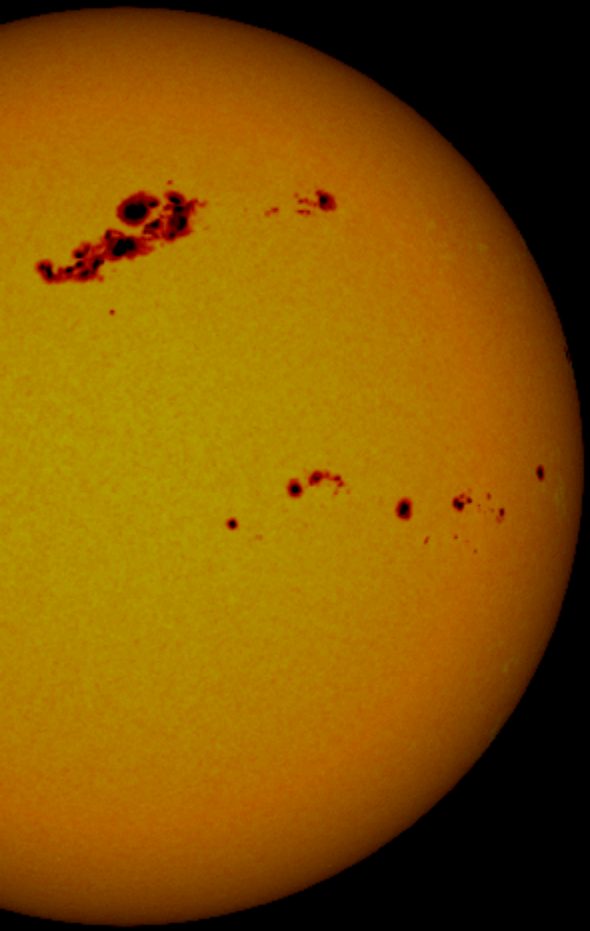
Past Variation of Total Solar Irradiance and Future Monitoring Needs



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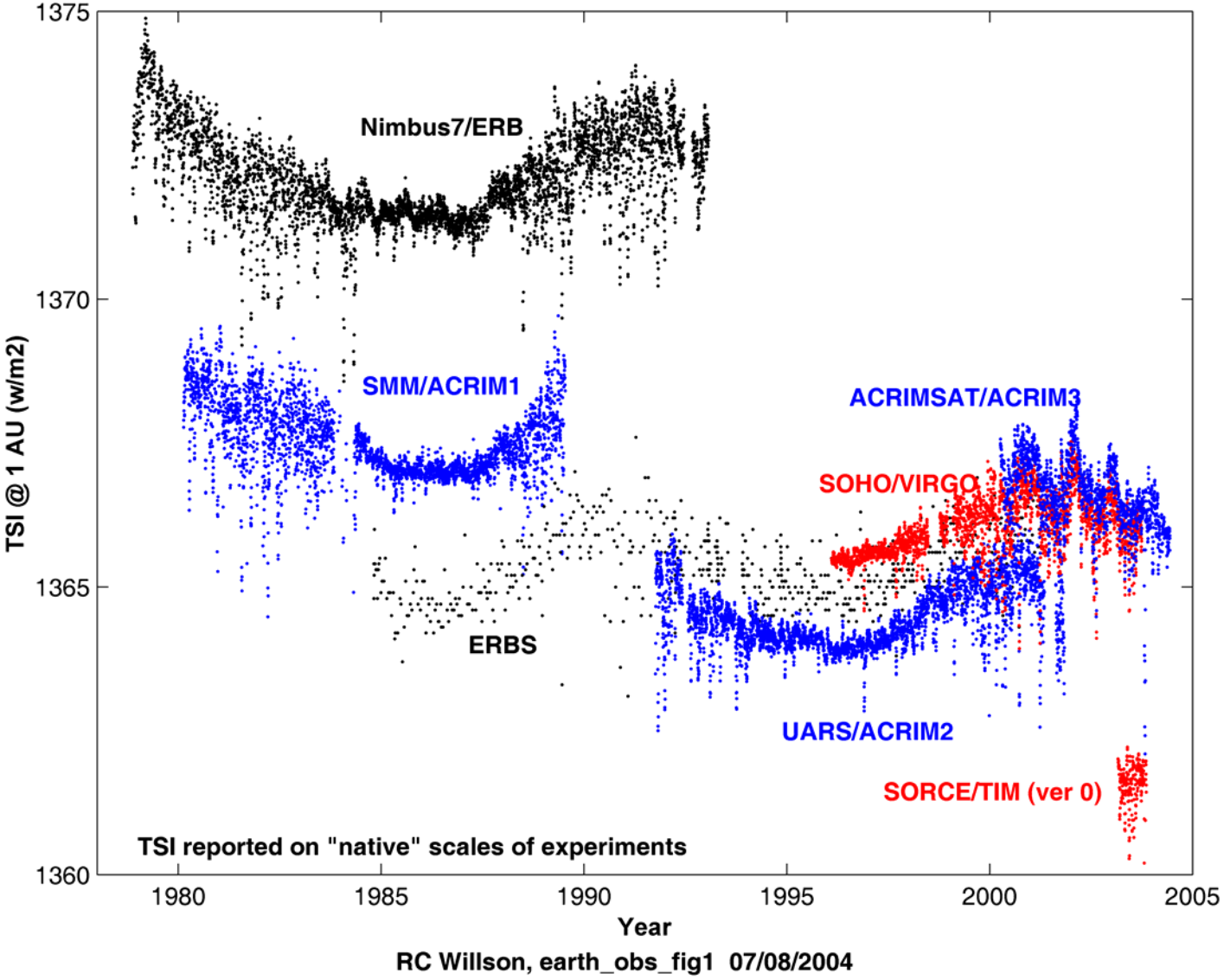
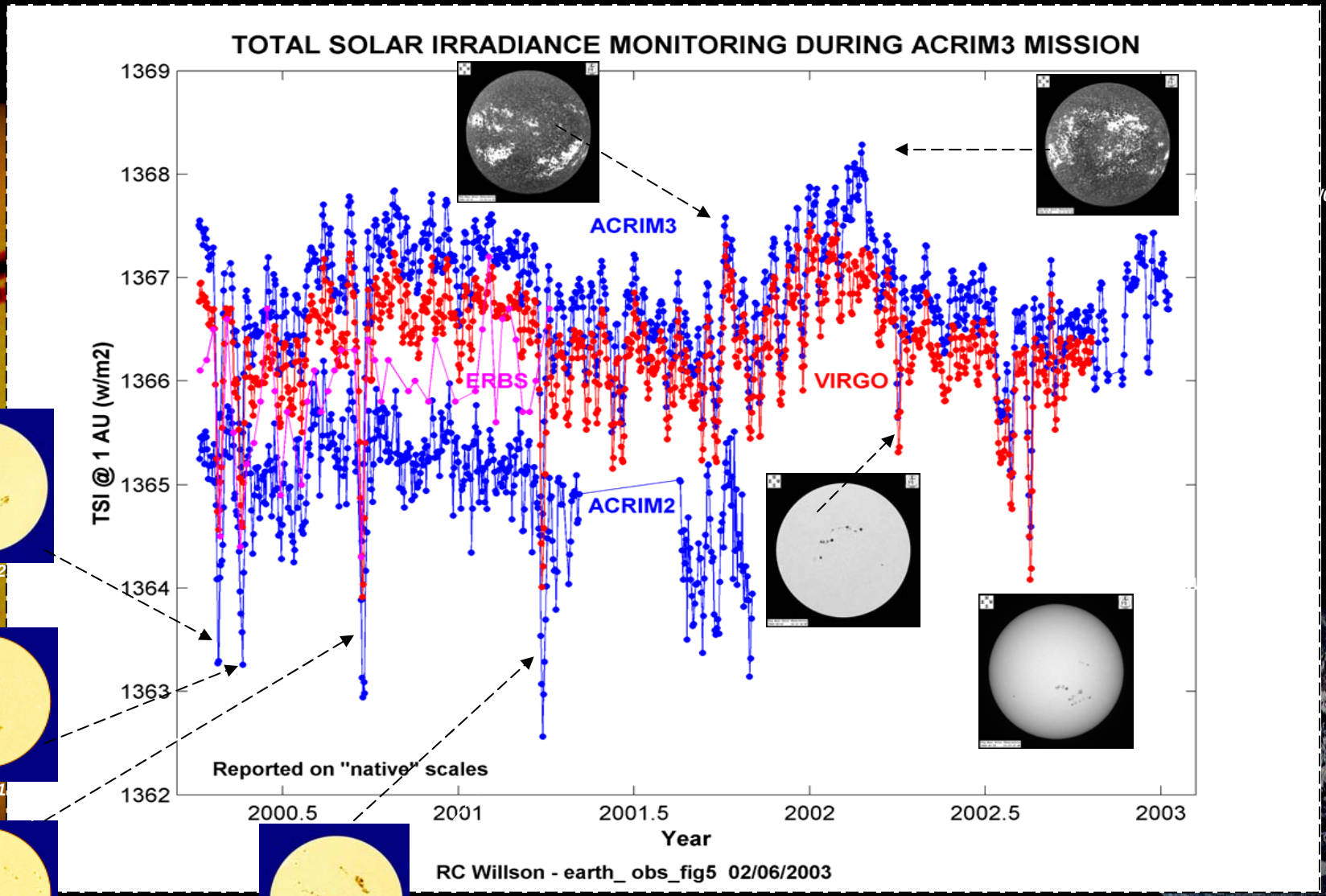

TOTAL SOLAR IRRADIANCE MONITORING RESULTS: 1978 to Present
1375
1370
1365
1360
TSI @ 1 AU (w/m2)
Nimbus7/ERB
SMM/ACRIM1
ACRIMSAT/ACRIM3
SOHO/VIRGO
ERBS
UARS/ACRIM2
SORCE/TIM (ver 0)
TSI reported on "native" scales of experiments
1980
1985
1990
1995
2000
2005
Year
RC Willson, earth_obs_fig1 07/08/2004

0.4 %

TSI Sunspot Deficit & Facular Excess Feature Correlations



Critical Characteristics of TSI Monitoring Experiments

Experiment	PI Mode	Observing Frequency	Shutter Calibration Frequency	Electrical Calibration Frequency	Degradation Calibration	Solar Pointed
Nimbus7/ERB 1978 – 1993	Quasi	3 of 4 days 5 min/LEO orbit	None	2 weeks	None	No
SMM/ACRIM1 1980 - 1989	Yes	55 min/LEO orbit	1 min. cycle	Continuous	3-fold redundant Monthly	Yes
ERBS 1984 - 2000	No	5 min. every 14 days	30 sec. cycle	2 weeks	None	No
UARS/ACRIM2 1991 →	Yes	35 min/LEO orbit	1 min. cycle	Continuous	3-fold redundant Monthly	Yes
SOHO/VIRGO 1996 →	Yes	Continuous L1 Point Orbit	Occasional using instrument door	Continuous	2-fold redundant SOHO Hiatus issues Degradation Rate issues	Yes
ACRIMSAT/ACRIM3 2000 - 2005	Yes	62 min/LEO orbit	1 min. cycle	Continuous	3-fold redundant Monthly	Yes
SORCE/TIM 2003 - 2008	Yes	TBD min/LEO orbit	100 sec. cycle	Continuous	3-fold redundant Monthly	Yes

Color				
Impact on Observations	Degrading	Sub-optimal	Optimal	Optimum

The Total Solar Irradiance (TSI) Observational Database

- Continuous satellite TSI monitoring since late 1978

  By redundant, overlapping, satellite experiments employing pyrheliometric sensors
  Experiments report TSI observations on the 'native scale' defined by their sensors

- 'Native scale' differences exist: up to ± 0.4 % about the mean of all observations

  Prior to 2003: differences caused by known systematic errors in sensor metrology
  Post 2003: cause of 0.4 % lower results of SORCE/TIM are TBD

- The 'absolute' uncertainties of the experiments in S.I. Units vary

  None is significantly less than ± 0.1 %
  TSI monitors (ACRIM, VIRGO and TIM) ~ ± 0.1 %
  ERB experiments (Nimbus7/ERB and ERBS) were designed for ± 0.5 %

The TSI Climate Change Observational Database

- The TSI-climate change record must resolve 0.05 % changes on centennial time scales
- Current sensor technology cannot provide the record with its 0.1 % uncertainty limit
- The traceability of sensors during their mission lifetimes varies among experiments

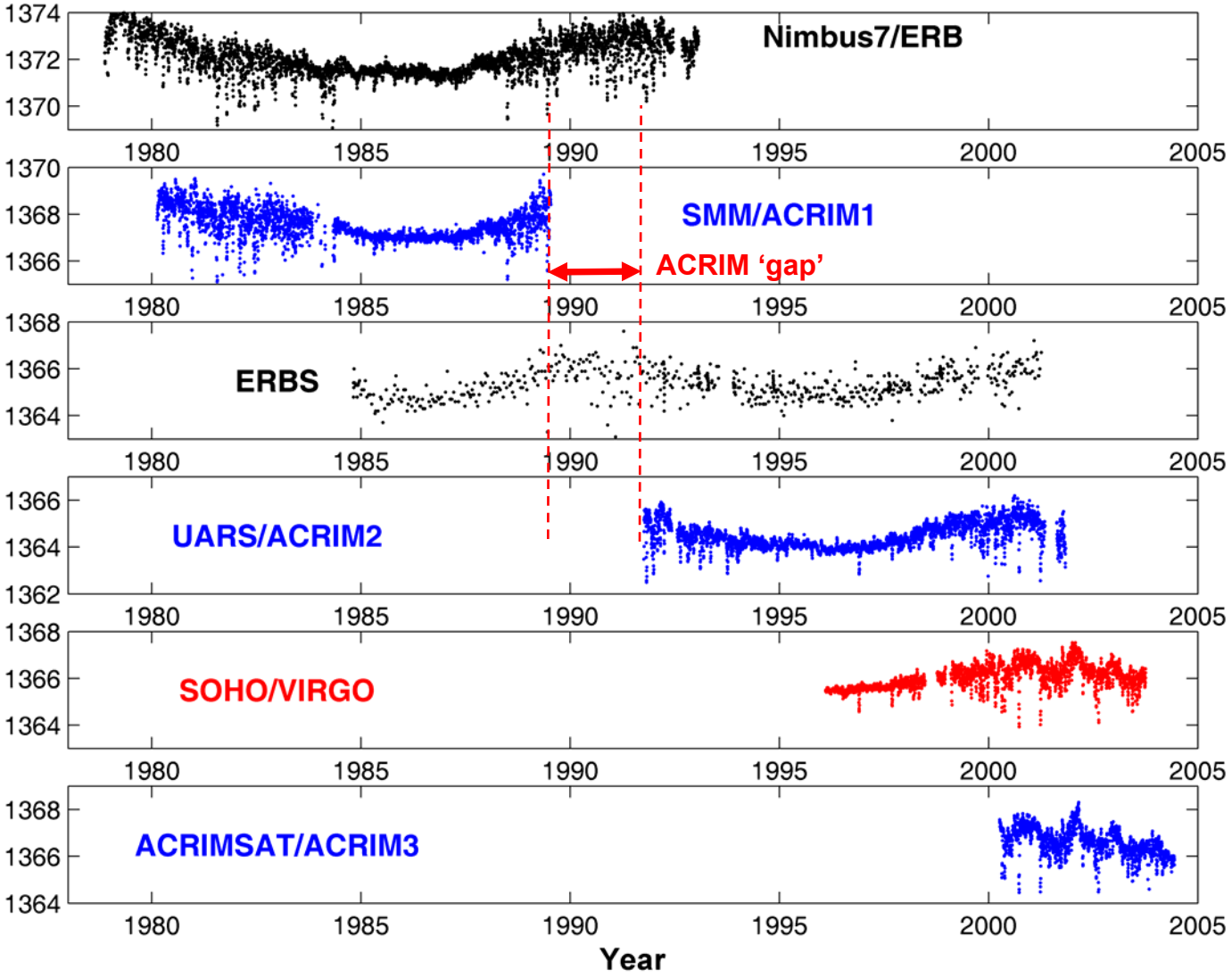
  TSI monitors (ACRIM, VIRGO & TIM) capable of ± 5 - 10 ppm/yr
  ACRIM3 is currently demonstrating 3 ppm/yr during its 1st four years of operation

- Overlapping experiments can provide contiguous results with the required traceability

Composite TSI Climate Change Databases

- Precise, long term ‘composite’ TSI records can be constructed from extant TSI data sets
- Composites will depend on the precision and traceability of subset of TSI data chosen
- More precise and traceable TSI monitoring results should be used when possible
- Less precise and traceable ERB results should be used only when necessary
- The relationship between ACRIM1 and ACRIM2 results must be established

Total Solar Irradiance Monitoring Results: 1978 - 2003



ACRIM Composite TSI Approach

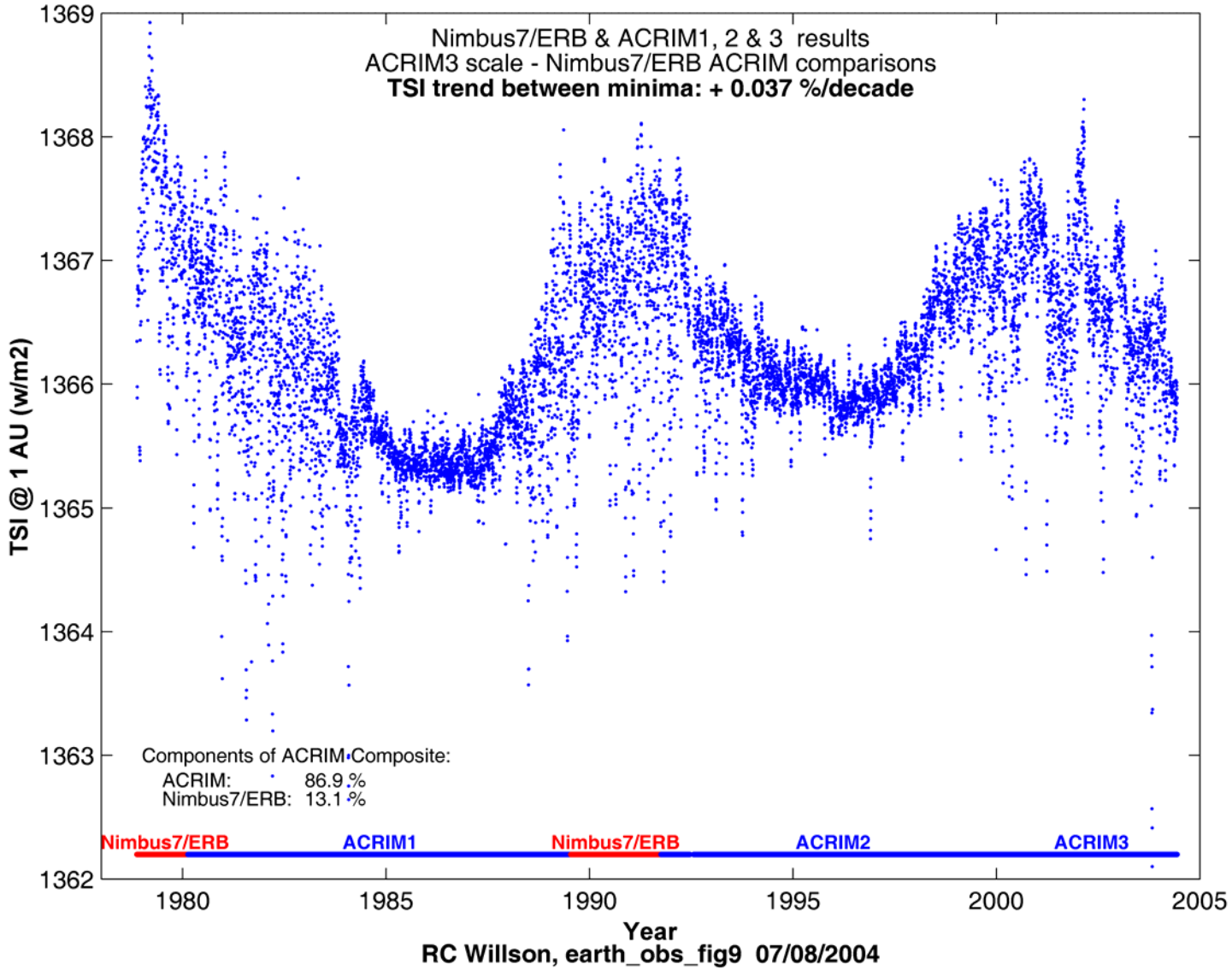
- The ACRIM Composite is compiled using:

  Original published results from TSI experiments

  Overlapping comparisons to relate experiments' results

  ACRIM 1 & 2 comparisons with Nimbus7/ERB to bridge the ACRIM 'gap'

- Composite time series is reconciled to the ACRIM3 'native scale'


ACRIM Composite TSI Time Series
Nimbus7/ERB & ACRIM1, 2 & 3 results
ACRIM3 scale - Nimbus7/ERB ACRIM comparisons
TSI trend between minima: + 0.037 %/decade
TSI @ 1 AU (w/m2)
1369
1368
1367
1366
1365
1364
1363
1362
1980
1985
1990
1995
2000
2005
Year
Components of ACRIM Composite:
ACRIM: 86.9 %
Nimbus7/ERB: 13.1 %
Nimbus7/ERB
ACRIM1
Nimbus7/ERB
ACRIM2
ACRIM3
RC Willson, earth_obs_fig9 07/08/2004

Composite TSI Measurements and Models

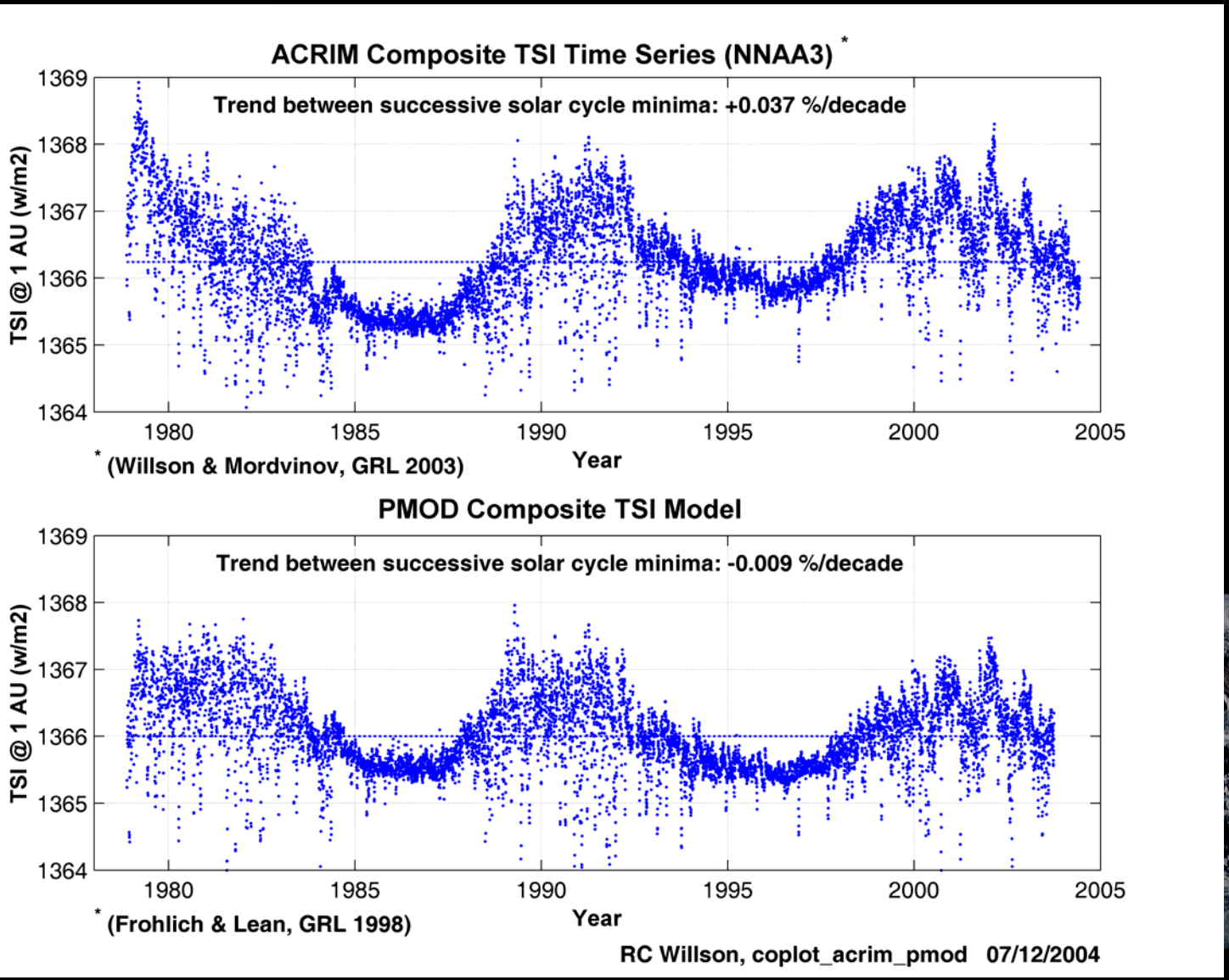
- **ACRIM Composite TSI**

  Uses original published results from TSI experiments
  Uses Nimbus7/ERB ACRIM 'gap' ratio to link ACRIM1 and ACRIM2

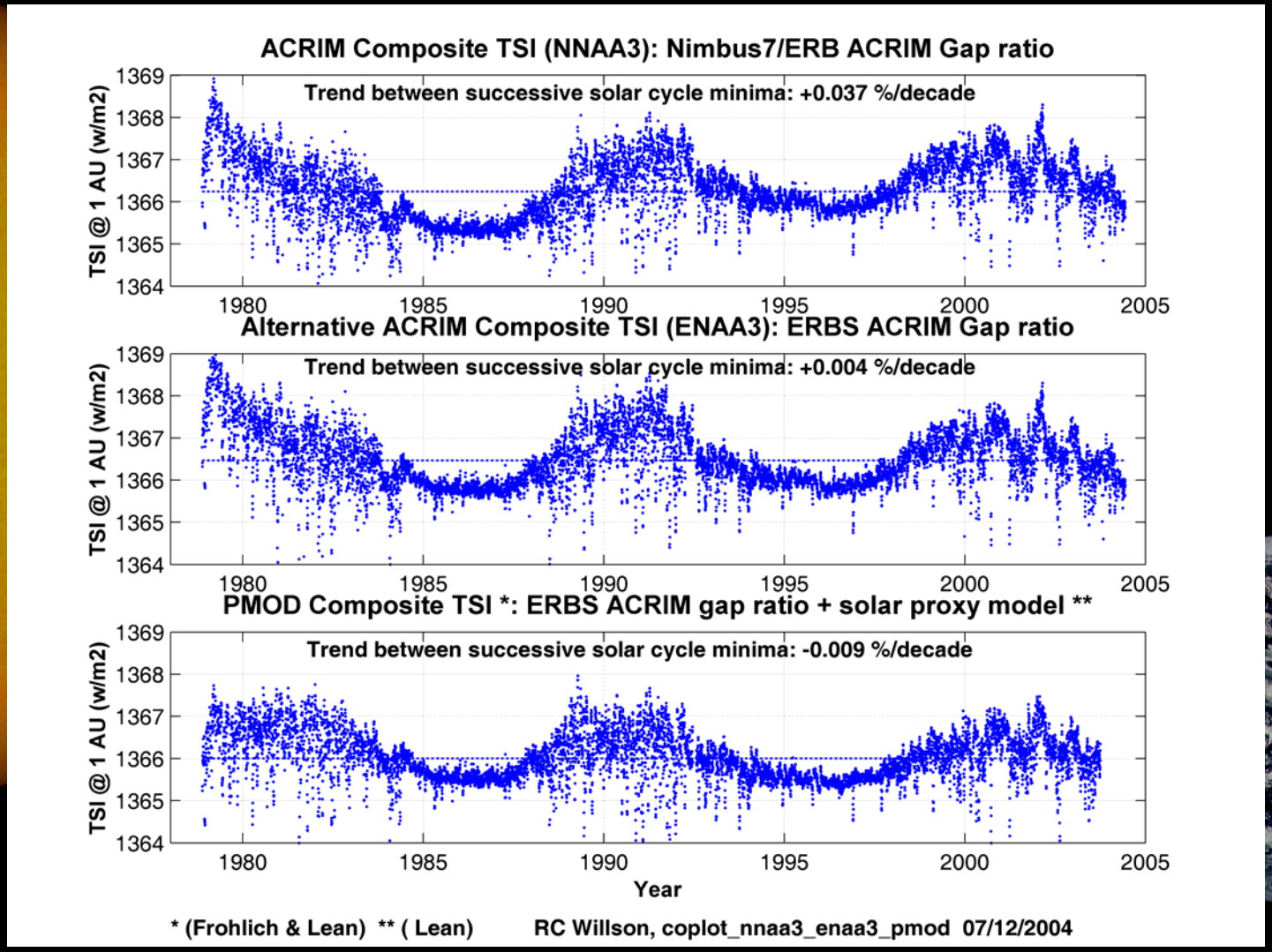
- **PMOD Composite TSI**

  Modifies published results from TSI experiments to fit proxy model predictions
  Uses ERBS ACRIM 'gap' ratio to link ACRIM1 and ACRIM2

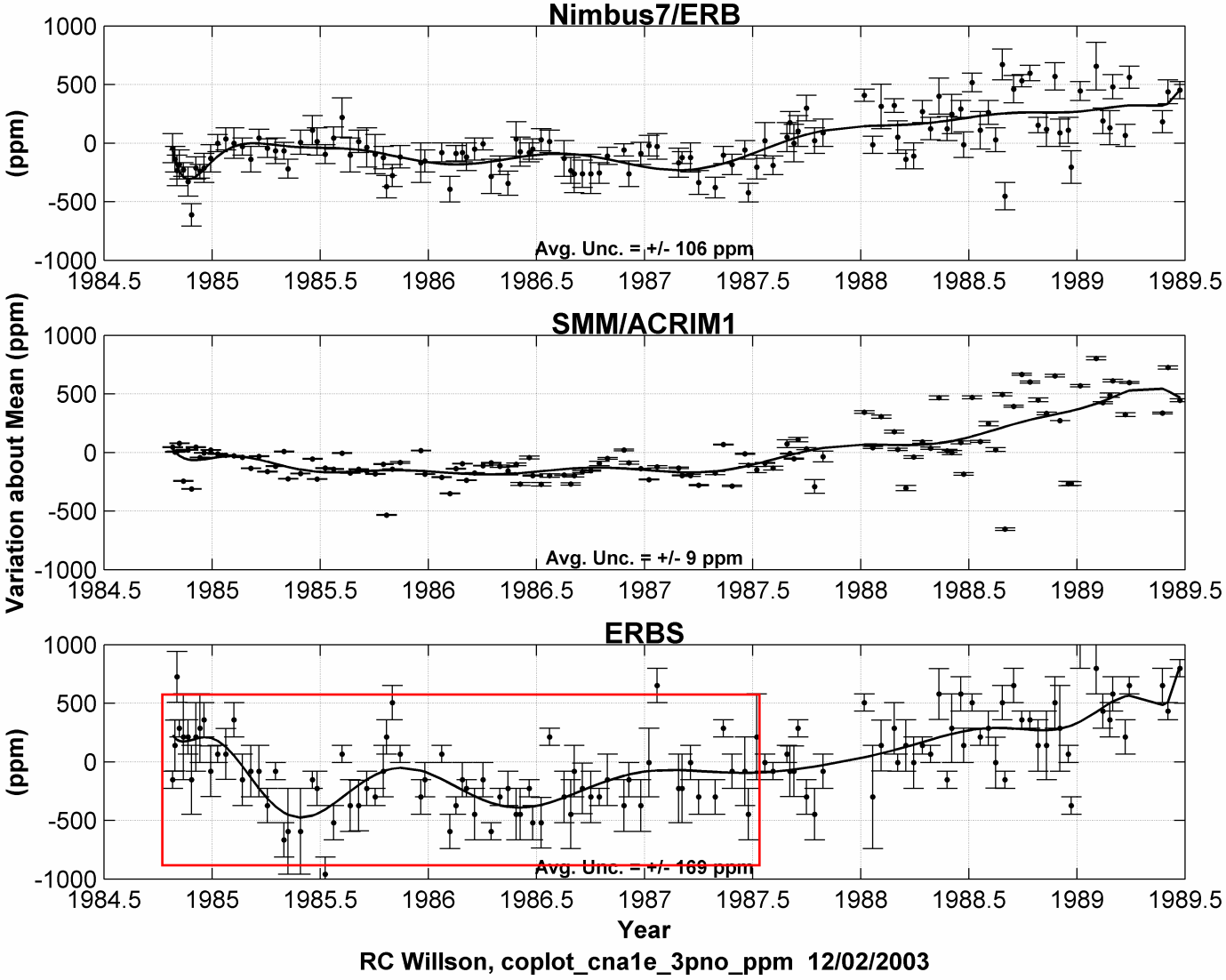
Comparison of ACRIM and PMOD Composite TSI



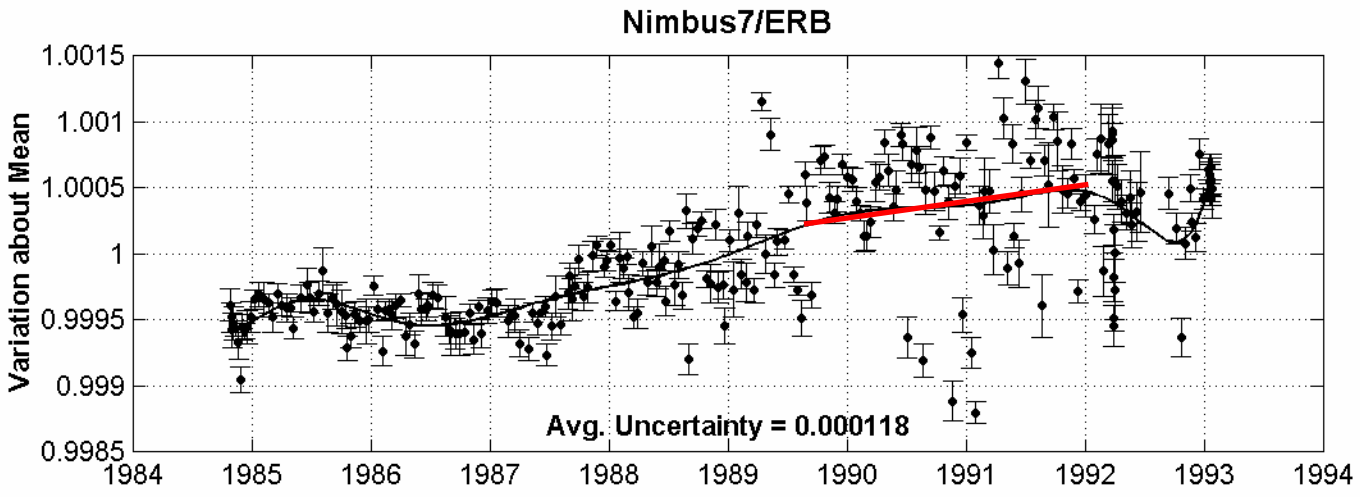
Composite TSI Trend Depends on Choice of Nimbus7/ERB or ERBS for the ACRIM 'gap' ratio

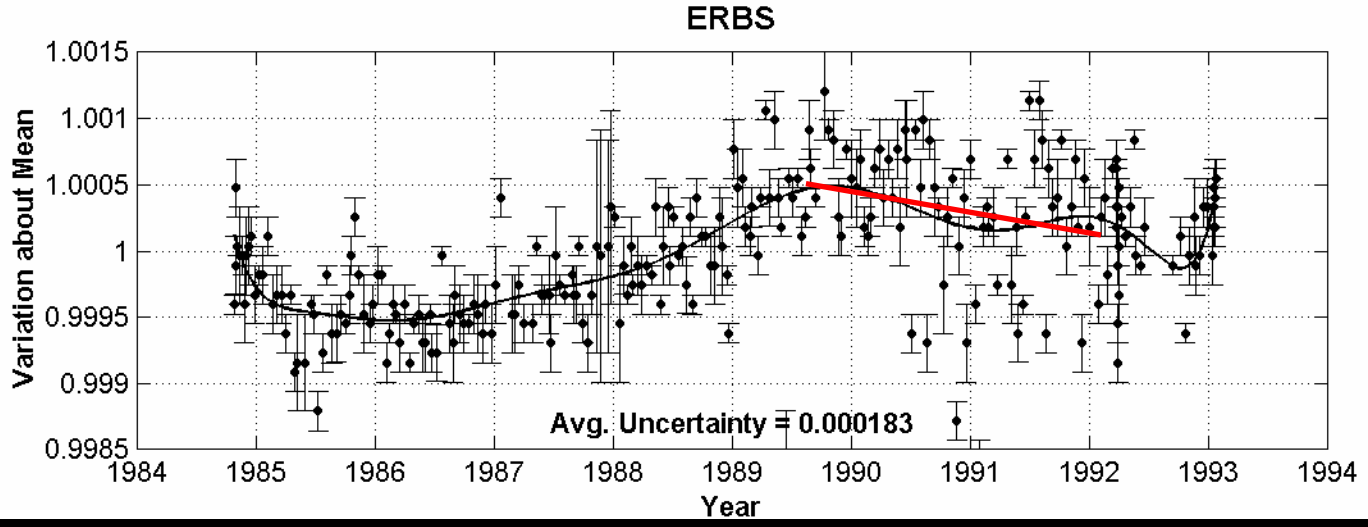


Comparison of Simultaneous daily means during ACRIM1 Period

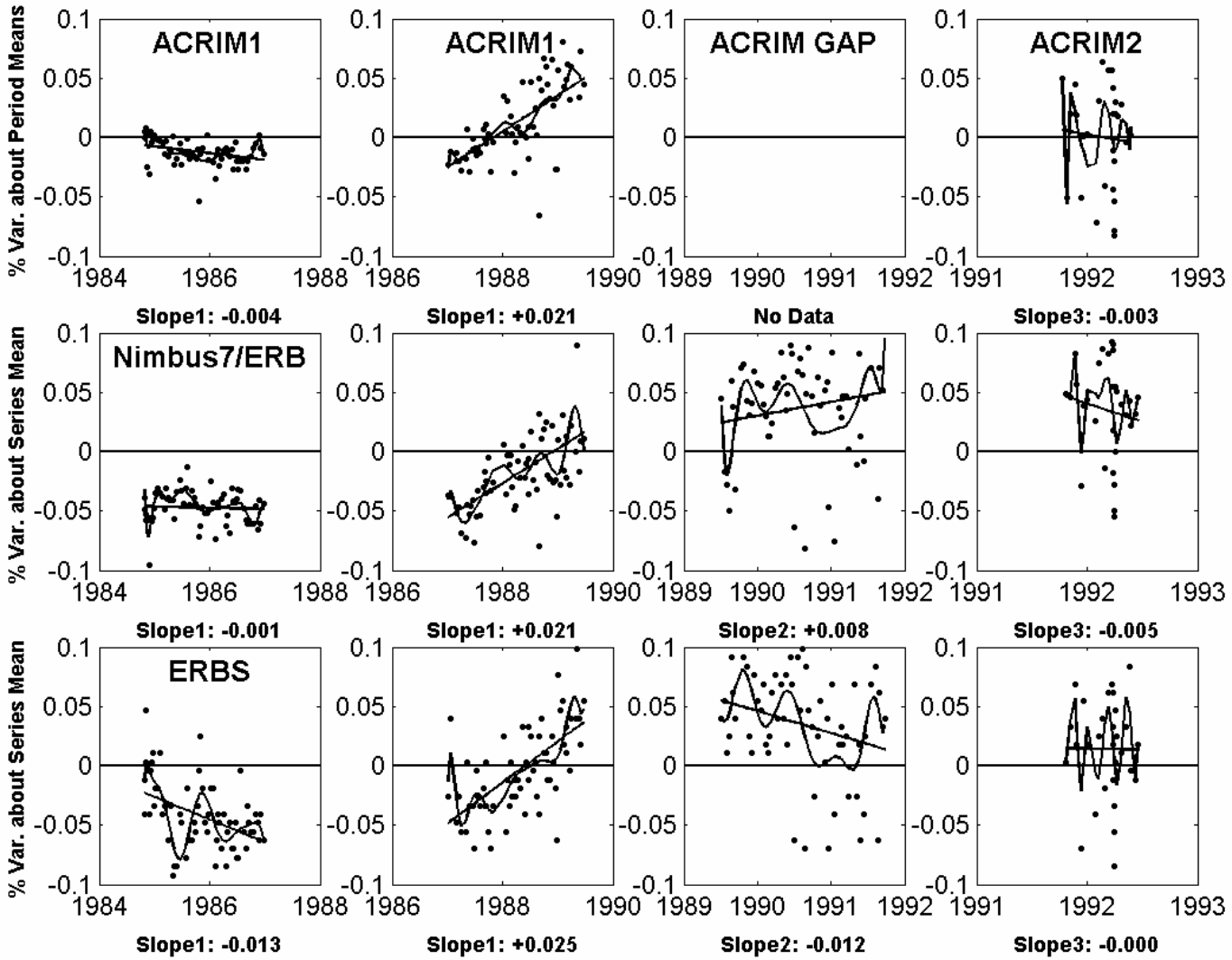


Comparison of Nimbus7/ERB and ERBS results
(Simultaneous Daily Means)





Comparison of 'ACRIM Gap' Overlapping Observations

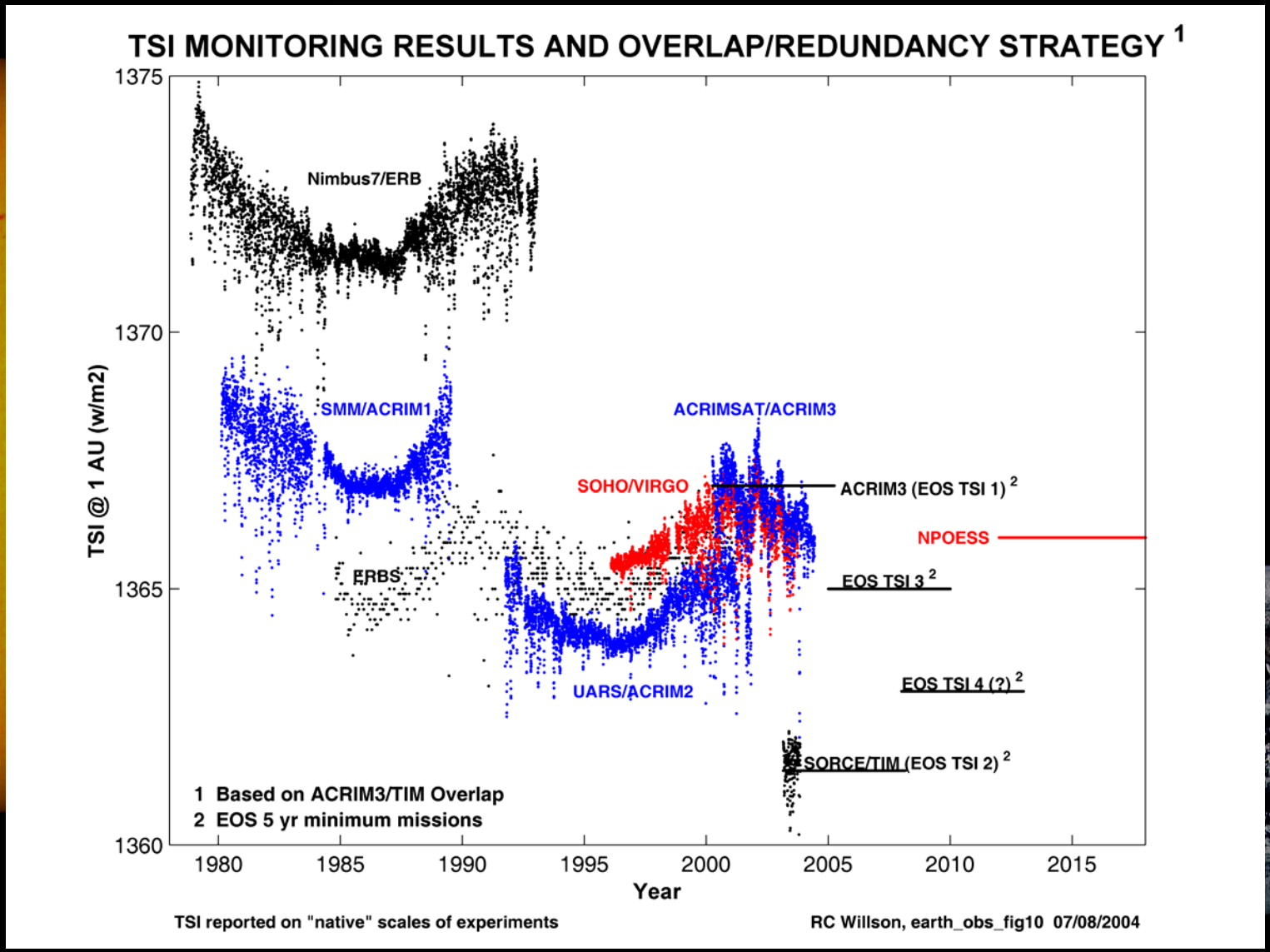


Secular Total Solar Irradiance trend during solar cycles 21-23_Figure 7_RC Willson_acrim@acrim.com_11/15/2002

‘ACRIM gap’ test of comparison TSI databases

- TSI variability paradigm: TSI is proportional to solar magnetic activity level on solar cycle time scales
- Solar magnetic activity level increased significantly during the ACRIM ‘gap’
- Nimbus7/ERB upward trend during ACRIM ‘gap’ is compatible with the paradigm
- ERBS downward trend during ACRIM ‘gap’ is incompatible with the paradigm
- ERBS degradation during ACRIM ‘gap’ equals the (ACRIM – PMOD) trend difference
- The absence of a minimum-to-minimum trend in composite models using ERBS results to bridge ACRIM ‘gap’ is an artifact of ERBS degradation
- Composite TSI time series using Nimbus7/ERB data exhibit a minimum-to-minimum trend of + 0.04 %/decade during solar cycles 21 - 23

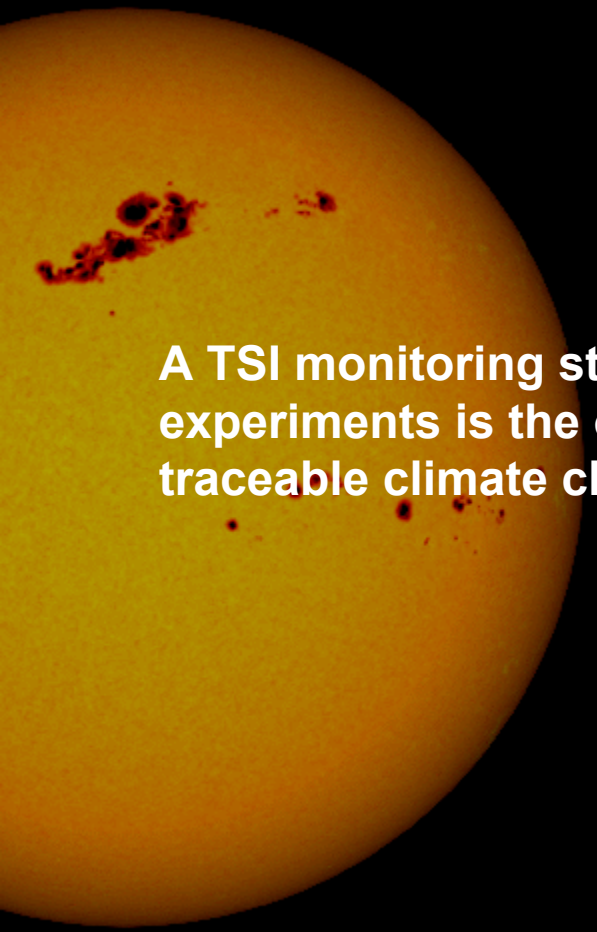
TSI Monitoring Strategy



Rationale and Strategy for TSI Database Continuity

- Traceability of composite TSI since 1978: ≥ 100 ppm
  - Depends on the subset of results and ACRIM gap comparisons used
  - Overlapping TSI monitoring experiments can provide high traceability
  - Redundant satellite TSI experiments have prevented database interruption
- Overlap Strategy provides maximum TSI database traceability with current technology
- Redundant satellite experiments required to prevent unrecoverable single point failures in the Overlap Strategy

CONCLUSIONS



A TSI monitoring strategy with redundant, overlapping satellite experiments is the only means of sustaining a sufficiently precise and traceable climate change TSI database with current technology

TSI Monitoring Instrumentation
The Active Cavity Radiometer (ACR)