Microwave radiative transfer in a snow pack: Models and experimental objectives for Cold Land Processes Experiment II

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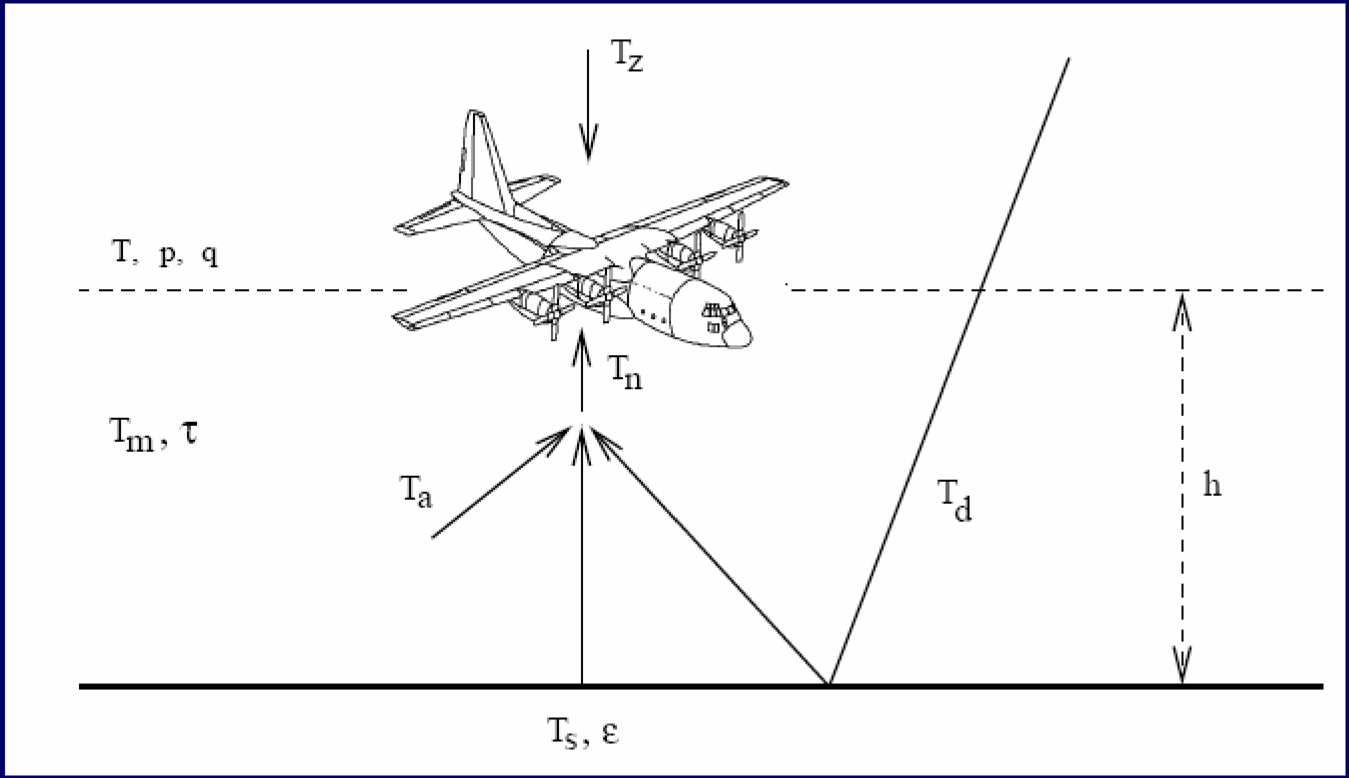
Outline

- Introduction, motivation, and relevance to JULES
- MEMLS Radiative Transfer
  - Classical RT with Empirical scattering and absorption properties
- Coherent collective scattering
  - Improved Born Approximation (Mätzler, 1998)
  - Dense Medium Radiative Transfer (Tsang & Kong, 2001)
- The second Cold Land Processes Experiment (CLPX-II)


BAE SYSTEMS
G-LUXE

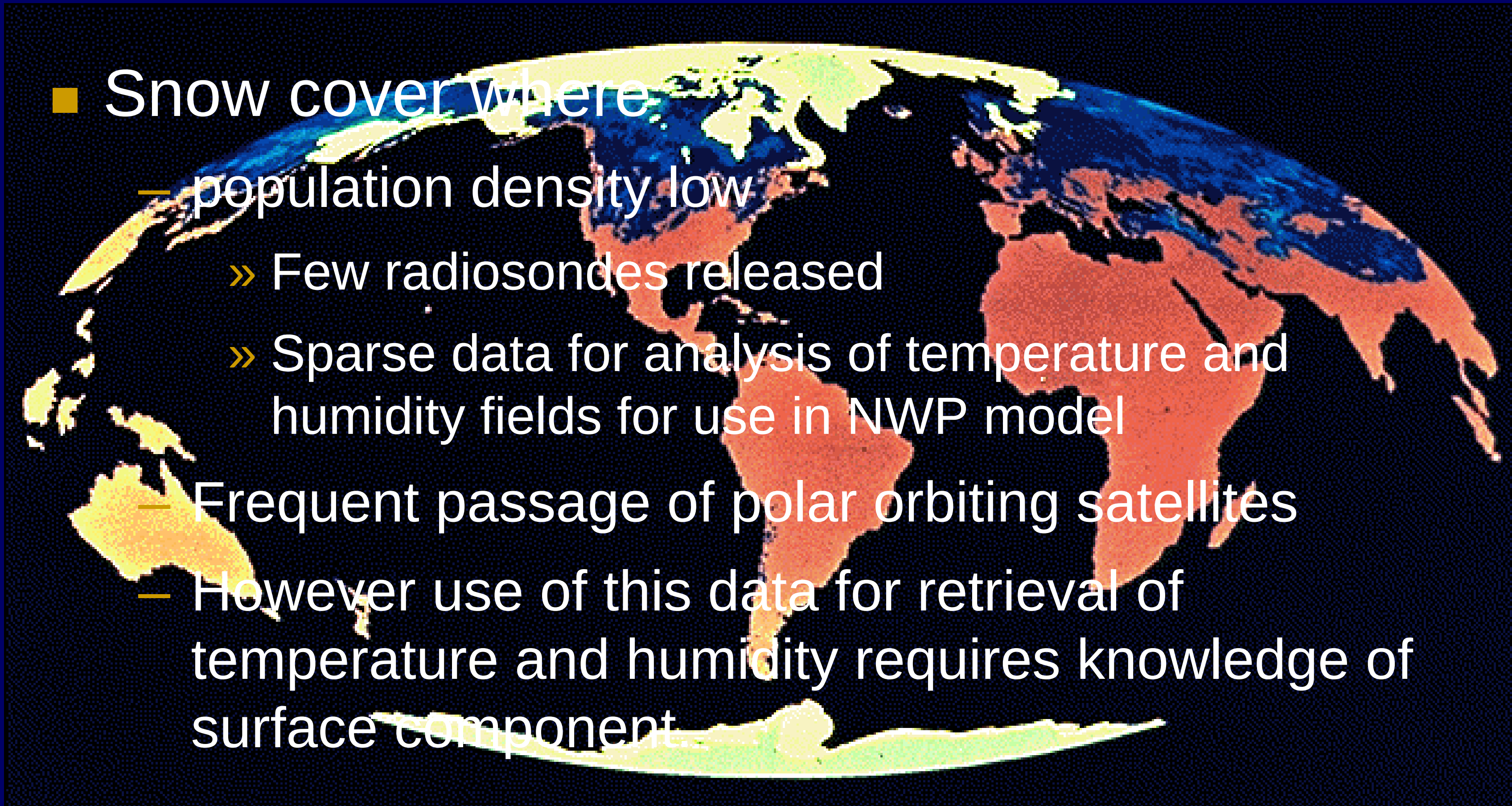
Reflected atmospheric and surface emission



$$T_n = T_a + \varepsilon_s T_s \exp(-\tau) + (1-\varepsilon_s) T_d \exp(-\tau)$$

$$T_d = T_z \exp(-\tau) + T_a$$

Snapshot of Snow and Ice Extent



- Snow cover where
  - population density low
    - » Few radiosondes released
    - » Sparse data for analysis of temperature and humidity fields for use in NWP model
  - Frequent passage of polar orbiting satellites
  - However use of this data for retrieval of temperature and humidity requires knowledge of surface component.

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Relevance to JULES

- JULES to be land surface scheme for future operational NWP.
- Hope to assimilate microwave sounding radiances over land (AMSU)
- Couple fast regression based microwave radiative transfer model to snow module.
- First need to validate complex snow radiative transfer models in 20 to 200 GHz range.

MEMLS

- Microwave Emissivity Model of Layered Snowpacks
- Mult-layer, multiple scattering radiative transfer model with empirically derived scattering coefficients.
  - Evaluated on frequency range: 5 to 100 Ghz.
- Option to use theoretically determined scattering and absorption properties.

MEMLS (cont'd)

- Plane stratified model.
- Input profile: density, temp., correlation length, wetness, layer thicknesses.
- Outputs: dual polarization emissivity
- Aux. Inputs: freq and look angle.
- Scattering and absorption properties need to be determined.

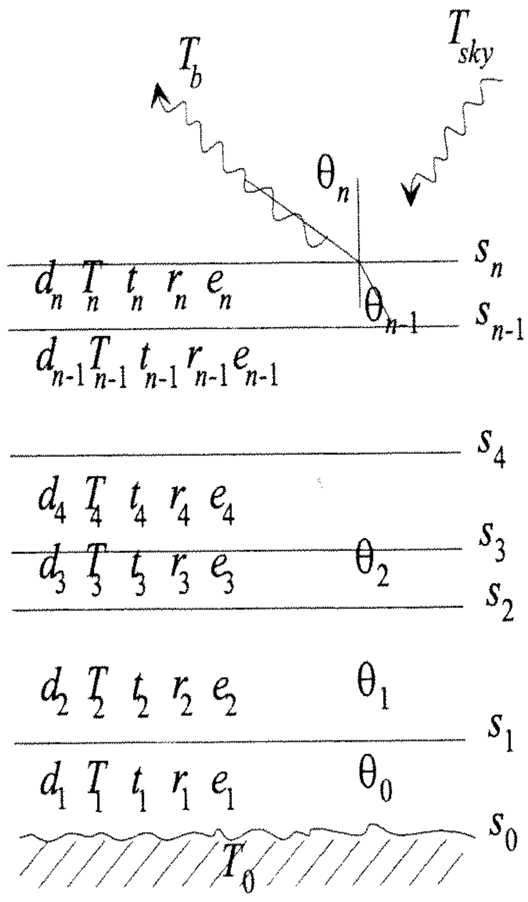


Figure 1. A multilayer system with a wave incident from above at an angle θ_n.

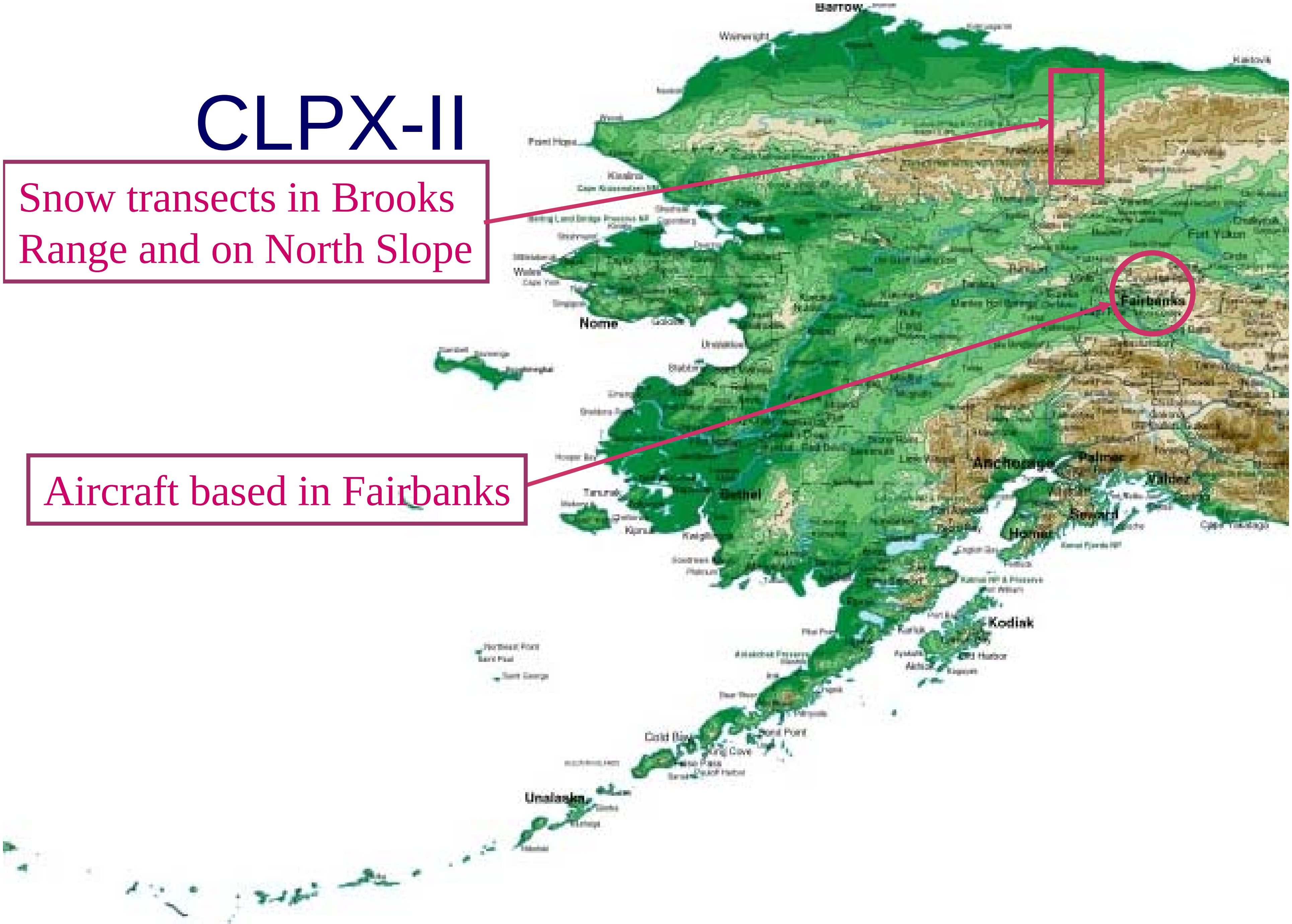
Models for calculating scattering and absorption properties

- Improved Born Approximation (IBA; Mätzler,1998)
  - one of the options in MEMLS
  - Parameter describing granular medium
    - Correlation length
- Quasi Crystalline Approximation (QCA; eg. Chapter 6 of Tsang and Kong, 2001)
  - Can handle particles in Mie scattering regime
  - Parameter describing granular medium
    - Particle radius (distribution)
- Evaluation of these models is underway (20-200 GHz)
  - Numerical simulations
  - Upcoming airborne campaign (CLPX-II)

CLPX-II

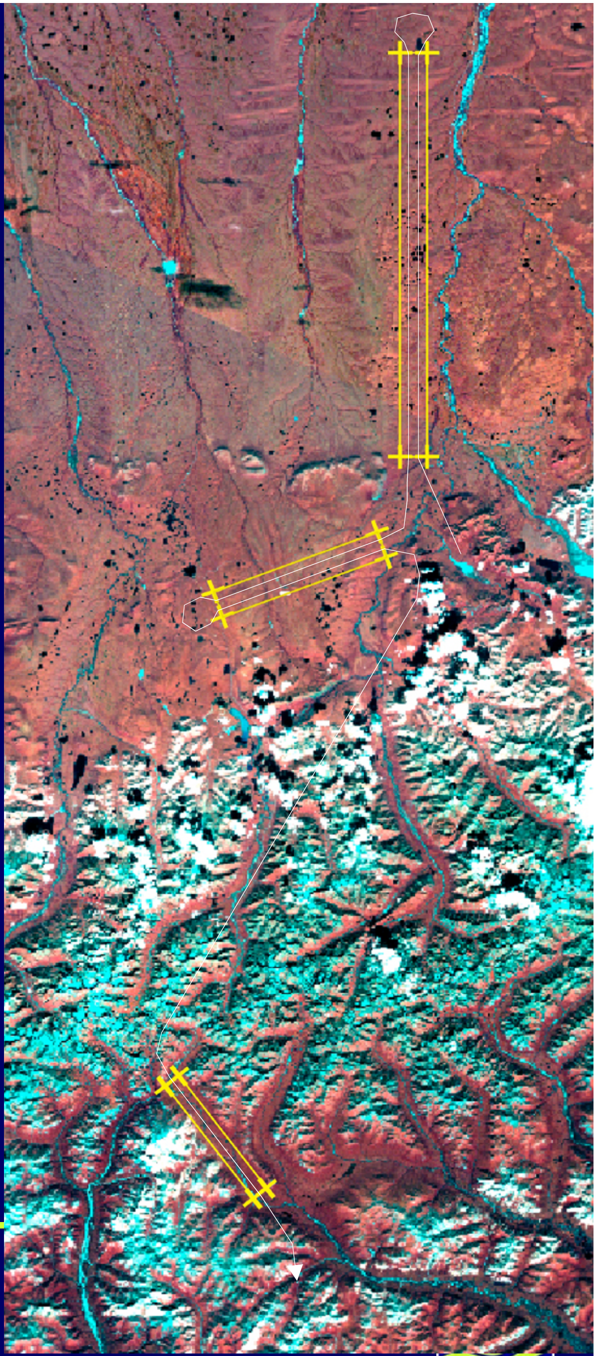
Snow transects in Brooks Range and on North Slope

Aircraft based in Fairbanks



CLPX-II

- Snow study areas (yellow)
- Snow survey transects
  - Snow depth (very frequent)
  - Snow pit profiles (periodic)
  - FMCW ground based radar
    - » Continuous snow depth transects
  - Input profiles for MEMLS
- Flight lines (white)
  - Measurements of T_B, T_{surf}, altitude
- Atmospheric profile data
  - Sonde dropping runs
  - In situ aircraft instrumentation
  - Water vapor profiling lidar
  - Allow retrieval of emissivities (Harlow, 2007)
- Scatterometer data
  - Active/passive synergy



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Demands on JULES snow module

- Profiles of temperature, density, wetness, stratigraphy
- Profiles snow grain size or correlation length.
- CLPX-II focus on arctic dry snow
  - Minimal wetness and stratigraghy (no thaw)
  - Strong temperature gradient
    - Temperature gradient metamorphosis
    - Penetration of microwaves
      - Temperature of emission of microwaves greater than IR surface temperature.

Grain size or Correlation length

- simulation of grain size depth profiles most difficult demand on snow module.
- Field data will provide pit profiles distributed in time and space.
  - With distributed met data can evaluate snow modules.
  - With observed microwave and IR brightness temperatures can evaluate snow microwave radiative transfer routines.

Conclusions

- Ability to retrieve emissivity with BAe-146 (Harlow, 2007)
- Three models of microwave emission (increasing complexity)
  - Weng and Yan (2003) (~msec/spectrum)
  - MEMLS with IBA (~sec/spectrum)
  - MEMLS with QCA (~10^5 sec/spectrum)
- Need data set to validate these models on the 100-200 GHz frequency range.
  - CLPX-II
- Need to evaluate a snow thermophysical model that provides depth and area distributed profiles of snow grain size, density and temperature.
- Coupling within JULES
  - Future data assimilation of AMSU radiances over land
  - Fast regression based snow rad transfer model

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