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An A-train climatology of extratropical cyclone clouds

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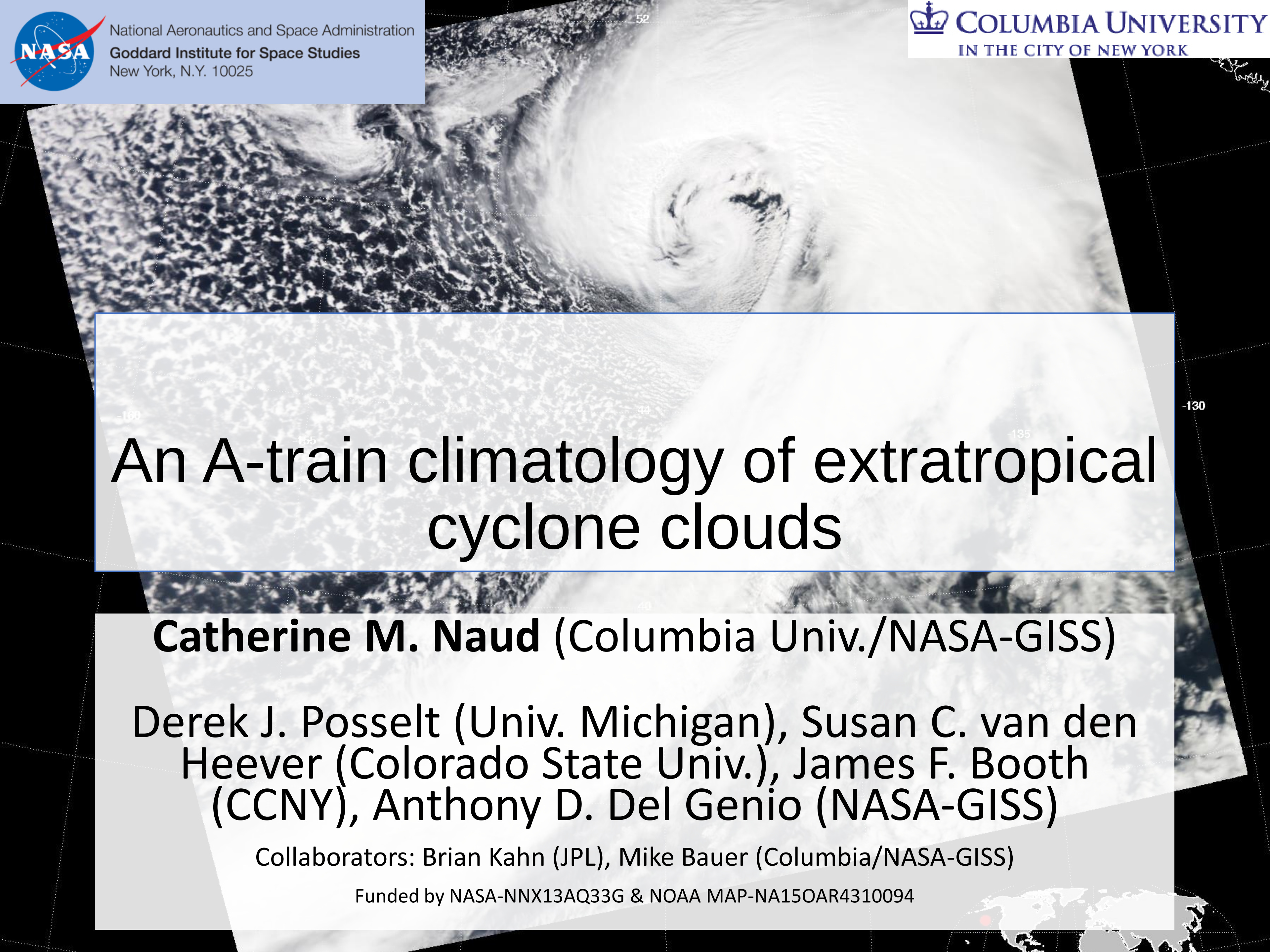
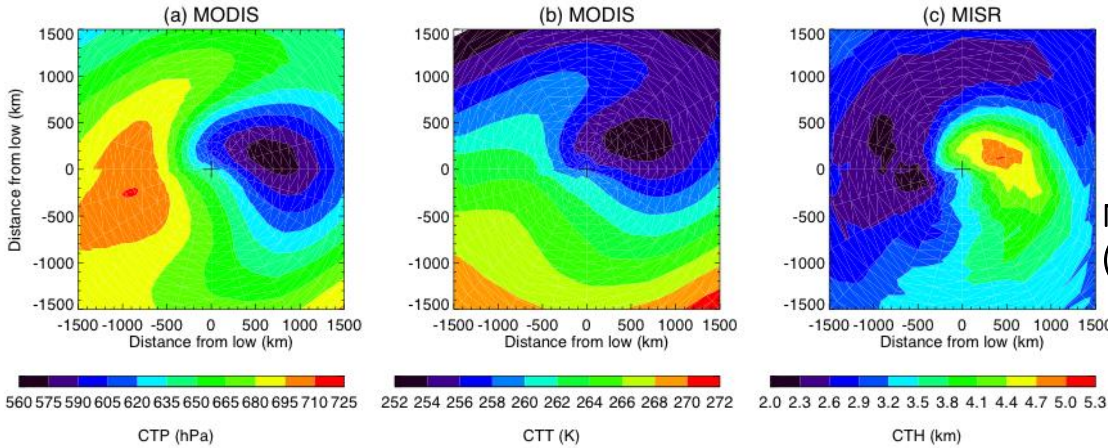


Why extratropical cyclones?

- Extratropical cyclones (ETC) = main purveyor of precipitation in midlatitudes (Catto et al., 2012)
- Models struggle to represent the right amount of cloud in SH cyclones (Bodas-Salcedo et al., 2014), causing an excess in absorbed shortwave radiation at the surface.
- No consensus amongst models on evolution of ETC strength in warming climate, presumably caused by issues with moist processes representation.
- What has the A-train taught us on the climatology of these systems, especially the less observed SH ETCs?
- How can we use the A-train observations to constrain and evaluate GCMs?

A-train observations of clouds in SH ETCs



Naud et al (2014)

Pole
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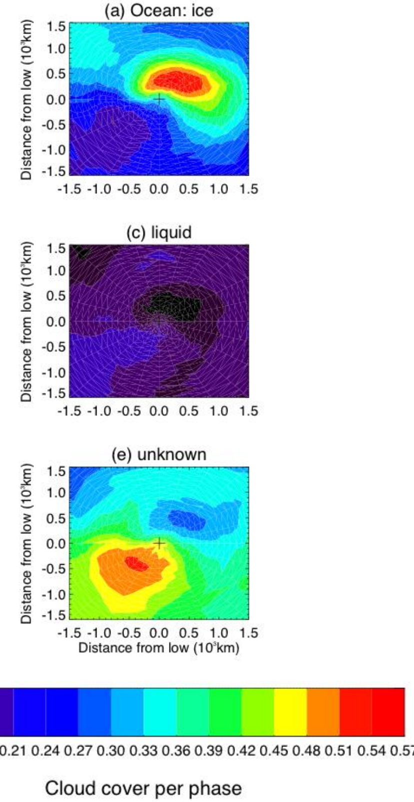
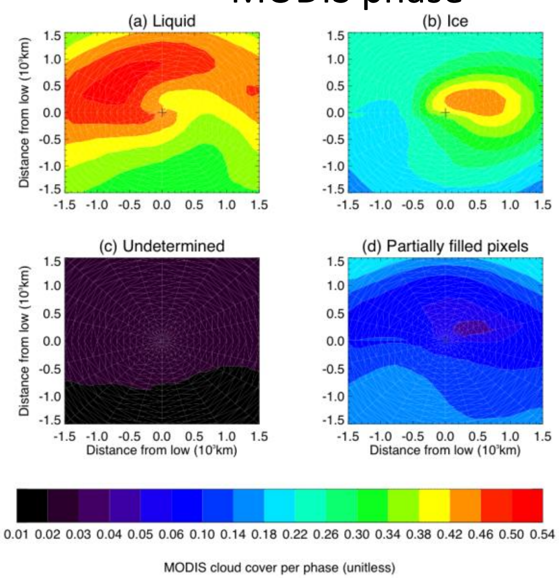
|
|
|
V
Equator

AIRS phase



MODIS phase



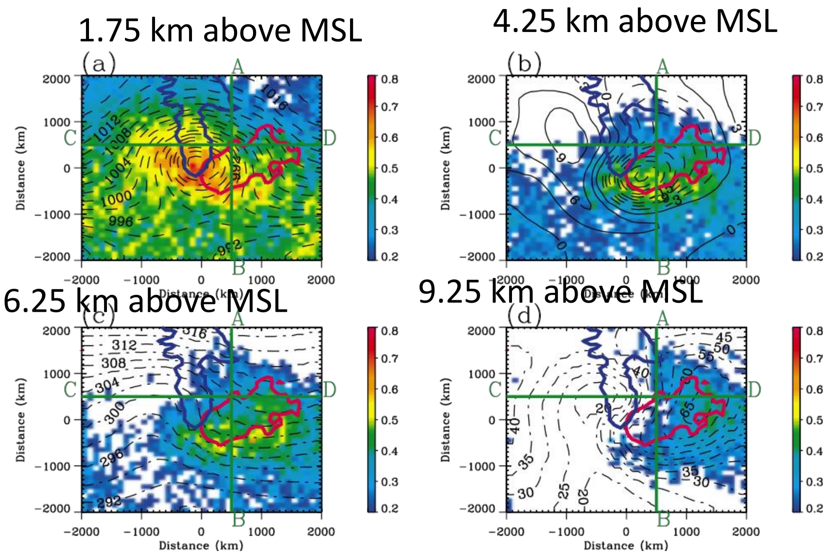
SH summer ocean ETC climatology

Cold sector clouds = low-level, warm top, liquid and/or supercooled liquid, scattered

Warm front: high/cold ice clouds

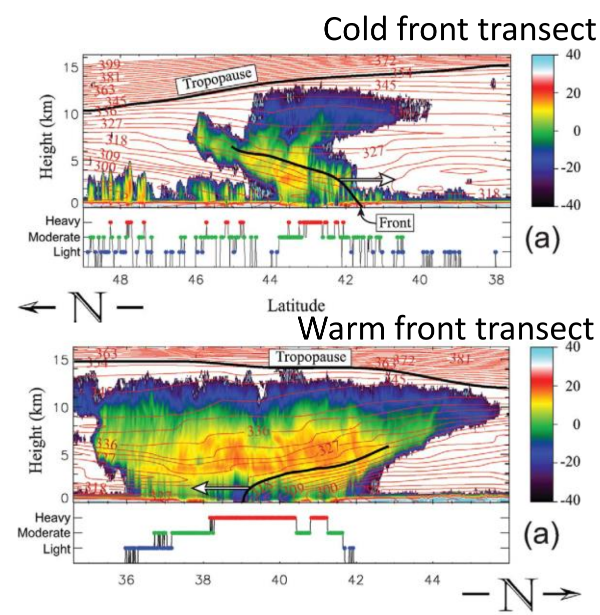
Warm sector: high but relatively warm ice clouds

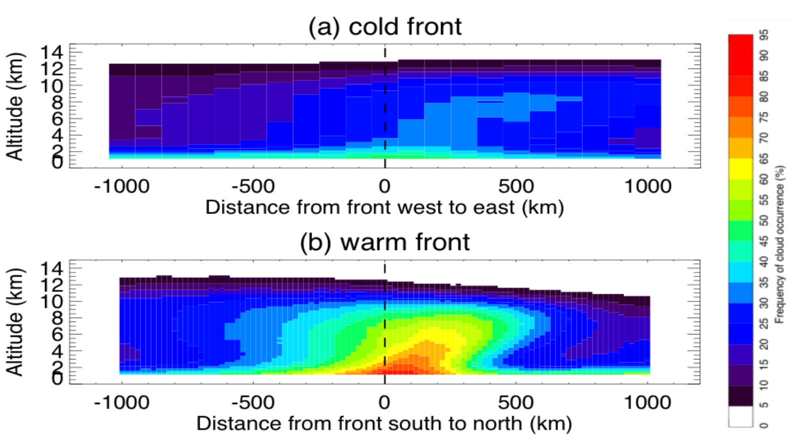
3D view: the advent of CloudSat & CALIPSO



Left: 3D view of cloud distribution in SH cyclones using GEOPROF-LIDAR Govekar et al (2011)

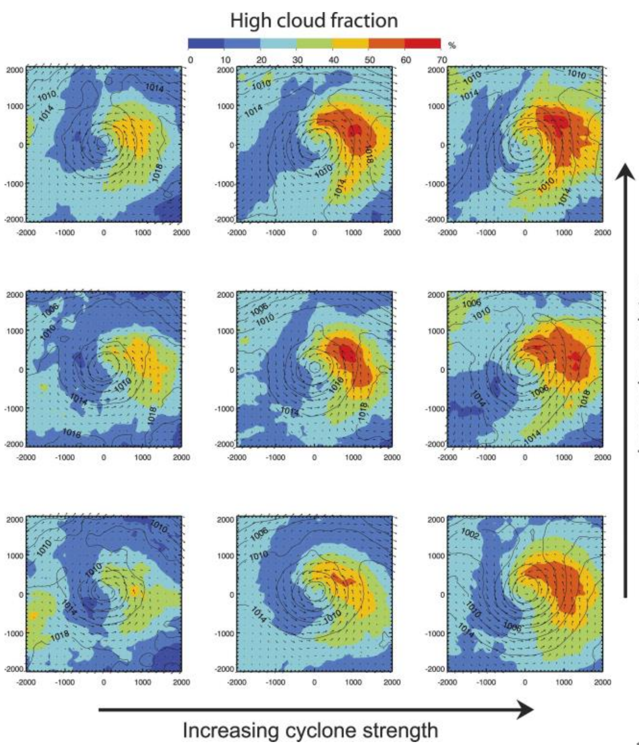
Below: first observations of vertical structure of radar reflectivity across warm and cold fronts from space. Below: individual cases (Posselt et al. 2008)





Left : global mean composites using GEOPROF-LIDAR (Naud et al., 2010; 2012; 2015)

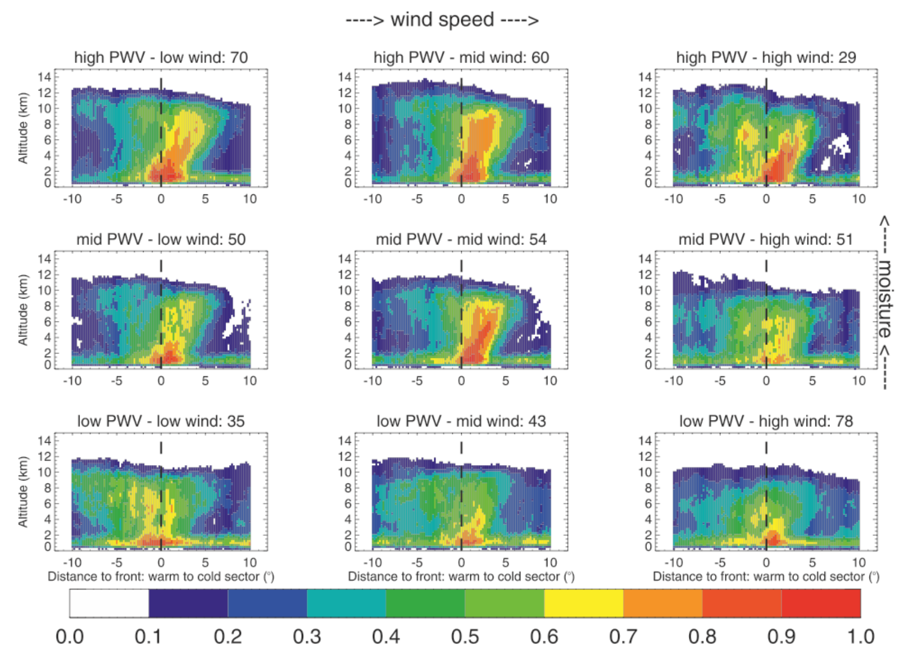
Cloud cover vs large-scale conditions

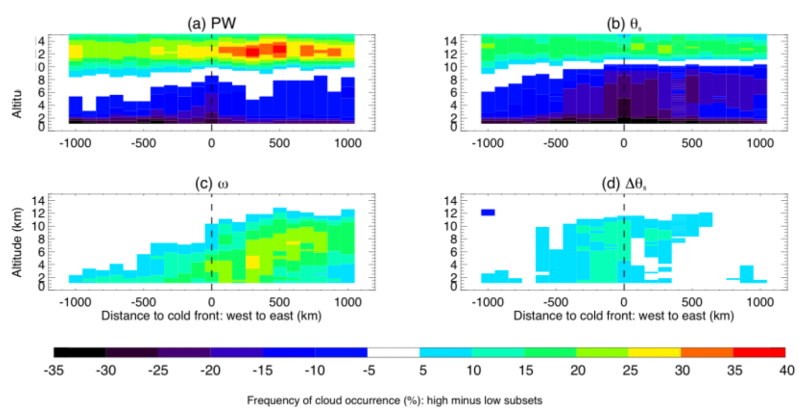


Field and Wood (2007): cyclone-centered composites of MODIS high-cloud fraction as a function of cyclone strength (surface wind) and moisture content: the role of the warm conveyor belt

SH ETCs drier than NH ETCs

Right: <u>Warm frontal</u> cloud cover more sensitive to changes in moisture amount than wind speed (Naud et al., 2012)



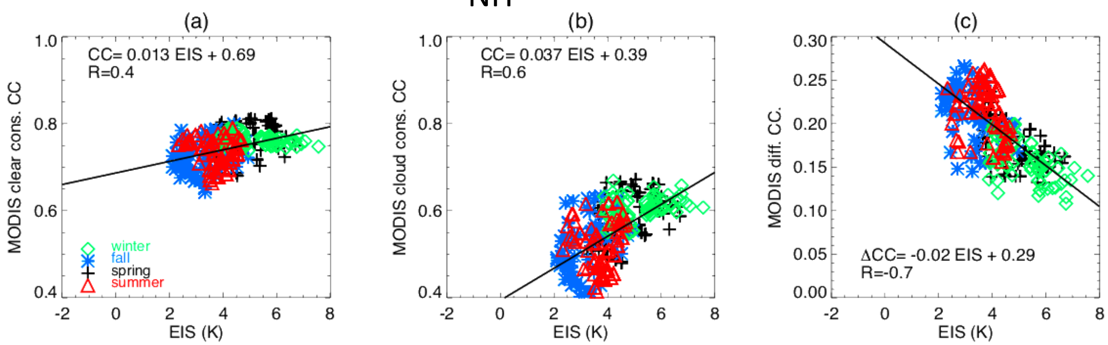


Impact of moisture/temperature strong across <u>cold front</u> too, but ascent strength has an impact in warm sector related to warm conveyor belt.

Cloud cover vs. inversion strength: post-cold frontal regions

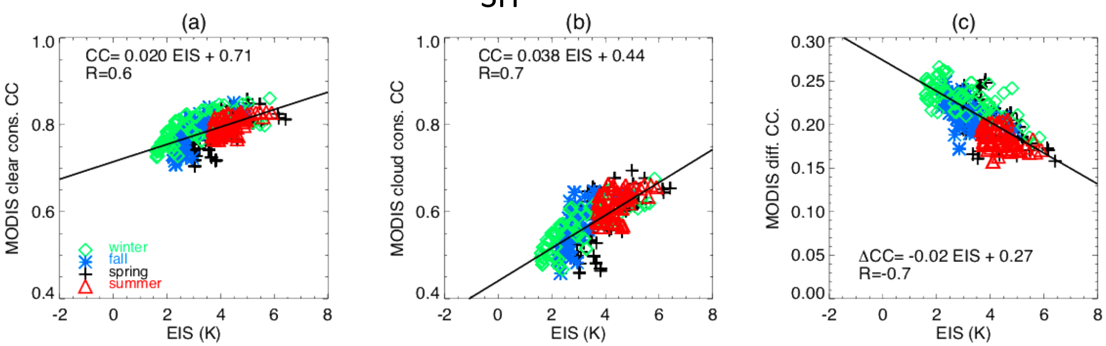
Post-cold frontal regions: subsidence regime, low level and scattered clouds
- Use MODIS low-level cloud cover and AIRS/AMSU-derived inversion strength parameter (EIS, Wood and Bretherton 2006)
- Explore relation between cloud cover and inversion strength across seasons and per hemisphere

NH



NH relation:
Linear across seasons, using 2 definitions of cloud cover and when using frequency of partially filled pixels

SH



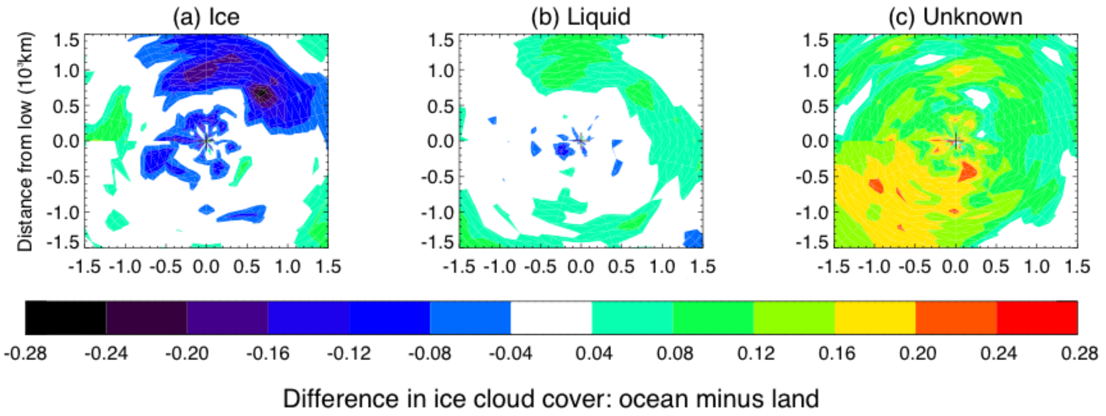
SH relation: stronger correlation per season, and across season

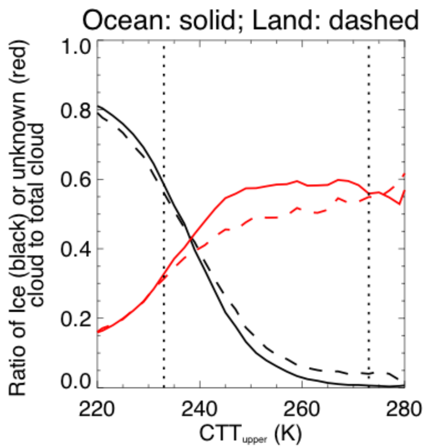
=> Large scale dynamics has less impact on cloud cover than expected vs. local conditions at seasonal scale

Naud et al., 2016

Land versus ocean ETCs: AIRS ice cloud fraction

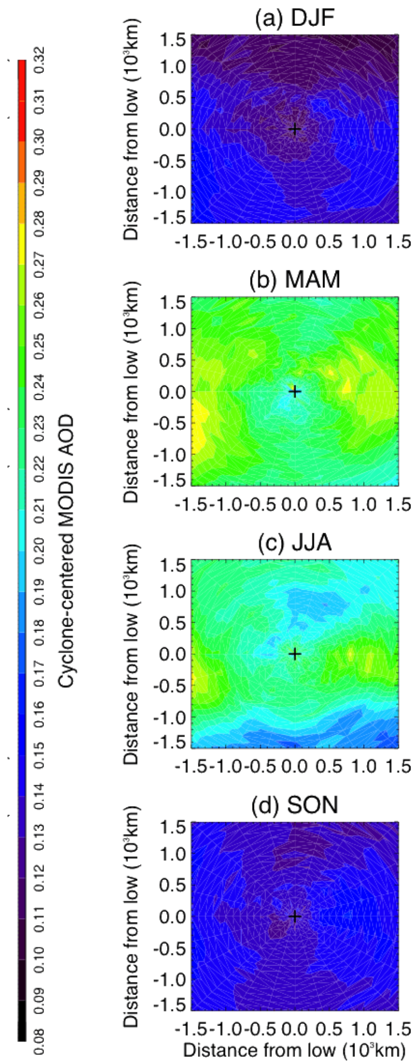
Land vs. Ocean: for similar PW/ascent land warm frontal regions display larger ice fractions than ocean cyclones => supercooled liquid more prevalent over ocean (Naud and Kahn, 2015)





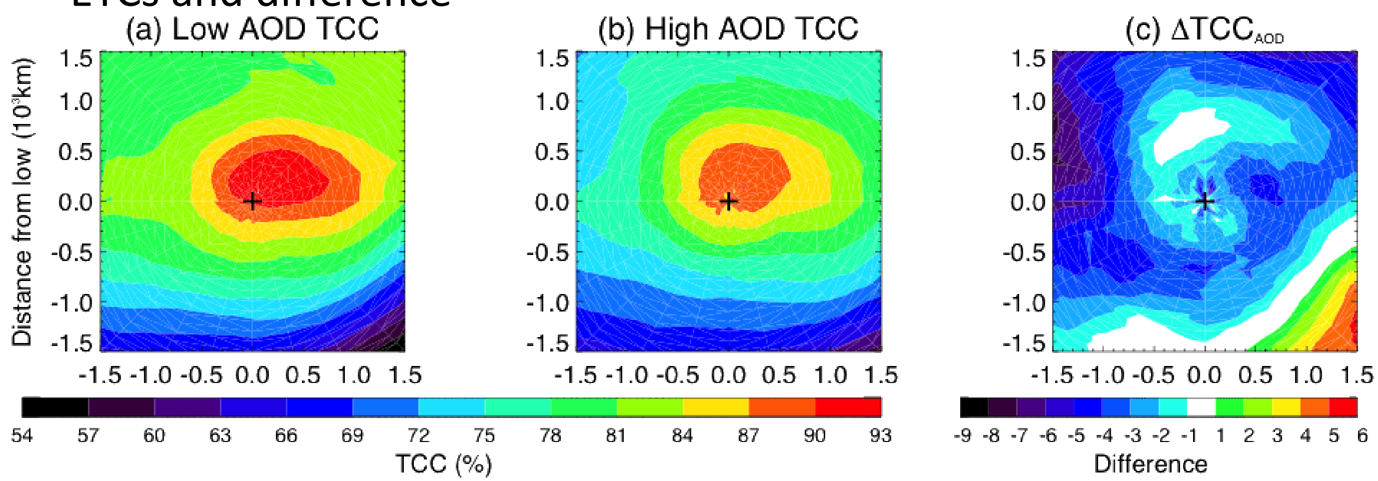
=> Impact of aerosols?

MODIS aerosols optical depth (AOD) in NH ETCs



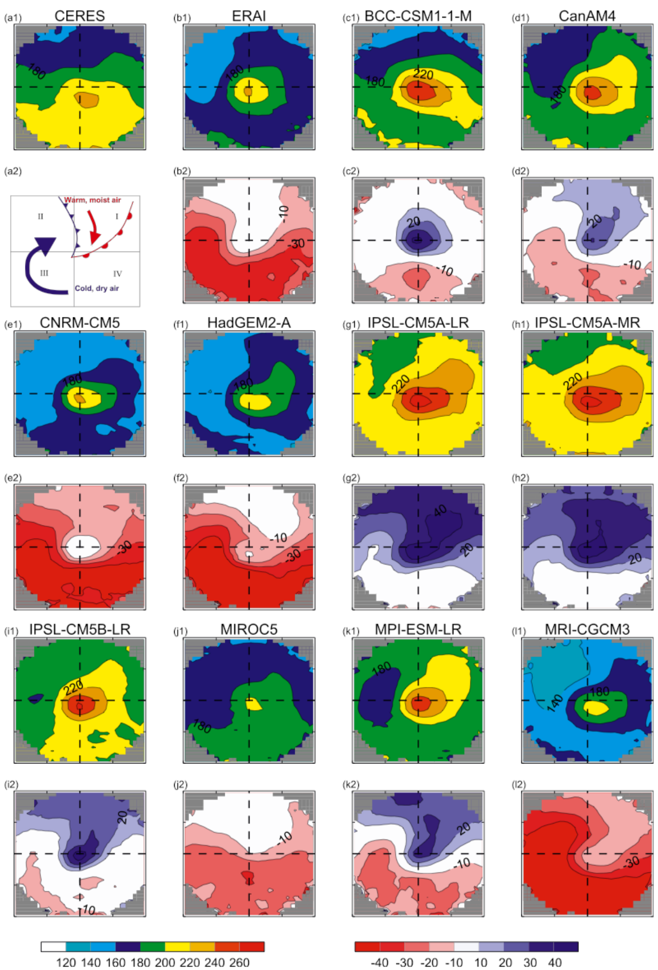
Left: NH ocean composites of mean MODIS AOD (Naud et al. 2016)

Composite of MODIS total cloud cover in high and low mean AOD ETCs and difference

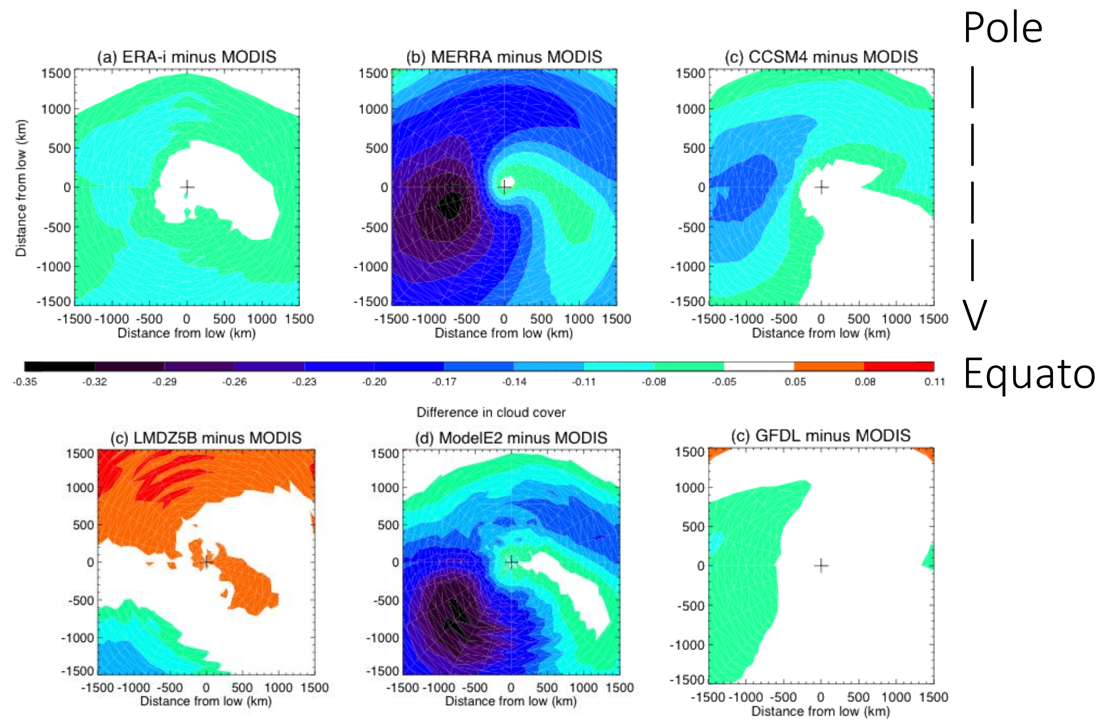


When constraining on PW and ETC strength, overall decrease in cloud cover between high and low AOD conditions in cold sector

A-train observations for model evaluation: ETC-centered metrics



TOA reflected shortwave radiation in CERES and 12 models, and difference Model minus CERES (Bodas-Salcedo et al, 2014)



Difference in SH warm season total cloud cover between ERA-interim, MERRA, NCAR-CCSM4, IPSL-LMDZ5B, GISS-ModelE2, GFDL-AM4 and MODIS. Naud et al. (2014)

Largest cloud cover bias in cold sector => A-train description of these clouds

Conclusions

- A-train observations have provided us with
- 1) new information on climatology of SH cyclones
- 2) New 3D perspective from CloudSat-CALIPSO of clouds in these systems and across their frontal boundaries
- 3) better understanding of impact of large scale and local scale conditions on clouds and precipitation in these systems
- 4) new tools to explore complex relationship between aerosols, clouds and ultimately dynamics
- 5) new tools to constrain and evaluate GCM simulations