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Mitigation of Errors in GOES-17 Atmospheric Motion Vectors in NAVGEM

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The Loop Heat Pipe Problem

- **Post-Launch testing of GOES-17 revealed problems with the imager cooling system**
  - "Loop Heat Pipe… not operating at designed capacity"
    - Carries heat from cryocoolers to a radiator that sheds heat to space
  - Advanced Baseline Imager (ABI) inadequately cooled under some conditions
    - Some infrared channels contaminated by heat emitted within the imager
    - Occurs during the night near the equinoxes when the ABI is "looking" at the sun
- **Several mitigation strategies have been implemented**
  - Yaw flip maneuver—180° rotation trading north for south
    - Performed near each equinox to keep the sun in its summer orientation
    - Keeps solar radiation from reaching as deep into the ABI
  - Using both of the ABI cryocoolers with increased maximum allowable temperature
  - Increasing the nominal operating temperature of the infrared detectors and optimizing the detector bias voltage and gain
  - Using Mode 3 during the worst time of day in the worst period, decreasing imaging

Excerpted from https://www.goes-r.gov/users/GOES-17-ABI-Performance.html and https://aerospaceamerica.aiaa.org/departments/saving-goes-17/

Channels Used for GOES-16/17

The GOES-R ABI provides imagery in 16 channels, six of which are used for AMVs

Table 8. Acceptable height range to use as a function of channel used and tracer type

NESDIS	Channel Number	Tracer Type	Central Frequency (μm)	Acceptable Height Range (hPa)	UW
VIS	2	Cloud-top	0.64	700 - 1000	VIS
SWIR	7	Cloud-top	3.9	700 - 1000	SWIR
WVD	8	Cloud-top	6.15	100 – 400	WVD
WVH	8	Clear-sky water vapor	6.15	100 - 1000	WVR
WVR	9	Clear-sky water vapor	7.0	100 - 1000	WVR
WVL	10	Clear-sky water vapor	7.4	450 - 700	WVR
IR	14	Cloud-top	11.2	100 - 1000	IR

Same identifier used for all three clear-sky bands

- **NESGOES15 and UWGOES15 water vapor channel naming**
  - **Band 3 - WVD 6.55 micron cloud-top WV**
  - **Band 3 - WVR 6.55 micron clear-sky WV**

"GOES-R Advanced Baseline Imager (ABI) Algorithm: Theoretical Basis Document For Derived Motion Winds"
J. Daniels, W. Bresky, S. Wanzong, C. Velden, and H. Berger
https://www.star.nesdis.noaa.gov/goesr/docs/ATBD/DMW.pdf

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Experiments

- GOES-15/GOES-17 Comparison Runs
- GOES-17 Mode 6 and Mode 3 Comparison
- GOES-16/GOES-17 Enterprise Algorithm Comparison Runs
- GOES-16/GOES-17 Stereographic Height Assignment Method

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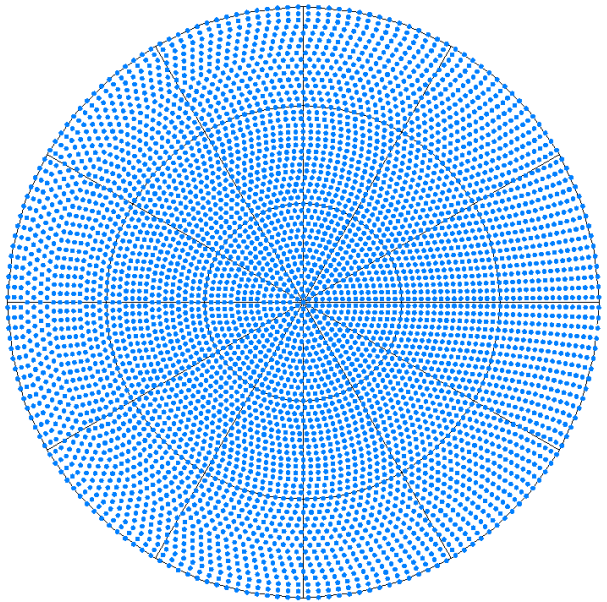
Superobbing Strategy

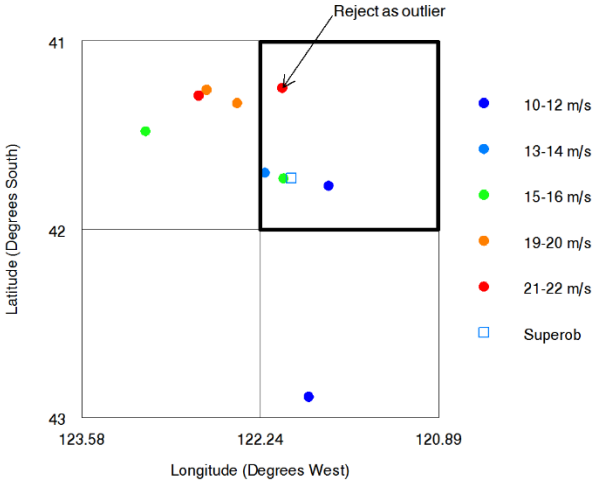
- Satellite winds contain horizontally correlated errors that the DA system assumes are not present.
- Thinning or averaging ("superobbing") is performed as mitigation.
- Most NWP centers use thinning; NRL/FNMOC uses superobbing

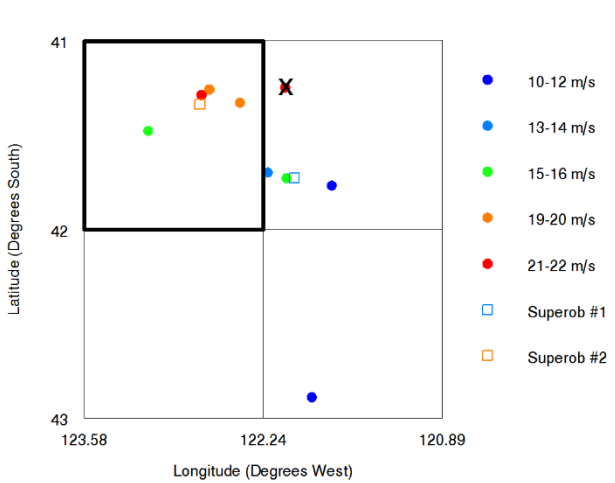


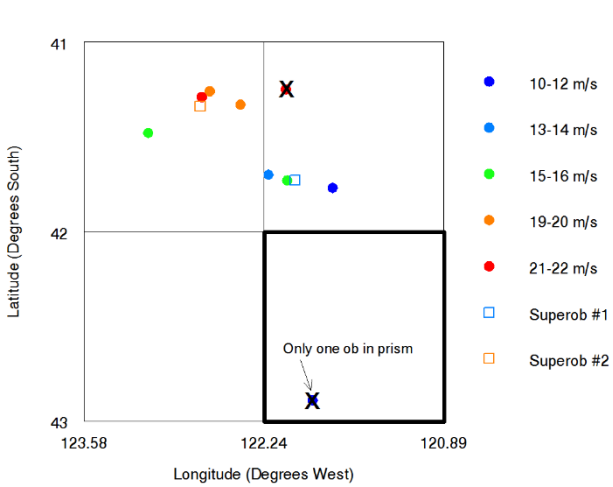
Basic philosophy: only average similar observations

- Same satellite, channel, processing center
- Similar time (within 1 hr)
- In the same horizontal 2° "prism" and 50 hPa layer; at least 2 obs present
- Similar wind direction (within 20°), speed (7-14 m/s depending on speed)
  - Can reject outliers
  - Can "quarter" prism horizontally and superob in each quarter
- Superob placed at centroid of obs at mean pressure
- Superobs corrected so the magnitude of the superob vector equals the mean speed of the obs

Superobbing Strategy







- Original 2° prism—directions from 281° to 296° (within 20°), but the speed range exceeds the 7 m/s threshold
- Superob prism is quartered
  - Rejecting one outlier allows a superob to be formed in the northeast quarter
  - Obs in the northwest quarter are within the thresholds so a superob is formed
  - Fewer than two obs are in the remaining quarters, so no superobs are formed
- **2° prisms are used for both GOES-15 and GOES-17, but quartering is invoked much more often for GOES-17 leading to many more superobs.**

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Experiments

- **GOES-15/GOES-17 Comparison Runs**
  - 18 Sept 2019 to 16 Dec 2019 (all Mode 6, before Mode 3 was introduced), NAVGEM 1.4
  - Broken into 10-day periods to see effects centered on equinox
- **GOES-17 Mode 6 and Mode 3 Comparison**
- **GOES-16/GOES-17 Enterprise Algorithm Comparison Runs**
- **GOES-16/GOES-17 Stereographic Height Assignment Method**

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GOES15/GOES17 Comparison Runs

- **Dual experiments with NAVGEM 1.4 (Navy Global Environmental Model)**
  - Forecast Model Resolution: T425L60
  - Data Assimilation: Hybrid 4DVAR
  - Forecast Sensitivity Observation Impact for 24-hr forecasts
  - Period of experiments: 18 Sept 2019 to 16 Dec 2019
- **GOES-15 experiment**
  - Operational QC (no NESDIS VIS)
- **GOES-17 experiment**
  - Less restrictive QC (allow VIS and a new clear sky WV channel)
- **The two experiments had similar results overall.**

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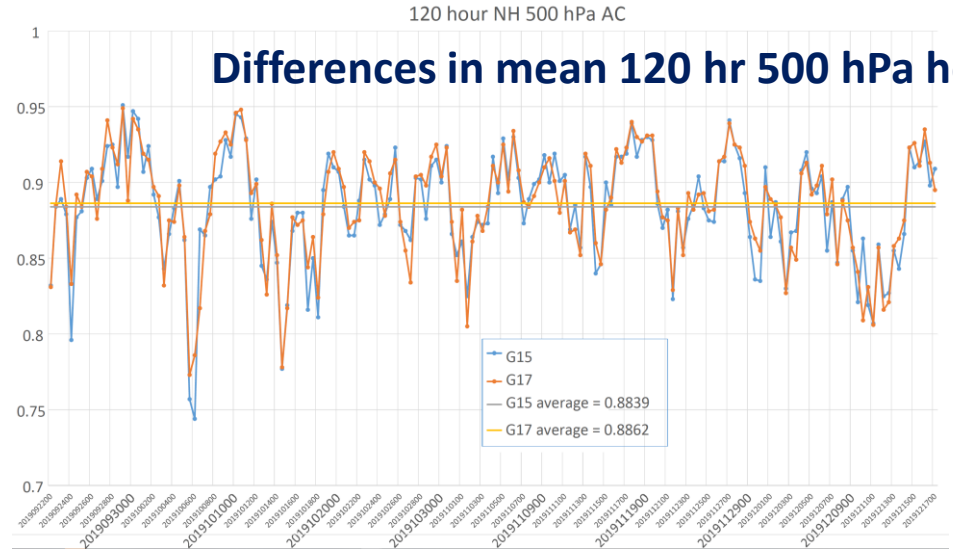
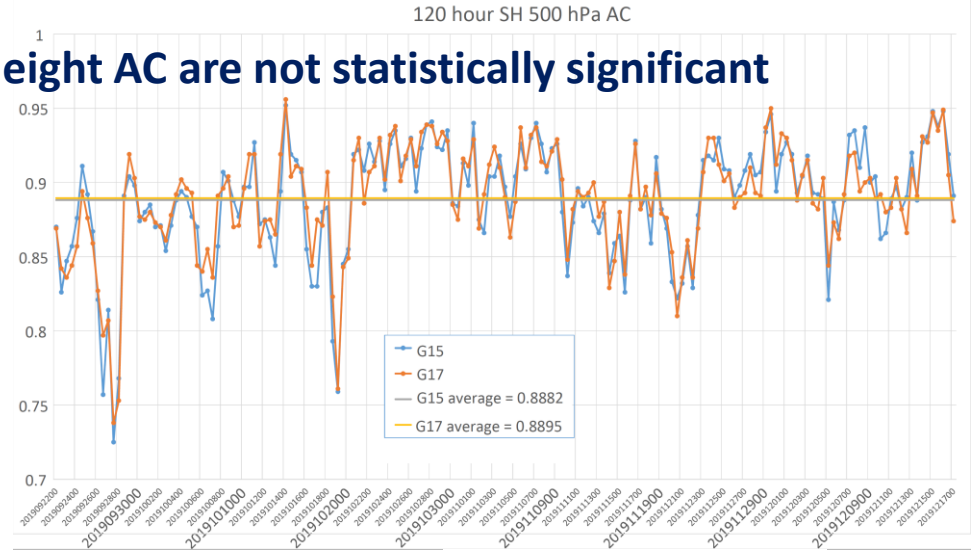
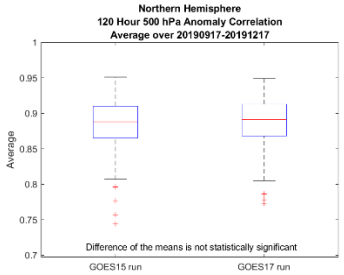
500 hPa Anomaly Correlation

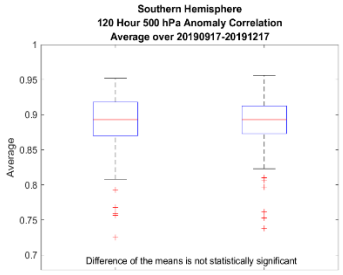
Differences in mean 120 hr 500 hPa height AC are not statistically significant

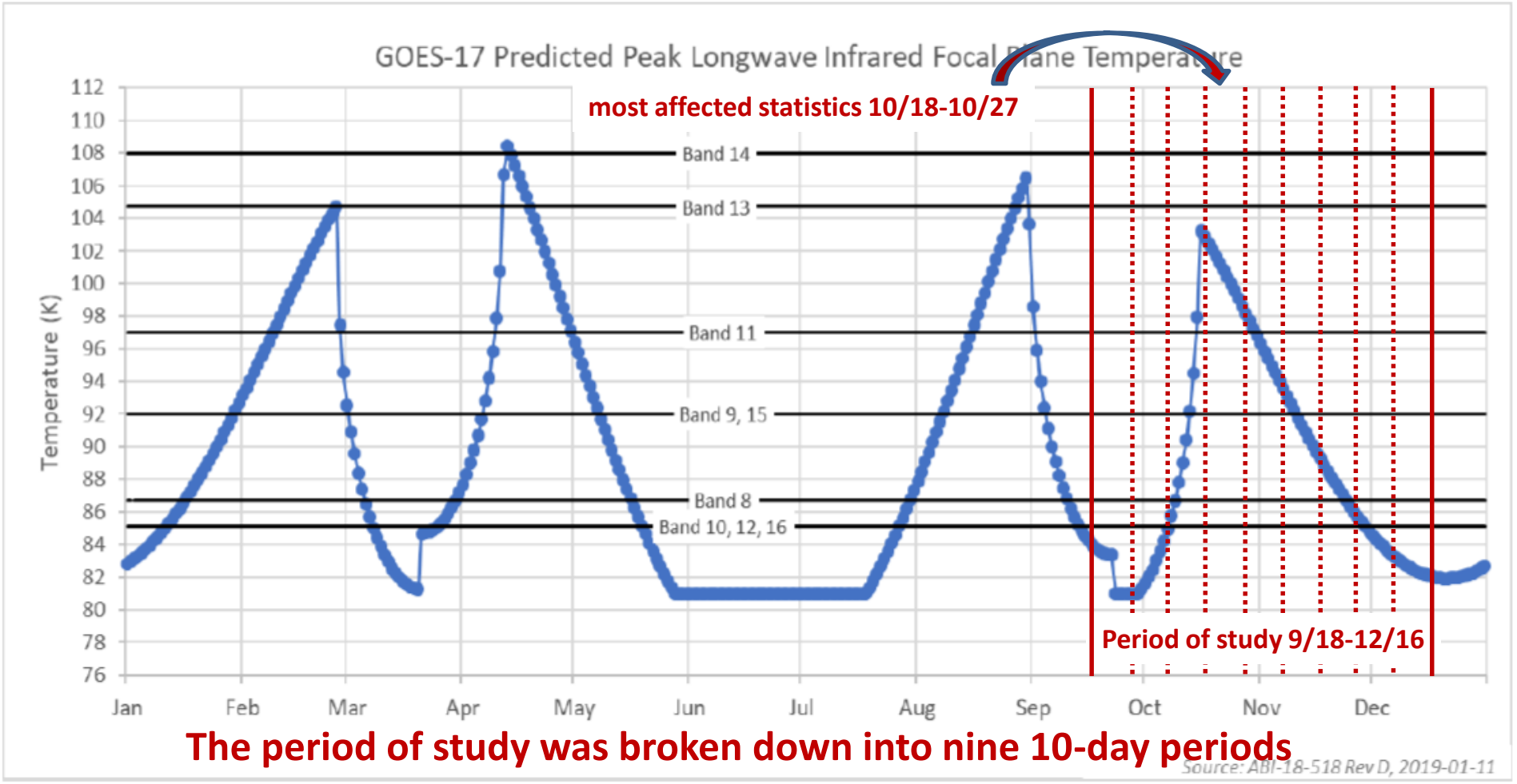






Box/whisker plots show some differences even though the difference in means is not statistically significant. The whiskers enclose approx. ±2.7σ, with the whisker plotted at the ob closest to and inside that limit. Note the difference in the lower whisker placement for GOES-17.





From Mozer et al, 2019: GOES-17 Saturation Prediction Reference Tools.
[http://cimss.ssec.wisc.edu/goes/GOES-17_ABI_Saturation_Prediction_Reference_Tools_v5.pdf

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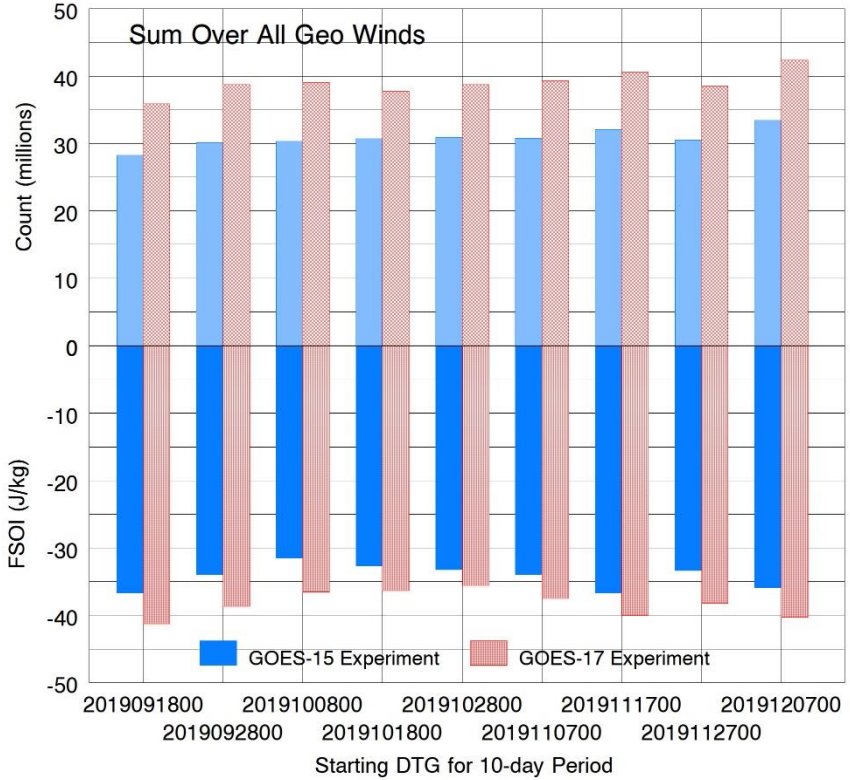
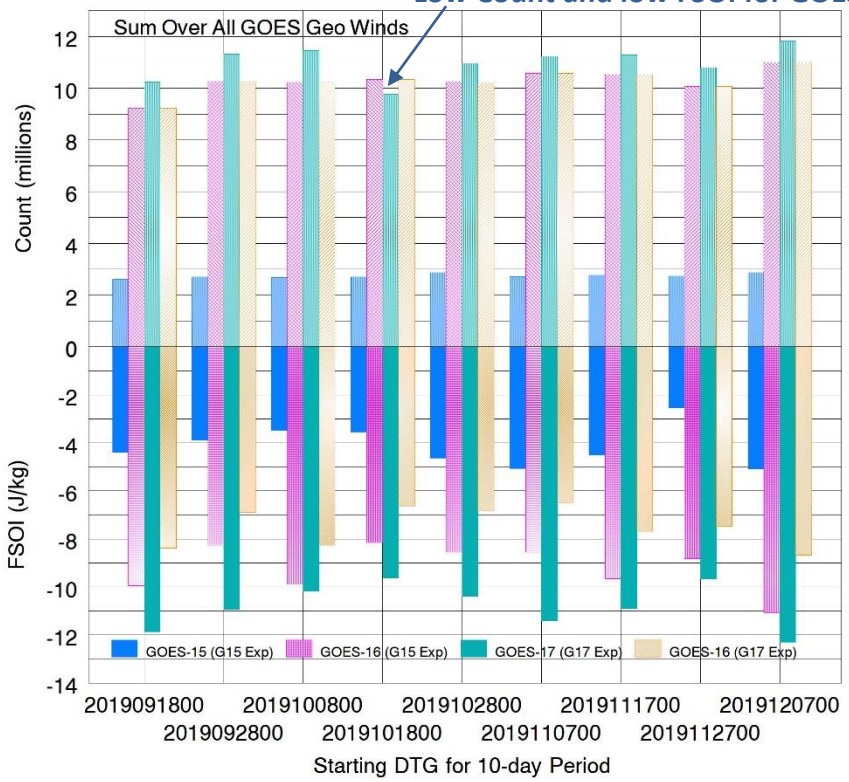
FSOI for Geo Winds



Low Count and low FSOI for GOES-17



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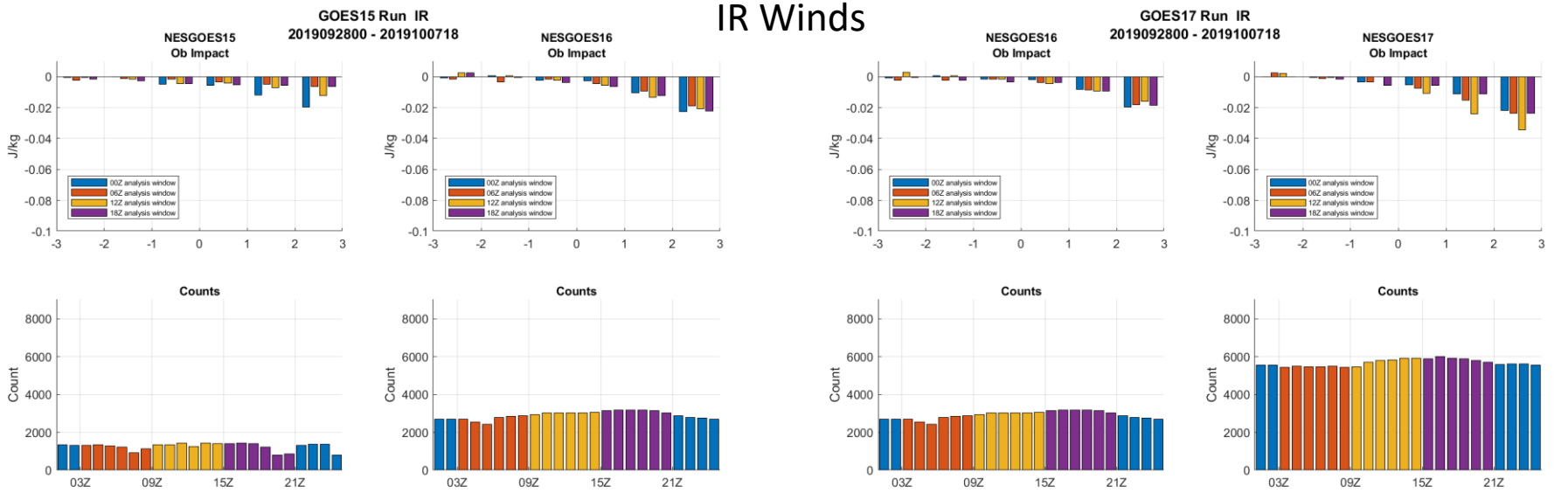
Comparison of Counts and Ob Impacts

2019092800 – 2019100718

IR Winds



GOES-15 GOES-16 GOES-16 GOES-17

GOES-15 Run GOES-17 Run

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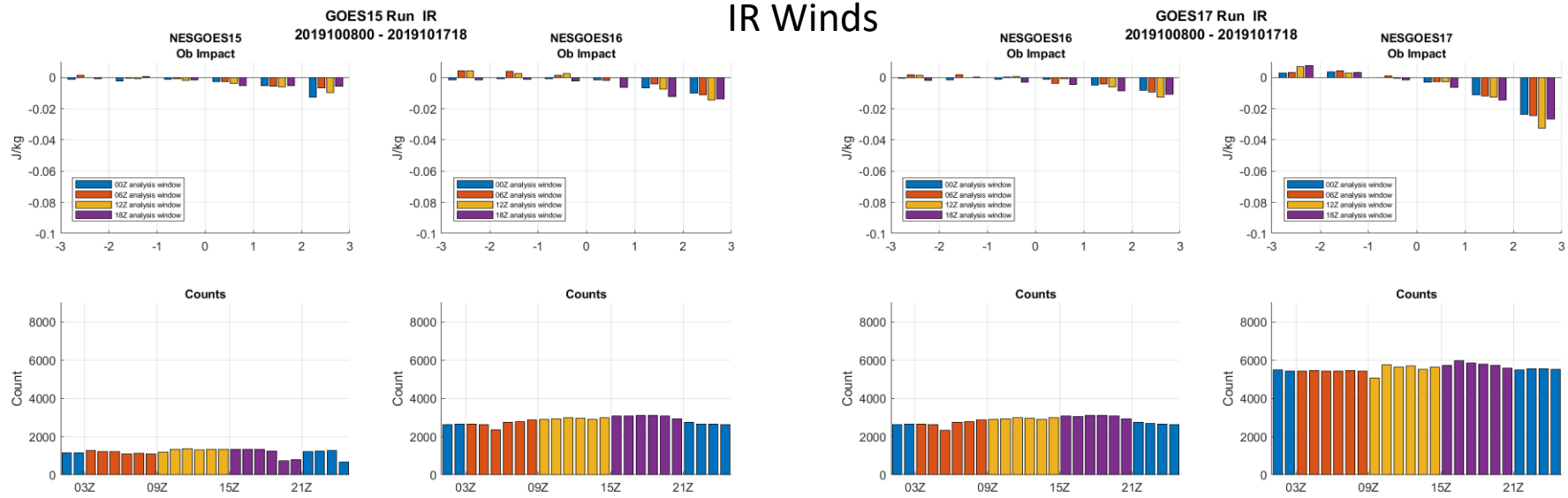
Comparison of Counts and Ob Impacts

2019100800 – 2019101718

IR Winds



GOES-15 GOES-16 GOES-16 GOES-17

GOES-15 Run GOES-17 Run

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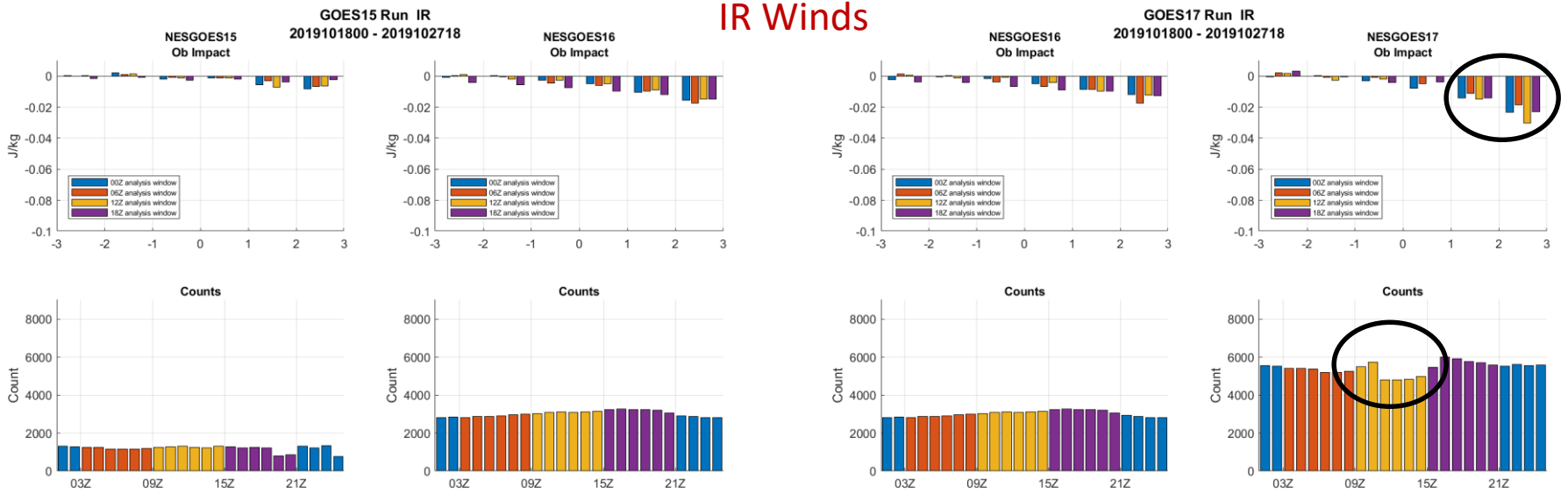
Comparison of Counts and Ob Impacts

2019101800 – 2019102718

IR Winds



GOES-15 | GOES-16 | GOES-16 | GOES-17

GOES-15 Run | GOES-17 Run

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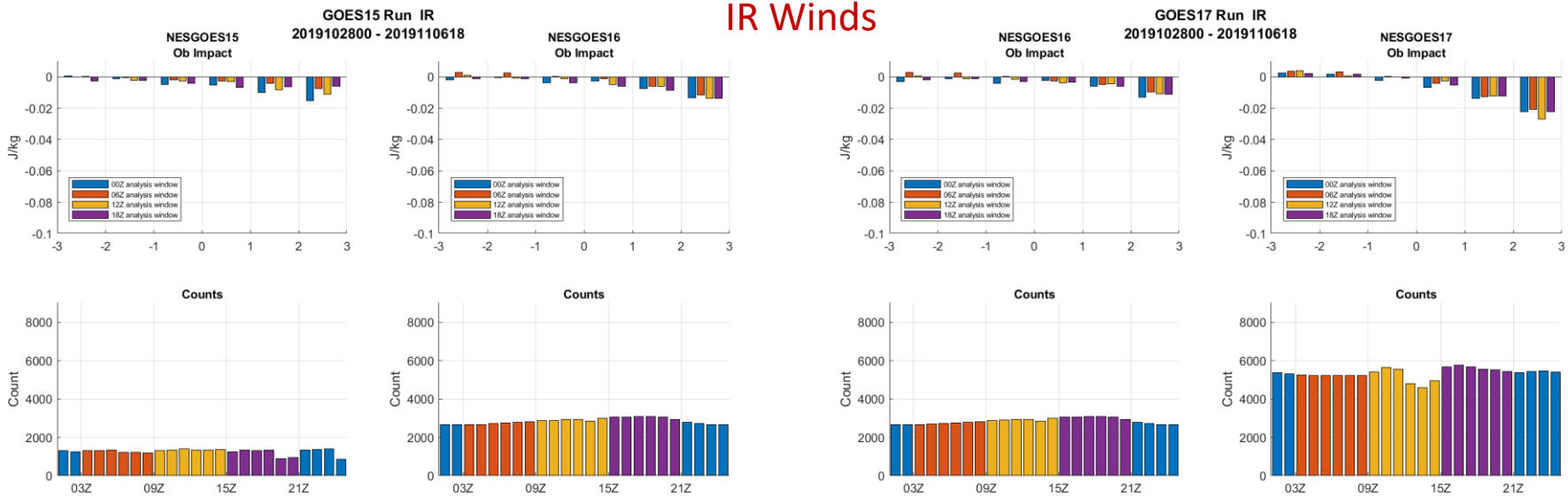
Comparison of Counts and Ob Impacts

2019102800 – 2019110618

IR Winds



GOES-15 | GOES-16 | GOES-16 | GOES-17

GOES-15 Run | GOES-17 Run

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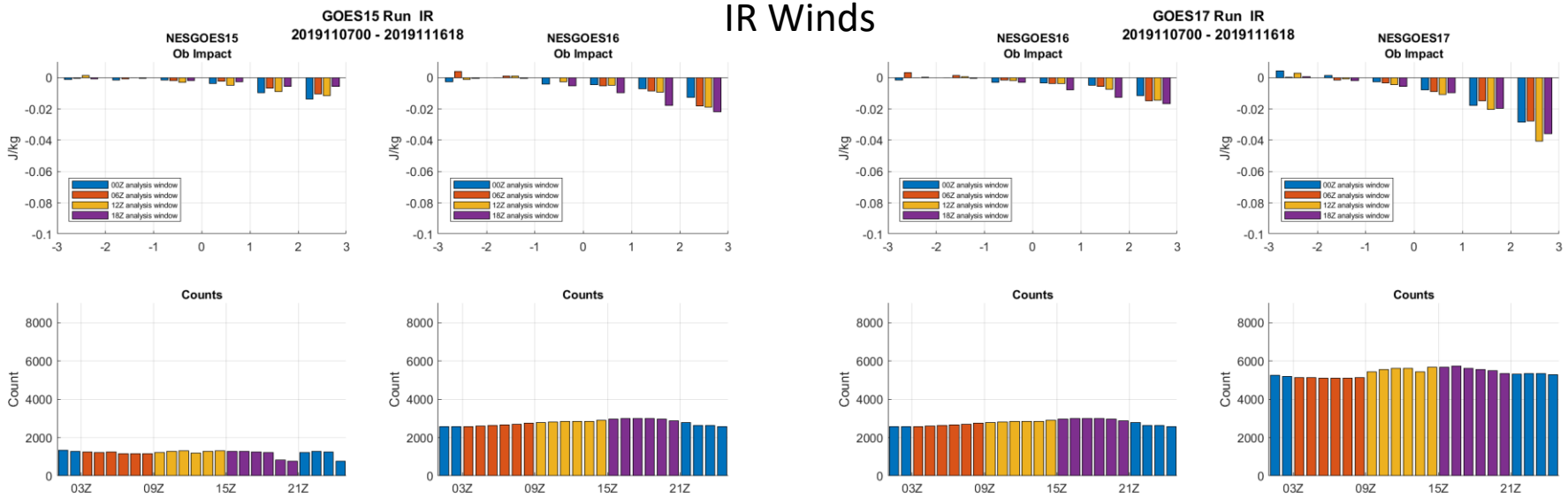
Comparison of Counts and Ob Impacts

2019110700 – 2019111618

IR Winds



GOES-15 GOES-16 GOES-16 GOES-17

NESGOES-17 IR AMVs provide beneficial impact even during the periods with high focal plane temperatures and despite the reduced counts.

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Experiments

- **GOES-15/GOES-17 Comparison Runs**
- **GOES-17 Mode 6 and Mode 3 Comparison**
  - NAVGEM 2.1 control run
  - 01-08 APR 2020, 06-12Z, Mode 6 operations
  - 09-16 APR 2020, 06-12Z, Mode 3 operations
- **GOES-16/GOES-17 Enterprise Algorithm Comparison Runs**
- **GOES-16/GOES-17 Stereographic Height Assignment Method**

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GOES-17 Mode 6 and Mode 3 Comparison

- Mode 3 timeline was implemented during April 9th to May 1st and is used between 0600 and 1200 each day.

- To compare the most homogeneous set possible, we used data from the same run (the NAVGEM 2.1 control run) for two time periods:
  - Mode 6: 06-12Z, 2020040106-2020040812
  - Mode 3: 06-12Z, 2020040906-2020041612

- Mode 3 reduces the number of scans; the time is used for sensor cooling.

- During Mode 3 operations, there were fewer AMVs overall.

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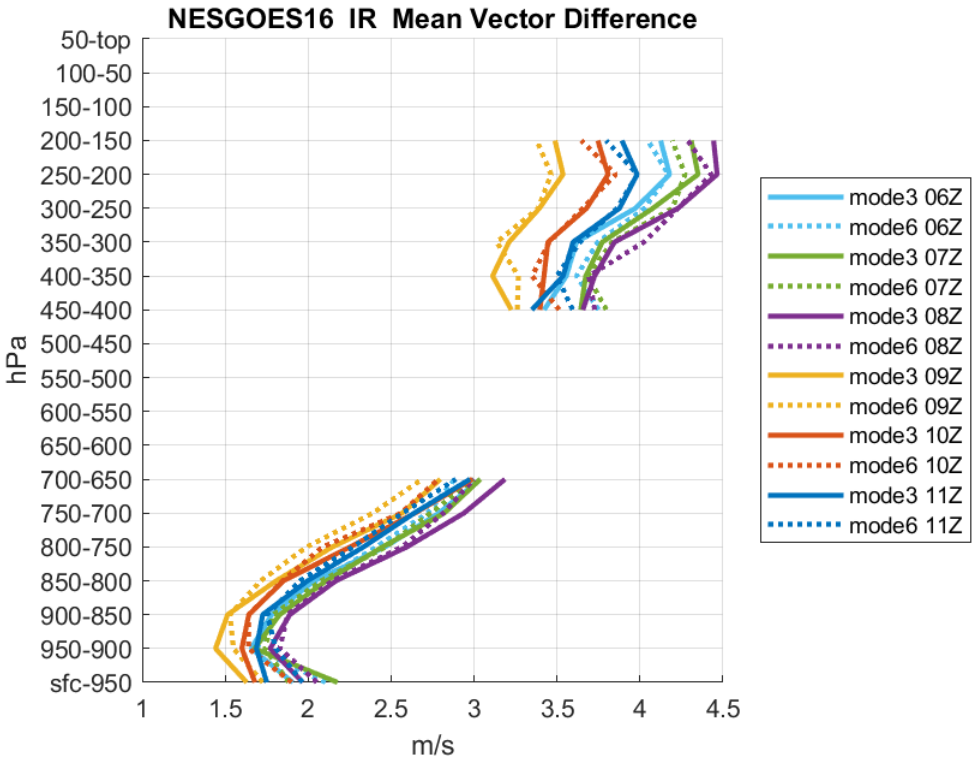
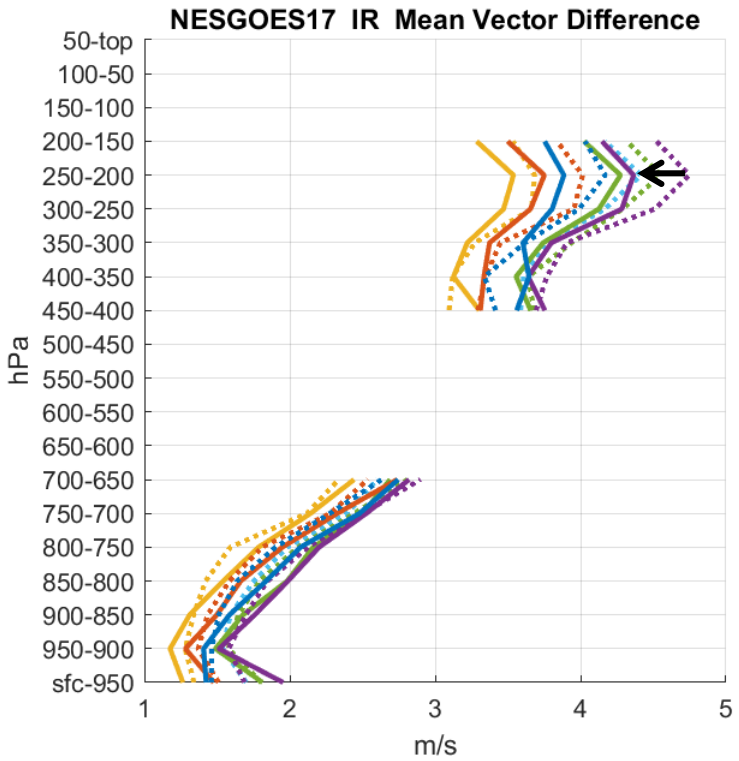
Mode 3 and Mode 6





Mode 3 gives reduced MVD at levels where the MVD was highest.

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Experiments

- **GOES-15/GOES-17 Comparison Runs**
- **GOES-17 Mode 6 and Mode 3 Comparison**
- **GOES-16/GOES-17 Enterprise Algorithm Comparison Runs**
  - 01-30 APR 2020, NAVGEM 2.1 control and experiment runs
  - Compare GOES-16/GOES-17 AMVs between control and experiment
  - Compare NESDIS GOES-17 Height Assignment and Tracking Mitigation Methods in the experiment run
- **GOES-16/GOES-17 Stereographic Height Assignment Method**

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GOES-16/GOES-17 Enterprise Algorithm Comparison Runs

- **Dual experiments with NAVGEM 2.1 (Navy Global Environmental Model)**
  - Forecast Model Resolution: T425L60
  - Data Assimilation: Hybrid 4DVAR
  - Forecast Sensitivity Observation Impact for 24-hr forecasts
  - Period of experiments: 1-30 Apr 2020
- **Control Run**
  - GOES-16 and GOES-17 NESDIS operational AMV algorithm
- **Enterprise Algorithm (with Mitigated Winds) Experiment Run**
  - GOES-16 and GOES-17 NESDIS updated algorithm, includes
    - cloud algorithm (height assignment) improvements for GOES-16 and GOES-17 AMVs
    - mitigation using alternate channels during heat-saturation periods for GOES-17 AMVs

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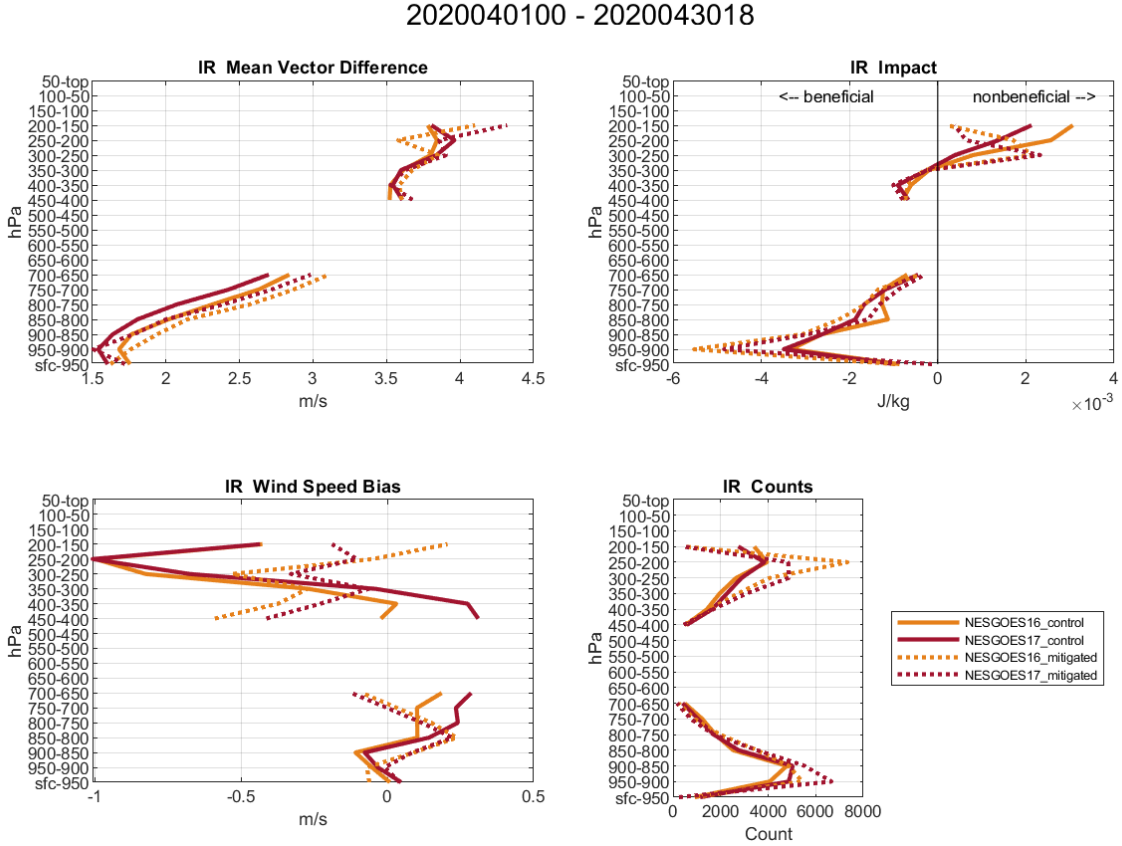
NESDIS GOES-16 and GOES-17 IR AMVs in Control and Enterprise Algorithm Runs

Enterprise Algorithm gives:

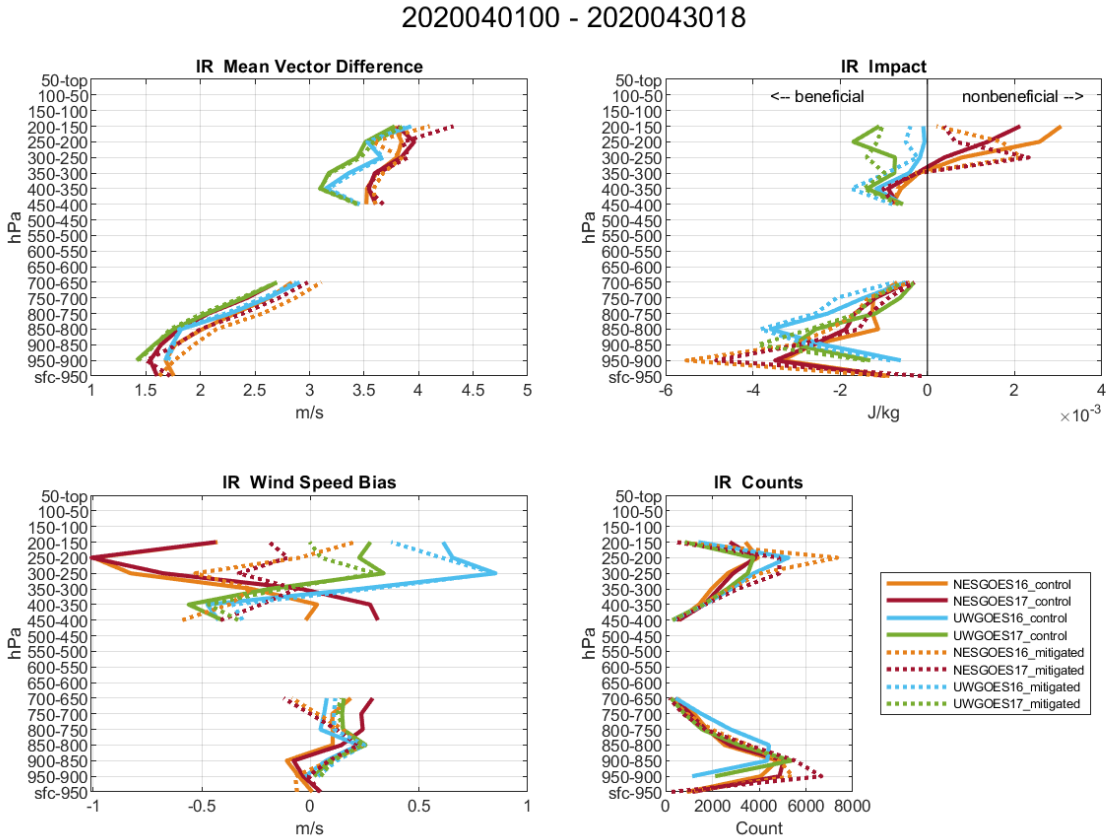
- Increased IR superob counts
- Decreased wind speed bias
- Decreased MVD for problematic upper-level IR winds, although MVD is slightly increased at other levels.

However, upper-level impact remains non-beneficial.



NESDIS and UW/CIMSS GOES-16 and GOES-17 IR AMVs in Control and Enterprise Algorithm Runs

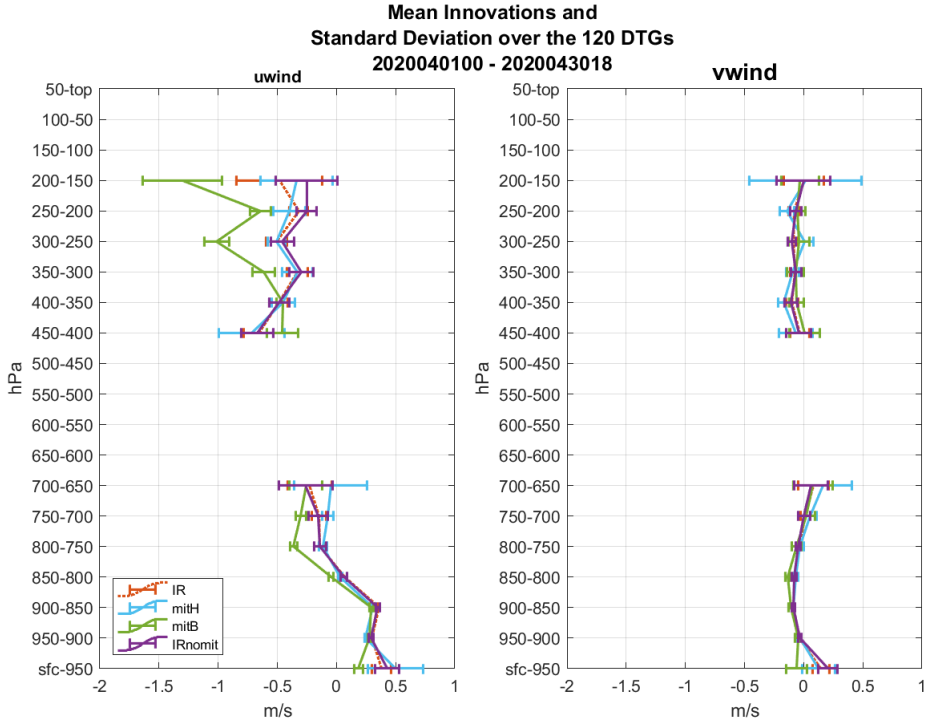
- Interestingly, CIMSS wind speed bias decreases as NESDIS bias is decreased.
- The background is a better fit to the CIMSS observations due to weaker bias in NESDIS winds' forcing.



Components and Speed Bias for Mitigated AMV Types

IRnomit has the smallest innovations. These are AMVs where no mitigation measures were applied (because not needed).

mitB uwind innovations and wind speed bias are significantly larger than those of the **mitH** AMVs.



IRnomit: standard-method IR superobs

mitH: mitigated height assignment method IR superobs

mitB: mitigated height assignment and tracking method IR superobs

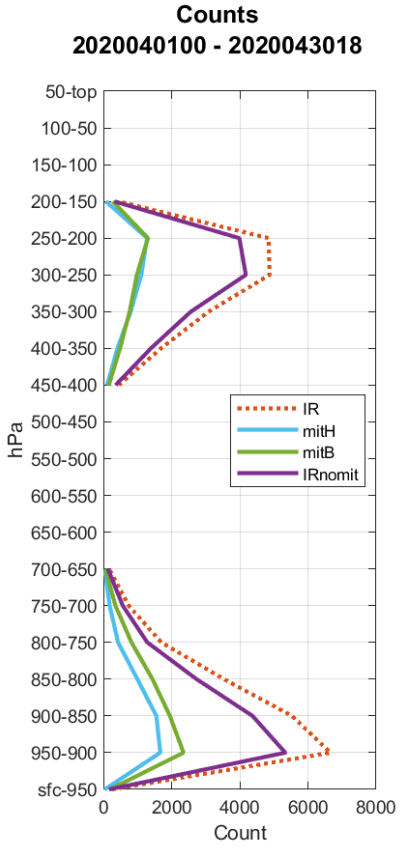
IR: all IR superobs

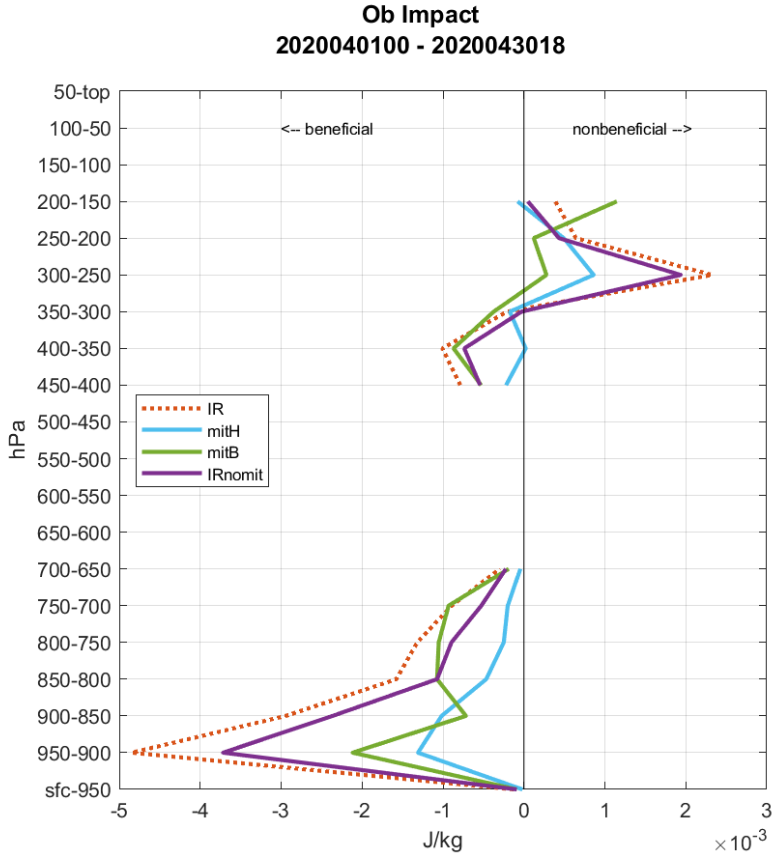
The large difference in uwind and speed biases between the **mitH** and **mitB** AMV types seems to indicate that the alternate channel tracking mitigation method introduces significant additional forcing to the model state.

This can be seen in upper-and lower levels.

Counts and Impact for Mitigated AMV Types

- Upper-level IR AMVs are still non-beneficial, even though **mitH** and **mitB** tend more toward neutral impact than the unmitigated AMVs.
- Impact is beneficial at levels 300 hPa and lower—the mitigation measures appear to be effective below 300 hPa.
- Observations near the midlevel cutout, both above and below, are consistently beneficial.





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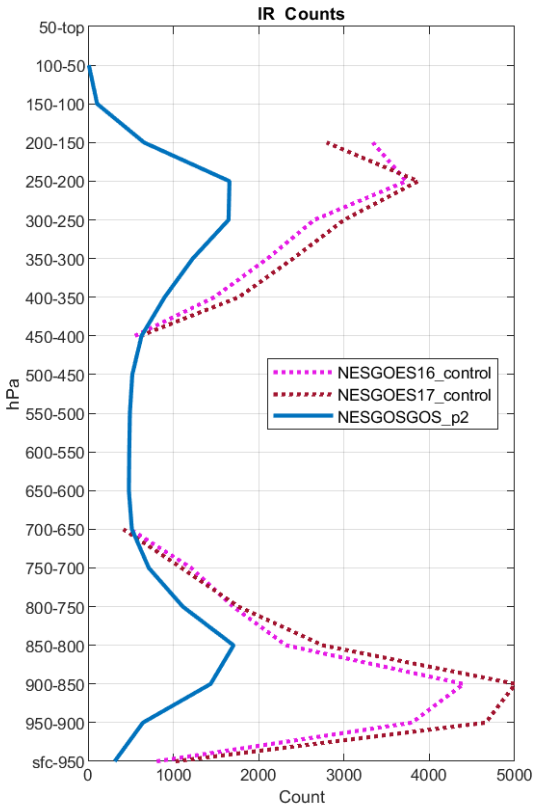
- **GOES-16/GOES-17 Stereographic Height Assignment Method**
  - 01-15 APR 2020, Data Monitoring Statistics using NAVGEM operations run

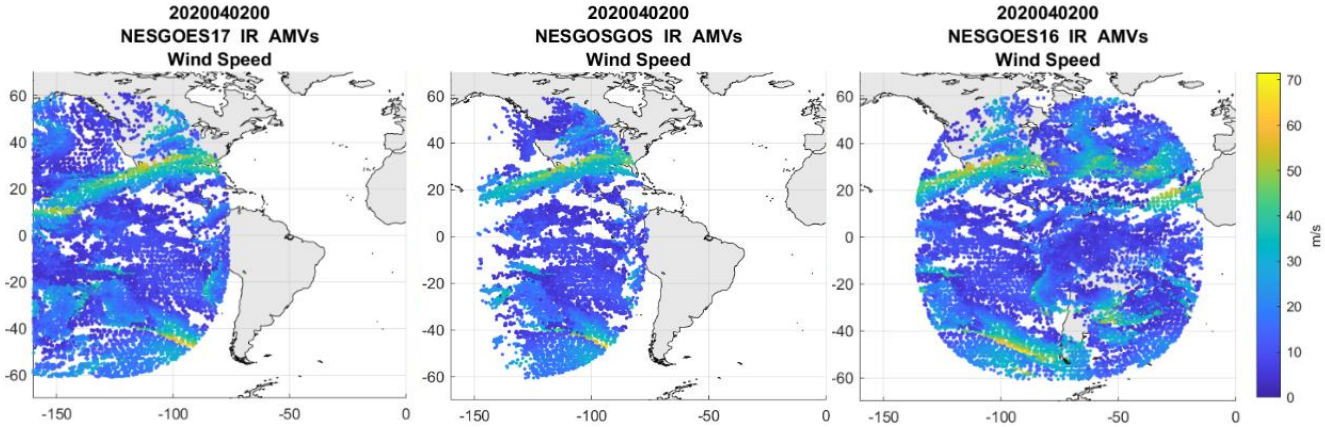
GOES17 Stereographic Height Assignment Method



Monitoring statistics for NAVGEM 1.4 (Navy Global Environmental Model)

- Forecast Model Resolution: T425L60
- Data Assimilation: Hybrid 4DVAR

Statistics period: 1-15 Apr 2020



Additional AMVS in GOES East GOES West overlap region

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Stereo Winds Compared to Control Run IR Winds

- MVD and wind speed biases of stereo winds near jet level are lower than those of control run IR winds.
- Assimilative test will be performed after Himawari-8/GOES-17 stereo winds test set is available.