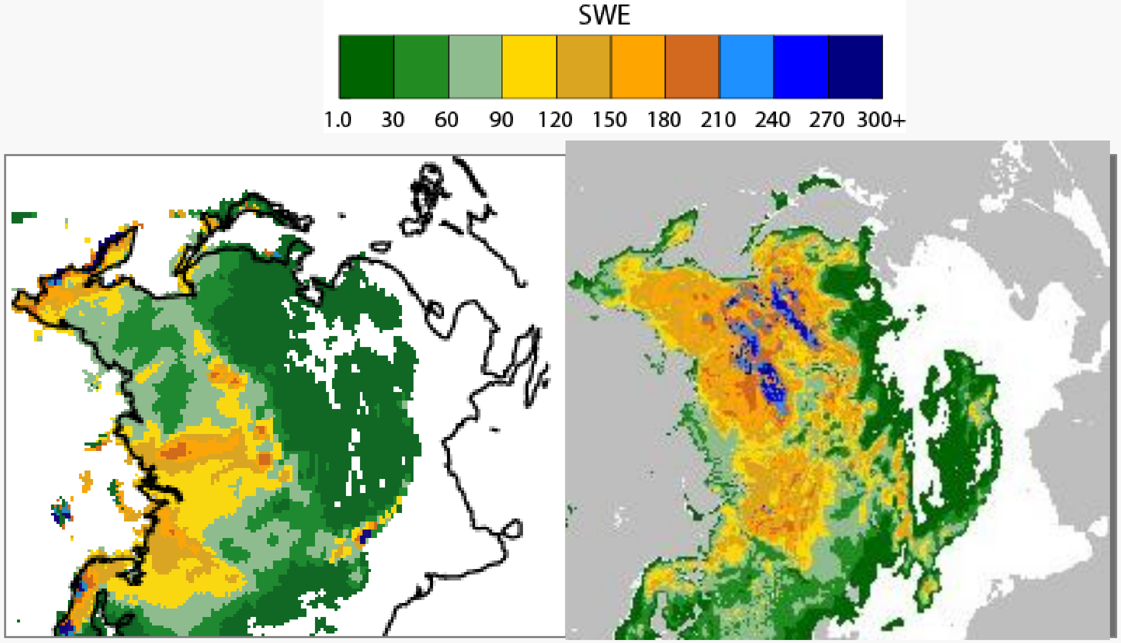
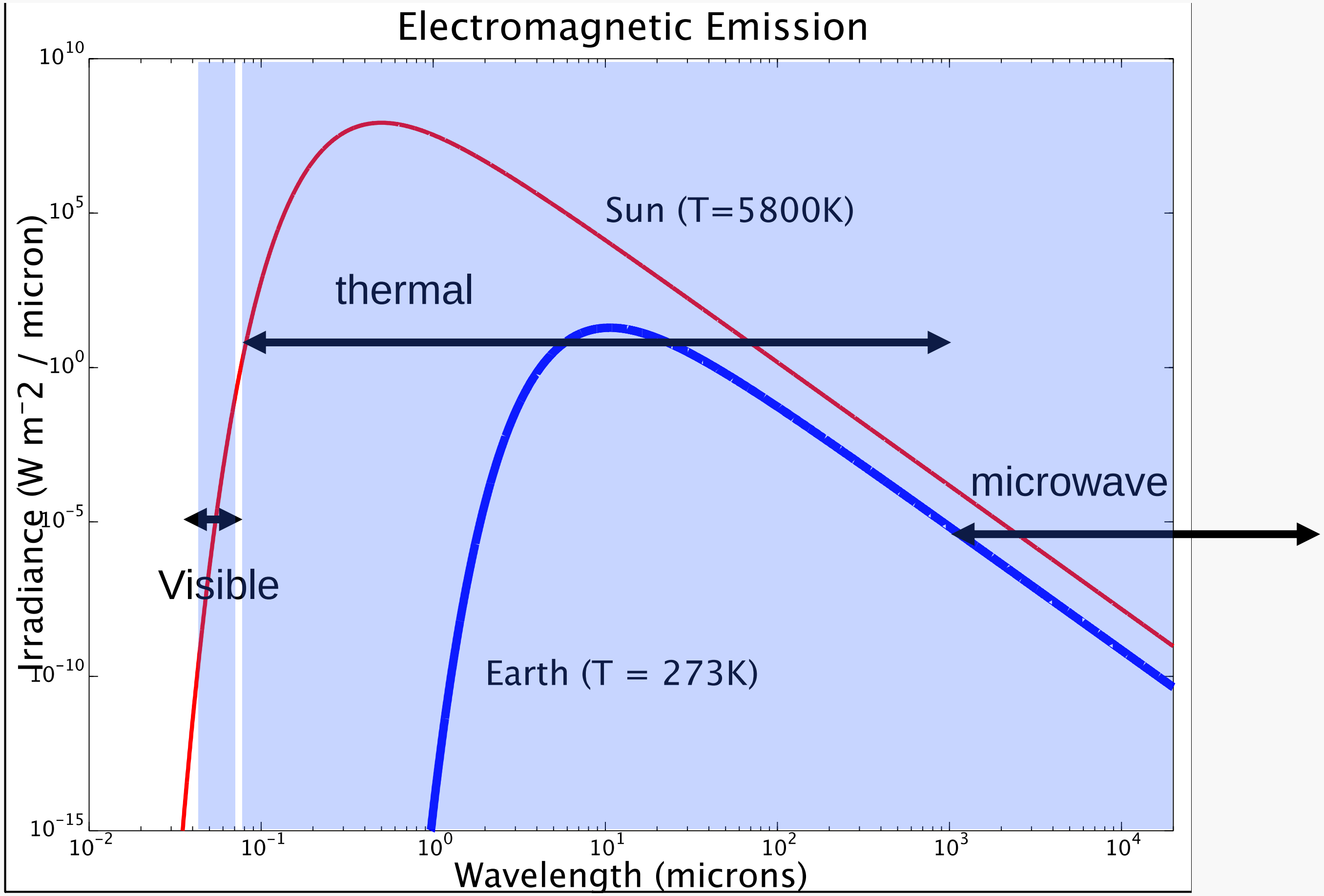


SWE = 4.77 * (18H - 37H)

MICROWAVE EMISSION OF THE LAND SURFACE

Mel Sandells -- Ian Davenport -- Debbie Clifford

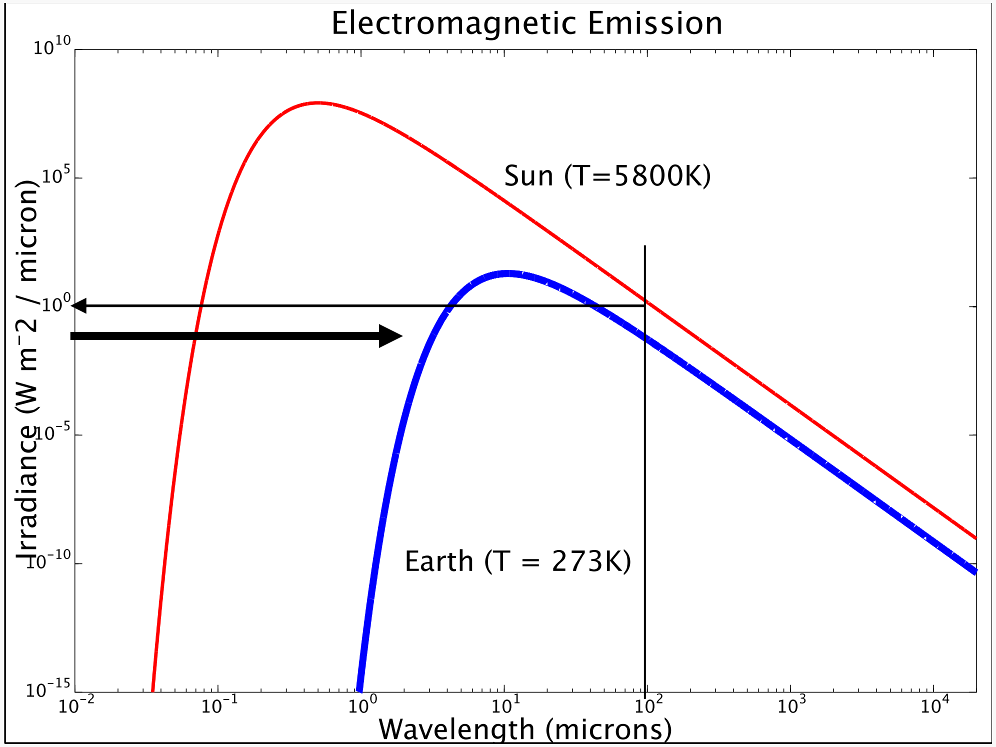
Microwave Emission



$$I = p\frac{2hc^2}{/^{5}\left[\exp\left(\frac{hc}{/k_BT}\right)-1\right]}$$

$$f = \frac{c}{/}$$

Brightness temperature

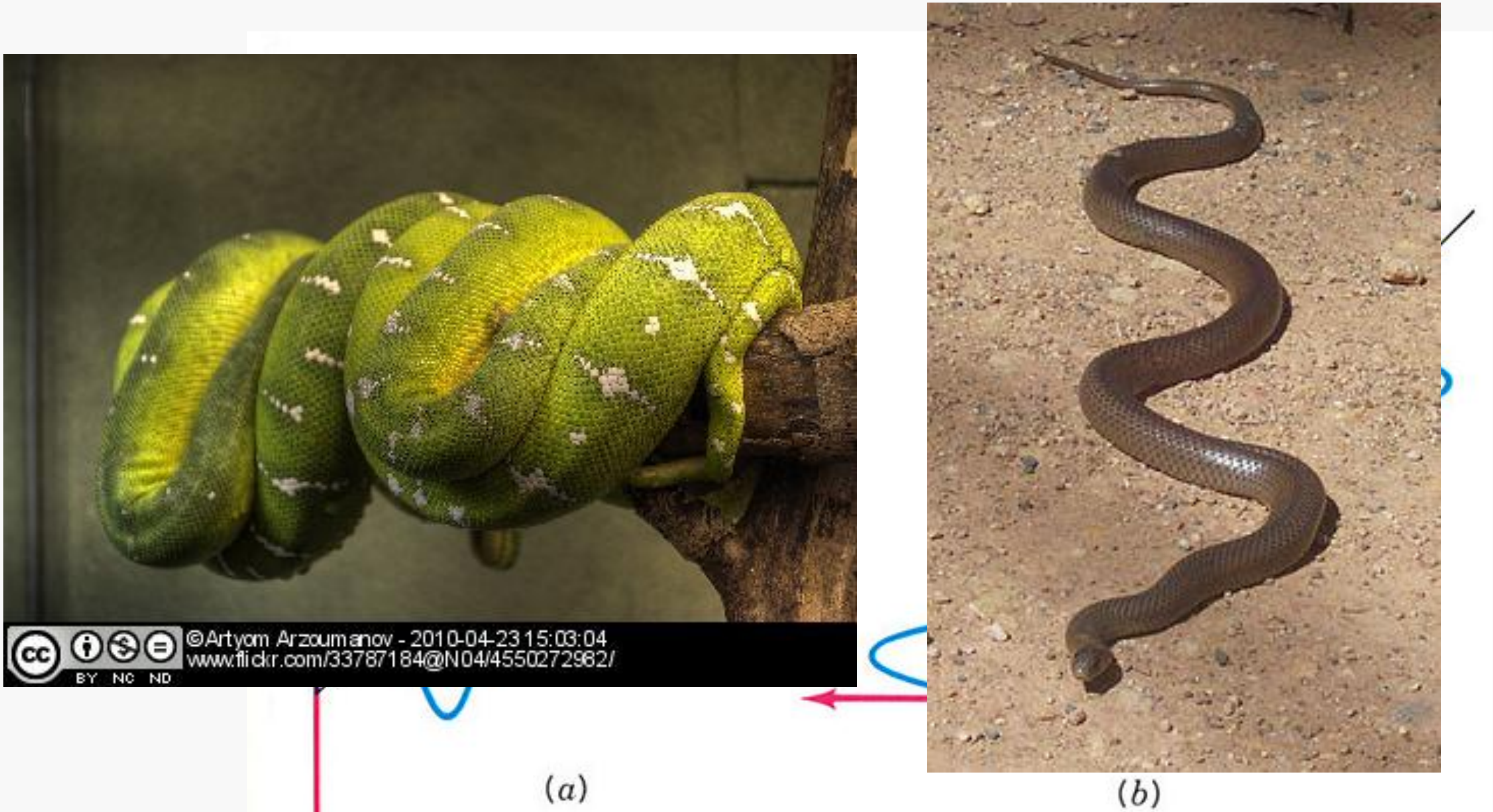


$$T_B = eT$$

$$e = 0.047$$

Physical properties of the surface

Horizontal vs Vertical Polarization



©Artyom Arzoumanov - 2010-04-23 15:03:04
www.flickr.com/33787184@N04/4550272982/

http://en.wikipedia.org/wiki/Eastern_brown_snake

FIGURE 38.25 A linearly polarized wave.

Frequency Choice

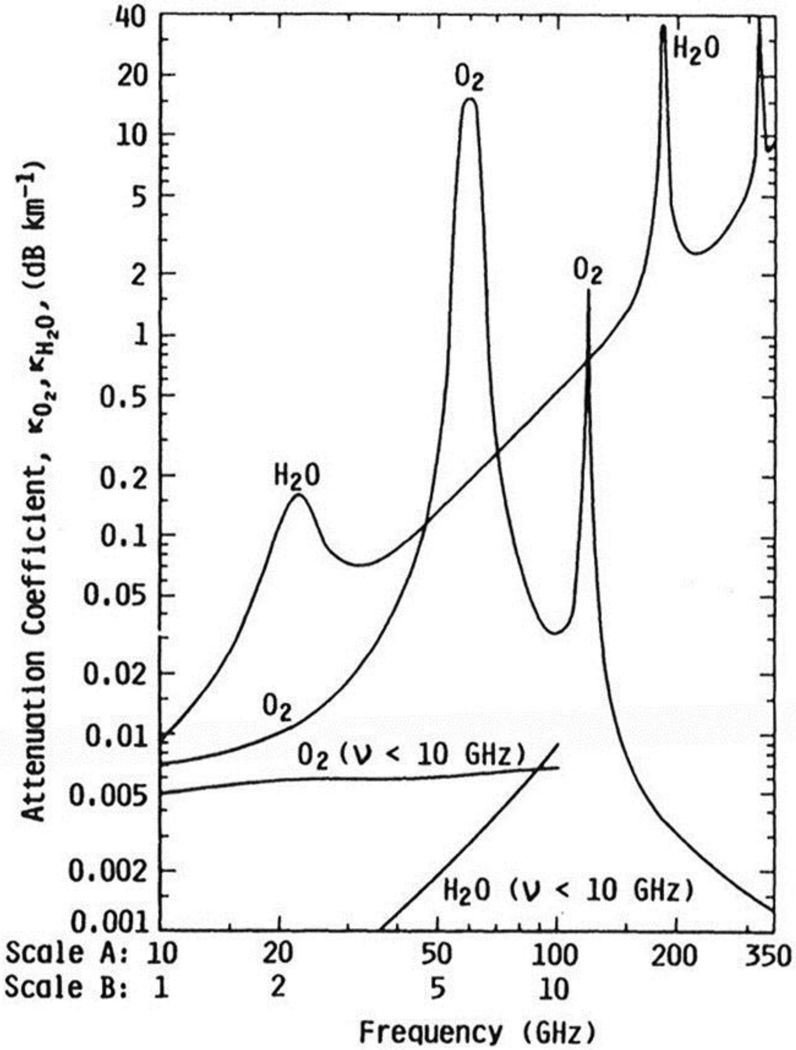


Fig. 17.7 Computed spectra of oxygen and water vapor at sea level; T_0 = 290 K, $\rho_0 = 7.5$ g m^{-3}, P_0 = 1013 mbar for the dry (O_2) atmosphere and 1020.5 mbar for the moist (H_2O) atmosphere (from Smith, 1982).

Atmospheric Transmission Windows:

- 25-50 GHz
- 70-115 GHz
- 125-160 GHz
- 200-250 GHz

Ulaby, Moore, Fung (1981-1986)

Ulaby, Moore,
Fung (1981-1986)

Frequency Choice

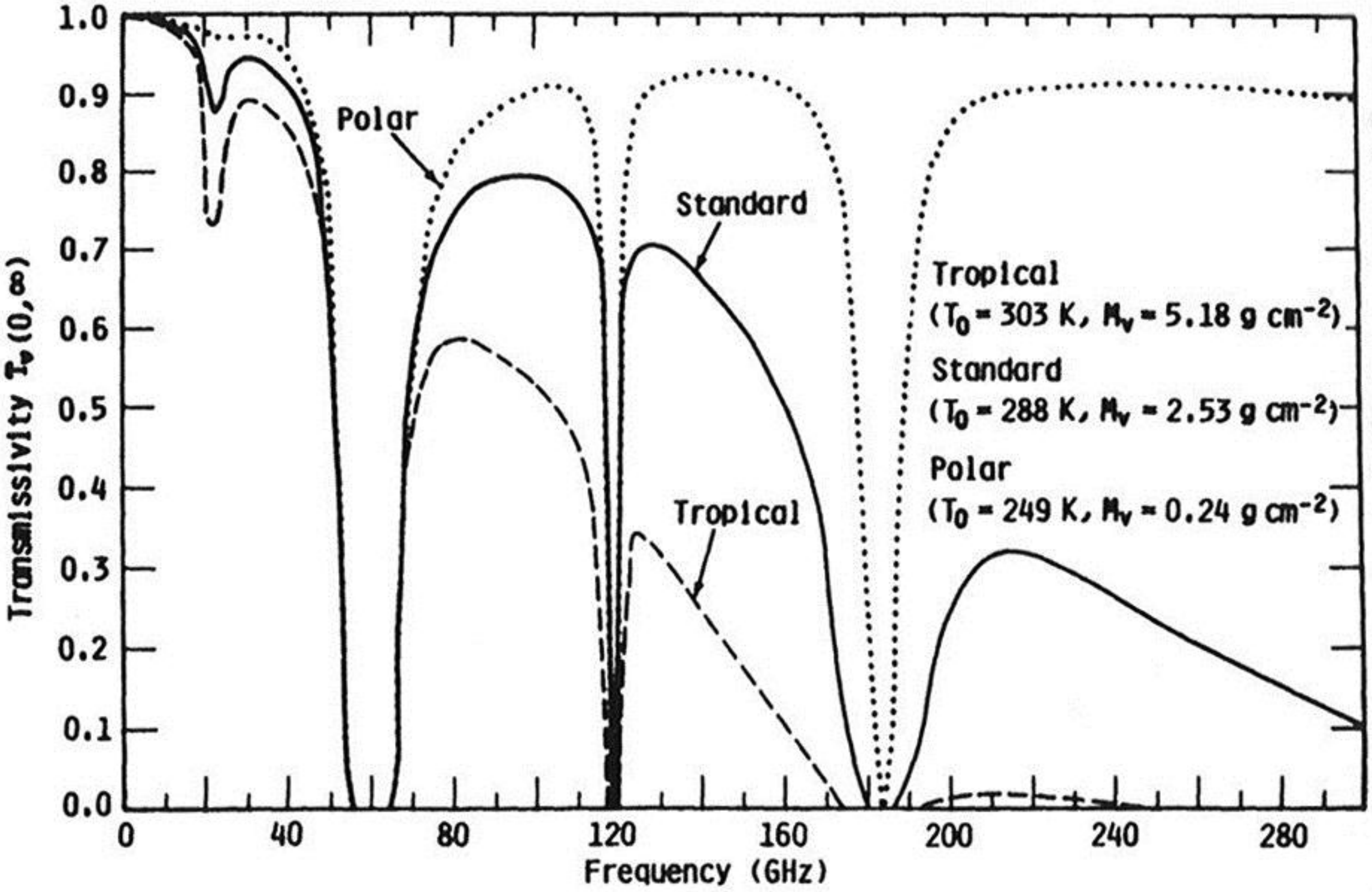
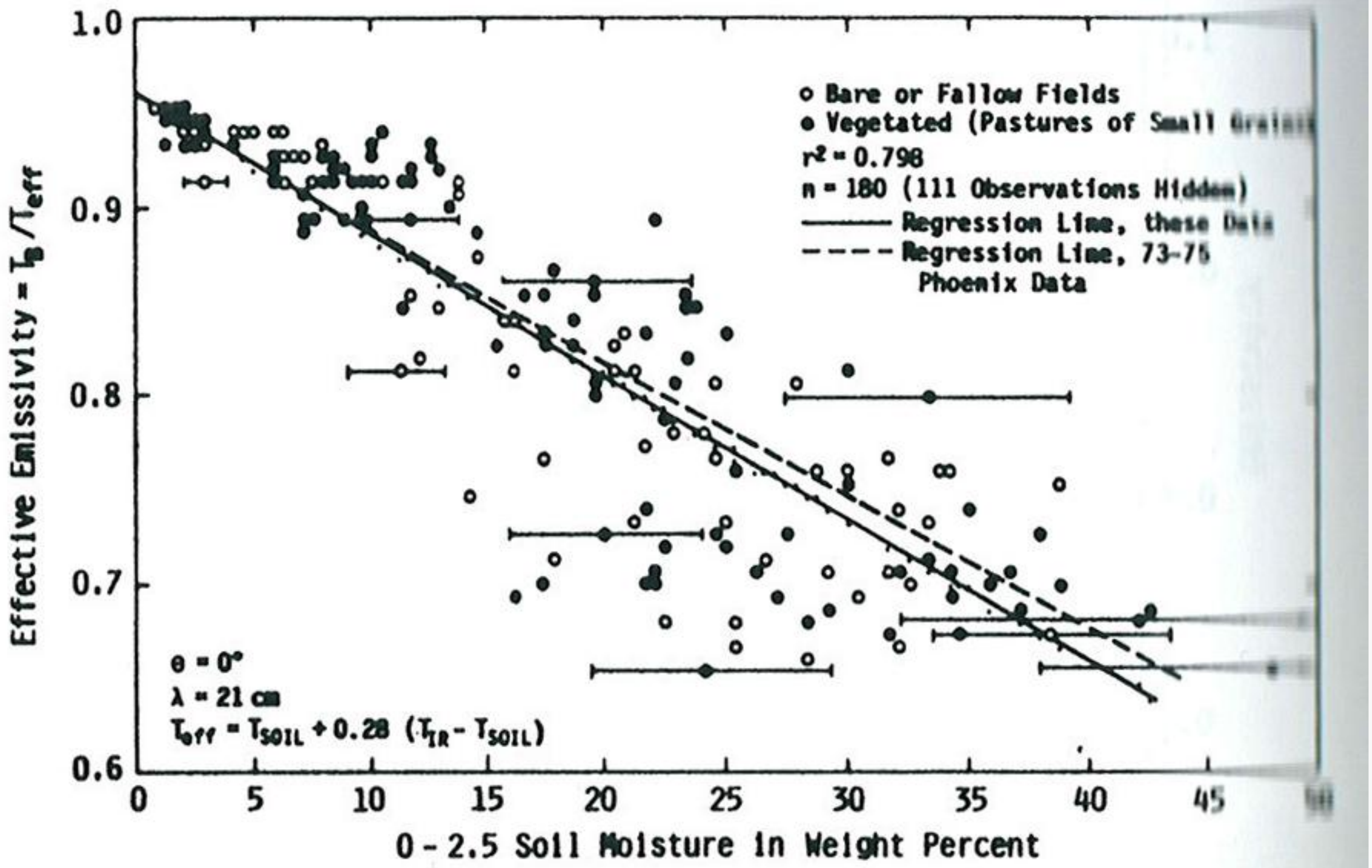


Fig. 17.11 Atmospheric transmissivity as characterized by different surface temperatures T_0 and integrated water-vapor content M_v (from Grody, 1976).

Land Surface Emissivity



Ulaby, Moore and Fung (1986)

Soil Type

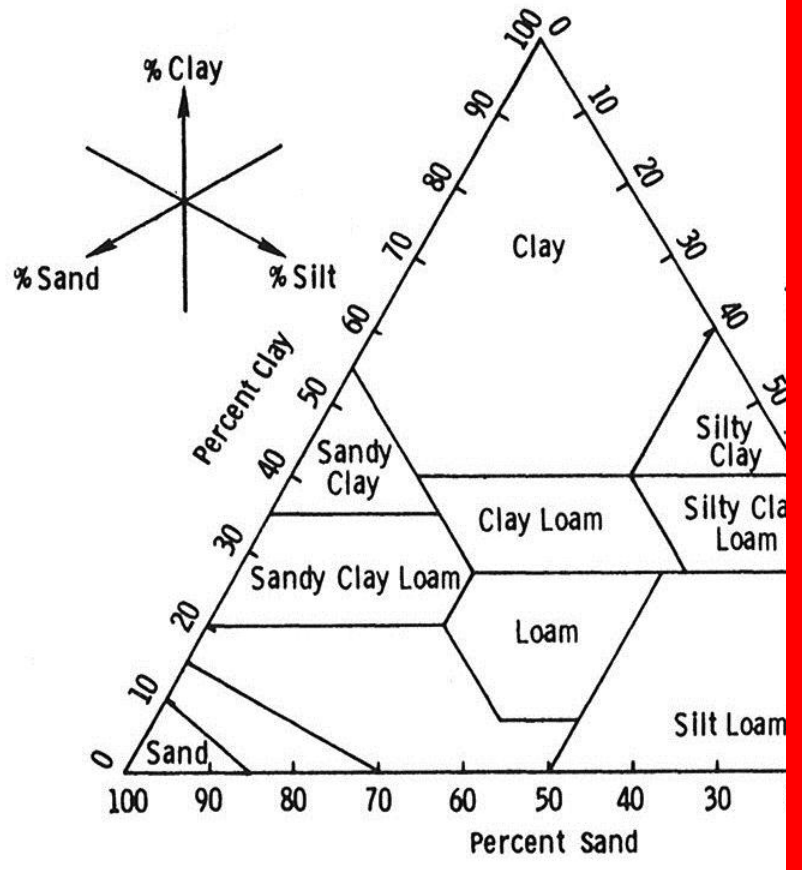
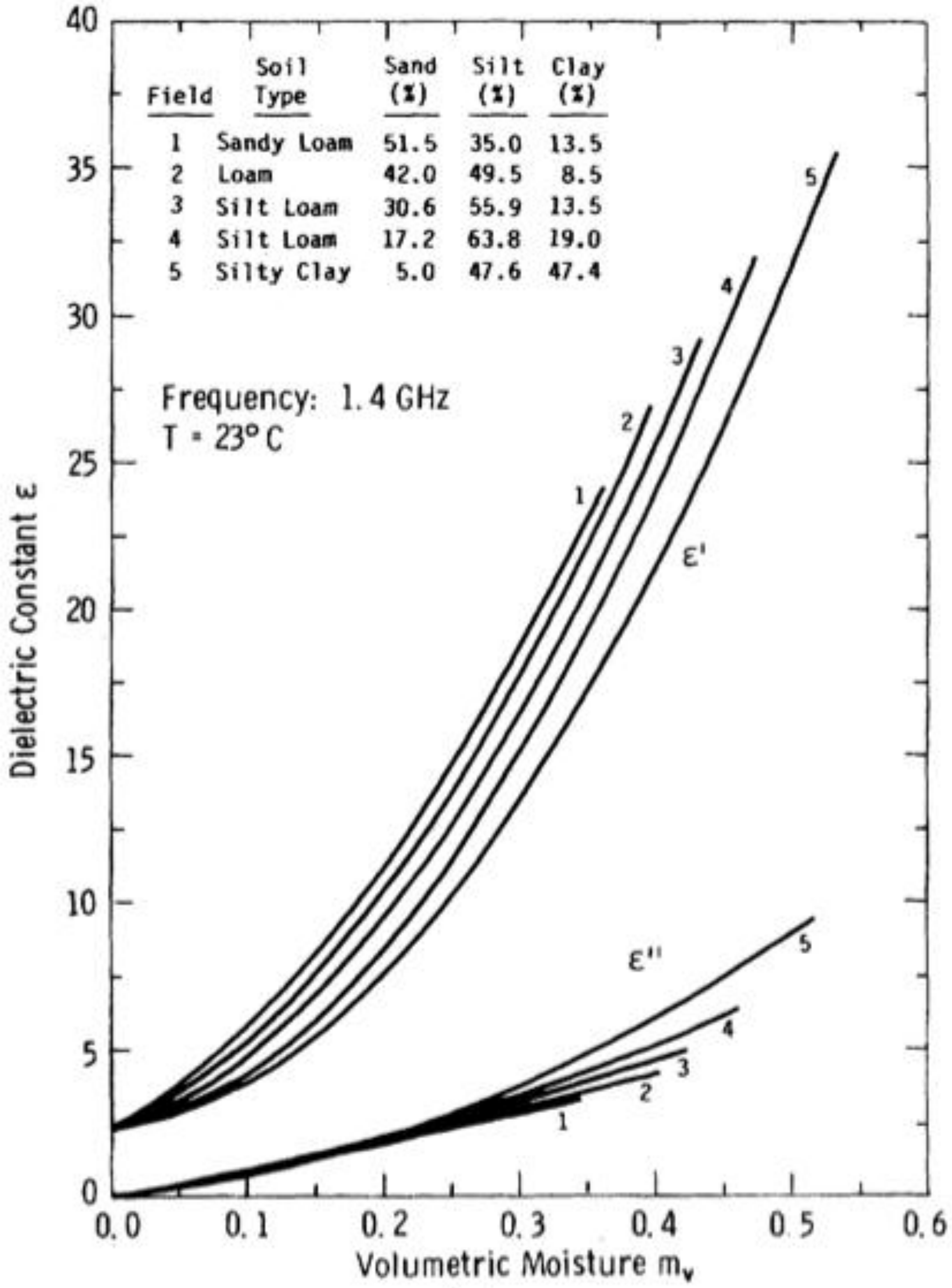


Fig. E.44 Soil textural classification triangle (US Departme

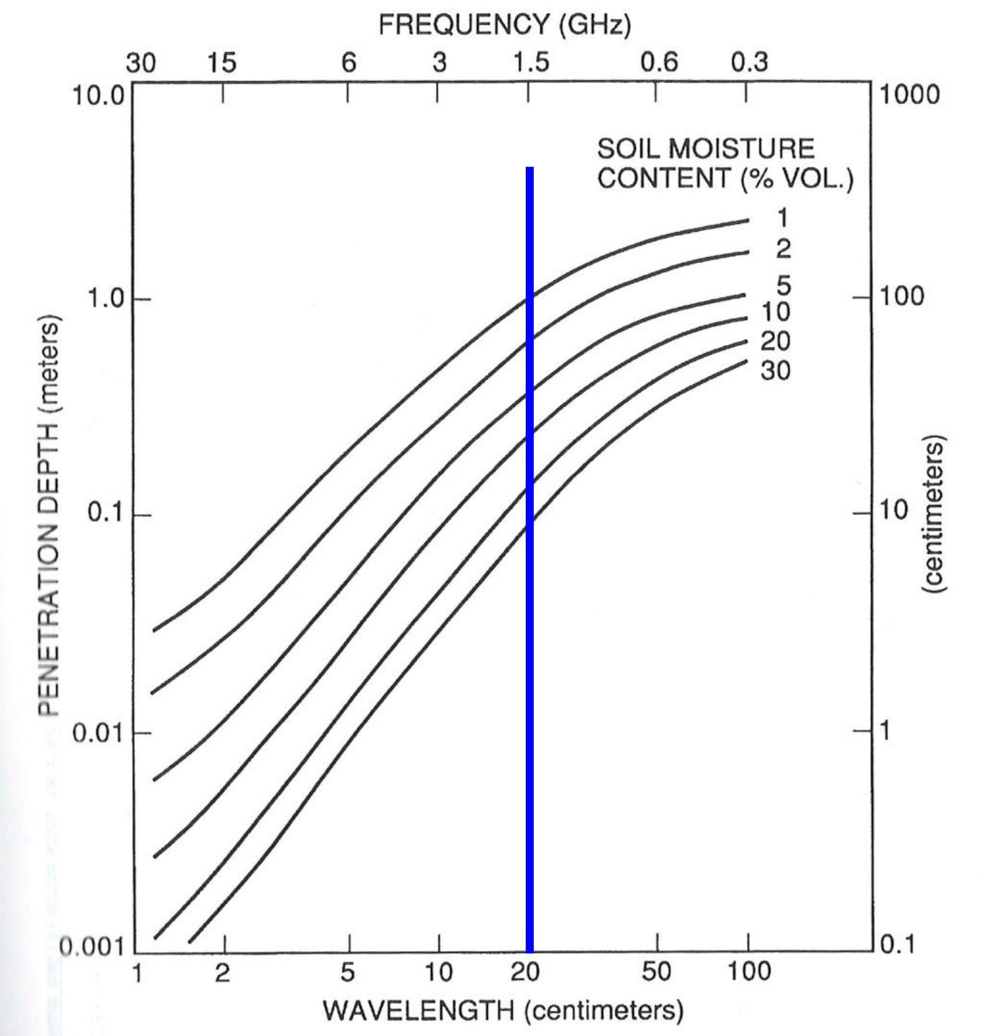


Field	Soil Type	Sand (%)	Silt (%)	Clay (%)
1	Sandy Loam	51.5	35.0	13.5
2	Loam	42.0	49.5	8.5
3	Silt Loam	30.6	55.9	13.5
4	Silt Loam	17.2	63.8	19.0
5	Silty Clay	5.0	47.6	47.4

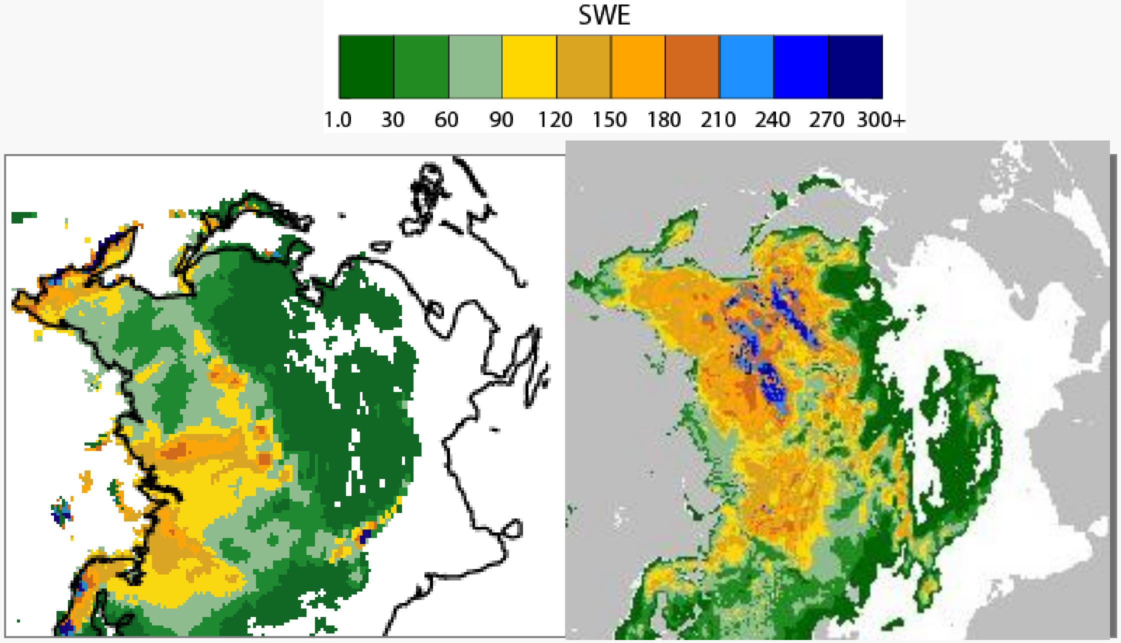
Hallikainen et al (1985) (a)

Ulaby, Moore and Fung (1986)

Penetration Depth



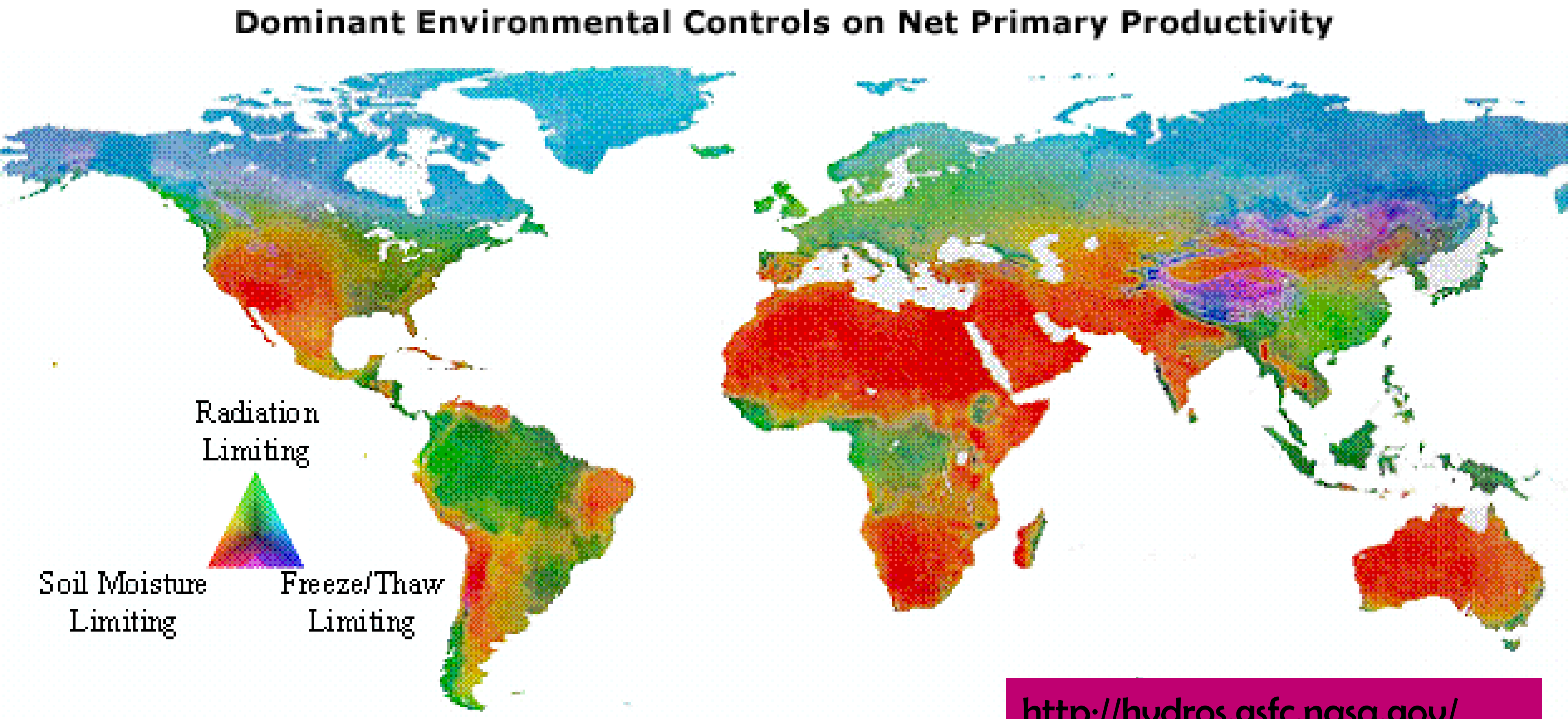
Njoku (1995). ESA / NASA International Workshop



$SWE = 4.77 * (18H - 37H)$

REMOTE SENSING OF SOIL MOISTURE

Why?



http://hydros.gsfc.nasa.gov/

SMOS Science Objectives:

- globally monitor surface soil moisture over land surfaces
- globally monitor surface salinity over the oceans, and
- improve the characterisation of ice and snow covered surfaces.

Soil Moisture Retrieval

$$T_B = e_{soil}\ T_{soil}$$

The emissivity of the soil ε_{soil} depends on…

1. The look angle α

2. The polarisation of the radiation

3. The soil’s dielectric constant, which depends on the soil moisture and texture.

Radiative transfer theory

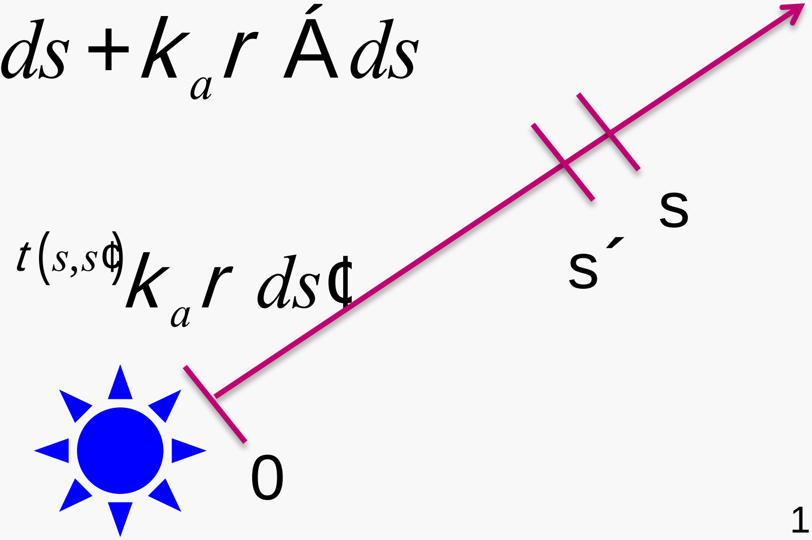
- Pure absorption: $dI = -\kappa_a \rho I \, ds$
- Scattering:
  - Source function $\mathfrak{J} = \dfrac{emission}{absorption}$
  - Single-scatter albedo: $\int p(\cos\Theta) \dfrac{d\omega'}{4\pi} = \omega_0 \le 1$
- Radiative transfer equation:

$$dI = -\kappa_a \rho I \, ds + \kappa_a \rho \mathfrak{J} \, ds$$

- Formal solution:

$$I(s) = I(0) e^{-\tau(s,0)} + \int_0^s \mathfrak{J}(s') e^{-\tau(s,s')} \kappa_a \rho \, ds'$$

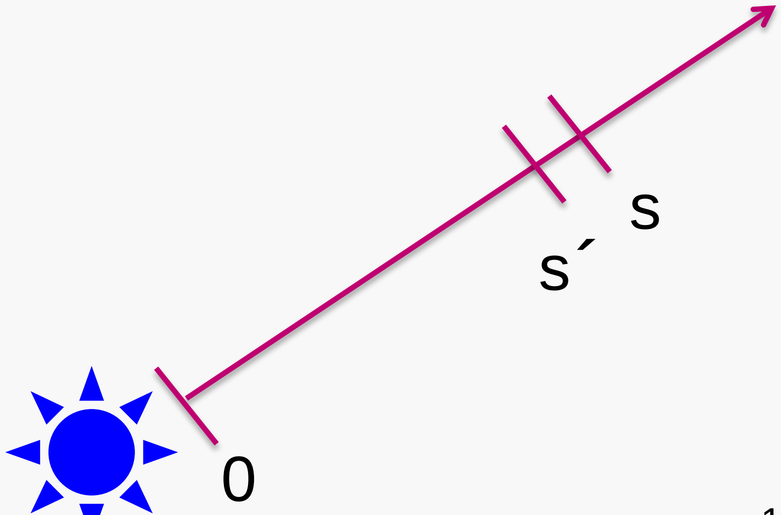
$$\tau(s,s') = \int_{s'}^{s} \kappa_a \rho \, ds$$



Radiative transfer theory

- Optical thickness

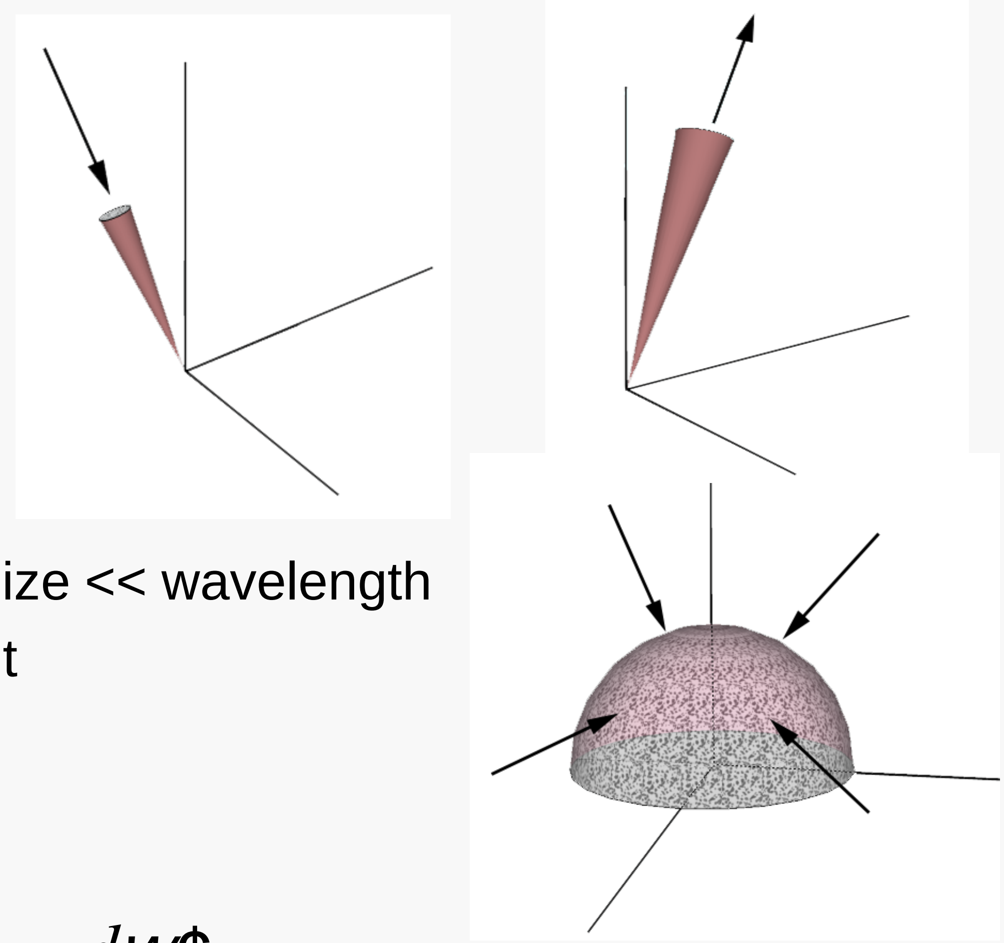
t



$$t\left(s, s¢\right) = \overset{s}{\underset{s¢}{ò}} k_{a} r \; ds$$

Radiative Transfer Theory Approximation

- Geometry
  - Two-stream
  - Discrete Ordinates
- Scattering medium
  - Spherical particles
  - Size distribution
  - Rayleigh scattering if size << wavelength
  - Coherent vs incoherent
  - Multiple scattering



$$\int p(\cos\Theta)\frac{d\omega'}{4\pi} = \omega_0 \le 1$$

Radiative Transfer Theory Approximation

- Single scatter albedo

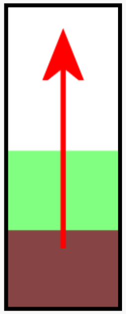
$$\omega$$

$$\int p(\cos\Theta)\frac{d\omega'}{4\pi} = \omega_0 \le 1$$

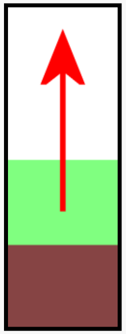
Components of the Tau-Omega model

$$T_B =$$

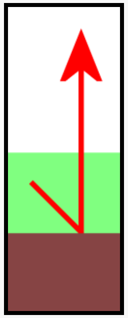
$$e_{soil} \cdot T_{soil} \cdot e^{\frac{-t}{\cos a}}$$



$$+(1- W)\cdot T_{veg} \cdot (1- e^{\frac{-t}{\cos a}})$$

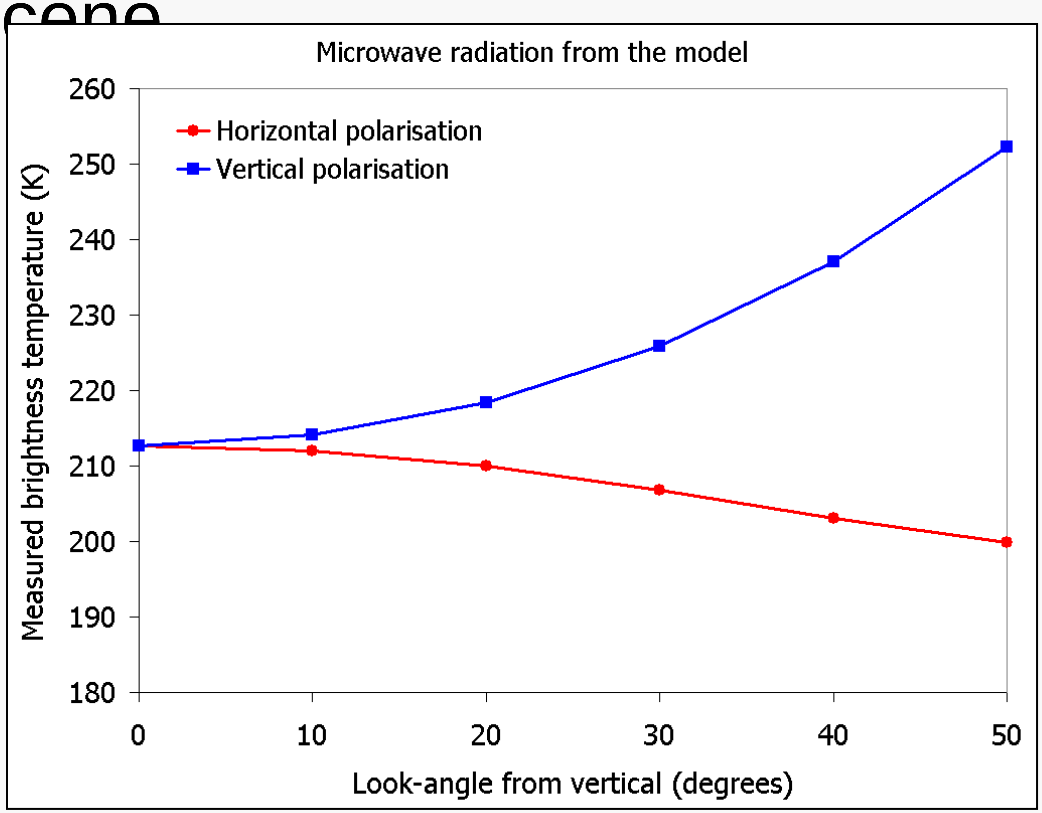


$$+(1- e_{soil})\cdot(1- W)\cdot T_{veg} \cdot (1- e^{\frac{-t}{\cos a}})\cdot e^{\frac{-t}{\cos a}}$$



Approach

- Generate brightness temperature curves for a scene



“known”
conditions

- Compare with observations

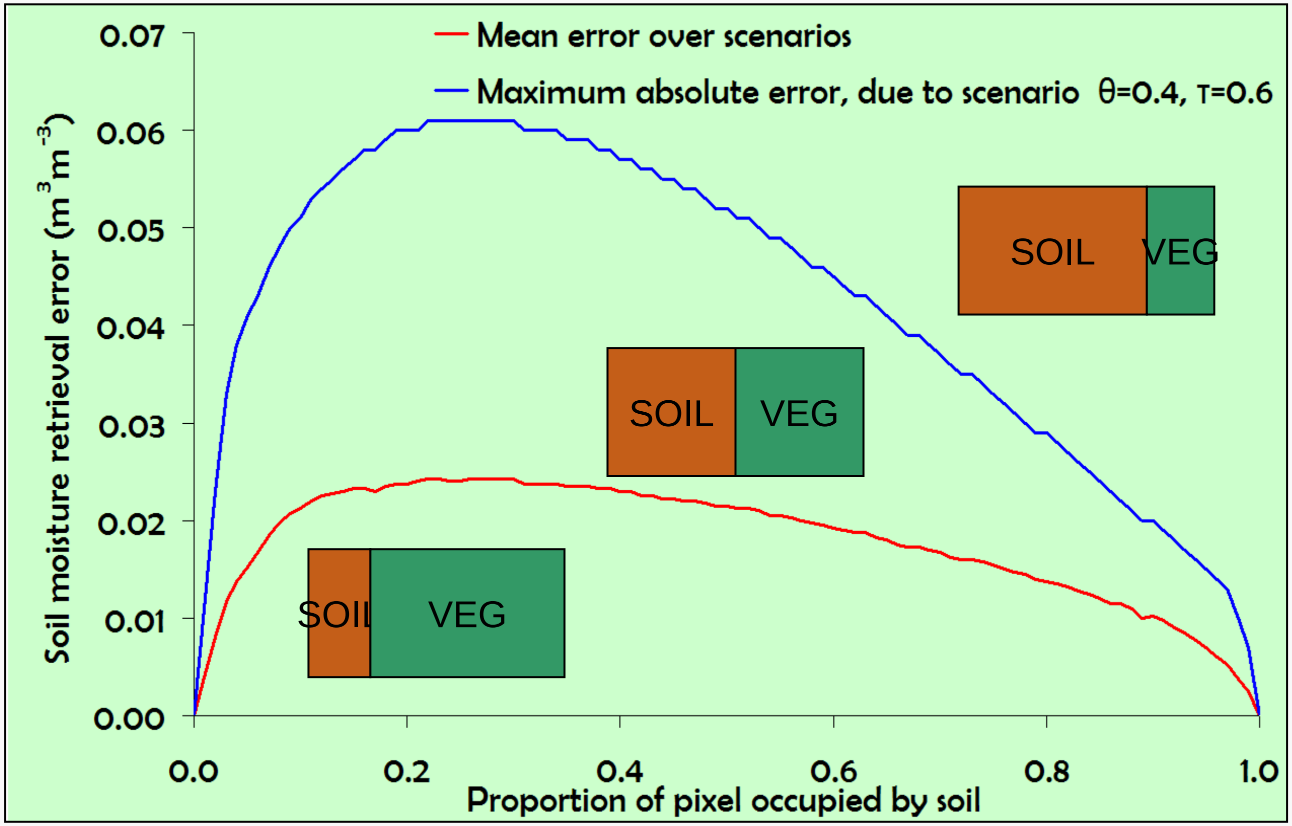
Heterogeneity - SMOS resolution 50km

Vegetation density

Vegetation is
rarely uniform

Error Budget Example: Heterogeneity in Vegetation

- For a simple combination of bare soil and vegetation, assuming a single land cover type in the retrieval:



Substantial error reduction with a model elaboration - retrieval of two different vegetation types and their relative proportions.

For a scene with 7 different vegetation optical depths, mean error is reduced to 0.1%

Instrument Errors

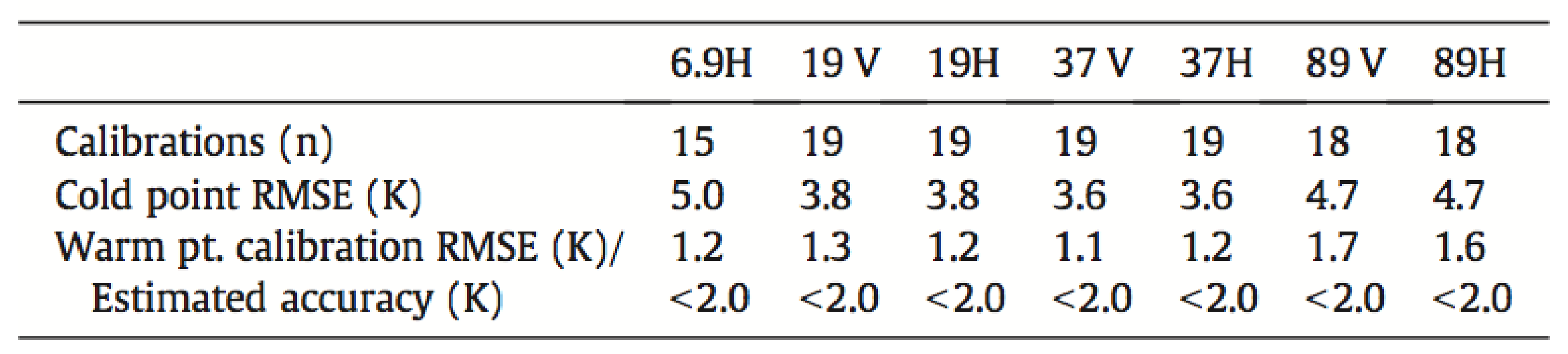
- Biases
- Long-term drifts
- Cyclical errors
- Random errors

Instrument Noise

- Calibration against hot / cold targets 2-5 days apart
- Non-linear, iterative procedure -> coefficients
- Coefficients relate V to TB

Instrument Noise

Derksen et. al (2012)



	6.9H	19 V	19H	37 V	37H	89 V	89H
Calibrations (n)	15	19	19	19	19	18	18
Cold point RMSE (K)	5.0	3.8	3.8	3.6	3.6	4.7	4.7
Warm pt. calibration RMSE (K)/	1.2	1.3	1.2	1.1	1.2	1.7	1.6
Estimated accuracy (K)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0

SMOS

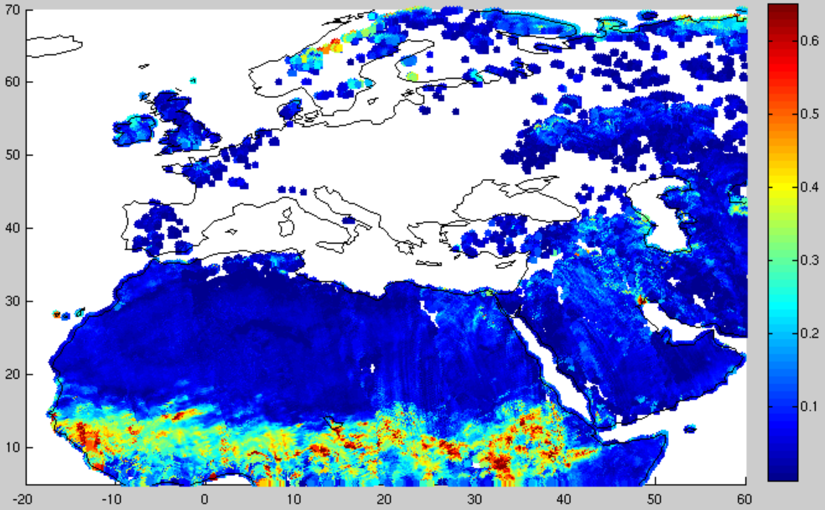
- Internal
- External
- Calibration strategy

RFI

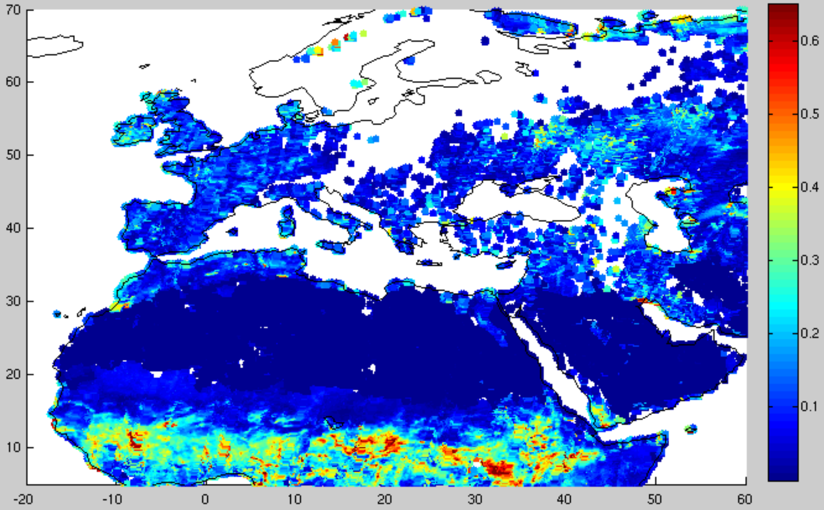
http://www.cesbio.ups-tlse.fr/SMOS_blog/

University of Reading

Retrieved Soil Moisture 20120910 20120912 Ascending

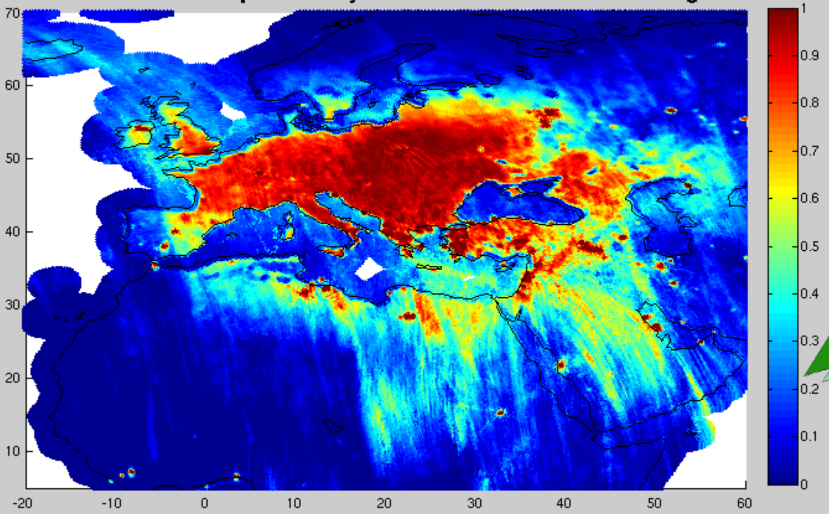


Retrieved Soil Moisture 20120910 20120912 Descending

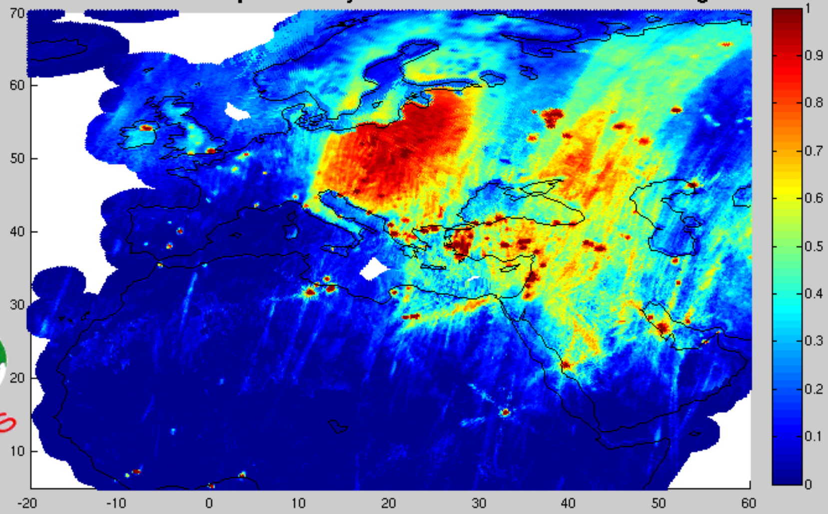


This situation started 20120822 and still last ! TOTALLY UNACCEPTABLE
Almost no soil moisture retrieval in Europe for ascending orbits and dubious for descending'

RFI occurence probability 20120910 20120912 Ascending

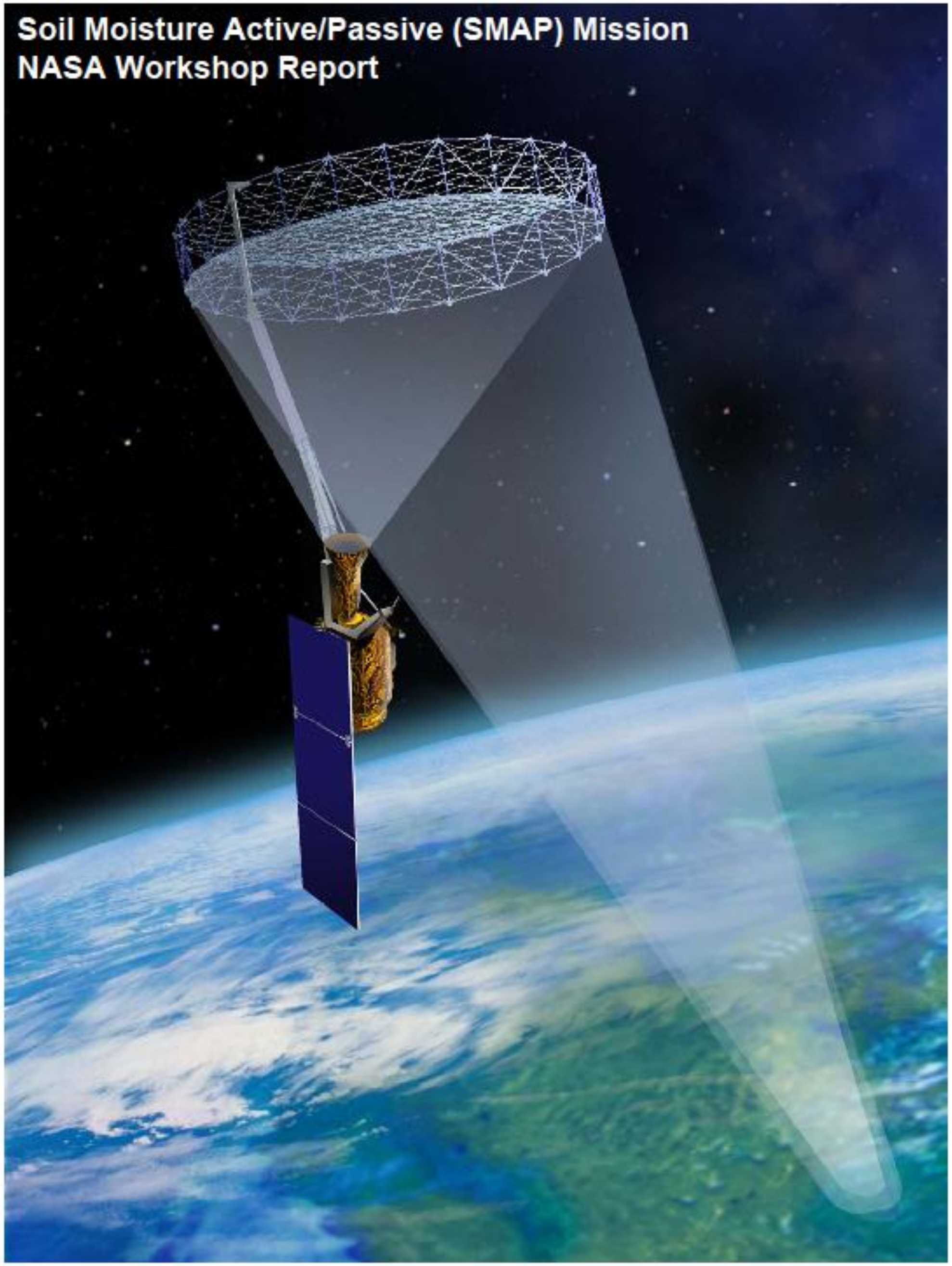


RFI occurence probability 20120910 20120912 Descending



CESBIO SMOS CATDS

NASA SMAP



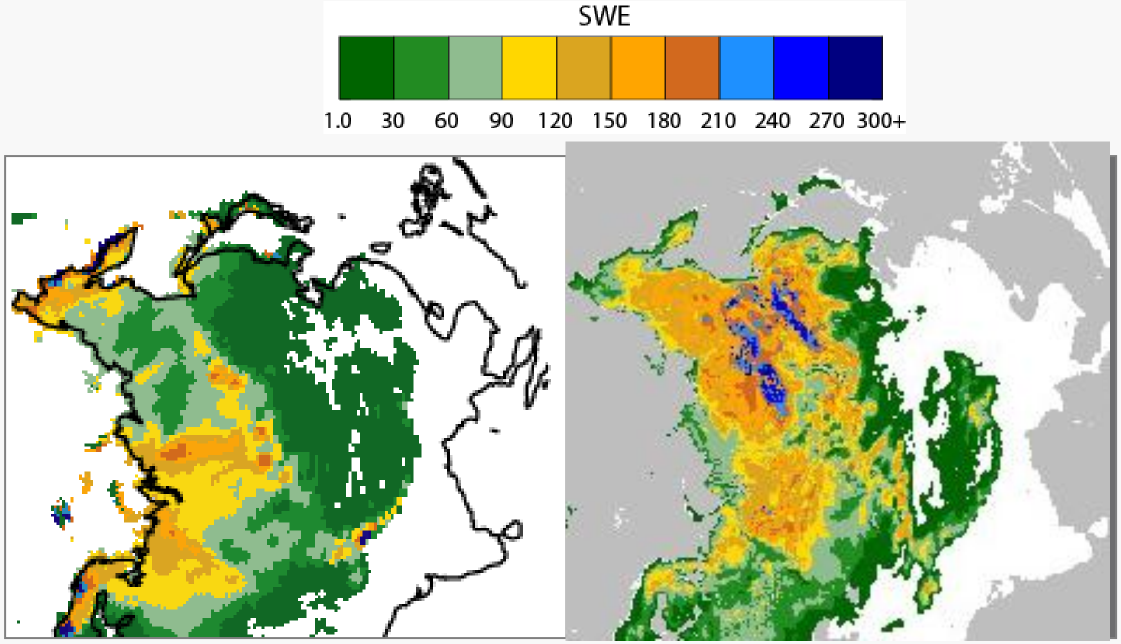
Soil Moisture Active/Passive (SMAP) Mission
NASA Workshop Report

Expected to launch November, 2014

Radar
Frequency: 1.26 GHz
Polarizations: VV, HH, HV

Radiometer
Frequency: 1.41 GHz
Polarizations: H, V, U
Relative accuracy: 1.5 K

Antenna
Configuration: Conically-scanning reflector
  Forms 1000 km wide swath
  Shared by both radar and radiometer
Diameter: 6 meters
Resolution:
  40 km radiometer
  1-3 km SAR



SWE = 4.77 * (18H - 37H)

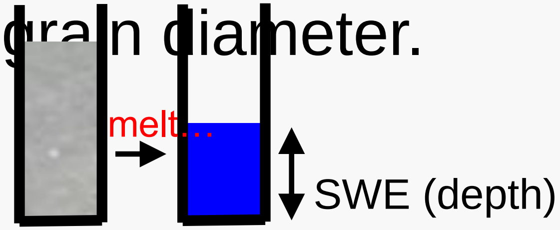
REMOTE SENSING OF SNOW

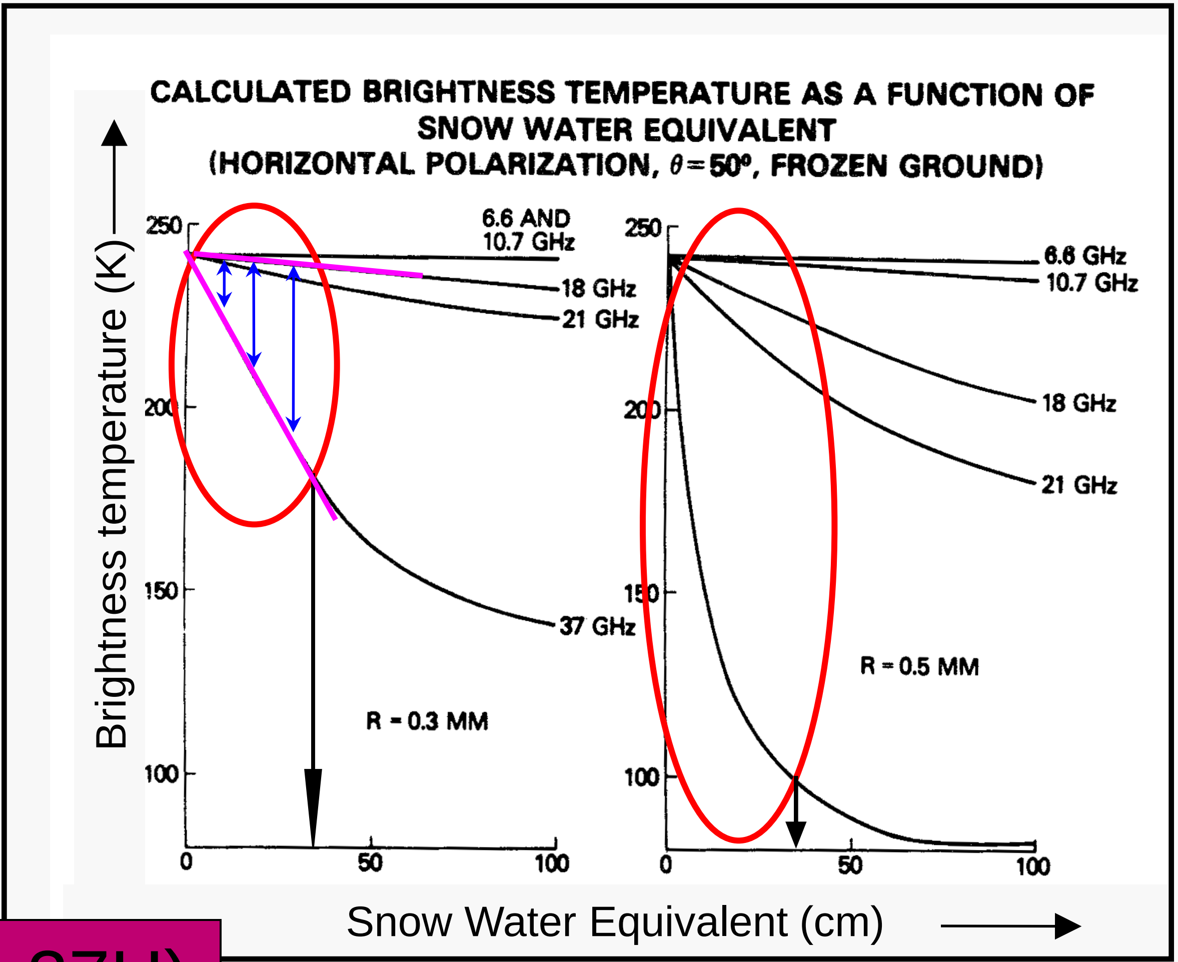
The basis of the Chang Algorithm

Microwave emission (Tb) vs snow mass (SWE) is derived using the Mie Scattering model

A simple relation is derived from the linear portion of graph (~1m snow)

However, this relation seems sensitive to snow grain diameter.





SWE = 4.77 * (18H - 37H)

Chang et. al. (1987) Ann. Glaciol. 9: 39-44

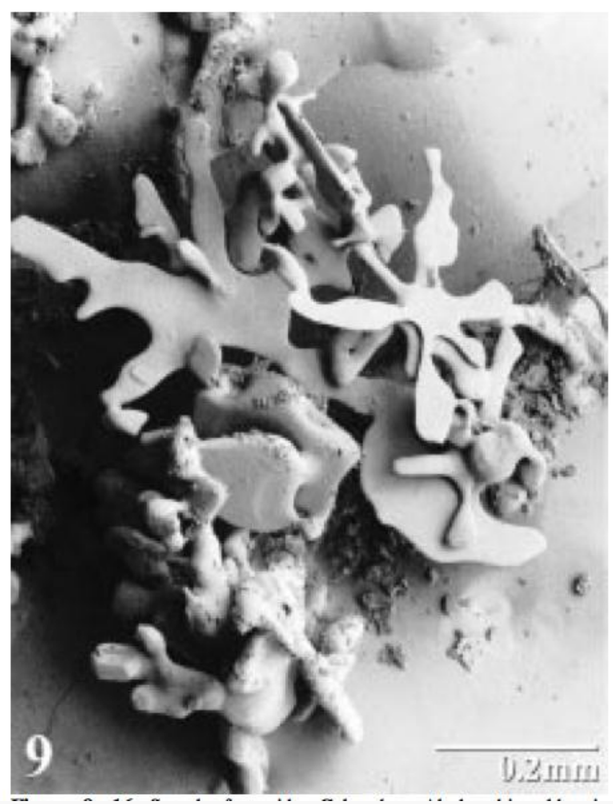
What’s in a snowpack?

Courtesy Nick

Snow properties: crystals

www.snowcrystals.com

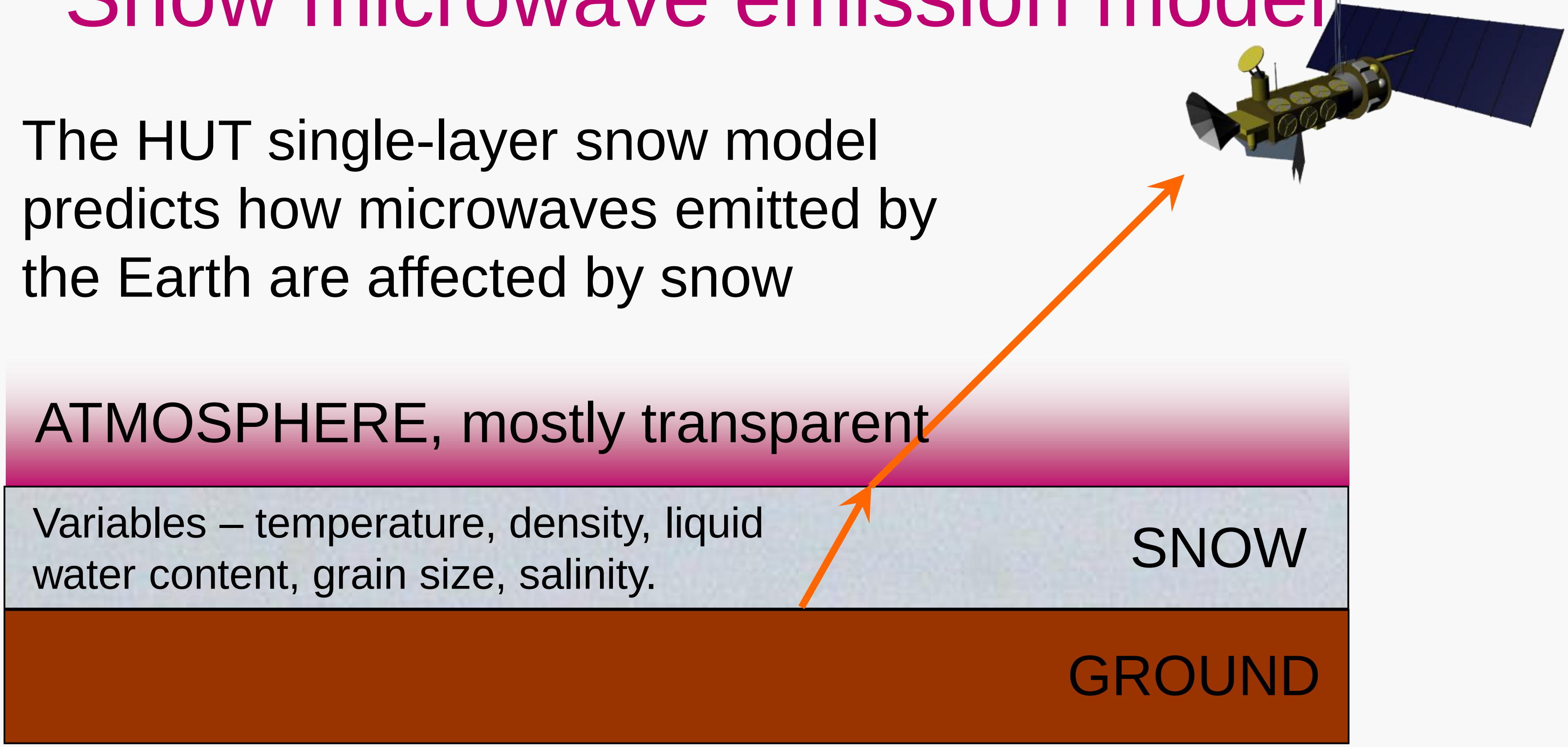
Snow properties: crystals



Wergin et al (1996). J. Microscopy Soc. Am. 2 (3)

Snow microwave emission model

The HUT single-layer snow model predicts how microwaves emitted by the Earth are affected by snow

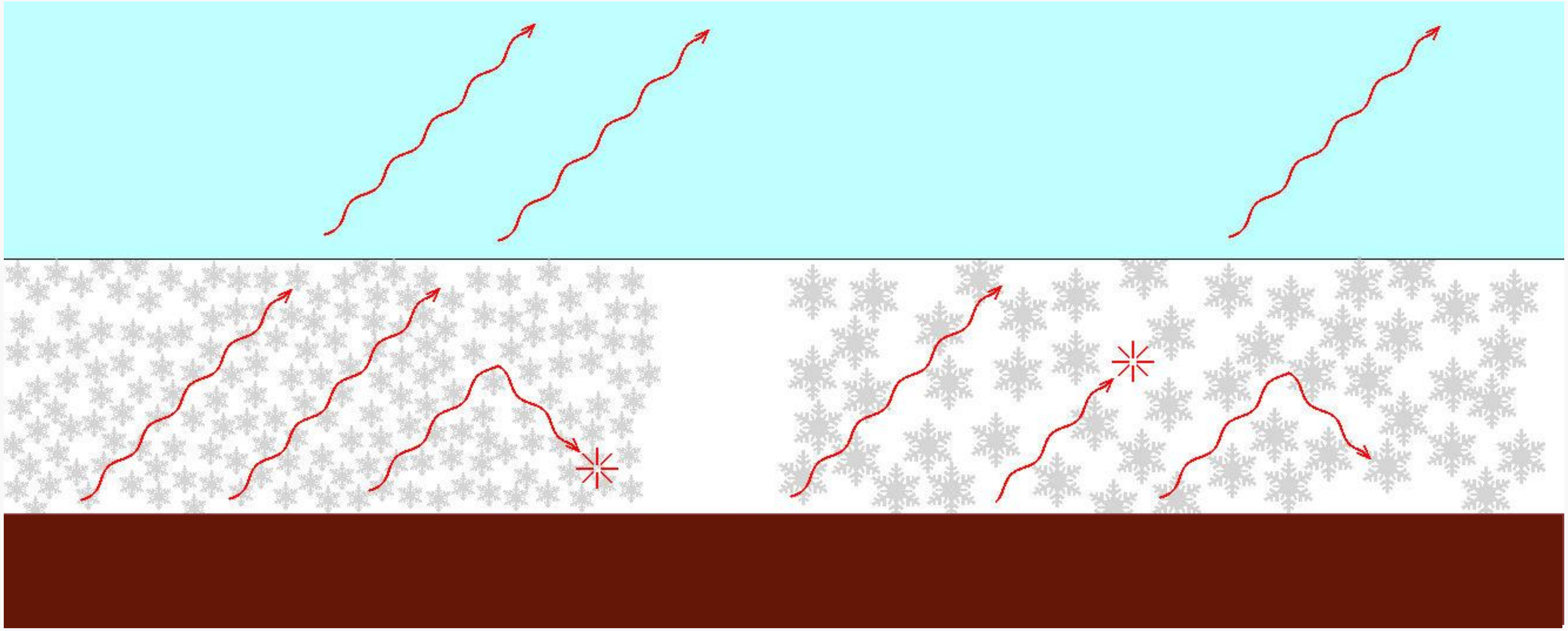


Variables – temperature, density, liquid water content, grain size, salinity.

Includes multiple scattering within the snow layer, scattering and reflectivity via Fresnel equations

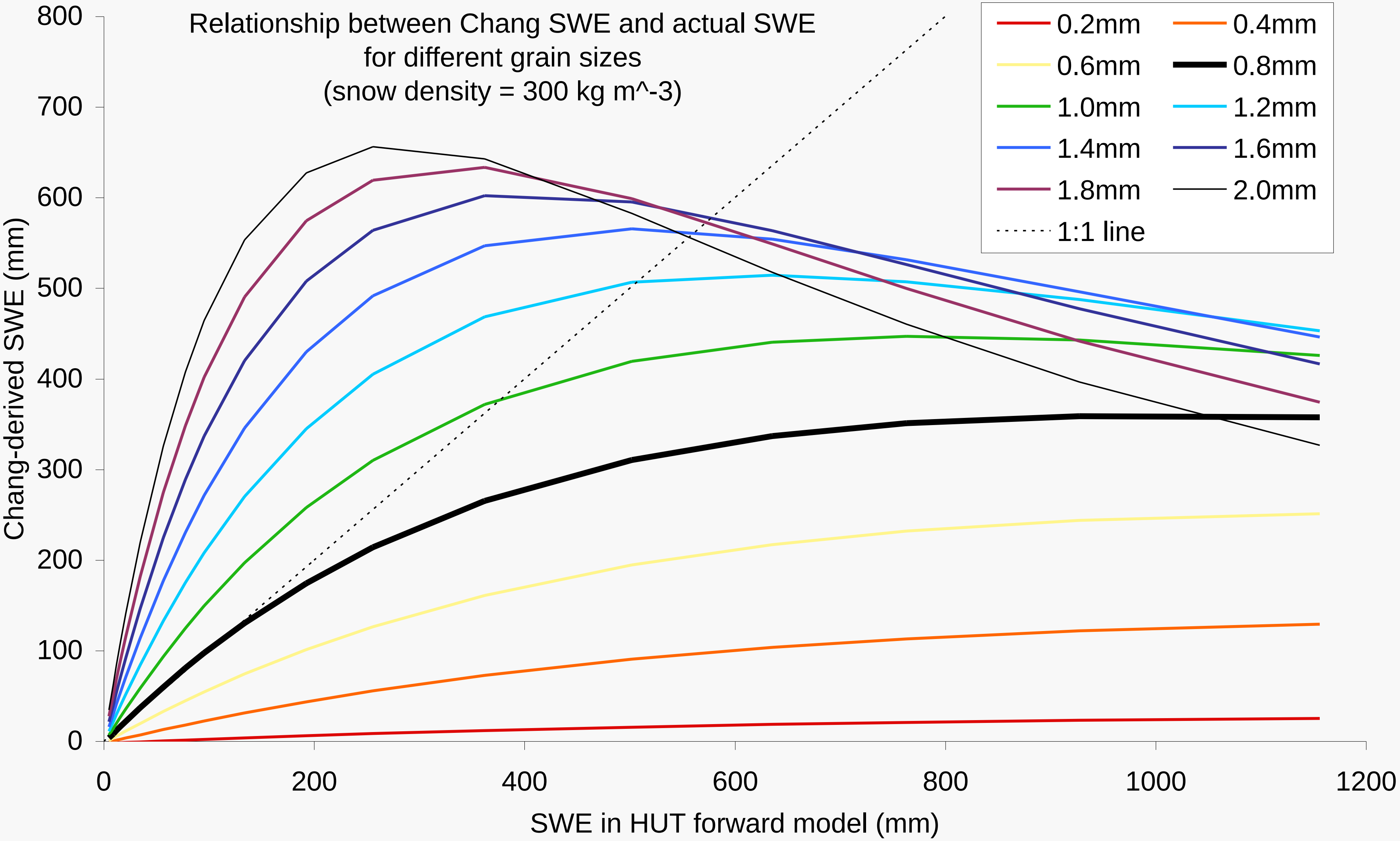
$$T_B\left(d^-, q\right) = T_B\left(0^+, q\right) e^{-\left(k_e - qk_s\right)\sec q\, d} + \frac{k_a T_s}{k_e - qk_s}\left(1 - e^{-\left(k_e - qk_s\right)\sec q\, d}\right)$$

Absorption and Scattering Within Snow

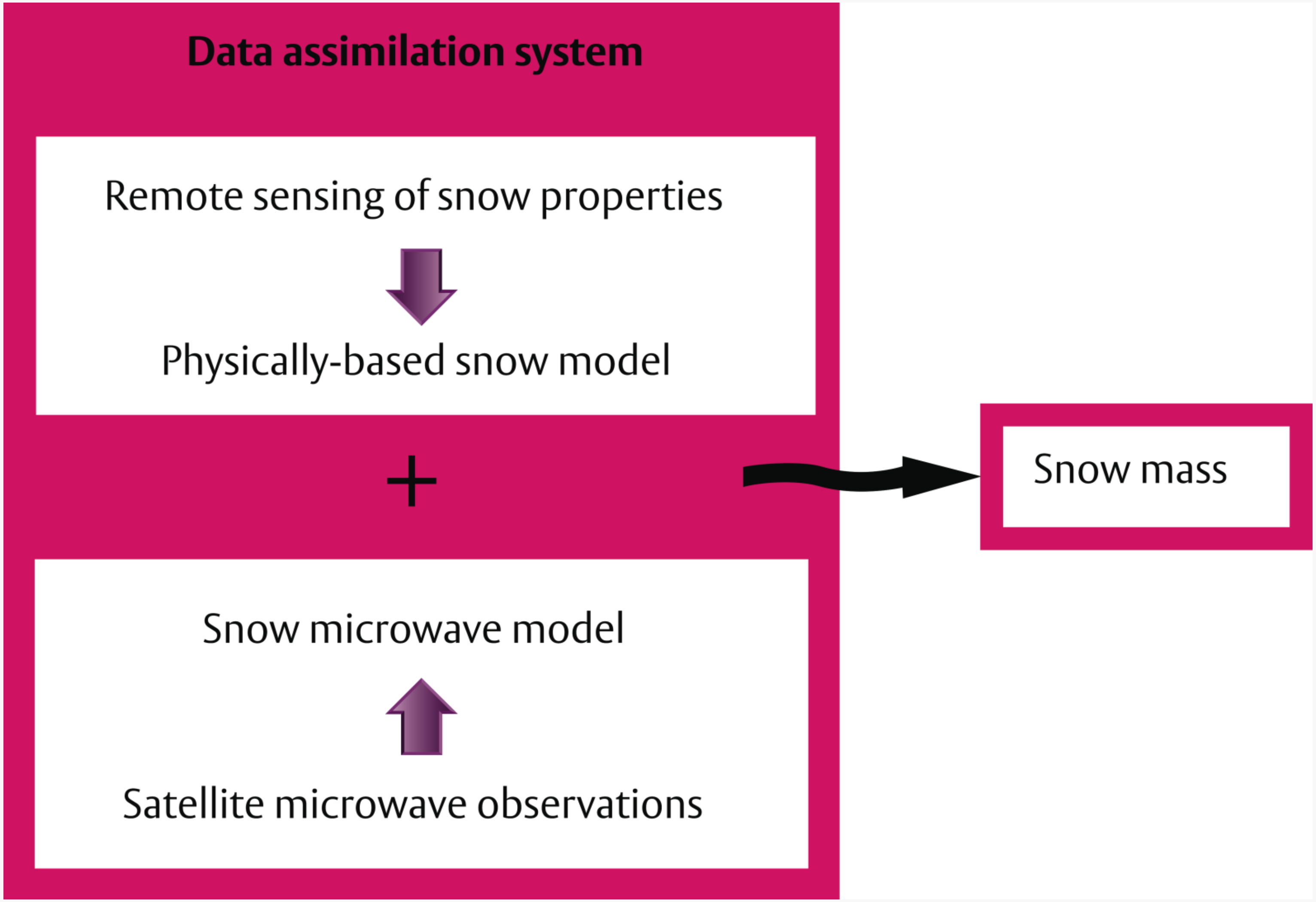


- Sensitive to the snow grain size (and density)
- Scattering mostly in the forward direction (96%)
- Wet snow highly absorptive, near blackbody

Sensitivity of snow mass algorithm to grain siz



Snow mass data assimilation system



Data assimilation system

Remote sensing of snow properties

Physically-based snow model

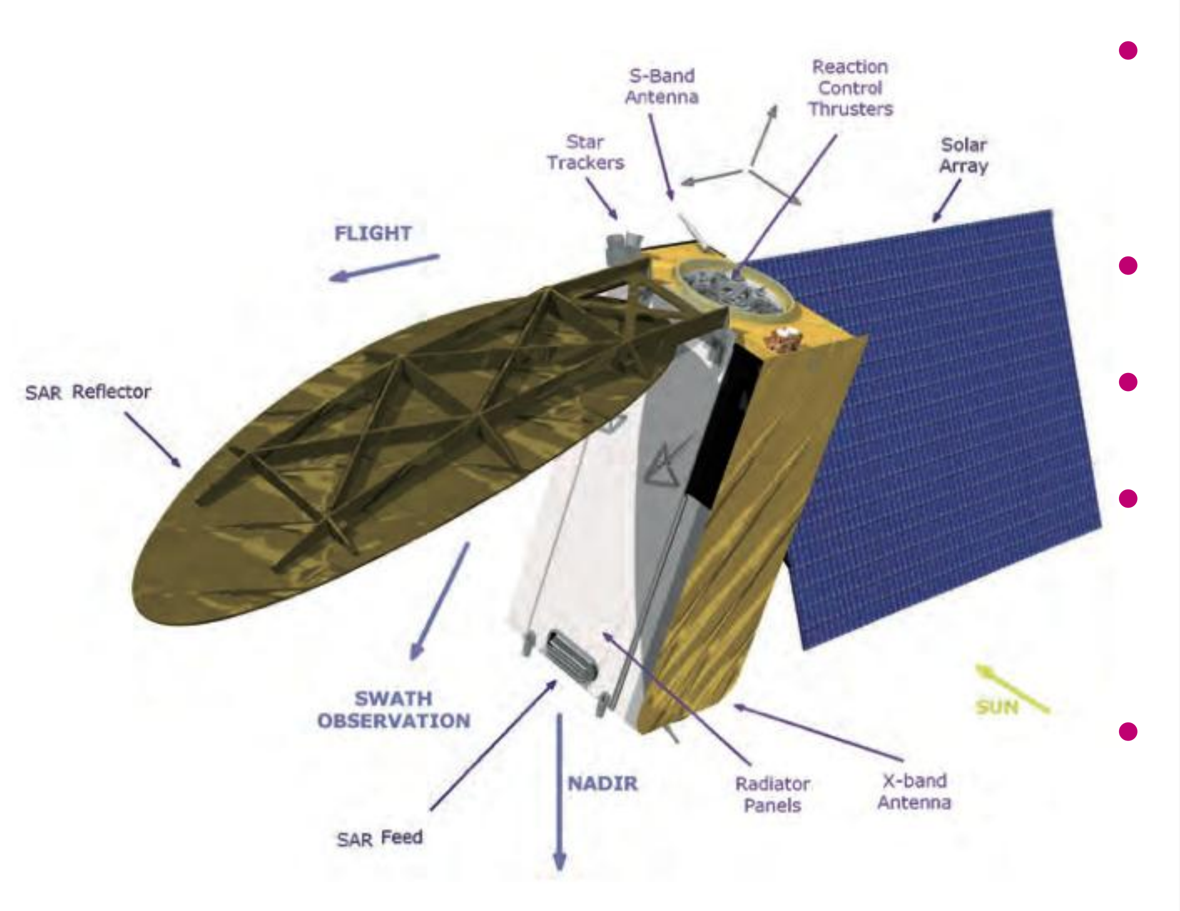
+

Snow microwave model

Satellite microwave observations

Snow mass

The future….CoReH20?



- Dual-band SAR (9.65 / 17.25GHz)
- 6am / pm overpass
- Revisit: 3 / 15 days
- Resolution:

  few 100m
- Launch in 2019?