17 Years of Highlights from the SORCE/TIM

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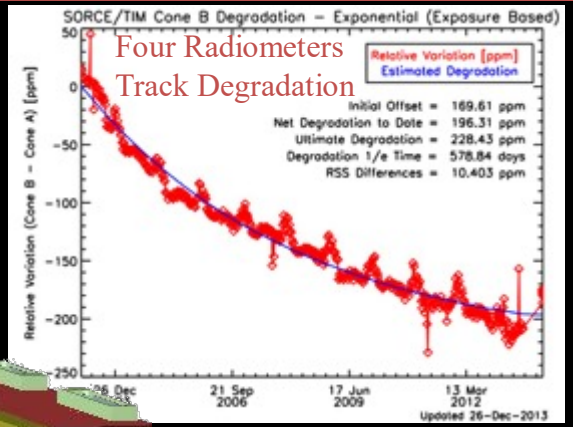
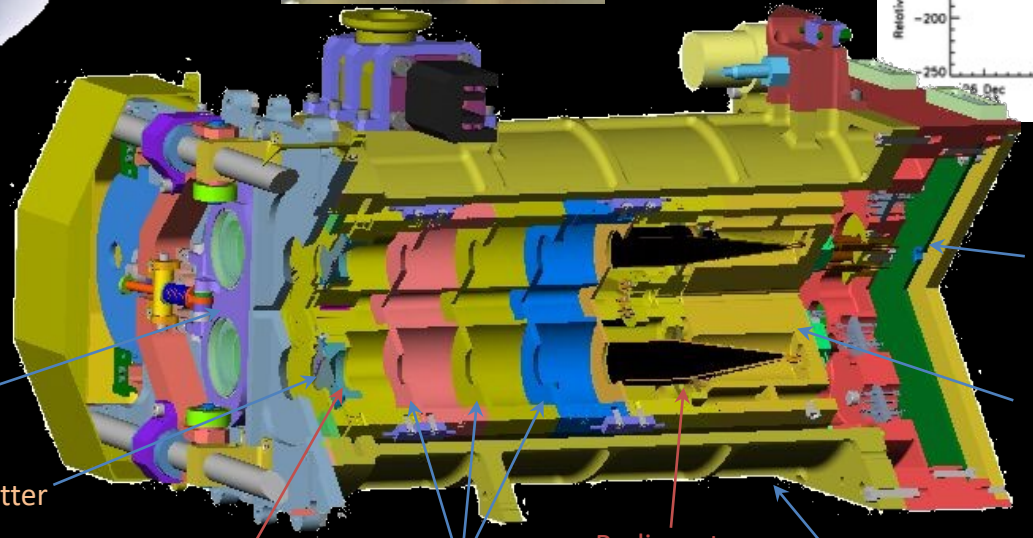
LASP / Univ. of Colorado

Total Irradiance Monitor (TIM) Instrument Overview

Total Irradiance Monitor (TIM)



Four Radiometers Track Degradation



Detector Head Board

Heat Sink

Vacuum Door

Shutter

Precision Aperture

Light Baffles

Radiometer

Vacuum Shell

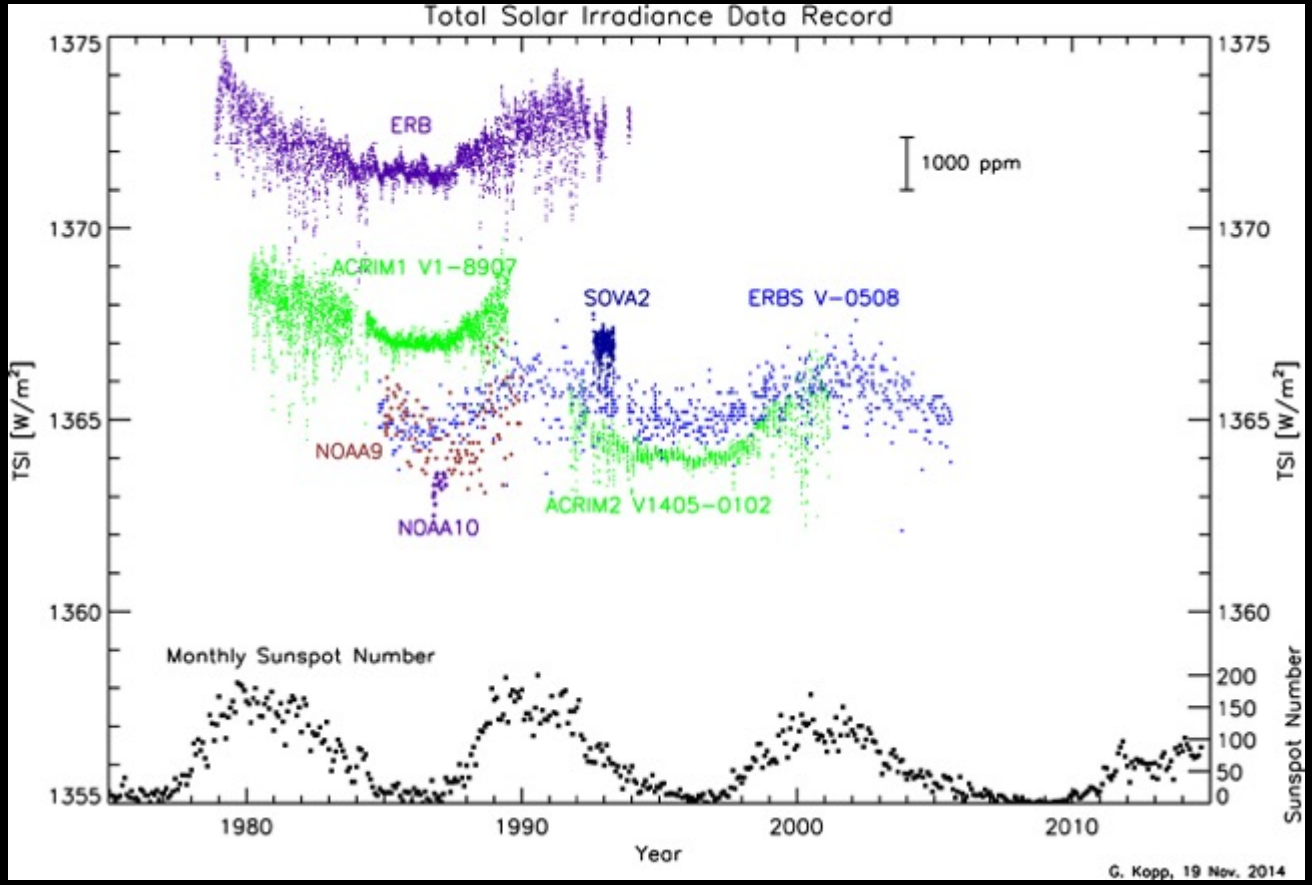
TIM Innovations Enable Accuracies & Stabilities

The Total Irradiance Monitor, first launched on NASA's SORCE mission in 2003, introduced several measurement innovations

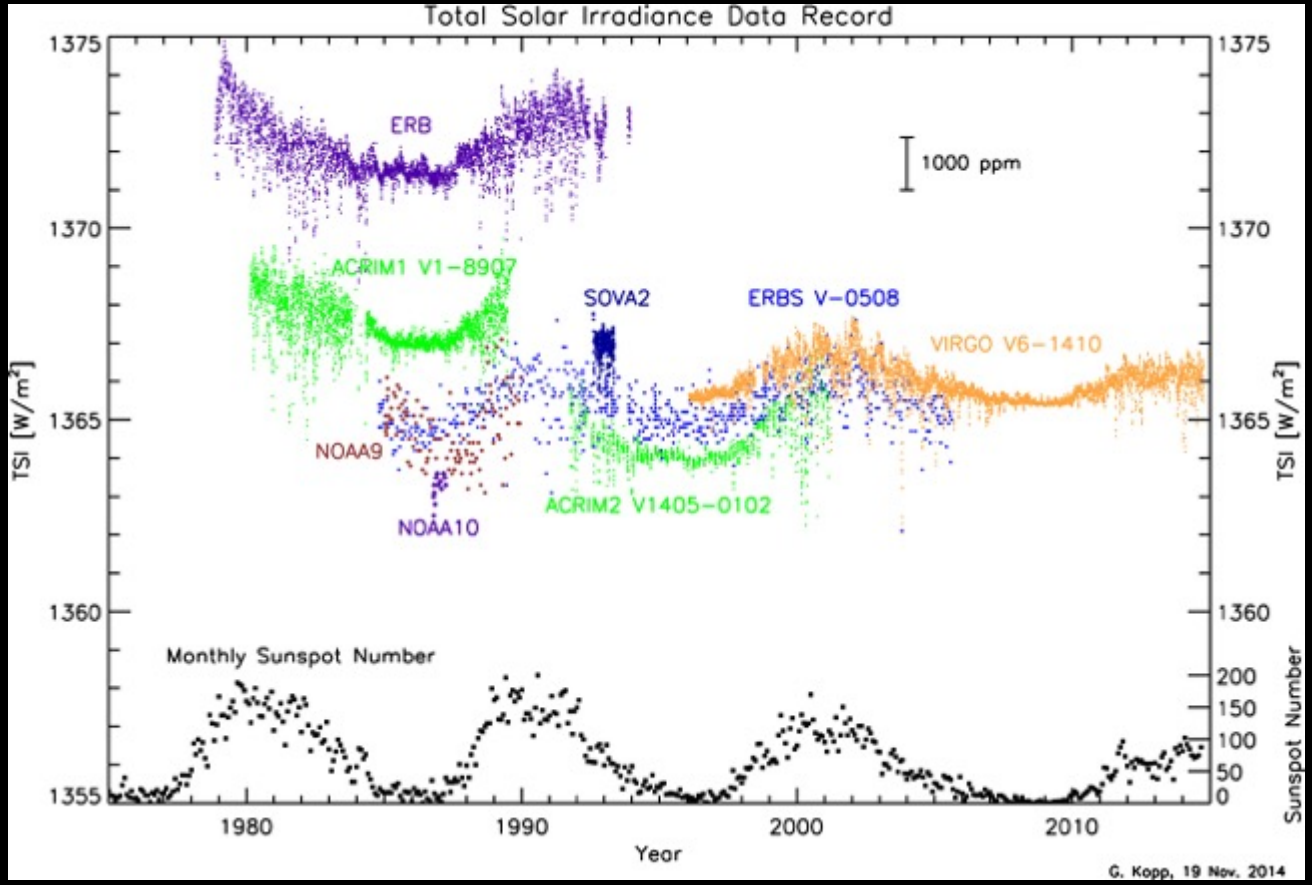
- Precision aperture at **front** of instrument
- **Nickel Phosphorus** cavity interiors demonstrate best inherent, on-orbit stability of any TSI instrument
- **Phase sensitive detection** of servo system and applied in signal analysis
  - Reduces sensitivity to out-of-band noise
  - Servo gain and non-equivalence only need to be known at shutter fundamental
- **Feedforward** maintains cavity thermal stability, improving servo response
- **Thermal contributions** are measured and modeled
- **Pulse width modulation** of precision DC voltage reference **applies power linearly**
- Digital servo system uses PID control
- Digital control of shutters

from (almost) every talk I give

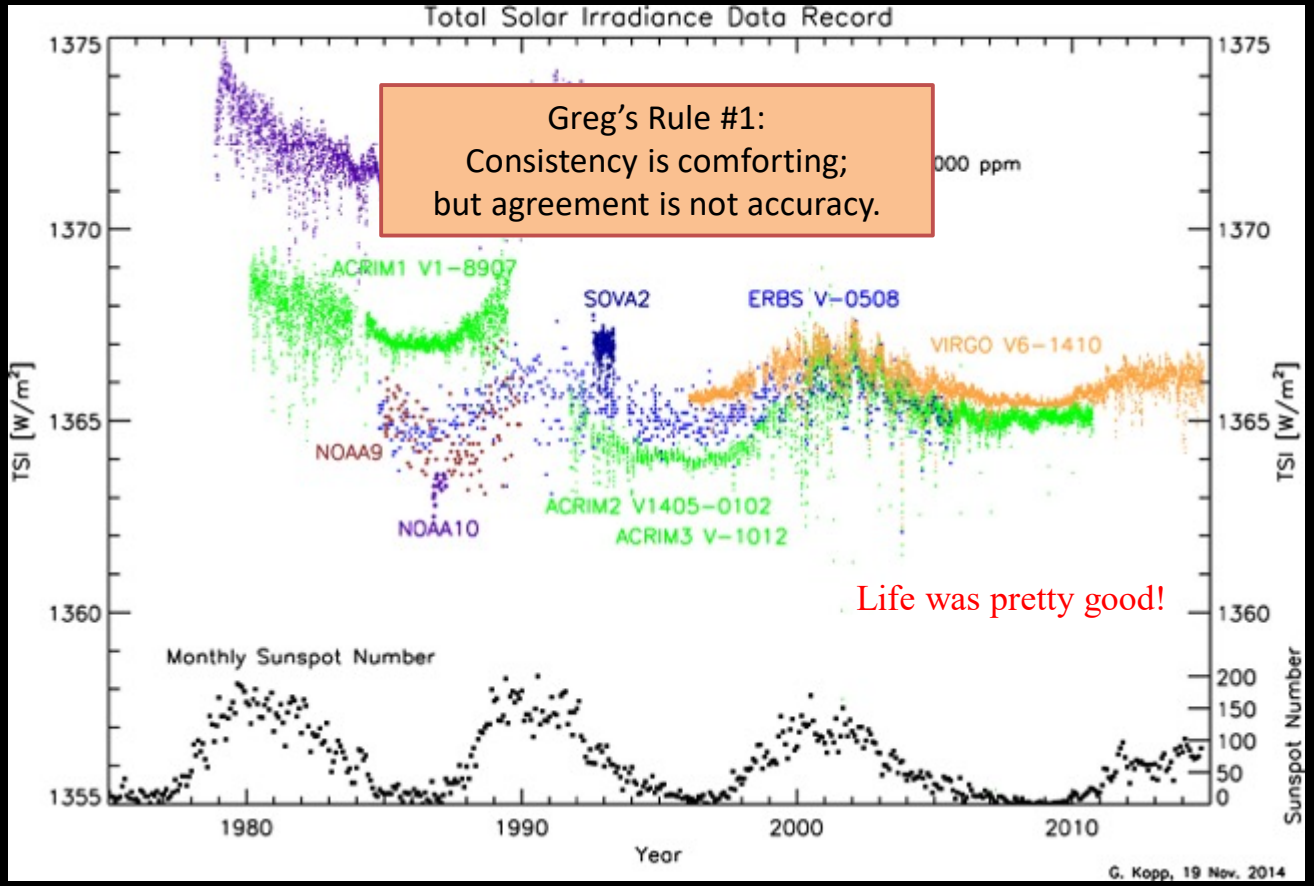
Evolution of the TSI Record



Evolution of the TSI Record



Evolution of the TSI Record



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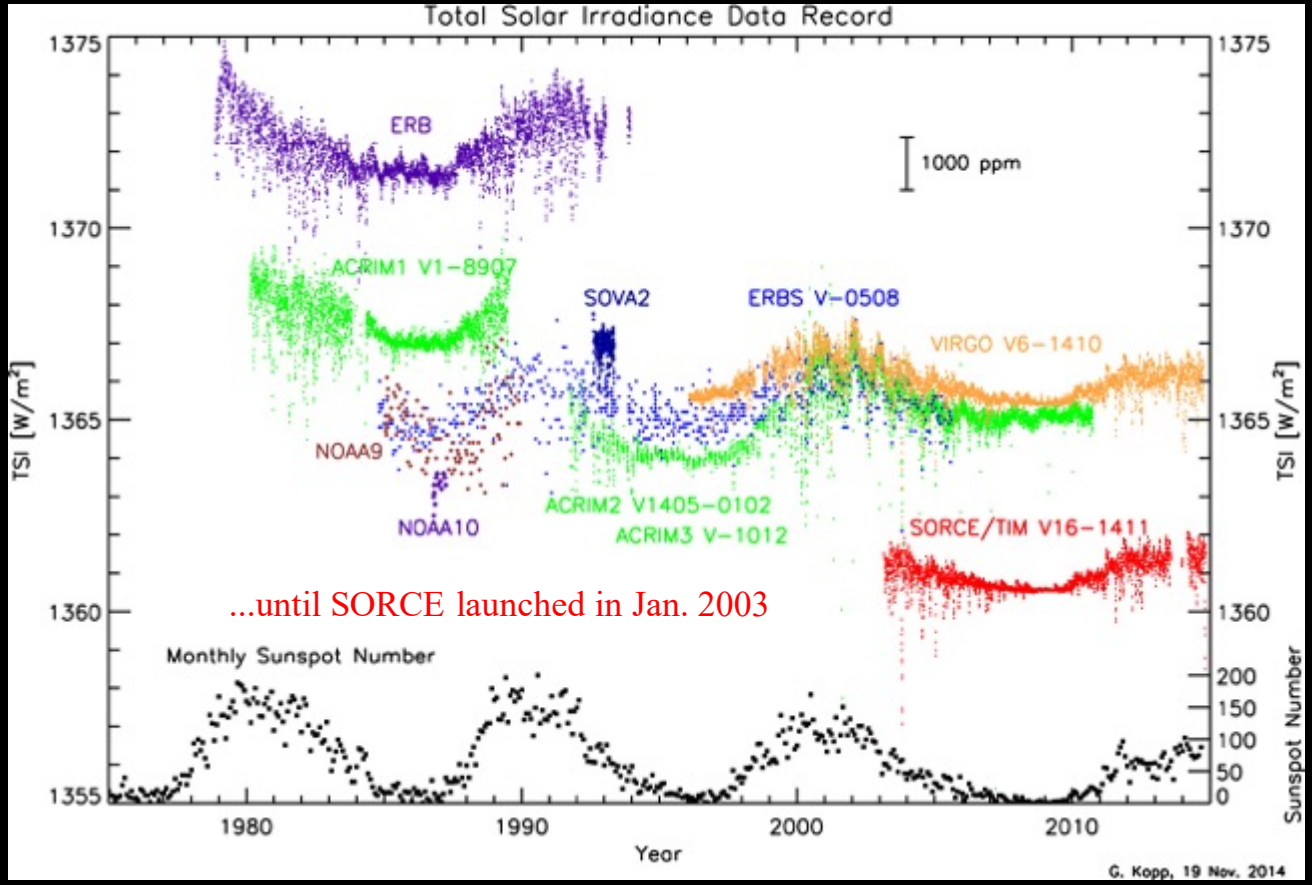
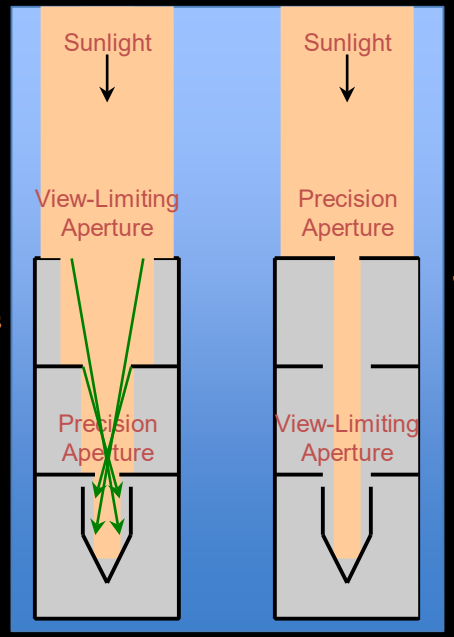


Diffraction & Scatter Erroneously Increase Signal

All instruments except the TIM put primary aperture close to the cavity

Expanding TRF beam from filling precision aperture while underfilling view-limiting aperture to overfilling view-limiting aperture causes increase in signal due to scatter and diffraction from front and interior sections of instrument

all other TSI instrument geometries



Additional light allowed into instrument can scatter into cavity

Majority of light is blocked before entering instrument

Kopp and Lean, *GRL*, 2011

TIM geometry

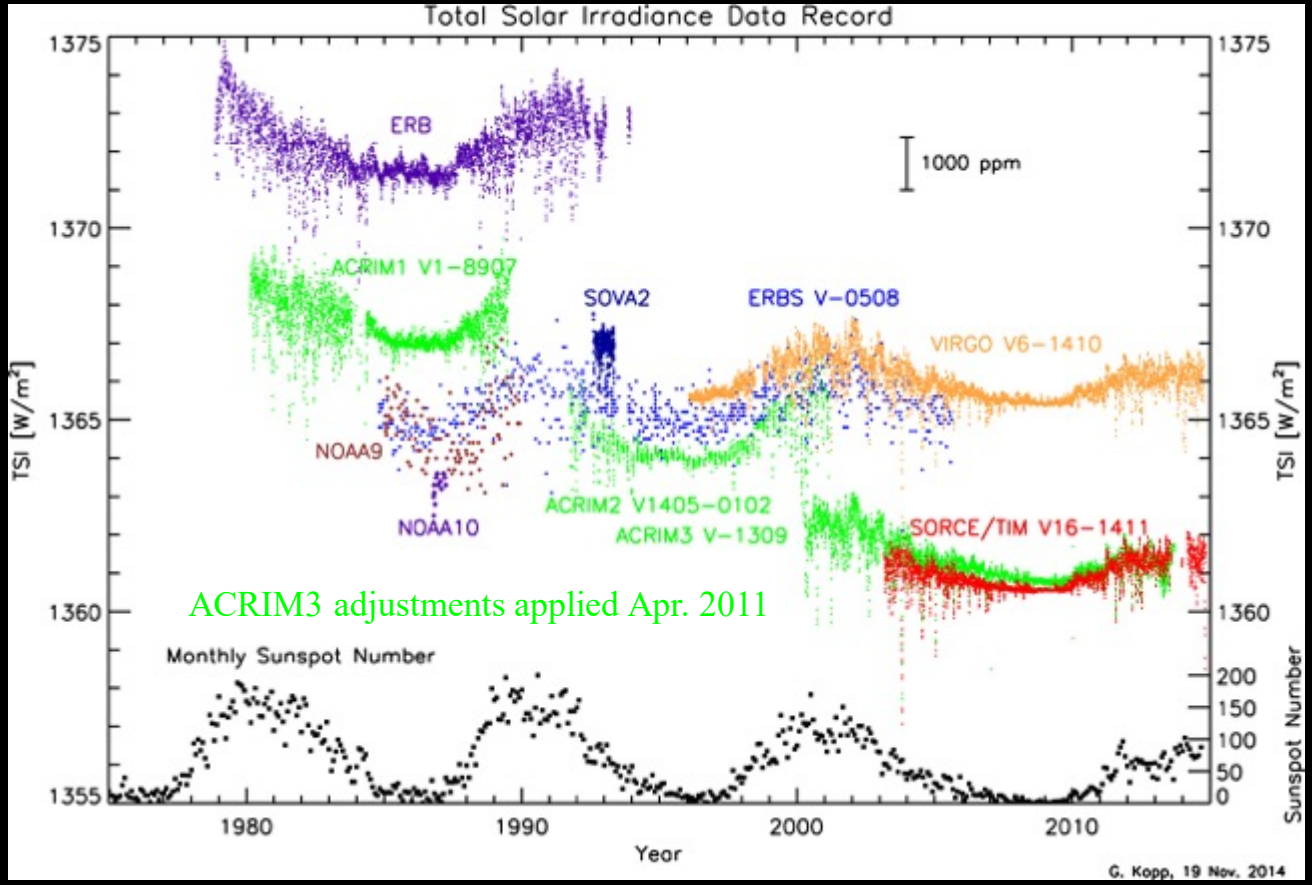
Measured increases due to uncorrected scatter/diffraction are surprisingly large

Instrument	Increase
PREMOS-1	0.10%
PREMOS-3	0.04%
VIRGO2	0.15%
ACRIM-3	0.51%
SOVAR	0.20%

This affects the World Radiometric Reference too

Fehlmann *et al.*, *Metrologia*, 2012 report the WRR measures TSI 0.34% higher than the true SI scale

Evolution of the TSI Record



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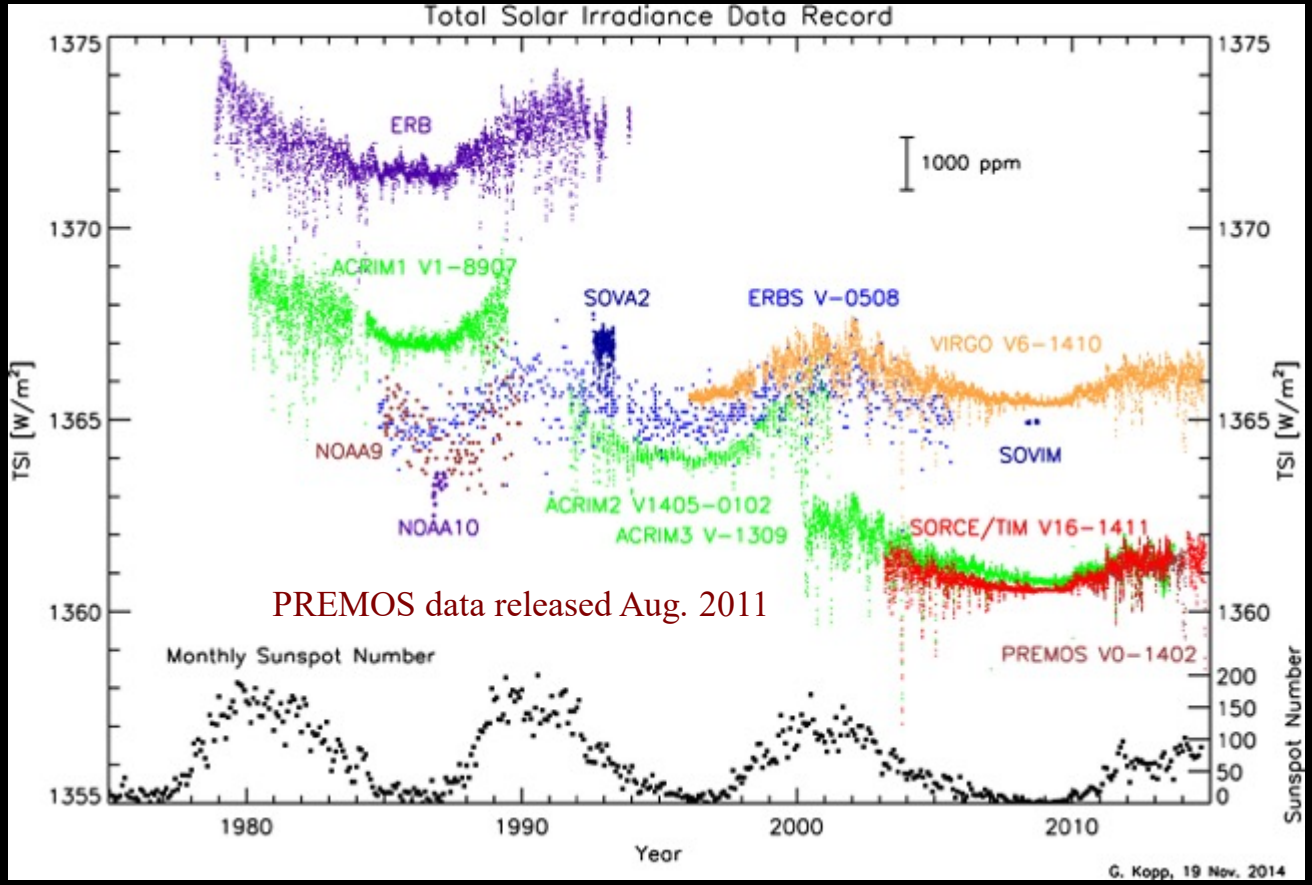

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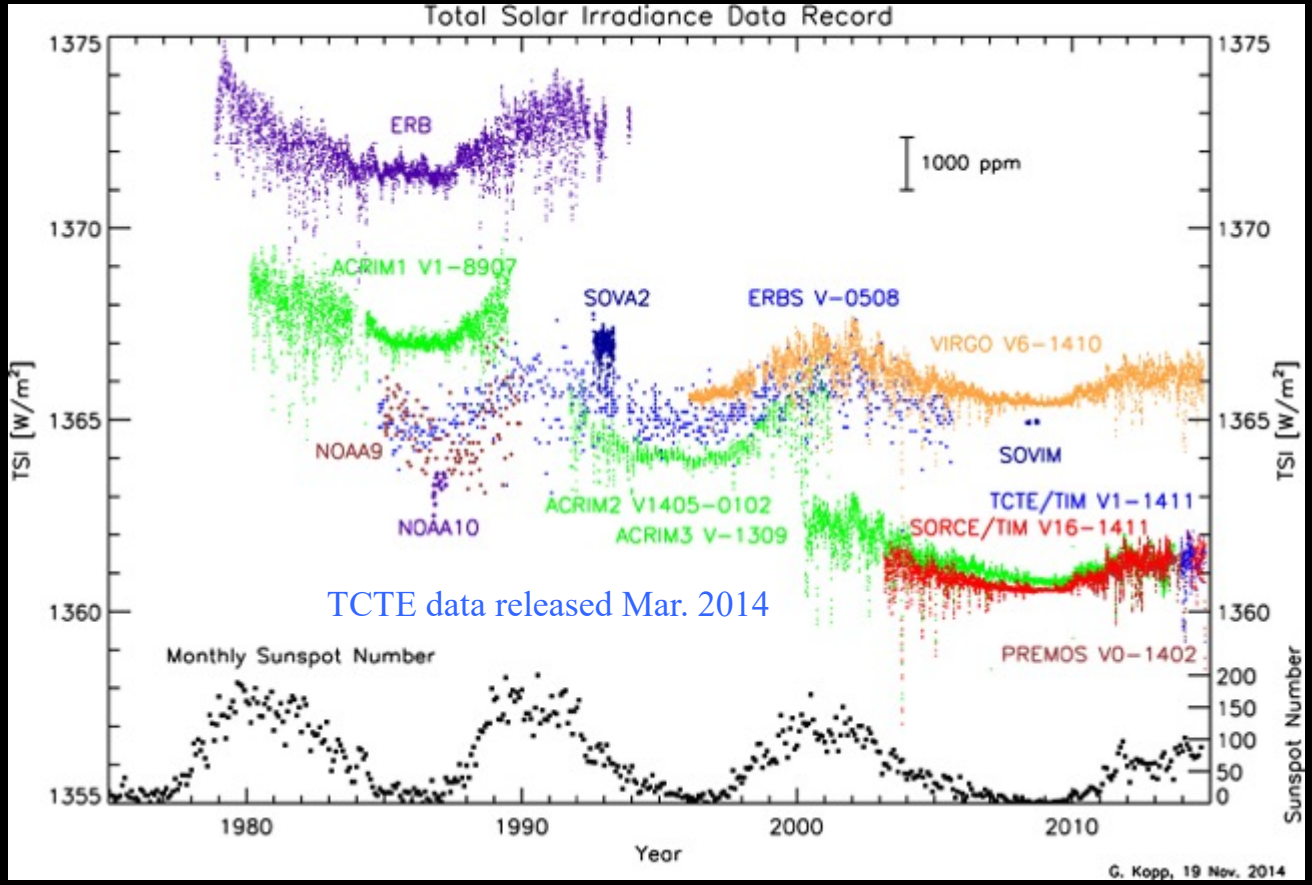
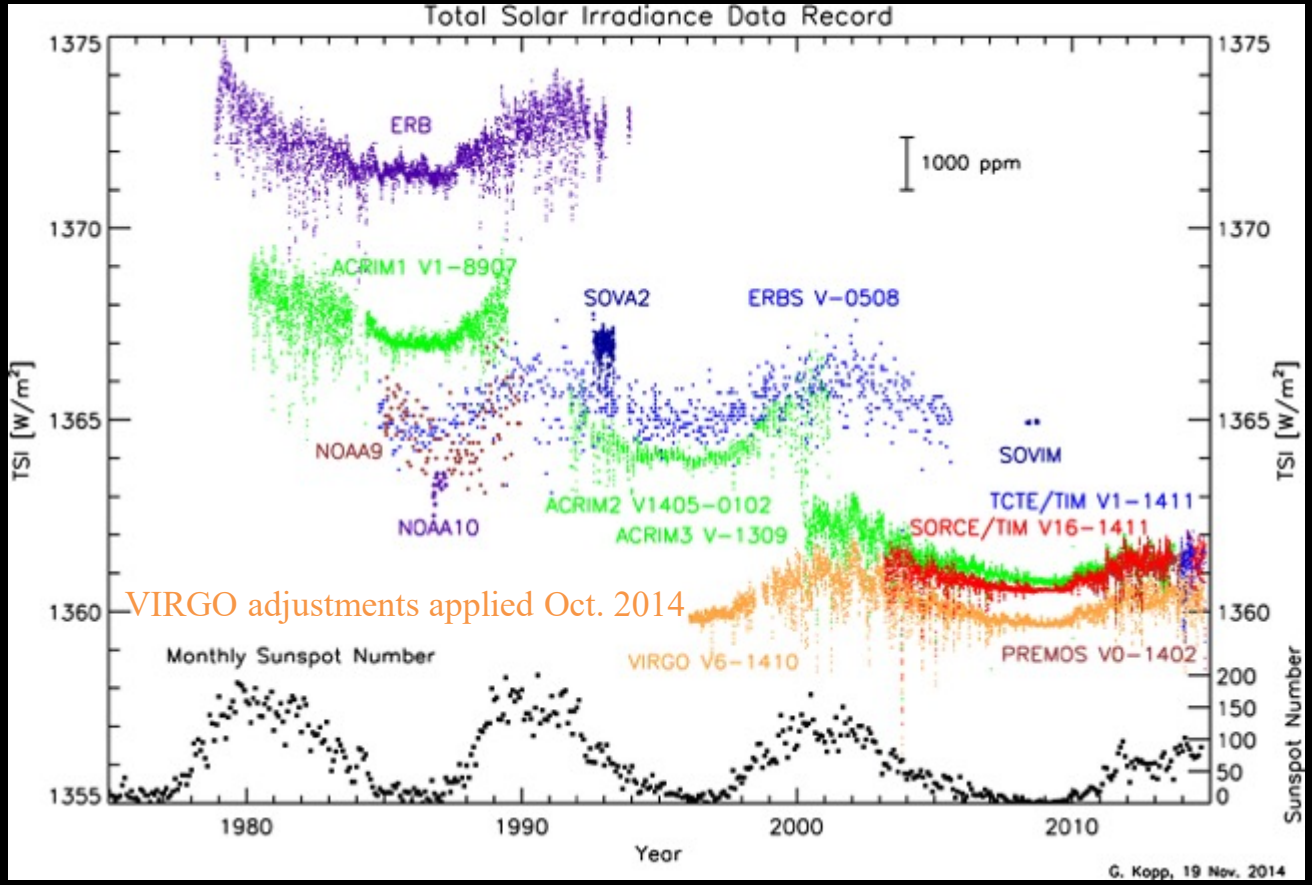


TCTE data released Mar. 2014

Evolution of the TSI Record



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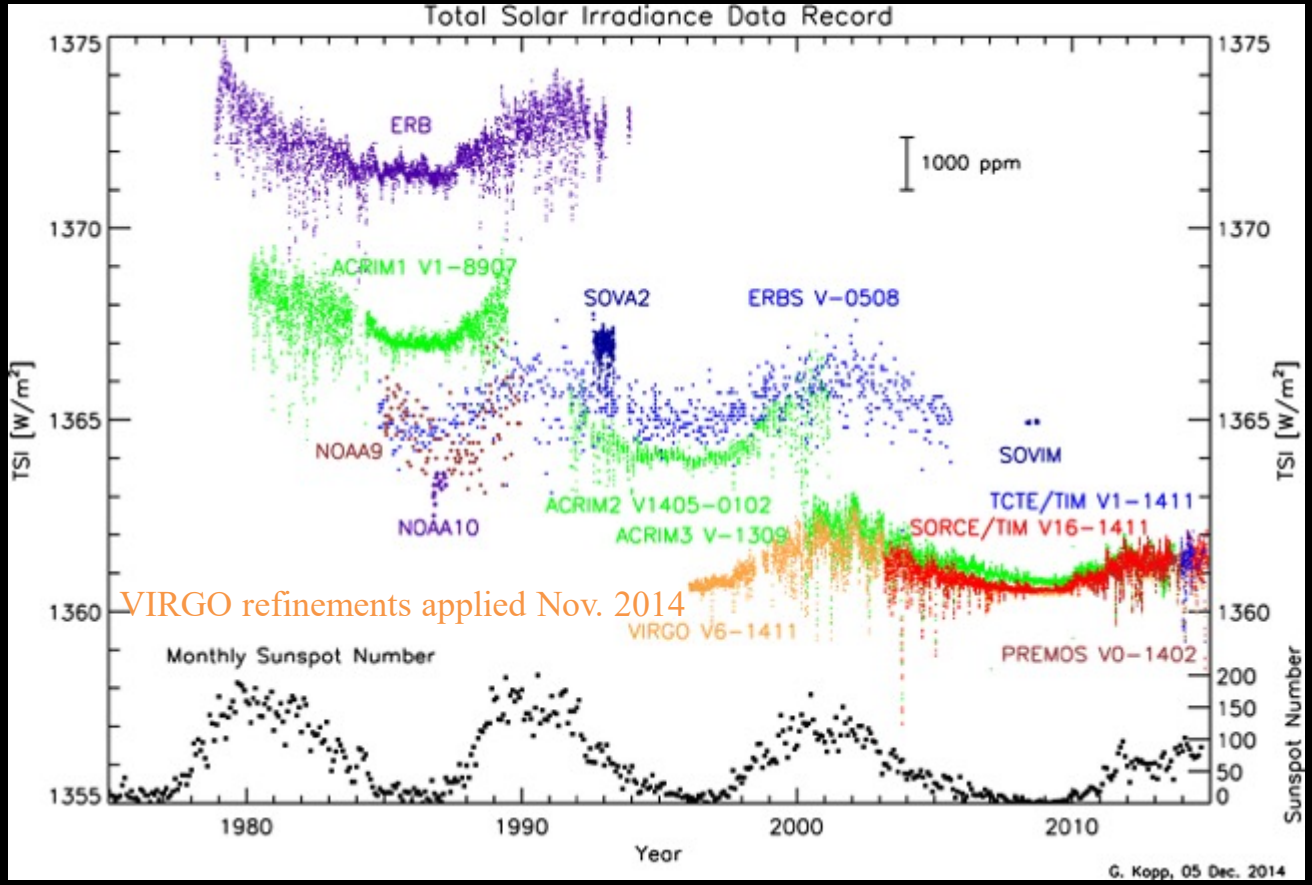

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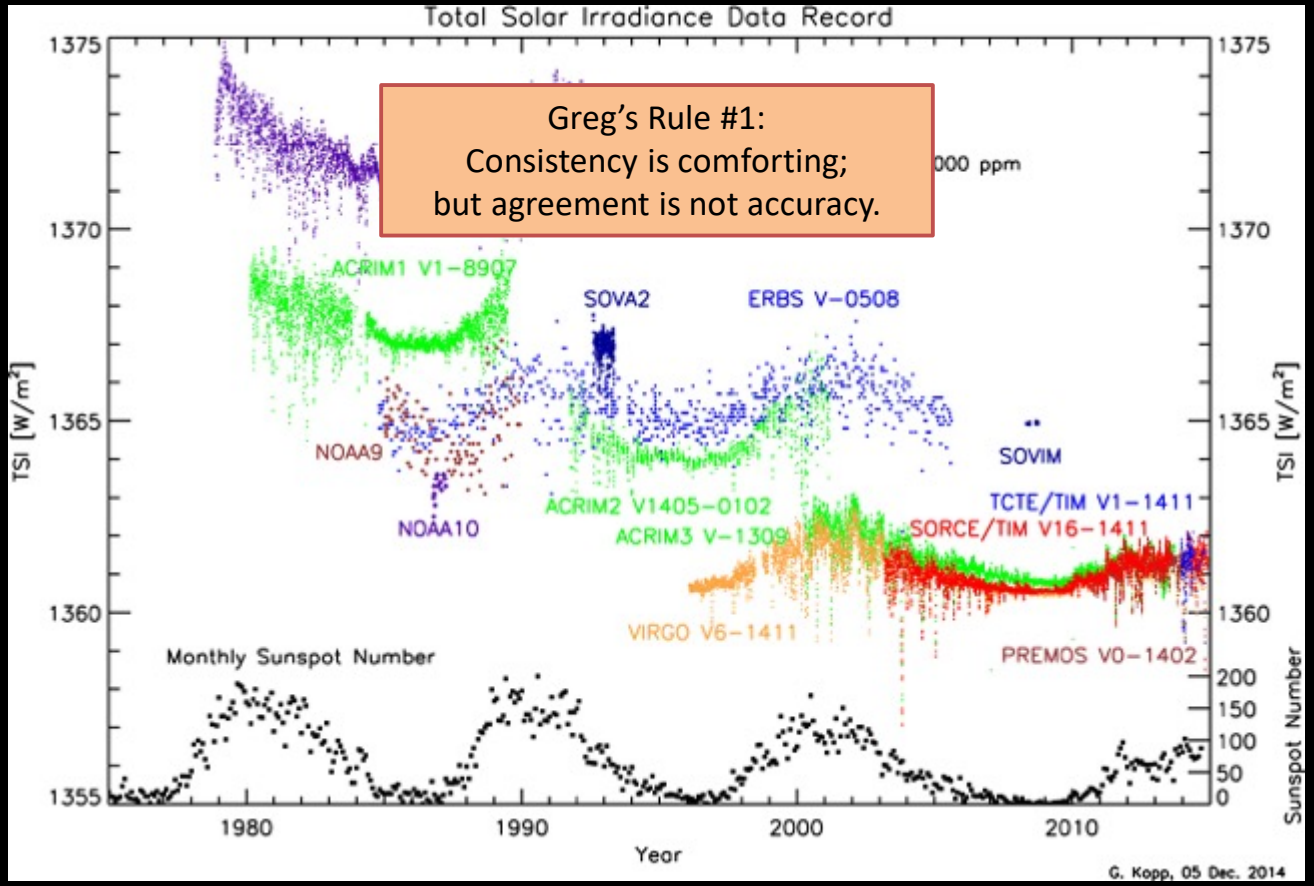
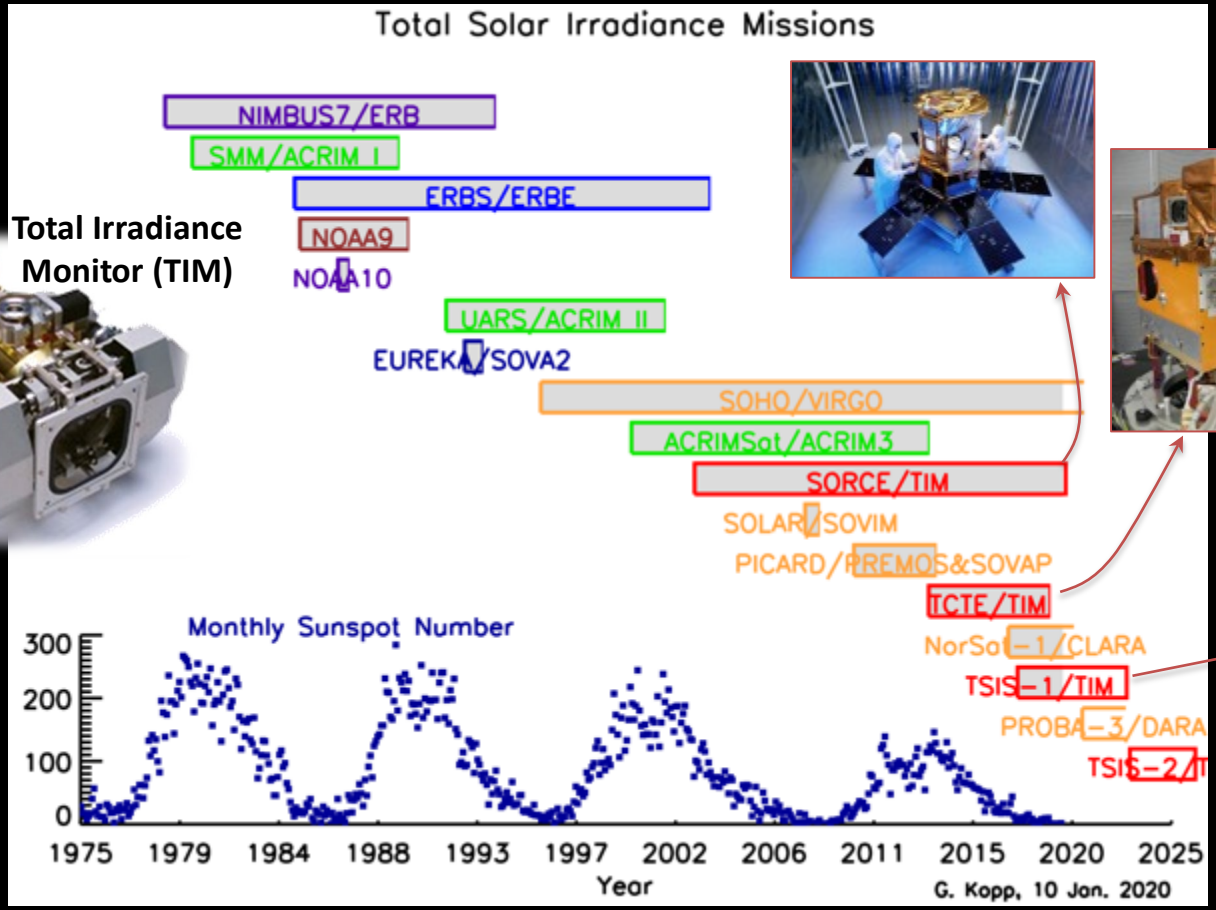
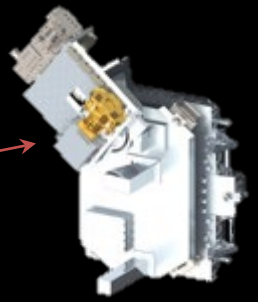


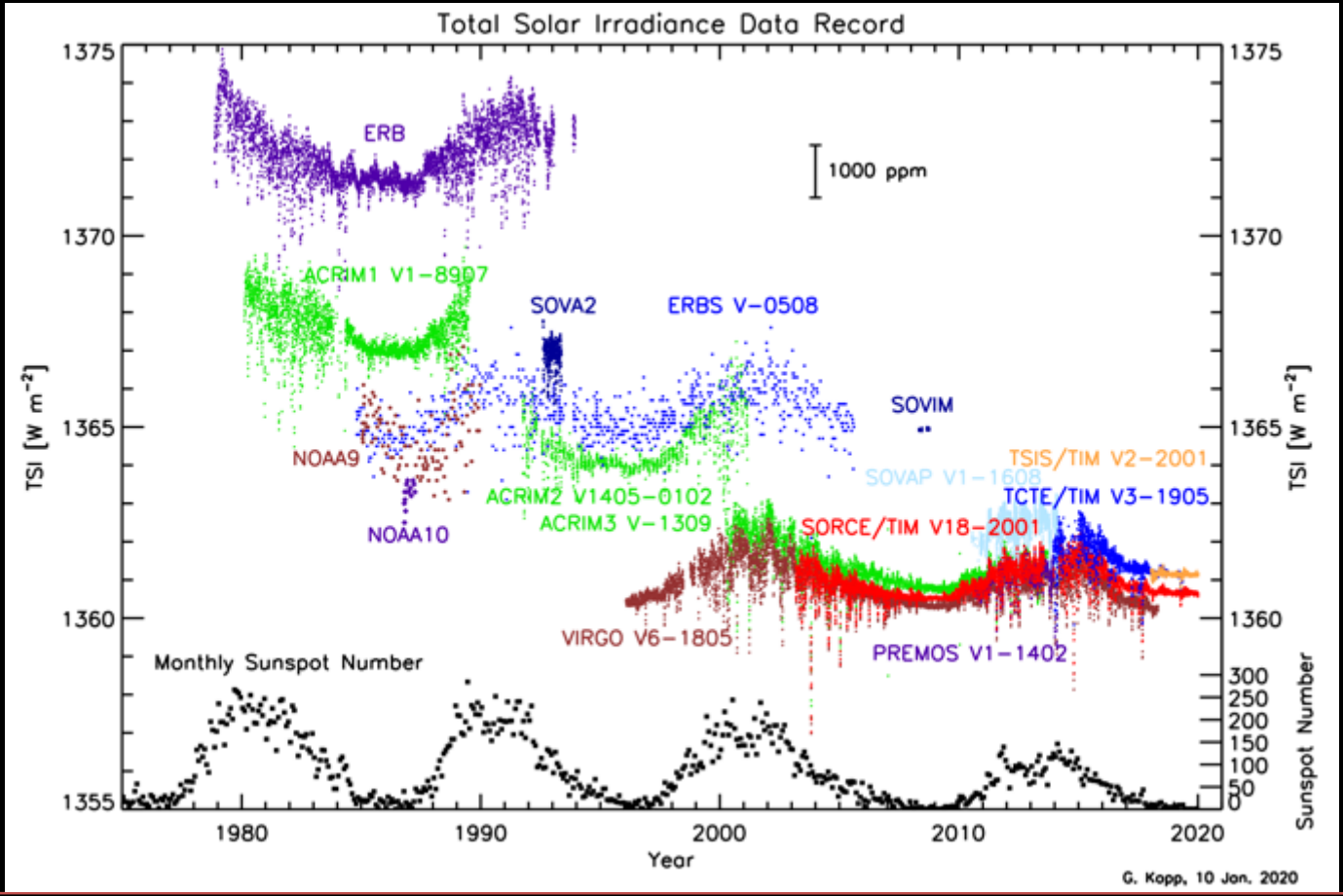
3 TIM Missions Currently On-Orbit

Total Irradiance Monitor (TIM)

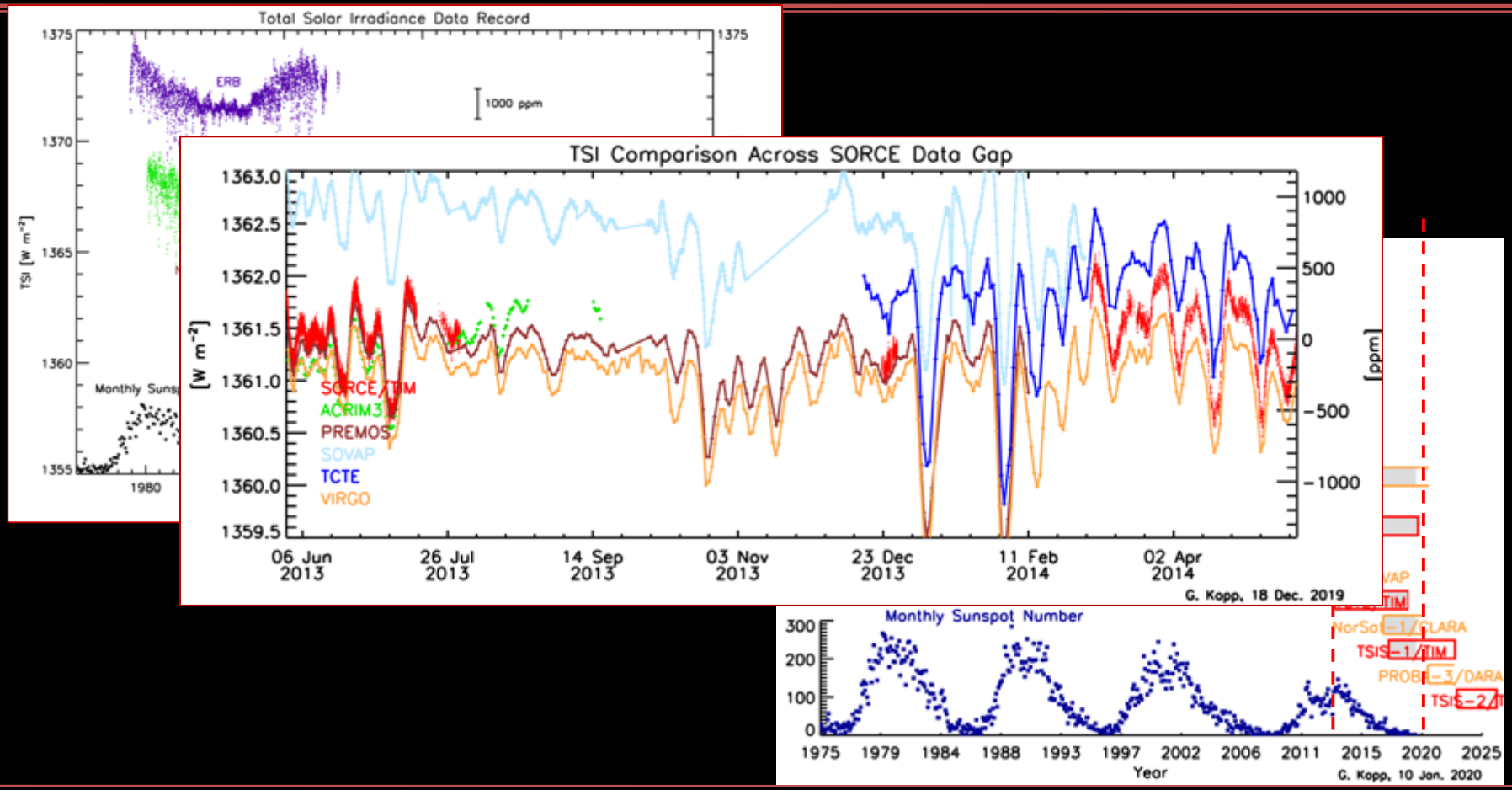




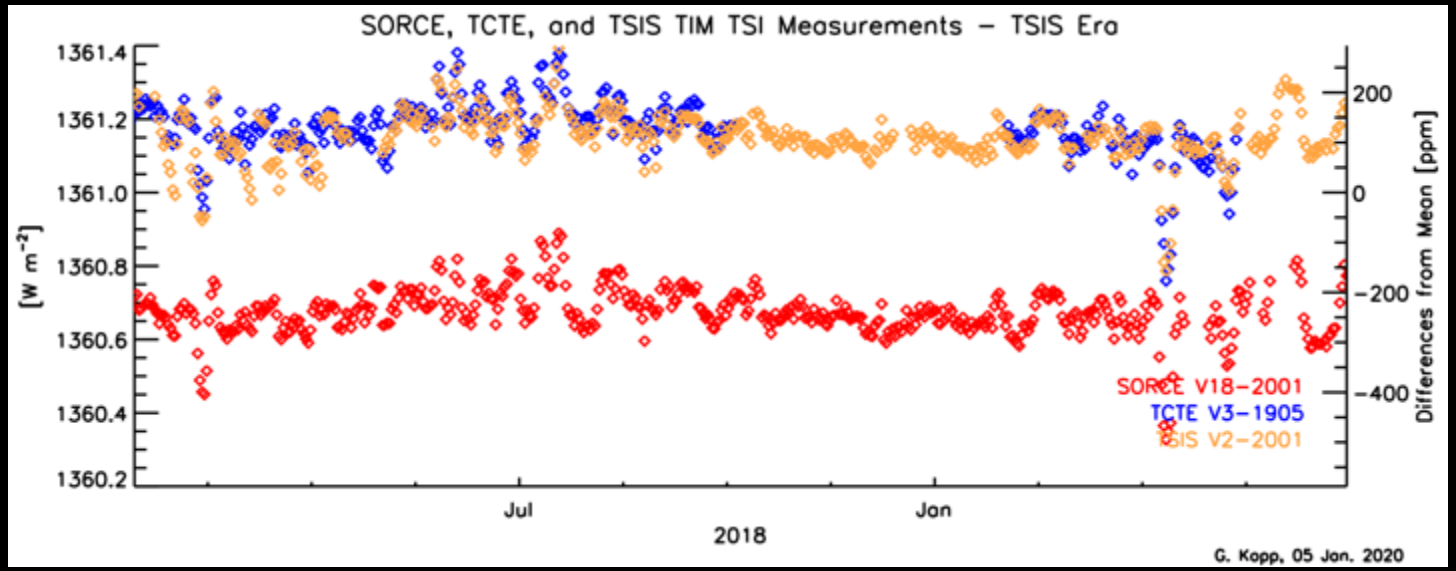
The Current TSI Record



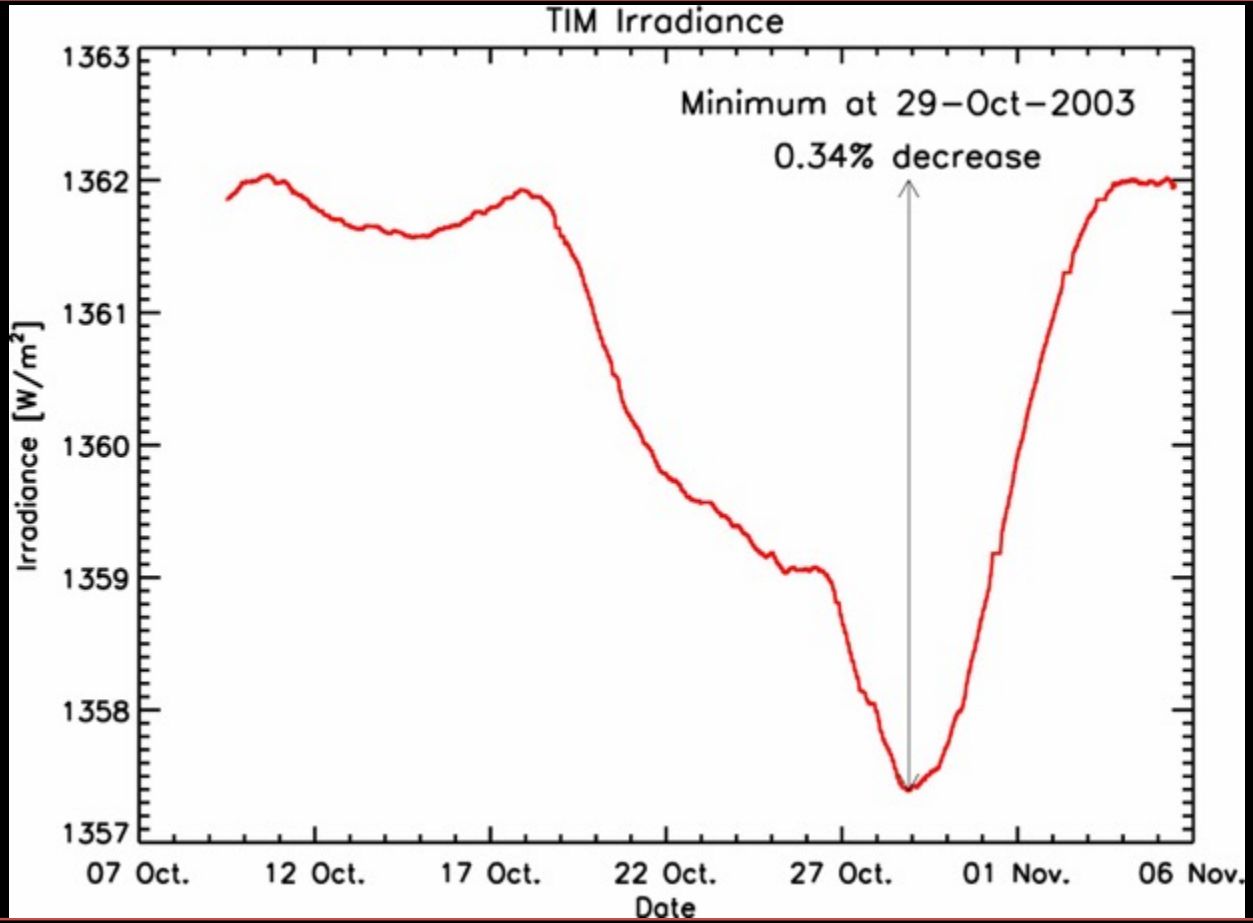
Status of Current TSI Instruments



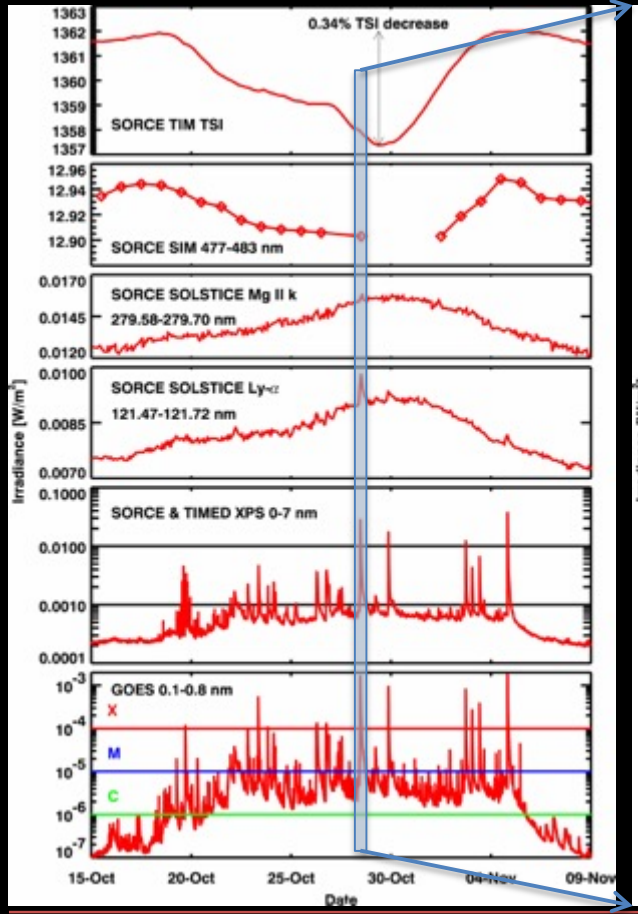
Measurements from Current TIM Instruments

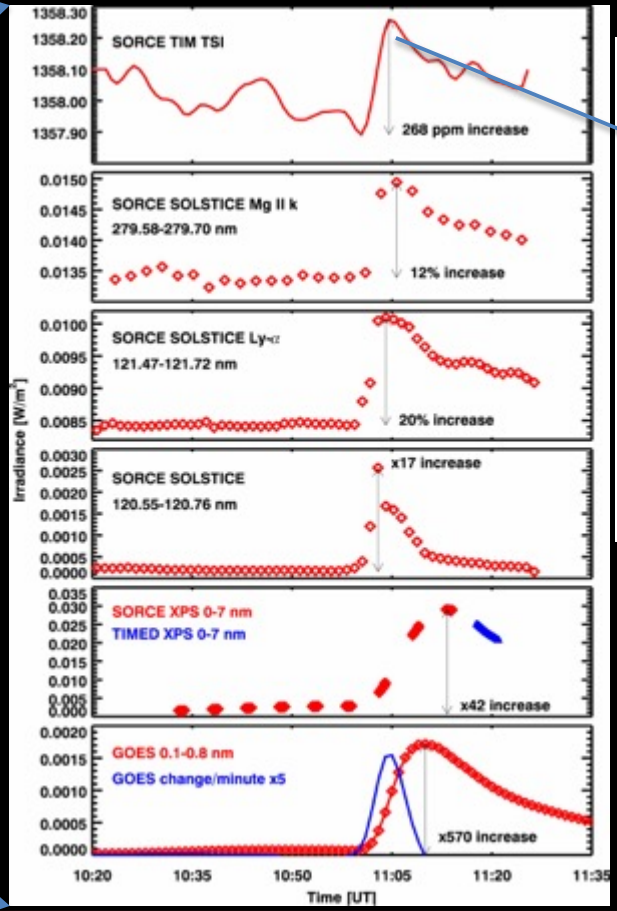


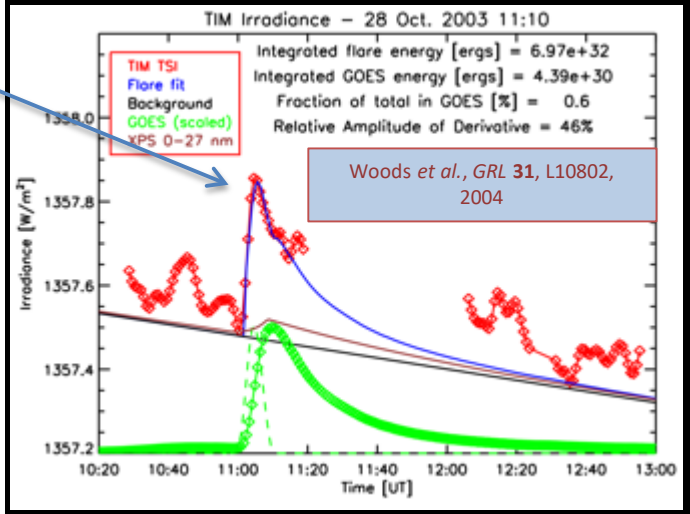
SORCE/TIM Observed the Largest Short-Term TSI Decrease Recorded



28 Oct. 2003 X17 SORCE Flare Observations





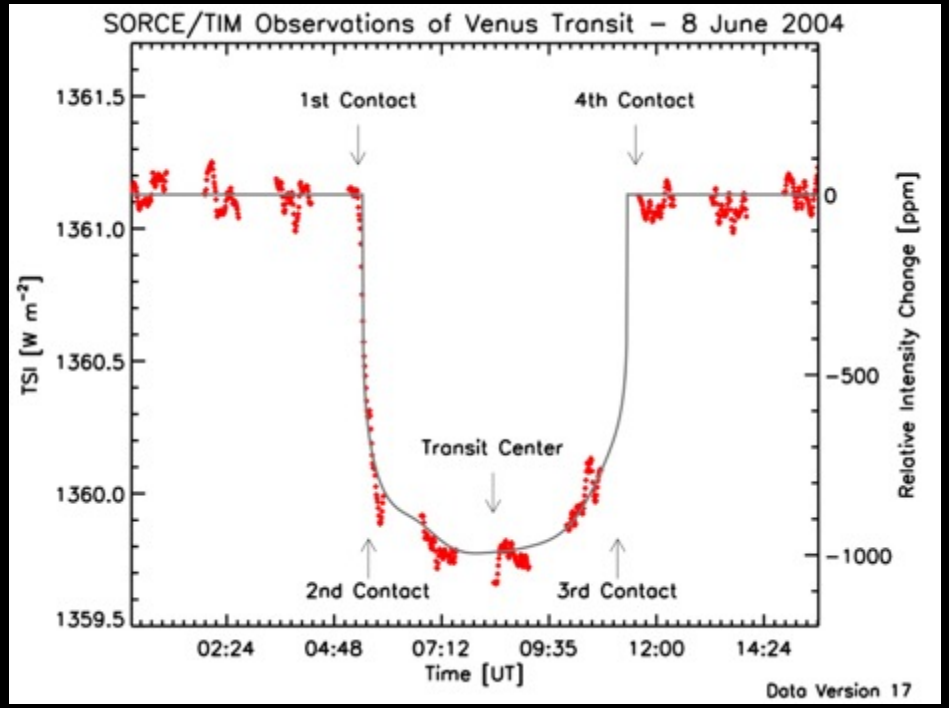


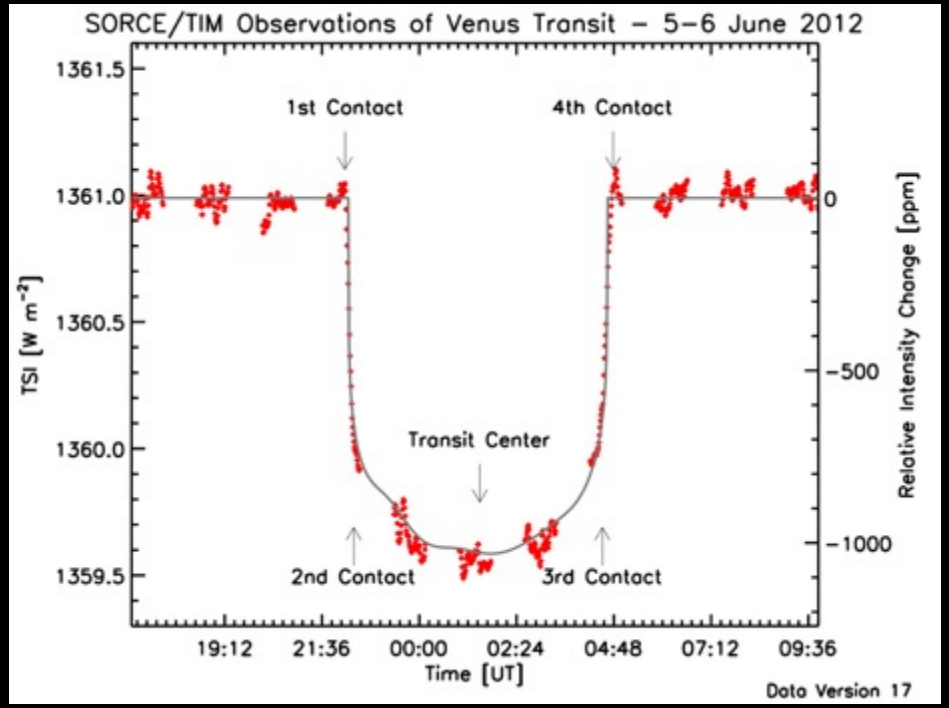
Woods *et al.*, *GRL* **31**, L10802, 2004

Perspective

Net flare energy is <0.008% of what the Sun emitted in that ~40-min. time range

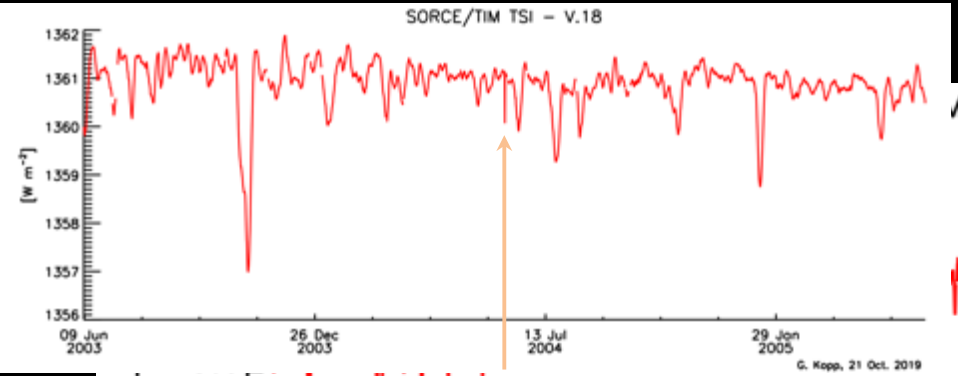
Two Venus Transit Measurements by SORCE/TIM

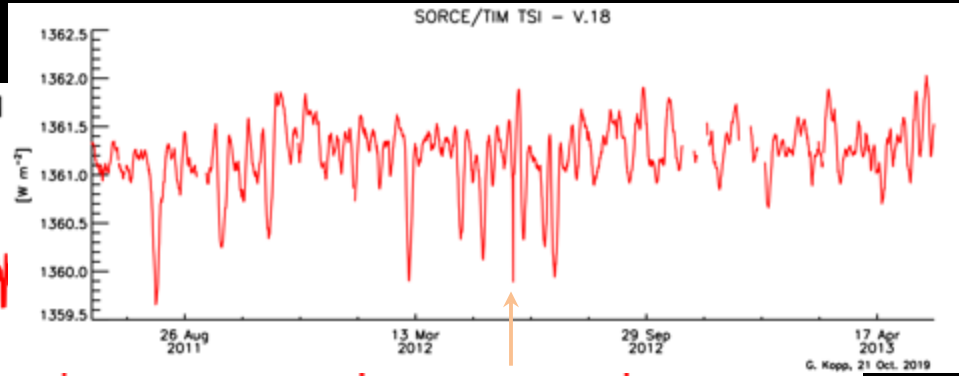


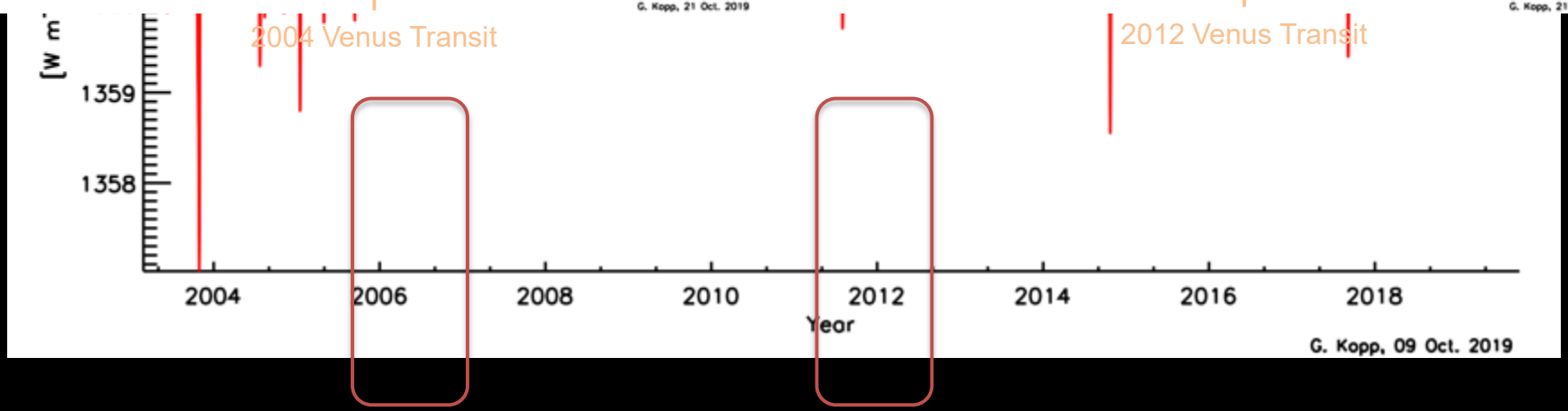


Venus transits occur in pairs 8 years apart separated by either 105.5 or 121.5 years

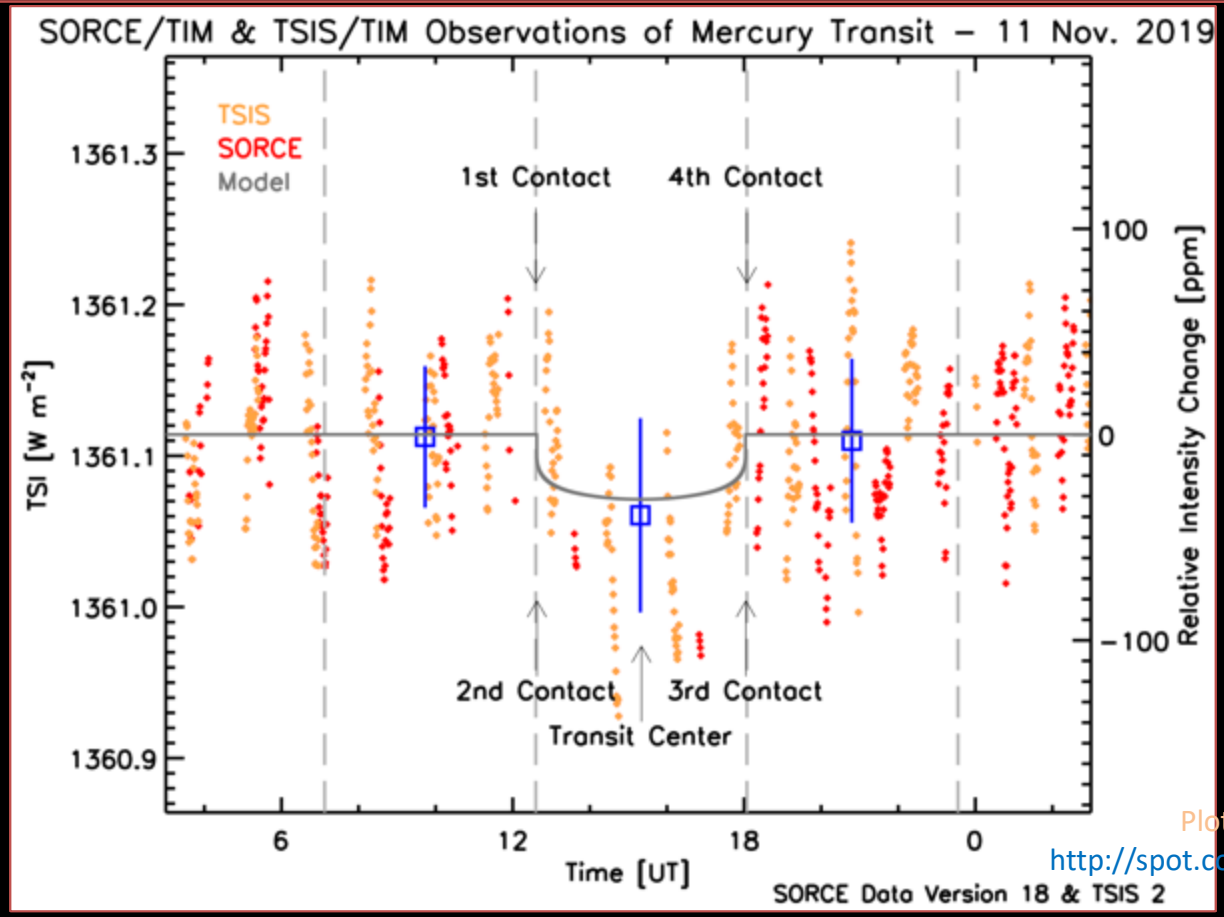
Venus Transit Detections





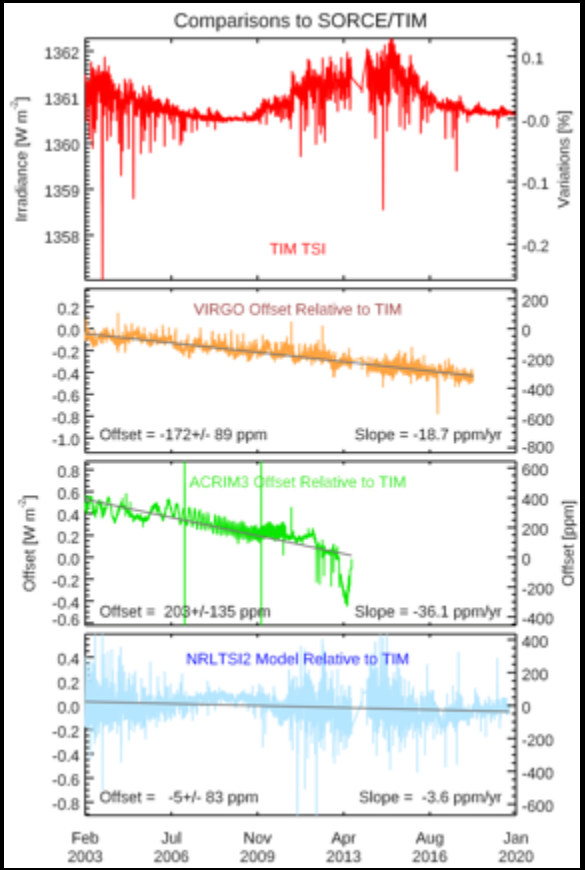


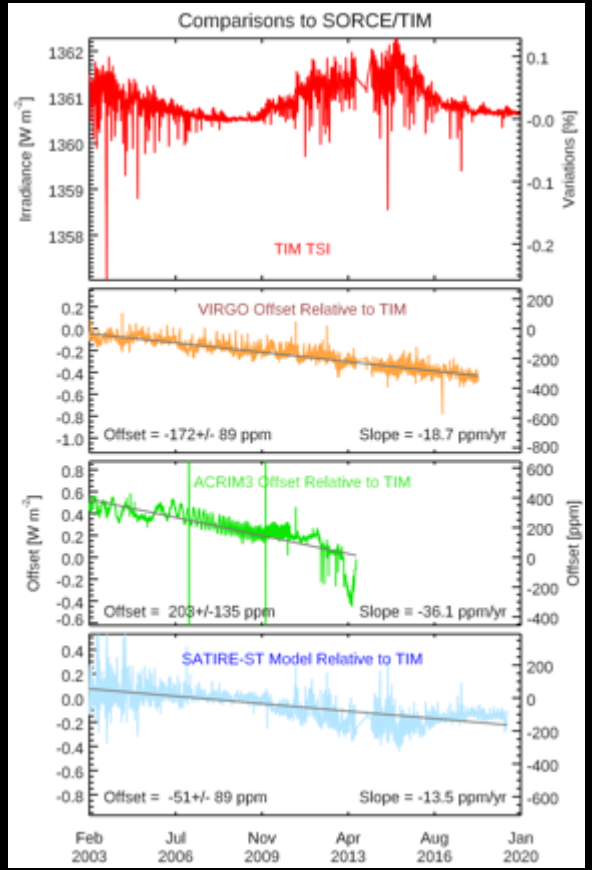
Mercury Transit "Observations"

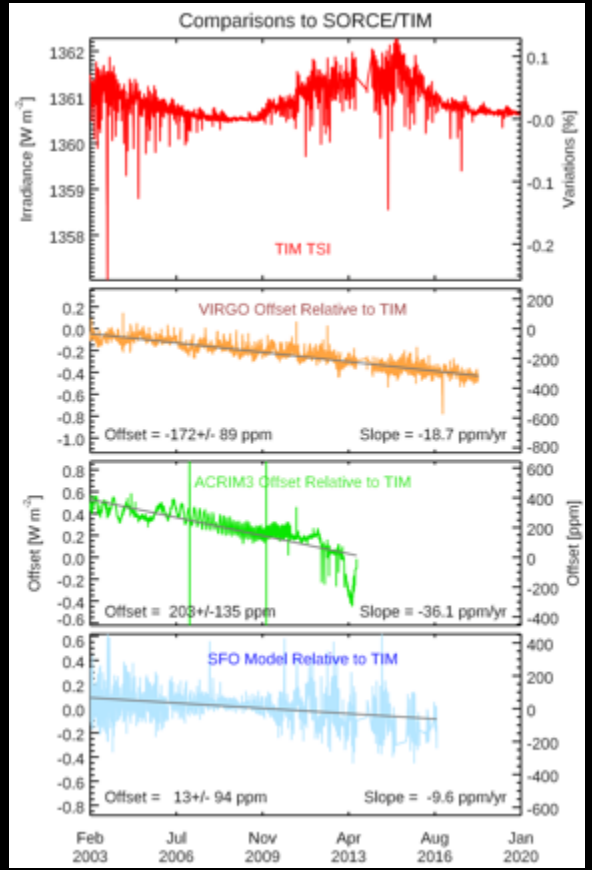


Plots available at
http://spot.colorado.edu/~koppg/TSI

What Are the TSI Trends?

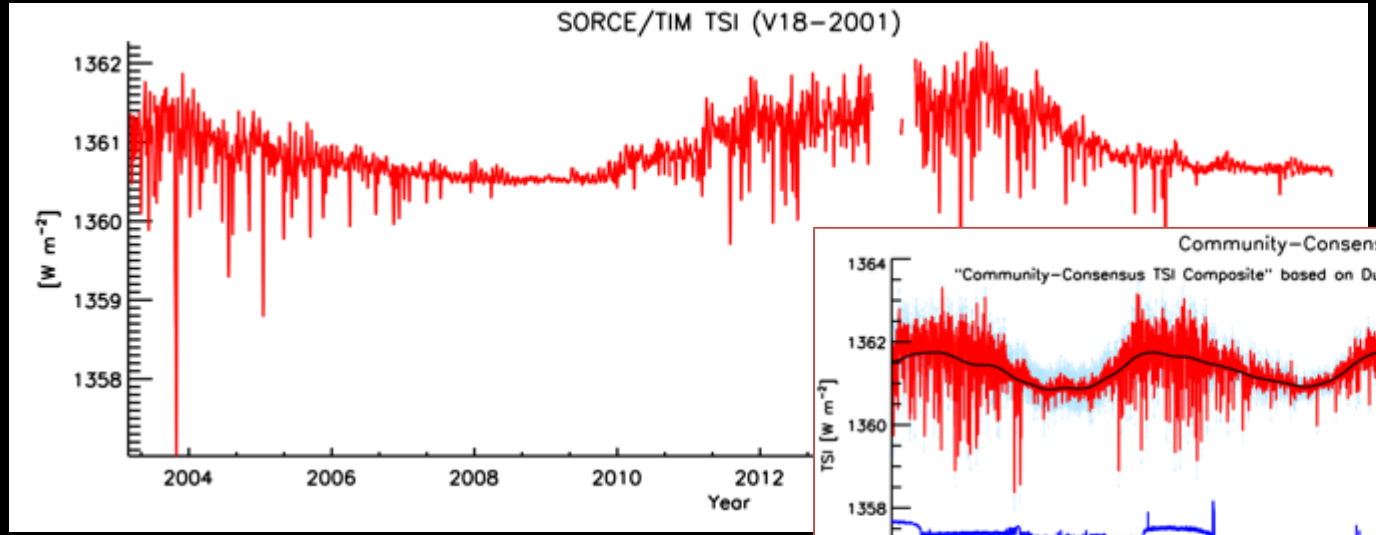
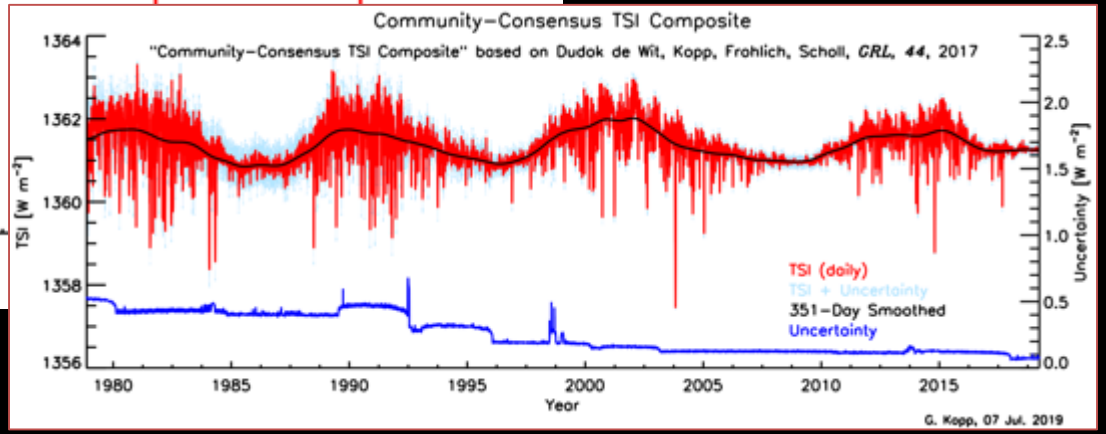






The SORCE/TIM Has:

- Established a *lower TSI value* of 1361 W m^{-2}
- Demonstrated *better inherent stability* than any other space-borne TSI instrument
- Shown *lower noise* than other contemporary TSI instruments
- Helped maintain measurement continuity of the TSI record
- Reported the *first measurement of a solar flare* in TSI
- Observed two Venus and four Mercury transits
- Recorded the largest short-term decrease ever measured in TSI

Value of TSI Measurements for Climate Science

1. Are the most stable solar-irradiance measurements
   - Achieve stabilities necessary to detect climate-relevant solar variability
2. Provide ~41-year solar-irradiance record of entire radiative input to Earth's climate system