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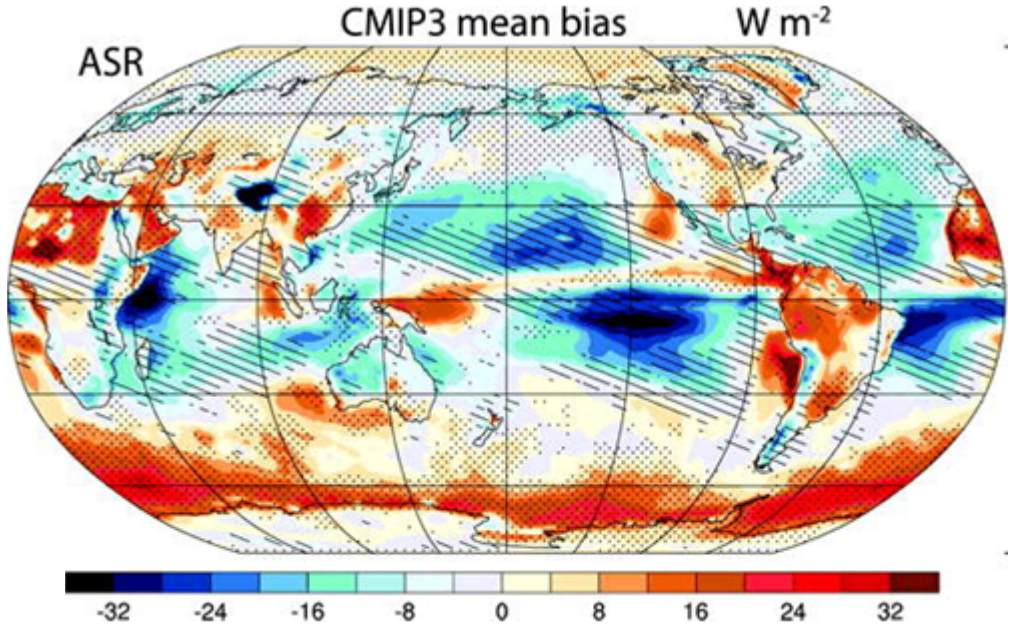
The Earth's radiation budget in the midlatitudes: the role of supercooled liquid clouds

Alejandro Bodas-Salcedo

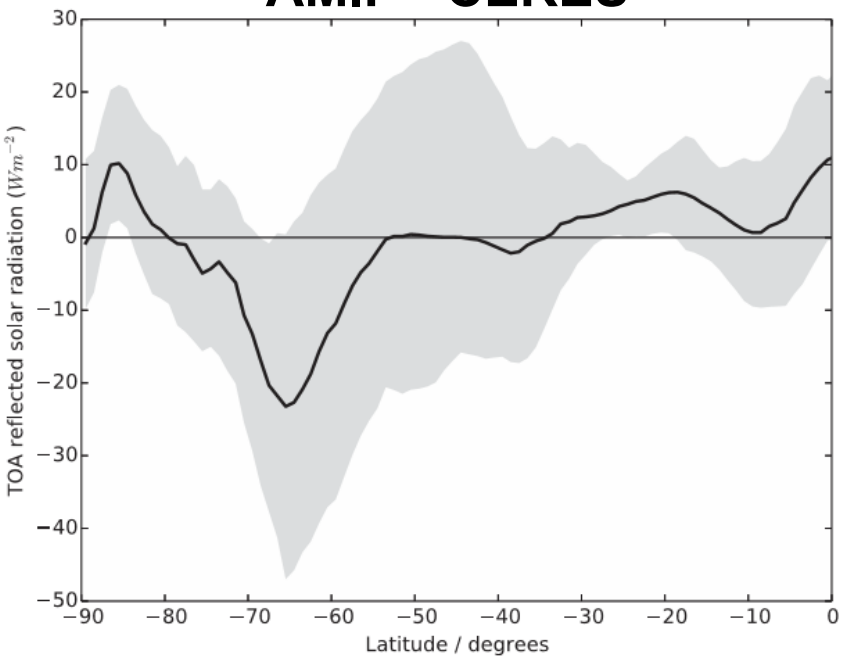
Thanks: P. G. Hill, K. Furtado, K. Williams, P. Field, J. Manners, P. Hyder, S. Kato, T. Andrews, A. V. Karmalkar, and M. A. Ringer

Large SW biases over the Southern Ocean

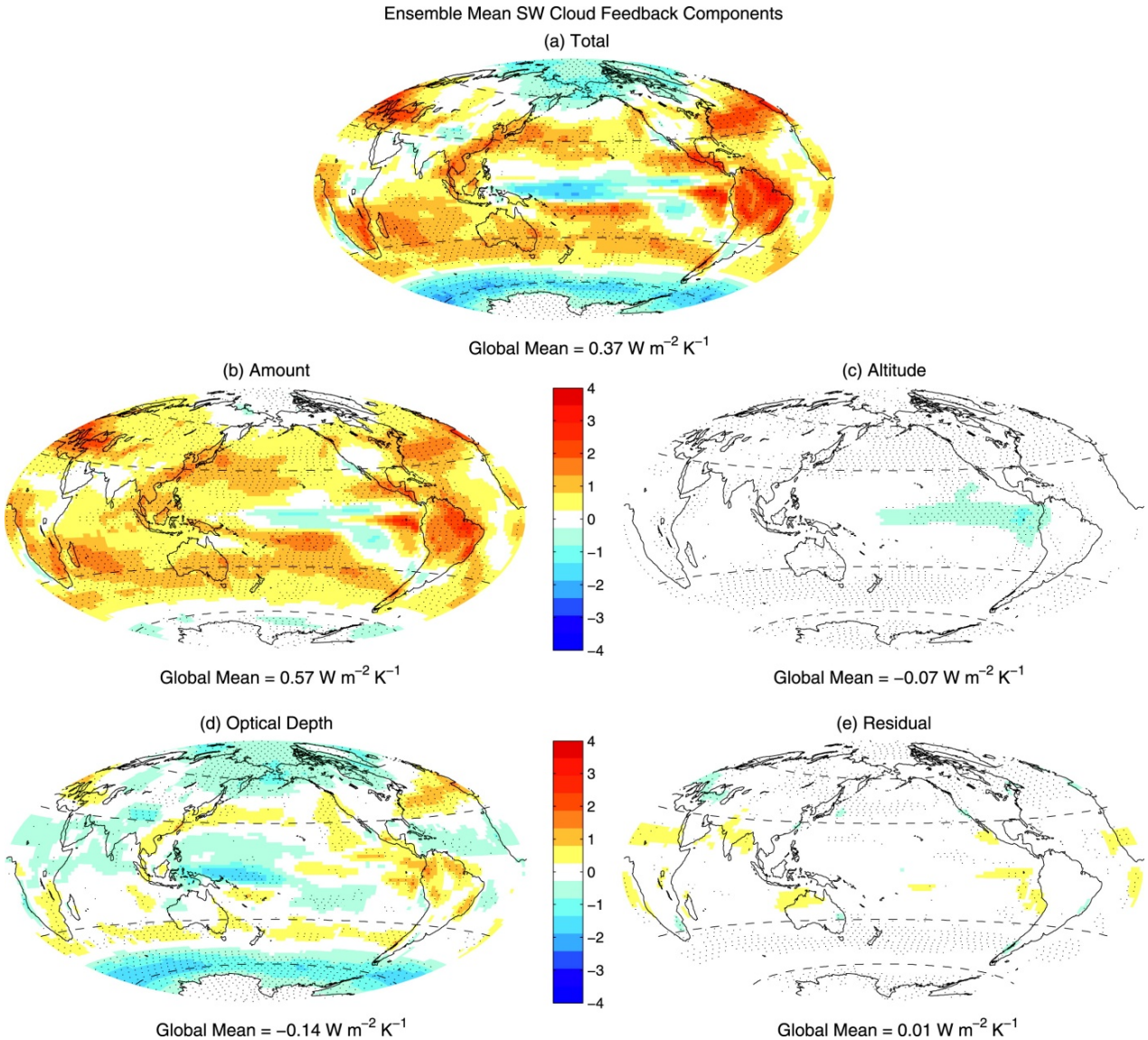


(Trenberth and Fasullo, *J. Climate*, 2010)

CMIP5 ensemble, DJF
AMIP - CERES



Strong negative SW cloud feedbacks



Zelinka et al., *J. Climate*, 2012.
Also: Mitchell et al., *Nature*, 1989; Tsushima et al., *Clim. Dyn.*, 2006

Observations

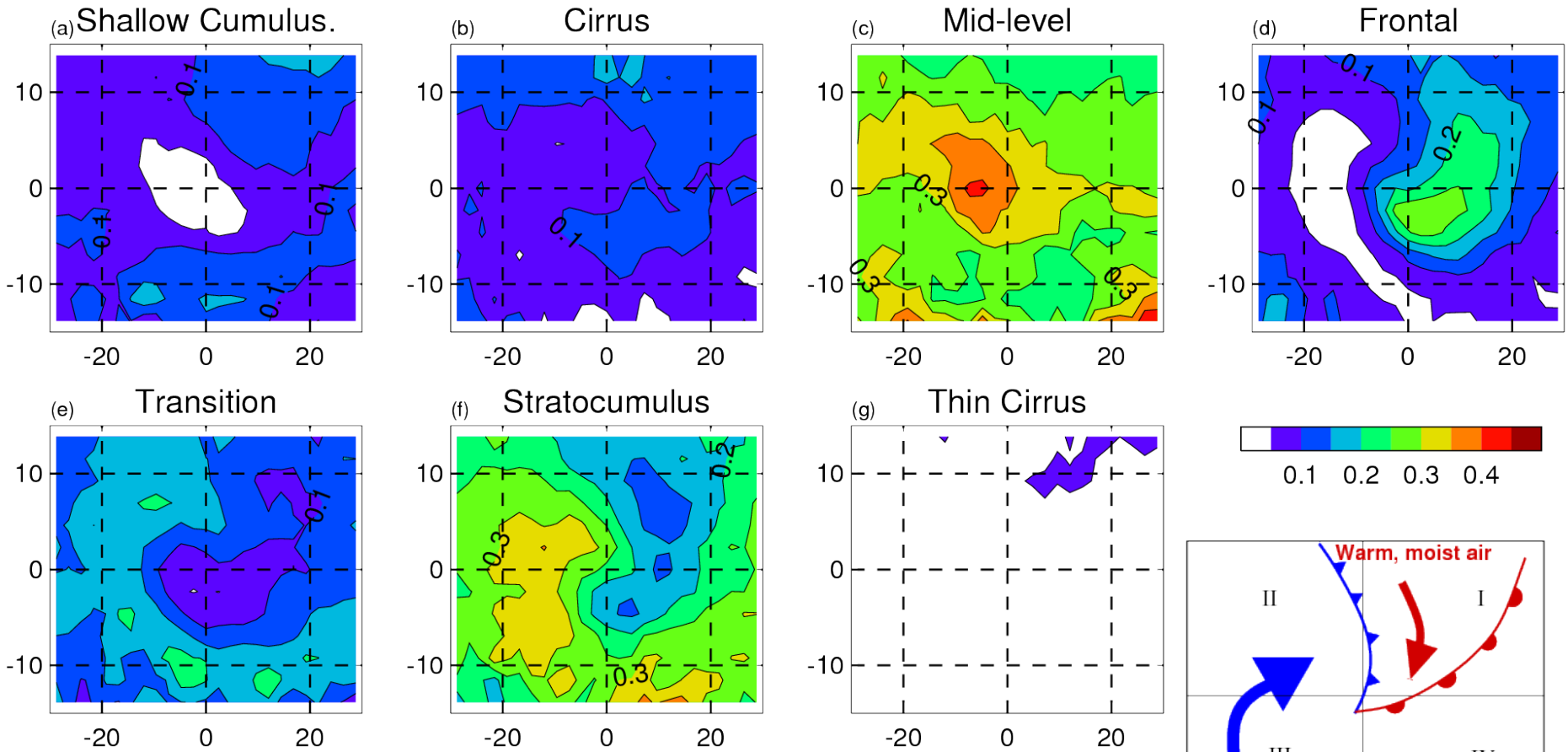
- ISCCP-D (Rossow and Schiffer, 1999)
- ISCCP FD (Zhang et al., 2004)
- CERES SYN1deg-Day_Ed2.6 (Wielicki et al., 1996)
- EBAF Ed2.6r & Ed2.8 datasets (Loeb et al., 2009)
- ERA-Interim (Dee et al., 2011)
- GCM-Oriented CALIPSO Cloud Product (GOCCP; Chepfer et al., 2010)
- U. Wisc. LWP (O'Dell et al., 2008)
- CCCM dataset (Kato et al. 2010, 2011)

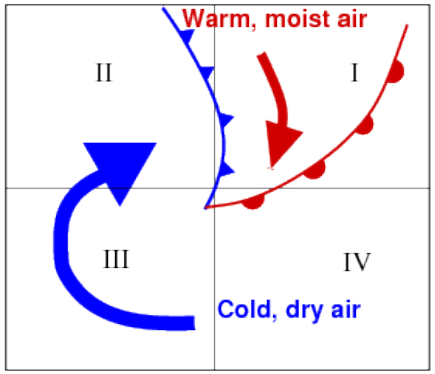
Methodology

- ISCCP cloud regimes (Williams and Webb, 2009)
- Cyclone compositing (Field and Wood, 2007)
- RT calculations:
    - CCCM data (Kato et al., 2010 & 2011)
    - SOCRATES RT code
- Model experiments: amip, amip4K, amipFuture
- 5 DJF seasons (2006-2010)
- 40S to 70S

Cyclone compositing

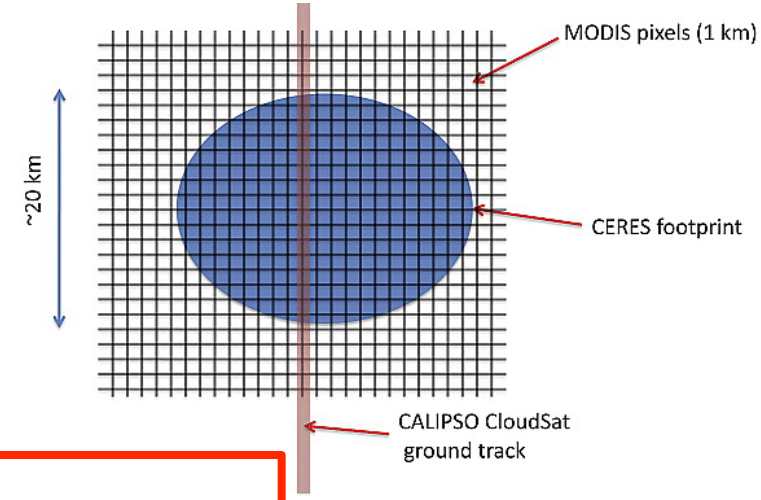
WW09 ISCCP cloud regimes

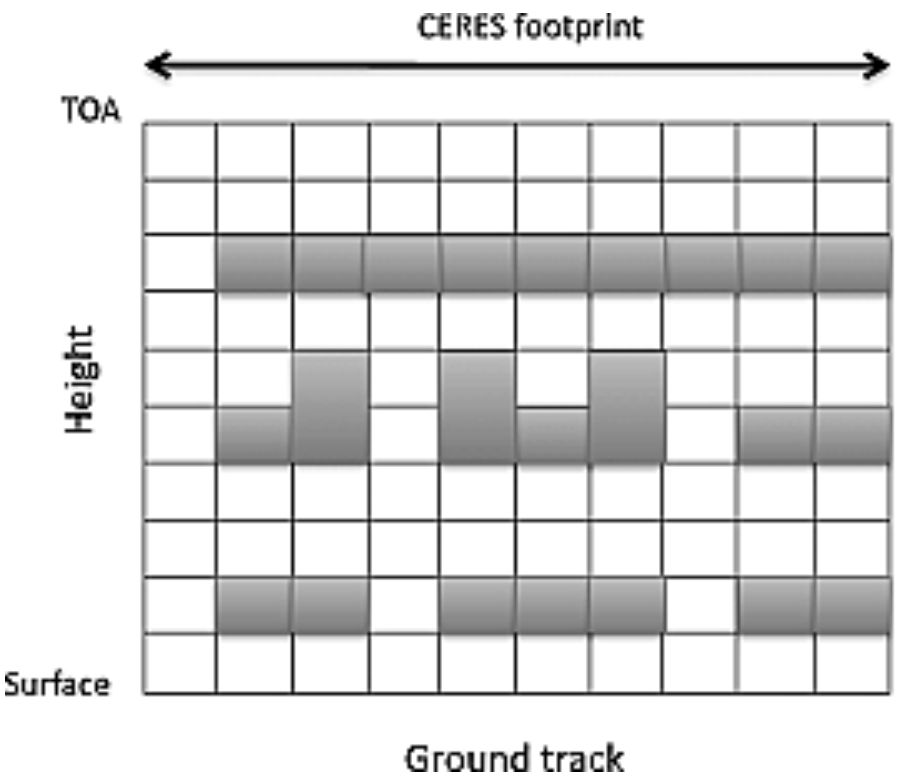


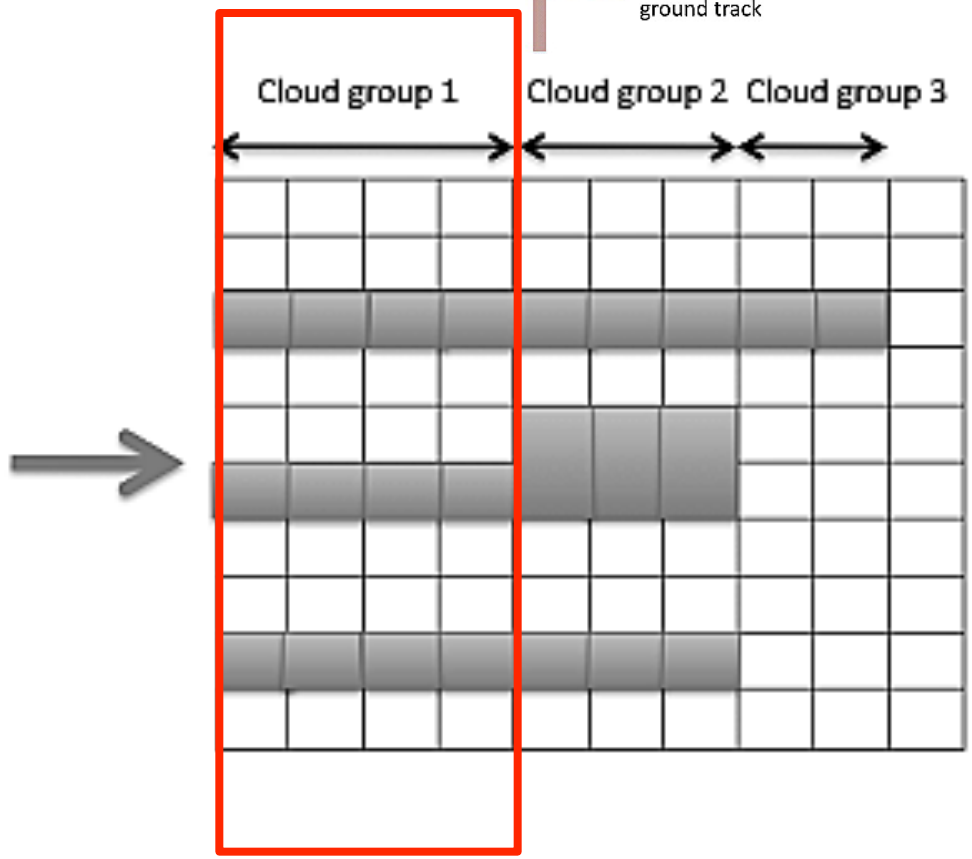


(Bodas-Salcedo et al., *J. Climate*, 2012)

CCCM data





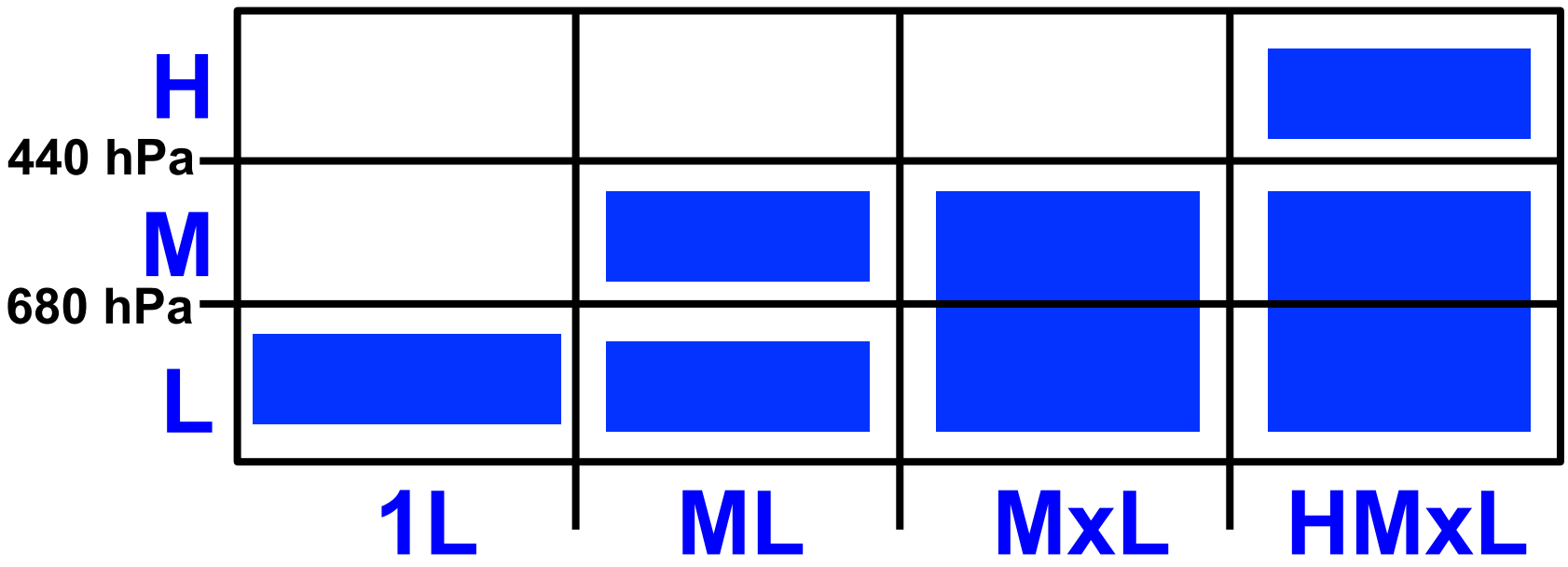


(Kato et al., *JGR*, 2010 & 2011)

RT calculations

Cloud vertical structure (CVS)

- Reduce dimensionality by using CVSs and cloud top phase classification
- A CVS is a combination of layers that contain cloud



(Tselioudis et al., *J. Climate*, 2013)

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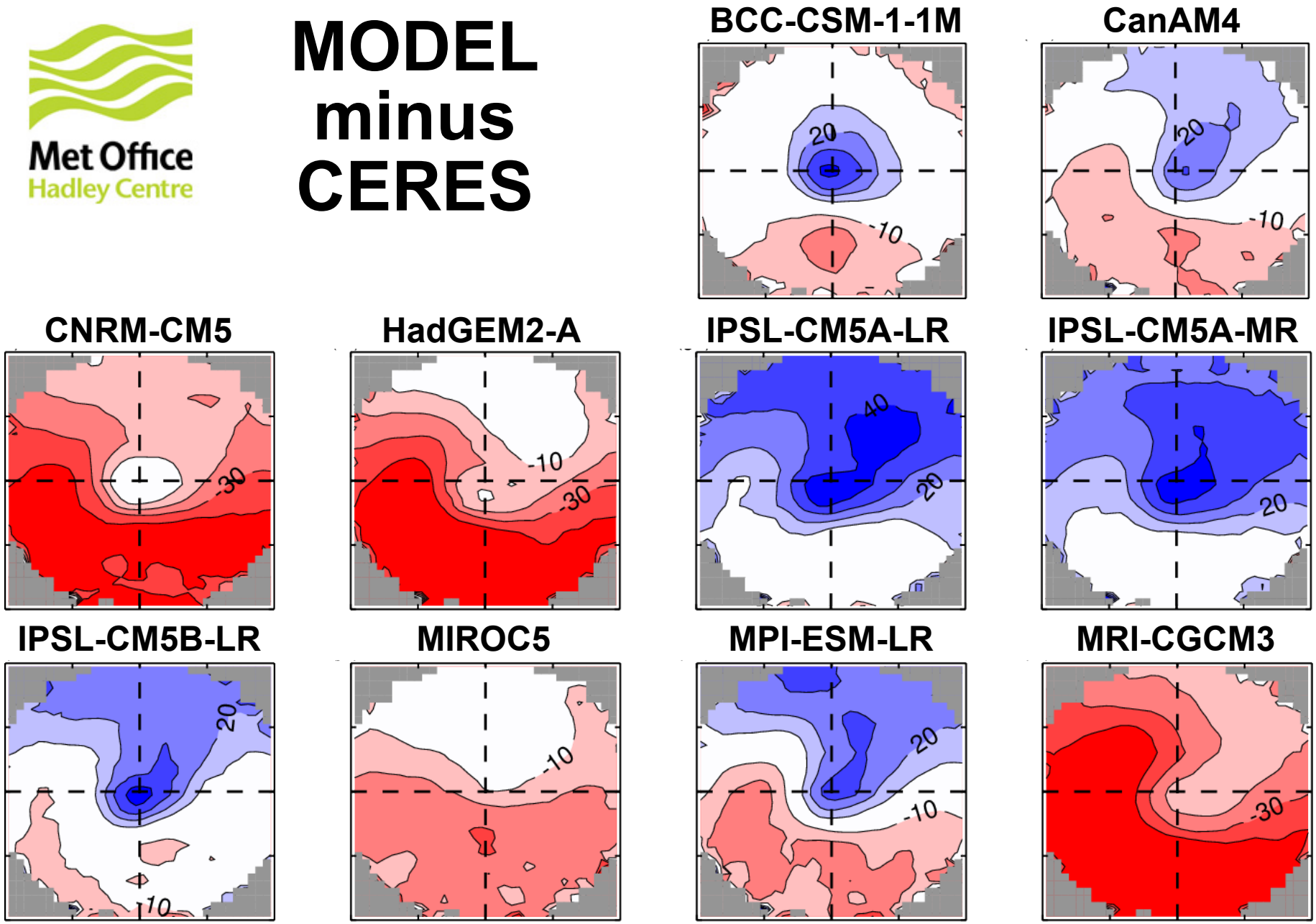
What is the origin of the climatological biases?

Bodas-Salcedo et al., *J. Climate*, 2014.

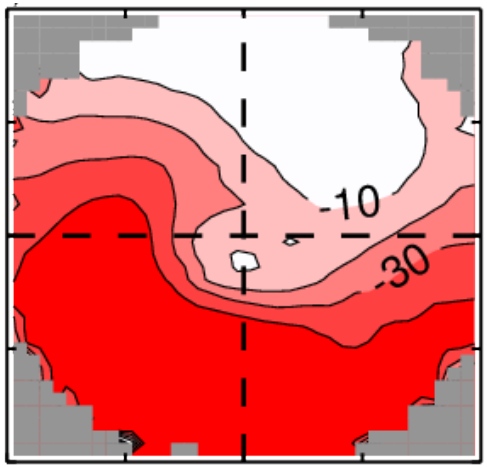
DOI:10.1175/JCLI-D-13-00169.1

MODEL minus CERES



Dynamics not main driver

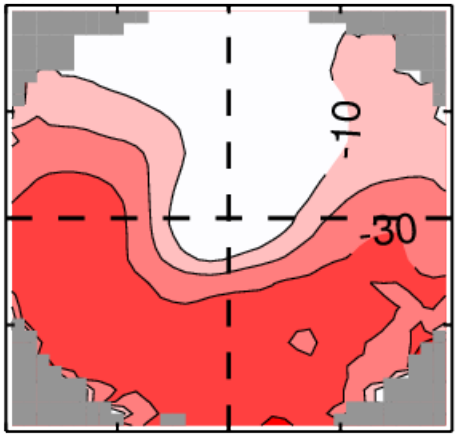
HadGEM2-A

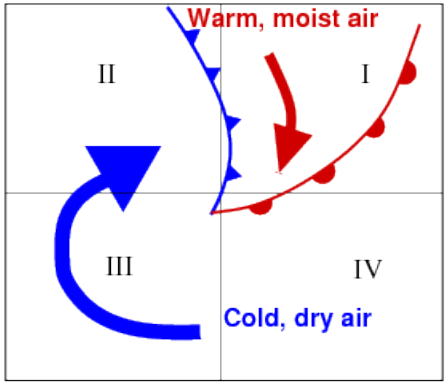


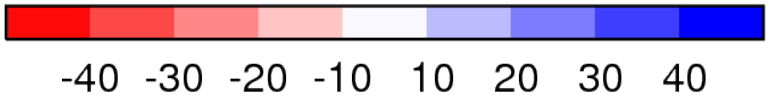
- Southern Ocean [40°S, 70°S]

- 7 DJF seasons

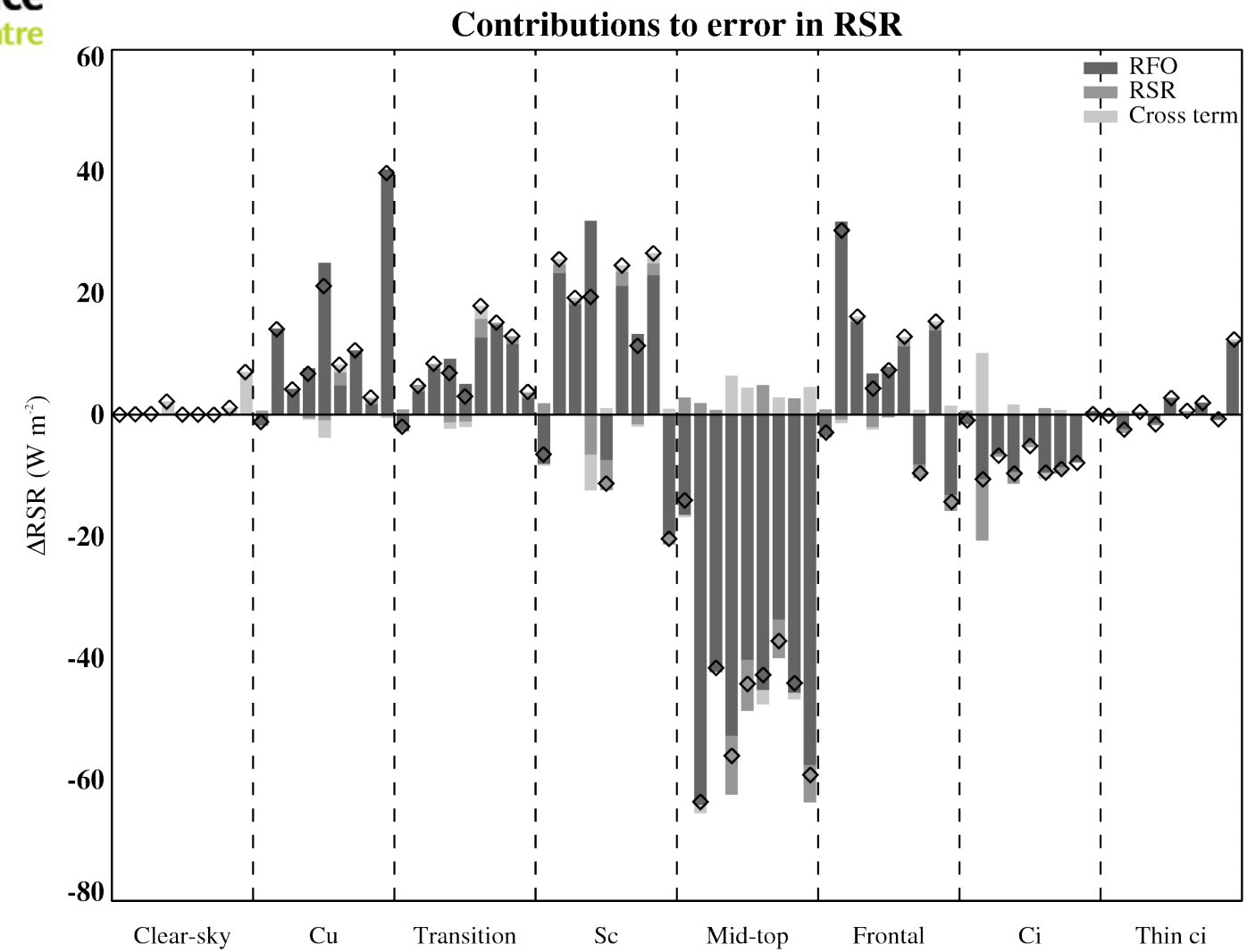
ERAI



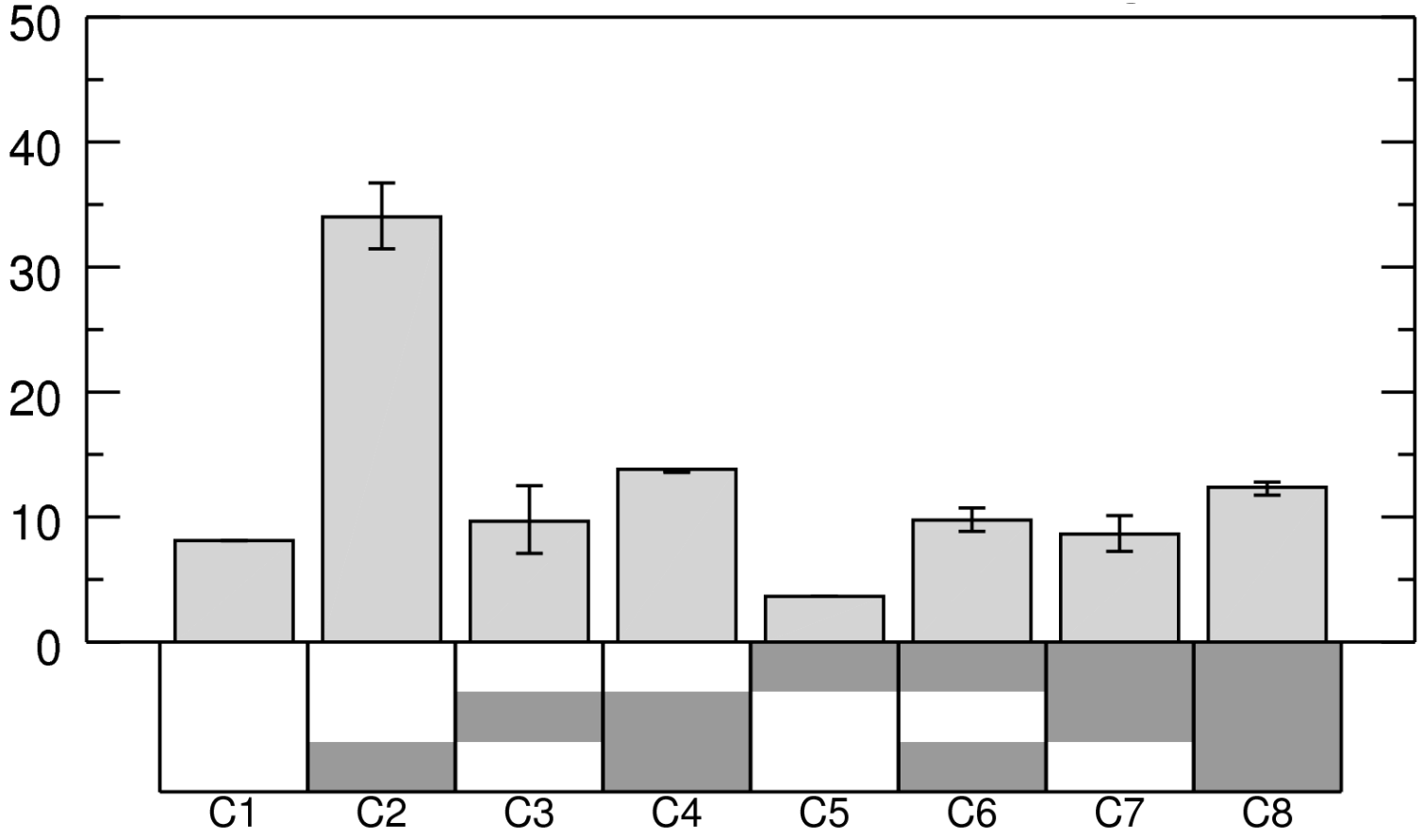


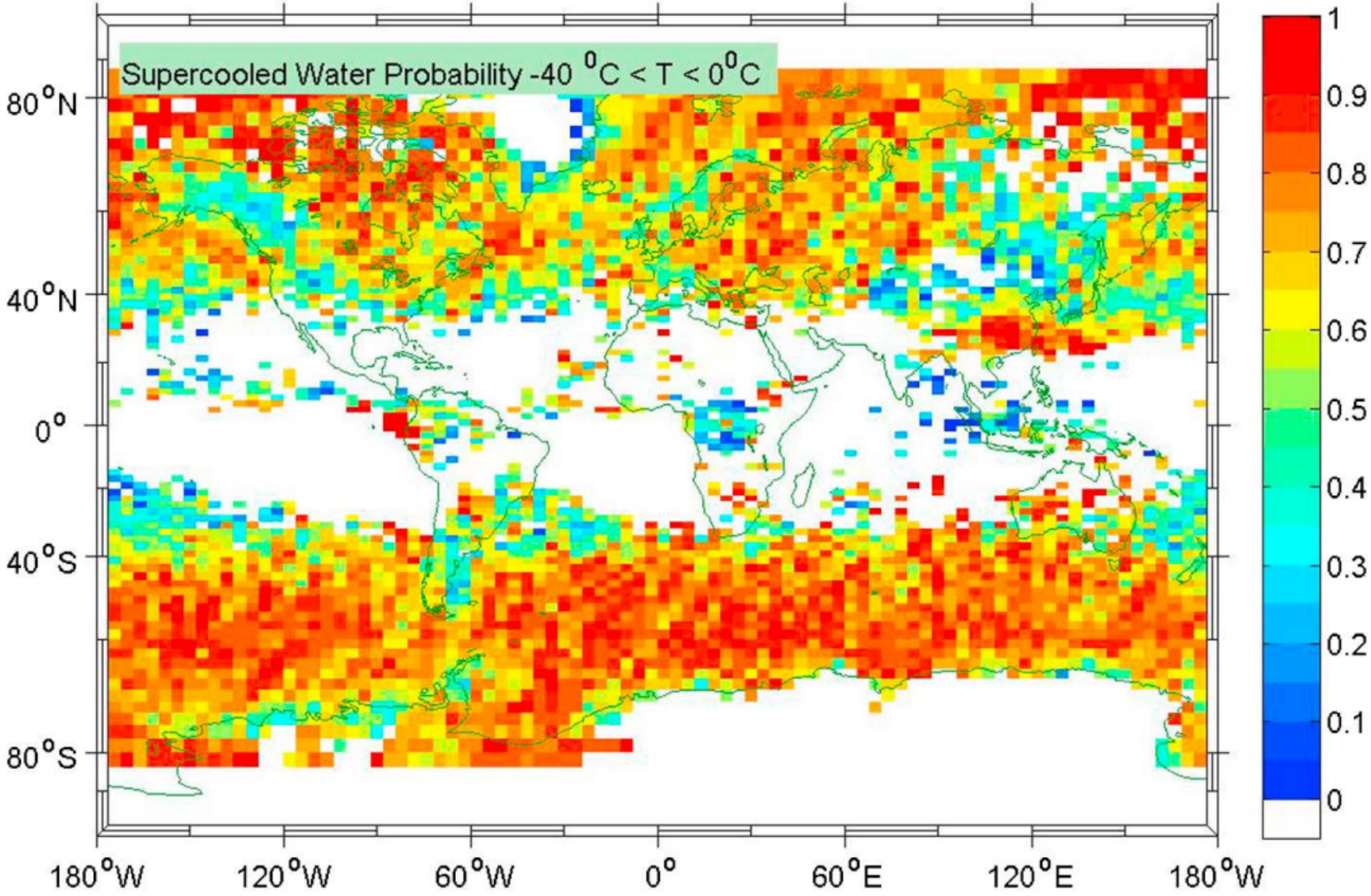


Which clouds contribute most to the error?



Is ‘mid-level’ really mid-level?





(Hu et al., *JGR*, 2010. DOI: 10.1029/2009JD012384)

(Also: Huang et al., *JGR*, 2012; Huang et al., *J. Climate*, 2015)

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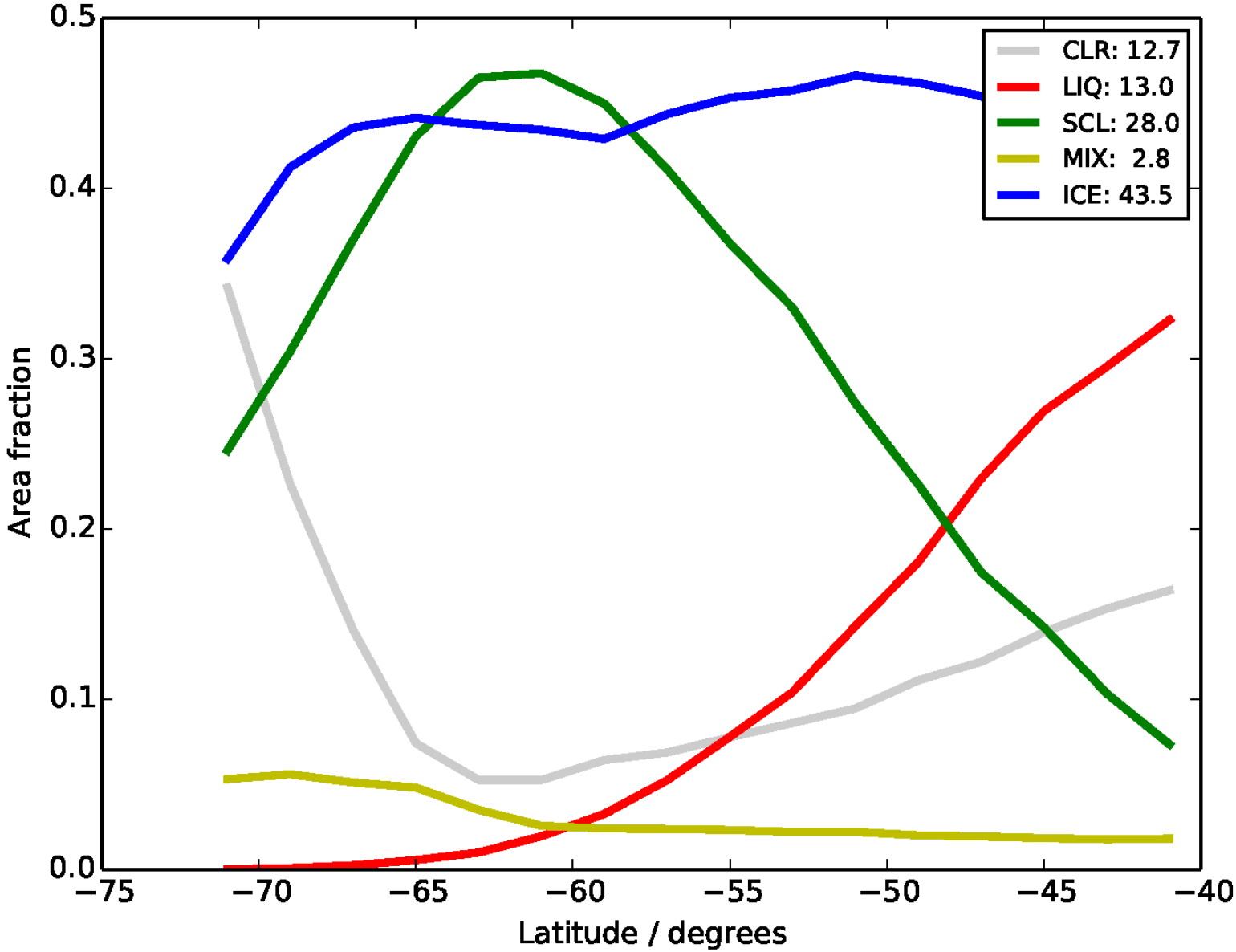
Beyond ISCCP cloud regimes: CCCM

Bodas-Salcedo et al., *J. Climate*, 2016.

DOI:10.1175/JCLI-D-15-0564.1

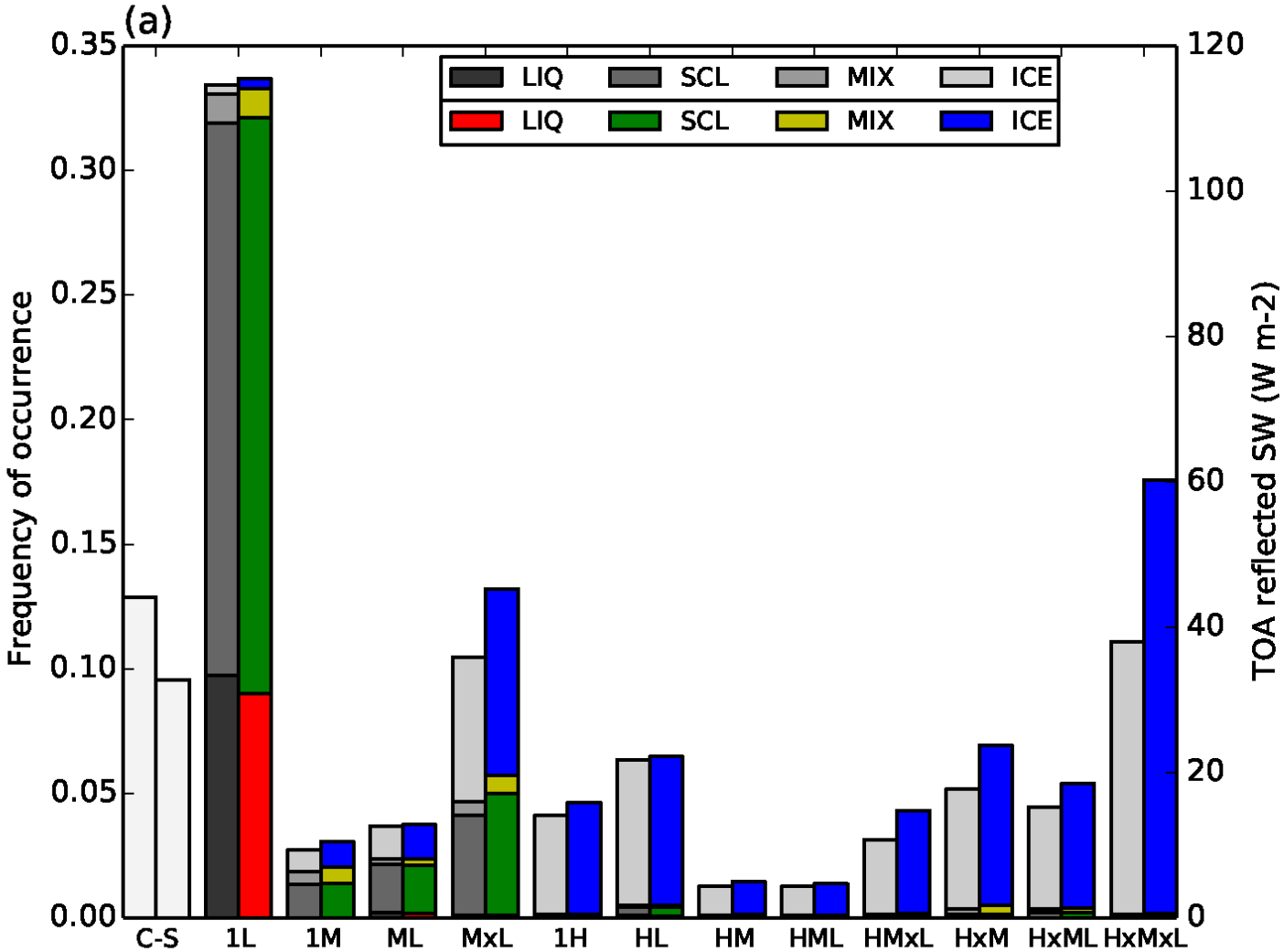


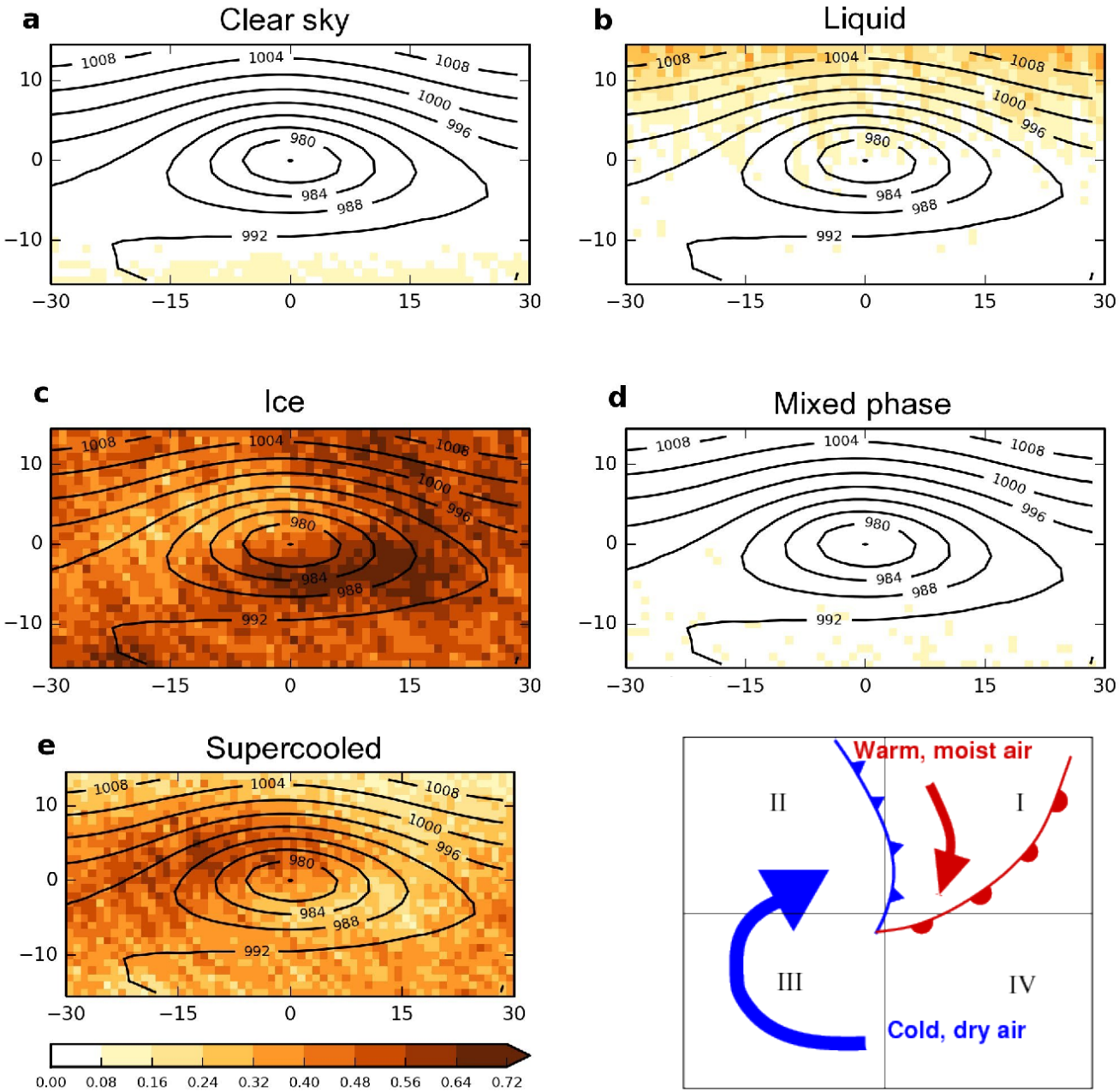
Contribution to TOA SW

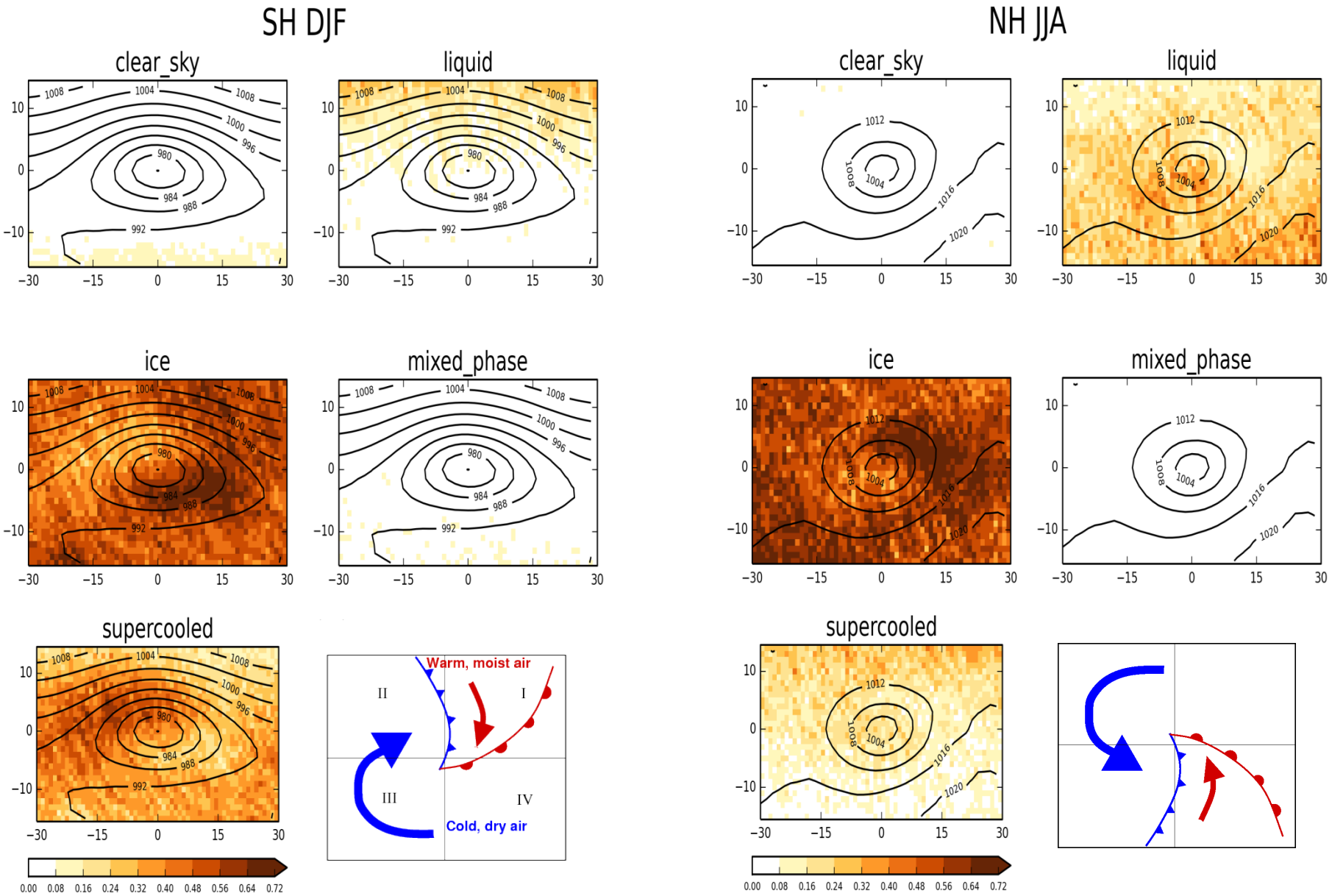
DJF, 40S to 70S

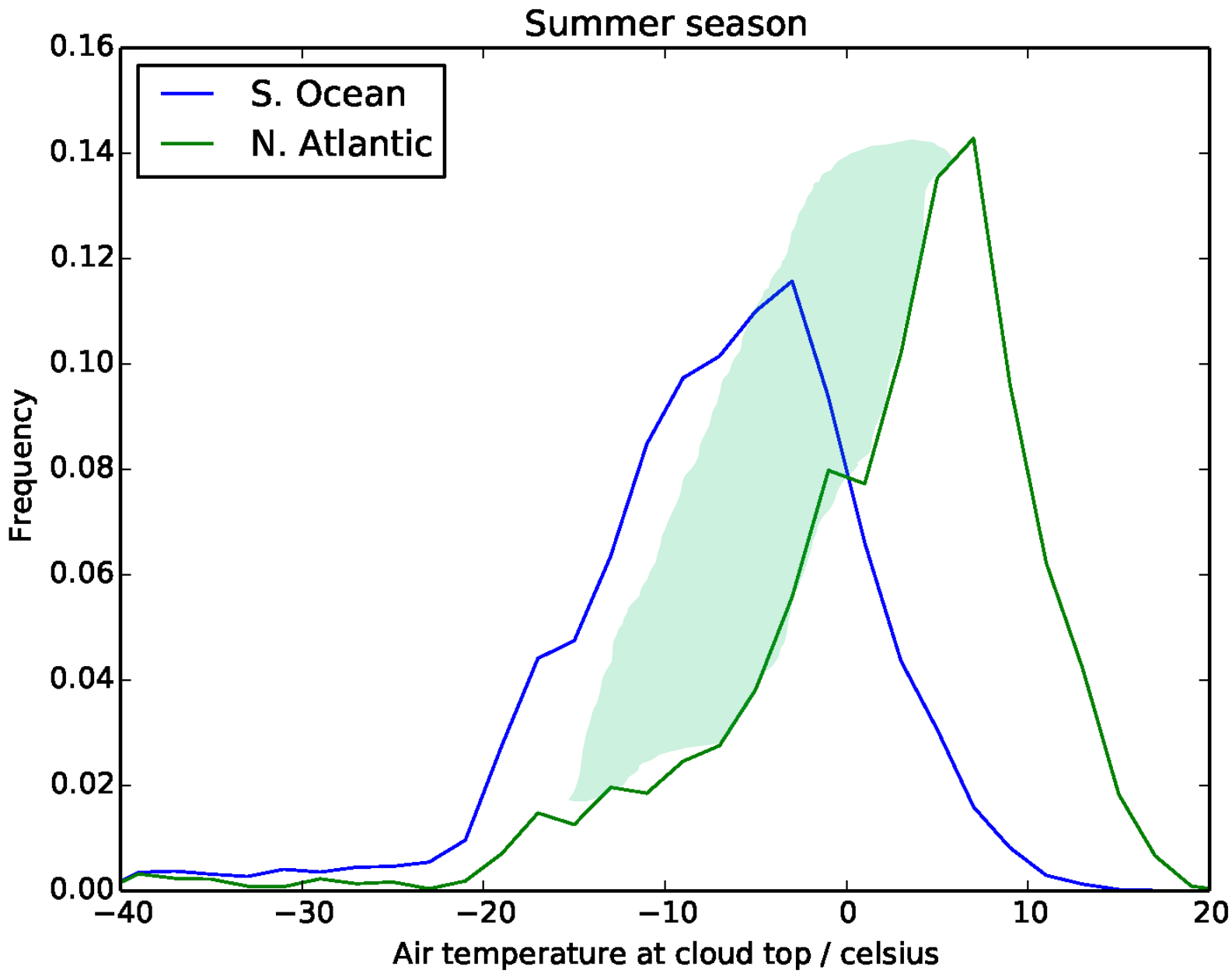
- L: ~30%
- M*: ~18%
- H*: ~43%

- ICE: 45%
- SCL: 30%
- LIQ: 11%
- MIX: 6%

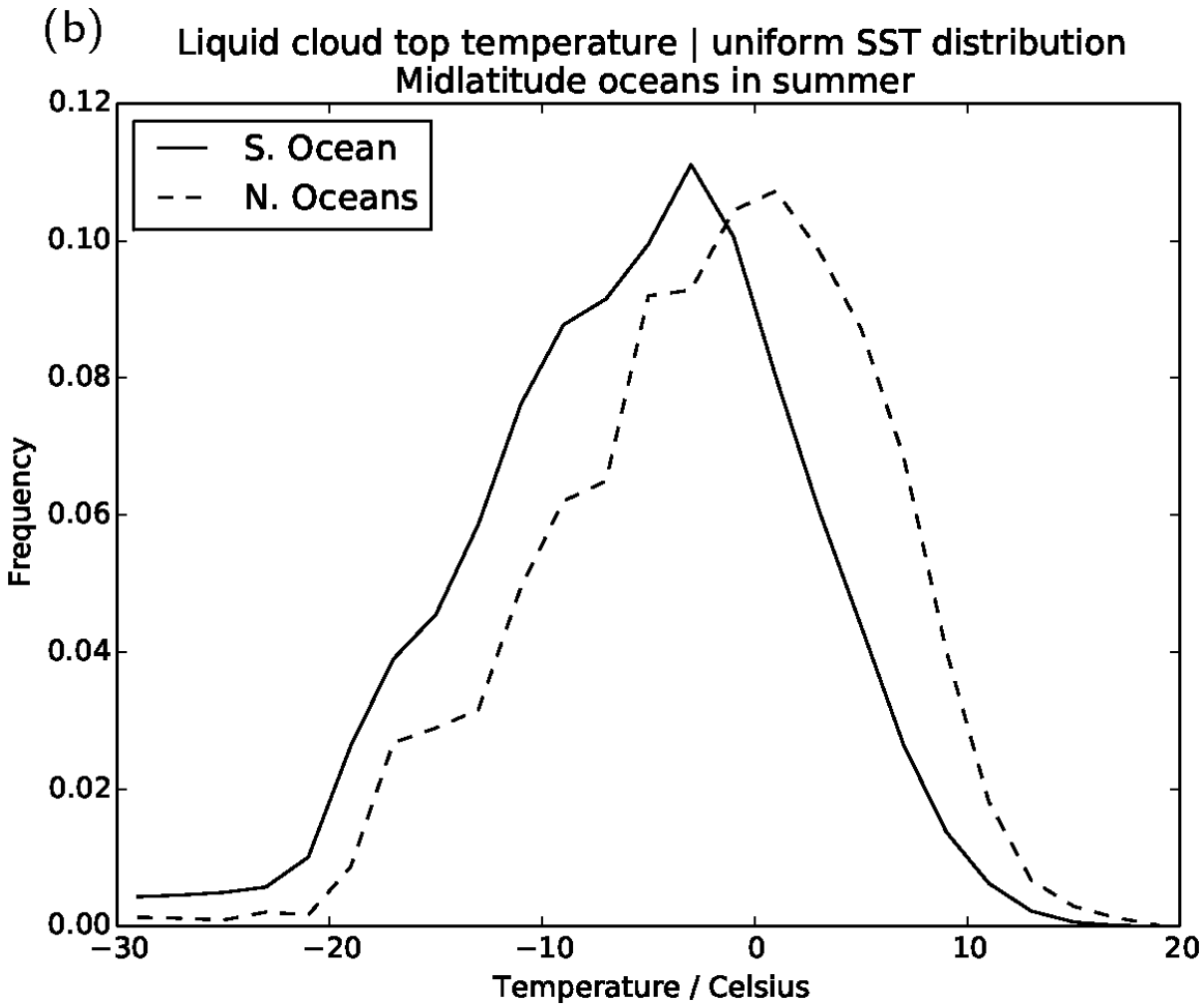


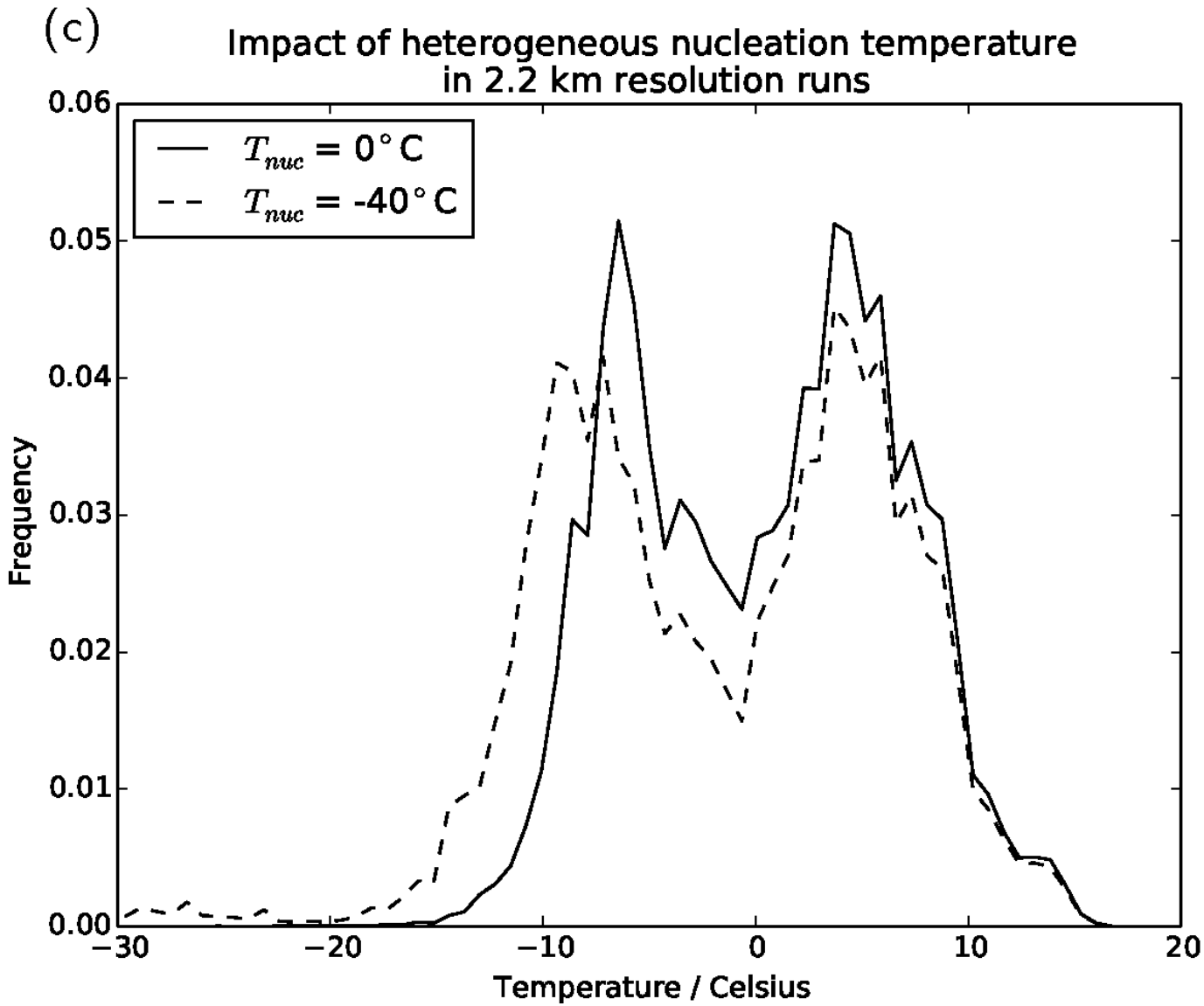




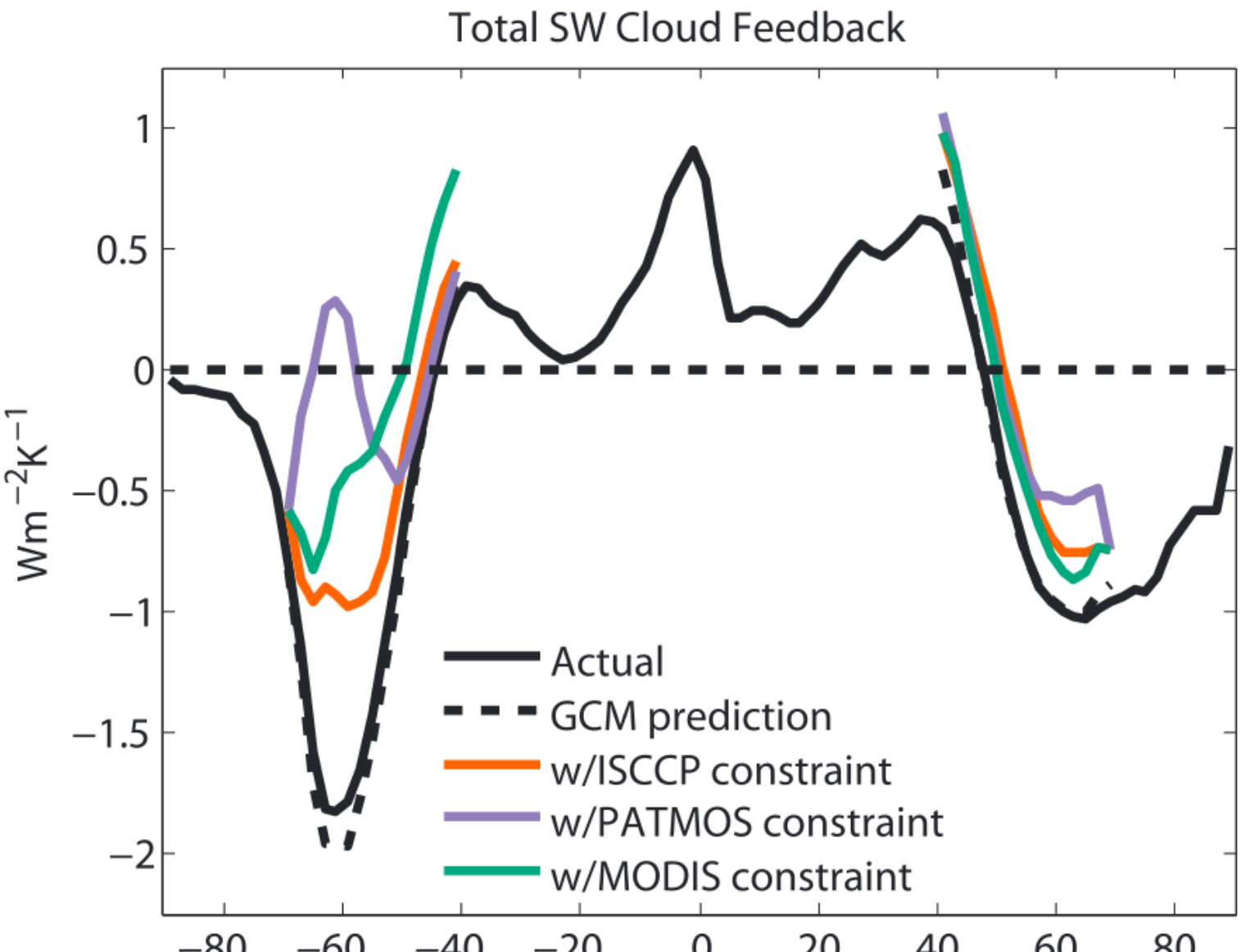


What controls the N-S differences?





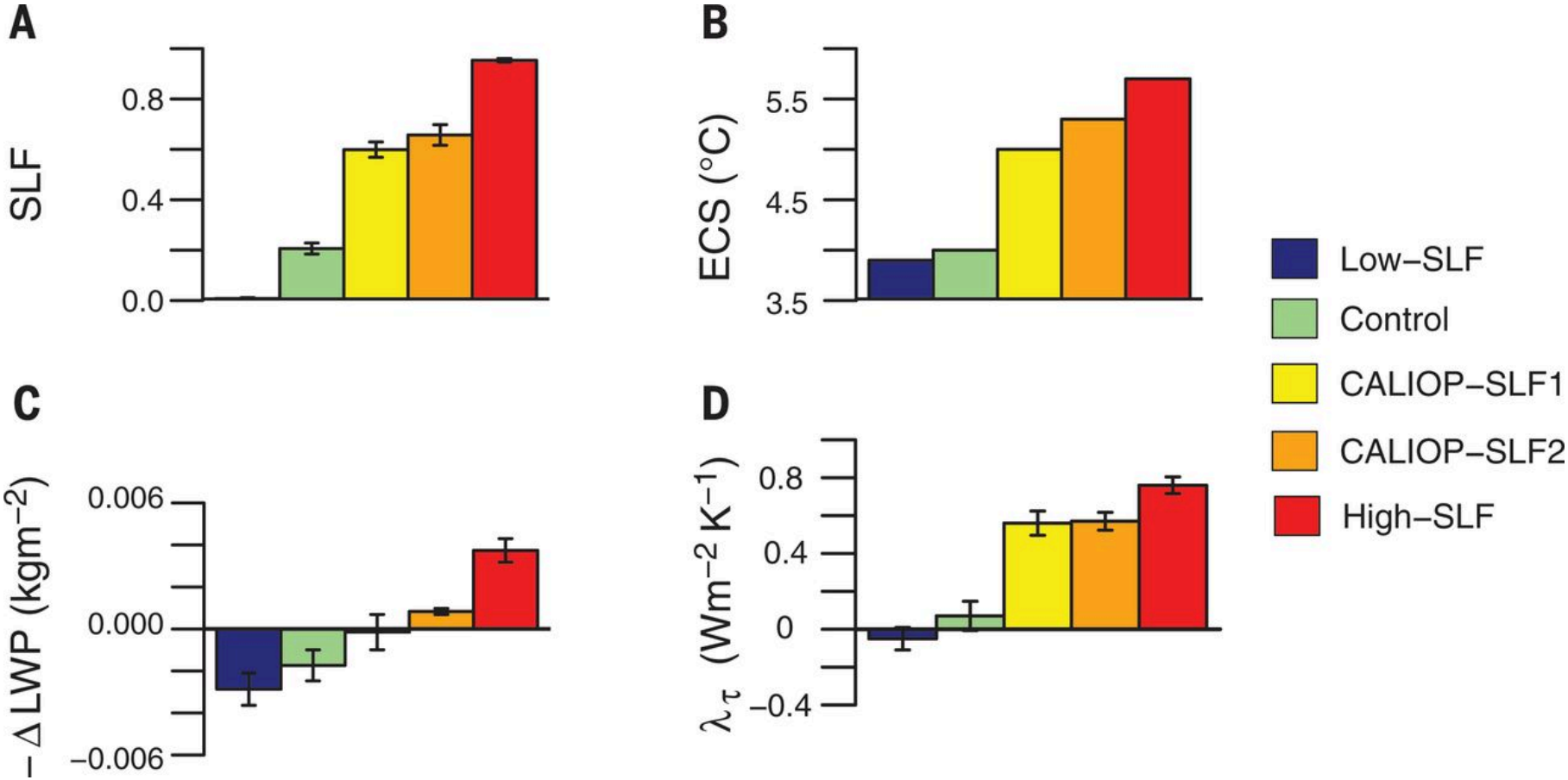
(Bodas-Salcedo et al., *J. Climate*, 2016. DOI:10.1175/JCLI-D-15-0564.1)



(Terai et al., *JGR*, 2016)

**(Also: Tselioudis et al., *J. Climate*, 1992;
Gordon and Klein, *JGR*, 2014; Ceppi et al., *GRL*, 2016)**

Cloud phase and climate sensitivity



(Tan et al., *Science*, 2016. DOI:10.1126/science.aad5300)

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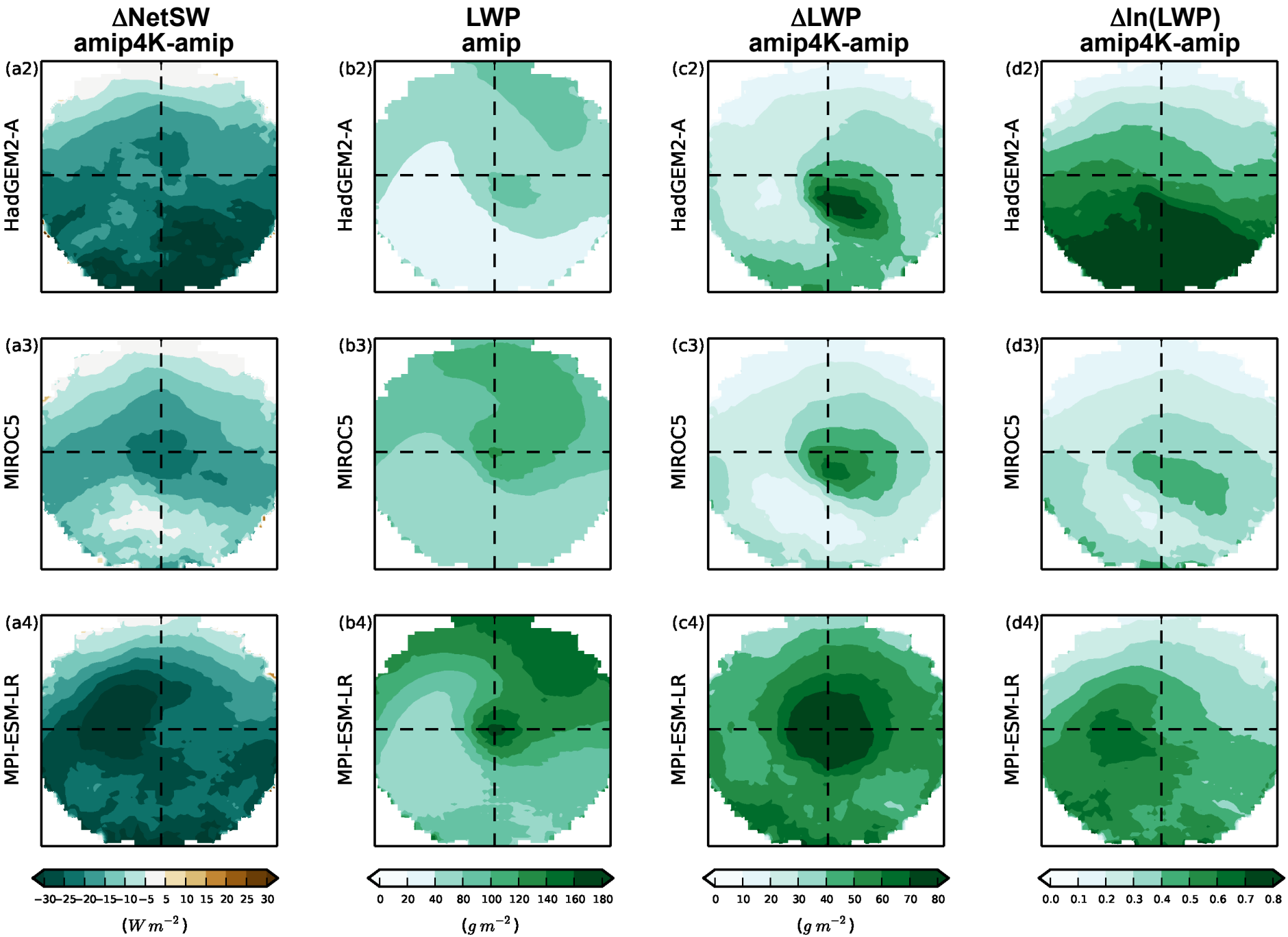
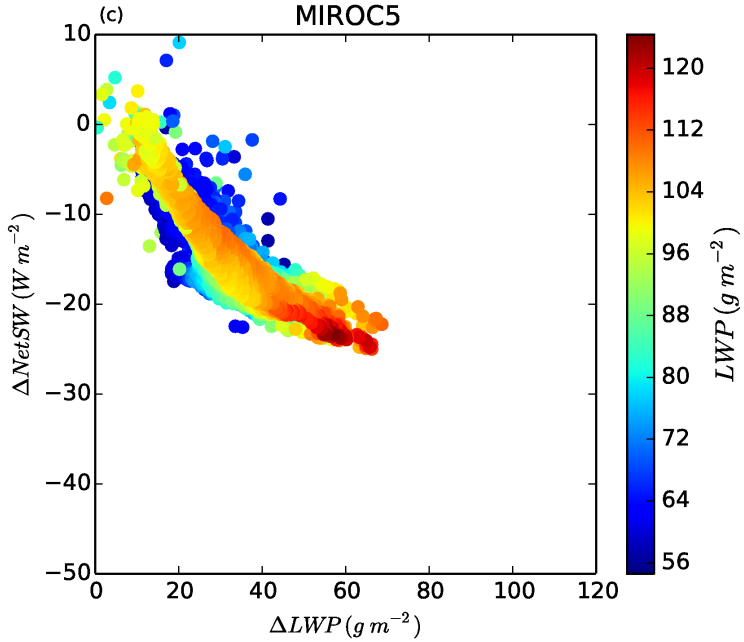
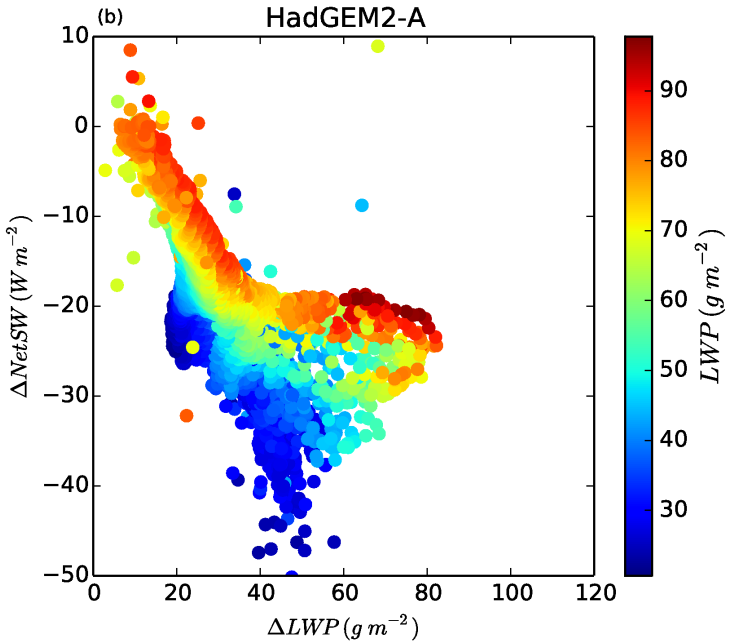
Are present-day biases relevant to cloud feedbacks?

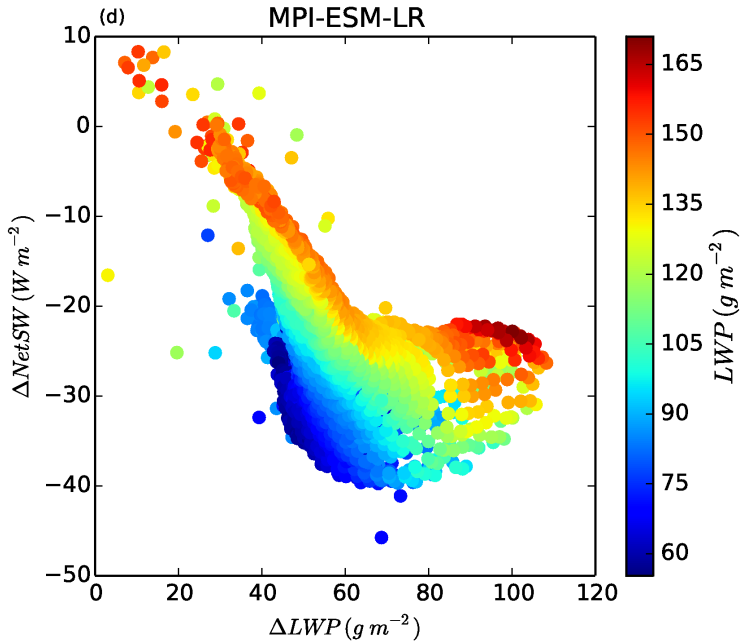
Bodas-Salcedo et al., *GRL*, 2016.

DOI: 10.1002/2016GL070770









Summary

- Cold-air side of cyclones dominate SW biases: tops at low- and mid-level
- ERA-I shows similar errors to other models -> parameterisations play a leading role in the bias.
- Supercooled liquid clouds are at the root of radiation biases in models.
- LWP and shortwave radiative feedbacks depend on cloud type.
- Cloud-phase changes may not be the main mechanism that controls shortwave radiative feedbacks in the midlatitudes.
- Models probably overestimate the intensity of the negative cloud-phase feedback.
- Need to improve representation of processes that control supercooled liquid clouds.

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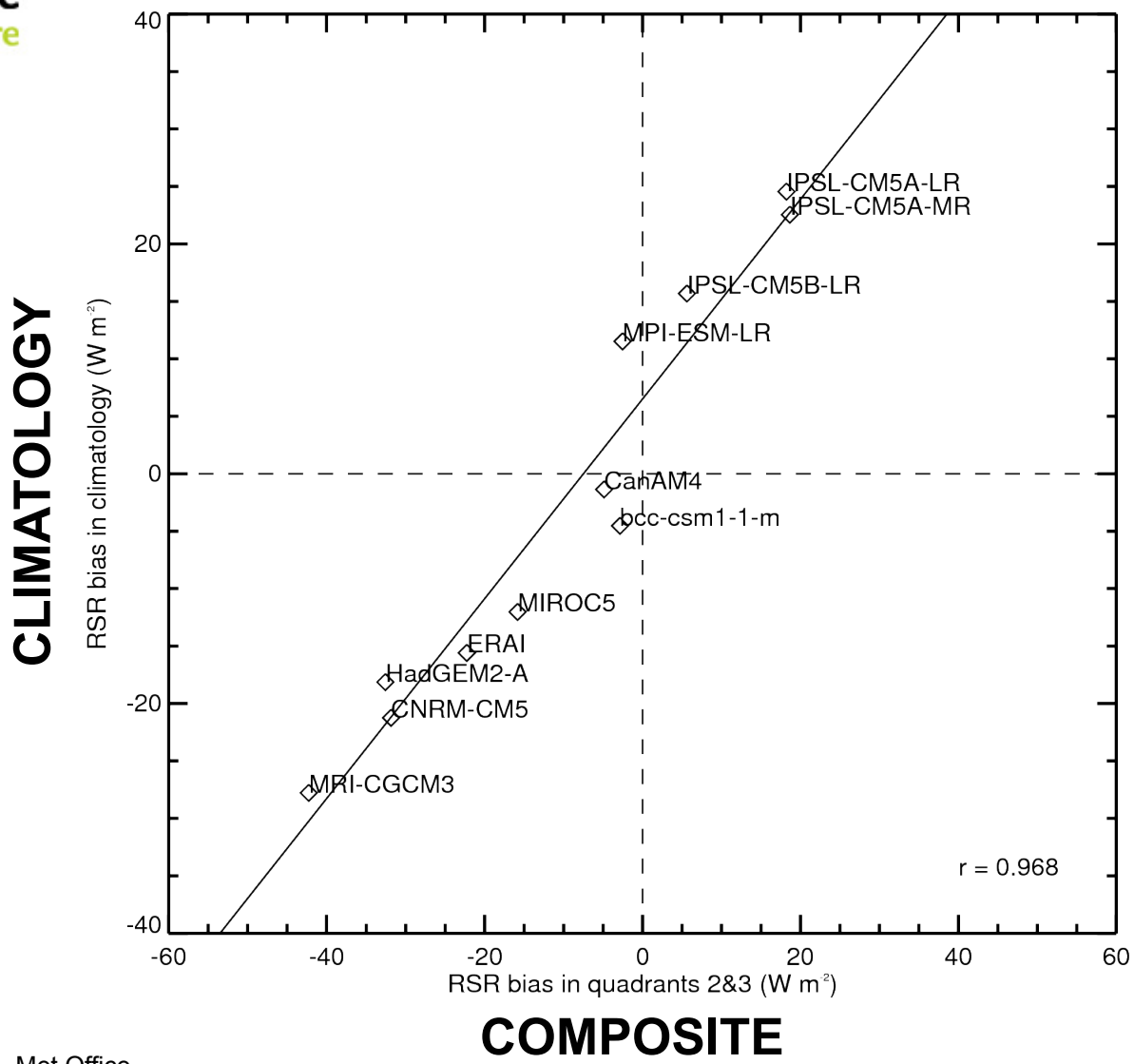
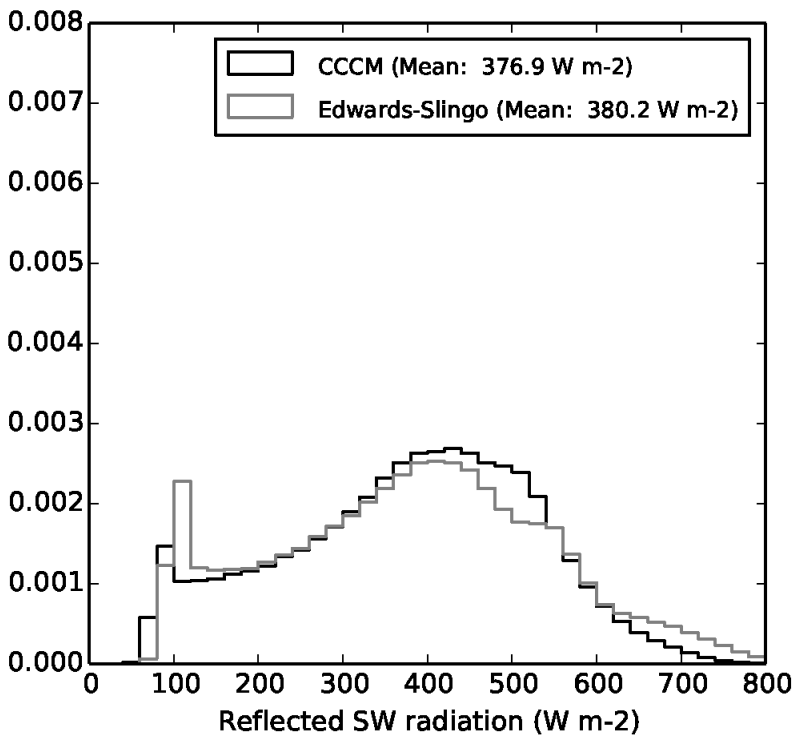
Thanks!

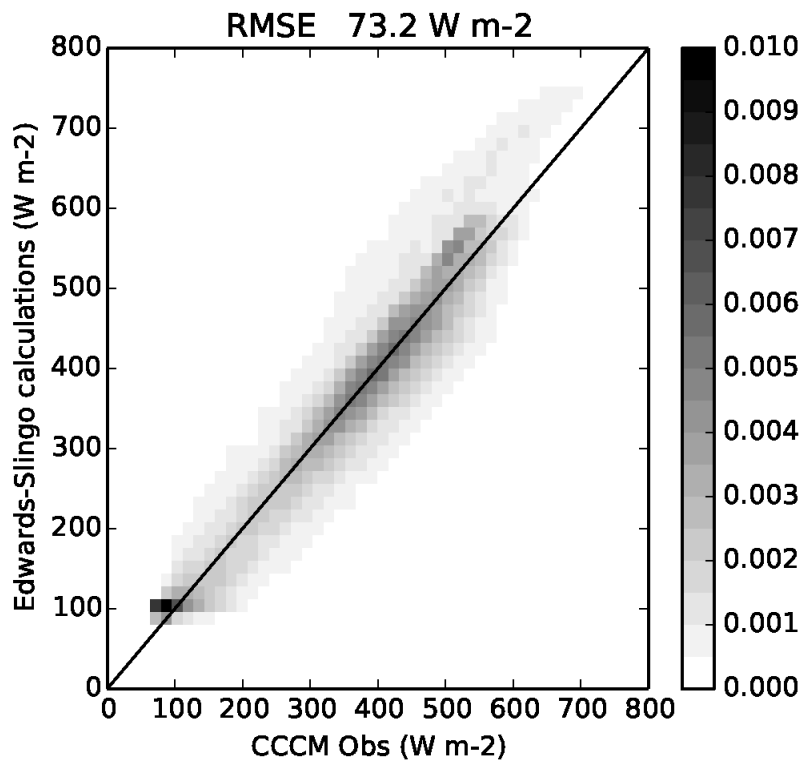
Bias in cold-air side correlates with climatological bias

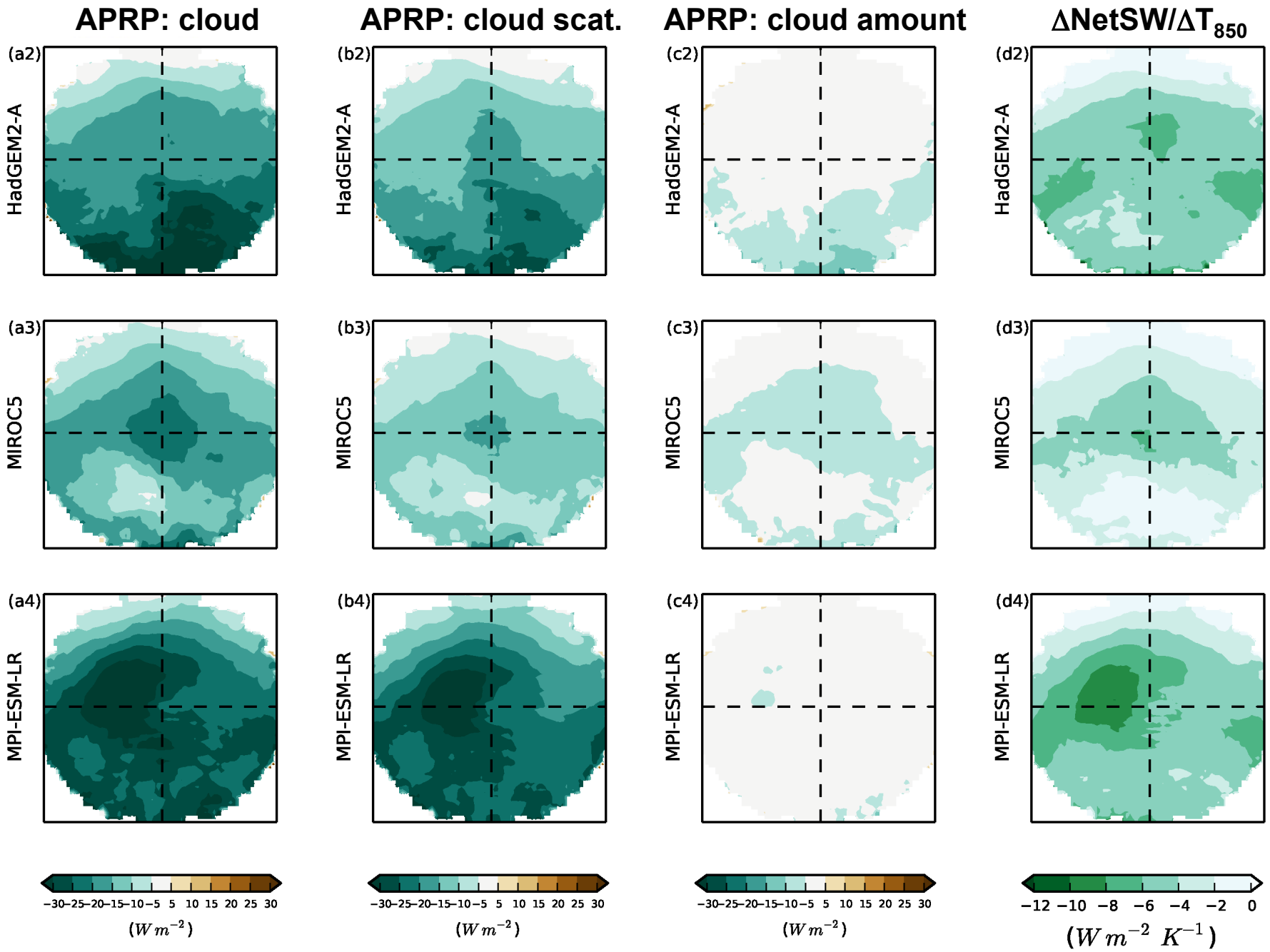


Evaluation of radiative transfer calculations

- 5 DJF seasons
- [40S, 70S]
- ~15 million profiles

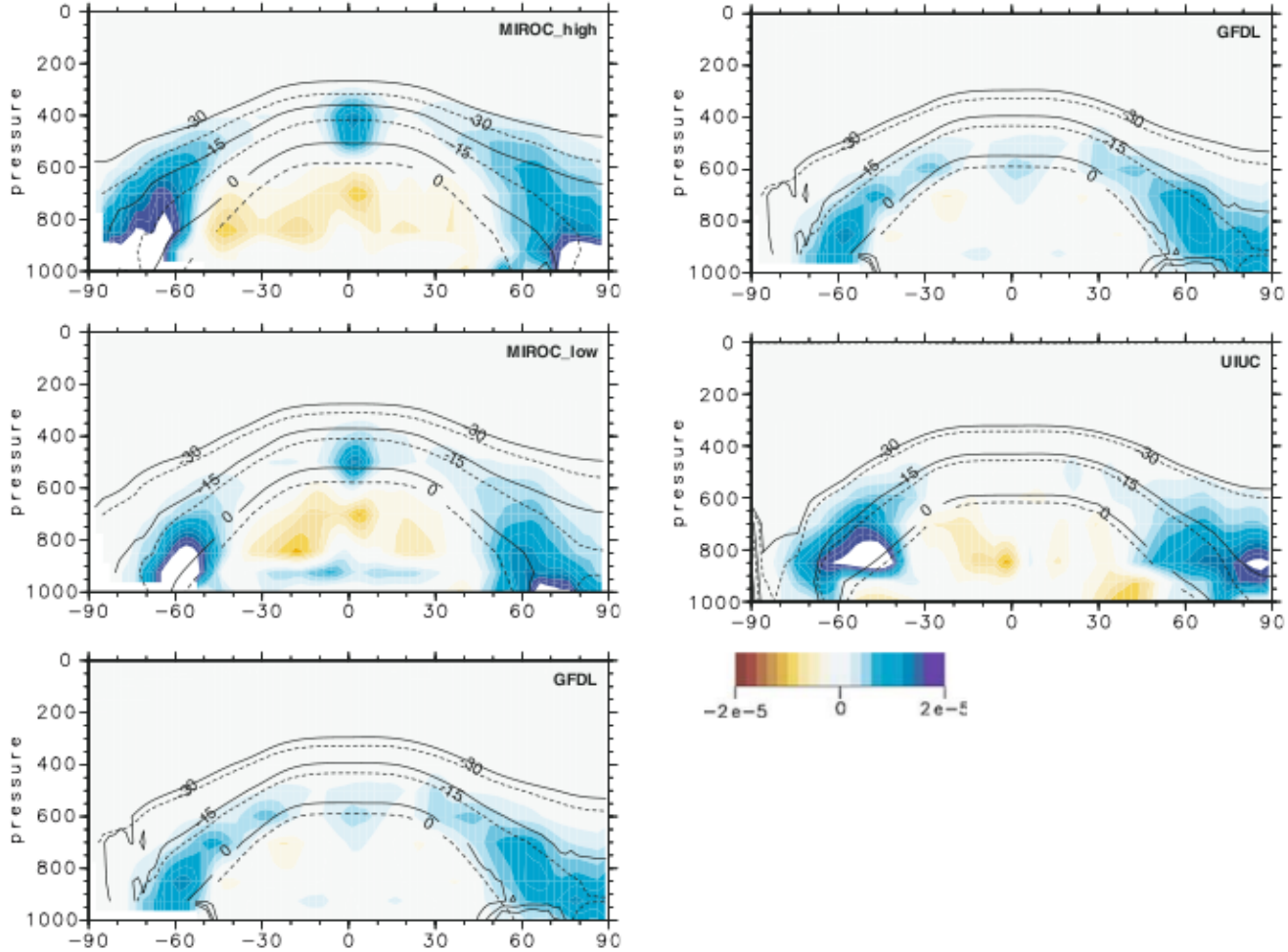






Phase-change feedback

(after Mitchell et al., *Nature*, 1989)

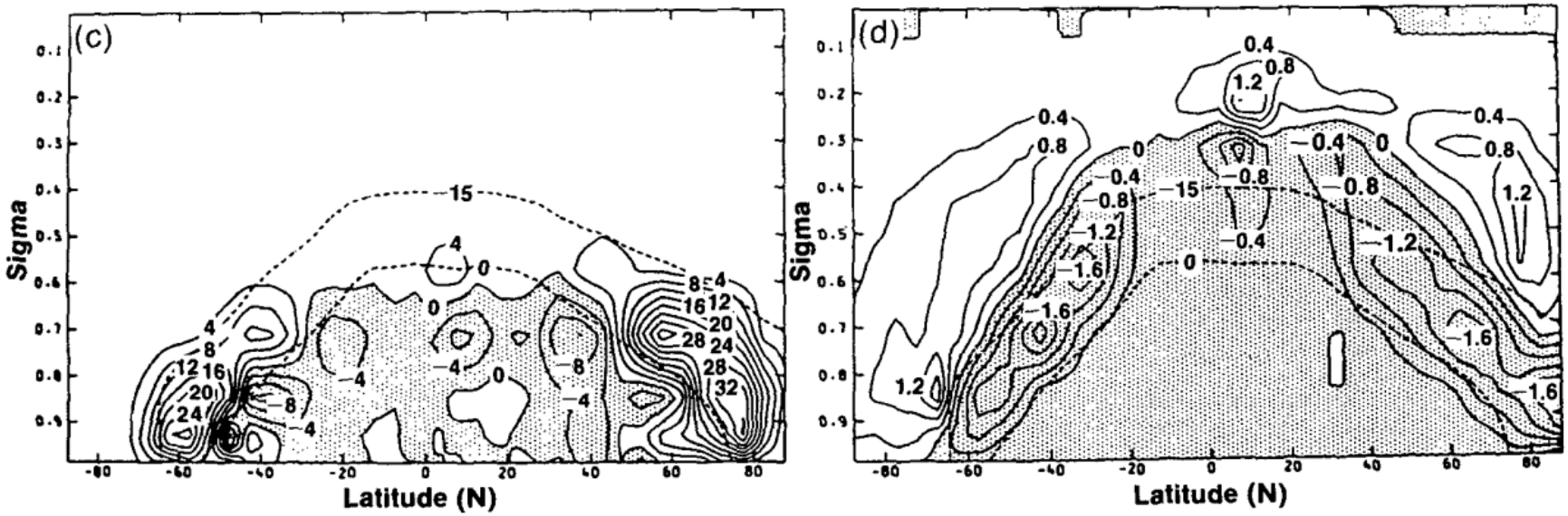


(Tsushima et al., *Clim. Dyn.*, 2006. DOI:10.1007/s00382-006-0127-7)

Phase-change feedback

(after Mitchell et al., *Nature*, 1989)

Δq_{liquid} Δq_{ice}



ECS from 5.4 to 1.9K

(Senior and Mitchell, *J. Climate*, 1993)

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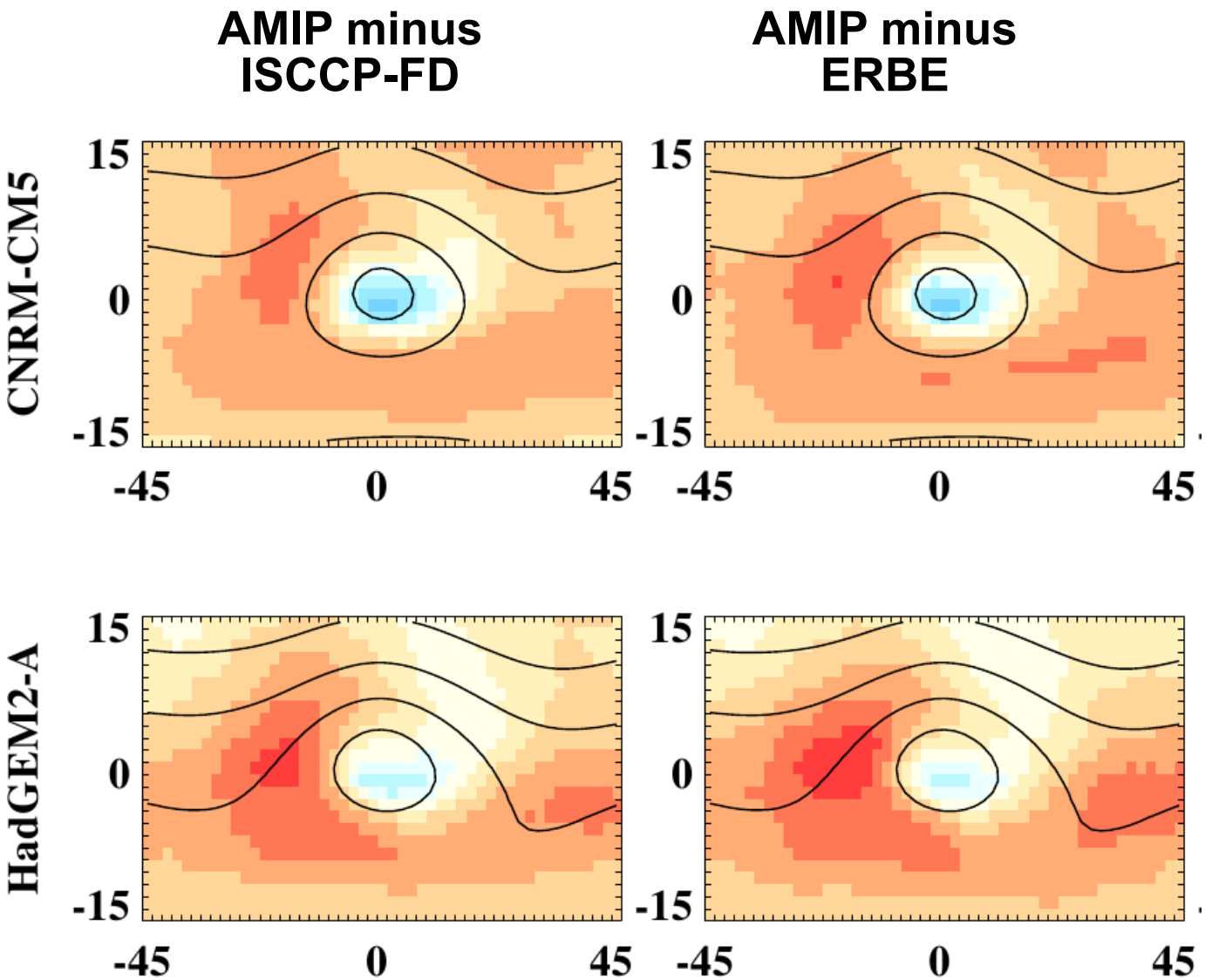
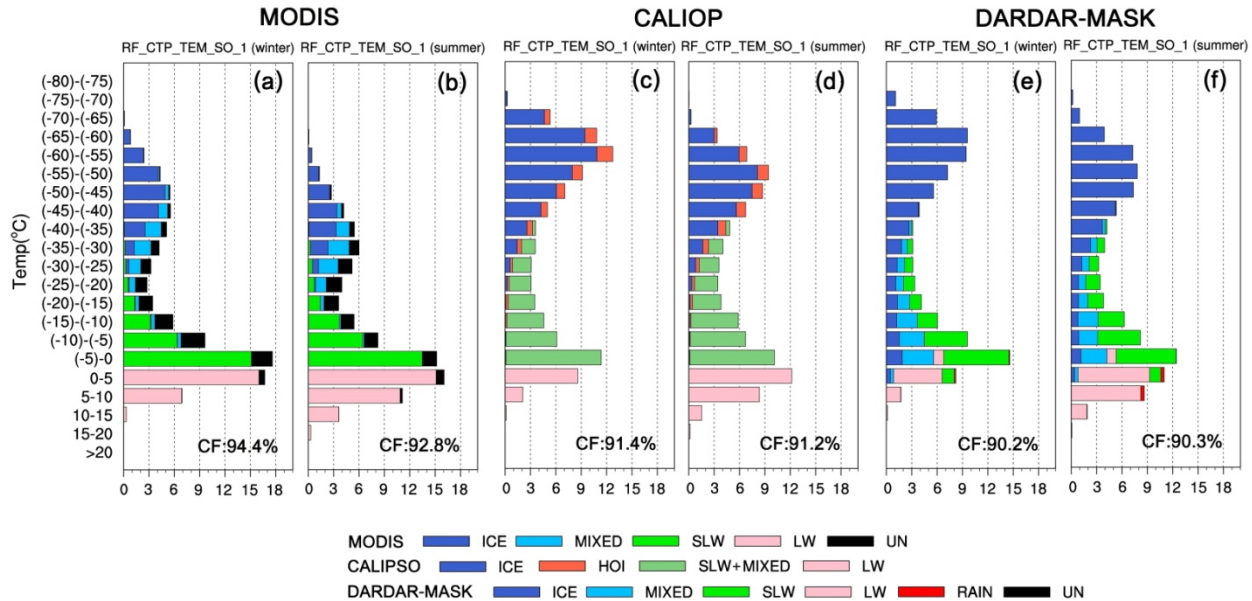
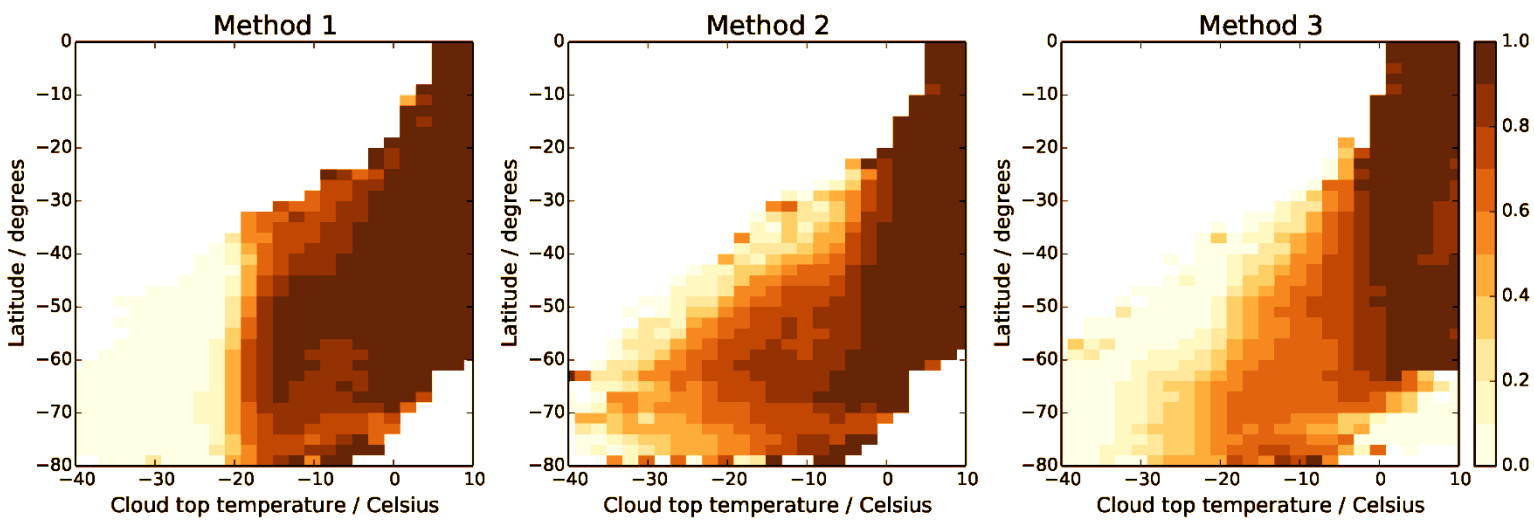


(Williams et al., *J. Climate*, 2013. DOI: 10.1175/JCLI-D-12-00429.1)

Cloud phase retrievals are uncertain

(Huang et al., *J. Climate*, 2015. DOI:10.1175/JCLI-D-14-00169.1)





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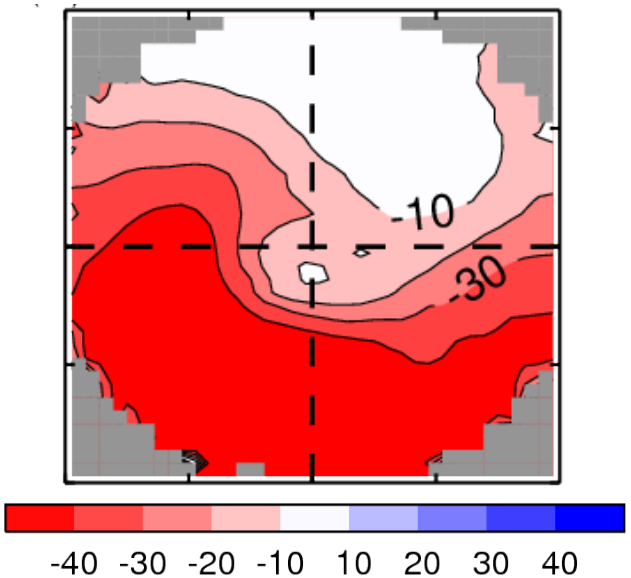
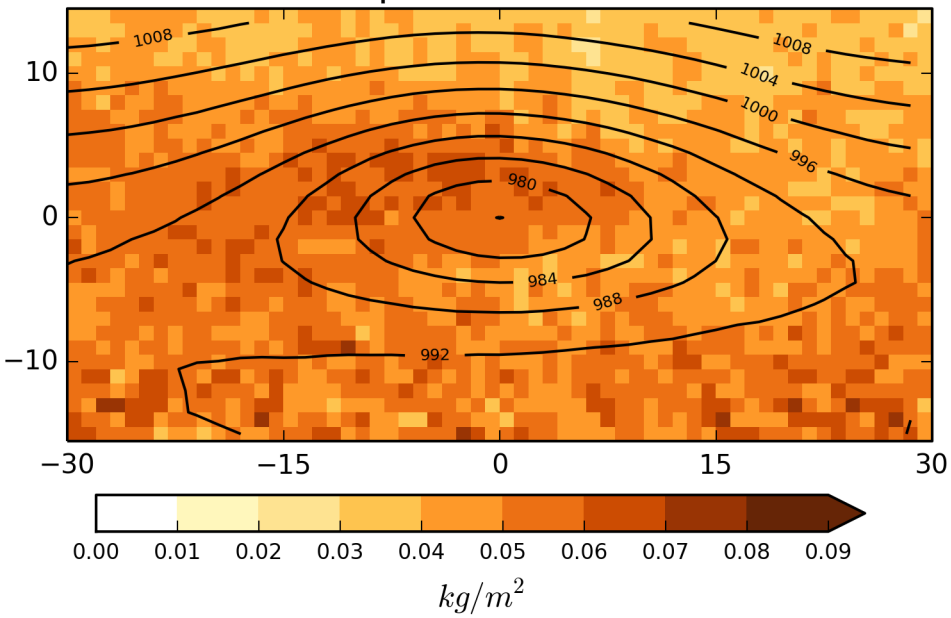


SH DJF - CCCM

Liquid Water Path



SH DJF - HadGEM2-A

Liquid Water Path