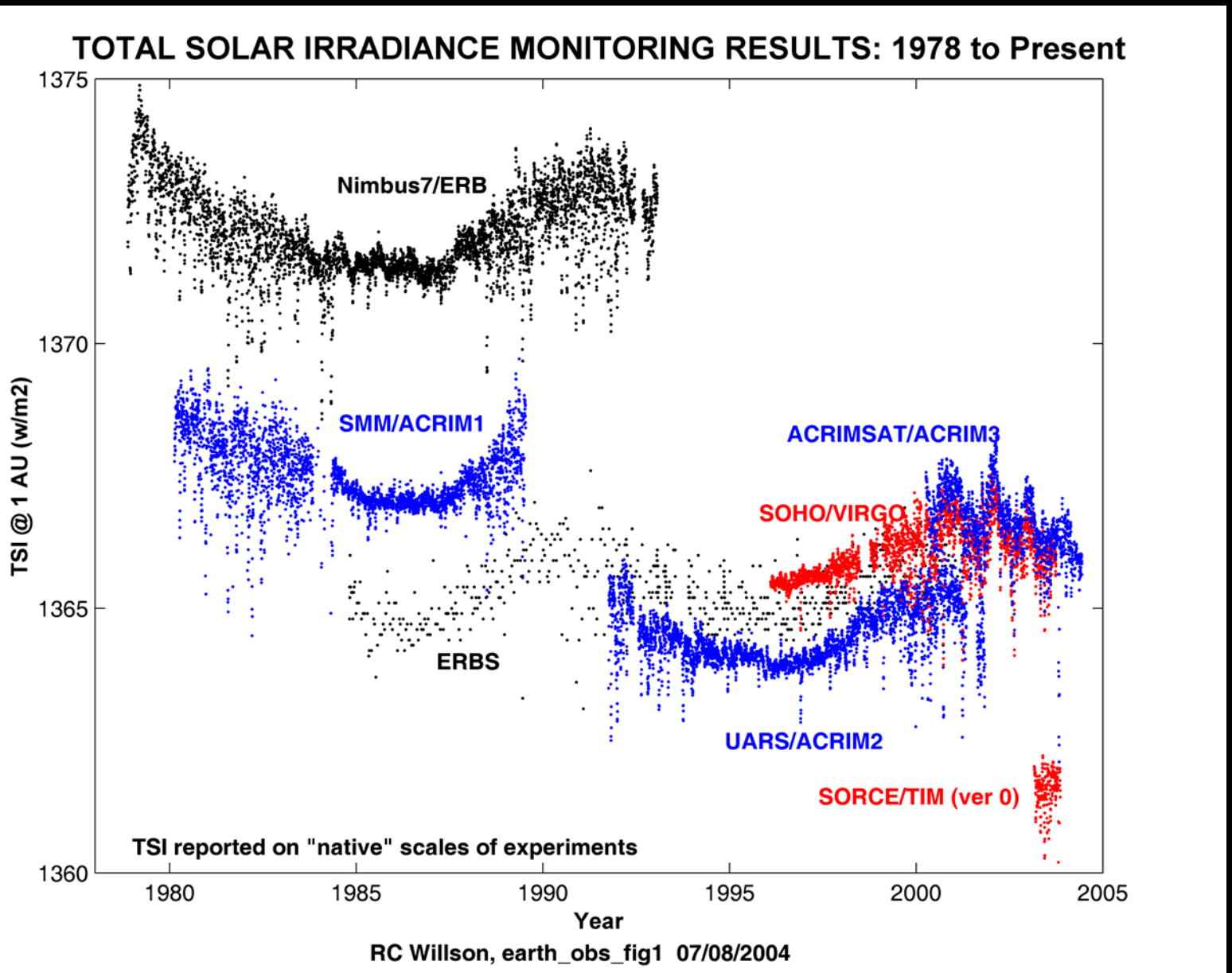
Variations in Total Solar Irradiance include a + 0.04 percent per decade trend in the satellite monitoring record during 1978 - 2004

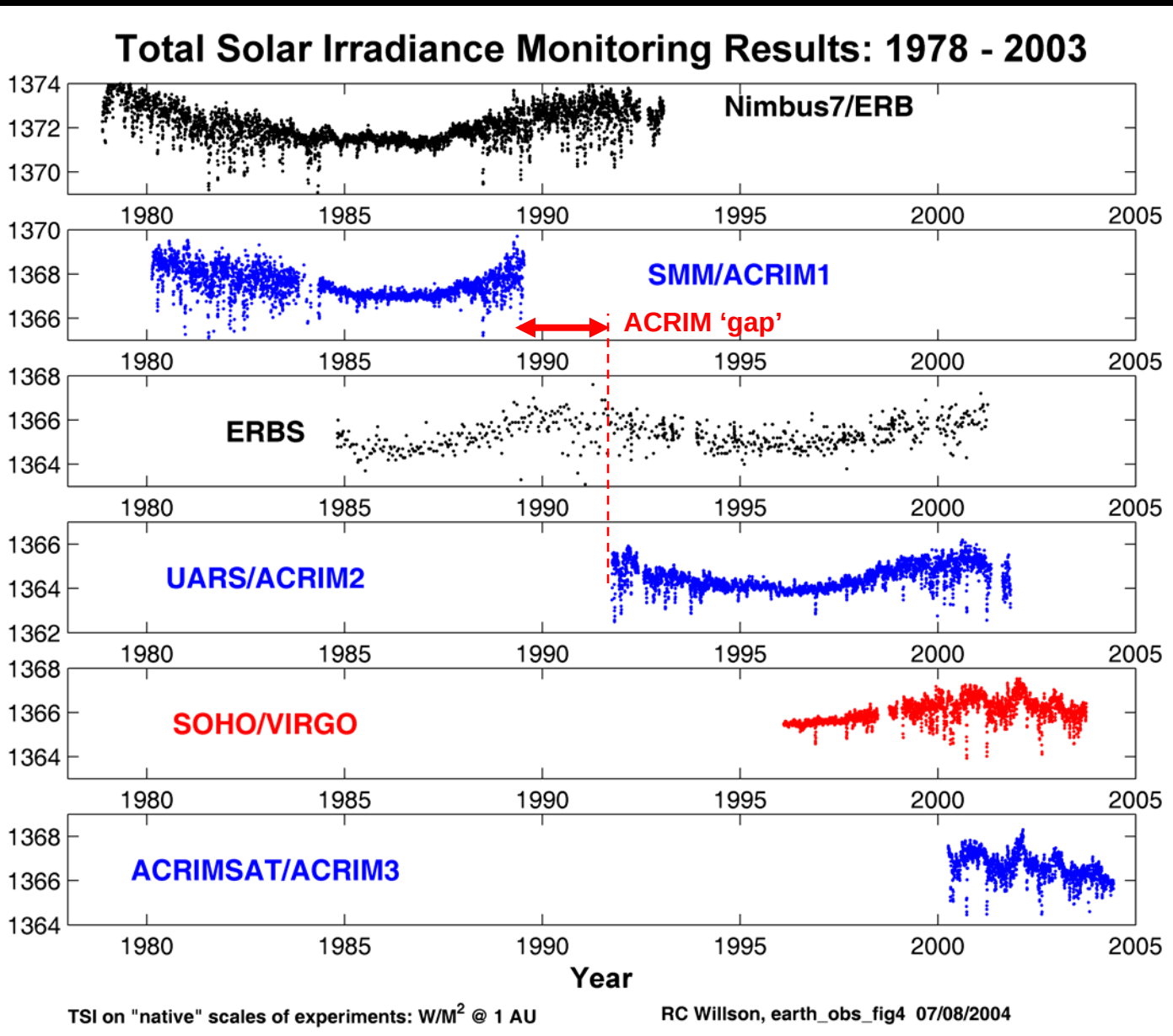
The Total Solar Irradiance (TSI) Observational Database

- Continuous monitoring since 1978 by redundant, overlapping, satellite experiments
- Satellite comparisons provide contiguous results at mutual precision levels
- Absolute uncertainty varies among experiments - is not significantly less than 0.1 %
- Accuracy inadequate to construct TSI database useful for climate change studies
- Traceability varies among experiments – state of the art is ~ 50 ppm/decade
- Scale differences of ± 0.4 % are likely due to systematic errors in sensor metrology
- Long term composite results depend on precision and traceability of experiments

R C Willson - Columbia University
Judit Pap & A V Mordvinov


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

0.4 %


Total Solar Irradiance Monitoring Results: 1978 - 2003
Nimbus7/ERB
SMM/ACRIM1
ACRIM 'gap'
ERBS
UARS/ACRIM2
SOHO/VIRGO
ACRIMSAT/ACRIM3
Year
TSI on "native" scales of experiments: W/M2 @ 1 AU
RC Willson, earth_obs_fig4 07/08/2004

ACRIM Composite TSI Approach

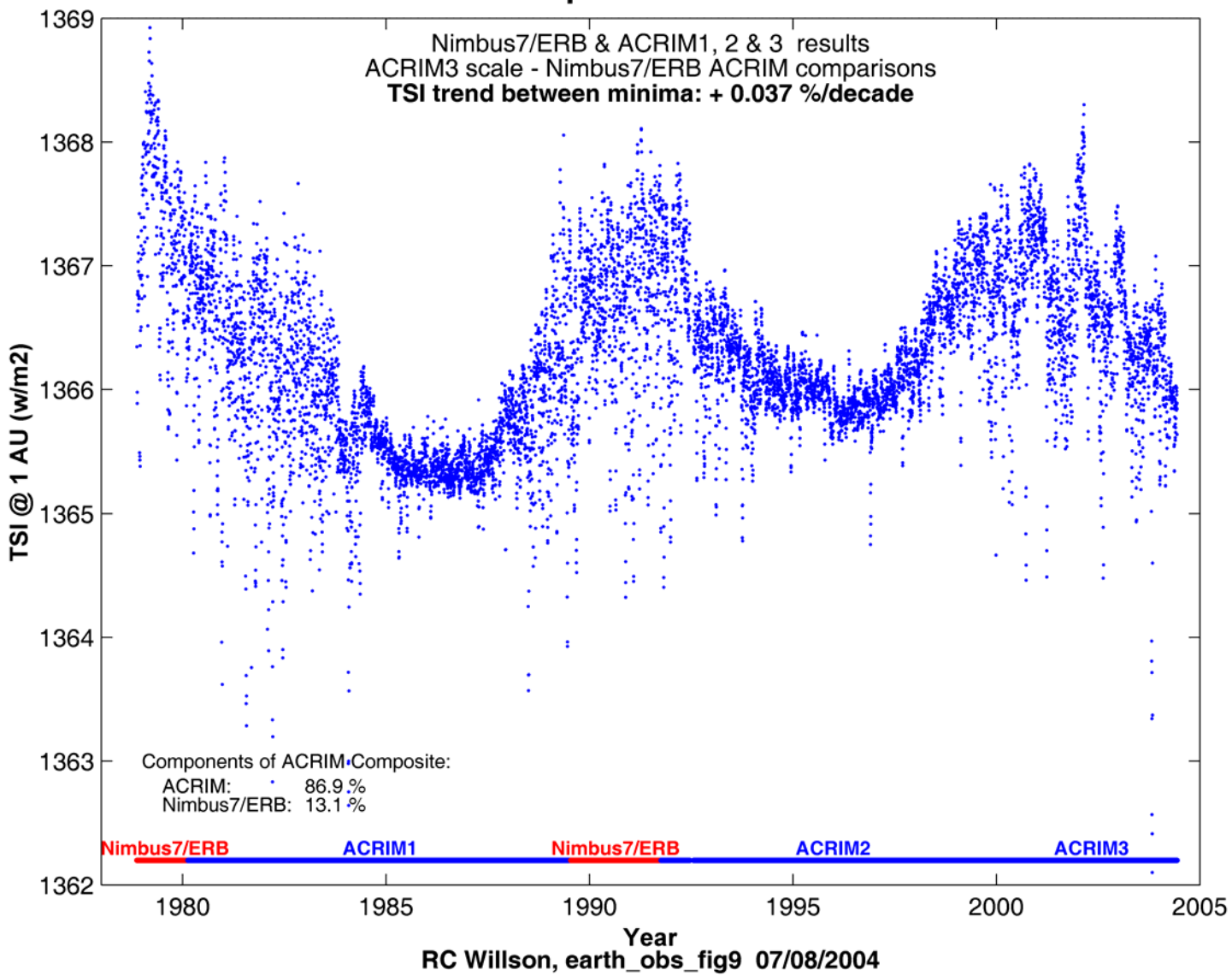
- **ACRIM Composite is compiled using:**

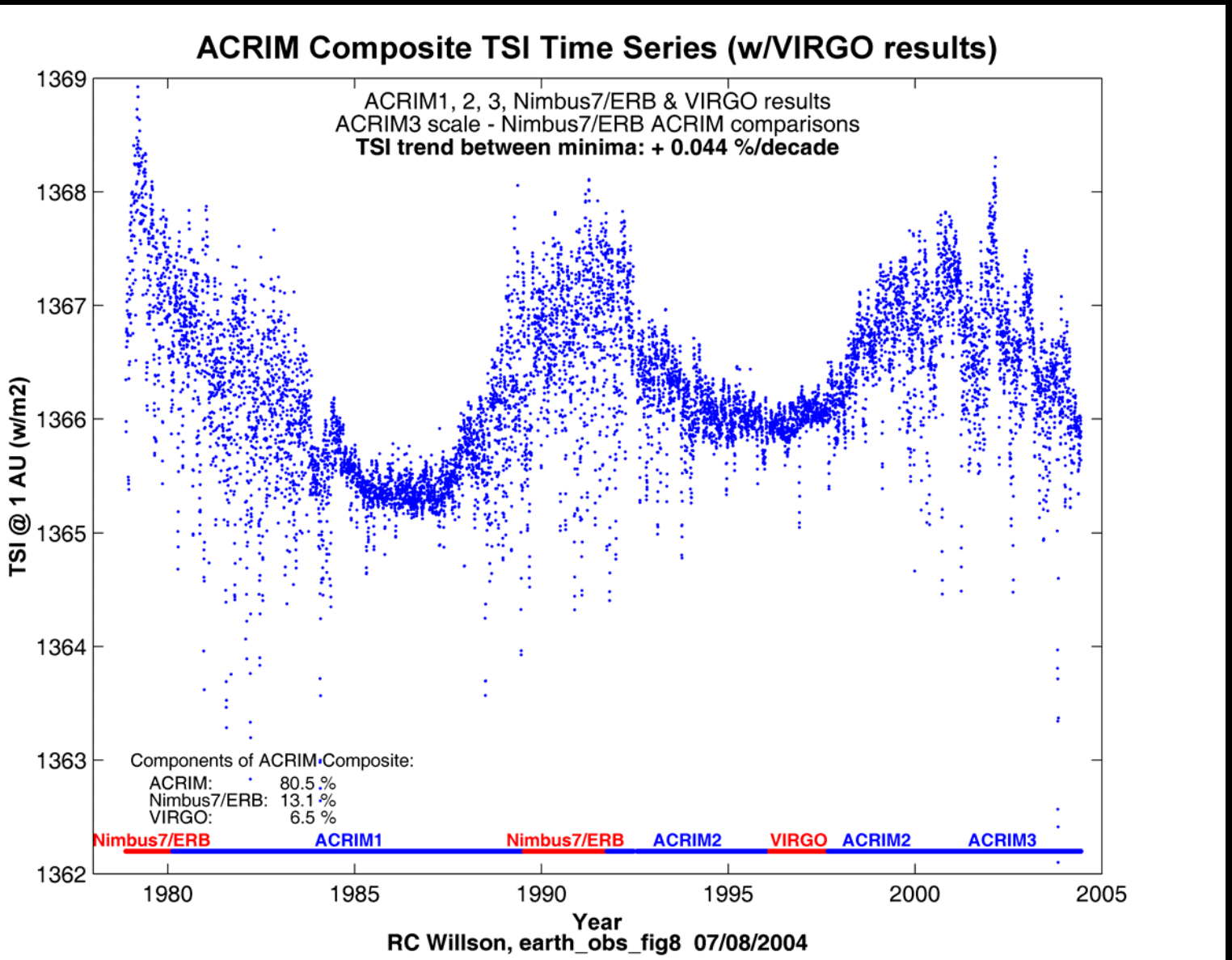
  Original published results from TSI experiments

  Overlapping comparisons to relate experiments' results

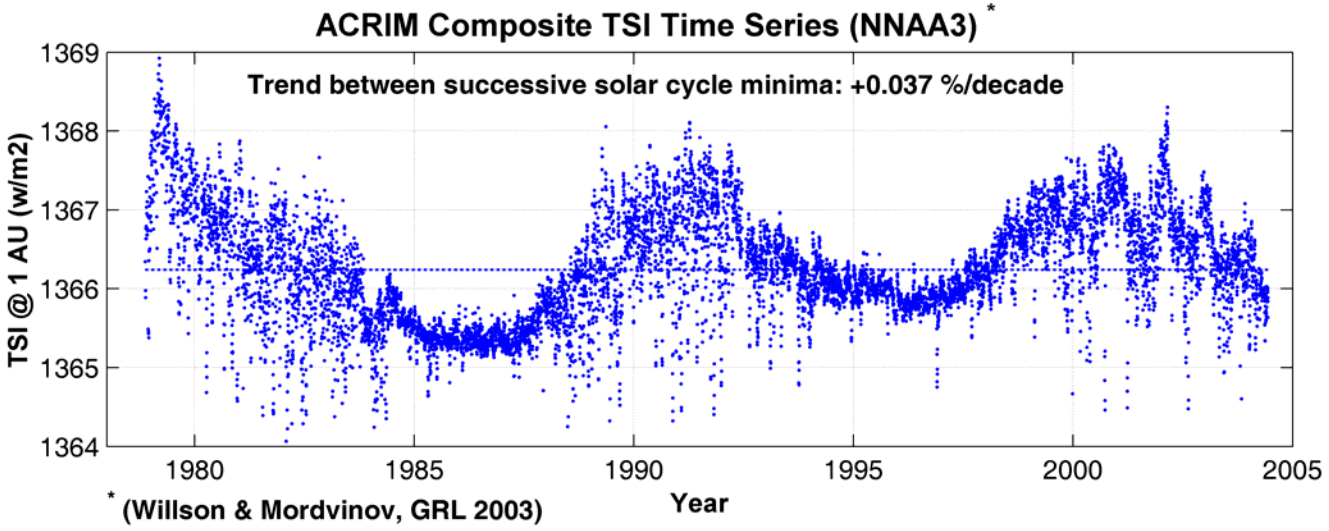
  ACRIM 1 & 2 comparisons with Nimbus7/ERB to bridge the ACRIM 'gap'

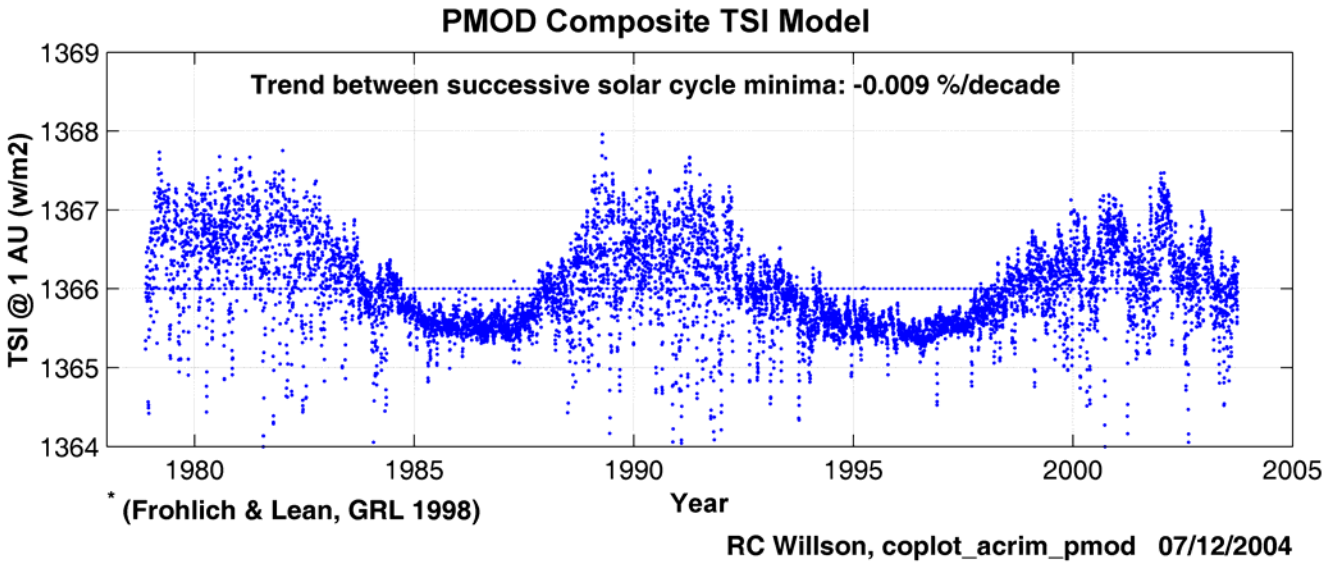
- **Reconciles Composite time series to ACRIM3 'native scale'**


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
Components of ACRIM Composite:
ACRIM: 86.9 %
Nimbus7/ERB: 13.1 %
Nimbus7/ERB
ACRIM1
Nimbus7/ERB
ACRIM2
ACRIM3
1980
1985
1990
1995
2000
2005
Year
RC Willson, earth_obs_fig9 07/08/2004


ACRIM Composite TSI Time Series (w/VIRGO results)
ACRIM1, 2, 3, Nimbus7/ERB & VIRGO results
ACRIM3 scale - Nimbus7/ERB ACRIM comparisons
TSI trend between minima: + 0.044 %/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: 80.5 %
Nimbus7/ERB: 13.1 %
VIRGO: 6.5 %
Nimbus7/ERB
ACRIM1
Nimbus7/ERB
ACRIM2
VIRGO
ACRIM2
ACRIM3
RC Willson, earth_obs_fig8 07/08/2004

Comparison of ACRIM and PMOD Composite TSI





Composite TSI Measurements and Models

- **ACRIM Composite TSI**

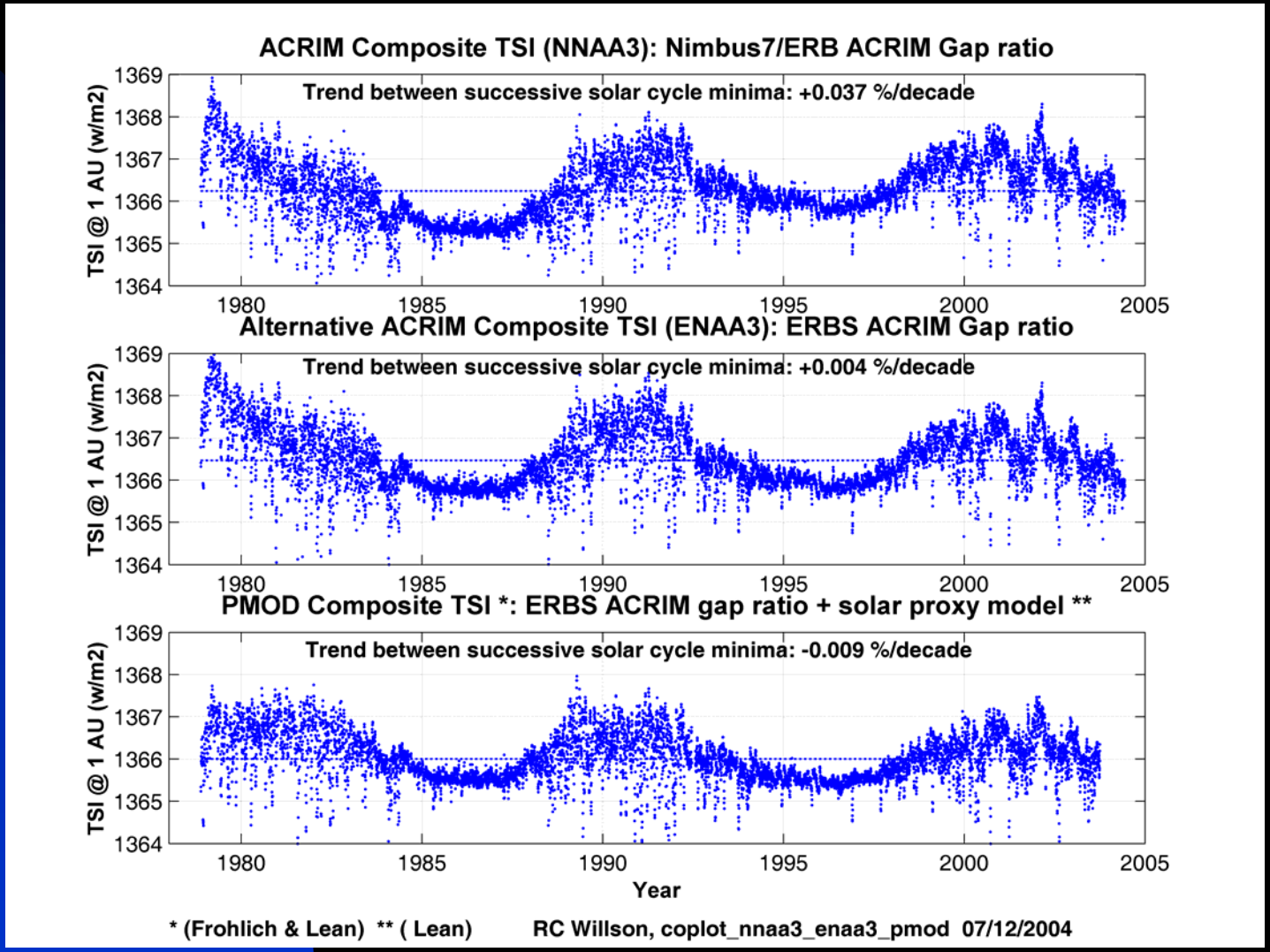
  Uses original published results from TSI experiments
  Uses Nimbus7/ERB ACRIM 'gap' ratio to link ACRIM1 and ACRIM2

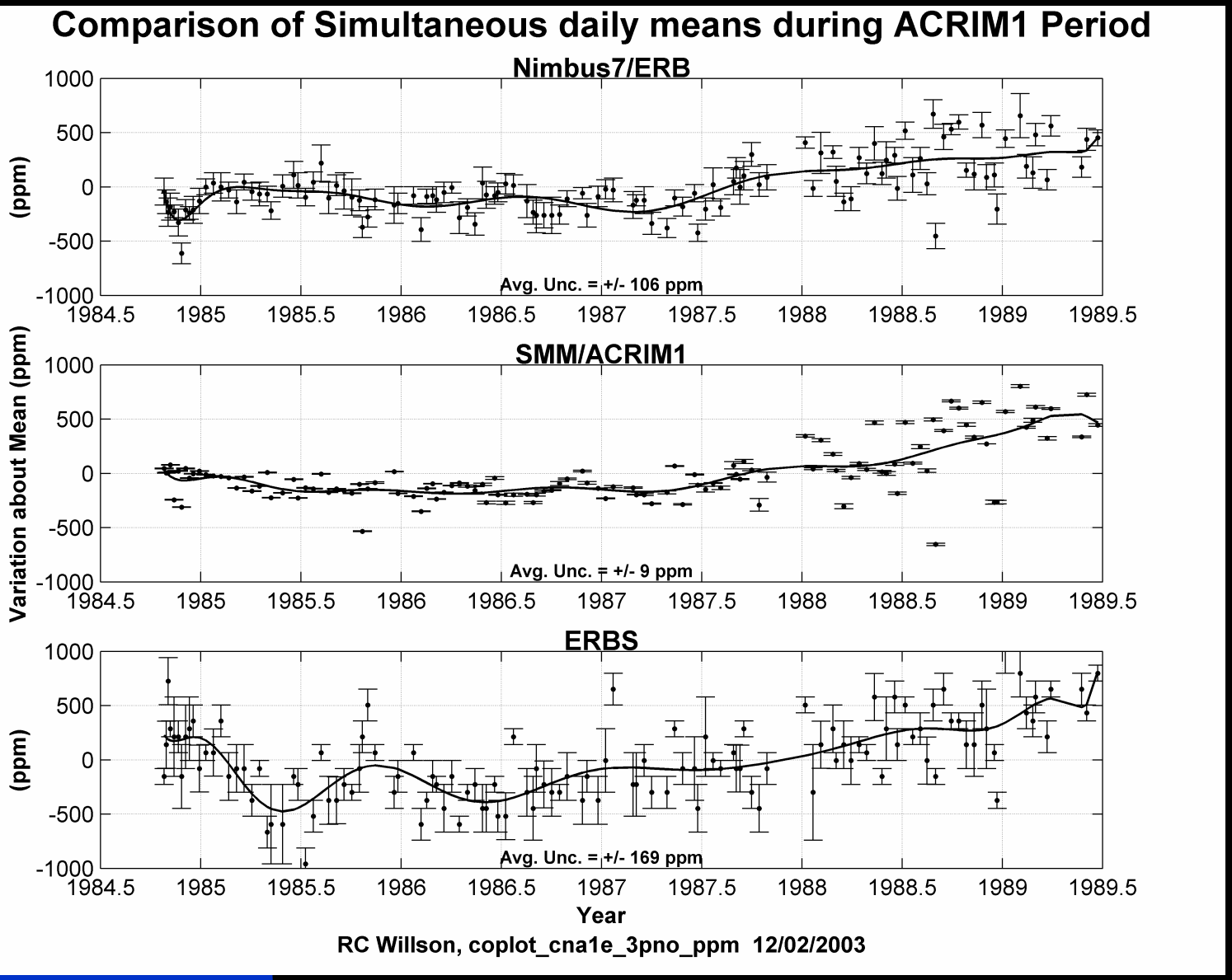
- **PMOD Composite TSI**

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

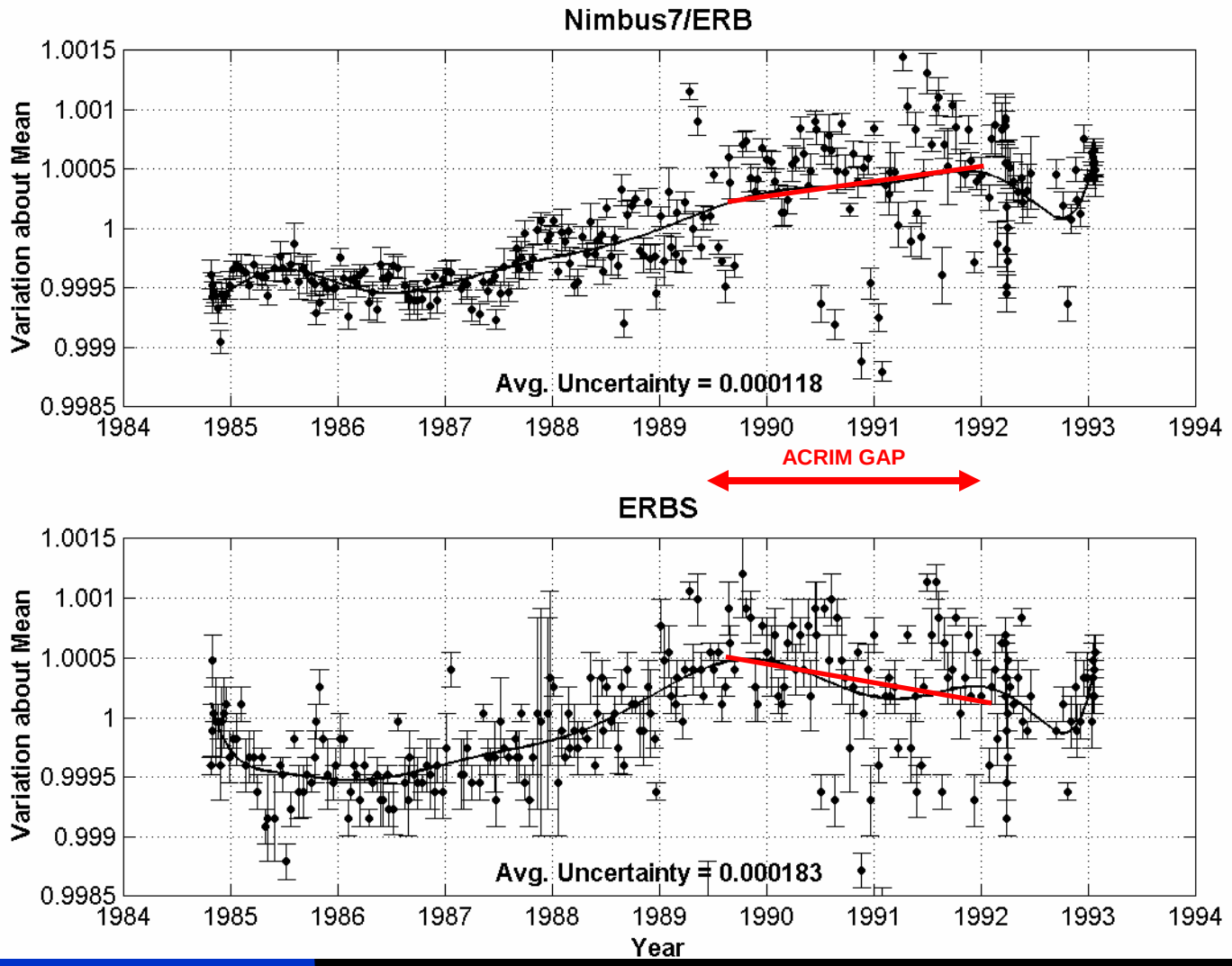
Composite TSI Dilemma:

Use Nimbus7/ERB or ERBS ACRIM 'gap' ratio ?

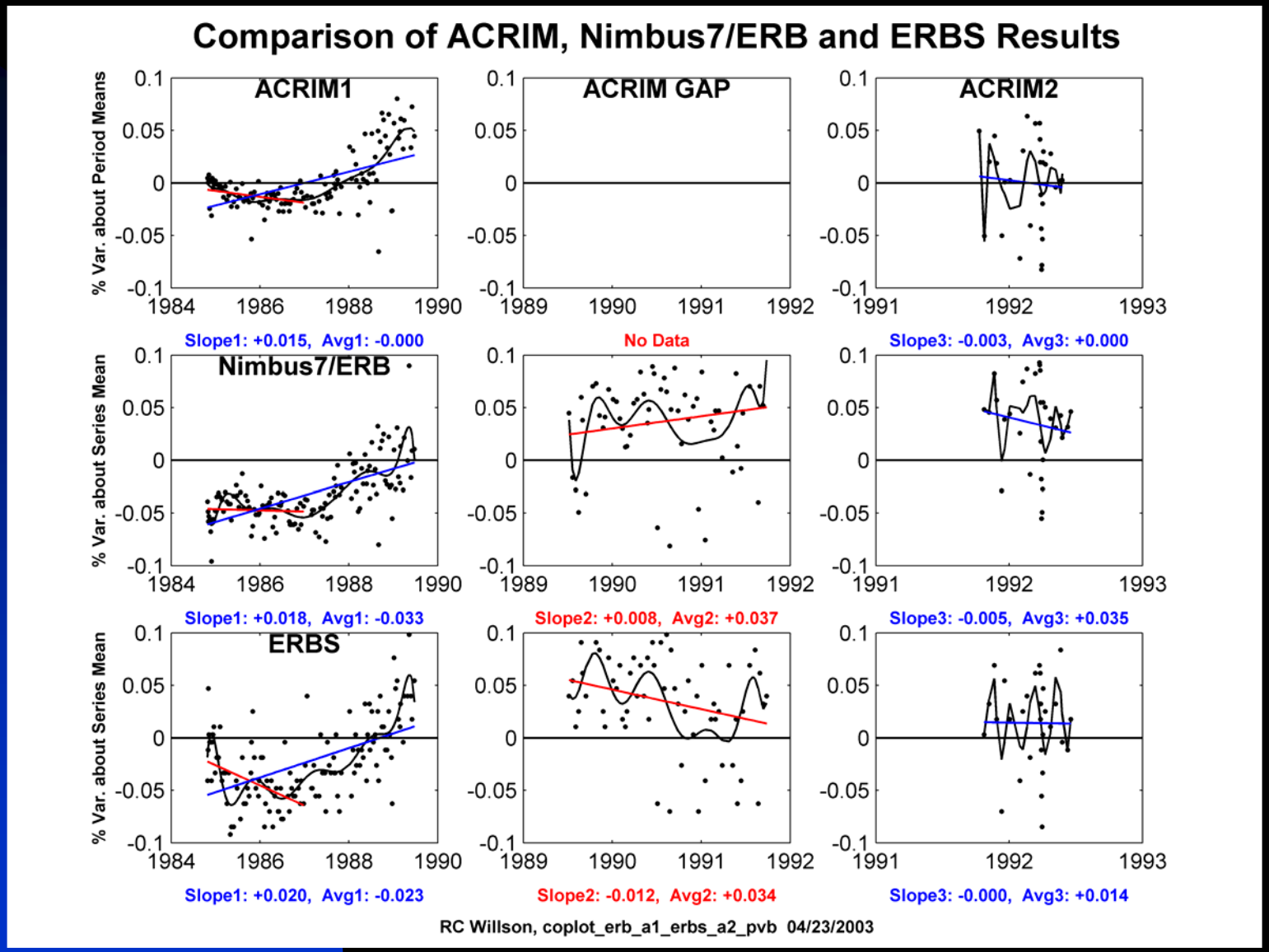



Comparison of Simultaneous daily means during ACRIM1 Period
Nimbus7/ERB
Avg. Unc. = +/- 106 ppm
SMM/ACRIM1
Avg. Unc. = +/- 9 ppm
ERBS
Avg. Unc. = +/- 169 ppm
(ppm)
Variation about Mean (ppm)
1000
500
0
-500
-1000
1984.5
1985
1985.5
1986
1986.5
1987
1987.5
1988
1988.5
1989
1989.5
Year
RC Willson, coplot_cna1e_3pno_ppm 12/02/2003

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



Comparison of Overlapping Observations during ACRIM1, ACRIM 'gap' and ACRIM2 Periods



ACRIM ‘gap’ test of comparison TSI databases

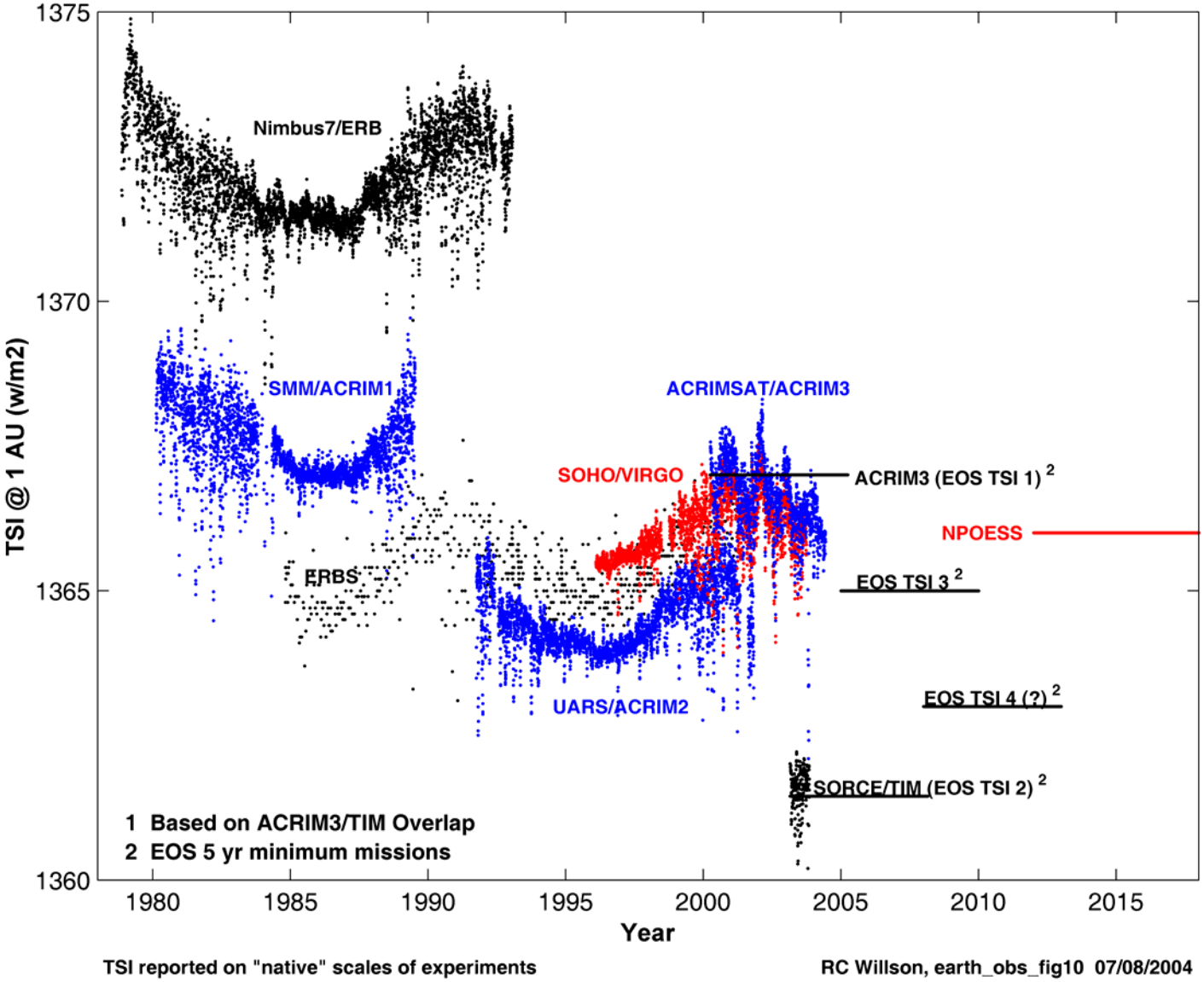
- **Fundamental finding: TSI is proportional to average solar magnetic activity level**
- **Average solar magnetic activity level increases during ACRIM ‘gap’**

  Nimbus7/ERB upward trend during ACRIM ‘gap’ is compatible

  ERBS downward trend during ACRIM ‘gap’ is incompatible

- **ERBS degradation during ACRIM ‘gap’ equals ACRIM - PMOD trend difference**
- **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 RESULTS AND OVERLAP/REDUNDANCY STRATEGY [1]



Rationale and Strategy for TSI Database Continuity

- 100 ppm TSI traceability since 1978 attributable to redundancy and overlap
- TSI observational traceability goal for climate change: ~ 100 ppm/century
- Traceability achieved by ACRIM3 to date: ~ 3 ppm/yr
- SI uncertainty achieved by TSI monitors to date: not significantly less than 1000 ppm
- An Overlap Strategy provides maximum TSI database traceability with current technology
- Redundant satellite experiments are required to prevent single point failures in the Overlap Strategy
- A redundant overlap satellite monitoring strategy is the only means of sustaining a climate change TSI database on centennial time scales with current technology