Virtual Research Presentation Conference

A radar concept to observe the cold pools generated by mesoscale moist convection

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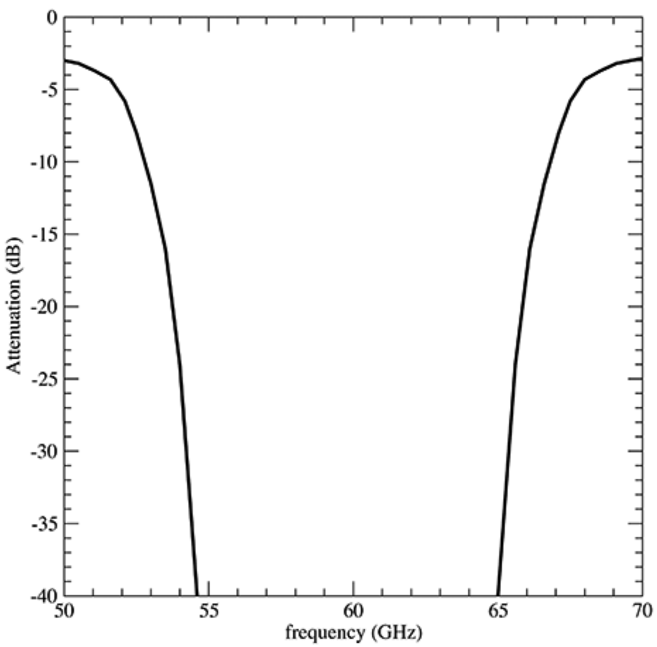
Tutorial Introduction

Abstract

JPL is developing a radar that would measure the total vertical absorption of its signal at two wavelengths, both close to the oxygen absorption band between 50 and 60 GHz.

The measurement would be sensitive to the column oxygen, which is a function of pressure, so an immediate application would be to estimate surface pressure, a very important quantity for numerical weather modeling and prediction. But numerical weather prediction is not a scientific research goal. What scientific questions (that cannot be tackled with other observations) could be addressed using this new technology?

This project was to quantify the extent to which an oxygen absorption radar could be used to observed the cold pools associated with convective storms. These regions of cooler and higher-pressure air form when precipitation falls out of the high anvil clouds of convective storms, into drier air (by definition), this precipitation starting the cycle of evaporative cooling, enhanced downward motion, more evaporation, more cooling etc. Could an O2 absorption radar see the cold pools?



Problem Description

Thunderstorms, especially when they organize into lines or clusters as Mesoscale Convective Systems, produce the lion's share of convective weather (and associated hazards).

The dynamics of this moist convection, its growth and organization, are still not represented realistically in our most advanced atmospheric models, and their evolution is therefore still poorly forecasted by the most advanced numerical guidance.

This was recognized in NASA's latest decadal survey, in which question W-4 ("why does convection form where and when it does?") is identified as one of the highest-priority questions to address in the coming decade.

JPL's A-Team study of "lifecycle of moist convection", led in the summer of 2019 by R. Ferraro, identified a short list of processes that need to be better understood to improve the representation of moist convection in models, and the "cold pools" generated by convective storms stood out as the main item that did not have any identified observation strategy.

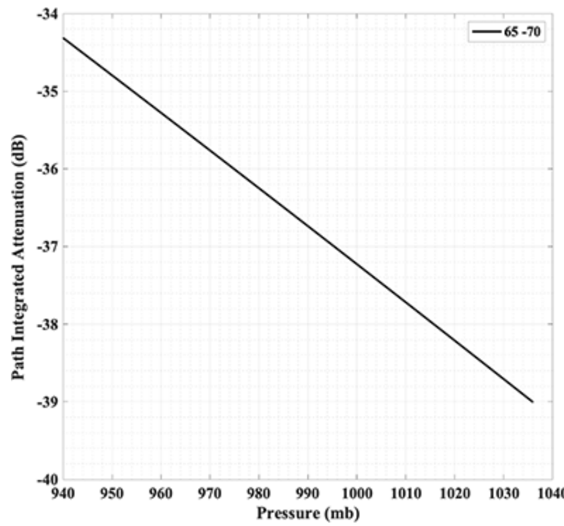
Understanding what controls the generation and morphology of the cold pools and their conflicting effects on the enhancement and organization or suppression of convection was recognized as a priority in the A-team study, but it will not be addressed at all in NASA's Clouds + Convection + Precipitation "Designated Observables" program because no instrument concepts (let alone instruments) have been proposed to observe the cold pools. Thus, there is a need, it is identified as high-priority in the decadal survey, and it will not be addressed by the corresponding decadal-survey designated-observables program.

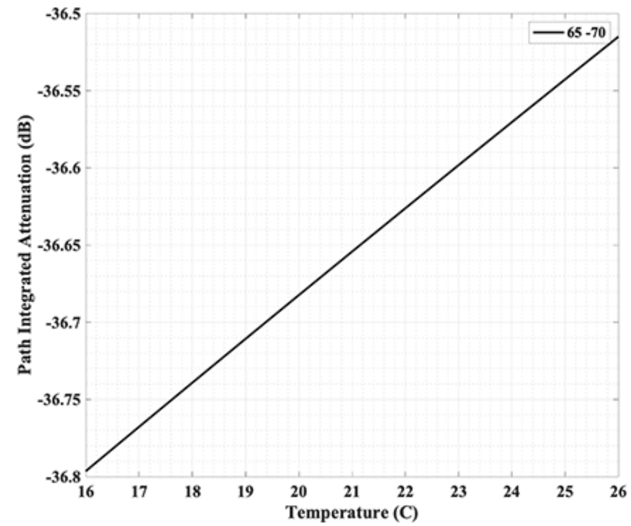
Millán et al ([1]) established the sensitivity to surface pressure of a radar operating between 50 and 55 GHz. That band conflicts with passive sensing, so we evaluate instead the band between 65 and 70 GHz, in light of the radar capability.

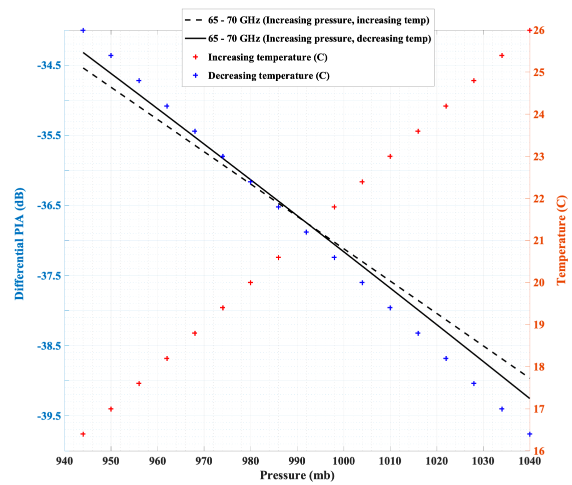
Methodology

We analyzed three cloud-resolving model simulations of Mesoscale Convective Systems that had already been conducted,

- first to calculate the expected radar signatures in the frequency band where the DABAV radar can operate (65 GHz to 70 GHz), and
- second to establish the relation between the variability across the storm of temperature, pressure, water vapor and condensed water within the radar field of view, on one hand, and the attenuation that the radar would measure at the given frequency.







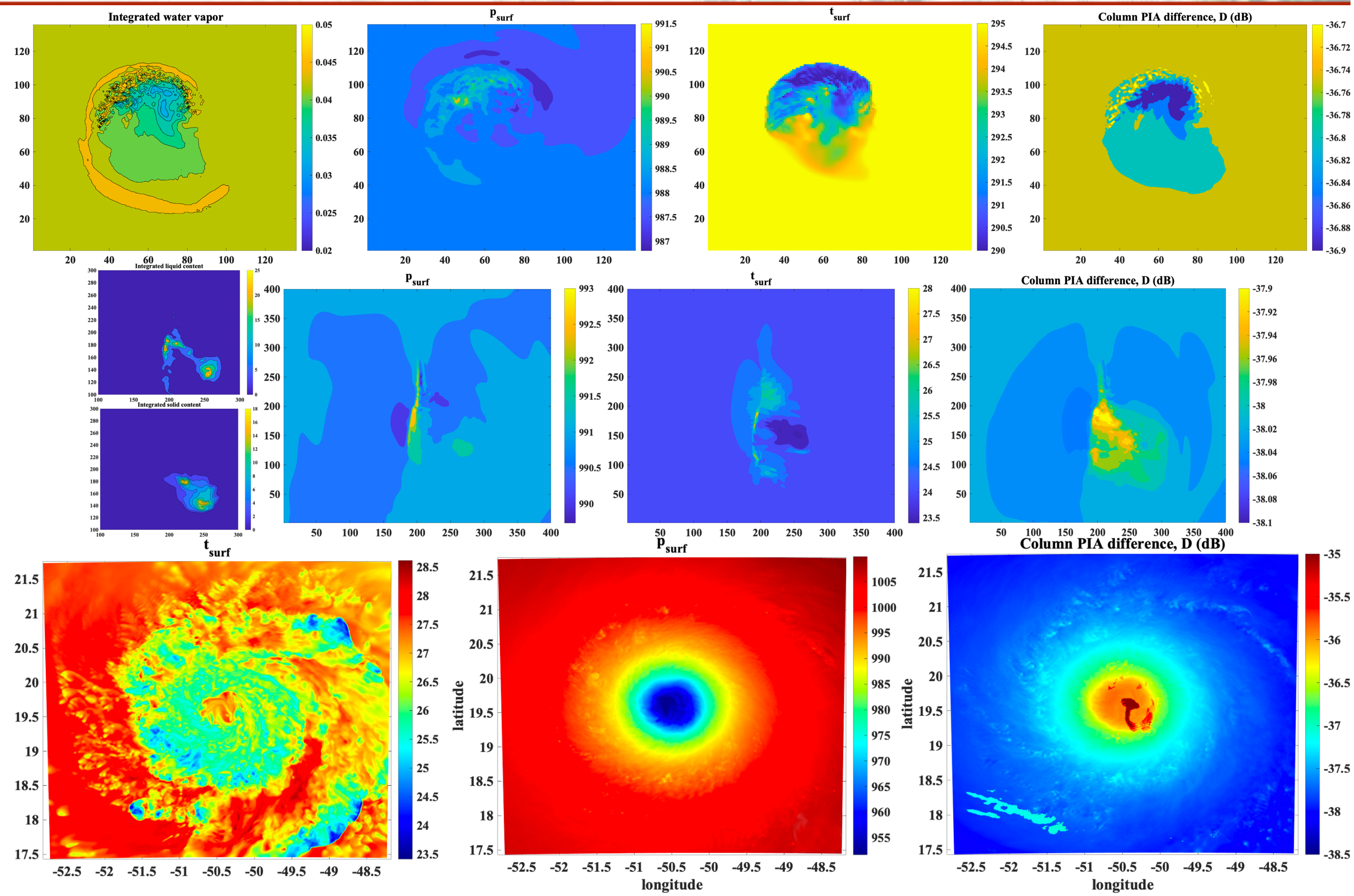
Results

Each row illustrates the analysis for one simulated storm.

The top row is a mid-latitudes storm ([2]), and already shows that the variation of the differential absorption in and out of the cold pool (navy in the rightmost panel) is a very small 0.2 dB.

The middle row, for a tropical simulation ([3]) confirms the extraordinarily high required sensitivity

The last row, a hurricane ([4]) is much more promising …



Publications and References

PUBLICATION in preparation

Sai Prashanth, Svetla M. Hristova-Veleva, and Ziad S. Haddad, “Sensitivity of oxygen absorption radar to the intensity of tropical and extra-tropical cyclones,” in preparation.

REFERENCES

[1] Luis Millán, Matt Lebsock, Nathaniel Livesey, Simone Tanelli and Graeme Stephens, “Differential absorption radar techniques: surface pressure”. Atmospheric Measurement Techniques volume 7, 2014, pp 3959-3970.

[2] Michael I. Biggerstaff, Eun-Kyoung Seo, Svetla M. Hristova-Veleva, and Kwang-Yul Kim, “Impact of Cloud Model Microphysics on Passive Microwave Retrievals of Cloud Properties. Part I: Model Comparison Using EOF Analyses,” J. Appl. Meteor. Climatol. Vol 45 (7), 2006, pp 930–954.

[3] Rachel L. Storer, and Derek J. Posselt, “Environmental impacts on the flux of mass through deep convection,” Quarterly Journal of the Royal Meteorological Society. Vol 145 (725), 2019, pp 3832-3845.

[4] David S. Nolan, Robert Atlas, Kieran T. Bhatia and Lisa R. Bucci, “Development and validation of a hurricane nature run using the joint OSSE nature run and the WRF model,” Journal of Advances in Modeling Earth Systems. Vol 5 (2), 2013, pp 382-405.