Recent Progress in Modeling TSI using Ground-Based Data

The Solar Output is Greater at Solar Max by 0.1%

- It is still not understood why the solar output is greater at solar max.
- The long-term emission of faculae outweighs the long-term darkness of sunspots
- How is energy partitioned between the different magnetic fields?
  - On the short term?
  - On the long term?
The next slide is the TSI composite for cycles 21, 22 & 23

- TSI composite created by Fröhlich and Fröhlich and Lean
- Composite created using data from ACRIM-1, Nimbus-7, ACRIM-2 and VIRGO space experiments
The Composite TSI (Fröhlich)

- The upper plot is the composite TSI created by Fröhlich for cycles 22 and 23
- As described in deToma et al. Cycle 23 appears to be anomalous
CFDT2 blue image

- 82 mm telescope objective lens
- 1024 x 1024 pixels
- 2.5” square pixels
- Wavelength = 472.3 nm
- Bandpass = 10 nm
- Image date = 2003 October 28
CFDT2 Narrow K-line image

- Wavelength = 393.4 nm
- Bandpass = 0.34 nm
- Date = 2003 October 28
Variations in TSI

• Variations in K-line excess dominated by facular regions larger than about 100 μhem
• Most of long-term variation in TSI is due to these larger facular regions
• This is true for data from both SFO CFDT1 (5” pixels) and HAO PSPT (1” pixels)
Area Distribution of PSPT K Faculae

The graph shows the distribution of faculae areas with the y-axis representing the number of regions per square micrometer and the x-axis representing the area in square micrometers. There are four curves, each labeled as CFDT1 1991, PSPT 1998, PSPT 1999, and PSPT 2002, indicating the area distribution from different years.
Definitions of photometric quantities:

\[ D_r = \text{Deficit from a Red Image} \]

\[ D_r = \sum_{\text{features}} C_i A_i \phi(\mu_i) \quad (1) \]

\[ \Sigma_K = \text{Sum of All K-line Pixels} \]

\[ \Sigma_K = \sum_{\text{all pixels}} C_i A_i \phi(\mu_i) \quad (2) \]
K-line faculae versus MgII c/w

• High correlation between SFO K-line spectral index and MgII core/wing ratio
K-line vs. MgII c/w
K-line from San Fernando Obs.
Residuals from fit to ACRIM2 TSI
Creation of a composite sunspot index

- Regressed HAO PSPT red spot deficits against SFO red and blue spot deficits
- Fit had an R-squared of 0.99 using SFO red (75%) and blue (25%) deficits
- Resulting composite fills in missing days
composite deficit, no time correction
composite using sfo(blue and red) cfdt2

ppm

01-Sep-03  17-Sep  03-Oct-03  19-Oct-03  04-Nov-03  20-Nov-03
date

--- pspt red --- sfo composite
Correlation of SORCE TSI with SFO irradiance indices
SFO/PSPT spot composite

- PSPT is given by 75% of SFO red and 15% of SFO blue
Jumps in the Nimbus-7 TSI

The next slide shows the period of two jumps in the Nimbus-7 TSI.

The first jump was 0.31 W/m^2 on 29 Sept. 1989 and the second jump was 0.37 W/m^2 on 9 May 1990.
NIMBUS-7 vs CFDT1 w/NOAA9 DATA
747 Data Points - 1988-93

RESIDUALS, (Nimbus-SnN), W/m²

Day of Year, May 88 - Dec 93
SFO data fit to SORCE TSI

• 8 calendar months
• CFDT2 (1024 x 1024 pixels, 2.5”)
• 2 parameters;
  – Spot deficit from red images
  – Facular excess from K-line images
• R-squared = 0.975
Comments

• Small Active Regions have an energy excess over their life (True for large ones?) Where does this energy come from?

• One cannot determine if the Quiet Sun is constant over time unless activity is properly removed. (This includes times near solar minimum.)

• Ignoring noise, about 10% or less of TSI variation is unexplained.
Summary

• The TSI record appears to be getting better over time.

• Sunspots and faculae can explain all but about 15% of the Fröhlich composite TSI over cycles 22 and 23 (similar to ACRIM2)

• For 8 months, fits to SORCE TSI have an unexplained variance of about 2.5%
Conclusions

- To understand all sources of variation in the solar output, we need to model the effects of magnetic features as well as possible.
- Observations should continue for a long time to search for possible secular solar changes.