

Total Irradiance: Calibration Issues & Recent Results

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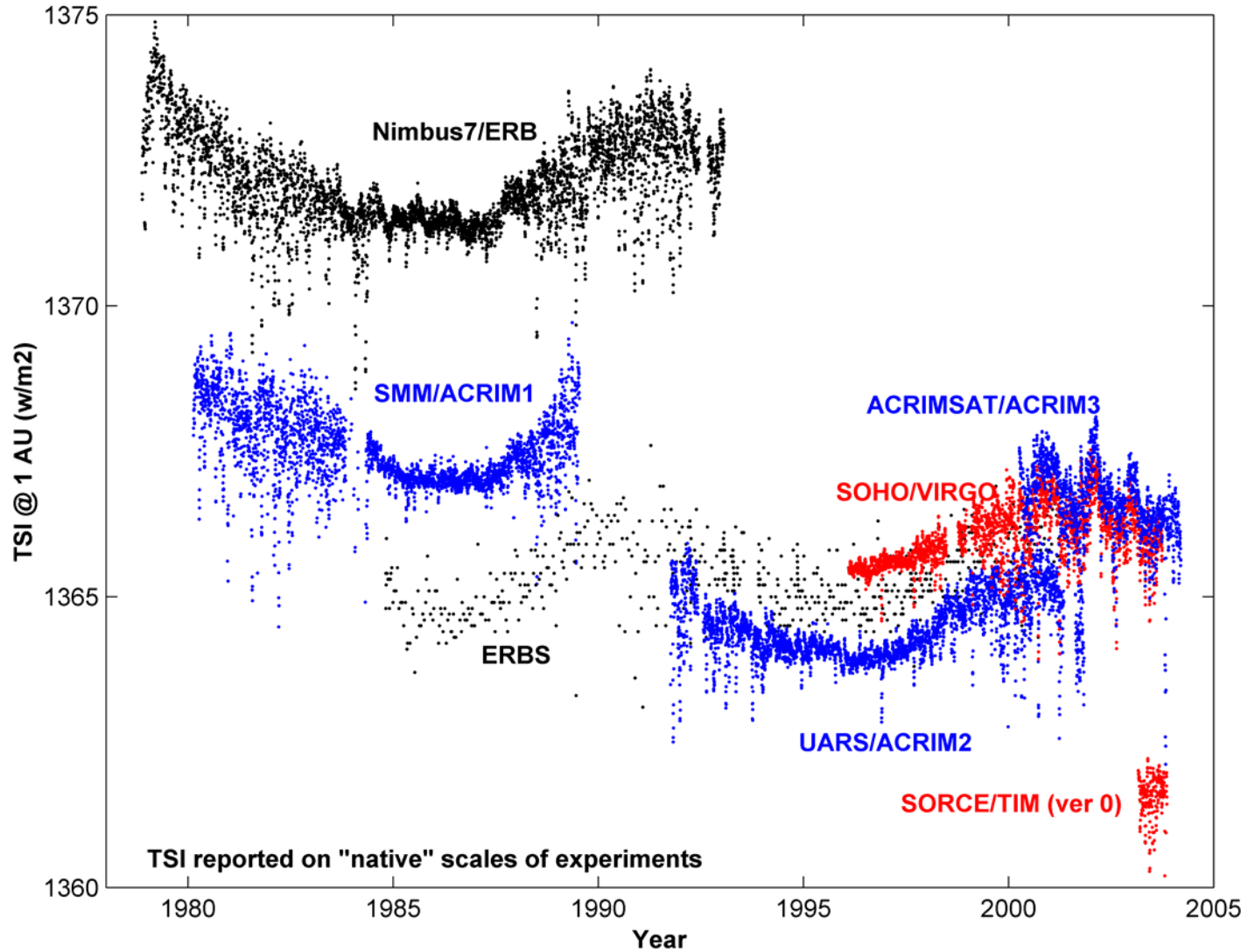
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Active Cavity Radiometer Irradiance Monitor

Status of The Total Solar Irradiance (TSI) Observational Database

- Continuous monitoring by *satellite* experiments conducted since late 1978
- Continuous monitoring since 1980 by *redundant, overlapping, satellite* experiments
- *Overlapping comparisons* facilitate contiguous results at mutual precision levels
- *Absolute uncertainty* varies by experiment with a lower limit of $\sim 0.1\%$
- *Internal traceability* of each experiments varies with ~ 3 ppm/year lower limit
- *Inter-experiment traceability* varies with ~ 50 ppm/decade lower limit
- *Scale differences* (of up to 0.4 %) likely due to systematic errors in sensor metrology

TOTAL SOLAR IRRADIANCE MONITORING RESULTS: 1978 to Present



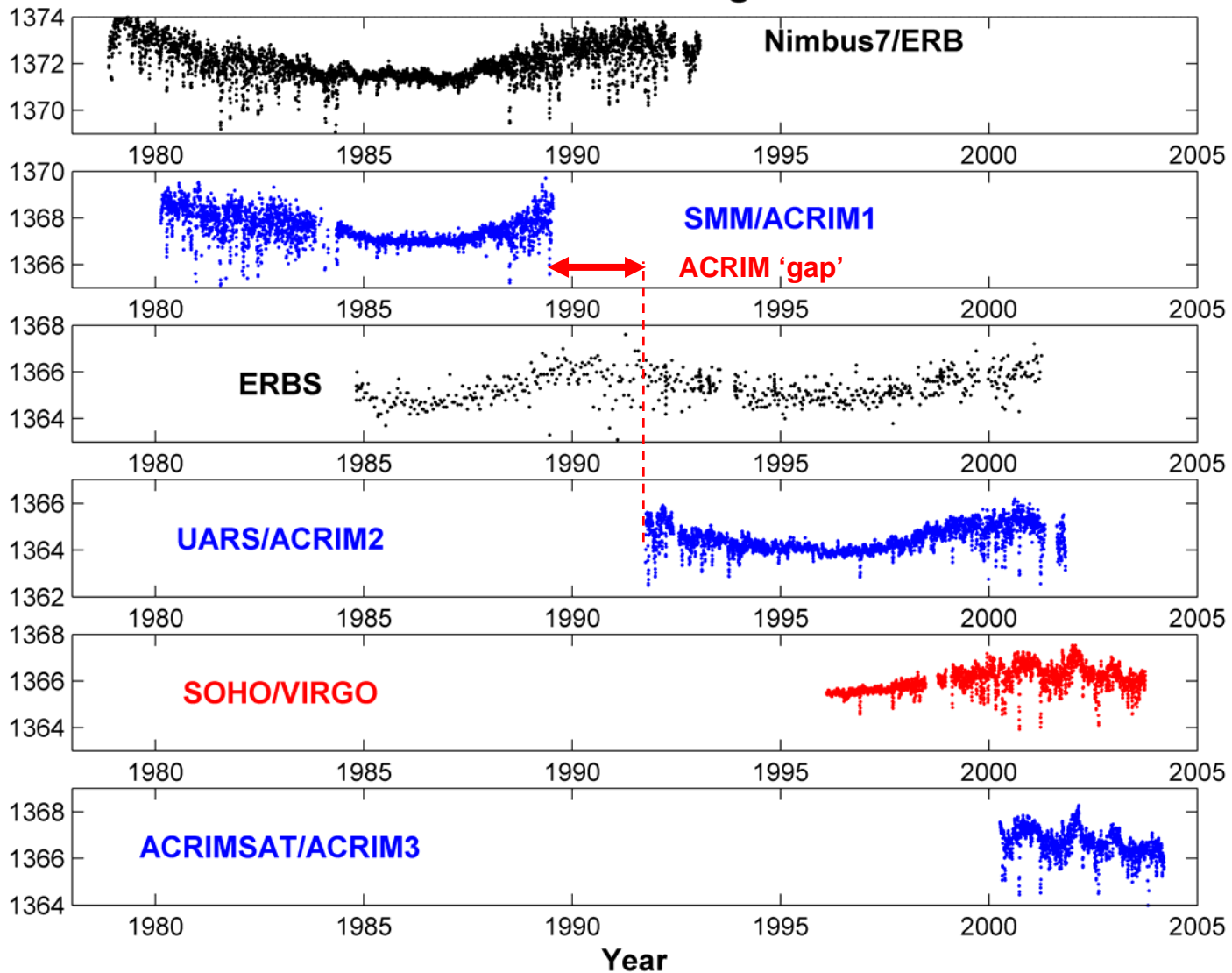
RC Willson, earth_obs_fig1 03/24/2004

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	Partial shutter failure limits Calibration capability	Continuous	2-fold redundant, Hiatus sensor changes Degradation rate issues	Yes
ACRIMSAT/ACRIM3 2000 →	Yes	62 min/LEO orbit	1 min. cycle	Continuous	3-fold redundant Monthly	Yes
SORCE/TIM 2003 →	Yes	~ 55 min/LEO orbit	100 sec. cycle	Continuous	3-fold redundant Monthly	Yes

Color				
Impact on Observations	Degrading	Sub-optimal	Optimal	Optimum

Total Solar Irradiance Monitoring Results: 1978 - 2003



TSI on "native" scales of experiments: W/m^2 @ 1 AU

RC Willson, earth_obs_fig4 03/24/2004

ACRIM Composite TSI Approach

- **Uses**

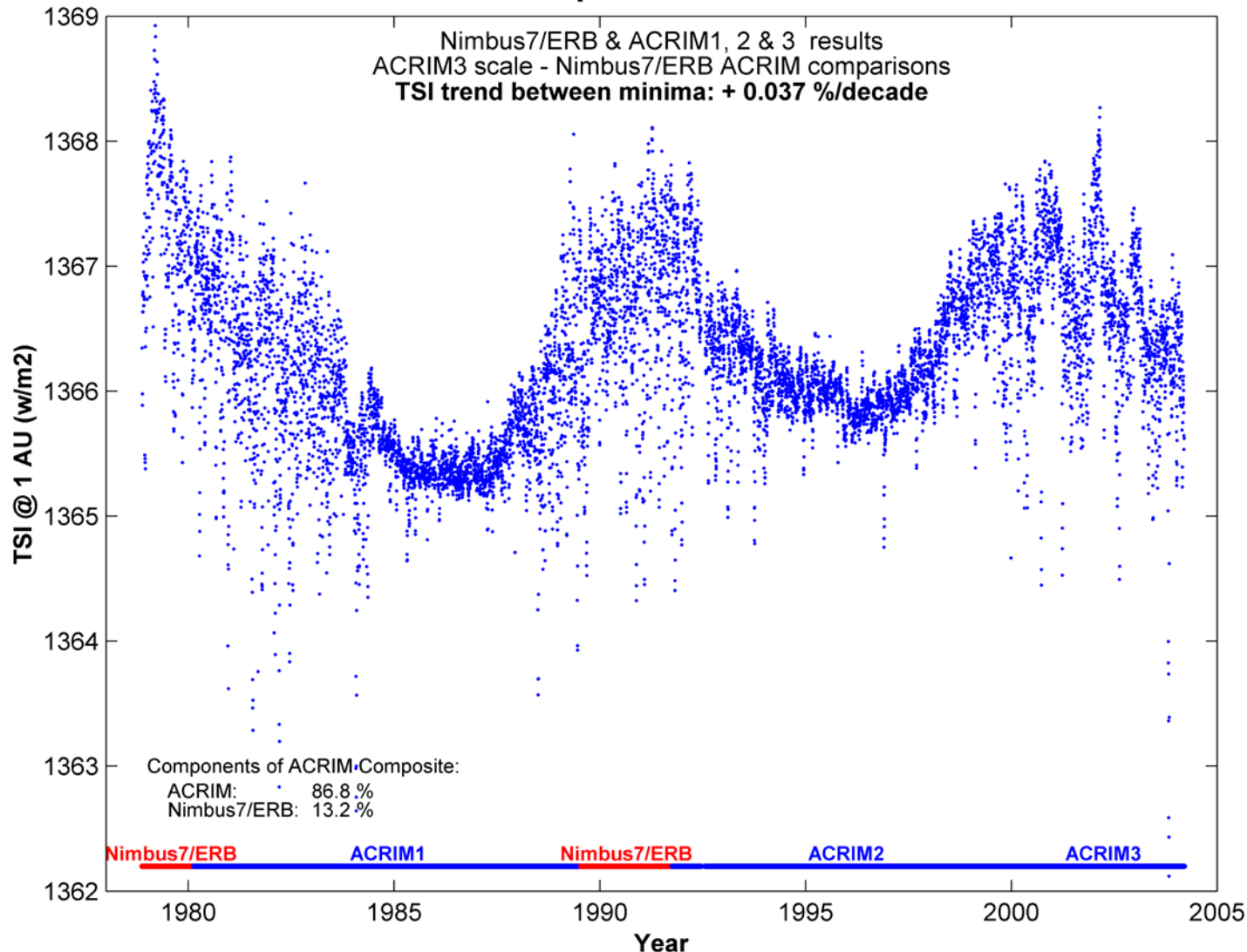
- Original published results from TSI experiments**

- Overlapping comparisons to relate experiments at mutual precision level**

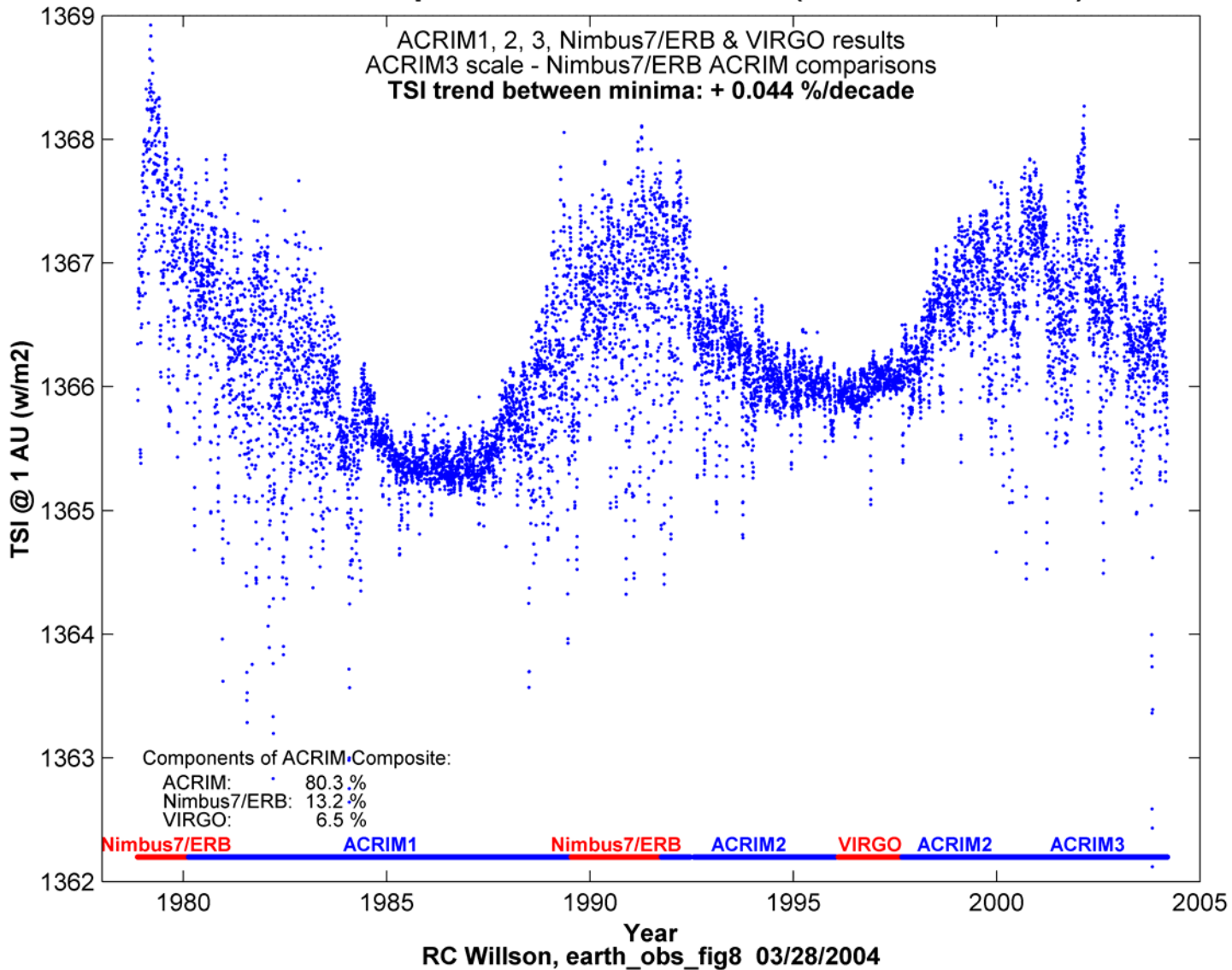
- ACRIM 1 & 2 comparisons with Nimbus7/ERB to bridge the ACRIM 'gap'**

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

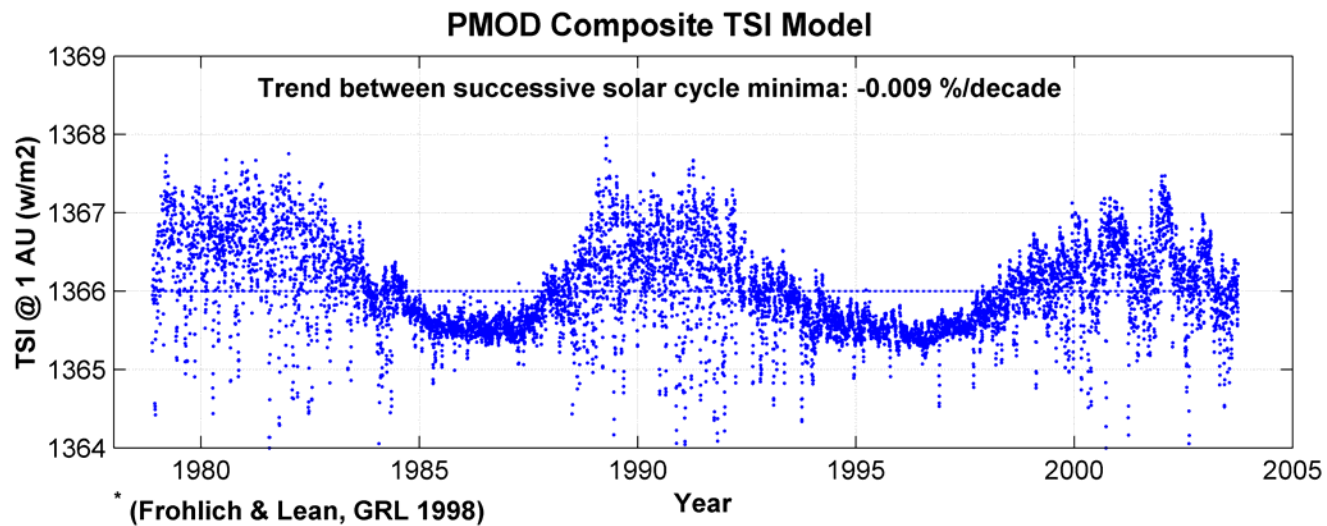
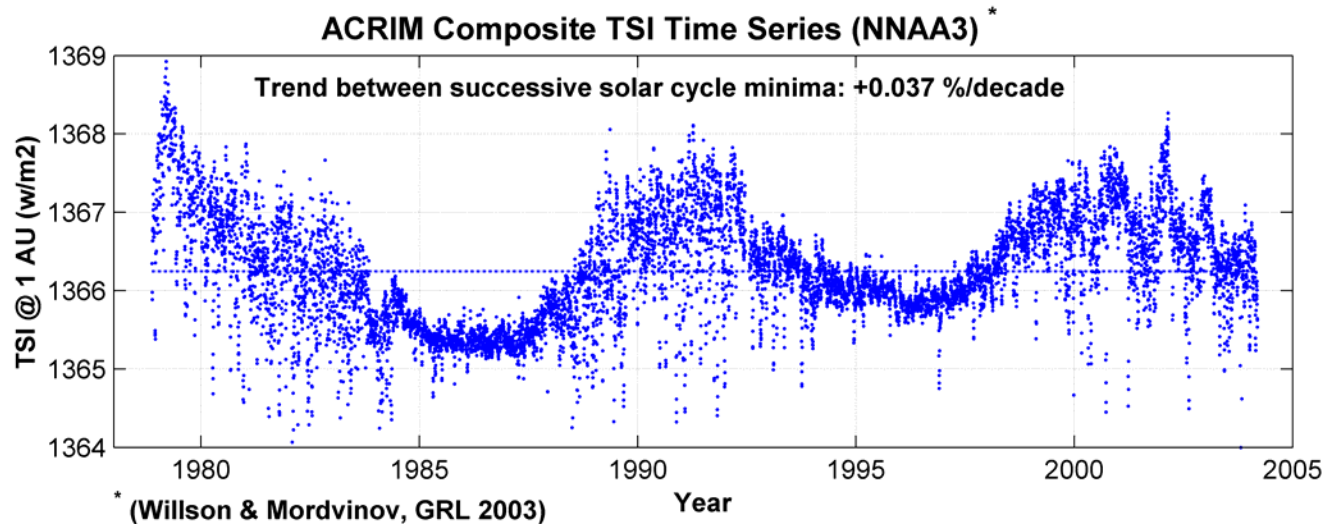
ACRIM Composite TSI Time Series



ACRIM Composite TSI Time Series (w/VIRGO results)



Comparison of ACRIM and PMOD Composite TSI



RC Willson, coplot_acrim_pmod 04/21/2004

Comparison of Composite TSI Approaches

- **ACRIM Composite TSI**

- Uses **original published results** from TSI experiments

- Uses results from **Nimbus7/ERB, ACRIM 1,2 & 3** experiments

- Uses **Nimbus7/ERB ACRIM 'gap' ratio** to link ACRIM1 and ACRIM2

- Normalizes to **ACRIM3 scale**

- **PMOD Composite TSI**

- Modifies published results** from TSI experiments

- Modifications justified by predictions of TSI proxy models

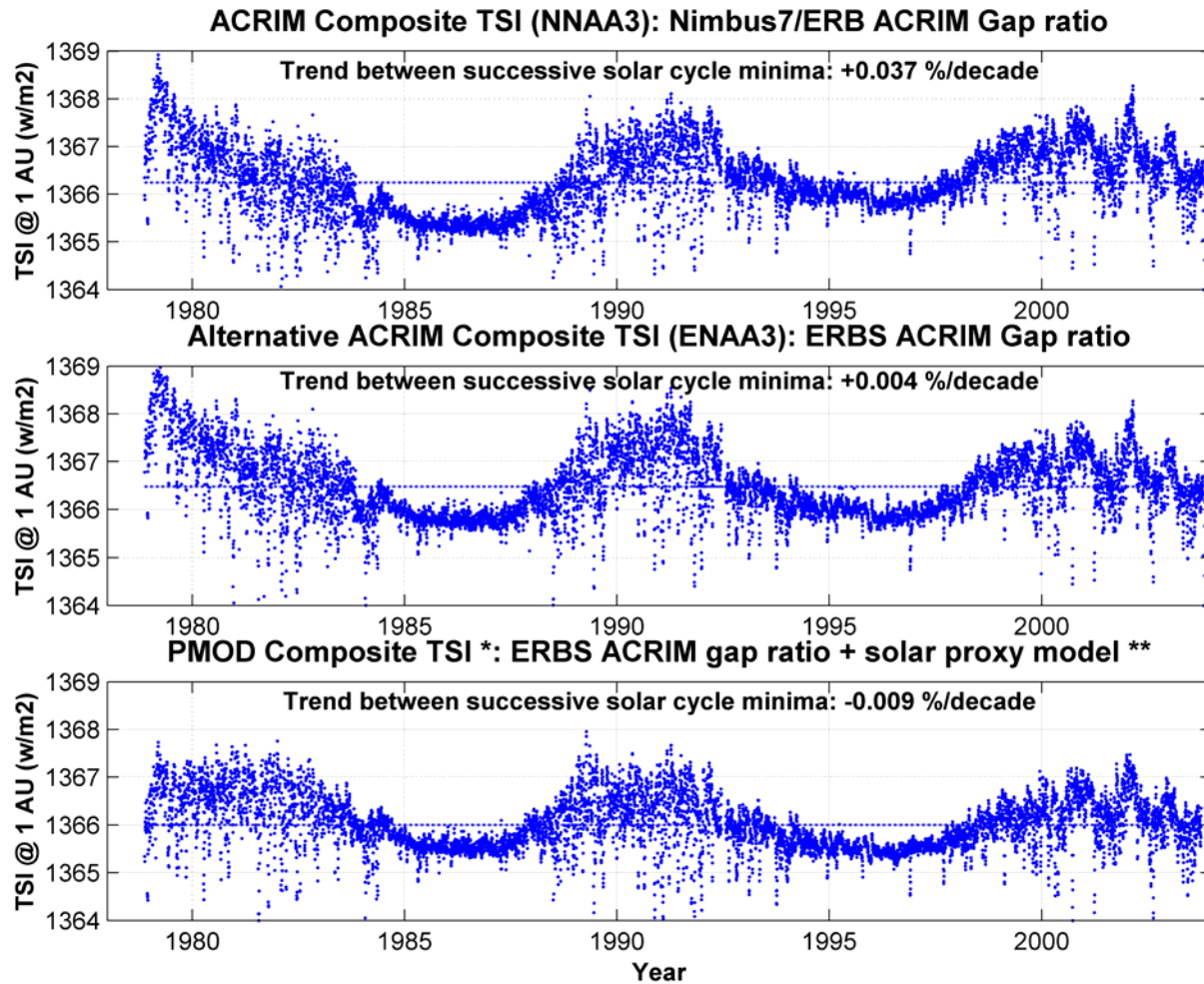
- Modifications not based on algorithm improvements/reprocessing

- Uses results from **Nimbus7/ERB, ACRIM 1,2 & VIRGO** experiments

- Uses **ERBS ACRIM 'gap' ratio** to link ACRIM1 and ACRIM2

- Normalizes to **VIRGO scale**

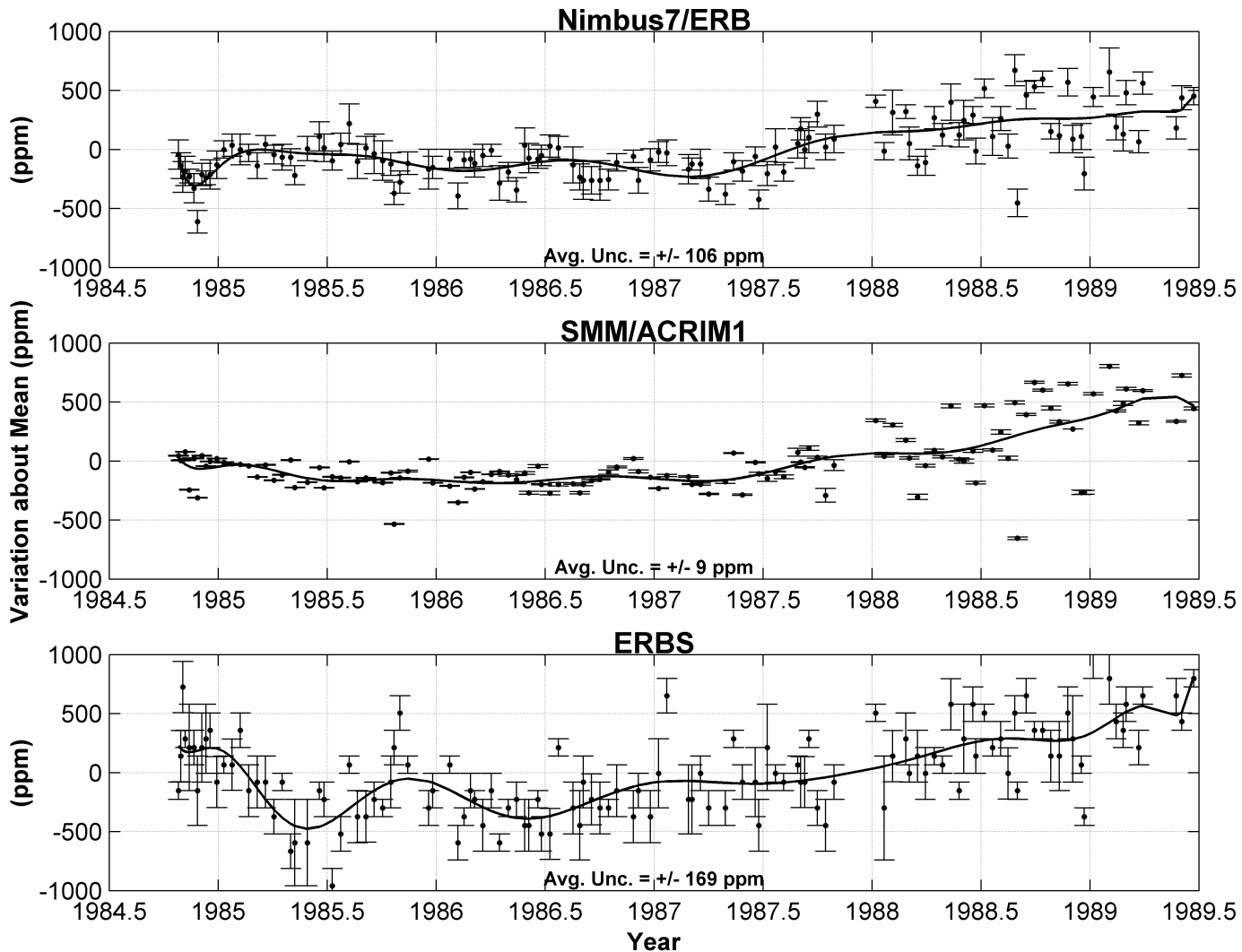
Composite TSI Dilemma: Use Nimbus7/ERB or ERBS ACRIM 'gap' ratio ?



* (Frohlich & Lean) ** (Lean)

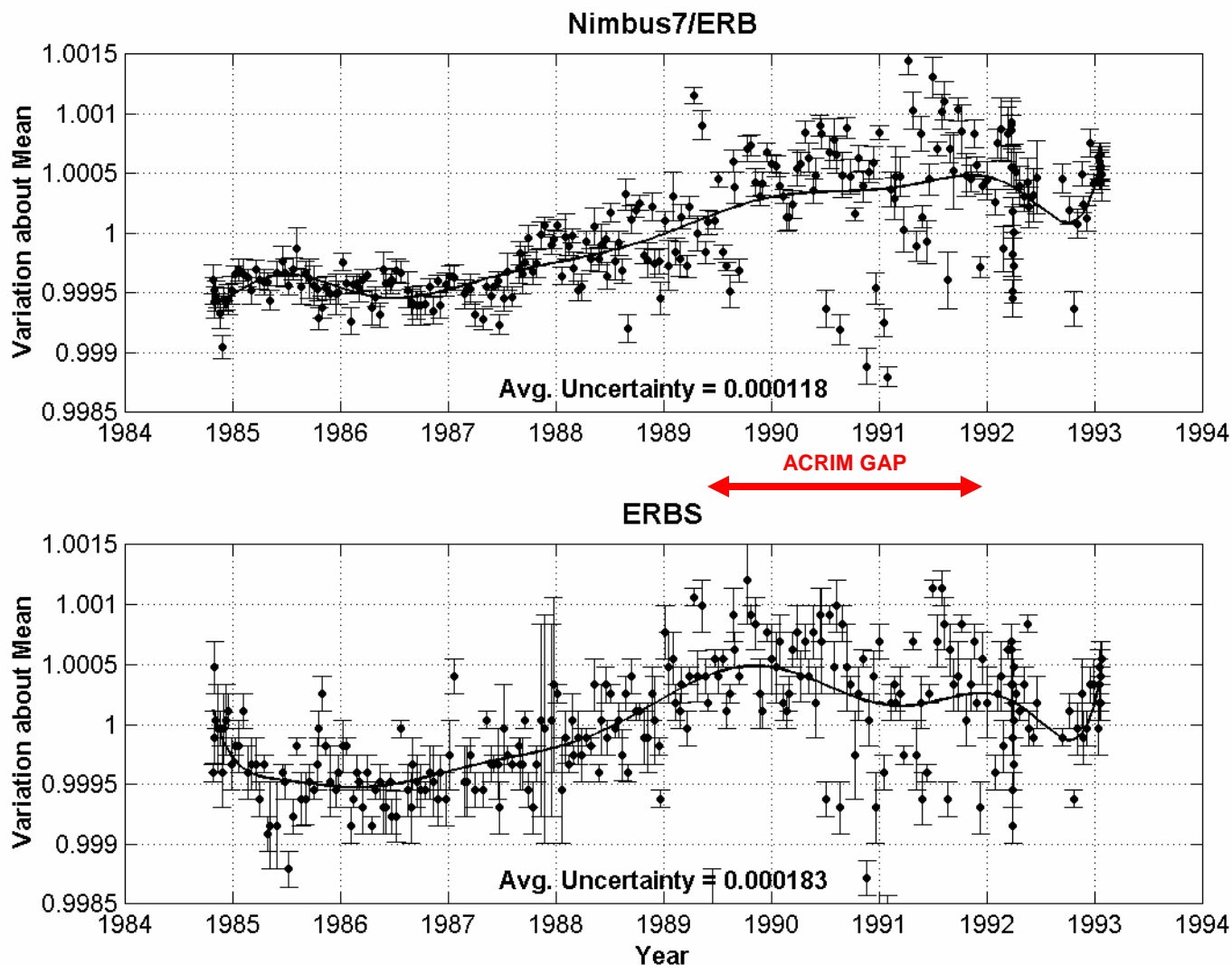
RC Willson, coplot_nnaa3_ena3_pmod 04/27/2004

Comparison of Simultaneous daily means during ACRIM1 Period



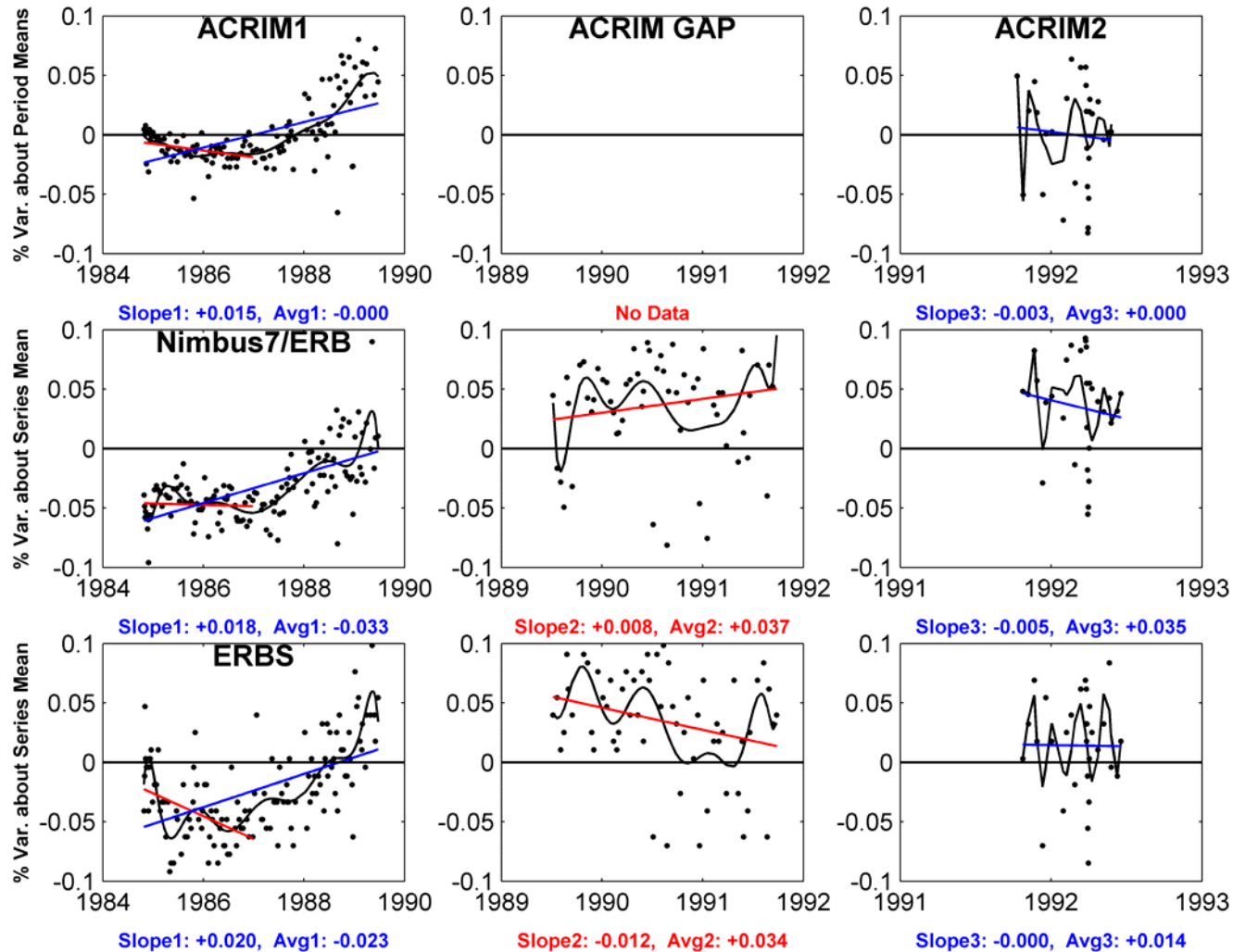
RC Willson, coplot_cna1e_3pno_ppm 12/02/2003

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



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

Comparison of ACRIM, Nimbus7/ERB and ERBS Results



RC Willson, coplot_erb_a1_erbs_a2_pvb 04/23/2003

Composite TSI Summary and Conclusions

- **ACRIM 'gap' test: proportionality of TSI and rising solar magnetic activity**
 - Nimbus7/ERB upward trend is compatible***
 - ERBS downward trend is incompatible - caused by sensor degradation***
- **ERBS degradation during ACRIM 'gap' equals ACRIM - PMOD trend difference**
- **The absence of a minimum-to-minimum trend in composite models using ERBS results to bridge the ACRIM 'gap' is an artifact of ERBS degradation**

Quality of Extant TSI Database

- Traceability from 1978 to present provided by *overlap strategy*: ~ **100 ppm**
- Traceability achievable by current instrumentation: ~ **5 ppm/yr**
- SI uncertainty achieved by satellite instrumentation to date: ~ **1000 ppm**
- SI uncertainty required for paradigm change in observational strategy: **100 ppm**
- Realization of 100 ppm SI uncertainty to date: **lab sensors at LHe temperatures**

A Strategy for TSI Database Continuity

- **Redundant, overlapping observations** yield maximum traceability with current technology
- **Redundant** experiments required to prevent a single point failure in the Overlap Strategy
- TSI operational monitoring begins on NPOESS ~ 2012
- Two additional EOS TSI experiments required to bridge SORCE/TIM – NPOESS gap

TSI MONITORING RESULTS AND AN OVERLAP- REDUNDANCY STRATEGY

