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Passive Microwave Sensor Inter-calibration Using Stable Land Surface Targets

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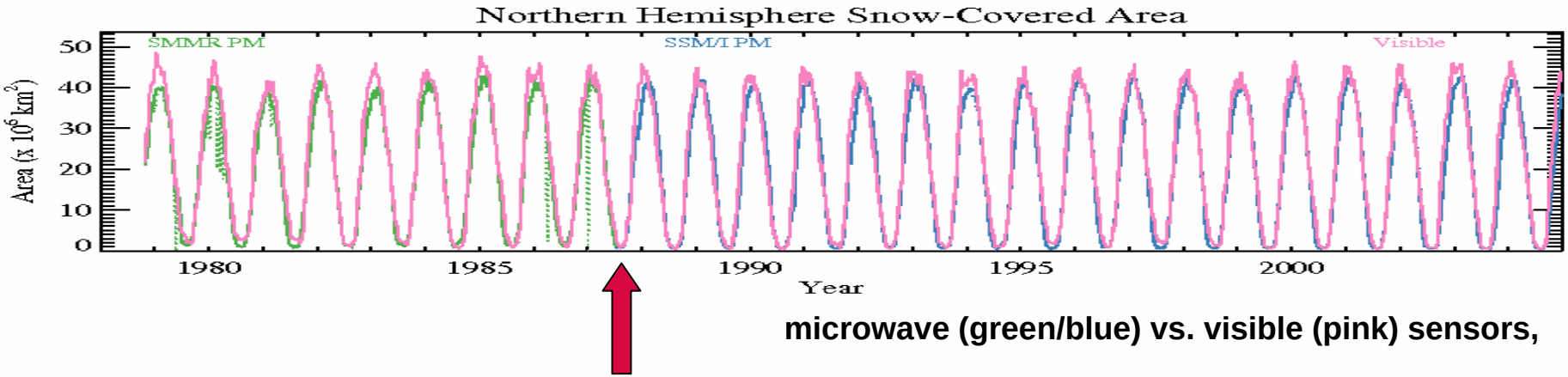
Northern Hemisphere Satellite-Derived Snow Extent
1978 – 2006 Visible (NOAA) Passive Microwave (SMMR & SSM/I)

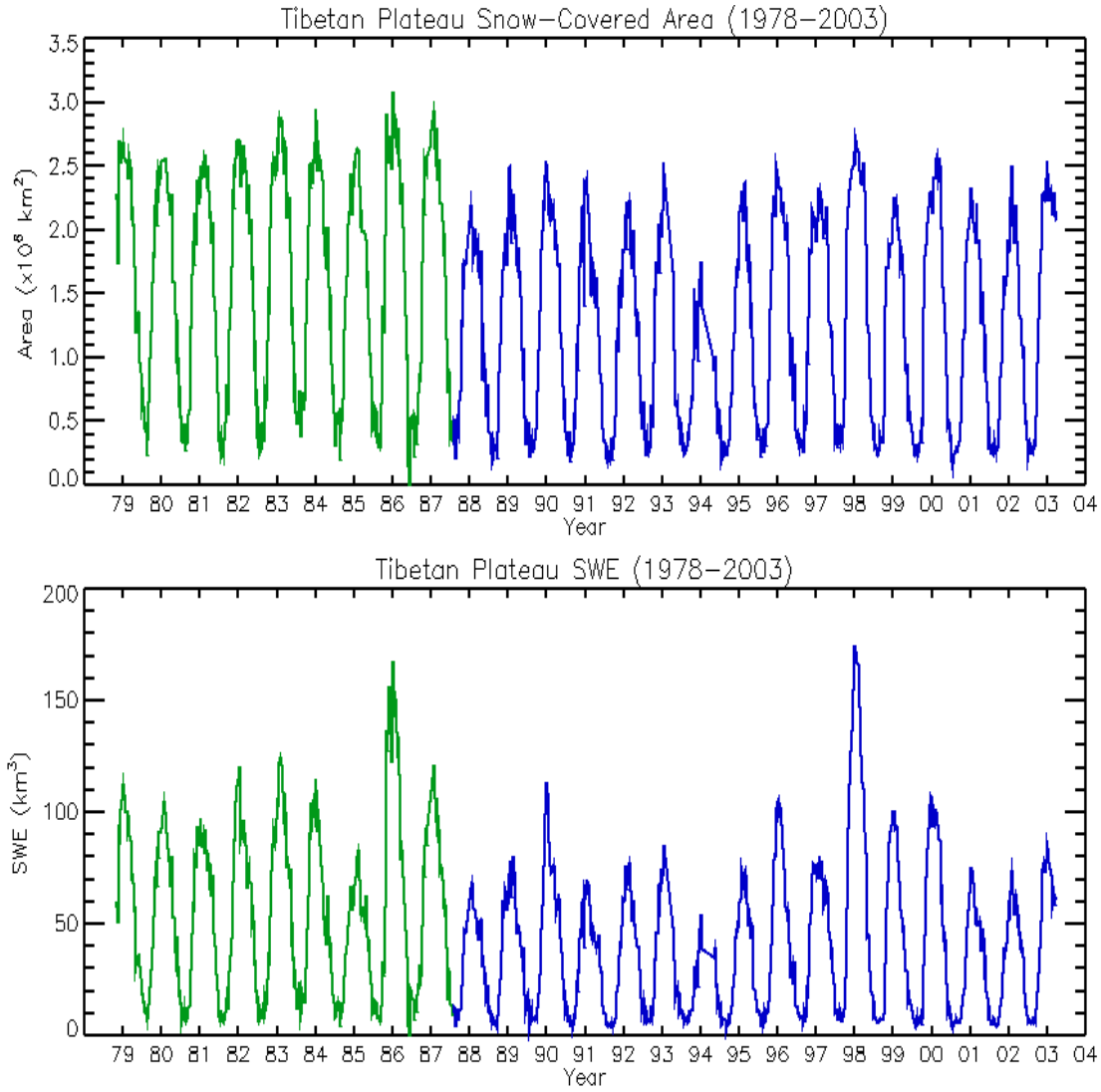


microwave (green/blue) vs. visible (pink) sensors,

Analysis is complicated by the change in sensors from SMMR to SSM/I and short duration of simultaneous operation during July and August of 1987 (40 days).

(Further complicated by the fact that Robinson and Frei (2000) noted an apparent step change in the mean snow extent from the NOAA data in 1987)

Tibet Plateau

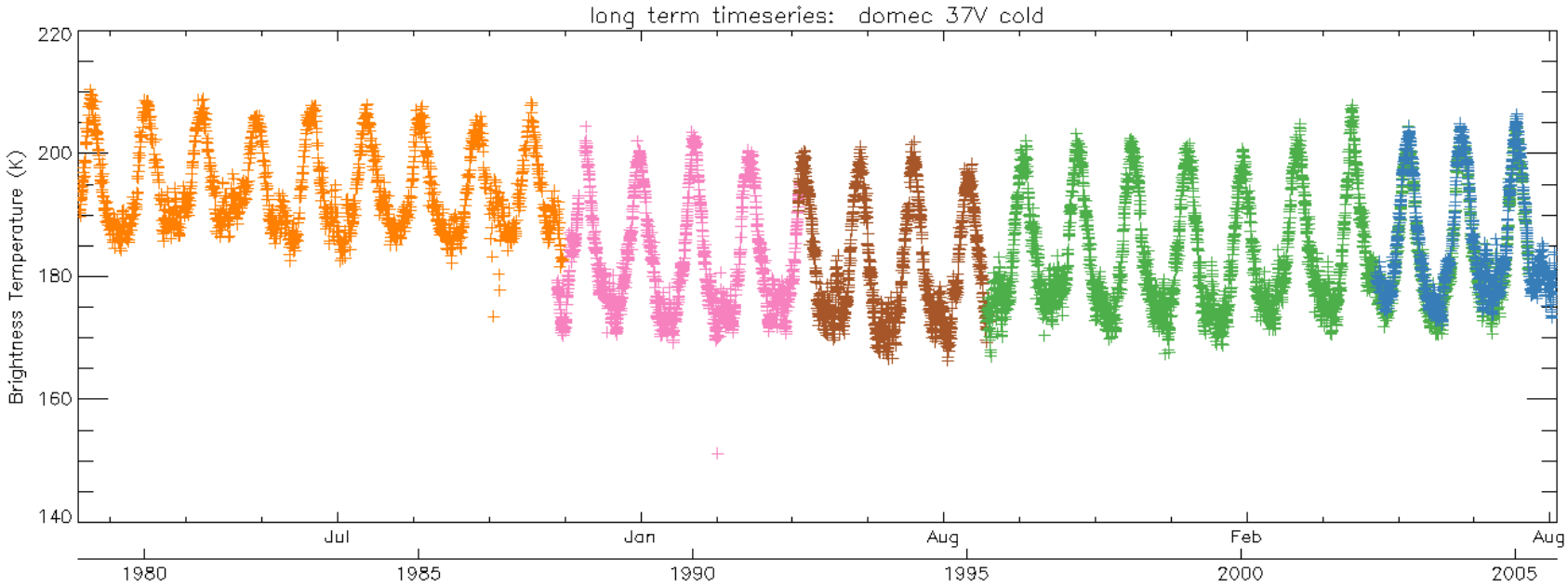


snow extent

snow water equivalent

Time series of Tibetan Plateau snow-covered area and average snow water equivalent (SWE) derived from passive microwave sensors, 1978-2004.

Time Series of 36/37 GHz at Dome C Antarctica, SMMR-SSM/I-AMSR-E



Time series of 36/37 GHz, vertically-polarized "cold pass" brightness temperatures at Dome C (Antarctica) from SMMR (1978-1987, orange), various SSM/Is (1987-2006, pink/brown/green), and AMSR-E (2002-2006, blue). Note cross-sensor calibration issues, indicated by higher mean and compressed annual amplitude in SMMR data, compared to SSM/I and AMSR-E.

Locating Suitable Calibration Targets over Land

Select land targets with surface characteristics that represent the cold through warm microwave emission range. The final targets are chosen for temporal and spatial stability. This is done by way of statistical analysis within a moving 3x3 array of pixels to determine the specific locations with minimal spatial and temporal variability.

- A sub-array 'footprint' area was defined as a set of 3 x 3 grid cells (approximately 75 km x 75 km) for a given day, with indices *j,* centered at a particular grid point
- The following statistics were considered:
- Regions analyzed consisted of 100 x 100 arrays of 25-km EASE-Grid cells centered at 1.5°S, 21.6°E (Salonga, Zaire) and 75.0°S, 123.3°E (Dome C, Antarctica)
- Over land, the spatial homogeneity and temporal stability of brightness temperatures (*Tb*) over selected regions such as tropical forest and ice sheet regions were examined

Spatial mean and standard deviation of *Tb* within a footprint on day *i*:

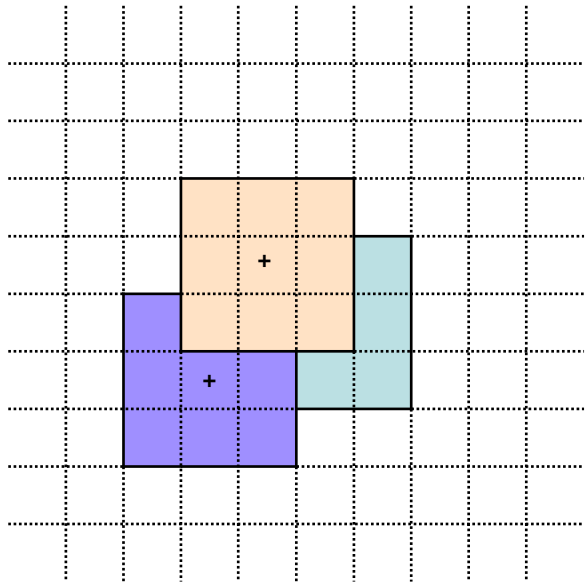
$$m_i = \frac{1}{N}\sum_{j=1}^{N} Tb_{ij} \;\; ; \quad \sigma_i = \sqrt{\frac{1}{N-1}\sum_{j=1}^{N}(Tb_{ij} - m_i)^2}$$

Temporal means (over one year) of m_i and σ_i:

$$\overline{m} = \frac{1}{N_D}\sum_{i=1}^{N_D} m_i \;\; ; \quad \overline{\sigma} = \frac{1}{N_D}\sum_{i=1}^{N_D} \sigma_i$$

Temporal standard deviation of m_i over one year:

$$\sigma_m = \sqrt{\frac{1}{N_D - 1}\sum_{i=1}^{N_D}(m_i - \overline{m})^2}$$



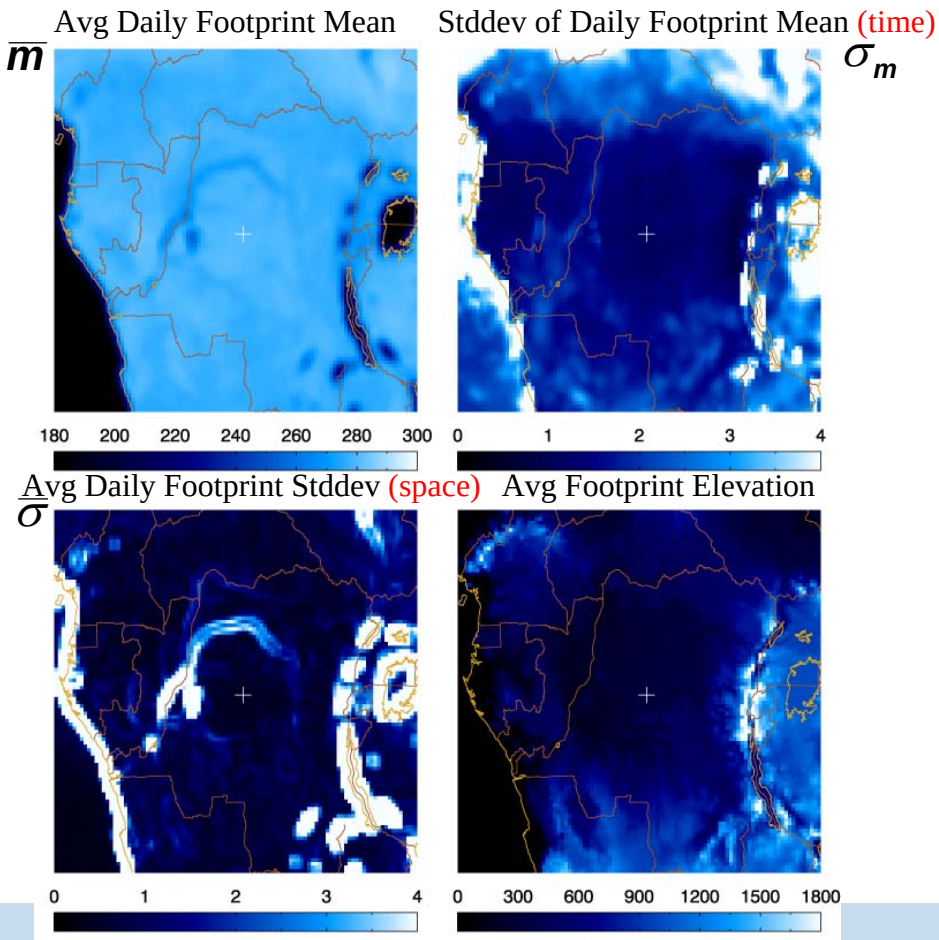
Statistics Definitions for Stable Targets Study

- **Footprint mean = the mean of the brightness temperatures of each grid cell in a footprint.**
- **Footprint standard deviation =spatial variance at an instant in time or how the grid cells change in brightness temperature over the footprint. Needs to be small to have a homogeneous target.**
- **Average daily footprint mean = time average of the footprint mean, e.g. over one year**
- **Standard deviation of the daily footprint mean = standard deviation of the footprint mean over time. Sites with a low SDDFM when the time period is long are sites that generally have low seasonal brightness temperature variation.**
- **Average daily footprint standard deviation = the average of each footprint standard deviation over some time series. Sites that are spatially homogeneous or have low brightness temperature gradients across a footprint will have low values of ADFSD. An area with a large ADFSD would not be a suitable calibration target, such as locations near land/water boundaries.**

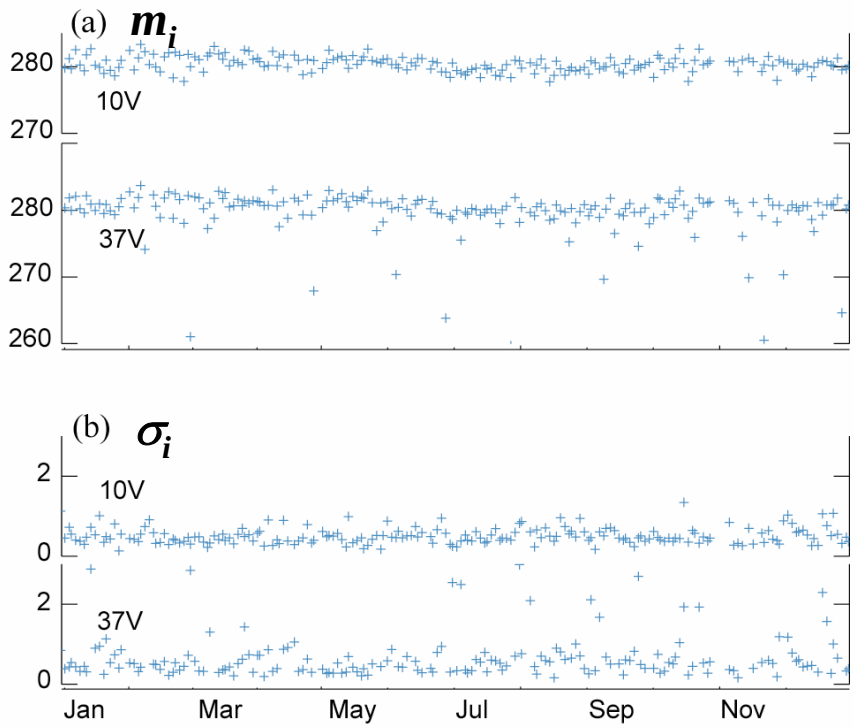
Tropical Forest - Salonga, Zaire

AMSR-E 10 GHz vertical polarization *Tb* statistics,central African tropical forest, descending passes, in 2003.

(a) *Upper left:* $\overline{m}$ (K). (b) *Upper right:* σ_m (K). (c) *Lower left:* $\overline{\sigma}$ (K). (d) *Lower right:* Surface topography (meters above sea level).

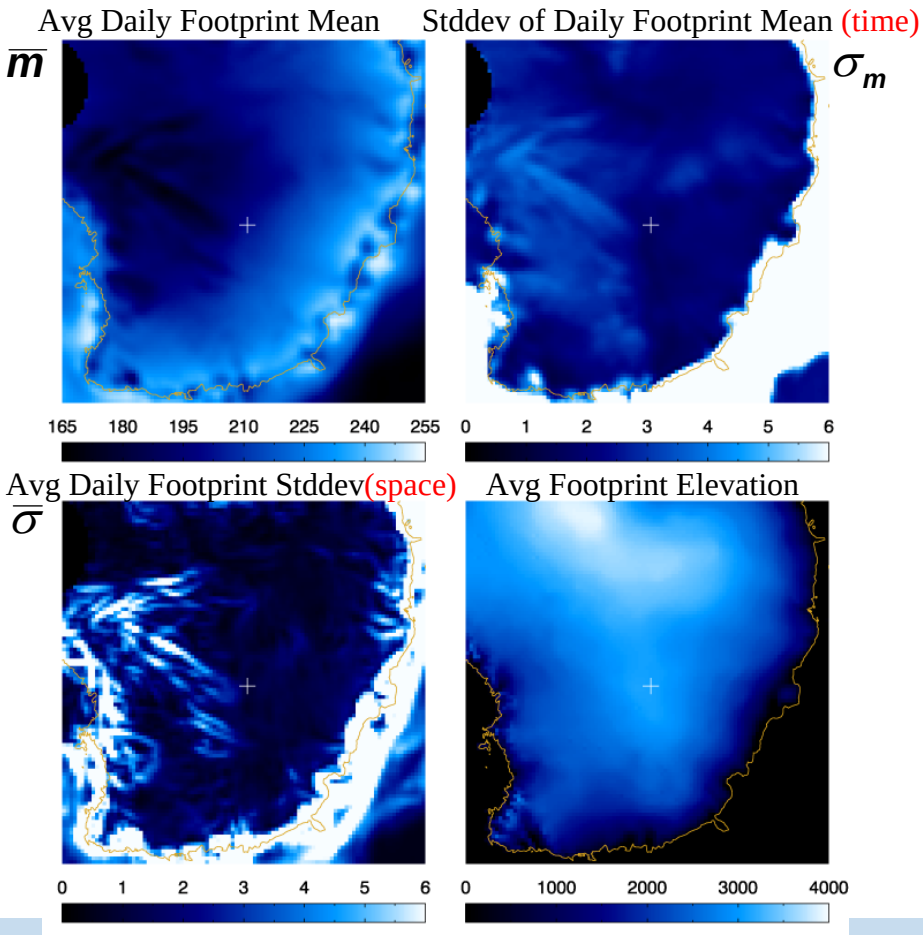


Statistics for the year 2003 at Salonga, Zaire, for 10 GHz and 37 GHz vertical polarizations, descending passes: (a) Foot print mean, m_i ; (b) Foot print standard deviation, σ_i. Units are in Kelvins.

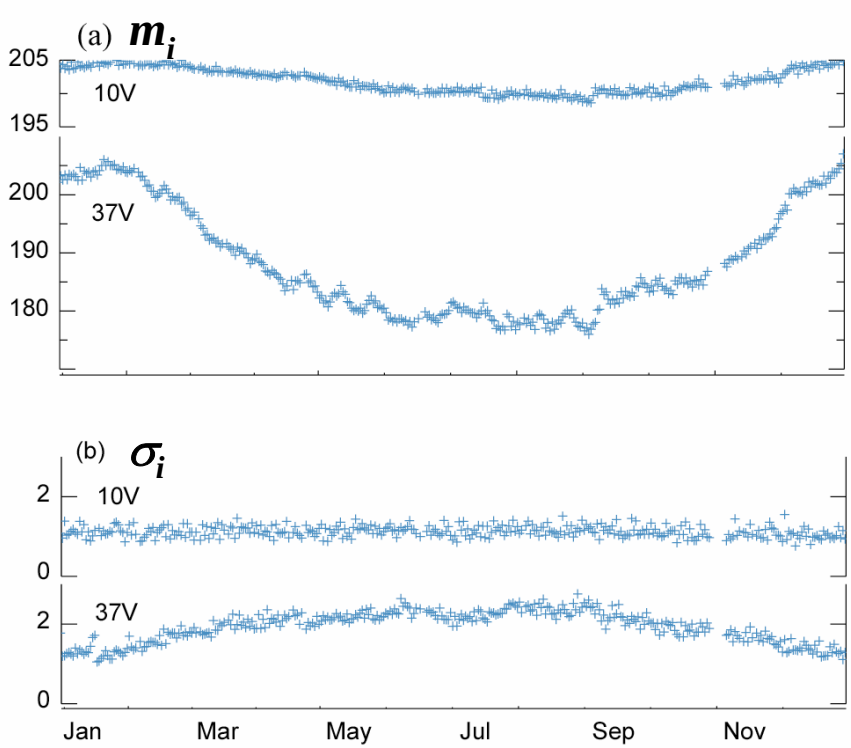


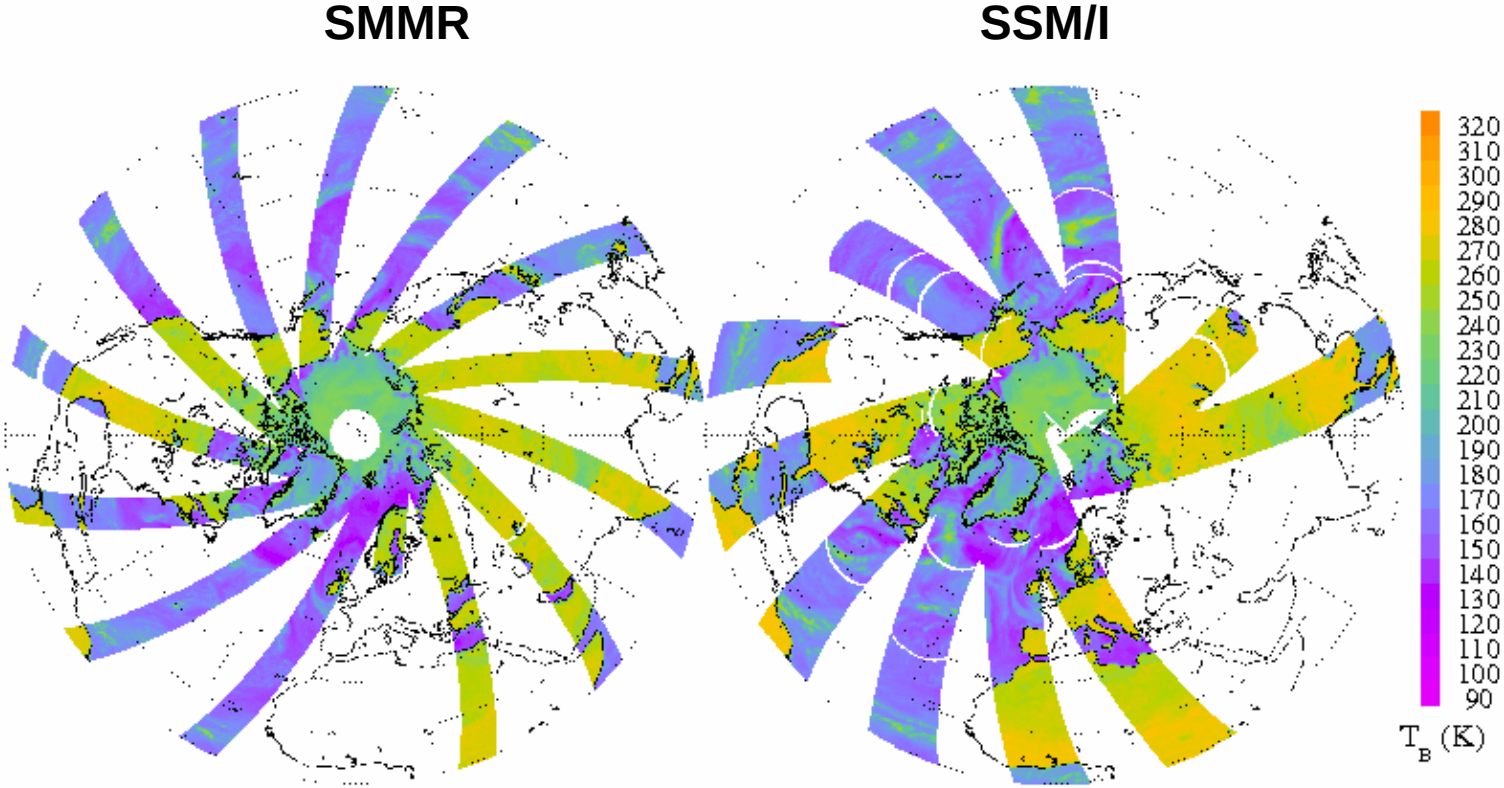
Antarctica - Dome C

AMSR-E 10 GHz vertical polarization *Tb* statistics for East Antarctica, descending passes, in 2003. (a) *Upper left:* $\overline{m}$(K). (b) *Upper right:* σ_m(K). (c) *Lower left:* $\overline{\sigma}$(K). (d) *Lower right:* Surface topography (meters above sea level).



Statistics for the year 2003 at Dome 'C', Antarctica, for 10 GHz and 37 GHz vertical polarizations: (a) Footprint mean, m_i; (b) Footprint standard deviation, σ_i. Units are in Kelvins.





Sensors are similar but exhibit important differences in spatial and temporal coverage that affect the sampling density within the long-term record.

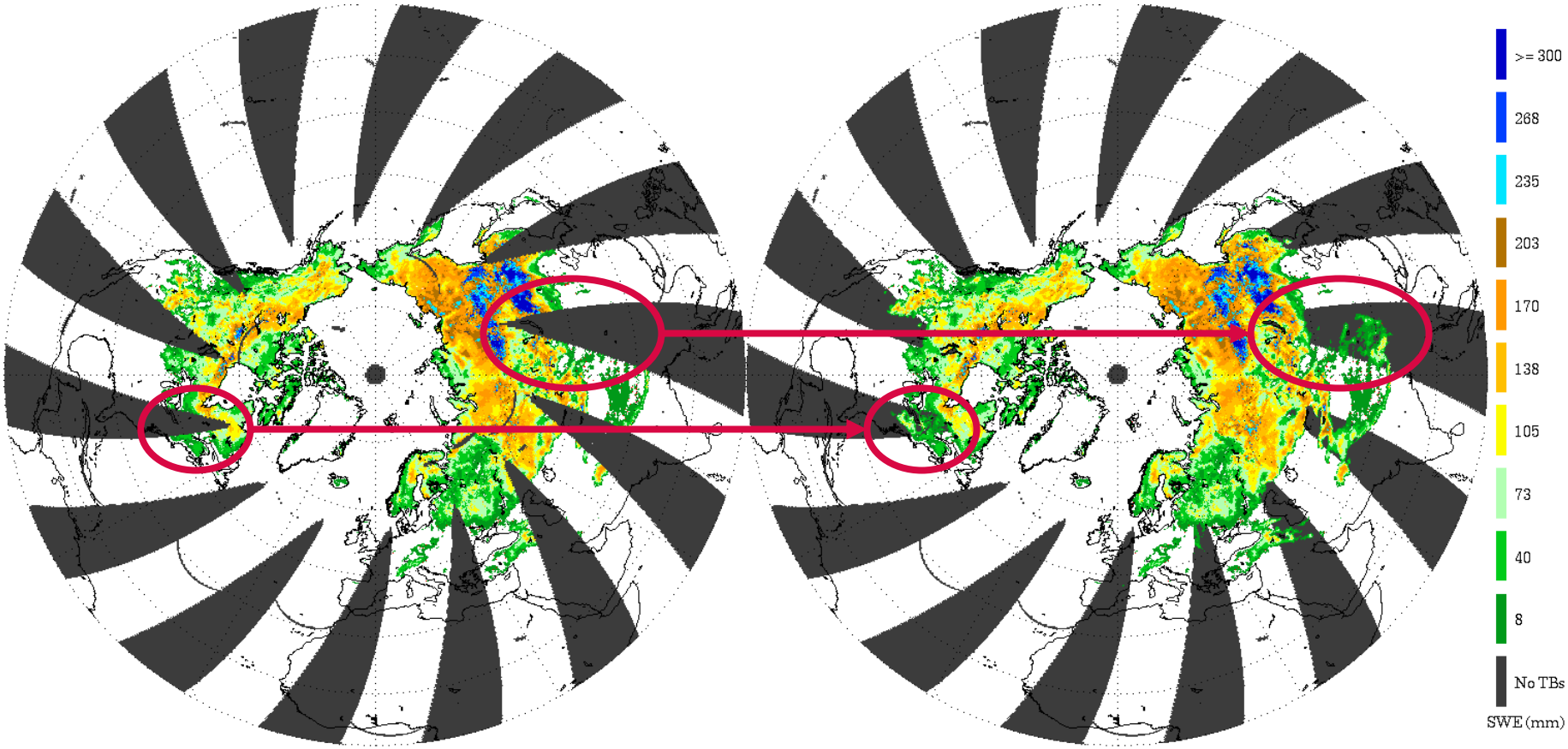
Daily passive microwave 37 GHz, horizontally polarized brightness temperatures, July 19, 1987, showing smaller coverage area of SMMR (left) vs. SSM/I (right).

Microwave Sensor (SMMR-SSM/I) Issues

- **Sensor overlap occurred in July and August 1987 (Northern Hemisphere summer, essentially no seasonal snow cover).**
- **The SMMR swath width was about half that of SSM/I, further reducing the probability of overlapping observations.**
- **The overlap is about 40 days, effectively 20 days of data, since SMMR was cycled on/off on a daily basis.**
- **Low latitude sites may require up to 5 or 6 days for one SMMR overpass**

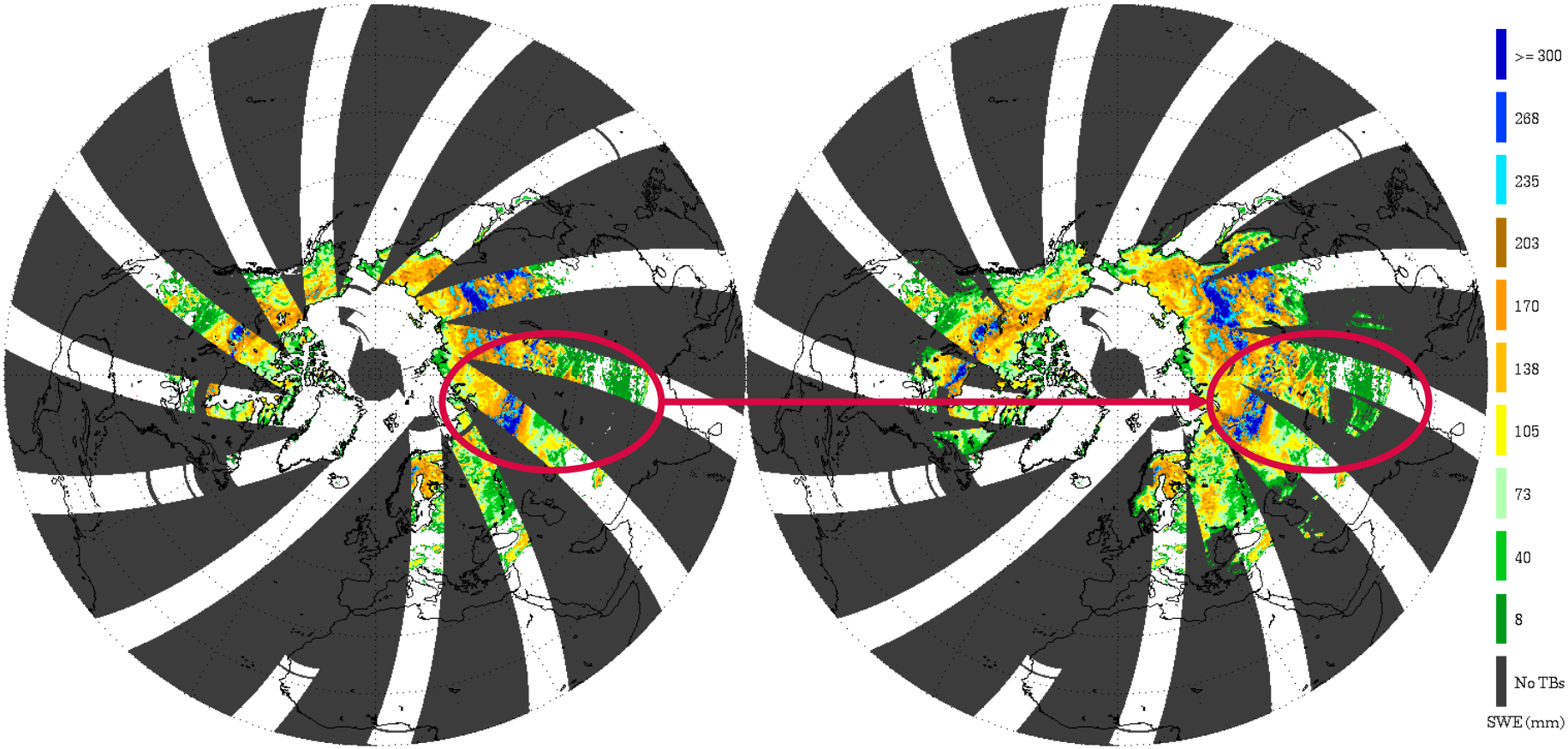
=> we used temporal piece-wise linear interpolation to fill in coverage gaps, interpolating across any gaps of 6 days or fewer =>

SSM/I Before Interpolation After Interpolation

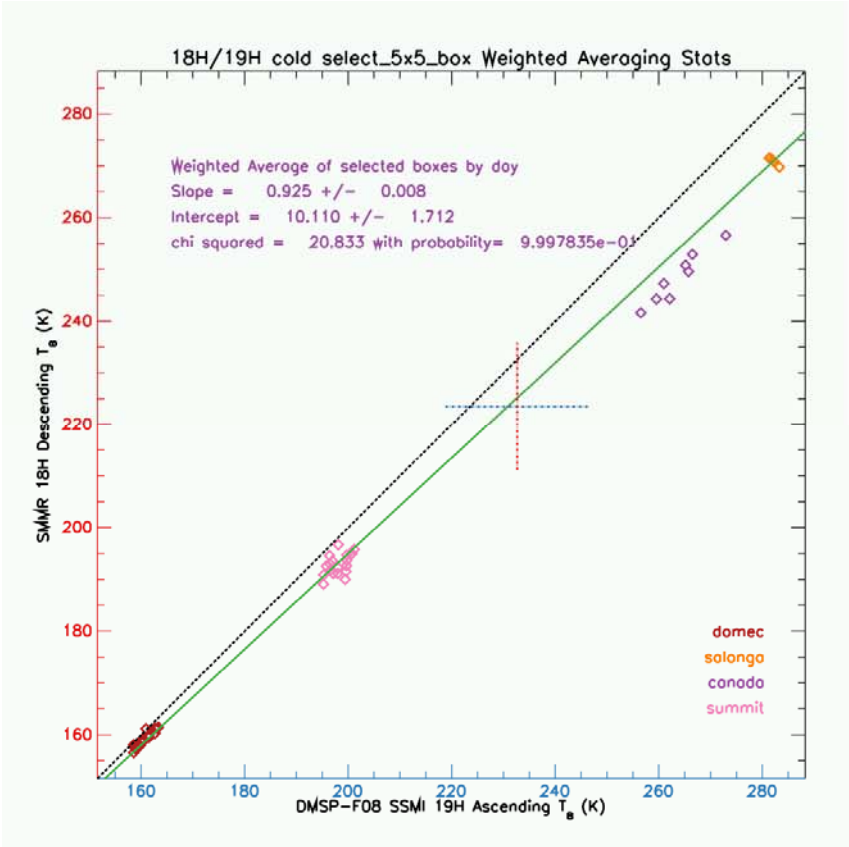


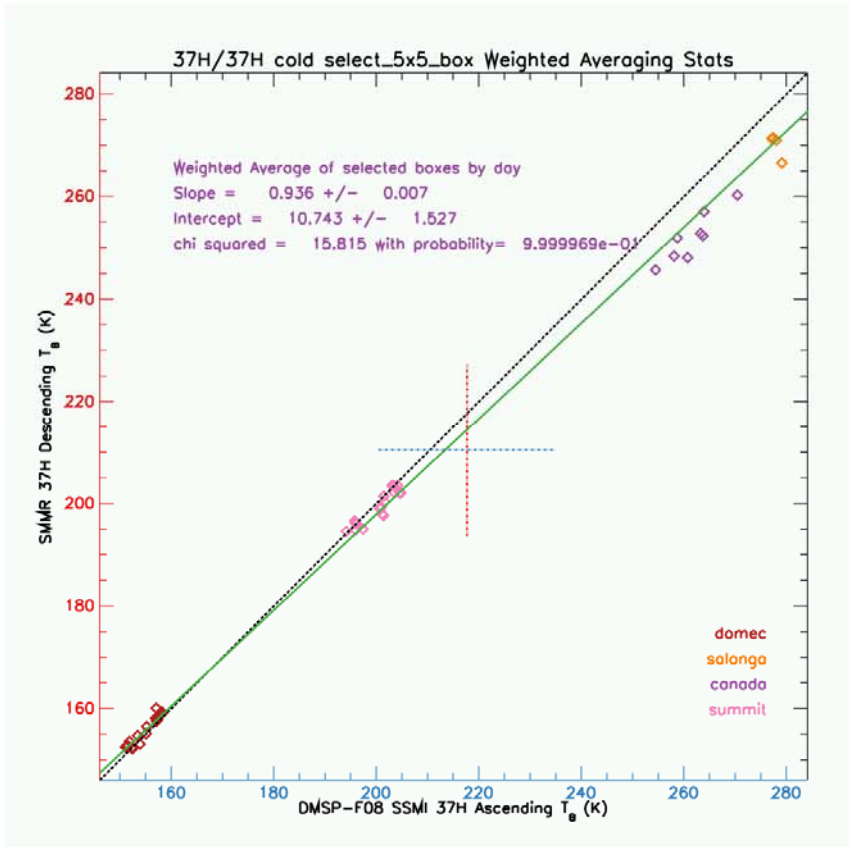
Before and after piece-wise interpolation of daily SSM/I SWE map, February 24, 2004

SMMR Before Interpolation After Interpolation

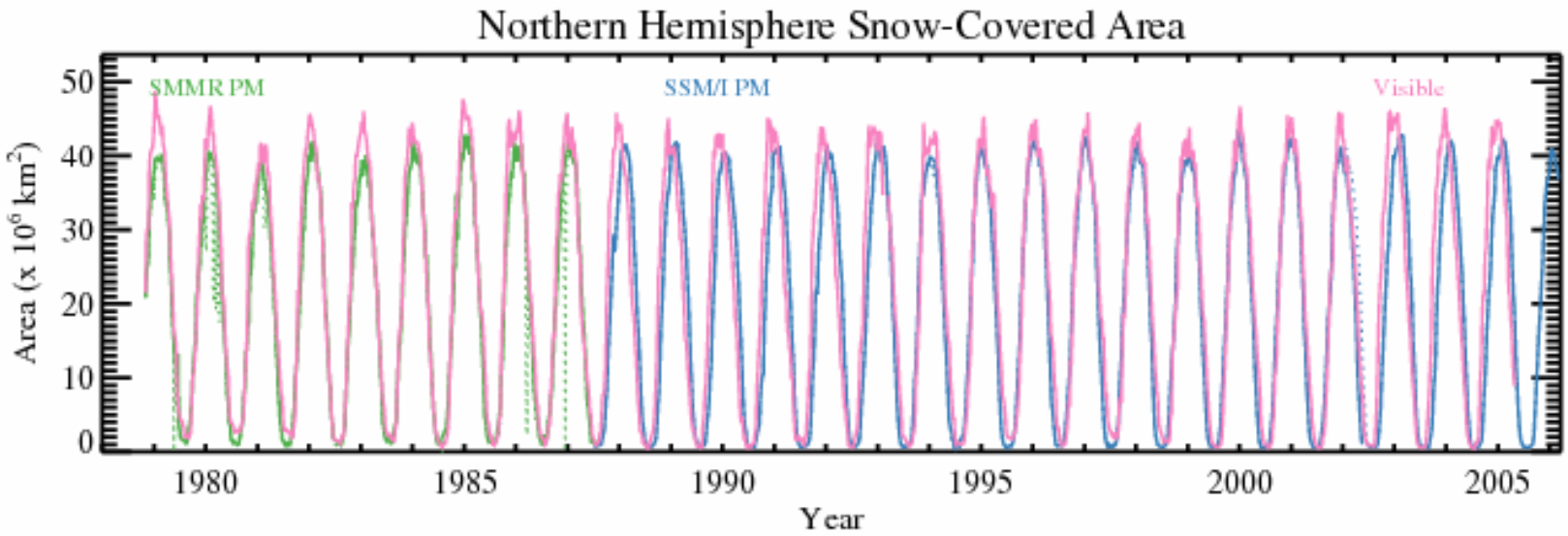


Before and after piece-wise interpolation of daily SMMR SWE map, February 24, 1980

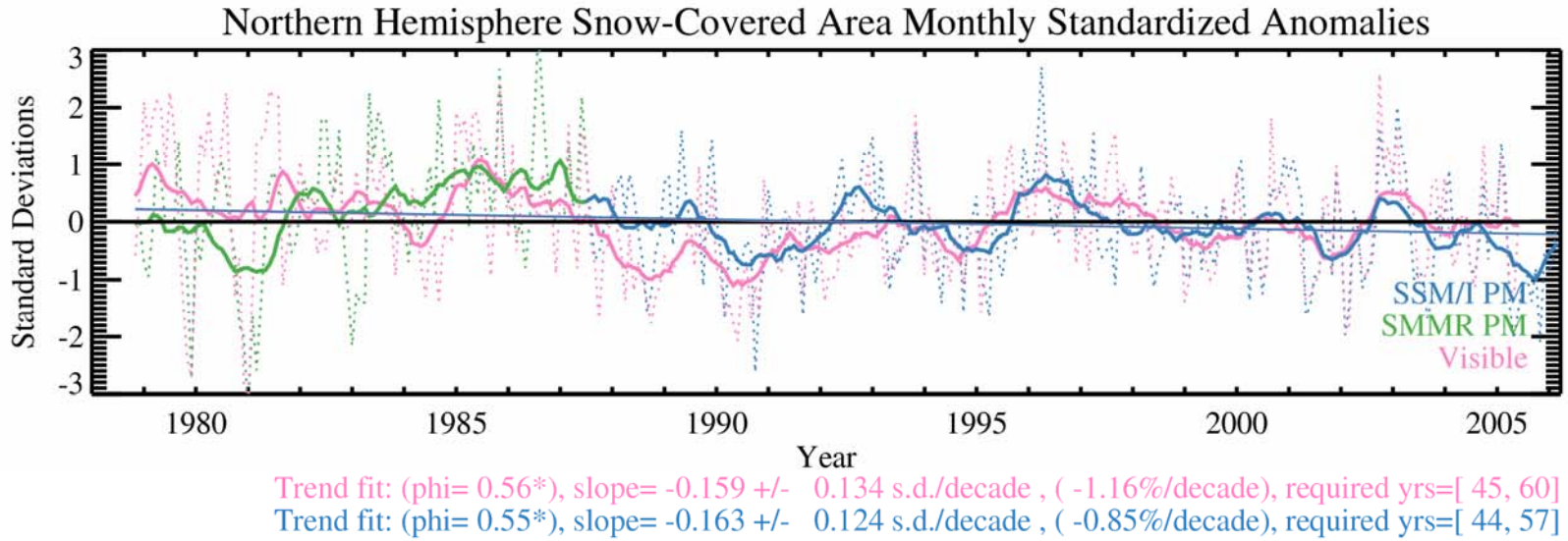




Scatter plots of SSM/I vs. SMMR brightness temperatures (19/18 GHz, left, and 37 GHz, right) at Earth targets selected for spatial stability (Dome C (Antarctic ice sheet), Salonga (African tropical forest), Canada (plains), Summit (Greenland ice sheet)).The large plus sign in each plot represents the typical range (+/- 1 standard deviation) of wintertime brightness temperatures in seasonally snow-covered regions.

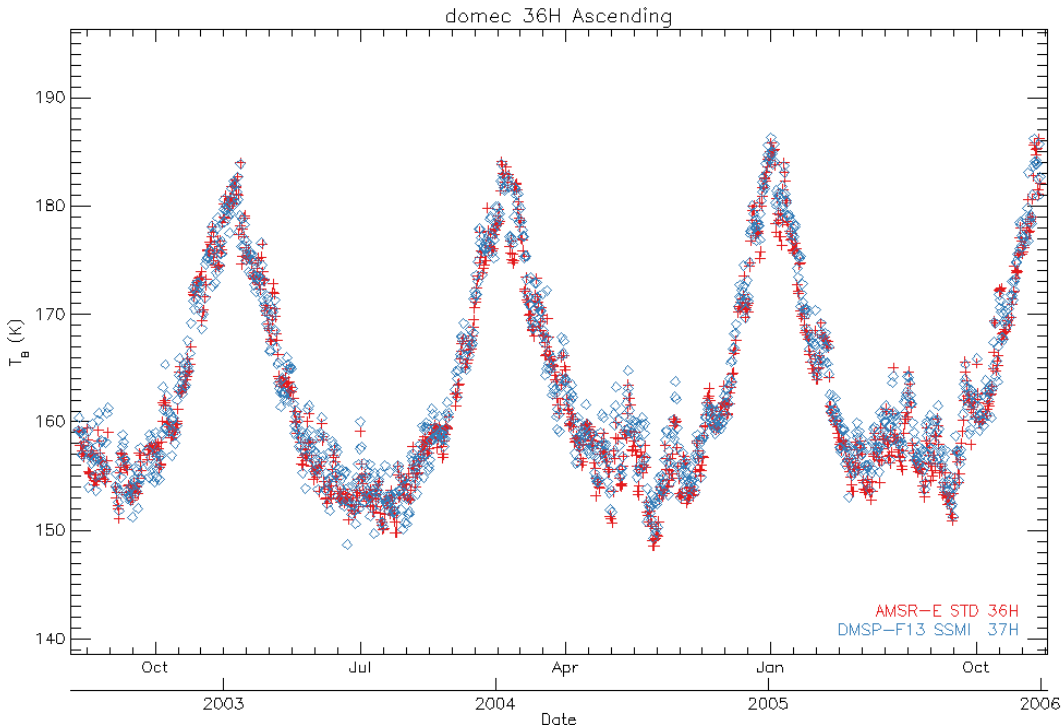


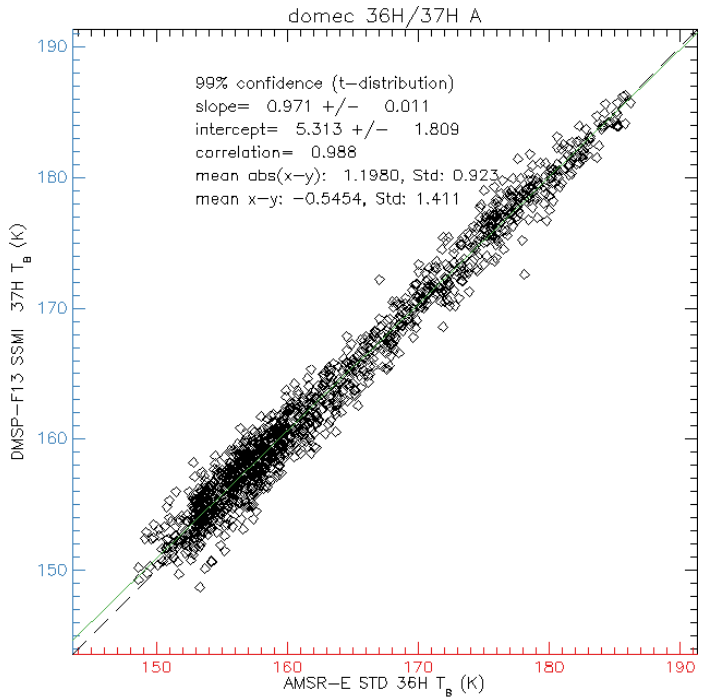
Time series of Northern Hemisphere snow-covered area derived from passive microwave (green/blue) and optical (pink) sensors, 1978-2006.



Northern Hemisphere snow-covered area monthly standardized anomalies (12 – month smoothed).

Comparison of NASA Aqua AMSR-E (36 GHz) and DMSP SSM/I (37 GHz) Dome-C Antarctica, June 2002 to December 2005.





Continuing Work

- **Improve/refine cross-calibration of SMMR and SSM/I brightness temperatures.**
- **Cross-calibrate SSM/I and AMSR-E and merge the historical snow cover times series with NASA EOS data and products.**
- **Continue work on optimal blending MODIS and AMSR-E data including use of 89 GHz**
- **Produce regional scale snow cover trend analysis (Fall AGU 2006)**

Surface Temp & 37 GHz T_Bs – Dome C

- **Radiative transfer modeling and in-situ data are needed to indicate how much of the observed offsets are explainable by sensor observation configuration differences.**