Interannual Variability of Earth Radiation

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in the beginning...

On October 5, 1984, Challenger returned to flight with its launch at 7:03 am EDT, marking the start of the STS 41-G mission. It was Challenger's sixth mission and the 13th liftoff in the Space Shuttle program.

Nine hours after liftoff, the 5,087-lb. Earth Radiation Budget Satellite (ERBS) was deployed from the payload bay by the RMS arm, and its on-board thrusters boosted it into an orbit 350 miles above the Earth. ERBS was the first of three planned satellites designed to measure the amount of energy received from the Sun and reradiated into space. It also studied the seasonal movement of energy from the tropics to the polar regions.

from NASA archives, STS 41-G Mission Summary

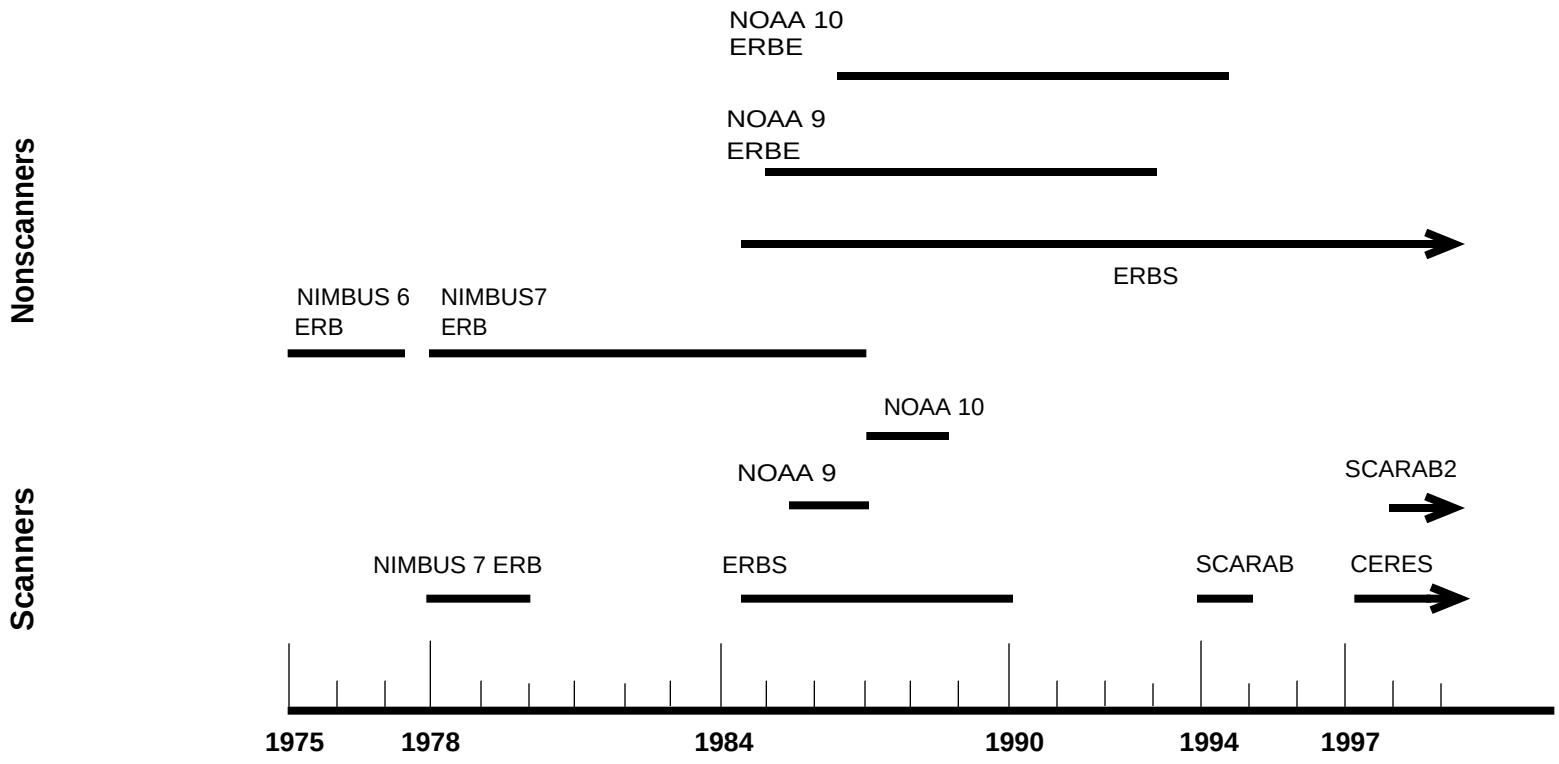
Historical Perspective

- Interannual variations of climate have a great impact on mankind, and an understanding of these which would lead to skill in forecasting these changes would be extremely valuable.
  --*Barkstrom and Smith, 1986*

- The ERBE ... monthly average radiation budget components on regional, zonal, and global scales ... will constitute the kind of multiple-year data set which is required for understanding interannual variability.
  --*Barkstrom and Smith, 1986*

- ... the ERBE data appear to be a new, highly calibrated source of information regarding the Earth's radiation fields. It may be hoped that the data collection will continue beyond the design life goal of two years for these instruments, so that the record of the Earth's radiation budget may continue to be studied.
  ---*ERBE Science Team, in BAMS, 1986*

Radiation Budget Data Sets



Motivation

- 15-year data set of radiative fluxes from Earth Radiation Budget Experiment (ERBE) available

- Variability of SWR and OLR is an important factor in trend detection.

- Interannual variations of OLR and SWR important as part of the mechanism governing year-to-year variations of climate.

Flux Analysis Procedure

- Monthly mean shortwave and longwave TOA fluxes for each region between 60 N and 60 S latitude for each year from ERBE 5-degree gridded S10 data product

- 172 months of flux data available (November 1984 - September 1999)

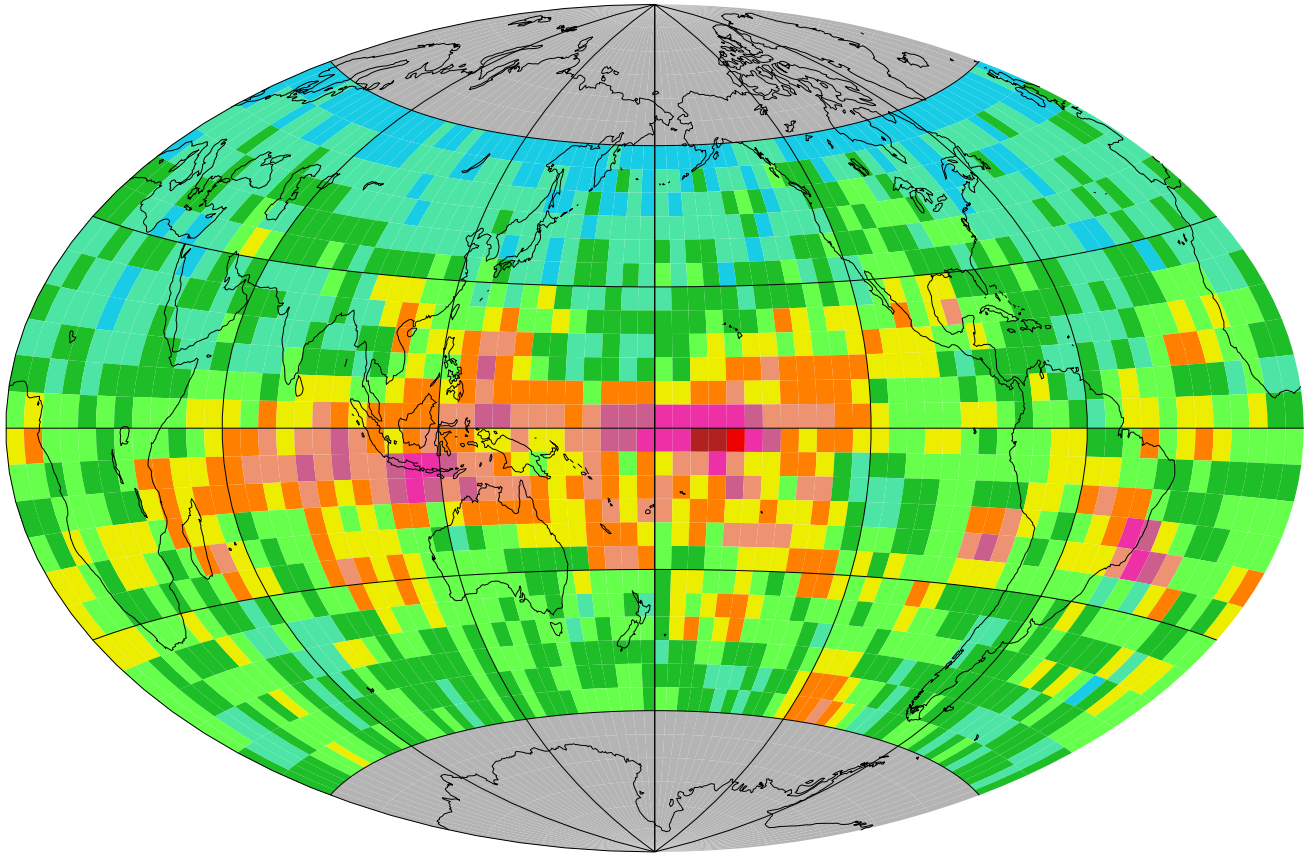
- Calculate climatological monthly mean fluxes and standard deviations for each region over all available years

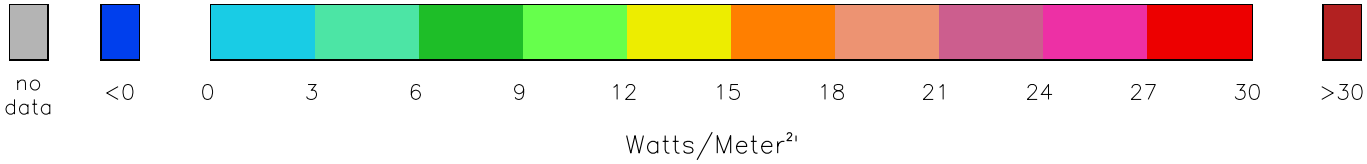
- Calculate regional monthly anomalies by subtracting climatological mean from monthly mean for each region for each data month

- Perform empirical orthogonal function (EOF) analysis on regional monthly anomalies (172 data months x 1728 regions)

ERBS Shortwave Standard Deviation

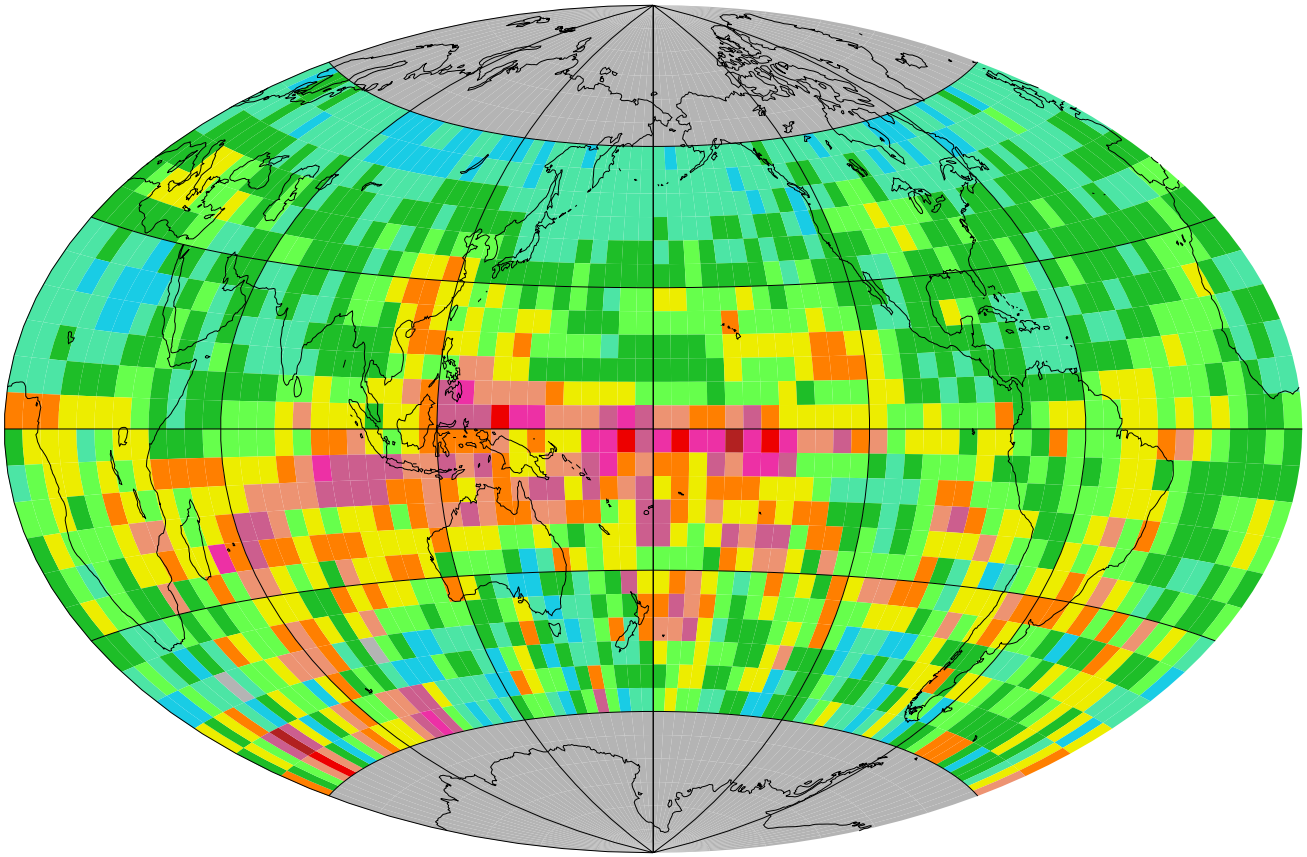
January 8411 – 9909

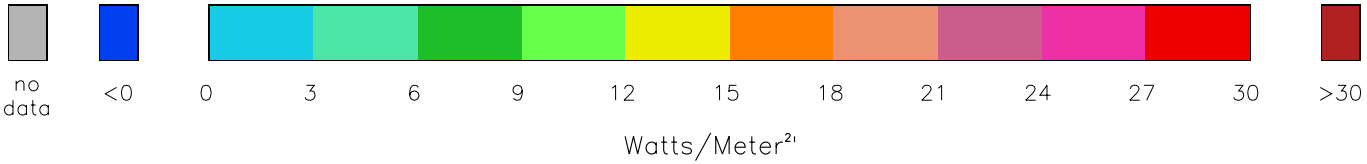




ERBS Shortwave Standard Deviation

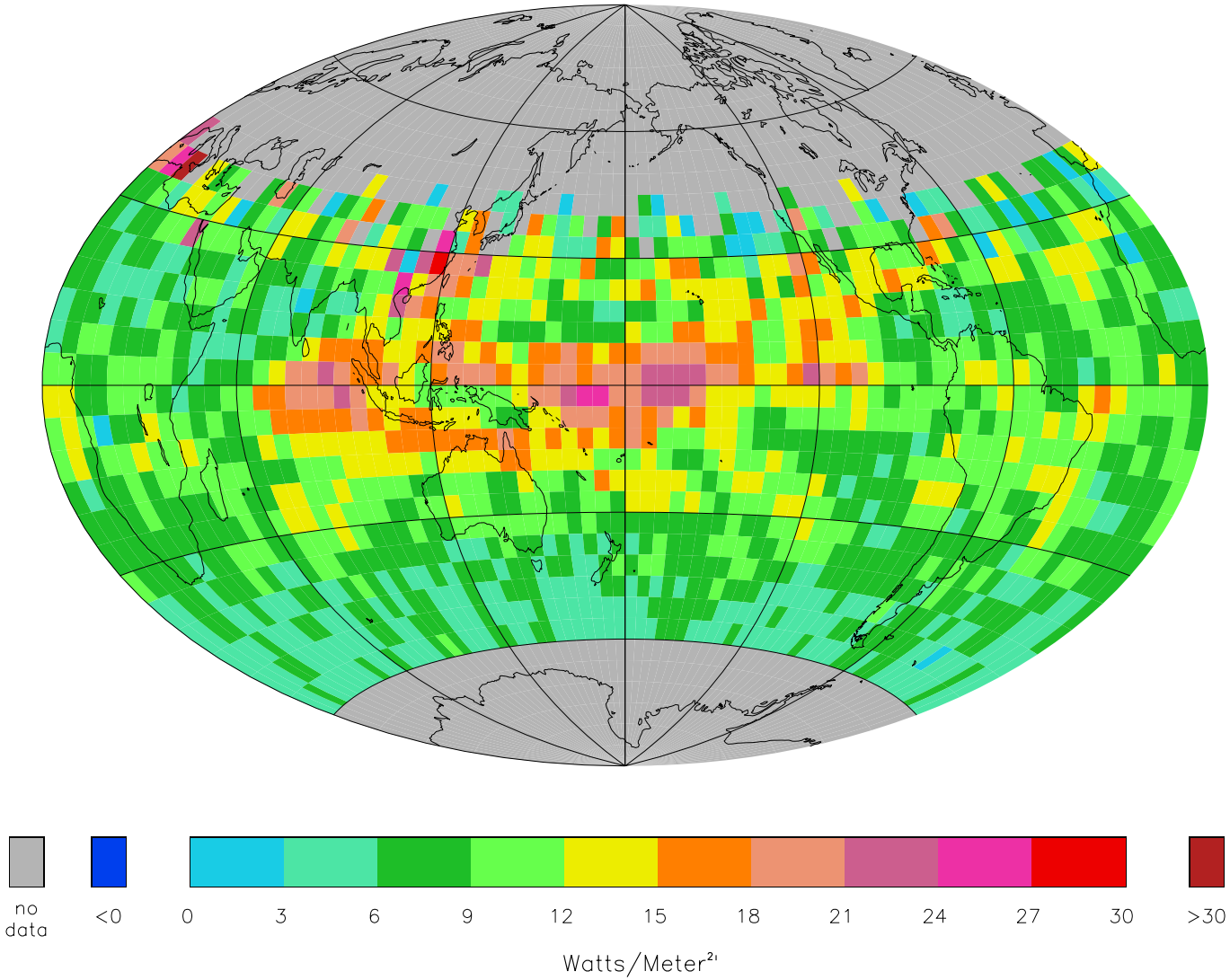
February 8411 – 9909





ERBS Shortwave Standard Deviation

March 8411 – 9909



ERBS Shortwave Standard Deviation

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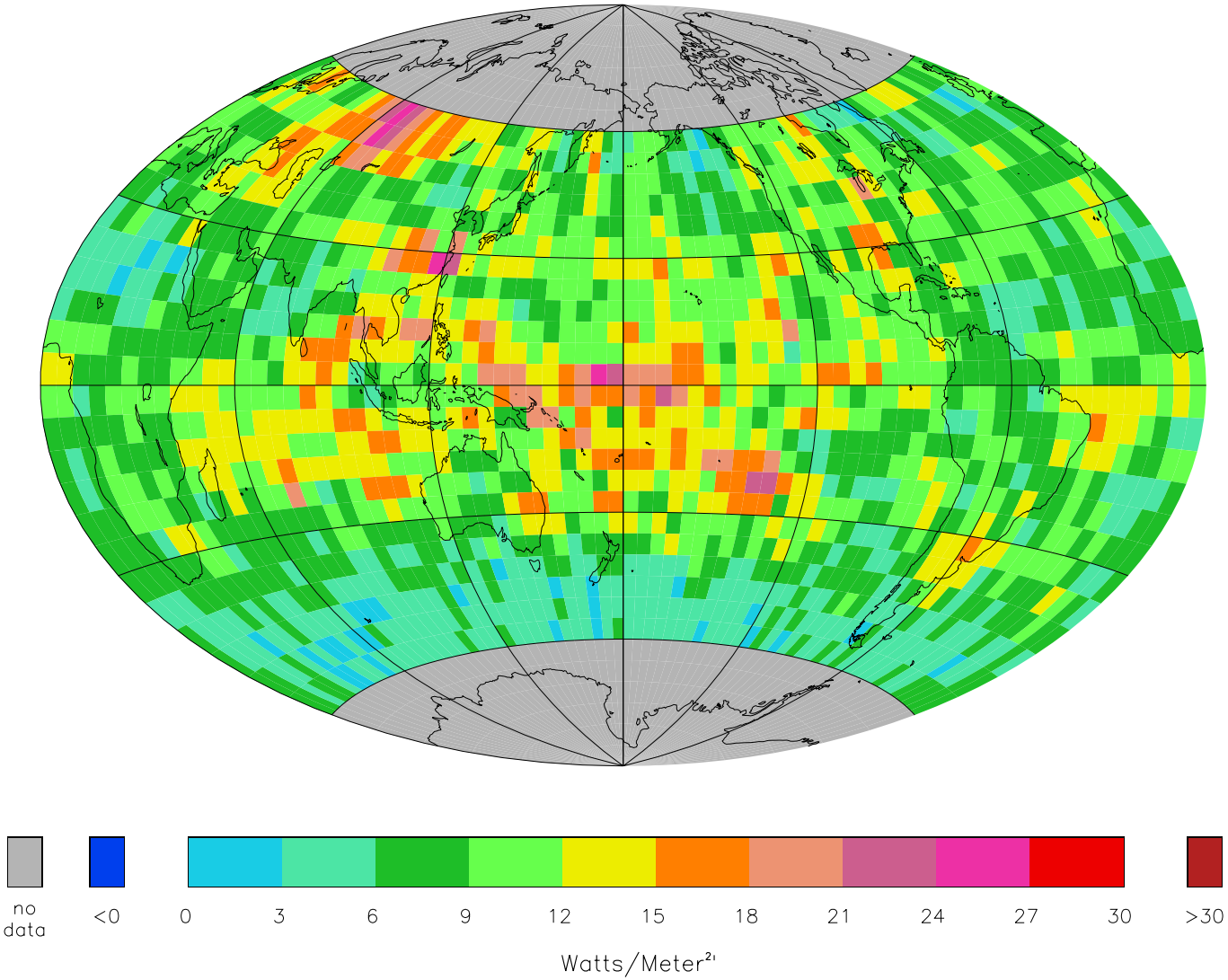

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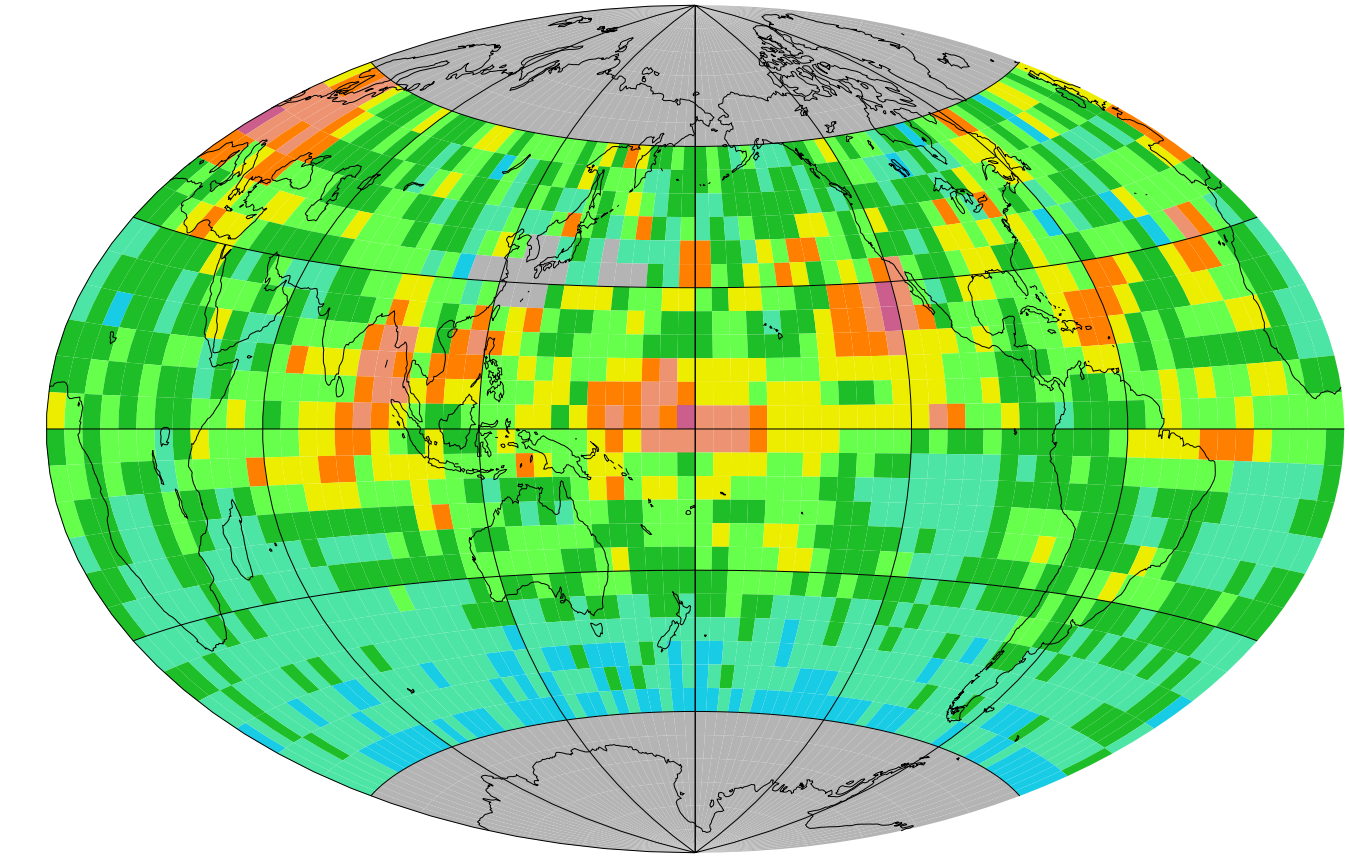

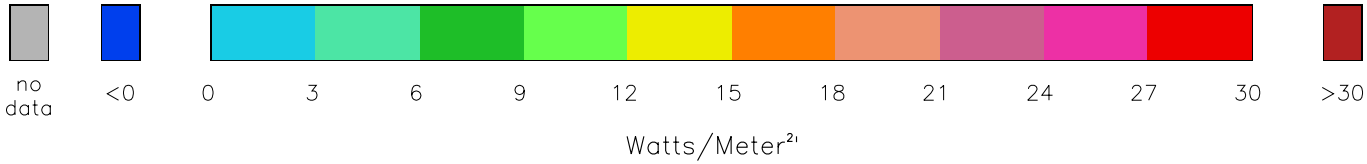

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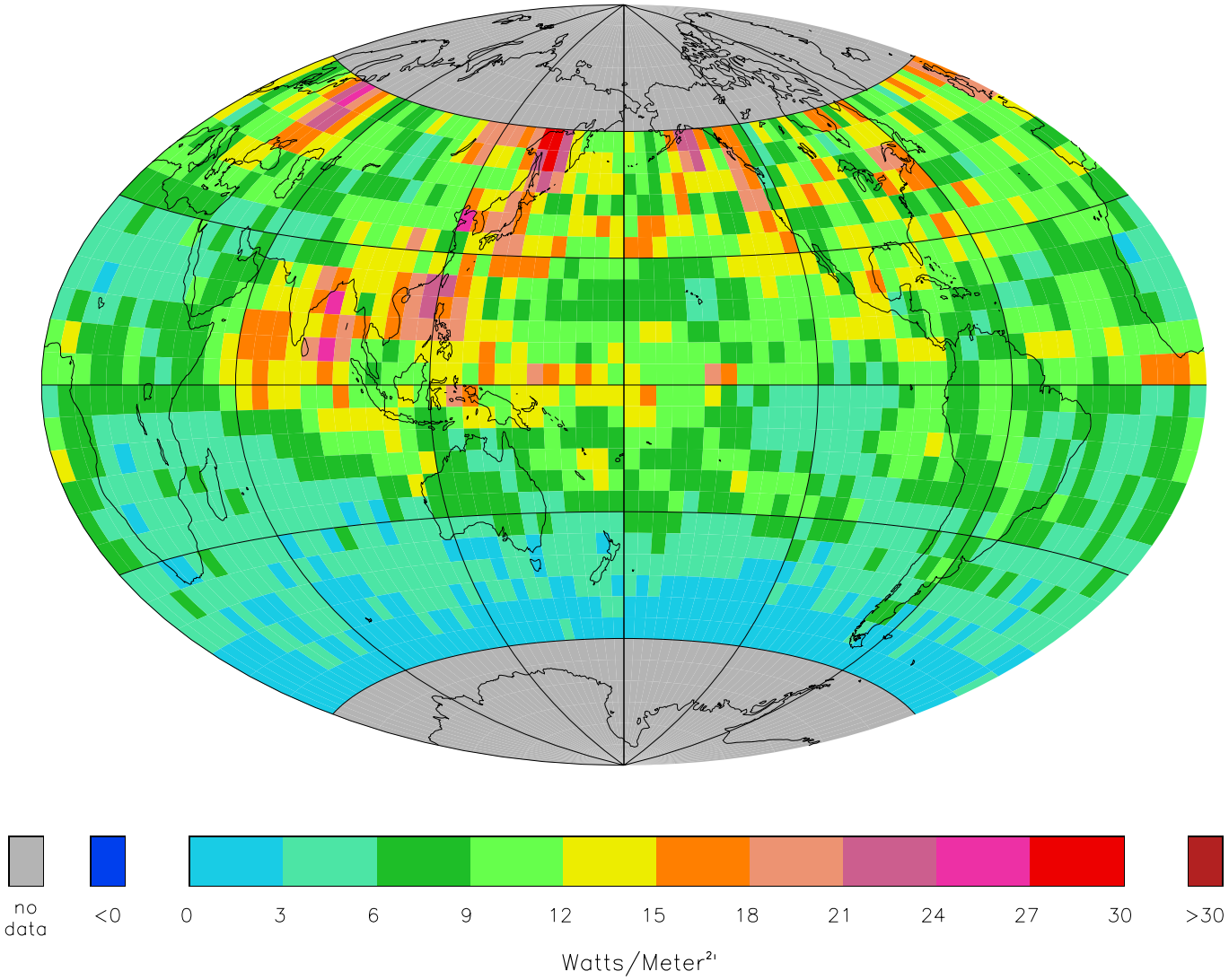

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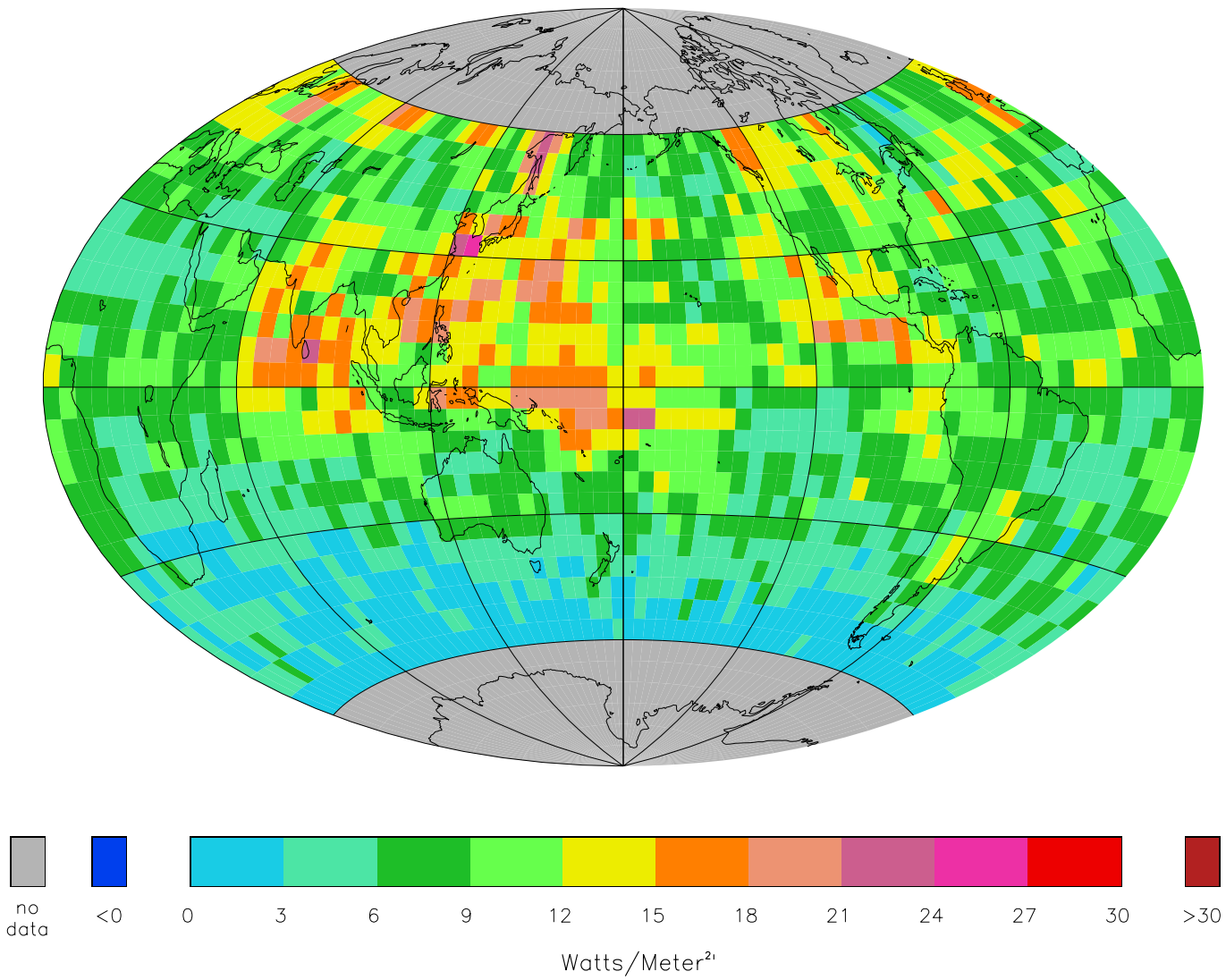

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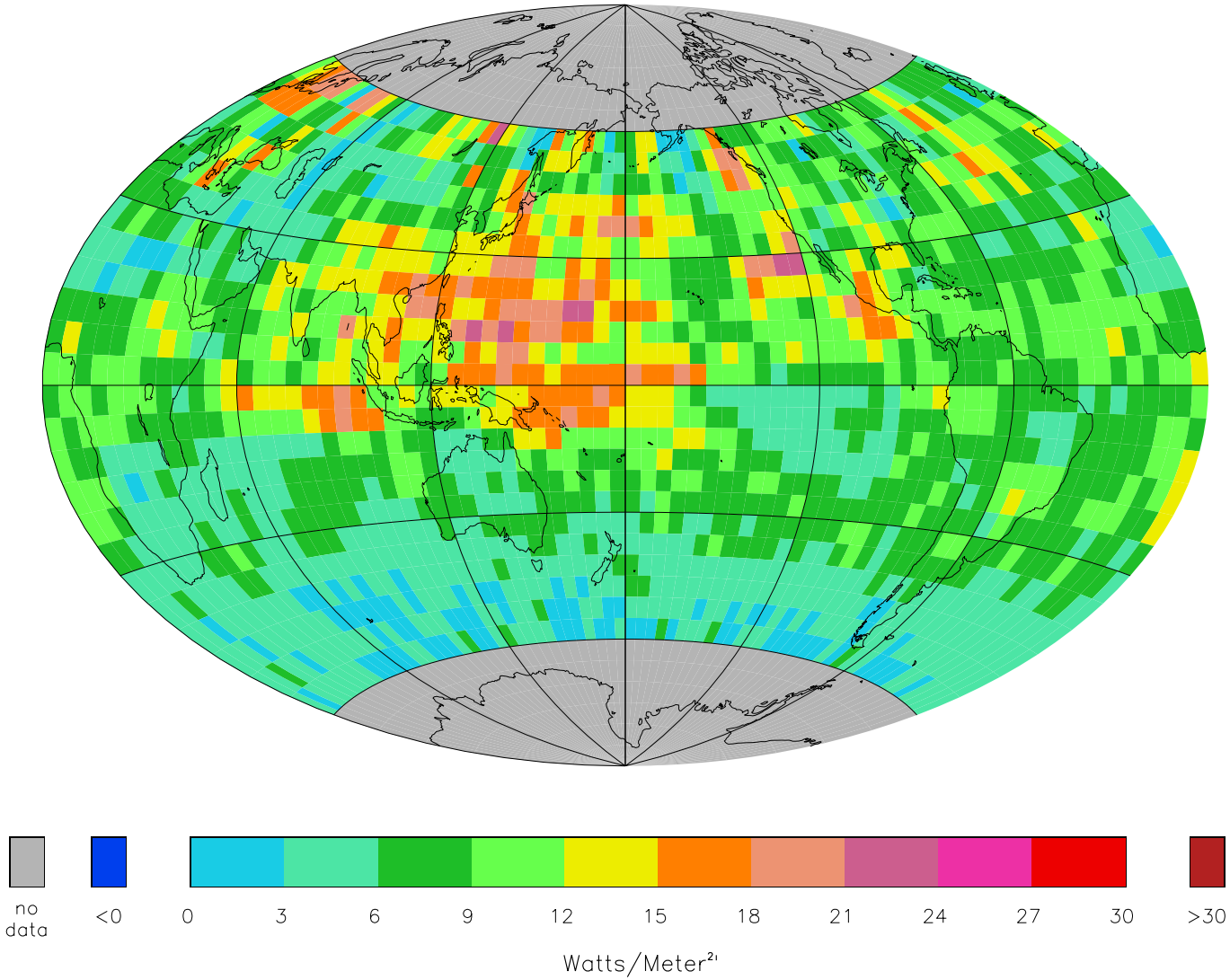

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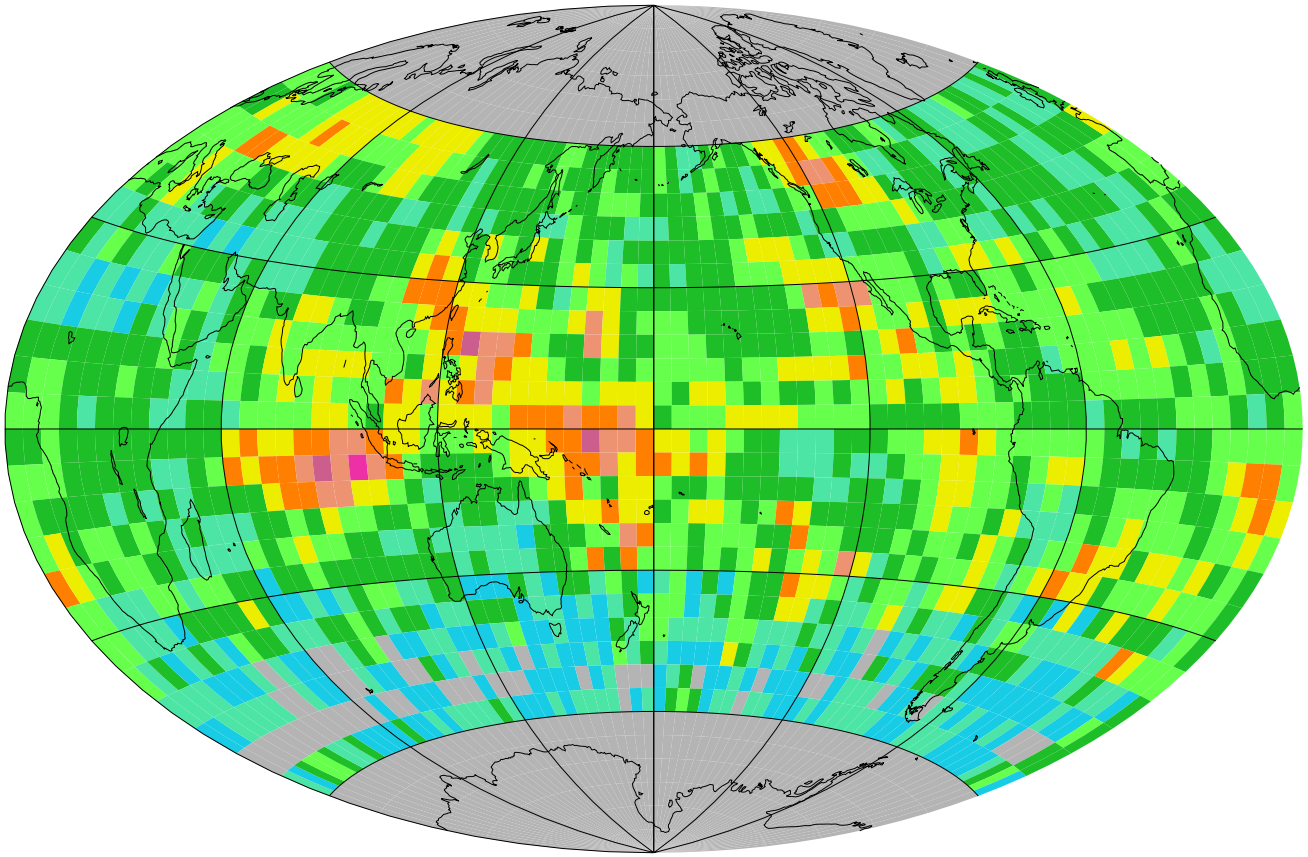

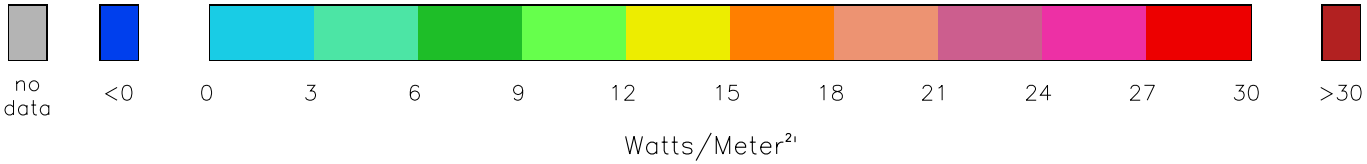

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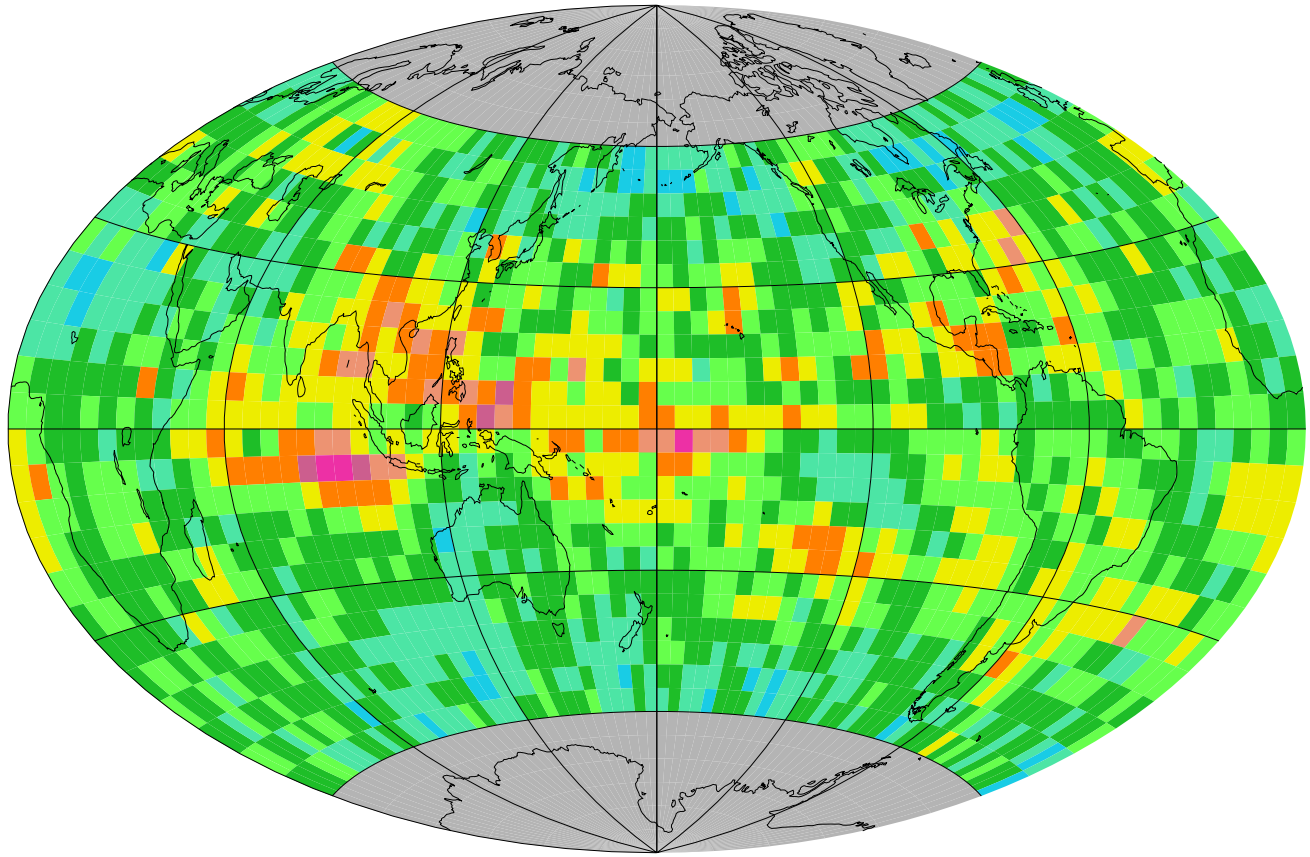

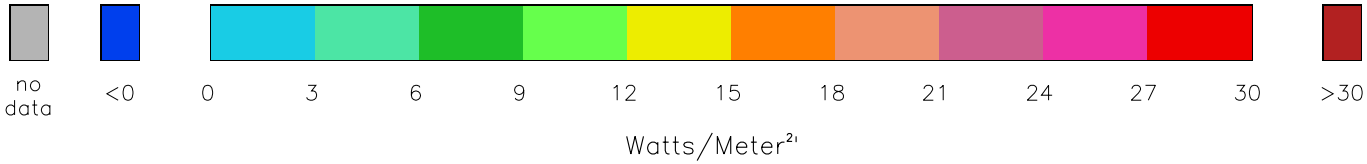

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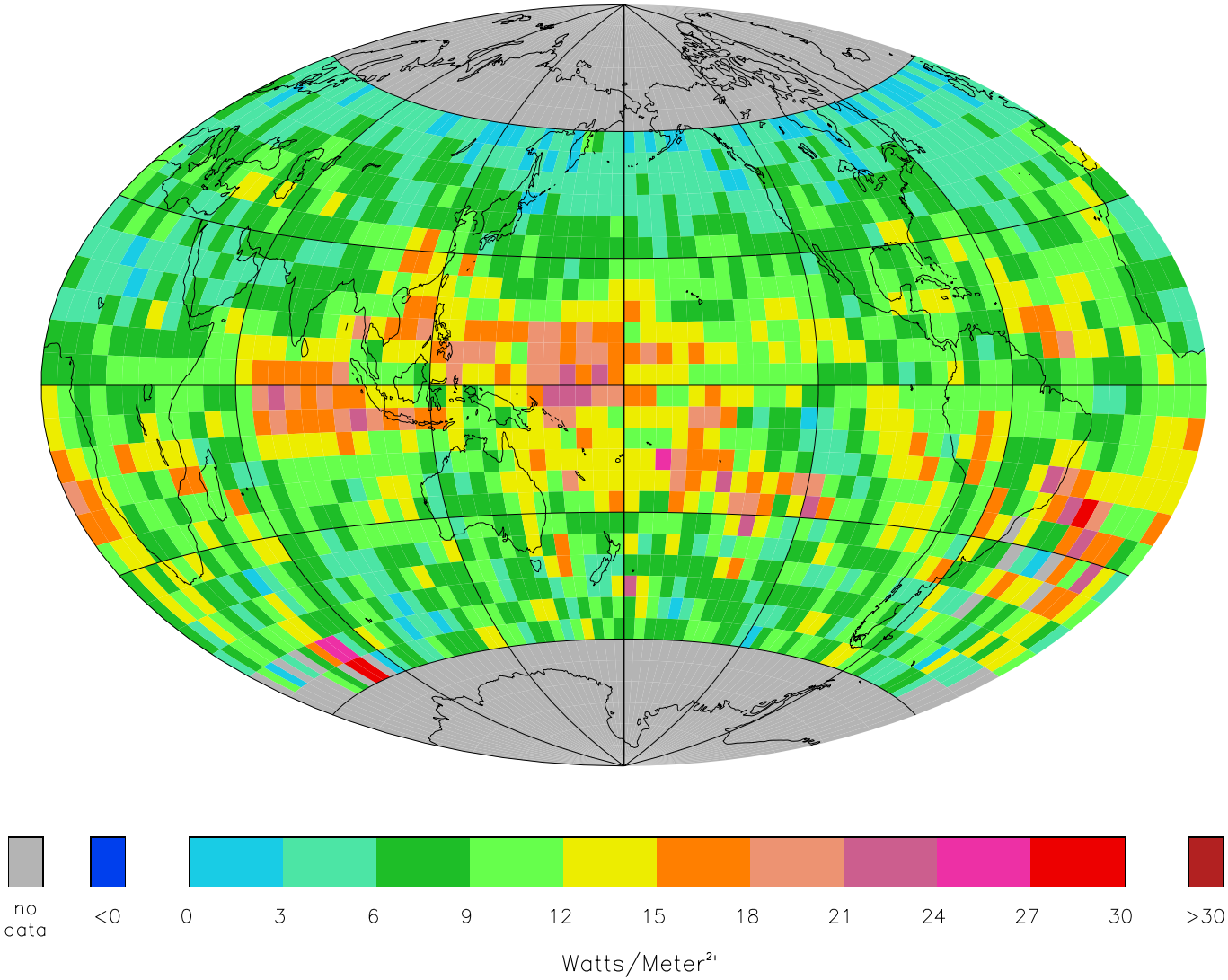

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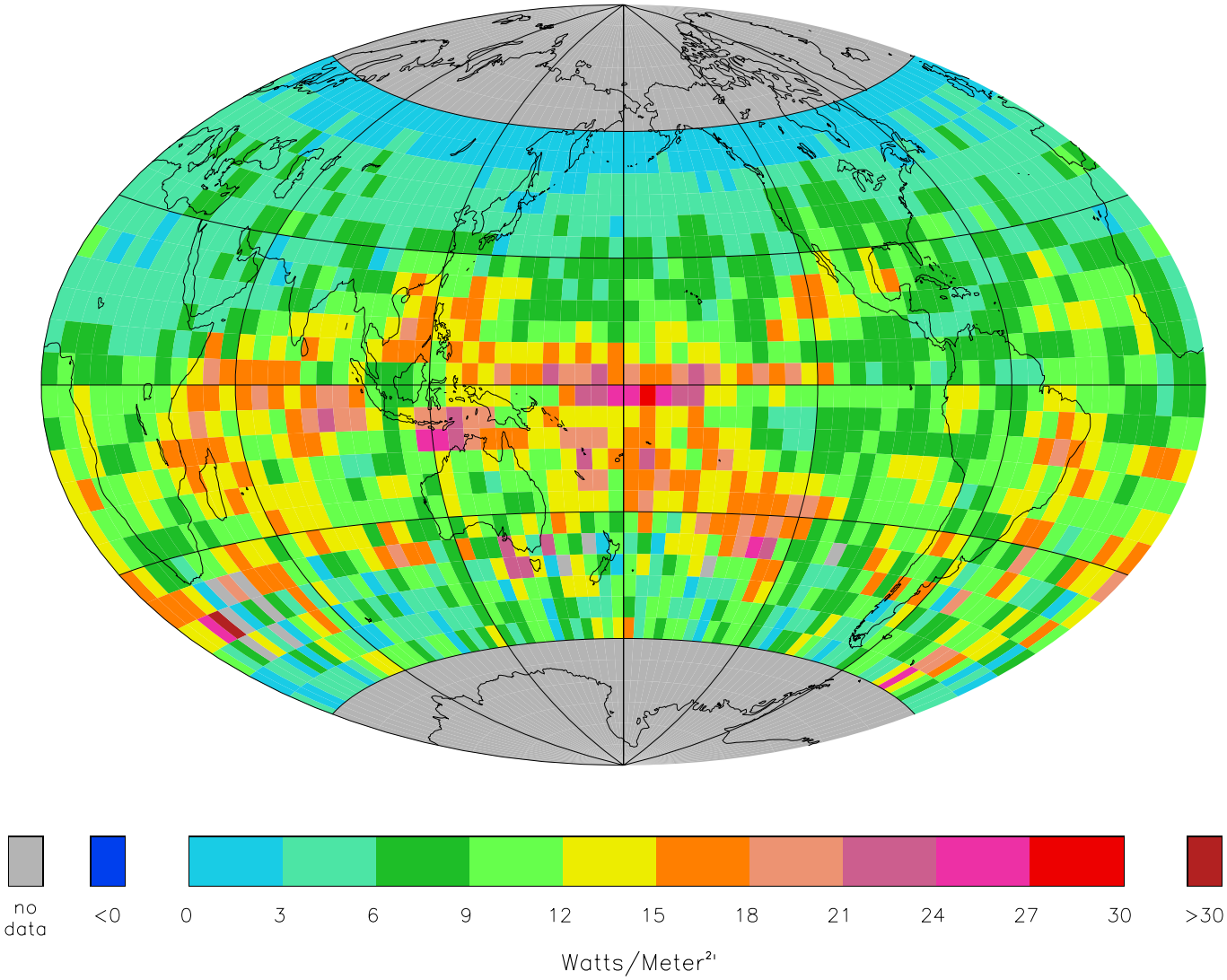
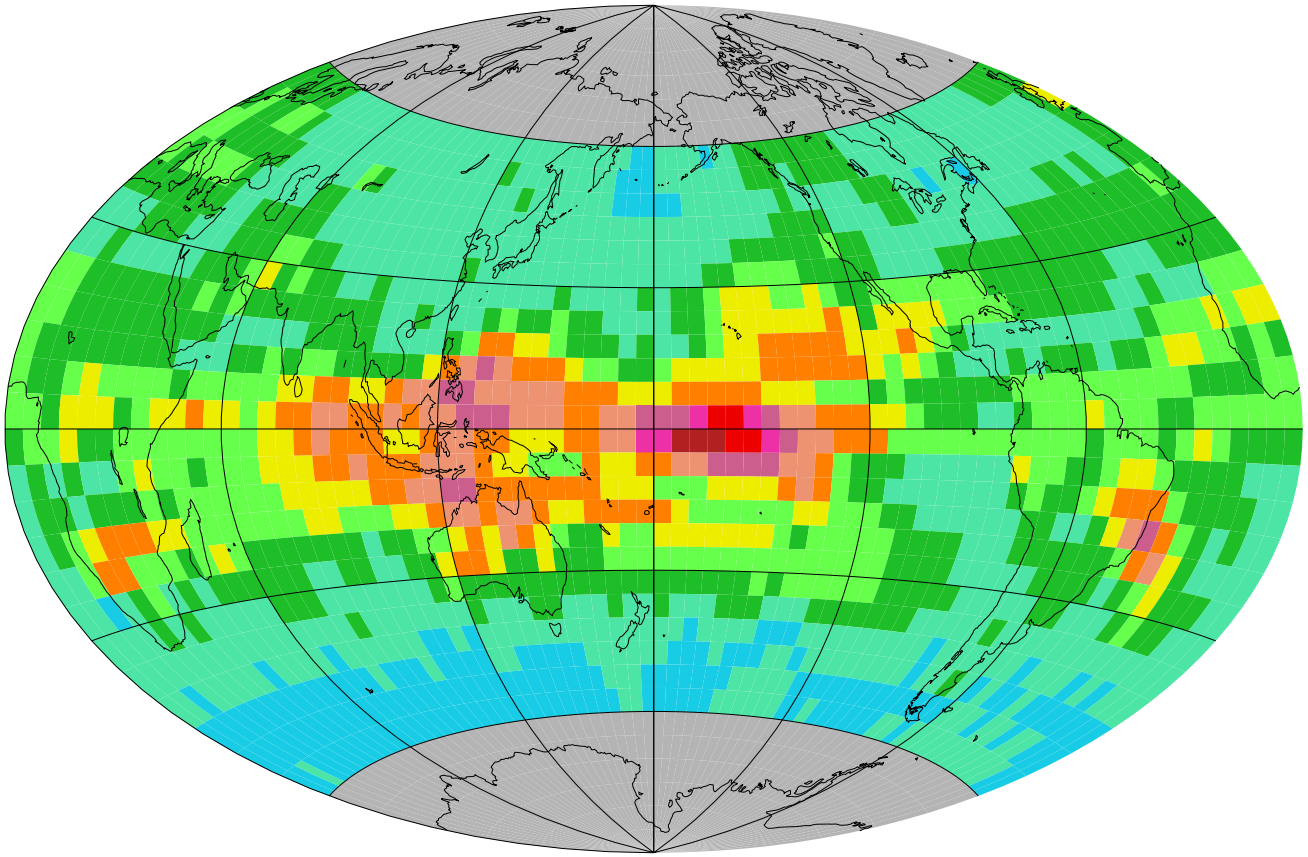
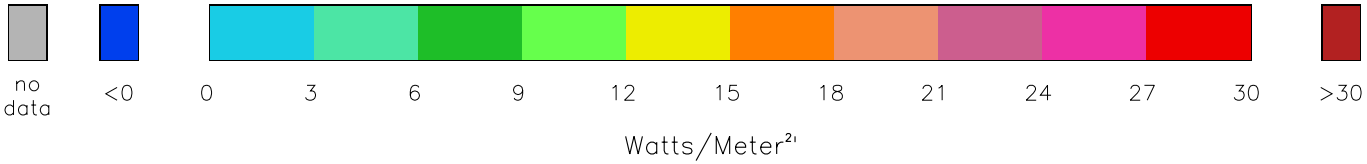


ERBS Longwave Standard Deviation

January 8411 – 9909





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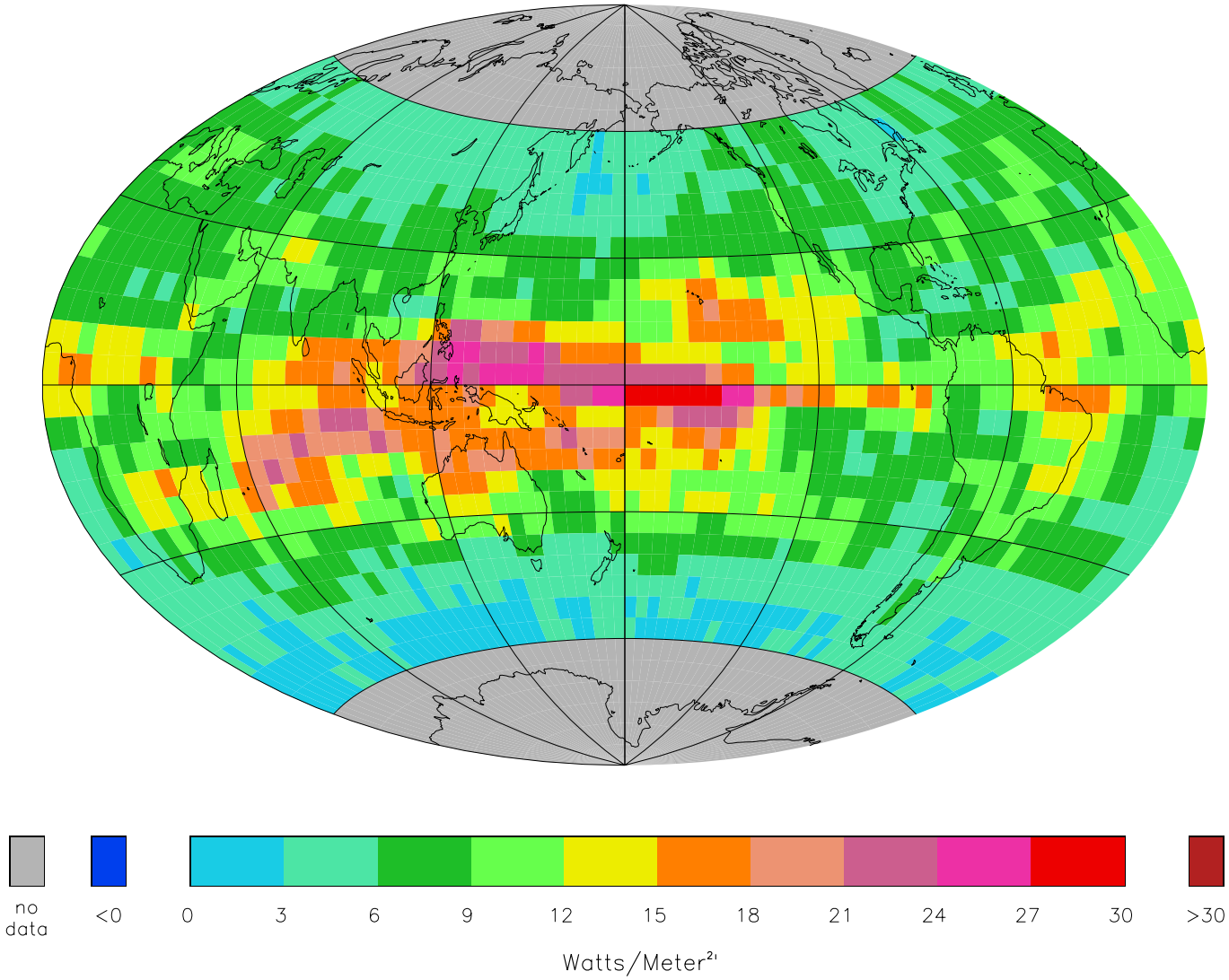

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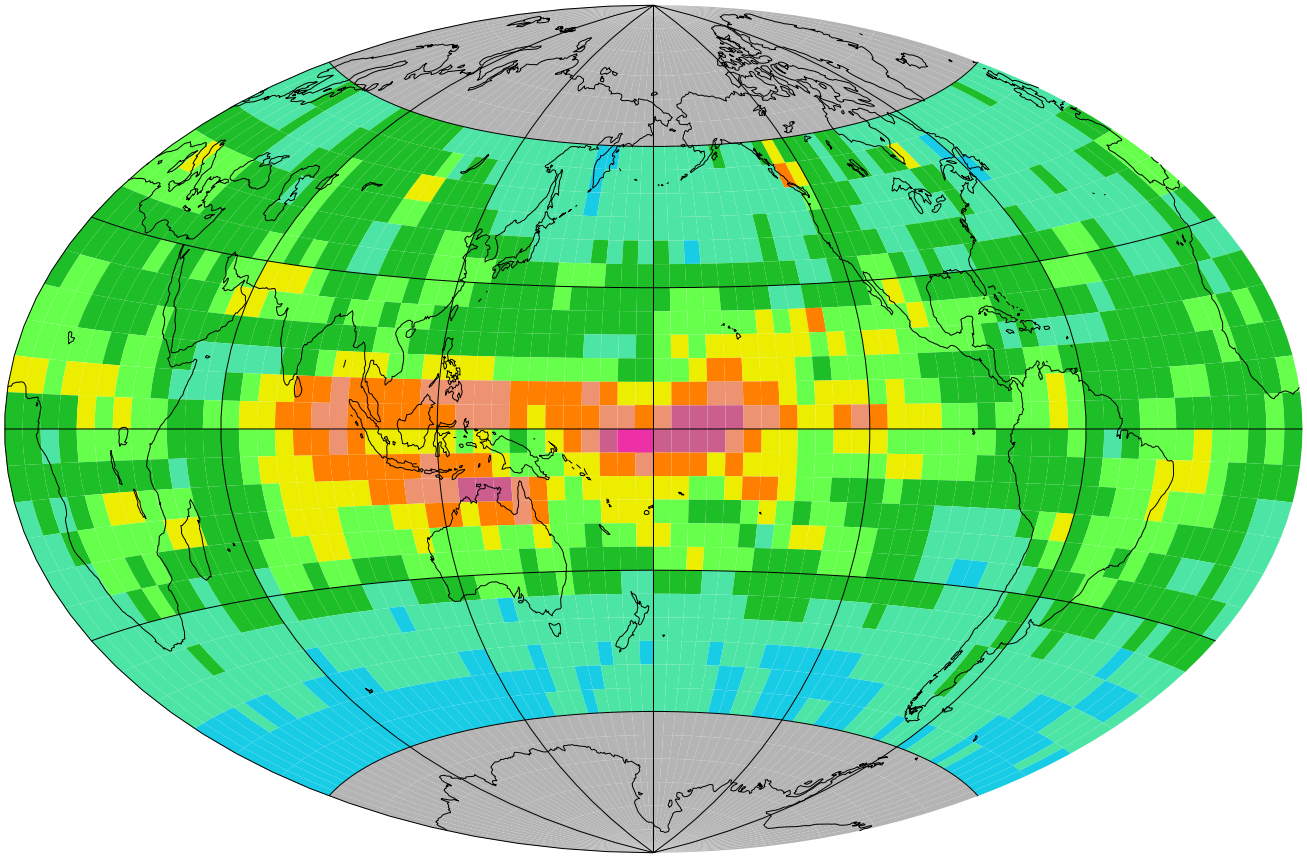

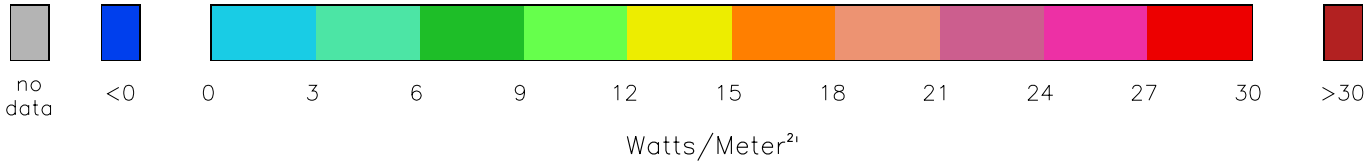

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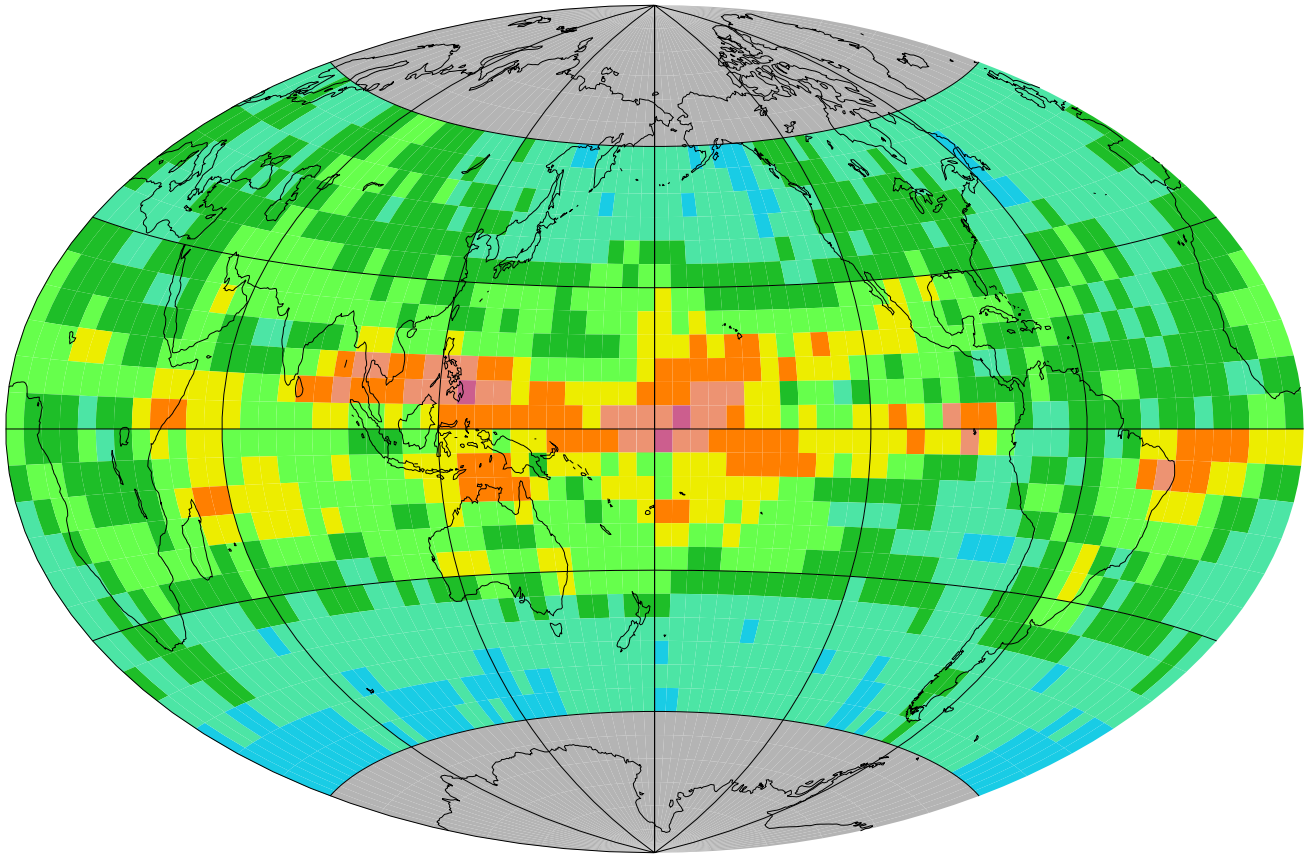

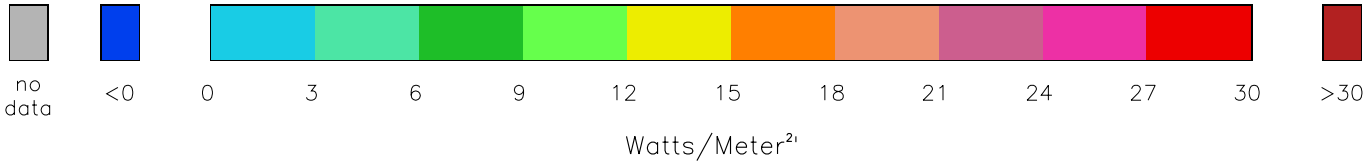

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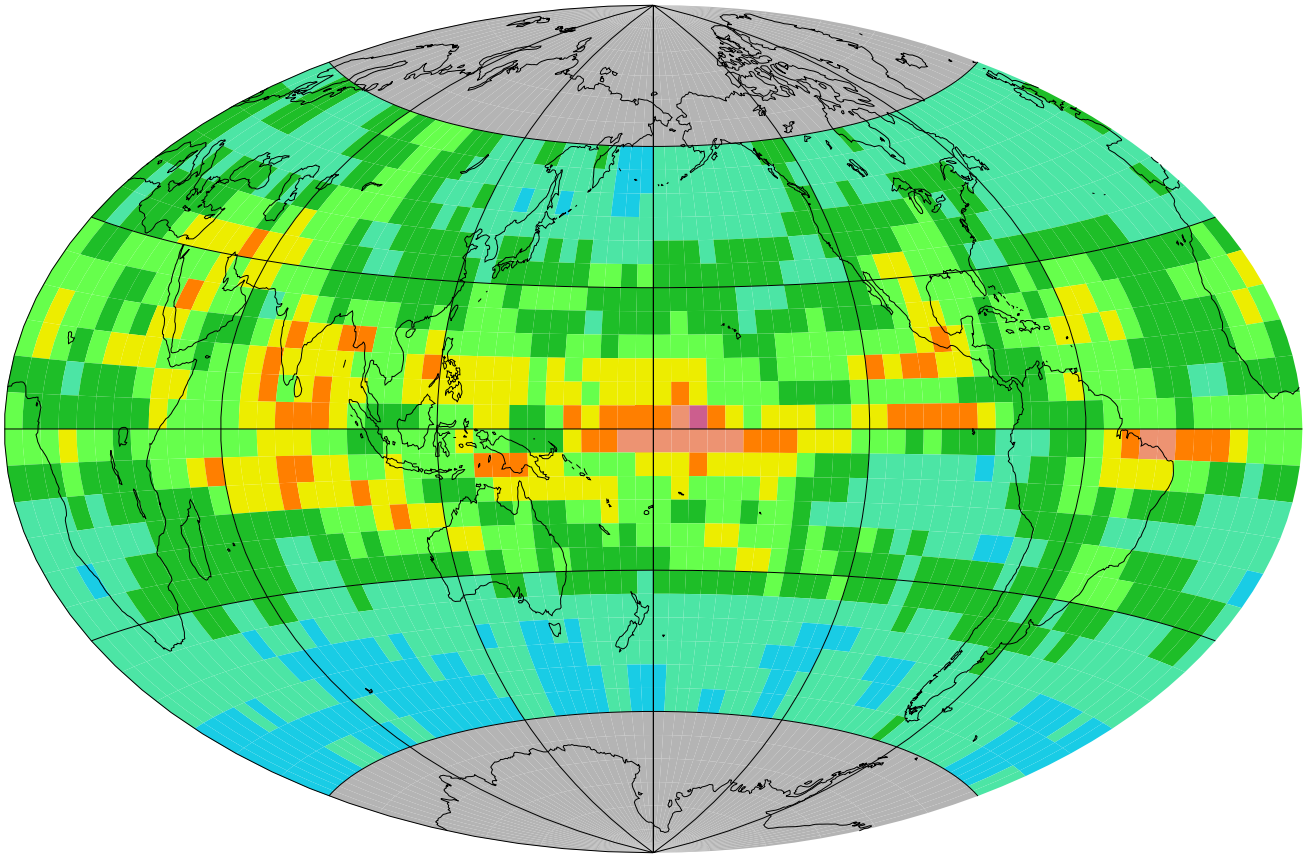

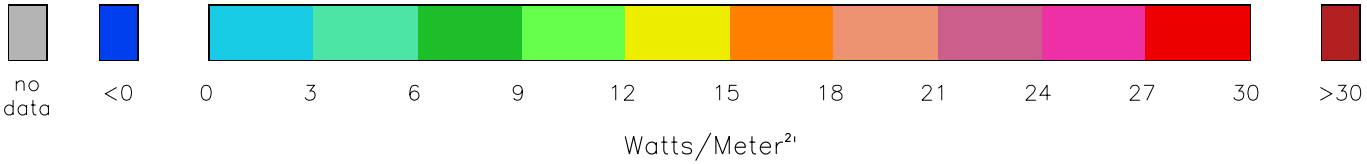

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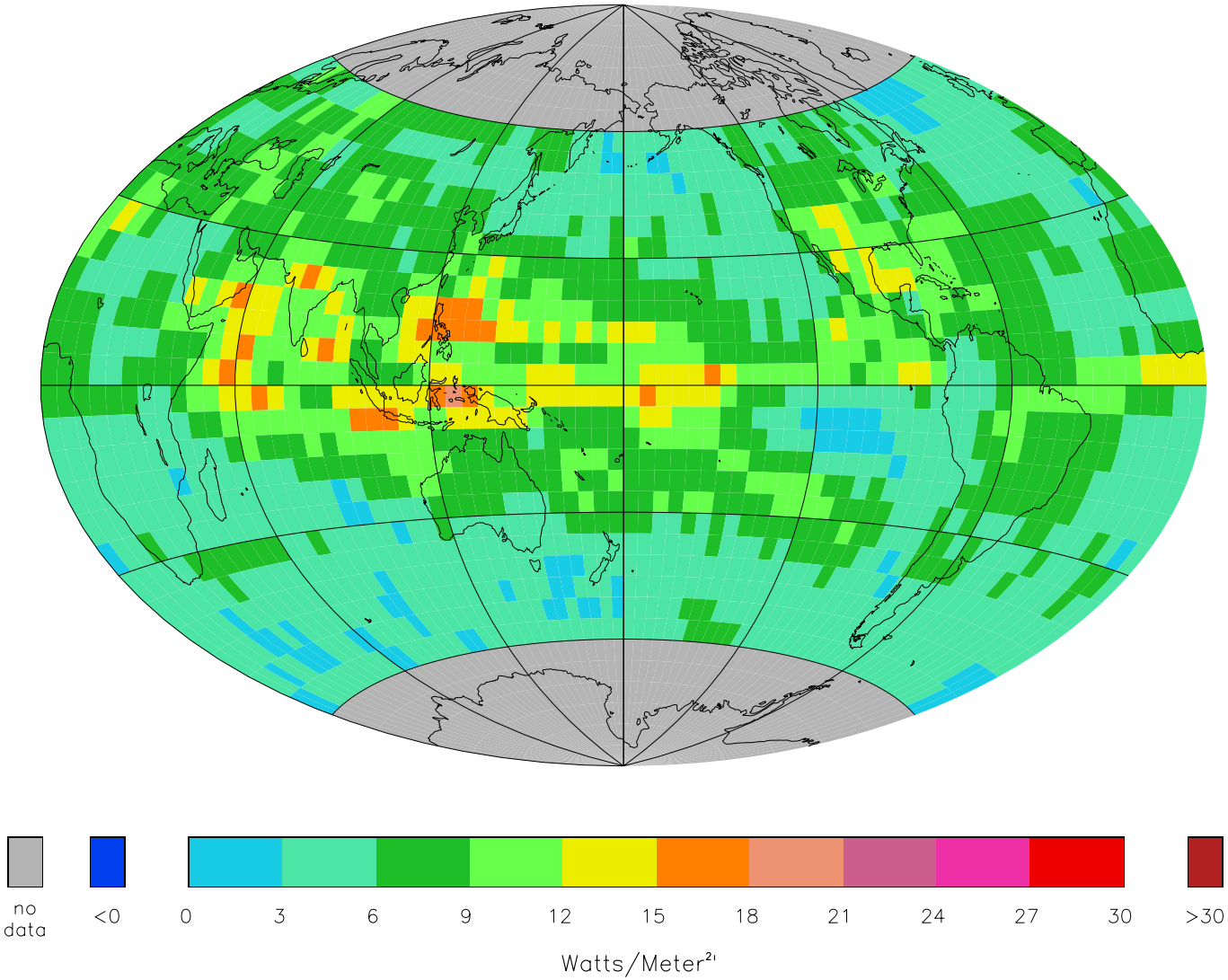

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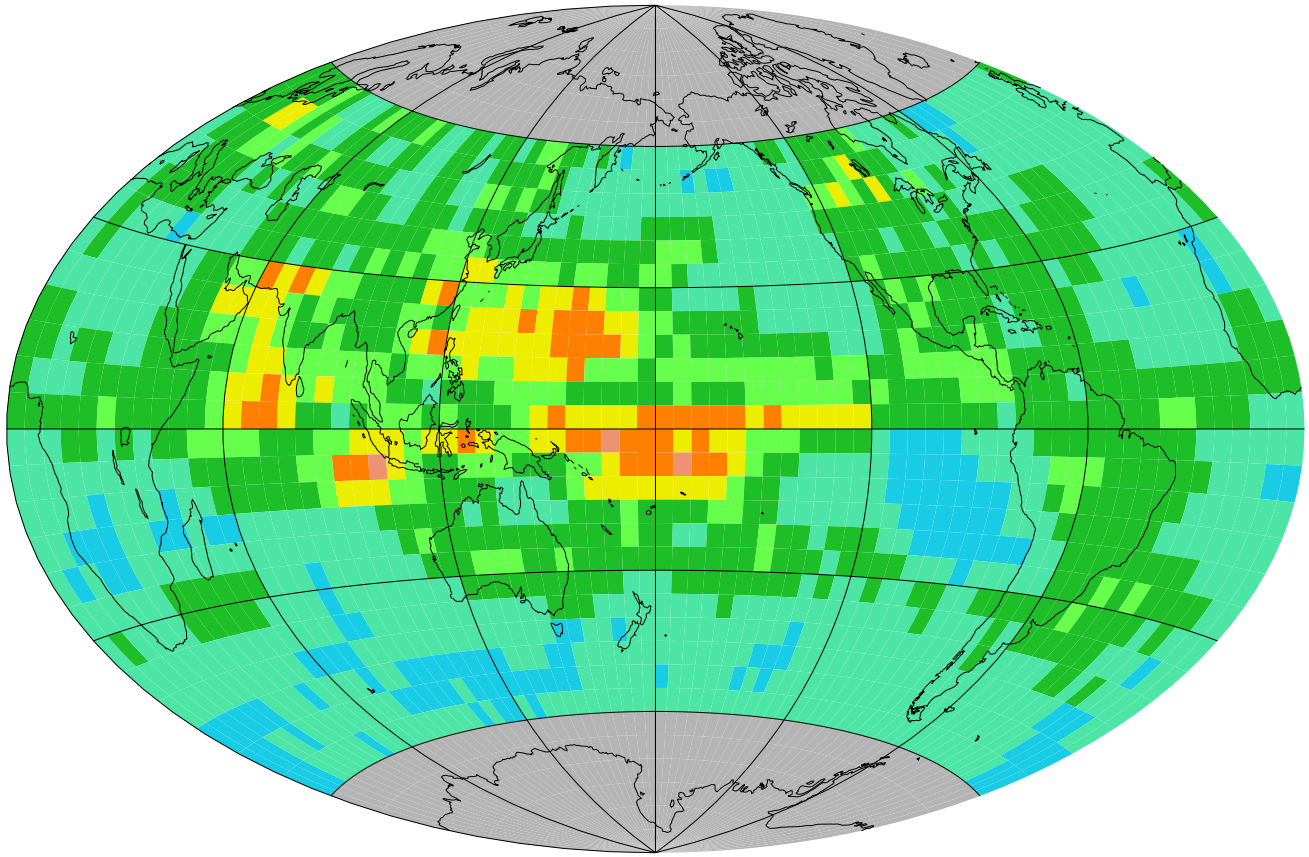

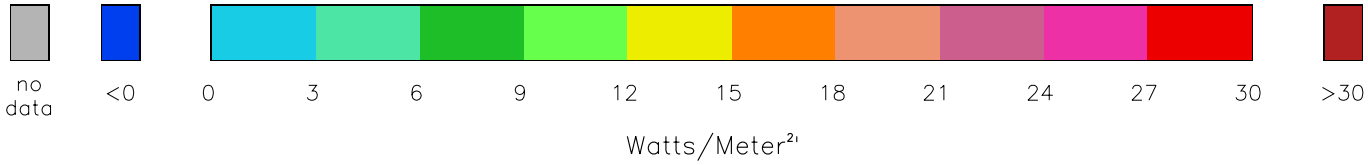

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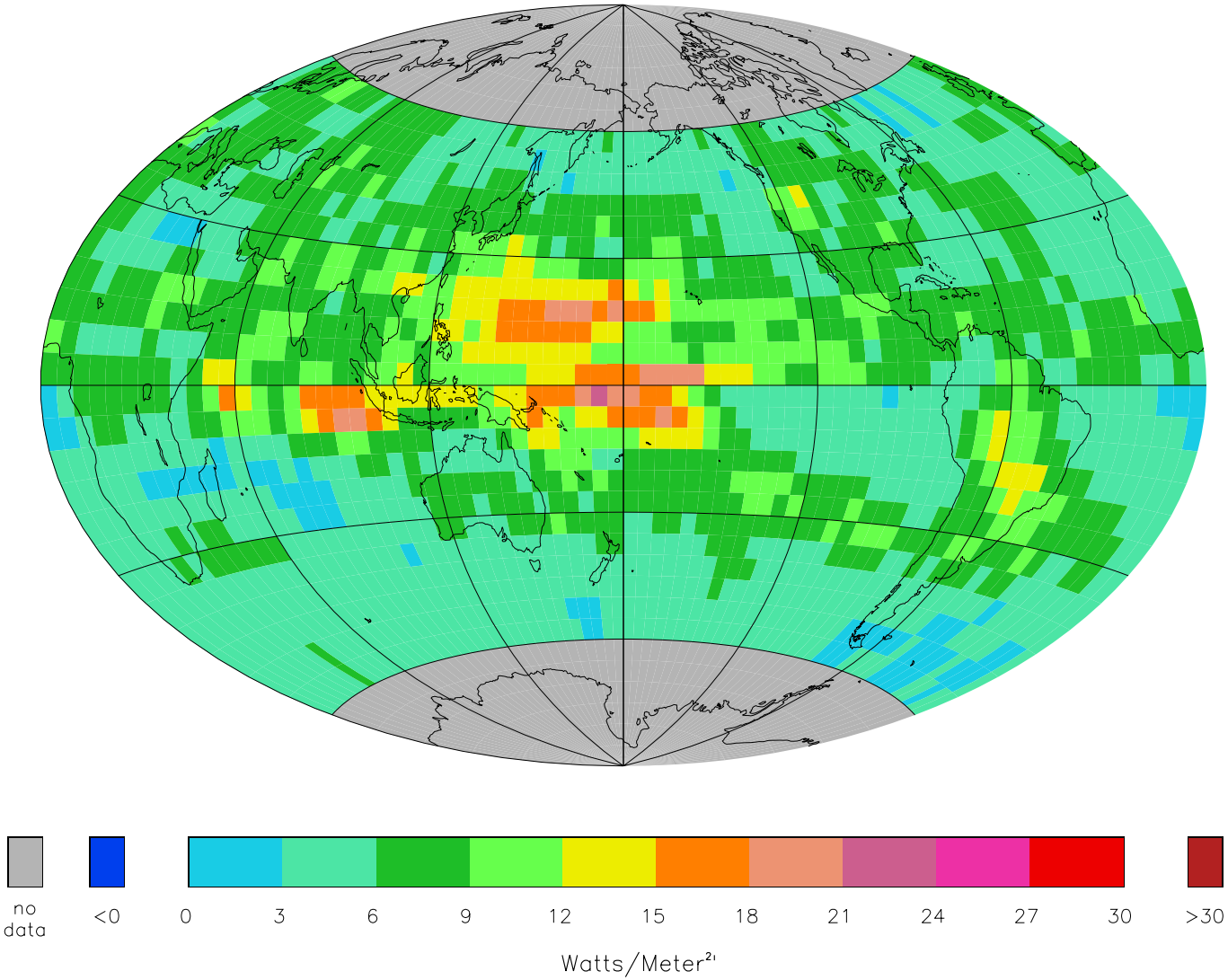

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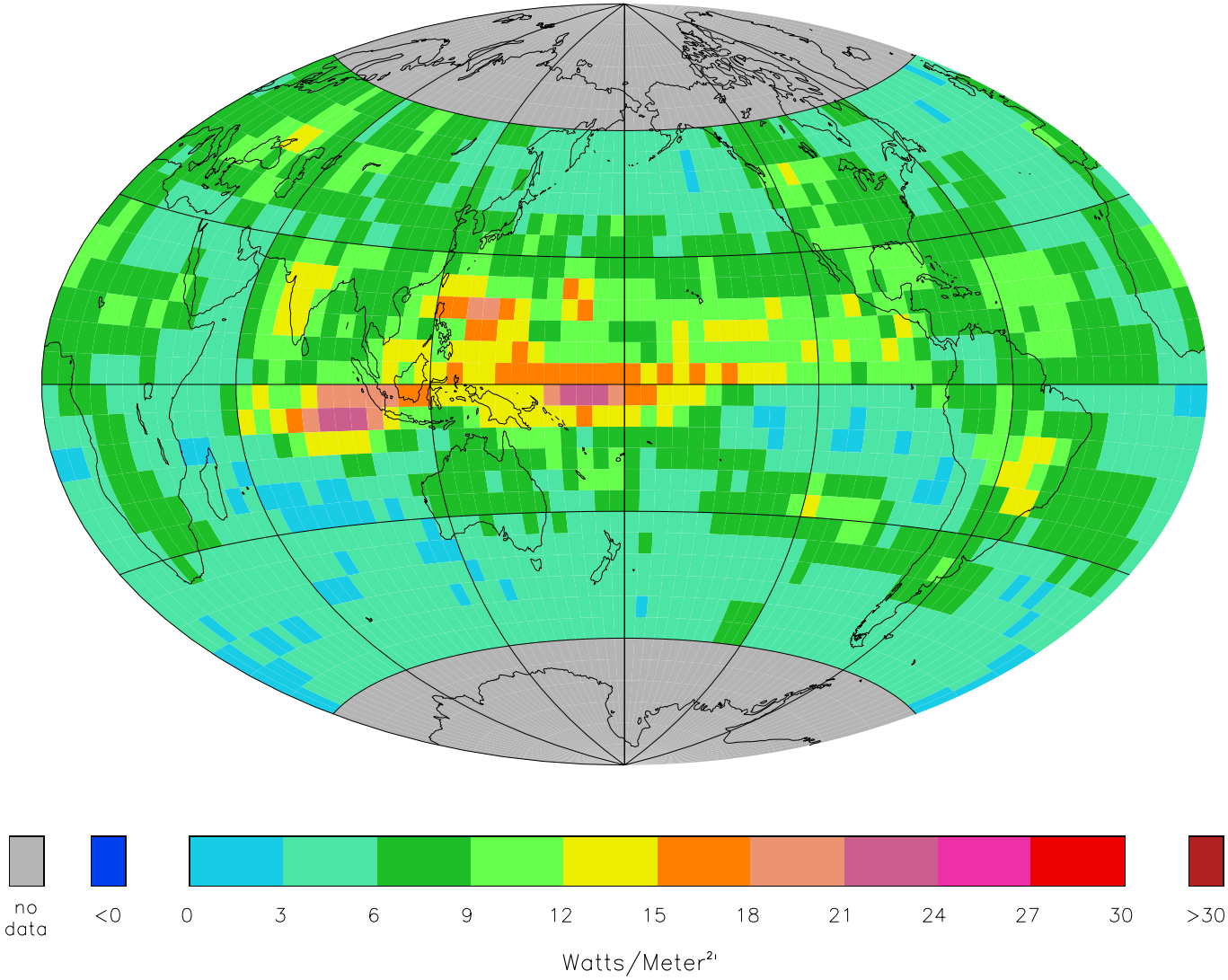

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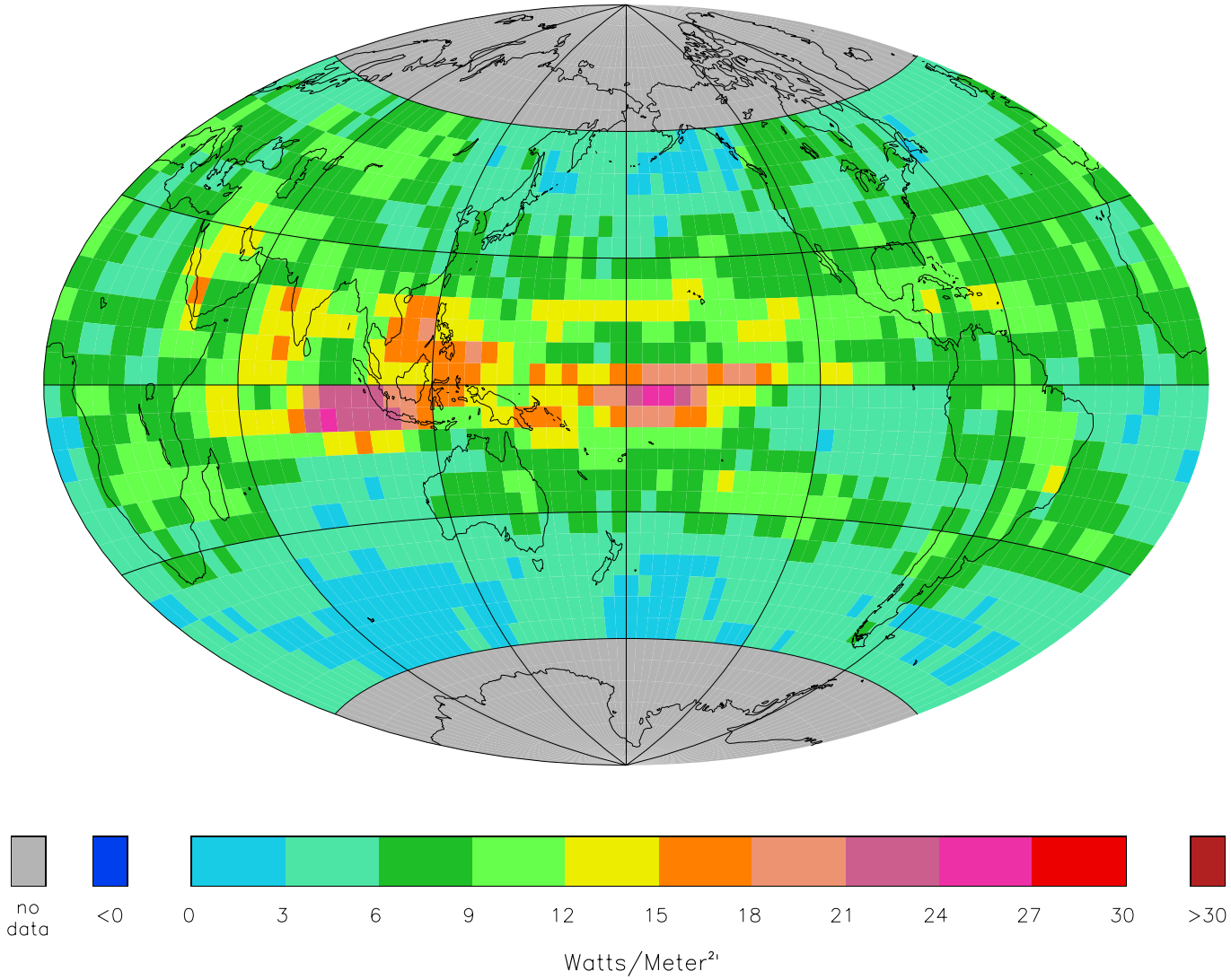
October 8411 – 9909



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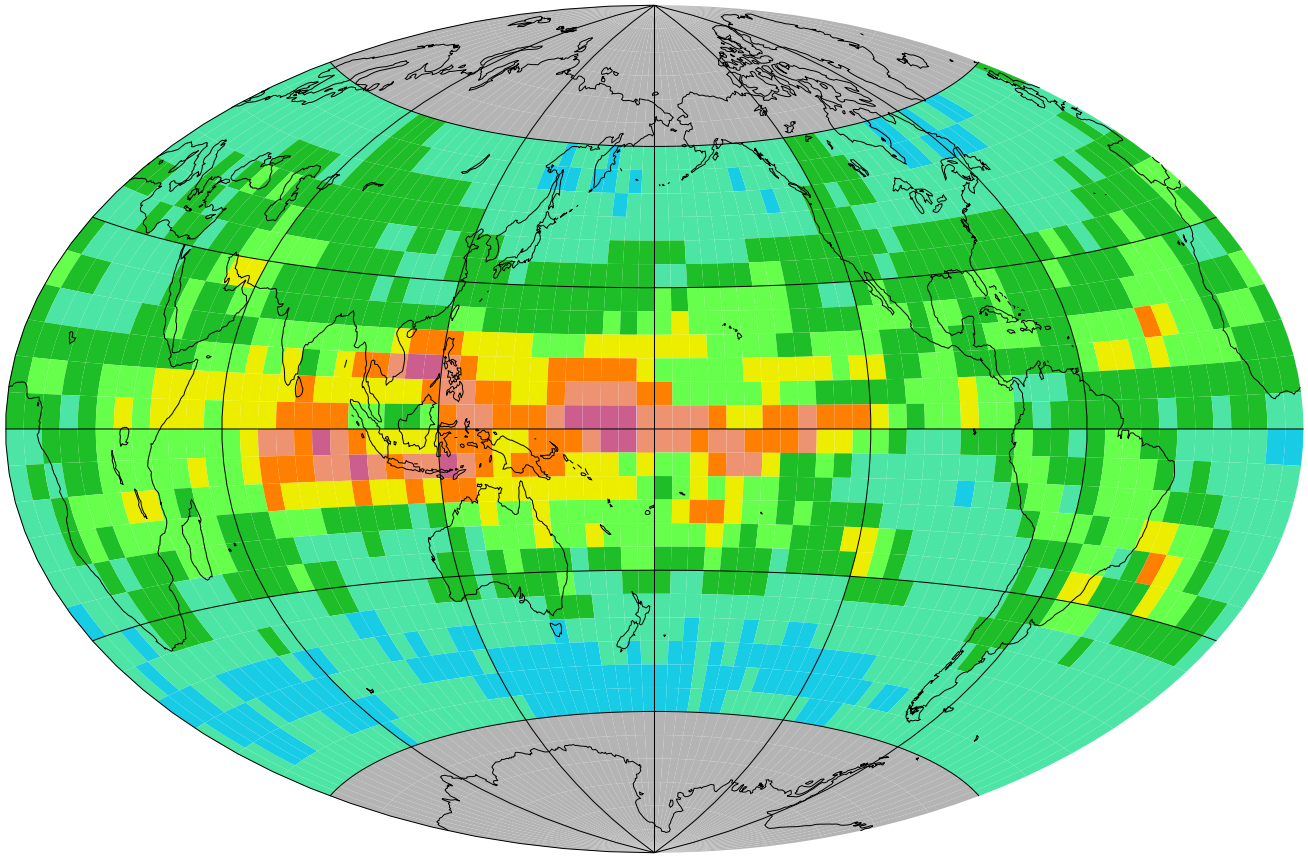

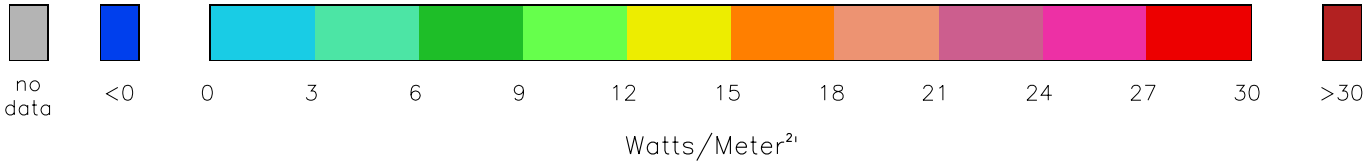

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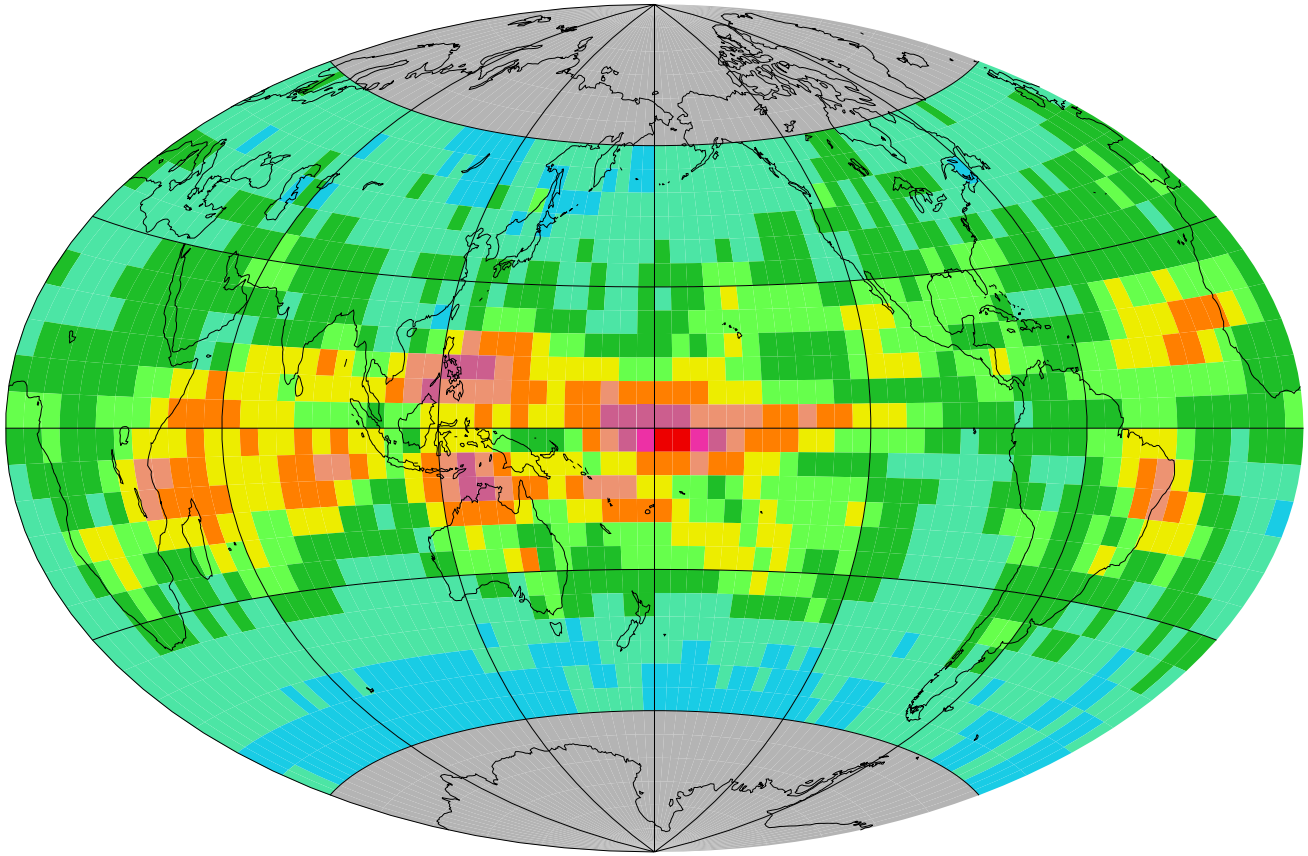
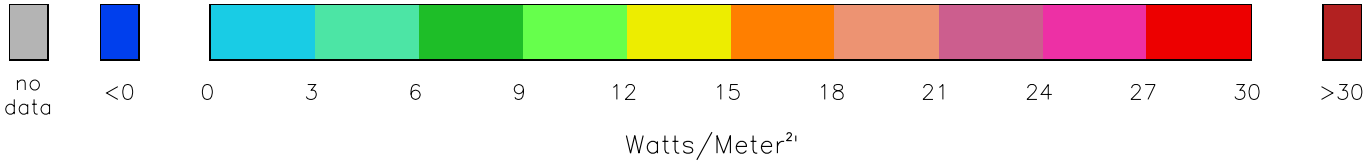




Longwave Variance Results

- Most of the OLR variability lies within 20 degrees of the equator and is associated with ENSO events.

- OLR variability is greatest in northern hemisphere winter (November - February) and least in northern hemisphere summer (June - August).

- OLR variability over the Indian Ocean is likely associated with interannual variations in the Indonesian Throughflow.

Shortwave Variance Results

- Most of the SWR variability lies in the ENSO region of the Pacific.
- SWR variability greatest in northern hemisphere winter (December - February).
- High SWR variability in northern hemisphere spring - summer over Eurasia and western North America.

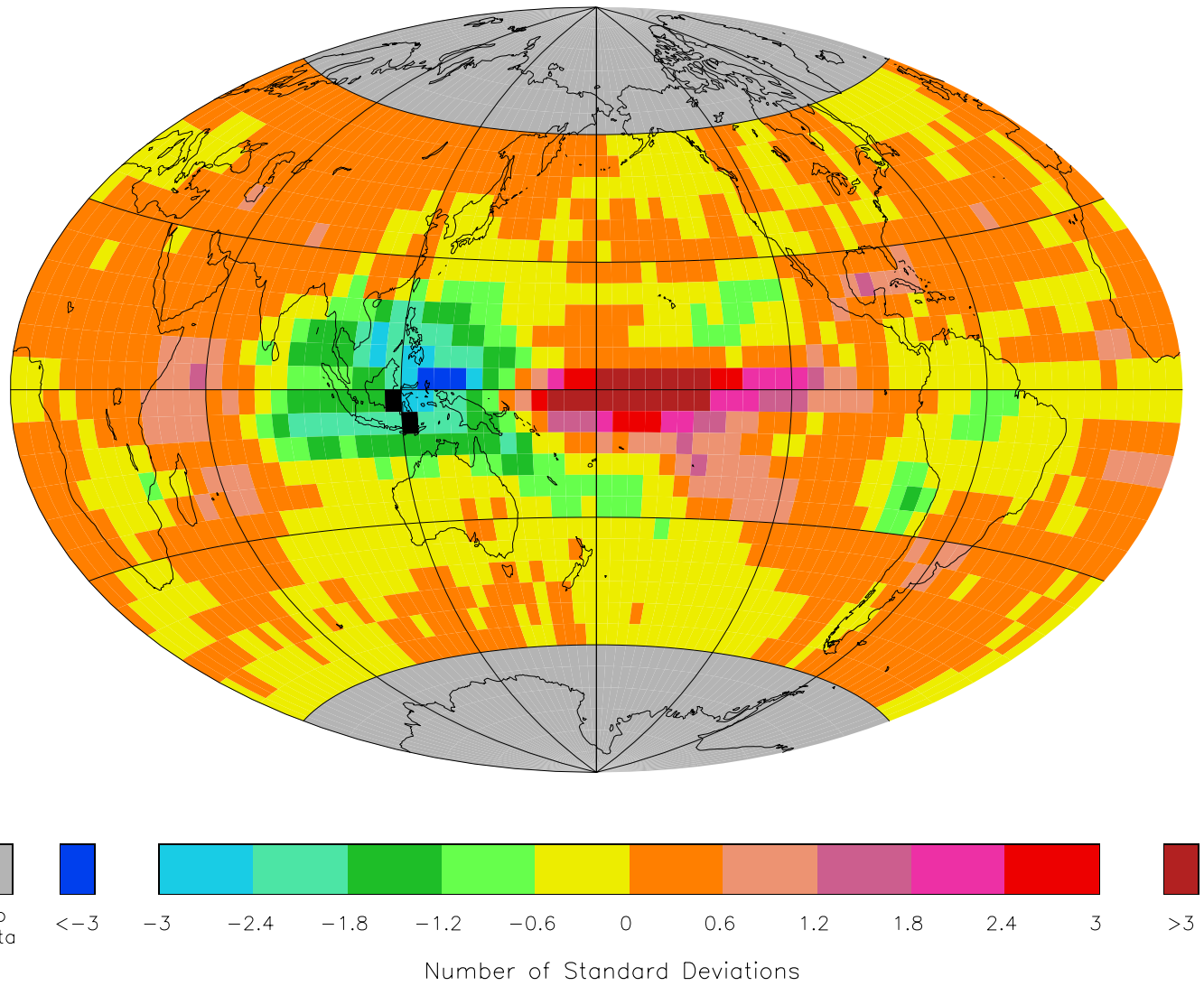
Empirical Orthogonal Function (EOF) Analysis

$$y(\vec{x}, t) = \bar{\phi}_o(\bar{x}) + \Sigma c_n(t)\phi_n(\vec{x})$$

- $\bar{\phi}_o$ = mean value
- $c_n(t)$ = principal components (temporal variability)
- $\phi_n(\vec{x})$ = empirical orthogonal functions (spatial variability)

ERBS SWR Flux Anomaly First EOF

8411 – 9909



ERBS SWR Flux Anomaly Second EOF

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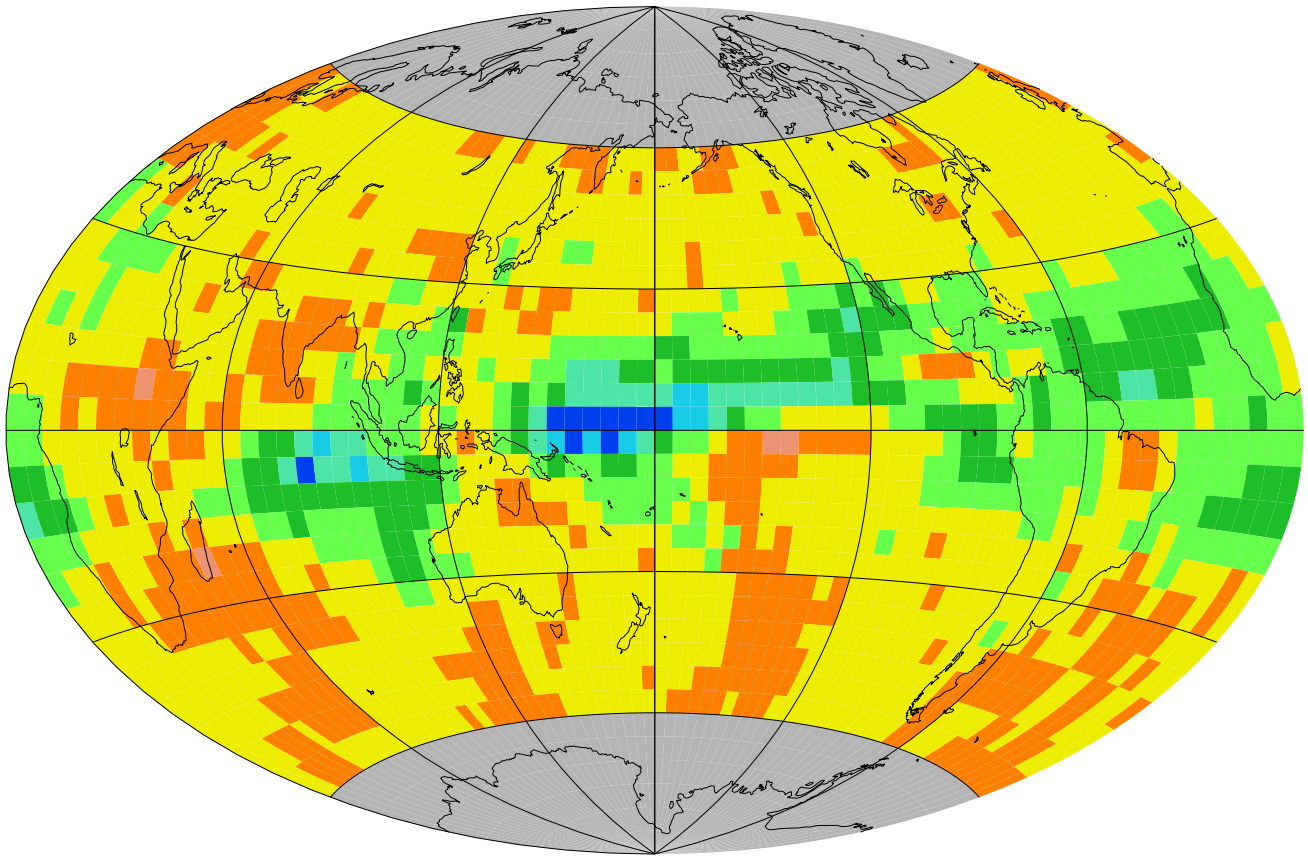

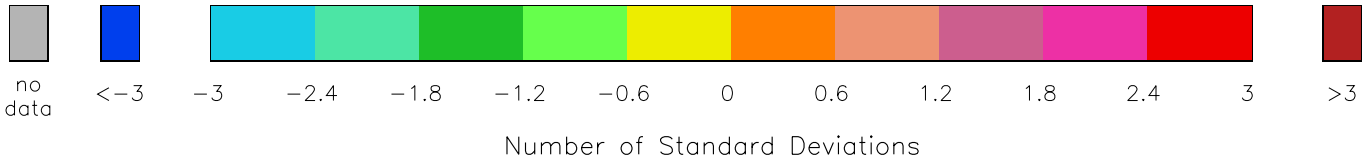

ERBS SWR Flux Anomaly Third EOF

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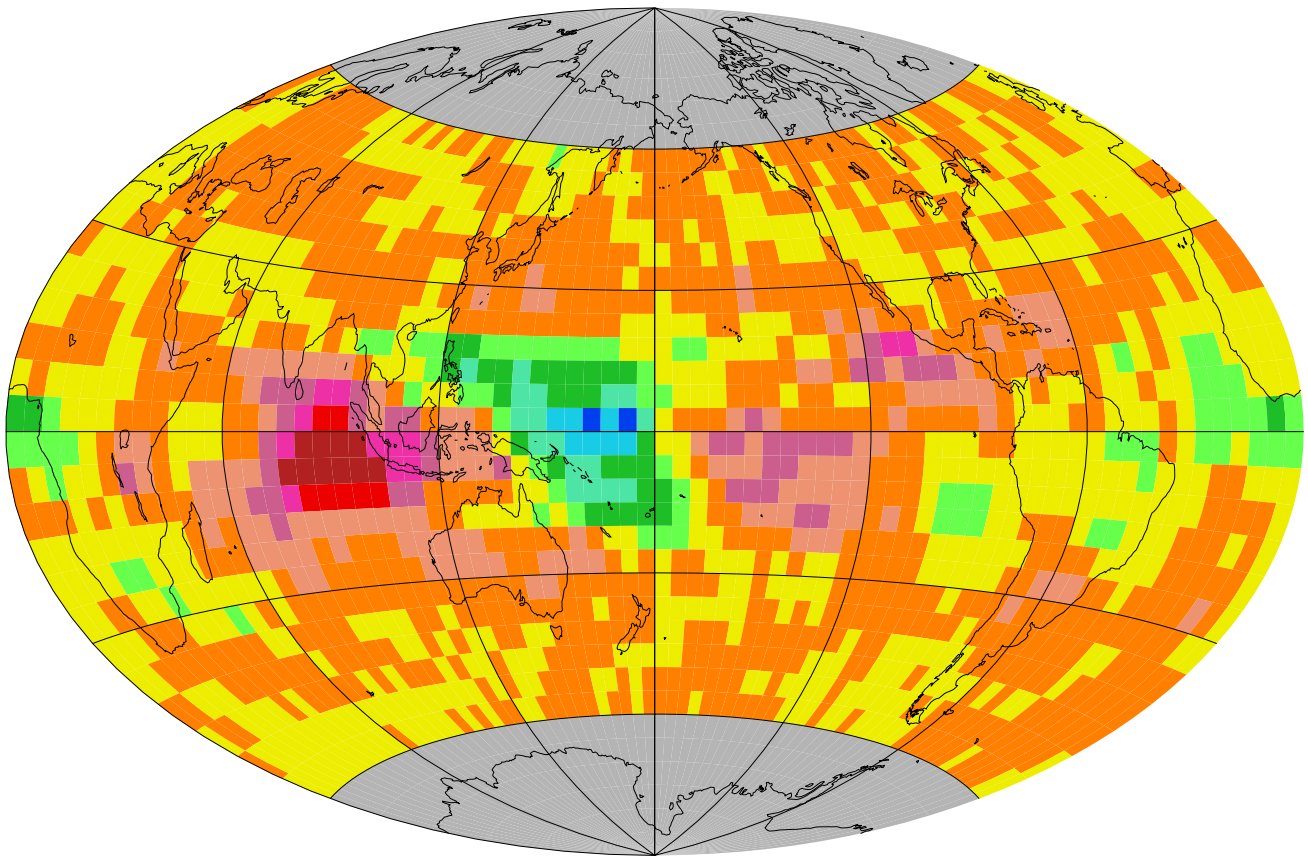
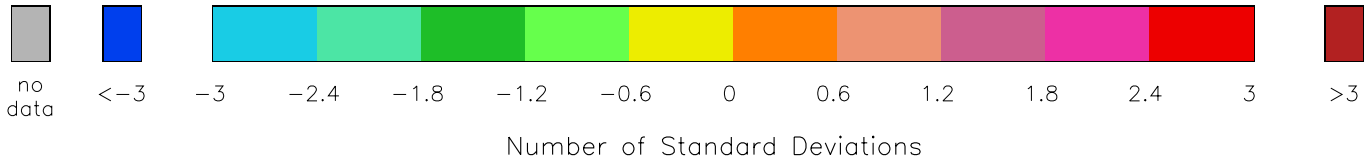
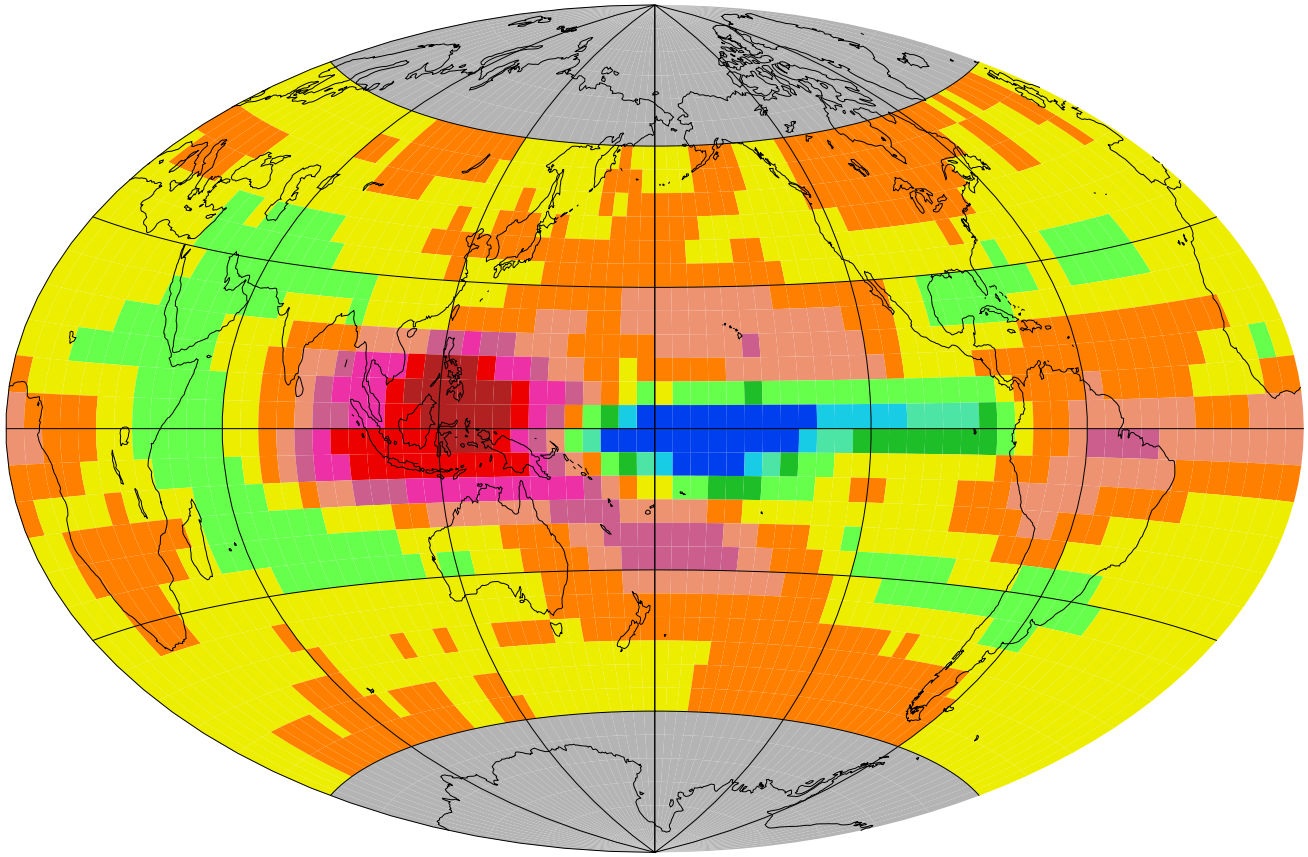
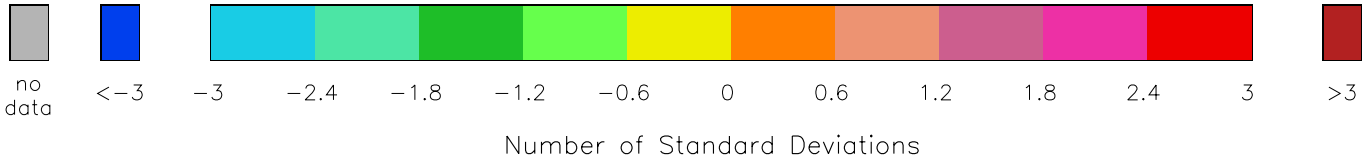




ERBS LW Flux Anomaly First EOF

8411 – 9909





ERBS LW Flux Anomaly Second EOF

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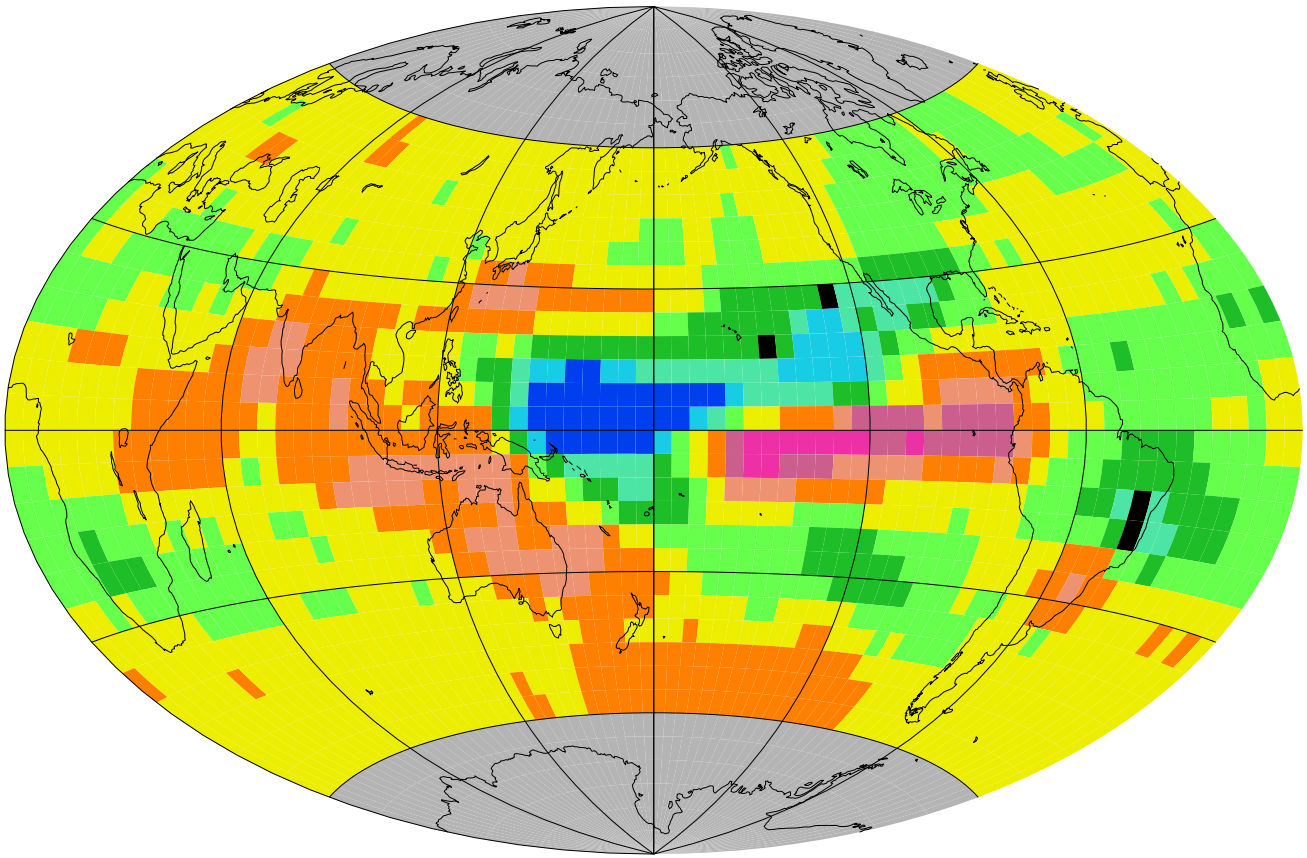
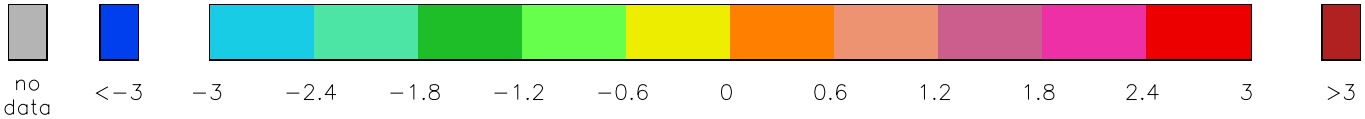
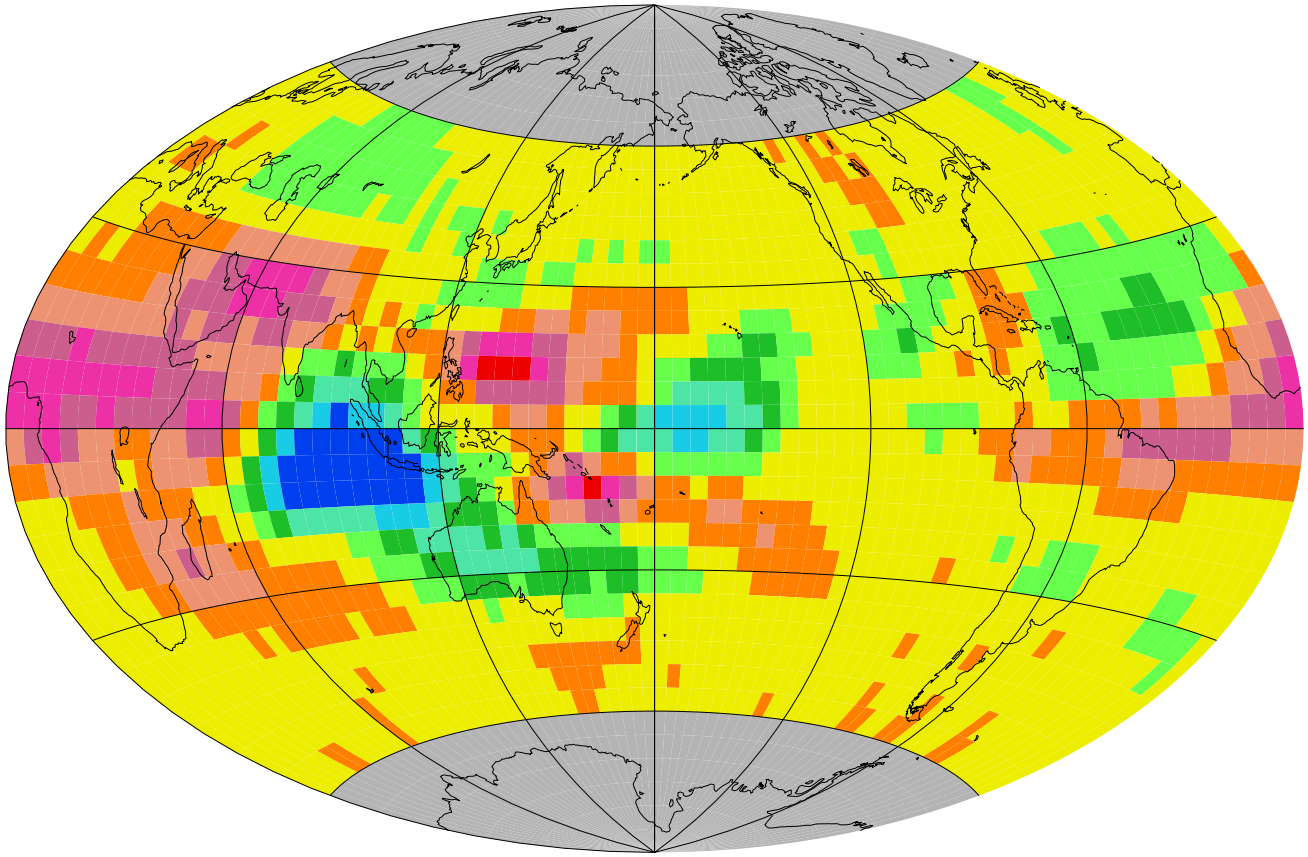


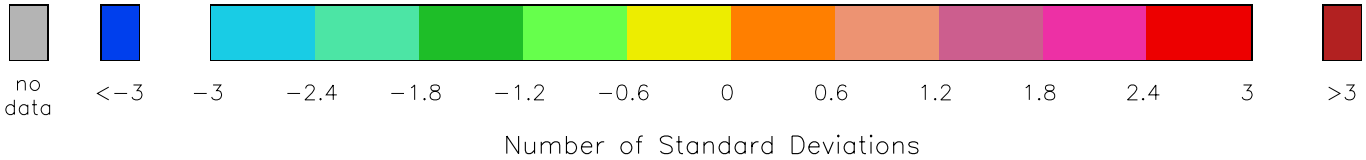


Number of Standard Deviations

ERBS LW Flux Anomaly Third EOF

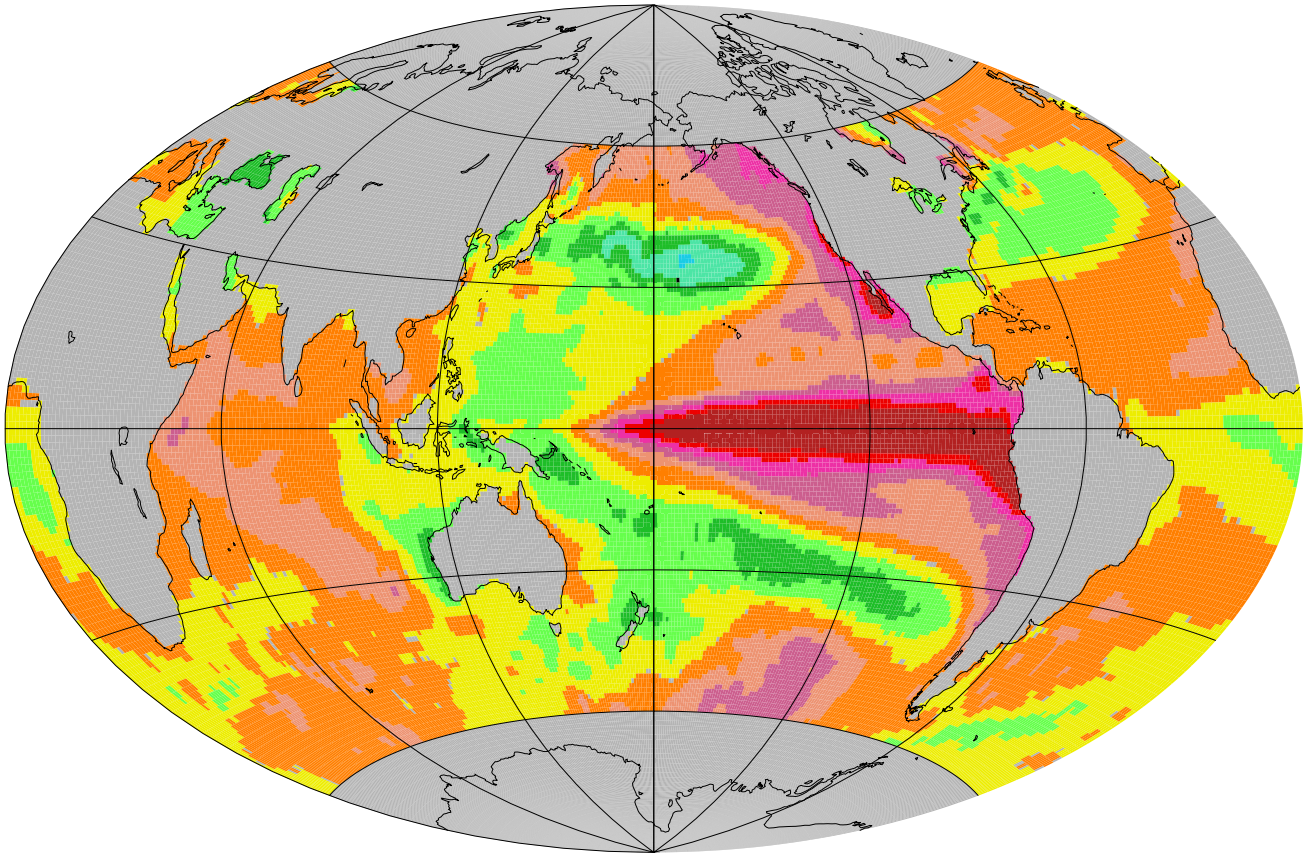
8411 – 9909

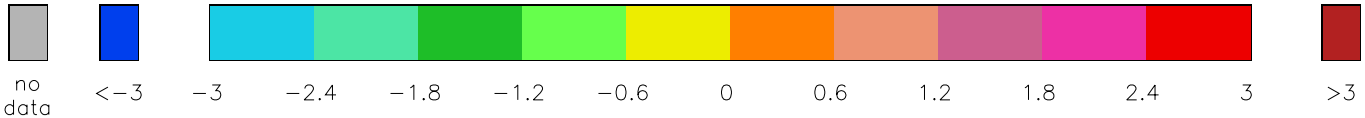




SST Anomaly First EOF

8411 – 9909





Number of Standard Deviations

SST Anomaly Second EOF

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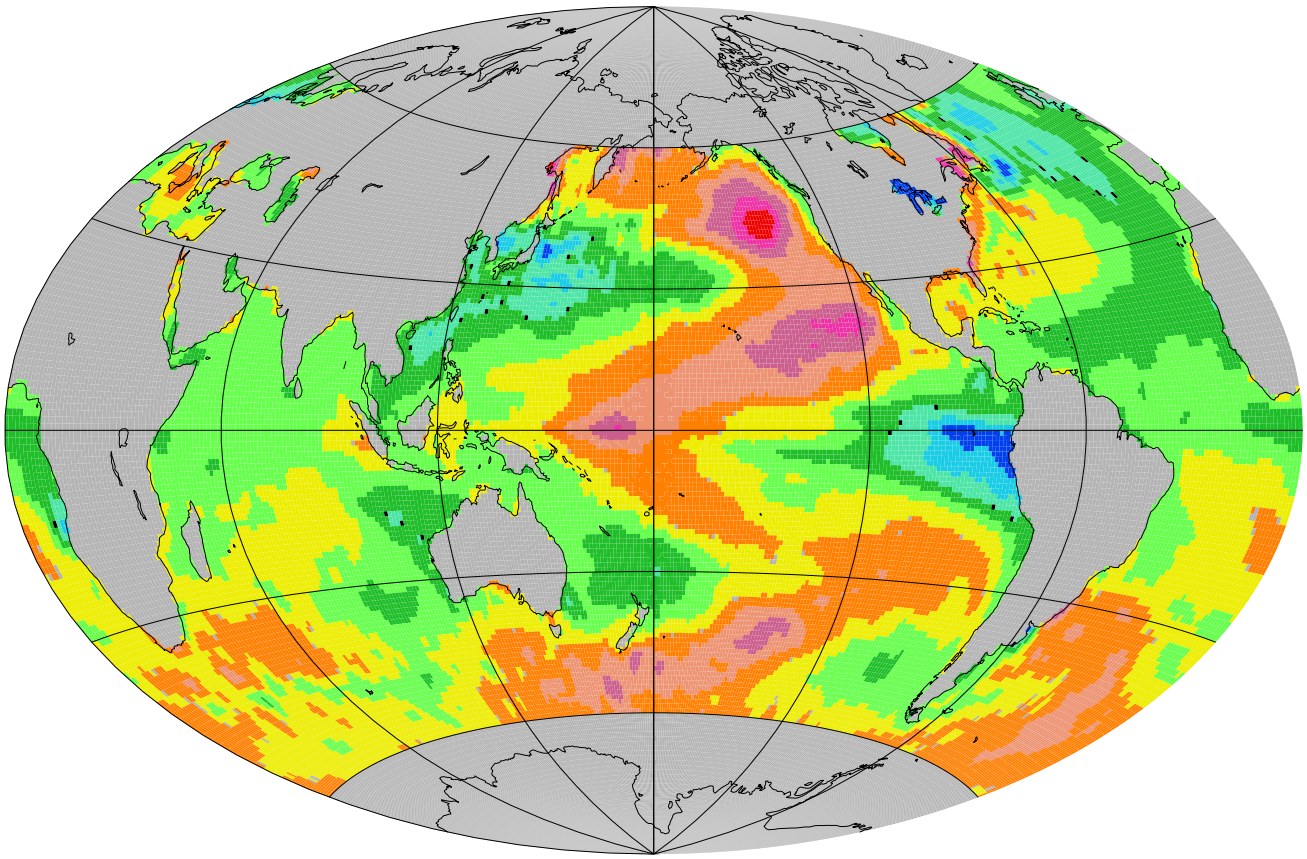
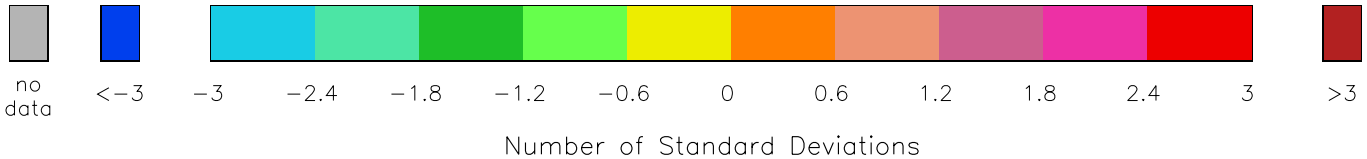
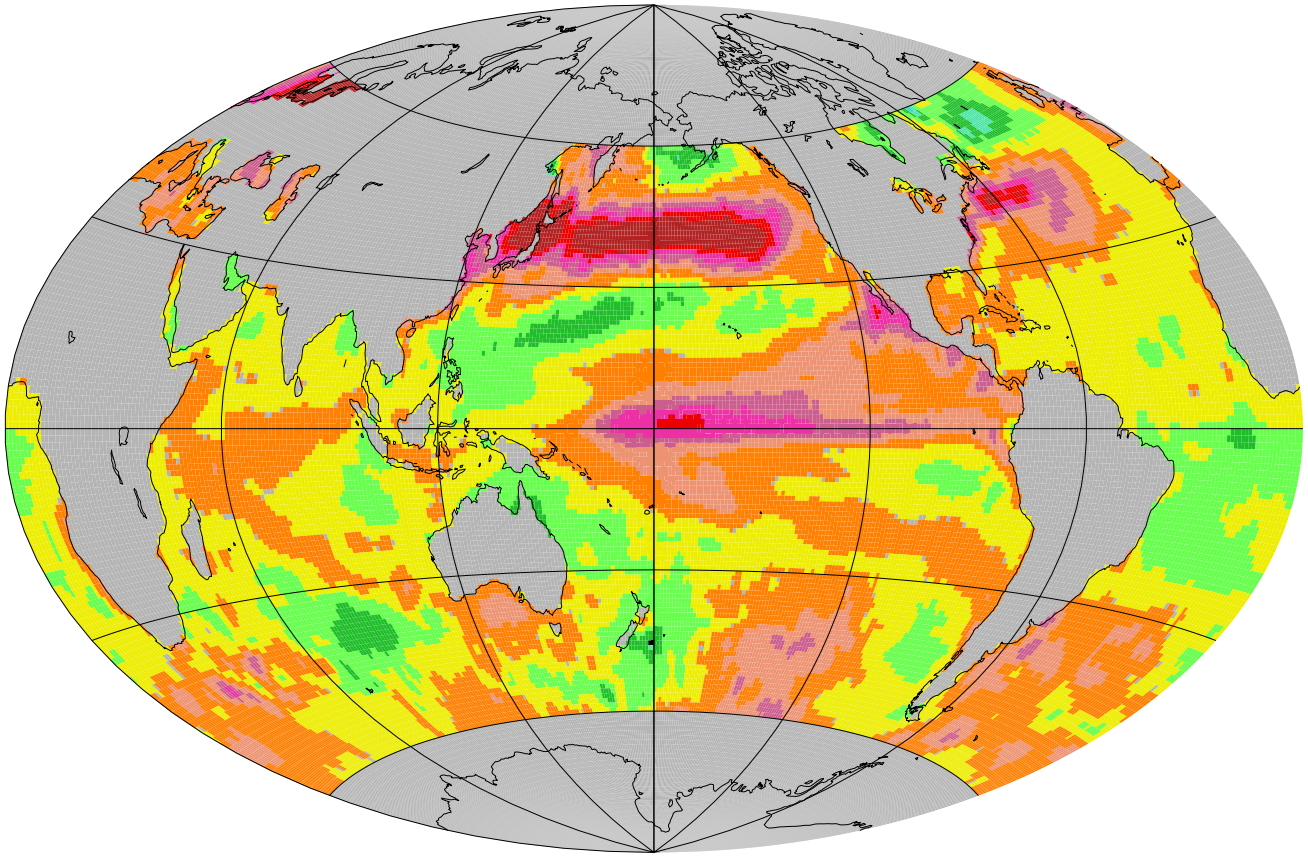
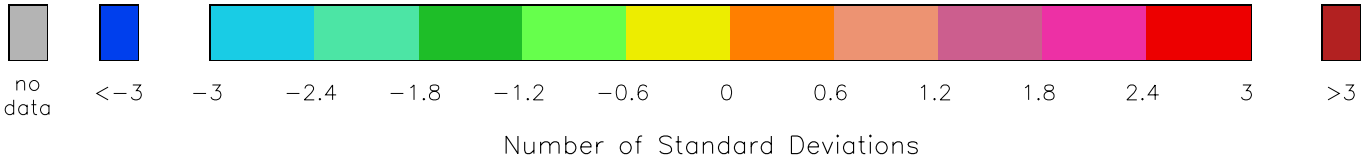


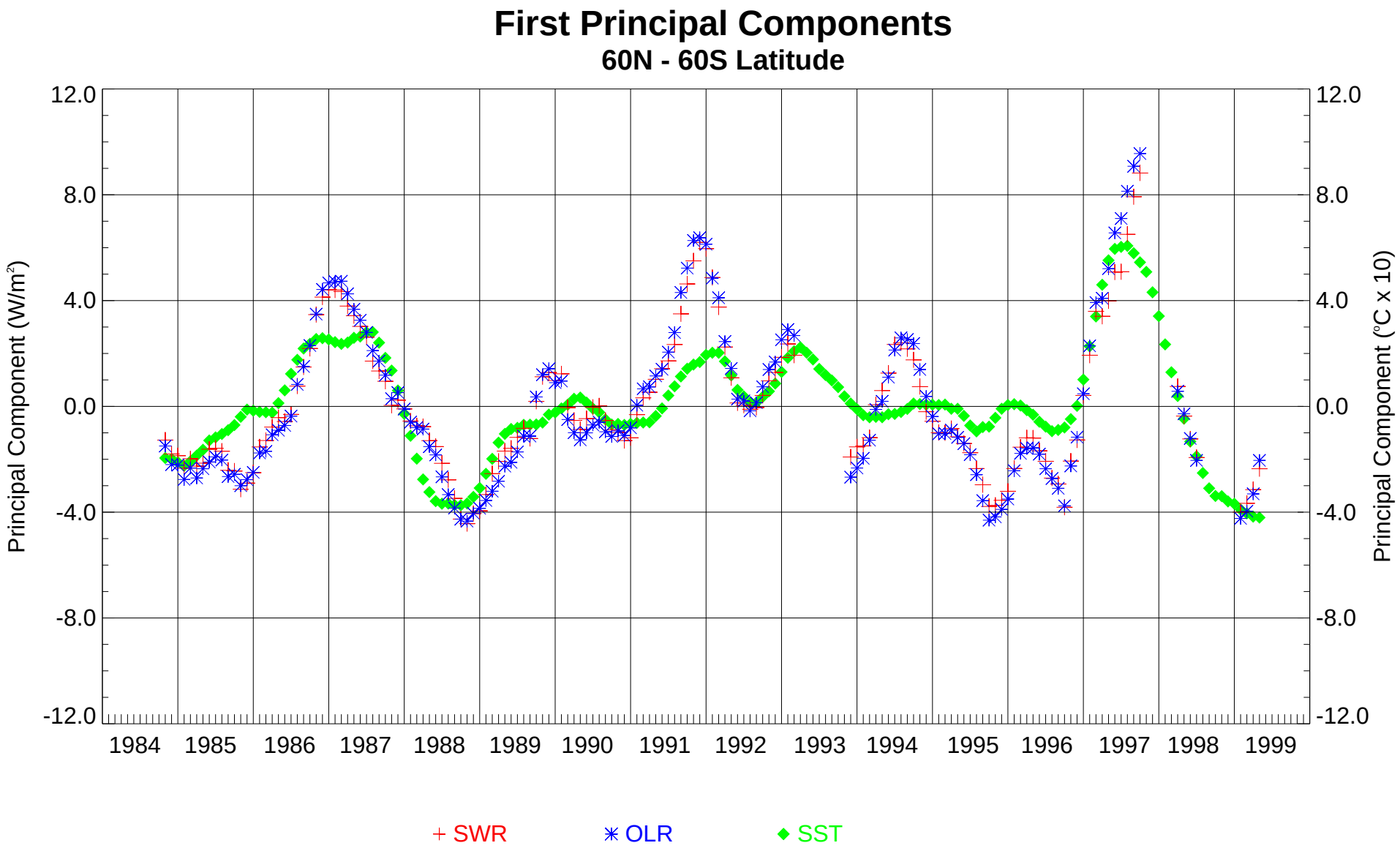


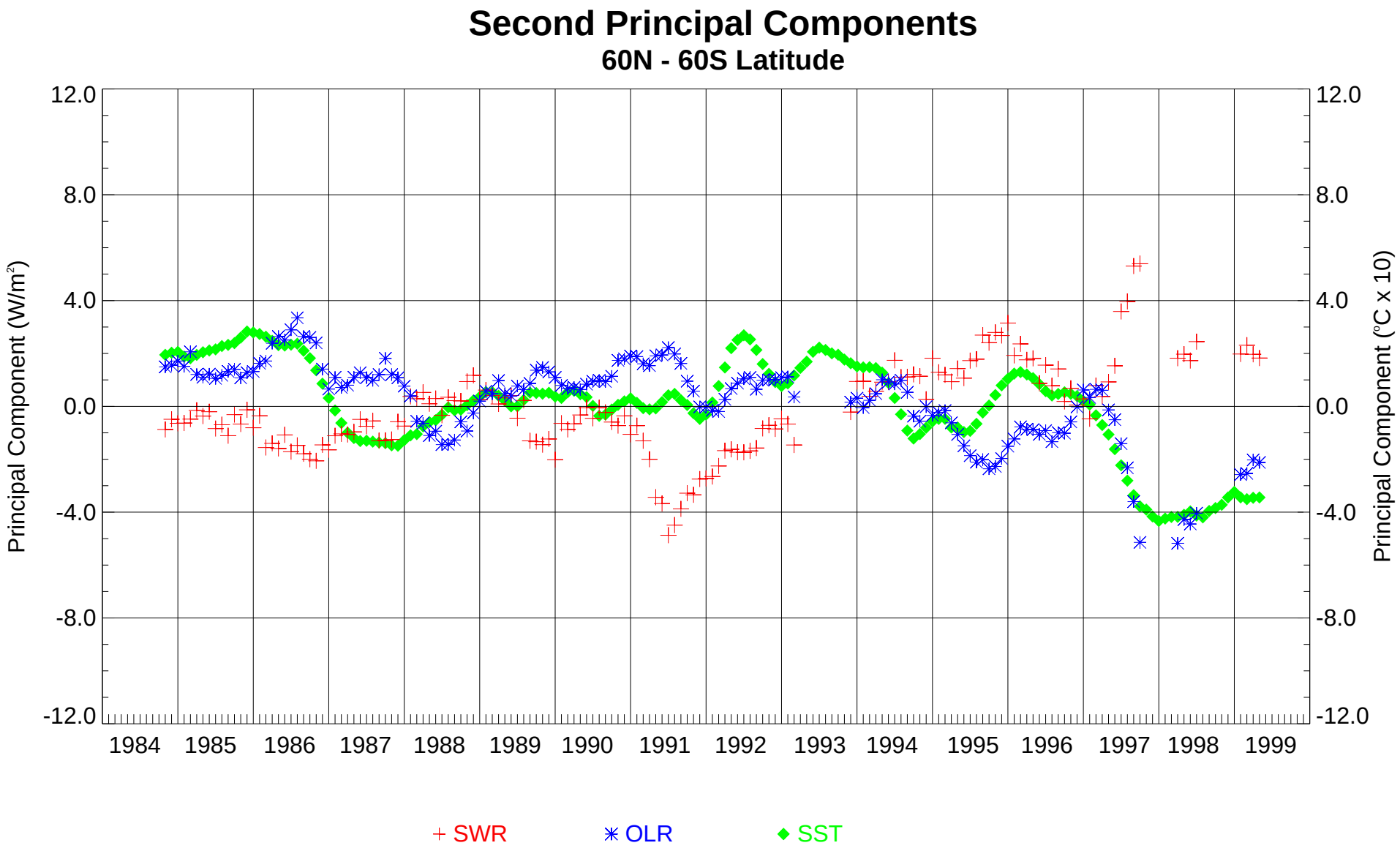
SST Anomaly Third EOF

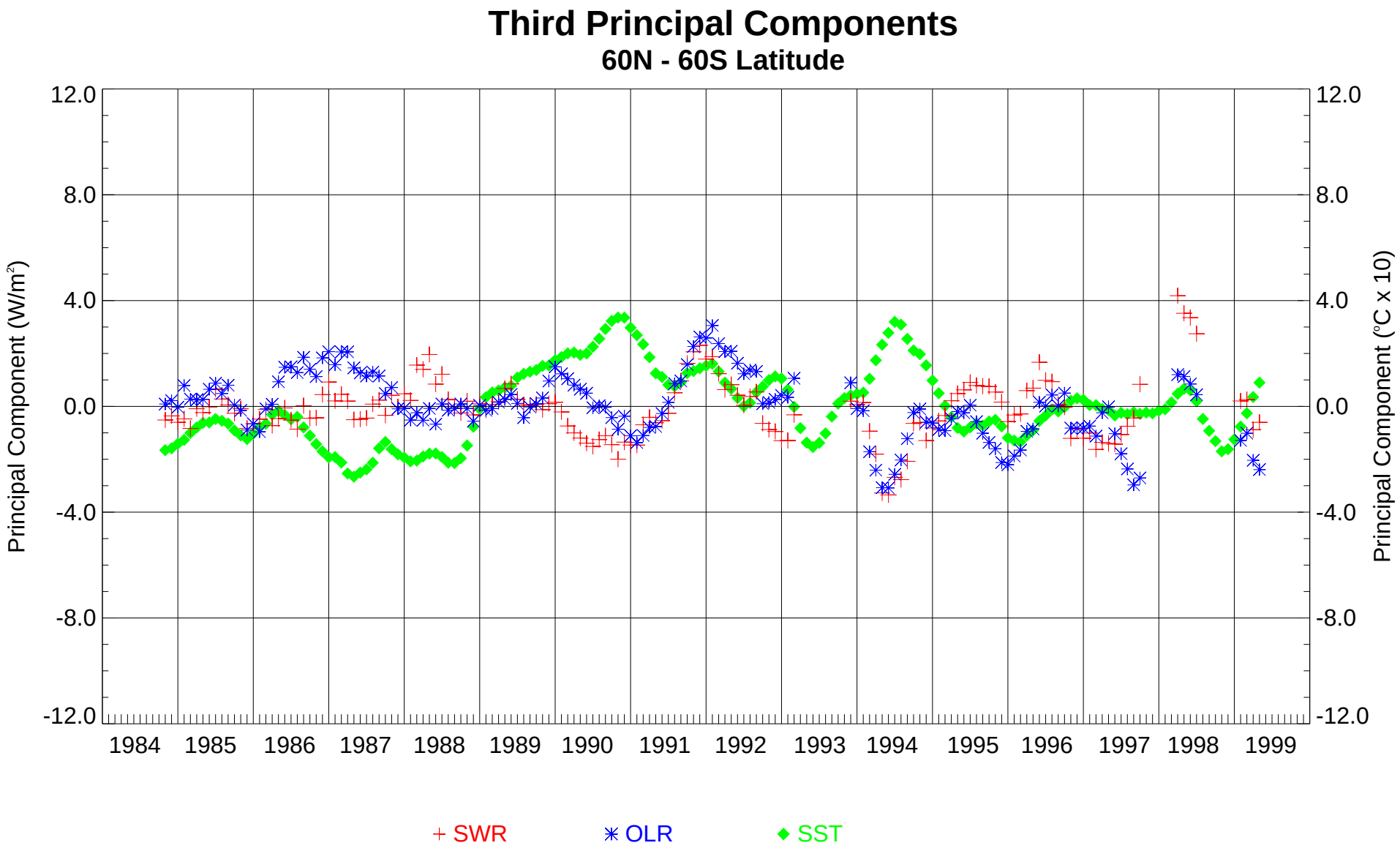
8411 – 9909






First Principal Components
60N - 60S Latitude
Principal Component (W/m²)
Principal Component (°C x 10)
12.0
8.0
4.0
0.0
-4.0
-8.0
-12.0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
SWR
OLR
SST


Second Principal Components
60N - 60S Latitude
Principal Component (W/m²)
Principal Component (°C x 10)
12.0
8.0
4.0
0.0
-4.0
-8.0
-12.0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
SWR
OLR
SST


Third Principal Components
60N - 60S Latitude
Principal Component (W/m²)
Principal Component (°C x 10)
12.0
8.0
4.0
0.0
-4.0
-8.0
-12.0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
SWR
OLR
SST

Longwave Flux EOF Results

- First mode OLR accounts for about 17% of variance and corre-sponds to ENSO

- Second mode OLR accounts for about 7% of variance. A hint of ENSO signal still visible.

- Third mode OLR accounts for about 5% of variance. Likely related to variability in the Indonesian throughflow.

Shortwave Flux EOF Results

- First mode SWR accounts for about 10% of variance and corre-sponds to ENSO

- Second mode SWR accounts for 6% of variance. ENSO signal still apparent.

- Third mode of SWR accounts for 4% of variance. Likely related to variability in the Indonesian throughflow.

Sea Surface Temperature EOF Results

- First mode SST accounts for about 17% of variance and corresponds to ENSO
- ENSO manifests itself in both the first and second modes.
- Second mode SST accounts for about 13% of variance. Most of the tropical ocean is out of phase with the Pacific warm pool.
- Third mode of SST accounts for about 8% of variance, and is not well separated from the fourth mode. Likely related to variability in the Indonesian throughflow.