IMPROVING SFMR RETRIEVALS IN MID-LATITUDE WINTER STORMS

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Outline

- SFMR and winter operations
- Revisions to Radiative Transfer Model
    - Melting Layer model
    - Surface Layer model
- Results
- Summary

Stepped Frequency Microwave Radiometer (SFMR)

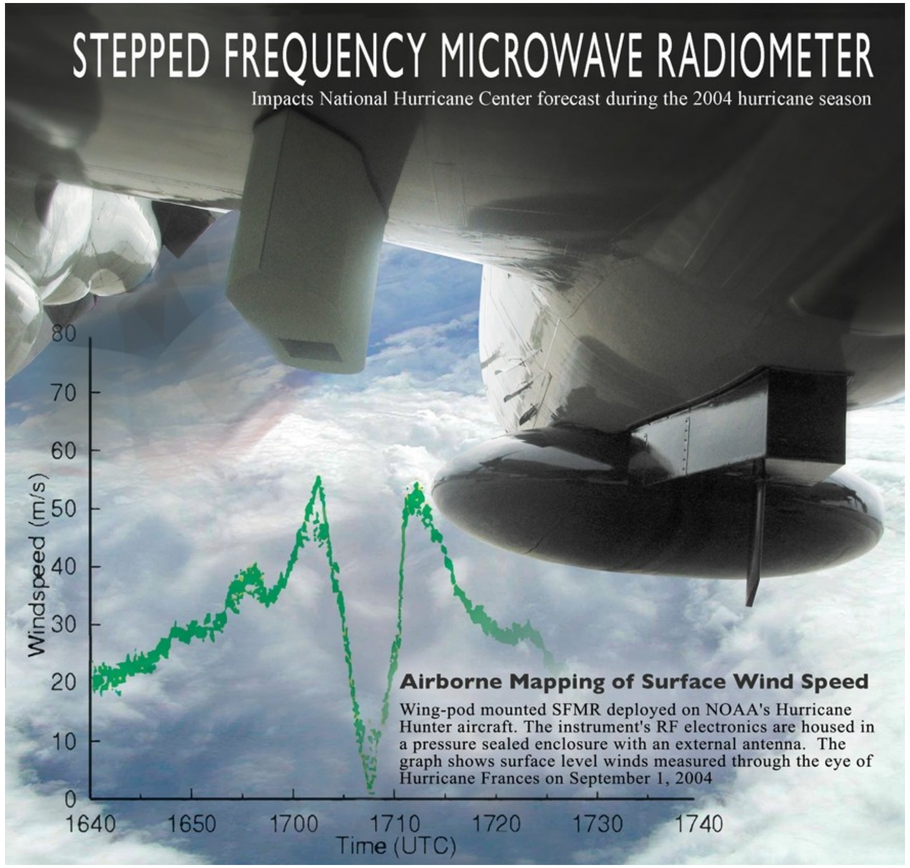
Airborne, nadir-looking, C-band

Measures Tb at 6 freqs. 4-7 GHz

Compare Tb with Radiative Transfer Model given wind speed and rain rate

Find wind speed and rain rate that minimize diff between measured and modeled Tb.

Extensively developed for Tropical Cyclones

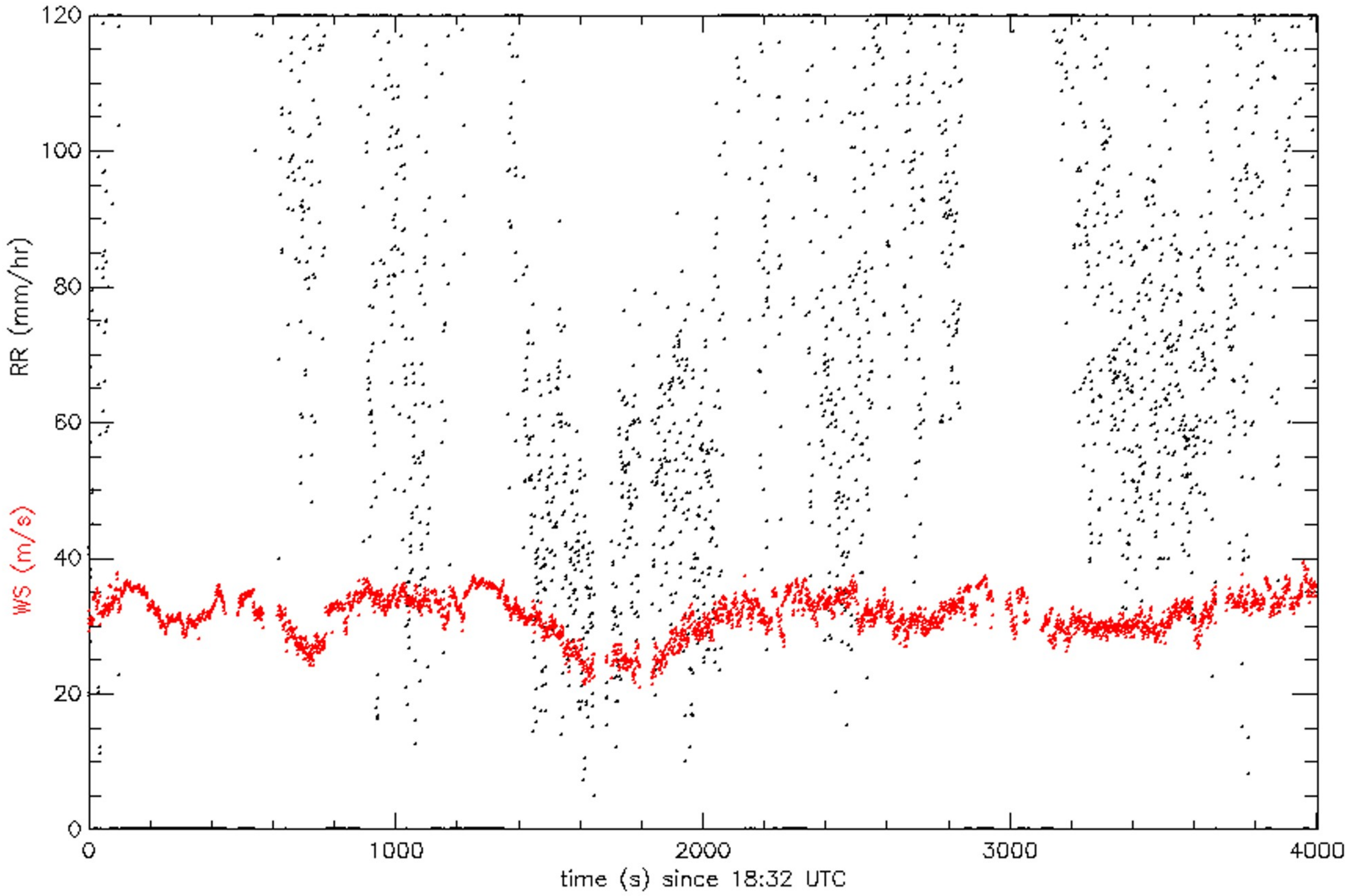


Winter time behavior

Tendency to retrieve excessive rain rates

Example from 2/28/2021

Tendency for wind speeds to be high



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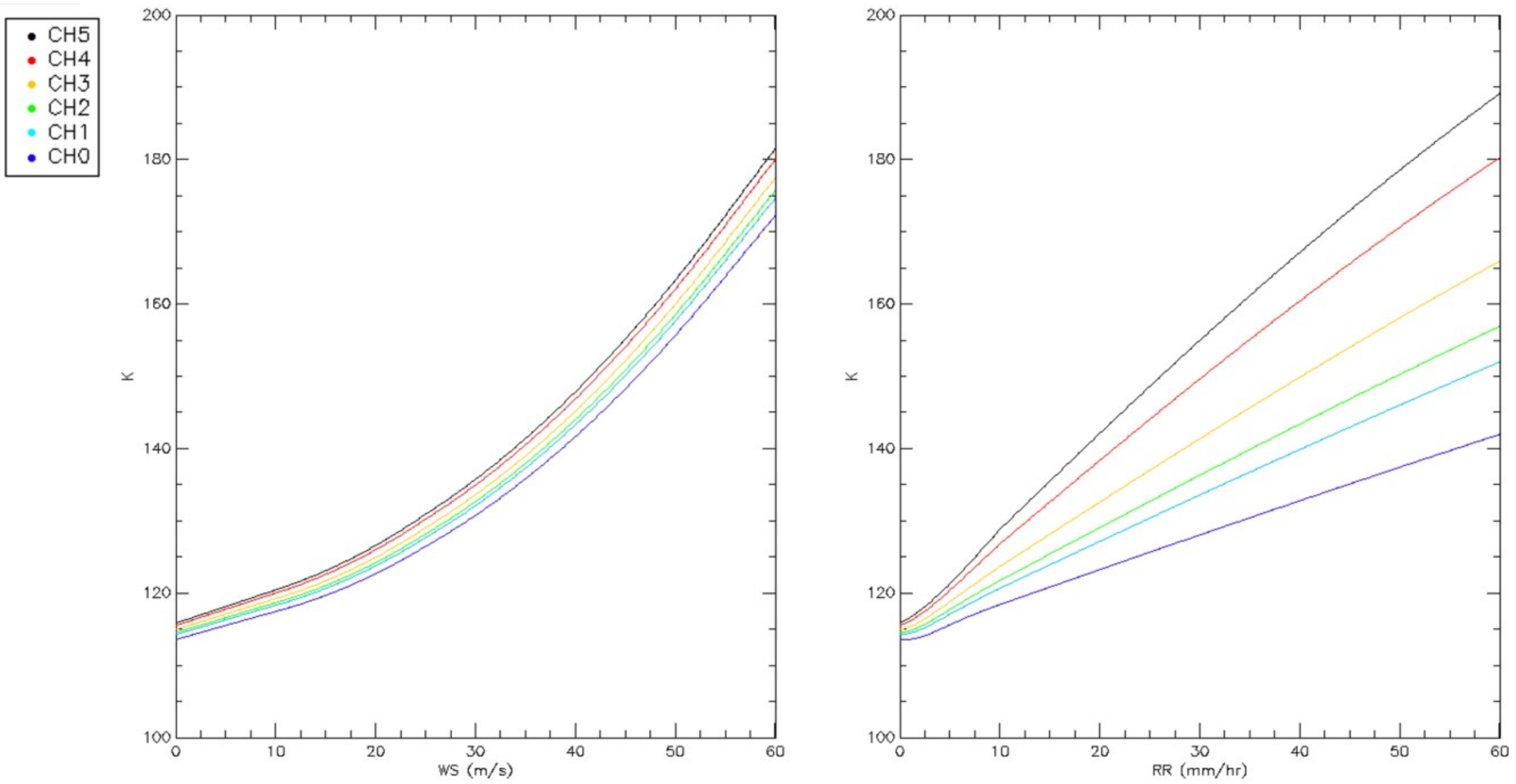
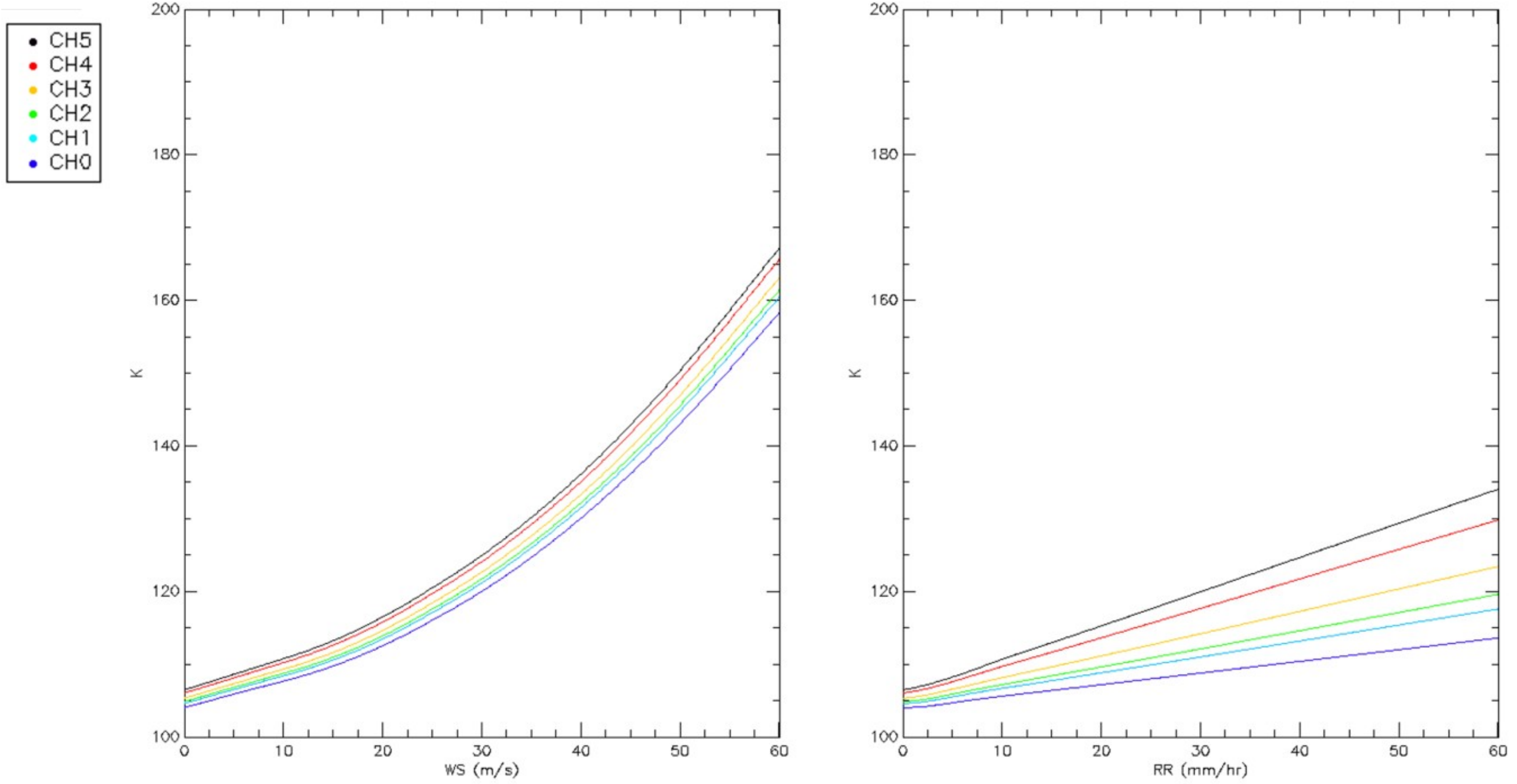
Radiative Transfer Model (TCs)

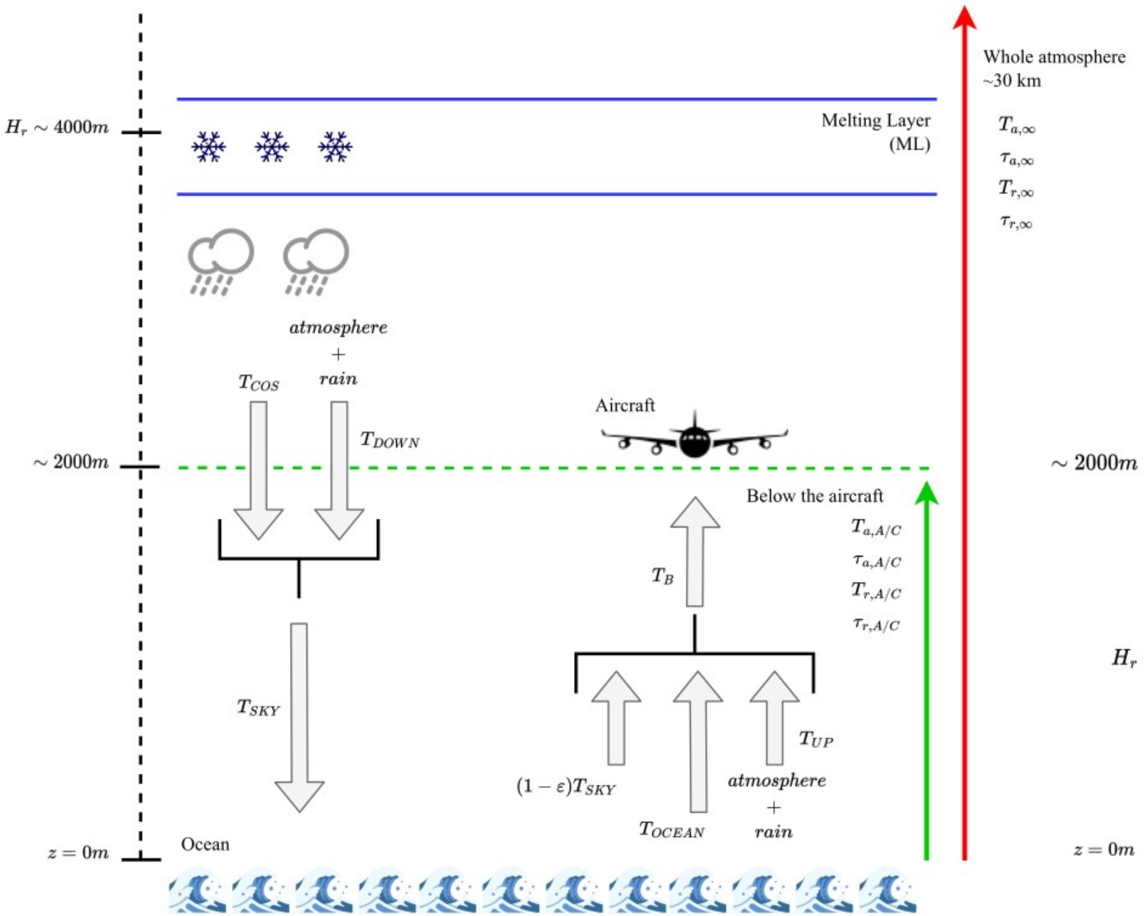


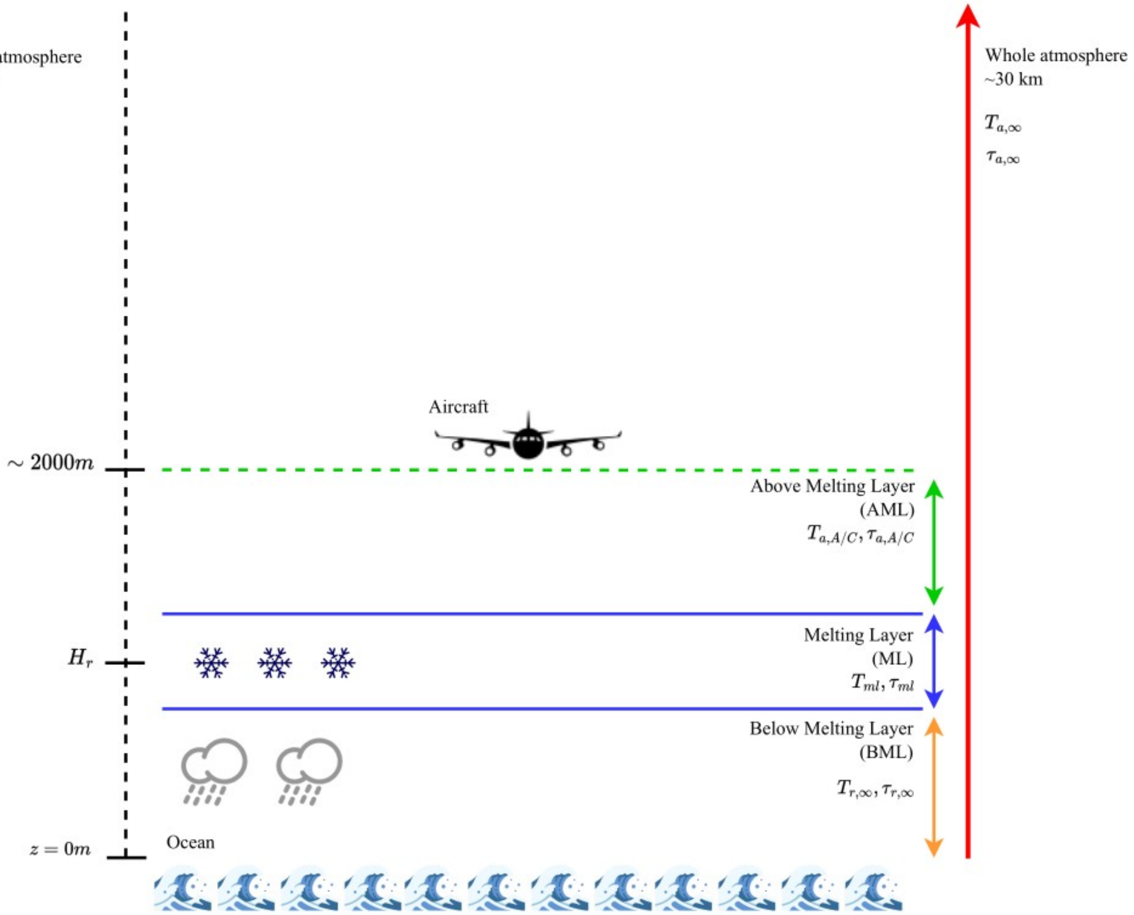
Sapp, J.W., S.O. Alsweiss, Z. Jelenak, P.S. Chang, J. Carswell, 2019. "Stepped Frequency Microwave Radiometer wind-speed retrieval improvements," *Remote Sens.*, **11**(3), p. 214.

Radiative Transfer Model (winter)



Radiative Transfer Model (TC vs Winter)





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Data Set

SFMR data provided by NOAA/NESDIS

82 research flights over 10 years

Tbs and aircraft environmental/navigation

Tb, f, Ta, H, pitch, roll, salinity, SST

$100 < Tb < 200$
$-5 < pitch/roll < +5$
$1800\ m < H < 2200\ m$
RFI: 5.31 GHz channel omitted

Year	Flight Days	Location
2012	8	St. John’s (NL)
2013	10	St. John’s (NL)
2014	10	Halifax (NS)
2015	23	Halifax (NS)
2016	15	Ireland
2017	6	Ireland
2018	5	Ireland
2021	5	Anchorage, AK (USA)

Melting Layer Model

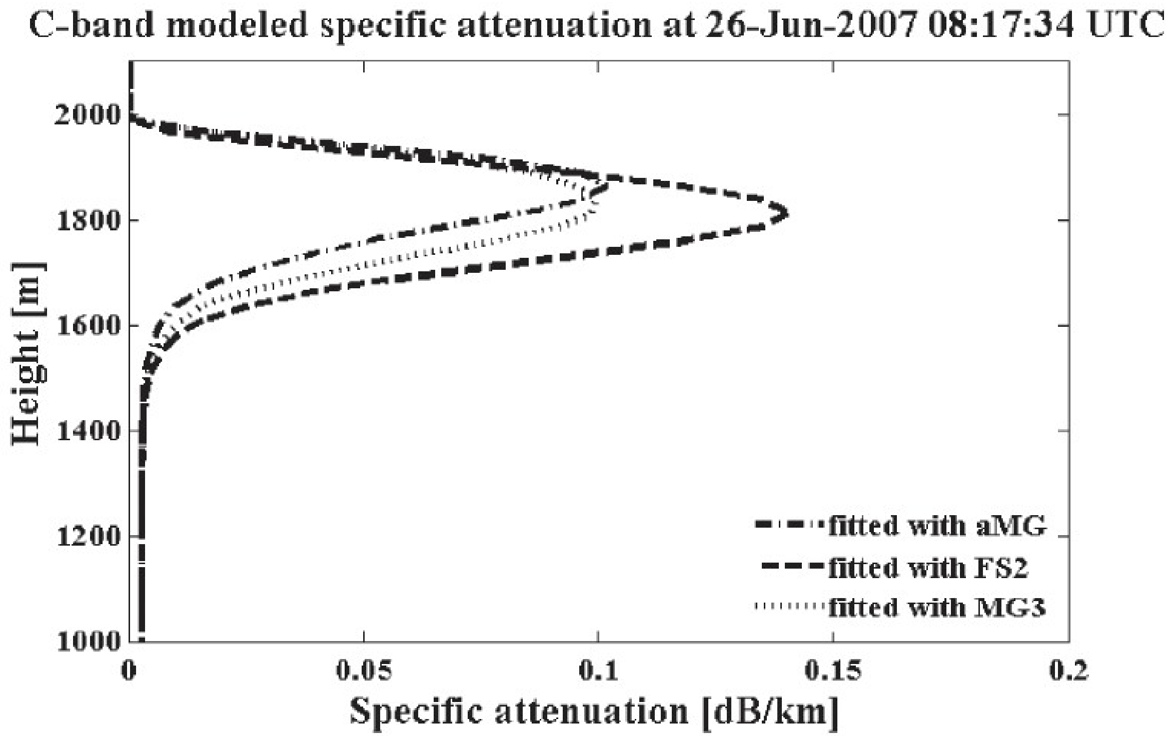
What about excess attenuation
and self emission from an intervening
melting layer?

$$\tau_{ml} = e^{-c_{ml} \cdot \kappa_r \cdot \sec\theta}$$

Kr = specific attenuation by
rain

Cml ~ 10 * ml thickness

ml thickness ~ 300-400 m



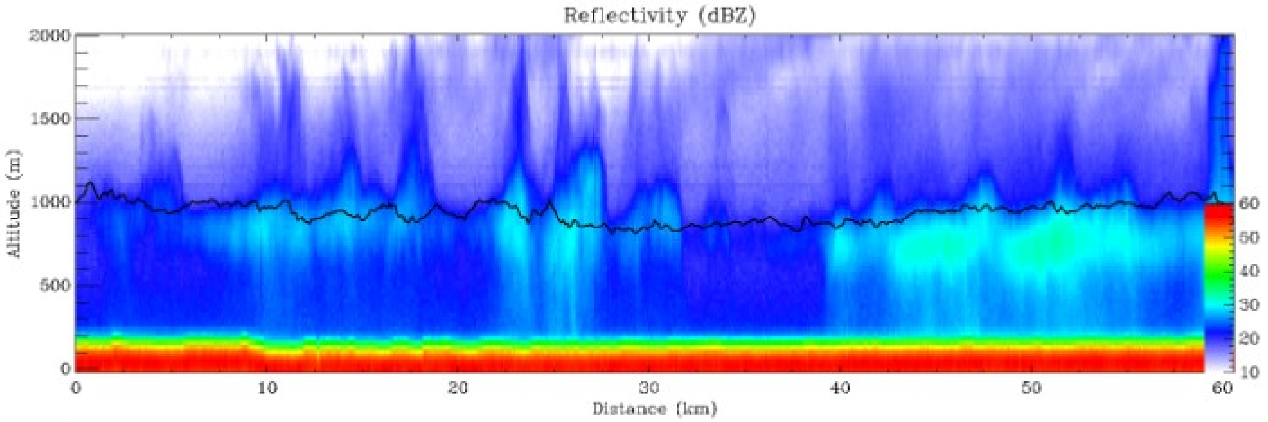
Von Lerber, et al. 2015. “Modeling Radar Attenuation by a Low Melting Layer with Optimized Model Parameters at C-band,” IEEE TGRS, 53(2), Figure 9

ML model

2/3/2012 (St. Johns)

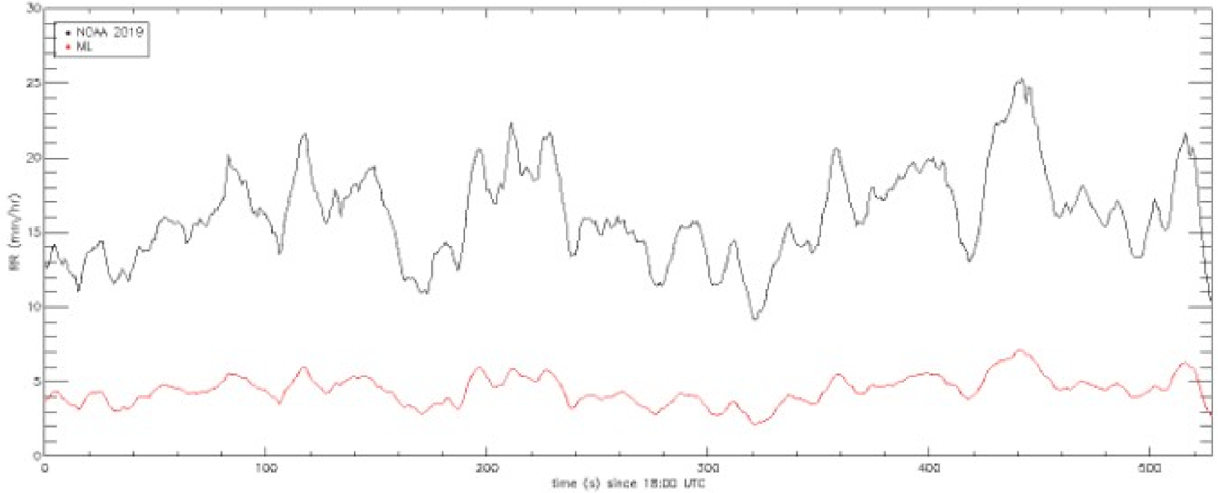
Substantially reduces RR

Slightly reduces WS



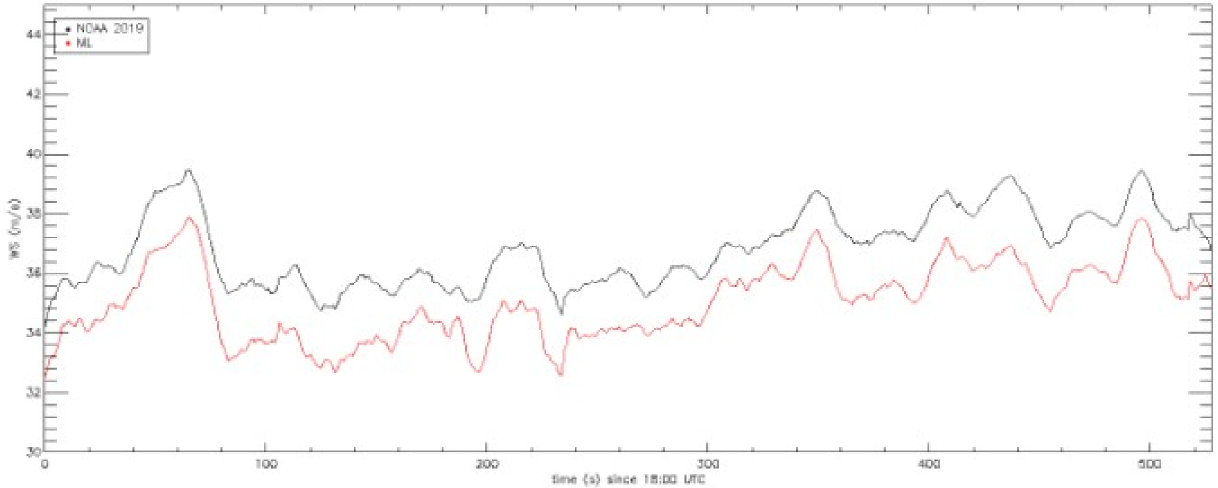
IWRAP Ku-band Reflectivity

Freezing level (black)



S19 RR (black)

ML RR (red)



S19 WS (black)

ML RR (red)

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Shortcomings of ML model

+ ML has the effect of “amplifying” the rain input to RTM

+ The self-emission of the ML results in more spreading of the Tb, which is desired

+/- The effect of the ML is parameterized by the rain rate.

- It requires that rain be always present

- Sometimes there is no rain, esp when T < 0 everywhere.

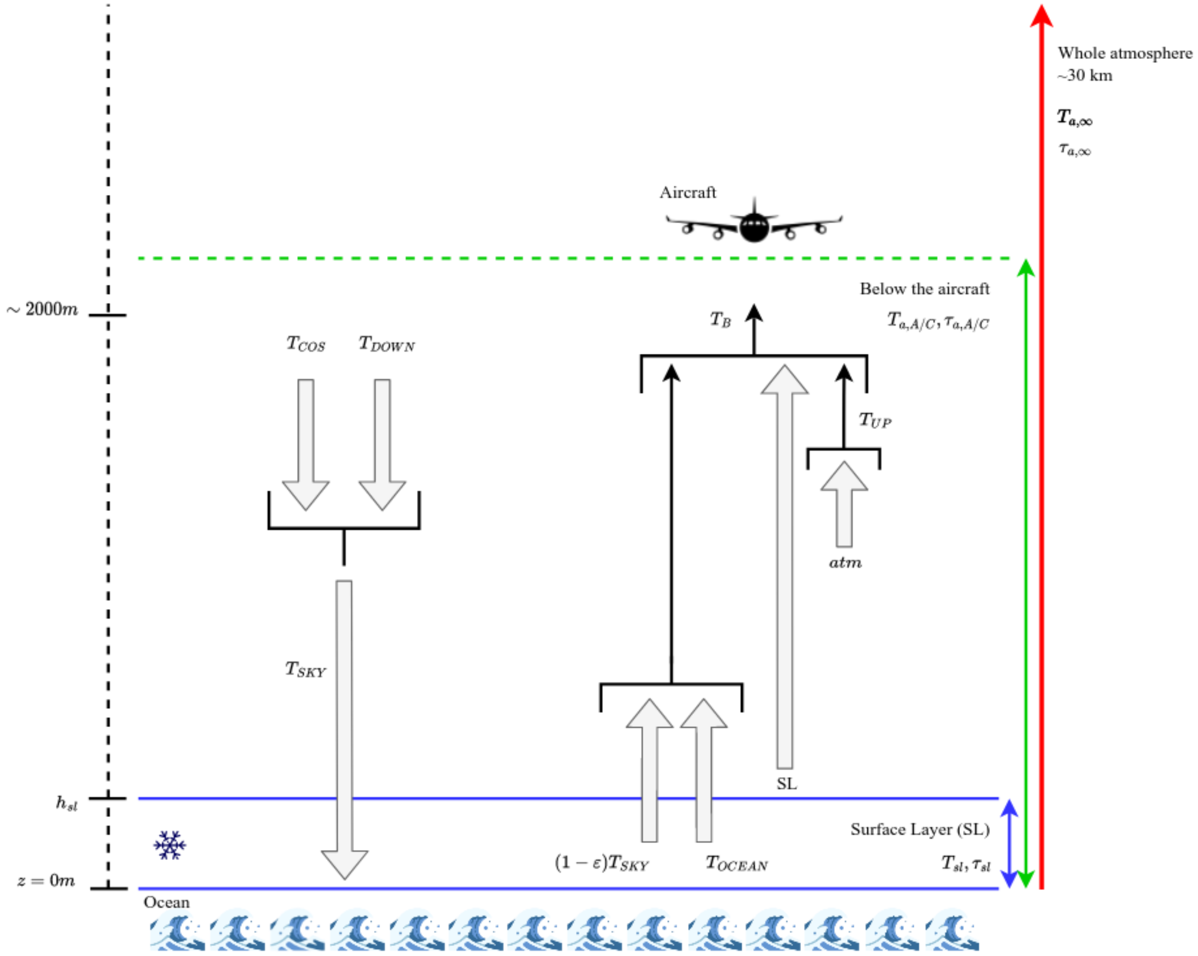
Surface Layer Model

Hypothesized presence of a "surface layer" of lofted mixed-phased particles

Excess emission from this surface-based layer would behave similarly to ML

Excess emission parameterized by the wind speed.

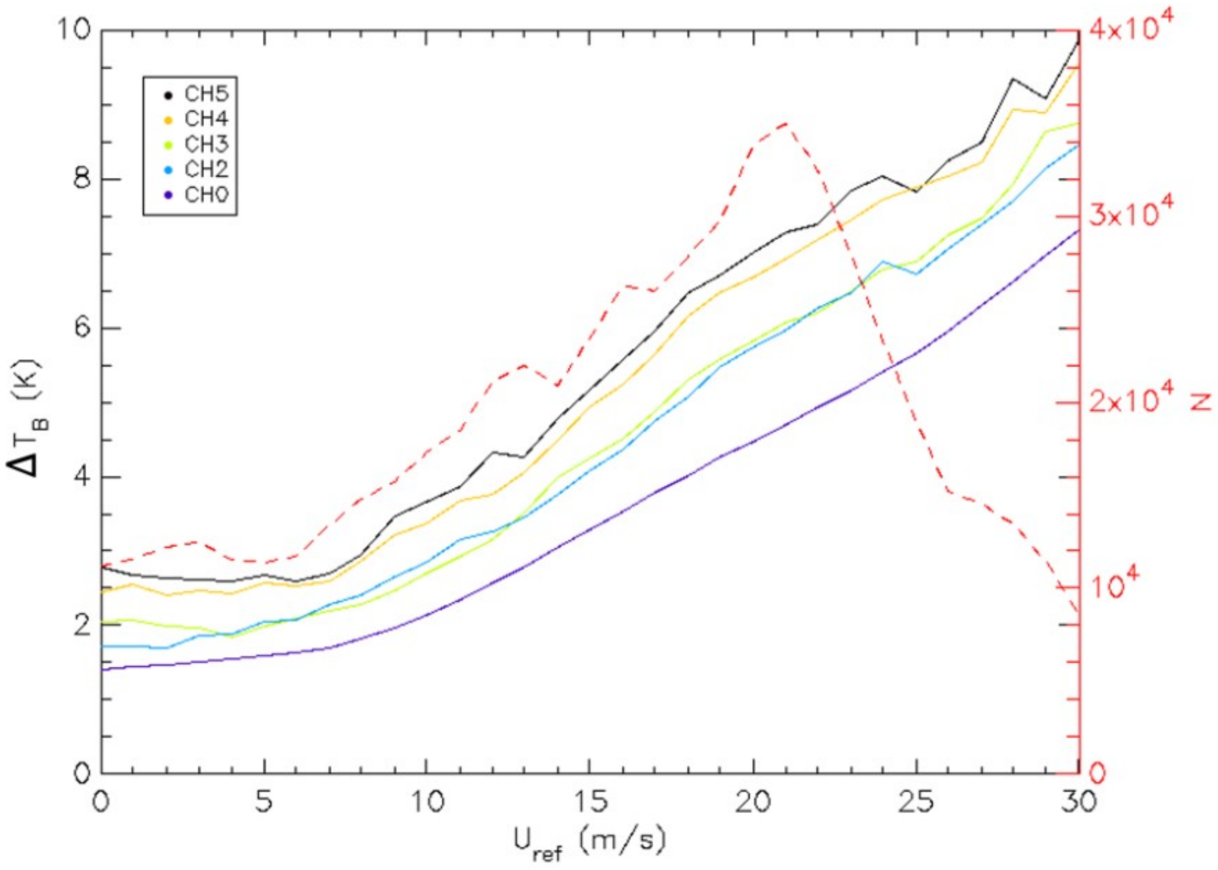
Icing conditions for surface vessels/platforms



Results

Measured minus Modeled Tb
vs reference wind
and frequency (solid lines)

Number of independent
observations (dashed line)

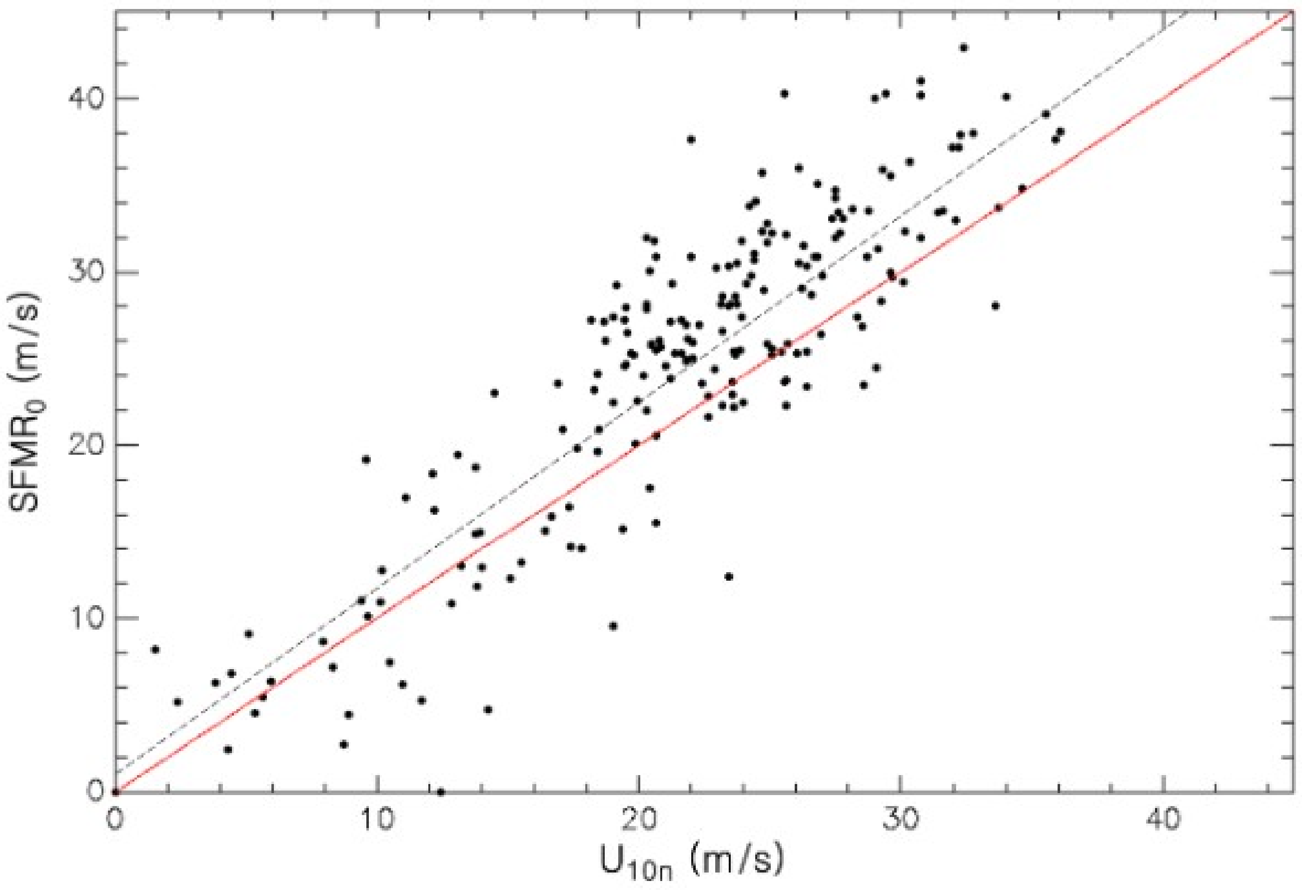


Reference Wind

We have surface truth at specific point in space and time via dropwindsondes

Use lowest freq channel in rain free conditions to obtain WS and compare with sondes

Use relationship to obtain 'equivalent' sonde wind for all locations, call it Uref.



Dropsondes

We have surface truth at specific point in space and time via dropwindsondes

Use lowest freq channel in rain free conditions to obtain WS and compare with sondes

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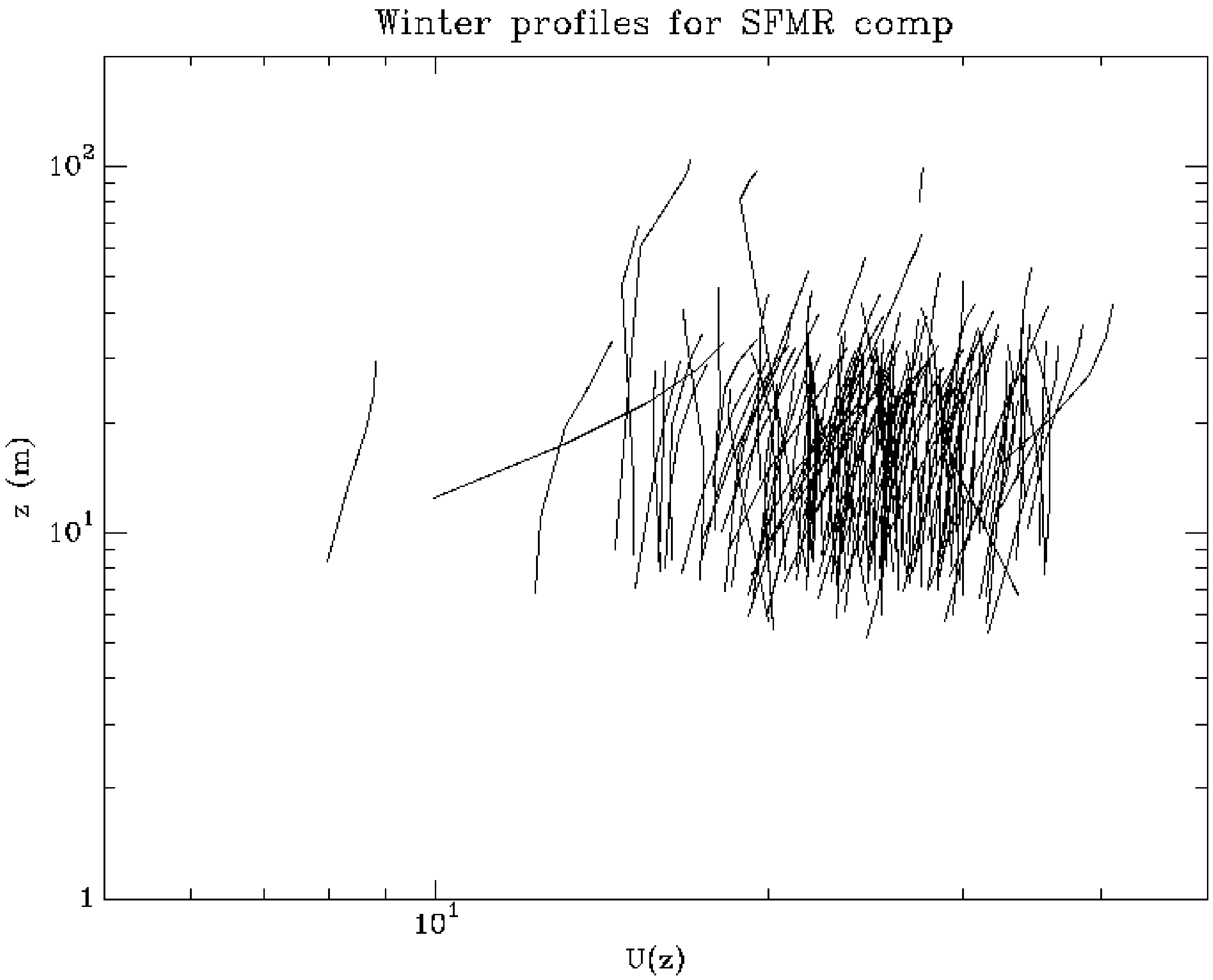
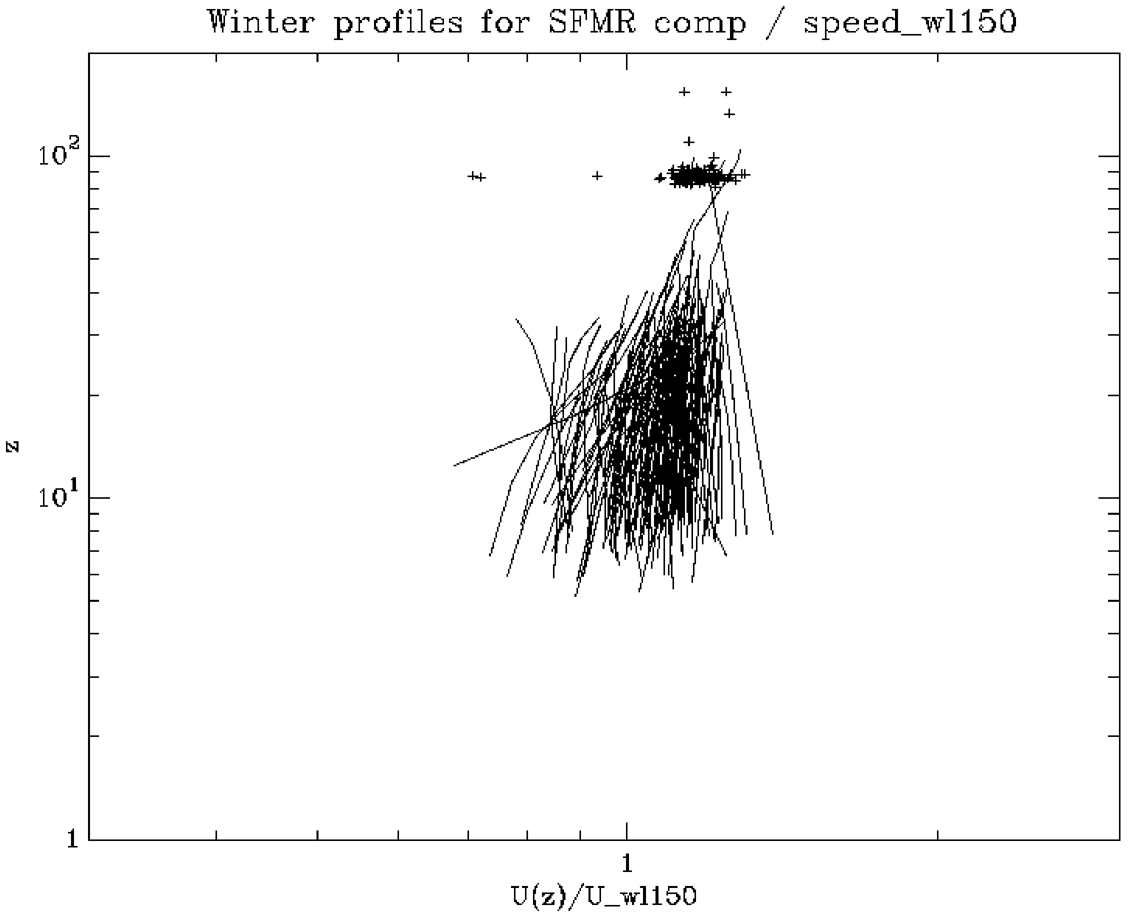
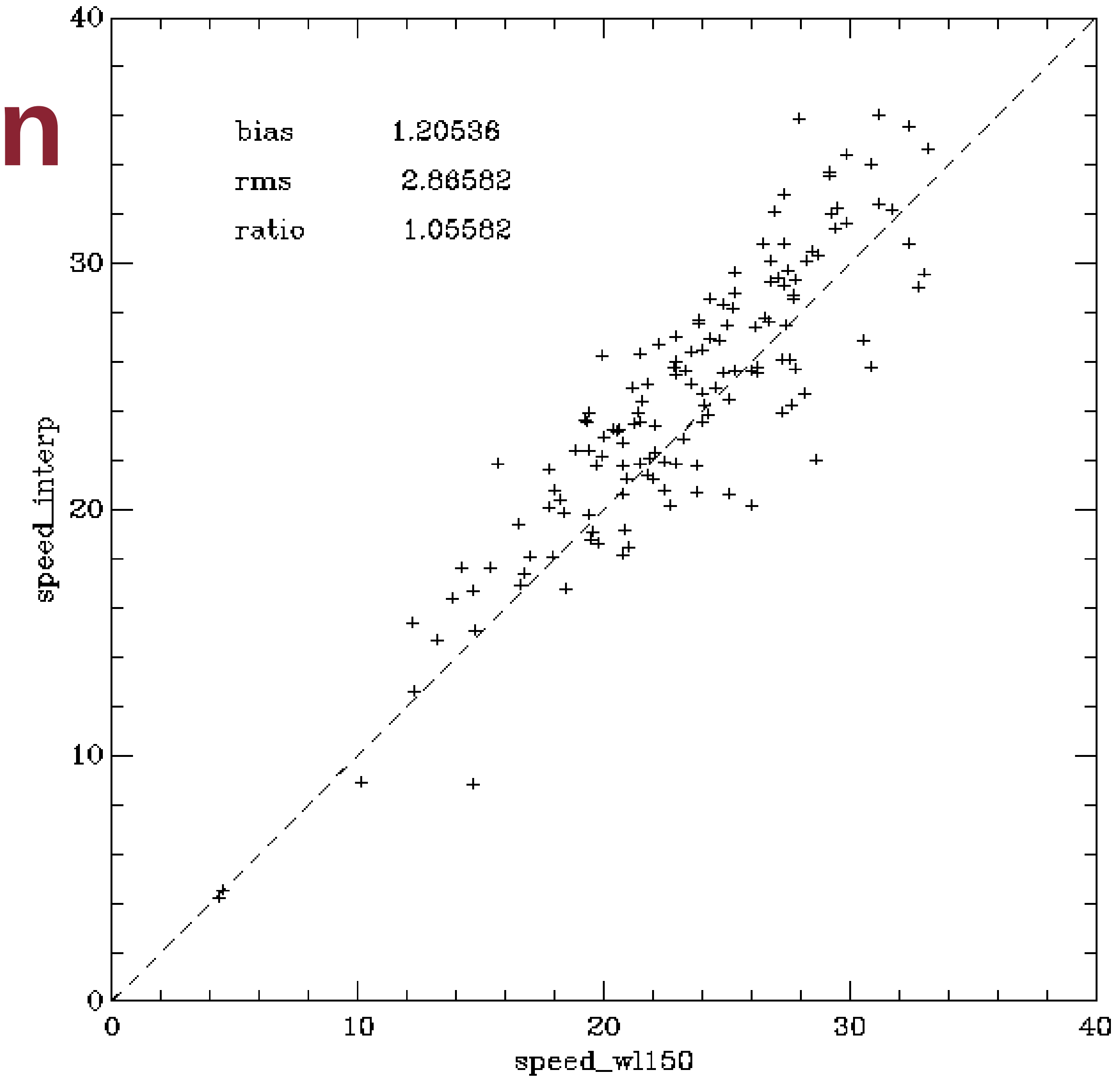


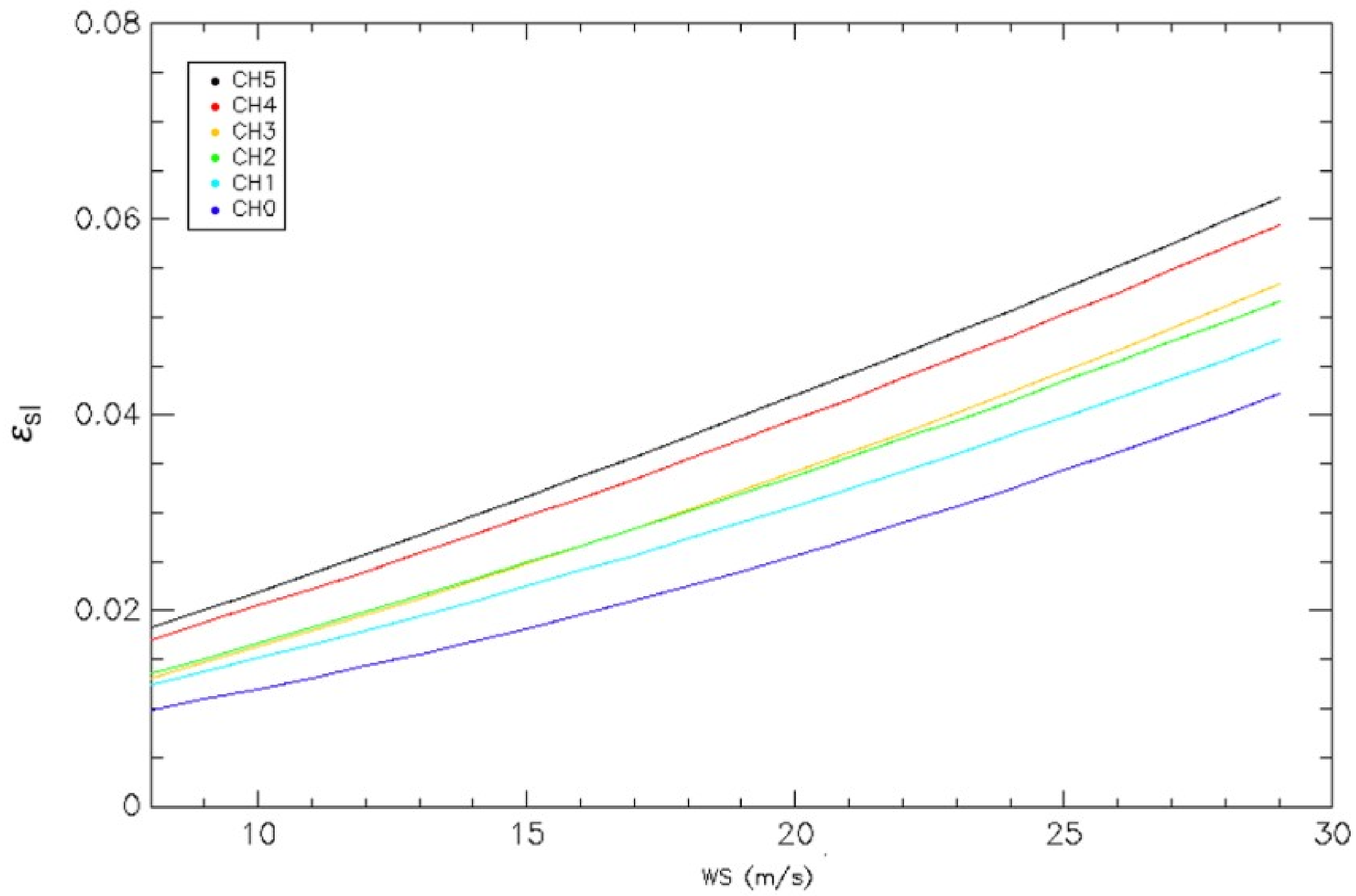
WL150 vs Interpolation





Results

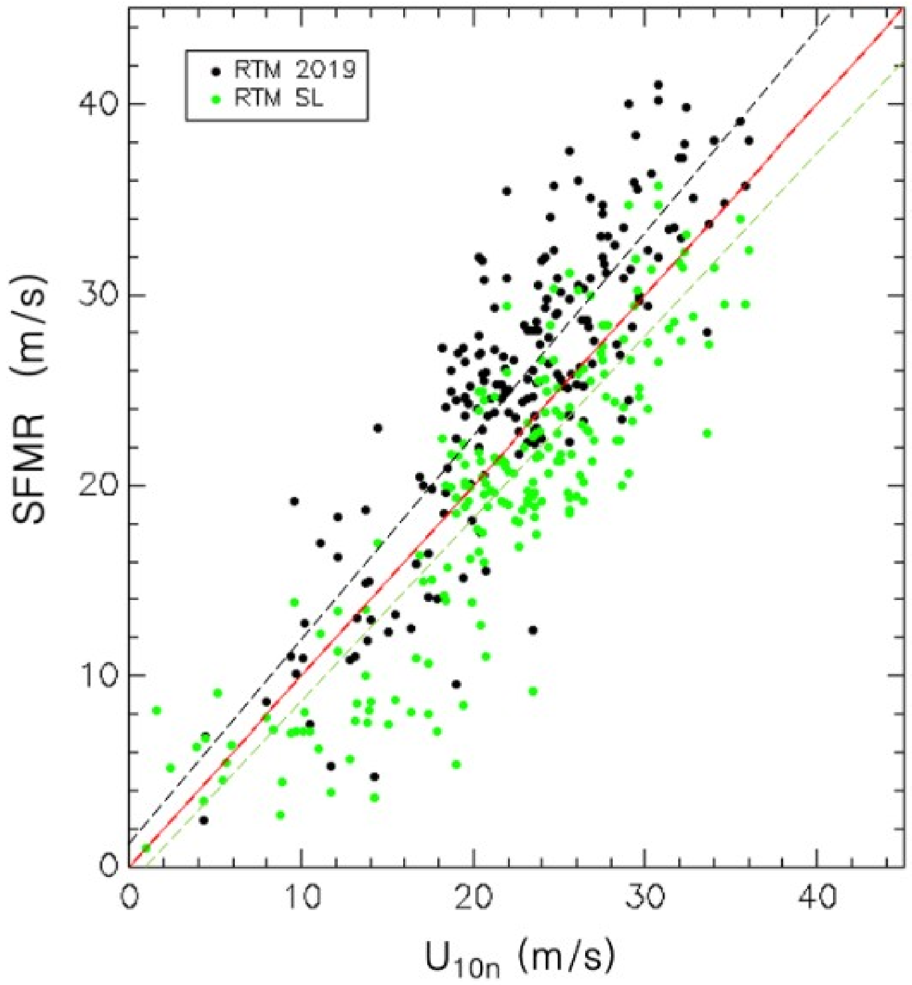
Excess emission over modeled result vs reference wind
And frequency



Results

Impact of incorporating excess emission on wind retrievals

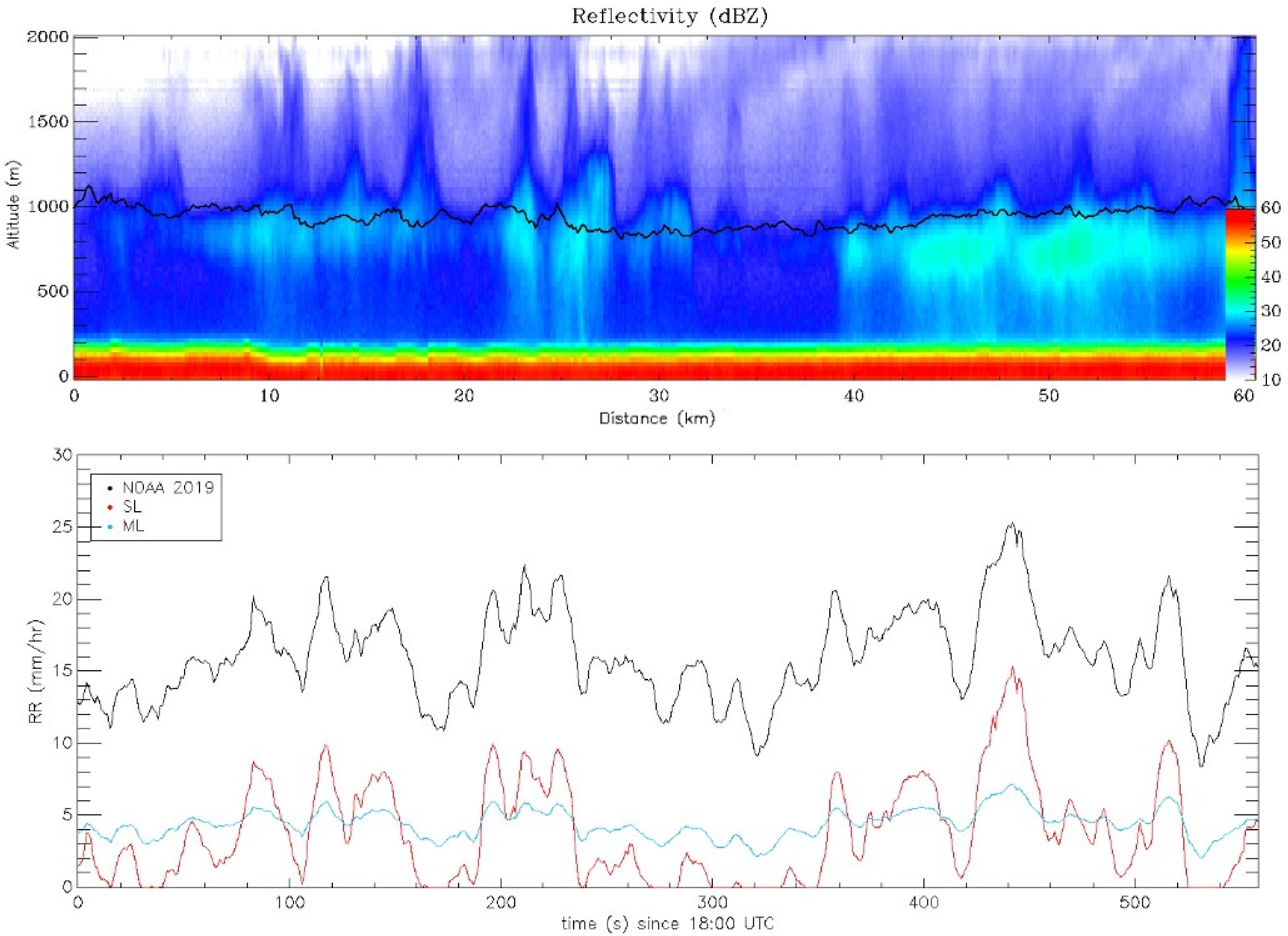
Comparison with sondes shows reduced bias at higher winds



RR revisited

SL model also reduces RR while preserving observable structure

Rain rates appear more consistent with observed radar reflectivity



Summary

Application of the usual SFMR RTM in winter conditions underestimates the observed Tb

More spreading of channels than predicted

Considered two sources of excess emission: melting layer (rr), surface layer (ws)

Estimated the excess emission assuming it is due to a surface-based layer

Resulting RTM reduces the bias in SFMR winds compared to sondes for high winds

Rain rates also appear to be more consistent.

QUESTIONS & ANSWERS

WL150 vs Interpolation