Sampling Errors in Satellite Derived Sea Surface Temperature Associated with Climate Data Records

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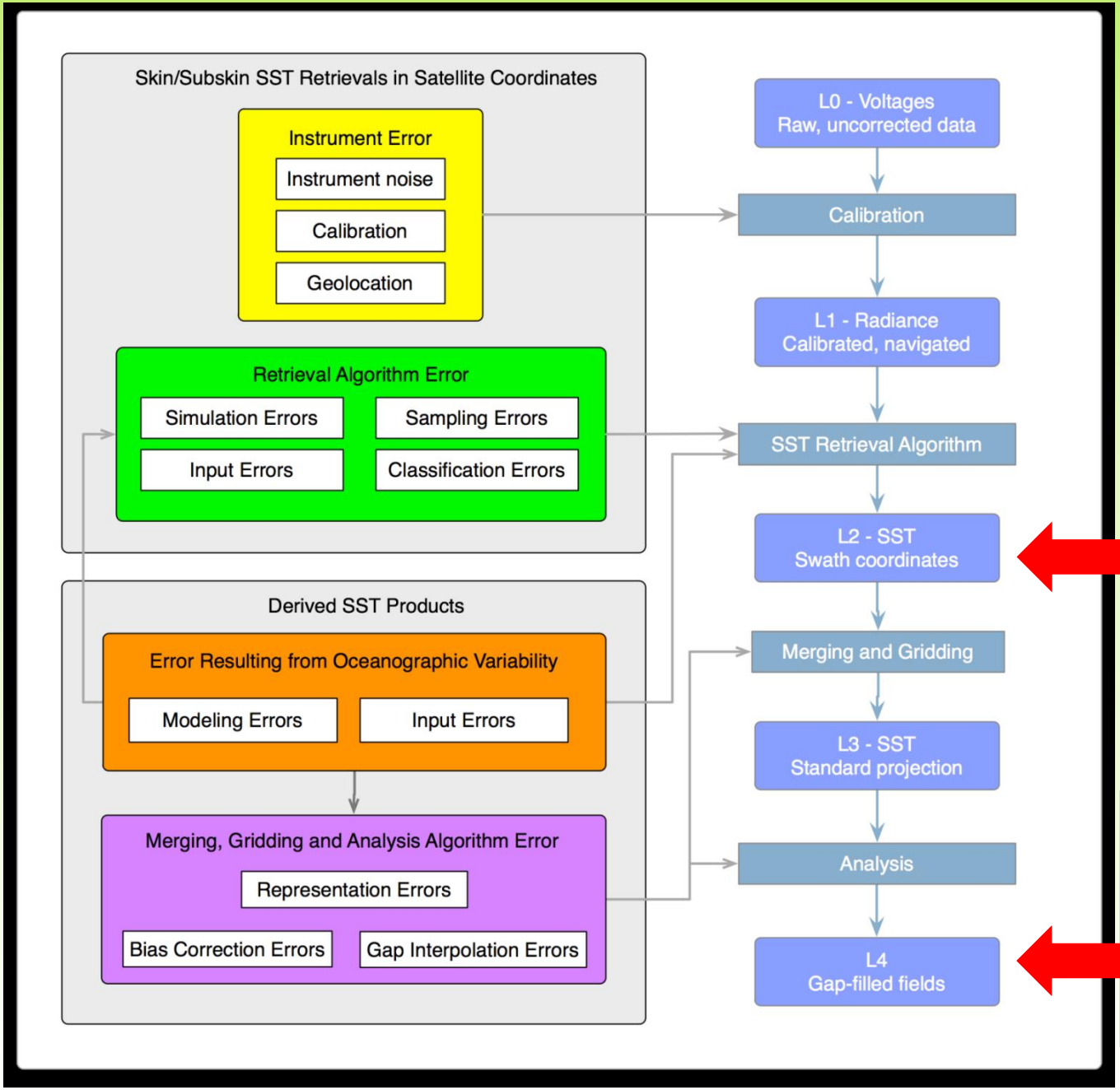
Error sources



Sea Surface Temperature Error Budget: ISSTST White Paper.

L2 is where the uncertainties in the SST retrievals are derived by comparison with independent measurements.

L4 fields are used to initialize climate models, and in other climate studies.

Motivation

Uncertainties in satellite-derived SSTs are usually derived at Level 2 (swath data), but climate analysis and model input generally use Level 4 fields

Additional sources of uncertainty in Level 4 include:

- ✓ **Clouds** cause significant undersampling; typically only ~10% of all pixels pass cloud screening

- ✓ **Gaps between swaths** for some IR sensors cause undersampling

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Data and Methods

Simulation

L3 data: MODIS_T Cloud Mask 4km-1d

Cloud Mask ONLY

"Sampled" SST 4km-1d

L4 SST 4km-1d

Base Resolution: 4km and daily

L4 data:G1SST 1km-1d

L4 SST fields, providing a complete SST field, are sampled through real MODIS cloud mask

Time:
2010.12.26 – 2011.01.25

Subsampling

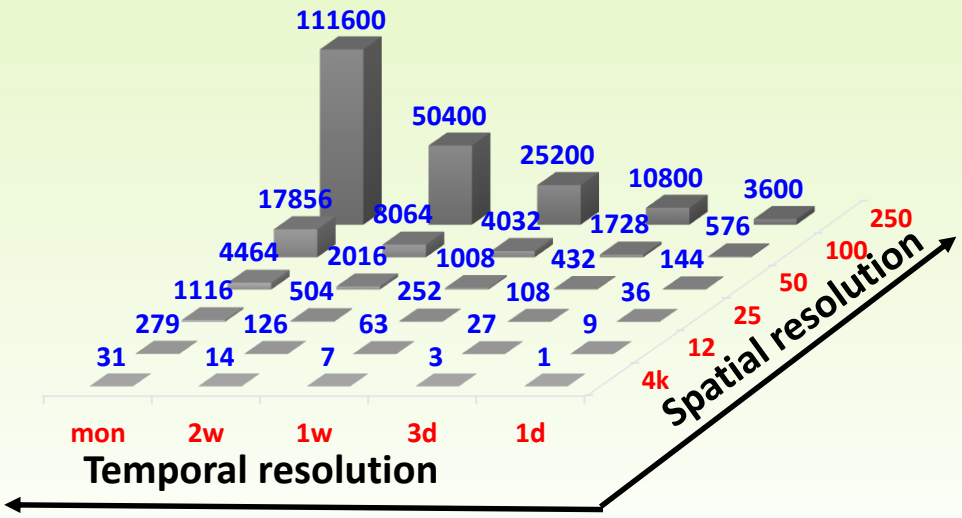
12, 25, 50,100, 250 km
1day, 3day, 1w, 2w, 1m

Resolutions at the equator

Comparison

"Sampled" SST VS Reference SST

Maximum number of SST in resampling box



Error Quantification Framework

Point to Point statistics:

Base resolution	Downsized resolution	Max number of SST	Sampled number of SST
$R_0 = 4km$	$R = [4,12,25,50,100,250\ km]$	$N_r = \frac{R}{R_0} \times \frac{R}{R_0}$	$n_r = [0,1,2,3 \dots \dots N_r]$
$T_0 = 1d$	$T = [1d, 3d, 1w, 2w, mon]$	$N_t = T$	$n_t = [0,1,2,3 \dots \dots N_t]$

$$Gap\ Fraction = 1.0 - \frac{n_r \times n_t}{N_r \times N_t} \quad (0 \le Gap\_F \le 1)$$

"Sampled" SST: $$SST = \frac{1}{n_r \times n_t} \sum_{i=1}^{n_r} \sum_{j=1}^{n_t} SST_0^{rf}$$

Reference SST: $$SST^{rf} = \frac{1}{N_r \times N_t} \sum_{i=1}^{N_r} \sum_{j=1}^{N_t} SST_0^{rf}$$

Reference SST at base resolution

Difference: $$Diff = SST - SST^{rf}$$

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Geographic statistics:

$N_x = Num\ of\ grids\ in\ longitude$

$n_x = Num\ of\ samples\ \ldots\ldots$

$N_y = Num\ of\ grids\ in\ latitude$

$n_y = Num\ of\ samples\ \ldots\ldots$

$$\widehat{SST} = \frac{1}{\sum_{i=1}^{n_x}\sum_{j=1}^{n_y}\cos(lat_j)}\sum_{i=1}^{n_x}\sum_{j=1}^{n_y} SST \times \cos(lat_j)$$

$$\widehat{SST}^{rf} = \frac{1}{\sum_{i=1}^{N_x}\sum_{j=1}^{N_y}\cos(lat_j)}\sum_{i=1}^{N_x}\sum_{j=1}^{N_y} SST^{rf} \times \cos(lat_j)$$

$$\widehat{Diff} = \frac{1}{\sum_{i=1}^{n_x}\sum_{j=1}^{n_y}\cos(lat_j)}\sum_{i=1}^{n_x}\sum_{j=1}^{n_y} (SST - SST^{rf}) \times \cos(lat_j)$$

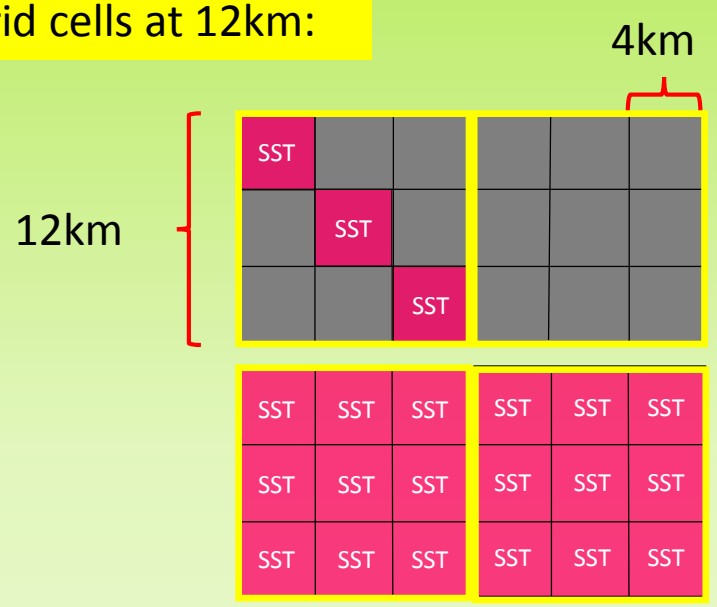
....."Global Mean of Difference"

" $\widehat{SST} - \widehat{SST}^{rf}$ "

....."Difference of Global Mean"

$$RMSE = \sqrt{\frac{1}{\sum_{i=1}^{n_x}\sum_{j=1}^{n_y}\cos(lat_j)}\sum_{i=1}^{n_x}\sum_{j=1}^{n_y} Diff^2 \times \cos(lat_j)}$$

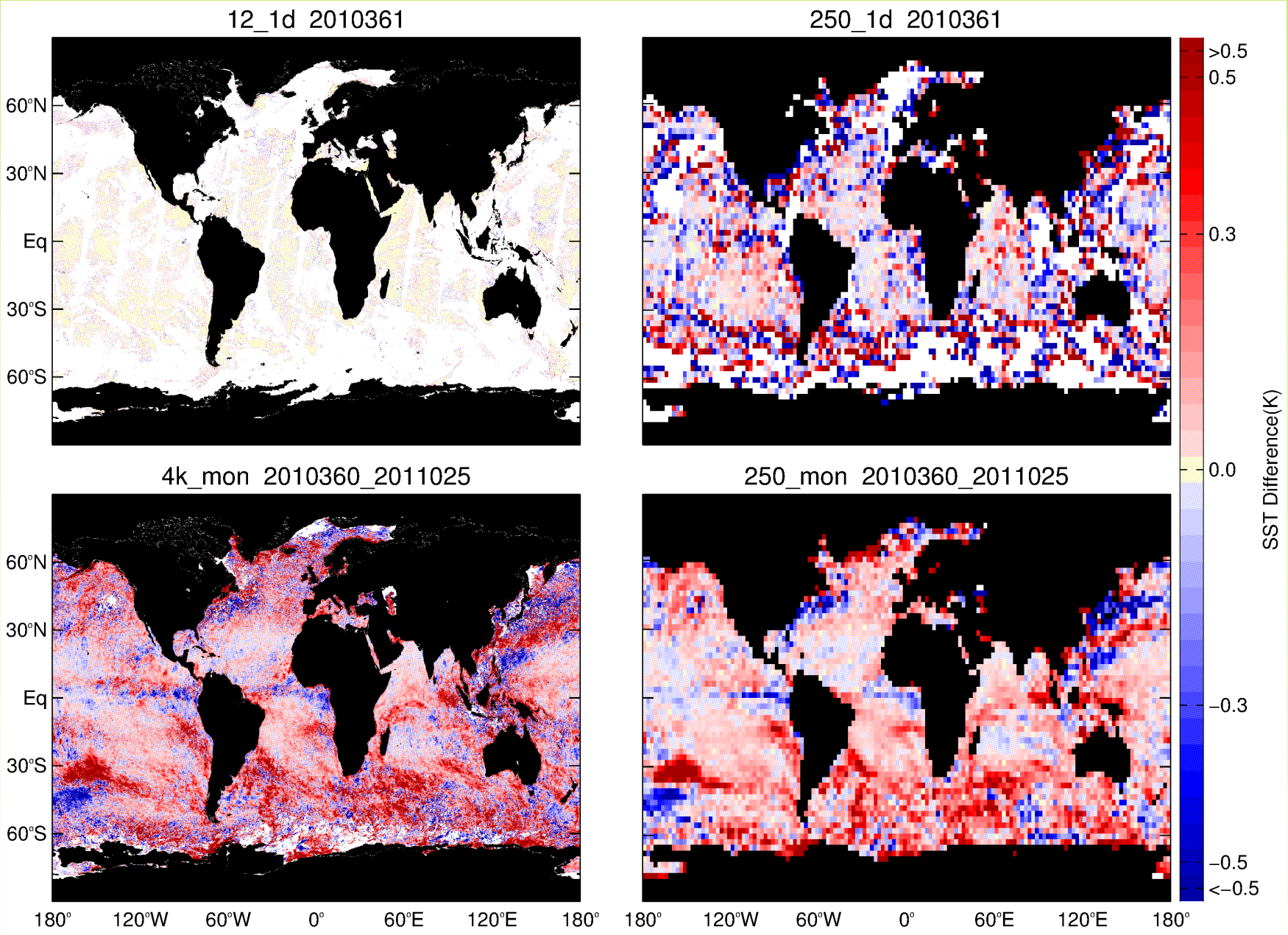
4 grid cells at 12km:



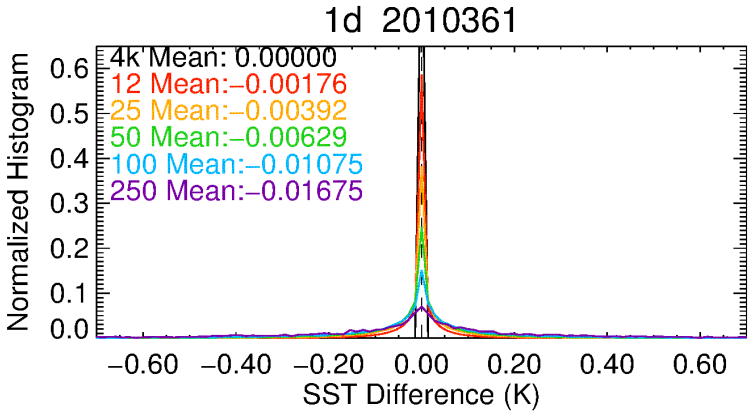
At each grid cell of 12km, the gap fraction is 6/9, 9/9, 0/9, 0/9. But the global Gap fraction would be 1/4.

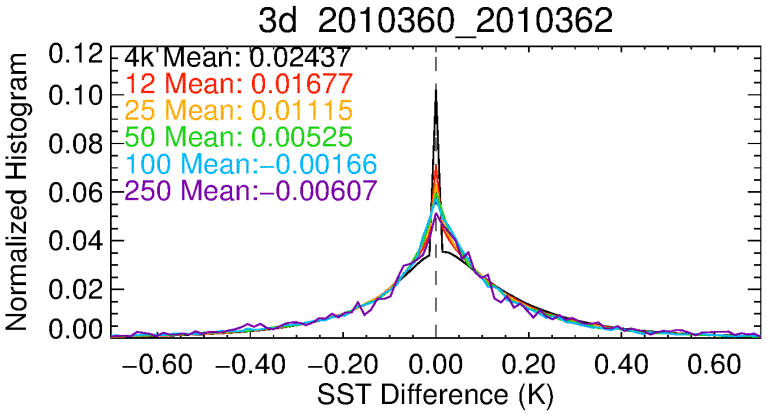
$$Global\ Gap\ Fraction = 1.0 - \frac{\sum_{i=1}^{n_x}\sum_{j=1}^{n_y}\cos(lat_j)}{\sum_{i=1}^{N_x}\sum_{j=1}^{N_y}\cos(lat_j)}$$

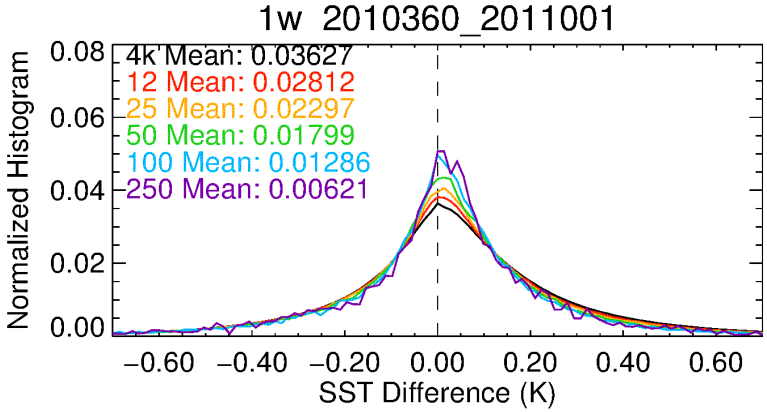
Results

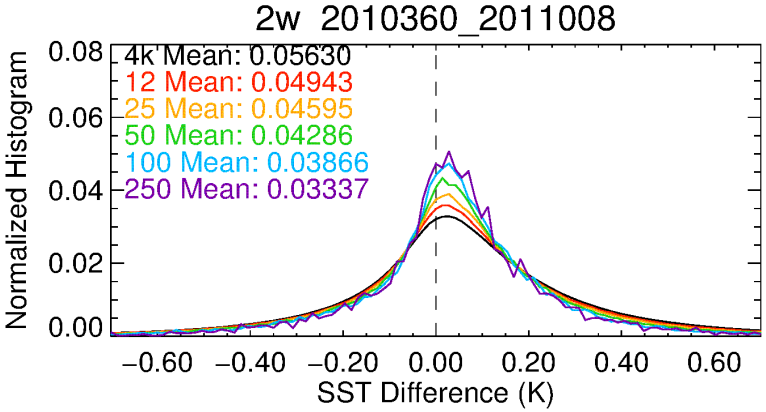


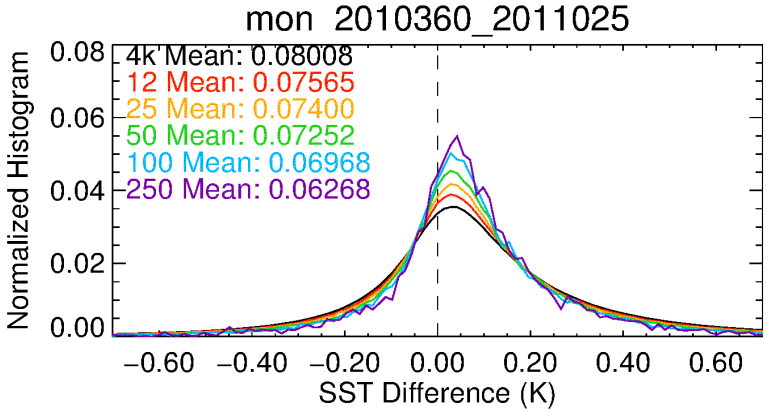
Global Day



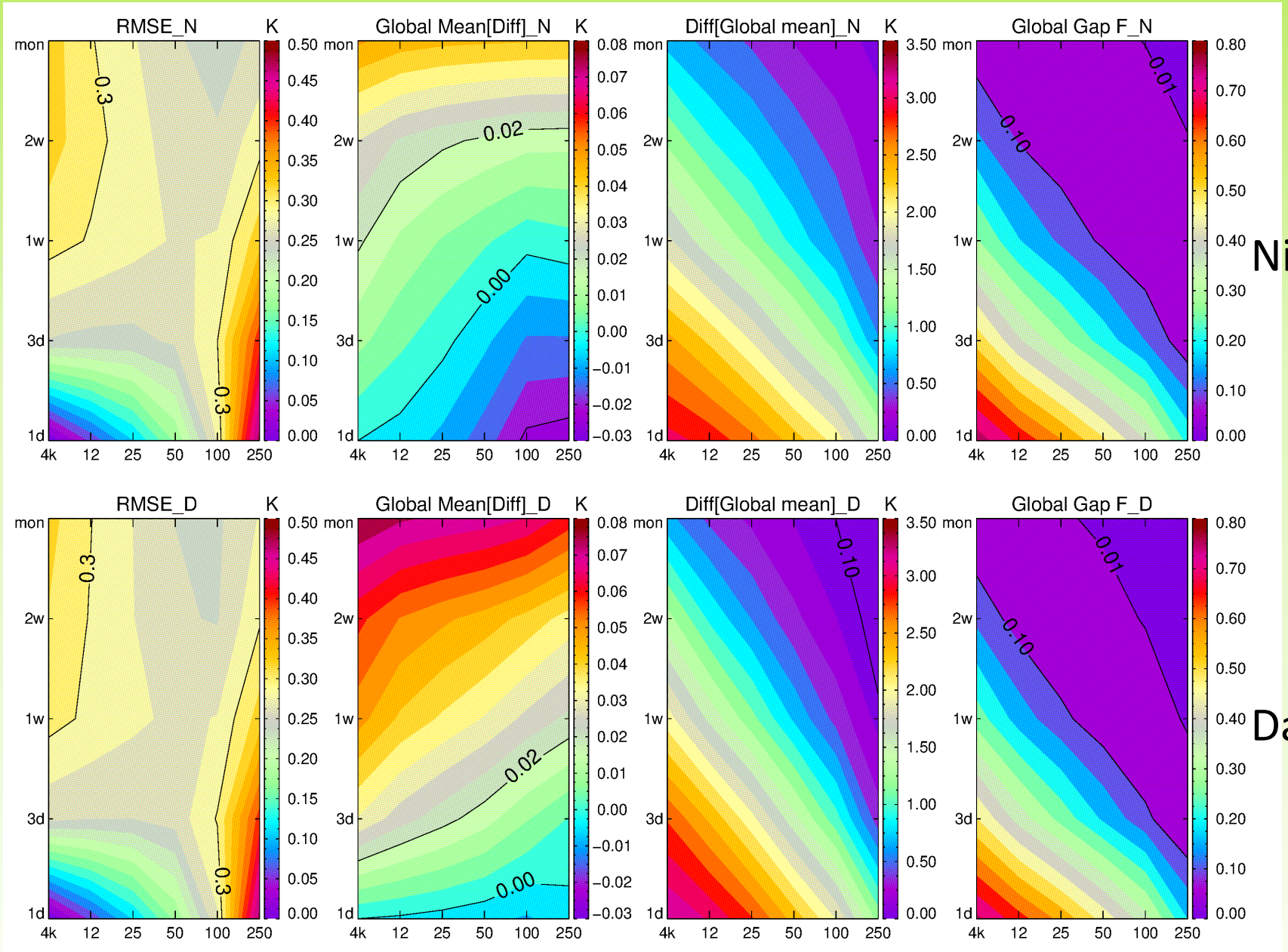


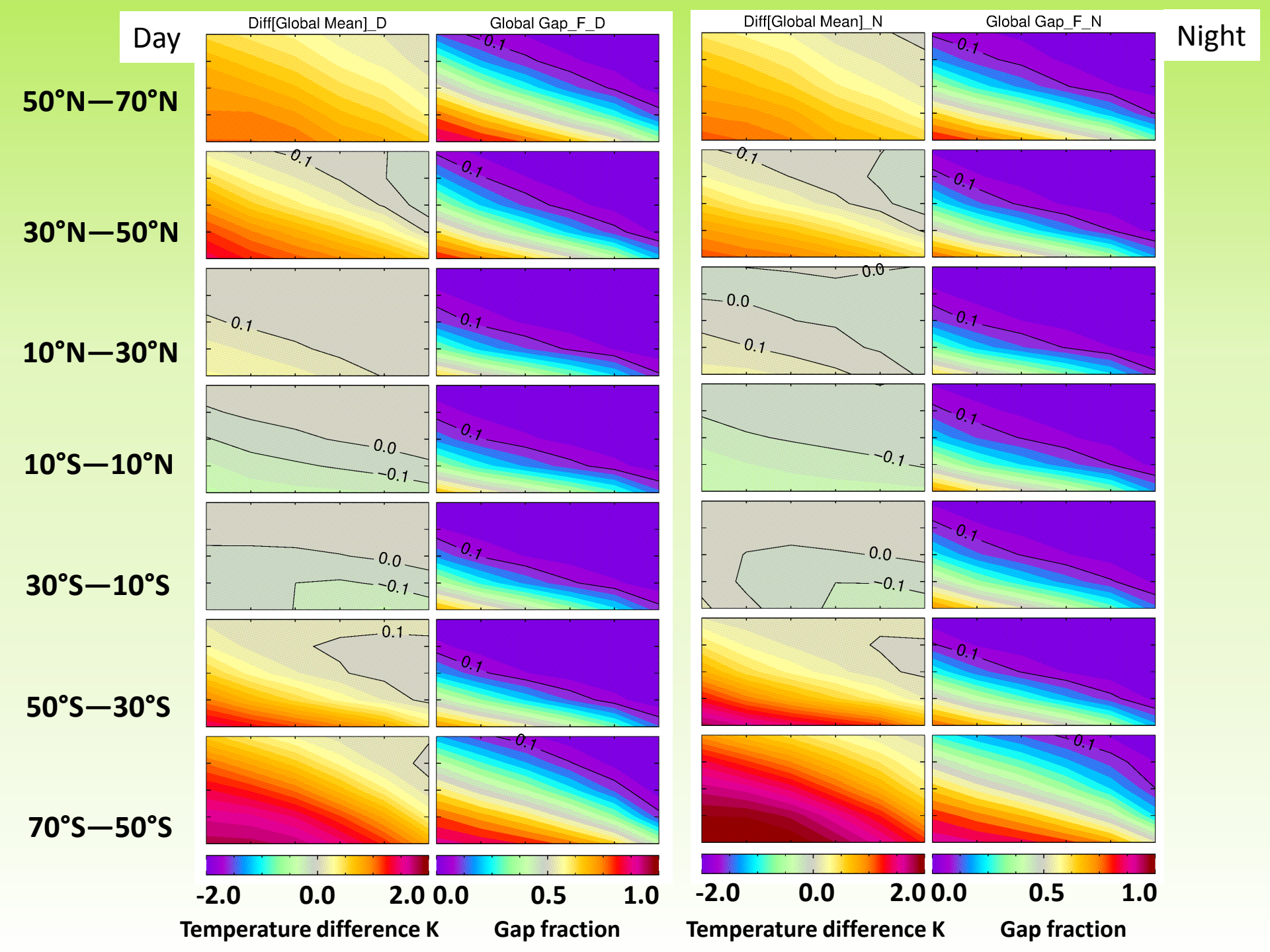


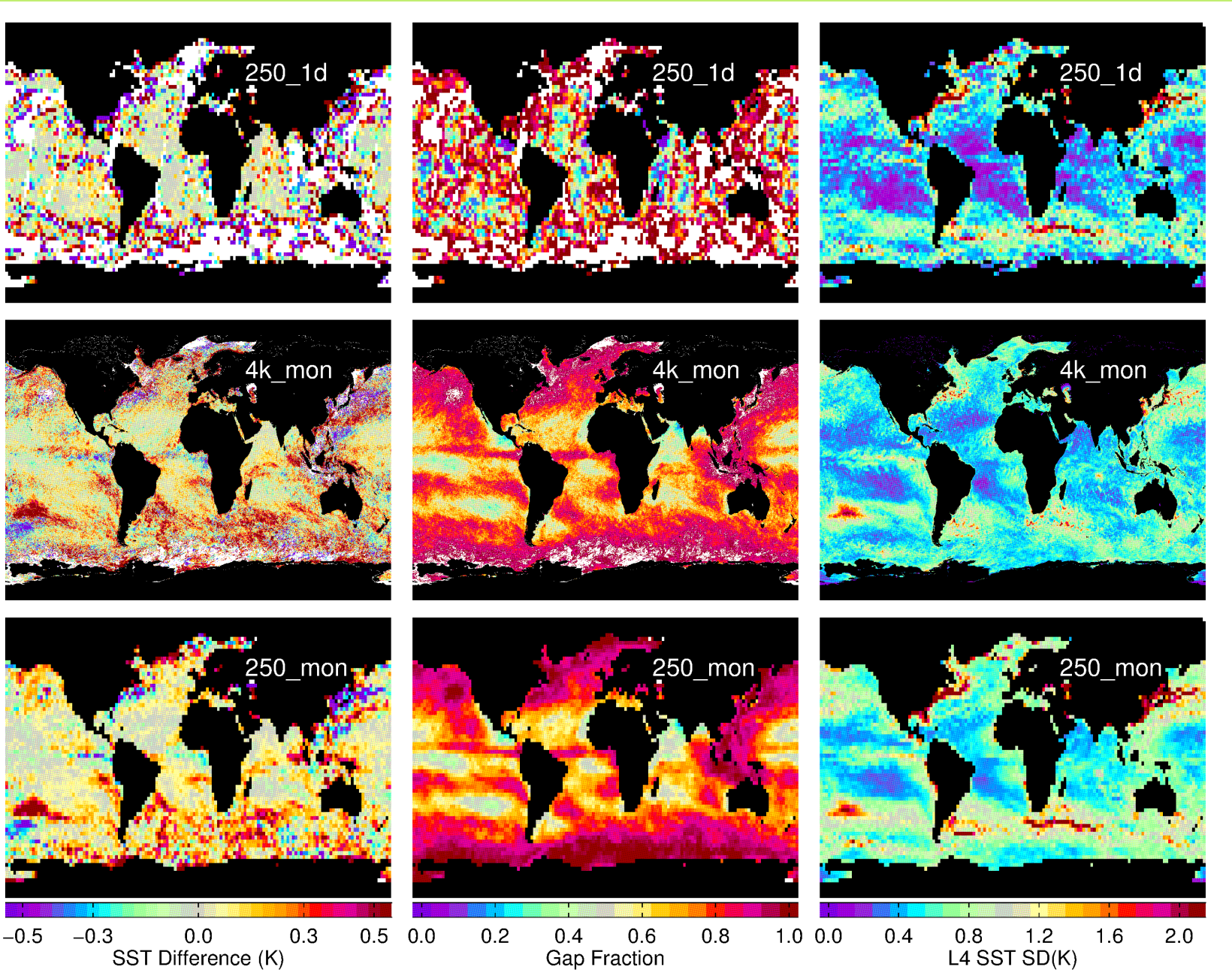




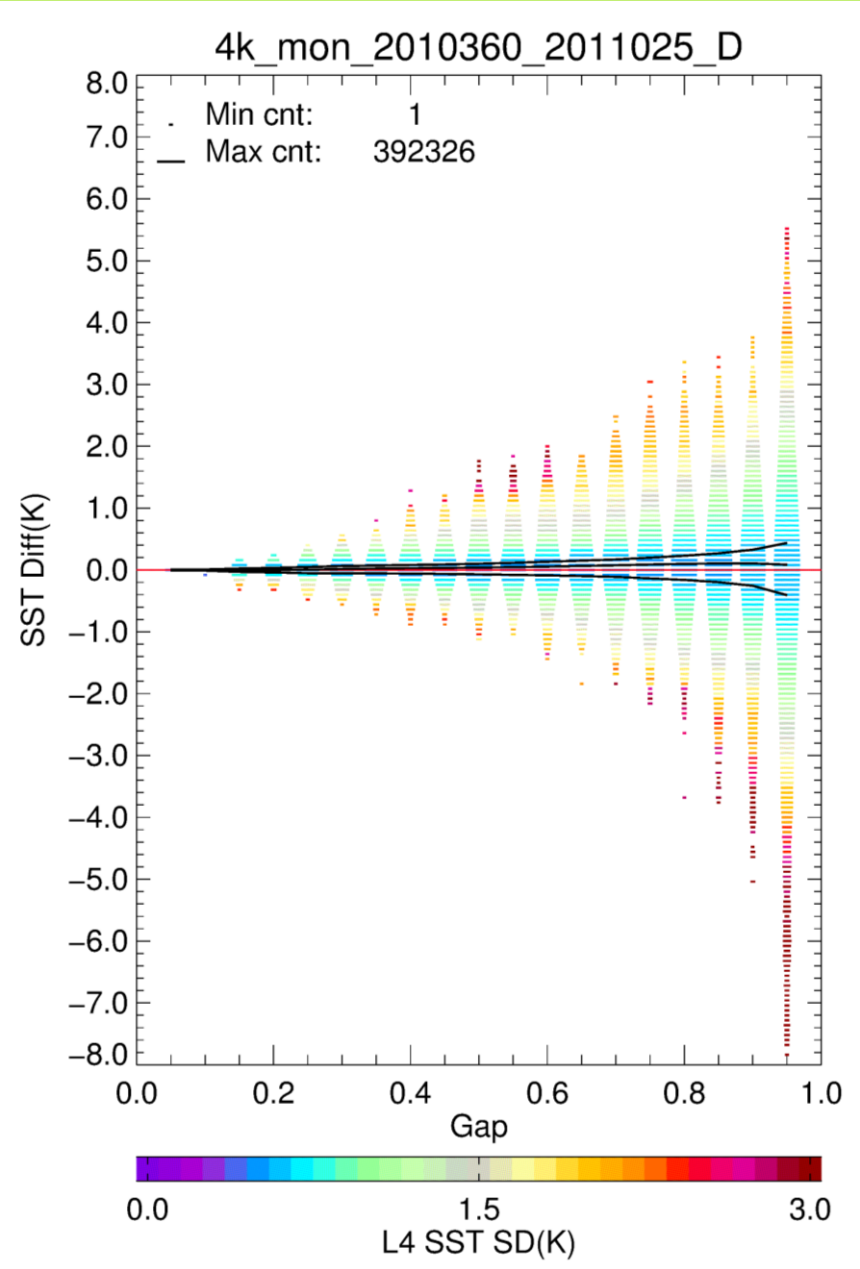
- Histograms of SST difference at different temporal averaging.
- Colors indicate spatial averaging size

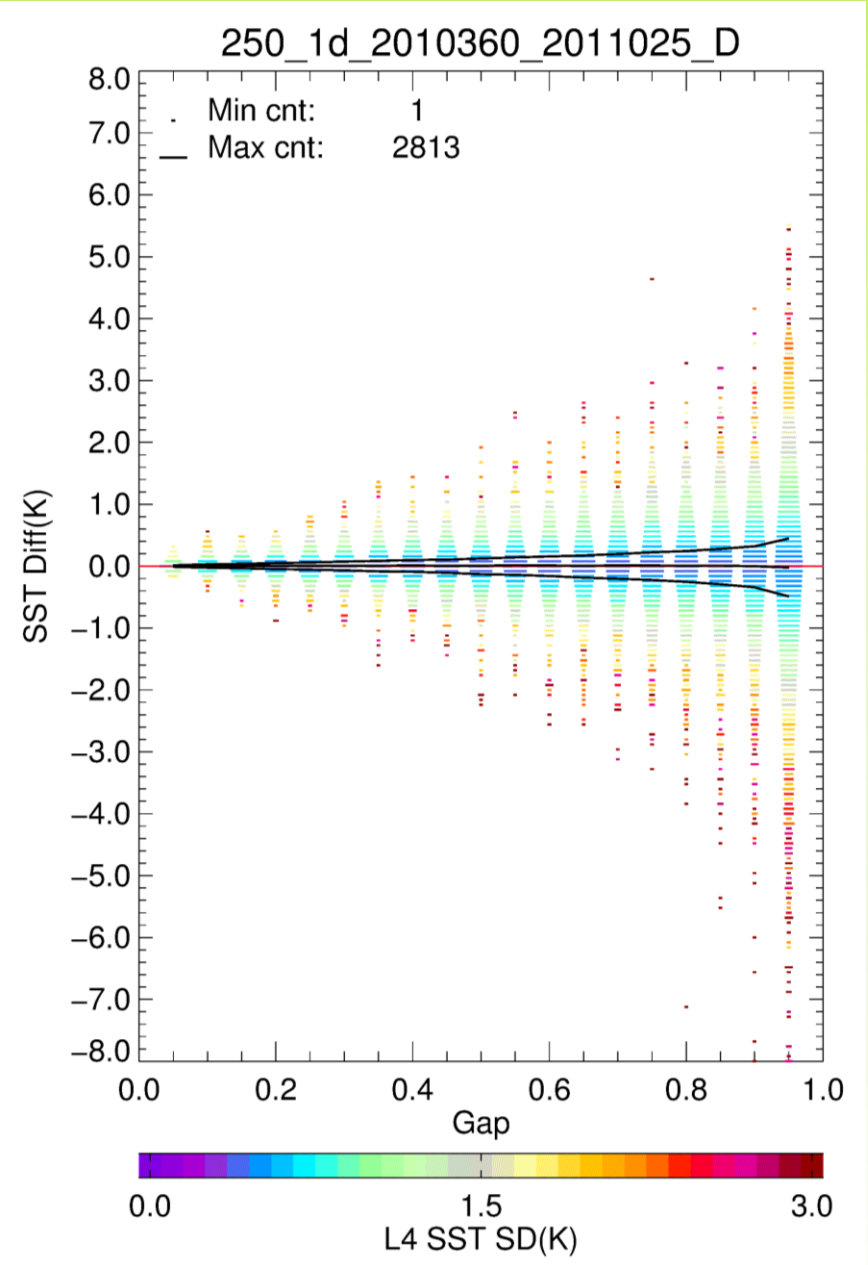

RMSE_N
Global Mean[Diff]_N
Diff[Global mean]_N
Global Gap F_N
RMSE_D
Global Mean[Diff]_D
Diff[Global mean]_D
Global Gap F_D
K
mon
2w
1w
3d
1d
4k
12
25
50
100
250
0.3
0.02
0.00
0.10
0.01
Night
Day
Decreasing temporal resolution →
Decreasing spatial resolution →


Day
Night
Diff[Global Mean]_D
Global Gap_F_D
Diff[Global Mean]_N
Global Gap_F_N
50°N—70°N
30°N—50°N
10°N—30°N
10°S—10°N
30°S—10°S
50°S—30°S
70°S—50°S
-2.0
0.0
2.0
0.0
0.5
1.0
Temperature difference K
Gap fraction
Temperature difference K
Gap fraction

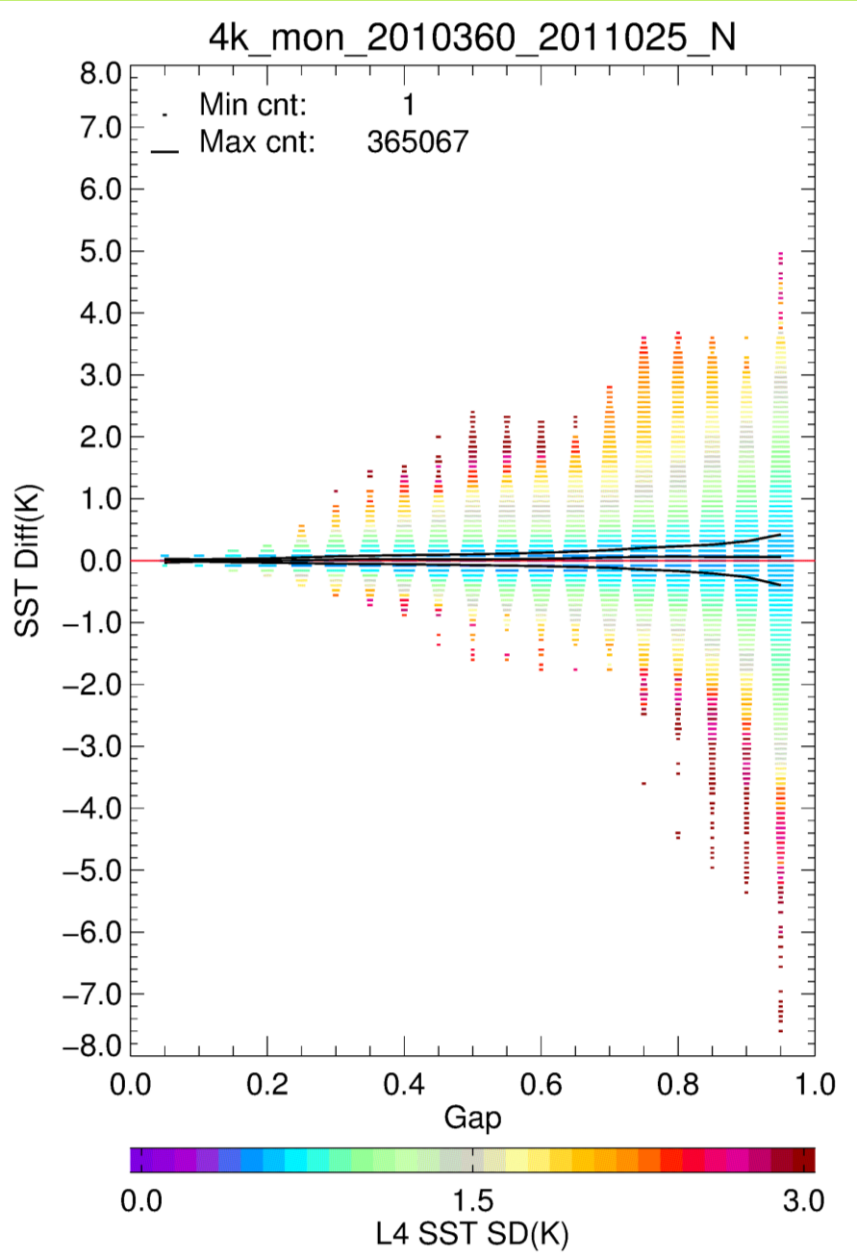

SST Difference
Gap Fraction
L4 SST SD
Spatial variability
Temporal variability
Spatio-Temporal variability
250_1d
4k_mon
250_mon
−0.5 −0.3 0.0 0.3 0.5
SST Difference (K)
0.0 0.2 0.4 0.6 0.8 1.0
Gap Fraction
0.0 0.4 0.8 1.2 1.6 2.0
L4 SST SD(K)
Global Day

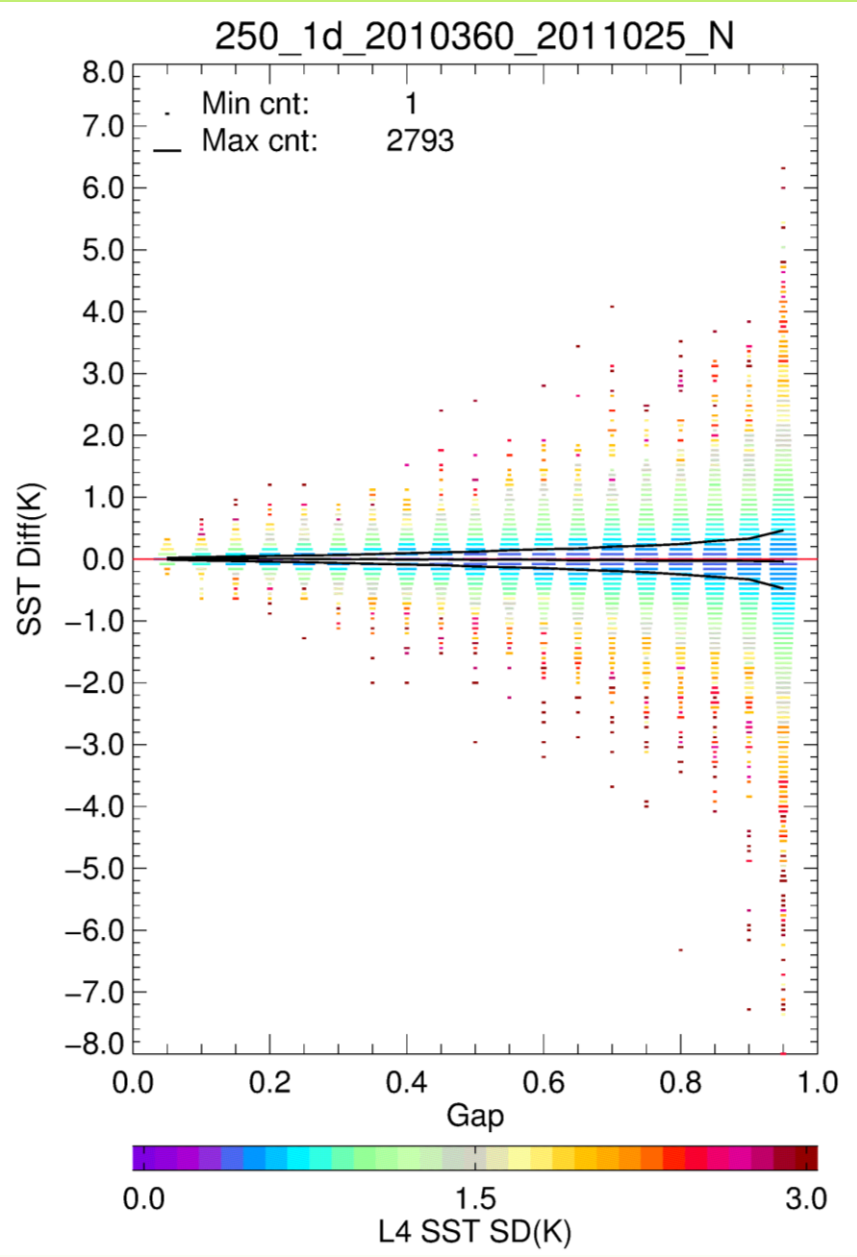
Global Day


4k_mon_2010360_2011025_D
Min cnt: 1
Max cnt: 392326
SST Diff(K)
Gap
L4 SST SD(K)


250_1d_2010360_2011025_D
Min cnt: 1
Max cnt: 2813
SST Diff(K)
Gap
L4 SST SD(K)

Global Night





Summary

- Sampling errors caused by clouds are large and can not be neglected when interpreting L4 fields.
- For sampling error less than 0.1K, only L4 fields with 100-mon, 250-2w, or 250-mon should be used.
- Spatial distribution of errors over global ocean is complex. And some areas are prone to larger errors than others.
- Real L4 fields have additional errors accumulated at the production of each Level, including those due to satellite retrieval errors, aerosols and unresolved clouds …
- The method of gap filling in real L4 fields introduces further complications.

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Future Work

- Compare different seasons
- Use Aqua MODIS for a different time of day
- Regional analyses
- AATSR - added issue of narrow swath
- VIIRS - no gap between swaths……..

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