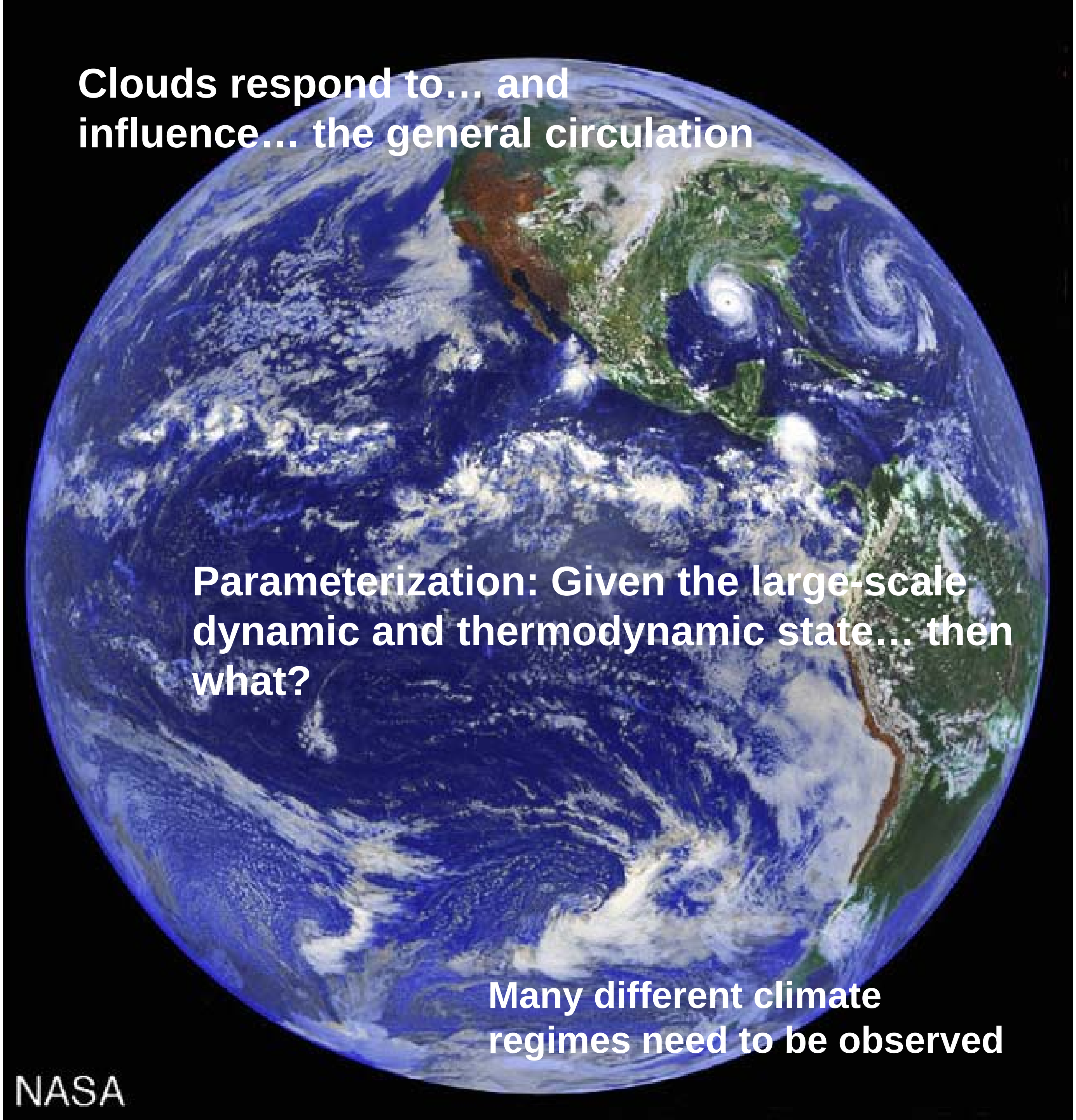
Challenges for cloud modeling

and the role of ASR

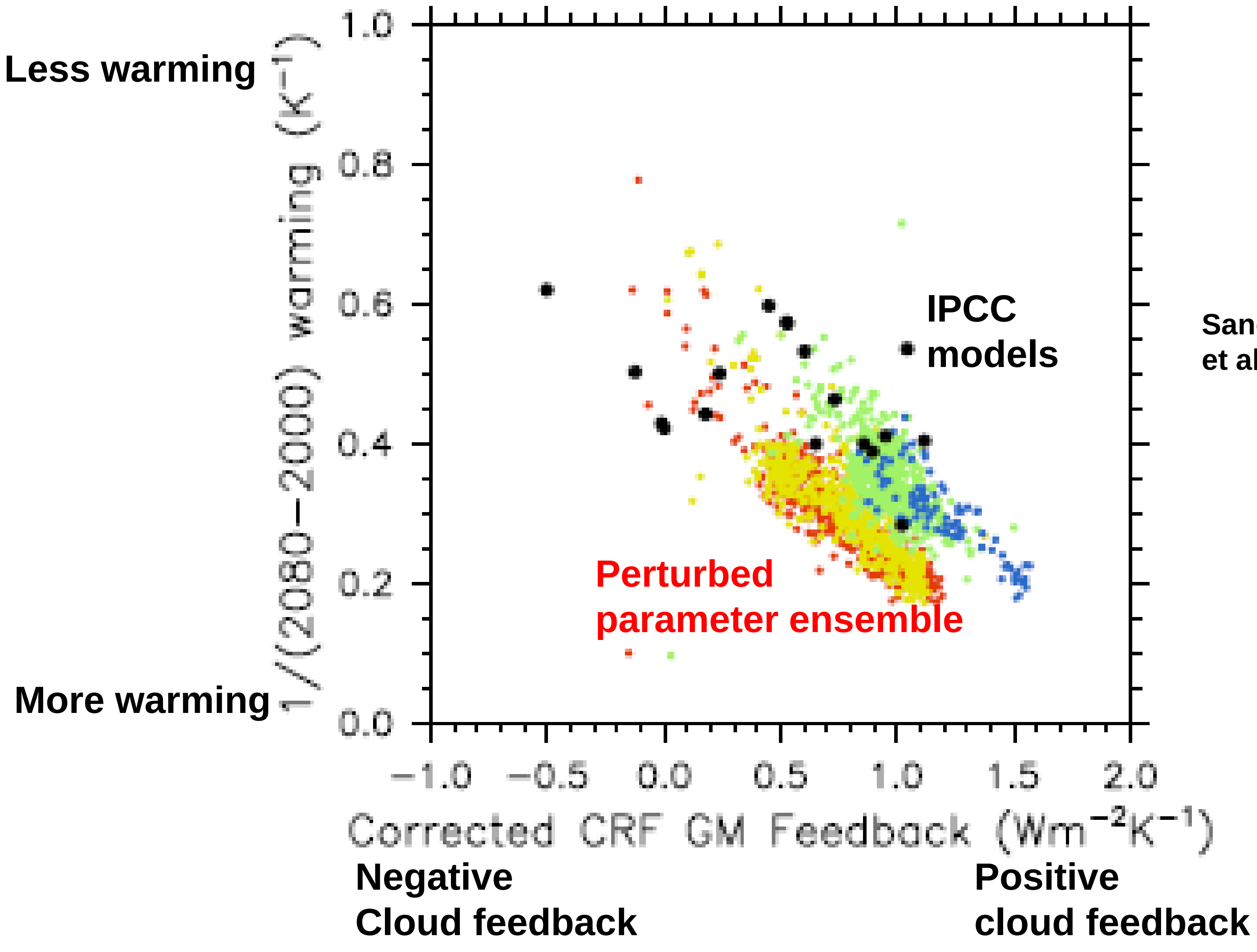
Cloud Life Cycle Working Group
Matt Shupe and Tony Del Genio, co-chairs

Steering Group: Jennifer Comstock, Jay Mace,
Steve Klein, Steve Krueger

ASR Science Team Meeting
3/16/10

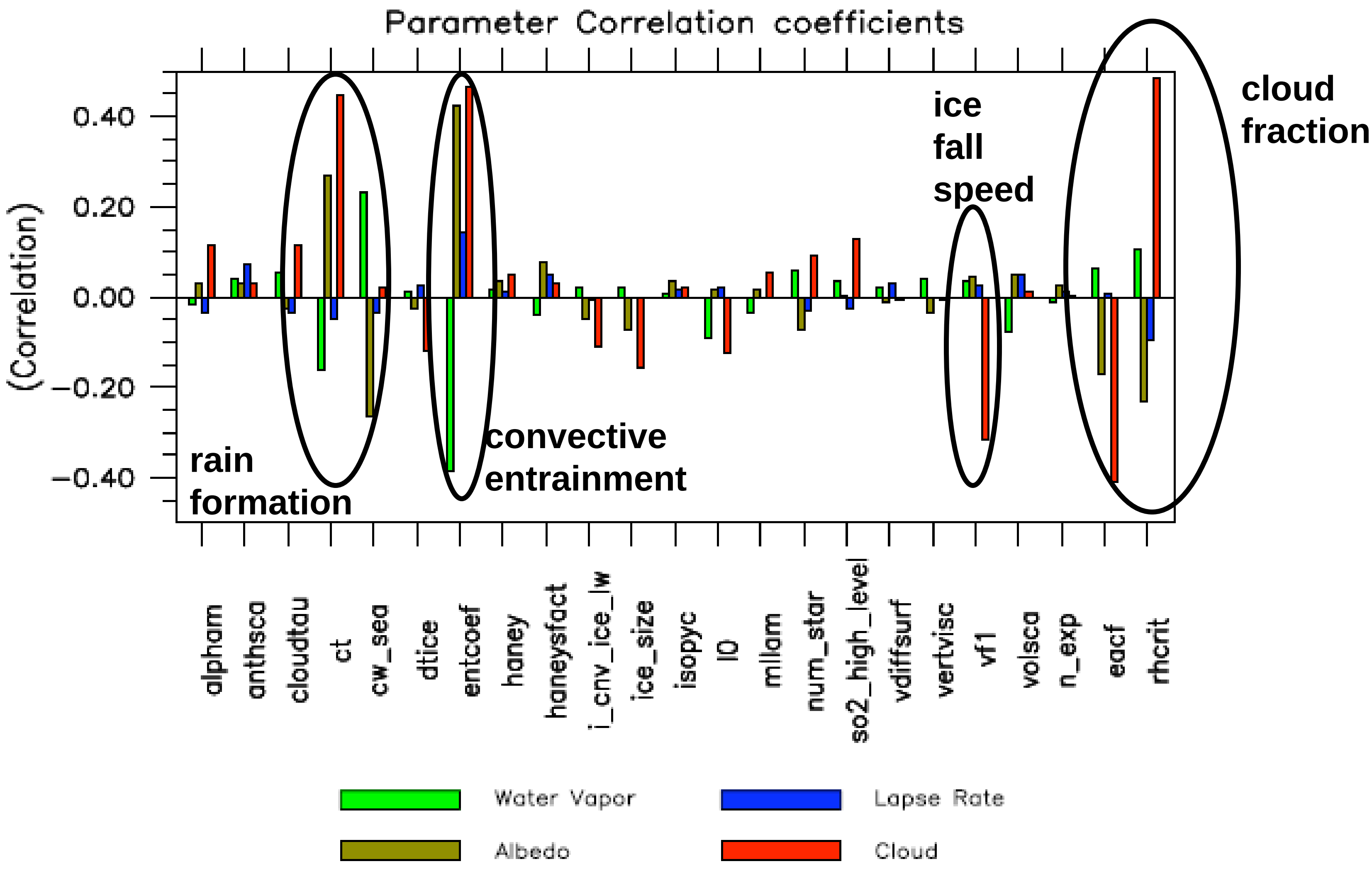

Clouds respond to… and influence… the general circulation
Parameterization: Given the large-scale dynamic and thermodynamic state… then what?
Many different climate regimes need to be observed
NASA

Clouds have a lot to say about how much we'll warm…

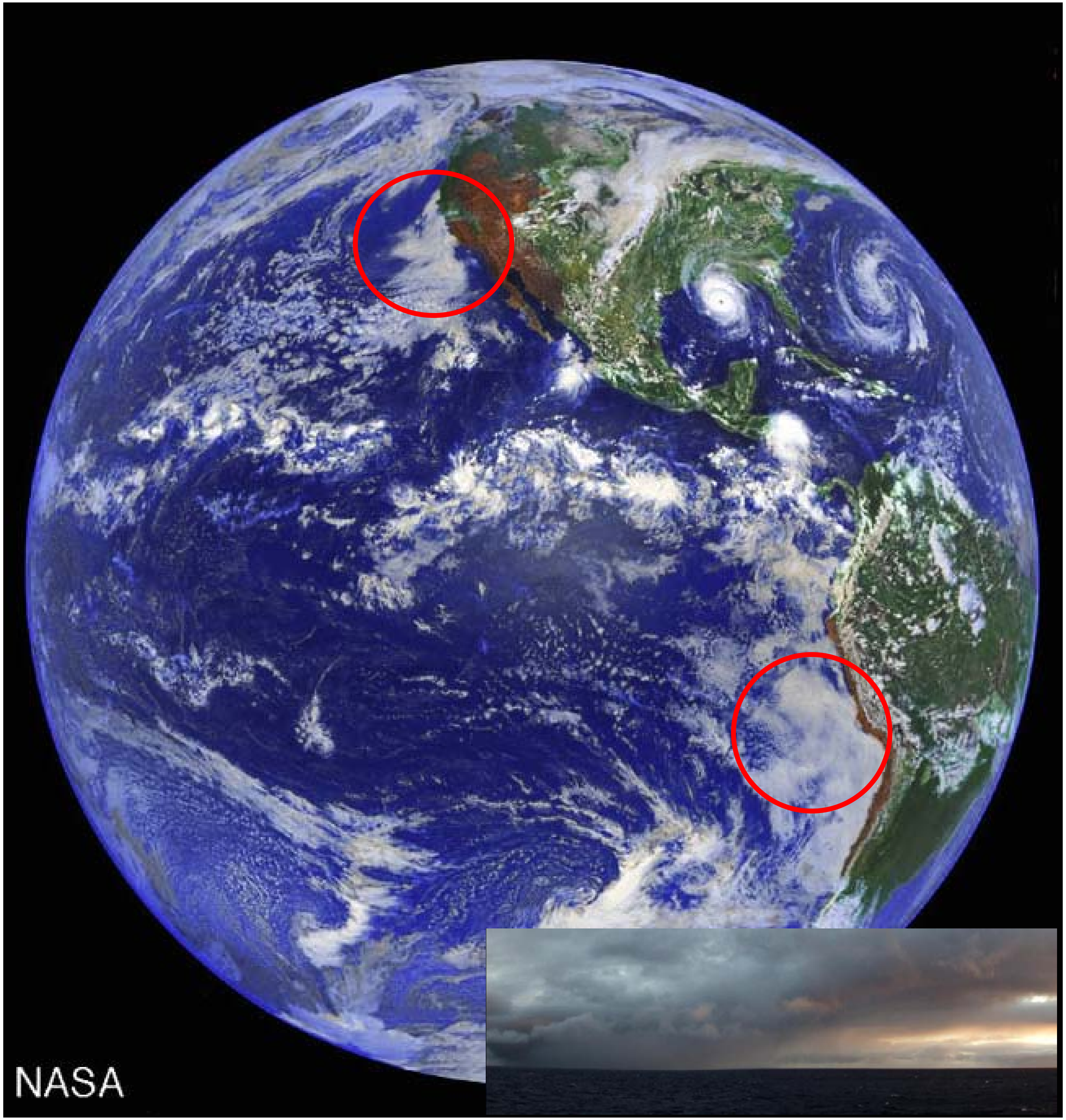


Sanderson et al. (2010)

Effects of individual parameterization elements on feedbacks

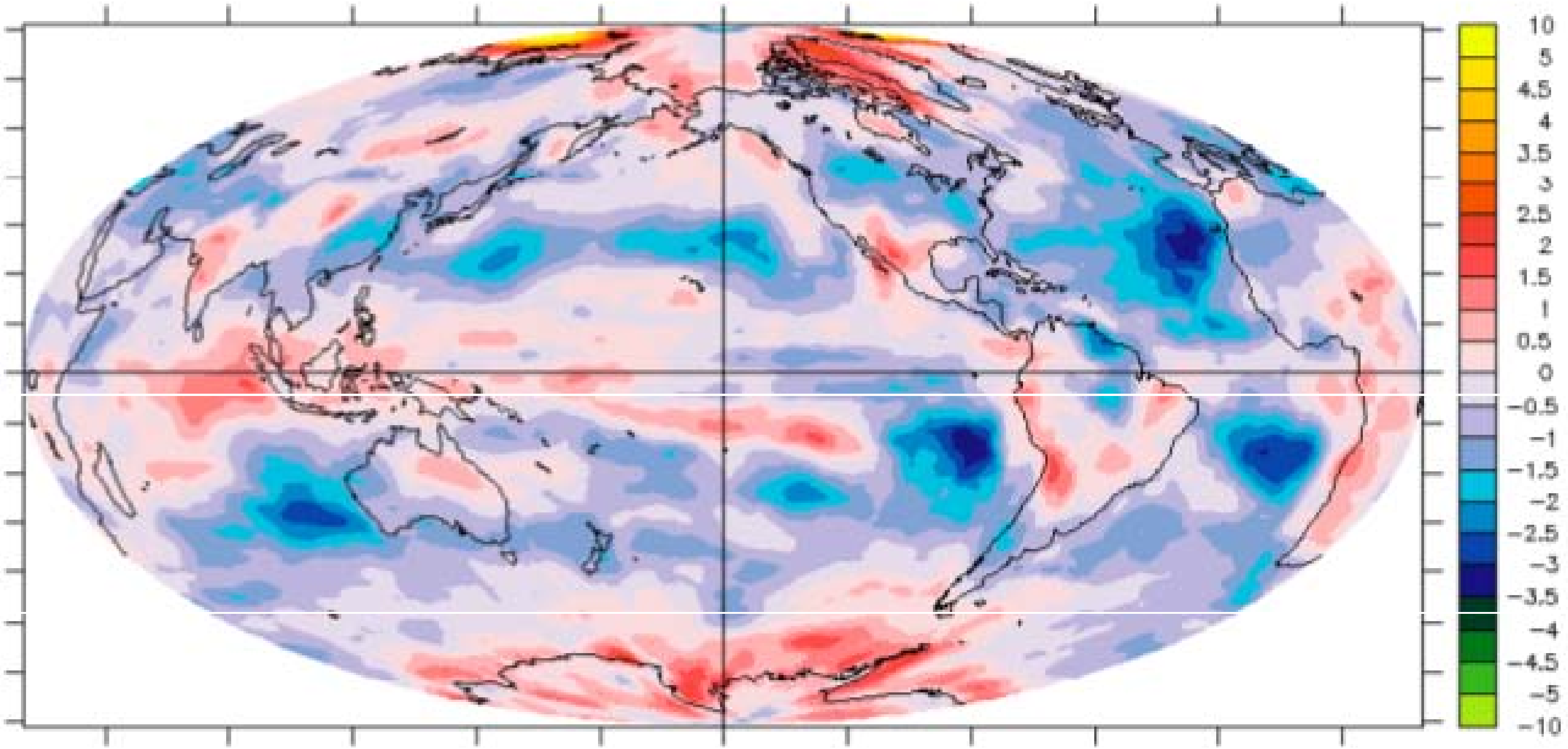


Sanderson et al. (2010)



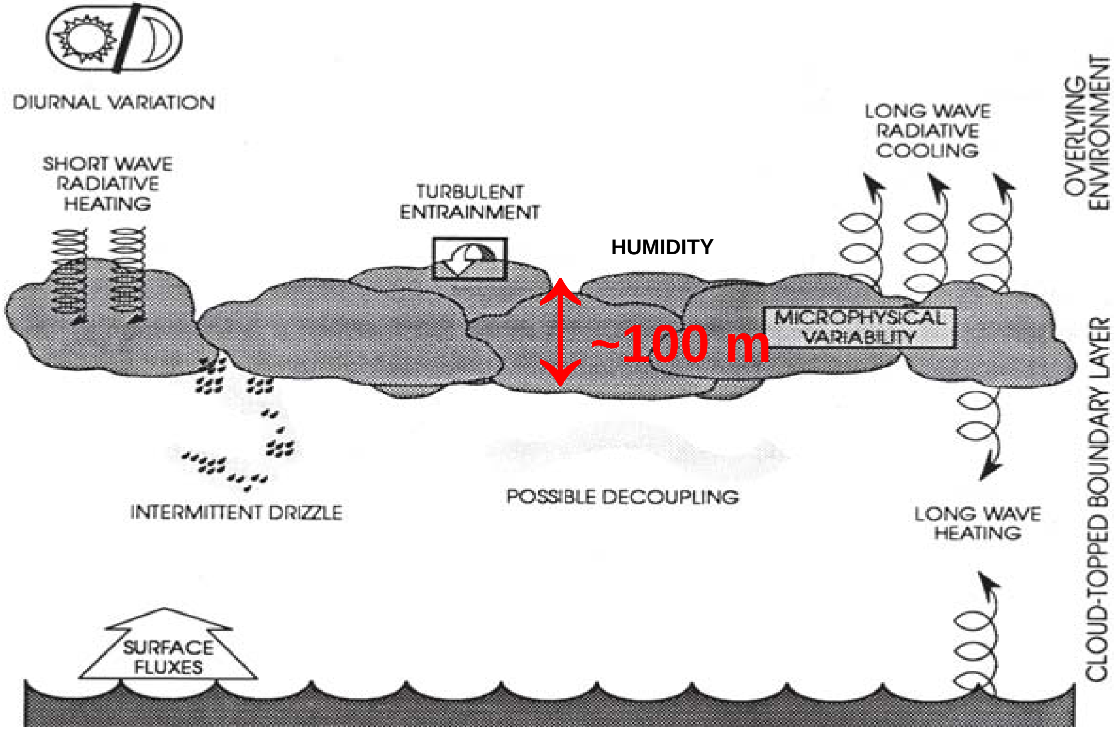
Low clouds

A “known unknown”…



Disagreement about cloud feedback among existing IPCC models is greatest in regions dominated by low cloud

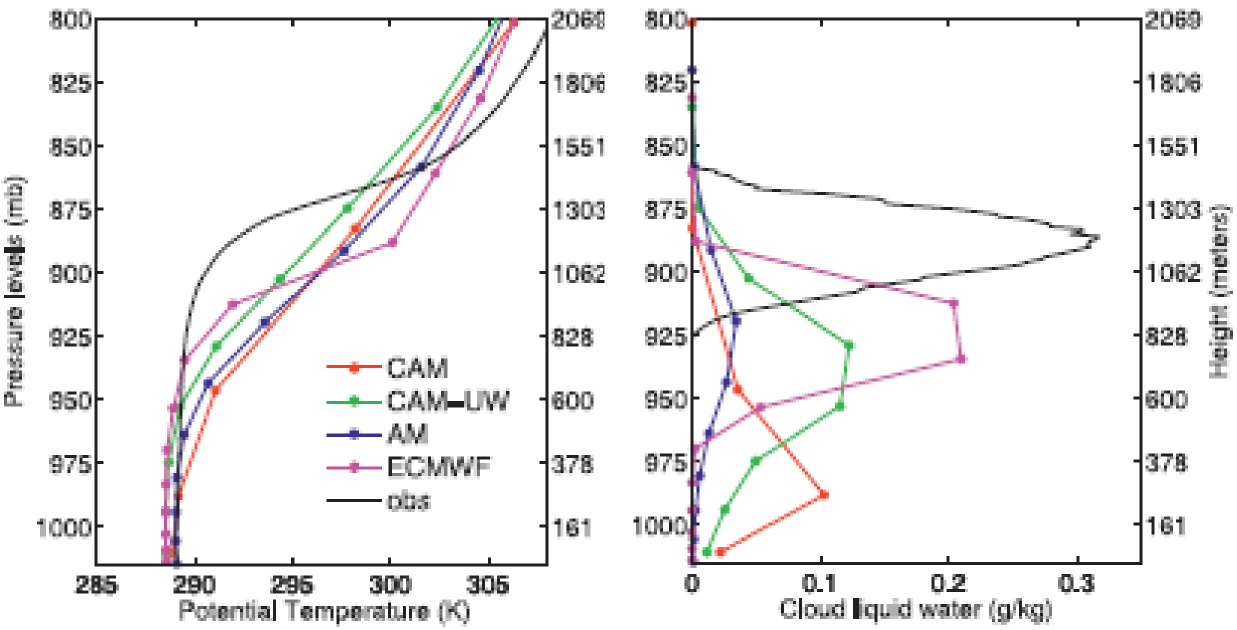
(Soden et al.)



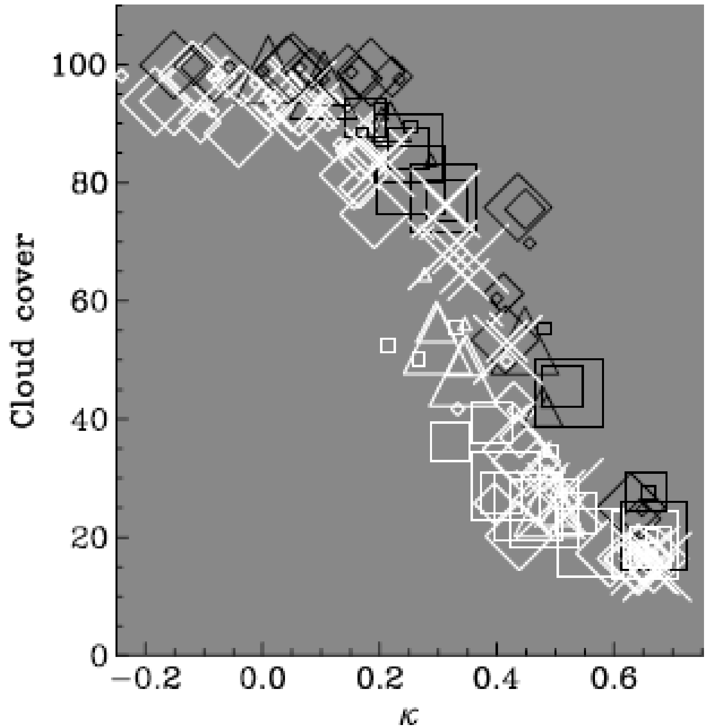
Marine stratocumulus: Many complex processes, on very small scales, matter

Bretherton et al. (2004)

Models have a very hard time simulating these clouds – implications for climate sensitivity, SST error in coupled models



Hannay et al. (2009)



Lock (2009)

more stable, wetter

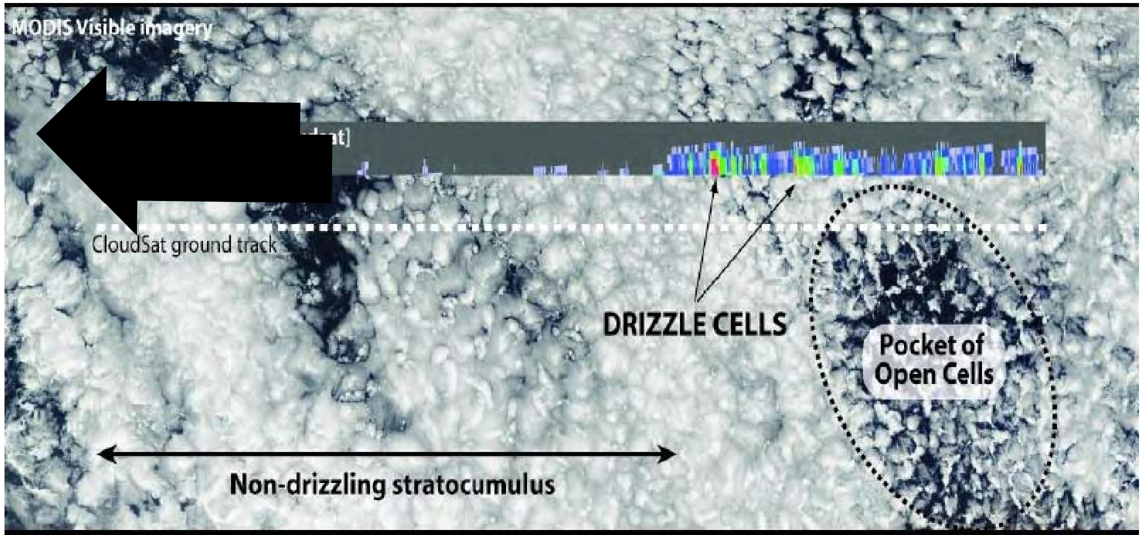
less stable, drier

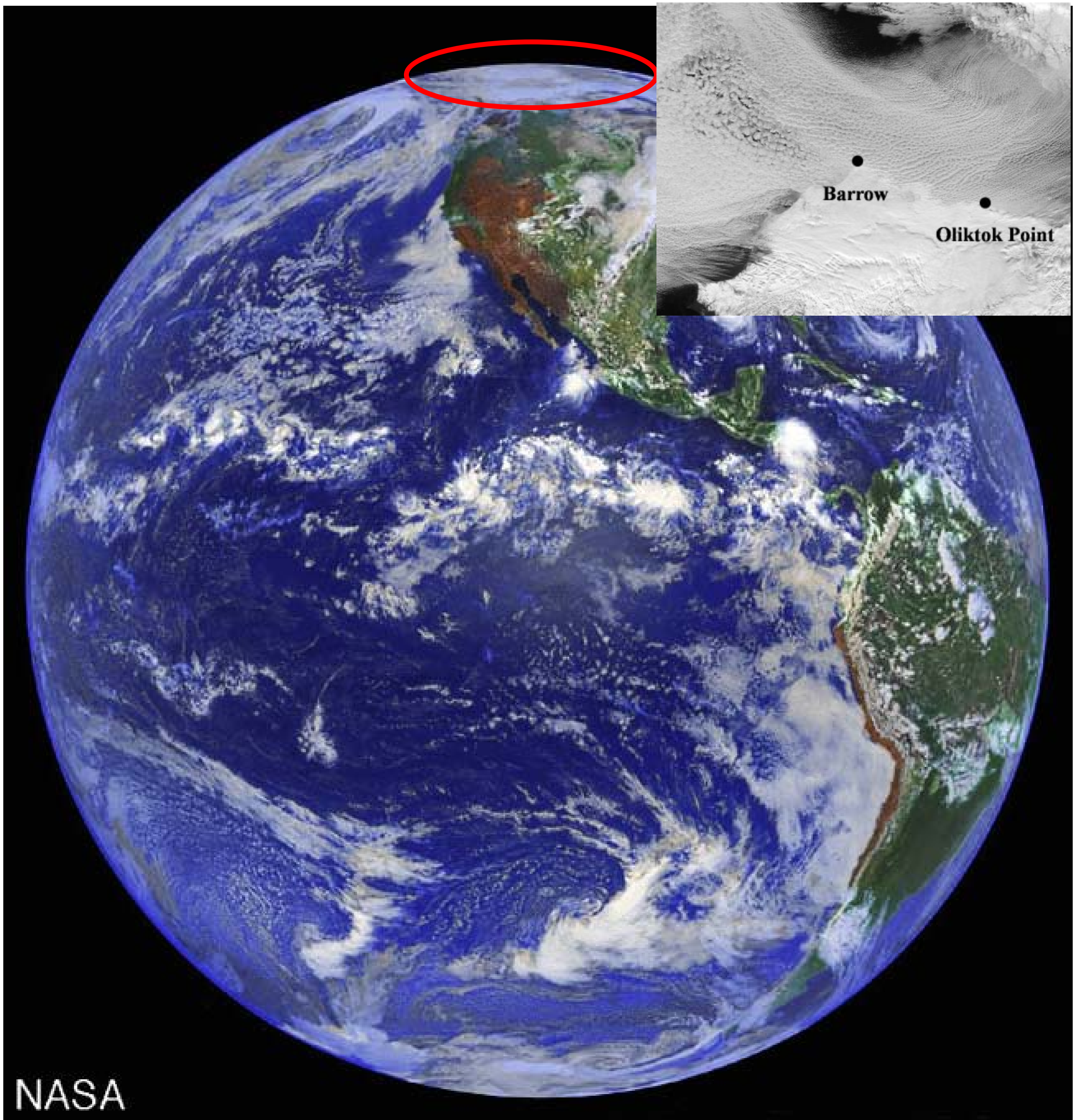
Conditions across cloud top interface may influence transition from stratocumulus to trade cumulus

Drizzle can also have a catastrophic effect on cloud cover

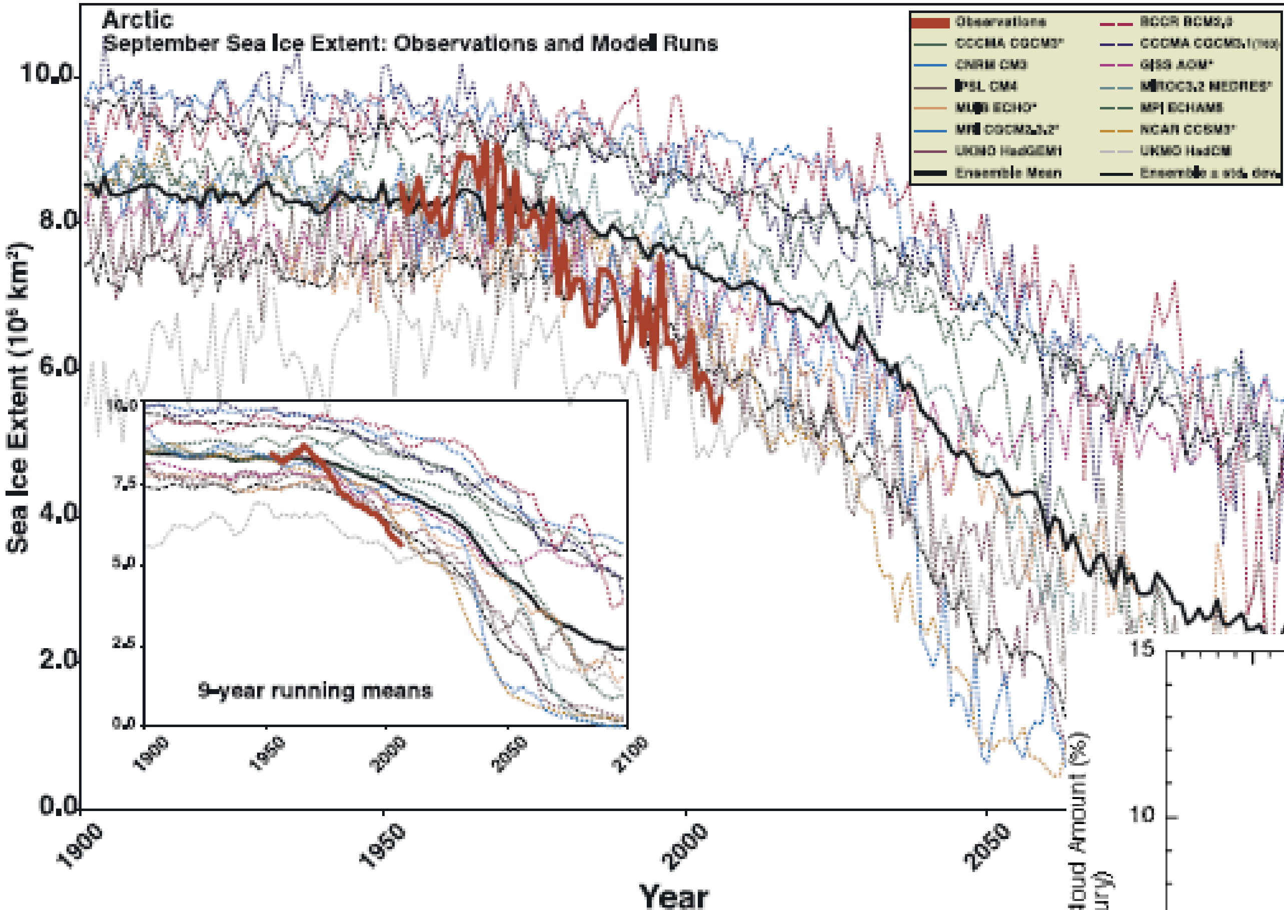
AMF deployment In the Azores

Wood (2009)



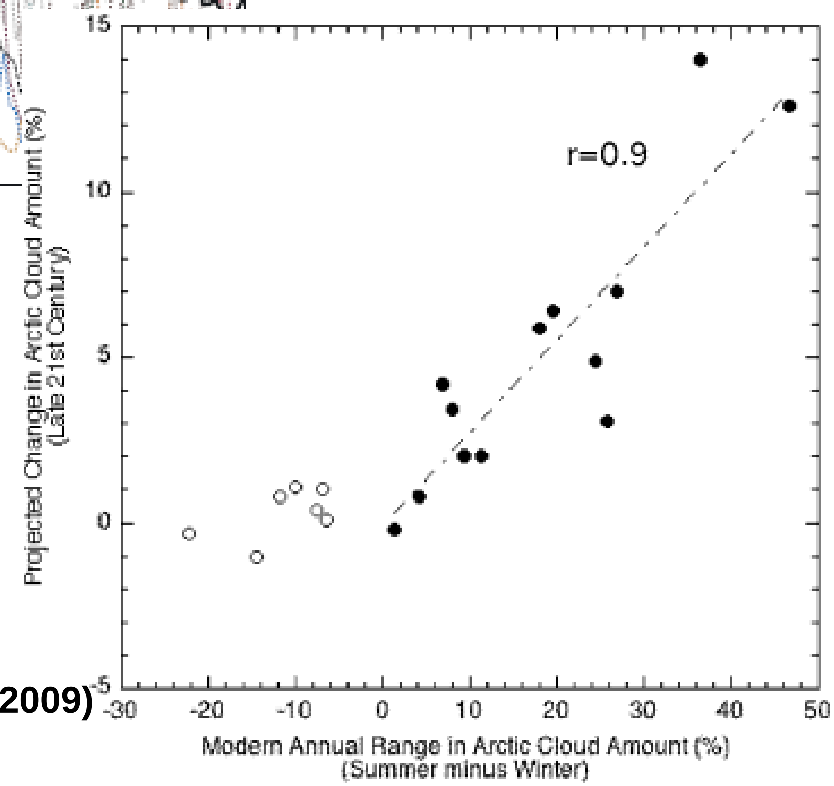


Arctic clouds



Arctic sea ice is declining faster than IPCC models predict; several possible reasons

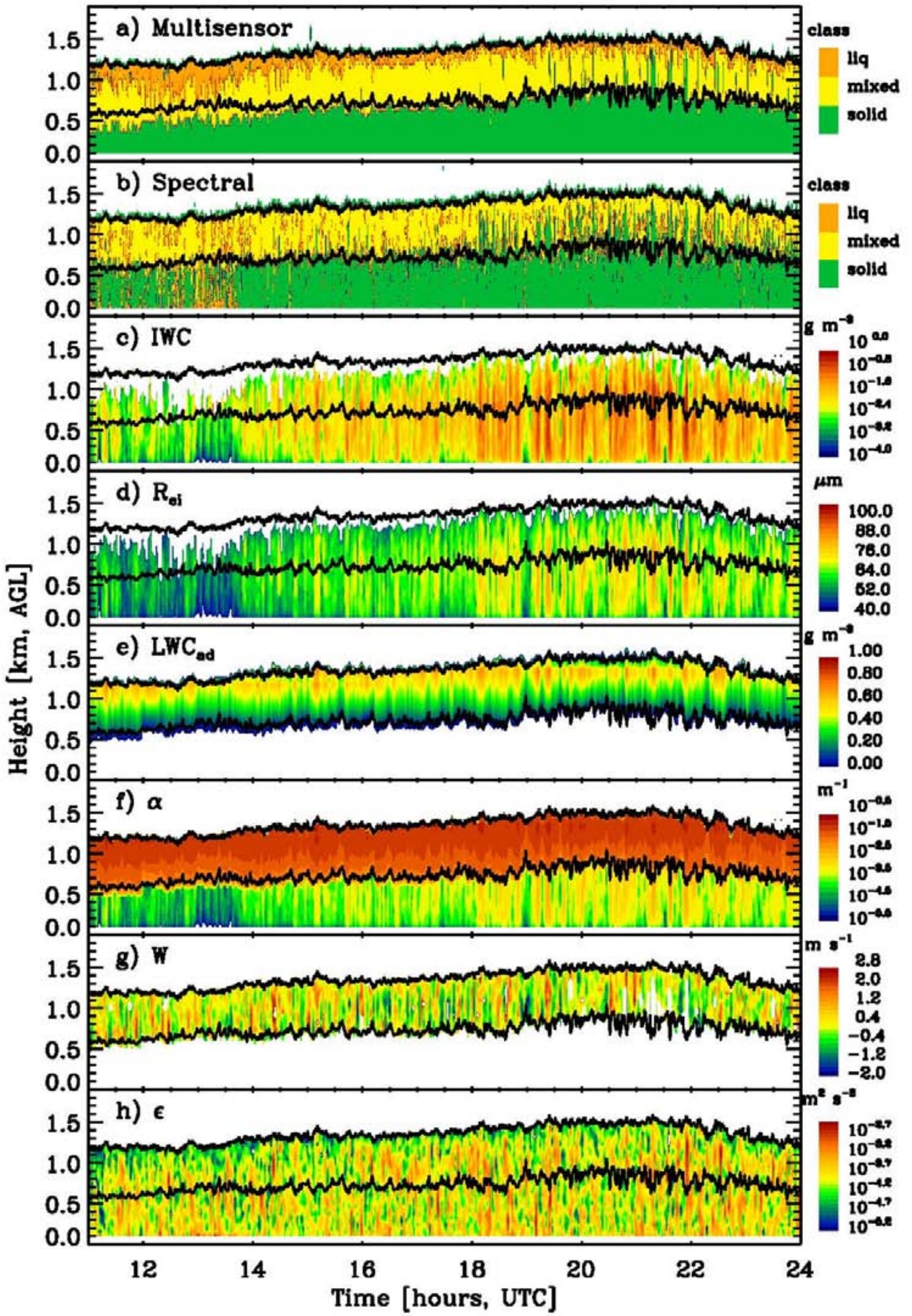
Stroeve et al. (2008)



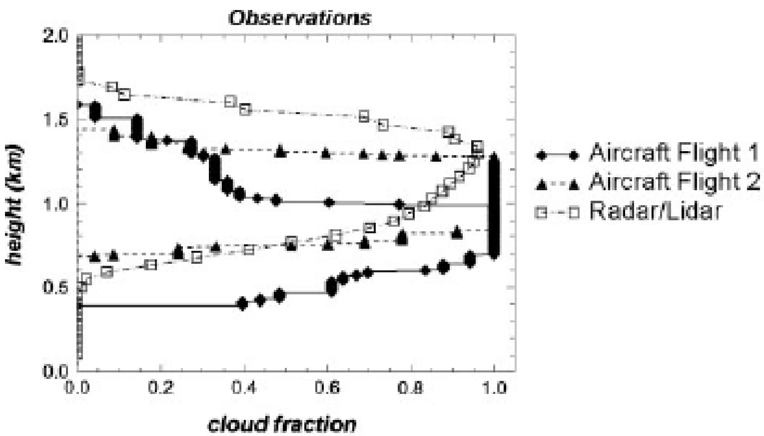
Vavrus et al. (2009)

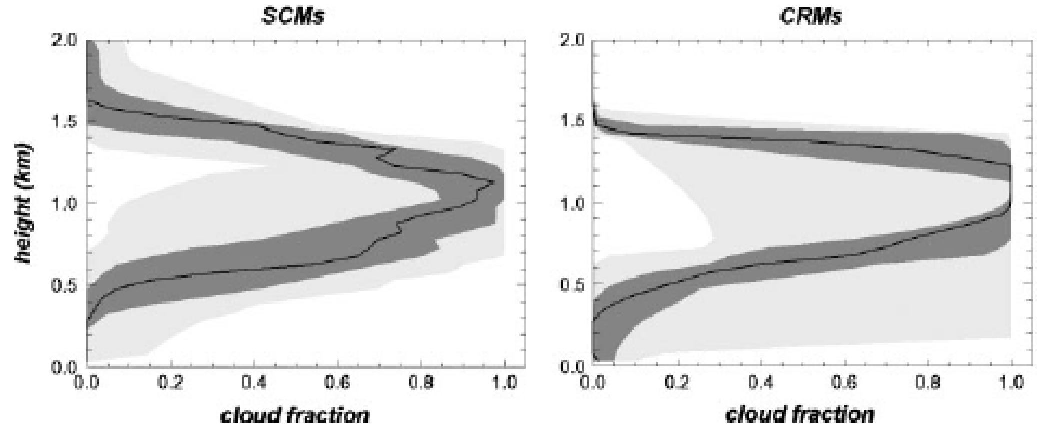
Many of the models predict a future increase in Arctic cloud cover – a reaction to the sea ice decline or a cause of it?

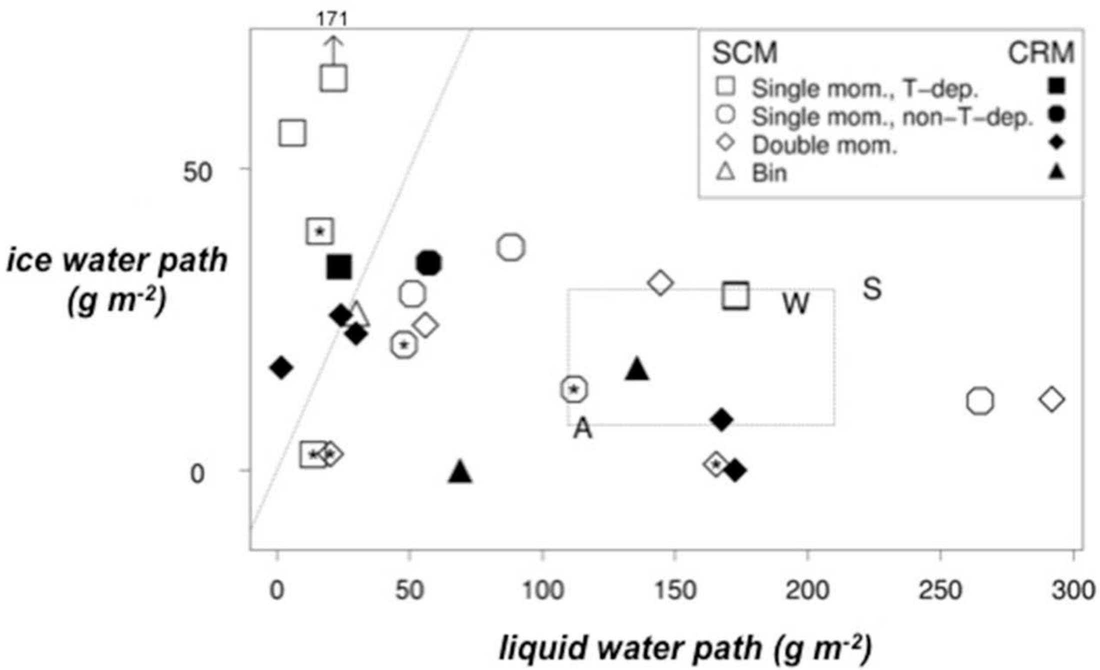
Microphysical, radiative and small-scale dynamical property retrievals in mixed-phase clouds at Barrow



Shupe et al. (2008)





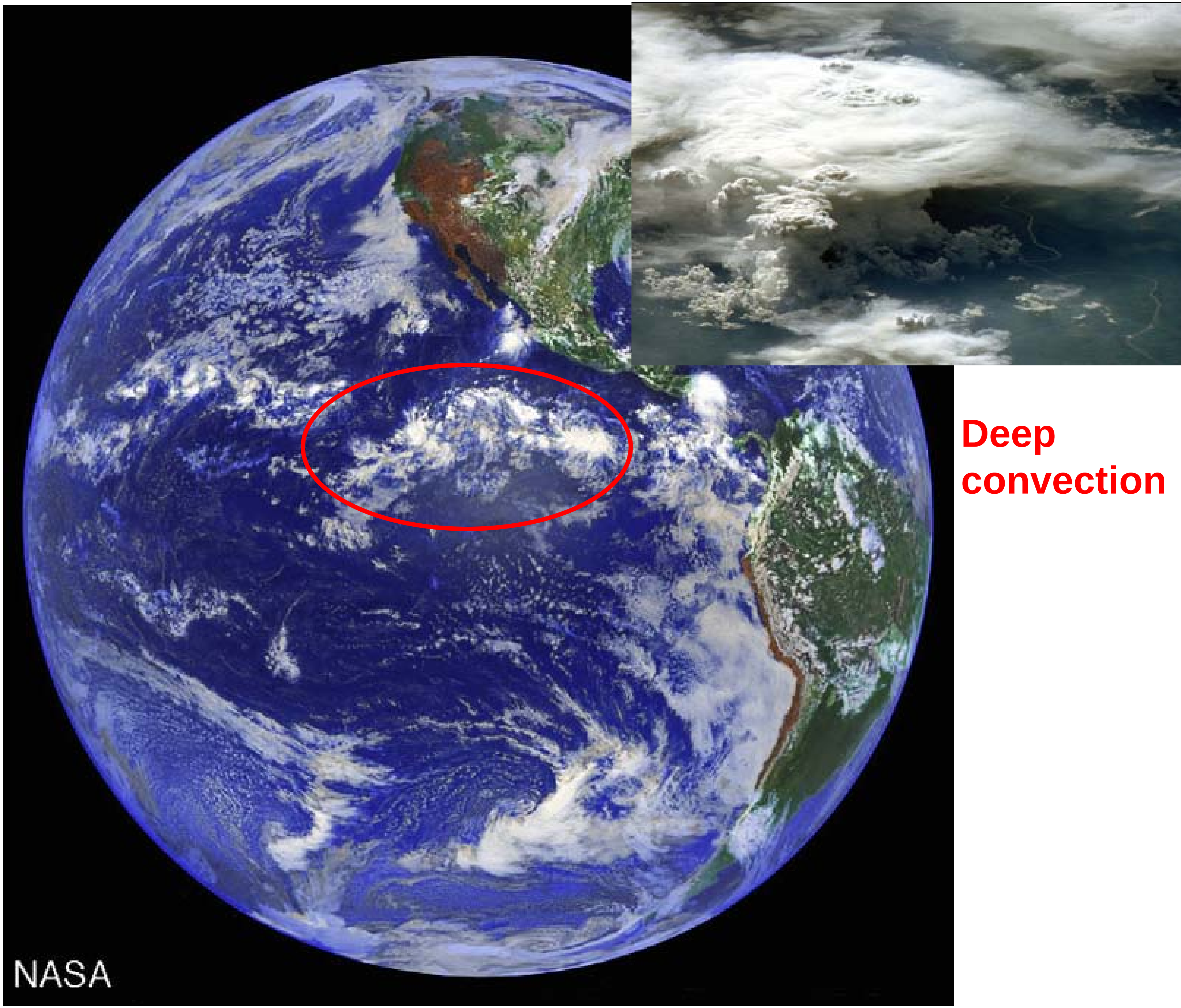


M-PACE case study:

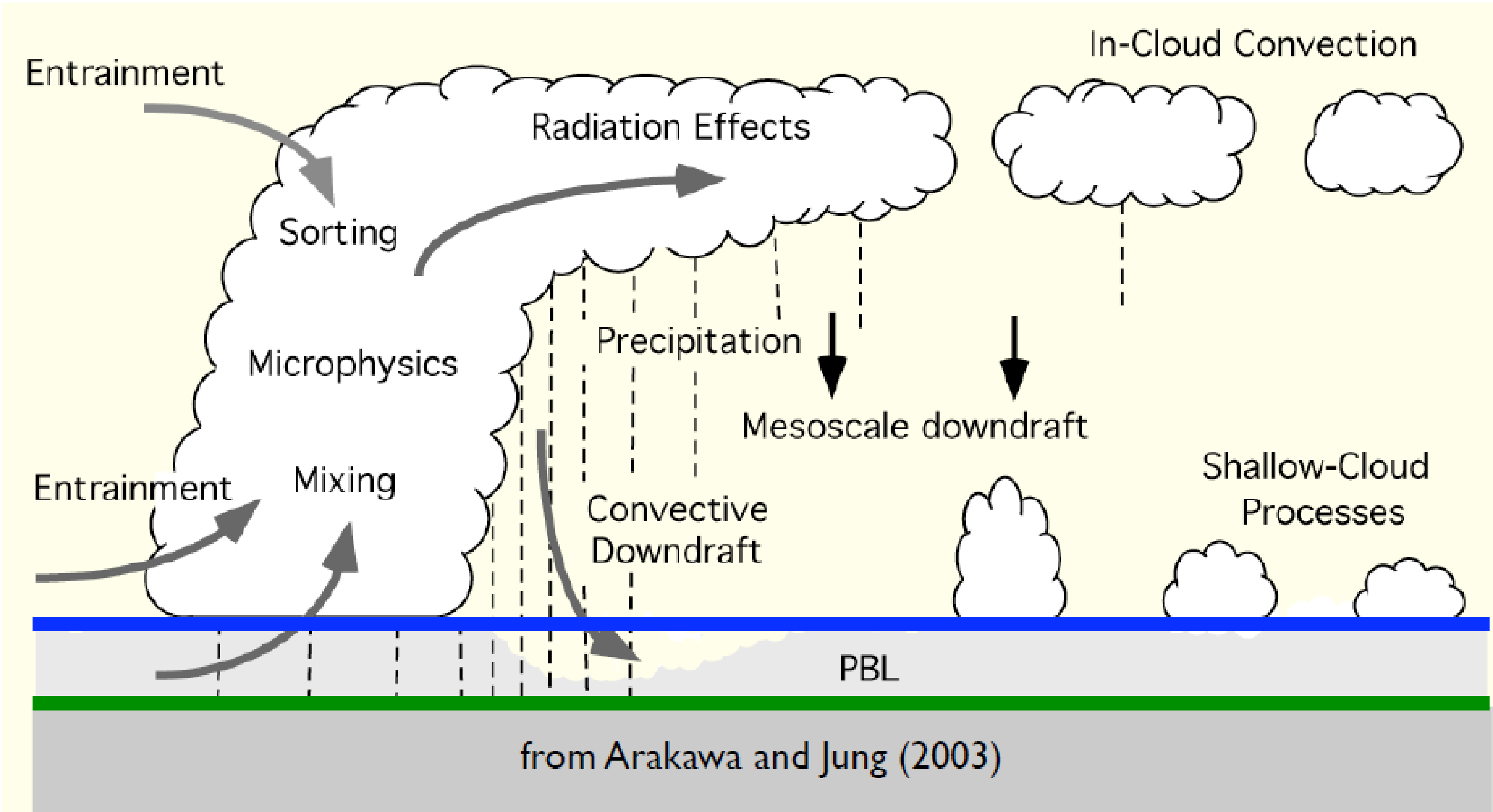
-Models do OK on cloud fraction but large spread; CRMs not necessarily better

-Cloud phase still a major source of uncertainty in models

Klein et al. (2009)



Deep convection



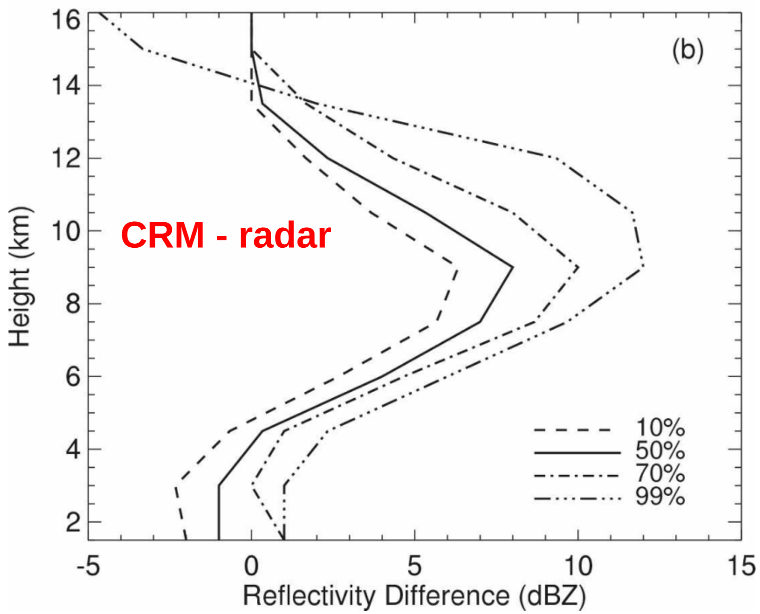
Upcoming IOPs: AMIE, MC3E

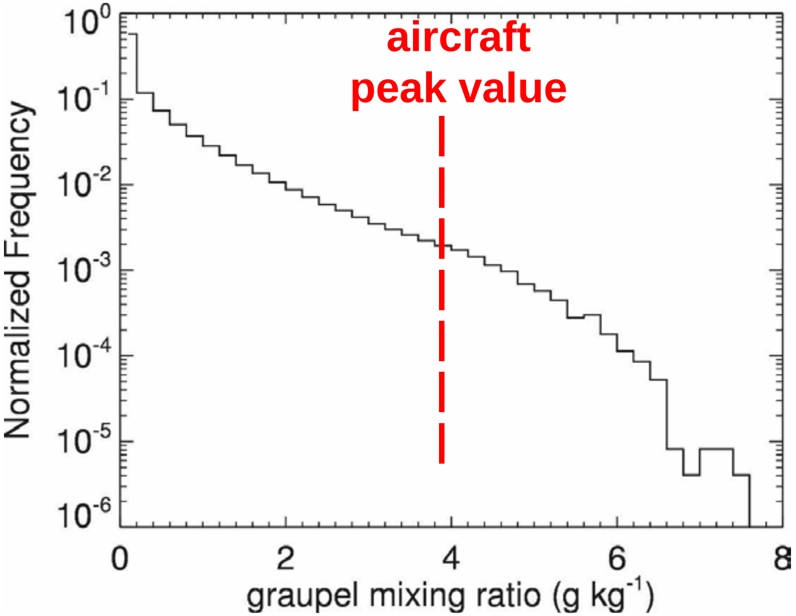
Ice microphysics is a major uncertainty in CRMs

Tendency for overactive graupel formation in bulk microphysics models

(see TWP-ICE intercomparison posters - Fridlind et al., Varble et al.)

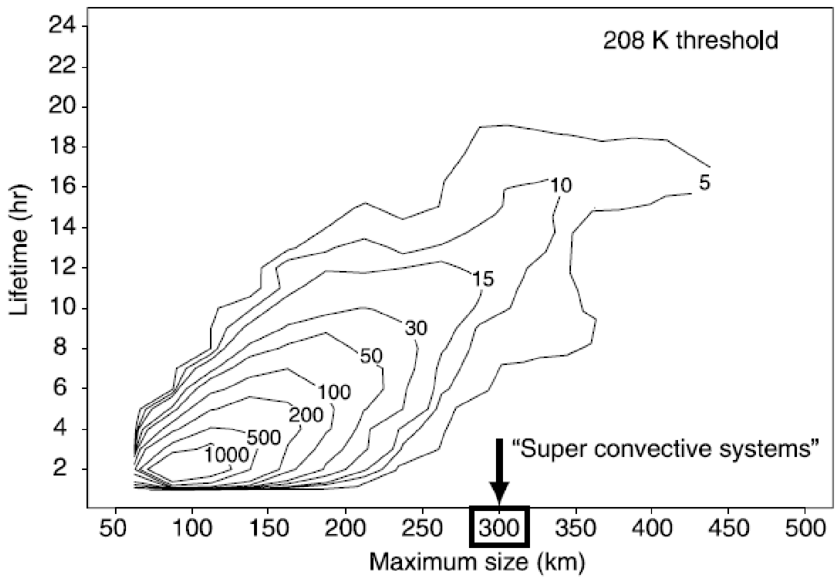
Limits use of CRMs to constrain GCM cloud parameterizations



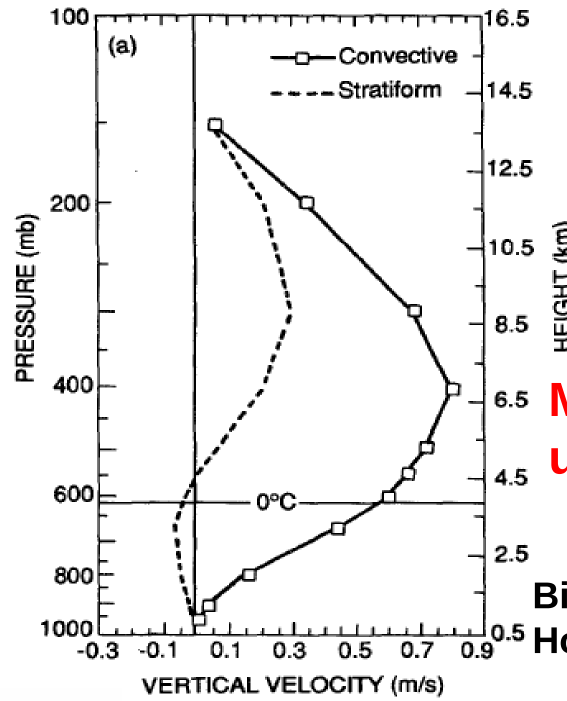


Li, Zipser, Krueger, and Zulauf (2008)

Challenges for global models: Convective organization and lifetime

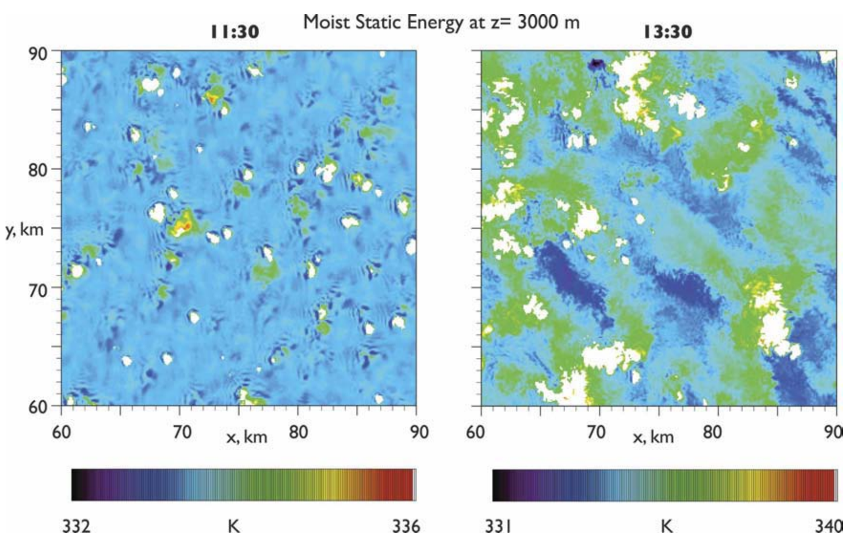


Houze (2004)



Mesoscale updrafts

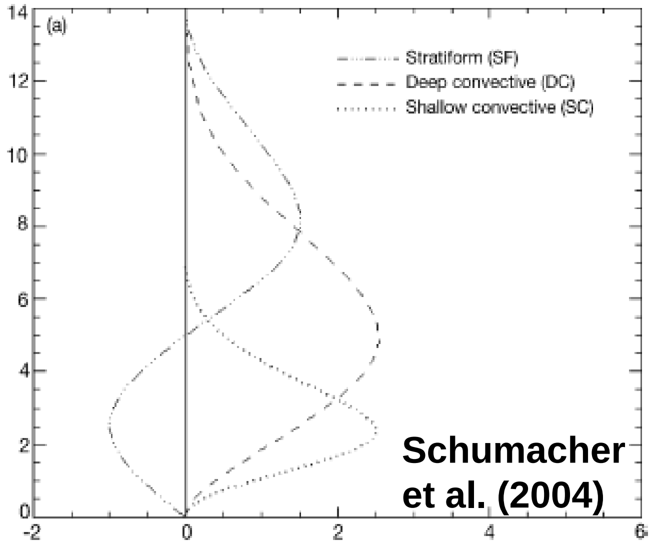
Biggerstaff and Houze (1991)



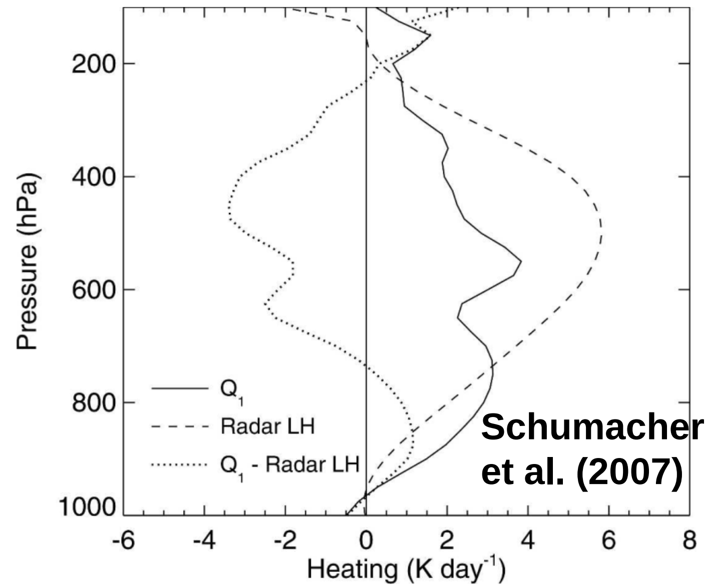
Khairoutdinov and Randall (2006)

Cold pool triggering of deep convection

Challenge for ASR: Latent heating profiles

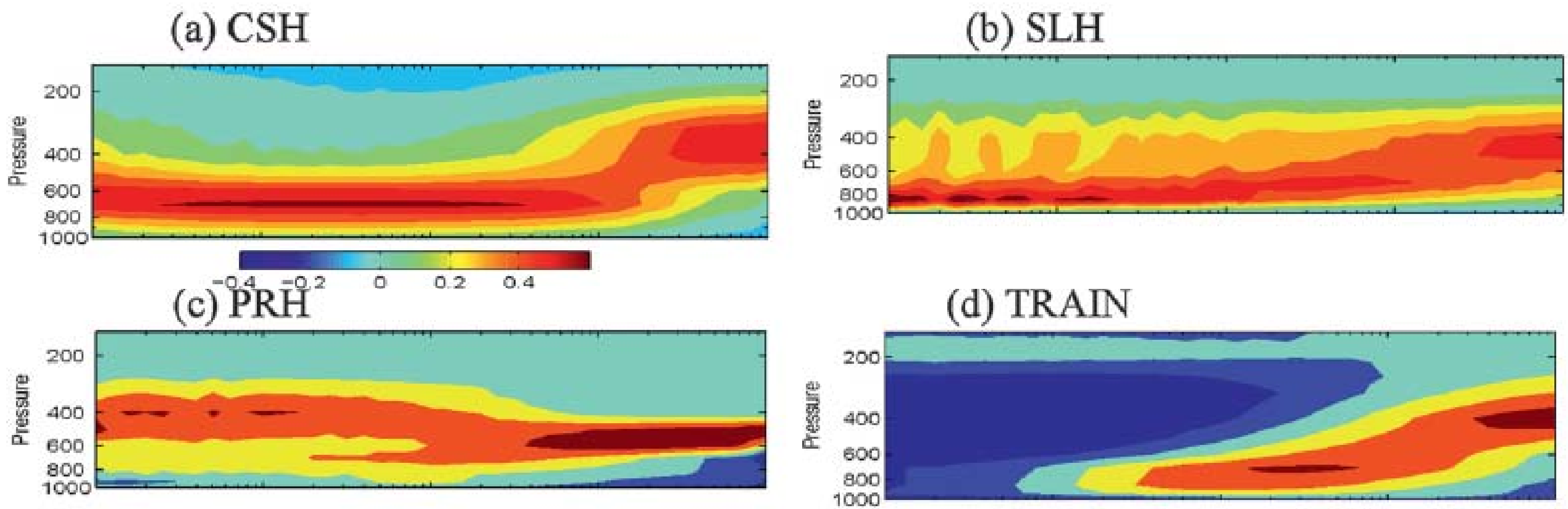


Identification of rain type

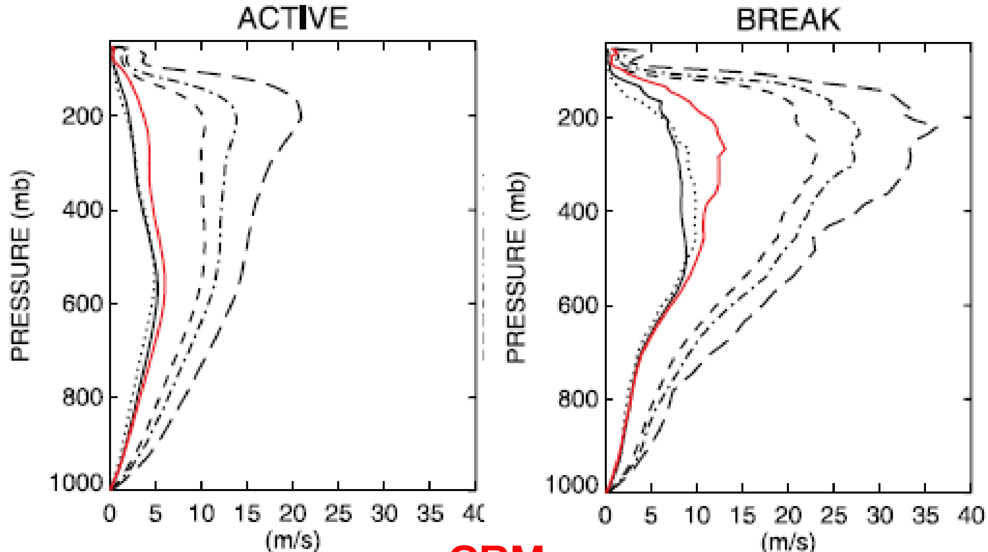


Detection of shallow convection

TRMM latent heating products

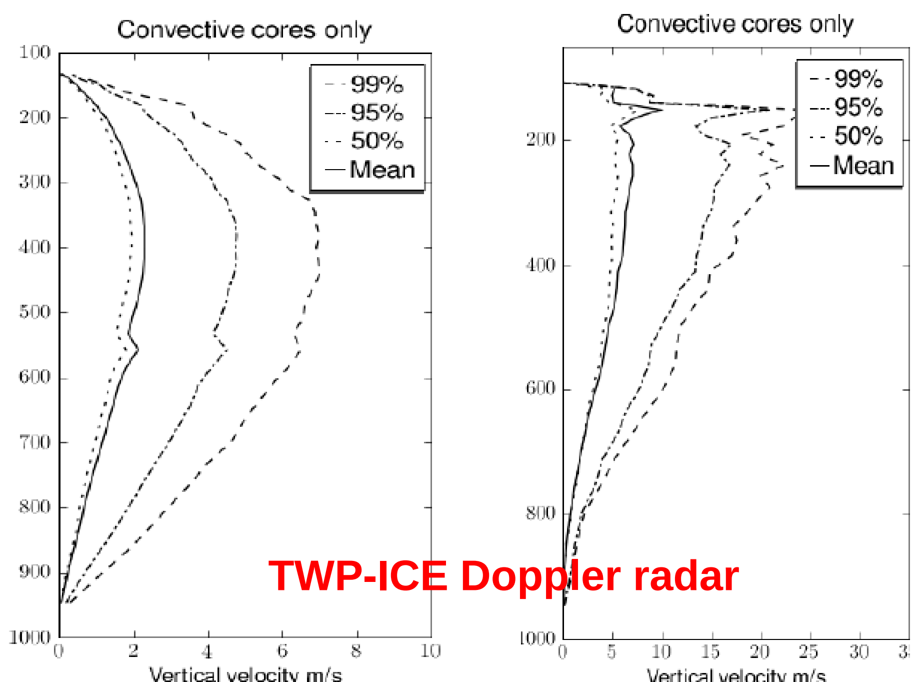


Hagos et al. (2010)



CRMs

Wu et al. (2009)



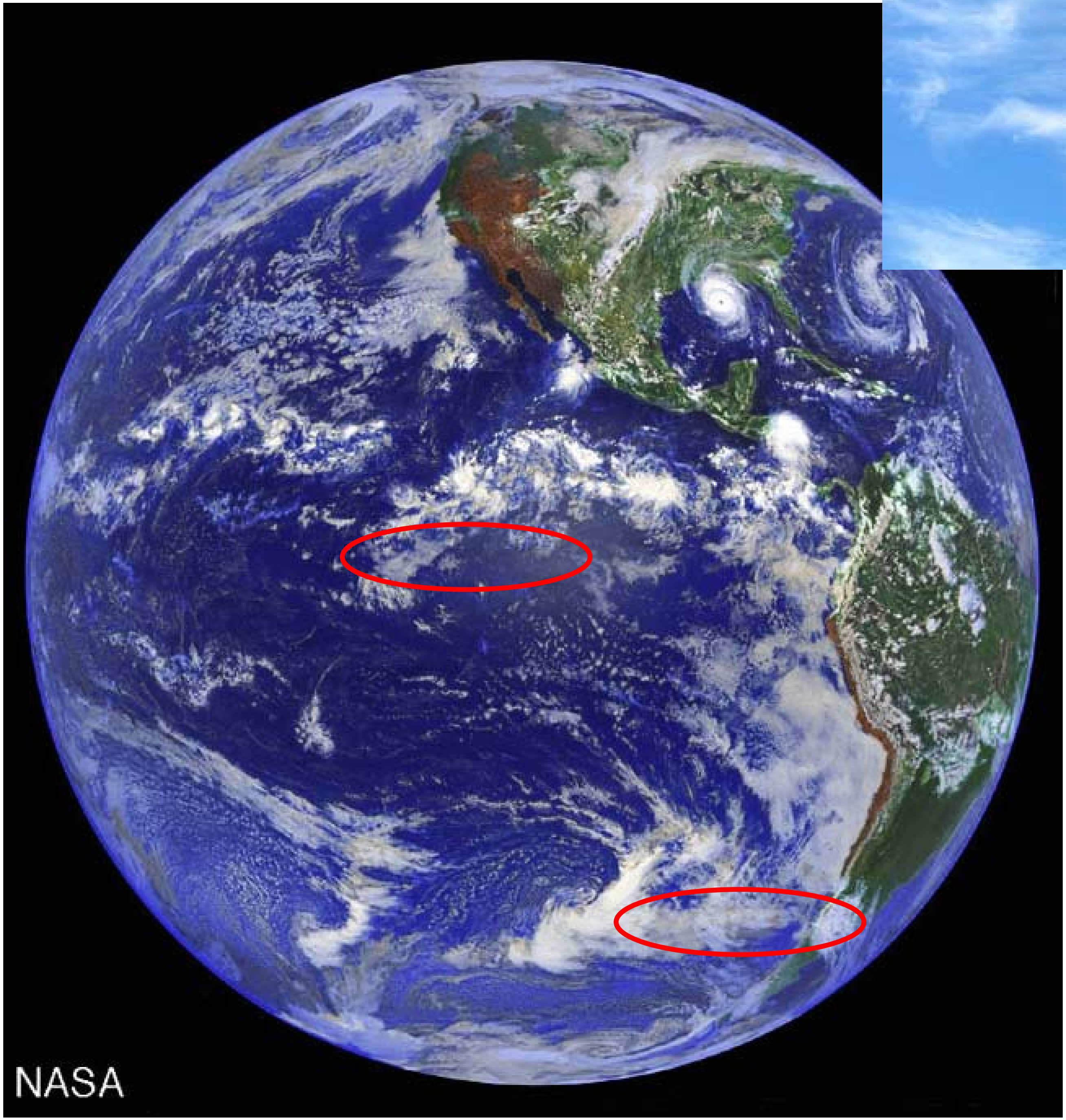
TWP-ICE Doppler radar

Collis et al. (2009)

Small-scale statistics of convective properties are now becoming available from both CRMs and ASR observations

More needed, especially for boundary layer

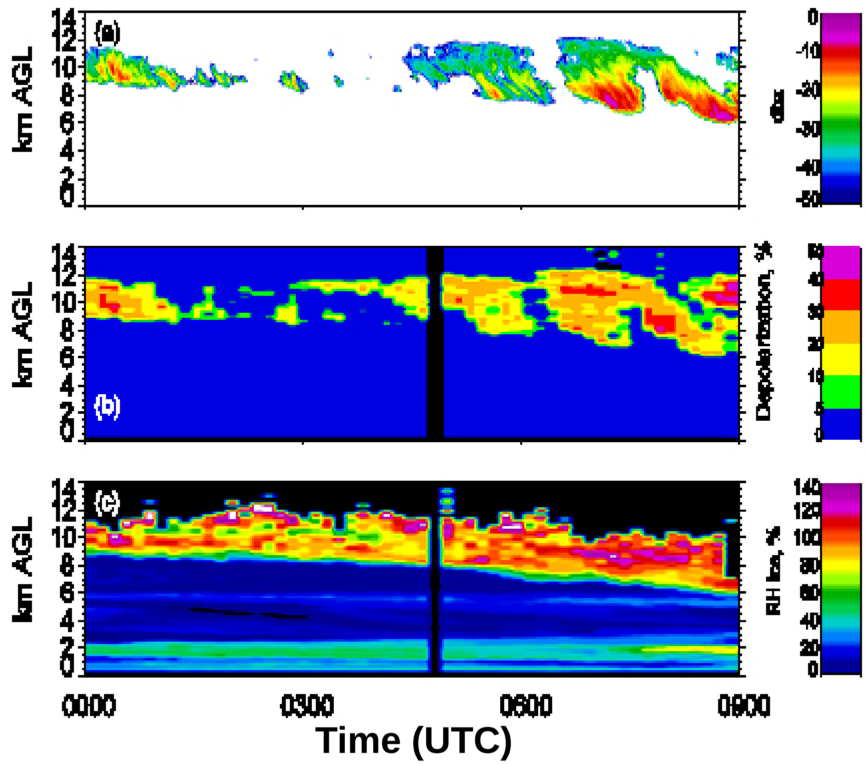
Basis for pdf-based or stochastic approaches to cumulus parameterization

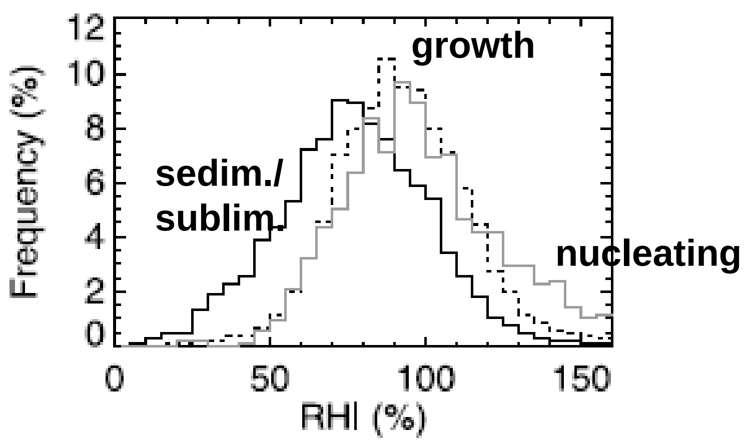


Cirrus

Evidence for high ice supersaturation in cirrus clouds

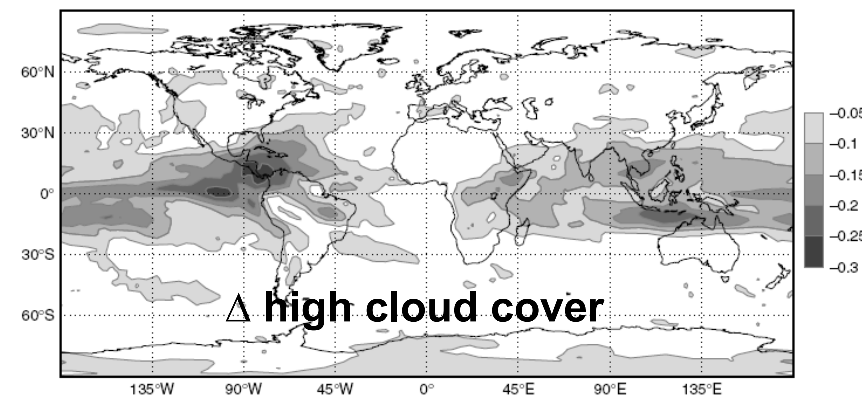
SGP Raman lidar/MMCR

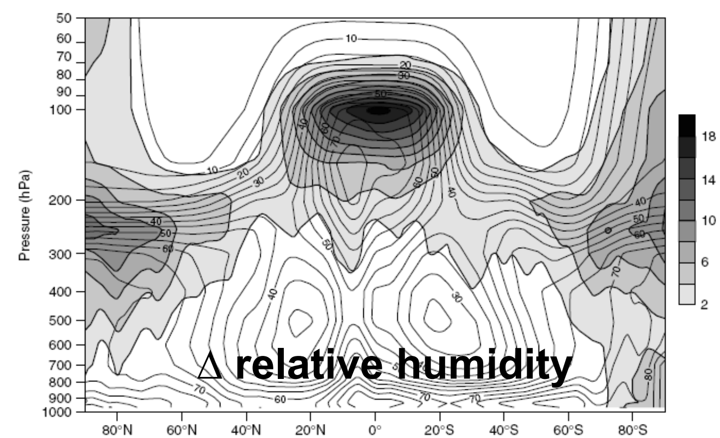




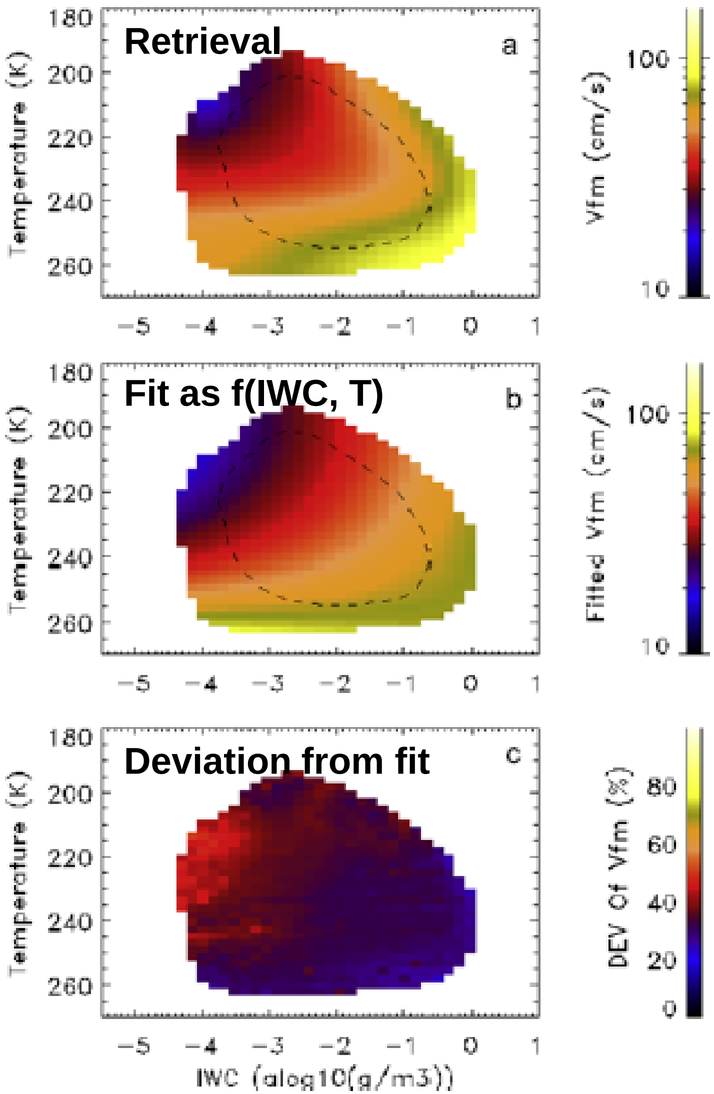
Comstock et al. (2004)

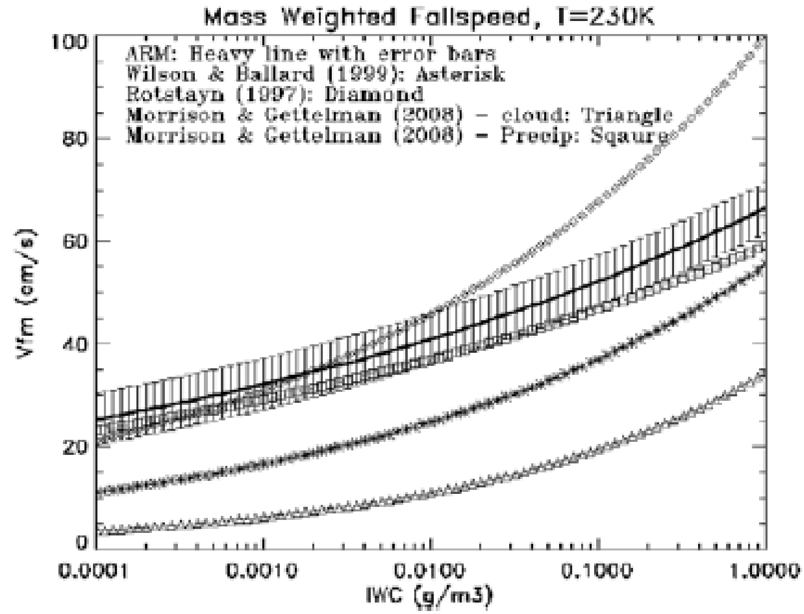
Effect in ECMWF IFS





Tompkins et al. (2007)



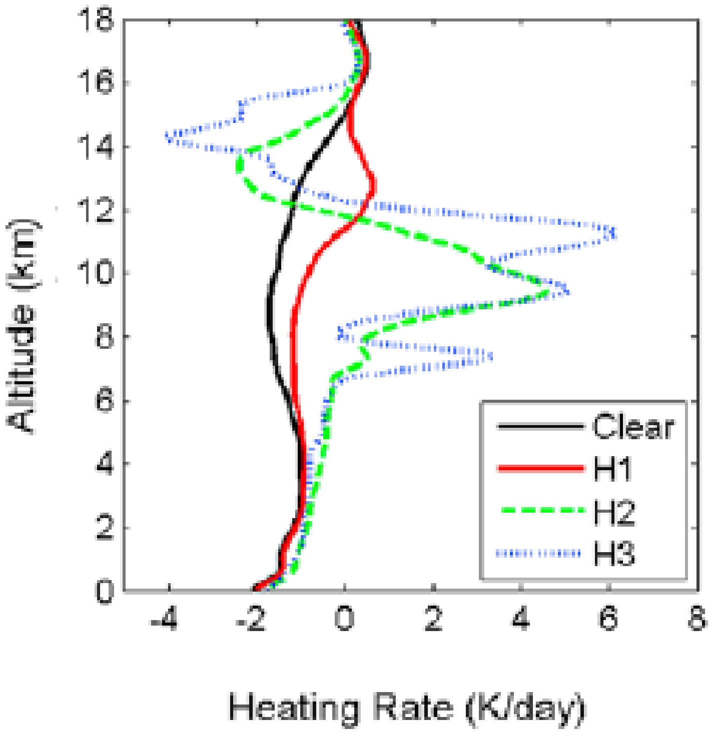


Comparison to GCM parameterizations

Ice fall speeds constrained by MMCR data at SGP, TWP

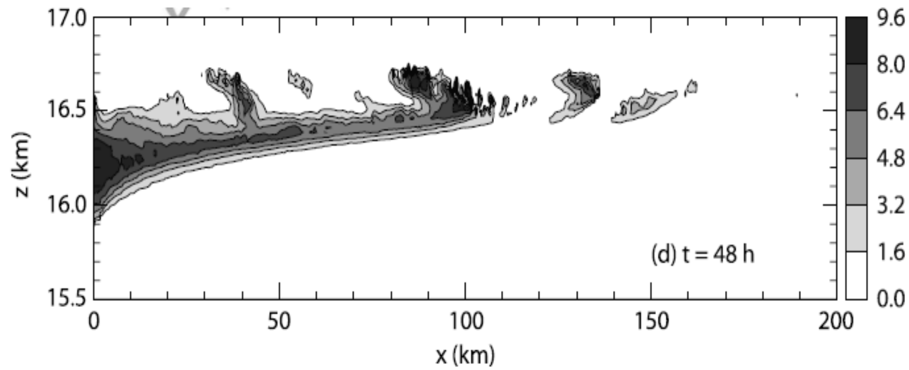
Deng and Mace (2008)

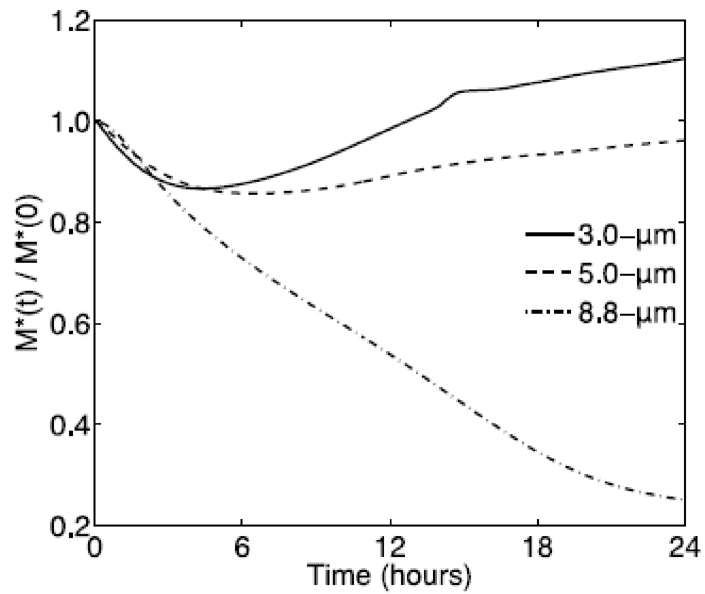
Manus/Nauru retrievals



Mather and McFarlane (2009)

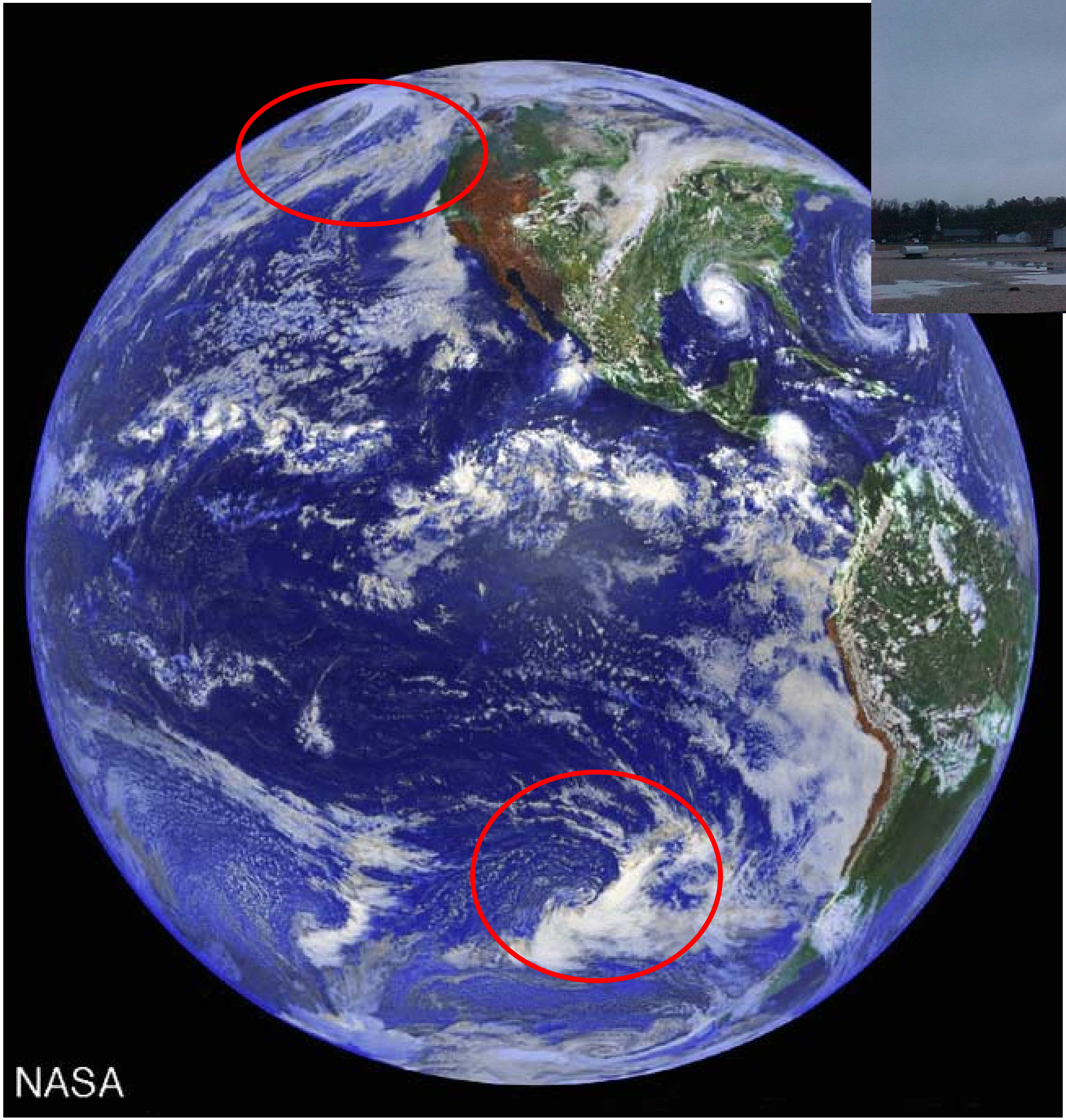
Tropical tropopause cirrus 2-D model





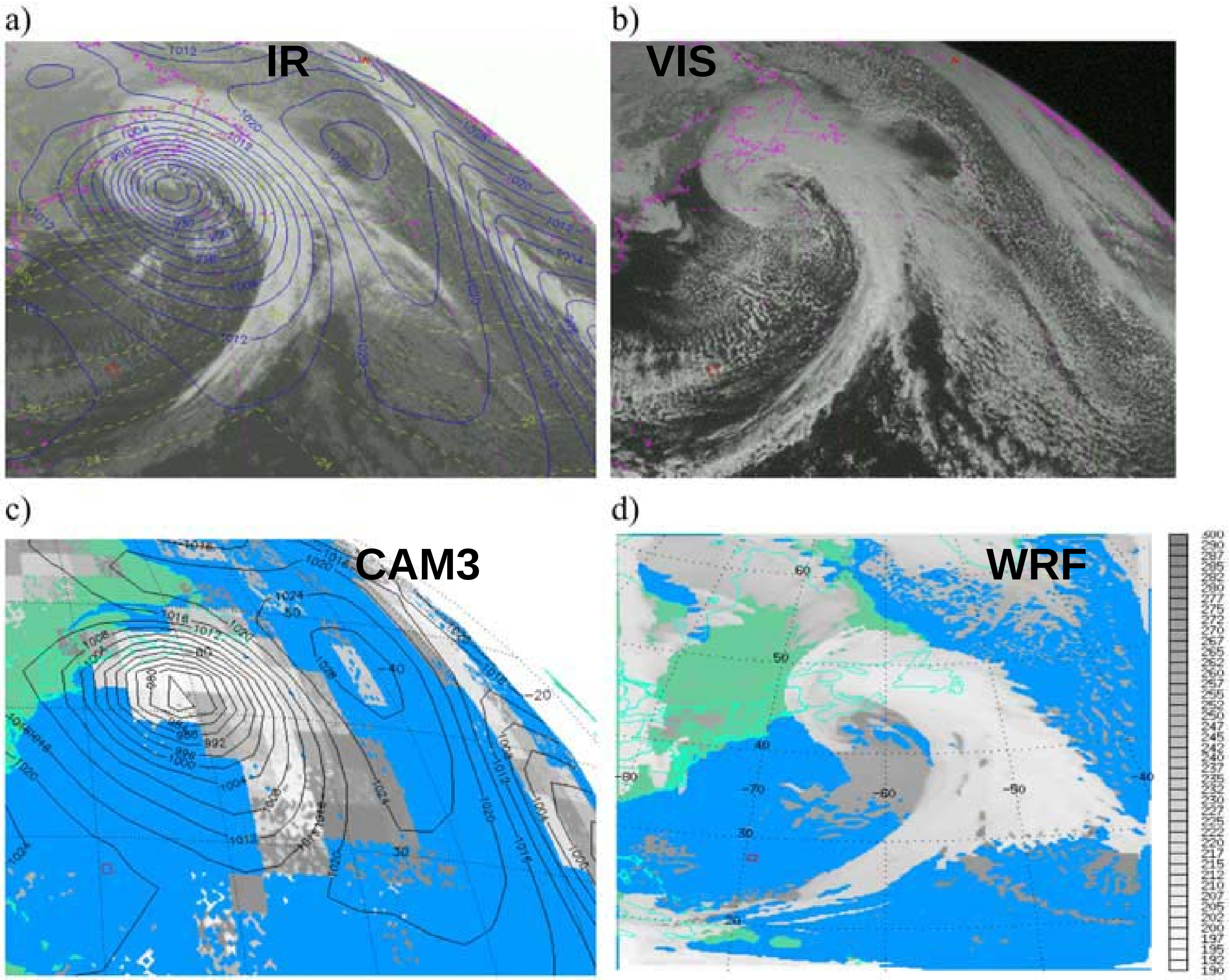
Dinh, Durran, Ackerman (2010)

Radiative heating inside cirrus drives circulation that can maintain cirrus without external large-scale upwelling…if initial particle size is small enough

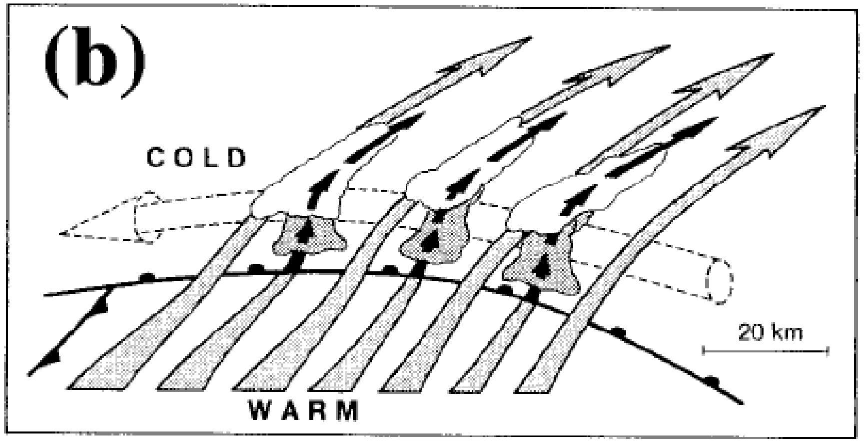


Midlatitude storm clouds

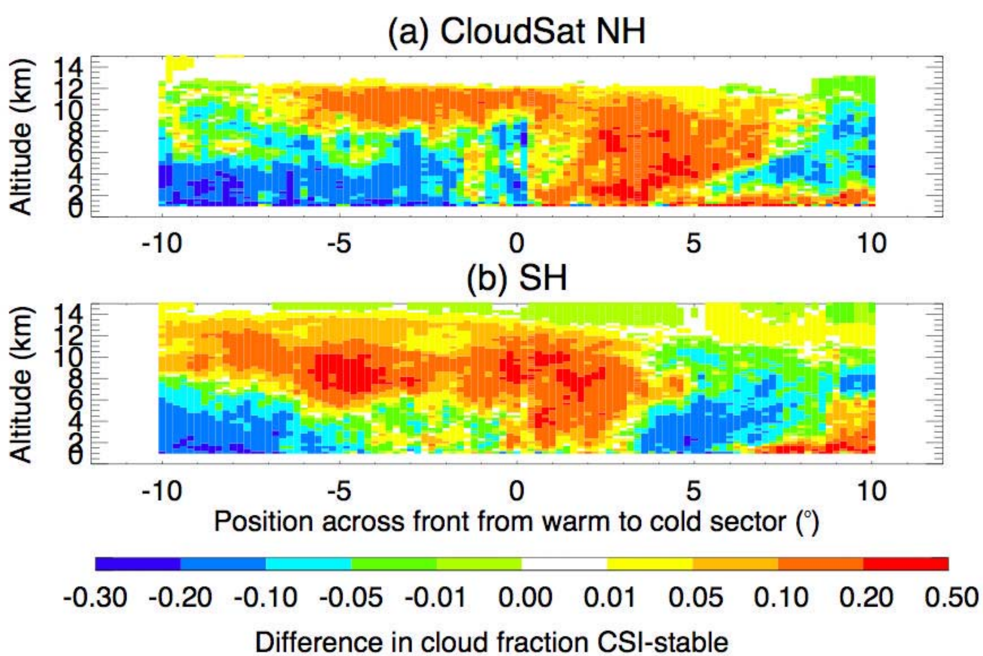
Not all clouds in midlatitude storms form from synoptic-scale motion



Lin et al. (2009)

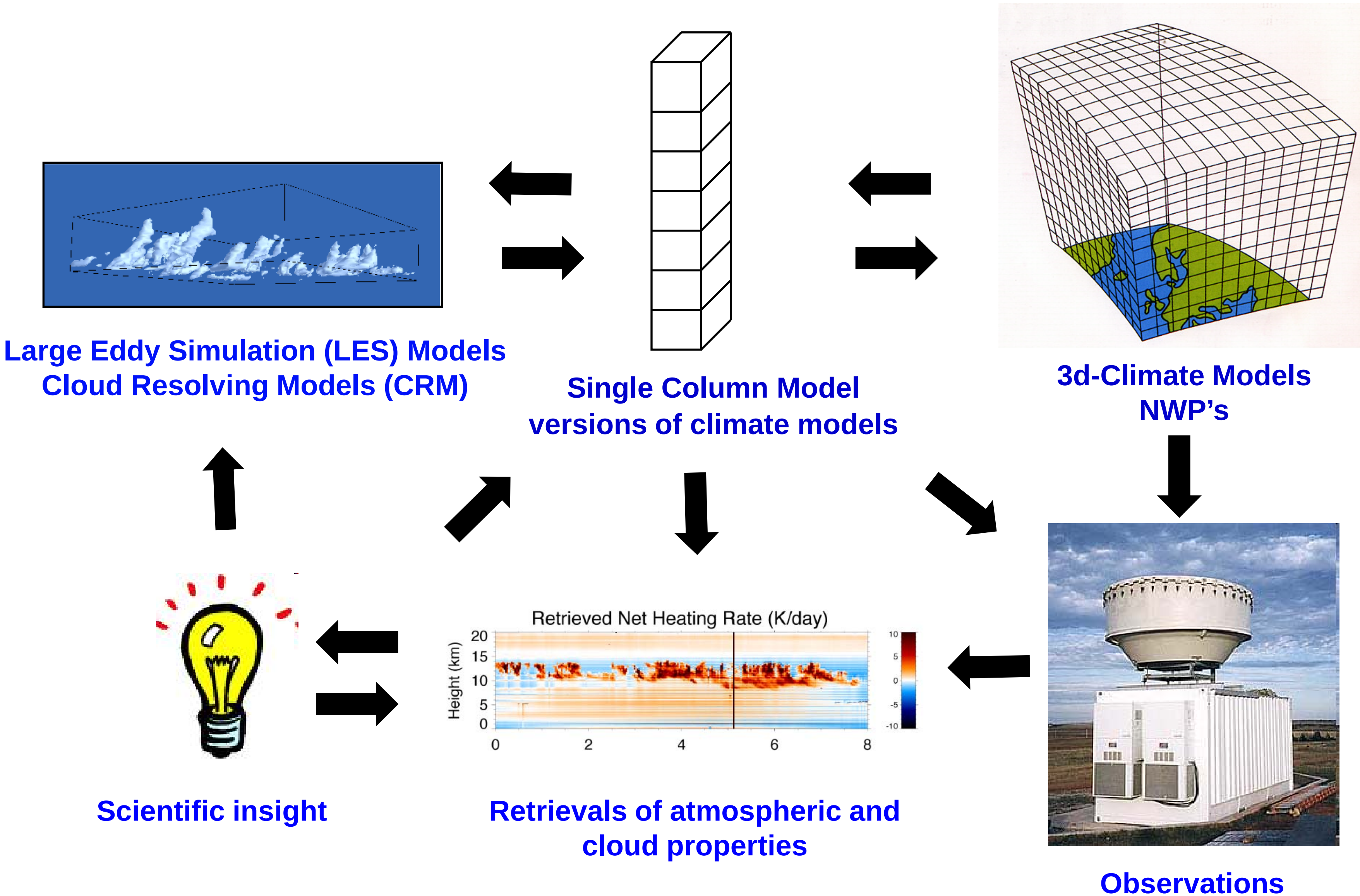


Neiman et al. (1993)



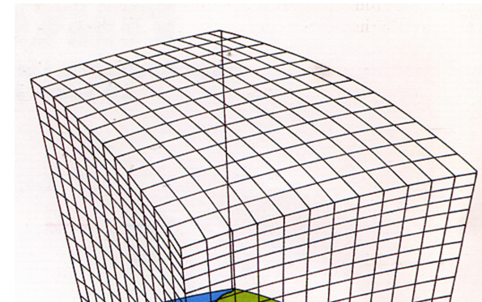
Naud et al. (2010)

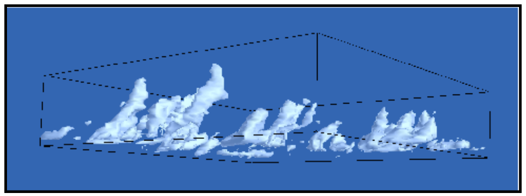
Slantwise convection in midlatitude cyclones: A missing source of strong vertical motion and cloud in GCMs?



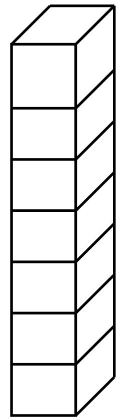
Modified from Siebesma (2008)

A new day dawns…



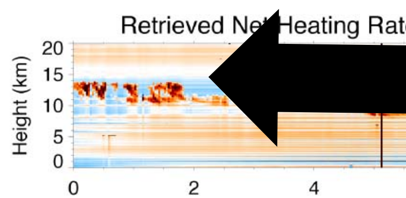


Large Eddy Simulation (LES) Models
Cloud Resolving Models (CRM)



Single Colum
versions of clima

Scientific insight



Retrievals of atmos
cloud proper

Modified from Siebesma (2008)