Lambertian snow emissivities

Summary of recent work and application to Antarctica

R. Chawn Harlow, CONCORDIASI Workshop, 30 March 2010

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- FAAM and Met Office aircraft crew taking part.

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- Implications for efforts in Antarctica.

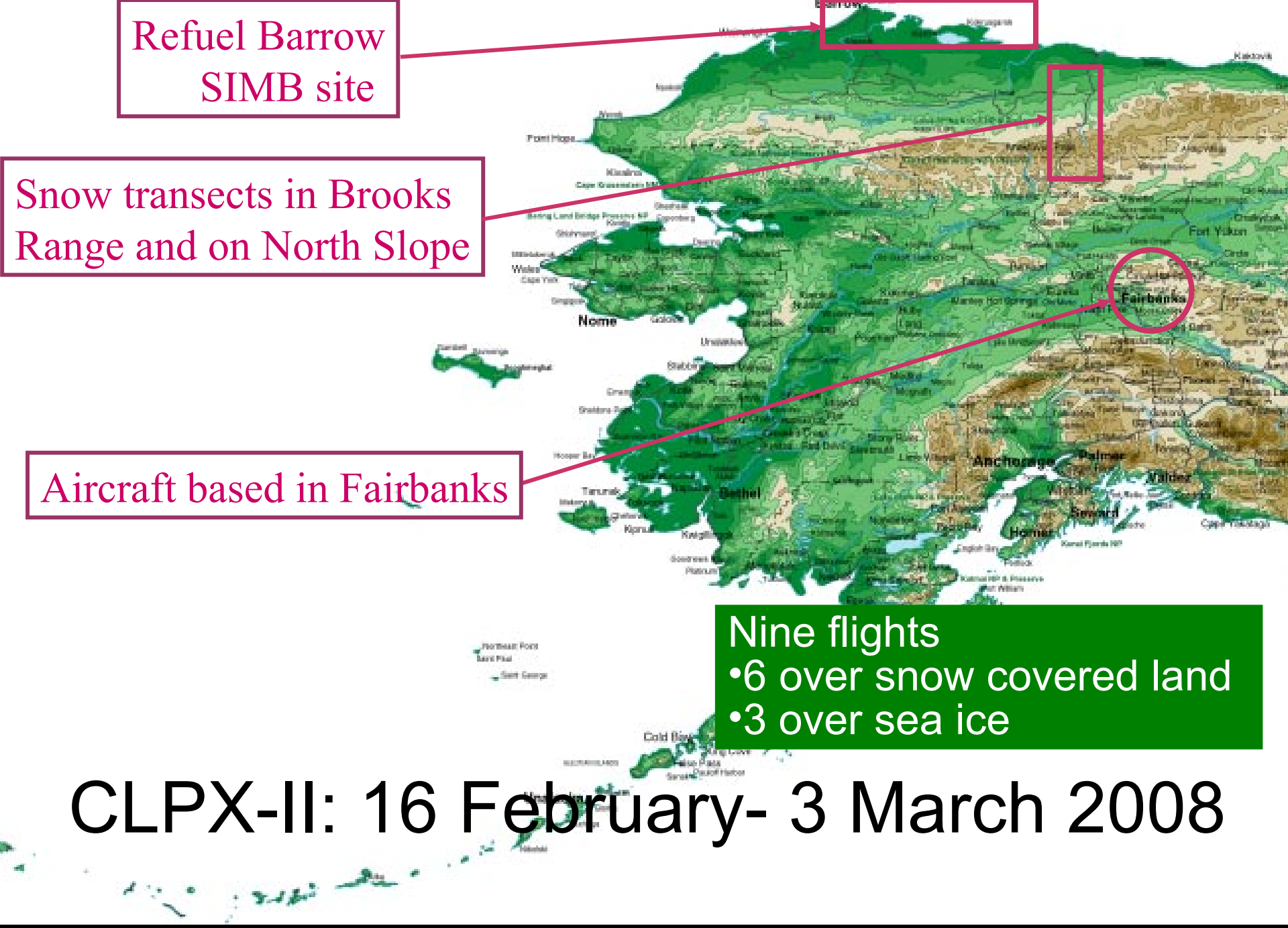
Introduction

Motivation

- Hope to assimilate satellite microwave (AMSU and MHS) data over land and sea ice
  - Provide atmospheric temp and humidity profile information where there are holes in the conventional profile data.
- Need surface emissivity information derived from models and satellite observations.
- New snow module to be included in future Met Office land surface component JULES. Future data assimilation opportunities?
- First need to validate snow radiative transfer models in 20 to 200 GHz range.

POLEX Campaign March 2001

- Five flights over sea ice
  - Three over pack ice
  - Two over Marginal Ice Zone
- One flight over snow covered land

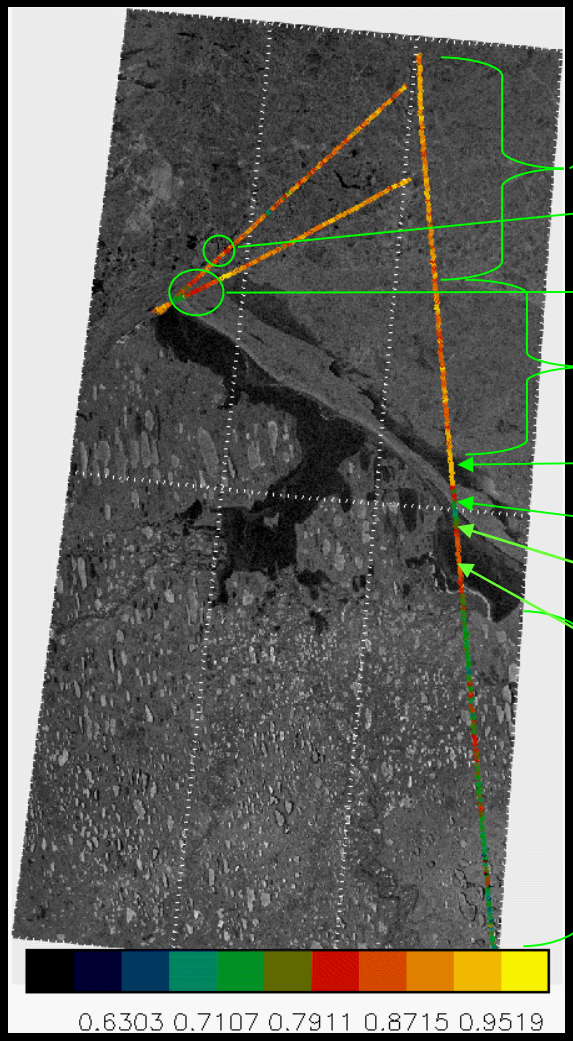


CLPX-II: 16 February- 3 March 2008

Major outcomes

- AMSU-B emissivities at 89, 157 and 183 GHz.
  - mm-waves
- Snow surfaces are Lambertian at 183 GHz (Harlow, 2009).
- Sea ice mm-wave Lambertian emissivities can be related to sea ice type through typical snow cover stratigraphic sequences (Harlow, 2010a).
  - Coupled atmosphere-snow-ice-ocean models may lead to better analysis of snow water content, ice type, and atmospheric temperature and humidity via assimilation of microwave emissivities on the 20-200GHz range.
- mm-wave Lambertian snow emissivities may be modeled with MEMLS if mm-scale surface roughness is taken into account (Harlow, 2010b).
  - Extension of MEMLS to ~200GHz.
  - To be confirmed in future campaigns.

Snow surfaces are Lambertian at 183 GHz



Broken FYI

Nilas and Open Leads

Fast Ice North of Elson

Heterogeneous LFI

Northern Fast Ice

Rubble in Smith Bay

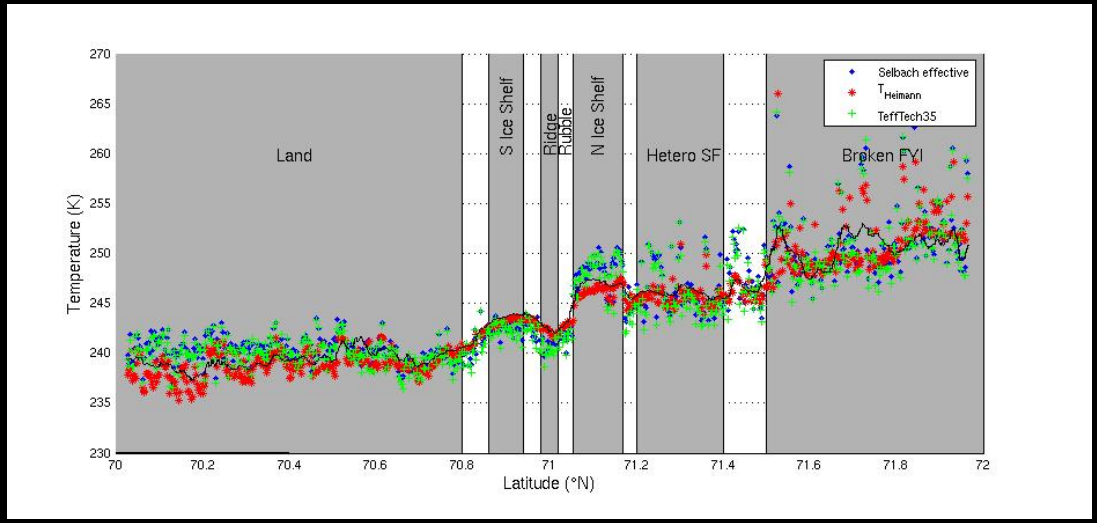
Ridge in Smith Bay

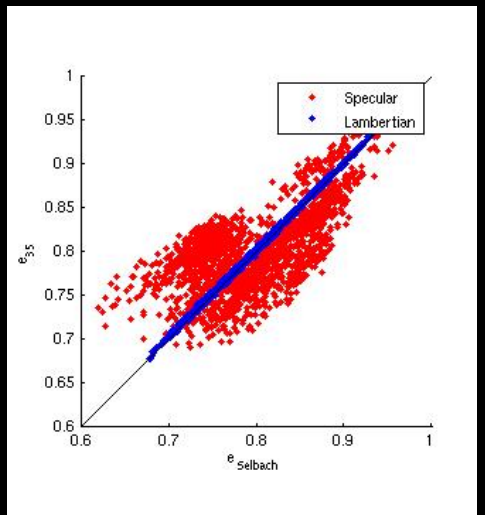
Southern Fast Ice

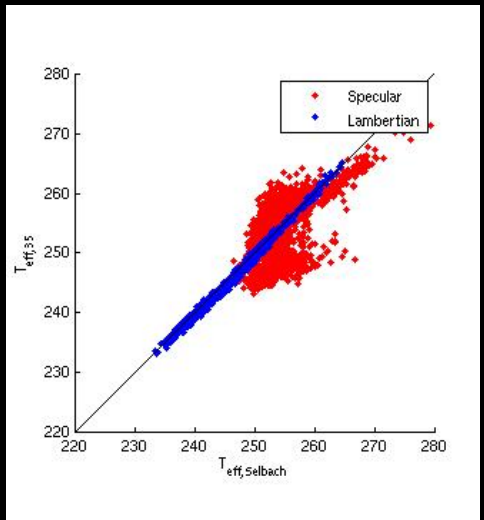
Wetlands

Snow surfaces are Lambertian at 183 GHz

- Two estimates of 183 GHz effective temperature and emissivity based on microwave T_B's
- Close agreement under Lambertian scattering
  - RMSD ≅ 0.5 K
  - RMSD = 4.4 K for specular.
- Confirmed with data from 12 flights







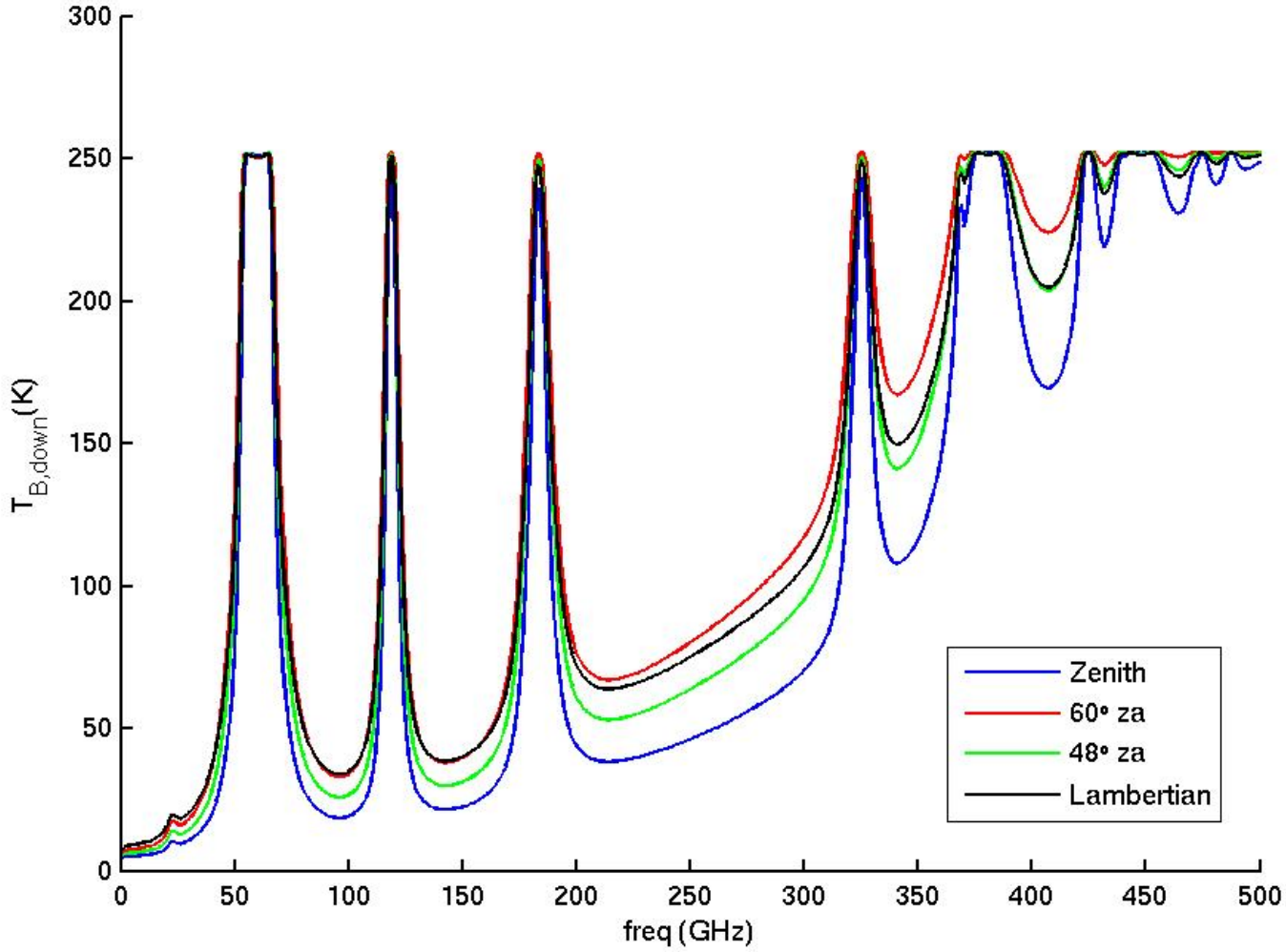
Impact of diffuse scattering in the 20-200 GHz range

- The degree to which Antarctic surface is Lambertian has been studied at 37 and 50 GHz by Rosenkranz and Matzler (2008).
  - Scattering characterized as linear combination of Lambertian and specular scattering with weight for Lambertian given by A_L
  - A_L~0.7 to 1.0 but spatially variable
- Guedj (2009) discussed emissivities retrieved with various degrees of Lambertivity (A_L)
  - Suggested seasonal variation from Lambertian in the winter to semi-Lambertian or specular in the summer.
- Goal now is to quantify the impact of Lambertian scattering on the upwelling radiation at the surface.

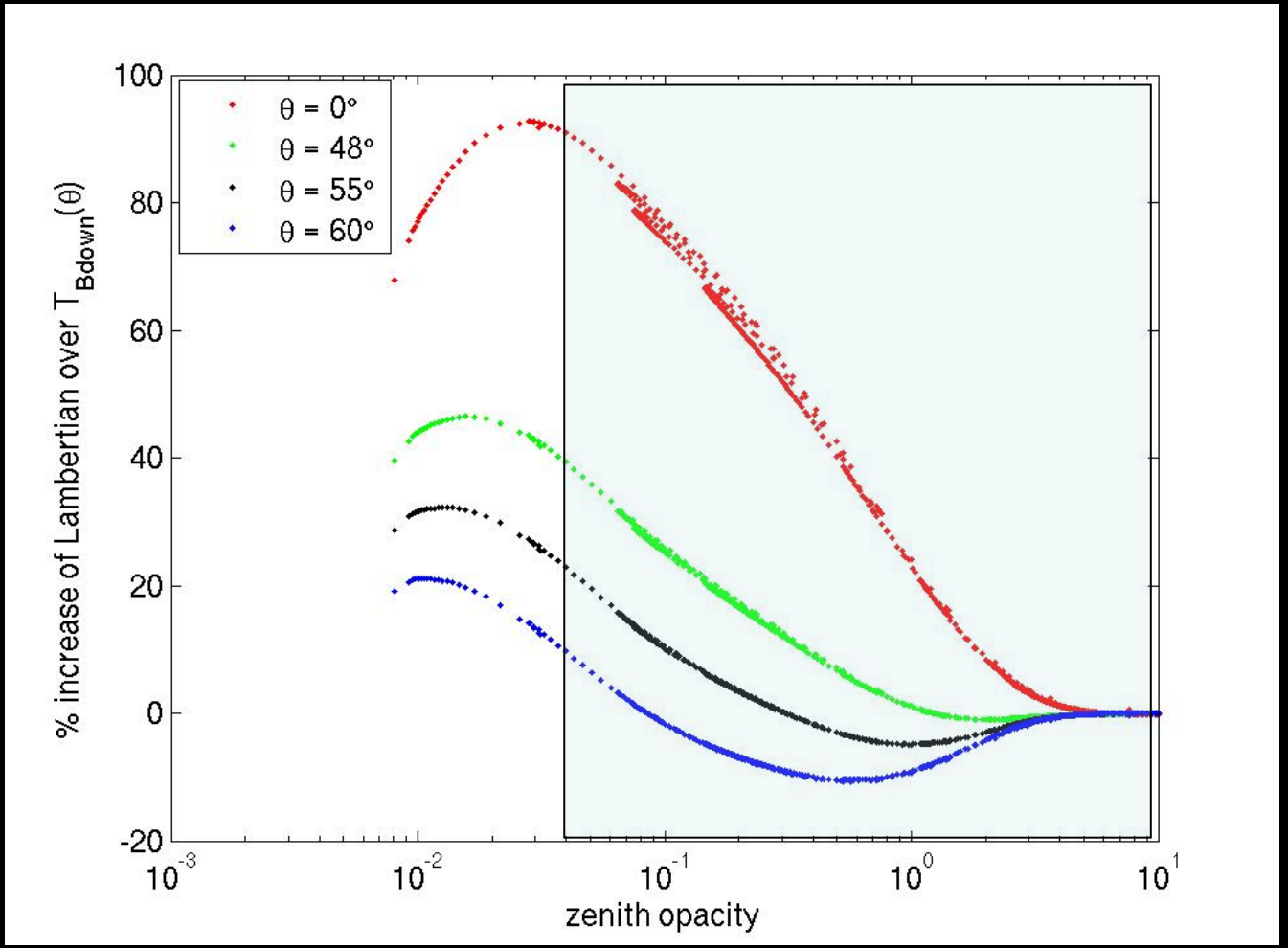
Methodology

- Use ARTS to generate downwelling T_B's at 10 zenith angles (θ) between 0 and 90°.
- Frequencies – 1 to 1000 GHz in 1 GHz steps
- B345 atmospheric conditions– Cold and dry.
- Integrate T_B's over the Lambertian BSF.
- This approximates the effective downwelling seen by a Lambertian surface.
- Specular surface reflects like a mirror so nadir measurements see reflections of the zenith T_B
- Compare Lambertian T_B's to those from a specific direction θ in the sky for a range of optical depths
- Compare upwelling Lambertian and specular T_B's.
- Summarize differences in terms of acceptable uncertainties for sounding.

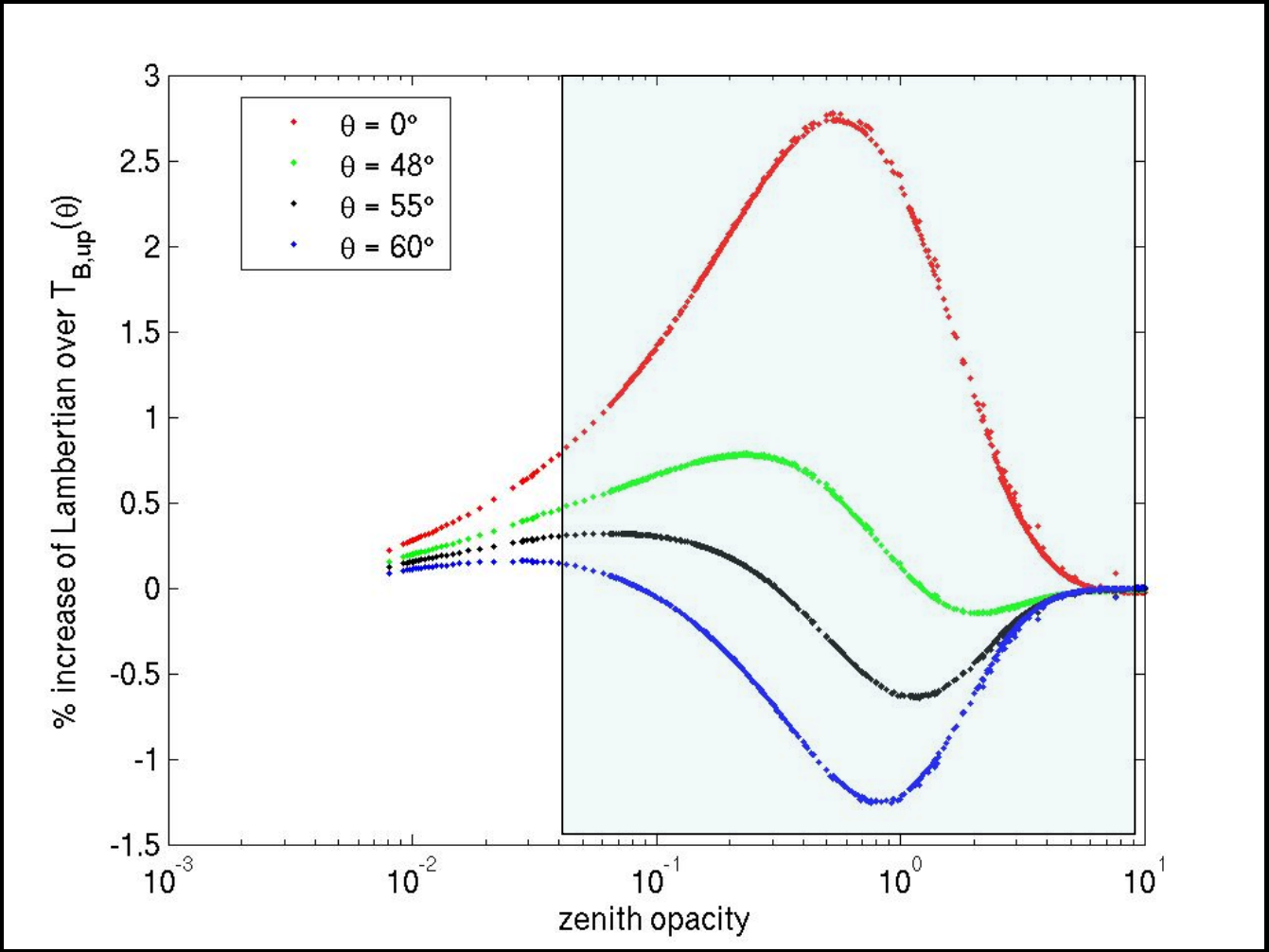
Lambertian effective downwelling



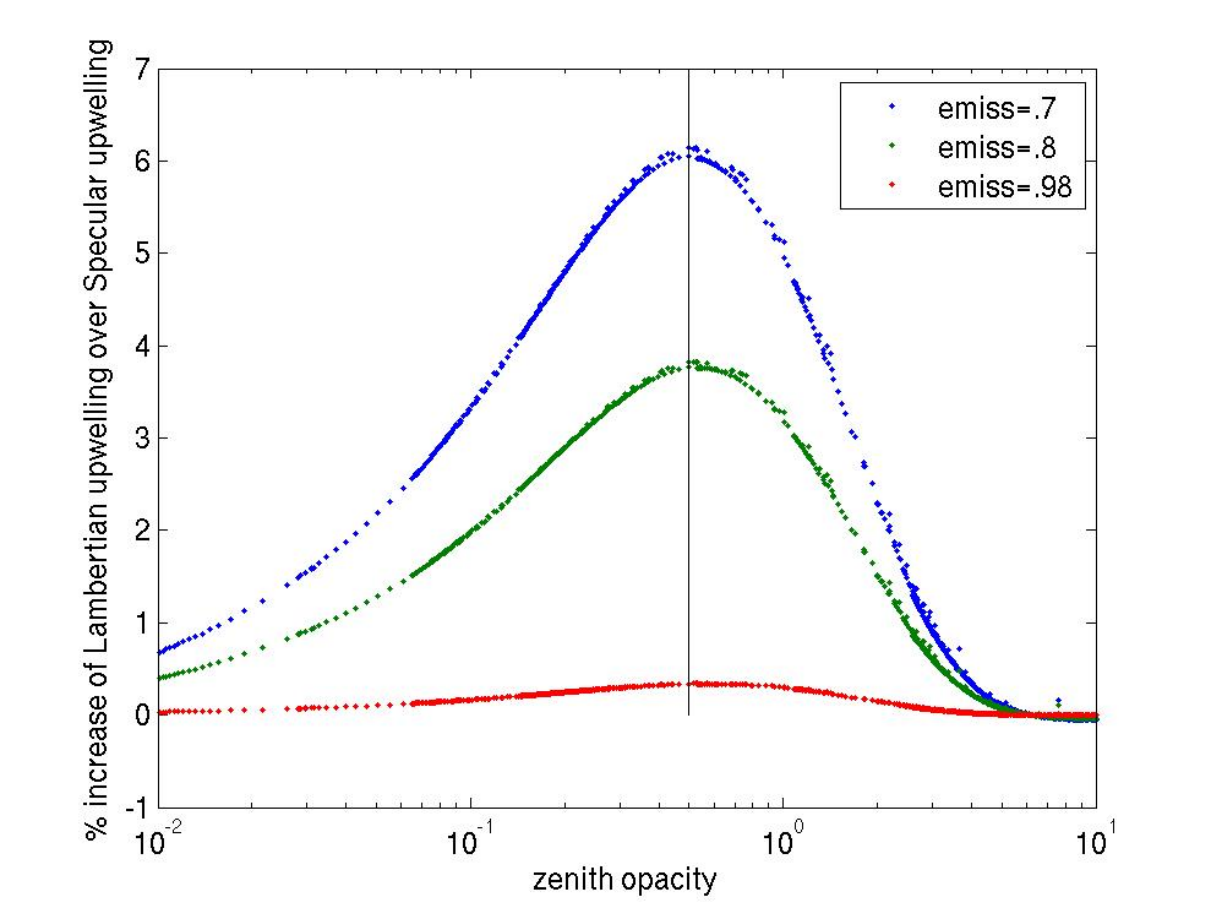
Impact of Lambertian scattering a function of zenith opacity



Difference between Lambertian and Specular upwelling when emiss=.85



Effect of Lambertian scattering as a function of zenith opacity



Max effect at Zen op of 0.5

Why worry about Lambertian effect?

- Lambertian effect is a function of zenith opacity: Change in spectral shape of retrieved surface emissivity.
  - Retrieval of geophysical variables must ingest any error in emissivity.
- These differences in emissivity introduce ambiguity of ~5-10 K in upwelling TB which may contaminate any retrieved profile using radiance assimilation at TOA.

Influence of Lambertian scattering on RT

- Where emissivities are relatively small there are large impacts on the radiances and thus retrieved emissivities particularly at opacities of 0.5.
- Lambertian scattering should have a strong impact for
  - snow covered surfaces in the microwave
  - desert surfaces in the IR.

Impacts of Lambertian scattering on sounding over Antarctica

- Microwave emissivities are likely to vary with frequency and elevation in Antarctica from ~0.7 to near unity (Picard et al, 2009; Guedj et al, 2009; etc.).
- For near nadir instruments (AMSU-A/B & MHS) the degree of diffuse scattering needs to be taken into account.
  - Up to 15 K error in upwelling at surface otherwise.
  - Up to 3 K for observations at 55° incidence (SSMI, SSMI/S, etc).
  - Both are larger than acceptable for sounding purposes (English, 2008).
- The seasonal variation needs to be investigated as well as the Lambertivity at frequencies lower than 183 GHz.

Future work

- Added capabilities from ISMAR
  - Suites of channels on 118 and 325 GHz water vapour lines will be useful in evaluating A_L at other frequencies.
- TAIGASEE in Finland
  - Nov 2012, Jan and Mar 2013
  - Evaluate performance of MEMLS over a season.
- Sea ice campaign 2013/14 in Alaska(?)

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