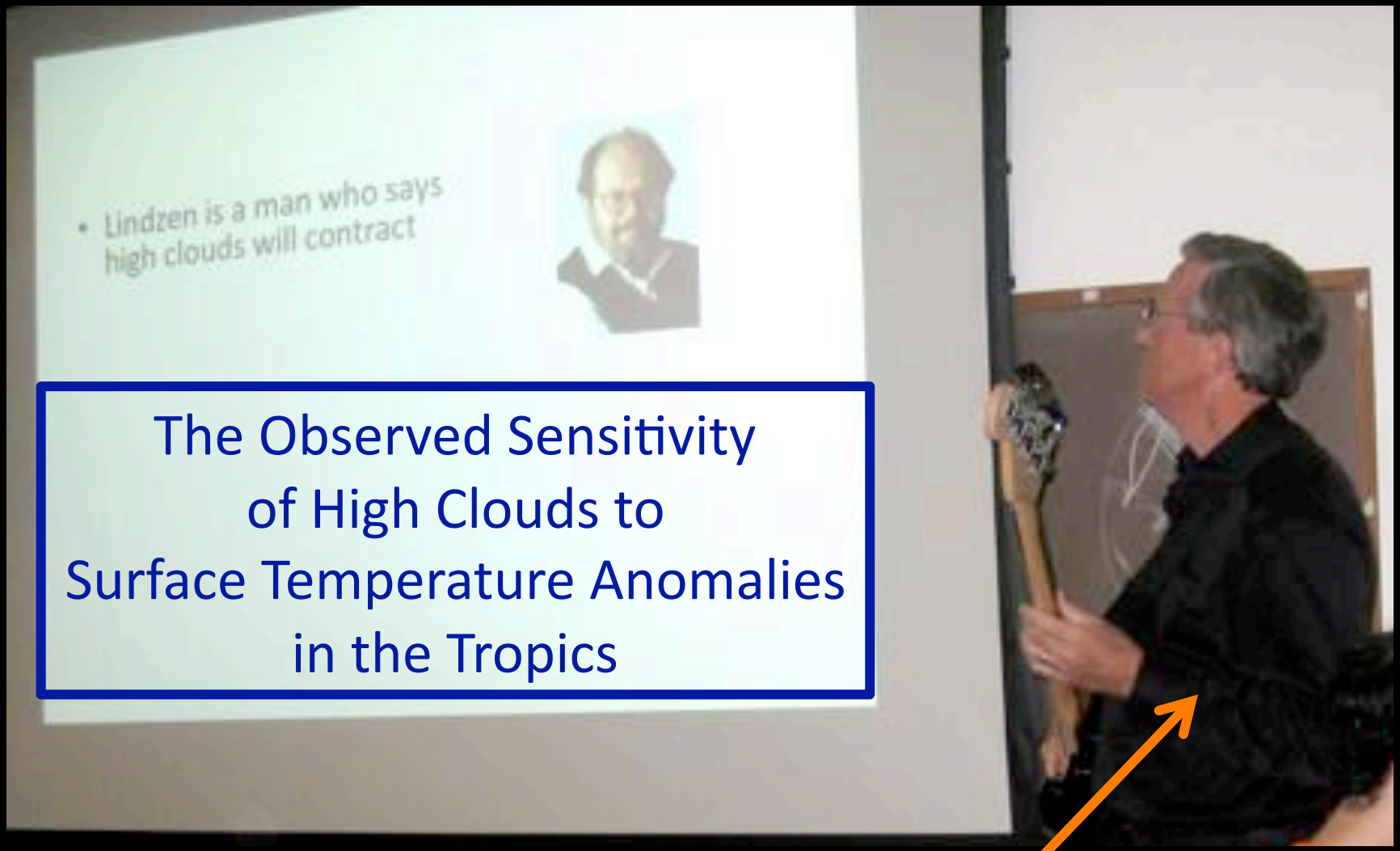


The Observed Sensitivity of High Clouds to Surface Temperature Anomalies in the Tropics

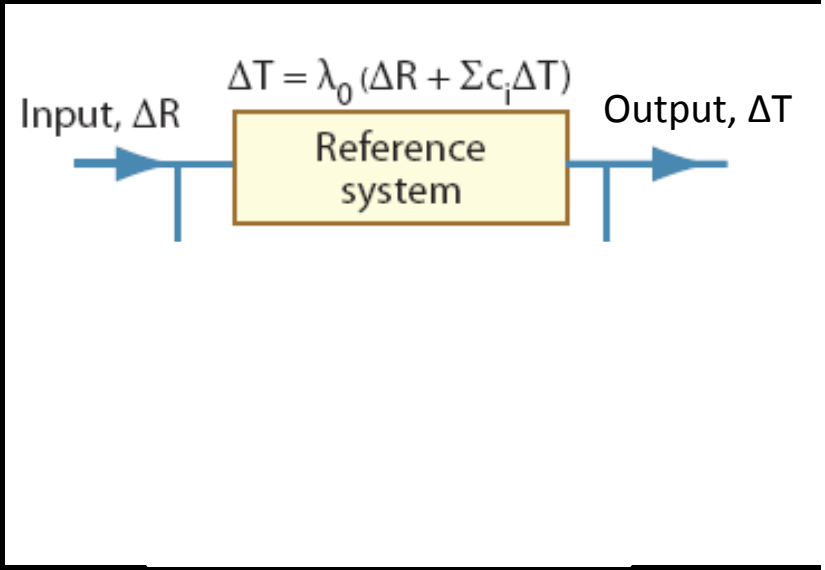
Mark Zelinka and Dennis Hartmann

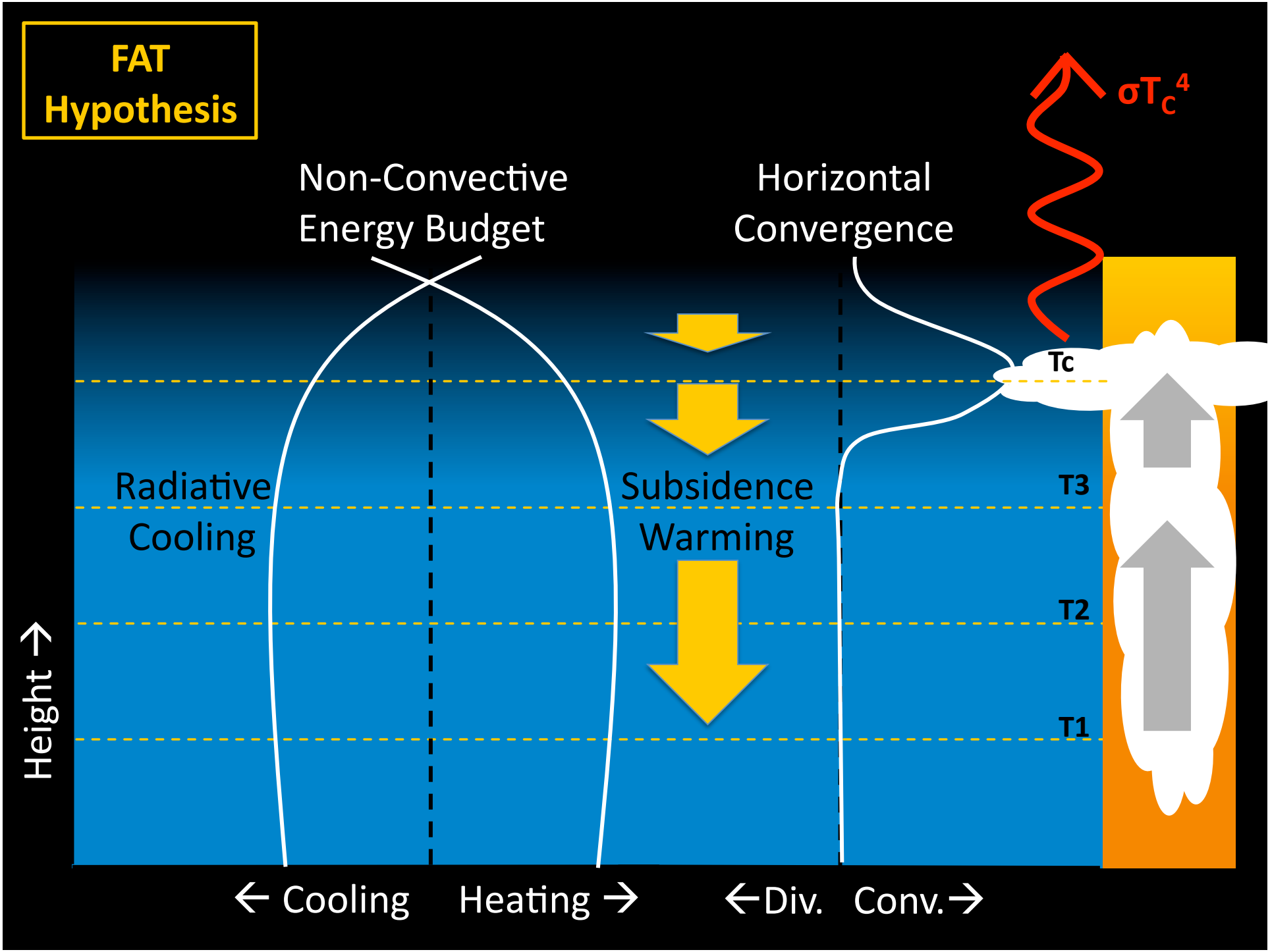
CERES Science Team Meeting

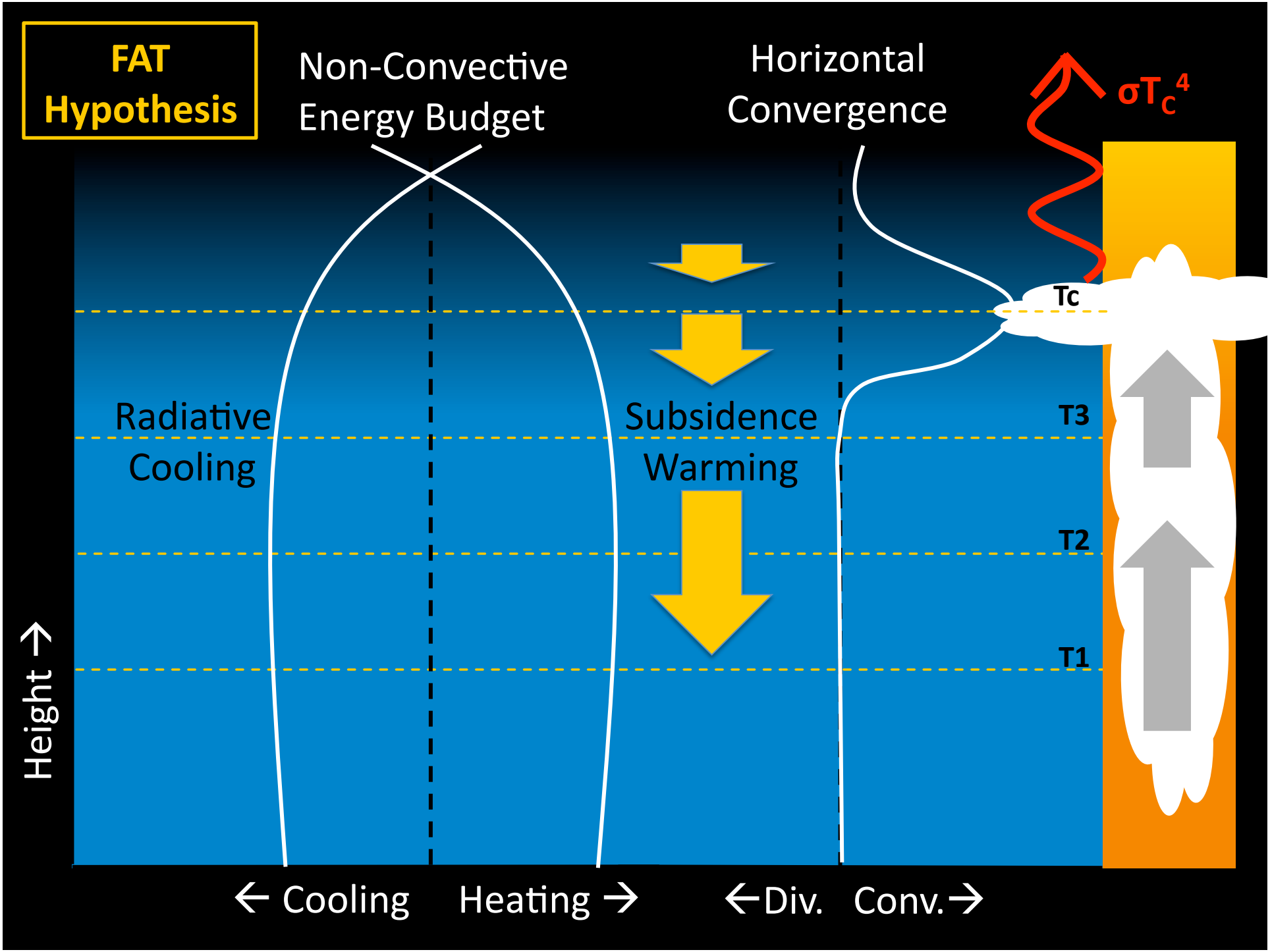
6 October 2011

- Lindzen is a man who says high clouds will contract
- It works just like an iris
- Other people say that clouds will be found higher
- Hartmann's FAT hypothesis

- Feedback! Feedback!
- Feedback is what we must constrain!
- Feedback! Feedback!
- Feedback is what we must constrain!




FAT Hypothesis
Non-Convective Energy Budget
Horizontal Convergence
σT_C^4
Tc
Radiative Cooling
Subsidence Warming
T3
T2
T1
Height →
← Cooling
Heating →
←Div.
Conv.→


FAT Hypothesis
Non-Convective Energy Budget
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σT_C^4
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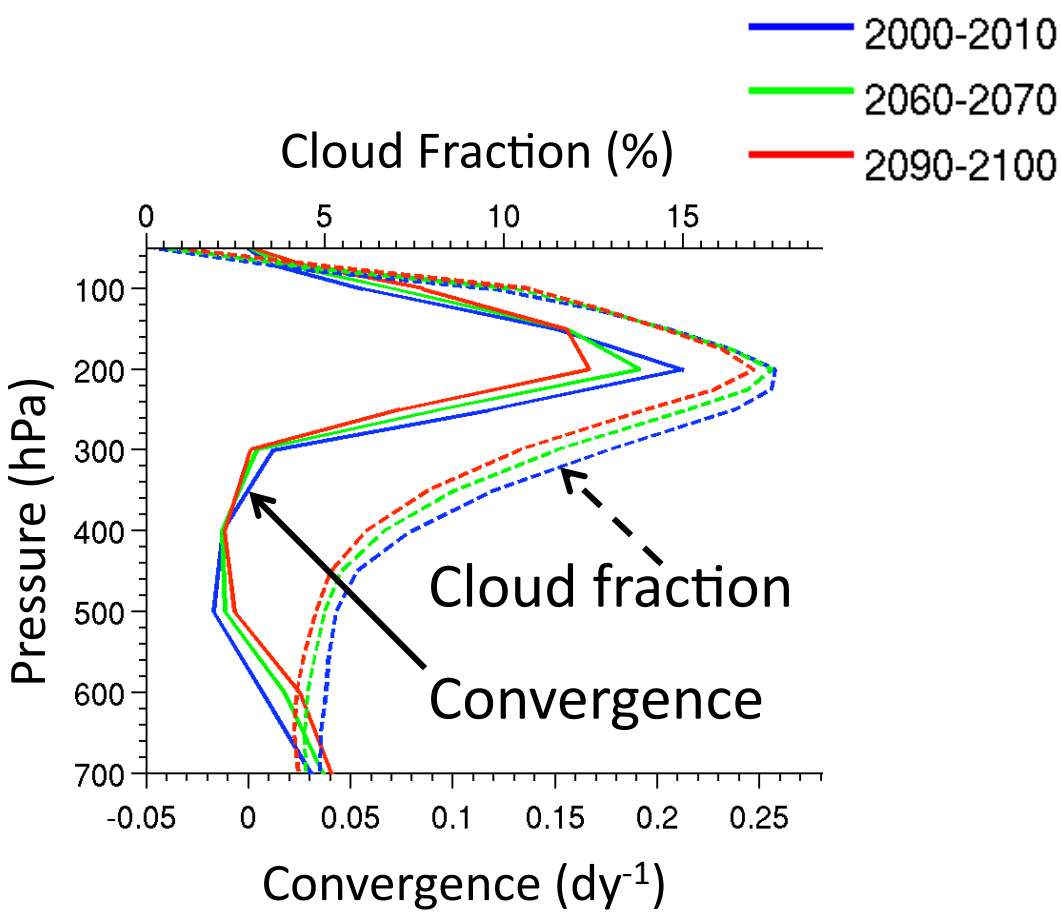
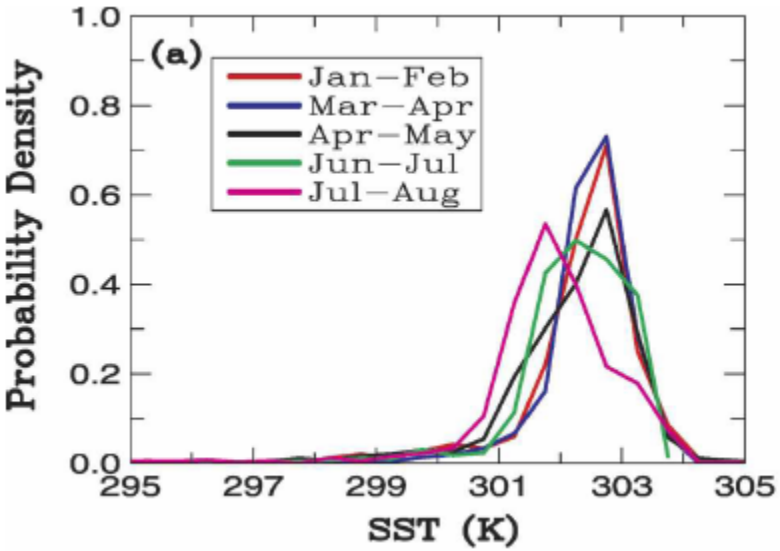
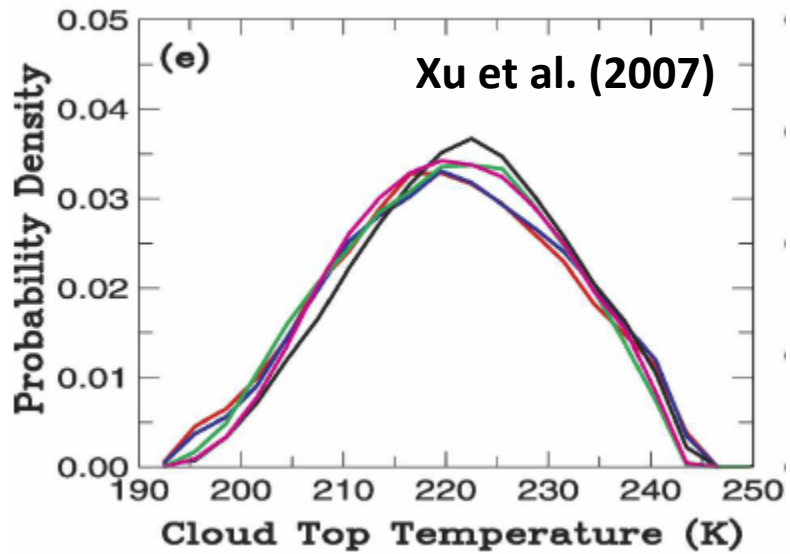
CMIP3 Multi-model mean

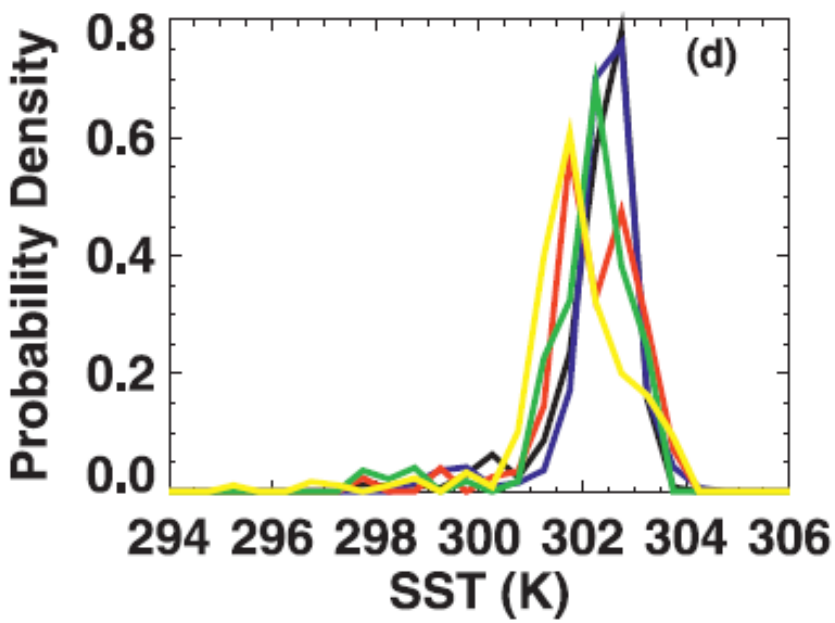


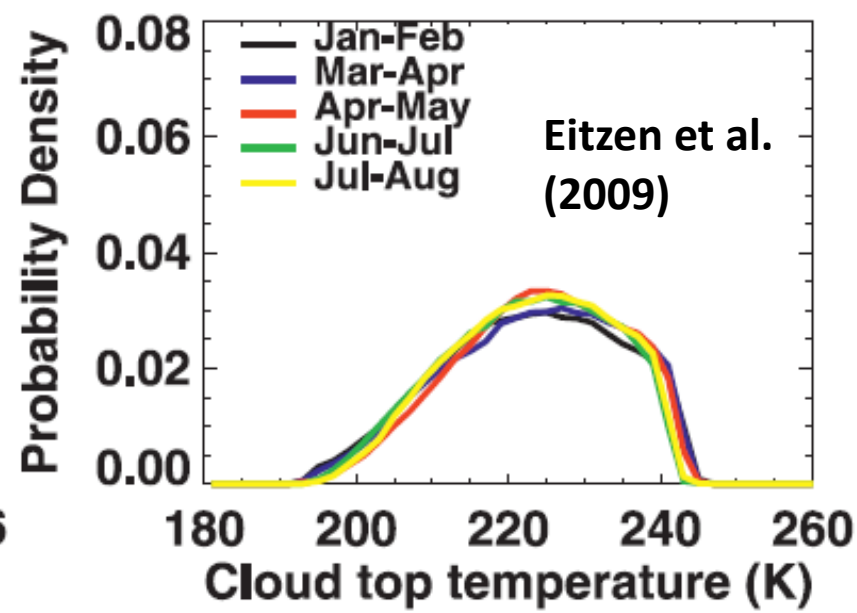
Zelinka and Hartmann 2010

Observational support

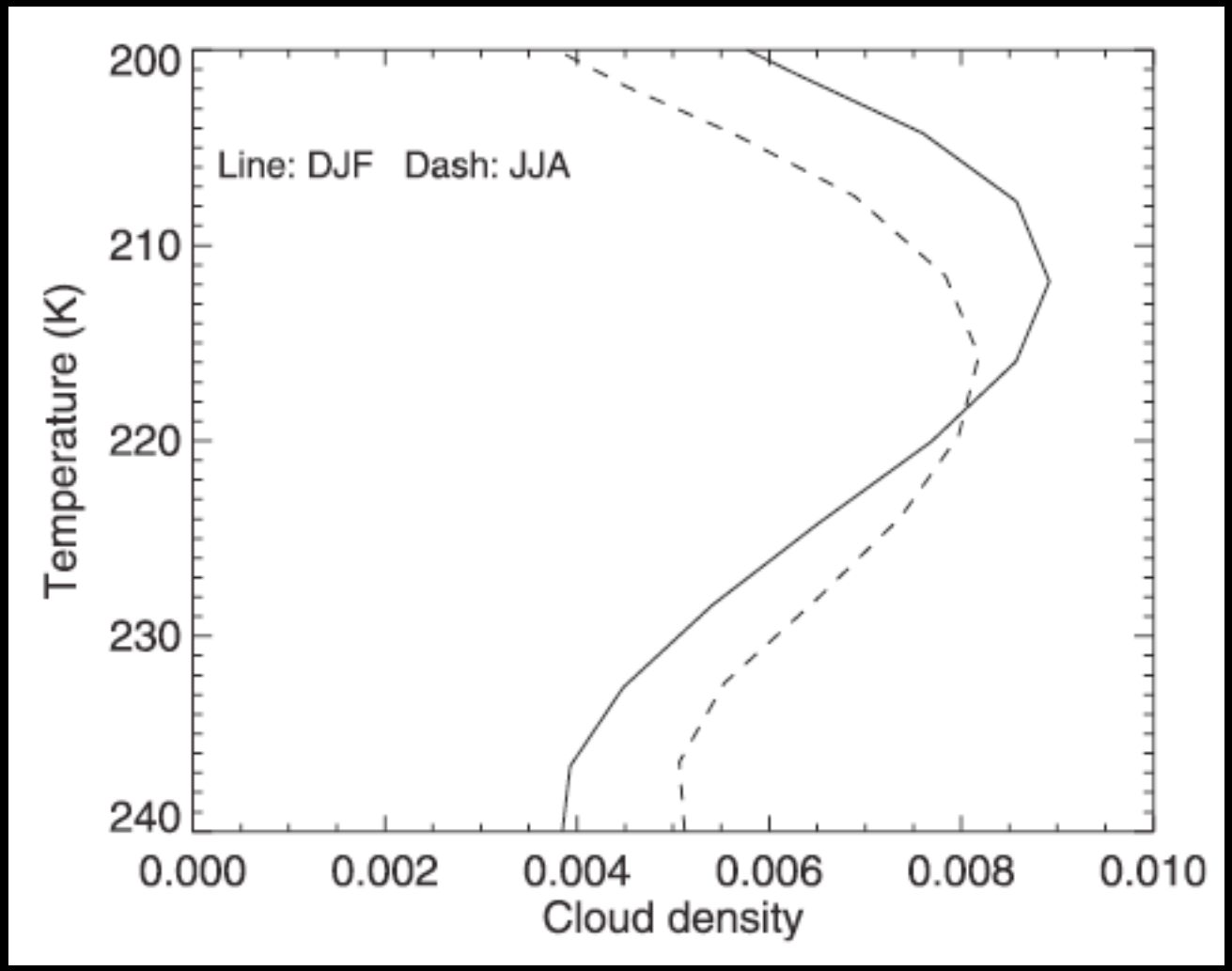




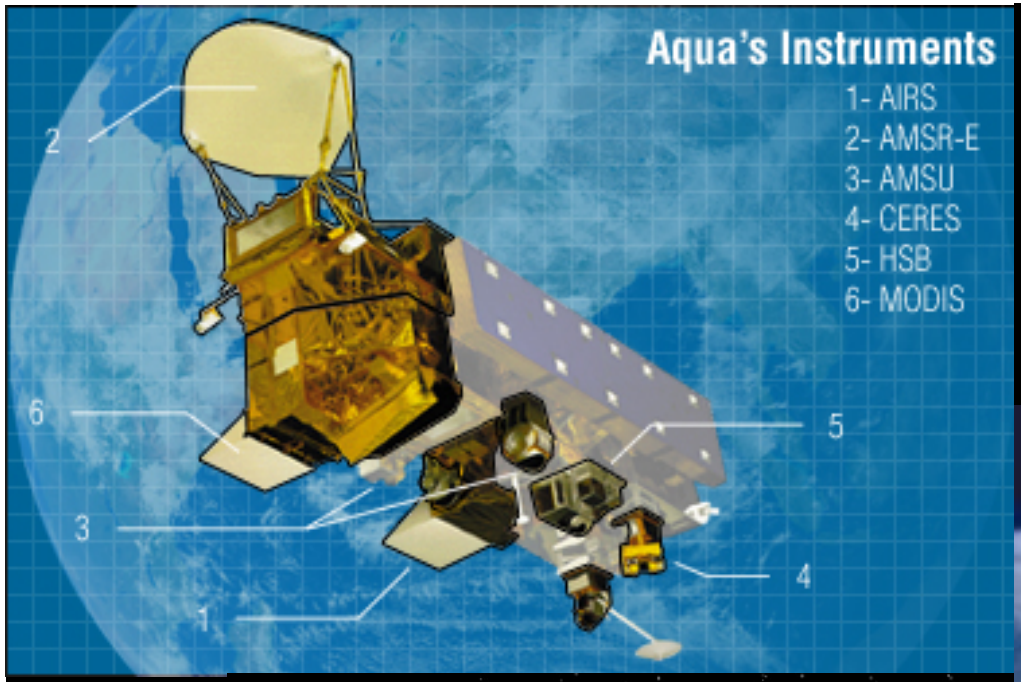


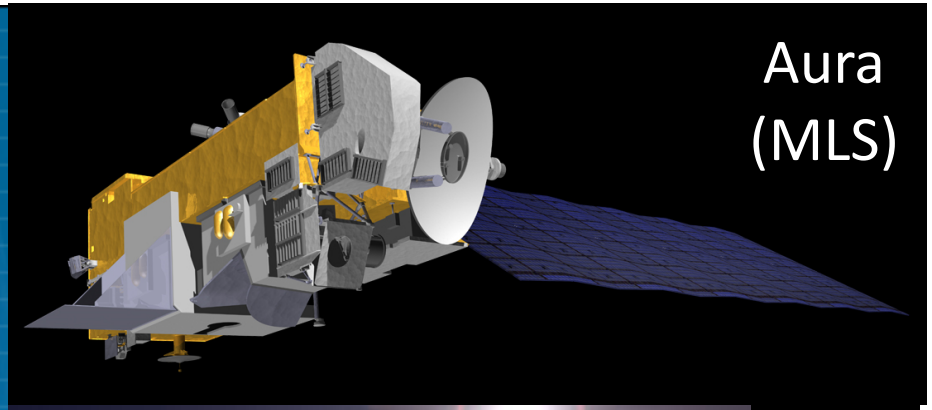


Observational un-support?

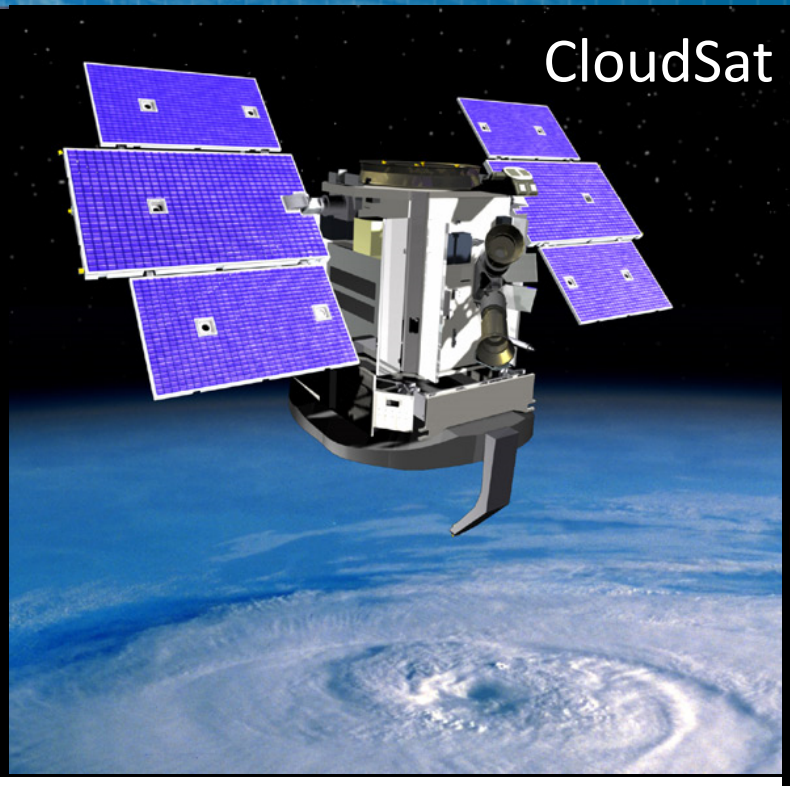


Chae and Sherwood 2010

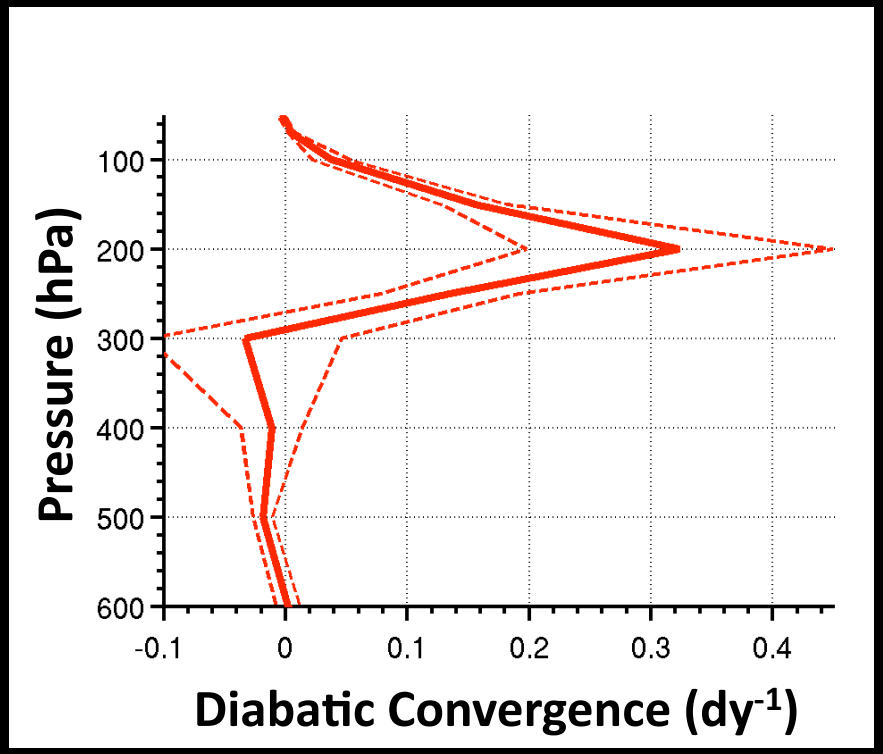

Aqua's Instruments
1- AIRS
2- AMSR-E
3- AMSU
4- CERES
5- HSB
6- MODIS
2
6
3
1
5
4


Aura
(MLS)

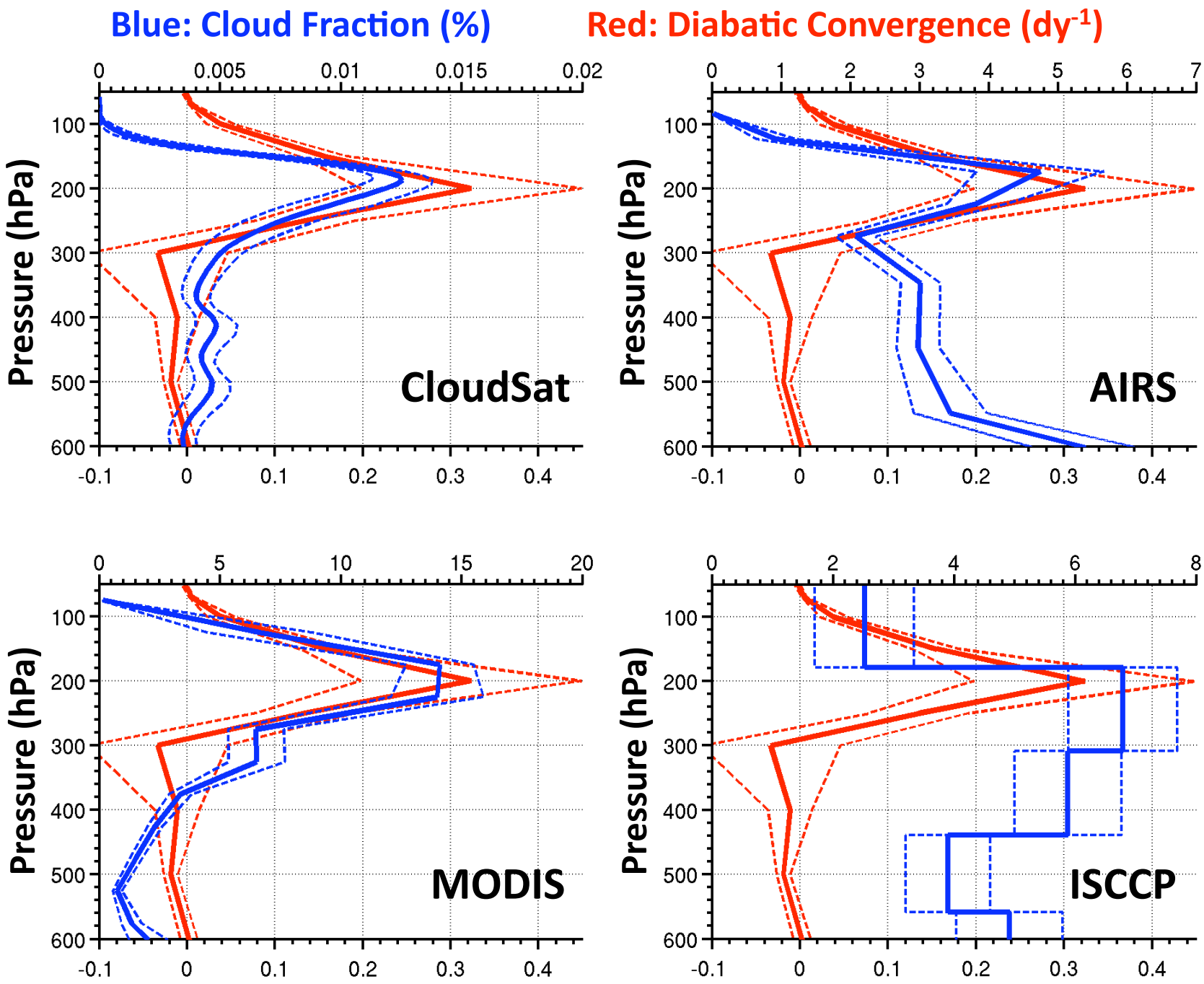
Terra (CERES)

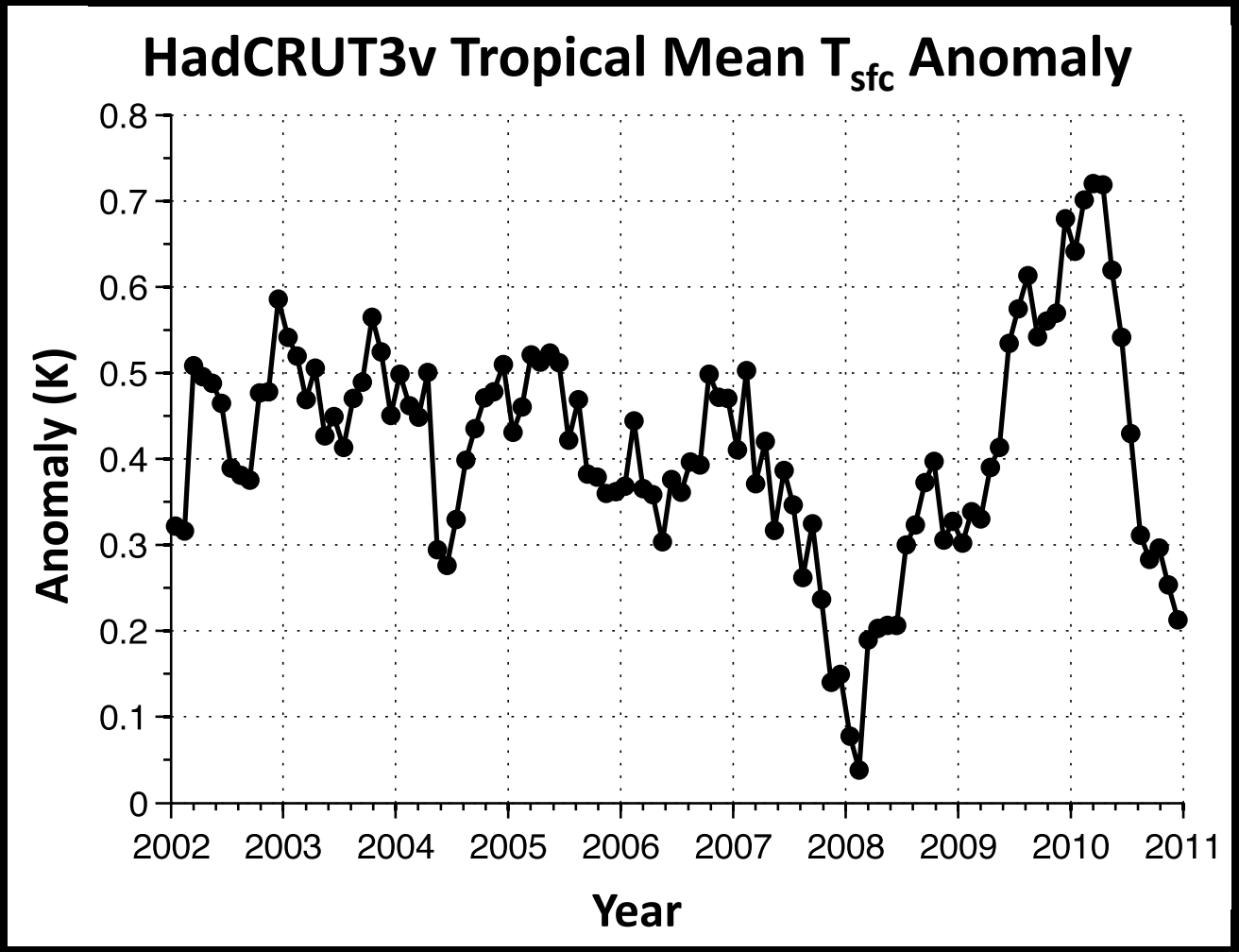

CloudSat

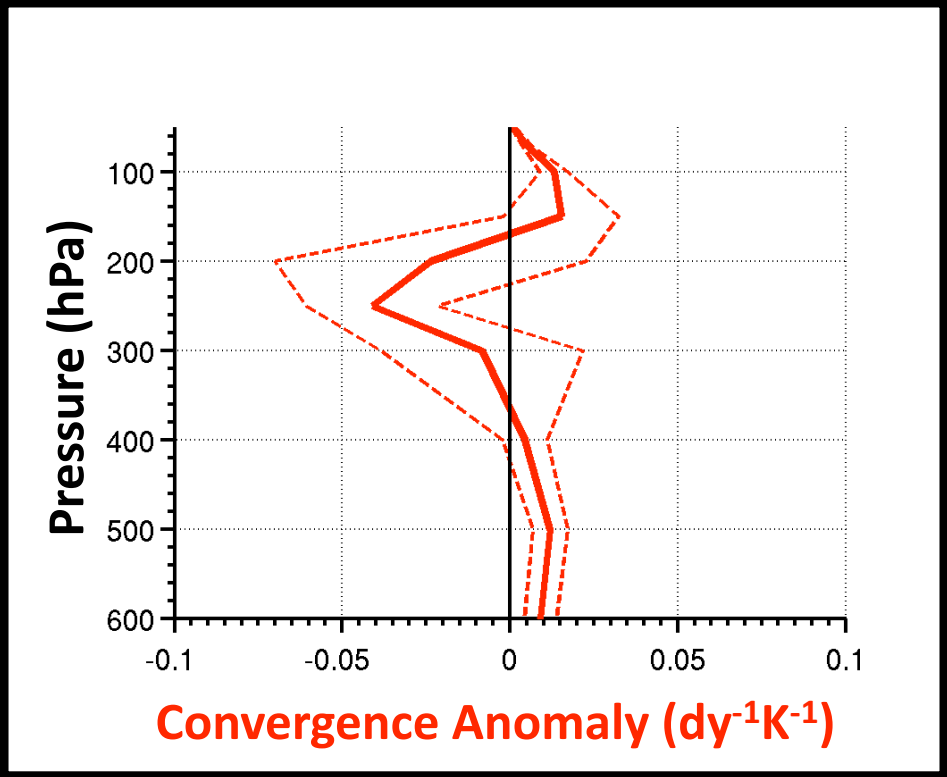
ISCCP



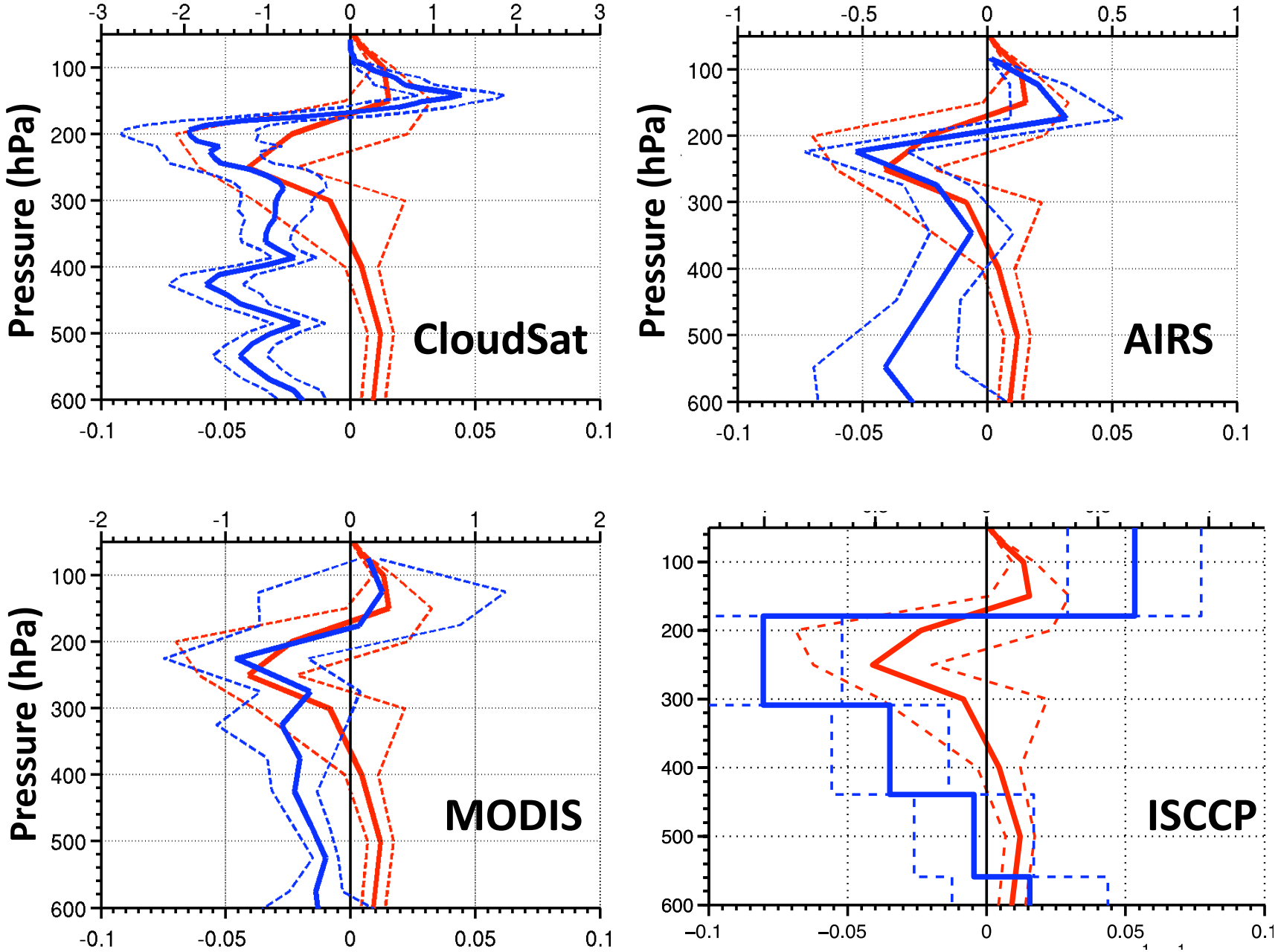
- AIRS and MLS data combined into one temperature and humidity product
- This is used as input to Fu-Liou radiative transfer code to compute radiative cooling
- Assume radiative cooling is balanced by subsidence
- Assume mass continuity: take pressure derivative of diabatic subsidence profile to compute diabatic convergence

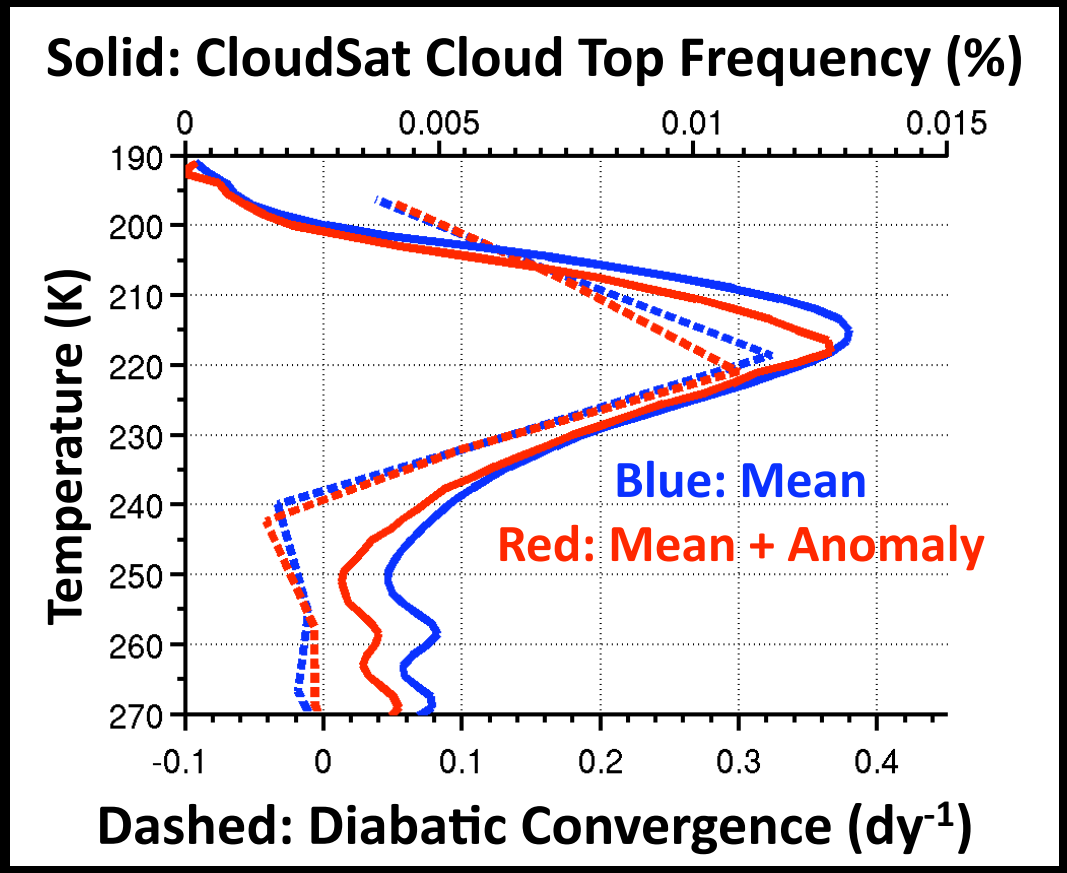

Blue: Cloud Fraction (%)
Red: Diabatic Convergence (dy-1)
Pressure (hPa)
CloudSat
AIRS
MODIS
ISCCP


HadCRUT3v Tropical Mean T_{sfc} Anomaly
Anomaly (K)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year


Pressure (hPa)
100
200
300
400
500
600
-0.1
-0.05
0
0.05
0.1
Convergence Anomaly (dy-1K-1)

Blue: Cloud Fraction Anomaly (% K^{-1}) Red: Diabatic Convergence Anomaly (dy^{-1} K^{-1})

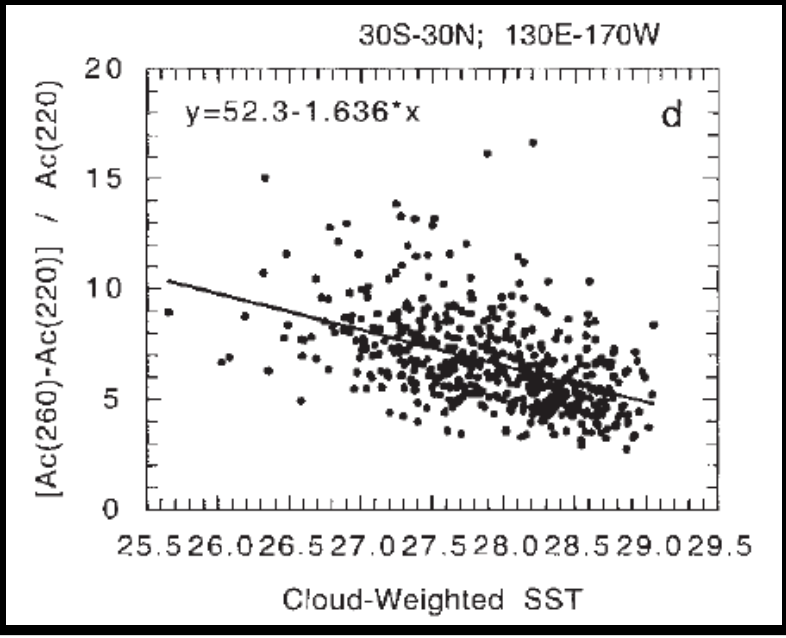




Looks PHAT-like but not statistically different from FAT

Does the Earth Have an Adaptive Infrared Iris?

Richard S. Lindzen,* Ming-Dah Chou,+ and Arthur Y. Hou+



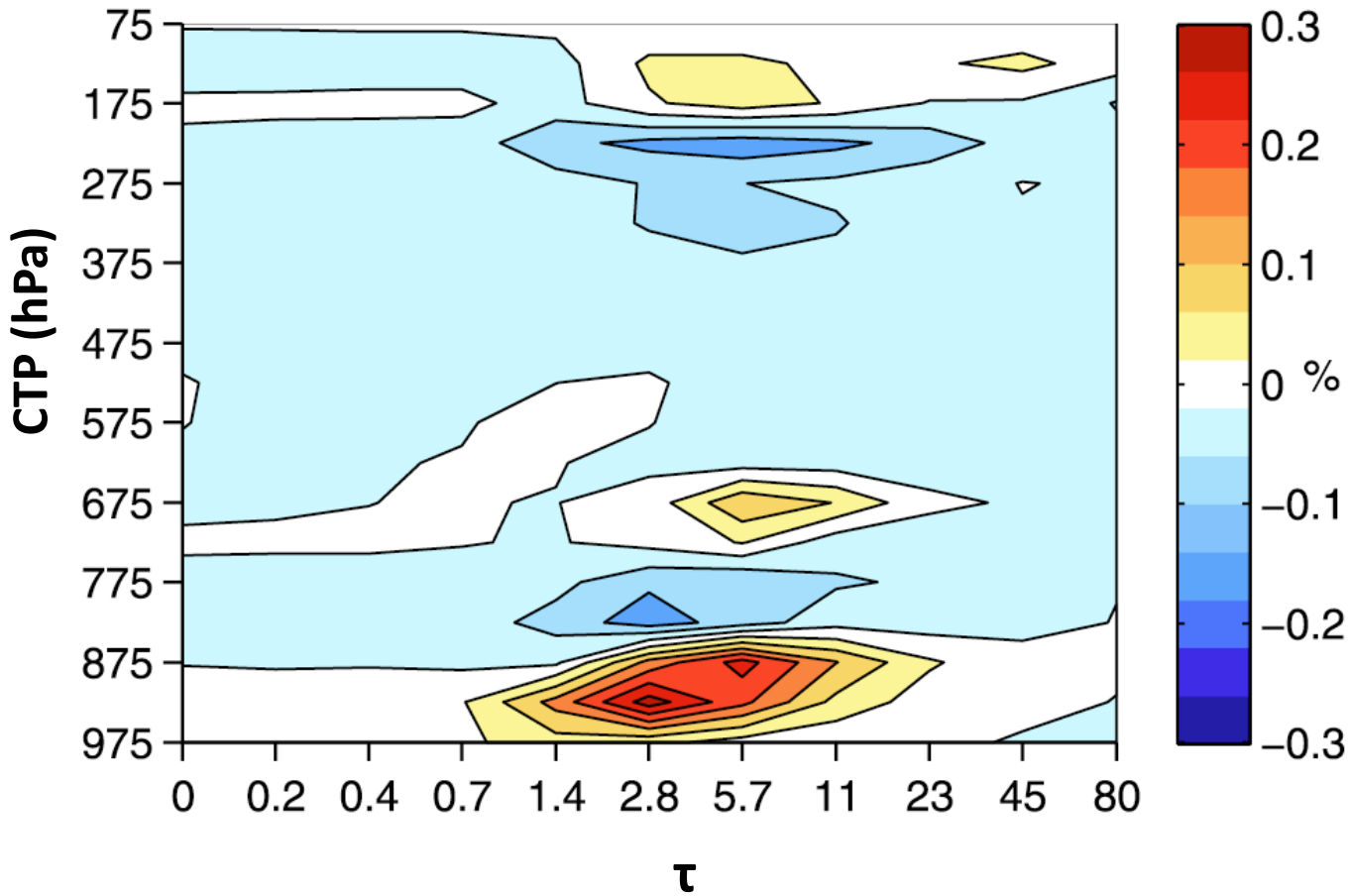
Refuted by:

Harrison (2002), Hartmann and Michelsen (2002 + replies), Fu et al. (2002), Del Genio and Kovari (2002), Lin et al. (2002 + reply), Chambers et al. (2002), Lin et al. (2004 + reply), Rapp et al. (2005), Del Genio et al. (2005), Lin et al. (2006), Wong et al. (2006), Lin et al. (2007), Su et al. (2008)

MODIS Cloud Fraction Anomaly (% K^{-1})

Total = -0.2±2.2 % K^{-1}

High Only: -1.1±1.1% K^{-1}



Dataset (Platform)	Temporal Coverage	LW ($W\ m^{-2}\ K^{-1}$)	SW ($W\ m^{-2}\ K^{-1}$)
MODIS (Aqua) x Kernel	Sep 2002 – Jul 2010	-1.1 ± 1.6	0.7 ± 2.7
MODIS (Aqua) x Kernel [High Clouds Only]	Sep 2002 – Jul 2010	-1.0 ± 1.4	**1.3 ± 1.3**
ISCCP x Kernel	Jul 1983 – Jun 2008	-0.3 ± 0.4	0.7 ± 1.3
ISCCP x Kernel [High Clouds Only]	Jul 1983 – Jun 2008	-0.2 ± 0.4	**0.5 ± 0.4**

Suggests that **SW "iris"** dominates over **LW "iris"**

→ consistent with Lin et al. (2002)

Dataset (Platform)	Temporal Coverage	LW ($W\ m^{-2}\ K^{-1}$)	SW ($W\ m^{-2}\ K^{-1}$)
MODIS (Aqua) x Kernel	Sep 2002 – Jul 2010	-1.1 ± 1.6	0.7 ± 2.7
MODIS (Aqua) x Kernel [High Clouds Only]	Sep 2002 – Jul 2010	-1.0 ± 1.4	**1.3 ± 1.3**
ISCCP x Kernel	Jul 1983 – Jun 2008	-0.3 ± 0.4	0.7 ± 1.3
ISCCP x Kernel [High Clouds Only]	Jul 1983 – Jun 2008	-0.2 ± 0.4	**0.5 ± 0.4**
CERES SSF (Terra)	Mar 2000 – Dec 2010	-0.4 ± 1.0	0.8 ± 1.1
CERES SSF (Aqua)	Jul 2002 – Dec 2010	-0.8 ± 1.1	**1.3 ± 1.2**
CERES SYN (Terra)	Mar 2000 – Dec 2010	-0.7 ± 1.0	**1.1 ± 1.1**
CERES SYN (Aqua)	Jul 2002 – Dec 2010	-0.5 ± 1.2	0.6 ± 1.3
CERES EBAF (Aqua & Terra)	Mar 2000 – Dec 2010	-0.7 ± 1.0	0.7 ± 1.0

Conclusions

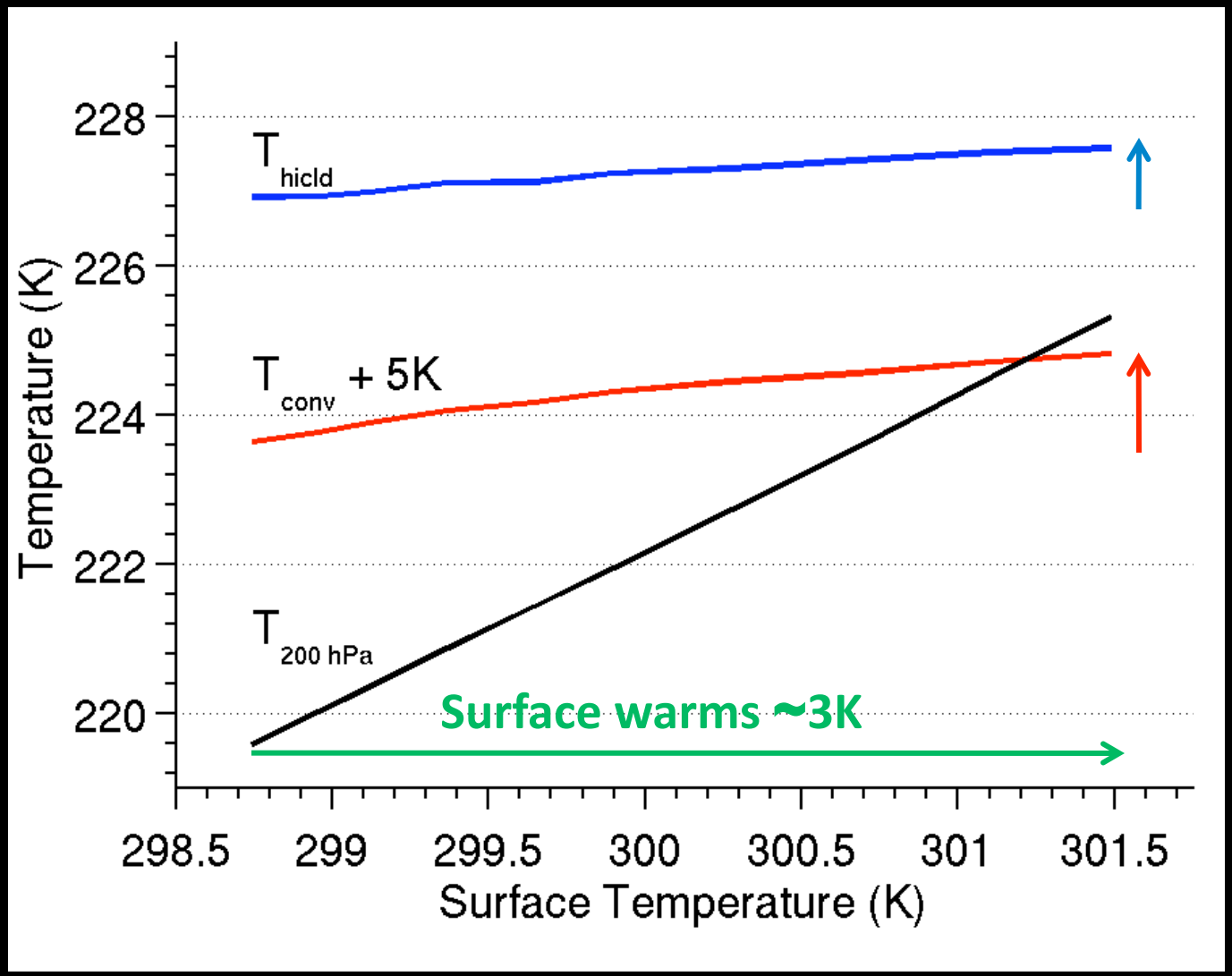
- Clear-sky convergence metric **closely tracks** observed cloud profiles
- Clouds **rise** but exhibit a **decrease in coverage** as the Tropics warm
- Cloud changes **suggestive of PHAT**, but can't rule out FAT
- Reduction in high cloud coverage results in a **net heating** of the Tropics because enhanced SW absorption exceeds enhanced LW emission

This research was supported by NASA Grant NNX09AH73G, NASA Earth and Space Science Fellowship NNX06AF69H, and by the Lawrence Livermore National Laboratory (LLNL) Institutional Postdoc Program.

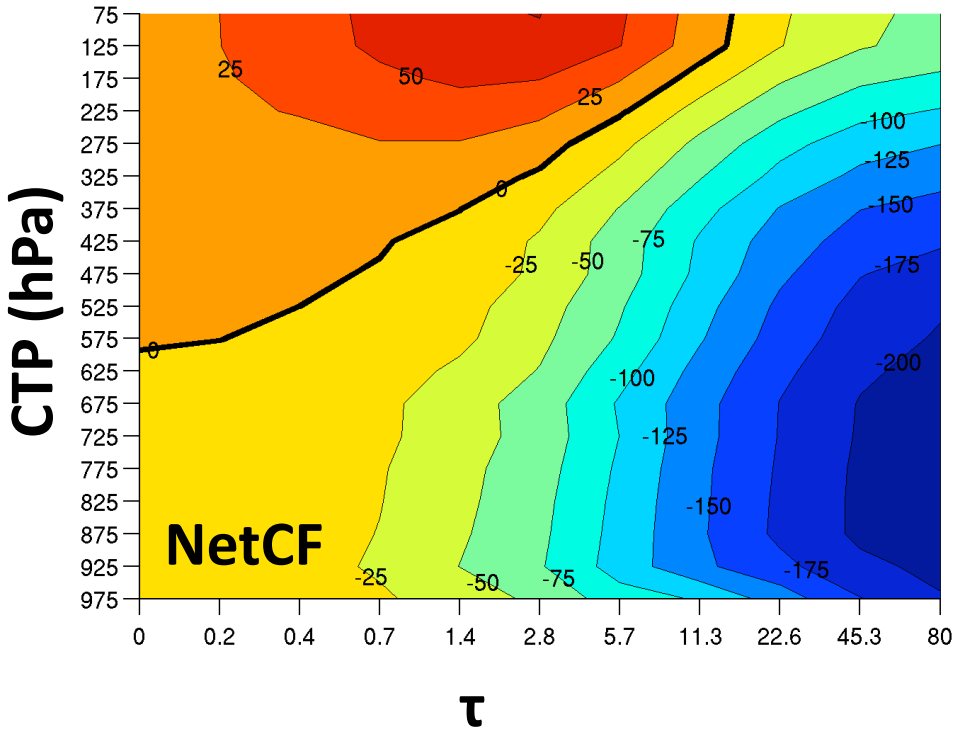
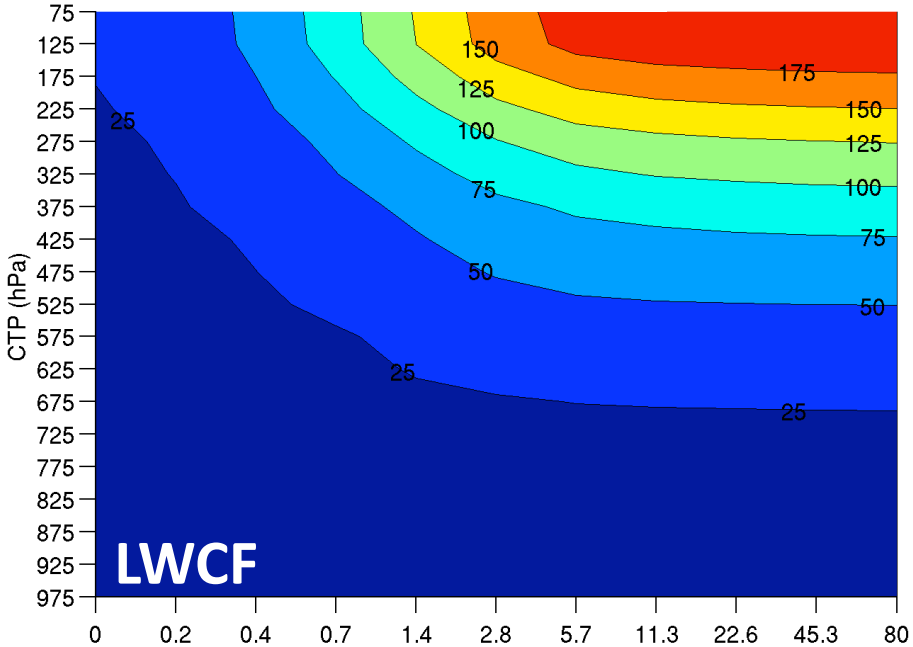
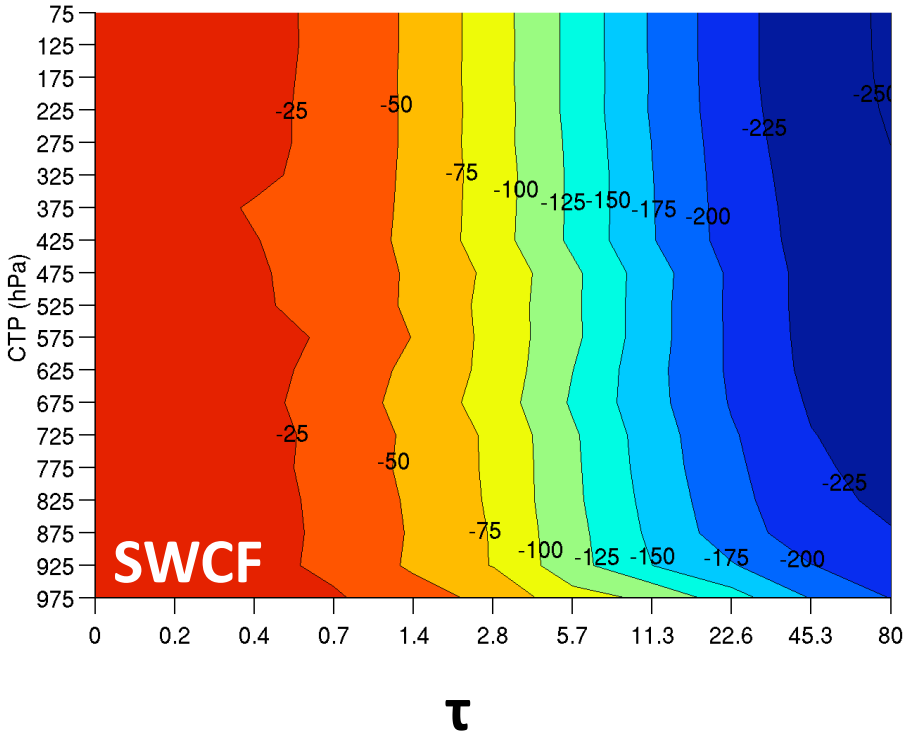
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

IM Release #LLNL-PRES-501873

Extra Slides



Clouds & convergence warm ~1K

Upper troposphere warms ~6K

Overcast sky cloud forcing histograms