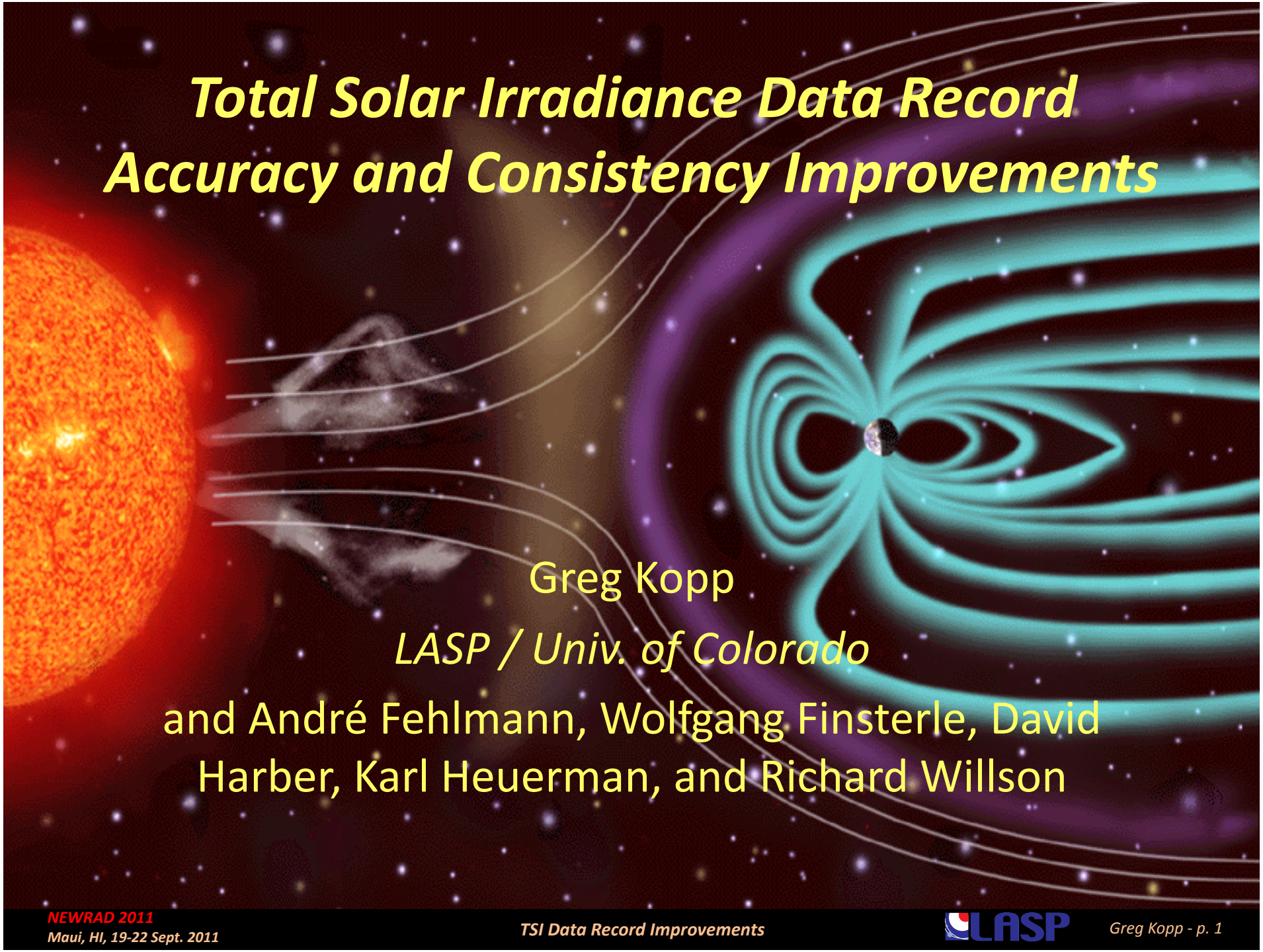
Total Solar Irradiance Data Record Accuracy and Consistency Improvements

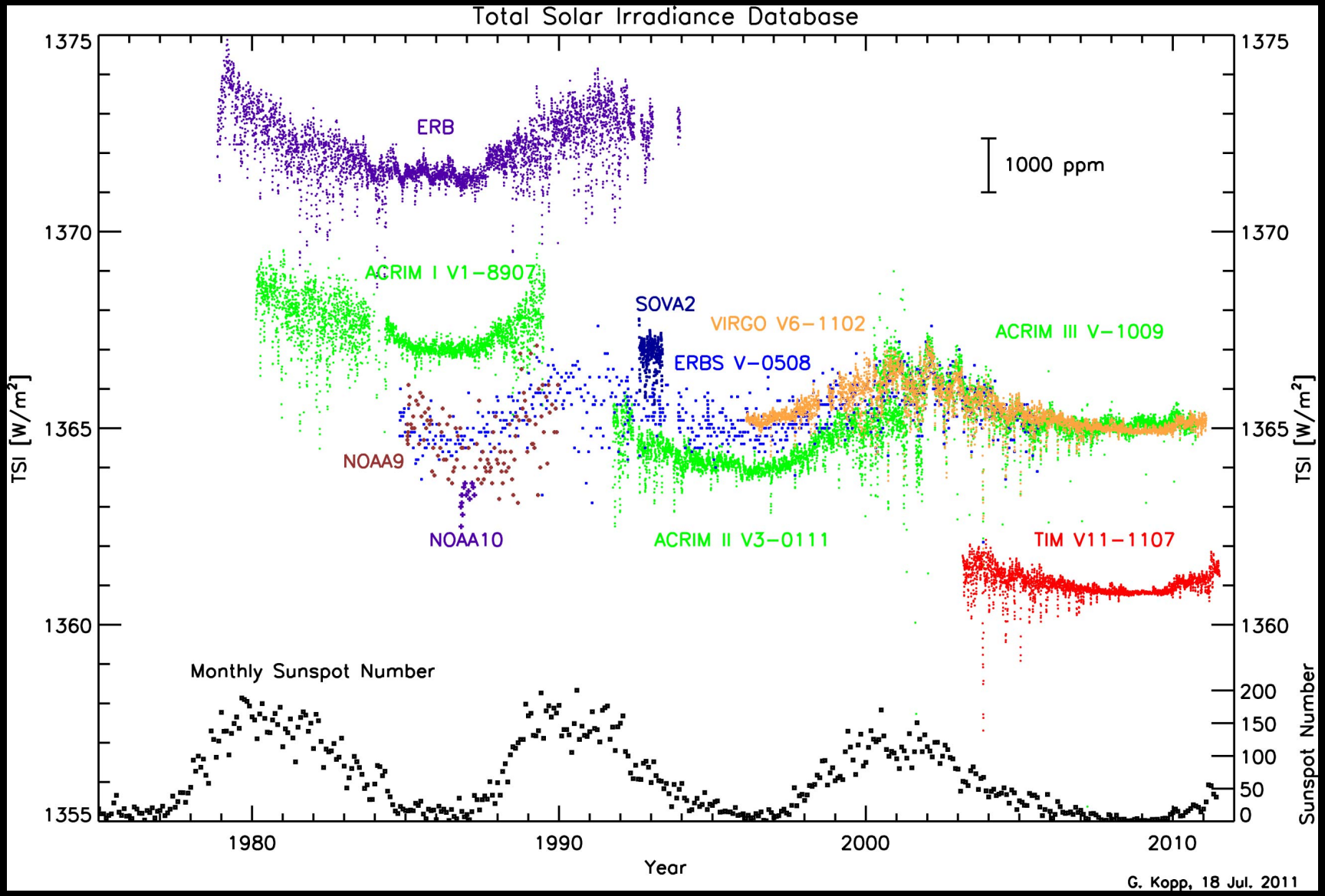


Greg Kopp

LASP / Univ. of Colorado

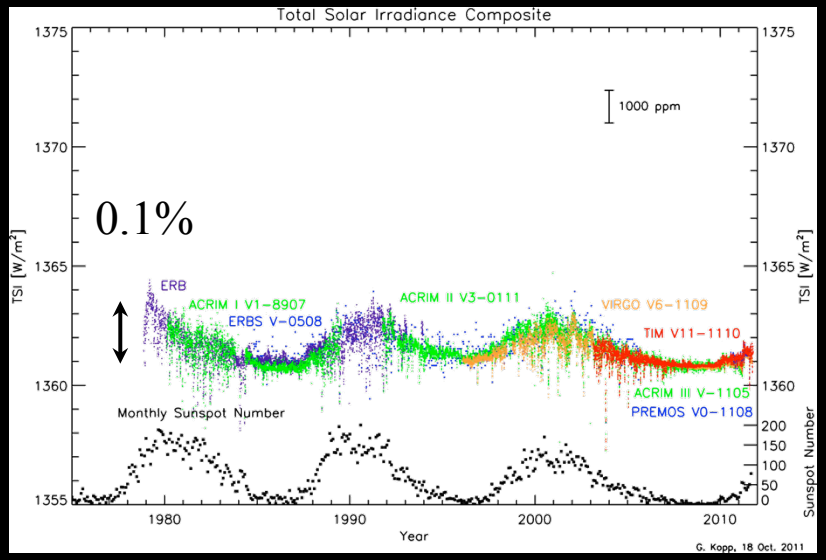
and André Fehlmann, Wolfgang Finsterle, David Harber, Karl Heuerman, and Richard Willson

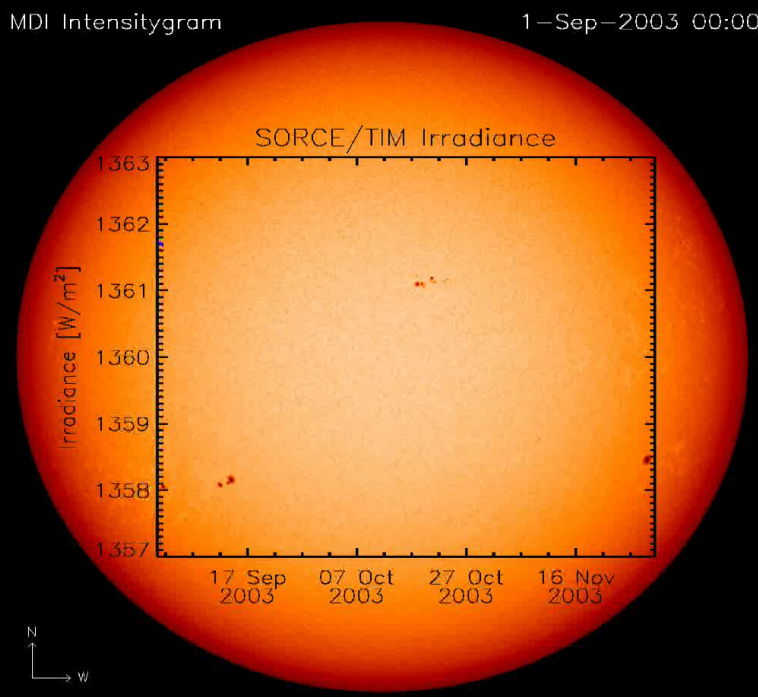
The Total Solar Irradiance Data Record



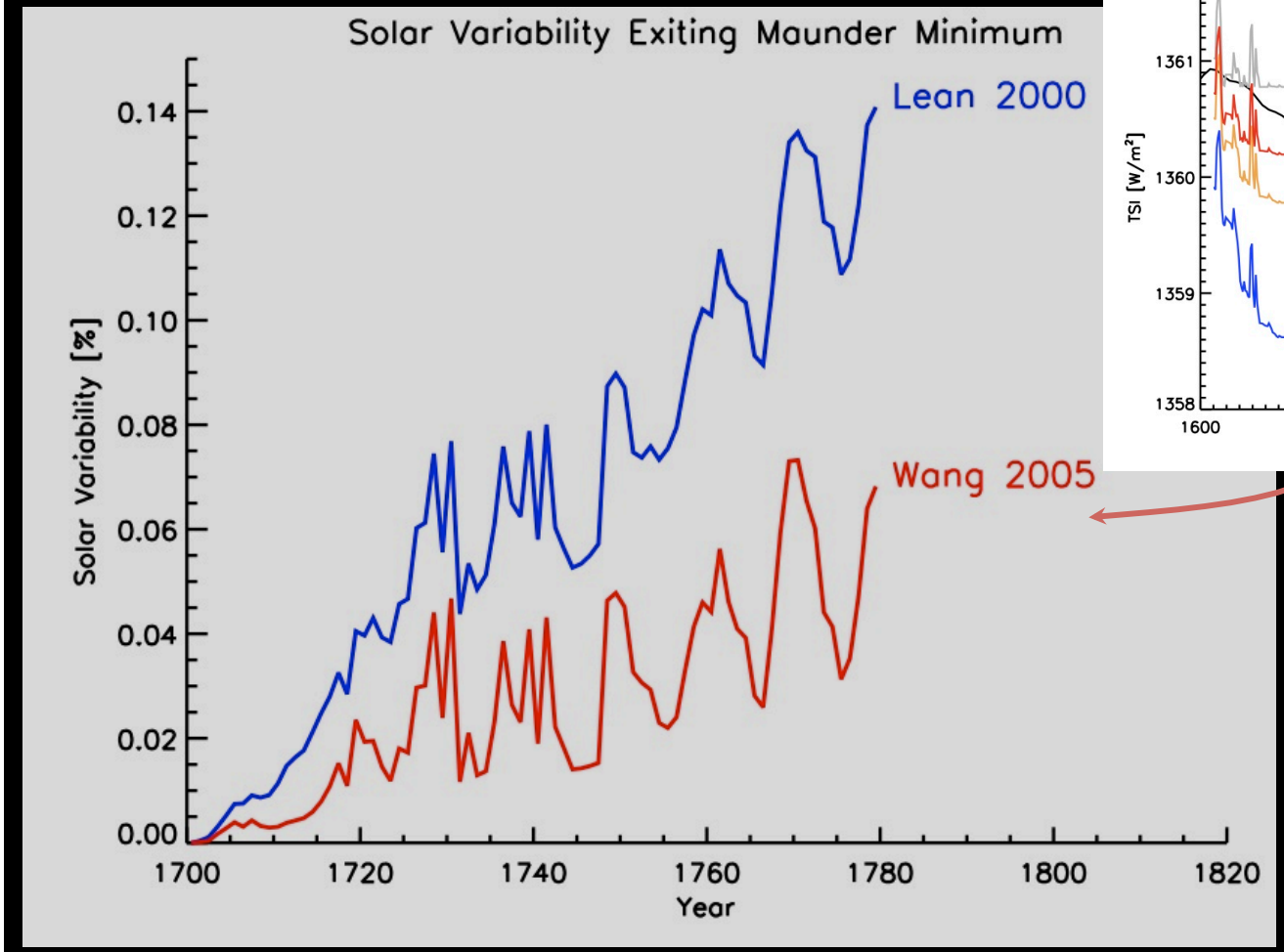
What Are the Time Scales of TSI Variability?

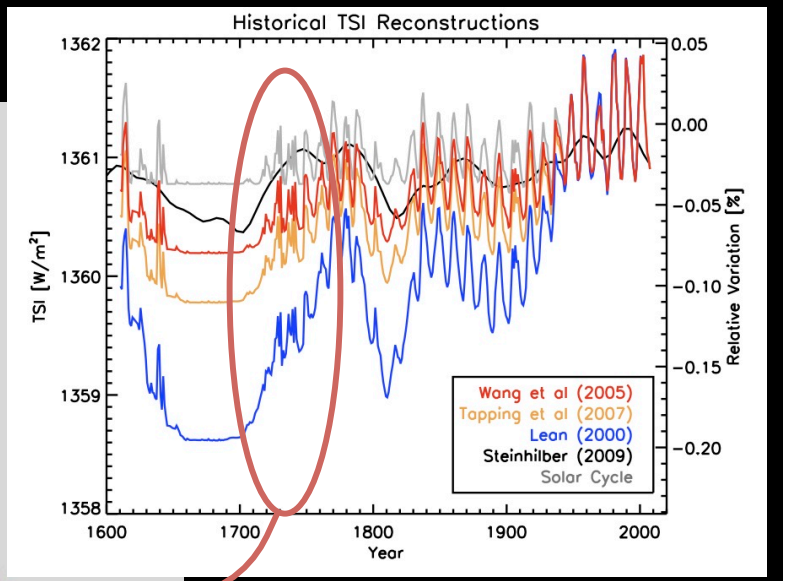
- 0.1-0.3% over a few days
  - Short duration causes negligible climate effect
- 0.1% over 11-year solar cycle
  - Small but detectable effect on climate
- 0.05-0.3% over centuries (unknown)
  - Direct effect on climate (Maunder Minimum and Europe's Little Ice Age)



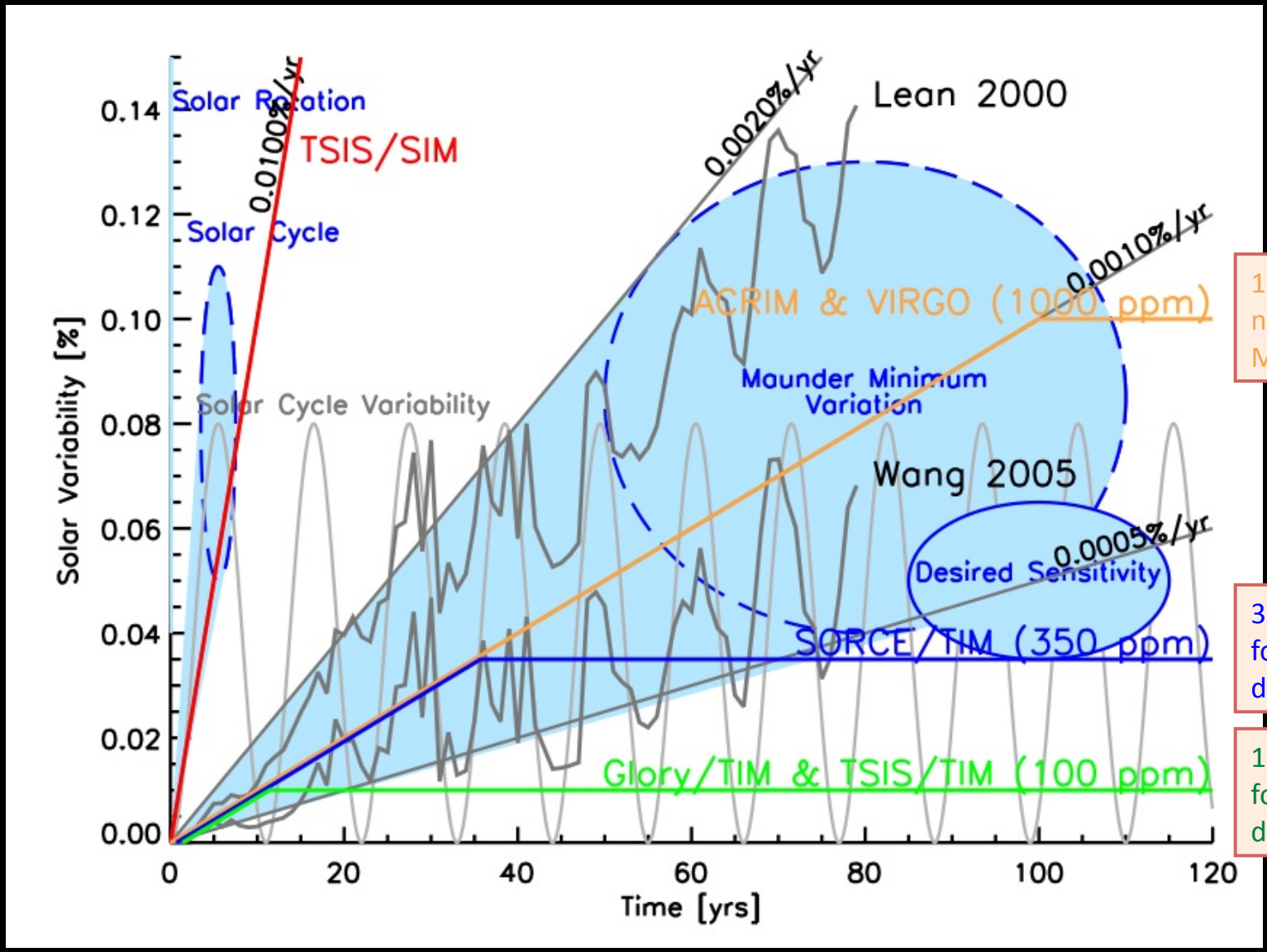


Climate-Quality Measurements Are Difficult





Solar Variability Drives Measurement Requirements



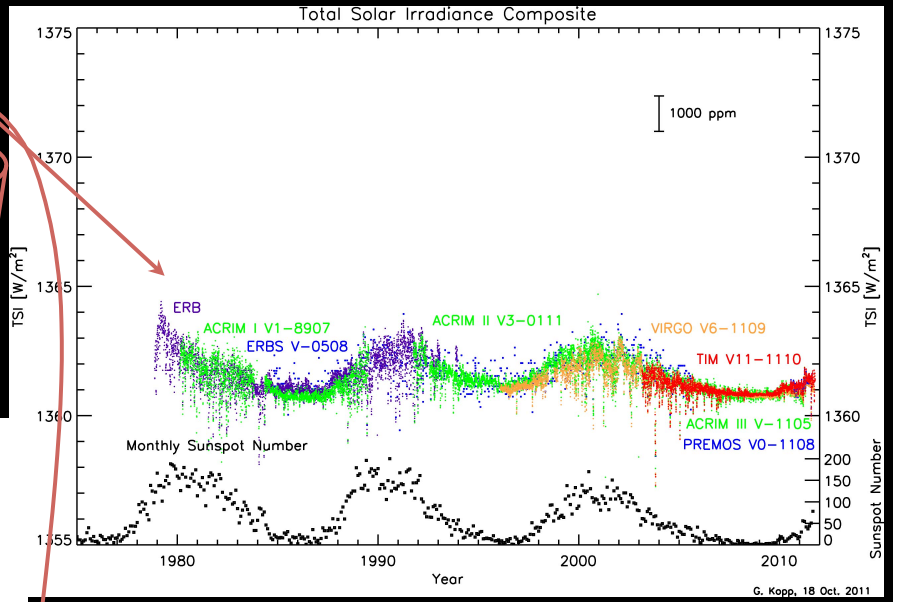
100-yrs needed for MM detection

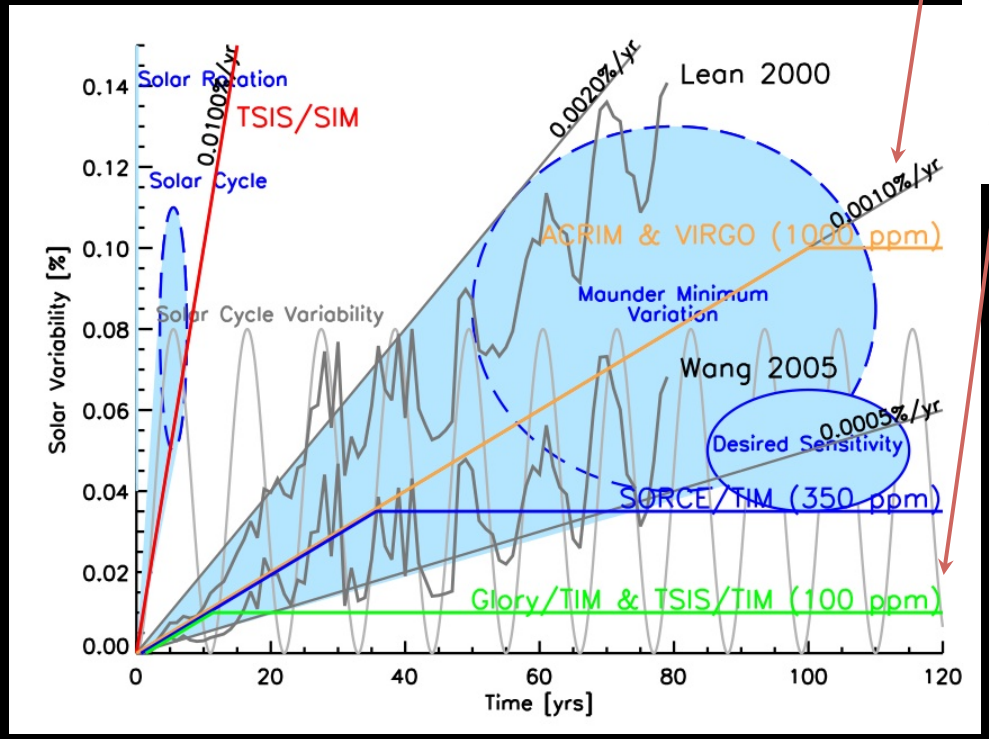
35-yrs needed for MM detection

10-yrs needed for MM detection

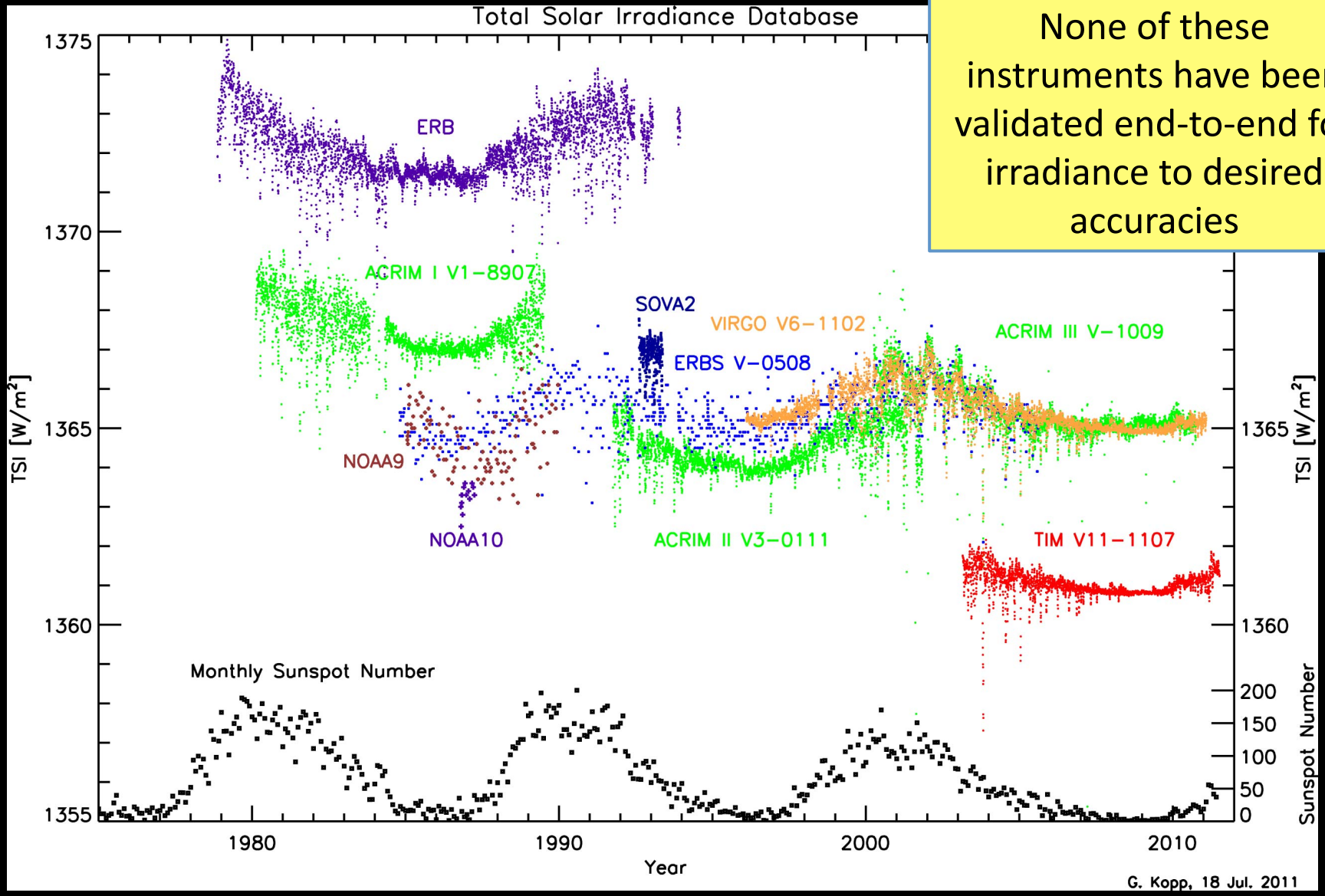
TSI Requirements To Address Climate Needs

- TIM Performance Requirements
  - Accuracy — 0.01% (1 σ)
  - Stability — 0.001%/yr (1 σ)
  - Noise — 0.001% (1 σ)





Glory Has Fixed This Problem – Without Even Flying



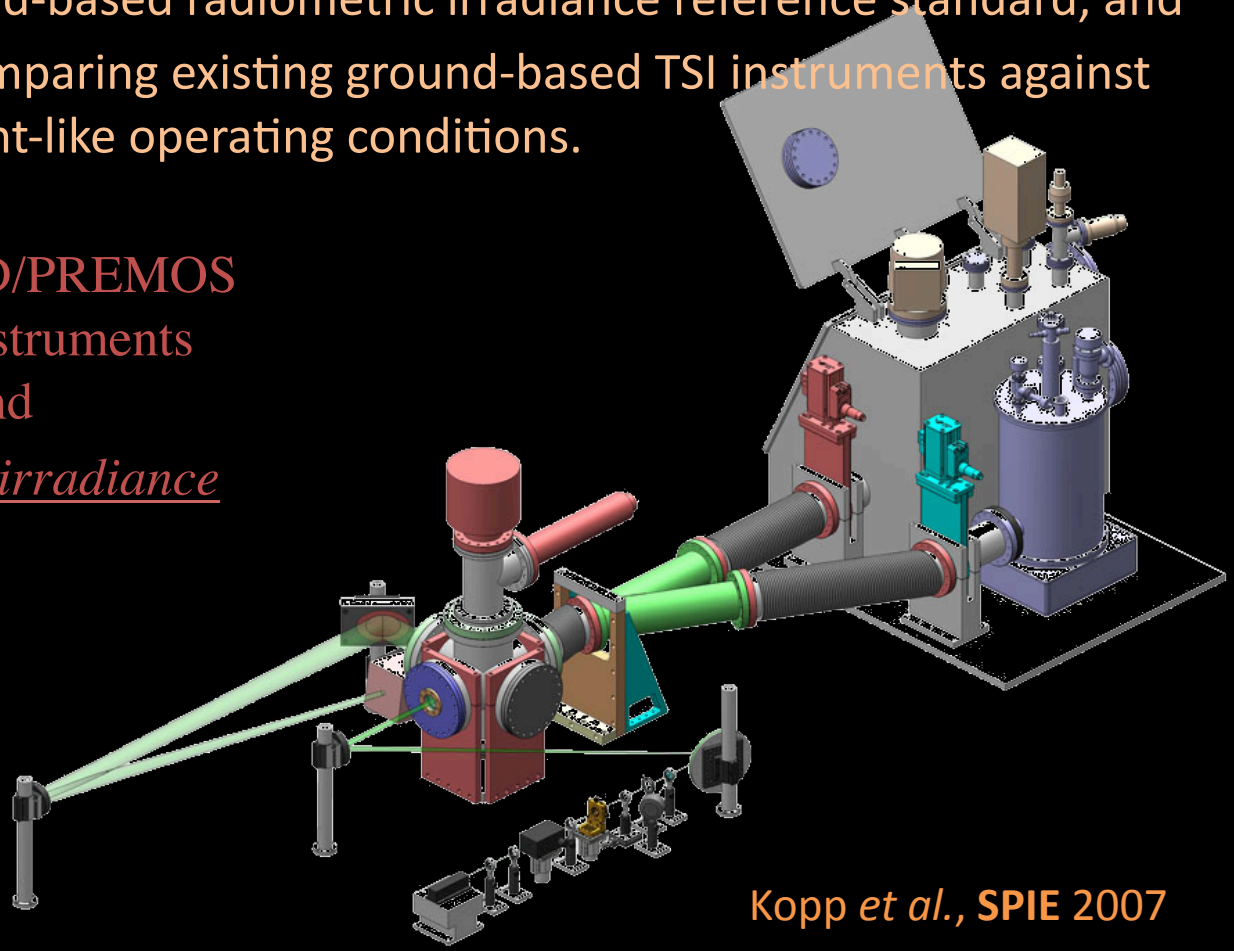
None of these instruments have been validated end-to-end for irradiance to desired accuracies

TSI Radiometer Facility (TRF) Measures Irradiance

The TRF

1. Improves the calibration accuracy of future TSI instruments,
2. Establishes a new ground-based radiometric irradiance reference standard, and
3. Provides a means of comparing existing ground-based TSI instruments against this standard under flight-like operating conditions.

- Glory/TIM and PICARD/PREMOS are the first flight TSI instruments to be validated end-to-end
- First facility to measure *irradiance*
  - at solar power levels
  - in vacuum
  - at desired accuracies
- NIST calibrations of L-1 cryo radiometer

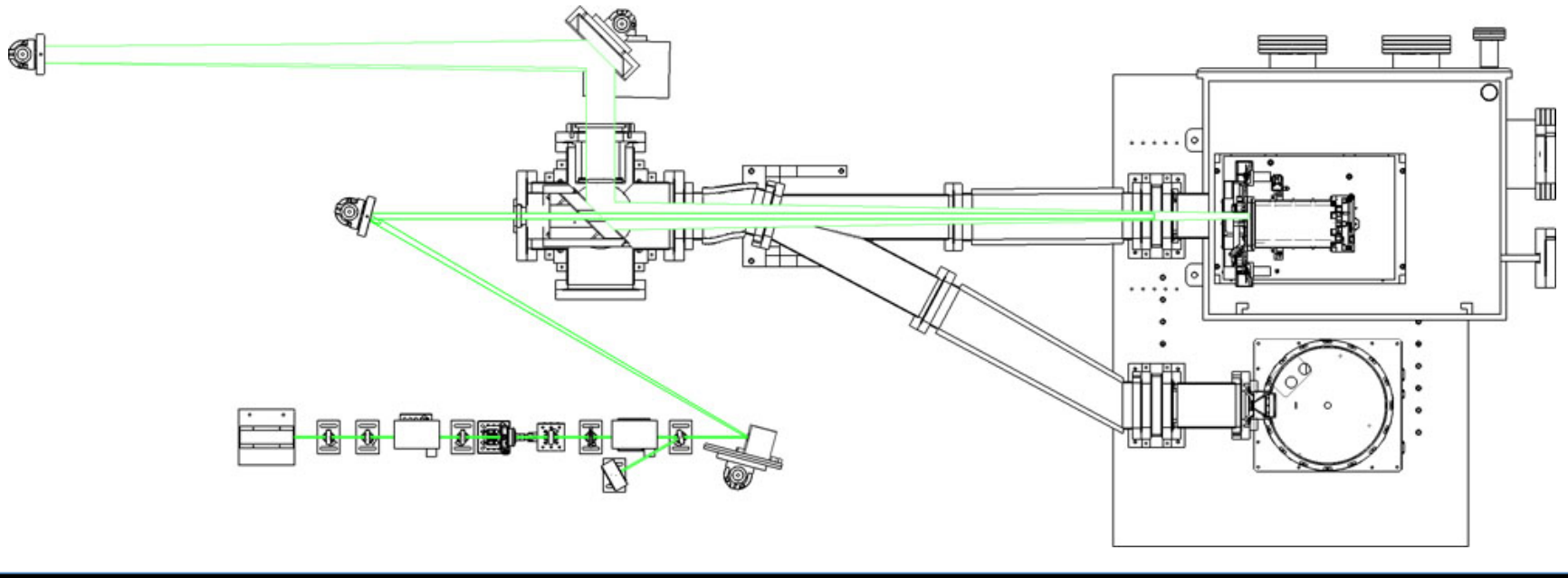


Kopp *et al.*, **SPIE** 2007

Common Vacuum Beam Path

- The facility is designed to allow a TSI instrument or the cryogenic radiometer to sample exactly the same beam
  - Beam is not displaced, instruments are placed at the same location in a stationary beam

Top-view of optical path: TSI instrument in beam



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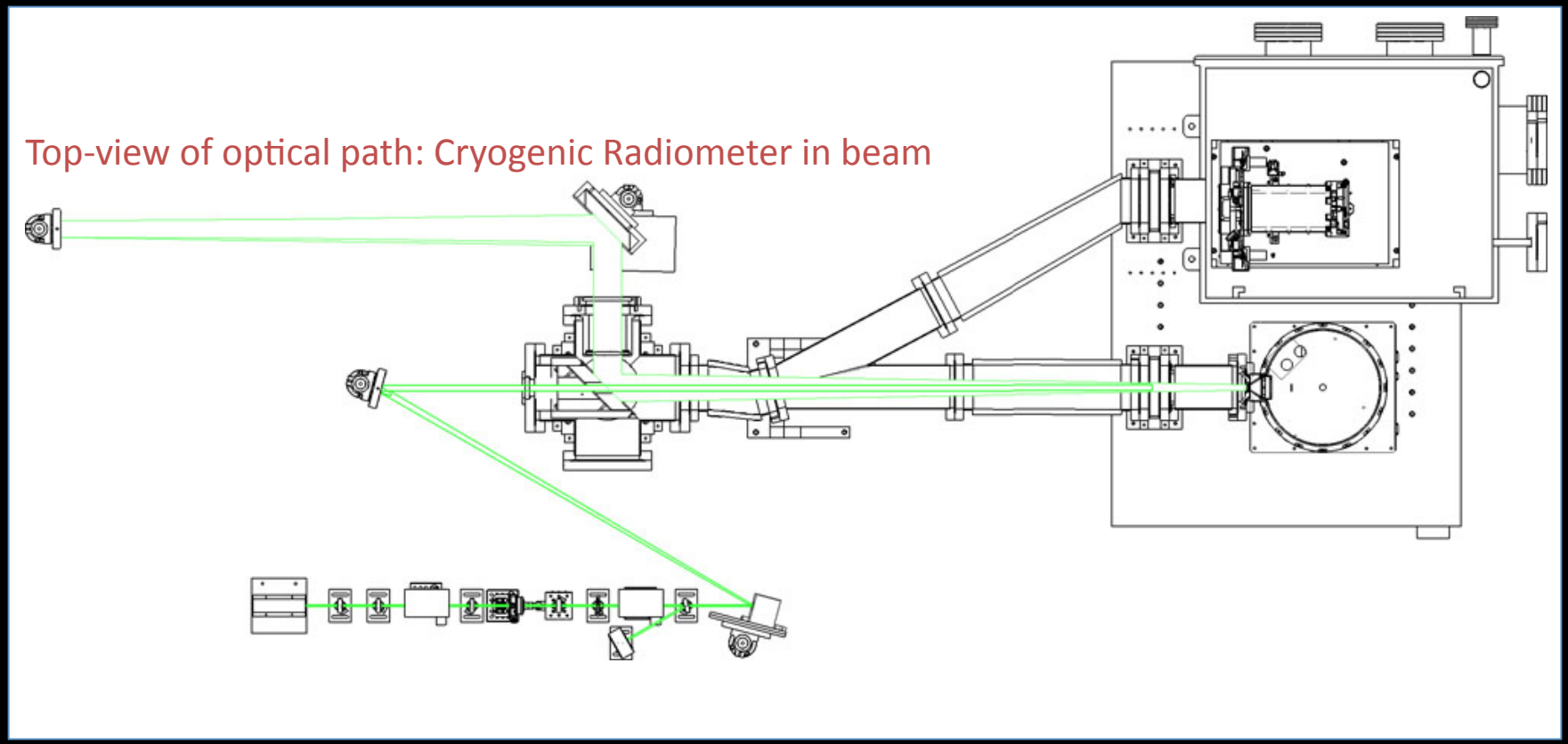
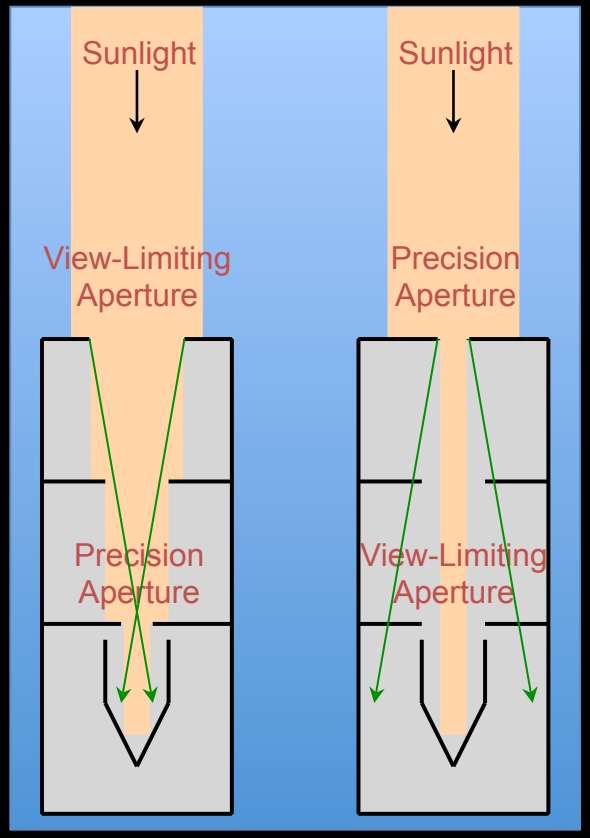


Diffraction & Scatter Erroneously Increase Signal

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

all other TSI instrument geometries



TIM geometry

NIST calculates this to be a 0.16% effect in the ACRIM instruments

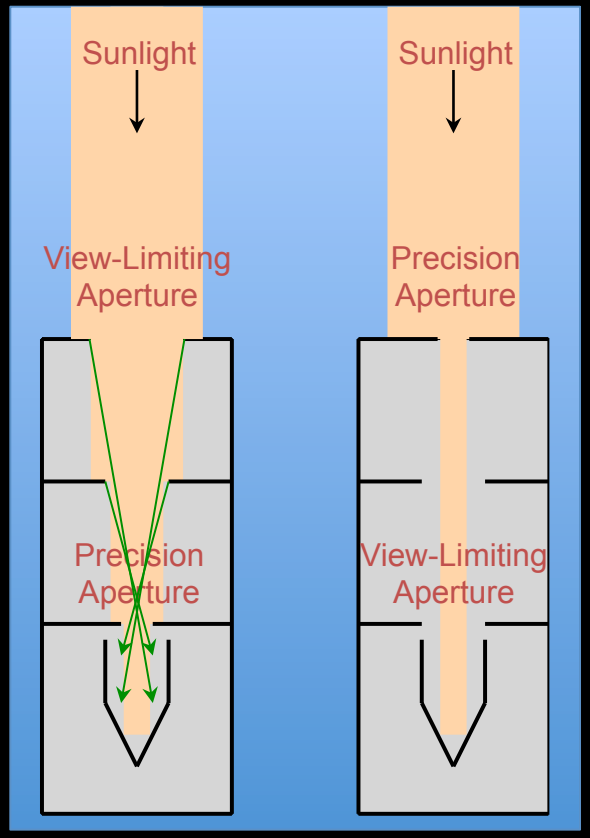
Failure to correct for light diffracted into cavity erroneously increases signal

Failure to correct for light diffracted out of cavity erroneously decreases signal

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

TIM geometry

Measured increases due to uncorrected scatter/diffraction are surprisingly large

Instrument	Increase
PREMOS-1	0.10%
PREMOS-3	0.04%
VIRGO	0.15%
ACRIM-3	0.51%

Additional light allowed into instrument can scatter into cavity

Majority of light is blocked before entering instrument

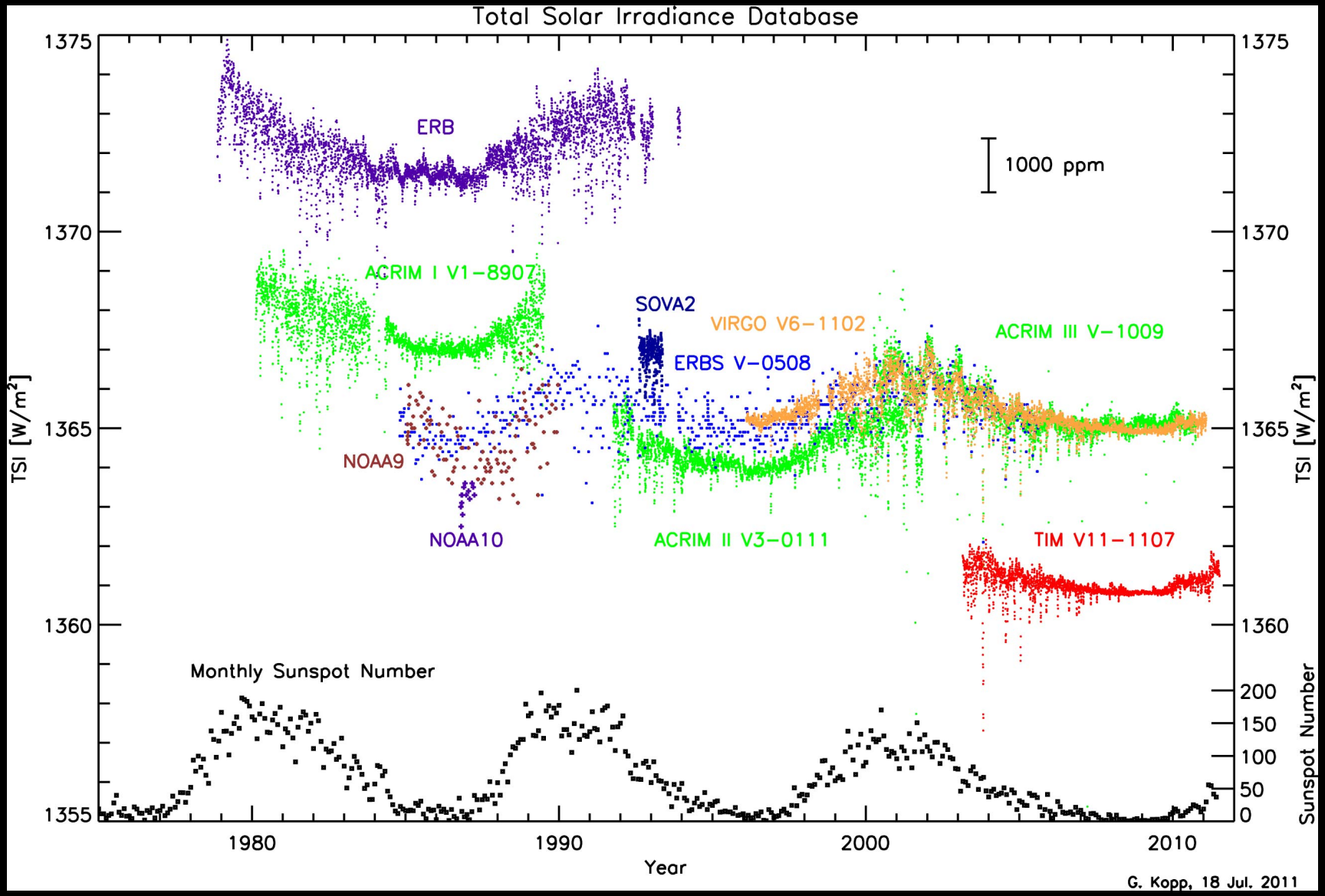
TRF Measurements Validating TSI Instruments

- Currently performed on SORCE/TIM Witness, Glory/TIM, PICARD/ PREMOS-1 and PREMOS-3, VIRGO-2, and ACRIM3
- Planned with EURECA/SOVA and SOVA-P
- Social aspects are even more impressive...

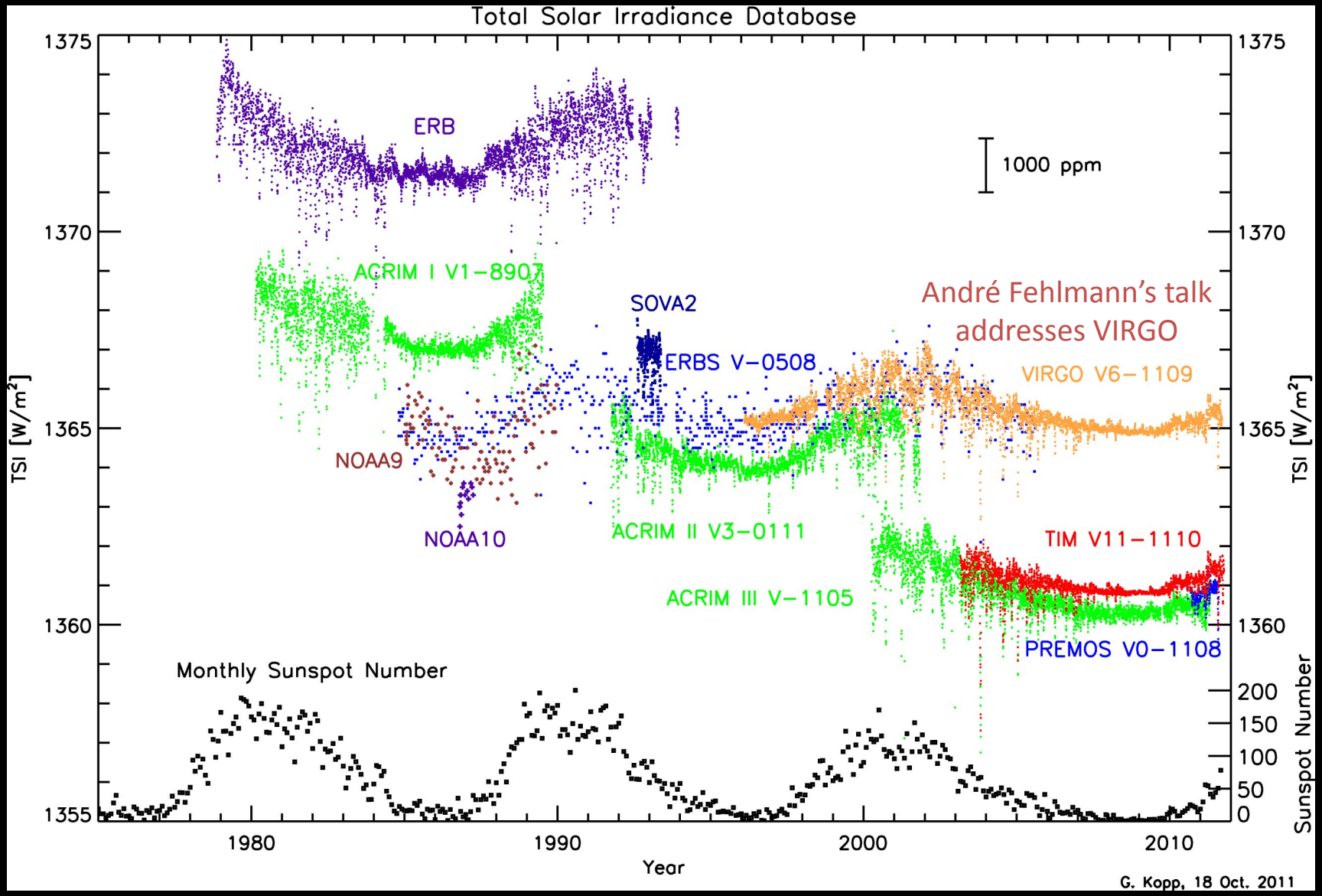
see André Fehlmann's thesis for updated values

Difference Relative to TSI Radiometer Facility						
Instrument	**Measured Optical Power Offset**	**Irradiance: Precision Aperture Overfilled**	**Irradiance: Entrance Aperture Overfilled**	**Difference Attributable To Scatter Error**	**Residual Irradiance Offset**	**Uncertainty**
SORCE/TIM *ground*	-0.035%	-0.035%	-0.035%	0.000%	0.000%	0.025%
Glory/TIM *flight*	-0.020%	-0.012%	-0.012%	0.000%	0.007%	0.020%
PREMOS-1 *ground*	-0.049%	-0.104%	-0.005%	0.098%	-0.055%	~0.038%
PREMOS-3 *flight*	0.631%	0.605%	0.642%	0.037%	-0.026%	~0.027%
VIRGO-2 *ground*	0.730%	0.743%	0.897%	0.154%	0.013%	~0.025%
ACRIM3 *ground*	0.021%	0.308%	0.534%	0.506%	0.007%	0.059%

TRF Corrections Now Applied by ACRIM Team ...



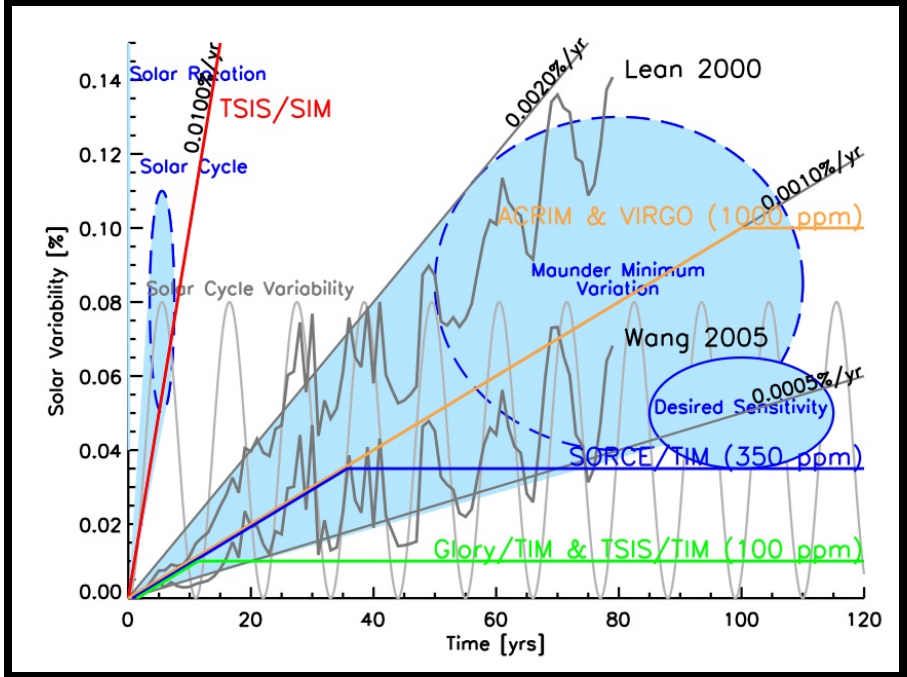
... And PREMOS Data Are Recently Available

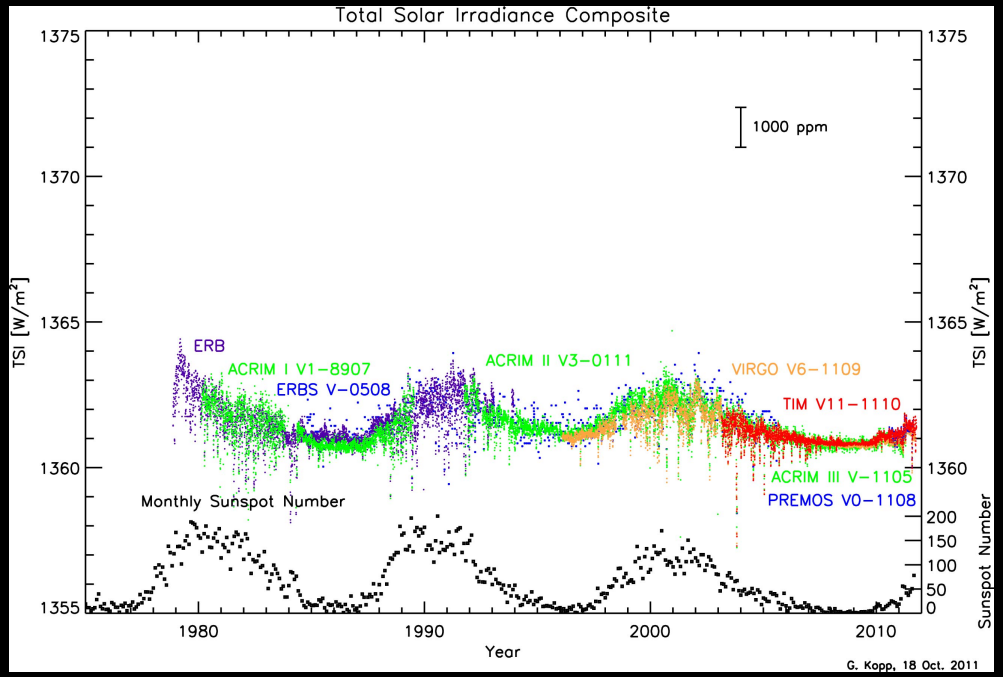


Value of TSI Measurements for Climate Science

TSI Measurements

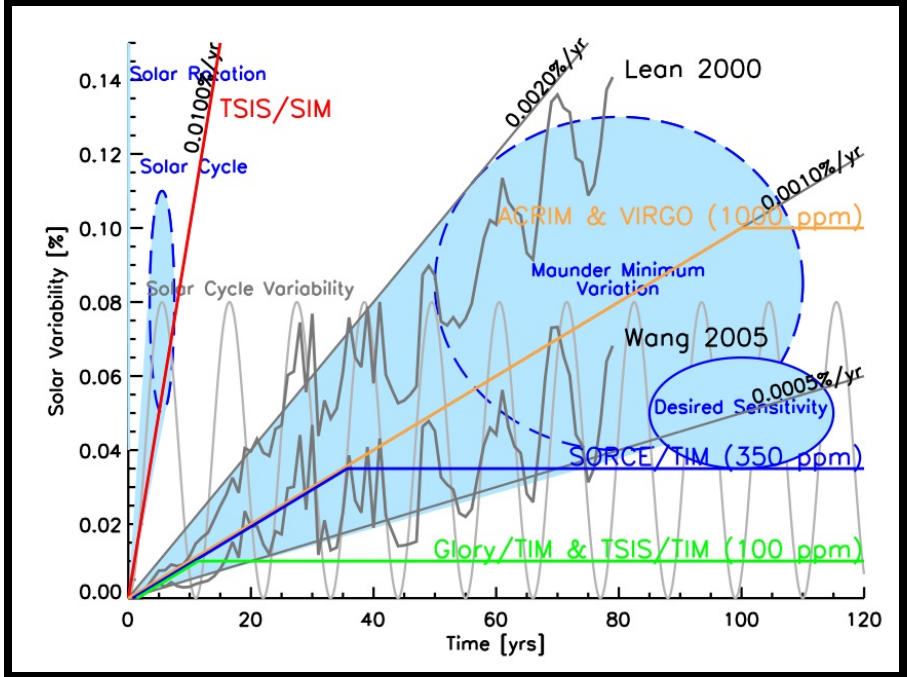
1. Are the most stable solar irradiance measurements
   - Approaching stabilities necessary to detect climate-relevant solar variability
2. Provide >30 year solar irradiance record of entire radiative input to Earth's climate system

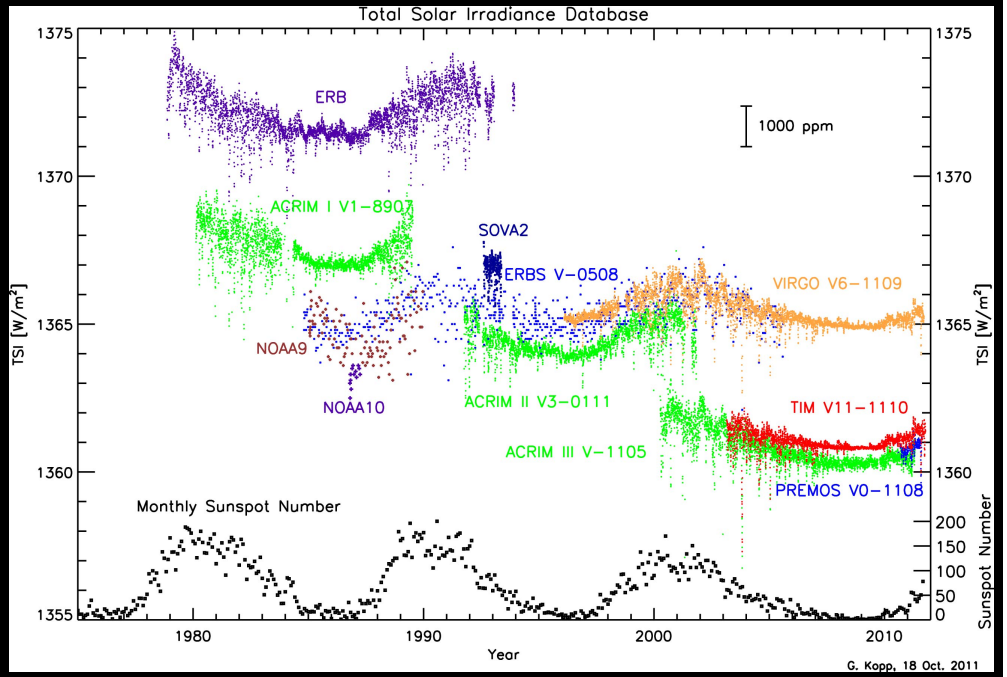




Requirements of TSI Measurements for Climate Science

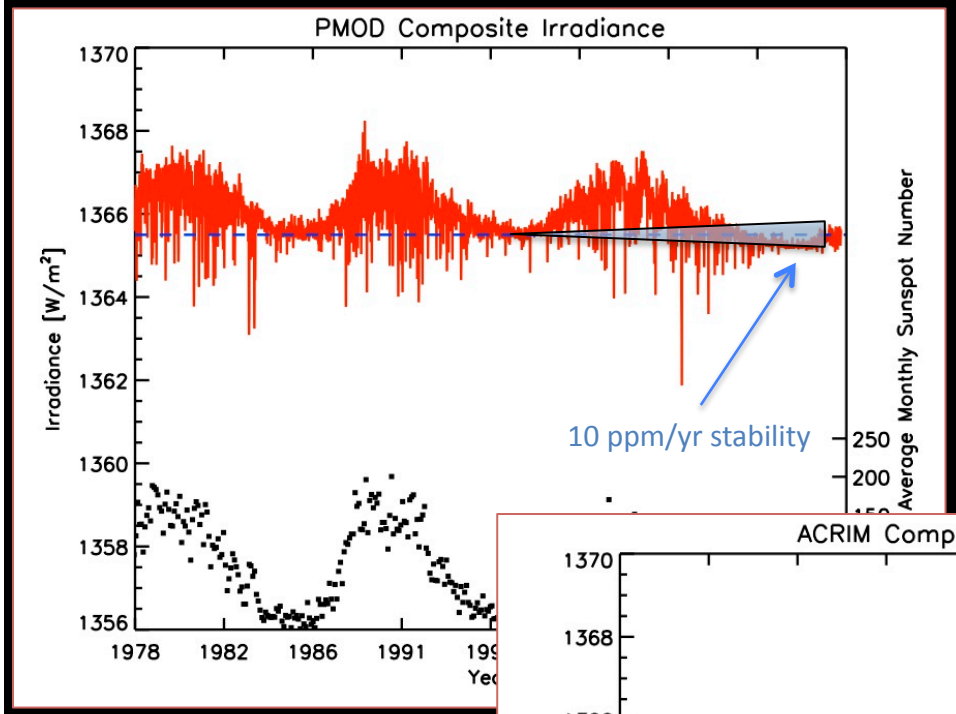
1. Improve absolute accuracy to 100 ppm. In the meanwhile,
2. Continue to rely on continuity and stabilities of <10 ppm/yr
3. Perform end-to-end ground irradiance validations against an SI-traceable reference (such as TRF)

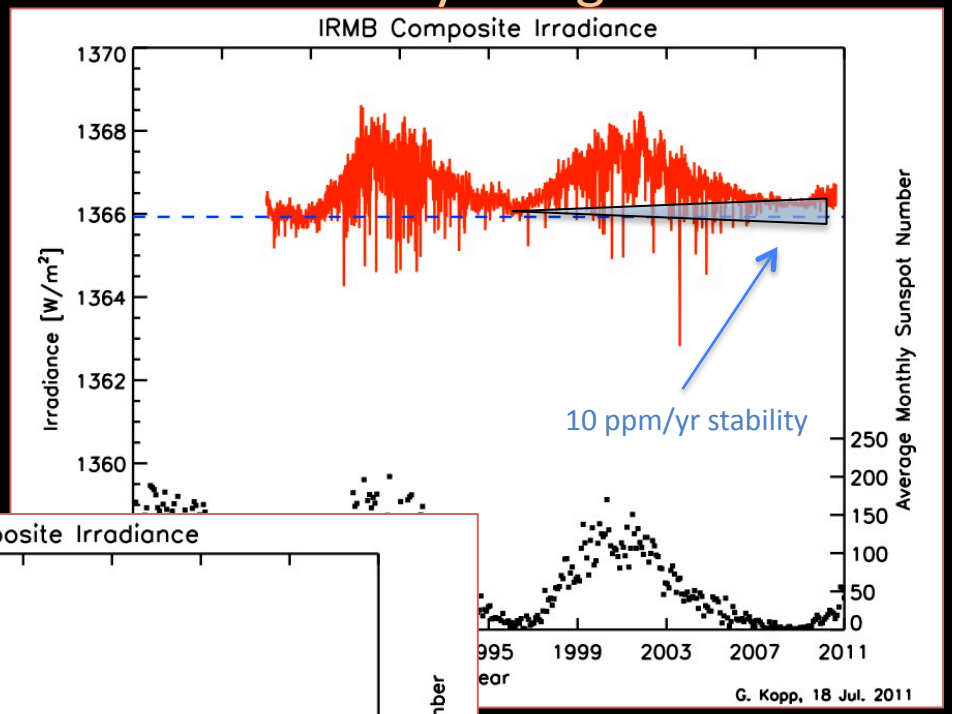


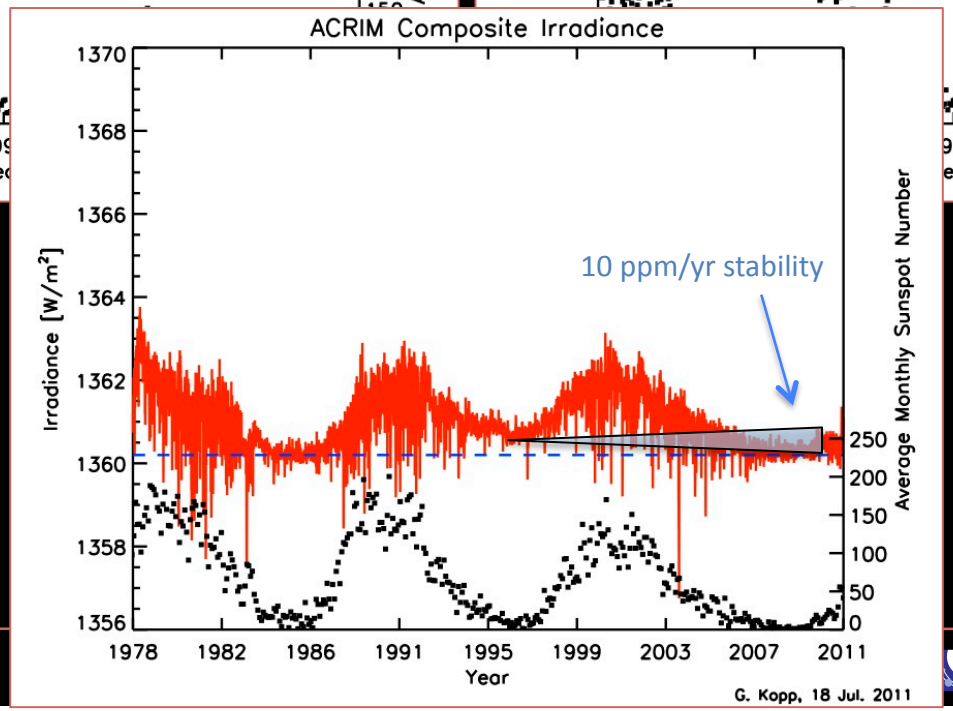


How Good Are Resulting Composites?

- Trend detection between solar minima is currently marginal

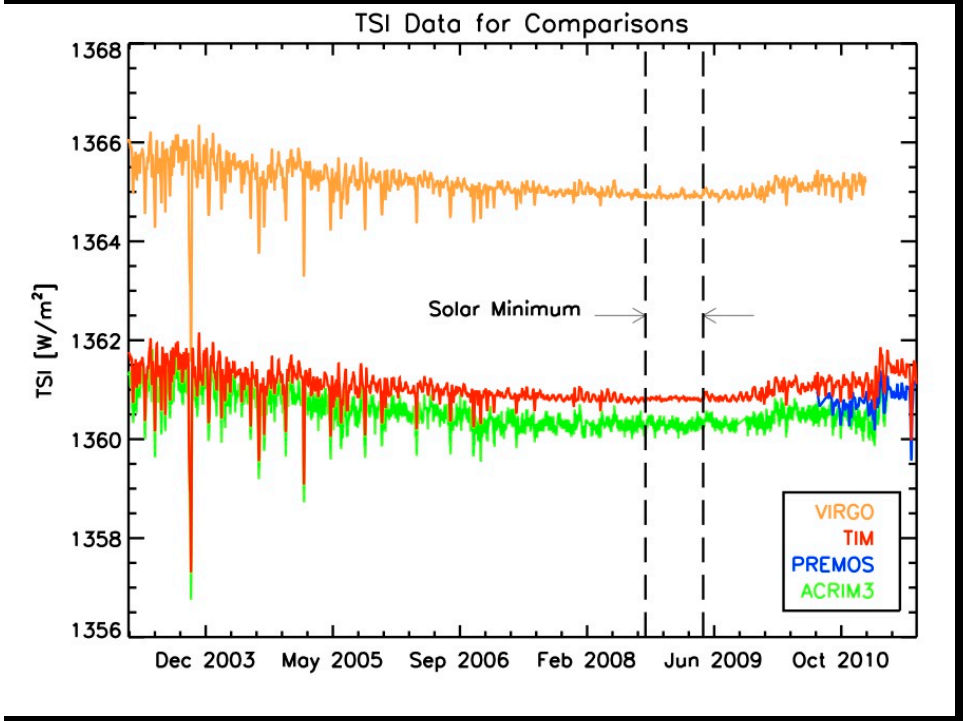


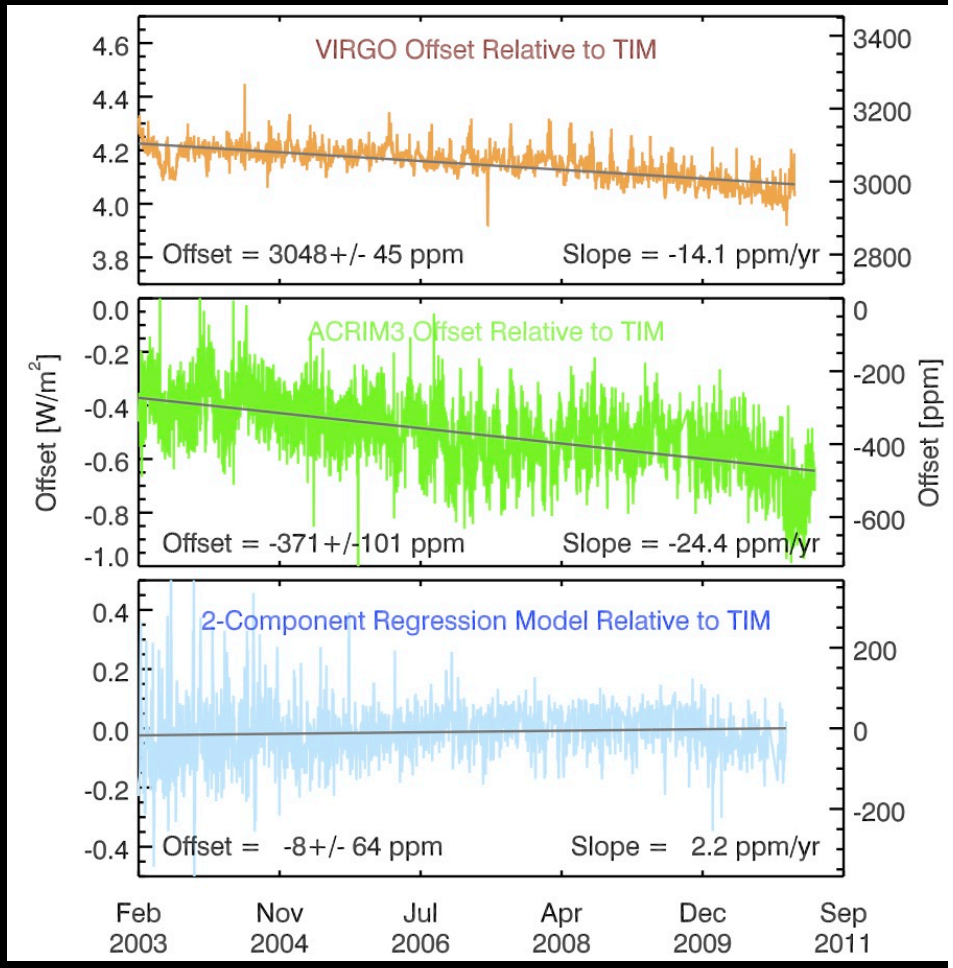




Desired Stabilities Not Yet Achieved

- There remain significant differences between existing instruments

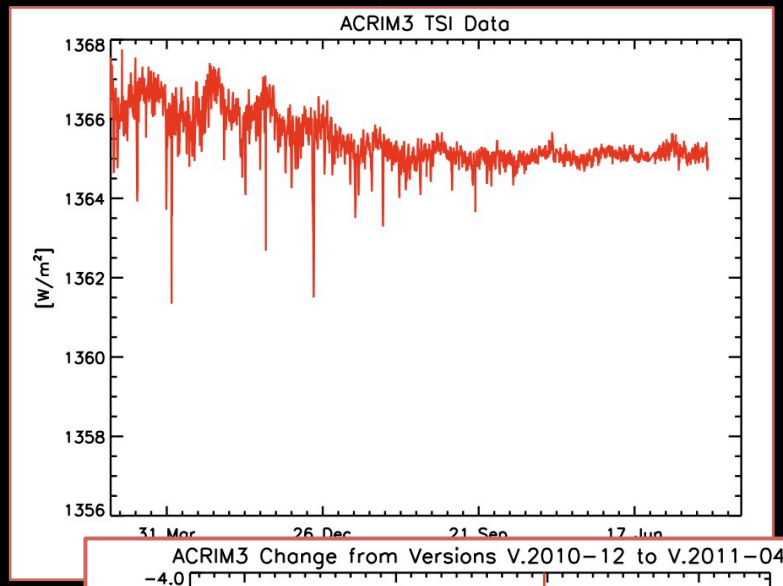


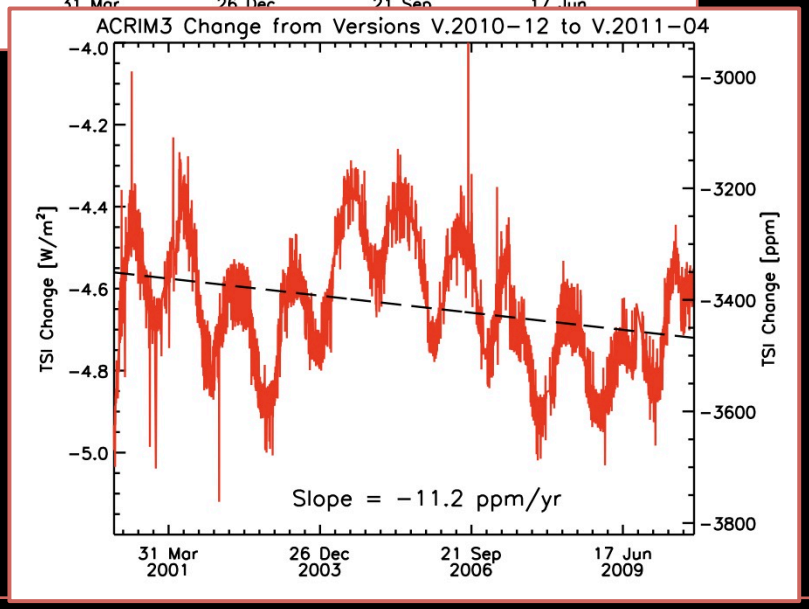


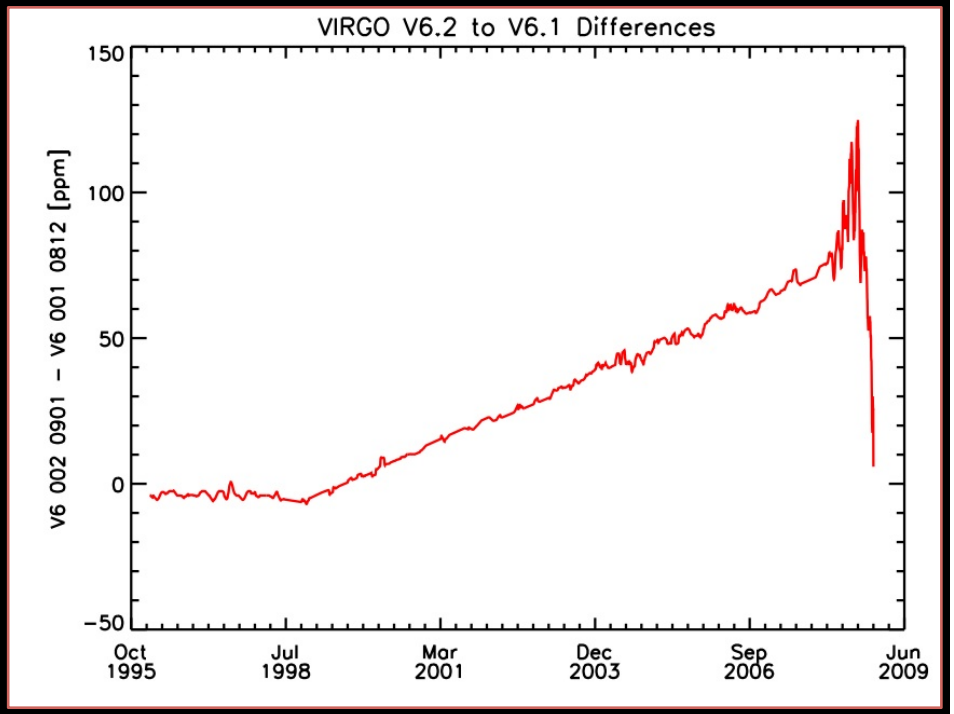
NRL, SATIRE, SFO models

Desired Stabilities Not Yet Achieved

- There are significant differences between instrument data versions

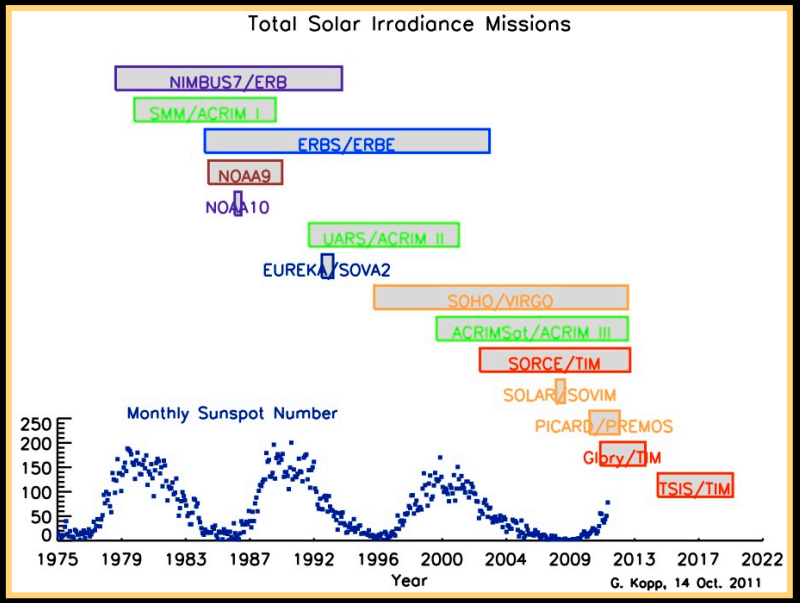




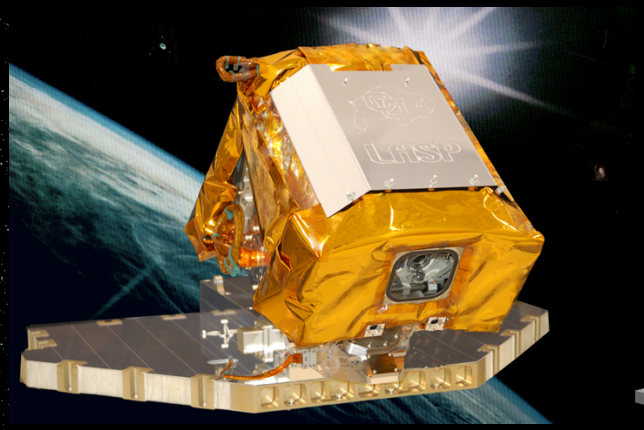


TIM Was Planned to Fly on Three Missions

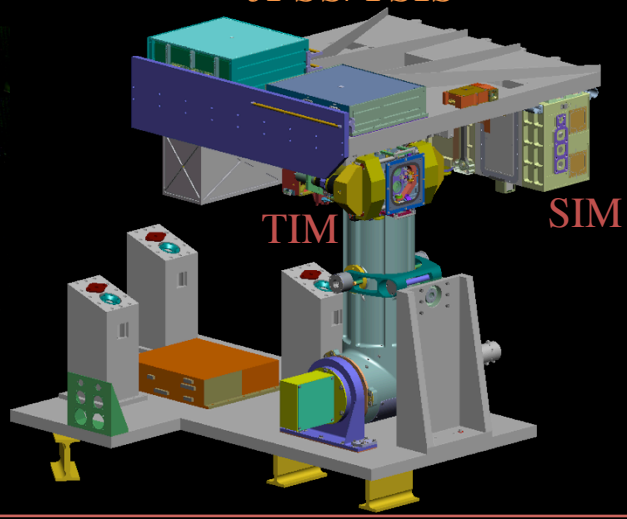
- SORCE (SOlar Radiation and Climate Experiment)
  - Launched Jan. 2003
- Glory
  - Launch (failure) 4 March 2011
- JPSS/TSIS
  - Launch 2014 (?)



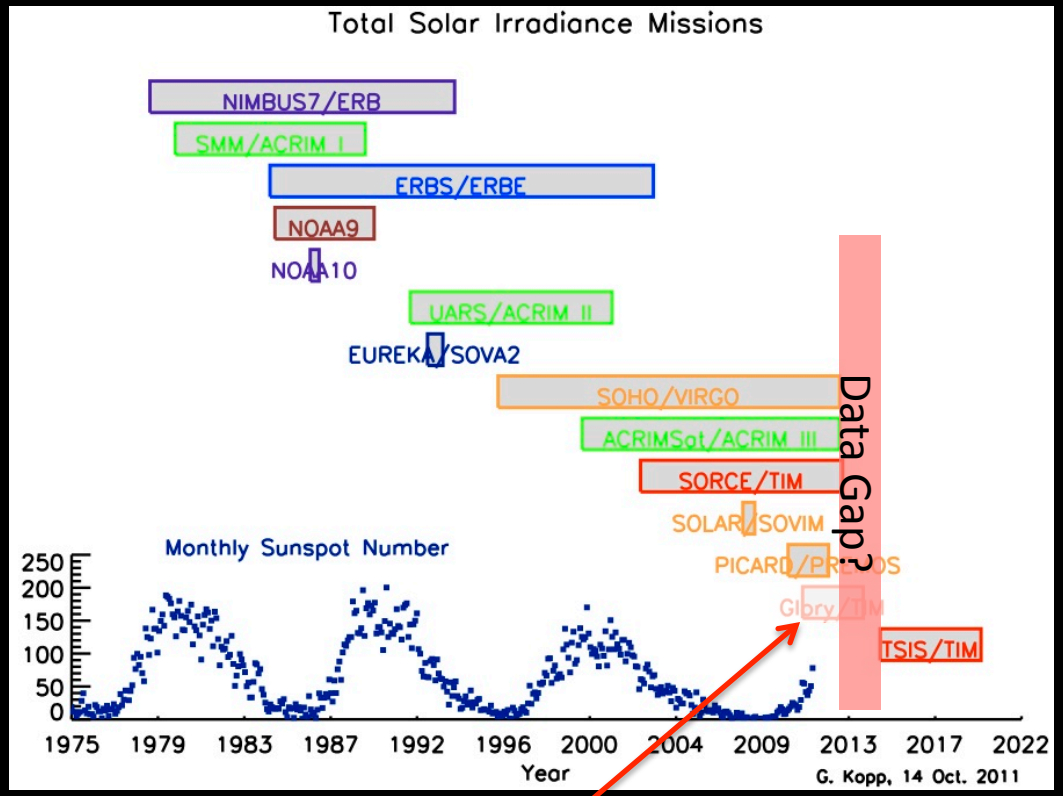
Glory/TIM

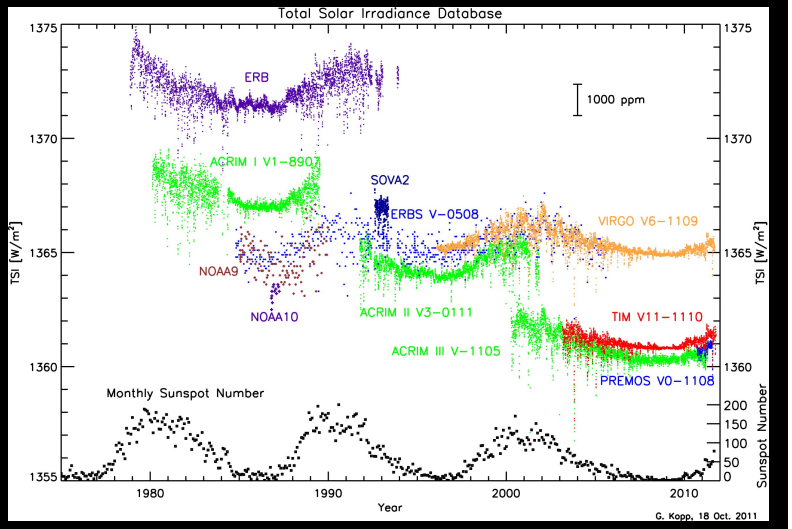


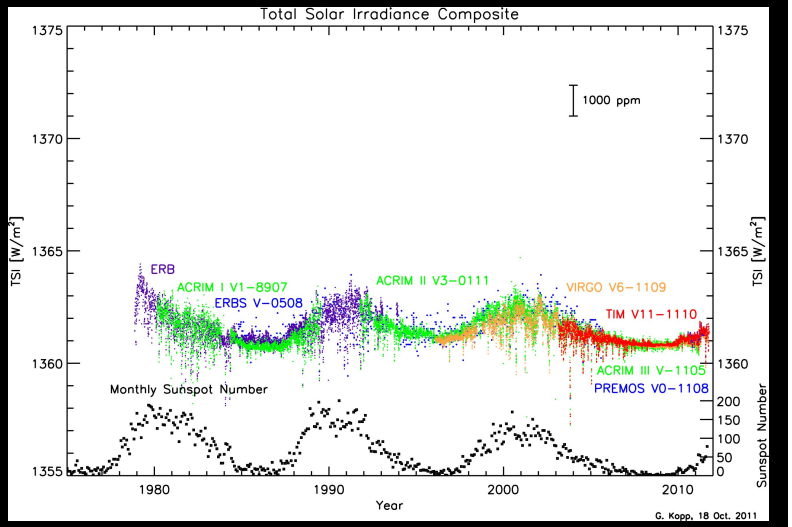
JPSS/TSIS



TSI Record Currently Relies on Stability & Continuity







With launch failure of NASA's Glory mission, TSI record continuity is currently at risk

TSI plots updated regularly at:
http://spot.colorado.edu/~koppg/TSI/