LASP/TRF diagnostic test and results for the ACRIM3 experiment

Implications for the multi-decadal TSI database

ACRIM3 TEAM

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SORCE Science Team Mtg.
Sept 13, 2011

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ACRIM3 Guidance from the NASA 2009 Senior Review

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Senior Review 2009 directed task areas:

- ACRIM Gap (TSI trends)
- Annual signal (short term variability)
- Scale difference (Calibration)

TOTAL SOLAR IRRADIANCE MONITORING RESULTS: 1978 to Present

Daily mean results reported on experiments' native scales
Investigation of ACRIM3 - TIM TSI Scale Difference

Approach: Characterize ACRIM3_EM (flight backup) instrument at the LASP/TRF

- The LASP/TRF team led by Greg Kopp conducted the TRF testing including:
  - Comparison of ACRIM self-calibration with the TRF cryo-radiometric scale
  - Diagnostic testing to measure ACRIM scattering and diffraction effects

- The ACRIM3 Team accomplished the following:
  - Prepared the ACRIM and operated the Instrument at the TRF
  - Analyzed ACRIM TRF data and provided results to LASP and NRL
  - Derived scale/scattering/diffraction corrections for ACRIM3 observations
  - Applied corrections to ACRIM3 database and ACRIM Composite TSI time series

- NRL led by Jeff Morrill participated and:
  - Provided independent oversight as TRF testing observers
  - Convened a review of the process and findings (Dec. 2010)
  - Conducted independent scattering, diffraction, cavity reflectance modeling/testing
  - Is preparing a final report on NRL activities

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1 Laboratory for Astronomy and Space Physics (LASP) Total Solar Irradiance Radiometer Facility (TRF)
2 Naval Research Laboratory (NRL)
ACRIM3 Sensor

- Most key components fabricated during ACRIM3 flight instrument build
- ACRIM3_EM representative of ACRIM3 flight instrument properties and performance
Laboratory for Atmospheric And Space Physics (LASP) Total Solar Irradiance Radiometer Facility (TRF)

532nm transfer laser

ACRIM3_EM Instrument

Moveable Transfer Stage

Test Chamber

Collimator

Steering Mirror

TRF Cryogenic Radiometer

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ACRIM3 Sensor Module and Irradiance Testing Modes

15mm Circular Beam
Over-fill View Limiting aperture
Calibrates total scattering & diffraction

5mm Circular Beam
Under-fill Primary aperture
Basic Power measurement in SI Units

10mm Circular Beam
Over-fill primary aperture, Under-fill View Limiting aperture and Baffle
Calibrates scattering in lower view limiting assembly

Front View of Sensor Module
October 2010 results

- Basic optical power scale: ACRIM3 sensors and TRF agree within +/- ~ 500 ppm
- Significant scattered light signal from ACRIM3 view-limiter (~ 5000 - 6000 ppm)
- ACRIM3_EM precision apertures not conform to ACRIM3 flight spec.'s
  Primary aperture surface below quality spec.'s for flight apertures
  A more diffuse reflective surface assumed to increase scattered light in the sensor
- ACRIM3 TRF re-test required to evaluate scattering effect of primary aperture surface
  Sensor B aperture replaced with ACRIM3 flight spare
  Sensor A left unchanged as a control for second test

January 2011 Re-test

- Similar set of testing procedures employed with modified sensor B
ACRIM3 LASP/TRF Characterization Summary

Basic optical power scale observations ¹

- Sensor A: ~ 200 ppm (+/- ~ 600 ppm)
- Sensor B: ~ 450 ppm (+/- < 100 ppm)

Scattered light and diffraction results ¹,²

- 2010 test:
  - Sensor A: ~ 7000 ppm
  - Sensor B: ~ 6000 ppm
- 2011 test:
  - Sensor A: ~ 6500 ppm
  - Sensor B: ~ 5000 ppm
- Diffraction component ~ 1000 ppm ³

¹ Ratio to the TRF cryo-radiometric scale
² Uncertainty of scattering & diffraction results ~ 500 ppm
³ Based on LASP interpretation of annular beam test results

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ACRIM3 LASP/TRF Characterization

Conclusions

- Basic optical power scale observations: ACRIM3 agrees within 500 ppm with TRF & NIST
- Scattering and diffraction effects: 5000 ppm (+/- ~ 500 ppm)

Comments and Observations

- Correction of ACRIM3 results for scattering and diffraction is required
- ACRIM3 basic scale agrees with TRF and NIST scales within the uncertainty of TRF testing
- ACRIM and LASP analyses of TRF data agreed within their bounds of uncertainty
- The LASP/TRF is a valuable diagnostic tool for TSI radiometry
- Substitution of flight quality aperture in Sensor B reduced scattering by ~ 1000 ppm
- Additional testing could reduce TRF test uncertainties
• The ACRIM3 flight data algorithm was updated per TRF test findings

  A temperature dependent reference voltage correction was found necessary and implemented with the following effects:

  An ‘annual’ component in the ACRIM3 results was reduced by ~ 300 ppm
  The average noise level increased slightly (~ 50 ppm)
  The ACRIM3 self-calibration scale increased by ~ 1000 ppm

• A TRF-derived Scattering, Diffraction and Cryogenic scale (SDC) correction was applied

  ACRIM3 data were reprocessed to level 1 (prior to 1 A.U. distance correction)
  The SDC correction was applied at level 1 - reducing results by 5025 ppm
  The SDC-corrected results were processed to level 2 (1 A.U. distance correction)
  Final results were corrected for ACRIM3 self-calibration of degradation
Graphical Summary of ACRIM3_EM TRF Test Results
TOTAL SOLAR IRRADIANCE MONITORING DURING ACRIM3 MISSION

 Reported on experiment's native scales

RC Willson - earth_obs_fig2 09/11/2011
Satellite Total Solar Irradiance Monitoring Results Since 1978

Daily mean results reported on "native" scales of experiments (W/m² @ 1 AU)

RC Willson, earth_obs_fig5  09/06/2011
ACRIM Composite TSI Time Series

Minima trend between during solar cycles 21 - 23: + 0.037 %/decade

TSI trend between minima during solar cycles 21 - 24, approaching next minima: + 0.004 %/decade

ACRIM Composite:  
- Uses Nimbus7/ERB, ACRIM1, 2 & 3 results
- Uses Nimbus7/ERB comparisons to bridge the ‘ACRIM Gap’
- Uses TSI results published by satellite experiment teams
- Results reconciled to ACRIM3 scale

Fractional components of ACRIM Composite:
- ACRIM: 89.7 %
- Nimbus7/ERB: 10.3 %

TRF-derived correction reduces calibration scale, does not affect TSI trending

Components of ACRIM Composite:
- ERB
- ACRIM1
- ERB
- ACRIM2
- ACRIM3

Willson & Mordvinov, GRL, 2003

RC Willson, earth_obs_fig26 09/09/2011
TSI Monitoring Continuation Scenario

ACRIM Composite TSI during solar cycles 21 - 24

TSI trend during solar cycles 21 - 23: +0.037 %/decade
TSI trend during solar cycles 21 - 24: +0.003 %/decade

ESA Missions
NASA Missions

SOHO/VIRGO
ACRIMSAT/ACRIM3
SORCE/TIM
PICARD, SOVAP, & PREMOS
JPSS1/TSIS.

Willson & Mordvinov, GRL, 2003
RC Willson, earth_obs_fig39 06/16/2011
Resolution of ‘ACRIM Gap’ Issue

Comparison of ACRIM, Nimbus7/ERB and ERBS/ERBE Results

Solar Cycle Minimum

ACRIM1

Solar Cycle 22

ACRIM1

ACRIM Gap

No Data

Overlap with ACRIM2

Slope: -0.004

Slope: +0.021

Slope: +0.008

Slope: -0.003

Slope: -0.005

Slope: +0.021

Slope: -0.012

Slope: -0.000

% Var. about Period Means


% Var. about Series Mean


% Var. about Series Mean


RC Willson, earth_obs_fig15, 05/03/2011
ACRIM Composite TSI Time Series (Daily Means) *

TSI trend between minima during solar cycles 21 - 23: + 0.037 %/decade
TSI trend between minima during solar cycles 21 - 24, approaching next minima: + 0.003 %/decade

ACRIM Composite:
Uses Nimbus7/ERB, ACRIM1, 2 & 3 results
Uses Nimbus7/ERB comparisons to bridge the ‘ACRIM Gap’
Uses TSI results published by satellite experiment teams
Results reconciled to ACRIM3 scale

PMOD Composite TSI Time Series (Daily Means) *

TSI trend between minima during solar cycles 21 - 23: -0.007 %/decade
TSI trend between minima during solar cycles 21 - 24, approaching next minima: -0.011 %/decade

PMOD Composite:
Uses Nimbus7/ERB, ACRIM1, ACRIM2 & VIRGO results
Uses ERBS/ERBE comparisons to bridge the ‘ACRIM Gap’
Adjusts published TSI results to conform to TSI proxy models
Results reconciled to VIRGO scale

* Willson & Mordvinov, GRL, 2003
* Frohlich & Lean, GRL, 1998

RC Willson, earth_obs_fig28  06/11/2011
ACRIM3 TSI Proxy Results for Exoplanet Exploration

J. Pasachoff

ACRIM3 Total Solar Irradiance during Venus Transit

% var

Hour (UT 6/08/04)

RC Willson, acrim3_venus_transit_1p_30m 06/30/2004
Experimental

• Continue data processing, analysis and dissemination of ACRIMSAT/ACRIM3 results
• Re-test ACRIM3_EM to reduce uncertainties in scattering, diffraction and basic scale results
• Investigate apparent absence of an annual scattering & diffraction signal (~ 200 ppm)
• Investigate the signal noise level increase (~ 50 ppm) with updated algorithm
Science Investigations

- TSI trending and ‘ACRIM Gap’ implications of new solar magnetic activity data
- Possible solar/Planetary barycentric motion effects on Solar Activity, TSI and climate (w/Scafetta)
- TSI signature of the 2012 transit of Venus (w/Pasachoff)
- Co-convene AGU special session GC43: ‘Climate Change and the Sun 2. Improvements to the Total Solar Irradiance Record’ with Greg Kopp (LASP) at the 2011 Fall Meeting
- Publish ACRIM/TRF findings and their TSI monitoring significance