Advances in the assimilation of MW sounding data over snow and sea-ice

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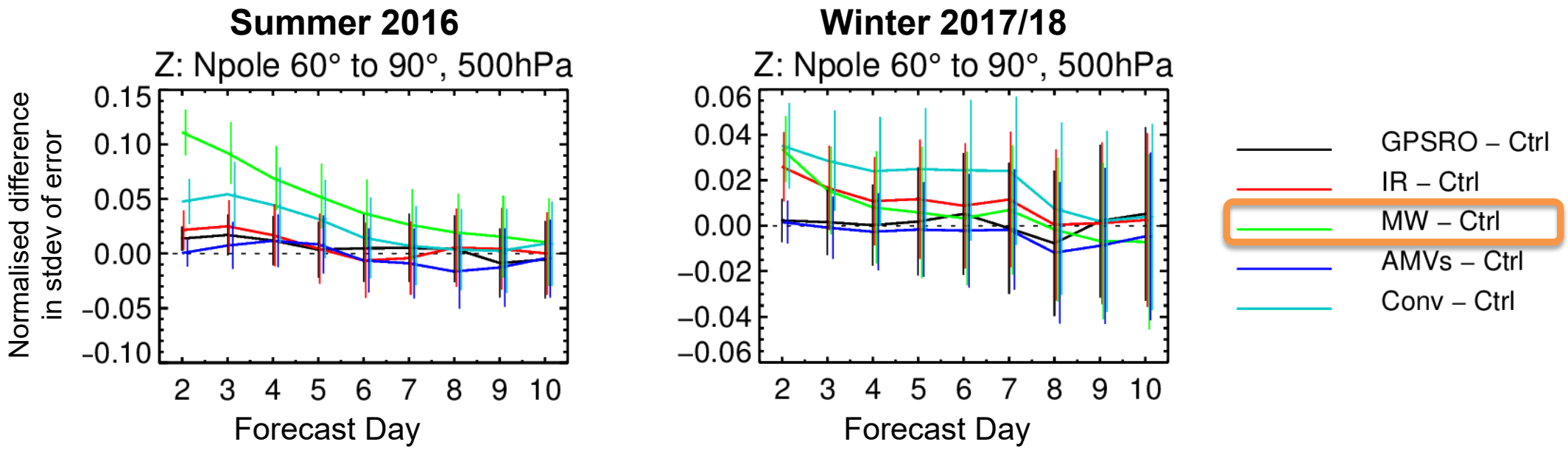
Background: Impact from denying polar observations: Z 500

APPLICATE.eu
Advanced prediction in polar regions and beyond



- **Summer:** Largest impact from MW radiances
- **Winter:** Poorer impact from MW radiances
  - Attributed to poorer use of surface-sensitive sounding radiances over snow and sea-ice (e.g., poorer forward modelling, issues in forecast model, background error modelling etc)
- See *Lawrence et al, QJRMS, 2019*

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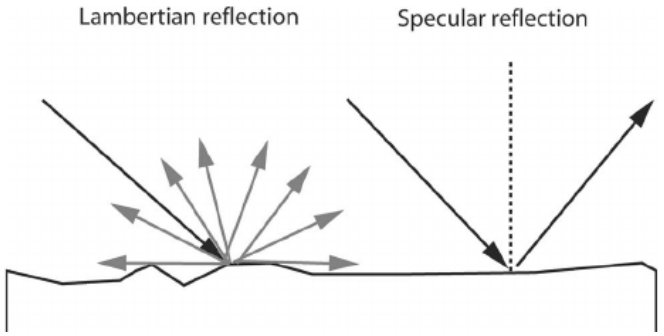
Background: How do we treat surface characteristics for MW sounders over snow and sea-ice?

- Use **effective skin temperature and emissivity**; **specular assumption**.
- **Skin temperature:**
  - Model surface temperature used as background
  - For AMSU-A and ATMS: Retrieved as sink variable during the assimilation, separately for each FOV
- **Emissivity:**
  - Retrieved prior to assimilation from an otherwise not assimilated window channel (e.g., Karbou et al 2006)

Assimilated sounding channels	Emissivity channel
50-60 GHz band	50.3 GHz
183 GHz band	150/165 GHz over snow, sea-ice

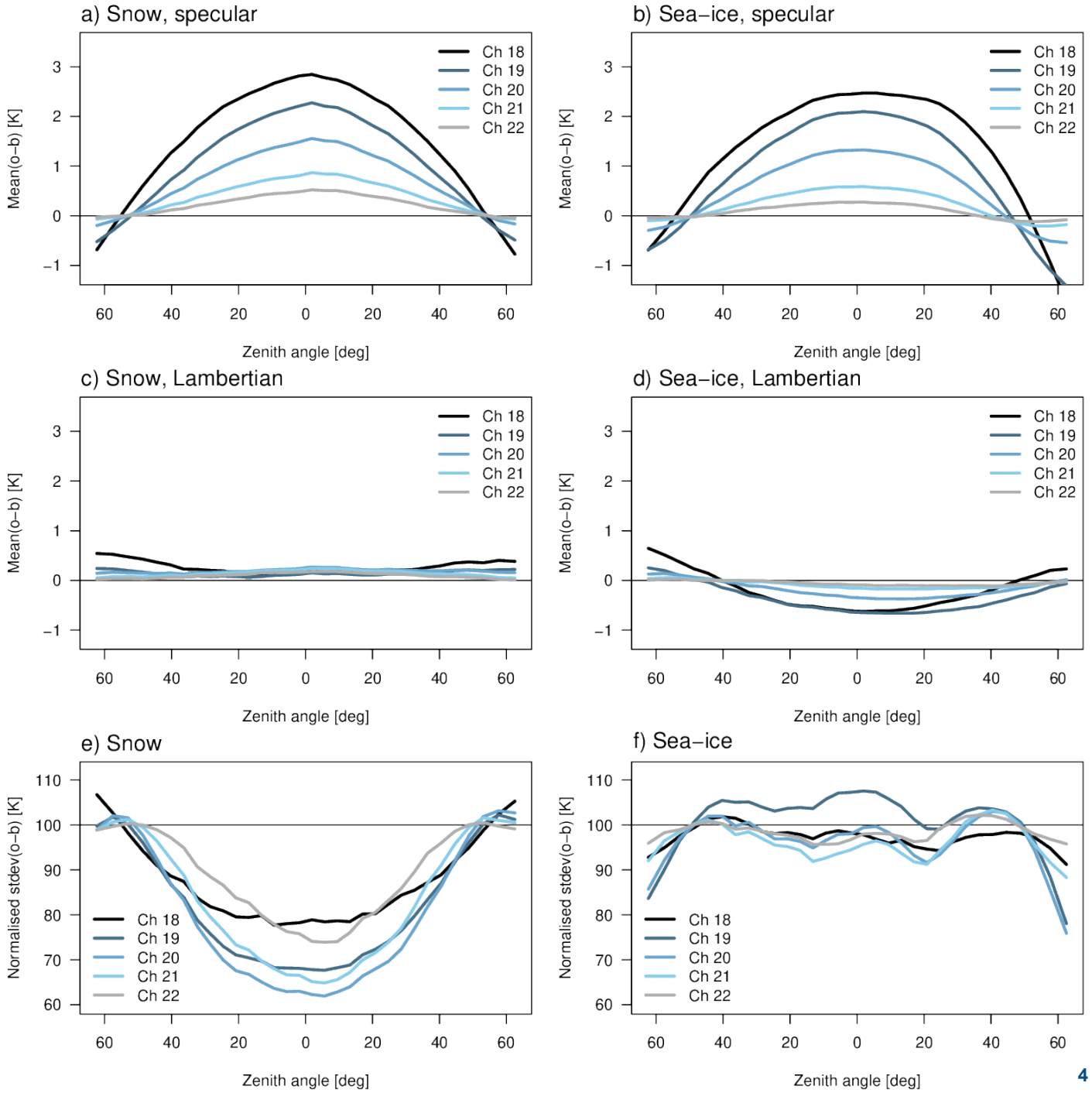
- **Investigated here:**
  - What biases are arising from using the specular assumption?
  - What is the role of the skin temperature estimate?

Lambertian effects over snow and sea-ice for 183 GHz channels



(Guedj et al. 2010)

- Assuming Lambertian reflection leads to better simulations over snow and sea-ice for 183 GHz channels.
- Parameterisation available in RTTOV for clear-sky simulations (not yet for RTTOV-SCATT).

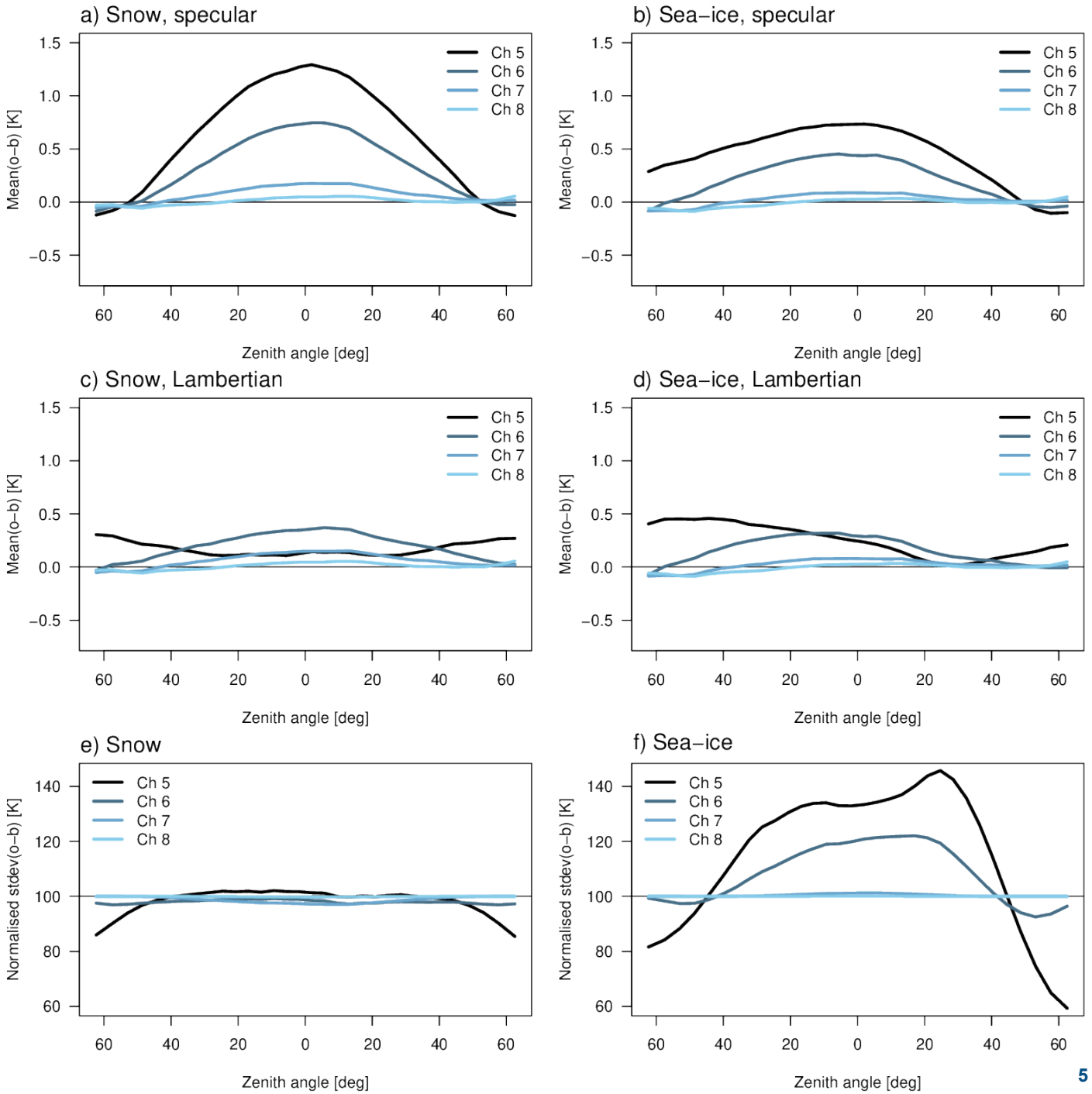


(ATMS data before screening, Jan 2020, Arctic)

Lambertian effects over snow and sea-ice for 50-60 GHz channels?

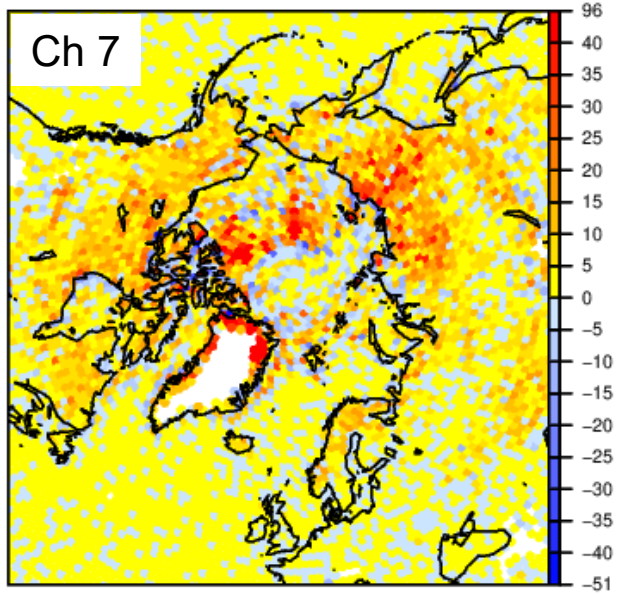
- Situation less clear for 50 GHz, particularly over sea-ice
- Partial-Lambertian behaviour and seasonal variations?
- Mixed with poor skin-temperature estimate?

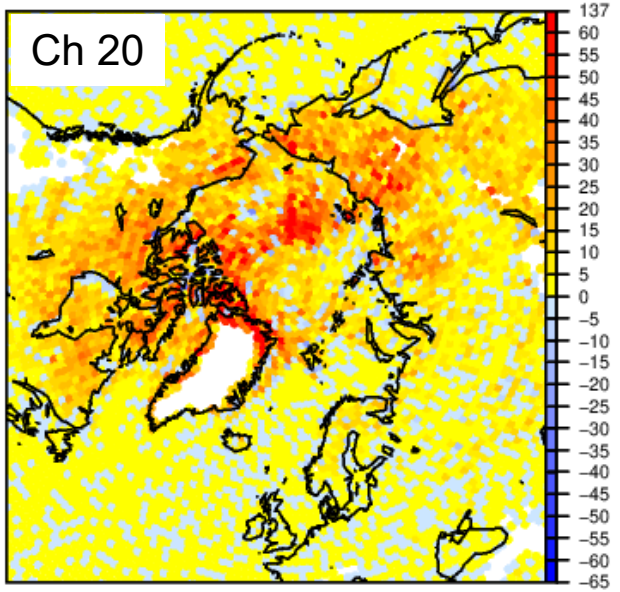
(ATMS data before screening, Jan 2020, Arctic)



Assimilation experiments with Lambertian reflection over snow/sea-ice

- **Control:** Full observing system, specular assumption used over land/snow/sea-ice throughout
- **Lamb:** As Control, but using:
  - Lambertian reflection over snow and sea-ice for 183 GHz channels on ATMS
  - Semi-Lambertian reflection over snow and sea-ice for 50 GHz channels on ATMS and AMSU-A
- Periods:
  - 20 June – 30 Sept 2019;
  - 1 Dec 2019 – 31 March 2020
- 12-h 4D-Var; T_{CO} 399 model resolution (~25 km)

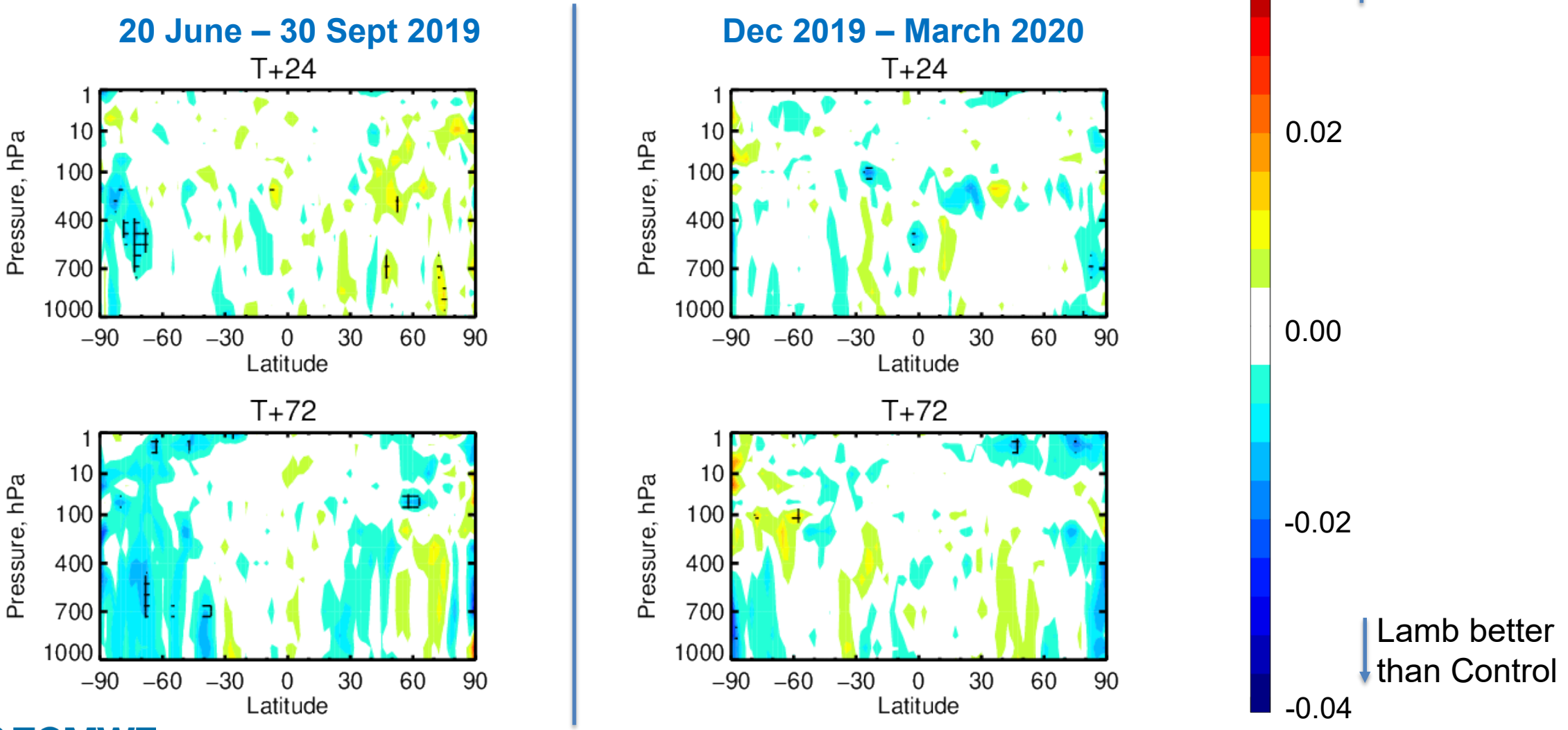




Additional S-NPP ATMS observations assimilated, Feb 2020

Forecast impact from Lambertian surface treatment

Normalised difference in RMSE of vector wind, verified against own analyses

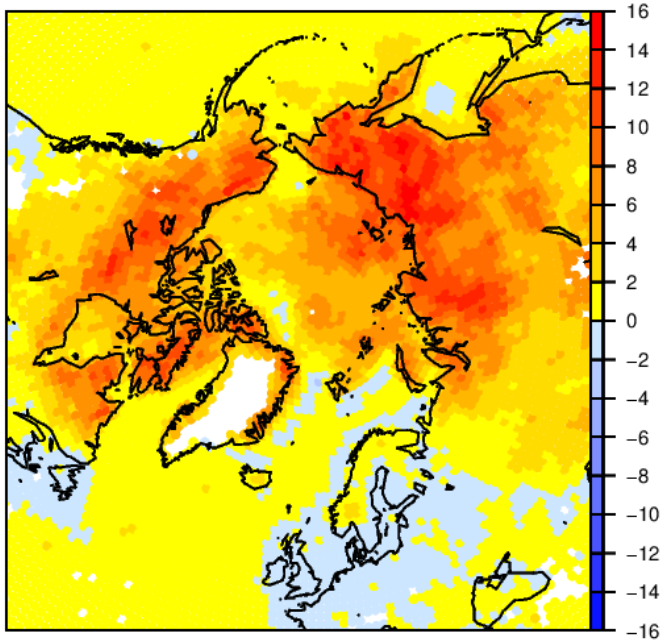


Advancing the treatment of skin temperature

- Over snow and sea-ice, the model surface temperature is likely to be a poor effective skin temperature at MW frequencies, due to neglected penetration depth.
- **Experimental new approach:**
  - Retrieve an effective skin-temperature **field** (instead of separate values for each FOV):
    - "**Augmented control variable**": Hourly skin-temperature fields, with separate fields for MW and IR instruments
  - Skin-temperature background errors include spatial and temporal correlations
  - The new skin-temperature field is constrained simultaneously by all instruments affected
  - See Massart et al (2021), GMDD
  - In addition, **address skin-temperature biases** by **persisting the increments** for the MW skin temperature fields (using the result from 24 h prior as background).
- Preliminary additional experiment:
  - **Lamb+TskinACV:** As Lambertian experiment, but applying the new skin temperature approach for all surfaces and to all instruments assimilated in clear-sky (for MW: AMSU-A and ATMS only).

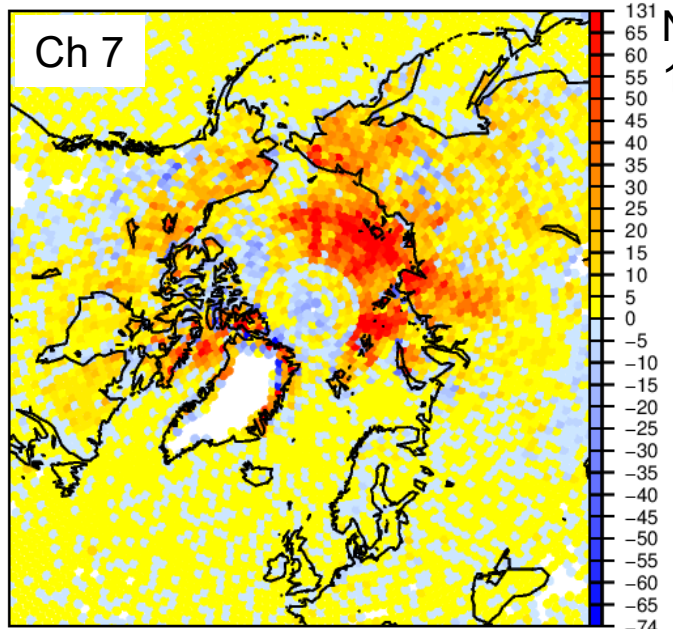
Preliminary results from the new skin-temperature treatment

- Large difference between retrieved skin-temperature and model surface temperature over snow and sea-ice.
- Reduced biases in background departures for surface-sensitive channels.
- Further increase in the number of observations passing quality control, primarily for the 50-GHz channels.

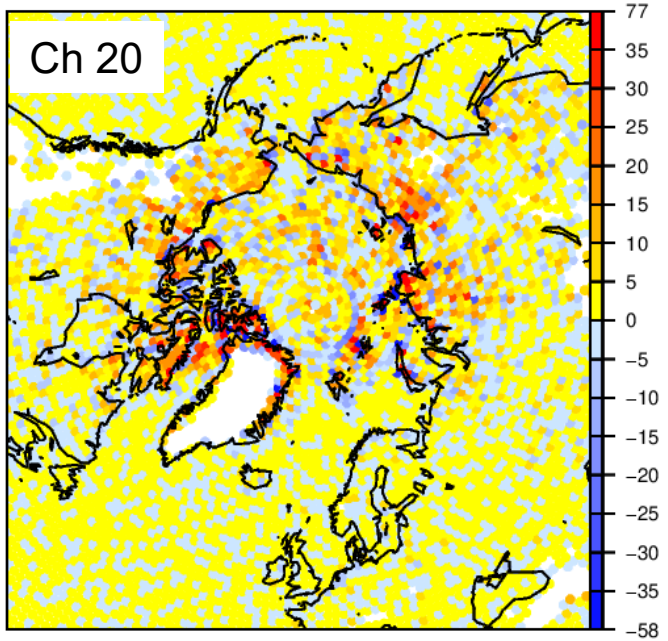


Mean difference between retrieved skin-temperature field and model surface-temperature field [K] in **Lambert+TskinACV** experiment;
11-31 Dec 2019

Difference in the number of used observations
Lamb+TskinACV vs Lamb



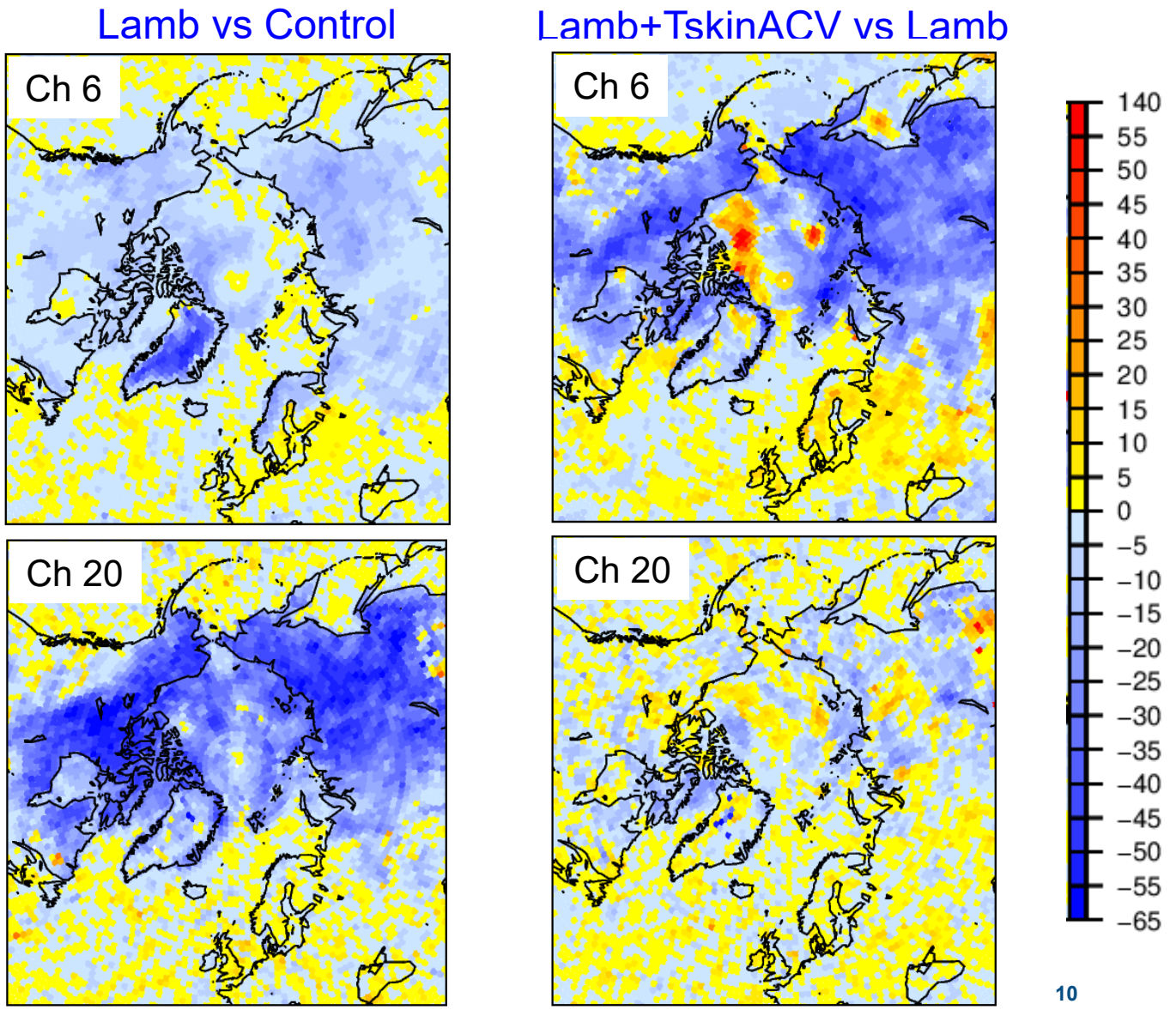
NOAA-20 ATMS,
11-31 Dec 2019



Preliminary results from using the new skin-temperature treatment and Lambertian reflection

- Large reductions in stdev(o-b) from Lambertian surface treatment and new skin-temperature approach
  - ➢ Skin-temperature impact larger for 50-GHz channels
  - ➢ Lambertian effect larger for 183-GHz channels

Normalised differences in standard deviation [%], NOAA-20 ATMS, 11-31 Dec 2019, all data



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Summary and conclusions

- Two potential sources of bias in the forward modelling of surface-sensitive MW sounding radiances over snow and sea-ice have been explored:
  - Assuming (part-)Lambertian rather than specular reflection leads to better background departures, particularly for 183-GHz channels
  - The use of the model surface temperature as effective skin temperature appears to significantly contribute to the biases, particularly for the 50-GHz channels
- Ways to address these biases have been investigated:
  - Assuming Lambertian reflection in the assimilation leads to an increase in the number of observations passing quality control (esp for 183 GHz), and neutral-to-positive forecast impact
  - Addressing skin-temperature biases via an augmented control variable framework allows further increases in the data usage for 50-GHz channels, with promising benefits in departure statistics
    - Further experimentation is required to assess the overall performance of the new skin-temperature approach
- So far only considered instruments assimilated in clear-sky conditions – further work is required to adapt these methods in the all-sky framework.
- Possibilities to address some of the issues through better radiative transfer of the surface contribution and atmosphere-surface interaction in the future?