Cloud processes in midlatitude cyclones

Catherine Naud (Columbia Univ.) & **Brian Kahn** (JPL)
Collaborators:
Jimmy Booth (CCNY)
Anthony Del Genio (NASA-GISS)
Derek Posselt (Michigan Univ.)
Susan van den Heever (Colorado State Univ.)
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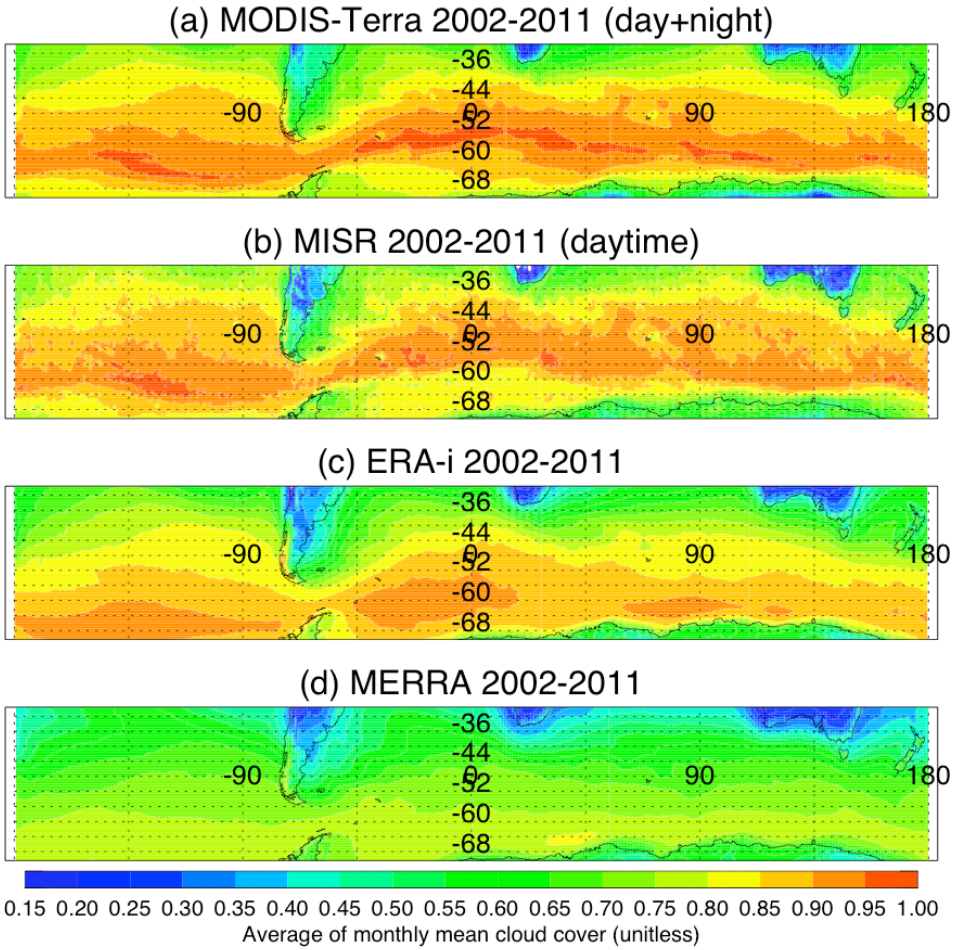
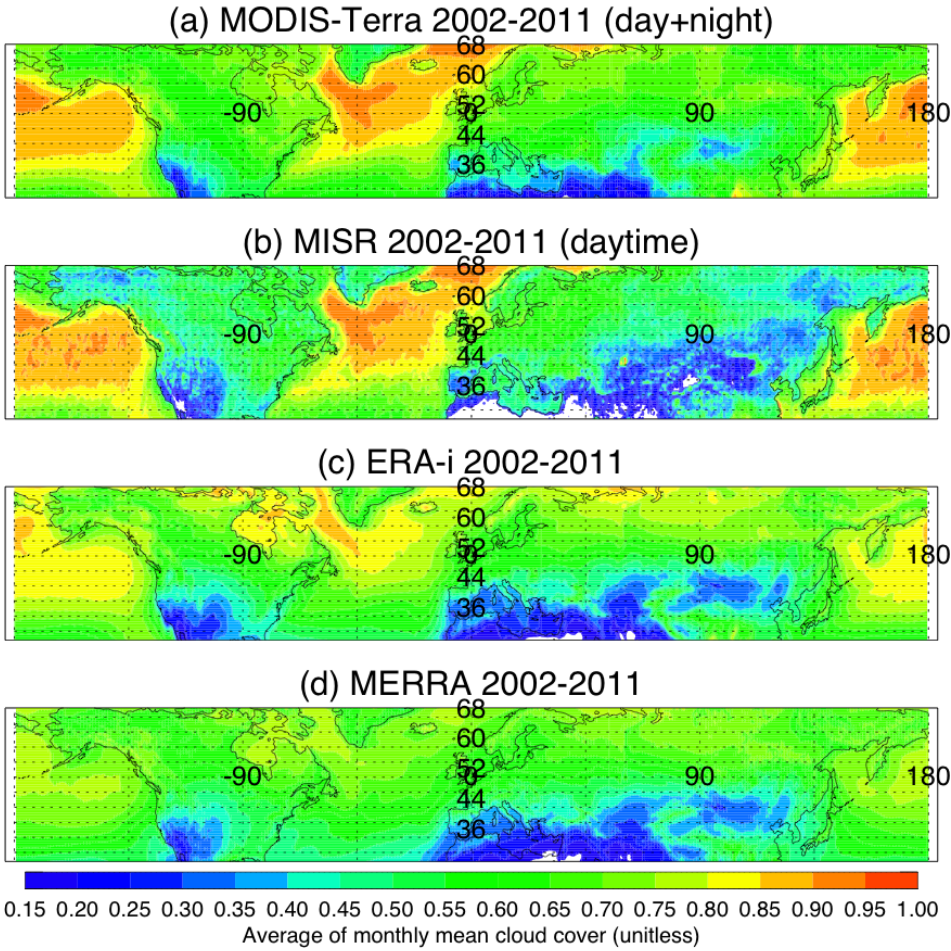
ERA-interim & MERRA cloud cover bias in the midlatitudes (2002-2011)

GCMs underestimate cloud cover in SH&NH midlatitude oceans: Same for reanalyses => Why?

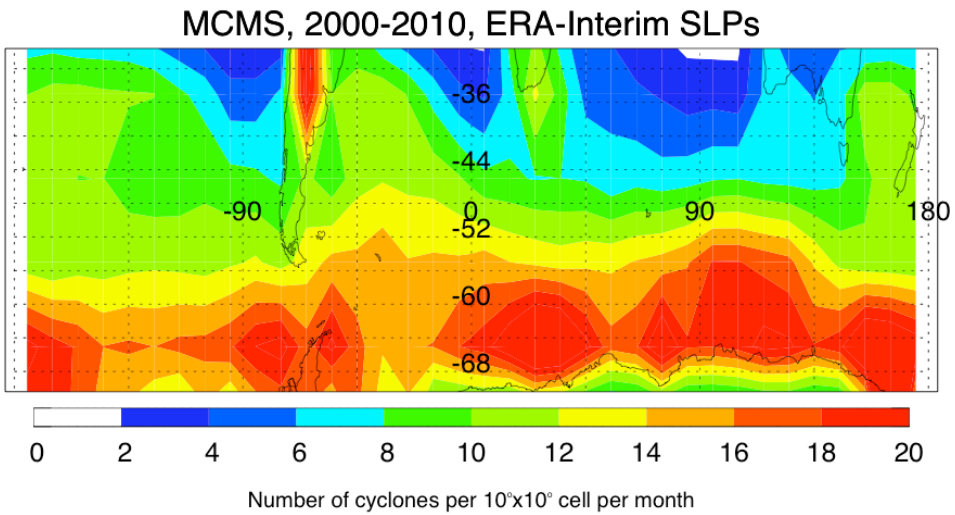
SH



NH



Extratropical cyclones



Number of cyclones that travel through 10°x10° boxes per month in SH (average 2000-2010)

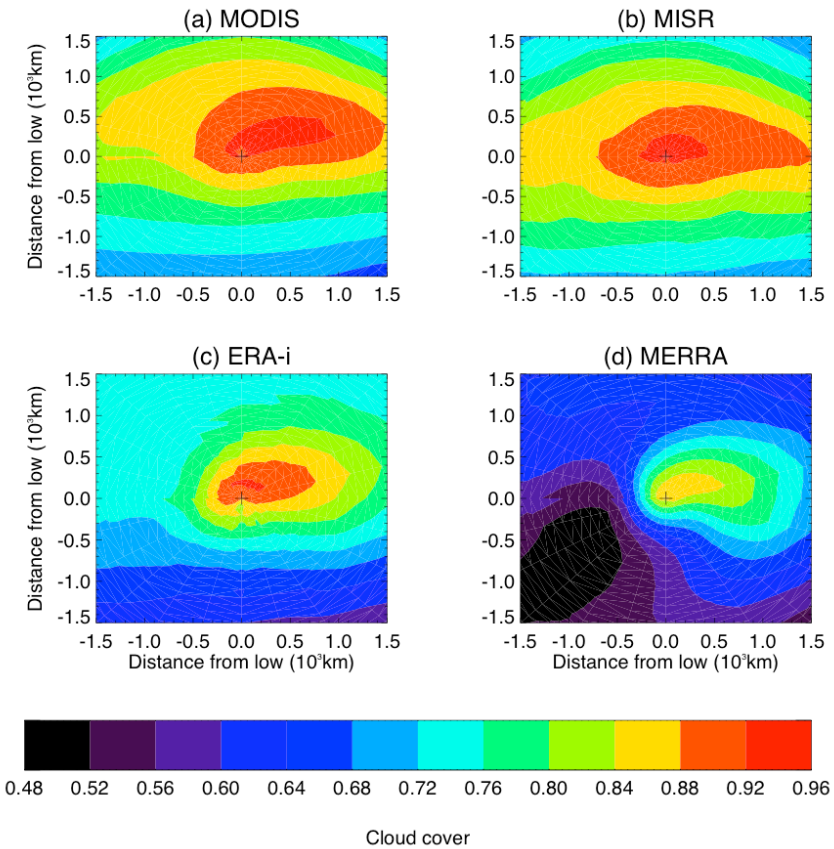
⇒ More than 1 cyclone every other day at some locations

⇒ Where maximum occurrence, also maximum cloud cover and maximum bias

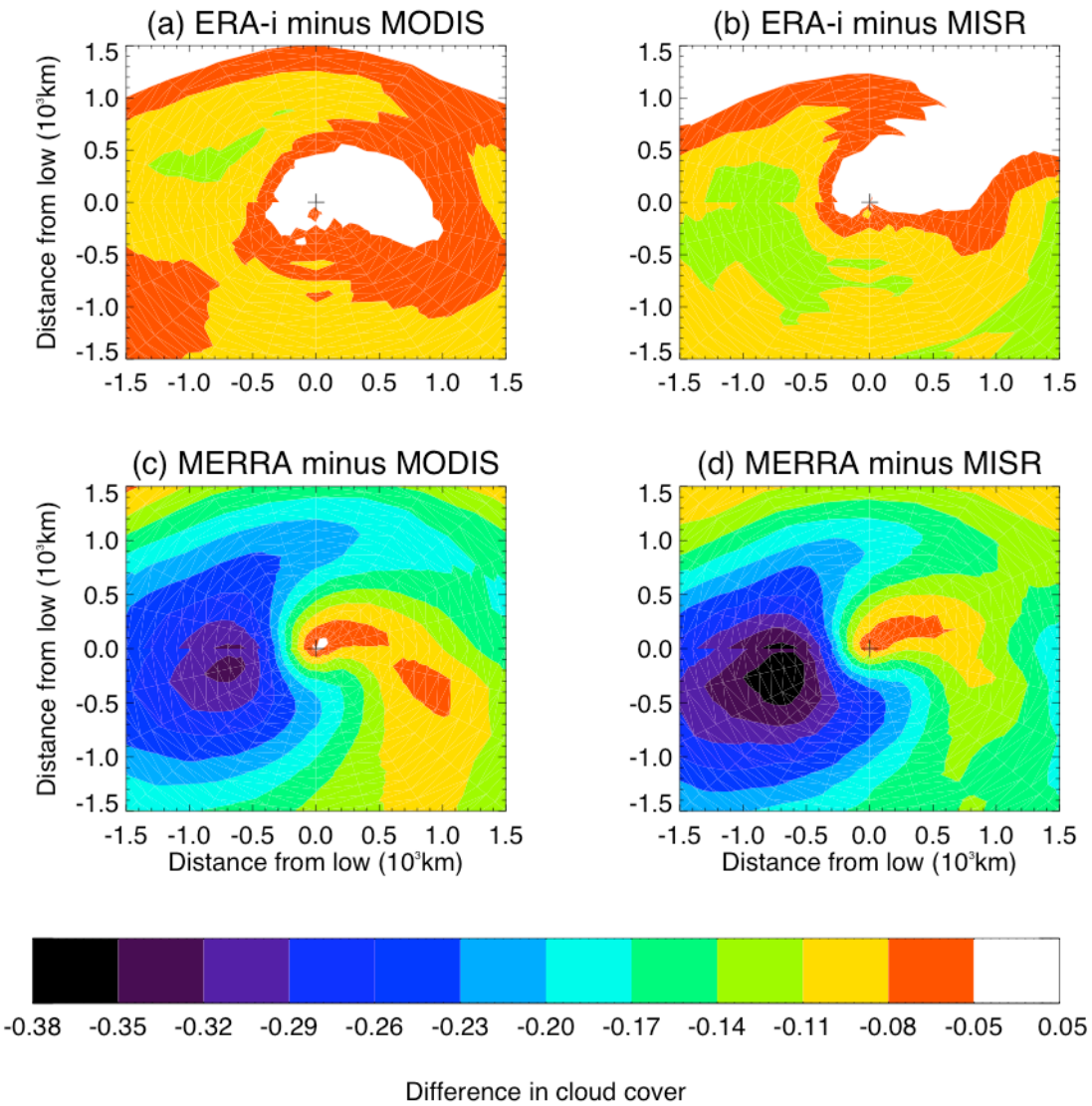
⇒ **Cyclones ideal laboratory to study diverse cloud processes: subsidence and ascent, moist vs. dry conditions**
+ convenient set up to evaluate models

Technique: isolate cyclones, locate cold and warm fronts and composite various fields of interest

Example: Cyclone-centered composite of cloud cover in SH warm season (NDJFM 2006-2010)



Reanalyses vs. observations cloud cover composites



ERA-interim:

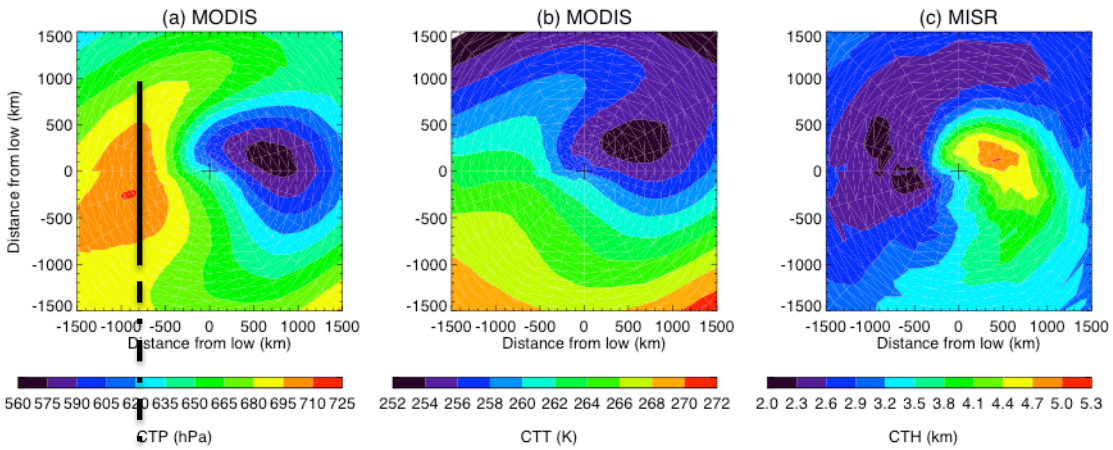
- Within observational uncertainty (4%) in warm frontal zone and on polar edge
- Largest difference 11-14% in western quadrant and 8-11% on equator side

MERRA:

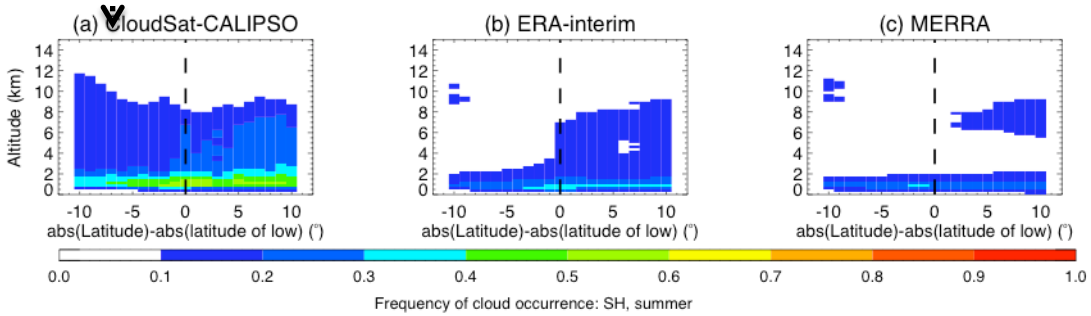
- Even in warm frontal and warm quadrant at least 5 to 11% low bias
- Western side of cyclone with low bias up to 38%

Western side of cyclones: what kind of clouds?

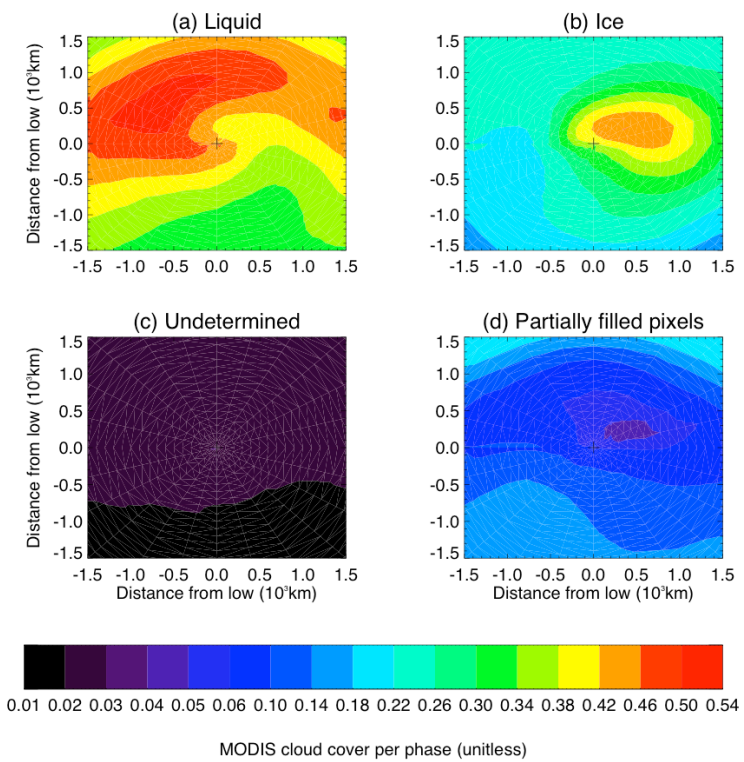
Cloud properties in SH cyclones



Western side: high MODIS CTP, fairly warm MODIS CTT and low MISR CTH

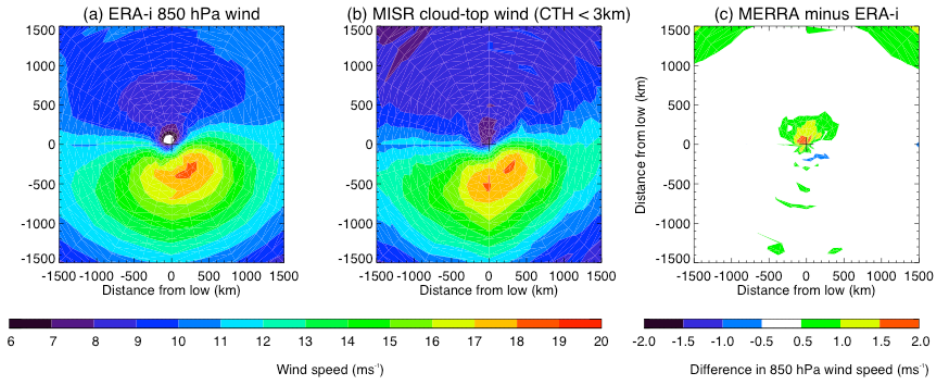


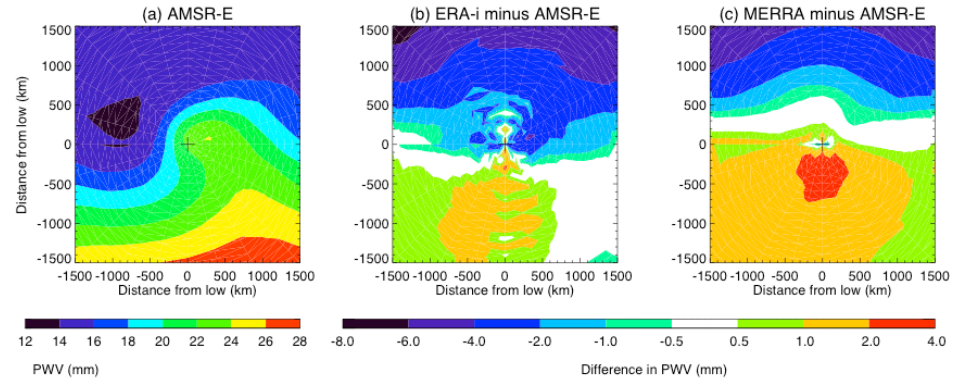
CloudSat-CALIPSO confirm mostly low level clouds, and low cloud fractions (i.e. possibly broken clouds)



Liquid/Supercooled clouds, and broken clouds (i.e. high freq. partially filled pixel)

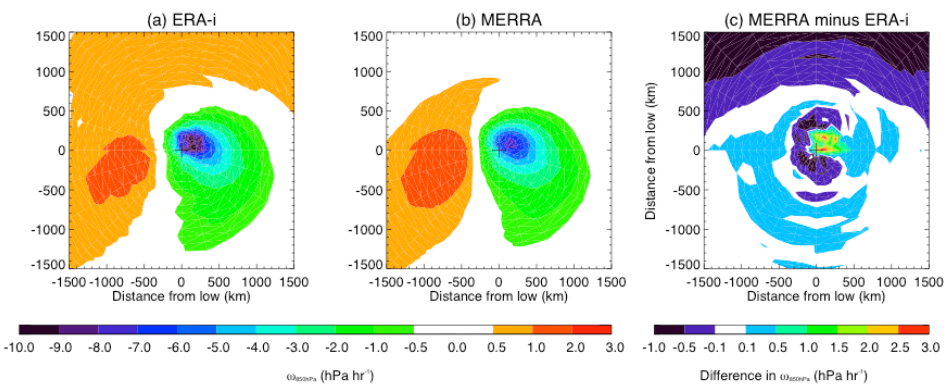
Difference between MERRA and ERA-I: different cyclones?





No difference in 850 hPa winds, similar to MISR CTH < 3km winds

No difference in PWV, less difference between each other than with AMSR-E and latter small



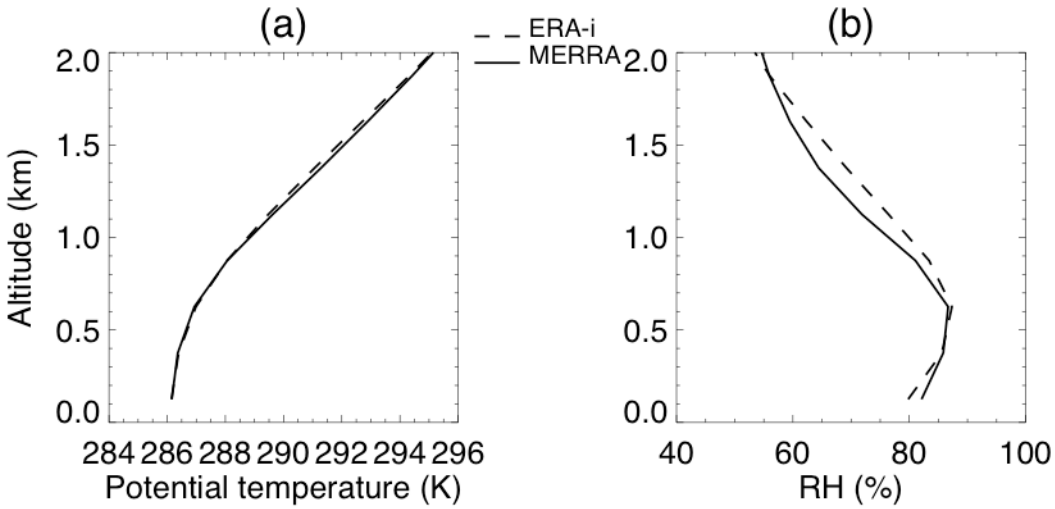
No difference in vertical velocity

⇒ Cyclones have similar dynamics and thermodynamics properties

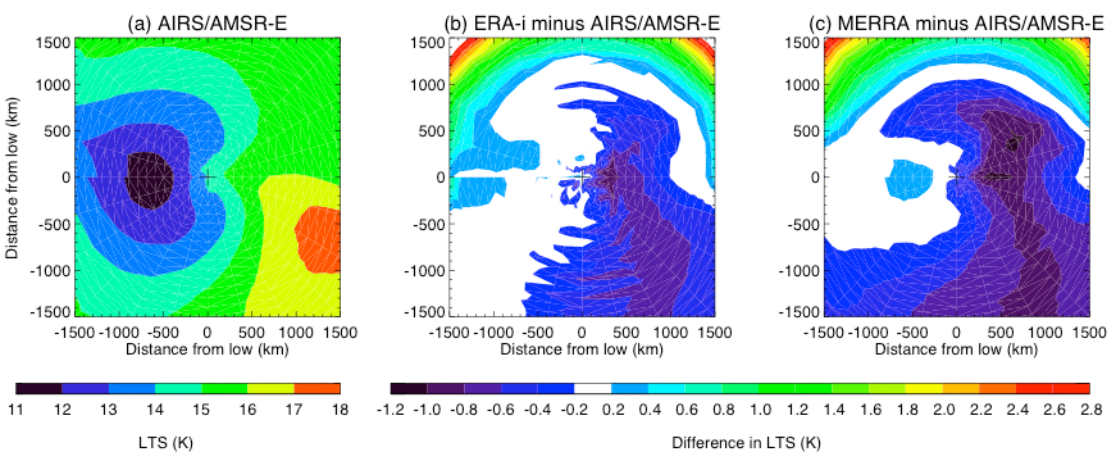
⇒ Bias largest where subsidence and low PWV

⇒ Issue probably with low-level cloud parameterization: cloud scheme, PBL scheme or shallow convection

Other western-equator quadrant properties



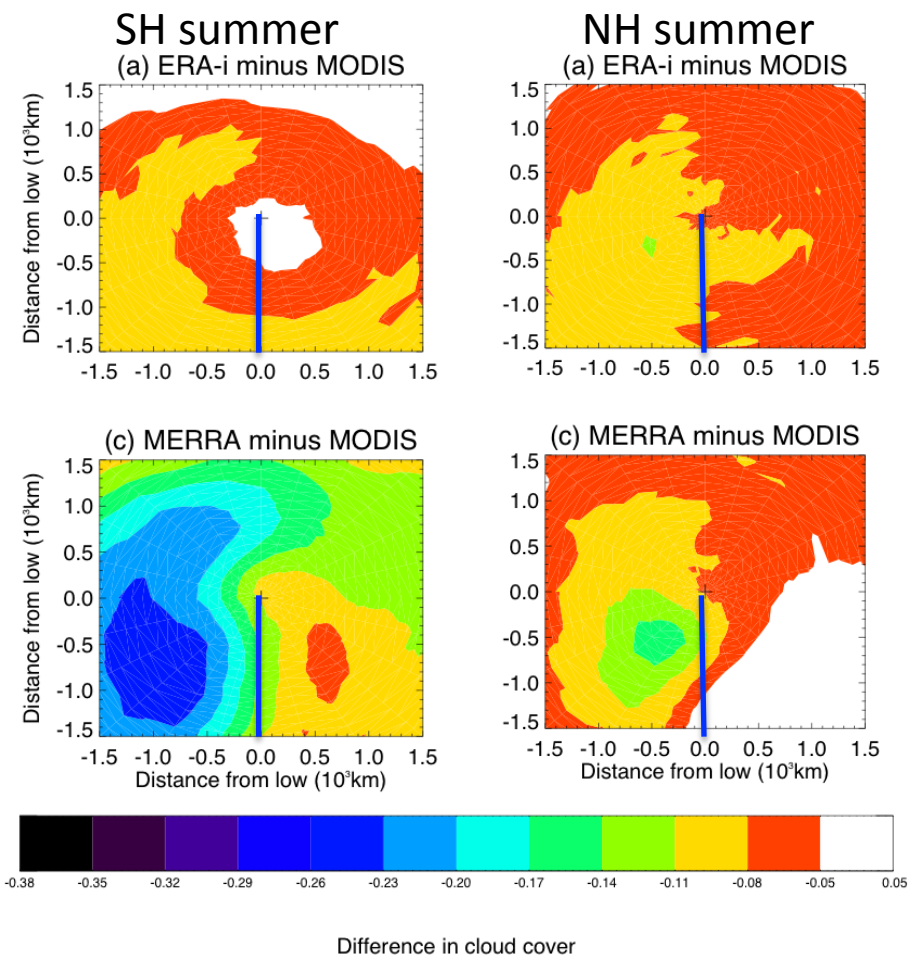
(a) MERRA and ERA-I share similar boundary layer temperature profiles
(b) BL drier in ERA-I than MERRA but wetter above BL => differences in cloud removal processes?



MERRA and ERA-interim agree on average value of LTS (and frequency of occurrence of LTS > 20 K) => not a stratocumulus flag issue + confirm similar temperature profiles
=> Largest bias where LTS lowest: shallow convection issue?

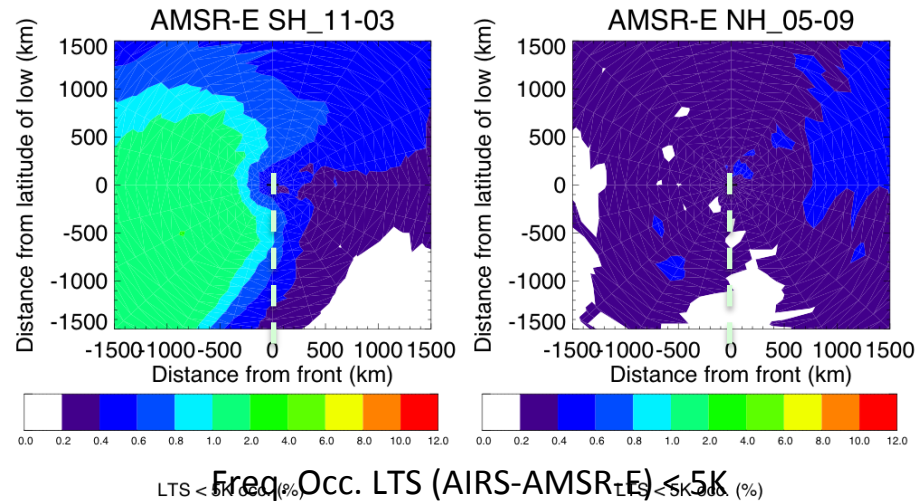
LTS= AIRS 700 hPa minus AMSR-E surface potential temperature

SH summer vs NH summer: cold-fronts aligned



Composites rotated and translated to align cold fronts along blue bar.

Bias behind cold fronts: SH > NH summer

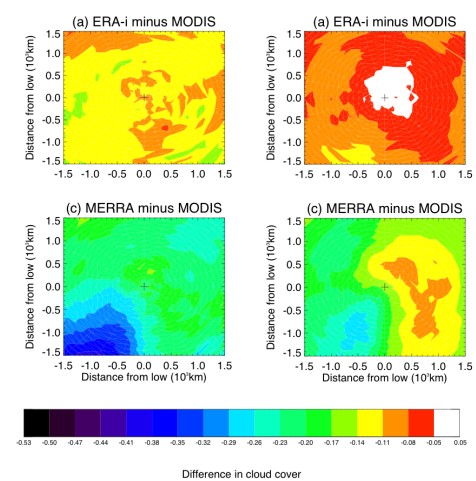


Freq. Occ. LTS (AIRS-AMSR-E) < 5K

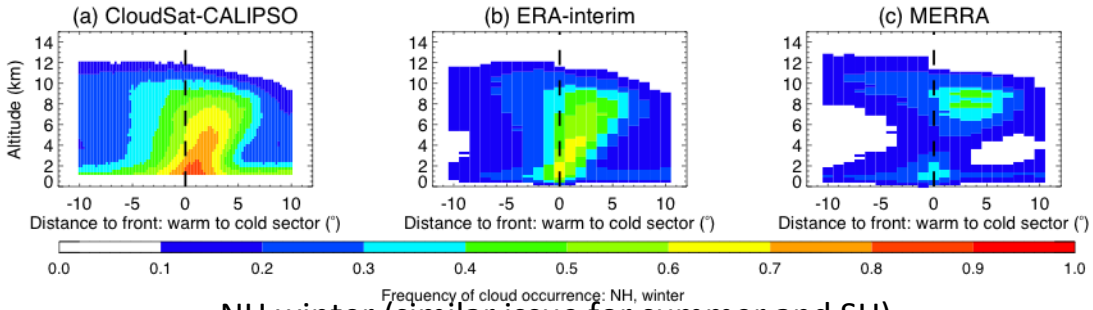
⇒ Cumulus less frequent in NH summer than winter or SH

Example for NH winter:

ERA-I and MERRA perform better where LTS > 10 K (right) than < 5K (left)



Also issues at warm front



NH winter (similar issue for summer and SH)

Cloud cover transects across warm fronts: warm to cold sector

⇒ Lack of low level clouds but also mid to high clouds

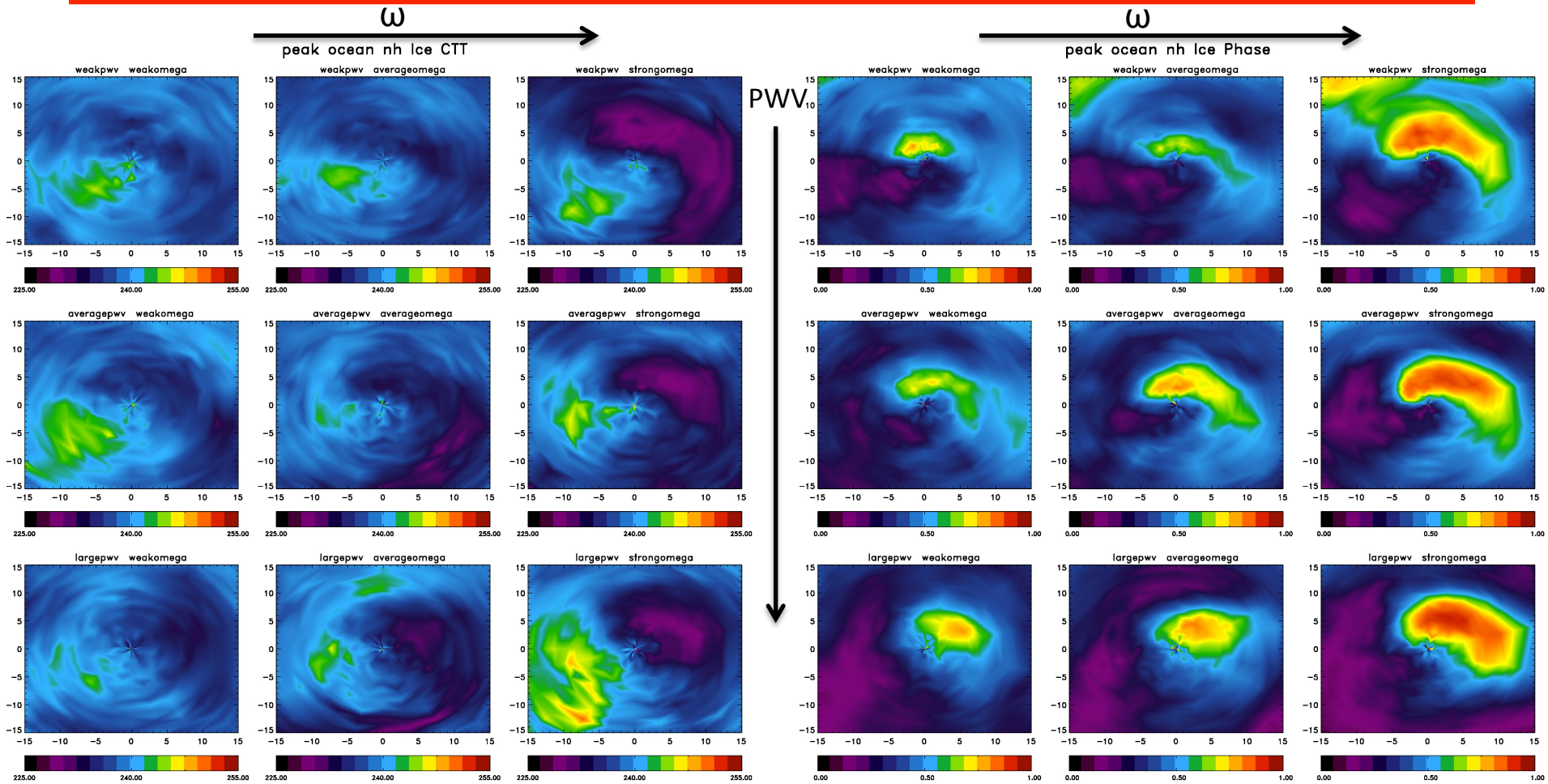
Problems with ice cloud processes? Use AIRS ice cloud retrievals to examine relation with atmospheric conditions

Question: how do AIRS ice cloud microphysical retrievals relate to cyclone dynamics and thermodynamics?

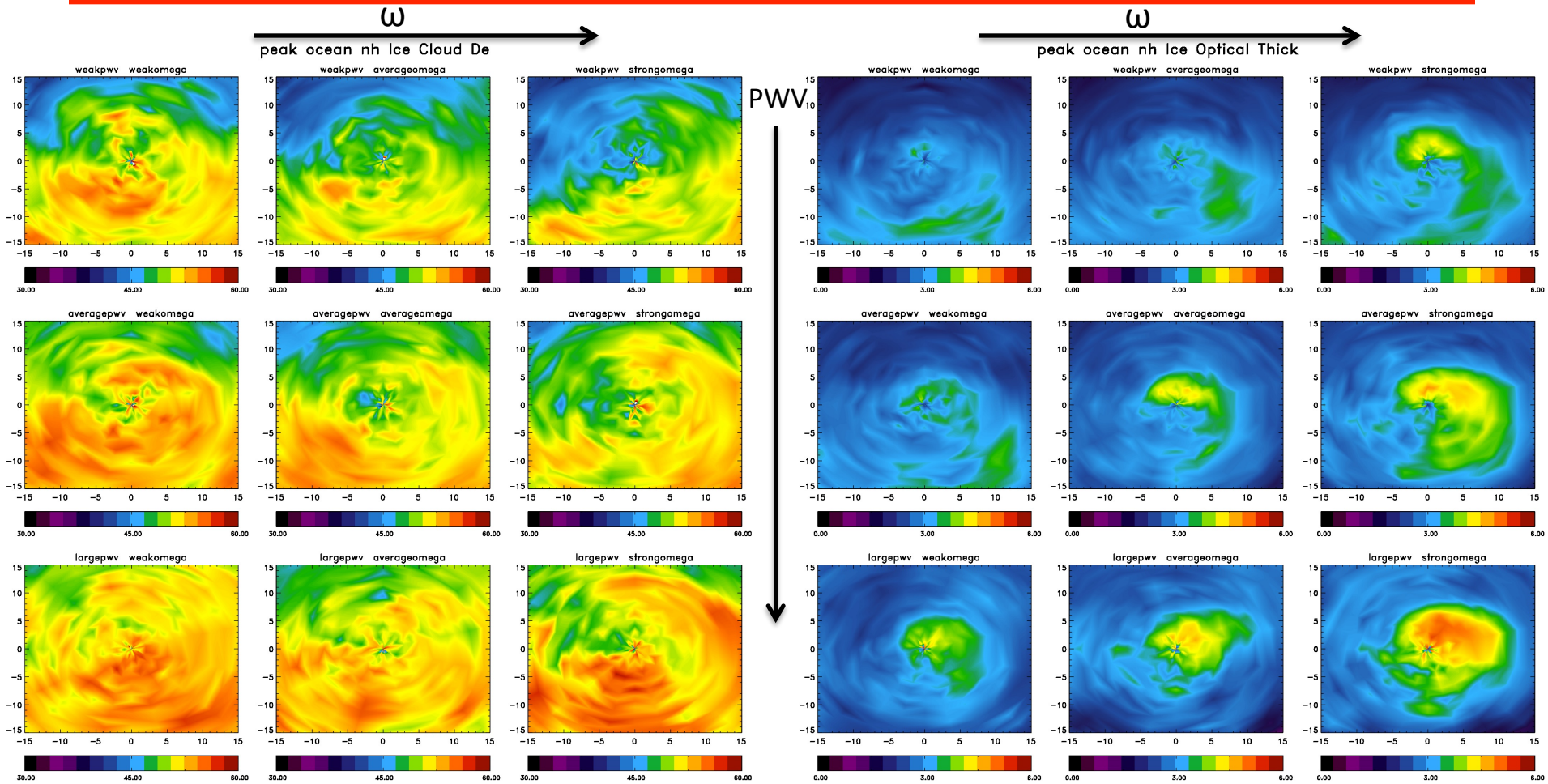
Analysis of NH winter cyclones: sort cyclones by age, average ascent and PWV and check how these impact ice cloud tau, De, ice phase occurrence

Focus on cyclones at peak (second half of the time period from first detection to minimum in SLP)

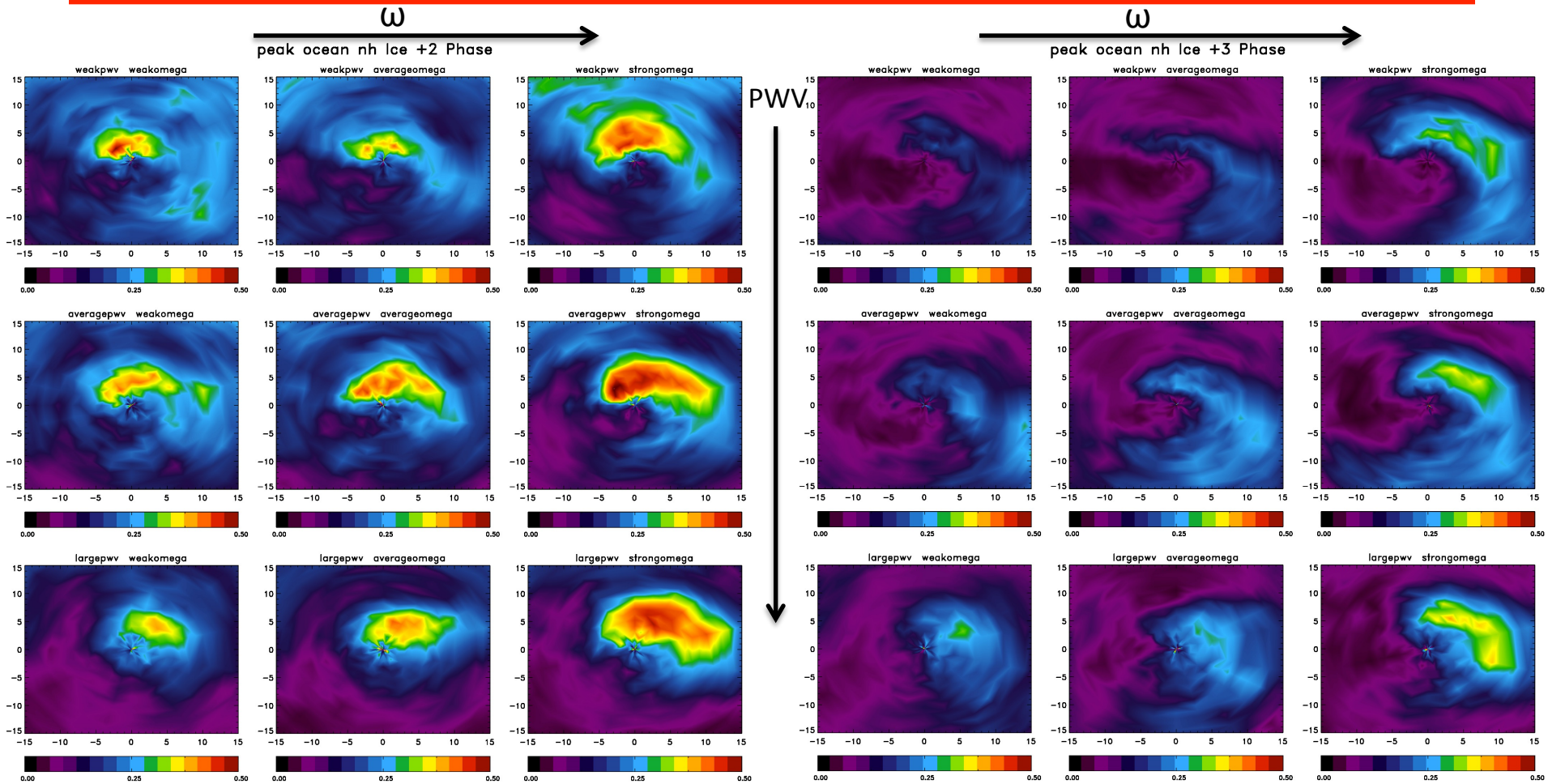
AIRS Ice CTT and Ice Cloud Frequency Stronger Function of ω than PWV at Warm Front



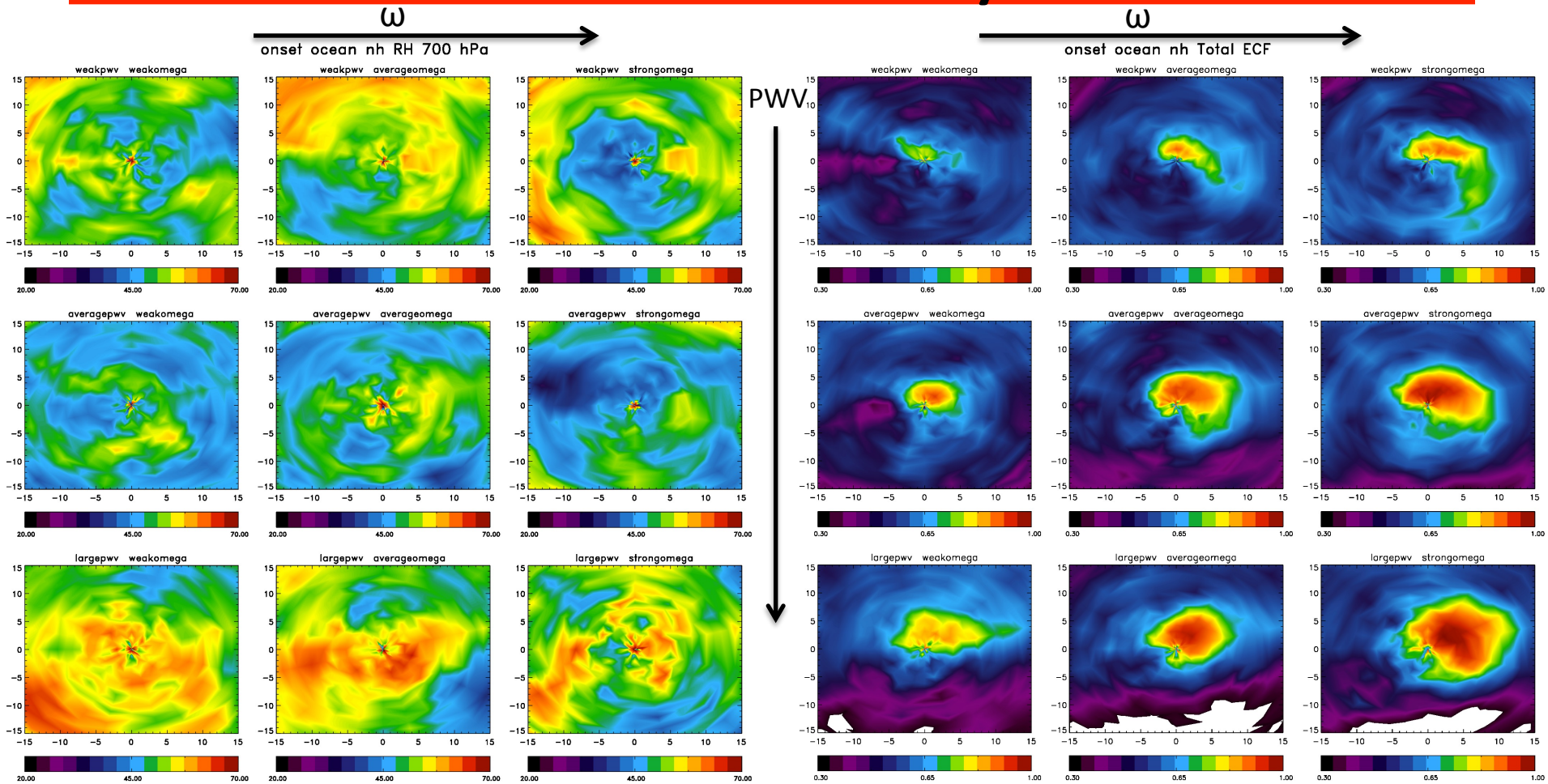
Ice Cloud τ and D_e a Function of Both ω and PWV at Warm Front



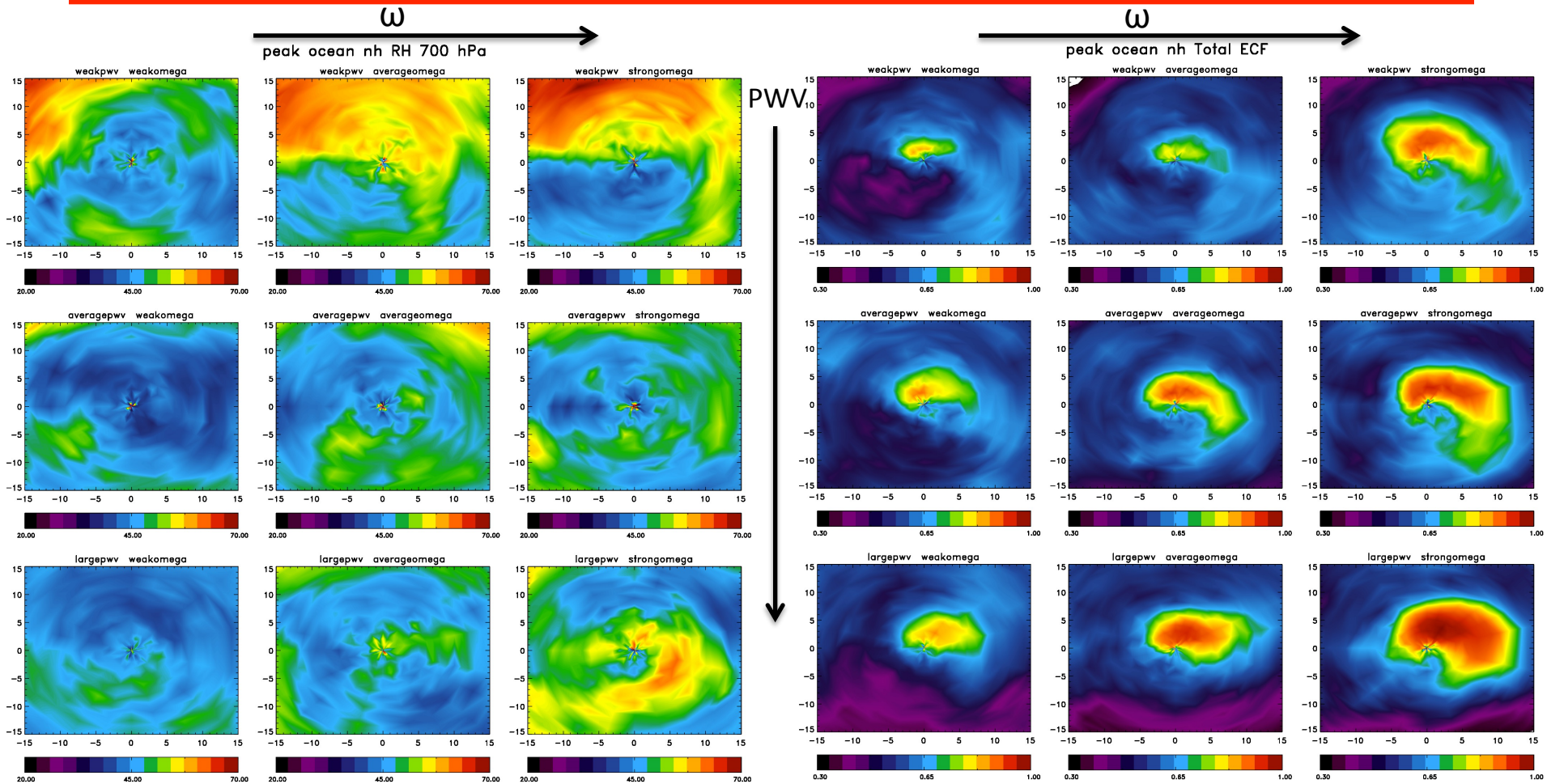
Ice Test=2 & 3 Show Spatial Shift Consistent with Stratiform vs. Convective Cloud at Warm Front



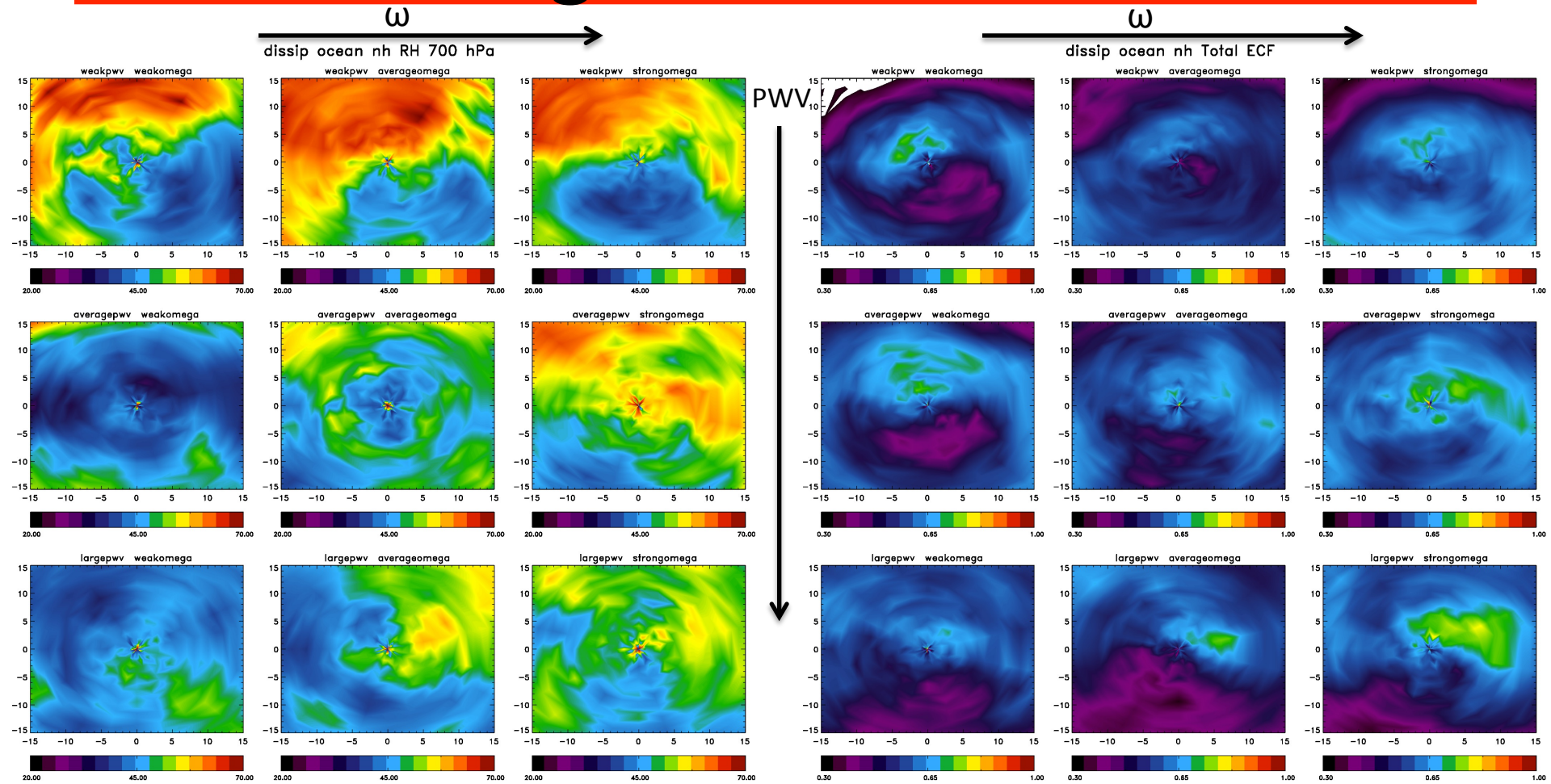
RH and Total ECF at Cyclone Onset: Moist RH and Confined Cloud Field Near Center of Cyclone



RH and Total ECF at Cyclone Peak: Drop in RH and Expanded Warm Frontal Cloudiness



RH and Total ECF During Cyclone Dissipation: Further Drop in RH and Less Organized Cloudiness



Conclusions

- ERA-interim and MERRA underestimate cloud cover in midlatitude oceans
- Largest cloud bias to the west of cyclone centers, where clouds are 1) low-level, 2) liquid and 3) broken
- Why? not an issue with cyclones themselves but with parameterizations:
  - possible issues with cloud removal parameterization
  - different schemes for shallow convection, both may be wrong
  cf. *Naud et al JCLI 2014* & *Naud et al JGR 2013*
- Also issues in warm frontal region => use AIRS ice cloud properties to understand ice cloud processes at warm front