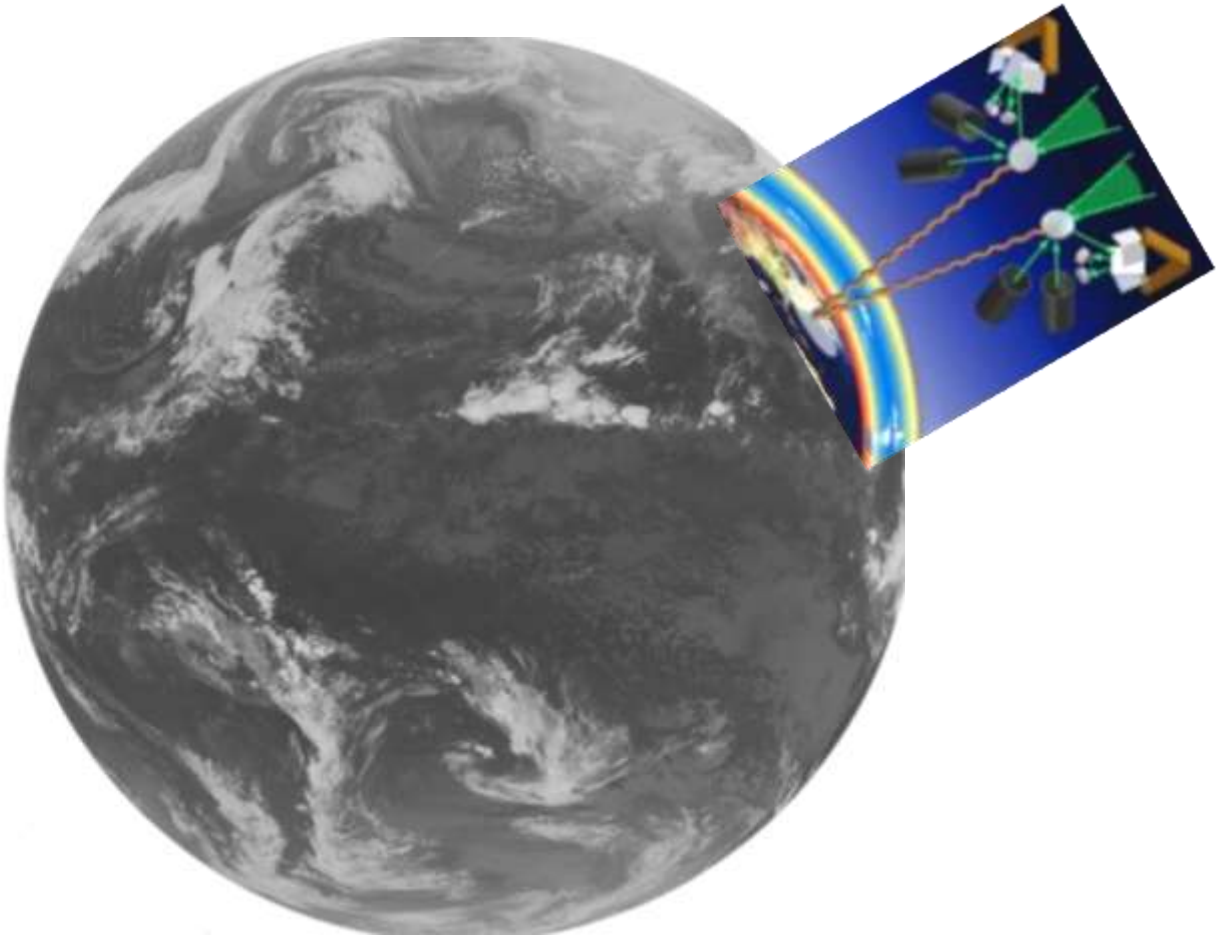
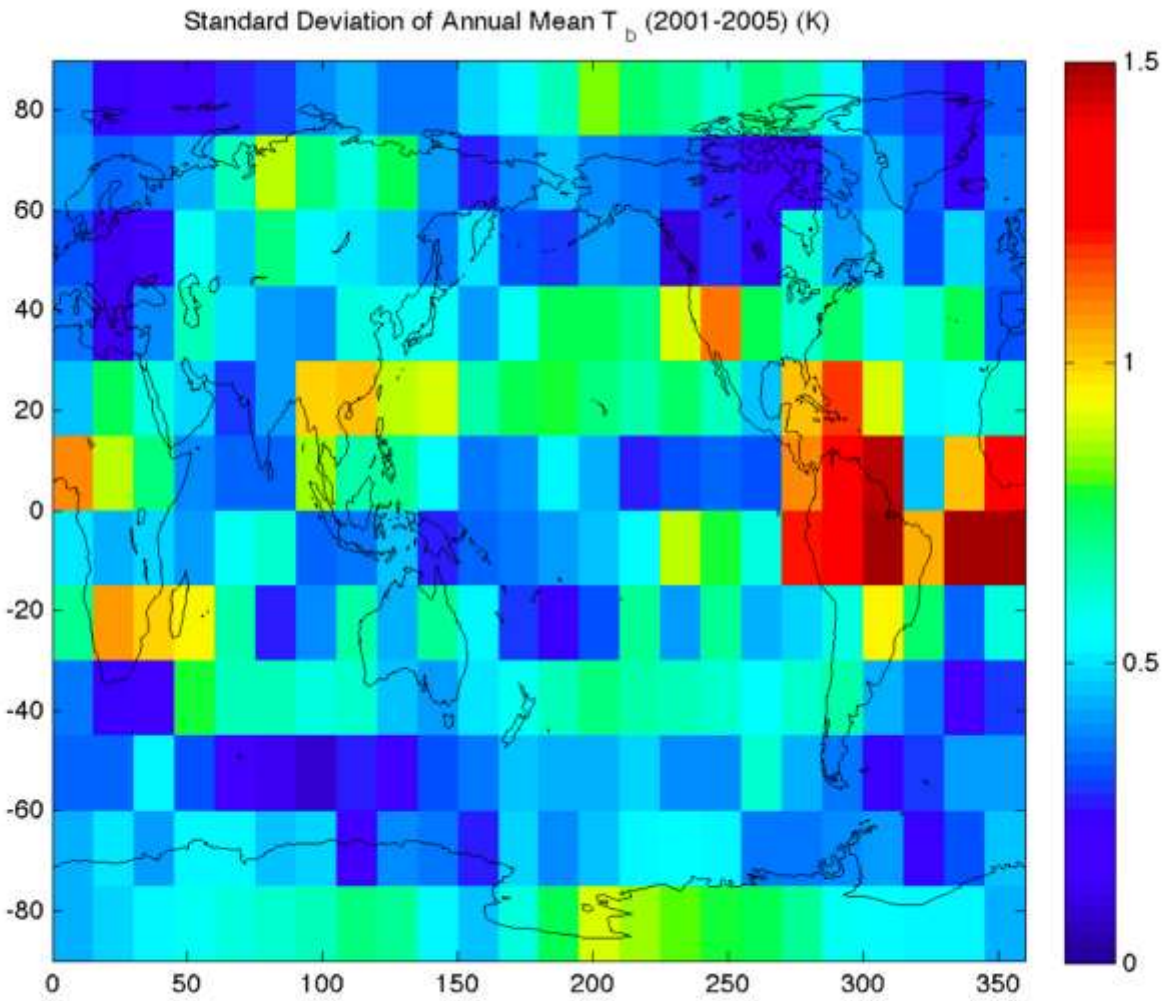
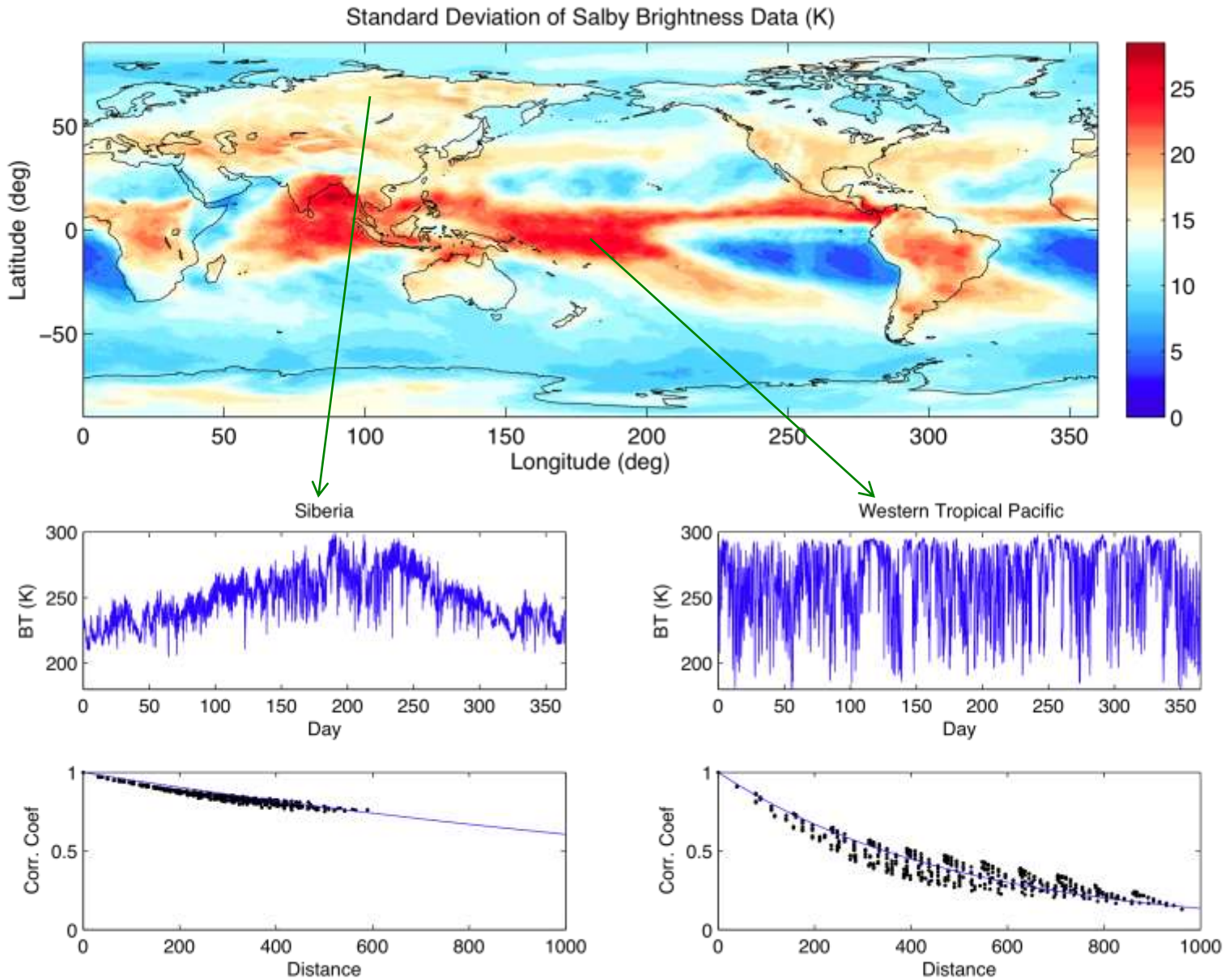


Minimizing Satellite Sampling Errors for Climate Monitoring

Daniel Kirk-Davidoff, Benjamin Johnson, Renu Joseph
University of Maryland

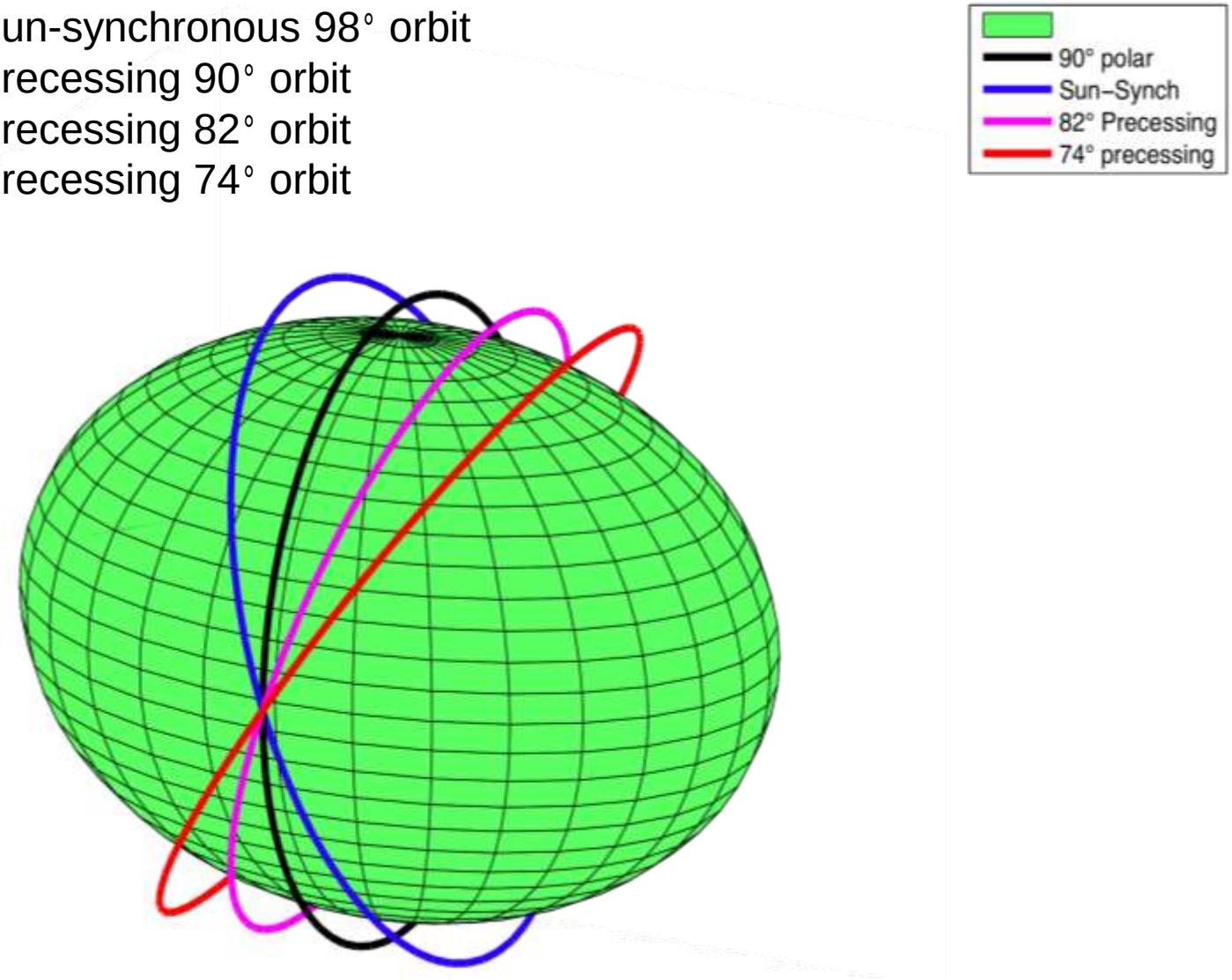


Interannual variability of brightness temperature derived from broadband radiance. The variability is defined as the standard deviation of annual mean brightness temperature in each 15° grid box for the years 2001-2005.

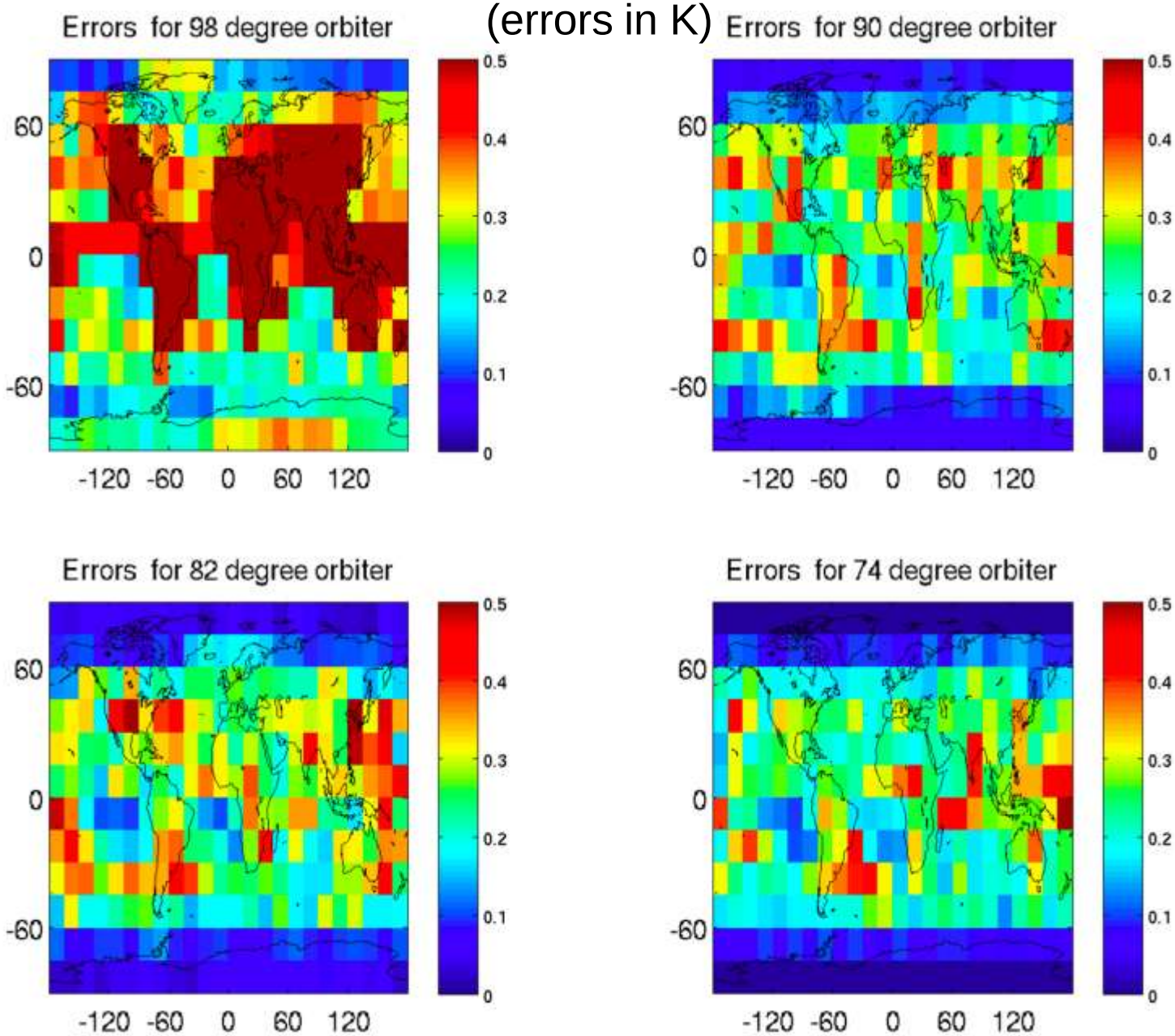

Standard Deviation of Salby Brightness Data (K)
Latitude (deg)
Longitude (deg)
Siberia
Western Tropical Pacific
BT (K)
Day
Corr. Coef
Distance

We consider the following orbits:

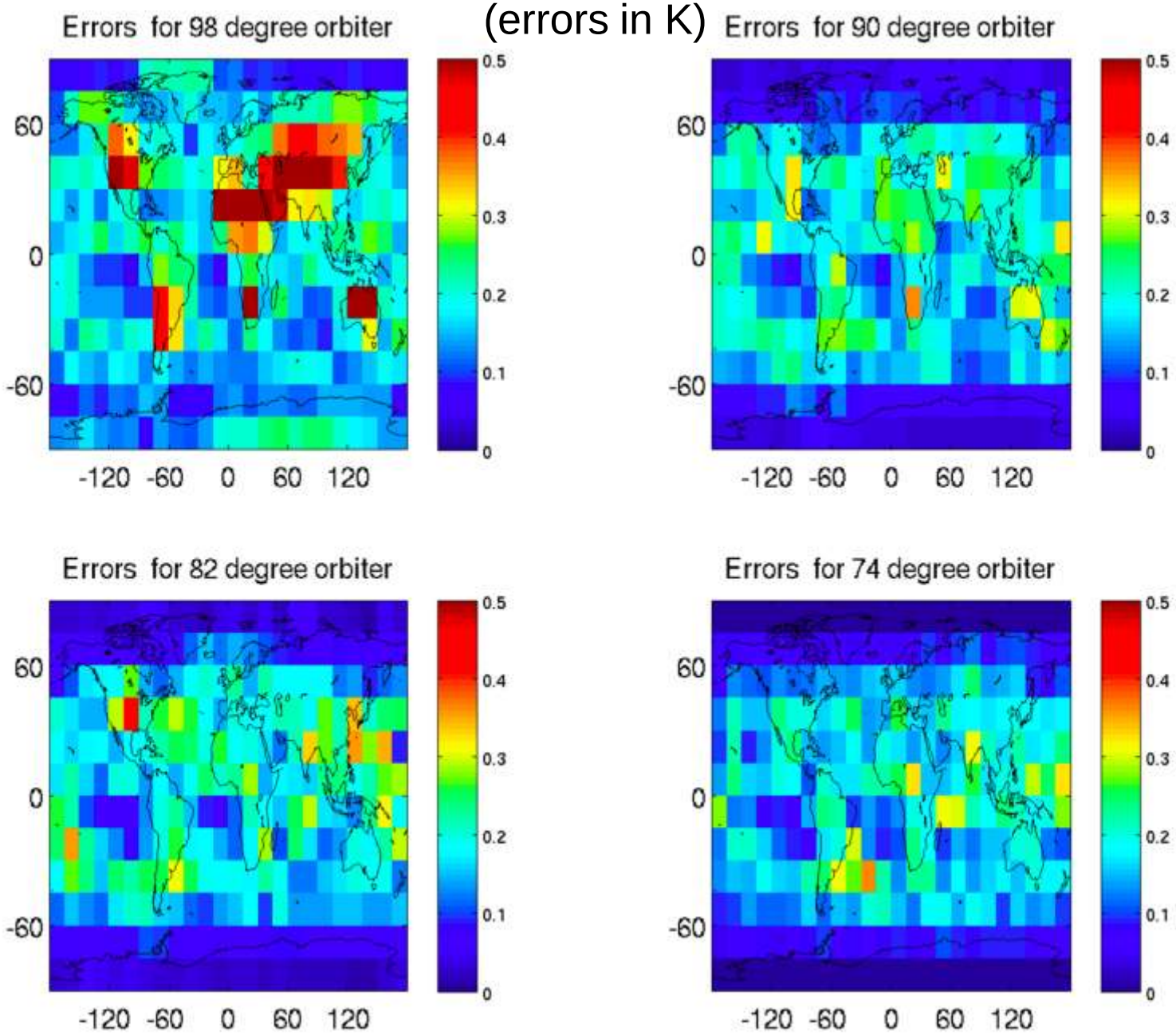
- Sun-synchronous 98° orbit
- Precessing 90° orbit
- Precessing 82° orbit
- Precessing 74° orbit



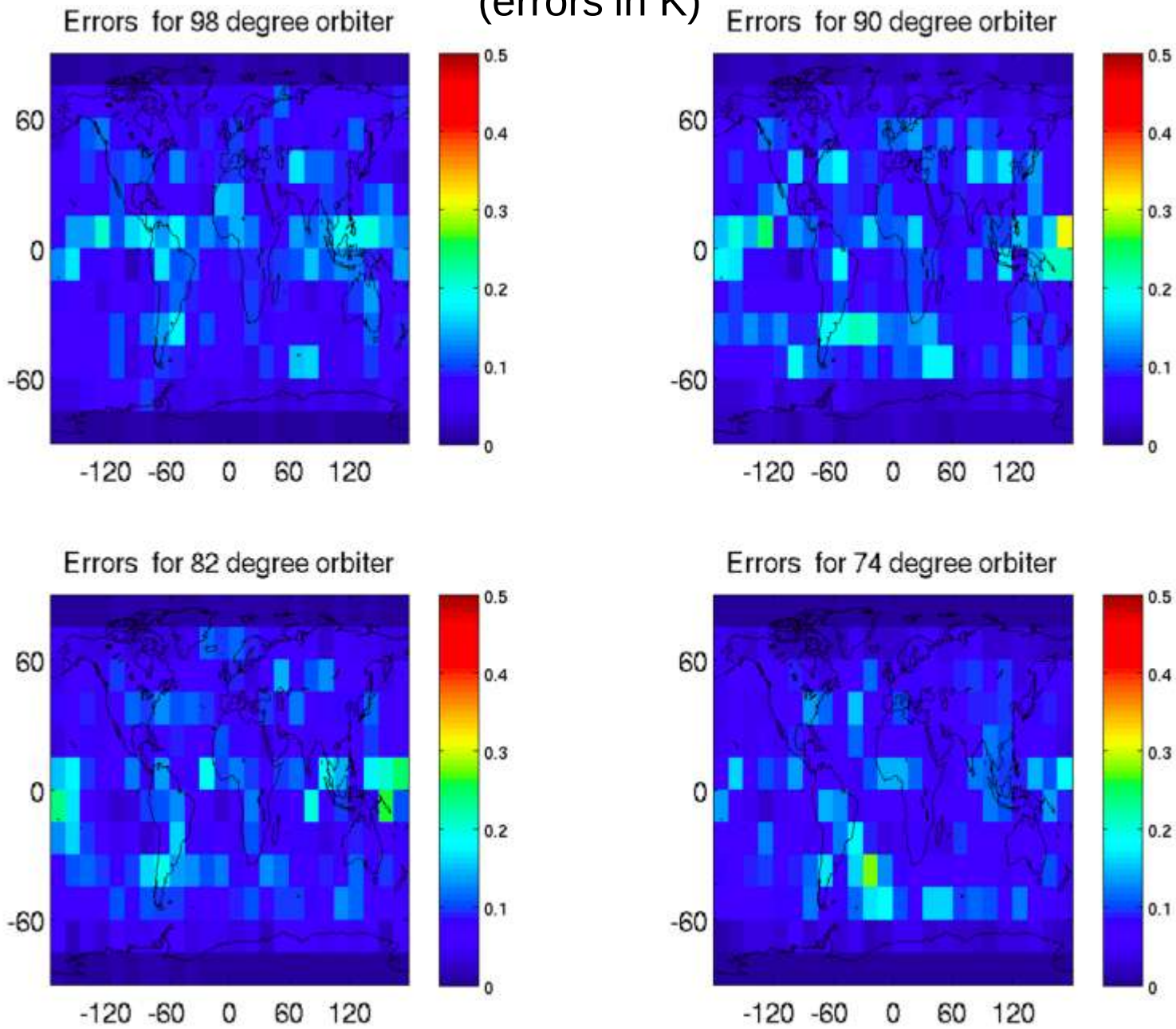
Single Orbiter
(errors in K)

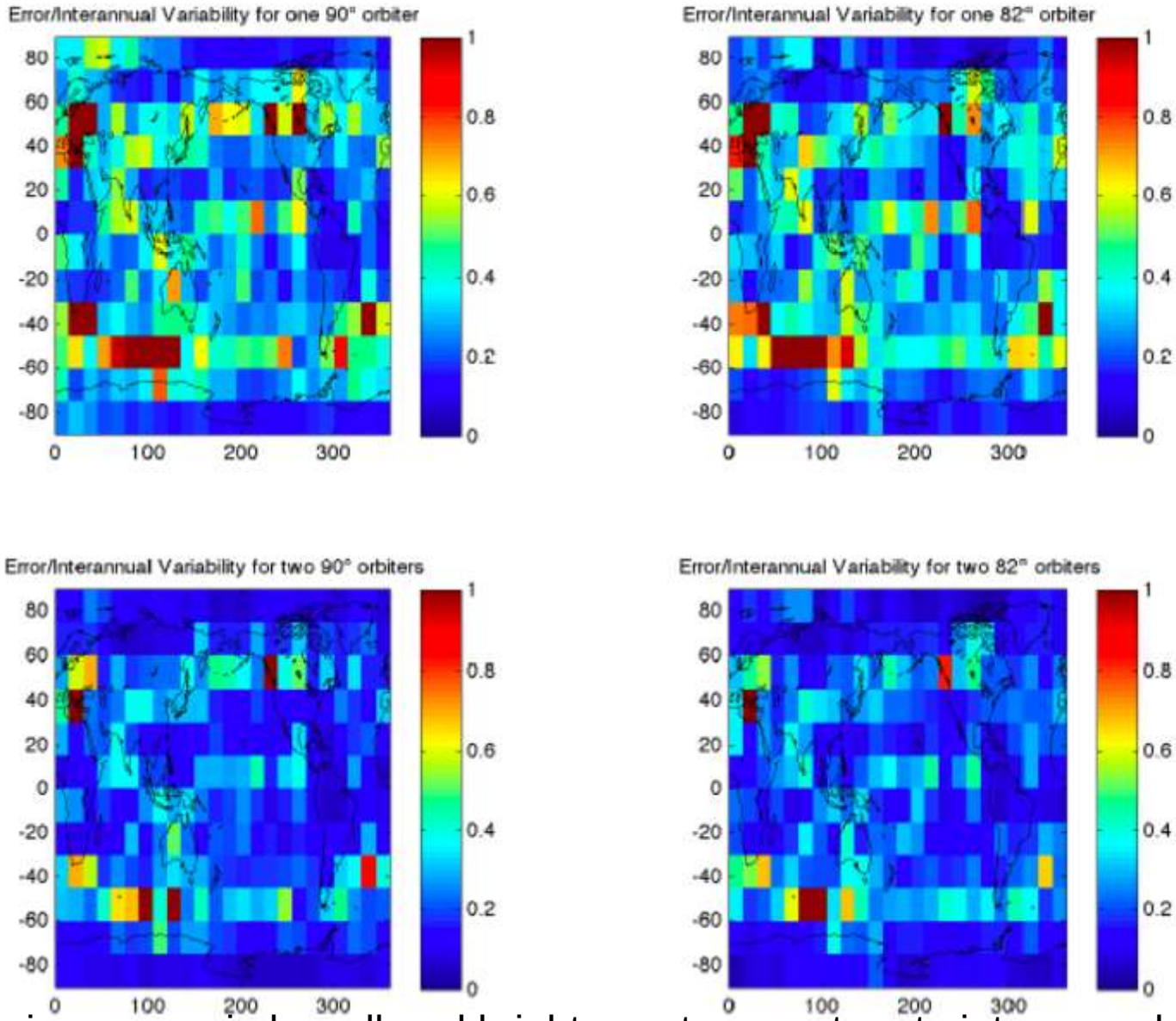


Two Orbiters
(errors in K)

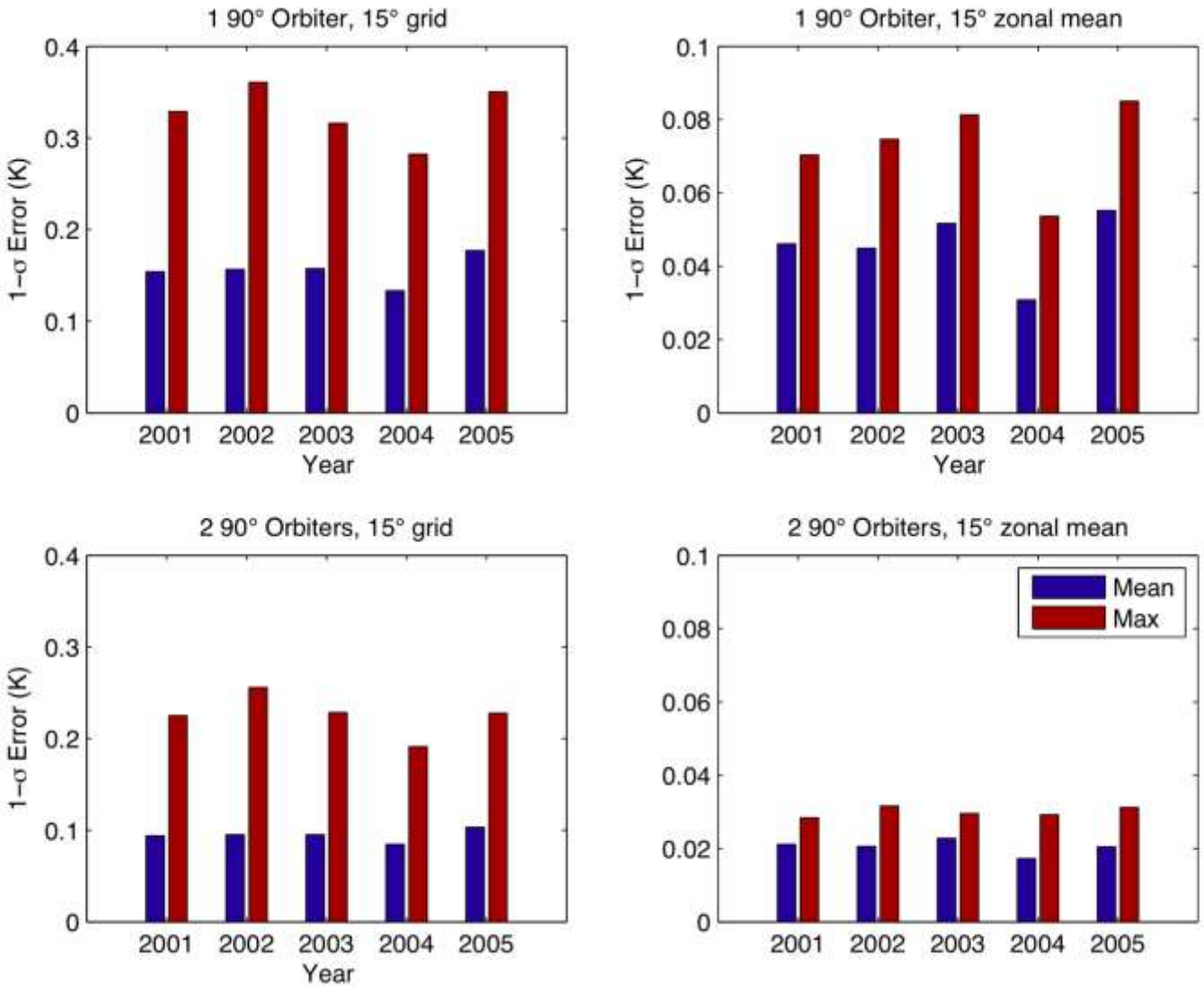


Three Orbiters
(errors in K)

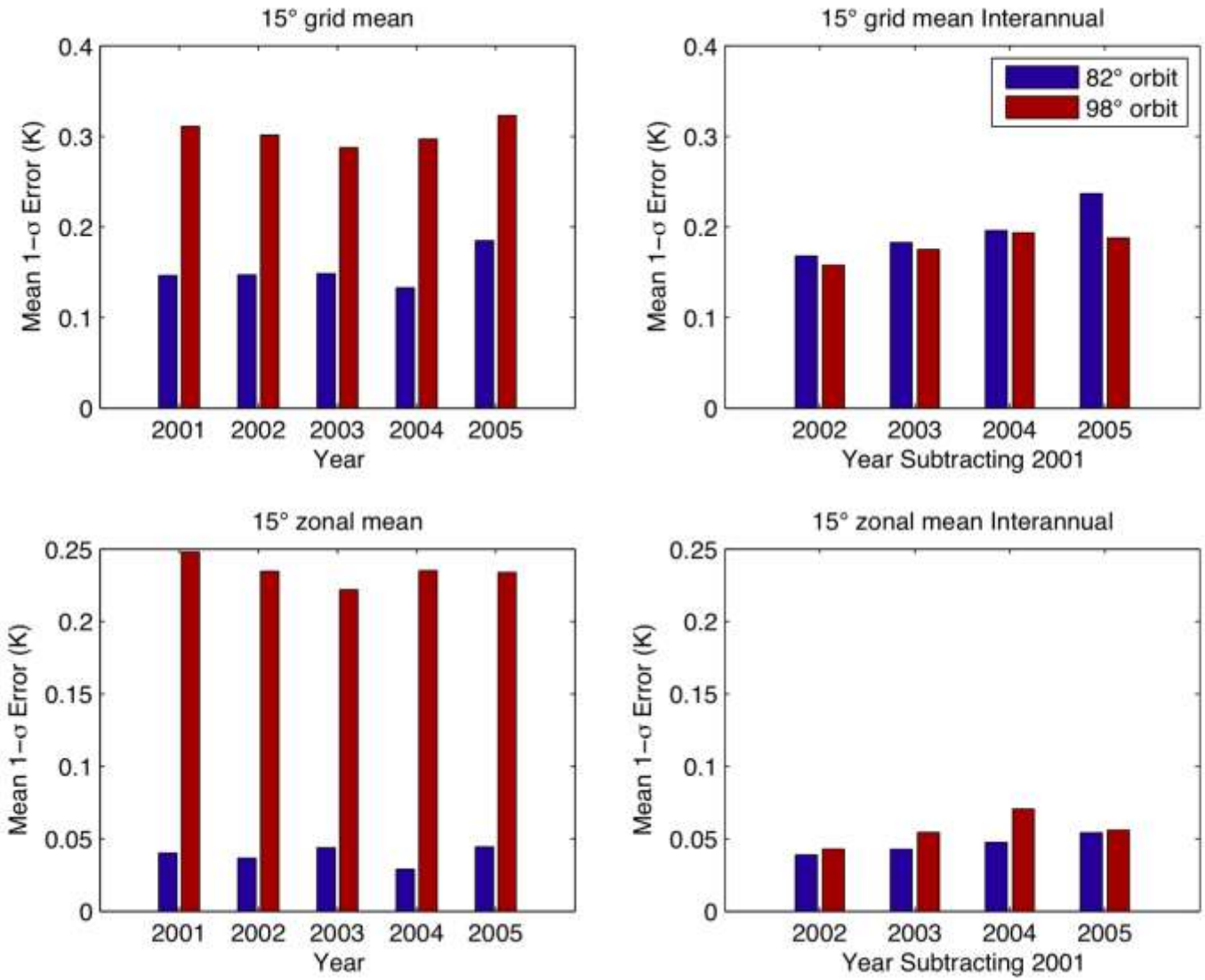




Ratio of 1-sigma error in broadband brightness temperature to interannual variability in broadband brightness temperature for the years 2001-2005 for one (top row) or two (bottom row) 90° orbiters (left column) or 82° orbiters (right column) separated by 90° in longitude



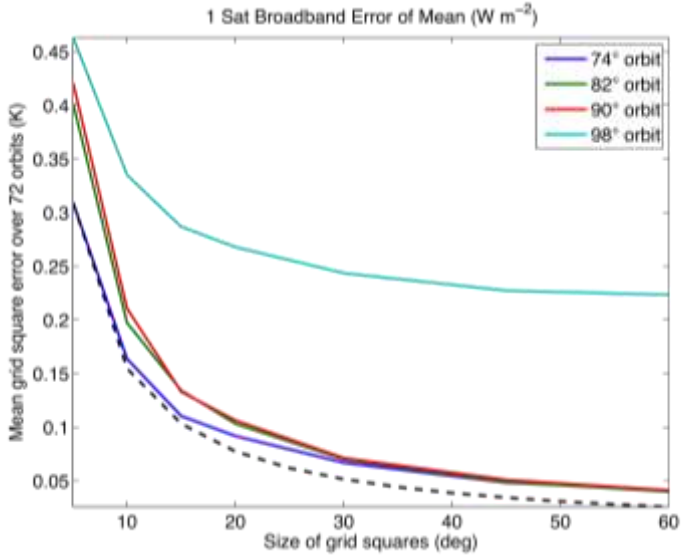
Comparison of annual mean errors for 15° grid squares and 15° zonal means over five years (2001-2005), and one or two 90° inclination orbiters. Red bars show maximum over all grid points or zonal bands, blue bars show means over all grid points or all zonal mean bands.



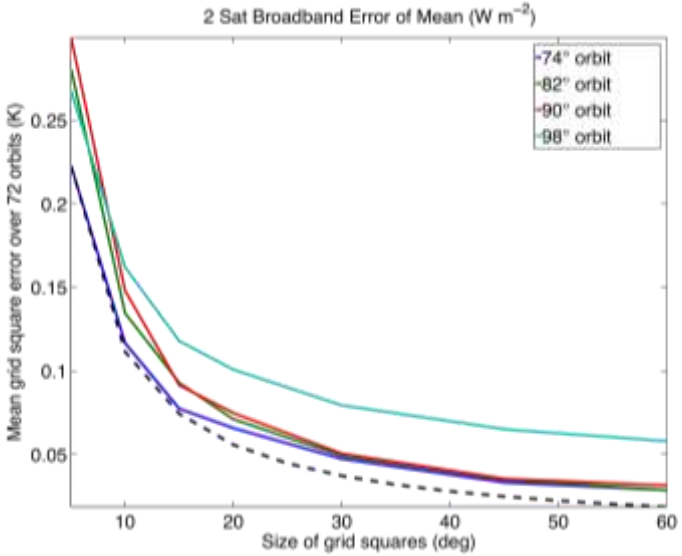
Comparison on 82 precessing orbit and 98 sun-synchronous orbit for 15° grid space errors and 15° zonal mean errors. Annual mean errors are in the left two plots. In the right two plots are errors in the difference between the annual mean for the indicated year and the annual mean for the year 2001

Averages of grid point errors

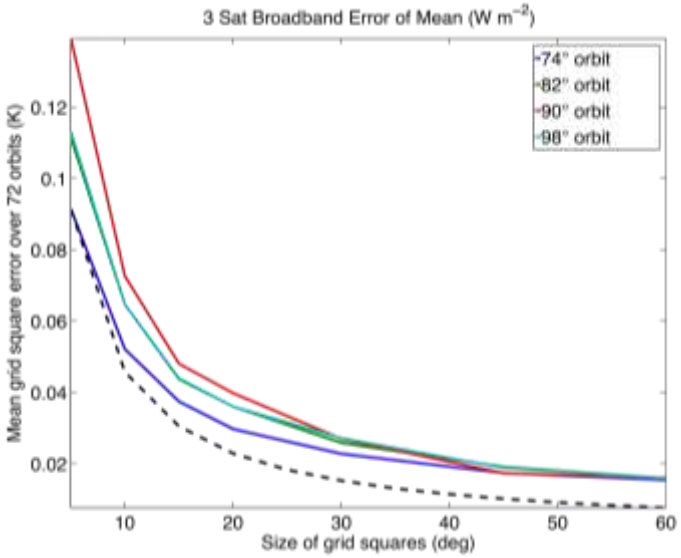
Single satellite errors



Two satellite errors



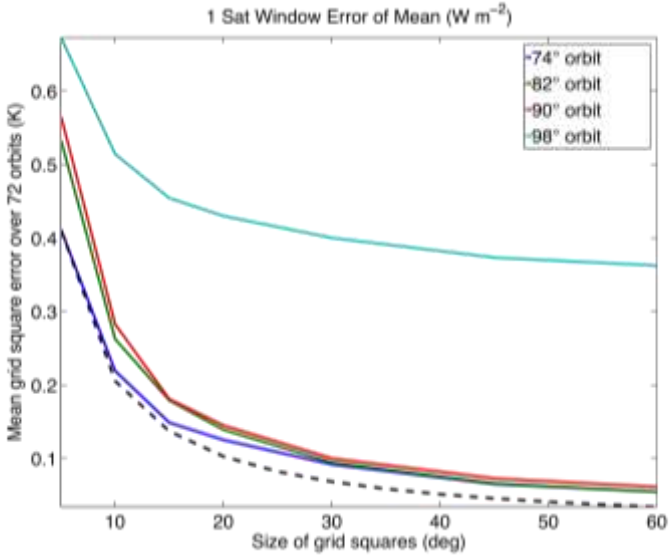
Three satellite errors



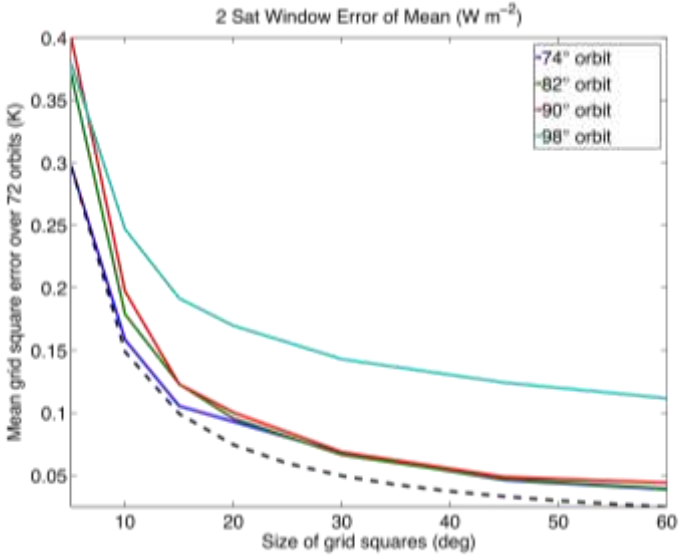
Broadband Channel

Averages of grid point errors

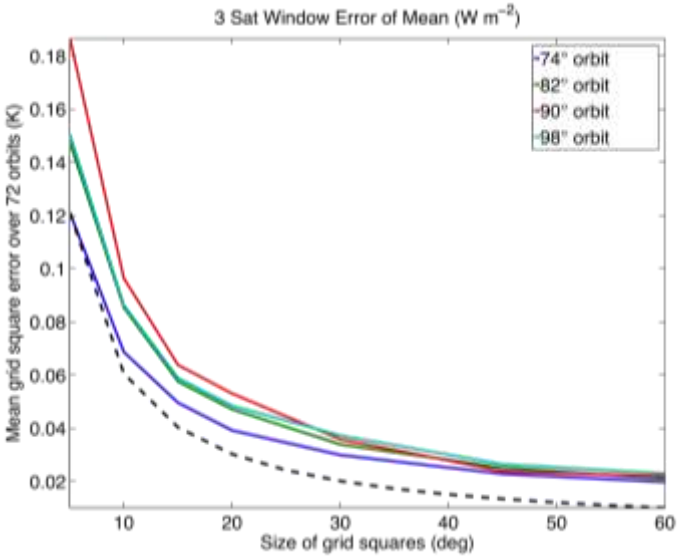
Single satellite errors



Two satellite errors



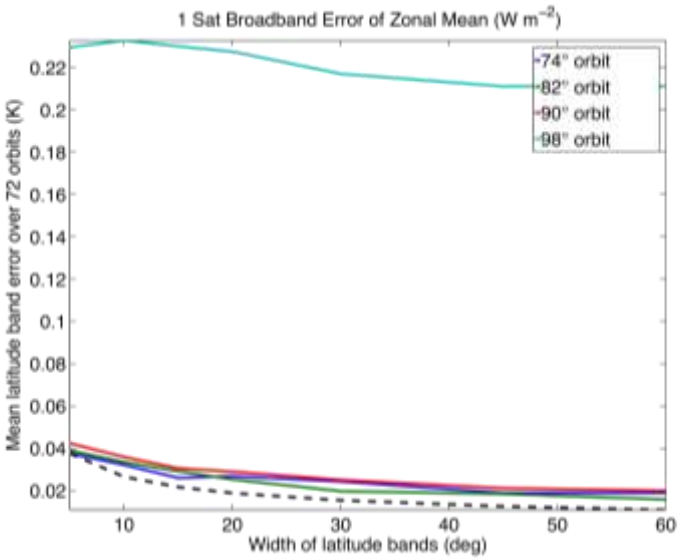
Three satellite errors



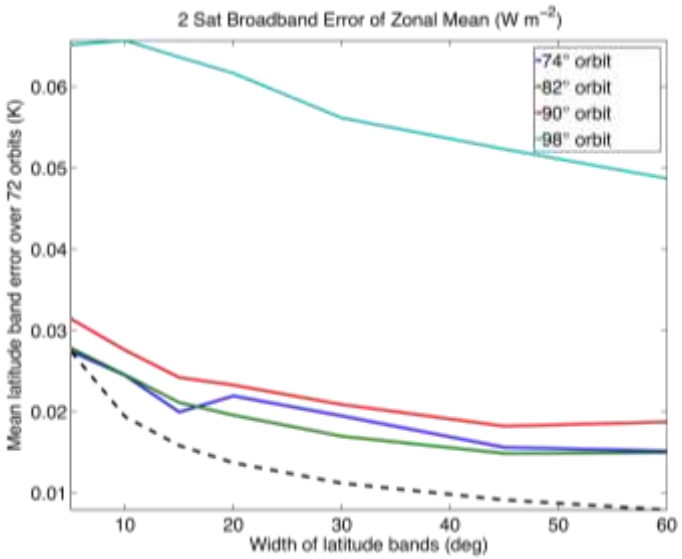
Window Channel

Averages of zonal mean errors

Single satellite errors



Two satellite errors



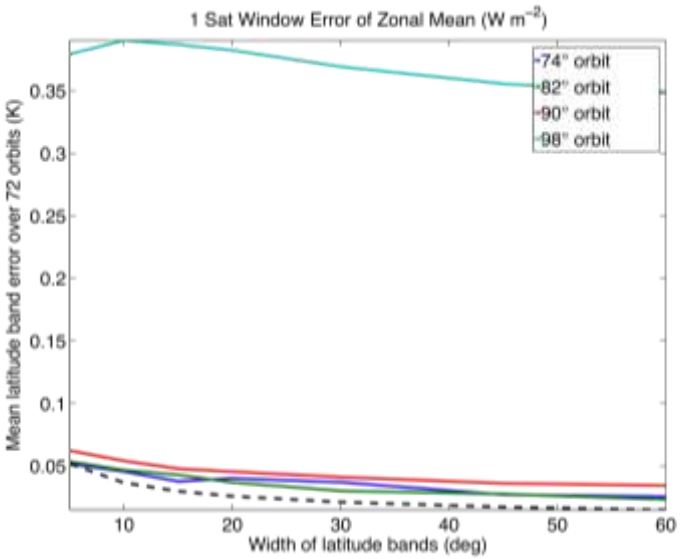
Three satellite errors

At 15 degree width:
74: <0.02 K
82: <0.02 K
90: <0.02 K
98: = 0.02 K

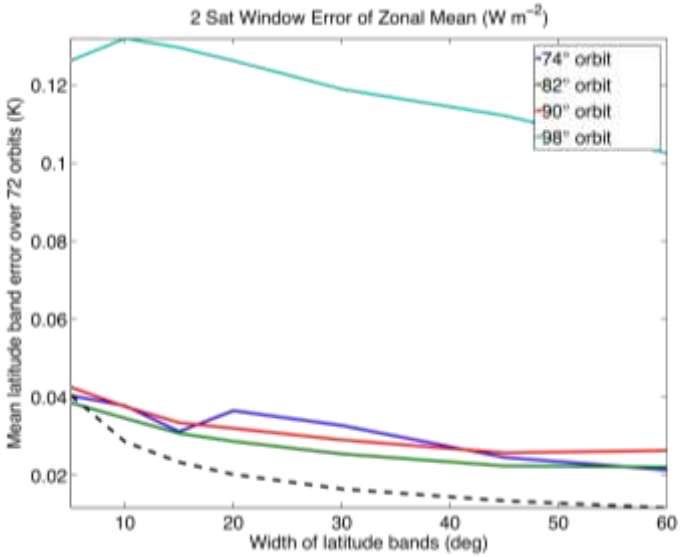
Broadband Channel

Averages of zonal mean errors

Single satellite errors



Two satellite errors



Three satellite errors

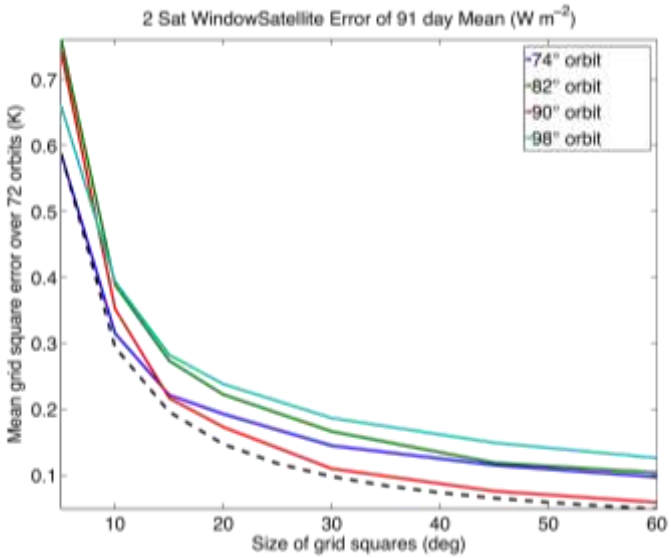
At 15 degree width:
74: 0.02 K
82: 0.02 K
90: 0.02 K
98: 0.03 K

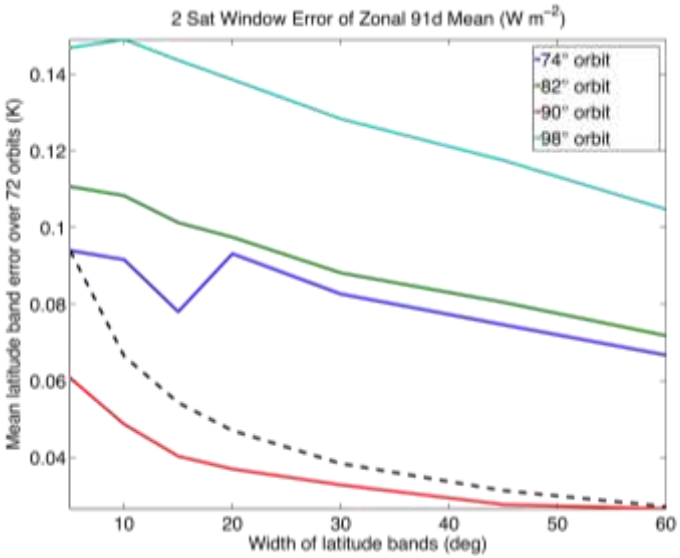
Window Channel

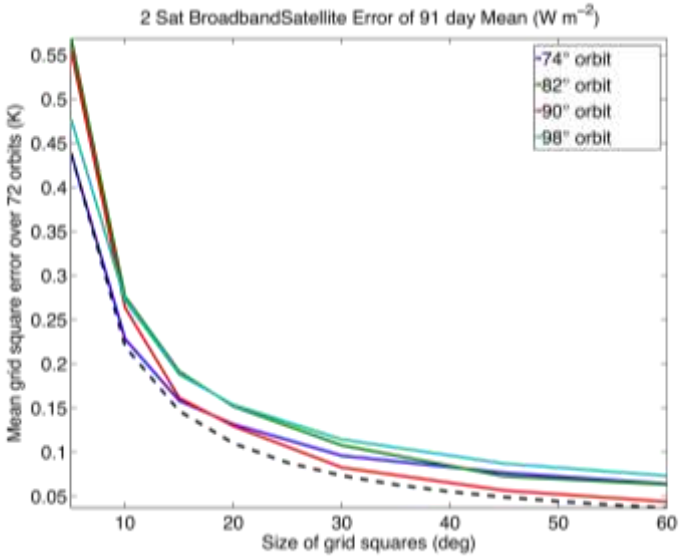
Errors for 3 month average, two satellites

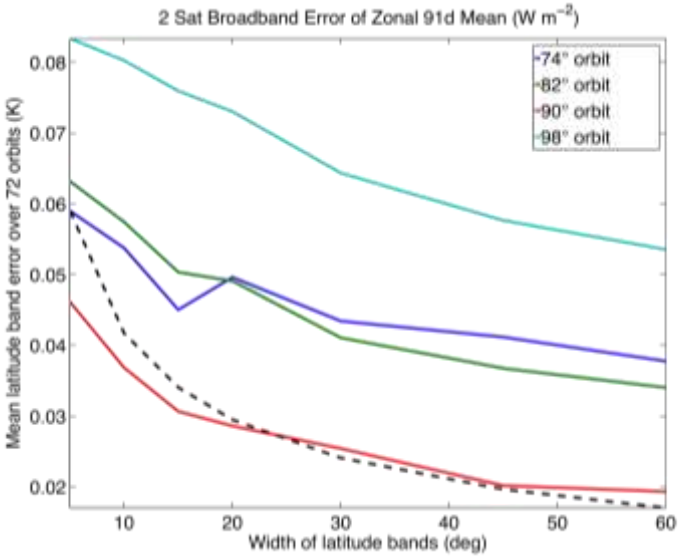
Mean Gridpoint errors

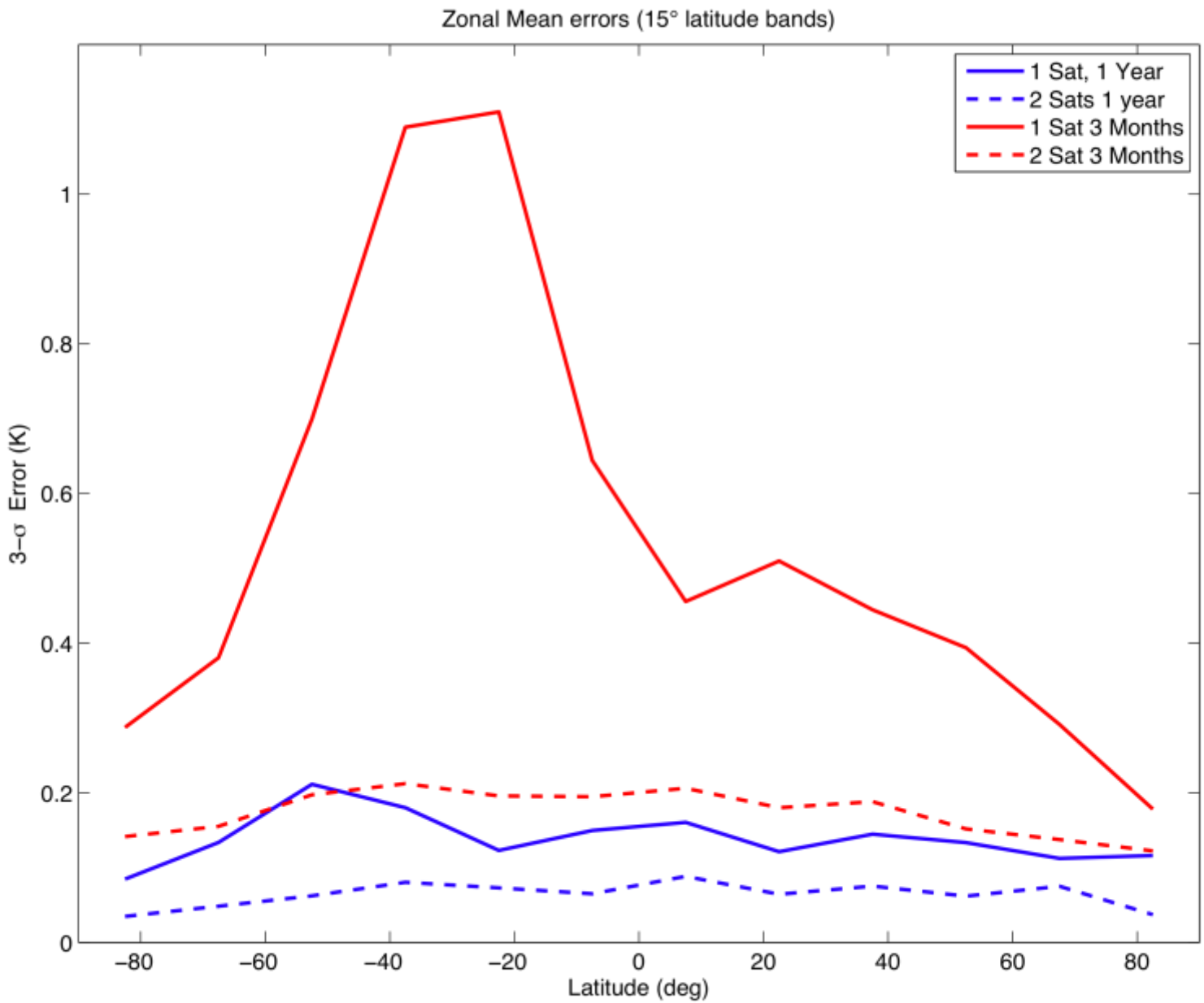
Zonal mean errors

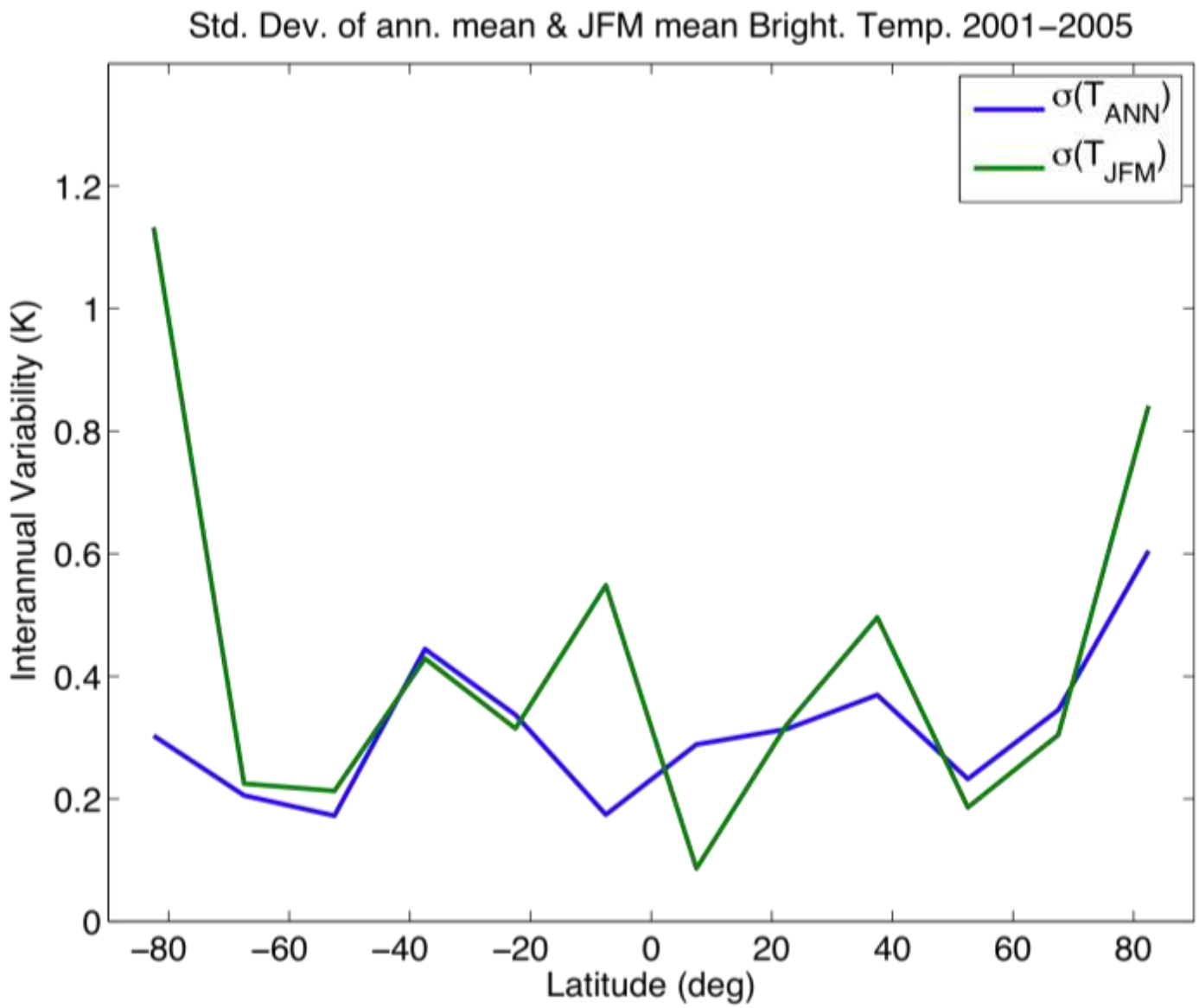









Zonal Mean errors (15° latitude bands)
1 Sat, 1 Year
2 Sats 1 year
1 Sat 3 Months
2 Sat 3 Months
3−σ Error (K)
Latitude (deg)
0
0.2
0.4
0.6
0.8
1
−80
−60
−40
−20
0
20
40
60
80

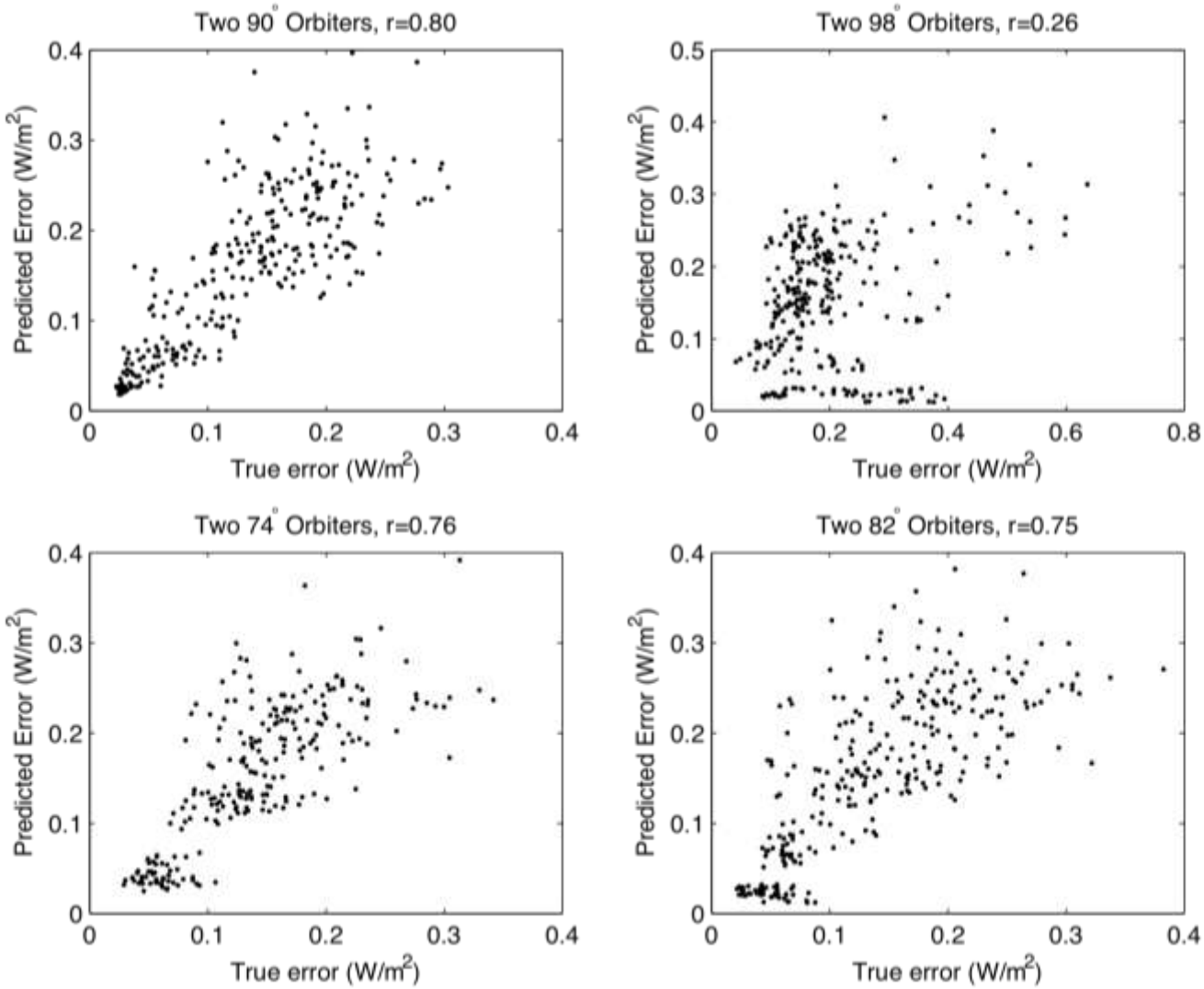

Std. Dev. of ann. mean & JFM mean Bright. Temp. 2001–2005
σ(T_ANN)
σ(T_JFM)
Interannual Variability (K)
Latitude (deg)
0
0.2
0.4
0.6
0.8
1
1.2
−80
−60
−40
−20
0
20
40
60
80

Predicting errors taking into account both seasonal and aperiodic variability.

$$e = \frac{\sigma}{\left(n \frac{(1-\rho_1)}{(1+\rho_1)} \frac{(1+\rho_2)}{(1-\rho_2)} \right)^{1/2}}$$

where *e* is the grid point error, σ is the standard deviation of observations in the grid point, *n* is the number of observations in each grid point, ρ_1 is the average lag-one temporal autocorrelation along the scan track for each overpass of the grid square, and ρ_2 is the lag-one autocorrelation of the time series of grid square averages for each overpass. The first fraction adjusts *n* for the independence of the data, while the second adjusts σ for the lack of randomness of seasonally varying radiances.

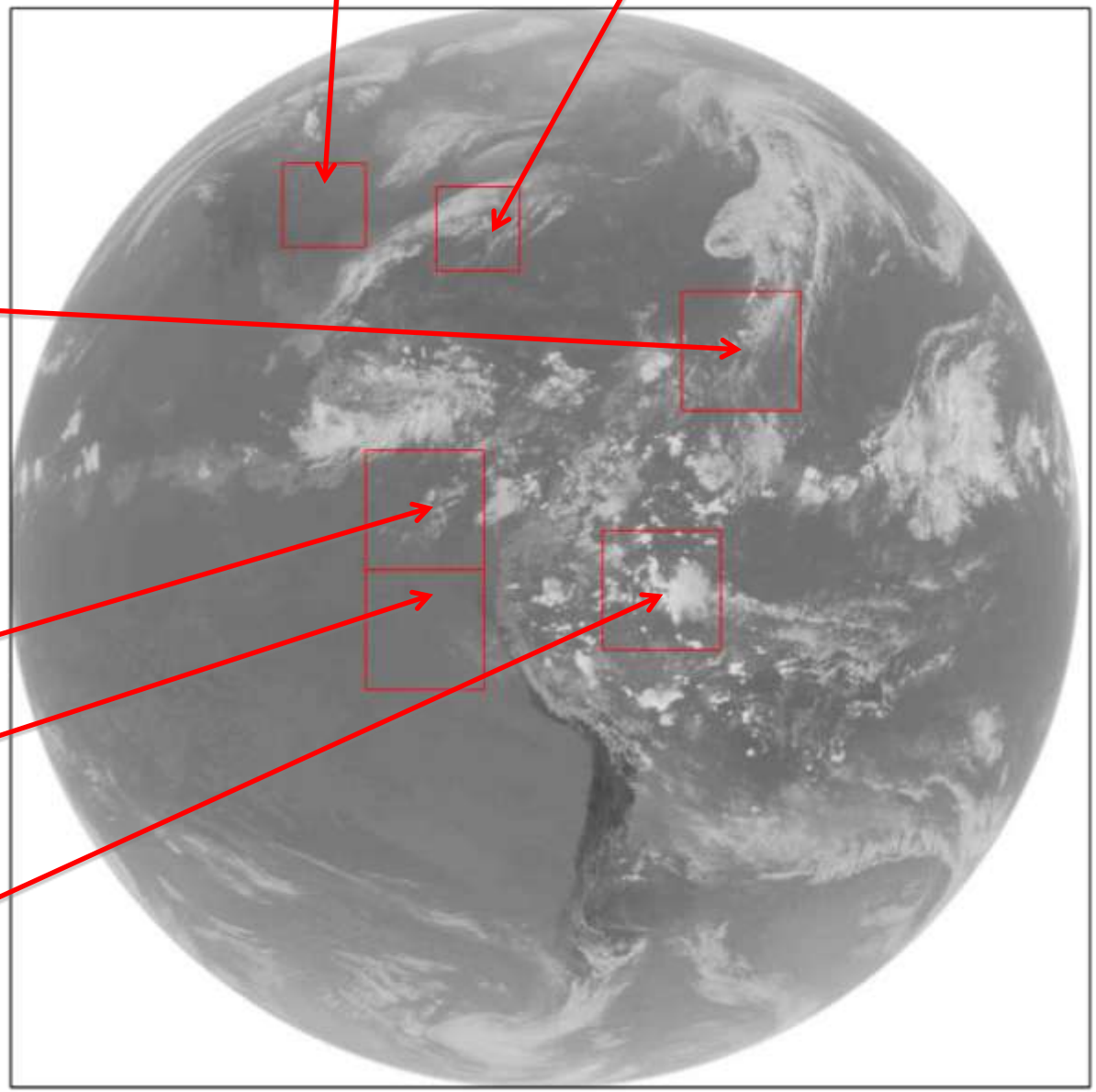
Here are results for four pairs of orbiters. Note the underprediction of error for the sunsynchronous orbiters, due to diurnal sampling bias.



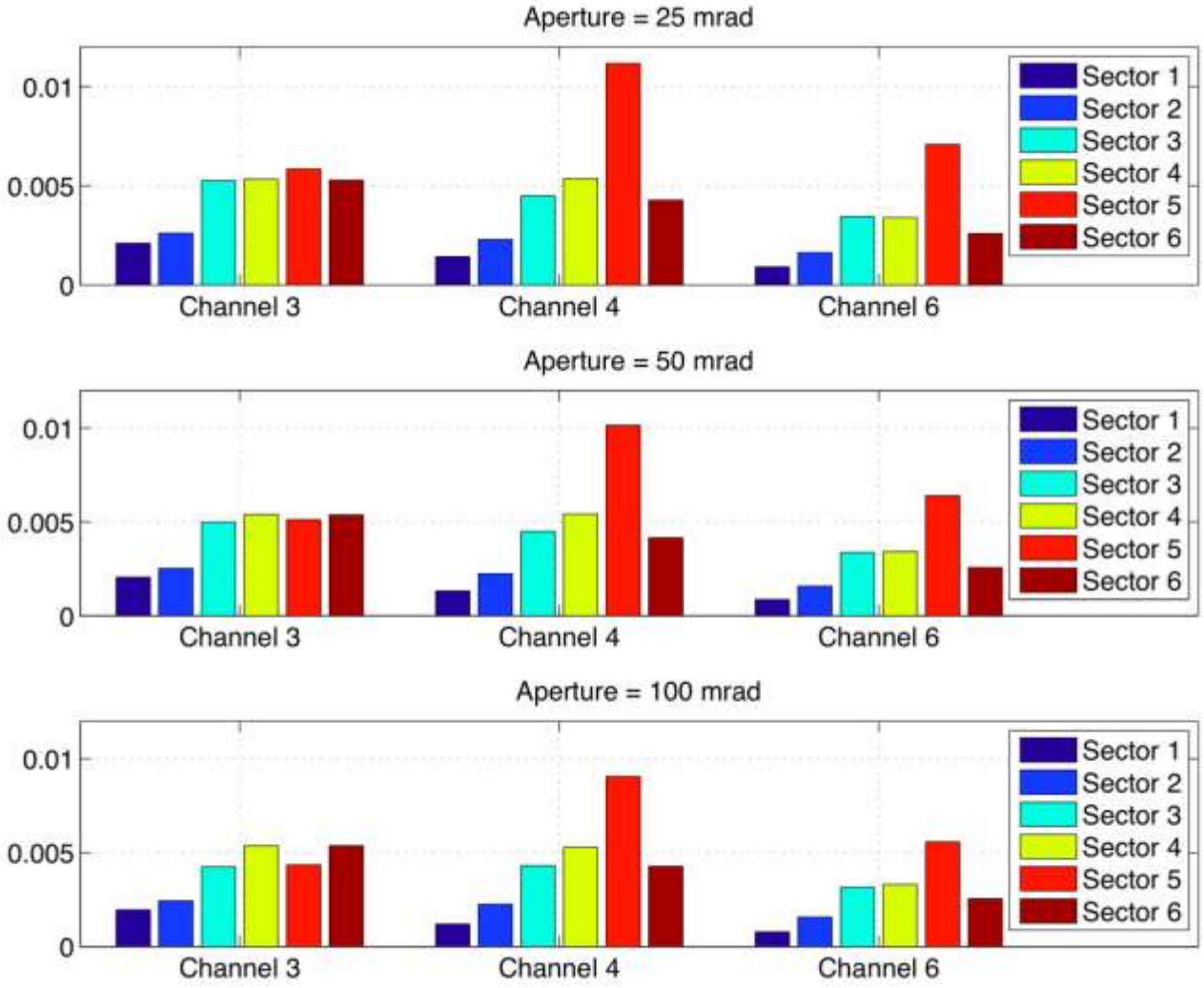
A check on random errors

Do our proxy data accurately reflect the real variability that a CLARREO orbiter would see?

We select six representative 15° x 15° regions within which to test the sensitivity of CLARREO sampling errors to the frequency and footprint of observations.



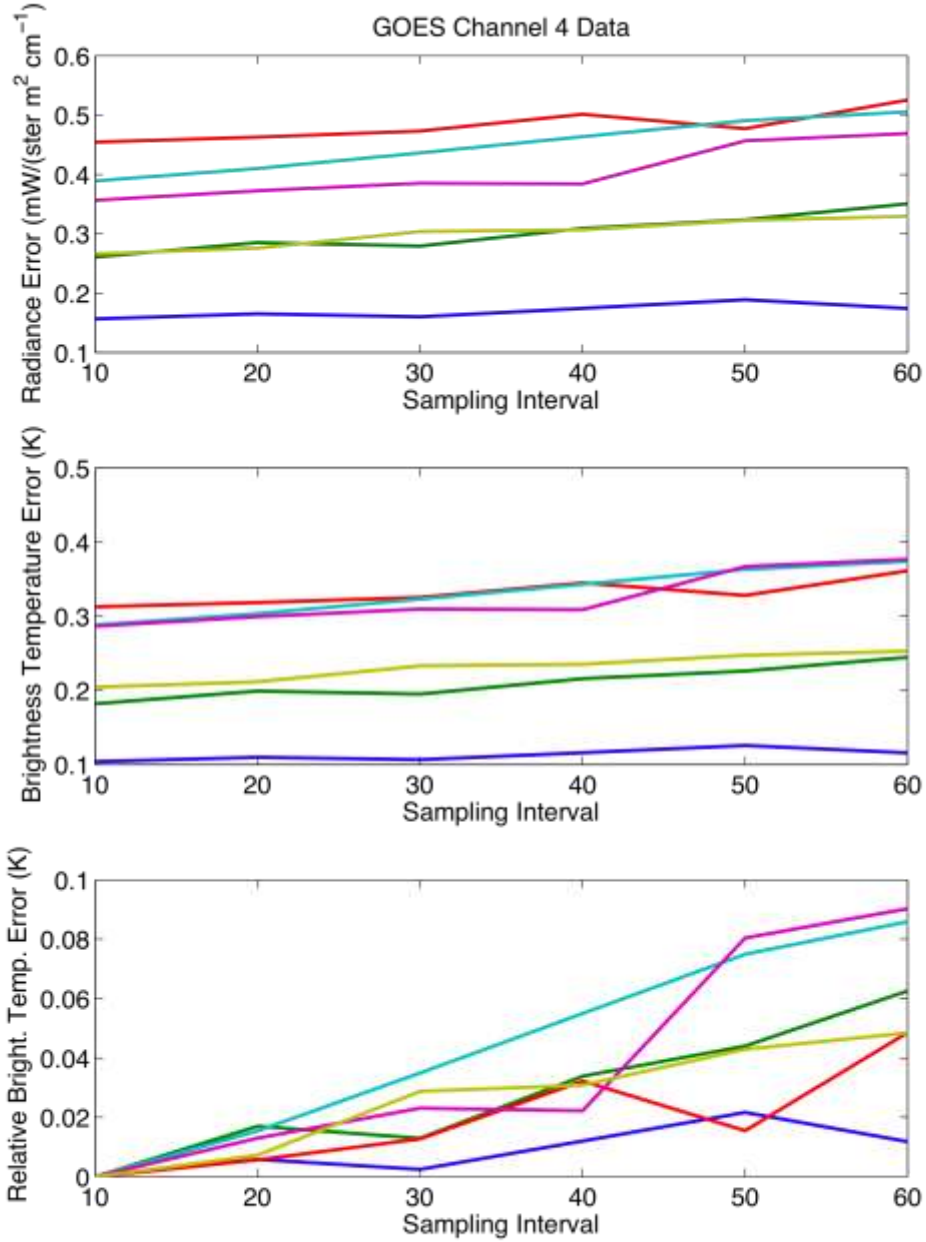
Footprint dependence of Sampling Errors



Over a range of a factor of 16 in sampled area size, the maximum increase in error for smaller footprint size is only 30%, and the usual increase is much smaller. High autocorrelation makes small footprint sizes feasible.

Sampling Frequency Dependence of Sampling Error

(Error shown for a single 90° precessing satellite)

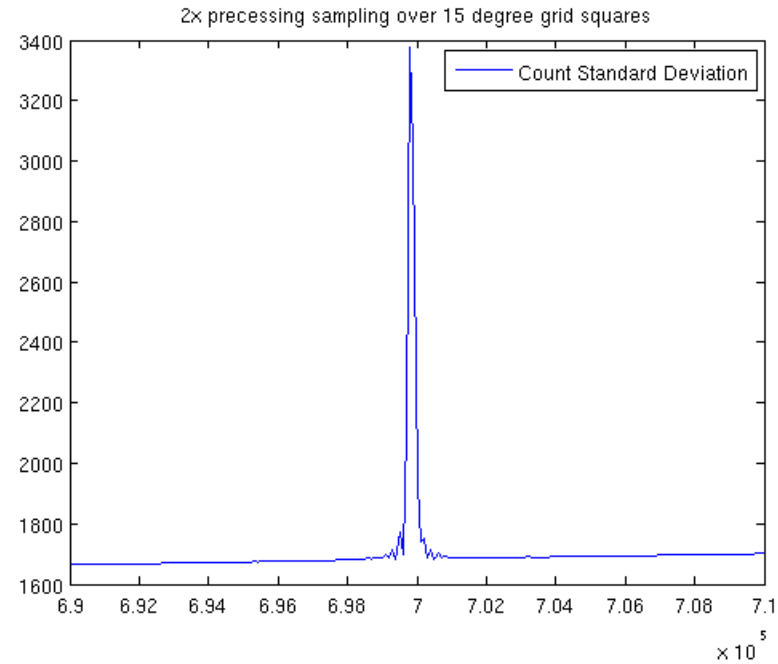


Ground track errors

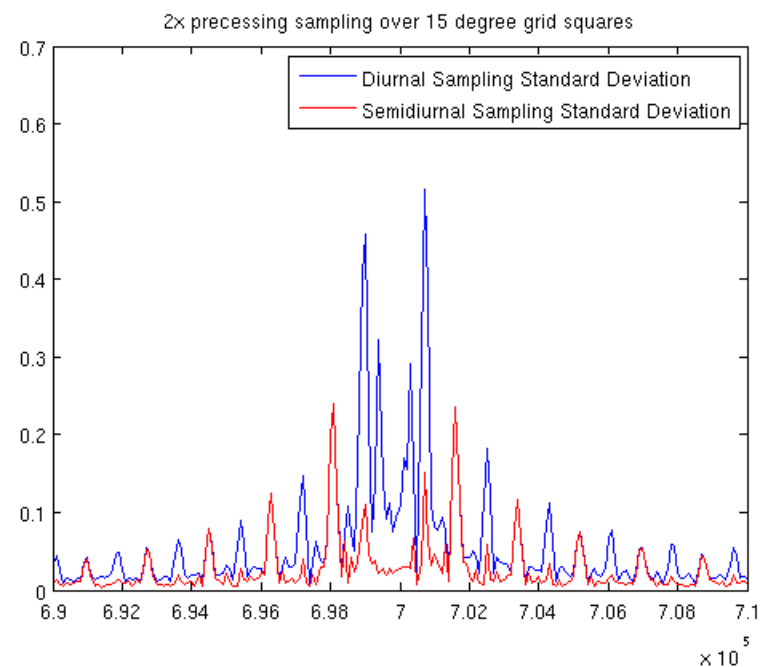
Sampling bias can be caused by ground track repeat cycles and their interaction with the diurnal and seasonal cycles. Figure *a* shows the standard deviation of observation numbers among 15 degree grid squares as a function of orbit altitude. For each altitude, the orbit inclination is adjusted so that the orbit precesses twice per year (approximately 82°).

In Figure *b* the standard deviation of the mean hour of the half-day over all 15° grid squares is shown in blue. That is, for each satellite observation, the local time in hours, modulo 12 is noted. All observations are averaged over each grid square; due to correlations between the orbit ground track repeat cycle and the diurnal cycle, this number is not the same in each grid square. The same phenomenon occurs for the seasonal cycle; shown in red is the standard deviation over all 15° grid squares of the mean day of the year of observations, modulo 182.5.

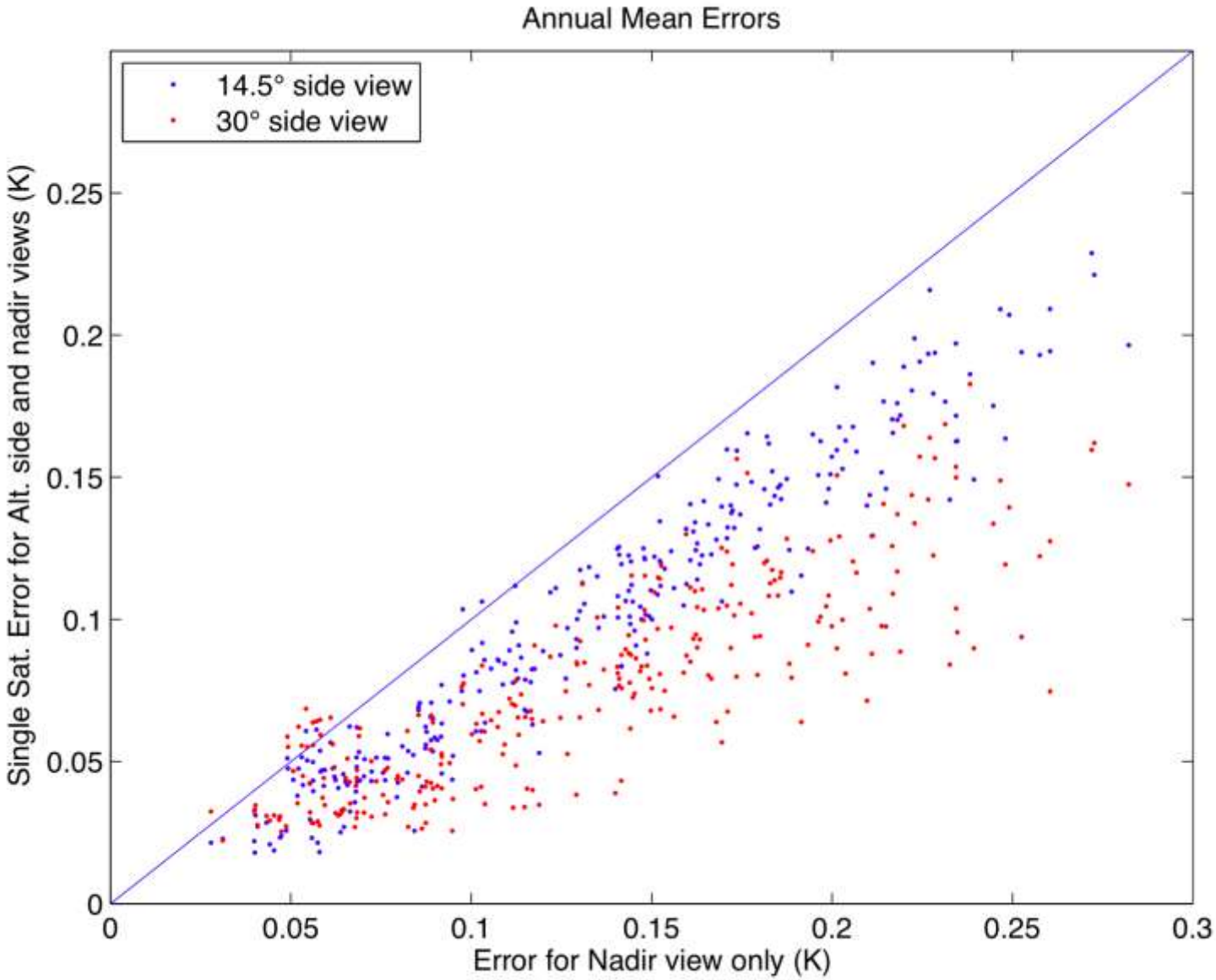
a



b



Can sampling errors be reduced by side views?



Yes.

Conclusions

Highly accurate sampling of annual or three month mean brightness temperature (relative to interannual variability and decadal trends) is possible for a suite of two nadir-viewing satellites.

Autocorrelation of weather noise makes feasible relatively small footprint sizes and sampling frequencies. It also means that side viewing, where feasible, is attractive, since it allows sampling of data that are uncorrelated with nadir data. However, the introduction of bias due to view angle must then be addressed.