Satellite-Derived Winds in the U.S. Navy's Global NWP System: Usage and Data Impacts in the Tropics

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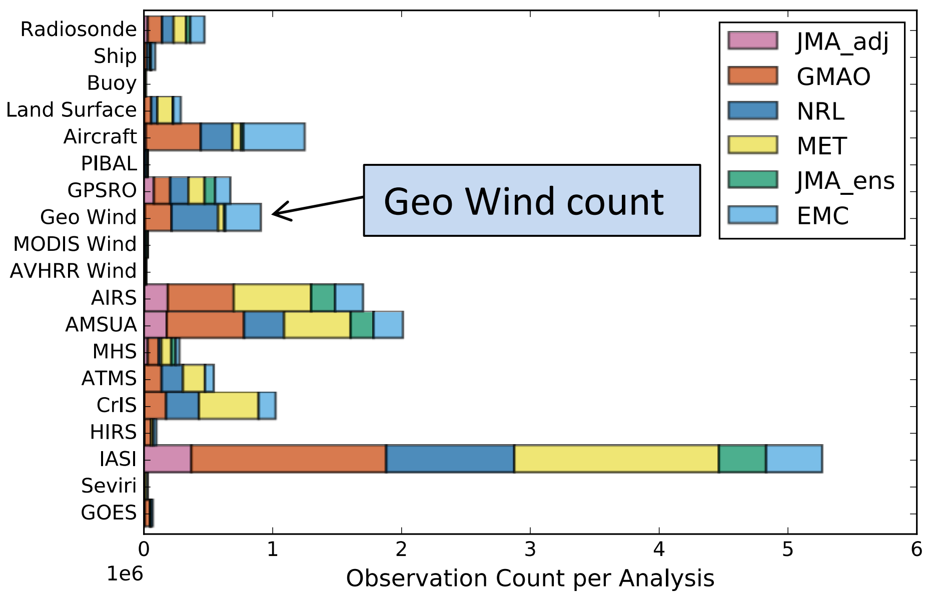
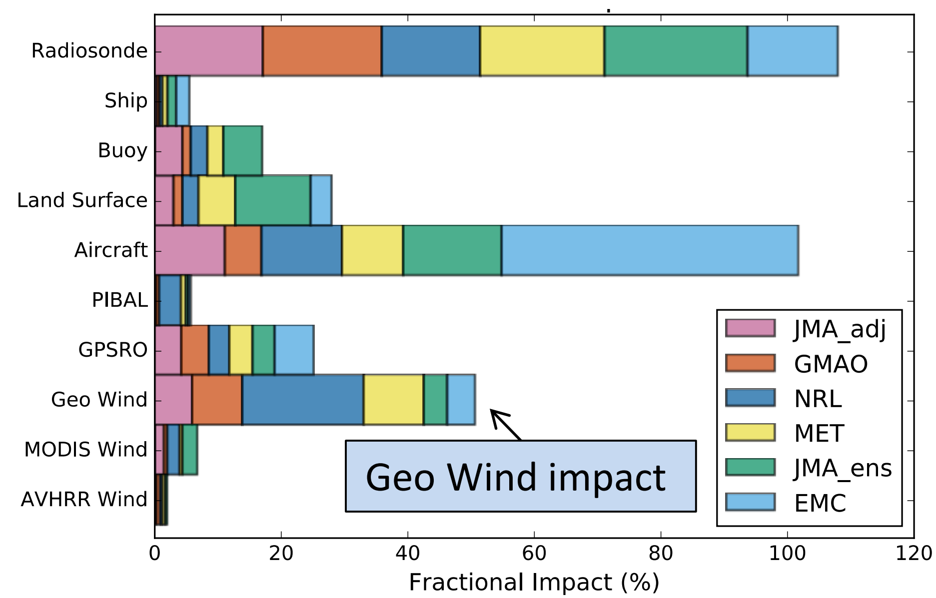
ECMWF/ESA Workshop: Tropical Modelling, Observations, and Assimilation

Overview

Satellite-derived winds provide a greater impact in the U.S. Navy's operational NWP system (NAVGEM: Navy Global Environmental Model) than is typically seen in other NWP systems.





Aulignè, Gelaro, Mahajan, Langland, Liu, Cotton, and Ota, 2016: Forecast Sensitivity-Observation Impact (FSOI) Inter-comparison Experiment. 6th WMO Workshop on the Impact of Various Observing Systems on NWP, Shanghai, China, 10-13 May 2016.

Overview

Satellite-derived winds provide a greater impact in the U.S. Navy's operational NWP system (NAVGEM: Navy Global Environmental Model) than is typically seen in other NWP systems.

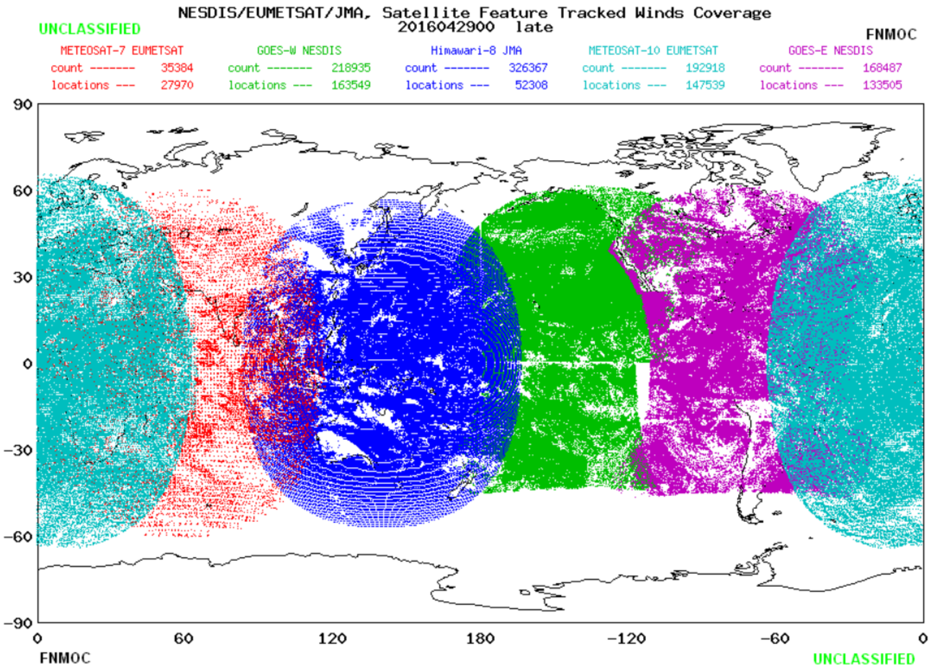
- Does this result from the way the satwinds are processed in NAVGEM?
- How much do observation impacts in the tropics differ from those in the extratropics?

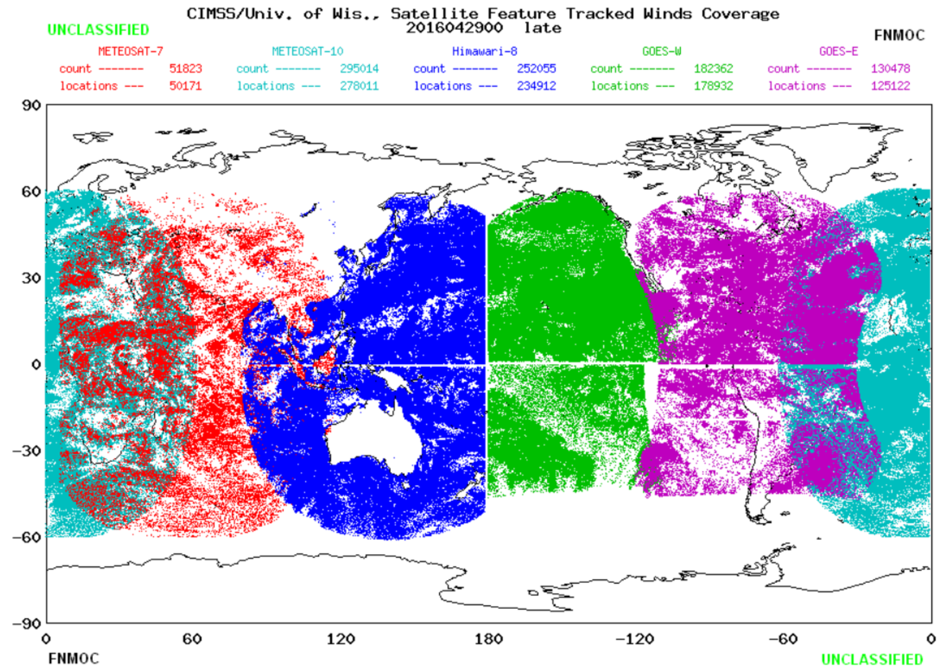
Satellite-Derived Wind Datasets

NAVGEM uses the following satellite-derived winds operationally:

- Geostationary Atmospheric Motion Vectors (AMVs)
  - GOES-13 and GOES-15 (NESDIS and CIMSS)
  - Meteosat-7 and Meteosat-10 (EUMETSAT and CIMSS) (and EUMETSAT Meteosat-9)
  - Himawari-8 (JMA and CIMSS)
- Polar AMVs
  - MODIS—Aqua and Terra (CIMSS and NESDIS)
  - AVHRR—METOP A and B; NOAA 15, 18, 19 (CIMSS and NESDIS)
  - VIIRS (CIMSS and NESDIS)
  - LeoGeo (CIMSS)
  - Global AVHRR (EUMETSAT)
- Surface winds
  - WindSat
  - ASCAT
  - SSMIS windspeeds

Use of Dual Datasets





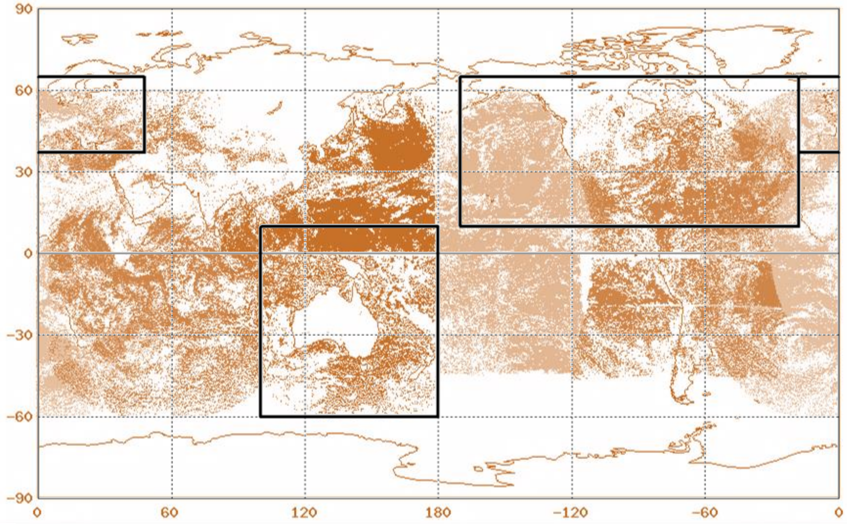
Unlike other operational global models, NAVGEM uses AMVs from both the operational providers (NESDIS, EUMETSAT, and JMA) and from CIMSS (University of Wisconsin-Madison).

- **“NoCIMSS” experiment excludes CIMSS geostationary AMVs**

Use of Quality Control

Quality Control (QC) is performed on individual observations prior to superobbing.

- Some QC is necessary:
  - Exclude obs with missing lat, lon, pressure, time, or background value
  - Exclude obs flagged as bad or having low confidence (QI)
- Other QC is debatable:
  - Impose land masking in selected regions
    - Mainly a factor in mid-latitudes
    - Not tested here
  - Impose vertical limits
  - Exclude winds with large vector innovations (ob minus background)



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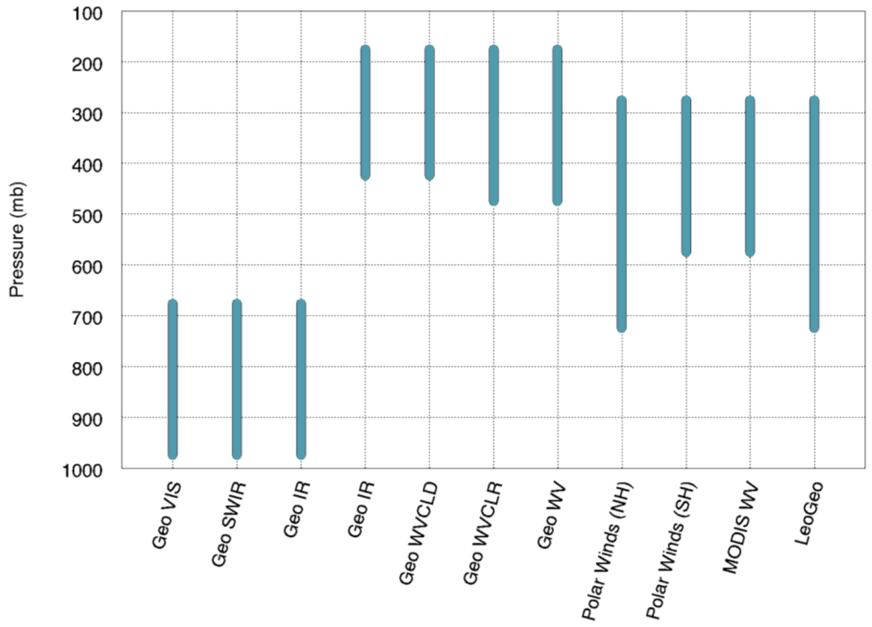
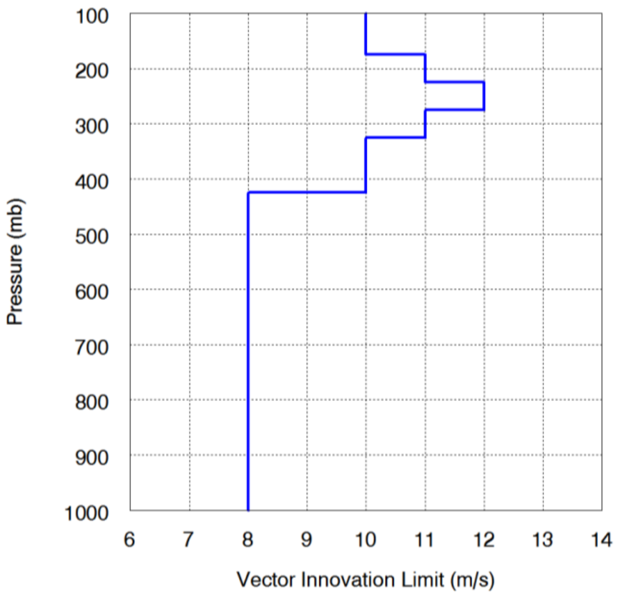
Vertical Limits and Vector Limits





Winds are used only within the indicated vertical ranges (left) with vector innovations less than thresholds (right).

- **"LessQC" experiment excludes these two checks**

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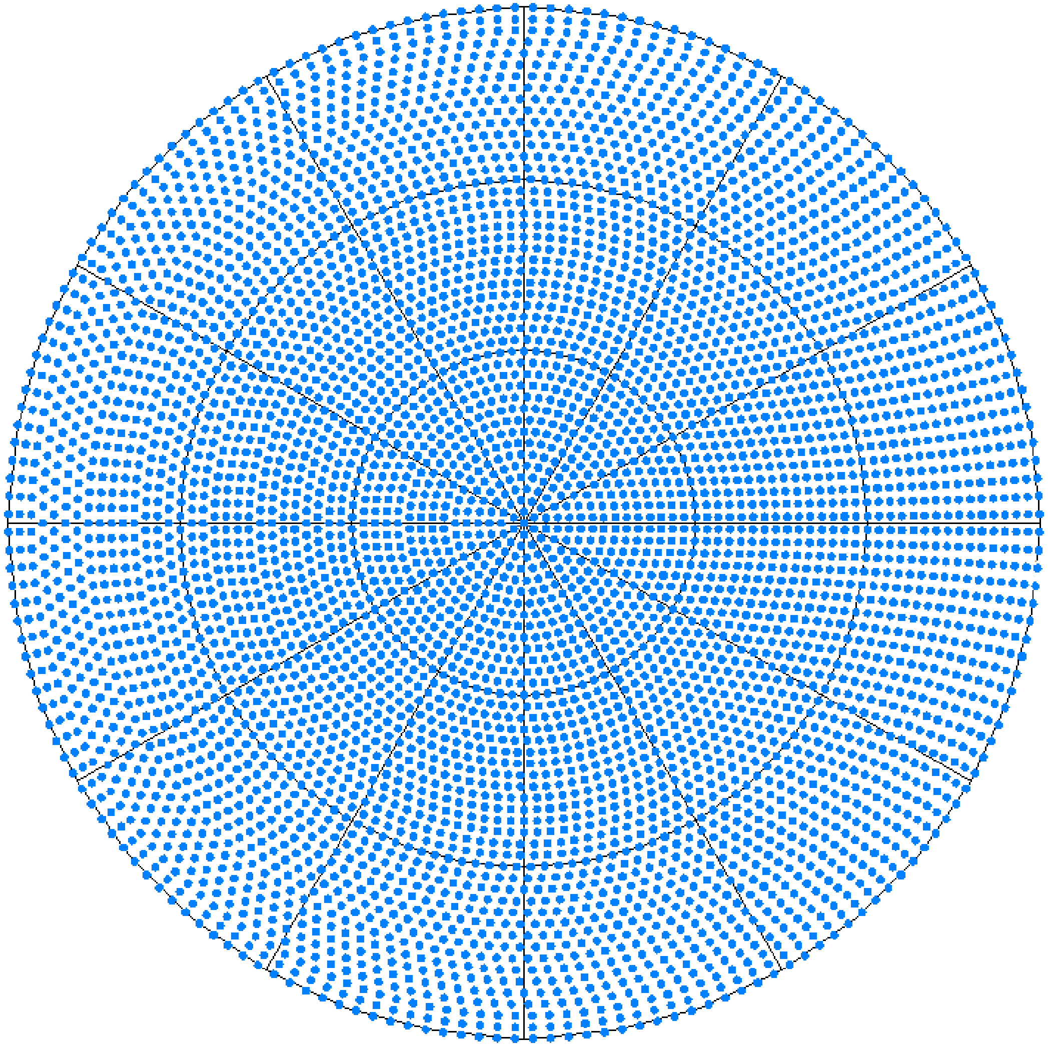
Use of Superobbing

- Satellite-derived winds contain horizontally correlated errors that the data assimilation system assumes are not present.
- Thinning or averaging (“superobbing”) is performed as mitigation.
- Nearly all centers use thinning, but NAVGEM uses superobbing.
- Basic philosophy: Only superob similar observations.
  - Same satellite, channel, processing center
  - Similar time (within 1 hr)
  - In the same “prism” and 50 mb layer (with at least two obs present)
  - Similar wind direction (within 20°) and speed (7 to 14 m/s depending on speed)
    - Can reject one or two outliers to get within these limits
    - Can quarter prism and make a superob in each quarter if the limits are met
  - Superob placed at centroid of obs at mean pressure
  - Superob values corrected so the magnitude of the superob vector equals the mean speed of the obs

Superob Prisms

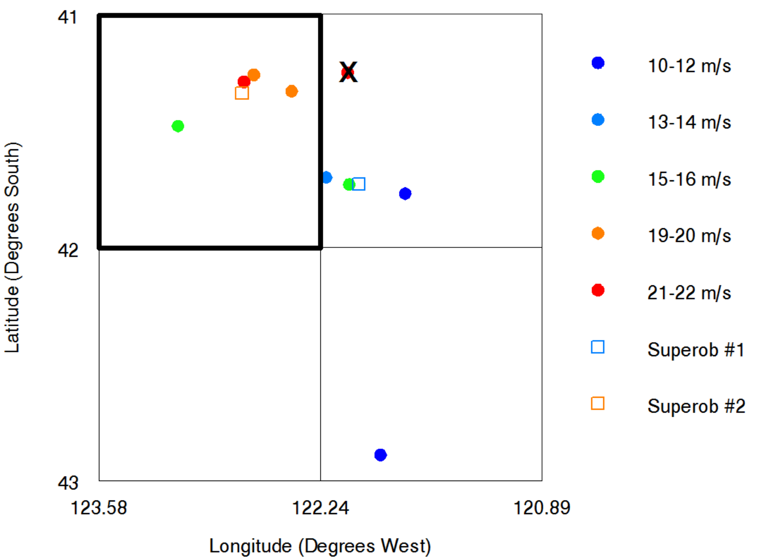


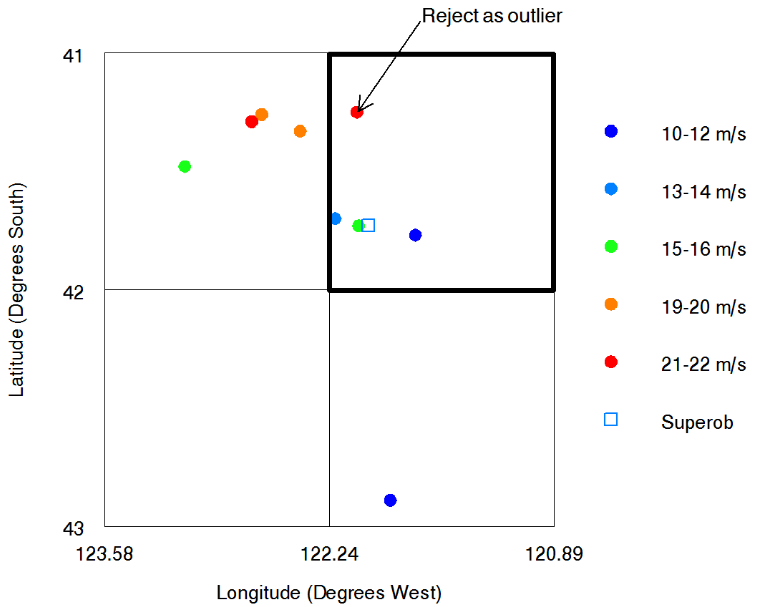
Satwinds are binned into 2° latitude-longitude "prisms" in 50 hPa layers for superobbing.

Dots indicate the centers of superob prisms in a hemisphere

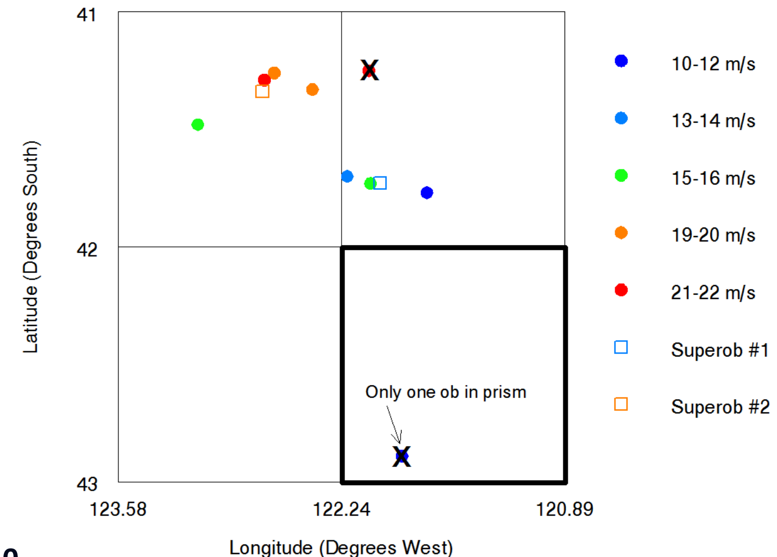
- All prisms are 2° lat "tall"
- Prisms at the equator are 2° lon "wide"
- Width varies to approximate equal area
- Each latitude band has an integer number of prisms

Superob Example





- GOES-11 example--1722 UTC 31 Aug 2010
  - Directions from 281° to 296°, within 20°
  - 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



Use of Superobbing

To evaluate the impact of superobbing, thinning is tested for geostationary AMVs only:

- Use same data and QC procedures as in control experiment
- Bin AMVs as for superobbing
  - 2° prisms, 50 hPa deep with times within one hour
  - Generated by same processing center for the same satellite and channel
  - Minimum of 2 AMVs
- Select AMV with the greatest QI
- If multiple AMVs share the greatest QI value, select the AMV closest to the centroid of all AMVs in that prism

No outlier detection or limits on range of speeds or directions are performed.

No prism quartering is performed.

- **"Thinning" experiment uses this procedure**

Evaluation of Experiments

Experiments are evaluated using the Forecast Sensitivity Observation Impact (FSOI) (Langland and Baker, 2004)

- Most commonly evaluated using the total energy norm (e.g., Errico, Raeder, and Ehrendorfer (2004), eq. 7 and 8)

$$E = \boxed{\frac{1}{N_\mathrm{w}} \sum_{i,j,k} \Delta\sigma_k (u'^2_{i,j,k} + v'^2_{i,j,k})} + \frac{C_p}{T_\mathrm{r} N_\mathrm{t}} \sum_{i,j,k} \Delta\sigma_k T'^2_{i,j,k} + \frac{R T_\mathrm{r}}{p^2_\mathrm{sr} N_\mathrm{t}} \sum_{i,j} p'^2_{\mathrm{s}\,i,j} + \frac{L^2}{C_p T_\mathrm{r} N_\mathrm{t}} \sum_{i,j,k} \Delta\sigma_k q'^2_{i,j,k}$$

- Results using kinetic energy norm (the first term--red box) also presented
- Contributions summed over subsets of values:
  - Various instrument types
  - Latitude bands and sum for tropics (30°N to 30°S)
  - Vertical layers

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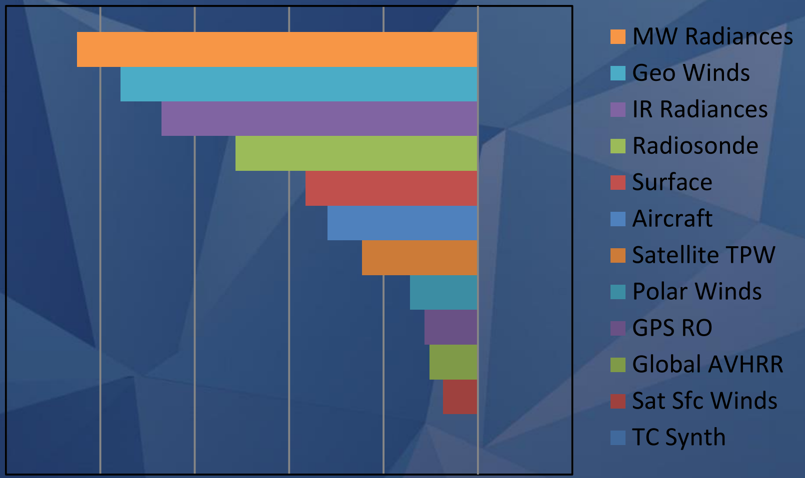

Results from the Control Experiment

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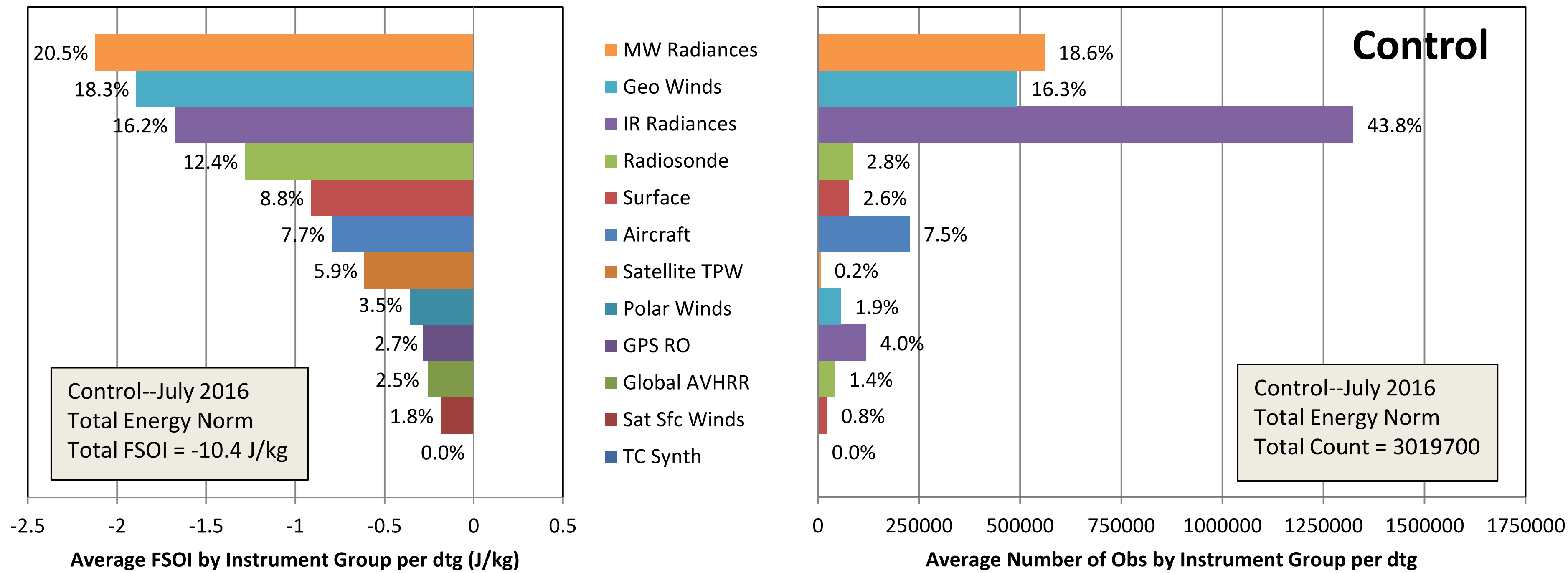
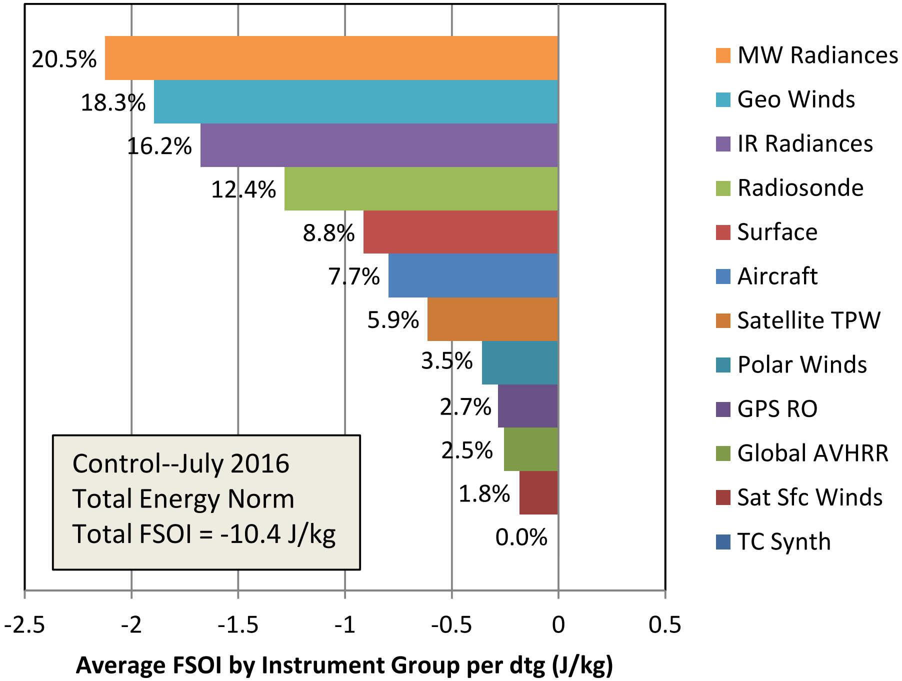
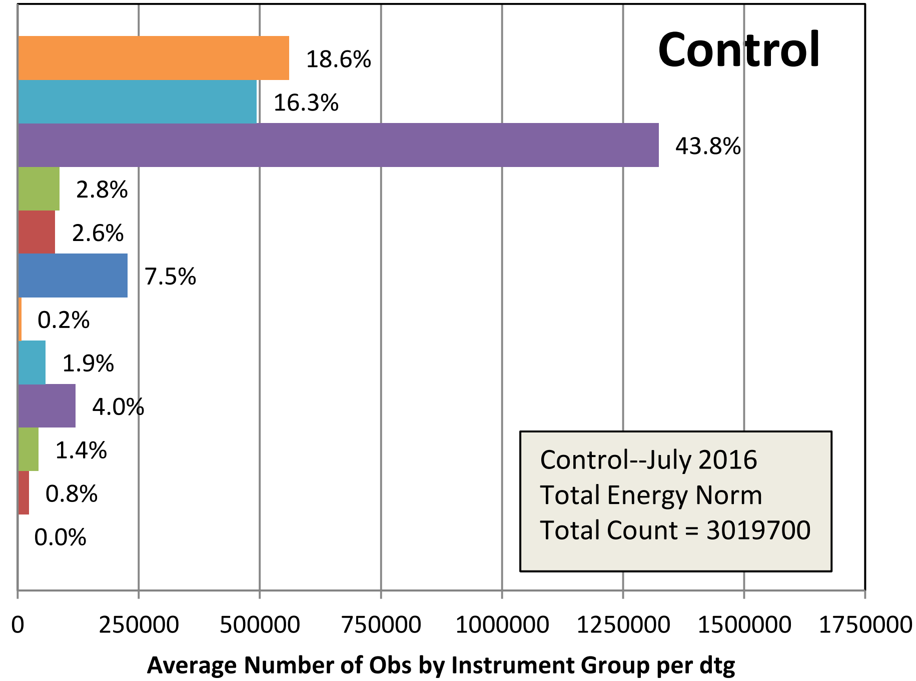
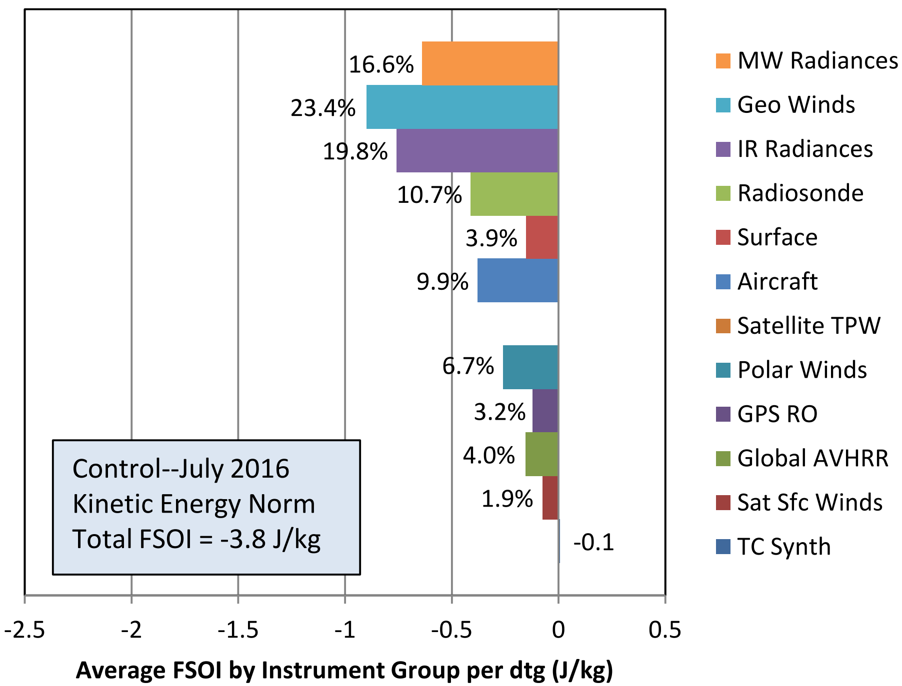


Groups of observations with % counts

- Microwave radiances
  - AMSU-A (50.1%)
  - ATMS (31.0%)
  - SSMIS (13.4%)
  - MHS (3.5%)
  - SSMIS UAS (2.0%)
- Infrared radiances
  - IASI (69.8%)
  - AQUA AIRS (30.2%)
- Satellite TPW
  - SSMIS (85.3%)
  - WindSat (14.7%)
- Aircraft
  - MDCRS (U.S. AMDAR) (72.3%)
  - AMDAR (non-U.S.) (22.8%)
  - AIREP (4.9%)
- Surface
  - Land (68.4%)
  - Coast (13.7%)
  - Buoy (moored) (8.3%)
  - Buoy (drifting) (4.5%)
  - Ship (5.1%)
- Polar Winds
  - LeoGeo (34.3%)
  - AVHRR (35.8%)
  - MODIS (23.9%)
  - VIIRS (6.0%)
- Satellite Surface Winds
  - ASCAT (57.3%)
  - SSMIS speed (29.6%)
  - WindSat (13.1%)







- Geo Winds provide 18.3% of the error reduction using the total energy norm, but 23.4% using the kinetic energy norm.
- Radiances provide roughly 36% of the error reduction using either norm—tracer effect for kinetic energy?

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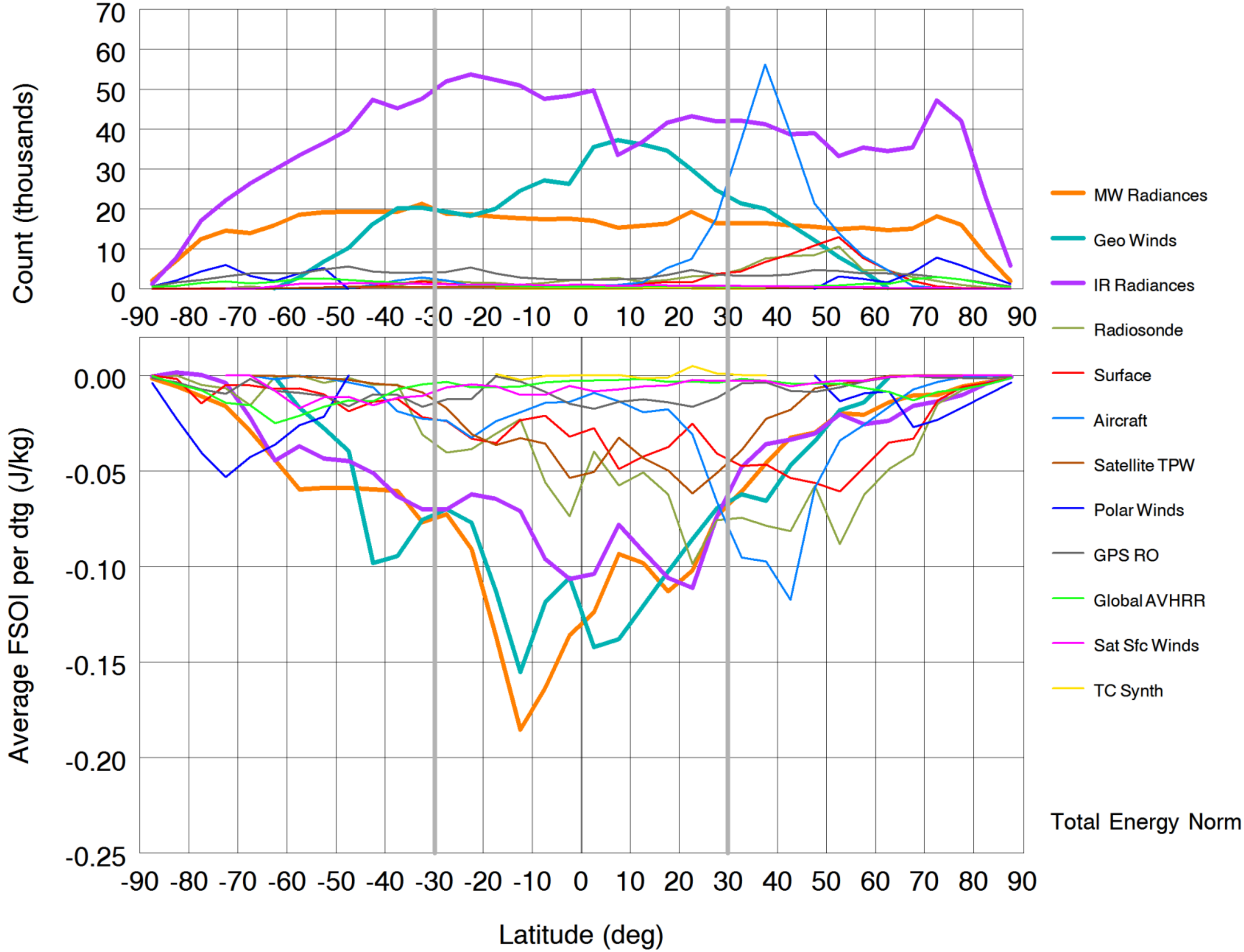
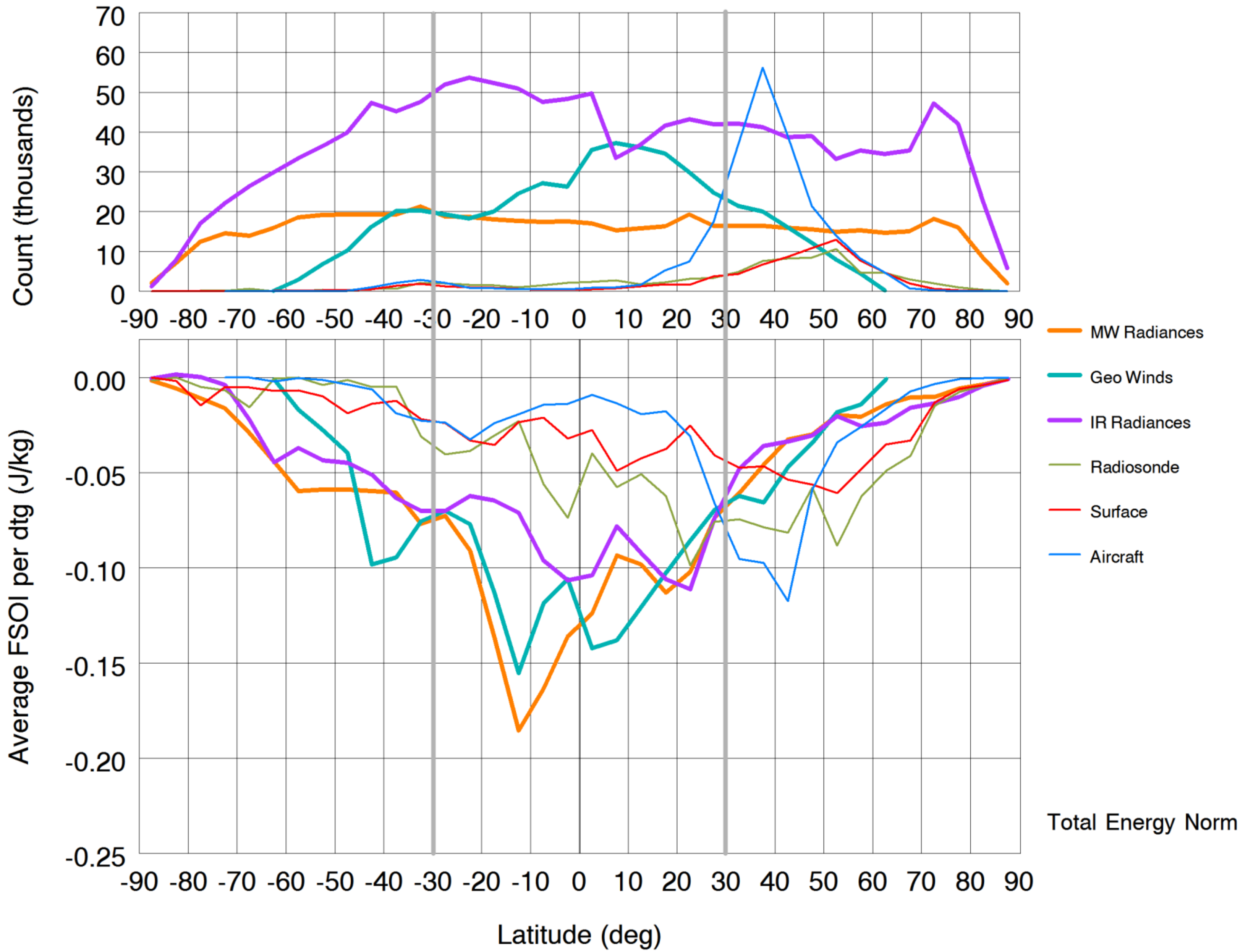
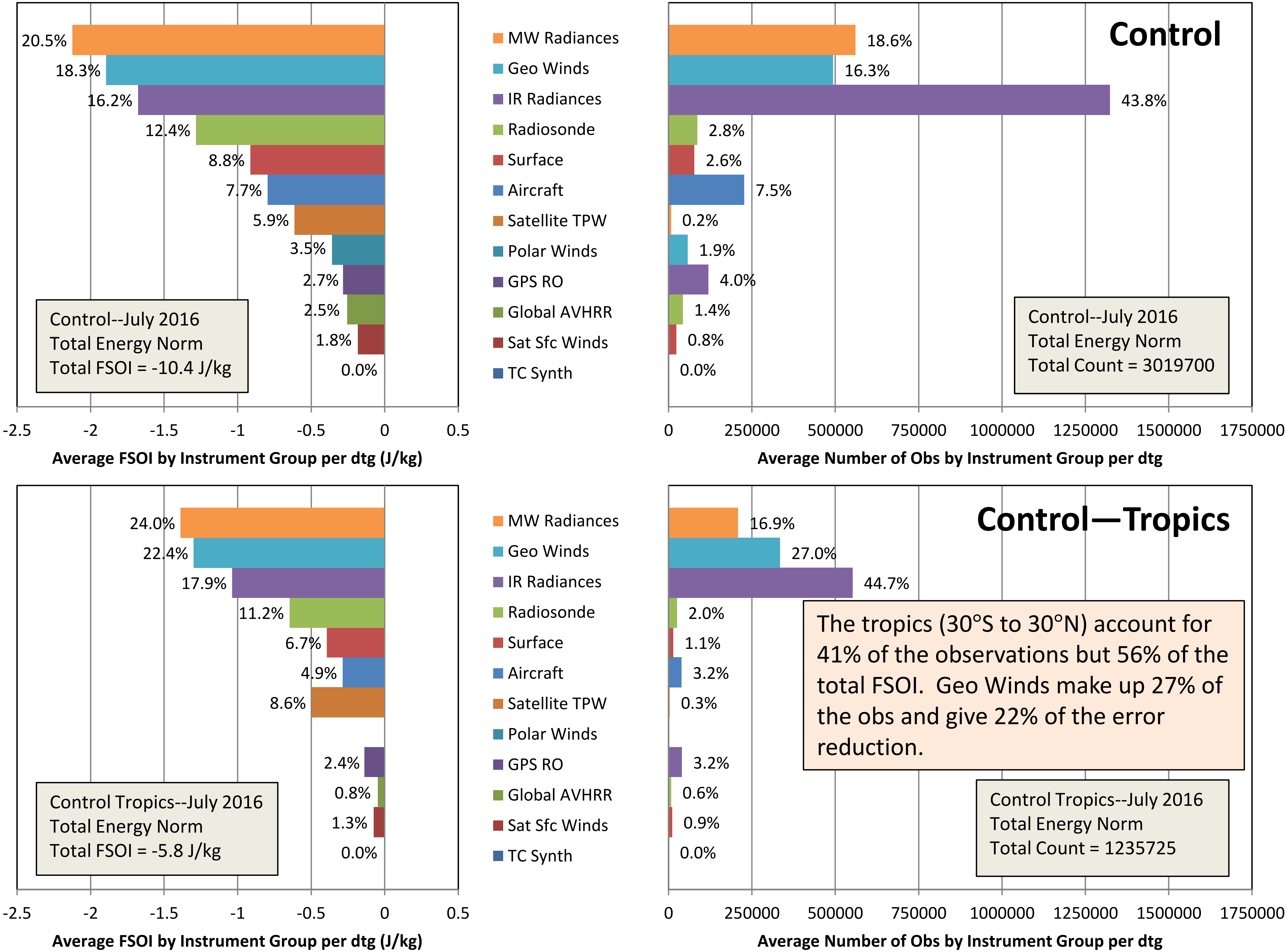
Counts and FSOI by 5° Latitude Band

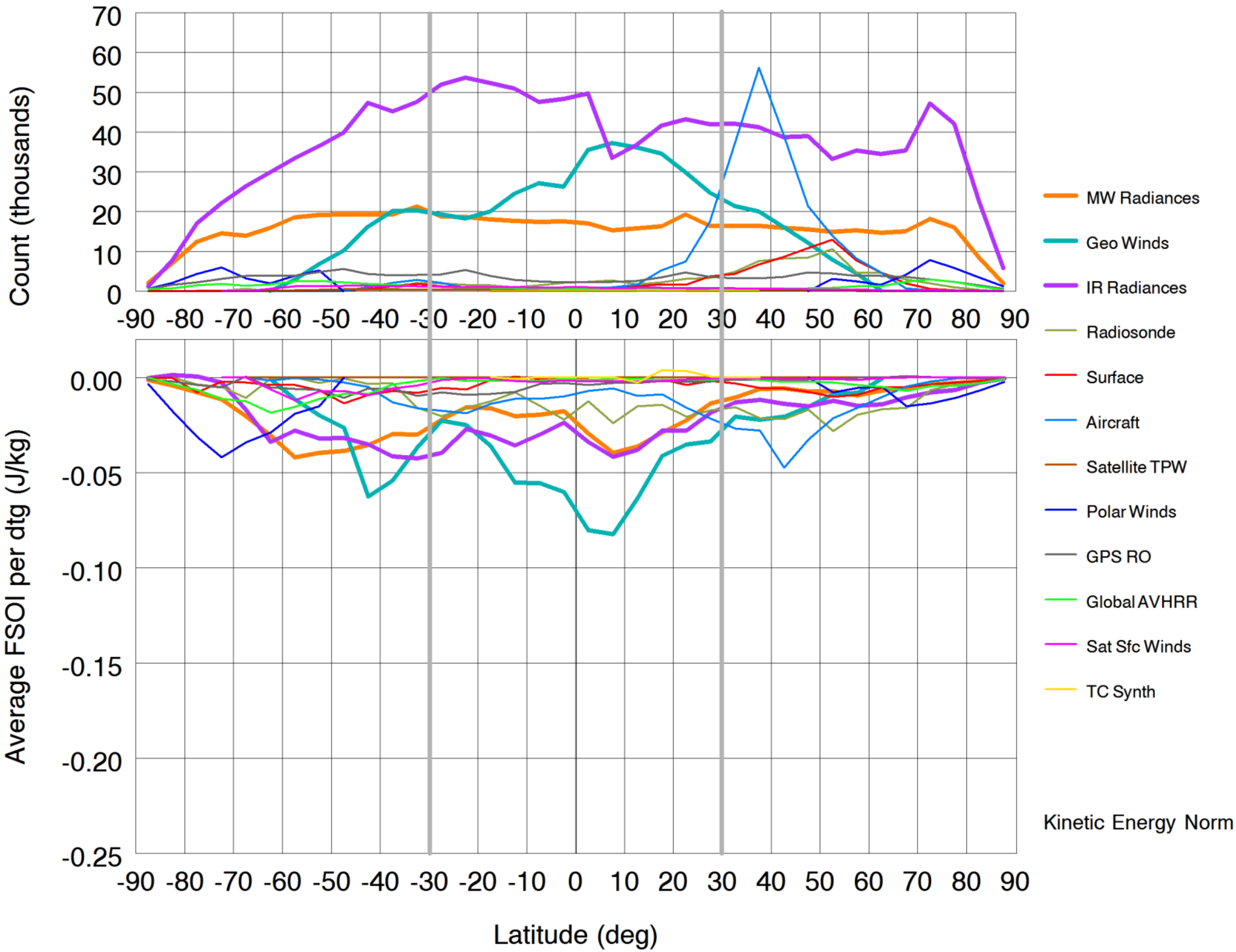


Counts and FSOI by 5° Latitude Band

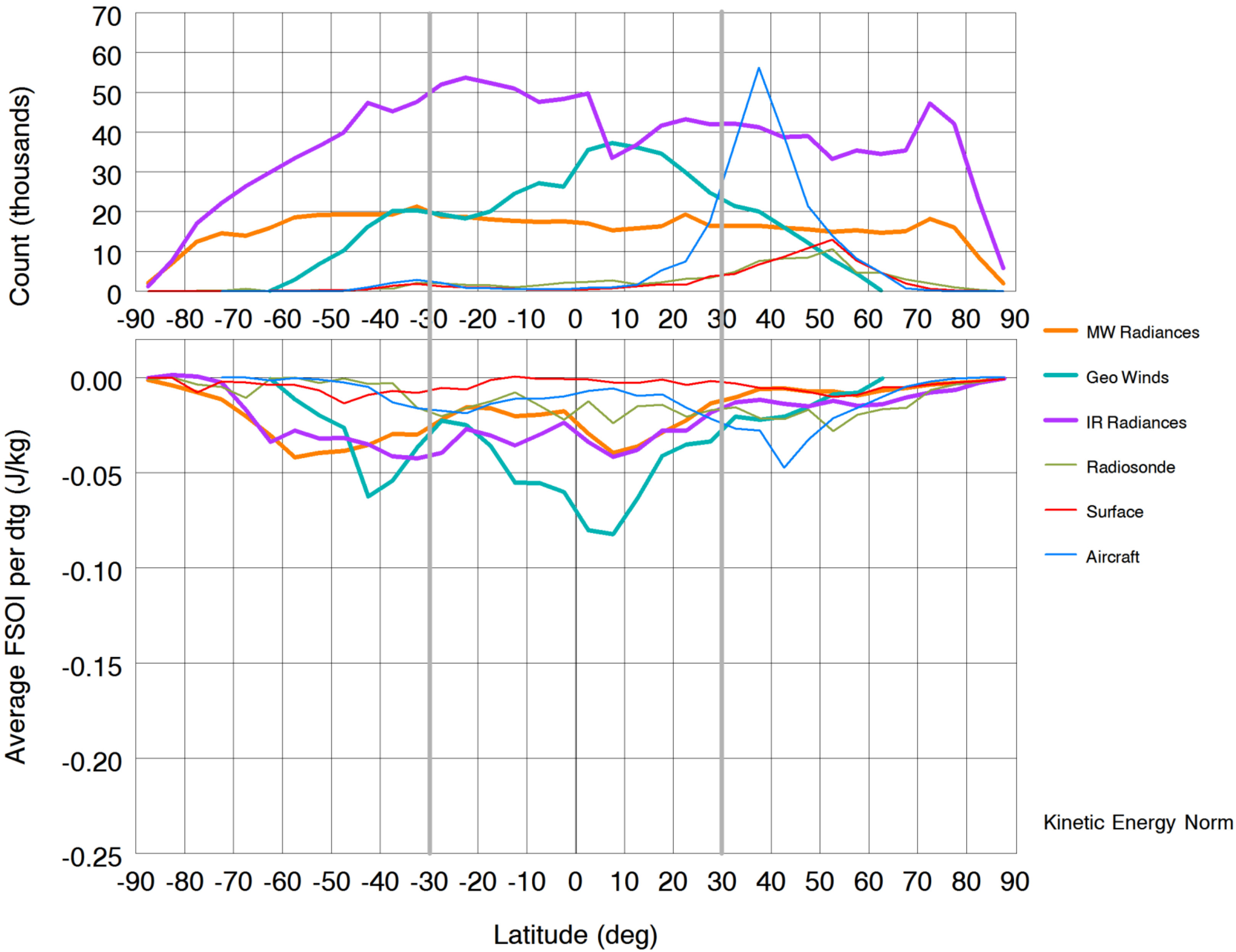


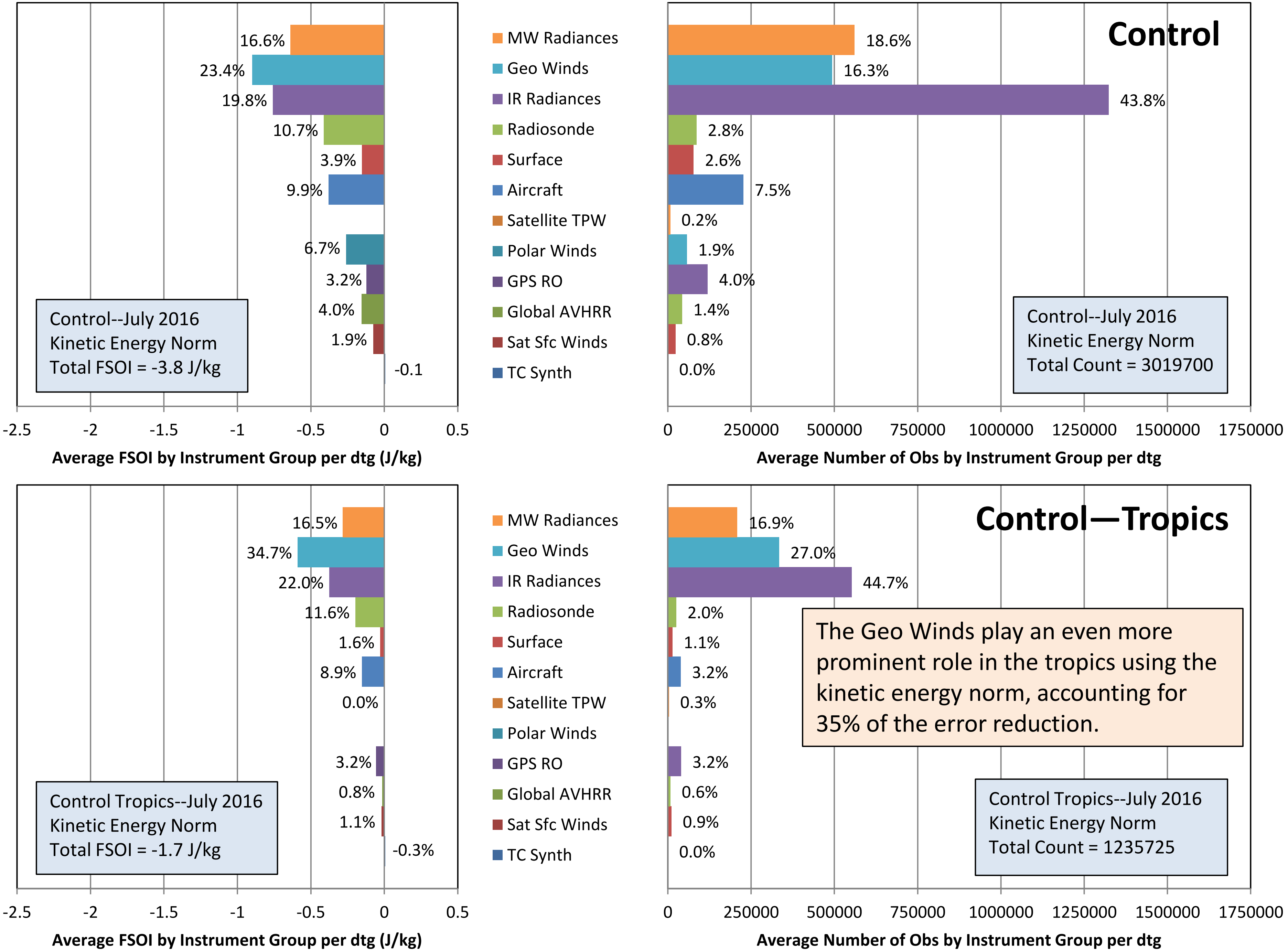

Control
Control—Tropics
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
20.5%
18.3%
16.2%
12.4%
8.8%
7.7%
5.9%
3.5%
2.7%
2.5%
1.8%
0.0%
18.6%
16.3%
43.8%
2.8%
2.6%
7.5%
0.2%
1.9%
4.0%
1.4%
0.8%
0.0%
Control--July 2016
Total Energy Norm
Total FSOI = -10.4 J/kg
Control--July 2016
Total Energy Norm
Total Count = 3019700
-2.5
-2
-1.5
-1
-0.5
0
0.5
Average FSOI by Instrument Group per dtg (J/kg)
0
250000
500000
750000
1000000
1250000
1500000
1750000
Average Number of Obs by Instrument Group per dtg
24.0%
22.4%
17.9%
11.2%
6.7%
4.9%
8.6%
2.4%
0.8%
1.3%
0.0%
16.9%
27.0%
44.7%
2.0%
1.1%
3.2%
0.3%
3.2%
0.6%
0.9%
0.0%
The tropics (30°S to 30°N) account for 41% of the observations but 56% of the total FSOI. Geo Winds make up 27% of the obs and give 22% of the error reduction.
Control Tropics--July 2016
Total Energy Norm
Total FSOI = -5.8 J/kg
Control Tropics--July 2016
Total Energy Norm
Total Count = 1235725
-2.5
-2
-1.5
-1
-0.5
0
0.5
Average FSOI by Instrument Group per dtg (J/kg)
0
250000
500000
750000
1000000
1250000
1500000
1750000
Average Number of Obs by Instrument Group per dtg

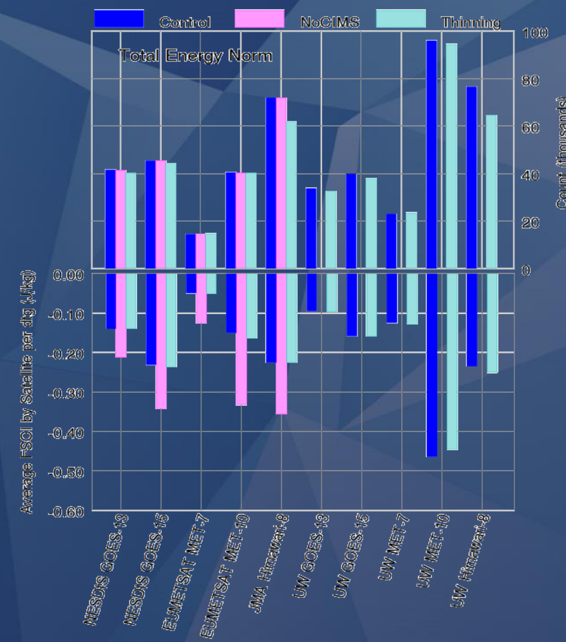
Counts and FSOI by 5° Latitude Band



Counts and FSOI by 5° Latitude Band




Control
Control—Tropics
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
Control--July 2016
Kinetic Energy Norm
Total FSOI = -3.8 J/kg
Control--July 2016
Kinetic Energy Norm
Total Count = 3019700
Control Tropics--July 2016
Kinetic Energy Norm
Total FSOI = -1.7 J/kg
Control Tropics--July 2016
Kinetic Energy Norm
Total Count = 1235725
The Geo Winds play an even more prominent role in the tropics using the kinetic energy norm, accounting for 35% of the error reduction.
Average FSOI by Instrument Group per dtg (J/kg)
Average Number of Obs by Instrument Group per dtg
16.6%
23.4%
19.8%
10.7%
3.9%
9.9%
6.7%
3.2%
4.0%
1.9%
-0.1
18.6%
16.3%
43.8%
2.8%
2.6%
7.5%
0.2%
1.9%
4.0%
1.4%
0.8%
0.0%
16.5%
34.7%
22.0%
11.6%
1.6%
8.9%
0.0%
3.2%
0.8%
1.1%
-0.3%
16.9%
27.0%
44.7%
2.0%
1.1%
3.2%
0.3%
3.2%
0.6%
0.9%
0.0%



Results from the NoCIMSS and Thinning Experiments

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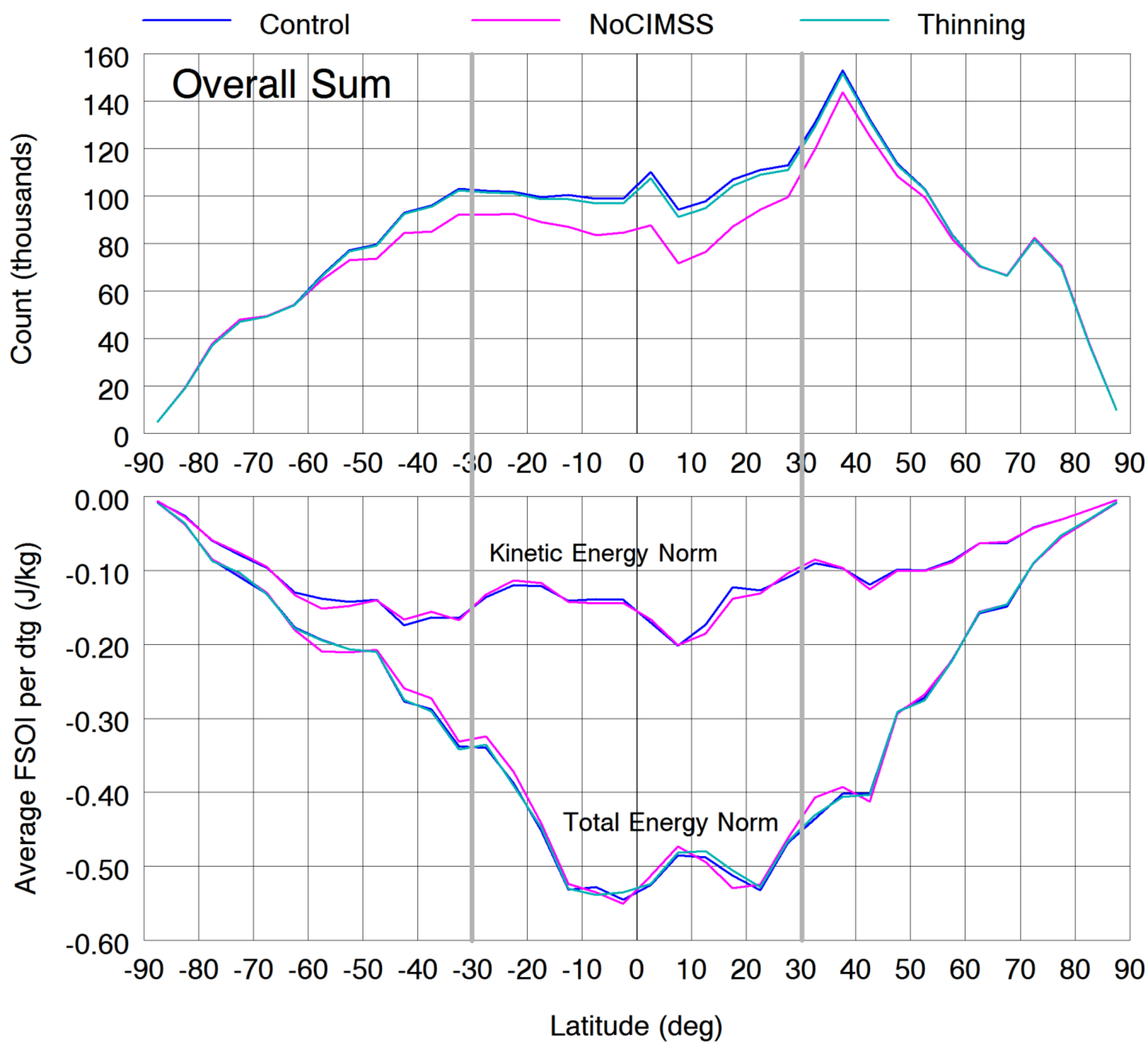
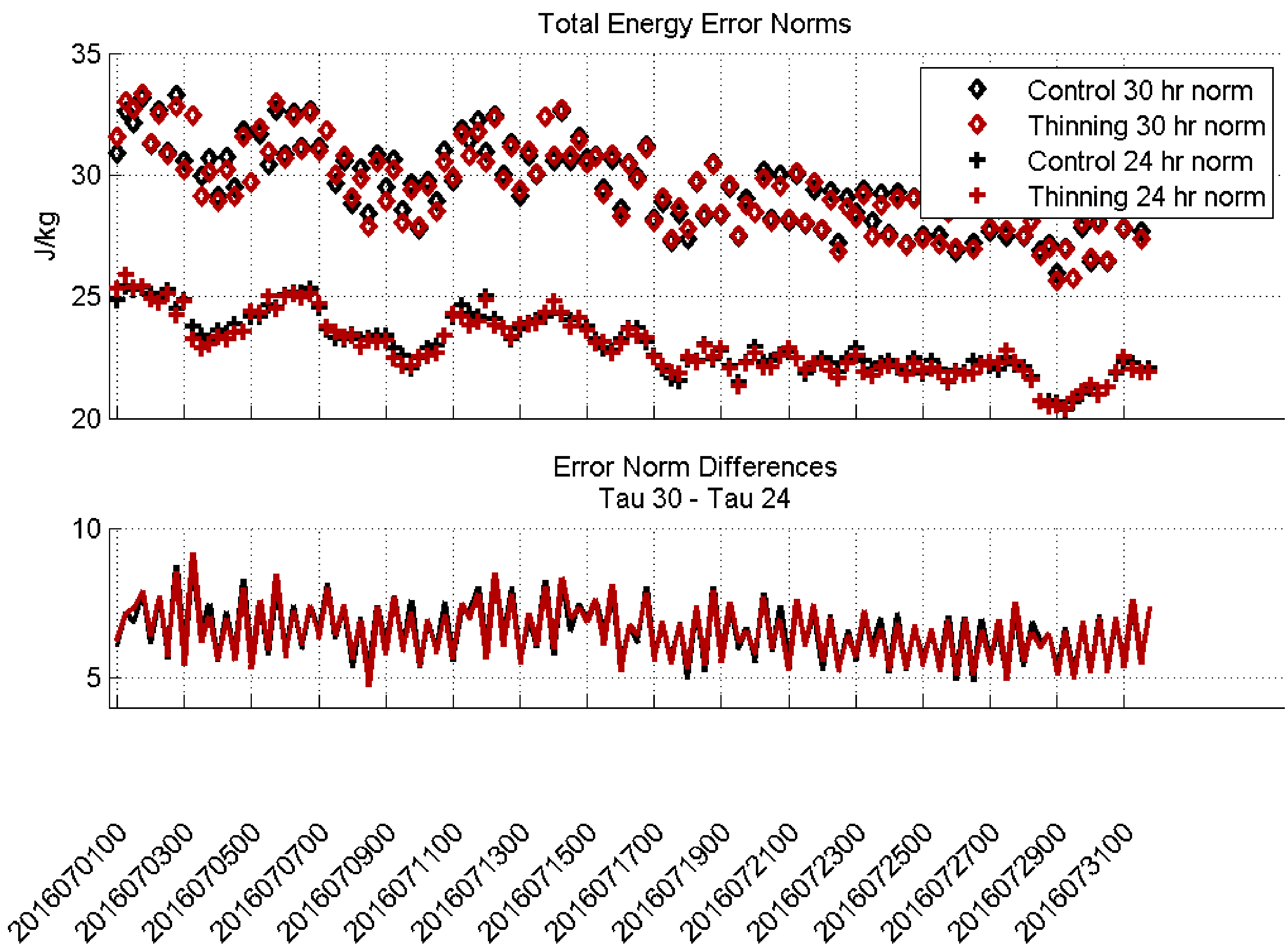
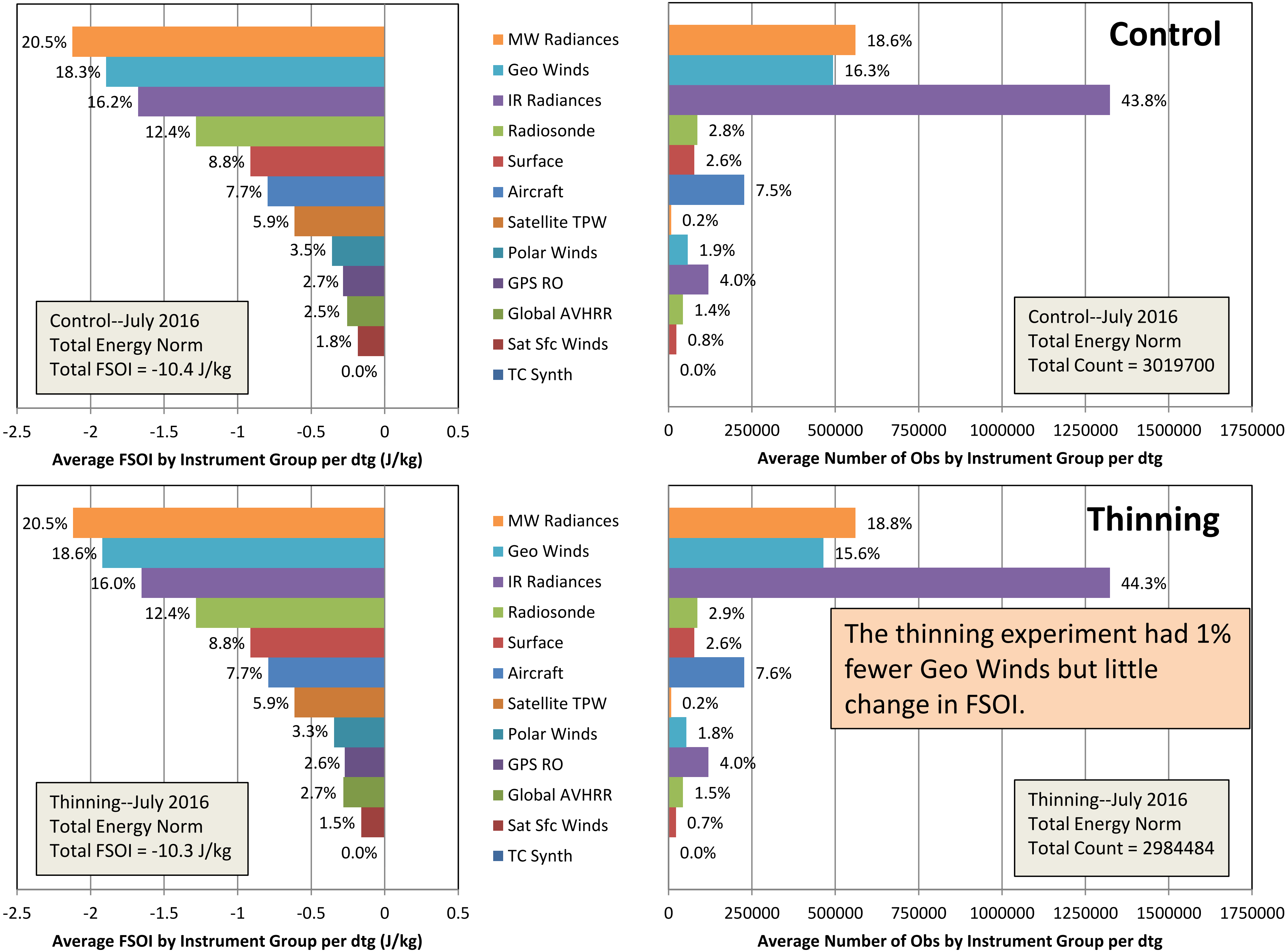
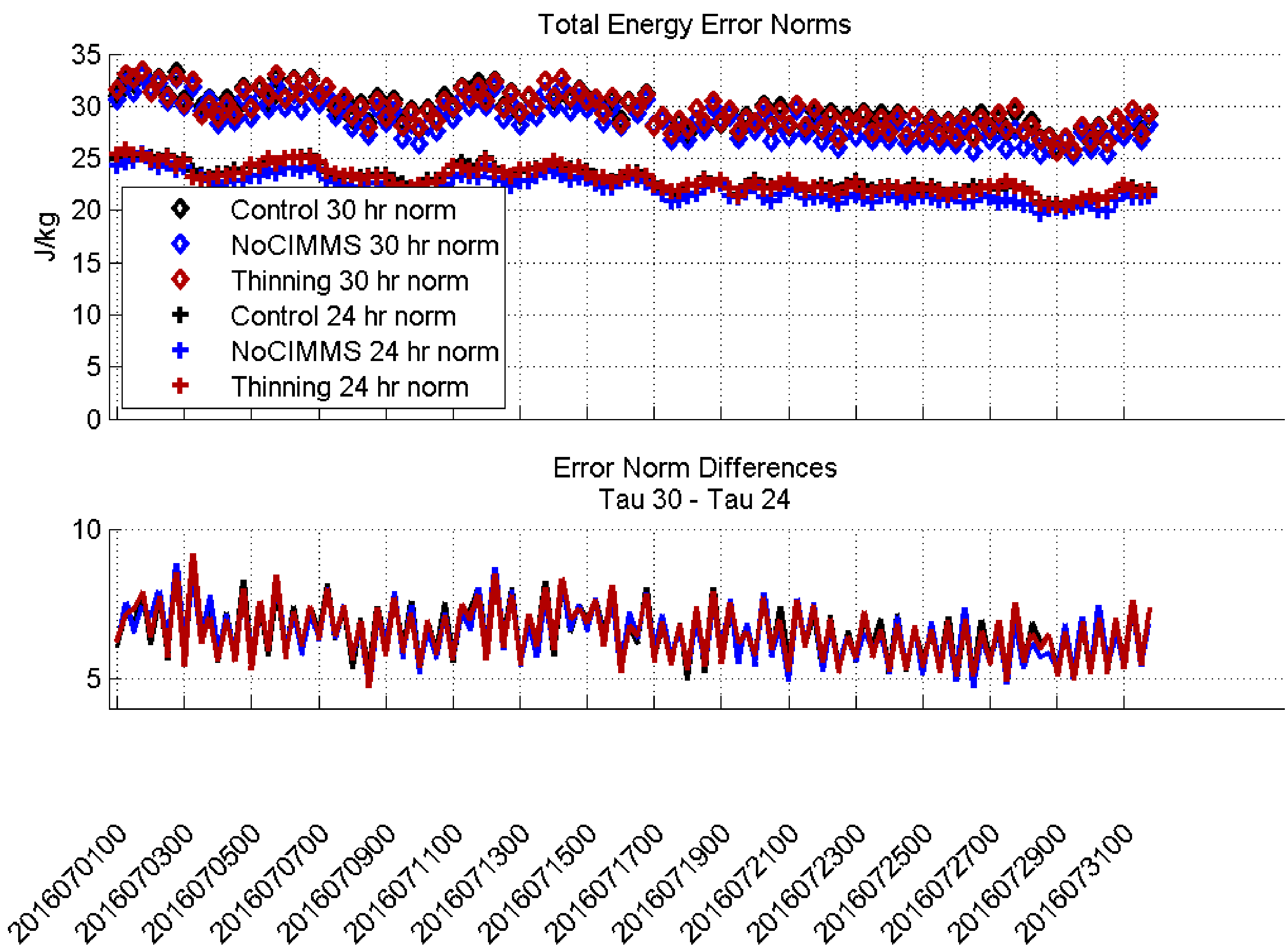


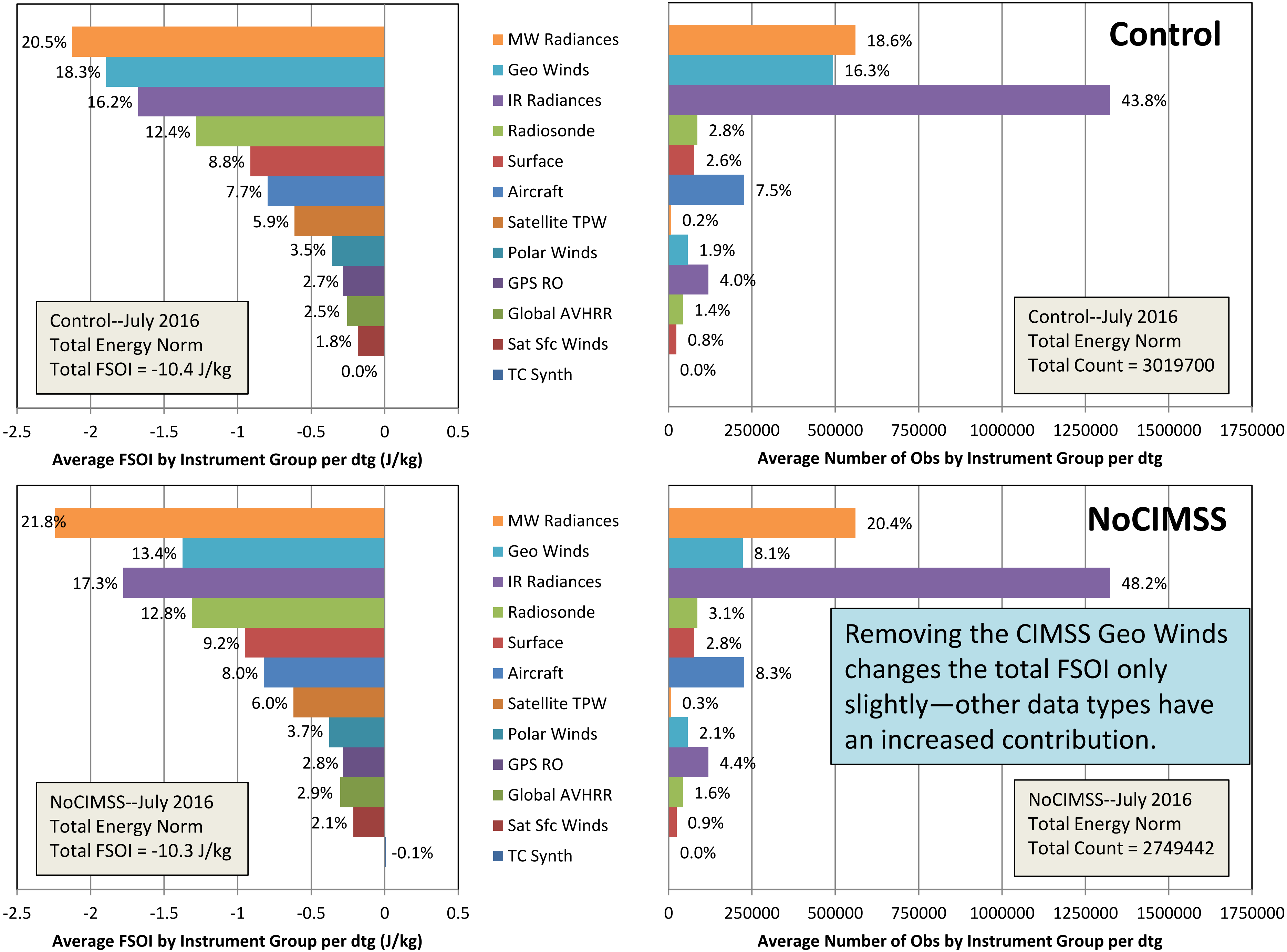
Control
NoCIMSS
Thinning
Overall Sum
Count (thousands)
160
140
120
100
80
60
40
20
0
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Average FSOI per dtg (J/kg)
0.00
-0.10
-0.20
-0.30
-0.40
-0.50
-0.60
Kinetic Energy Norm
Total Energy Norm
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Latitude (deg)



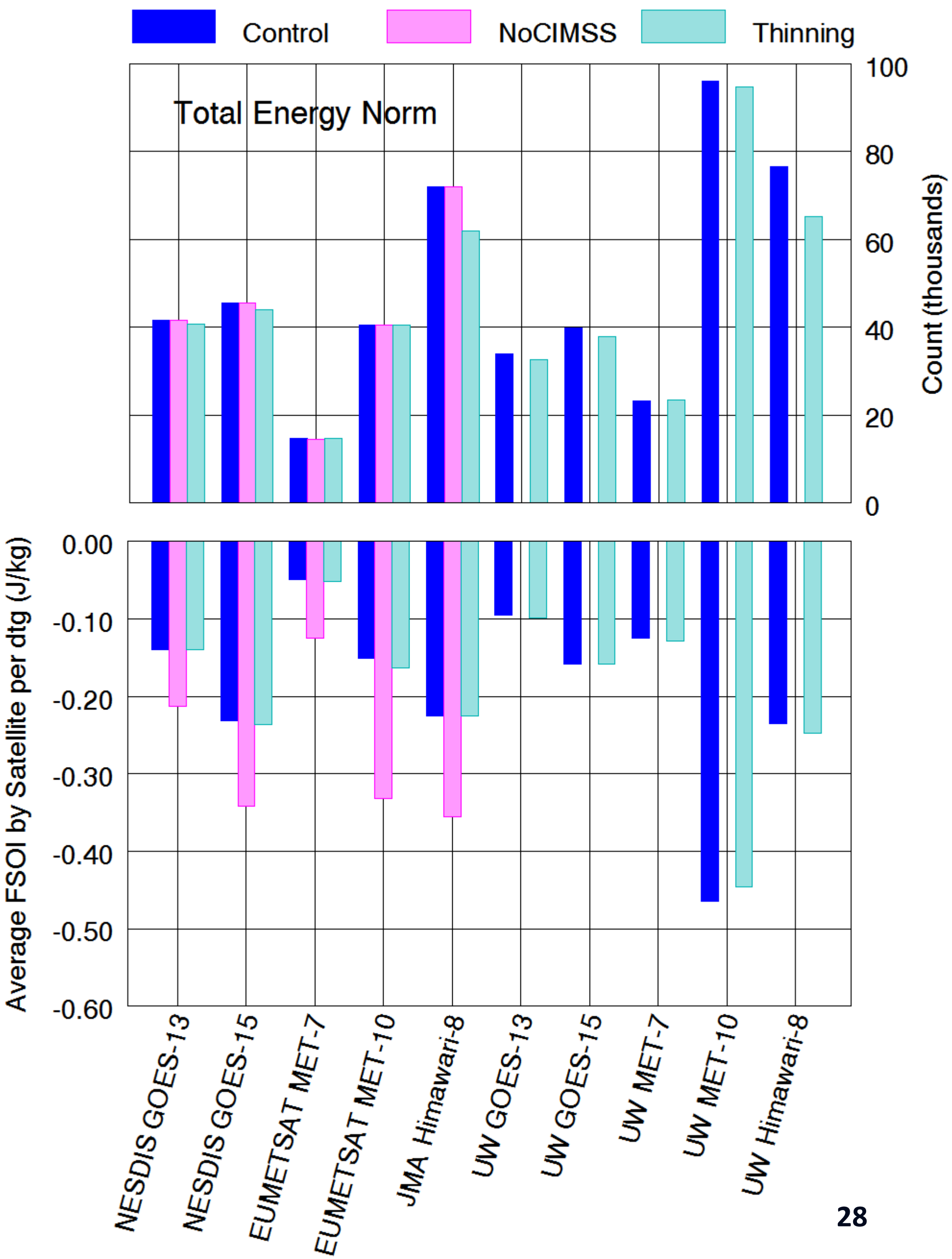
Total Energy Error Norms
35
30
25
20
J/kg
Control 30 hr norm
Thinning 30 hr norm
Control 24 hr norm
Thinning 24 hr norm
Error Norm Differences
Tau 30 - Tau 24
10
5
2016070100
2016070300
2016070500
2016070700
2016070900
2016071100
2016071300
2016071500
2016071700
2016071900
2016072100
2016072300
2016072500
2016072700
2016072900
2016073100


Control
20.5%
18.3%
16.2%
12.4%
8.8%
7.7%
5.9%
3.5%
2.7%
2.5%
1.8%
0.0%
Control--July 2016
Total Energy Norm
Total FSOI = -10.4 J/kg
-2.5 -2 -1.5 -1 -0.5 0 0.5
Average FSOI by Instrument Group per dtg (J/kg)
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
18.6%
16.3%
43.8%
2.8%
2.6%
7.5%
0.2%
1.9%
4.0%
1.4%
0.8%
0.0%
Control--July 2016
Total Energy Norm
Total Count = 3019700
0 250000 500000 750000 1000000 1250000 1500000 1750000
Average Number of Obs by Instrument Group per dtg
Thinning
20.5%
18.6%
16.0%
12.4%
8.8%
7.7%
5.9%
3.3%
2.6%
2.7%
1.5%
0.0%
Thinning--July 2016
Total Energy Norm
Total FSOI = -10.3 J/kg
-2.5 -2 -1.5 -1 -0.5 0 0.5
Average FSOI by Instrument Group per dtg (J/kg)
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
18.8%
15.6%
44.3%
2.9%
2.6%
7.6%
0.2%
1.8%
4.0%
1.5%
0.7%
0.0%
The thinning experiment had 1% fewer Geo Winds but little change in FSOI.
Thinning--July 2016
Total Energy Norm
Total Count = 2984484
0 250000 500000 750000 1000000 1250000 1500000 1750000
Average Number of Obs by Instrument Group per dtg


Total Energy Error Norms
J/kg
35
30
25
20
15
10
5
0
Control 30 hr norm
NoCIMMS 30 hr norm
Thinning 30 hr norm
Control 24 hr norm
NoCIMMS 24 hr norm
Thinning 24 hr norm
Error Norm Differences
Tau 30 - Tau 24
10
5
2016070100
2016070300
2016070500
2016070700
2016070900
2016071100
2016071300
2016071500
2016071700
2016071900
2016072100
2016072300
2016072500
2016072700
2016072900
2016073100



Control
20.5%
18.3%
16.2%
12.4%
8.8%
7.7%
5.9%
3.5%
2.7%
2.5%
1.8%
0.0%
Control--July 2016
Total Energy Norm
Total FSOI = -10.4 J/kg
-2.5 -2 -1.5 -1 -0.5 0 0.5
Average FSOI by Instrument Group per dtg (J/kg)
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
18.6%
16.3%
43.8%
2.8%
2.6%
7.5%
0.2%
1.9%
4.0%
1.4%
0.8%
0.0%
Control--July 2016
Total Energy Norm
Total Count = 3019700
0 250000 500000 750000 1000000 1250000 1500000 1750000
Average Number of Obs by Instrument Group per dtg
NoCIMSS
21.8%
13.4%
17.3%
12.8%
9.2%
8.0%
6.0%
3.7%
2.8%
2.9%
2.1%
-0.1%
NoCIMSS--July 2016
Total Energy Norm
Total FSOI = -10.3 J/kg
-2.5 -2 -1.5 -1 -0.5 0 0.5
Average FSOI by Instrument Group per dtg (J/kg)
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
20.4%
8.1%
48.2%
3.1%
2.8%
8.3%
0.3%
2.1%
4.4%
1.6%
0.9%
0.0%
Removing the CIMSS Geo Winds changes the total FSOI only slightly—other data types have an increased contribution.
NoCIMSS--July 2016
Total Energy Norm
Total Count = 2749442
0 250000 500000 750000 1000000 1250000 1500000 1750000
Average Number of Obs by Instrument Group per dtg



Comparison by satellite

- Counts differ greatly by satellite.
- EUMETSAT Meteosat-7 provides the fewest winds and smallest FSOI.
- CIMSS Meteosat-10 provides the most winds and the greatest FSOI.
- Counts in the thinning experiment are generally smaller since quartering is not used.
- The biggest difference in counts when thinning is used is for CIMSS (UW) Himawari-8, which shows a small increase in FSOI.
- FSOI increases for the operational winds when CIMSS winds not used.

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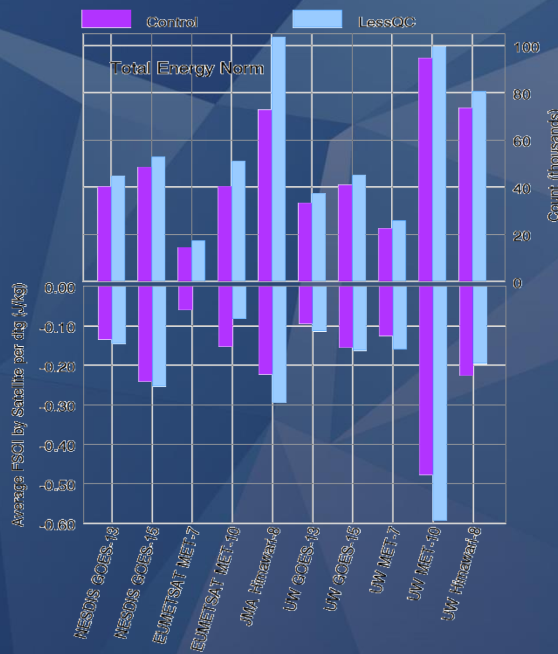
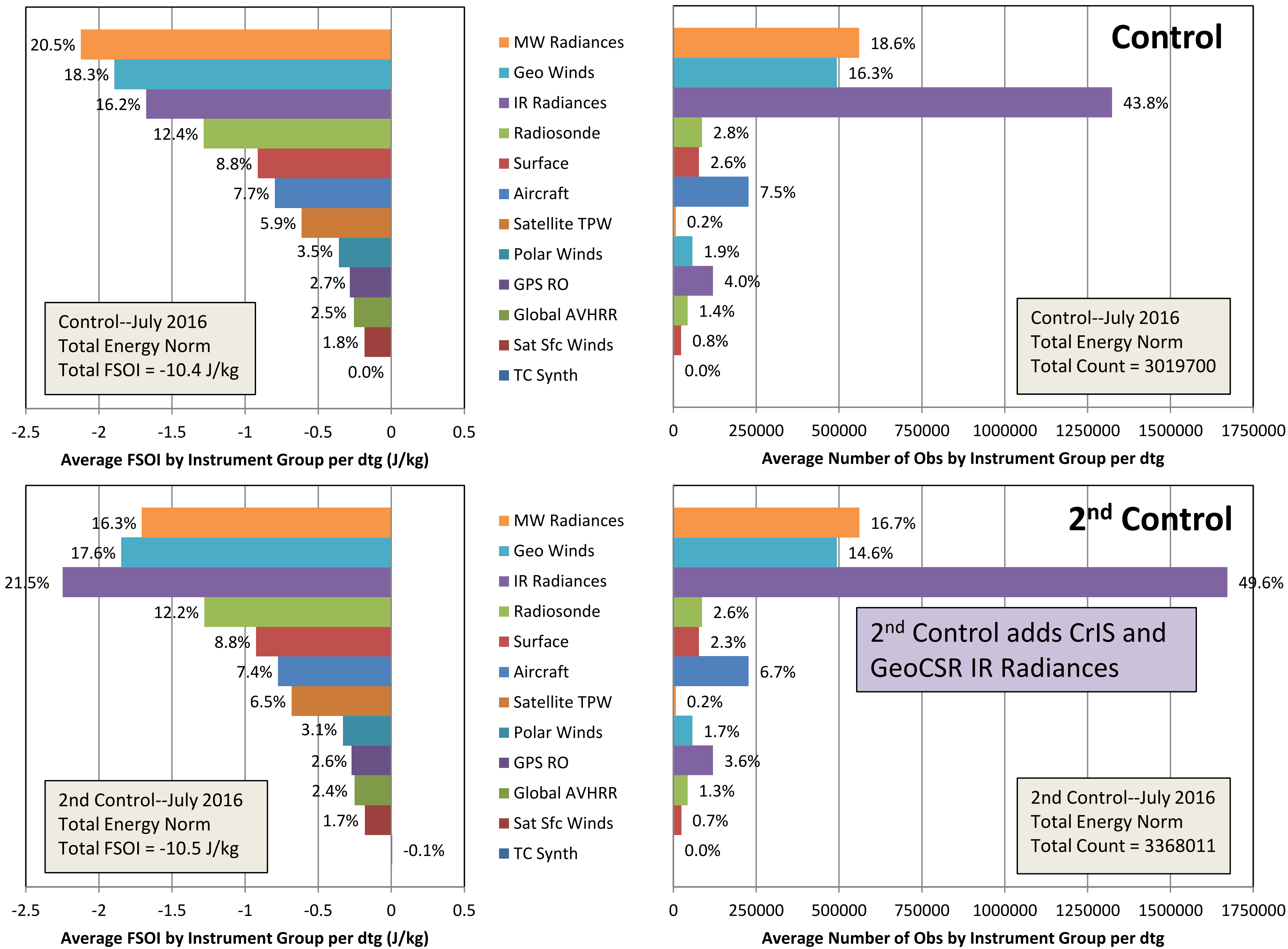
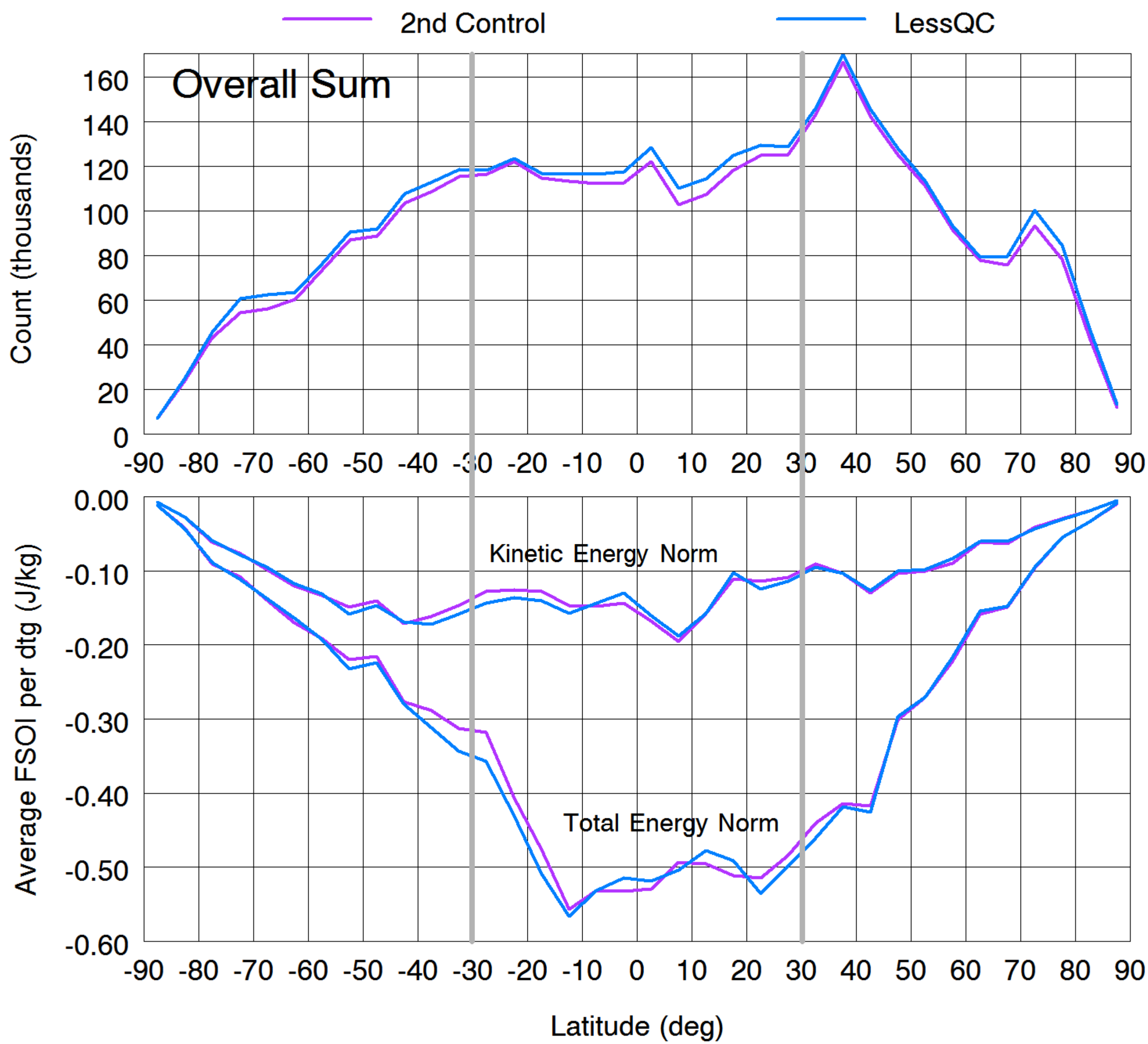
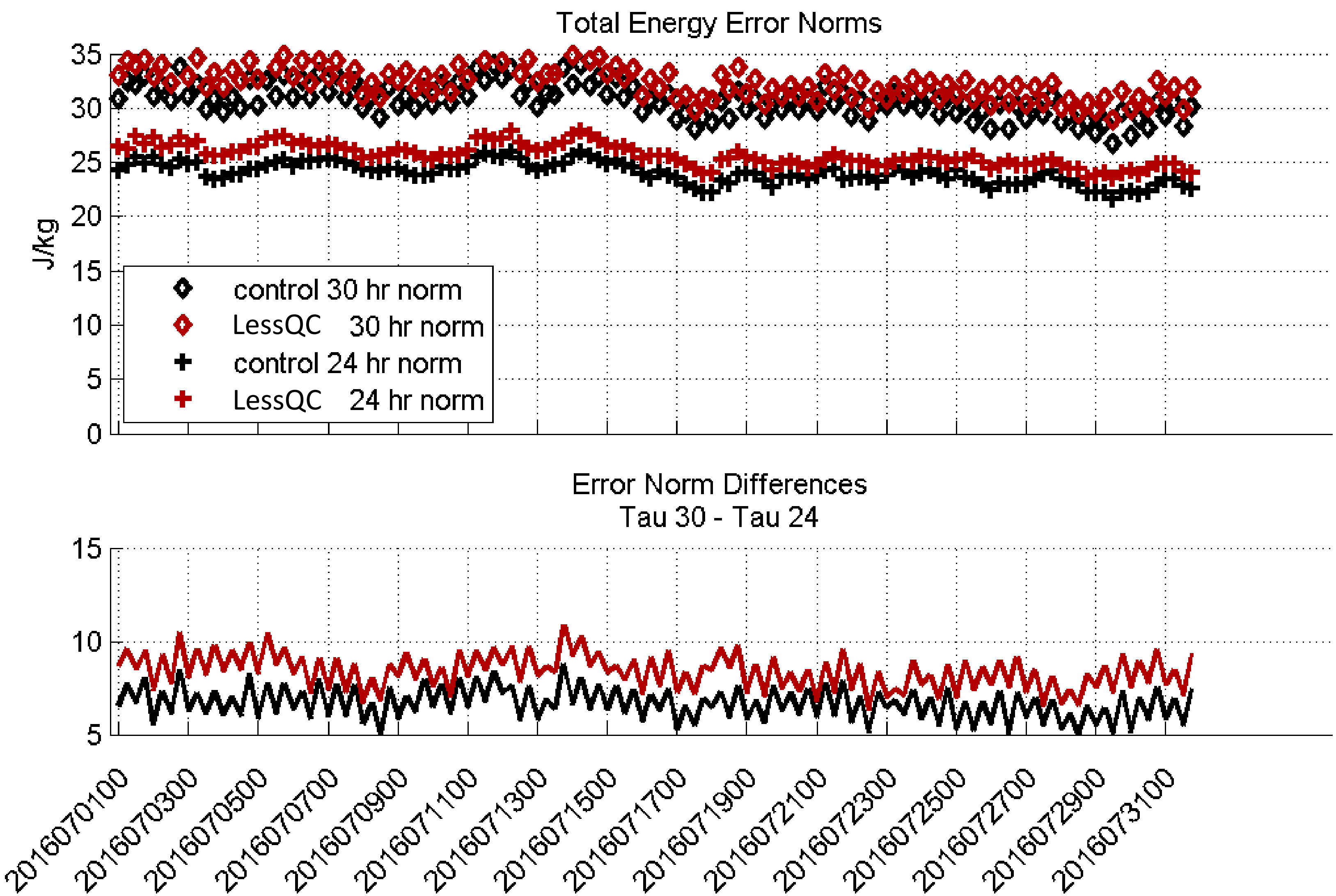


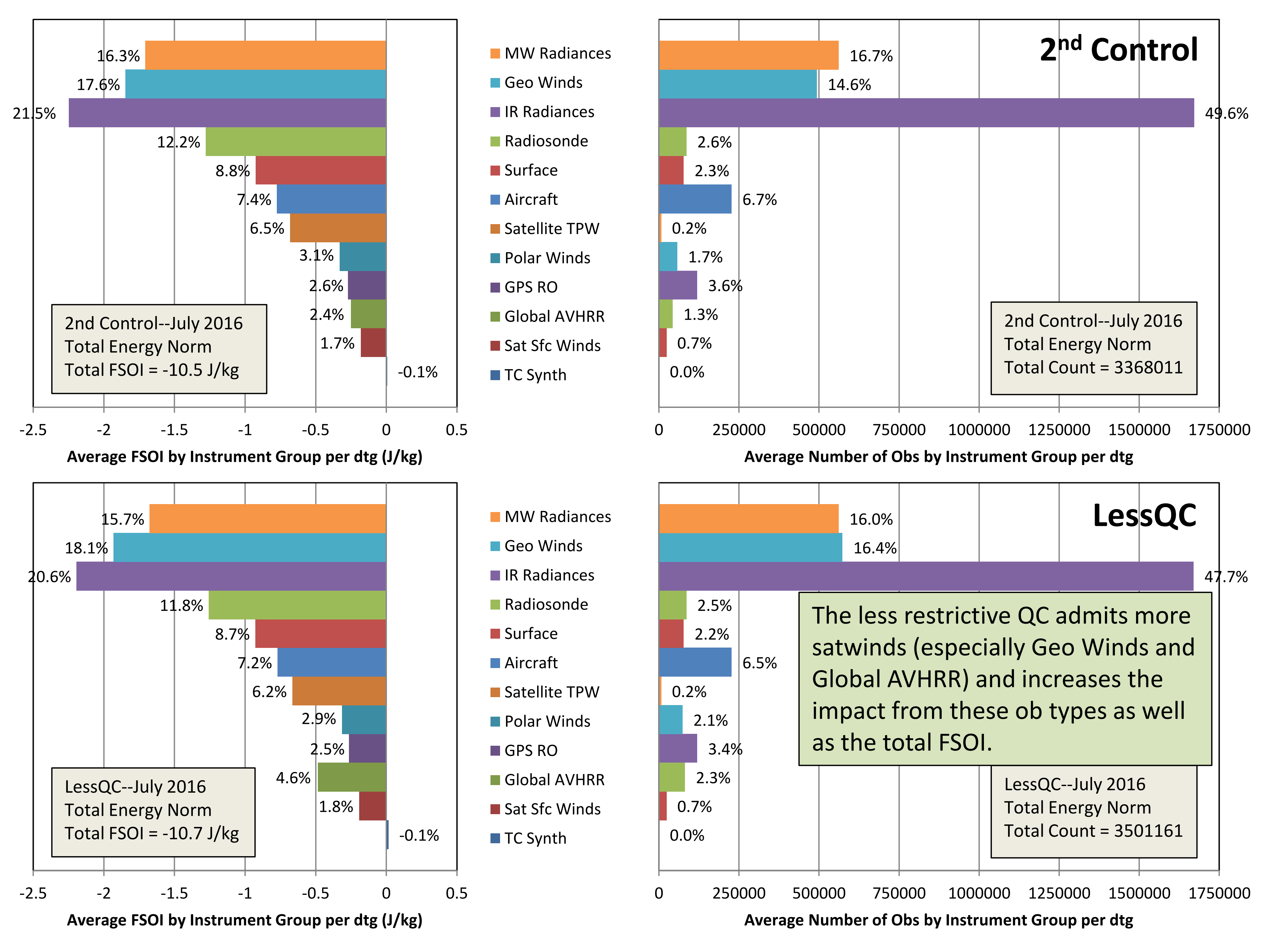
Results from the LessQC Experiment

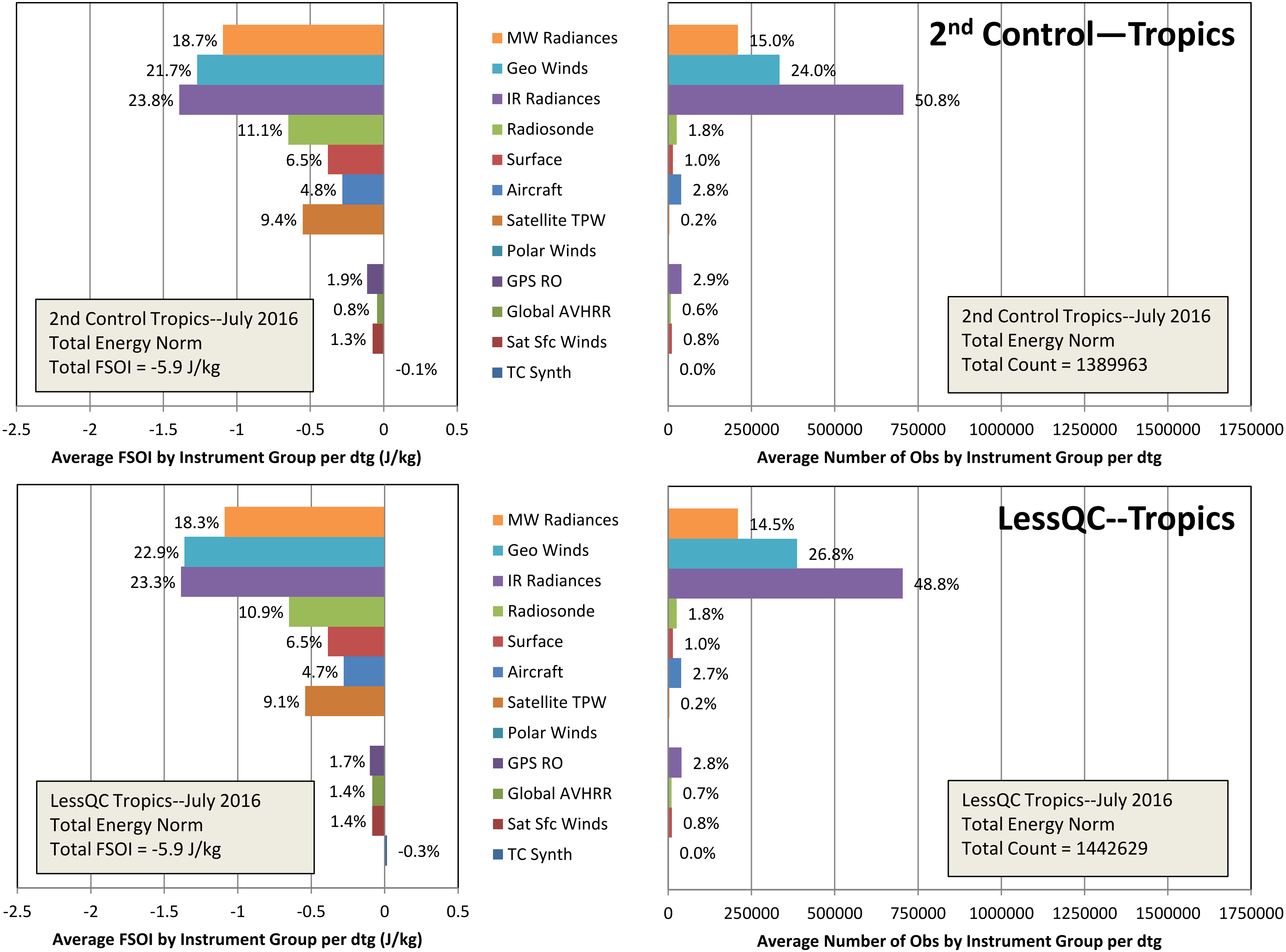

Control
20.5%
18.3%
16.2%
12.4%
8.8%
7.7%
5.9%
3.5%
2.7%
2.5%
1.8%
0.0%
Control--July 2016
Total Energy Norm
Total FSOI = -10.4 J/kg
-2.5 -2 -1.5 -1 -0.5 0 0.5
Average FSOI by Instrument Group per dtg (J/kg)
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
18.6%
16.3%
43.8%
2.8%
2.6%
7.5%
0.2%
1.9%
4.0%
1.4%
0.8%
0.0%
Control--July 2016
Total Energy Norm
Total Count = 3019700
0 250000 500000 750000 1000000 1250000 1500000 1750000
Average Number of Obs by Instrument Group per dtg
2nd Control
16.3%
17.6%
21.5%
12.2%
8.8%
7.4%
6.5%
3.1%
2.6%
2.4%
1.7%
-0.1%
2nd Control--July 2016
Total Energy Norm
Total FSOI = -10.5 J/kg
-2.5 -2 -1.5 -1 -0.5 0 0.5
Average FSOI by Instrument Group per dtg (J/kg)
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
16.7%
14.6%
49.6%
2.6%
2.3%
6.7%
0.2%
1.7%
3.6%
1.3%
0.7%
0.0%
2nd Control adds CrIS and GeoCSR IR Radiances
2nd Control--July 2016
Total Energy Norm
Total Count = 3368011
0 250000 500000 750000 1000000 1250000 1500000 1750000
Average Number of Obs by Instrument Group per dtg

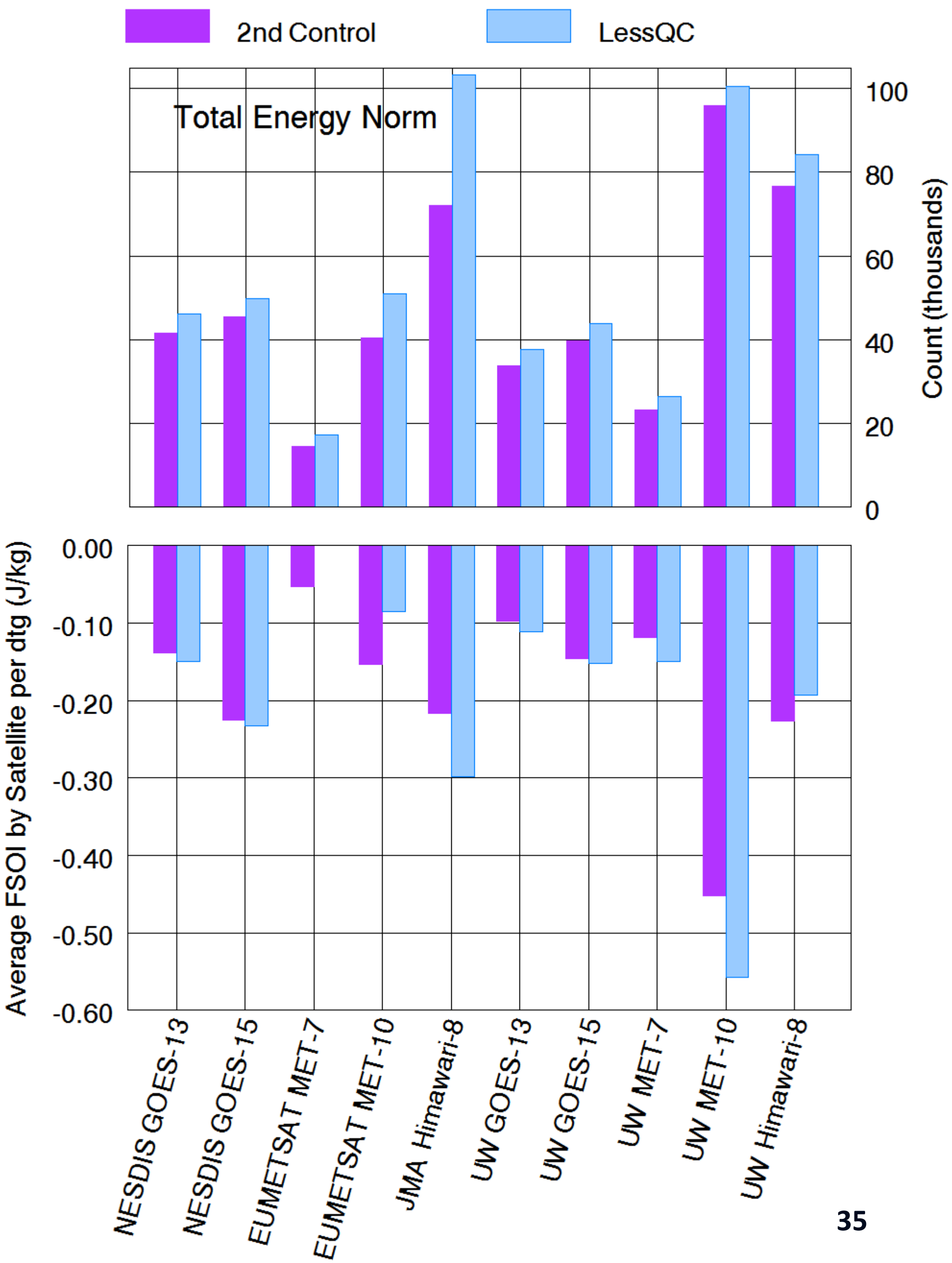


2nd Control
LessQC
Overall Sum
Count (thousands)
160
140
120
100
80
60
40
20
0
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Kinetic Energy Norm
Total Energy Norm
Average FSOI per dtg (J/kg)
0.00
-0.10
-0.20
-0.30
-0.40
-0.50
-0.60
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Latitude (deg)


Total Energy Error Norms
J/kg
35
30
25
20
15
10
5
0
control 30 hr norm
LessQC 30 hr norm
control 24 hr norm
LessQC 24 hr norm
Error Norm Differences
Tau 30 - Tau 24
15
10
5
2016070100
2016070300
2016070500
2016070700
2016070900
2016071100
2016071300
2016071500
2016071700
2016071900
2016072100
2016072300
2016072500
2016072700
2016072900
2016073100

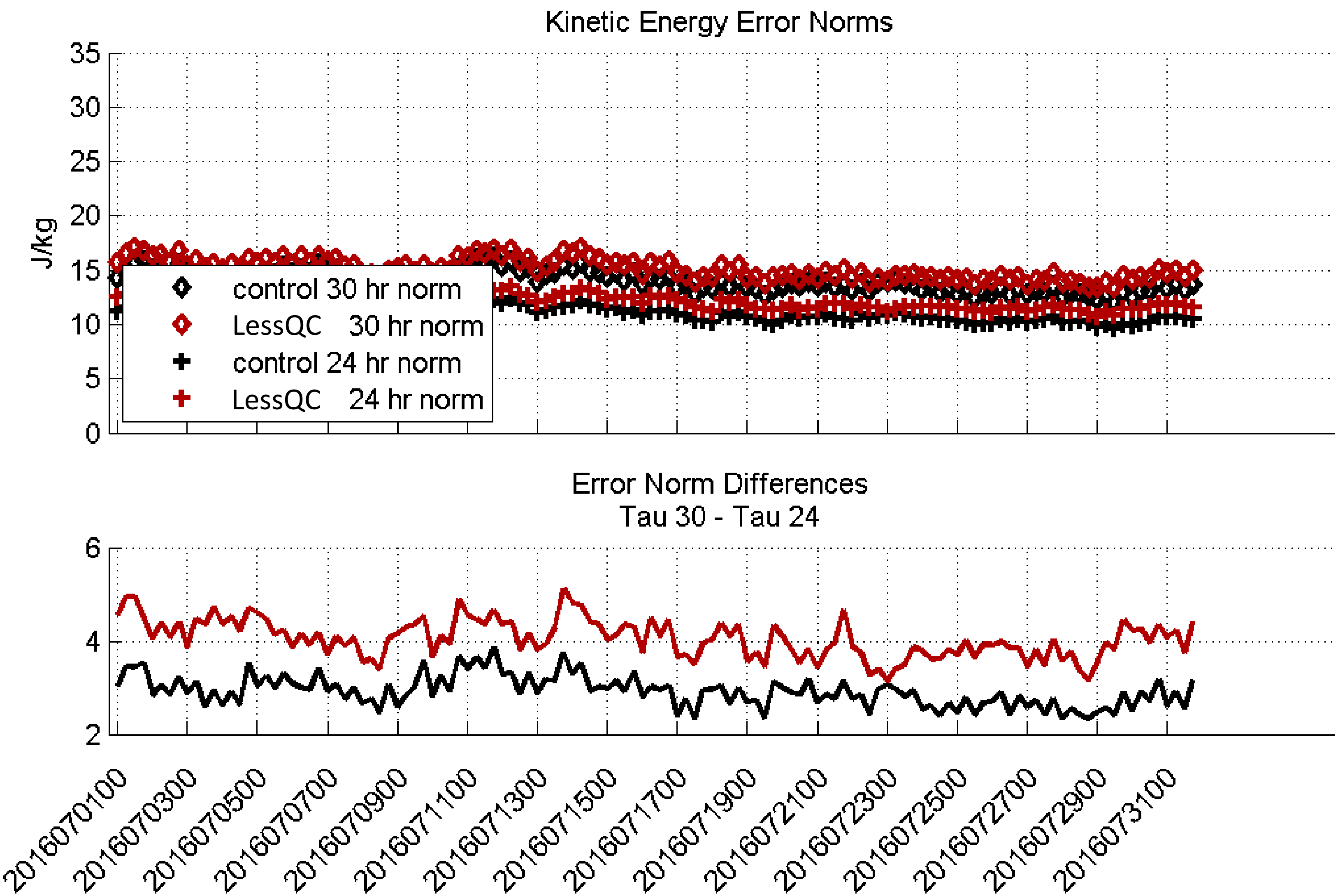

2nd Control
16.3%
17.6%
21.5%
12.2%
8.8%
7.4%
6.5%
3.1%
2.6%
2.4%
1.7%
-0.1%
2nd Control--July 2016
Total Energy Norm
Total FSOI = -10.5 J/kg
-2.5 -2 -1.5 -1 -0.5 0 0.5
Average FSOI by Instrument Group per dtg (J/kg)
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
16.7%
14.6%
49.6%
2.6%
2.3%
6.7%
0.2%
1.7%
3.6%
1.3%
0.7%
0.0%
2nd Control--July 2016
Total Energy Norm
Total Count = 3368011
0 250000 500000 750000 1000000 1250000 1500000 1750000
Average Number of Obs by Instrument Group per dtg
LessQC
15.7%
18.1%
20.6%
11.8%
8.7%
7.2%
6.2%
2.9%
2.5%
4.6%
1.8%
-0.1%
LessQC--July 2016
Total Energy Norm
Total FSOI = -10.7 J/kg
-2.5 -2 -1.5 -1 -0.5 0 0.5
Average FSOI by Instrument Group per dtg (J/kg)
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
16.0%
16.4%
47.7%
2.5%
2.2%
6.5%
0.2%
2.1%
3.4%
2.3%
0.7%
0.0%
The less restrictive QC admits more satwinds (especially Geo Winds and Global AVHRR) and increases the impact from these ob types as well as the total FSOI.
LessQC--July 2016
Total Energy Norm
Total Count = 3501161
0 250000 500000 750000 1000000 1250000 1500000 1750000
Average Number of Obs by Instrument Group per dtg


2nd Control—Tropics
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
18.7%
21.7%
23.8%
11.1%
6.5%
4.8%
9.4%
1.9%
0.8%
1.3%
-0.1%
2nd Control Tropics--July 2016
Total Energy Norm
Total FSOI = -5.9 J/kg
-2.5 -2 -1.5 -1 -0.5 0 0.5
Average FSOI by Instrument Group per dtg (J/kg)
15.0%
24.0%
50.8%
1.8%
1.0%
2.8%
0.2%
2.9%
0.6%
0.8%
0.0%
2nd Control Tropics--July 2016
Total Energy Norm
Total Count = 1389963
0 250000 500000 750000 1000000 1250000 1500000 1750000
Average Number of Obs by Instrument Group per dtg
LessQC--Tropics
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
18.3%
22.9%
23.3%
10.9%
6.5%
4.7%
9.1%
1.7%
1.4%
1.4%
-0.3%
LessQC Tropics--July 2016
Total Energy Norm
Total FSOI = -5.9 J/kg
-2.5 -2 -1.5 -1 -0.5 0 0.5
Average FSOI by Instrument Group per dtg (J/kg)
14.5%
26.8%
48.8%
1.8%
1.0%
2.7%
0.2%
2.8%
0.7%
0.8%
0.0%
LessQC Tropics--July 2016
Total Energy Norm
Total Count = 1442629
0 250000 500000 750000 1000000 1250000 1500000 1750000
Average Number of Obs by Instrument Group per dtg

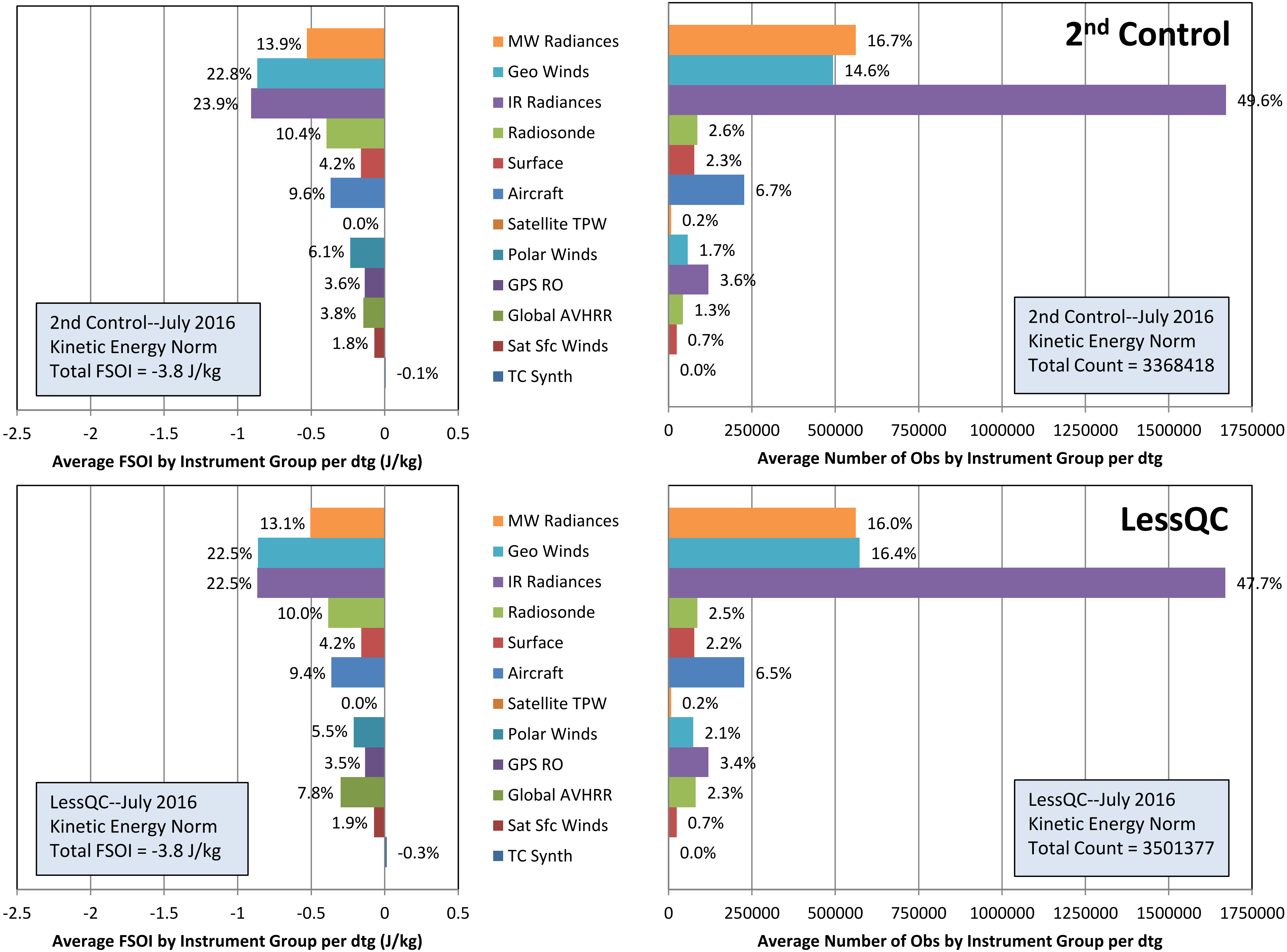


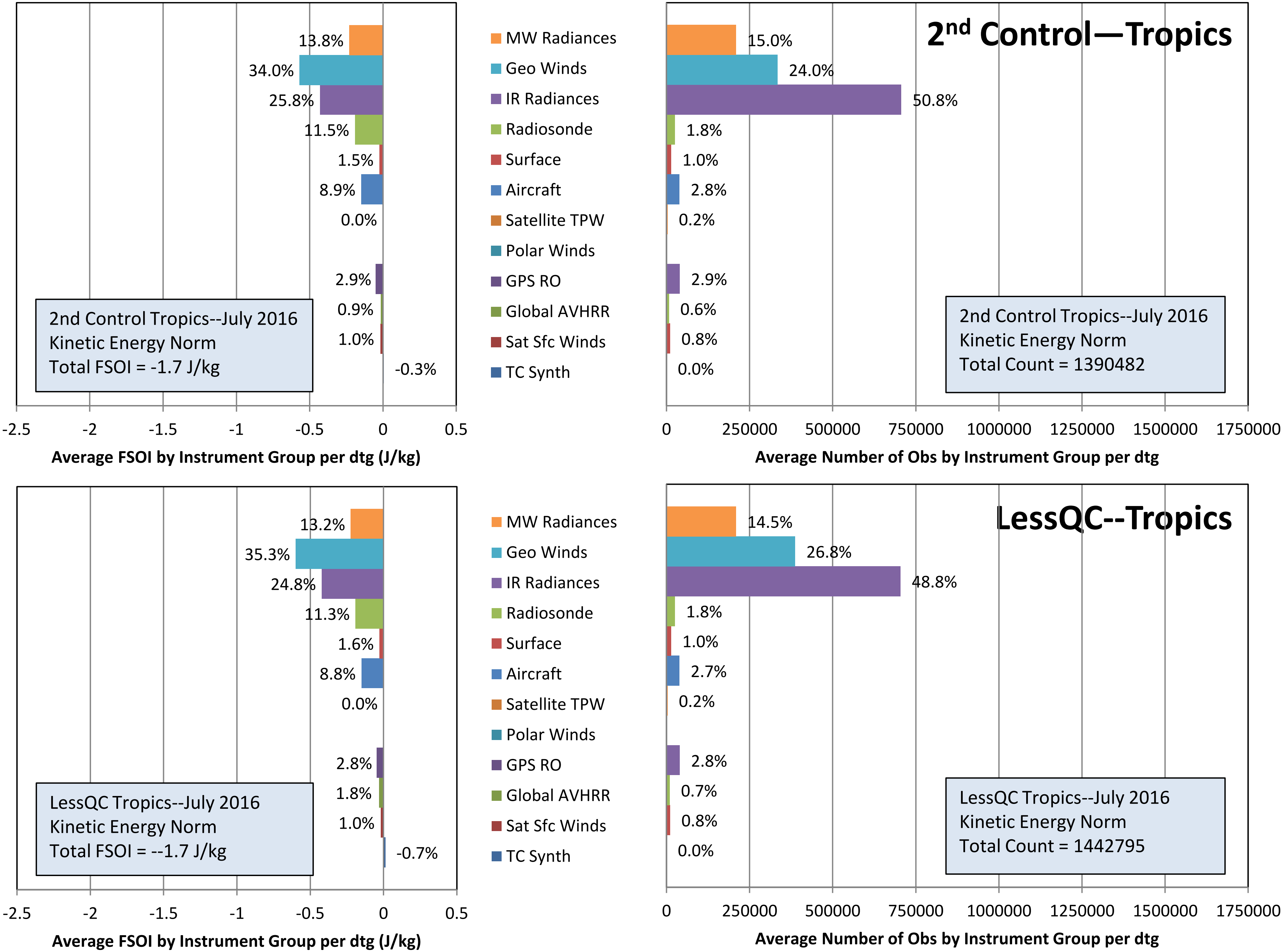
Comparison by satellite

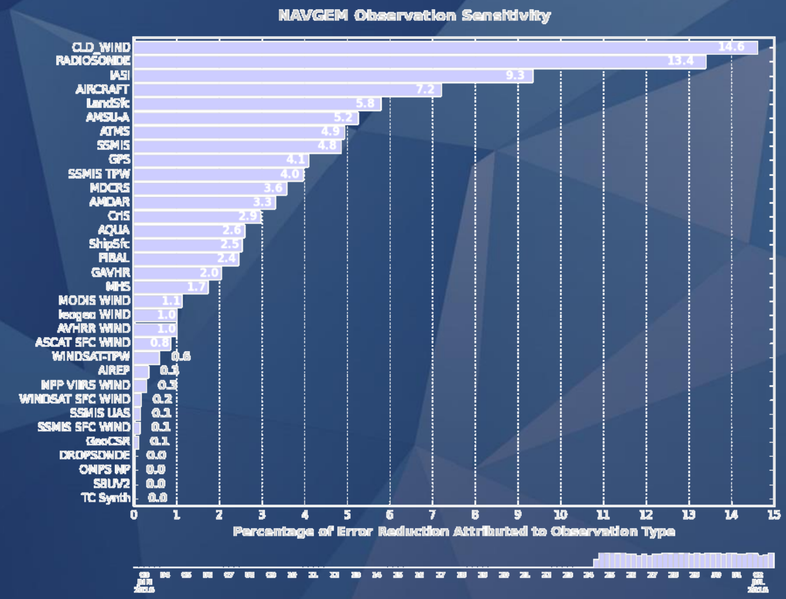
- The effect of the QC decisions varies by satellite and by wind producer.
- Making the QC less restrictive is beneficial for some, but non-beneficial for others.
- The details of how the QC is applied should be made a function of satellite and maybe even channel.



Kinetic Energy Error Norms
J/kg
35
30
25
20
15
10
5
0
control 30 hr norm
LessQC 30 hr norm
control 24 hr norm
LessQC 24 hr norm
Error Norm Differences
Tau 30 - Tau 24
6
4
2
2016070100
2016070300
2016070500
2016070700
2016070900
2016071100
2016071300
2016071500
2016071700
2016071900
2016072100
2016072300
2016072500
2016072700
2016072900
2016073100


2nd Control
LessQC
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
13.9%
22.8%
23.9%
10.4%
4.2%
9.6%
0.0%
6.1%
3.6%
3.8%
1.8%
-0.1%
2nd Control--July 2016
Kinetic Energy Norm
Total FSOI = -3.8 J/kg
16.7%
14.6%
49.6%
2.6%
2.3%
6.7%
0.2%
1.7%
3.6%
1.3%
0.7%
0.0%
2nd Control--July 2016
Kinetic Energy Norm
Total Count = 3368418
13.1%
22.5%
22.5%
10.0%
4.2%
9.4%
0.0%
5.5%
3.5%
7.8%
1.9%
-0.3%
LessQC--July 2016
Kinetic Energy Norm
Total FSOI = -3.8 J/kg
16.0%
16.4%
47.7%
2.5%
2.2%
6.5%
0.2%
2.1%
3.4%
2.3%
0.7%
0.0%
LessQC--July 2016
Kinetic Energy Norm
Total Count = 3501377
-2.5
-2
-1.5
-1
-0.5
0
0.5
Average FSOI by Instrument Group per dtg (J/kg)
0
250000
500000
750000
1000000
1250000
1500000
1750000
Average Number of Obs by Instrument Group per dtg


2nd Control—Tropics
13.8%
34.0%
25.8%
11.5%
1.5%
8.9%
0.0%
2.9%
0.9%
1.0%
-0.3%
2nd Control Tropics--July 2016
Kinetic Energy Norm
Total FSOI = -1.7 J/kg
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
15.0%
24.0%
50.8%
1.8%
1.0%
2.8%
0.2%
2.9%
0.6%
0.8%
0.0%
2nd Control Tropics--July 2016
Kinetic Energy Norm
Total Count = 1390482
-2.5 -2 -1.5 -1 -0.5 0 0.5
Average FSOI by Instrument Group per dtg (J/kg)
0 250000 500000 750000 1000000 1250000 1500000 1750000
Average Number of Obs by Instrument Group per dtg
LessQC--Tropics
13.2%
35.3%
24.8%
11.3%
1.6%
8.8%
0.0%
2.8%
1.8%
1.0%
-0.7%
LessQC Tropics--July 2016
Kinetic Energy Norm
Total FSOI = --1.7 J/kg
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
14.5%
26.8%
48.8%
1.8%
1.0%
2.7%
0.2%
2.8%
0.7%
0.8%
0.0%
LessQC Tropics--July 2016
Kinetic Energy Norm
Total Count = 1442795
-2.5 -2 -1.5 -1 -0.5 0 0.5
Average FSOI by Instrument Group per dtg (J/kg)
0 250000 500000 750000 1000000 1250000 1500000 1750000
Average Number of Obs by Instrument Group per dtg



Operational Results

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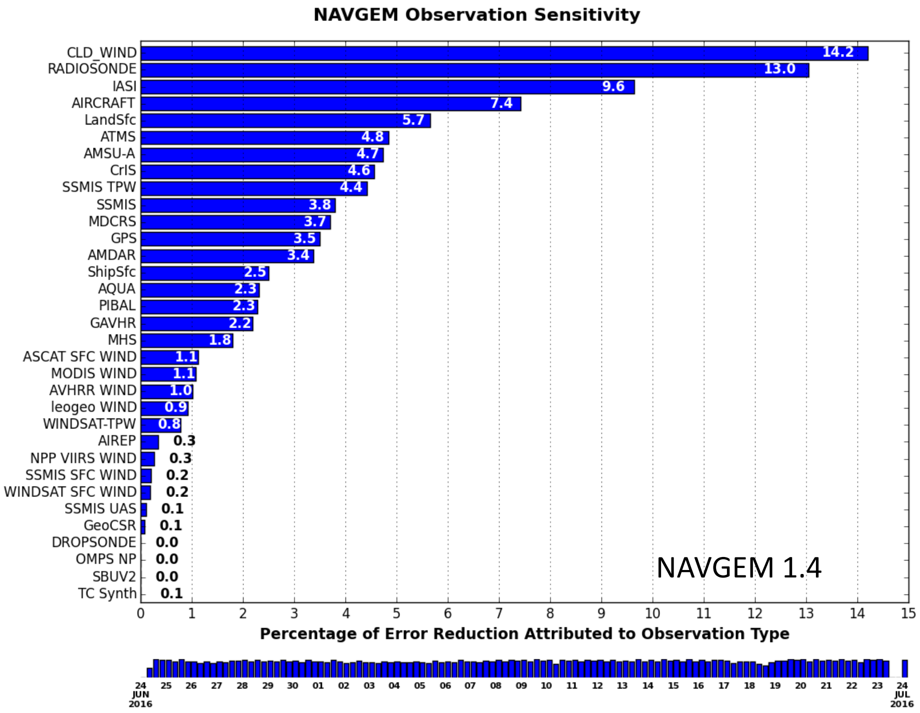
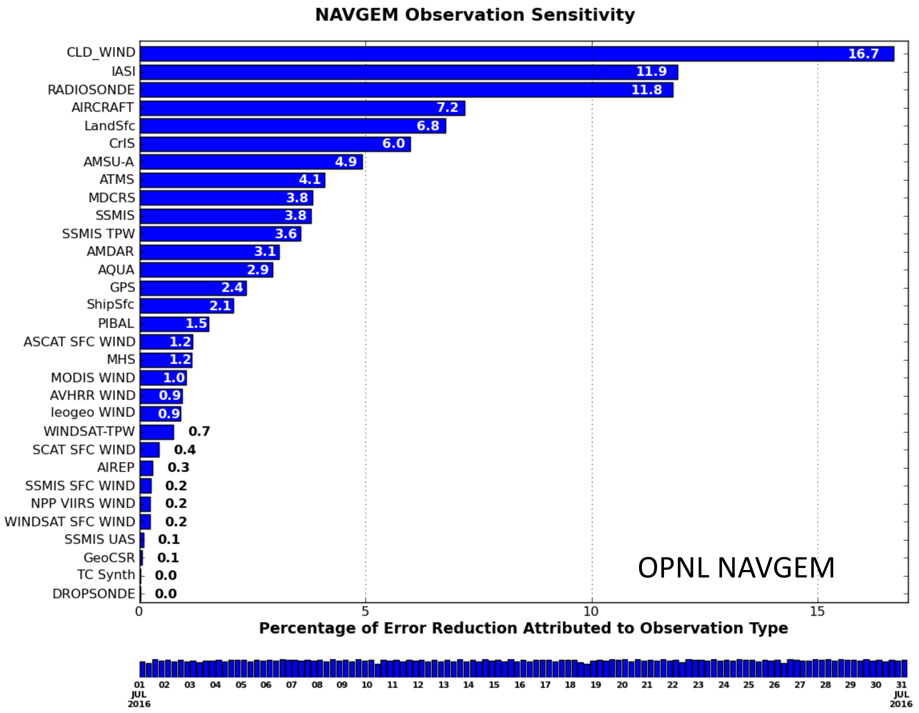
NAVGEM Update

NAVGEM 1.4 went into operational use on 12 Oct 2016

- Hybrid 4DVAR using ensemble error covariances
- Total FSOI is smaller—improved background field
- Relative importance of different observation types changes





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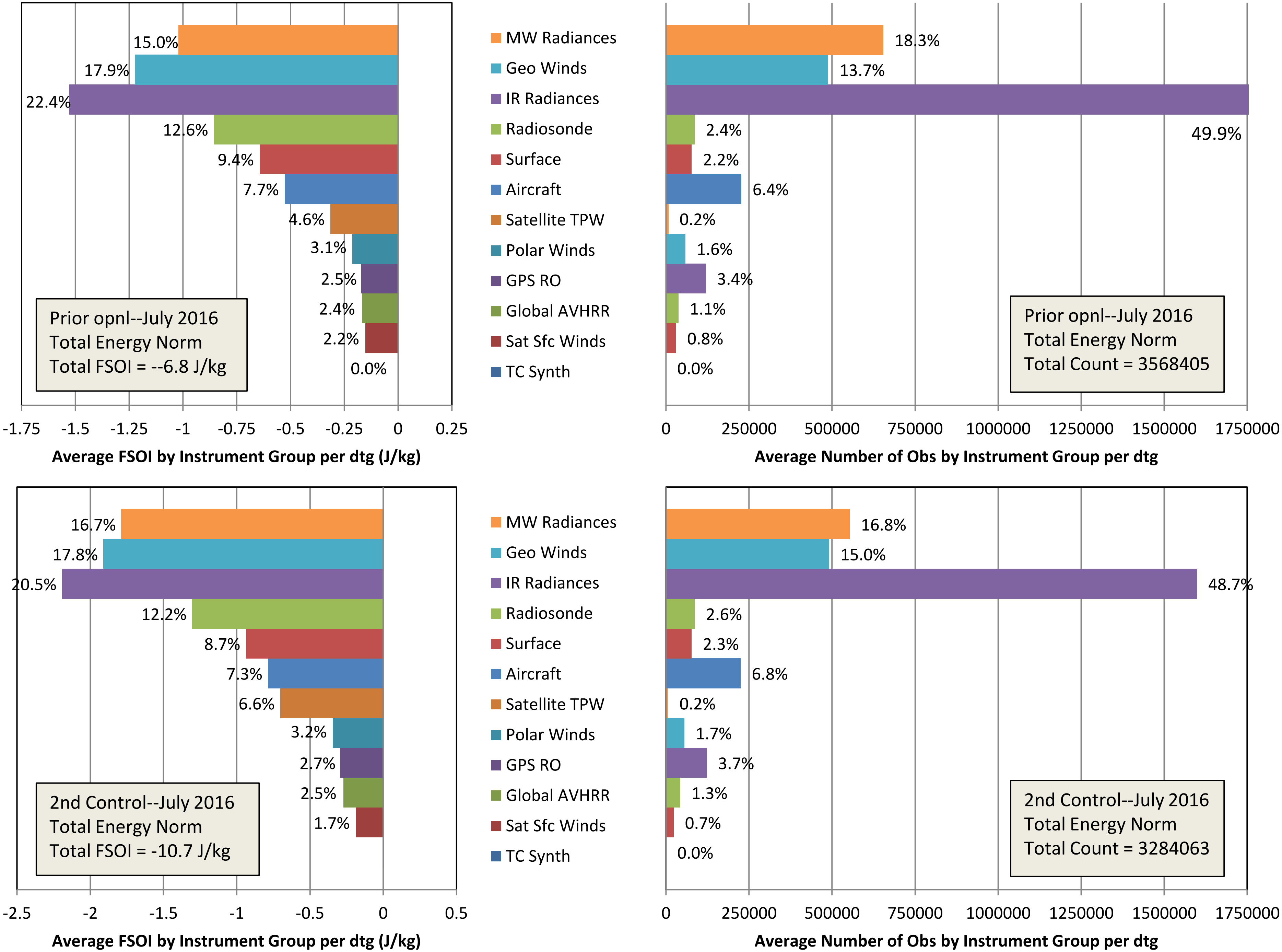
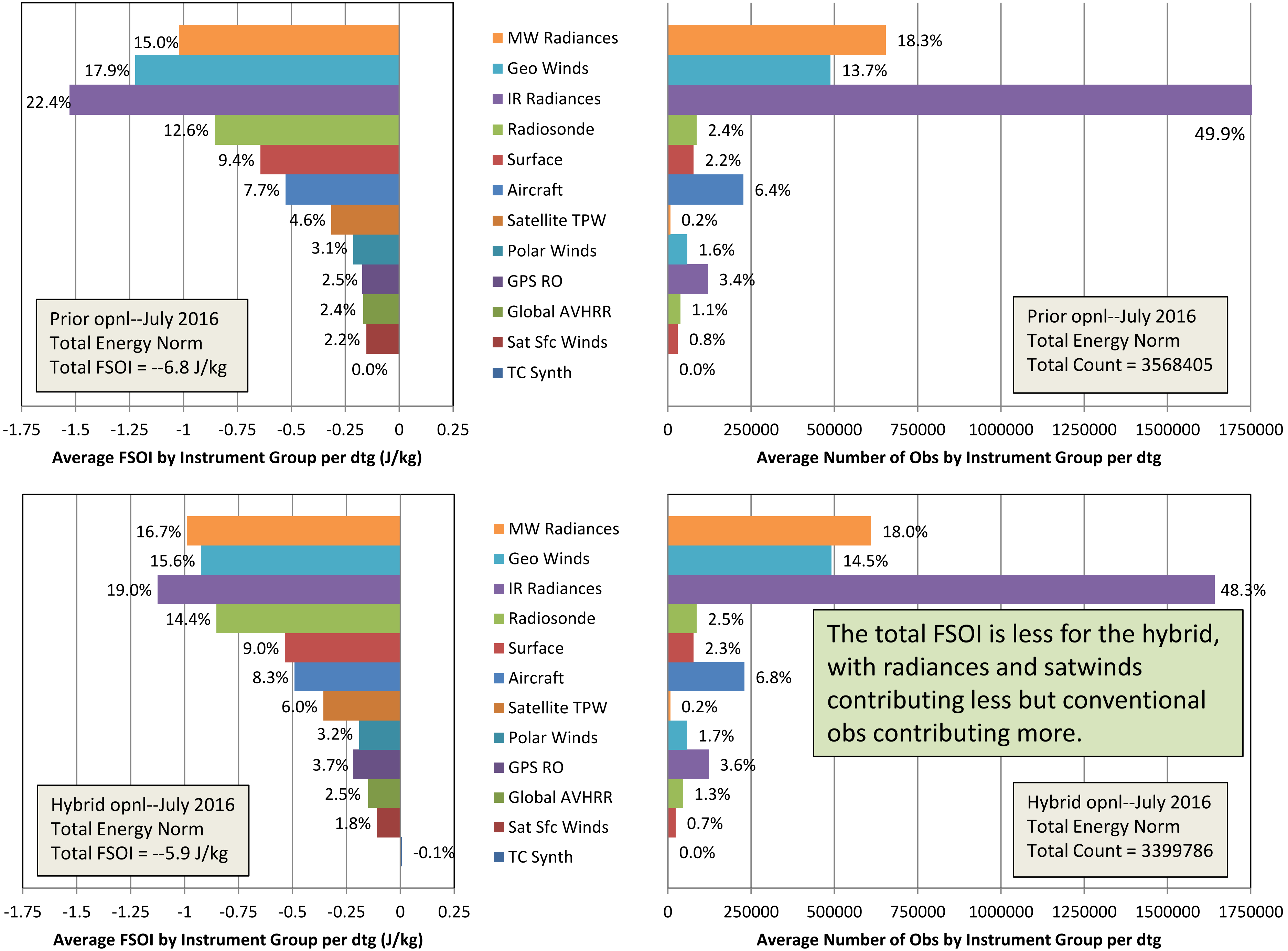


15.0%
17.9%
22.4%
12.6%
9.4%
7.7%
4.6%
3.1%
2.5%
2.4%
2.2%
0.0%
Prior opnl--July 2016
Total Energy Norm
Total FSOI = --6.8 J/kg
-1.75
-1.5
-1.25
-1
-0.75
-0.5
-0.25
0
0.25
Average FSOI by Instrument Group per dtg (J/kg)
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
18.3%
13.7%
49.9%
2.4%
2.2%
6.4%
0.2%
1.6%
3.4%
1.1%
0.8%
0.0%
Prior opnl--July 2016
Total Energy Norm
Total Count = 3568405
0
250000
500000
750000
1000000
1250000
1500000
1750000
Average Number of Obs by Instrument Group per dtg
16.7%
17.8%
20.5%
12.2%
8.7%
7.3%
6.6%
3.2%
2.7%
2.5%
1.7%
2nd Control--July 2016
Total Energy Norm
Total FSOI = -10.7 J/kg
-2.5
-2
-1.5
-1
-0.5
0
0.5
Average FSOI by Instrument Group per dtg (J/kg)
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
16.8%
15.0%
48.7%
2.6%
2.3%
6.8%
0.2%
1.7%
3.7%
1.3%
0.7%
0.0%
2nd Control--July 2016
Total Energy Norm
Total Count = 3284063
0
250000
500000
750000
1000000
1250000
1500000
1750000
Average Number of Obs by Instrument Group per dtg



15.0%
17.9%
22.4%
12.6%
9.4%
7.7%
4.6%
3.1%
2.5%
2.4%
2.2%
0.0%
Prior opnl--July 2016
Total Energy Norm
Total FSOI = --6.8 J/kg
-1.75
-1.5
-1.25
-1
-0.75
-0.5
-0.25
0
0.25
Average FSOI by Instrument Group per dtg (J/kg)
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
18.3%
13.7%
49.9%
2.4%
2.2%
6.4%
0.2%
1.6%
3.4%
1.1%
0.8%
0.0%
Prior opnl--July 2016
Total Energy Norm
Total Count = 3568405
0
250000
500000
750000
1000000
1250000
1500000
1750000
Average Number of Obs by Instrument Group per dtg
16.7%
15.6%
19.0%
14.4%
9.0%
8.3%
6.0%
3.2%
3.7%
2.5%
1.8%
-0.1%
Hybrid opnl--July 2016
Total Energy Norm
Total FSOI = --5.9 J/kg
-1.75
-1.5
-1.25
-1
-0.75
-0.5
-0.25
0
0.25
Average FSOI by Instrument Group per dtg (J/kg)
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
18.0%
14.5%
48.3%
2.5%
2.3%
6.8%
0.2%
1.7%
3.6%
1.3%
0.7%
0.0%
The total FSOI is less for the hybrid, with radiances and satwinds contributing less but conventional obs contributing more.
Hybrid opnl--July 2016
Total Energy Norm
Total Count = 3399786
0
250000
500000
750000
1000000
1250000
1500000
1750000
Average Number of Obs by Instrument Group per dtg

Conclusions

- Geostationary winds play an important role in the tropics.
  - Geo winds give 27% of the obs in the tropics and 22% of the FSOI in NAVGEM.
- The number of observations affects contribution to FSOI for a particular instrument type but not in a linear fashion.
  - Omitting the CIMSS winds led to approximately half the number of geo winds, but decreased the average error reduction for geo winds from 18.3% to 13.4% using the total energy norm.
  - FSOI for other instrument types tends to compensate at least in part for missing observations.
- The differences in FSOI for geostationary winds between NAVGEM and other global models cannot be explained by differences in processing.
- NAVGEM 1.4 has a lower total FSOI than the earlier version, suggesting an improved background depiction.
  - Less impact from radiances and satellite winds, more from conventional obs.

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Questions?

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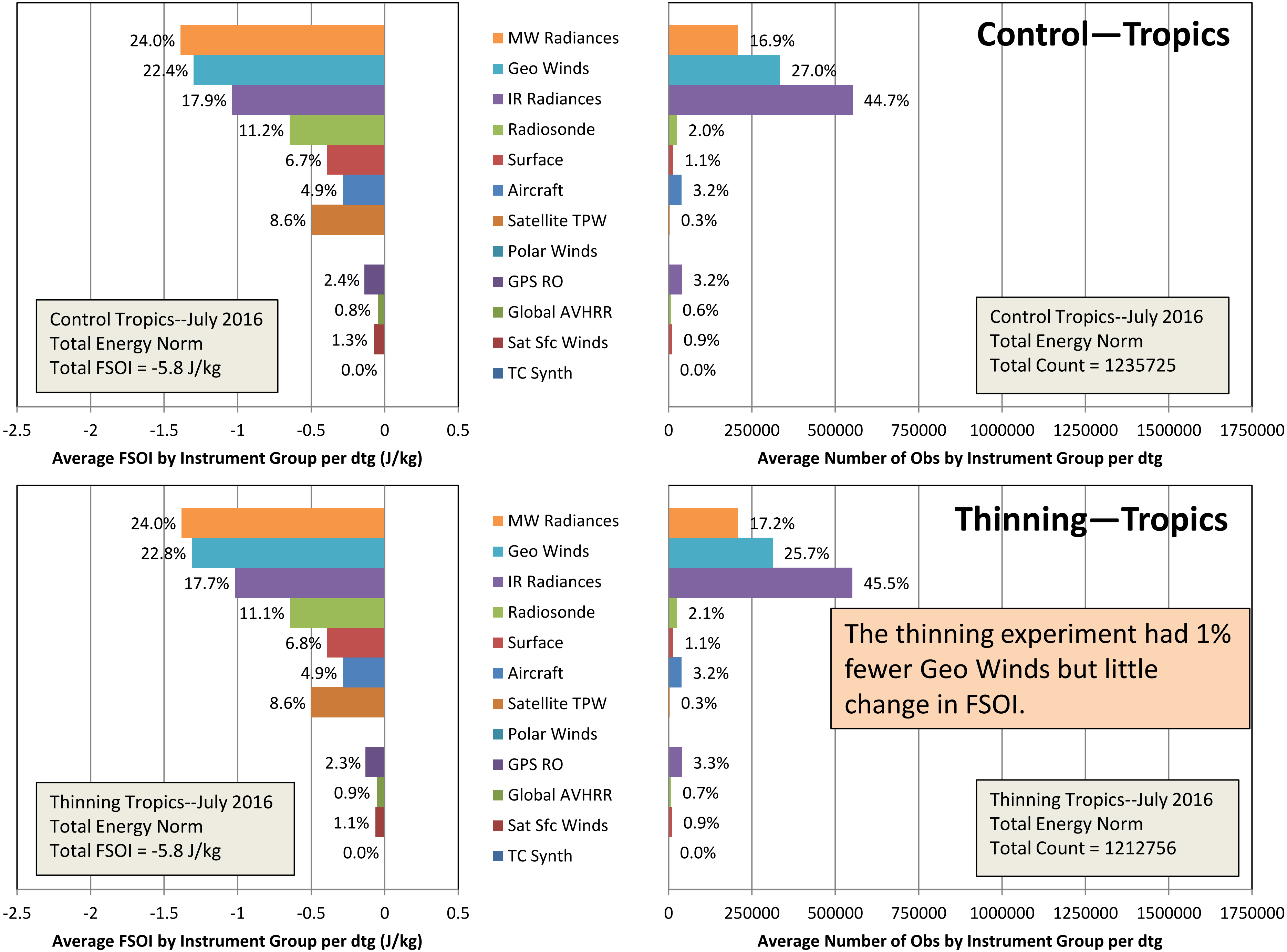
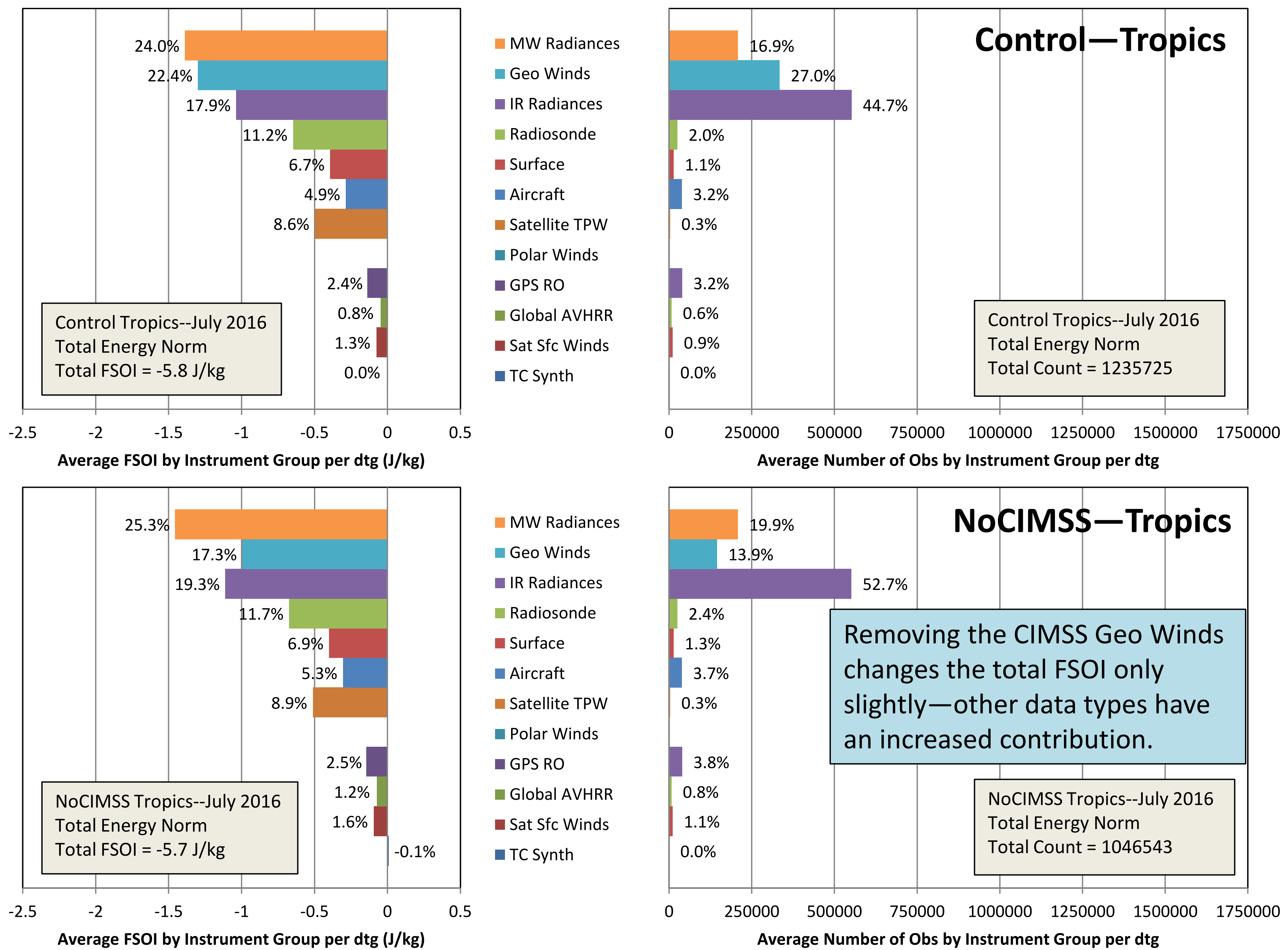
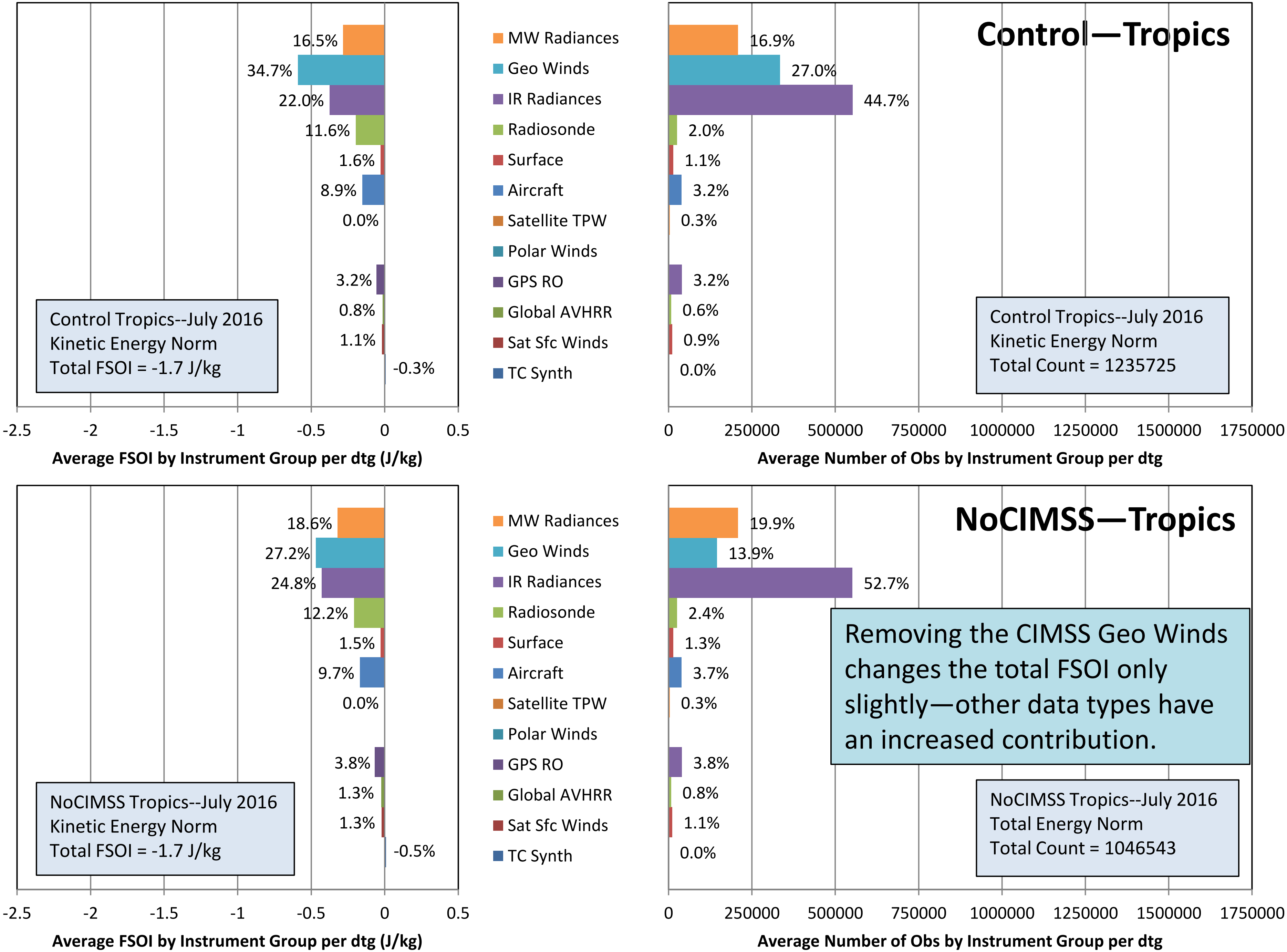
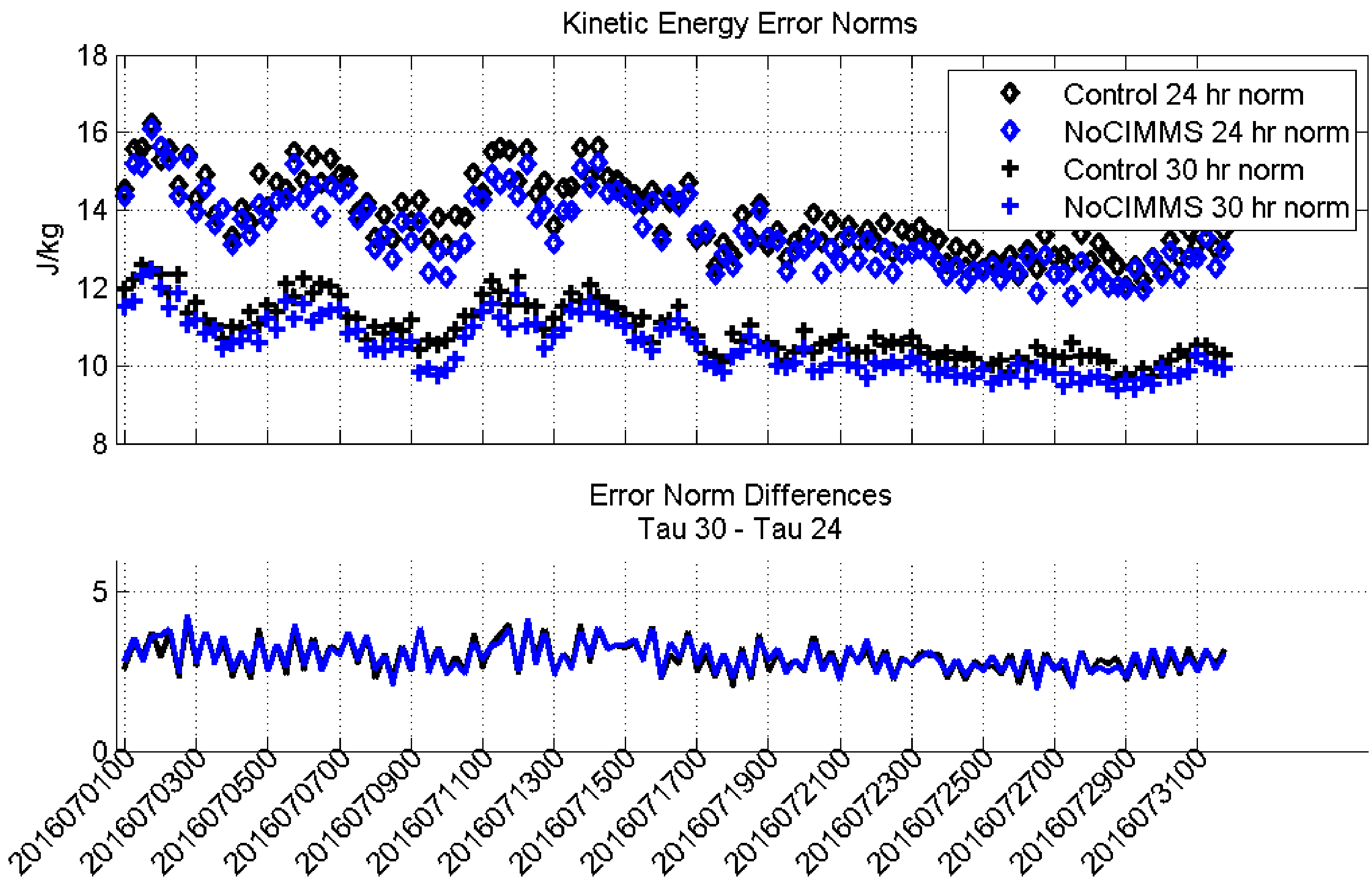
Use of Superobbing

- Winds to be superobbed are required to be:
  - in the same prism and 50 hPa layer
  - generated by the same processing center
  - from the same satellite and channel
  - with times within one hour
- In most cases, a minimum of two AMV obs is required.
- The winds in the prism must be within thresholds:
  - Speeds (or speed innovations) within 7 to 14 m/s depending on speed, and
  - Directions (or direction innovations) within 20° or u and v components (or u and v innovations) within 5 m/s.
- One or two outliers can be rejected to meet the thresholds if sufficient obs are present.
- Prism is quartered and superobbing is attempted in each quarter if necessary.
- Superob values are corrected so that the magnitude of the superob wind vector is equal to the mean speed of the obs used to form the superob.

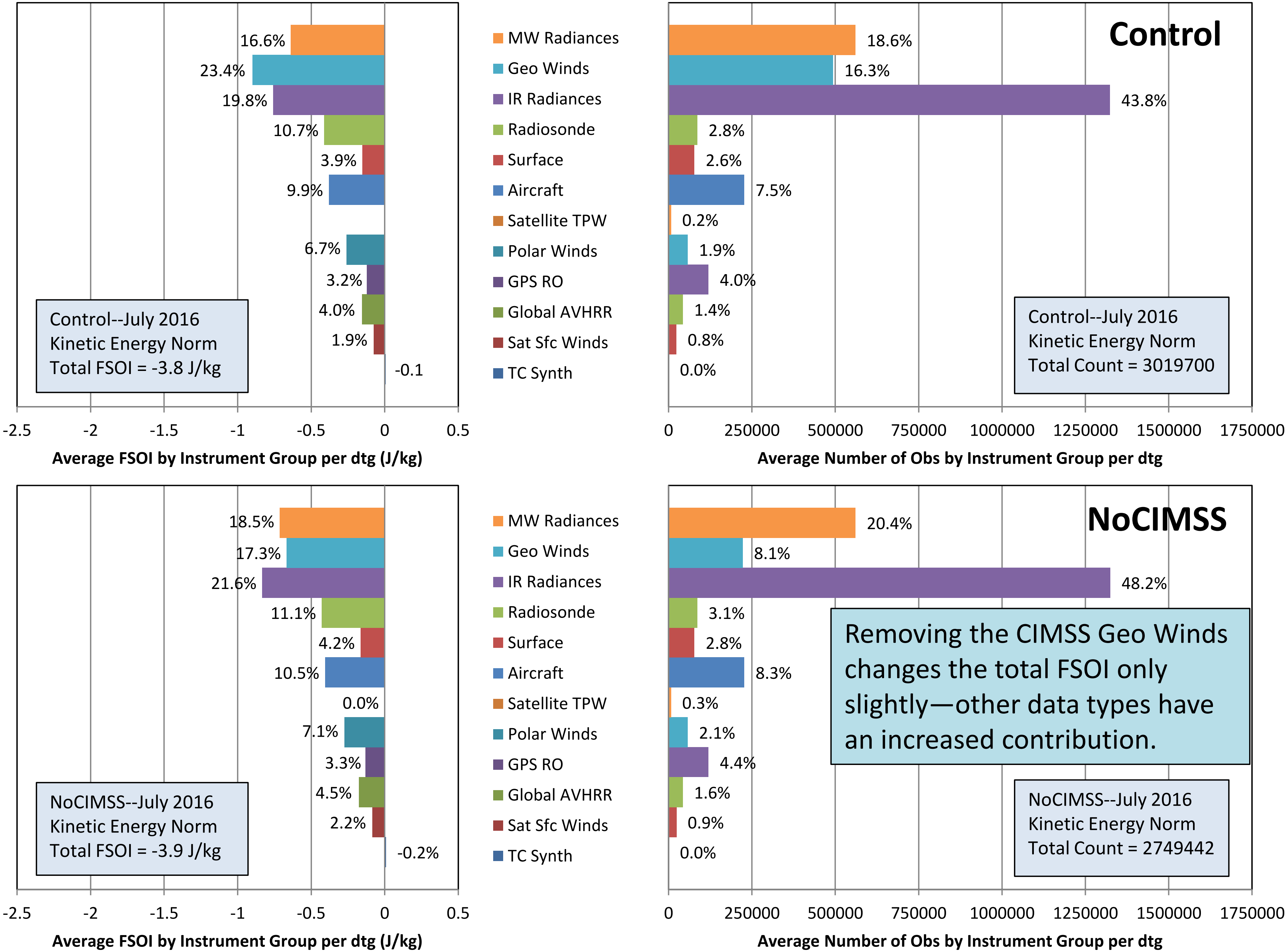

Control—Tropics
24.0%
22.4%
17.9%
11.2%
6.7%
4.9%
8.6%
2.4%
0.8%
1.3%
0.0%
Control Tropics--July 2016
Total Energy Norm
Total FSOI = -5.8 J/kg
-2.5 -2 -1.5 -1 -0.5 0 0.5
Average FSOI by Instrument Group per dtg (J/kg)
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
16.9%
27.0%
44.7%
2.0%
1.1%
3.2%
0.3%
3.2%
0.6%
0.9%
0.0%
Control Tropics--July 2016
Total Energy Norm
Total Count = 1235725
0 250000 500000 750000 1000000 1250000 1500000 1750000
Average Number of Obs by Instrument Group per dtg
Thinning—Tropics
24.0%
22.8%
17.7%
11.1%
6.8%
4.9%
8.6%
2.3%
0.9%
1.1%
0.0%
Thinning Tropics--July 2016
Total Energy Norm
Total FSOI = -5.8 J/kg
-2.5 -2 -1.5 -1 -0.5 0 0.5
Average FSOI by Instrument Group per dtg (J/kg)
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
17.2%
25.7%
45.5%
2.1%
1.1%
3.2%
0.3%
3.3%
0.7%
0.9%
0.0%
The thinning experiment had 1% fewer Geo Winds but little change in FSOI.
Thinning Tropics--July 2016
Total Energy Norm
Total Count = 1212756
0 250000 500000 750000 1000000 1250000 1500000 1750000
Average Number of Obs by Instrument Group per dtg


Control—Tropics
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
24.0%
22.4%
17.9%
11.2%
6.7%
4.9%
8.6%
2.4%
0.8%
1.3%
0.0%
Control Tropics--July 2016
Total Energy Norm
Total FSOI = -5.8 J/kg
-2.5
-2
-1.5
-1
-0.5
0
0.5
Average FSOI by Instrument Group per dtg (J/kg)
16.9%
27.0%
44.7%
2.0%
1.1%
3.2%
0.3%
3.2%
0.6%
0.9%
0.0%
Control Tropics--July 2016
Total Energy Norm
Total Count = 1235725
0
250000
500000
750000
1000000
1250000
1500000
1750000
Average Number of Obs by Instrument Group per dtg
NoCIMSS—Tropics
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
25.3%
17.3%
19.3%
11.7%
6.9%
5.3%
8.9%
2.5%
1.2%
1.6%
-0.1%
NoCIMSS Tropics--July 2016
Total Energy Norm
Total FSOI = -5.7 J/kg
-2.5
-2
-1.5
-1
-0.5
0
0.5
Average FSOI by Instrument Group per dtg (J/kg)
19.9%
13.9%
52.7%
2.4%
1.3%
3.7%
0.3%
3.8%
0.8%
1.1%
0.0%
Removing the CIMSS Geo Winds changes the total FSOI only slightly—other data types have an increased contribution.
NoCIMSS Tropics--July 2016
Total Energy Norm
Total Count = 1046543
0
250000
500000
750000
1000000
1250000
1500000
1750000
Average Number of Obs by Instrument Group per dtg

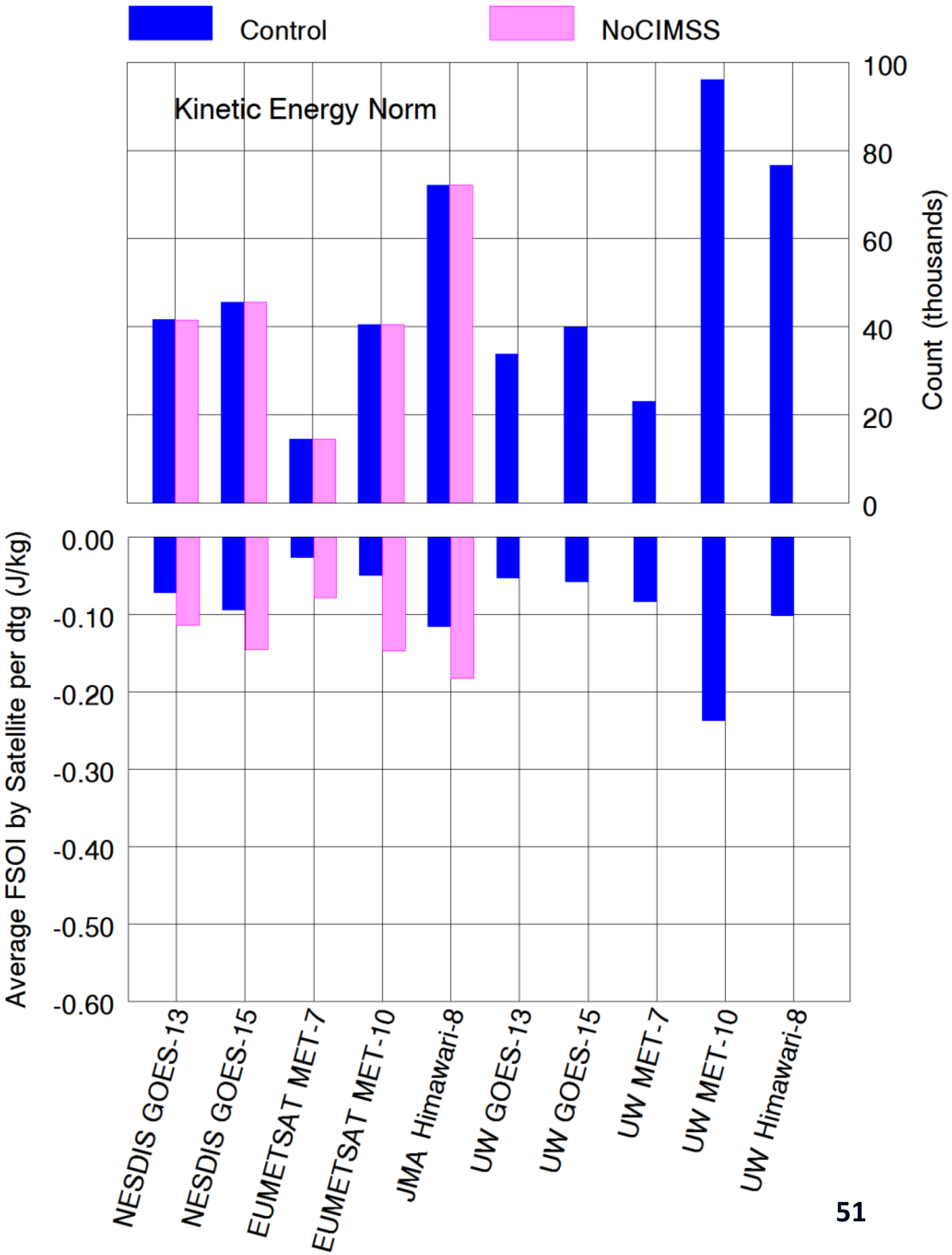

Control—Tropics
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
16.5%
34.7%
22.0%
11.6%
1.6%
8.9%
0.0%
3.2%
0.8%
1.1%
-0.3%
Control Tropics--July 2016
Kinetic Energy Norm
Total FSOI = -1.7 J/kg
-2.5
-2
-1.5
-1
-0.5
0
0.5
Average FSOI by Instrument Group per dtg (J/kg)
16.9%
27.0%
44.7%
2.0%
1.1%
3.2%
0.3%
3.2%
0.6%
0.9%
0.0%
Control Tropics--July 2016
Kinetic Energy Norm
Total Count = 1235725
0
250000
500000
750000
1000000
1250000
1500000
1750000
Average Number of Obs by Instrument Group per dtg
NoCIMSS—Tropics
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
18.6%
27.2%
24.8%
12.2%
1.5%
9.7%
0.0%
3.8%
1.3%
1.3%
-0.5%
NoCIMSS Tropics--July 2016
Kinetic Energy Norm
Total FSOI = -1.7 J/kg
-2.5
-2
-1.5
-1
-0.5
0
0.5
Average FSOI by Instrument Group per dtg (J/kg)
19.9%
13.9%
52.7%
2.4%
1.3%
3.7%
0.3%
3.8%
0.8%
1.1%
0.0%
Removing the CIMSS Geo Winds changes the total FSOI only slightly—other data types have an increased contribution.
NoCIMSS Tropics--July 2016
Total Energy Norm
Total Count = 1046543
0
250000
500000
750000
1000000
1250000
1500000
1750000
Average Number of Obs by Instrument Group per dtg



While differences are present between the 24 hr and 30 hr energy norms, the error norm differences are very similar.



Control
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
16.6%
23.4%
19.8%
10.7%
3.9%
9.9%
6.7%
3.2%
4.0%
1.9%
-0.1
Control--July 2016
Kinetic Energy Norm
Total FSOI = -3.8 J/kg
Average FSOI by Instrument Group per dtg (J/kg)
18.6%
16.3%
43.8%
2.8%
2.6%
7.5%
0.2%
1.9%
4.0%
1.4%
0.8%
0.0%
Control--July 2016
Kinetic Energy Norm
Total Count = 3019700
Average Number of Obs by Instrument Group per dtg
NoCIMSS
18.5%
17.3%
21.6%
11.1%
4.2%
10.5%
0.0%
7.1%
3.3%
4.5%
2.2%
-0.2%
NoCIMSS--July 2016
Kinetic Energy Norm
Total FSOI = -3.9 J/kg
20.4%
8.1%
48.2%
3.1%
2.8%
8.3%
0.3%
2.1%
4.4%
1.6%
0.9%
0.0%
Removing the CIMSS Geo Winds changes the total FSOI only slightly—other data types have an increased contribution.
NoCIMSS--July 2016
Kinetic Energy Norm
Total Count = 2749442



Comparison by satellite

- Results qualitatively similar to those from the total energy norm

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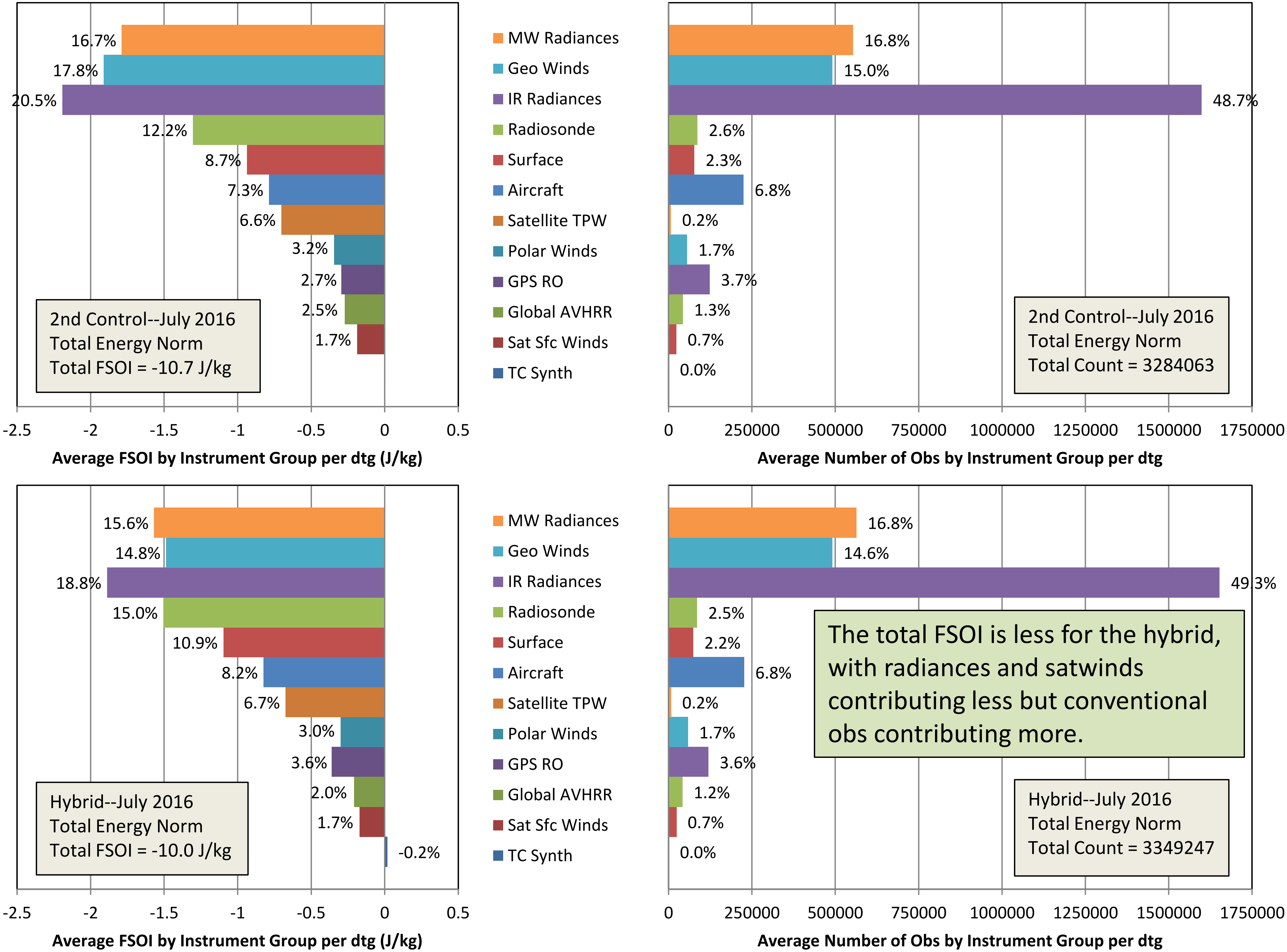
16.7%
17.8%
20.5%
12.2%
8.7%
7.3%
6.6%
3.2%
2.7%
2.5%
1.7%
2nd Control--July 2016
Total Energy Norm
Total FSOI = -10.7 J/kg
-2.5
-2
-1.5
-1
-0.5
0
0.5
Average FSOI by Instrument Group per dtg (J/kg)
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
16.8%
15.0%
48.7%
2.6%
2.3%
6.8%
0.2%
1.7%
3.7%
1.3%
0.7%
0.0%
2nd Control--July 2016
Total Energy Norm
Total Count = 3284063
0
250000
500000
750000
1000000
1250000
1500000
1750000
Average Number of Obs by Instrument Group per dtg
15.6%
14.8%
18.8%
15.0%
10.9%
8.2%
6.7%
3.0%
3.6%
2.0%
1.7%
-0.2%
Hybrid--July 2016
Total Energy Norm
Total FSOI = -10.0 J/kg
-2.5
-2
-1.5
-1
-0.5
0
0.5
Average FSOI by Instrument Group per dtg (J/kg)
MW Radiances
Geo Winds
IR Radiances
Radiosonde
Surface
Aircraft
Satellite TPW
Polar Winds
GPS RO
Global AVHRR
Sat Sfc Winds
TC Synth
16.8%
14.6%
49.3%
2.5%
2.2%
6.8%
0.2%
1.7%
3.6%
1.2%
0.7%
0.0%
The total FSOI is less for the hybrid, with radiances and satwinds contributing less but conventional obs contributing more.
Hybrid--July 2016
Total Energy Norm
Total Count = 3349247
0
250000
500000
750000
1000000
1250000
1500000
1750000
Average Number of Obs by Instrument Group per dtg