Scatterometer Climate Record Pathfinder

BYU Center for Remote Sensing

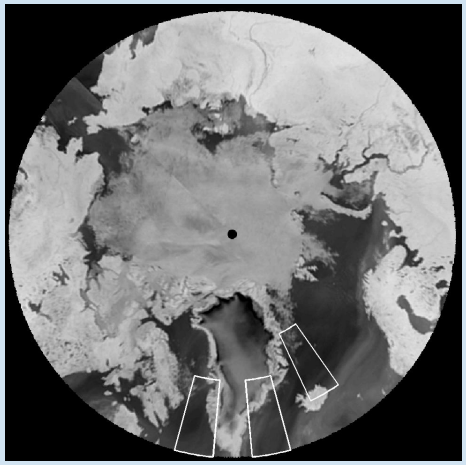
Microwave Earth Remote Sensing Laboratory (MERS)

BYU | IRA A. FULTON COLLEGE ENGINEERING AND TECHNOLOGY

National Snow and Ice Data Center
Advancing knowledge of Earth's frozen regions

CIRES

University of Colorado Boulder



A Climate Record of Enhanced Spatial Resolution Radiometer Data

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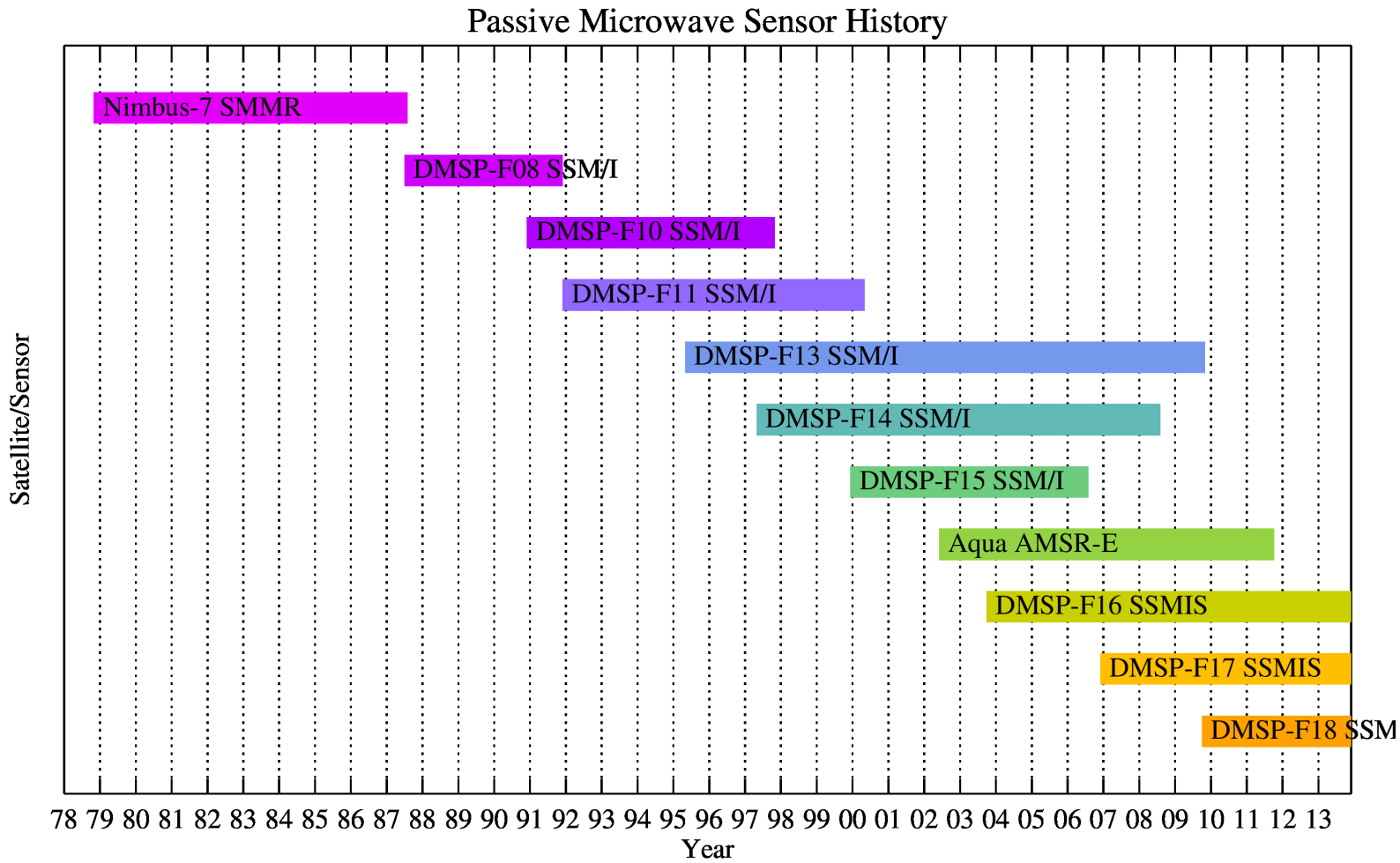
Project Goal

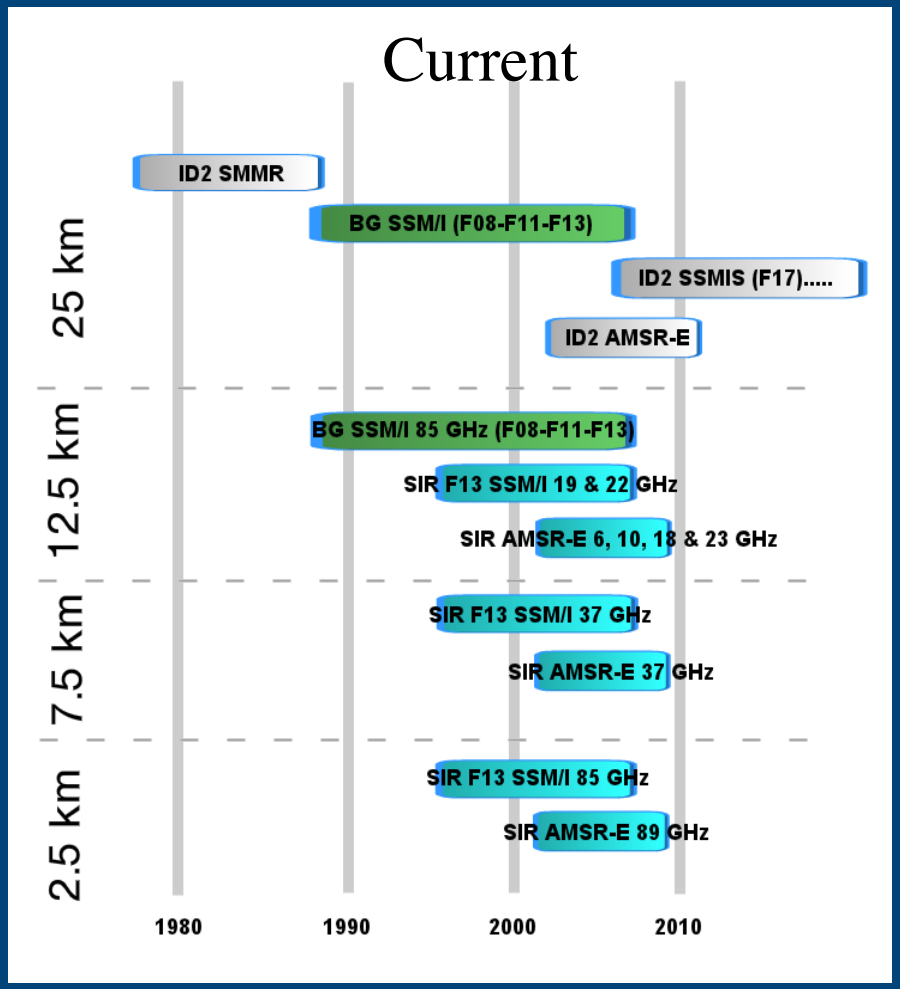
- Consistent Climate Record
- Intercalibrated
- Daily product
- High Resolution
  - Image Reconstruction
- Consistent Grid
  - EASE-Grid 2.0

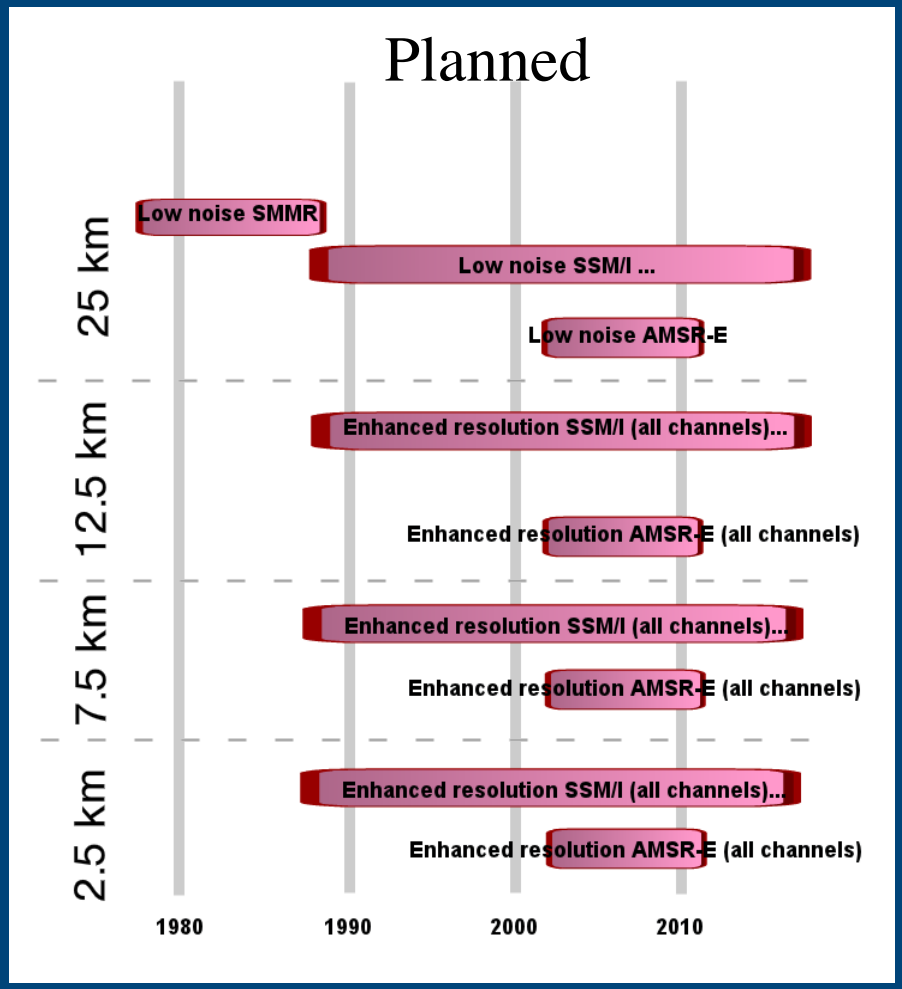
Earth-observing PM sensors



Availability of SMMR, AMSR-E, SSM/I and SSMIS sensors (dates are approximate); DMSP-F19 and F20 are not yet launched.

Passive Microwave EASE-Grid 2.0 ESDR



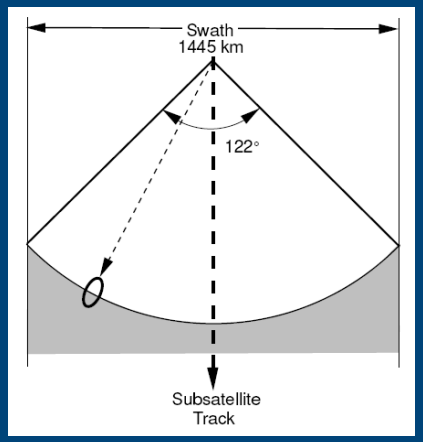


Time series of current (left) set of gridded passive microwave data sets, compared with proposed (right) ESDR. The various processing methods are indicated by colors; lengths of colored bars approximate respective periods of record. Note the consistency of the processing of the proposed products.

Advanced Microwave Sensor Radiometer for EOS

AMSR-E

- 2002-2008
- Frequency bands: 6.9, 10.7, 18.7, 23.8, 36.5, and 89 GHz (V- & H-polarization)
- Mean nominal spatial resolution for brightness temperatures:
  - 6.9 GHz (56 km) 0.3K
  - 10.7 GHz (38 km) 0.6K
  - 18.7 GHz (21 km) 0.6K
  - 36.5 GHz (12 km) 0.6K
  - 89 GHz (6 km) 1.1K



Antenna Temperature

Apparent antenna temperature distribution

$$T_{AP}(\theta,\phi) = \left[T_b(\theta,\phi) + T_{sc}(\theta,\phi)\right]e^{-\tau(\theta)\sec\theta} + T_{up}(\theta) + T_{sky}(\theta,\phi)$$

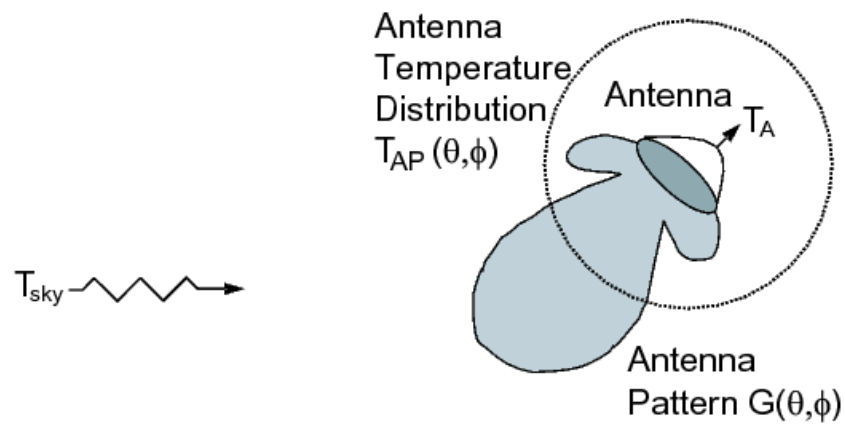
$T_b = \varepsilon T_p$ Surface brightness temperature

T_{sc} Surface scattering temperature

$e^{-\tau(\theta)\sec\theta}$ Atmospheric attenuation

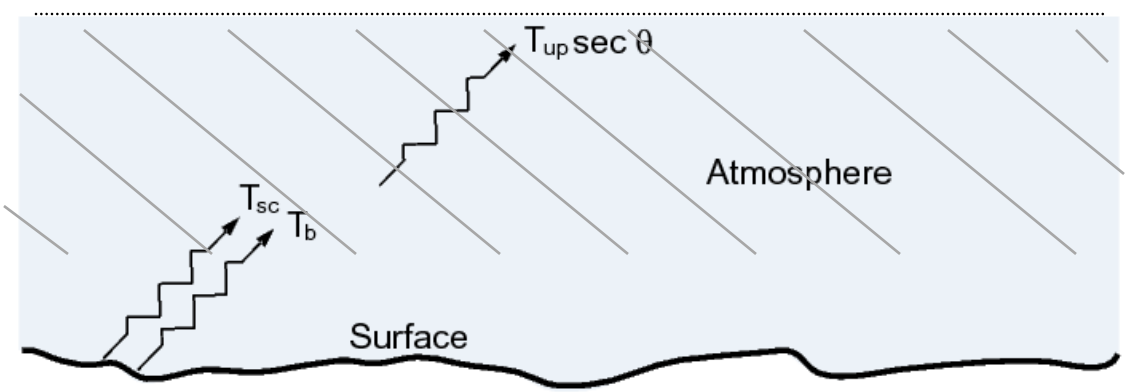
$T_{up}(\theta)$ Upwelling signal

T_{sky} Sky temperature



Antenna temperature

$$T_A = \frac{\iint G(\theta,\phi)\,T_{AP}(\theta,\phi)\,d\theta\,d\phi}{\iint G(\theta,\phi)\,d\theta\,d\phi}$$

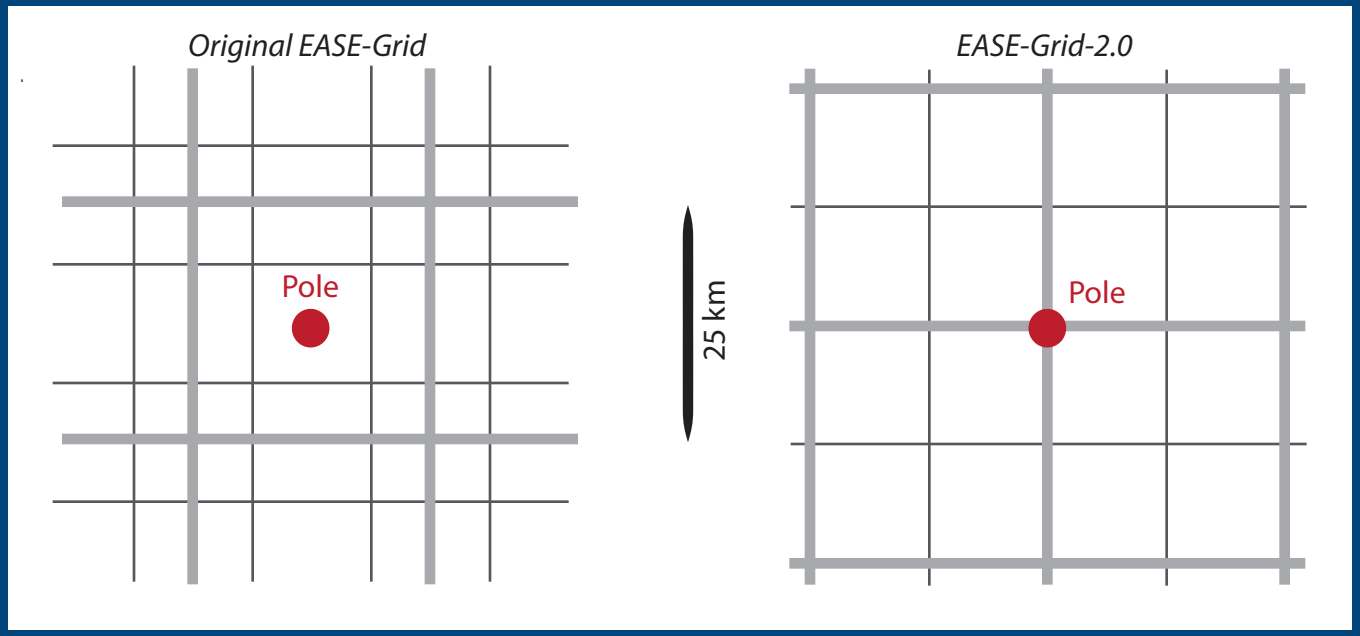


EASE-Grid (1.0) vs. EASE-Grid 2.0

	EASE-Grid (1.0)	EASE-Grid 2.0
Projection spheroid	International 1924 Authalic Sphere	WGS84*
Pole location	Center of center cell	Intersection of center cells
Scale (data-set specific)	Azimuthal/Cylindrical coupled, e.g. Nl/Sl/Ml 25.067525 km	Azimuthal: exact, e.g. 25.0 km or 36.0 km, etc.; Cylindrical: integer-multiples across latitude of true scale
Dimensions	Odd-numbered	Even-numbered
Nested Grids	Force choices between total coverage and nested cells	Coverage can stay the same, only number of cells changes
Corner Points	Undefined: azimuthal grids "wrapped beyond" opposite pole	No undefined corner cells
GeoTIFF	Requires reprojection	Supported w/o reprojection*
Software Issues	Usually requires user to understand "custom projection" settings	Most software will "do the right thing"*

**Key to success is setting projection ellipsoid to the reference datum.*

EASE-Grid (1.0) vs. EASE-Grid 2.0 at the poles

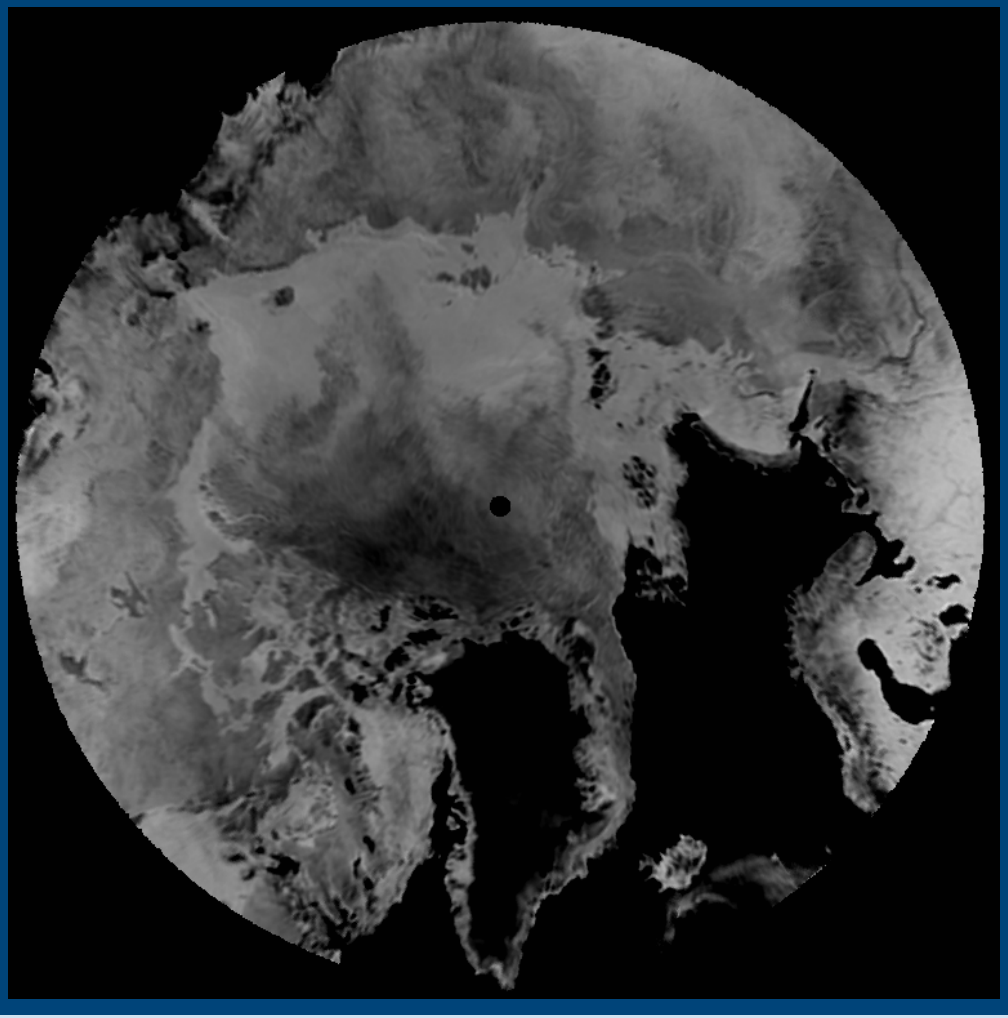


Relative gridding schemes for representative azimuthal 25 km and 12.5 km original EASE-Grid (left, bore-centered) vs. EASE-Grid 2.0 (right, nested) cells near the pole.

Brodzik, M. J., B. Billingsley, T. Haran, B. Raup and M. Savoie. 2012. EASE-Grid 2.0: Incremental but Significant Improvements for Earth-Gridded Data Sets. ***ISPRS Int. J. Geo-Inf.***, 1(32-45).

EASE-Grid 2.0

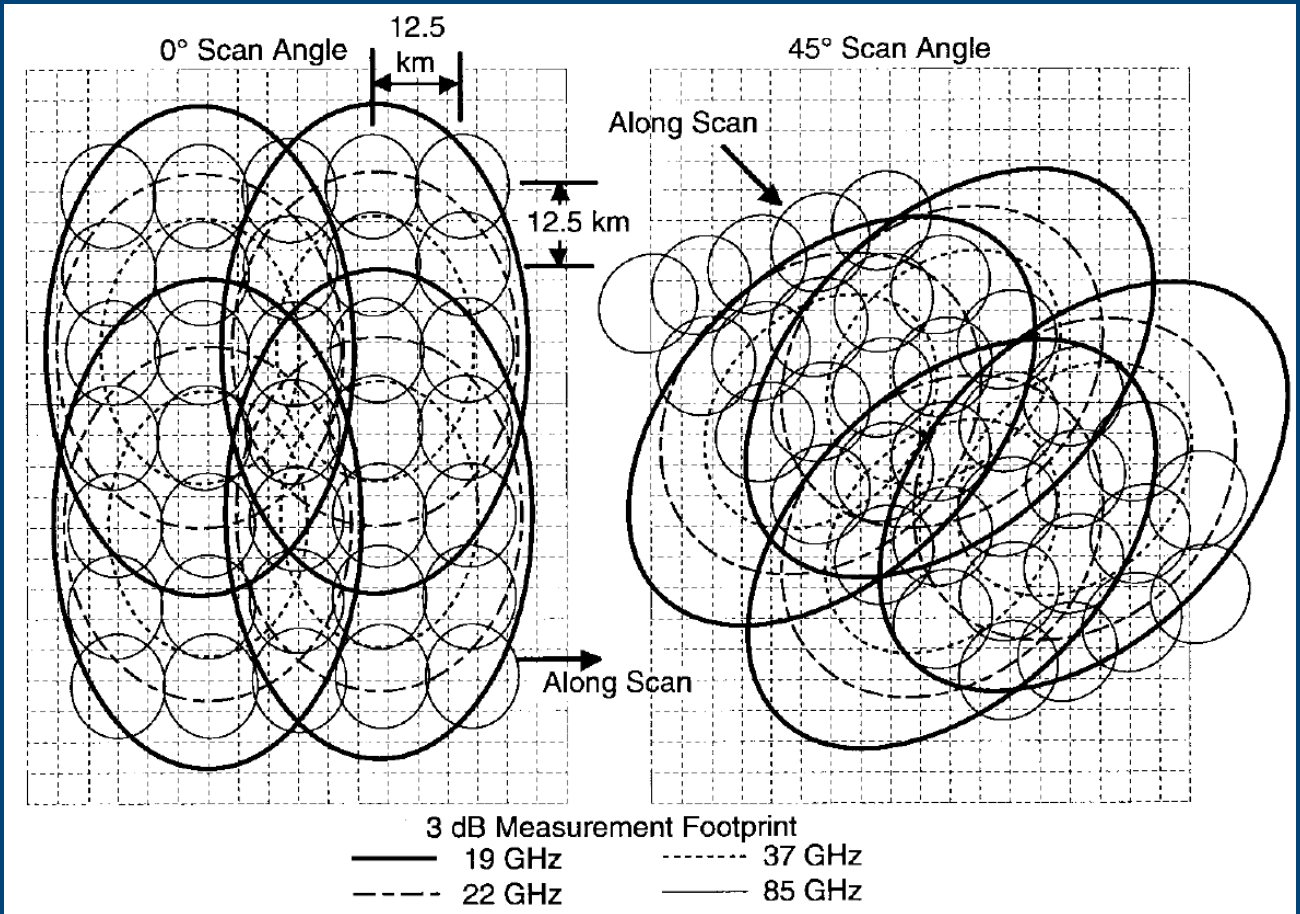
Useful for cryosphere and polar applications



AMSR-E (SIR) Enhanced Resolution

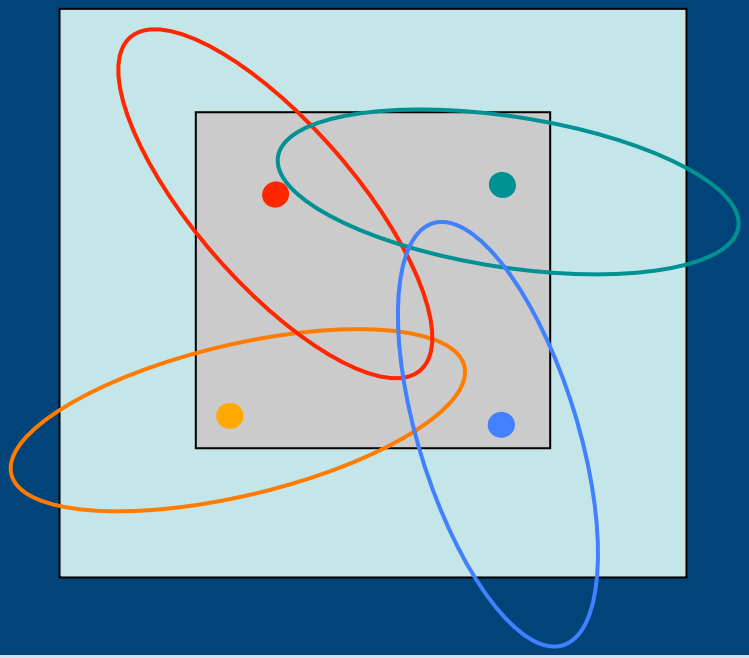
Comparison of footprints between channels

- SSM/I



Regridding to Useful and Uniform Format

- Image Reconstruction
  - Radiometer version of Scatterometer Image Reconstruction (SIR)
  - Backus-Gilbert (BG)



Comparison of SIR, Backus-Gilbert, and gridding

- "Gridding" (drop-in-the-bucket)
  - Define grid, measurements whose center fall within grid element are averaged together. Averaged value is reported as grid pixel value
  - Noise reducing
  - Low resolution (limited to about grid size + 3 dB footprint size)
- Backus-Gilbert
  - Least-squares (local) reconstruction or interpolation
  - Higher resolution, higher noise than gridding
- Radiometer version of SIR

Reconstruction

- Sampling can be represented as a matrix equation:

$$z = Hs$$

  - where s is the signal, z is the measurements, and H describes the sampling and measurement aperture function, i.e.

$$z_i = \int h_i(x)s(x)dx$$

- The reconstruction problem is then

$$\hat{s} = H^{-1}z$$

- Regularization techniques are applied to ensure a unique, computable inverse
- The SIR algorithm is representative of iterative algorithms
  - Regularization is done by selecting the number of iterations
- Backus-Gilbert inverts matrix with subjective regularization
  - Usually implemented as a local solution rather than global

SIR and gridding

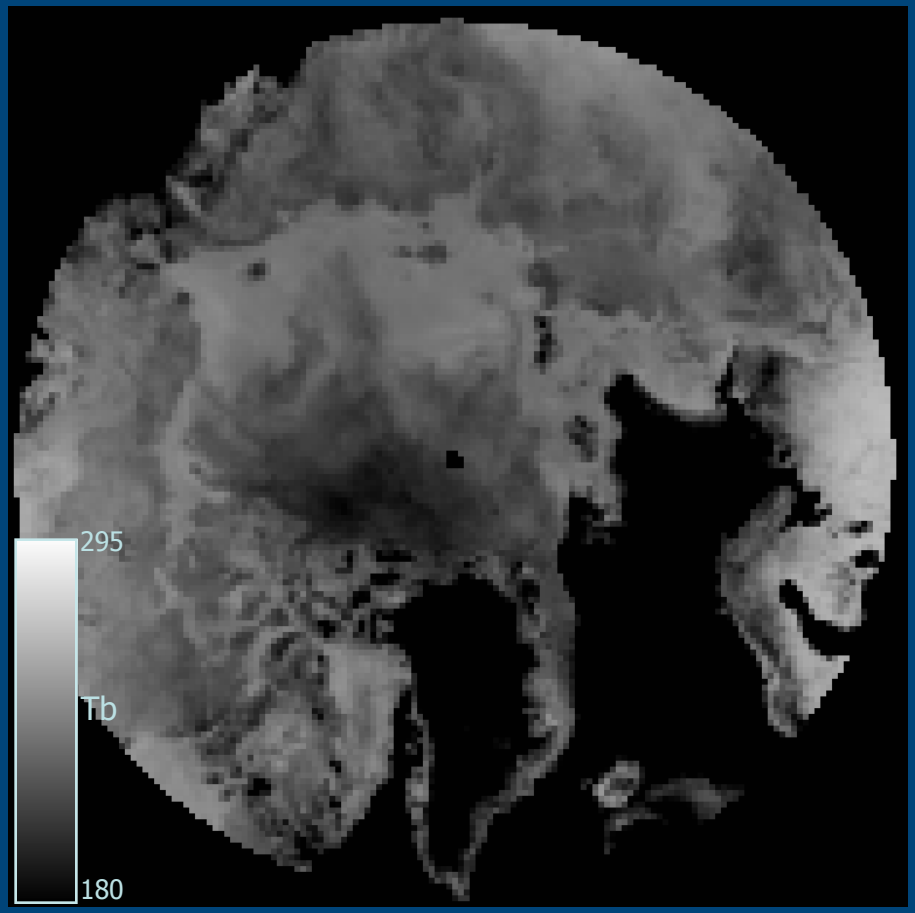
- Scatterometer Image Reconstruction (SIR) algorithm
  - Uses update weighting to minimize noise effects
  - Multivariate: can include incidence angle dependence for application to scatterometer measurements
  - Applicable for scatterometer and radiometer reconstruction / resolution enhancement
  - Requires antenna gain pattern.
- AVE (weighted averaging) is the first iteration of SIR
  - Weighted average of all measurements covering a pixel

Deliverables for Climate Record

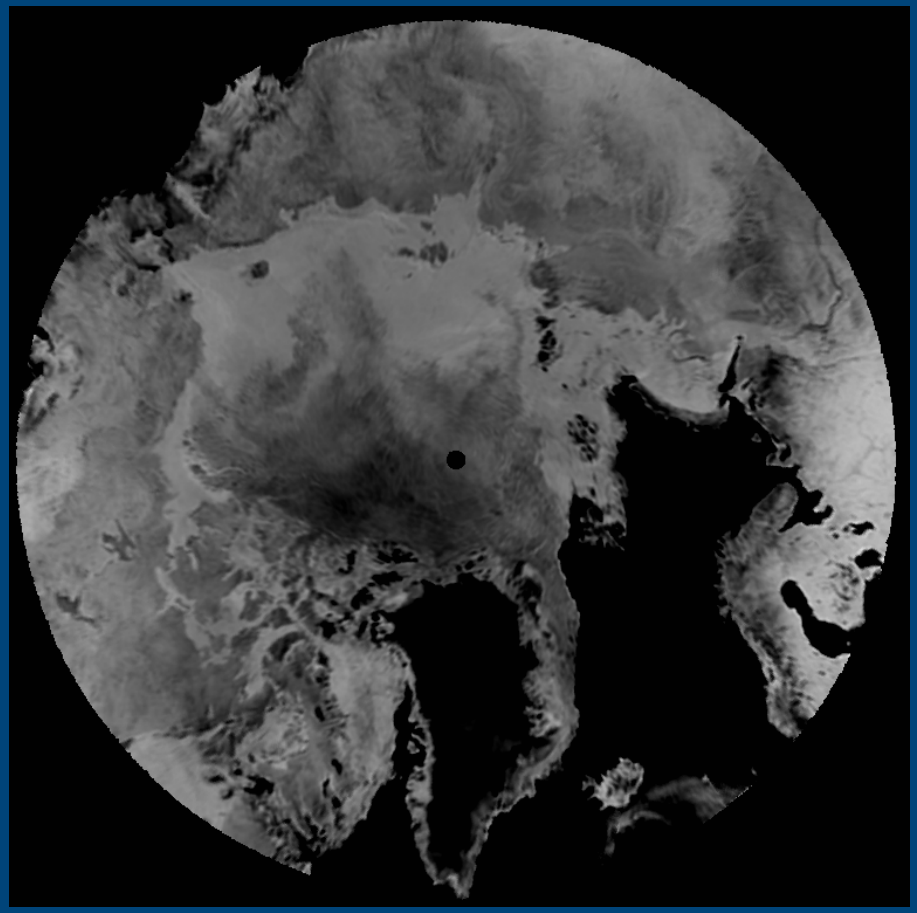
- Processing begins early 2014
- Initial data release expected Spring 2014
- Additional data release to follow (3-4 years)

AMSR Polar Images

Gridded (Conventional Resolution)



SIR (Enhanced Resolution)



- JD 002, 2007 37 GHz H-pol