GOES-R Sounder: Hyper-spectral Environmental Suite (HES)

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in collaboration with

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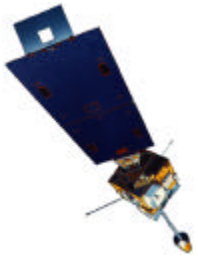
Cooperative Institute for Meteorological Satellite Studies (CIMSS)

Madison, WI

And the HES PORD Team



MURI Meeting
May 29, 2003

UW-Madison

The road to HES-IR

(~1600) ***HES*** (geo operational)

(~1600) ***GIFTS*** (geo experimental)

CrIS (leo operational)

(~3600) **IASI** (leo operational)

(~2400) **AIRS** (leo pseudo-operational)

NAST-I (airborne experimental)

IMG (leo experimental)

(18) ***GOES Sounder*** (geo operational)

HIS (airborne experimental)

(12) ***VAS*** (geo experimental)

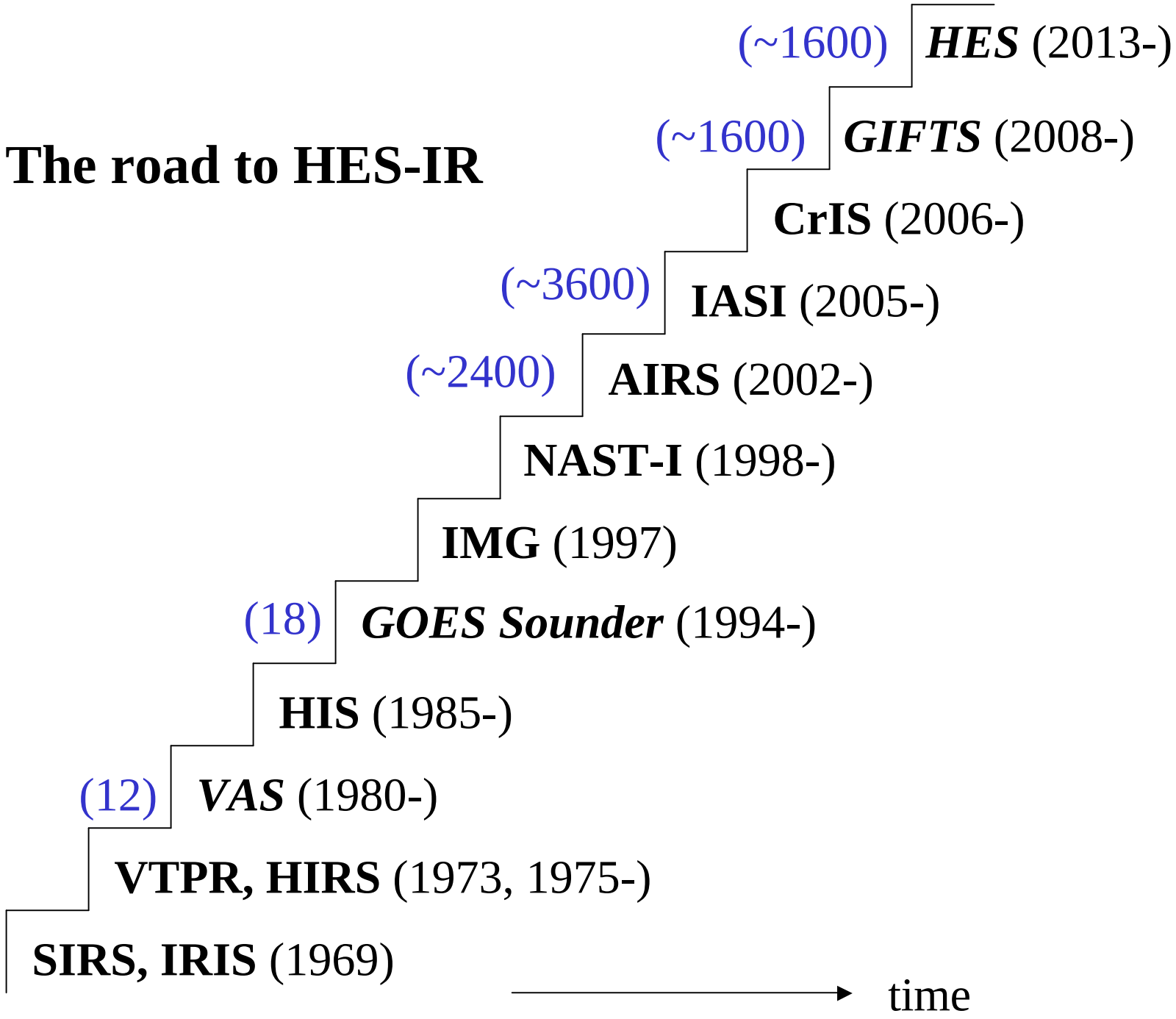
VTPR, HIRS (leo operational)

SIRS, IRIS (leo experimental)

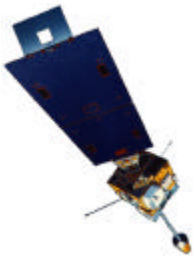
(# of spectral bands)

time

The road to HES-IR



Future GOES

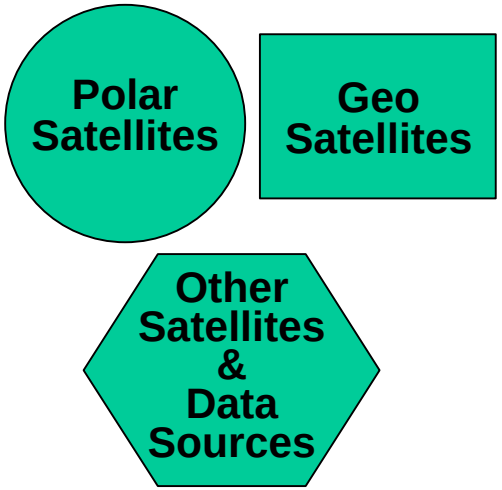


Future GOES will address all four key remote sensing areas

* **spatial resolution** – what picture element size is required to identify feature of interest and to capture its spatial variability;
* **spectral coverage and resolution** – what part of EM spectrum at each spatial element should be measured, and with what spectral resolution, to analyze an atmospheric or surface parameter;
* **temporal resolution** – how often does feature of interest need to be observed; and
* **radiometric resolution** – what signal to noise is required and how accurate does an observation need to be.

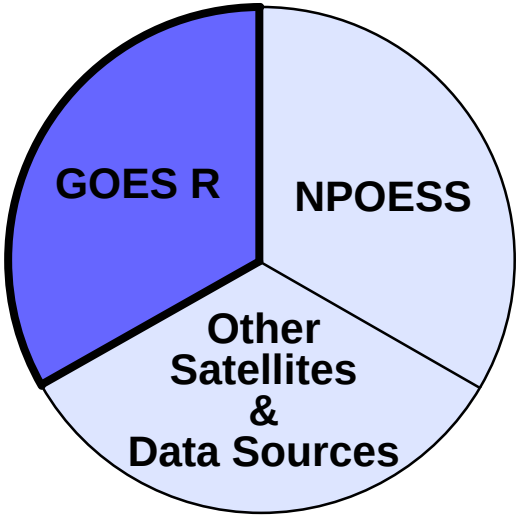
Goal - Transition from Individual Systems to "System of Systems" Architecture

Today



Programs formulated independent of one another

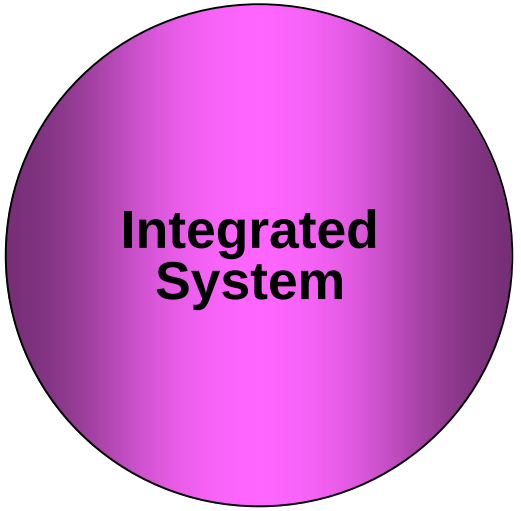
2012



Formulate integrated system – GOES R with

- **Defined NPOESS**
- **Structured approach to including Other Satellites**

2020+



Programs formulated as one integrated system

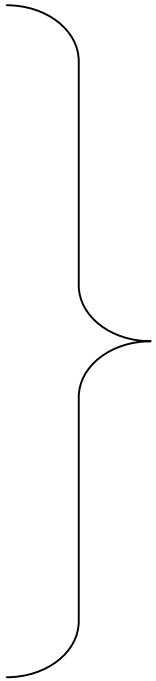
HES

- The Hyperspectral Environmental Suite (HES) will be located on a geostationary platform.
  - 2013
  - NOAA operational
  - Currently in formation phase

- HES is an outgrowth of earlier ABS efforts
  - HES includes the functionality of the old Advanced Baseline Sounder (ABS)
  - HES has been expanded to include other capabilities for environmental monitoring employing the improved temporal resolution from GEO.
    - Coastal Ocean
    - Open Ocean
    - Land

HES Tasks

- HES - Disk Sounding (HES-DS)
  - Formerly ABS -- Threshold Task
- HES - Severe Weather / Mesoscale (HES-SW/M)
  - Threshold Task
- HES - Coastal Waters (HES-CW)
  - Threshold Task
- HES - Ocean Waters (HES-OO)
  - Goal Task
- HES - Land (HES-L)
  - Goal Task



Not covered in this talk

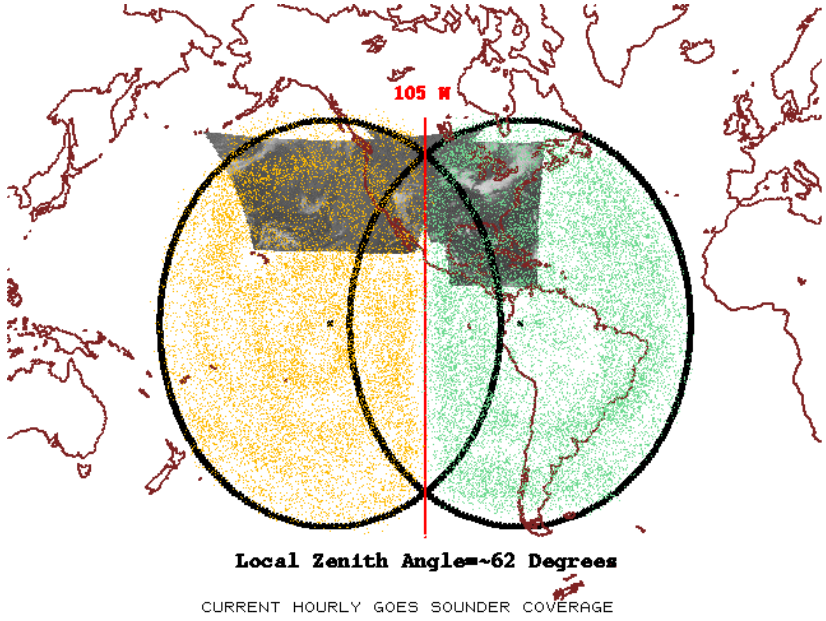
HES Tasks

- HES - Disk Sounding (HES-DS)
  - Provide **vertical moisture and temperature information**, and **other environmental data** that will be used by NOAA and other public and private agencies to produce routine meteorological analyses and forecasts
  - Provide data that may be used to extend knowledge and understanding of the atmosphere and its processes in order to **improve short/long-term weather forecasts**.

- HES - Severe Weather / Mesoscale (HES-SW/M)
  - Provide **environmental data** that can be used to expand knowledge of **mesoscale** and synoptic scale storm development and provide data that may be used to help in forecasting severe weather events.
  - Backup mode in the event of a GOES-R ABI failure (both).

HES-Disk Sounding (HES-DS) task

- Spatial Resolution
  - IR: Threshold=10 km, Goal=2 km,
  - Vis: Threshold=1.0 km, Goal= 0.5 km
- Coverage rate (Threshold)
  - 62 degree LZA / hour at 10 km resolution
    - Coverage area must be flexible and selectable.



HES-Disk Sounding (HES-DS) task

- Spectral Coverage
  - Three specific examples of coverage have been defined
  - Essentially: 15 um CO_2 band for temperature, clear windows from 13 um and extending past the ozone band at 9.6 um to 8.3 um, and either side of the 6 um H_2O band. More temperature: Coverage of 4.7 um to 4.4 um and goal coverage of 4.7 um to 3.7 um. Visible: 0.52-0.7 um

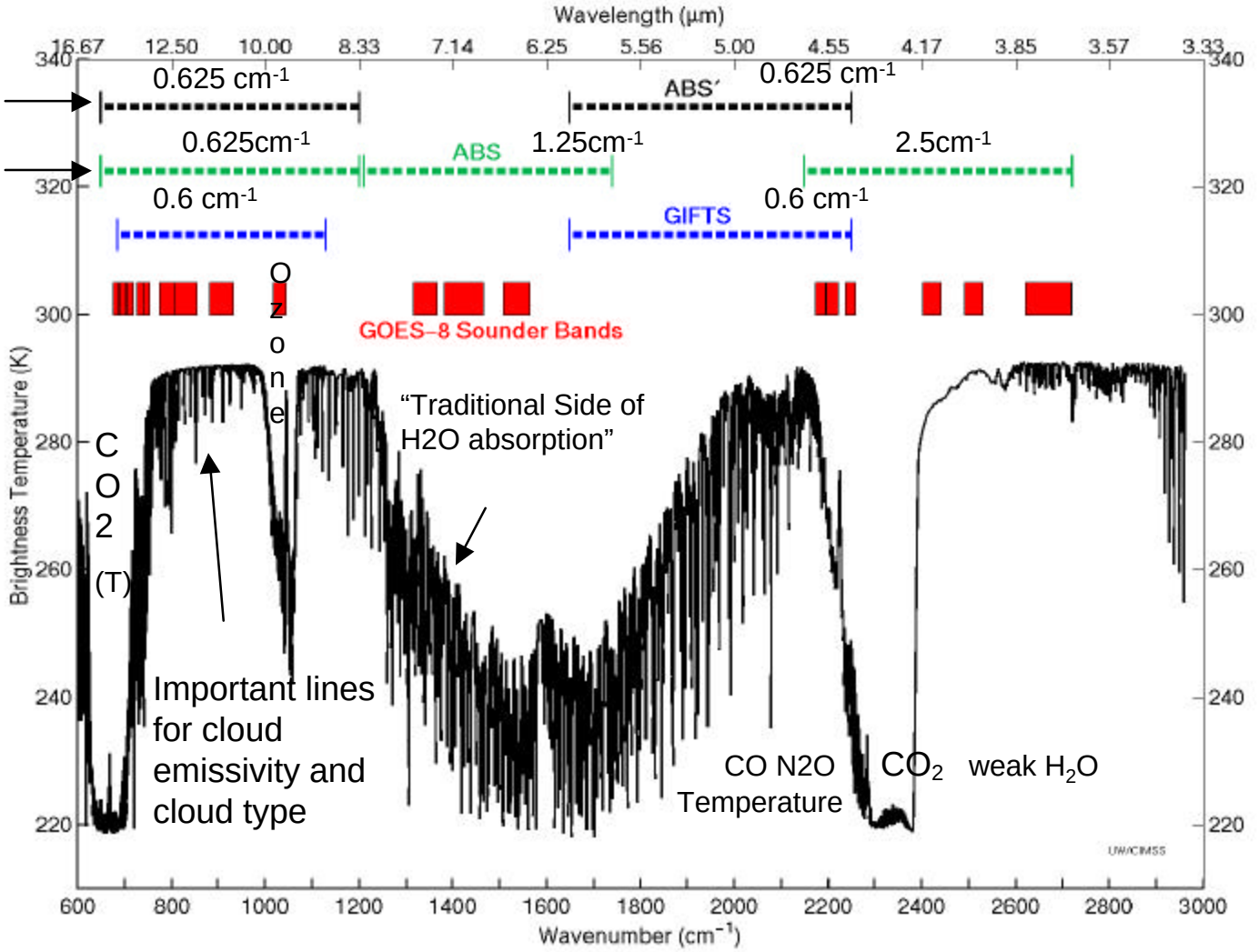
- Spectral resolution:
  - 15 um CO_2 band: 0.6 cm^{-1}, Windows: 0.6-1.0 cm^{-1}, Ozone: 1 cm^{-1}, H_2O: 1-2 cm^{-1}, near 4 um: 2.5 cm-1, Visible: 0.18 um

IR Spectral Coverage (DS or SW/M)

Example 1

Example 2

(Example 3 not shown)



Some uses of the **current GOES Sounder**

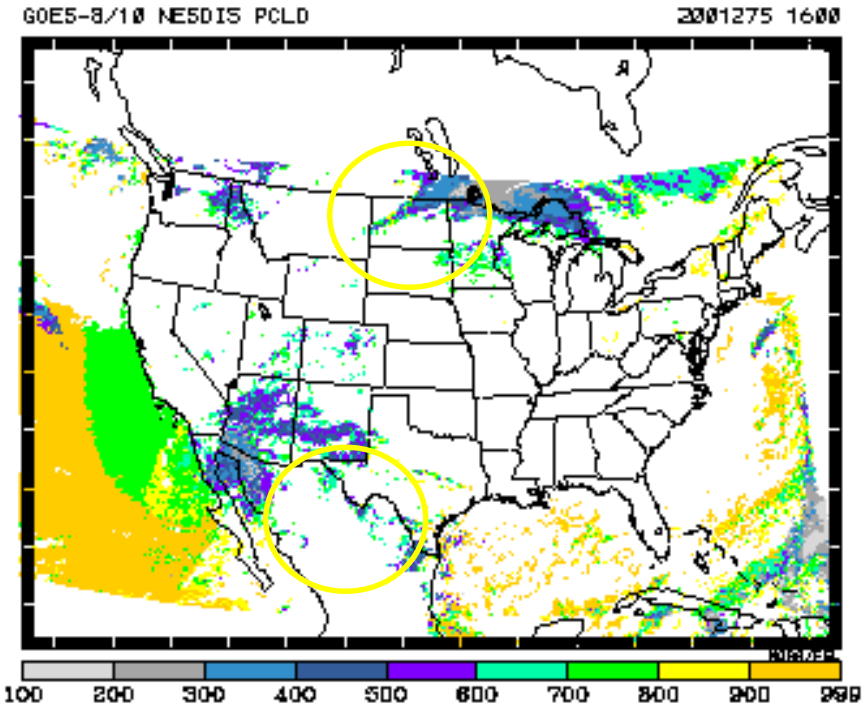
NWP (Numerical Weather Prediction):

- Clear-sky radiances (Global, Eta)
- Precipitable water layers (CRAS, RUC, Eta)
- Cloud-top information (CRAS, RUC)
- Winds (NOGAPS)

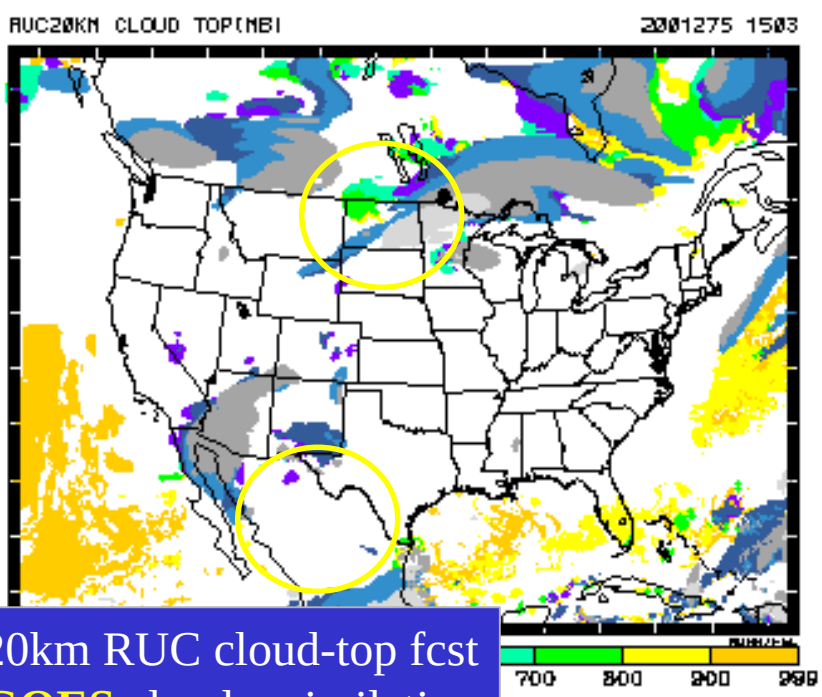
Nowcasting/short-term forecasting:

TPW	Skin Temperature
Lifted Index	CAPE
Total Ozone	Images
Cloud Height	Effective Cloud Amount

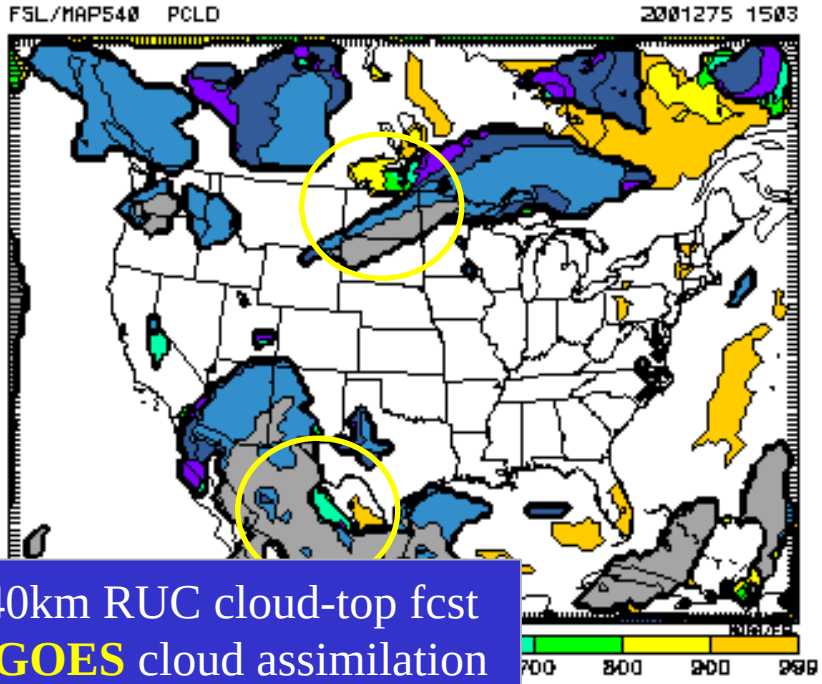
The range of uses will dramatically increase with the improved spatial, spectral and temporal coverage of the HES-IR.



Verification
Cloud-top pressure
based on NESDIS product



3h 20km RUC cloud-top fcst
w/ GOES cloud assimilation



3h 40km RUC cloud-top fcst
No GOES cloud assimilation

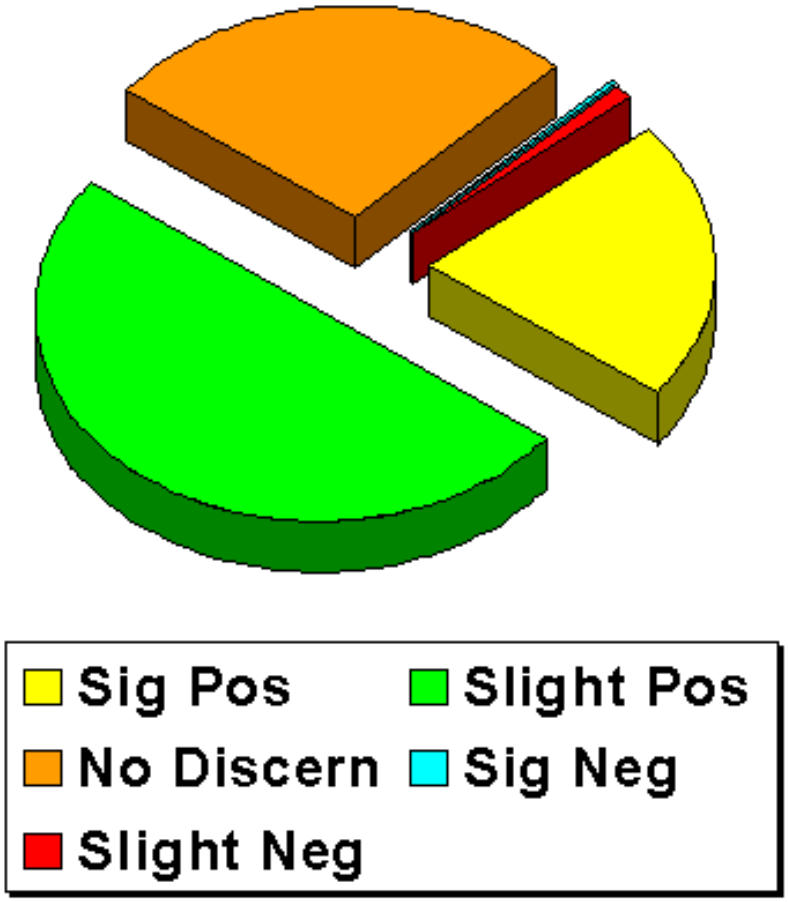
Effect of GOES (sounder cloud) data on 3-h RUC cloud **forecasts**

"much improved cloud forecasts"

Stan Benjamin – NOAA/FSL

1800 UTC
Tues 2 Oct 2001

NWS Forecast Office Assessment of GOES Sounder Total Precipitable Water

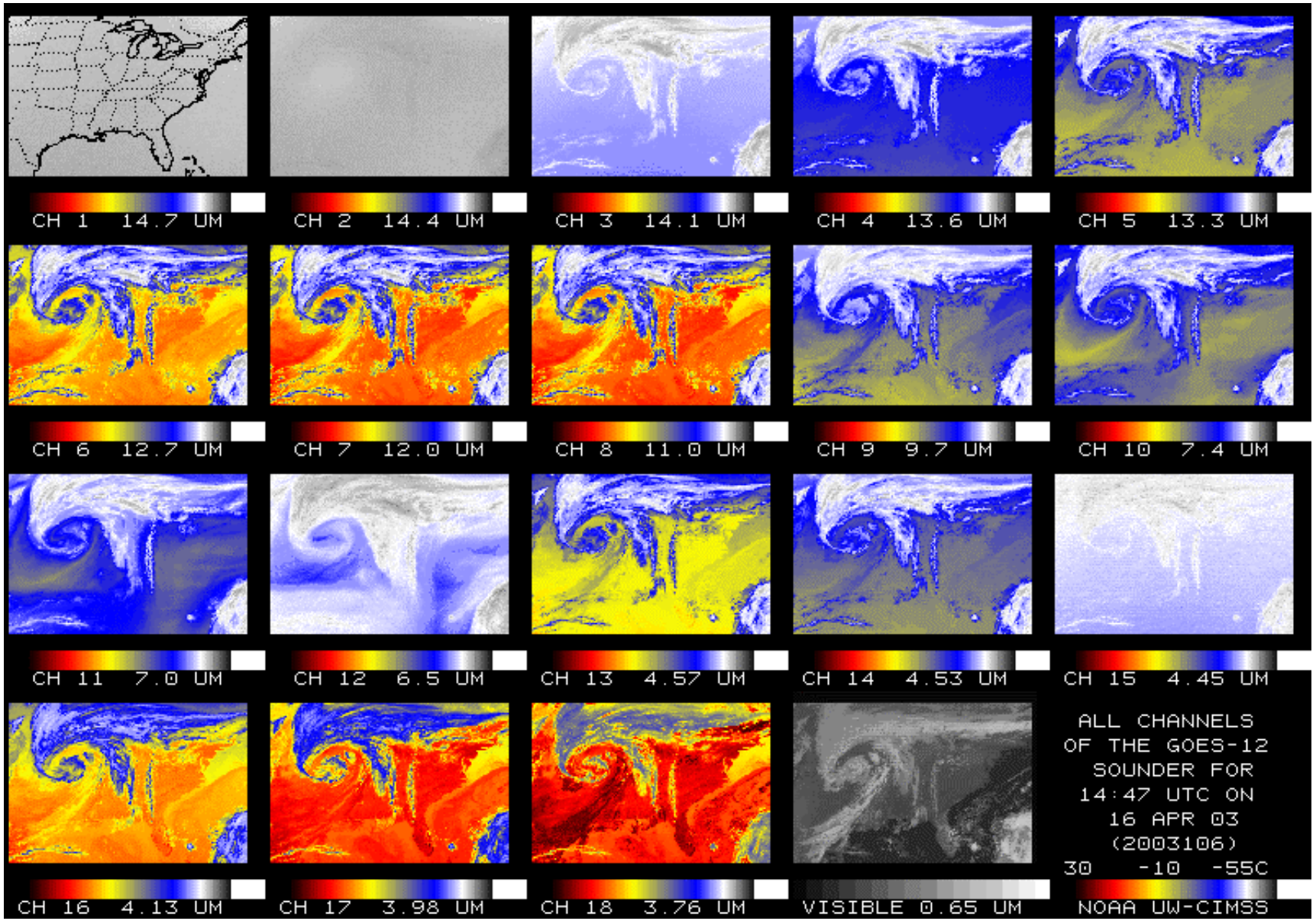


Summer 99 Forecaster assessment of usefulness of changes in hourly TPW product for precipitation forecast

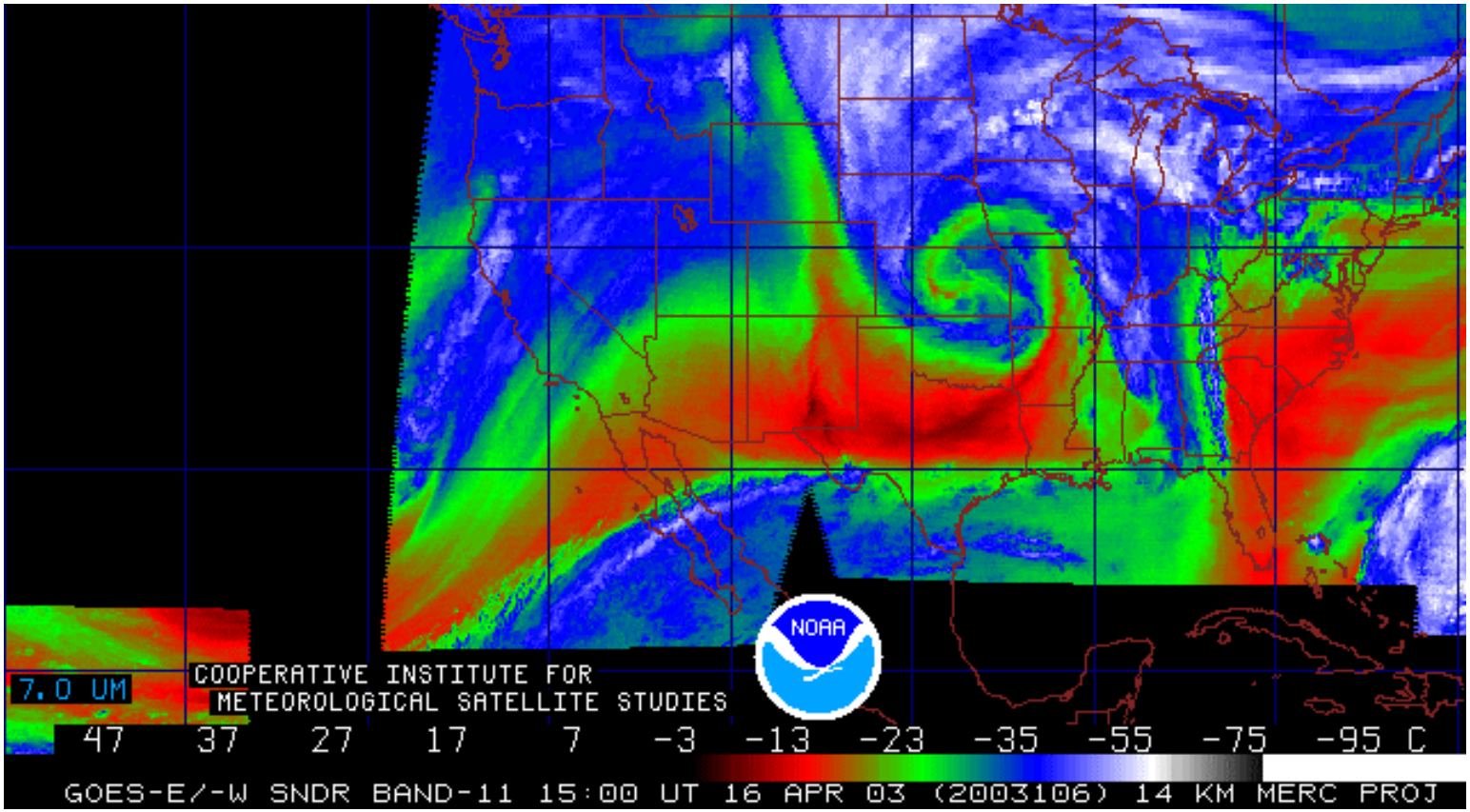
Out of 207 weather cases.
- Significant Positive Impact (21.3%)
- Slight Positive Impact (50.2%)
- No Discernible Impact (27%)
- Slight Negative Impact (1%)
- Significant Negative Impact (<1%)

Figure from the National Weather Service, Office of Services

GOES Sounder Spectral Bands: 14.7 to 3.7 um & Vis



GOES Sounder Spectral Band: 7 um



GOES Sounder Cloud-top Pressure

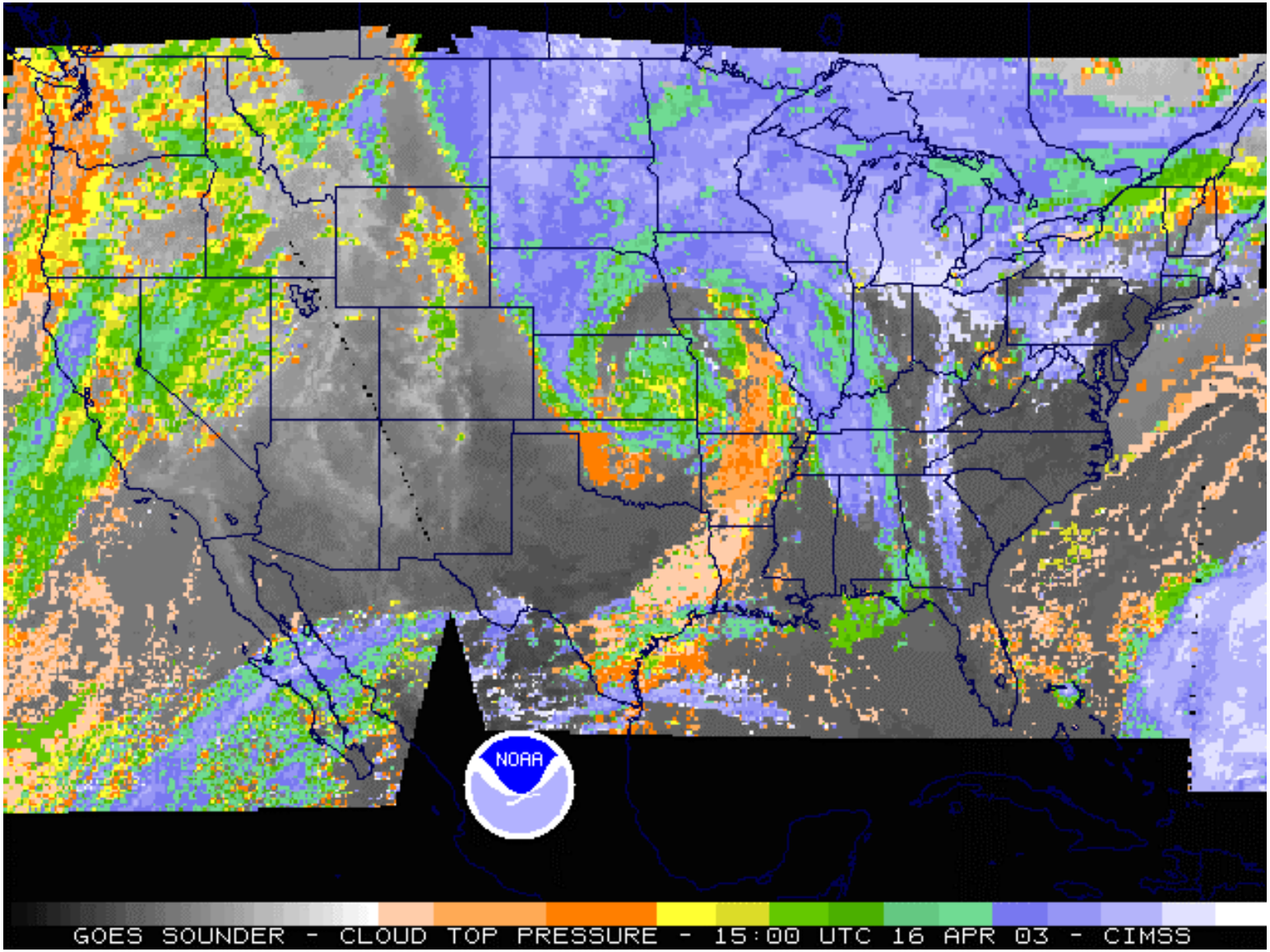


Table 3.2.1 Sounding sensor(s) THRESHOLD bands.

Band	HES Band Number	Spectral Range (cm^{-1})	Spectral Range (microns)	Band Continuity
LWIR	1	650 – 1200	15.38 - 8.33	Contiguous
MWIR (option 1)	2	1650 – 2150	6.06 - 4.65	Contiguous
MWIR (option 2)	2	1210 – 1740	8.26 - 5.74	Contiguous
SWIR	3	2150 – 2250	4.65 - 4.44	Contiguous
VIS	4	NA	0.52 - 0.70	Contiguous

As a GOAL, the sounding task sensor(s) SWIR contiguous spectral range (HES band 3) should be 2150 – 2720 cm^{-1} (4.65 – 3.68 microns).

The following is under review by the HES PORD Team

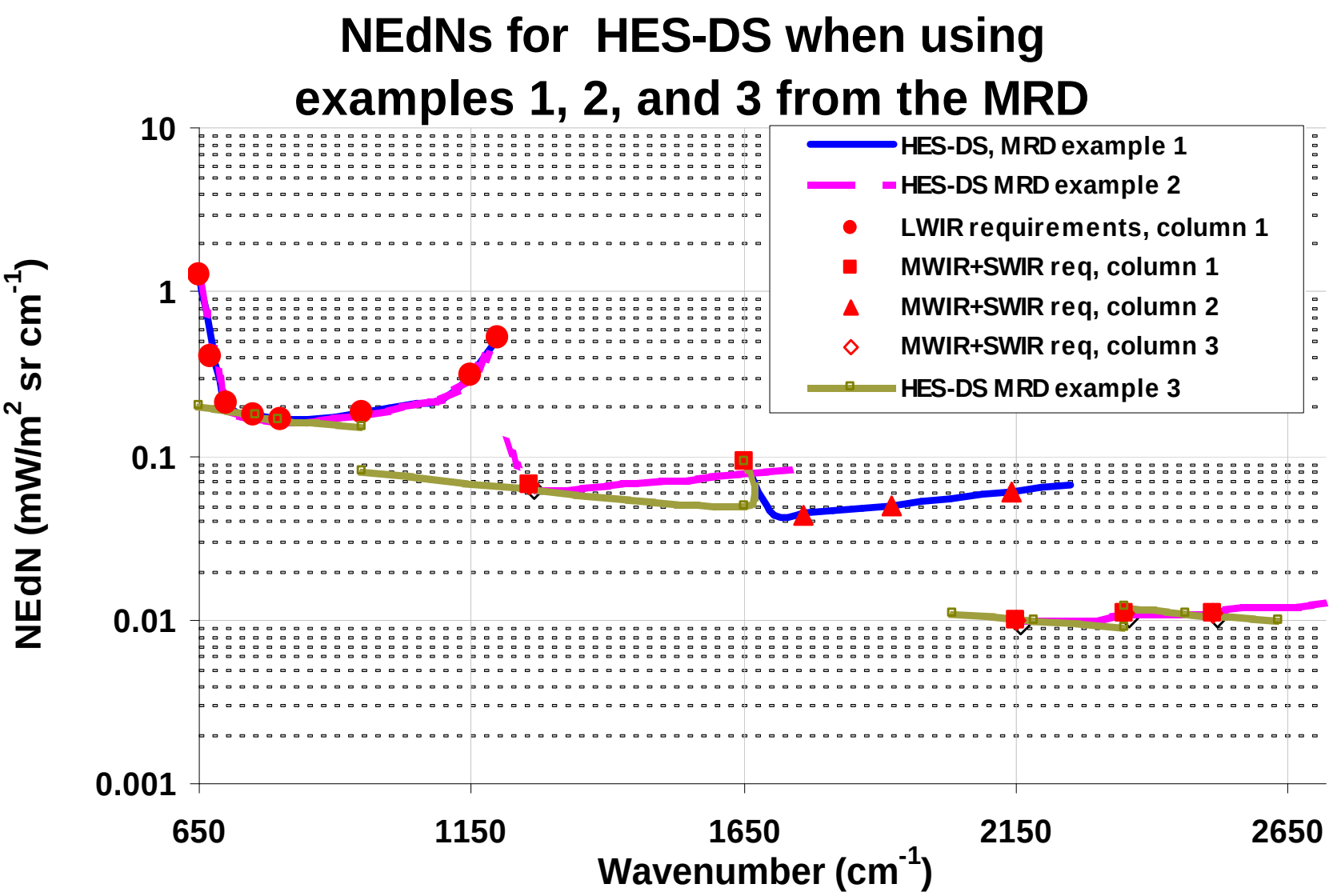
Table 3.2.4 Sounding sensor(s) THRESHOLD spectral resolution.

Band	HES Band Number	Spectral Resolution (cm^{-1})	Spectral Resolution (microns)
LWIR	1	0.625	TBS
MWIR (option 1)	2	1.25	TBS
MWIR (option 2)	2	1.25	TBS
SWIR	3	2.5	TBS
VIS	4	NA	0.18

Table 3.2.5 Sounding sensor(s) GOAL spectral resolution

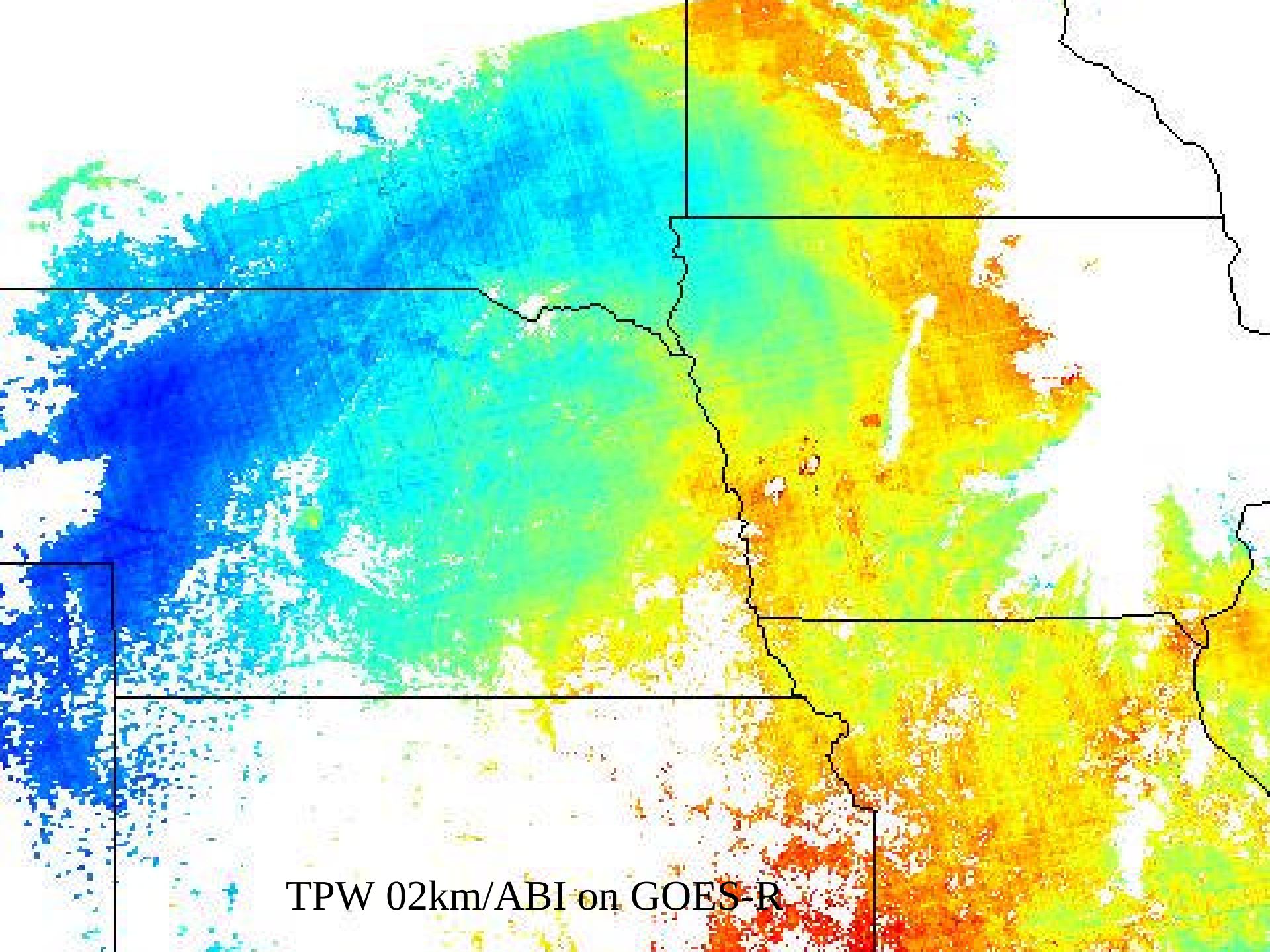
Band	HES Band Number	Spectral Resolution (cm^{-1})	Spectral Resolution (microns)
LWIR	1	0.625	TBS
MWIR (option 1)	2	0.625	TBS
MWIR (option 2)	2	0.625	TBS
SWIR	3	0.625	TBS

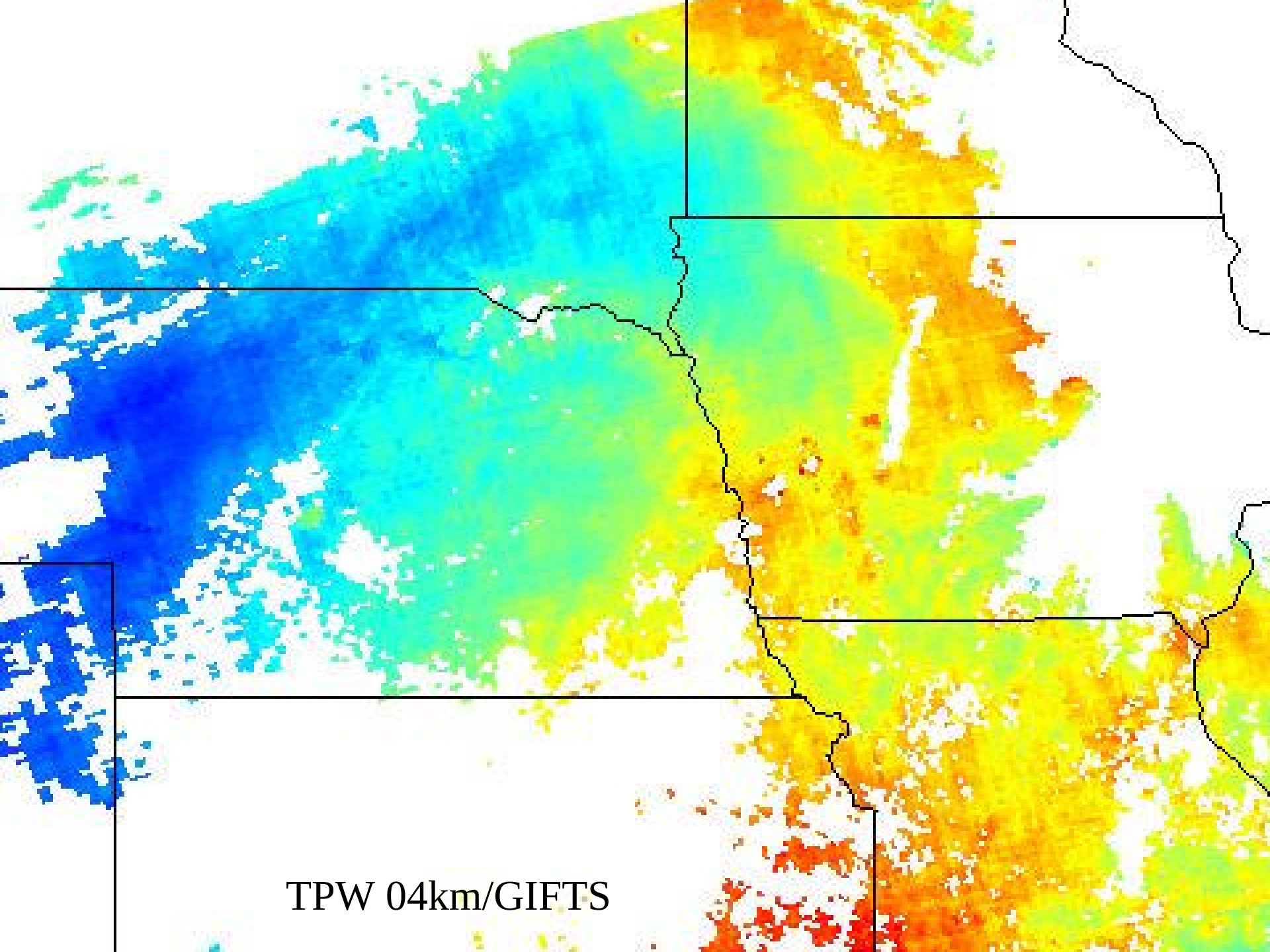
HES-DS Noise (Abstracted NEDN)

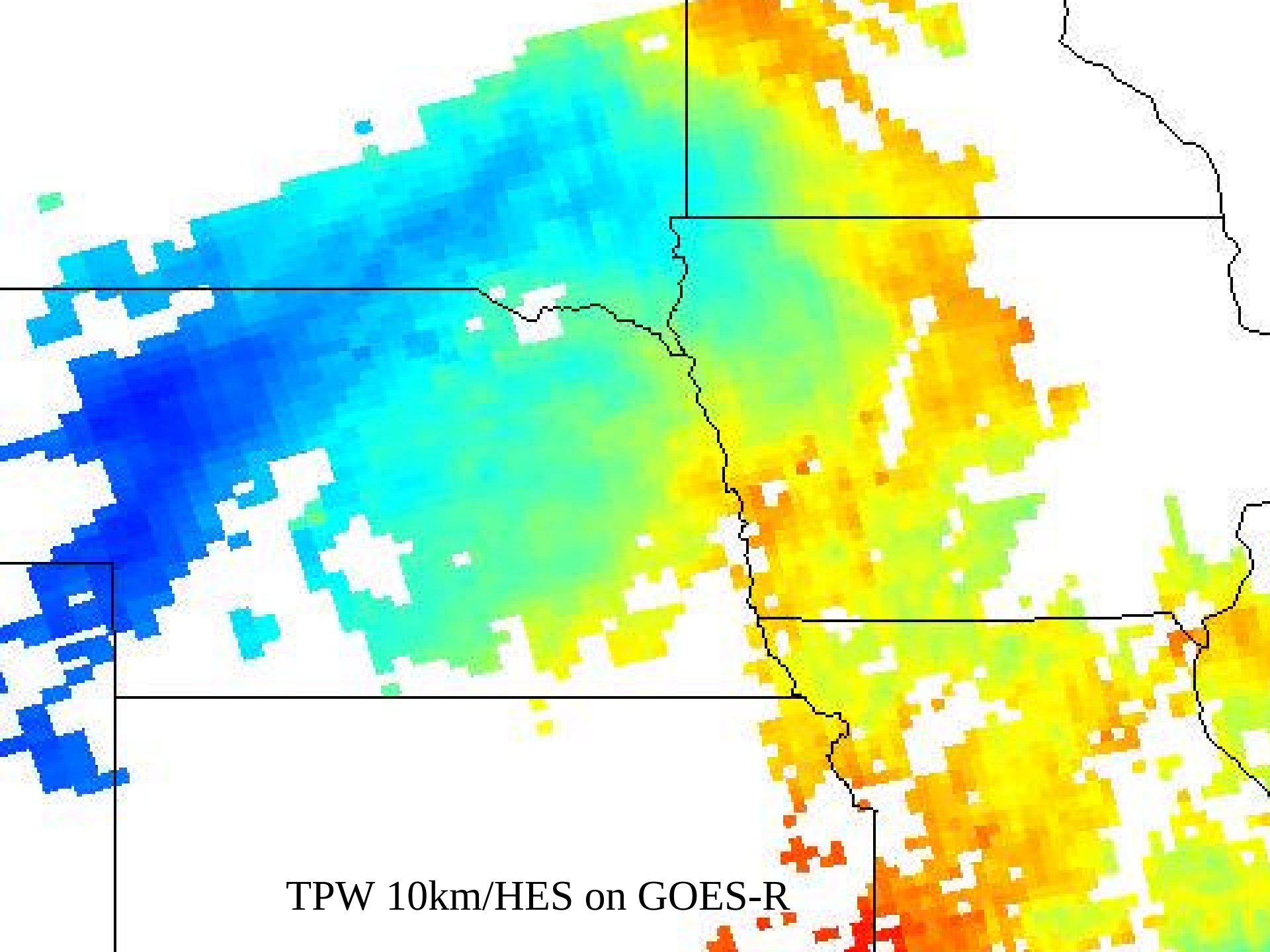


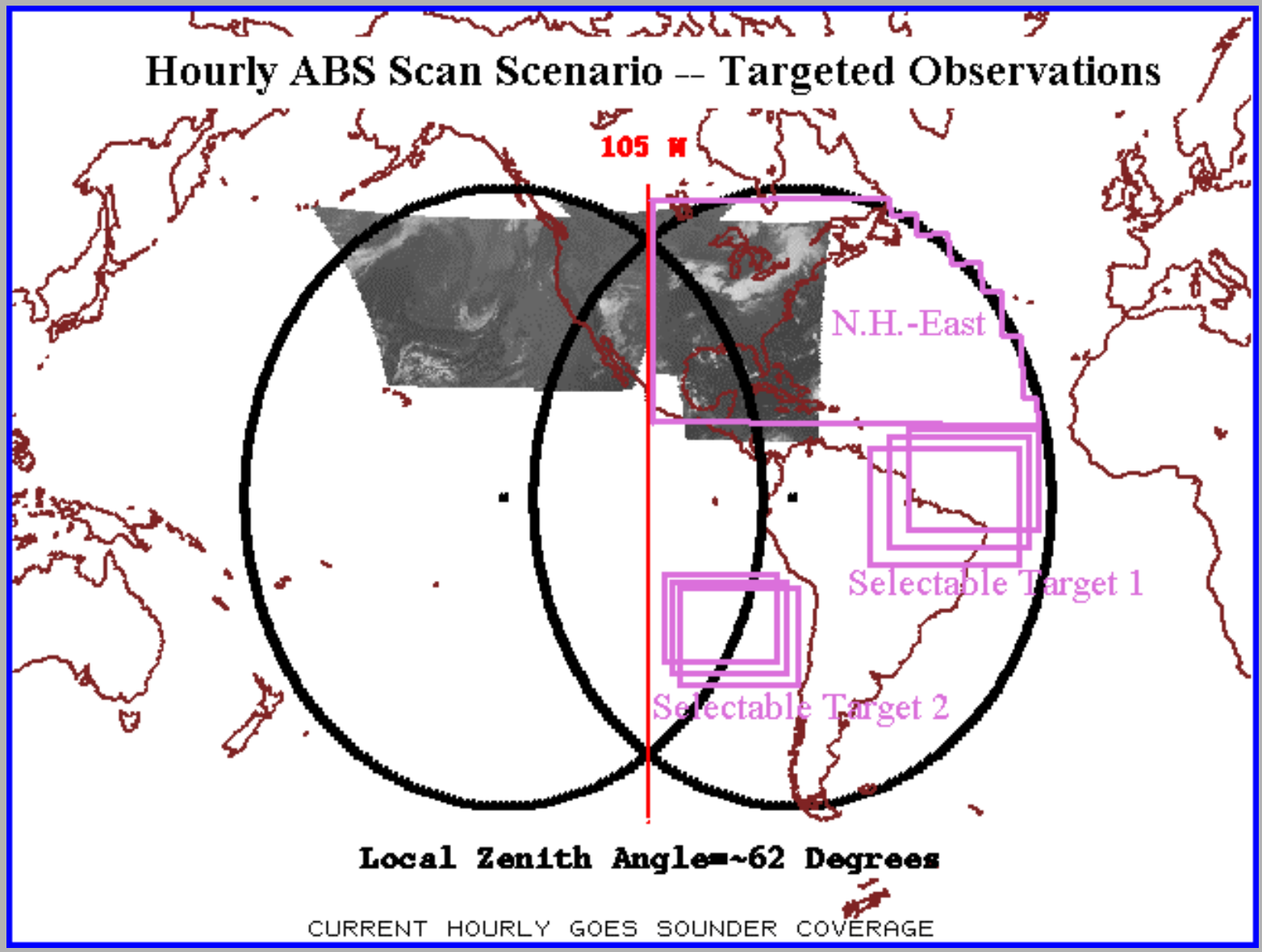
HES-Severe Weather/Mesoscale task

- Spatial Resolution
  - IR: Threshold=4 km, Goal=2 km,
  - Vis: Threshold=1.0 km, Goal= 0.5 km
- Coverage rate
  - 1000 km x 1000 km (locations vary) in 4.4 minutes
  - Coverage area must be flexible and selectable.
- Spectral coverage:
  - Specific examples are cited in the MRD, same as HES-DS
- Spectral resolution:
  - 15 um CO_2 band: 0.6 cm^{-1}, Windows: 0.6-1.0 cm^{-1}, Ozone: 1 cm^{-1}, H_2O: 1-2 cm^{-1}, near 4 um: 2.5 cm-1, Visible: 0.18 um


TPW 02km/ABI on GOES-R


TPW 04km/GIFTS


TPW 10km/HES on GOES-R



Targeted observations -- look where we need the information

Table 3.2.33 Expected scan times for the DS task sensor emissive bands (HES bands 1-3).

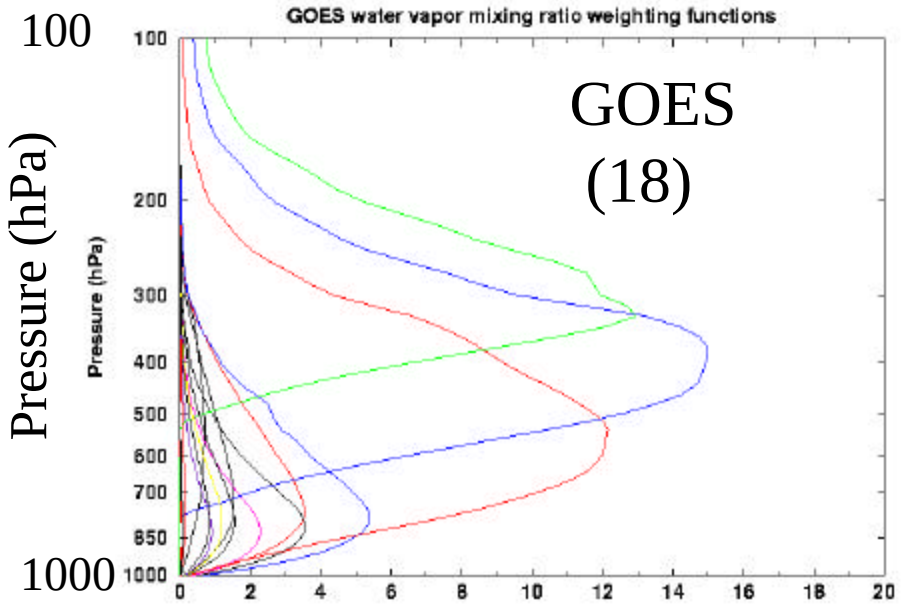
Coverage Region	Coverage Area (km^2)	GSR (Hz)	GSD (km)	Within Frame Scan Efficiency	Coverage Time
Full Disk	1.00E+08	300	10	0.6	1 hr 32.6 min
62-degree LZA	**7.00E+07**	**300**	**10**	**0.65**	**0 hr 59.8 min**
CONUS	1.50E+07	300	10	0.9	0 hr 9.3 min
Mesoscale	1.00E+06	300	10	0.8	0 hr 0.7 min
Coastal Waters	2.40E+06	300	10	0.95	0 hr 1.4 min

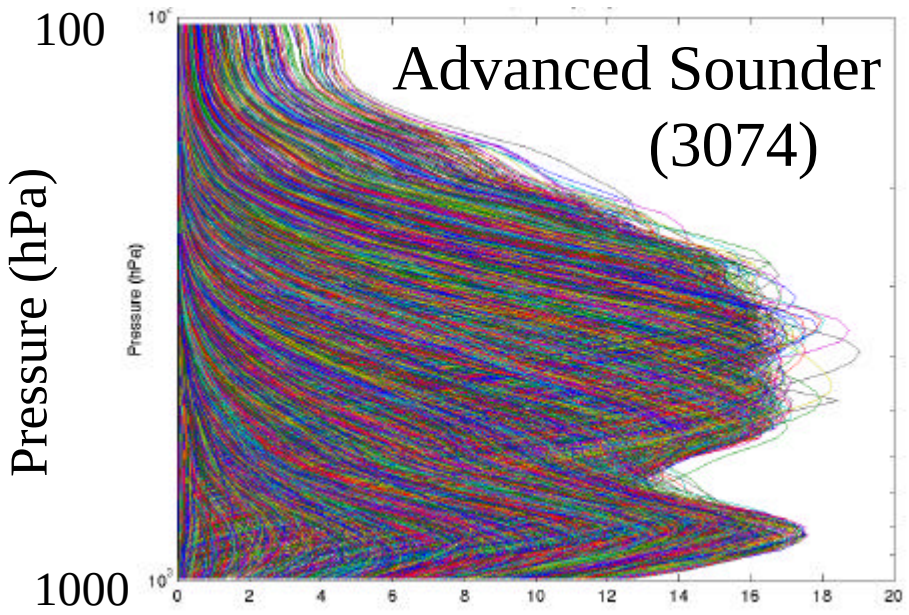
Table 3.2.34 Expected scan times for the SW/M task sensor emissive bands (HES bands 1-3).

Coverage Region	Coverage Area (km^2)	GSR (Hz)	GSD (km)	Within Frame Scan Efficiency	Coverage Time
Full Disk	1.00E+08	300	4	0.6	9 hr 38.7 min
62-degree LZA	7.60E+07	300	4	0.65	6 hr 46.0 min
CONUS	1.50E+07	300	4	0.9	0 hr 57.9 min
Mesoscale	**1.00E+06**	**300**	**4**	**0.8**	**0 hr 4.3 min**
Coastal Waters	2.40E+06	300	4	0.95	0 hr 8.8 min

Sounder Comparison (GOES-Current to HES-Req)

	Current	Requirement
Coverage Rate	CONUS/hr	Sounding Disk/hr
Horizontal Resolution		
- Sampling Distance	10 km	10 km
- Individual Sounding	30-50 km	10 km
Vertical resolution	~3 km	1 km
Accuracy		
Temperature	2 deg. K	1 deg. K
Relative Humidity	20%	10%

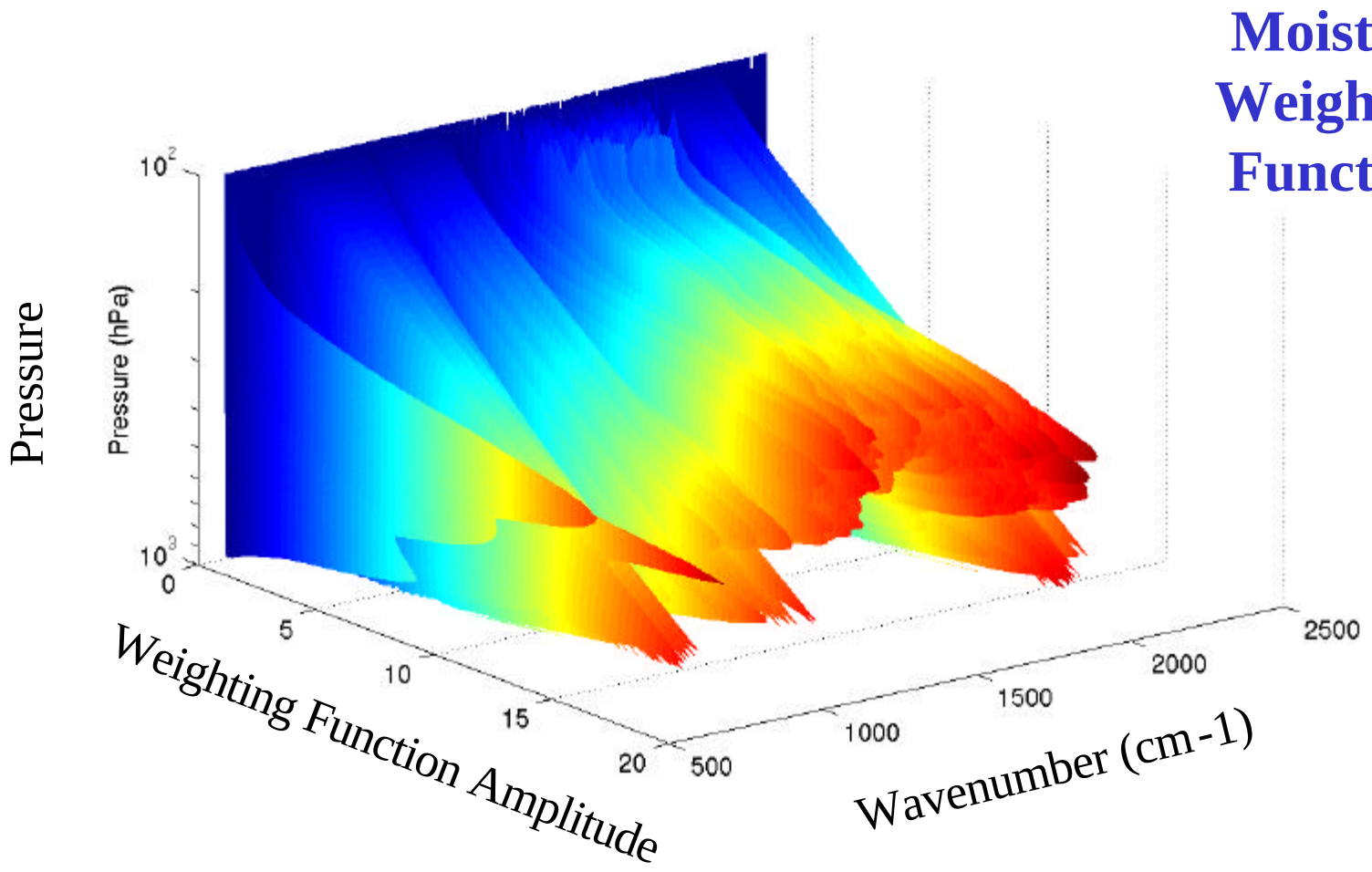




Moisture Weighting Functions

High spectral resolution advanced sounder will have more and sharper weighting functions compared to current GOES sounder. Retrievals will have better vertical resolution.

These water vapor weighting functions reflect the radiance sensitivity of the specific channels to a water vapor % change at a specific level (equivalent to dR/dlnq scaled by dlnp).

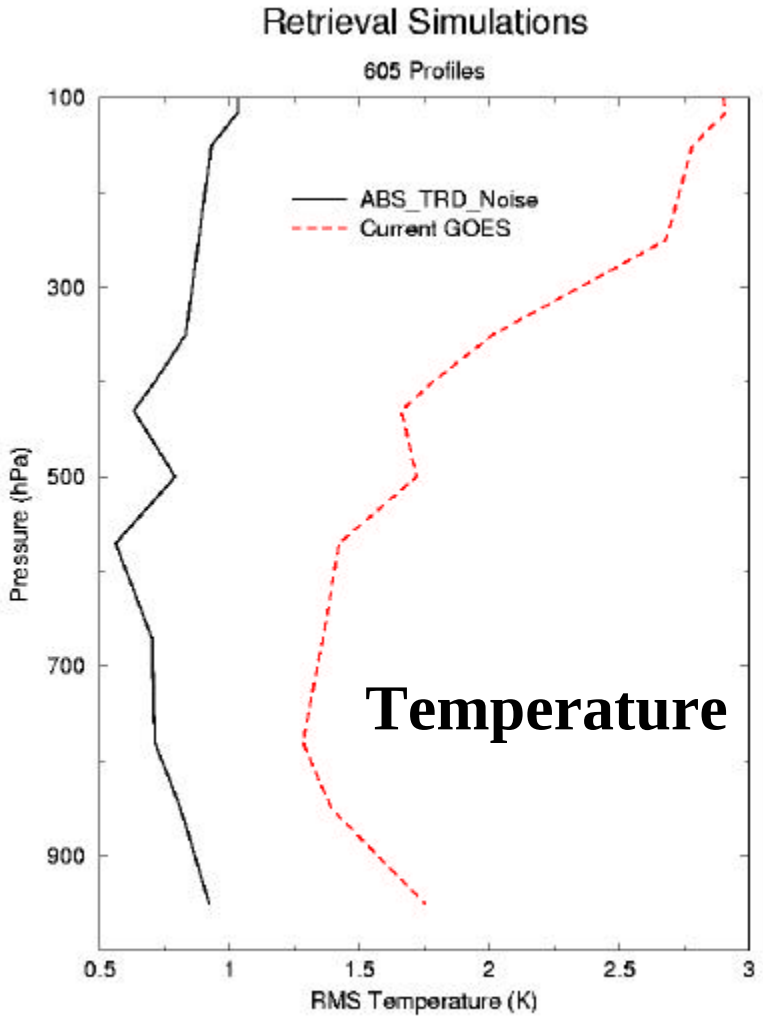


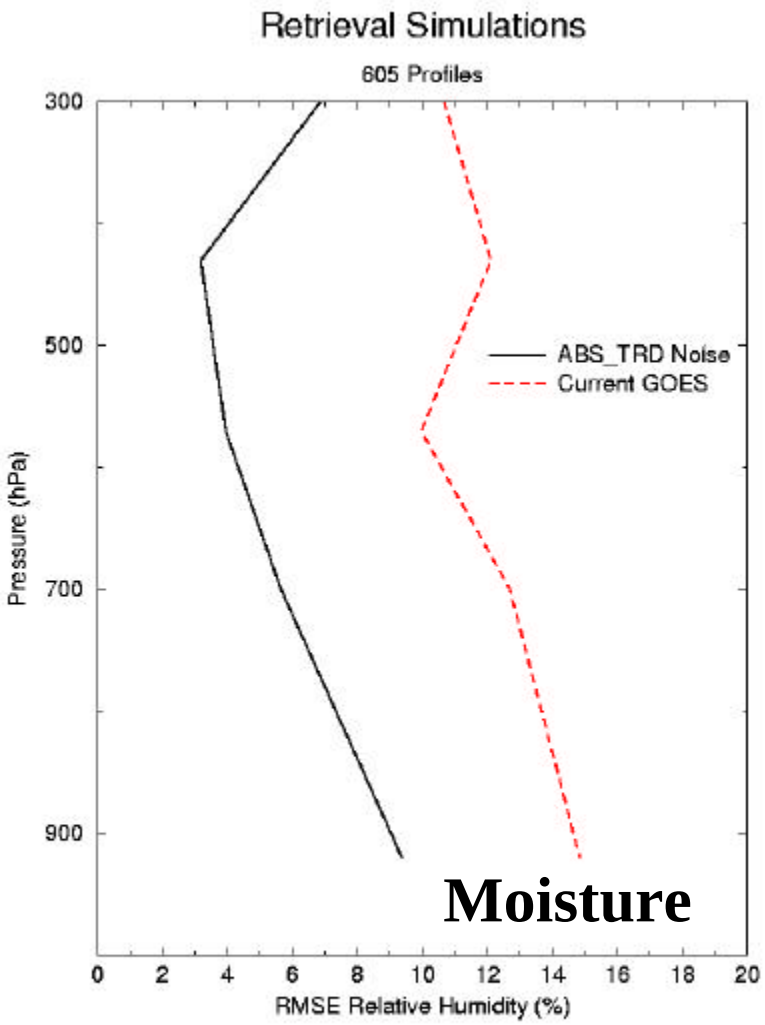
UW/CIMSS

The advanced sounder has more and sharper weighting functions

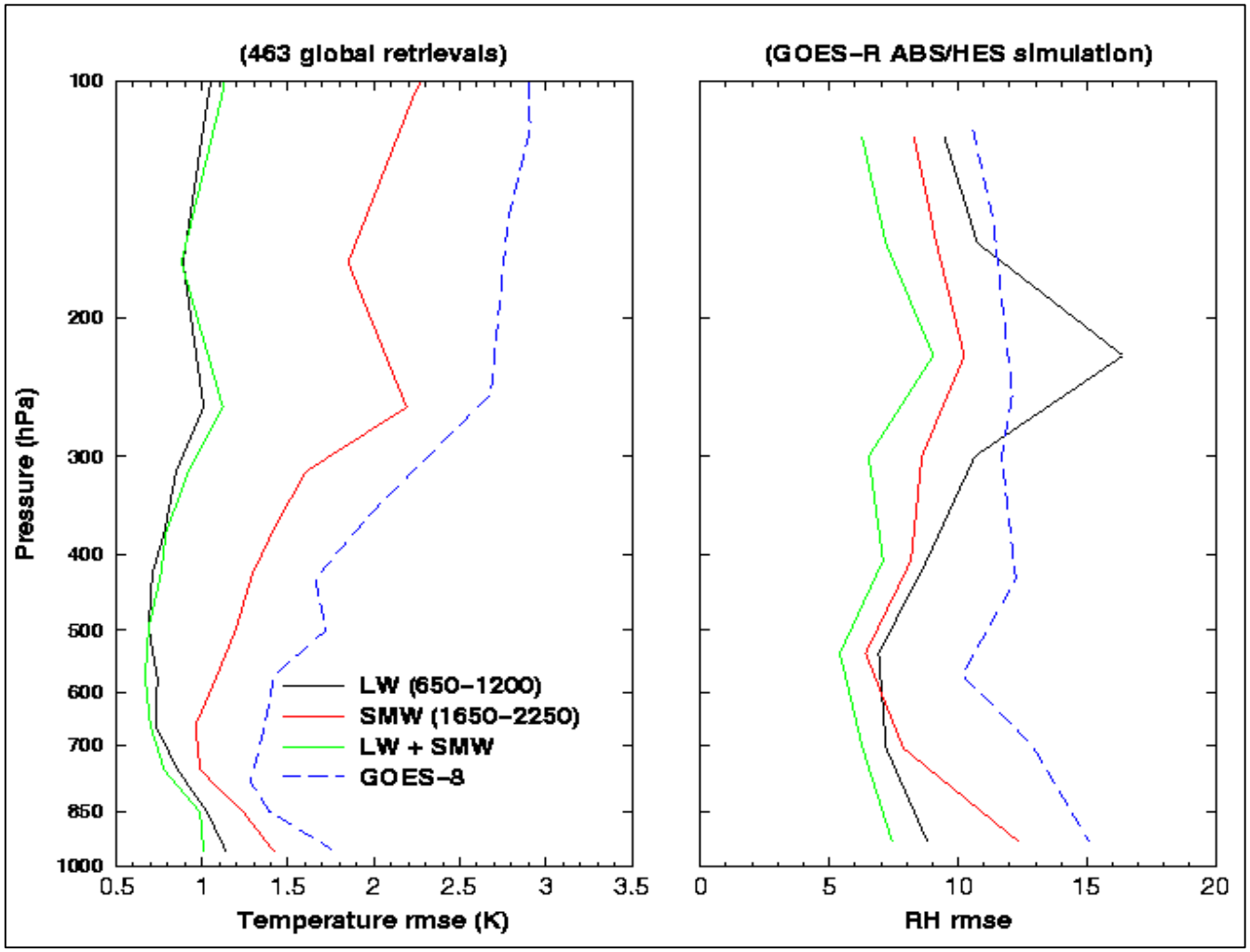
Simulations of Low vs High Spectral Resolution Retrievals

Geo-I gets <1 K rms for 1 km T(p) and <10% rms for 2 km RH(p)



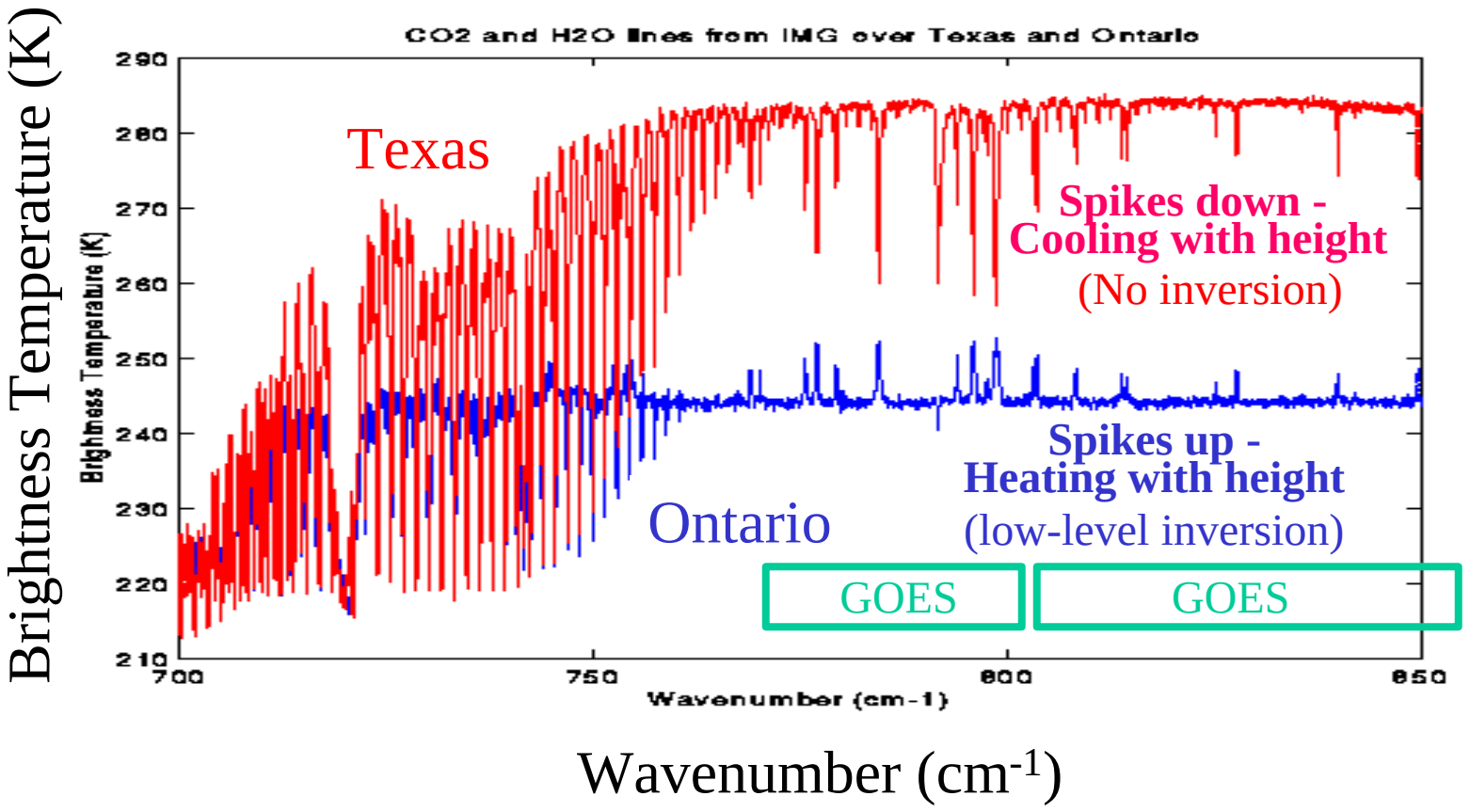


Strategy is (1) use all channels in a regression first guess and then (2) use sub-set of channels for physical retrieval



The 1km vertical temperature retrieval RMSE (left panel) and 2km vertical water vapor (RH) retrieval RMSE (right panel) from HES LW only, SMW only, LW + SMW, and current GOES sounder. 463 independent profiles distributed globally are included in the retrieval statistics; TRD noise is used in the simulation.

Detection of Temperature Inversions Possible with Interferometer



Detection of inversions is critical for severe weather forecasting. Combined with improved low-level moisture depiction, key ingredients for night-time severe storm development can be monitored.

The following is under review by the HES PORD Team

Table 3.2.8 THRESHOLD and GOAL spectral operability requirements

HES Band Number	Band/Task	Spectral Operability THRESHOLD	Spectral Operability GOAL
1	LWIR-Sounding	50%	100%
2	MWIR-Sounding	50%	100%
3	SWIR-Sounding	50%	100%
4	VIS-Sounding	100%	NA

Table 3.2.32 HES THRESHOLD and GOAL pixel operability and outage requirements

HES Band Number	Band/Task	Operability THRESHOLD	Outages THRESHOLD
1	LWIR-Sounding	87 %	4%
2	MWIR-Sounding	97 %	1%
3	SWIR-Sounding	99% (TBR)	0% (TBR)
4*	VIS-DS	99.9%	0% (TBR)
4*	VIS-SW/M	99.9% (TBR)	0% (TBR)

HES balance of temporal (30 min), spectral (0.5 cm-1), spatial (2-10 km), and radiometric (0.1 K) capabilities will

* depict water vapor as never before by identifying small scale features of moisture vertically and horizontally in the atmosphere

* track atmospheric motions much better by discriminating more levels of motion and assigning heights more accurately

* characterize life cycle of clouds (cradle to grave) and distinguish between ice and water cloud

* measure surface temperatures (land and sea) by accounting for emissivity effects

* distinguish atmospheric constituents with improved certainty; these include volcanic ash, ozone, and possibly others trace gases.

More information…

NASA's (draft) HES PORD (**PERFORMANCE AND OPERATION REQUIREMENTS DOCUMENT**):
http://goes2.gsfc.nasa.gov/HEShome.htm

Industry Day briefings:
http://goes2.gsfc.nasa.gov/goesr_industry.htm

CIMSS page:
http://cimss.ssec.wisc.edu/goes/abs/

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