Error analysis of a multi-instrument composite solar Mg II Index

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Introduction

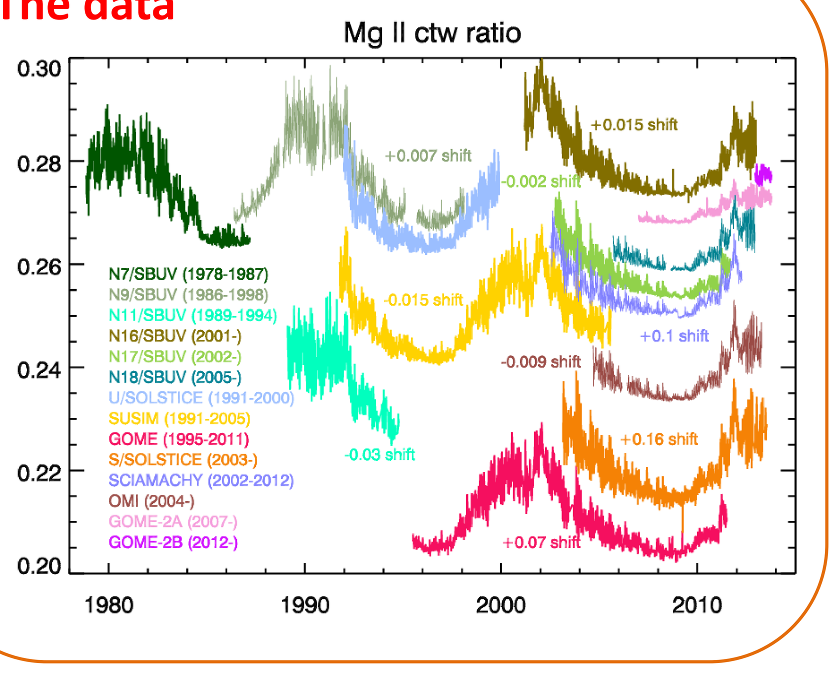
Mg II core-to-wing ratio near 280 nm

- indicator for chromospheric activity
- correlates well with UV and EUV SSI changes (e.g. Deland and Cebula 1993, Viereck et al., 2001)
- insensitive to instrumental degradation (to first order) (Heath & Schlesinger 1986)
- used for UV SSI reconstruction and SSI degradation corrections

Goals:

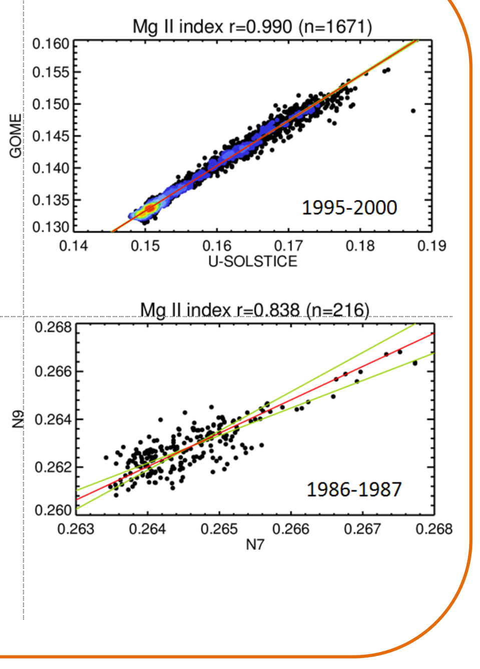
- **Combine various satellite datasets to a composite 35-year dataset**
- **Establish uncertainties for the composite data**

The data



Matching of Mg II indices for creating composites

- Scaling by linear regressions in overlapping time periods:
  - regress x vs y and y vs x (green)
    $$M' = c_0 + c_1 M$$
    $$M = d_0 + d_1 M'$$
  - take average from both regressions (red)
    $$M' = b_0 + b_1 M$$
    $$b_0 = (c_0 + d_0/d_1)/2$$
    $$b_1 = (c_1 + 1/d_1)/2$$
- scaling works best if large overlap periods exists (e.g. GOME-U/SOLSTICE)
  - Problematic: short overlap between N7 and N9 during solar minimum SC22
  - Use NOAA (N7/N9) composite with corrections using Ca II K ground data (Viereck & Puga, 1999)

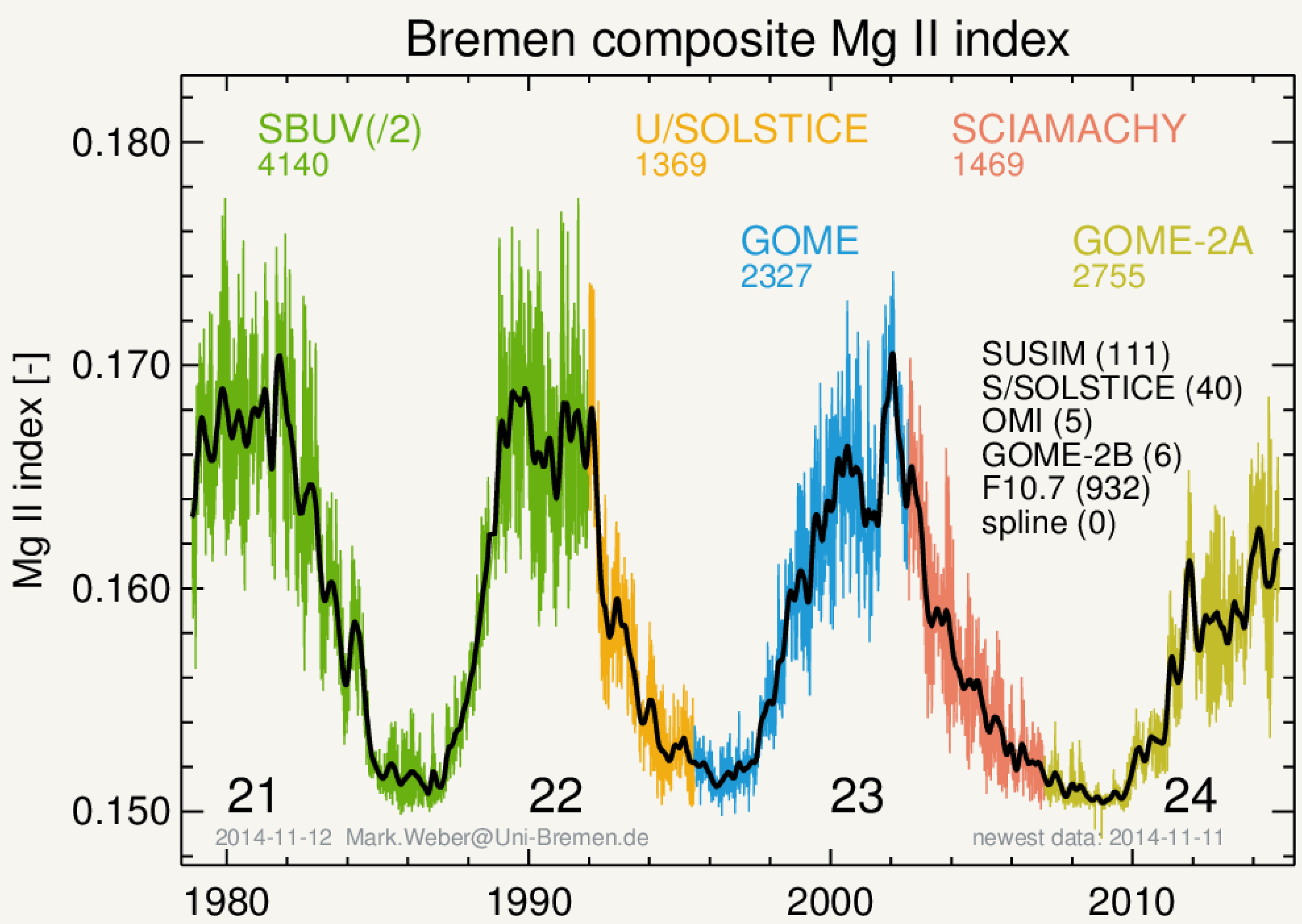


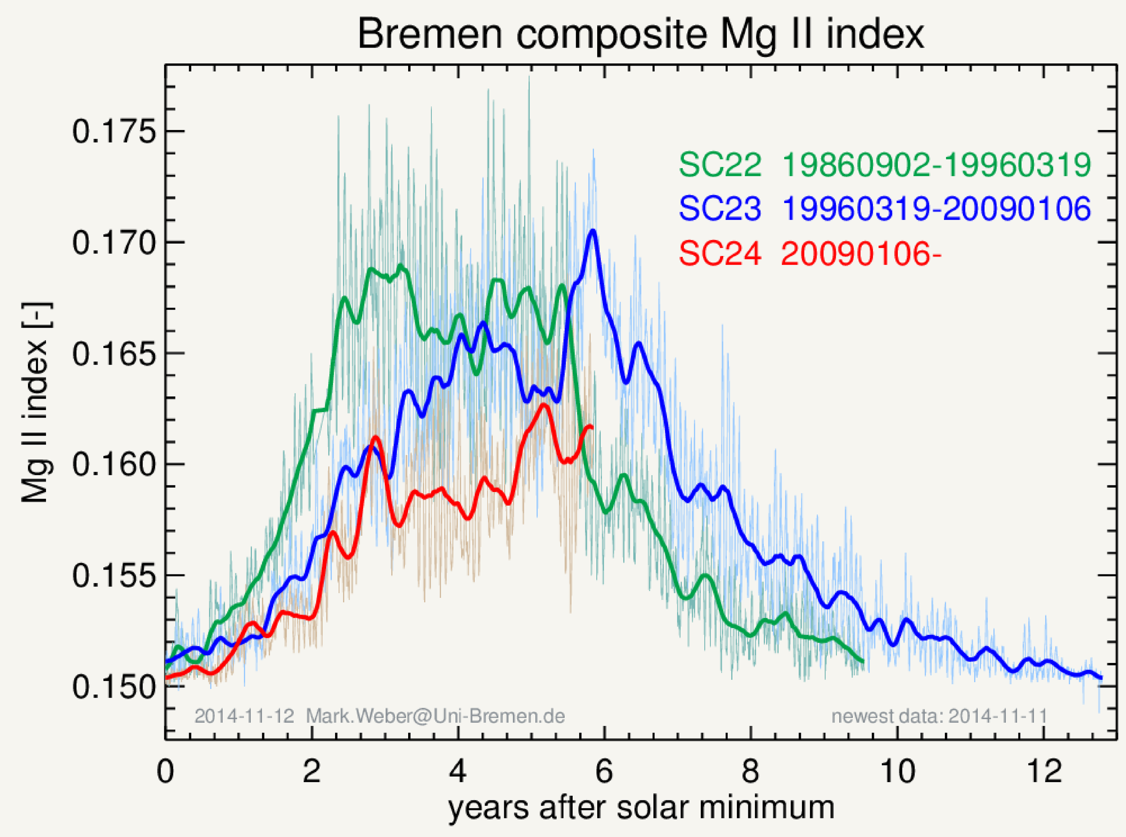
Composite making

- Major „planks" of the Bremen composite:

Data	reference	Coverage	major years
NOAA composite (N7, N9 only)	Viereck & Puga 1999	1978-1998	1978-1991
U-Solstice (classic)	Snow et al.	1992-2000	1992-1995
GOME	Weber et al. 1999	1995-2011	1995-2002
SCIAMACHY	Snow et al., 2014	2002-2012	2002-2009
GOME-2A	Snow et al., 2014	2007-present	2009-present

- other combinations possible (N16, S-Solstice), see SORCE composite
- all other data used for gap filling
- about 930 days are missing: use scaled F10.7





The Bremen composite Mg II index

Left: Bremen Mg II index timeseries. Colors indicate major "planks". Black line is the twice 55-day box-car smoothed timeseries.

Right: Comparison of solar activity from the last three Schwabe (11-year) solar cycles. Each solar cycle shows a distinct evolution. Solar minima (dates indicated) are determined from the smoothed time series

Data/plots updated daily and available from

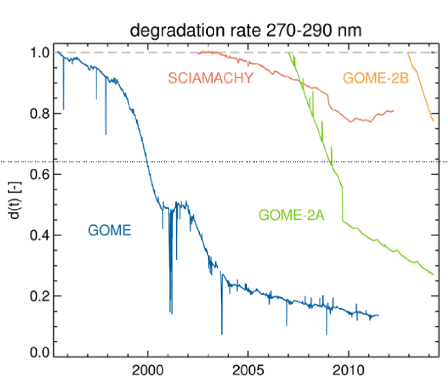
http://www.iup.uni-bremen.de/gome/gomemgii.html

Uncertainty analysis

- Establish uncertainties for individual instruments (GOME, SCIAMACHY, GOME-2)
- Estimate uncertainties for instrument data without information on uncertainties
- Propagate uncertainties into the composite (add uncertainties from scaling and matching)

Uncertainties of Mg II index from GOME(-2) & SCIAMACHY

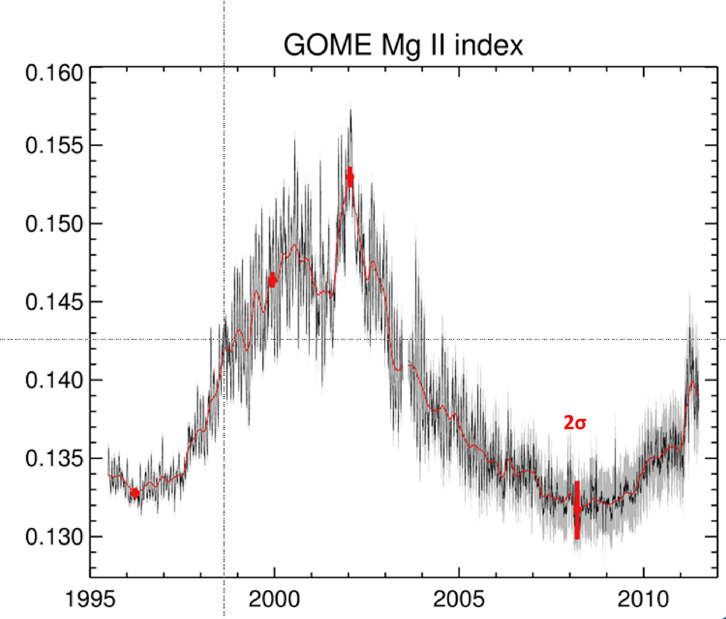
- Error calculation (very crude):
  $$M = C/W$$
  $$\Delta M = \sqrt{\left(\frac{dM}{dC}\right)^2 (\Delta C)^2 + \left(\frac{dM}{dW}\right)^2 (\Delta W)^2}$$
  $$\Delta C = \Delta W = \frac{\Delta I}{\sqrt{n}} \implies$$
  $$\Delta M = \frac{\Delta I}{I}\sqrt{\frac{1+M^2}{n}} \approx \frac{1}{\sqrt{n}\cdot \mathrm{SNR}}$$
- degradation rate *d(t)*:
  $$d(t) = \frac{I(t)}{I(t=0)} \implies$$
  $$\Delta M(t) = \left(\sqrt{n}\cdot \mathrm{SNR}(t=0)\cdot d(t)\right)^{-1}$$



n: number of wing (core) values

Long-term stability of GOME

- high resolution index SCIA, GOME): 9 core values and 12 wing values: n~10
- For the „classic" index (GOME-2), spectra are degraded to 1.1 nm (averaging 10 spectral elements). n~4*10
- Still true noise levels seems lower



Uncertainties in the composite index

- Uncertainties from scaling M_2 to M_1 scale (before merging):
  $$M_2 \longrightarrow M_1$$
  $$M_2' = b_0 + b_1 \cdot M_2$$
  $$\Delta M_2' = \sqrt{(\Delta b_0)^2 + M_2^2\,(\Delta b_1)^2 + b_1^2\,(\Delta M_2)^2}$$
- Propagate errors in both directions
  $$M_1 \longrightarrow M_2$$
  $$M_1' = c_0 + c_1 \cdot M_1$$
  $$\Delta M_1' = \sqrt{(\Delta c_0)^2 + M_1^2\,(\Delta c_1)^2 + c_1^2\,(\Delta M_1)^2}$$
  $$\Delta M_1 = \sqrt{(\Delta b_0)^2 + M_1'^2\,(\Delta b_1)^2 + b_1^2\,(\Delta M_1')^2}$$
- Issues:
  - Uncertainties not available for each instrument
  - for those instruments which have uncertainties reported (GOME, SCIA, GOME-2A, S-SOLSTICE), are they realistic?

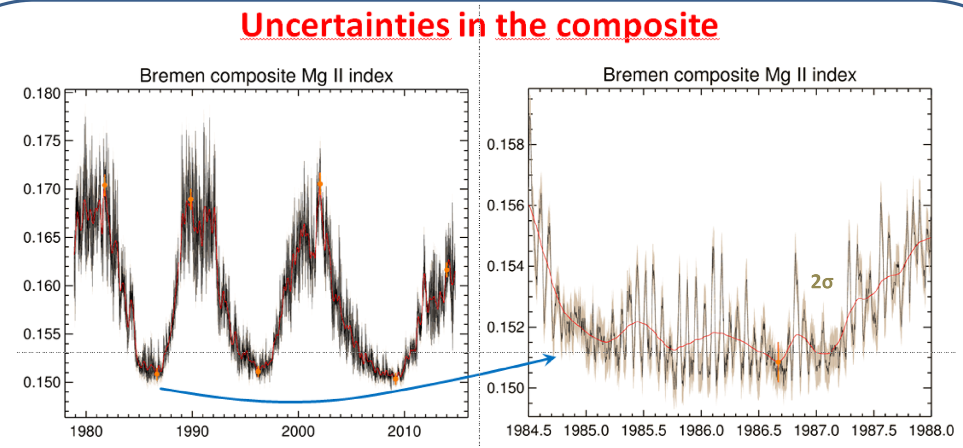
Uncertainties for selected datasets

Instrument	spectral resol. [nm]	precision [%]	precision wrt max-min (SC variability) [%]	precision GOME scale [%]	precision SCIA scale [%]	precision S-Solstice scale [%]	precision GOME-2A scale [%]
GOME	0.17	0.1-0.5	0.6-2.8 (18)	-	0.26	1.3	0.08
SCIAMACHY	0.21	0.03-0.04	0.2-0.3 (13)	0.31	-	1.1	0.06
S-SOLSTICE	0.1	0.6*	~1.3 (45)	0.40	0.26	-	0.08
GOME-2A (classic)	0.28 (1.1)	0.04-0.14	1.0-3.0 (4.1)	0.34	0.18	1.1	-

*Snow et al., 2005

- Note:
  - precision after scaling also includes errors due to time mismatch (local time) and combines errors from both instruments
  - Precision after scaling should be higher than the intrinsic precision
- Precision estimate for SCIAMACHY too low!
- Precision on
  - NOAA scale: 0.14-0.2% (U-Solstice, U-Solstice (cl.), SUSIM)
  - U-Solstice (cl.) scale: 0.2% (U-Solstice, GOME, SUSIM)

Uncertainties in the composite



- assume precision:
  - SCIA: 0.26%, GOME: 0.35%, GOME-2: 0.08%, SBUVs/SUSIM/U-SOLSTICE/OMI: 0.2%, S-Sorce: 1.1%
- add uncertainties from linear regressions (in both directions)
  - Before regressions, set minimum of index to zero (remove offset)
  - composite finally on SCIA scale (add offset)
- results: ~0.2-0.4% uncertainties for the composite

Conclusion

- Mg II index is an important UV SSI proxy
  - ❖ often used for SSI degradation corrections
- first attempt for providing uncertainties for the Bremen Mg II composite (1978-2014)
  - ❖ some assumptions for uncertainties of individual instruments have to be made
  - ❖ on SCIA scale: uncertainties are 0.2-0.4%
- Within 2σ, solar minimum in solar cycle 24 (2009) was not lower than the two previous minima

References

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