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High Latitude Cirrus Clouds and their Possible Relevance to Jet Steam Dynamics and Climate Engineering

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Arctic surface temperatures are increasing 2-4 times faster than the global average; a phenomenon known as Arctic Amplification (henceforth AA). Considerable scientific debate has emerged over the question of whether AA is influencing the jet stream via the relationship between temperature and wind, known as the thermal wind balance, which states that a decrease in the north-south (meridional) temperature gradient between polar and temperate regions is dynamically linked to a reduced vertical gradient in the zonal wind component of the jet stream. But factors other than AA may affect the jet stream, and recent work has shown that since AA primarily affects near-surface temperatures, its impact on the jet stream may be marginal.

Three independent satellite remote sensing studies have shown a substantial increase in Arctic cirrus cloud coverage during winter (a factor of $\sim$ 2 relative to all other seasons based on one study). Since the net warming from cirrus clouds is enhanced at high latitudes during winter (due to minimal shortwave cloud forcing), this winter build-up of Arctic cirrus will introduce net warming throughout the Arctic troposphere that may not be properly accounted for in climate models. If so, this would weaken the predicted meridional temperature gradient during winter, with climate models more likely to under-predict the waviness of the simulated jet stream and associated mid-latitude winter weather.

It can be argued that there are basically two types of cirrus clouds as far as their microphysical and radiative properties are concerned; those formed through homo- and heterogeneous ice nucleation (henceforth hom and het). Hom cirrus have higher ice particle number concentrations with smaller sizes than het cirrus, making them optically thicker for the same ice water path (with greater cloud net radiative forcing during Arctic winter). A CALIPSO satellite remote sensing study (Mitchell et al., 2016, ACPD) has recently provided evidence that hom cirrus are common in the Arctic, perhaps 50% or more. Current climate models that explicitly model cirrus clouds predict that het cirrus prevail in the Arctic; changing these cirrus clouds to hom cirrus should increase their tropospheric warming.

Using the Community Atmosphere Model version 5 (CAM5), we find that Arctic cirrus that microphysically conform to the above noted CALIPSO observations trap an additional 1 to 2 W m-2 relative to simulations that treat Arctic cirrus as het cirrus. This suggests that significant tropospheric Arctic warming (due solely to cirrus microphysics) is not accounted for in climate models, and that this warming will be greater if the winter cirrus build-up is not predicted.

Finally, the CALIPSO study noted above indicates that the climate engineering method known as cirrus cloud thinning (CCT) may be feasible since hom cirrus appear to prevail at high latitudes during the cold season. This is a pre-condition for CCT to be viable. Outside the $\pm$ 30° latitude zone, CAM5 simulations based on these CALIPSO observations indicate that CCT could yield a net TOA cooling of $\sim$ 1 W m-2.