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A-train based observational metrics for model evaluation in extratropical cyclones

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Introduction

- GCMs underestimate cloudiness in midlatitudes, esp. in SH
  => causes overestimate in SW absorption at surface (Trenberth and Fasulo, 2010) and possibly related to double ITCZ issue (Hwang and Frierson, 2013)
  => in SH oceans, cloudiness (and bias) mostly within extratropical cyclones (ETCs) (Bodas-Salcedo et al., 2014)
- Issue with representation of moist processes in models, possible impact on dynamics/ETCs and explain lack of consensus on evolution of ETCs strength or number in a warming climate (e.g. Lambert and Fyfe, 2006; Bengtsson et al 2009; Feser et al. 2015)
- Here focus on clouds in SH summer ETCs and use A-train to provide new metrics for process-oriented model evaluation

Methods & data

- Apply similar algorithms to reanalysis/observations and GCMs to:
  - detect cyclone centers (MCMS Bauer&Del Genio 2006)
  - detect cold fronts (Hewson 1998 and Simmonds et al 2012)
  - extract and composite cloud cover and other fields (e.g. PW, ω)
- Use A-train observations when possible, otherwise MERRA:
  - CloudSat-CALIPSO => cloud vertical transects
  - MODIS cloud cover
  - AMSR-E PW
- Construct composites for comparison between observations and models:
  1) cyclone-centered
  2) cold front centered plan view
  3) cold front centered vertical transects composites

Composites of cloud cover in SH summer: model versus MODIS

IPSL-LMDZ5B and GISS-ModelE2 minus MODIS: cyclone centered

LMDZ-5B minus MODIS   ModelE2 minus MODIS

Pole
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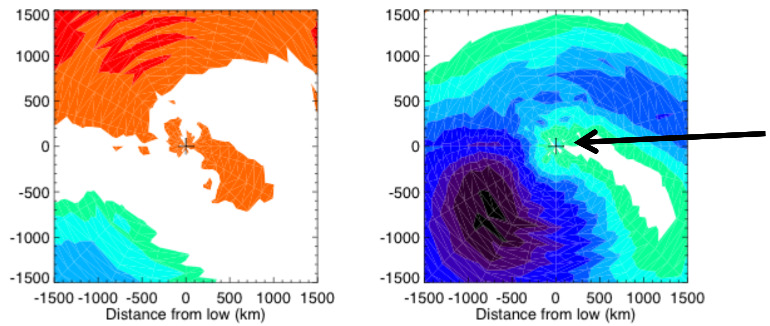
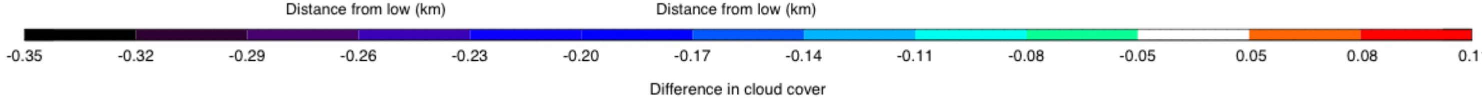


Cyclone center



LMDZ-5B: no SH cloud bias

GISS ModelE2: negative bias

Cold front centered plan view: post-cold frontal zone bias for both GCMs

LMDZ-5B minus MODIS   ModelE2 minus MODIS

Latitude of low
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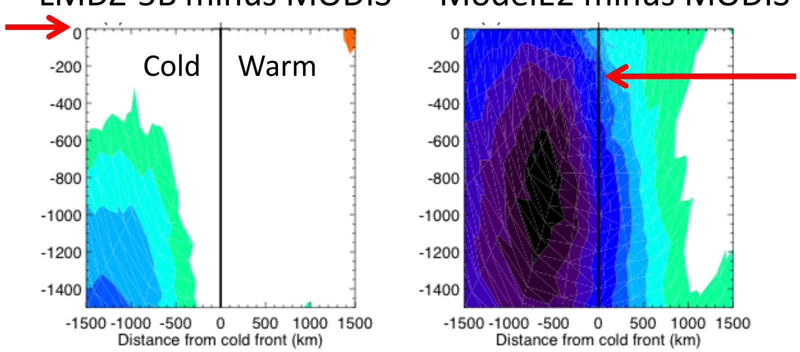


Cold front

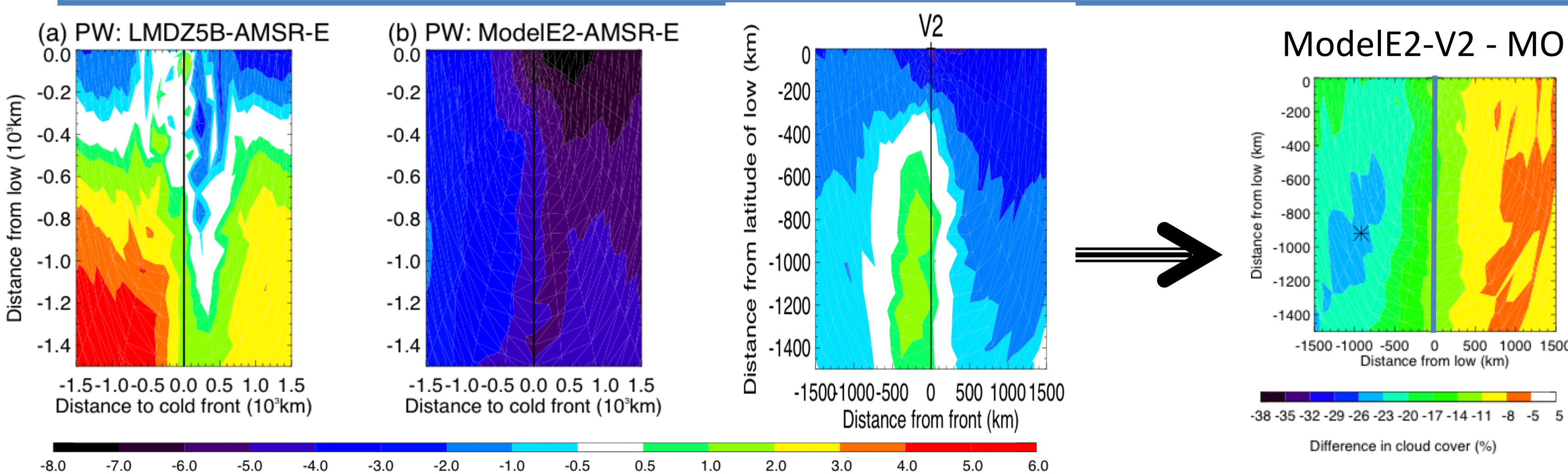
To check if post-cold frontal: rotate and translate to superimpose cold fronts
Issues with cyclones dynamics and moisture?
dynamics (ω/winds/SLP) similar to MERRA in post-cold frontal regions => issue not dynamics

Max bias: ~0.15 ~0.35

Differences in PW

- PW: may participate in cloud bias for ModelE2 BUT not the case for LMDZ (below vs. **AMSR-E**)

⇒New version of ModelE2: new PBL, new cumulus parameterization => better PW & cloud cover

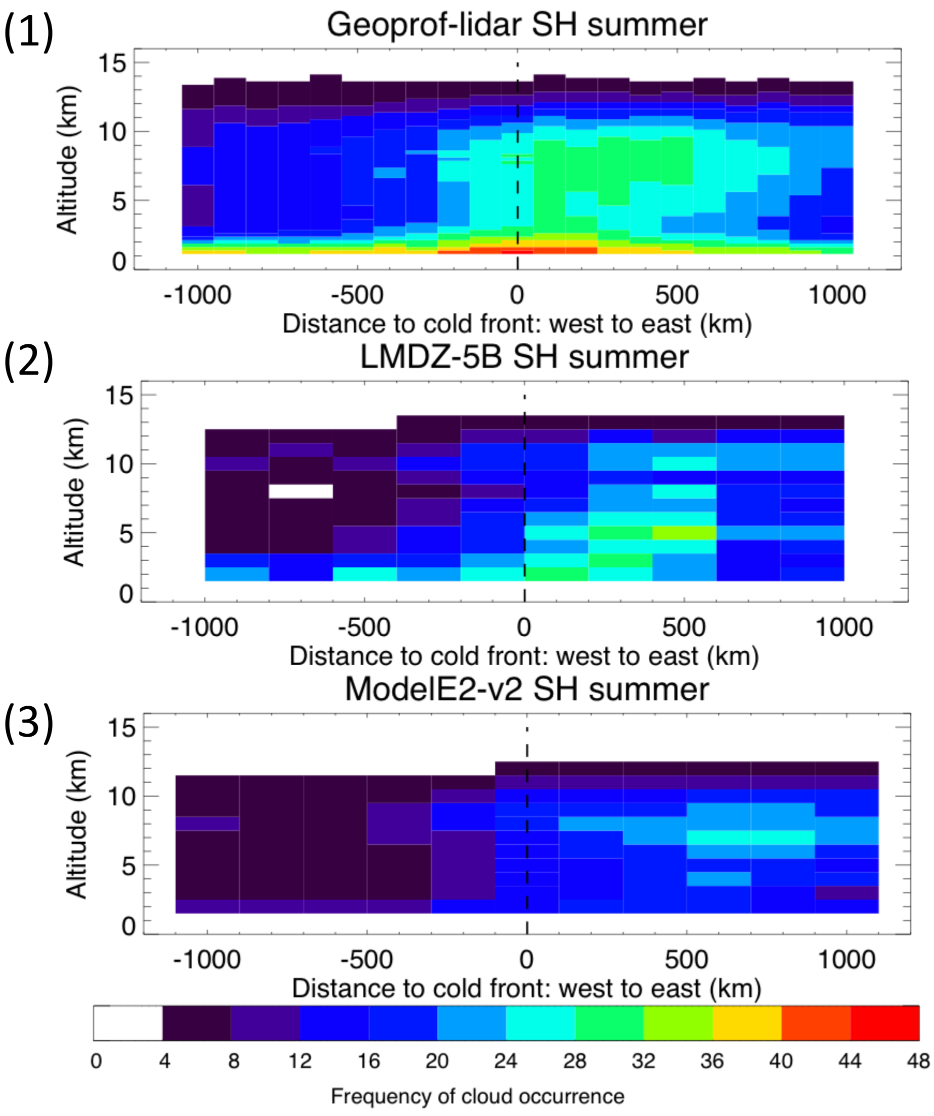


Difference with AMSR-E PW (mm)

Cloud cover: bias reduced by ~1/3
But still greater than 20%

MODIS 2D cloud cover overestimate + hides level of largest bias => use **vertical transects**

Vertical transects across cold fronts



Post-cold frontal region:

(1) Observations: CloudSat-CALIPSO

- Predominance of low-level clouds
- Freq. Occurrence up to 40% in observations

Both LMDZ (2) and ModelE2-V2 (3) underestimate cloud Freq. at all levels, except above 10 km

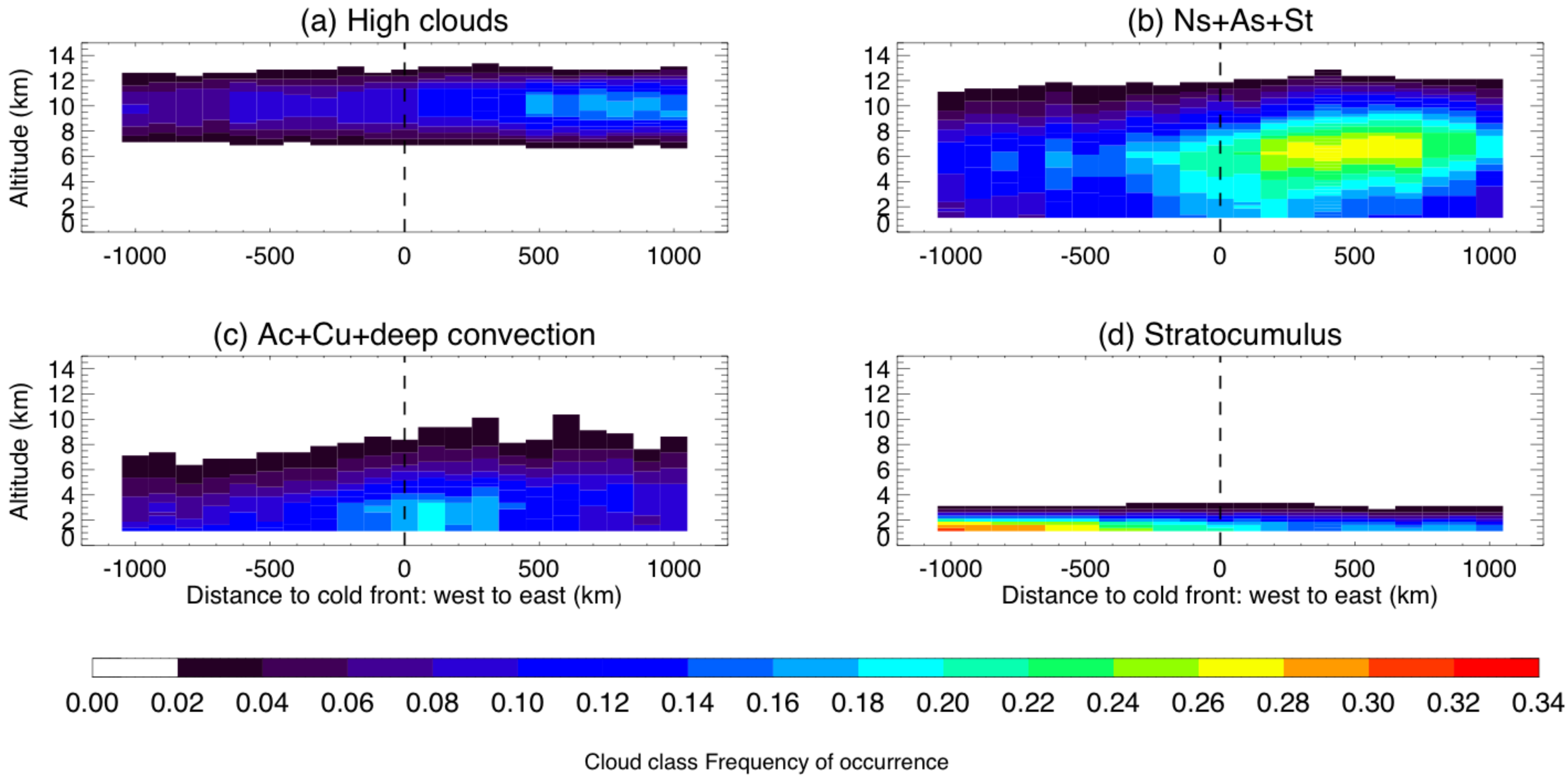
- Low-level clouds: LMDZ closer to observations than ModelE2V2
- mid/high level clouds: ModelE2V2 closer to observations

⇒ Confirms issue predominantly a low level cloud problem

⇒ Next: focus on cloud types

(Note: warm sector OK at high levels but also issue at low level)

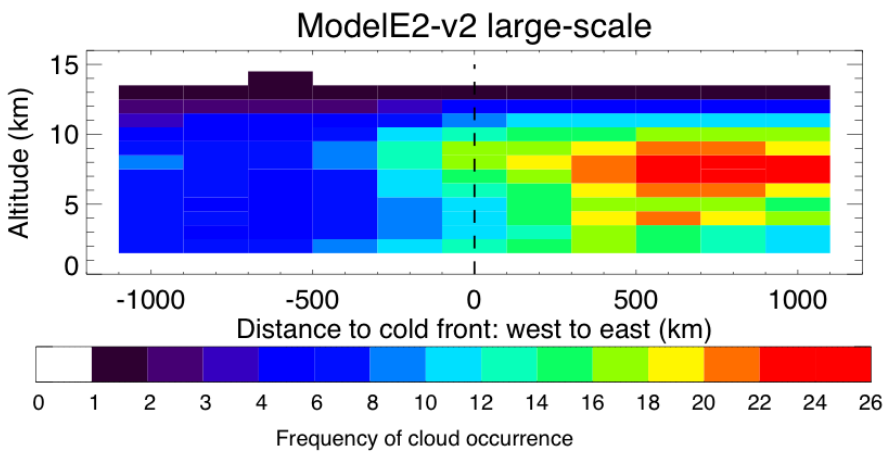
Cloud type occurrence across cold fronts

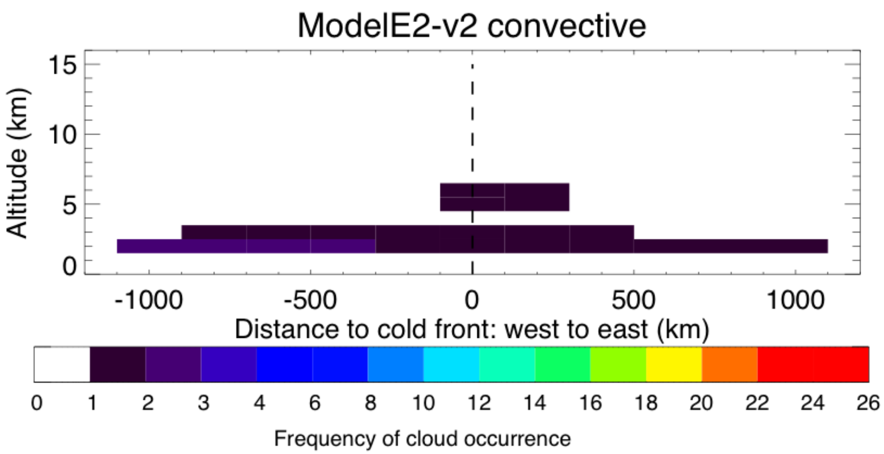


CloudSat-CALIPSO cloud classification: Dominant type in post-cold frontal region = stratocumulus

In ModelE2-V2: stratocumulus formed within large-scale cloud scheme

ModelE2-V2 convective vs. large scale





Not enough large scale clouds at low levels in post-cold frontal region.

Convective clouds in the right place but cover much too low.

- ⇒ Freq. Occ. of shallow convection large in post-cold frontal region (right) but cloud cover small (top right)
- ⇒ Where convective clouds form, large scale cloud cover suppressed (Booth et al., 2013)
- ⇒ Conflict between large scale and convective clouds, OK for subtropics but not for midlatitudes

Latitude of low
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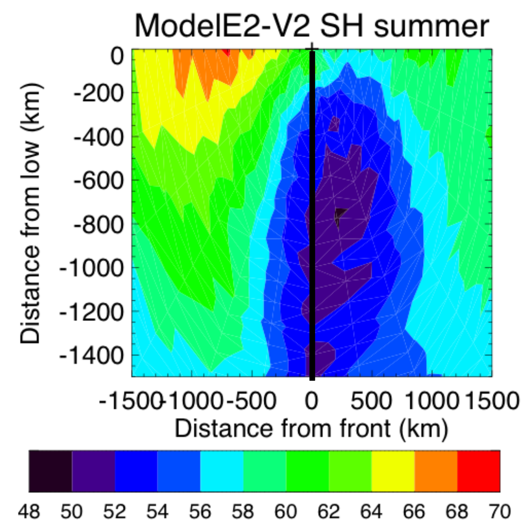

Cold front centered freq. occurrence of shallow convection

Future work - Conclusions

- Upcoming in ModelE2-V2: new moist (currently dry) turbulence PBL scheme + new cloud pdf scheme + new microphysics scheme all could help improve ModelE2-V2
- Unclear: is PBL scheme dominant factor? What about cloud microphysics representation?
- New metric needed to explore ice vs liquid vertical distribution in model and observations