

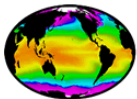
Microwave Radiometers

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To provide operational users and the science community
with the SST measured by the satellite constellation



GHRSSST
GROUP FOR HIGH RESOLUTION
SEA SURFACE TEMPERATURE

<http://www.ghrsst.org>



Committee on Earth Observation Satellites
Sea Surface Temperature Virtual
Constellation

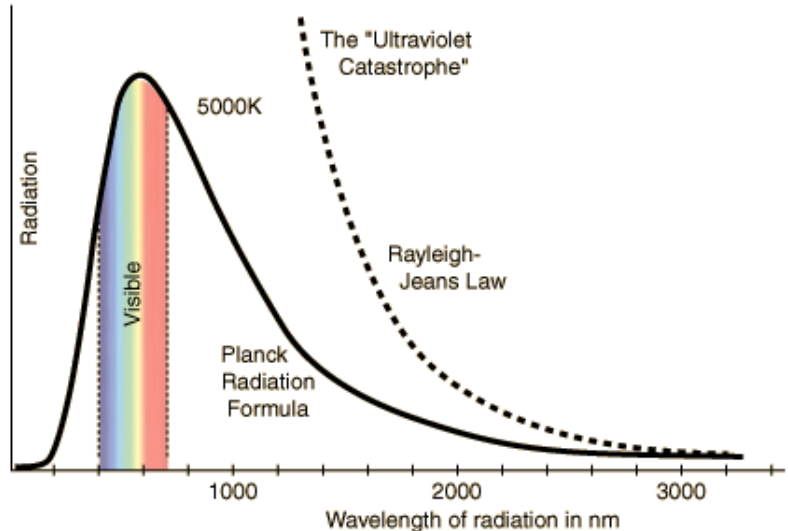
Rayleigh-Jeans Law

Rayleigh-Jeans Law corresponds to the Planck Law in the case of low frequencies, in which case $h\nu/(kT) \ll 1$ allows the approximation

$$e^{h\nu/(kT)} \approx 1 + \frac{h\nu}{kT} + \dots$$

Putting this into the Planck law gives

$$\begin{aligned} R_\nu(T) &\approx \frac{2\nu^3 h}{c^2} \frac{1}{\left(1 + \frac{h\nu}{kT} + \dots\right) - 1} \\ &= \frac{2\nu^2 kT}{c^2}. \end{aligned}$$



See <http://hyperphysics.phy-astr.gsu.edu/hbase/mod6.html>

Rayleigh-Jeans Law

Rayleigh-Jeans Law (an approximation used in the microwave):

$$h\nu / kT \ll 1$$

so that

$$\exp[h\nu/(kT)] \approx 1 + h\nu/(kT)$$

so Planck's function becomes

$$B_\nu = A\nu^2 T \quad (A \text{ is a const.})$$

For a non-black body

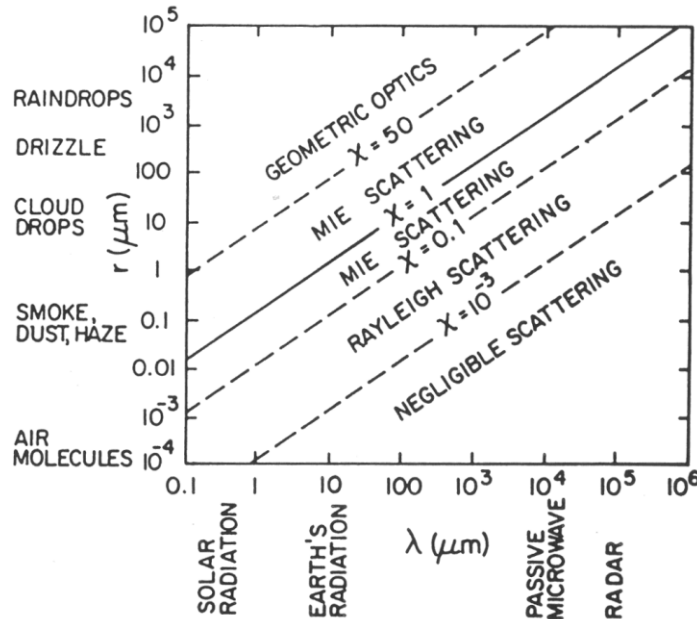
$$B_\nu(\lambda) = \epsilon(\lambda) A\nu^2 T$$

Thus the spectral radiance is linearly related to temperature. This is the *brightness temperature* (i.e. the temperature that a black-body emitter would have to emit the same spectral radiance). For objects at ~300K, this is good for $\nu < 600\text{GHz}$.

Microwave part of the spectrum

The microwave region of the electromagnetic spectrum ranges from about 300 MHz to 300 GHz (wavelengths from 1 meter to 1 mm).

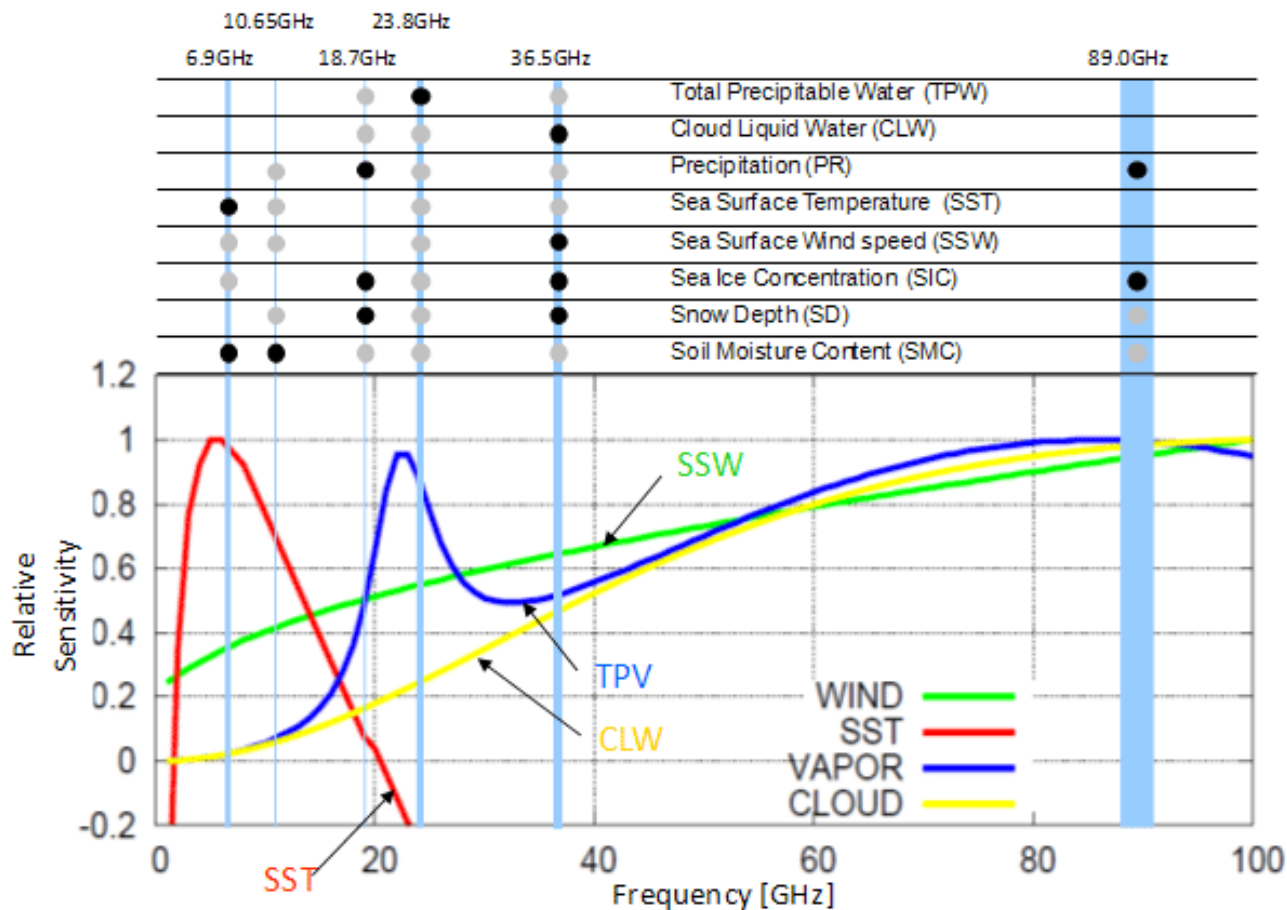
Scattering regimes



$$\chi = 2\pi a / \lambda$$

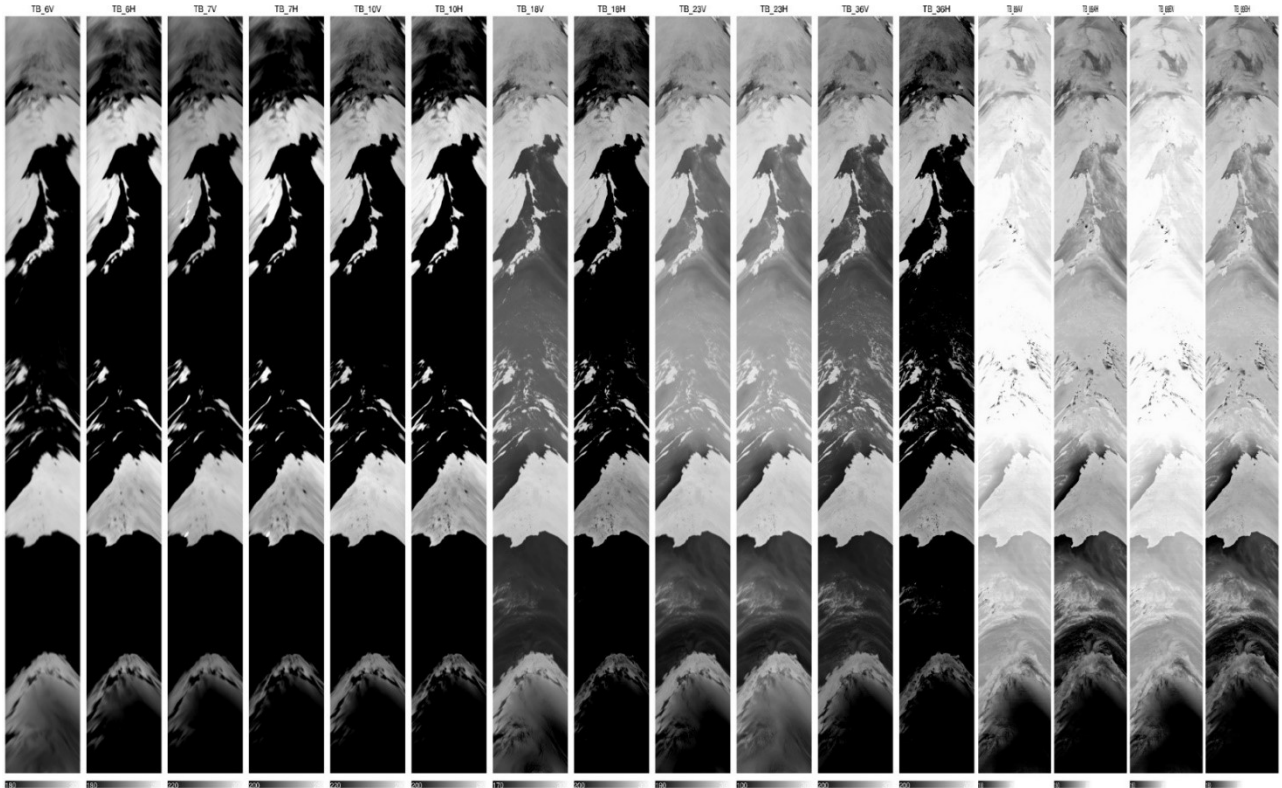
$$= q$$

Scattering regimes. [Adapted from Wallace and Hobbs (1977).]



AMSR-2 All Channels

6V 6H 7V 7H 10V 10H 18V 18H 22V 22H 37V 37H 89AV 89AH 89BV 89BH

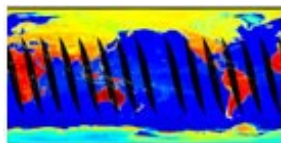


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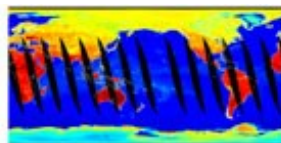
<http://www.ghrsst.org>



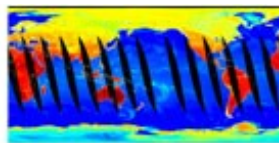
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Sea Surface Temperature Virtual Constellation



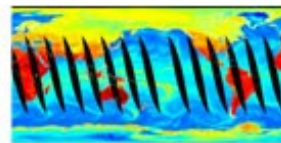
6.925GHz Vertical Polarization



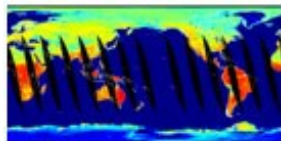
7.3GHz Vertical Polarization



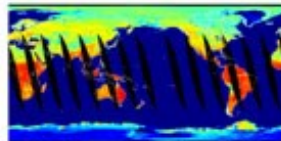
10.65GHz Vertical Polarization



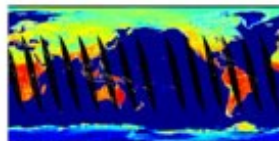
18.7GHz Vertical Polarization



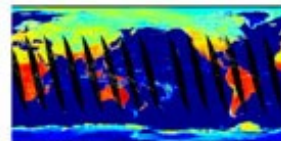
6.925GHz Horizontal Polarization



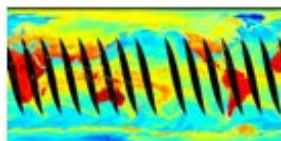
7.3GHz Horizontal Polarization



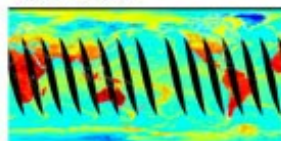
10.65GHz Horizontal Polarization



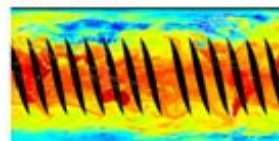
18.7GHz Horizontal Polarization



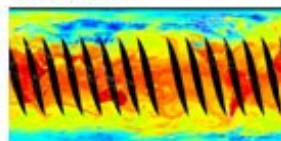
23.8GHz Vertical Polarization



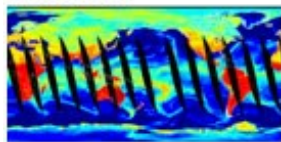
36.5GHz Vertical Polarization



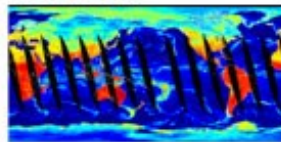
89.0GHz(A) Vertical Polarization



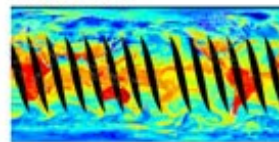
89.0GHz(B) Vertical Polarization



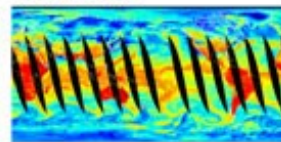
23.8GHz Horizontal Polarization



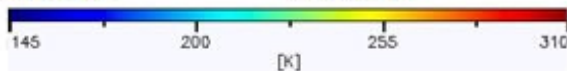
36.5GHz Horizontal Polarization



89.0GHz(A) Horizontal Polarization



89.0GHz(B) Horizontal Polarization



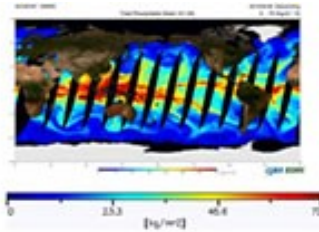
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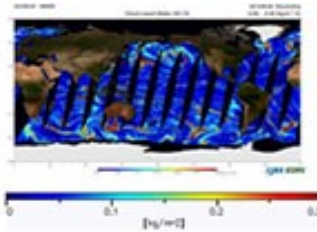


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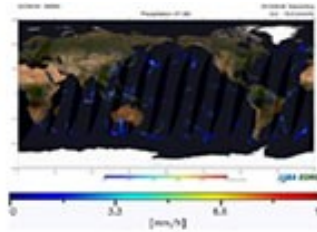
AMSR2 geophysical retrievals



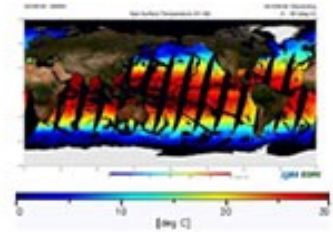
Total Precipitable Water



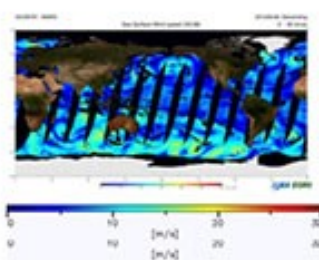
Cloud Liquid Water



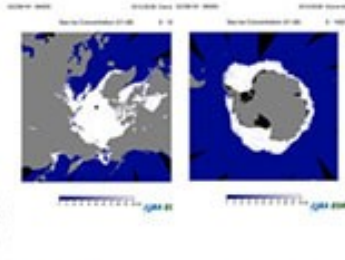
Precipitation



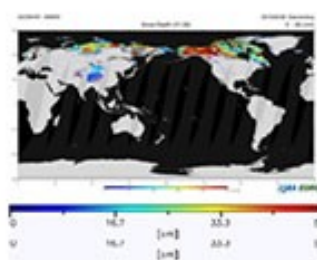
Sea Surface Temperature



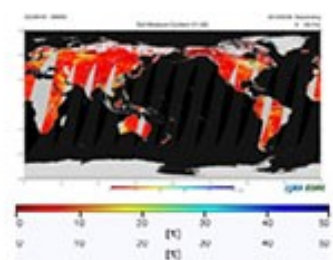
Sea Surface Wind speed



Sea Ice Concentration
(Left: North Pole Right: South Pole)

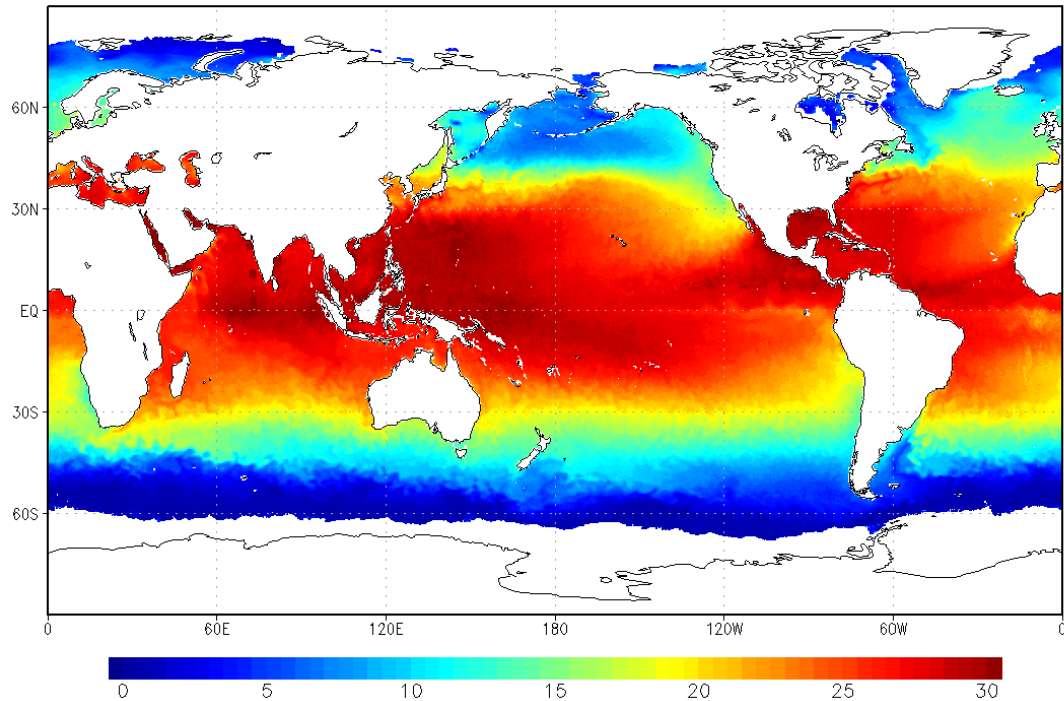


Snow Depth



Soil Moisture Content

AMSR-2 Weekly SST (3-8 July, 2012)



Simple bias correction is applied to AMSR-2 Tb before retrieval of SST by using comparison result between AMSR-2 and AMSR-E. Some RFIs and scan biases are not removed yet, but global distribution is totally reasonable.



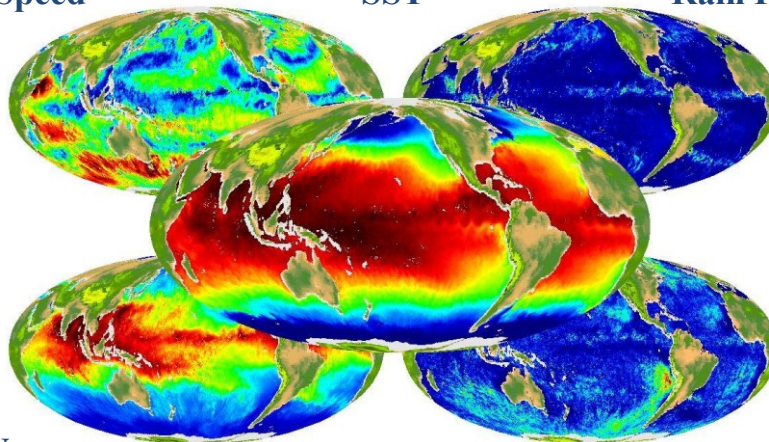
AMSR-E Ocean Products



Wind Speed

SST

Rain Rate



Water Vapor

Cloud

See: Wentz, F. J., 1997. A well-calibrated ocean algorithm for SSM/I, Journal of Geophysical Research, 102, 8703-8718.



Microwave antenna patterns

The spatial resolution is diffraction limited by the antenna size and the wavelength.

This gives rise to side-lobe contamination. The strong contrast near boundaries, such as coasts, means significant errors can occur.

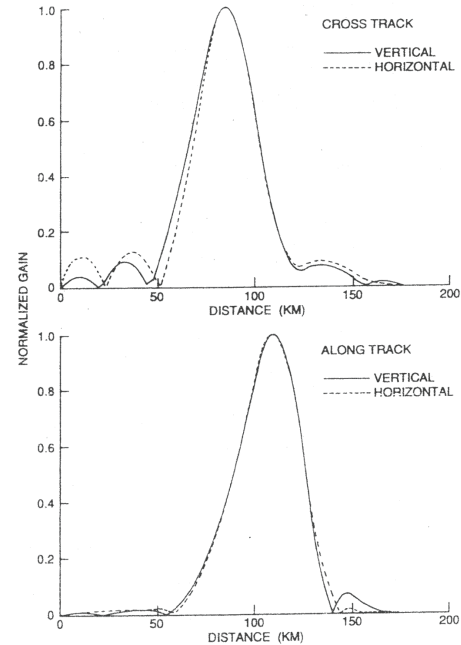
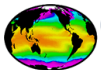


Fig. 6. 37 GHz antenna gain function derived from coastline overpasses.



Microwave radiometers

Electrically Scanning Microwave Radiometer (ESMR) on Nimbus 5 (1973-1976)

Scanning Multichannel Microwave Radiometer (SMMR) on SeaSat (1978) & Nimbus 7 (1978-1987).

Special Sensor Microwave Imager (SSM/I) on DMSP Series (1987) – evolved into SSMIS (Special Sensor Microwave Imager Sounder) in 2003.

TRMM (Tropical Rainfall Measuring Mission) Microwave Imager (TMI) on TRMM (1998...)

Advanced Microwave Scanning Radiometer (AMSR-E) on Aqua (2002 - 2011)

Advanced Microwave Scanning Radiometer (AMSR) on Midori (2002-2003)

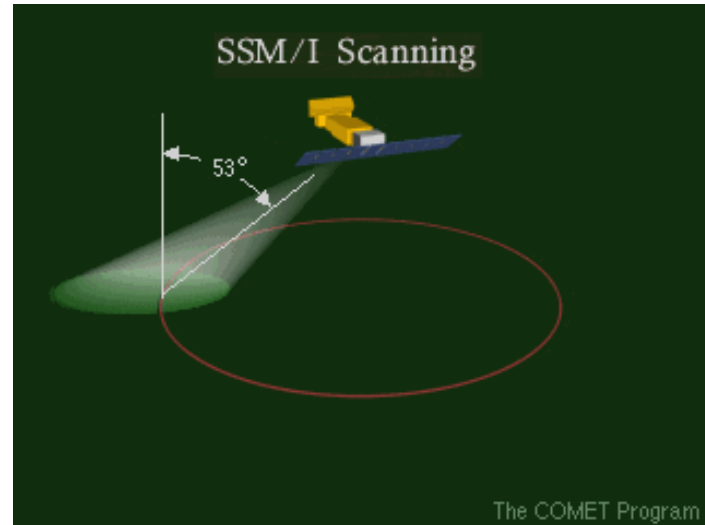
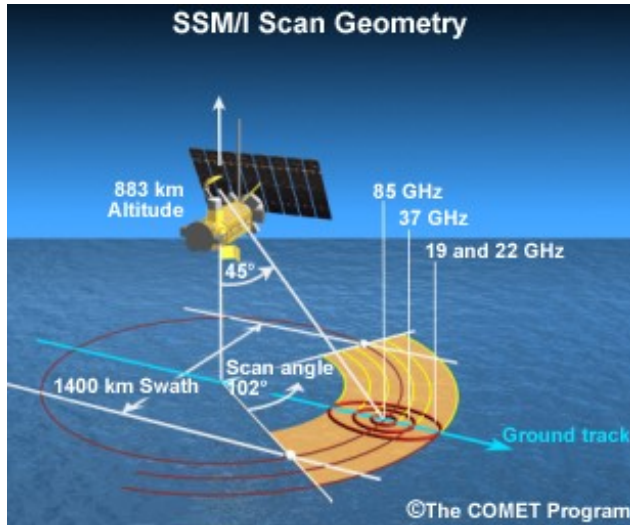
WindSat on Coriolis (2003...)

Microwave Imaging Radiometer using Aperture Synthesis (MIRAS) on SMOS (Soil Moisture and Ocean Salinity) Mission (2009...)

Aquarius on SAC-D (Satélite Aplicaciones Científicas-D) Mission (2011 ...)

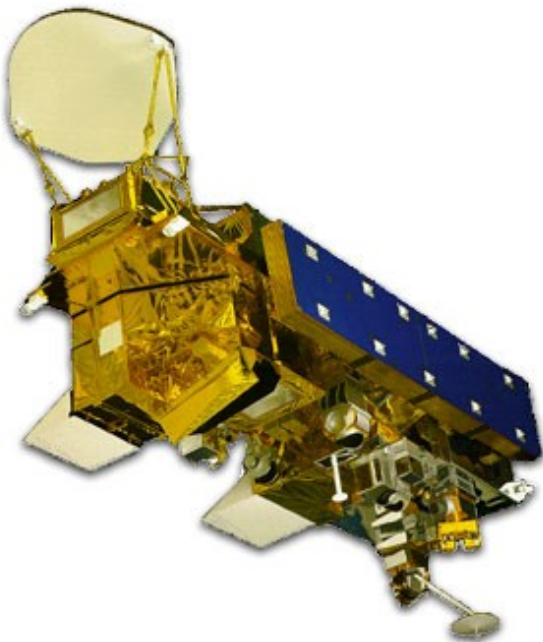
Advanced Microwave Scanning Radiometer - 2 (AMSR-2) on Shizuku (2012)

SSM/I scan



AMSR-E on EOS-Aqua

AMSR-E



MODIS

Aqua launched 4 May 2002.

Low frequency SST sensitivity means very large antenna is needed for even moderate surface resolution.

Offset parabolic reflector, 1.6 m in diameter, and rotating drum at 40 rpm.

But side lobe contamination is a significant issue, especially in coastal regions.

<http://aqua.nasa.gov/>

http://aqua.nasa.gov/about/instrument_amsr.php

AMSR-E: Advanced Microwave Scanning Radiometer for EOS.

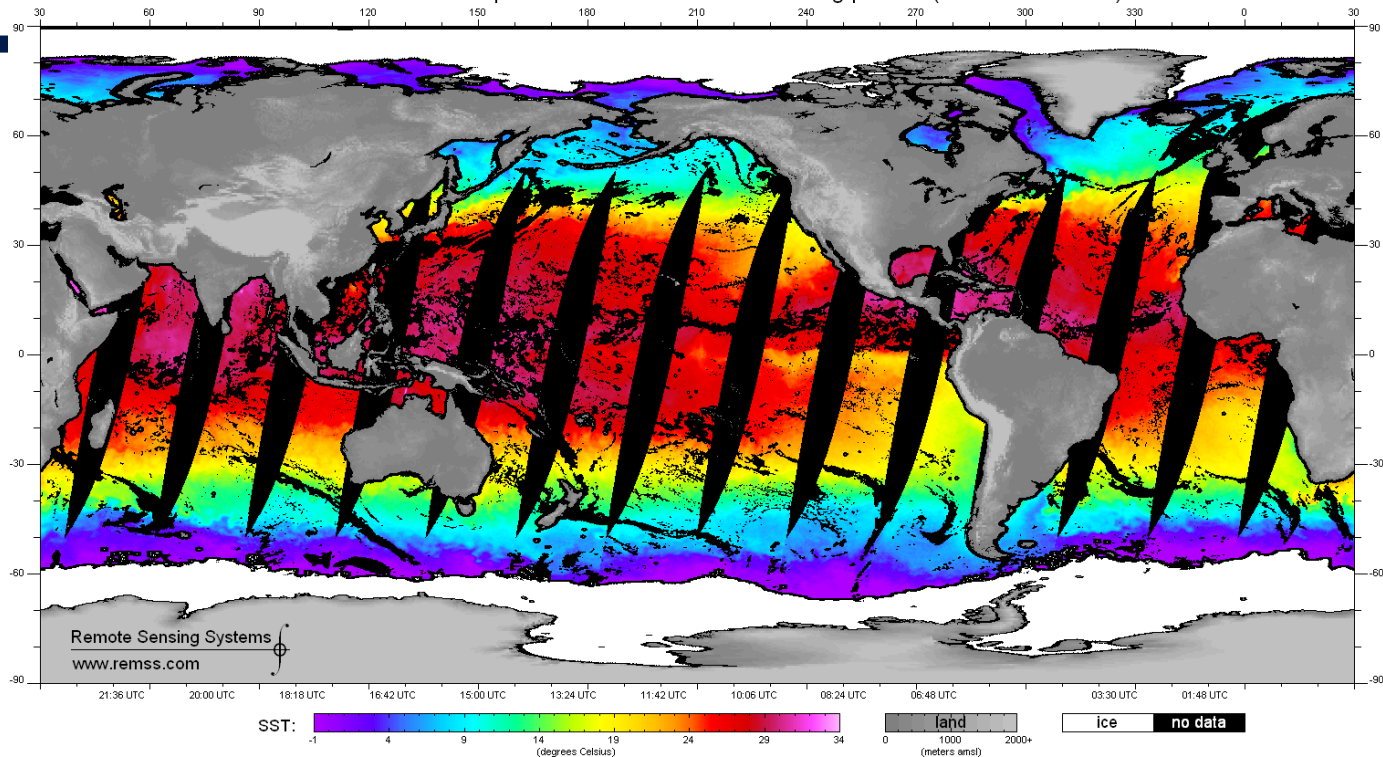
Table 1. AMSR-E PERFORMANCE CHARACTERISTICS

CENTER FREQUENCIES (GHz)	6.925	10.65	18.7	23.8	36.5	89.0
BANDWIDTH (MHz)	350	100	200	400	1000	3000
SENSITIVITY (K)	0.3	0.6	0.6	0.6	0.6	1.1
MEAN SPATIAL RESOLUTION (km)	56	38	21	24	12	5.4
IFOV (km x km)	74 x 43	51 x 30	27 x 16	31 x 18	14 x 8	6 x 4
SAMPLING RATE (km x km)	10 x 10	10 x 10	10 x 10	10 x 10	10 x 10	5 x 5
INTEGRATION TIME (MSEC)	2.6	2.6	2.6	2.6	2.6	1.3
MAIN BEAM EFFICIENCY (%)	95.3	95.0	96.3	96.4	95.3	96.0
BEAMWIDTH (degrees)	2.2	1.4	0.8	0.9	0.4	0.18

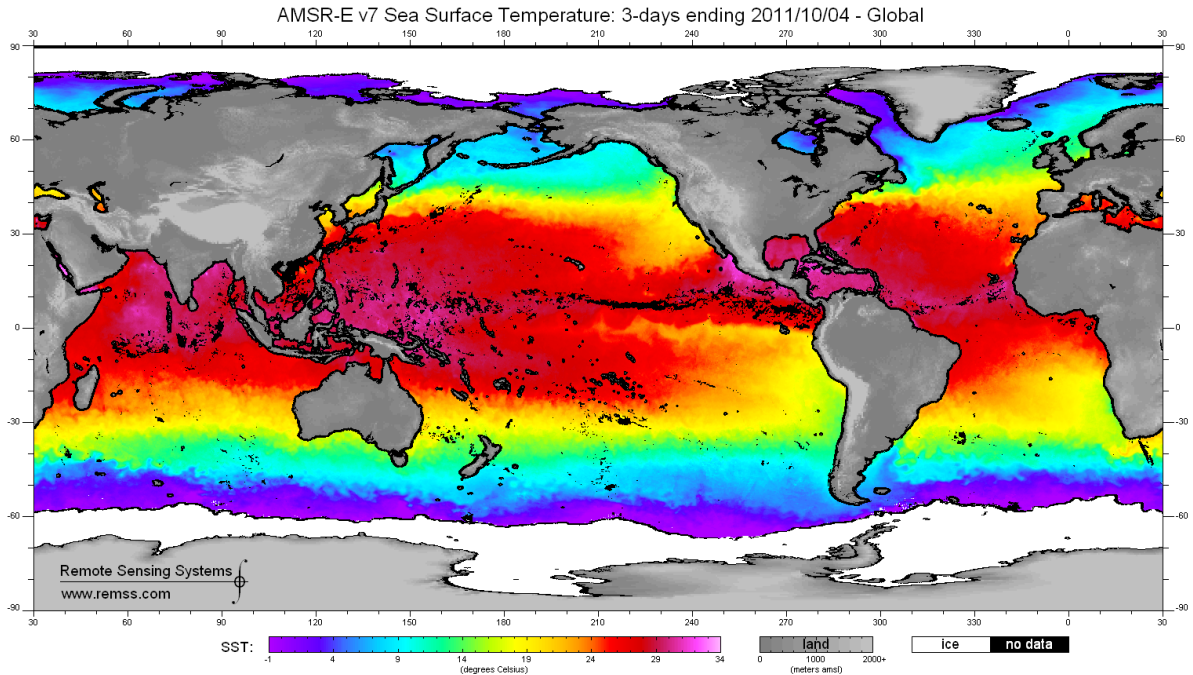
<http://www.ghcc.msfc.nasa.gov/AMSR/>

Microwave SSTs

AMSR-E v7 Sea Surface Temperature: 2011/10/03 - descending passes (~01:30 local time) - Global



Global microwave SSTs



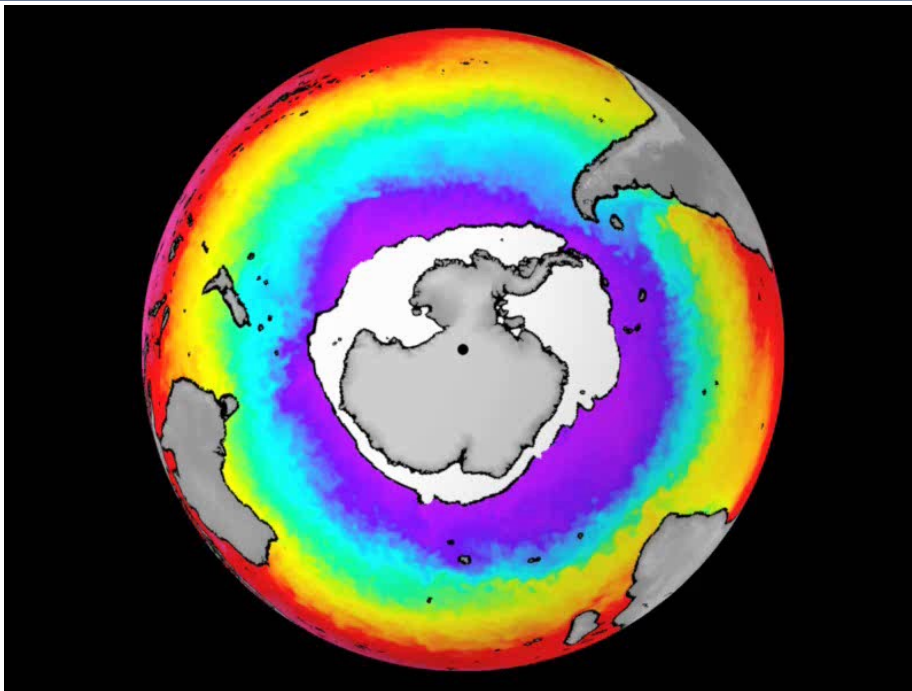
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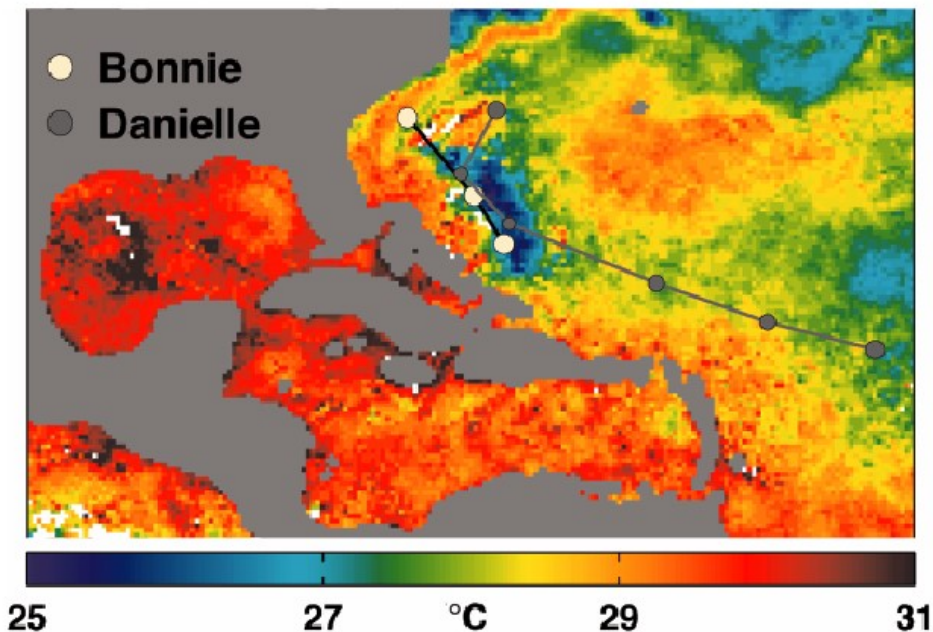


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AMSR-E SST

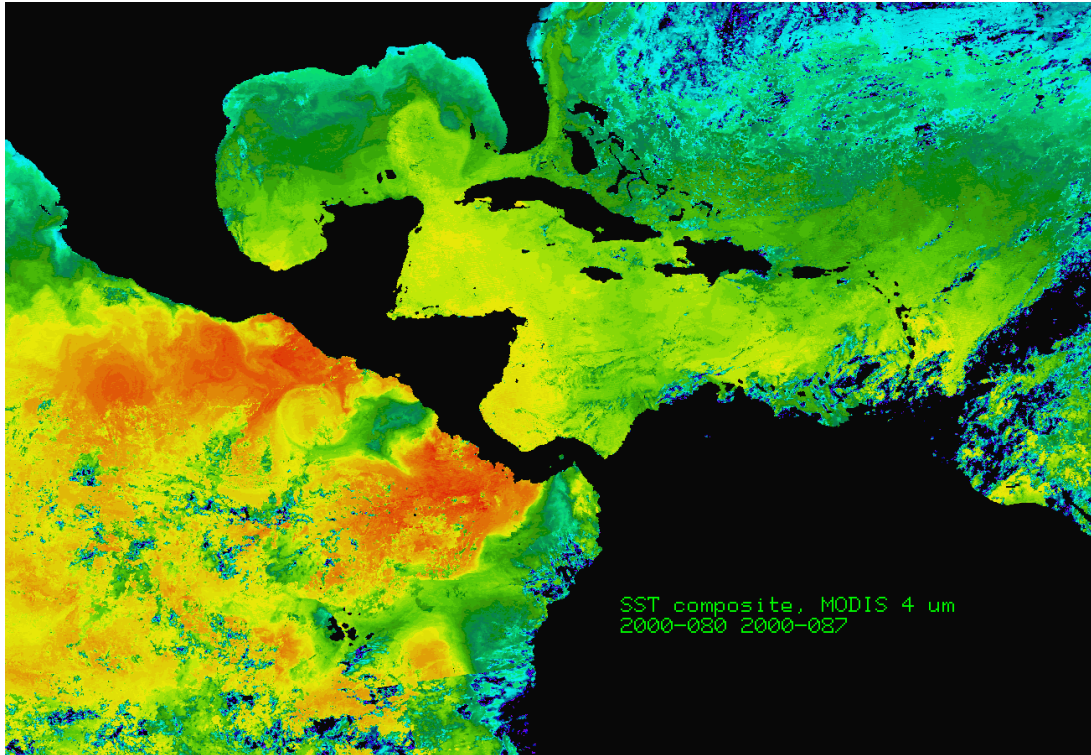


TMI microwave SST



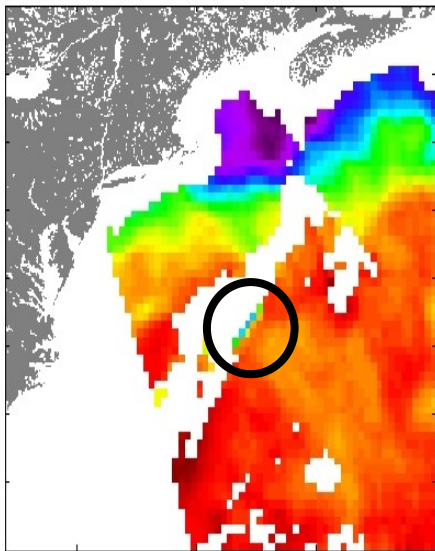
From: Wentz, F.J., C. Gentemann, D. Smith and D. Chelton, 2000. Satellite measurements of sea-surface temperature through clouds. *Science*, 288: 847-850.

MODIS 4 μ m SST Composite

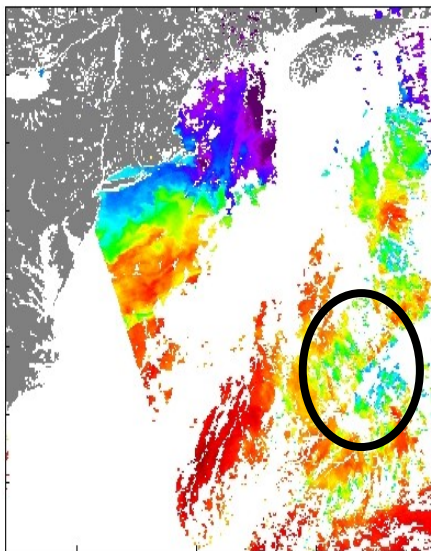


Blending of infrared and microwave SSTs

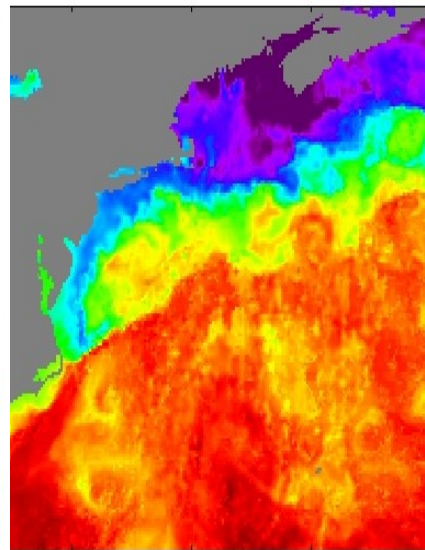
AMSR-E



MODIS



10km OI SST



Additional resources

For references and hyperlinks:

<http://www.infography.com/content/550915096677.html>

For access to data and imagery:

<http://www.remss.com/>

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