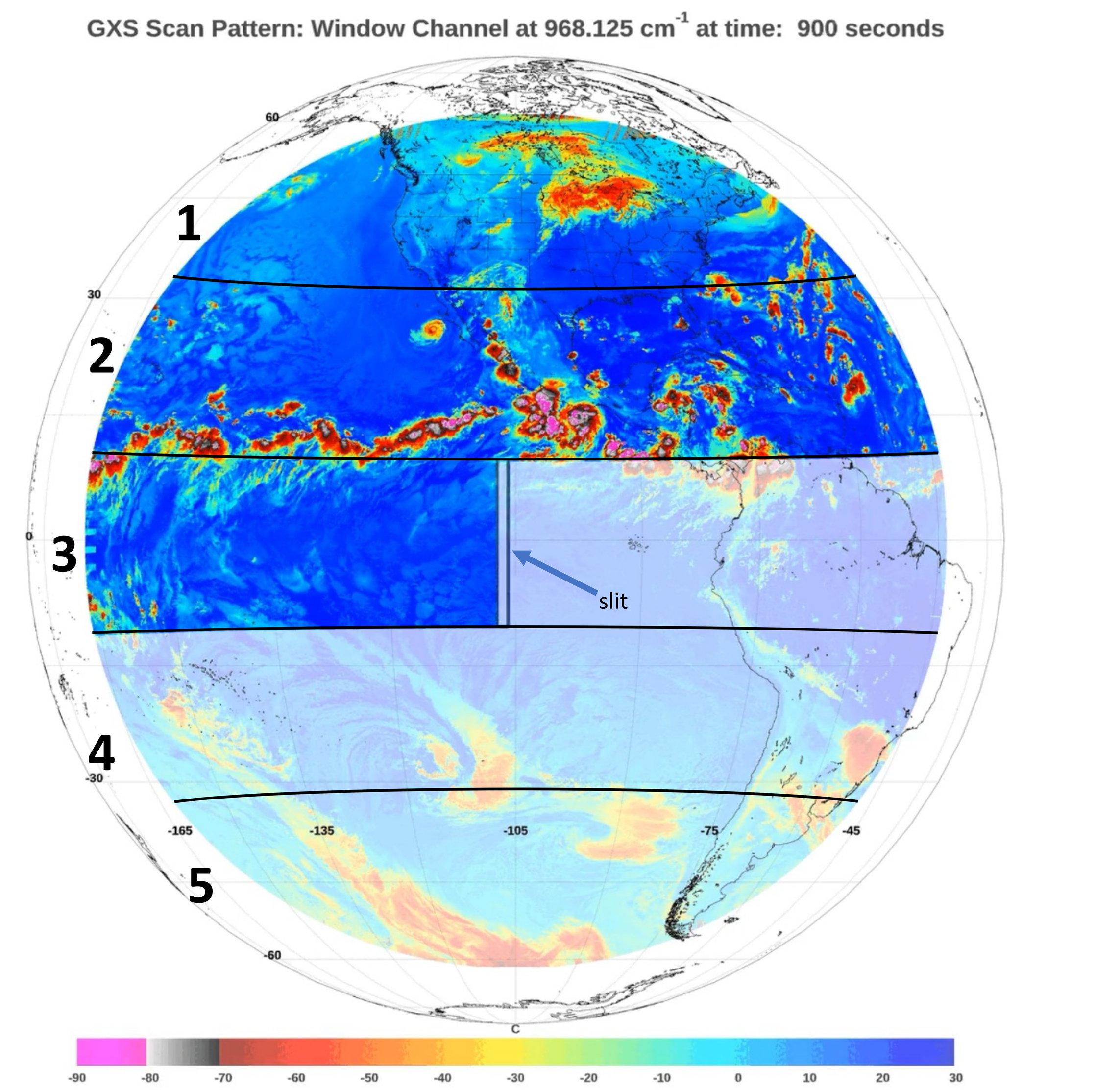

Fig. 6. Demo of GXS scan pattern using the proxy datasets for sounding disk. The 5 zones represent the 5 scans from west to east by the slit.

4.2 Temperature inversion monitoring

The rotational water vapor lines in the infrared window region are sensitive to low level atmosphere. The online/offline duo can be used to monitor the evolution of the temperature inversion in lower atmosphere.

4.2.1 Cross-section imagery

- 28 pairs of online/offline selected, ordered from strong to weak absorptions (top to bottom)
- 3 sets of cross section imagery: top panel shows the online/offline differences, and the bottom panel show the temperature difference from the lowest 20 levels above surface compared to the lowest level
- Strong inversions at 13:00 UTC: positive online – offline differences
- Medium inversions at 15:00 UTC: neutral online – offline differences
- No inversions at 20:00 UTC: negative online – offline differences

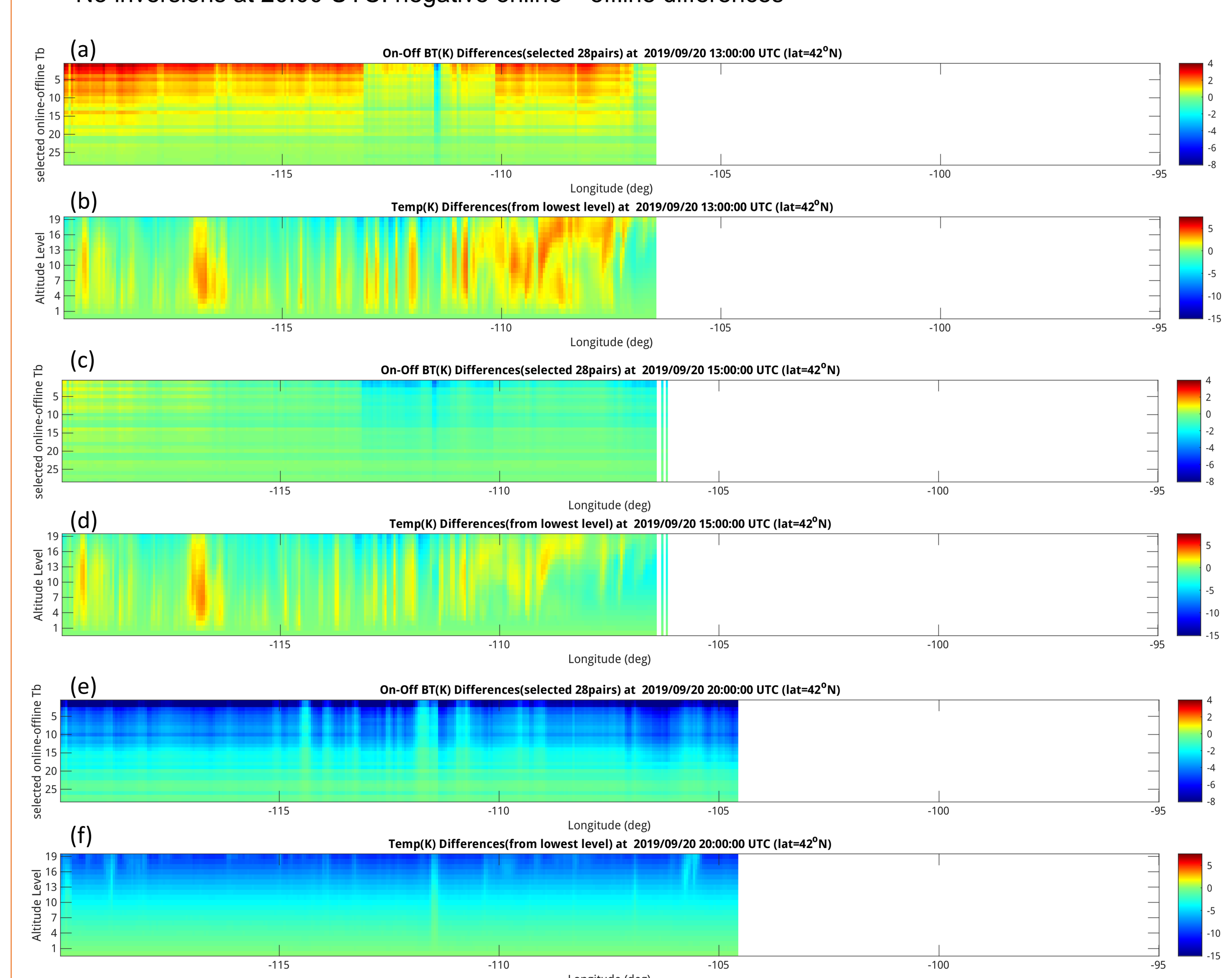

Fig. 7. Cross-section of (a/c/e) the 28 pairs of online – offline differences and (b/d/f) the temperature difference from the lowest 20 levels compared to the lowest level from (a/b) strong inversions at 13 UTC, (c/d) medium inversions at 15 UTC, and (e/f) no inversions at 20 UTC.

4.2.2 Sounding retrievals

- Deep neural network (DNN) based sounding retrievals
- The inversions start to build up around 02:00 UTC, slowly strength, reaching peak around 13:45 UTC; the dissipation starts around 14:00 UTC, becomes very quick once the sun comes out, no longer visible around 19:00 UTC.
- The retrievals capture the evolution of temperature inversions very well
- The moisture profiles are well retrieved as well
- The surface pressure is around 800 hPa at this Wyoming location

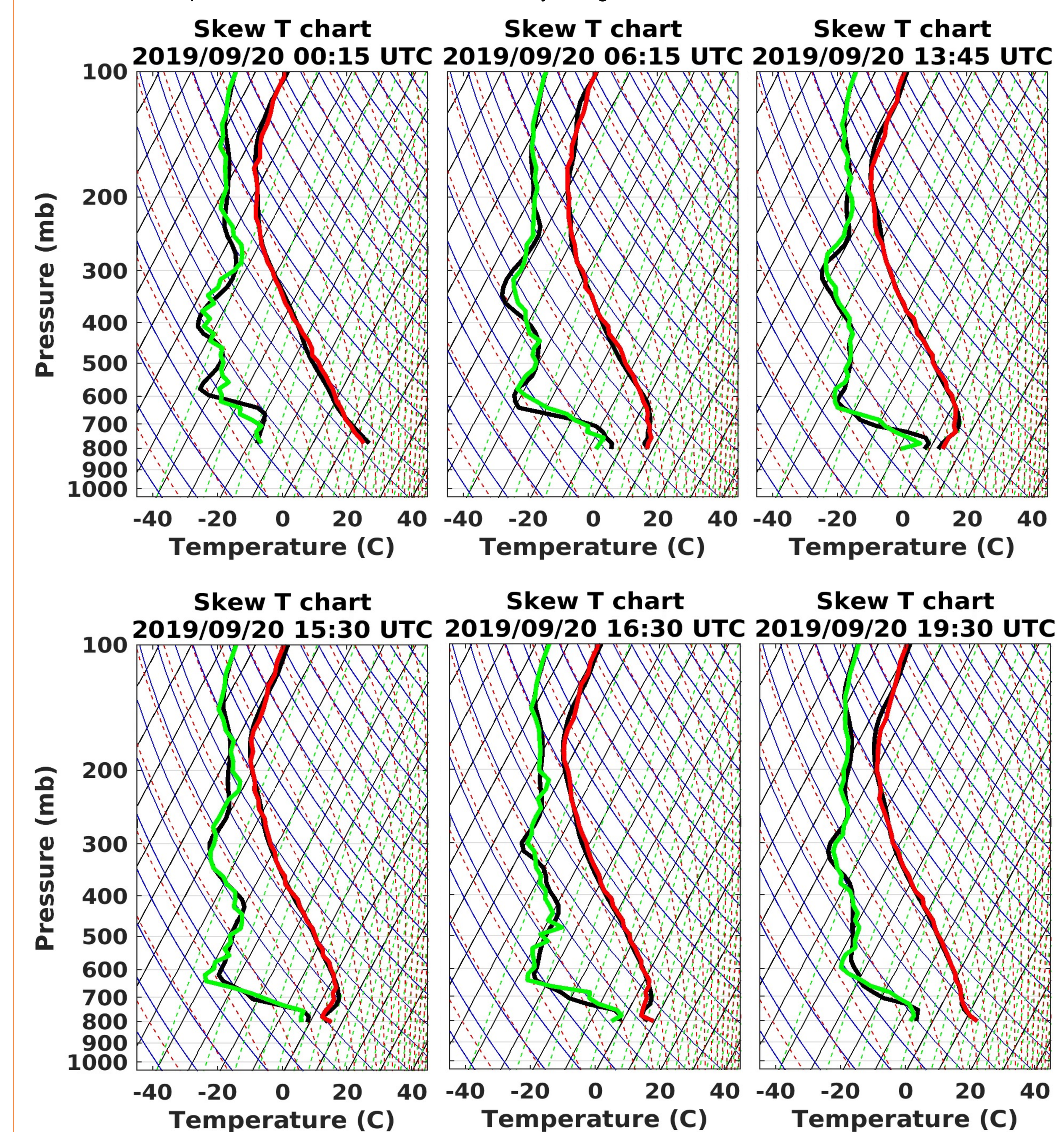

Fig. 8. Skew T chart of temperature and dew point from (red or green) DNN-based sounding retrievals and (black) the truth at 00:15 UTC, 06:15 UTC, 13:45, 15:30, 16:30, and 19:30 UTC

4.3 Sounding information content analysis

- GXS BAE has comparable information content as CrIS, both of which significantly more than GXI

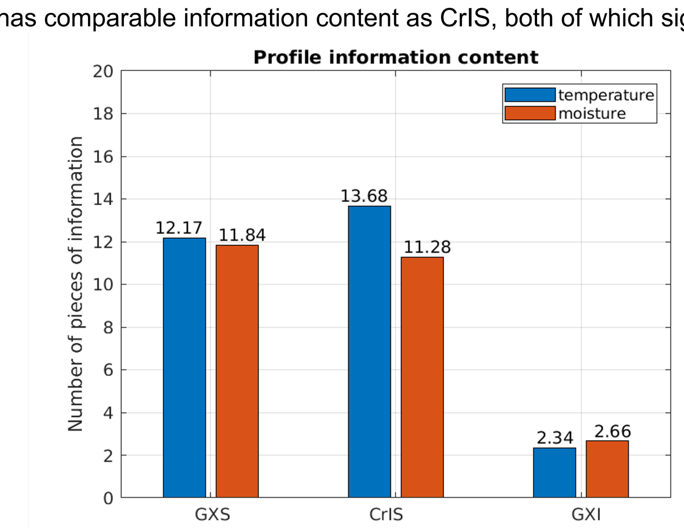

Fig. 9. Number of pierces of information (sum of vertical degree of freedom) for GXS BAE, CrIS, and GXI. Clear sky only.

4.4 T/Q sounding retrieval algorithm development and severe storm nowcasting

See Li et al (presentation 1A.6 at 9:45am on Jan 13) for more information about GXS sounding retrieval algorithm development using deep neural network and the severe storm nowcasting

5. Summary

- NOAA's next generation geostationary satellite system GeoXO is scheduled to launch in 2030s.
- The GXS is going to be the nation's first GEO hyperspectral infrared sounder
- BAE Systems has been selected as the vendor to manufacture the GXS instrument
- GXS proxy datasets V2 have been generated and ready for community use
  - 1-km ECMWF nature run (XNR1K) as input
  - CIMSS/SSEC/UW-Madison in-house PFAAST
  - 3 CONUS local severe storm cases (36-72 hours) and 1 full disk case (18 hours)
  - Outputs in NetCDF including T/Q/U/V/Ts/Emis/lat/lon/geometry/BT/noise/clouds
  - Proxy datasets can be used for various quantitative and qualitative applications
- Visit https://www.ssec.wisc.edu/geo-ir-sounder/proxy-data-demonstration/ for information on access of the GXS proxy datasets
- Contact Zhenglong Li (zhenglong.li@ssec.wisc.edu) with any questions

6. Acknowledgement

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