Tropical variability and global trends of clouds as viewed by the Atmospheric Infrared Sounder

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Bill Rossow Symposium
June 8, 2017

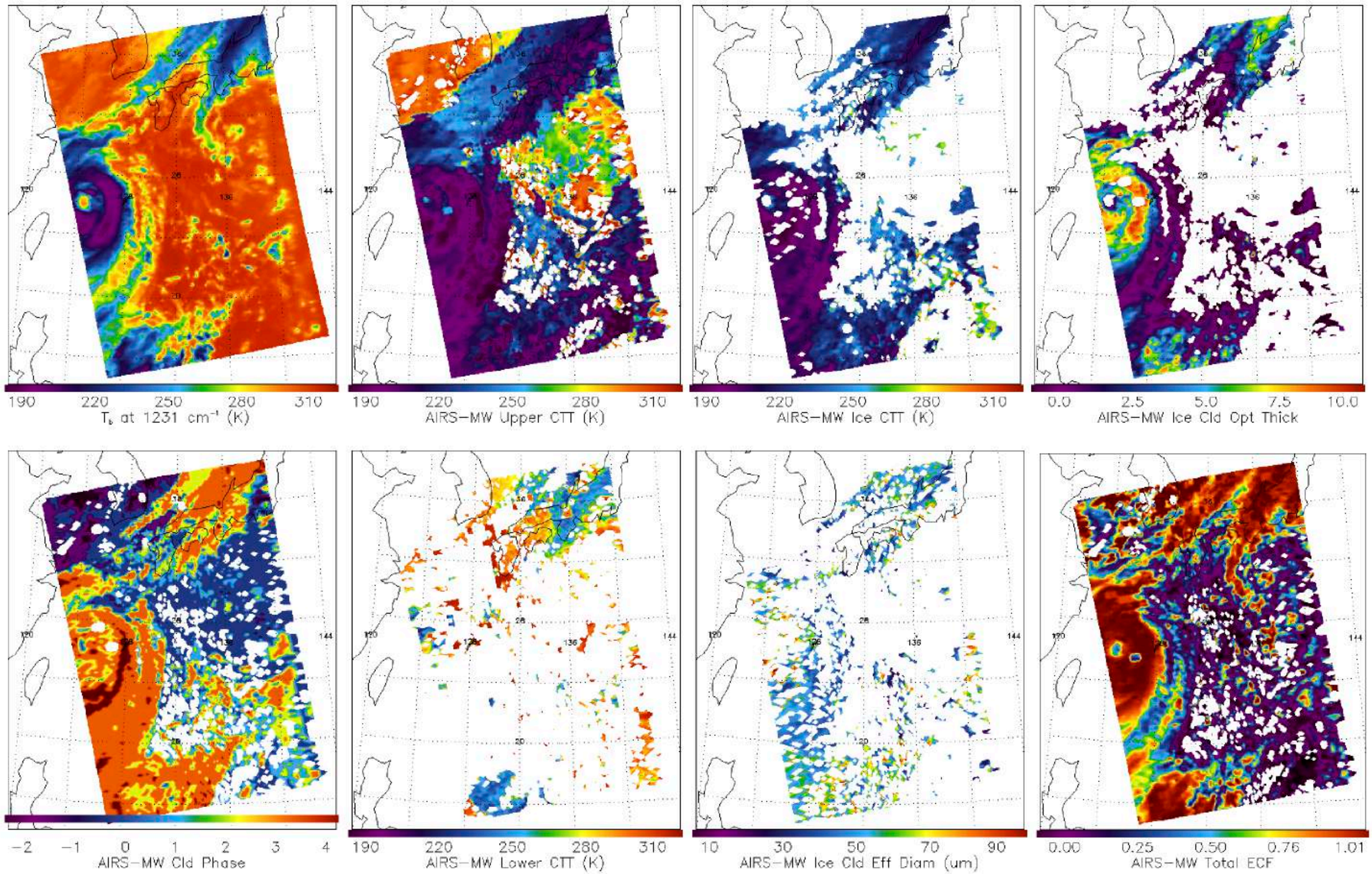
Two Topics

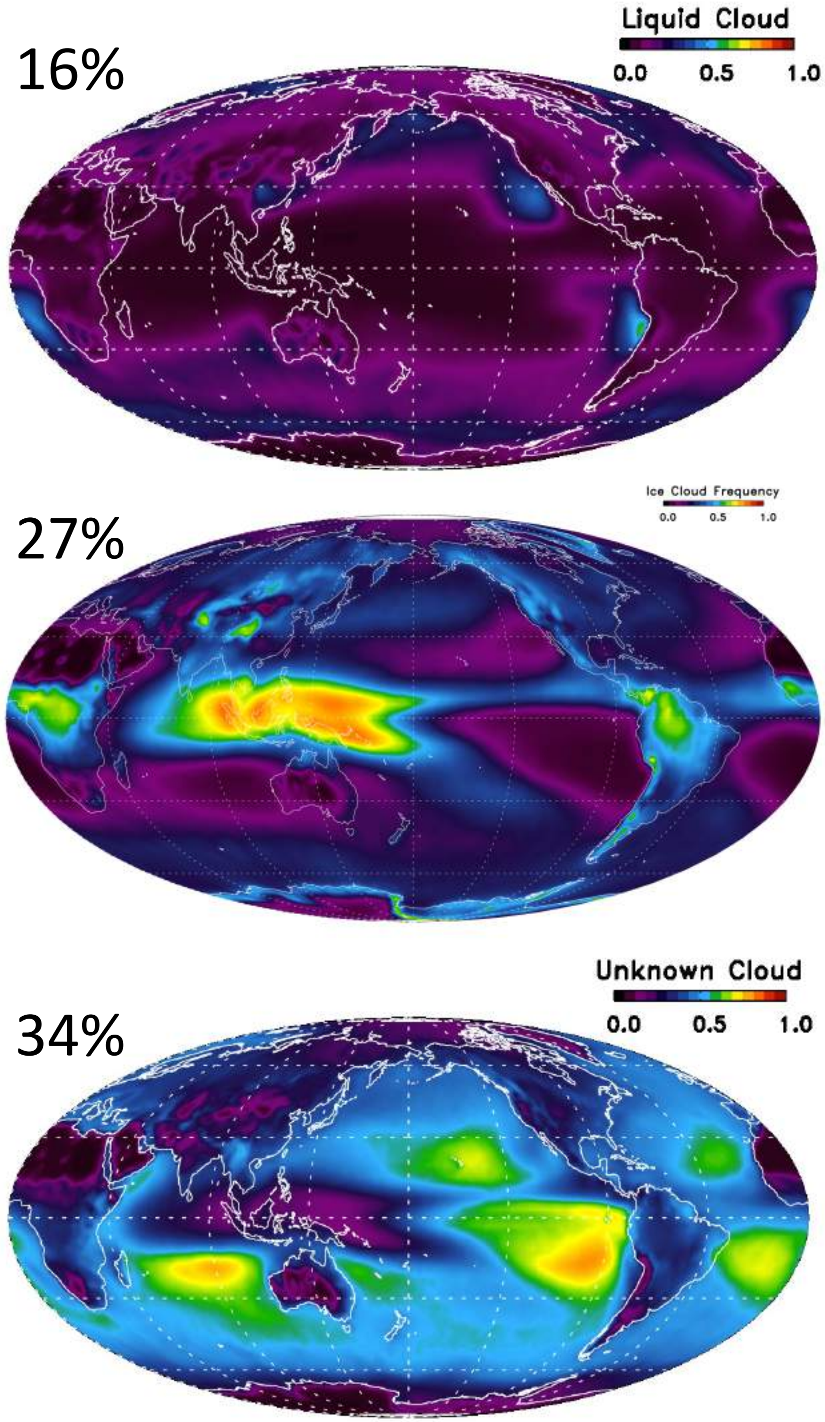
(unpublished work in progress)

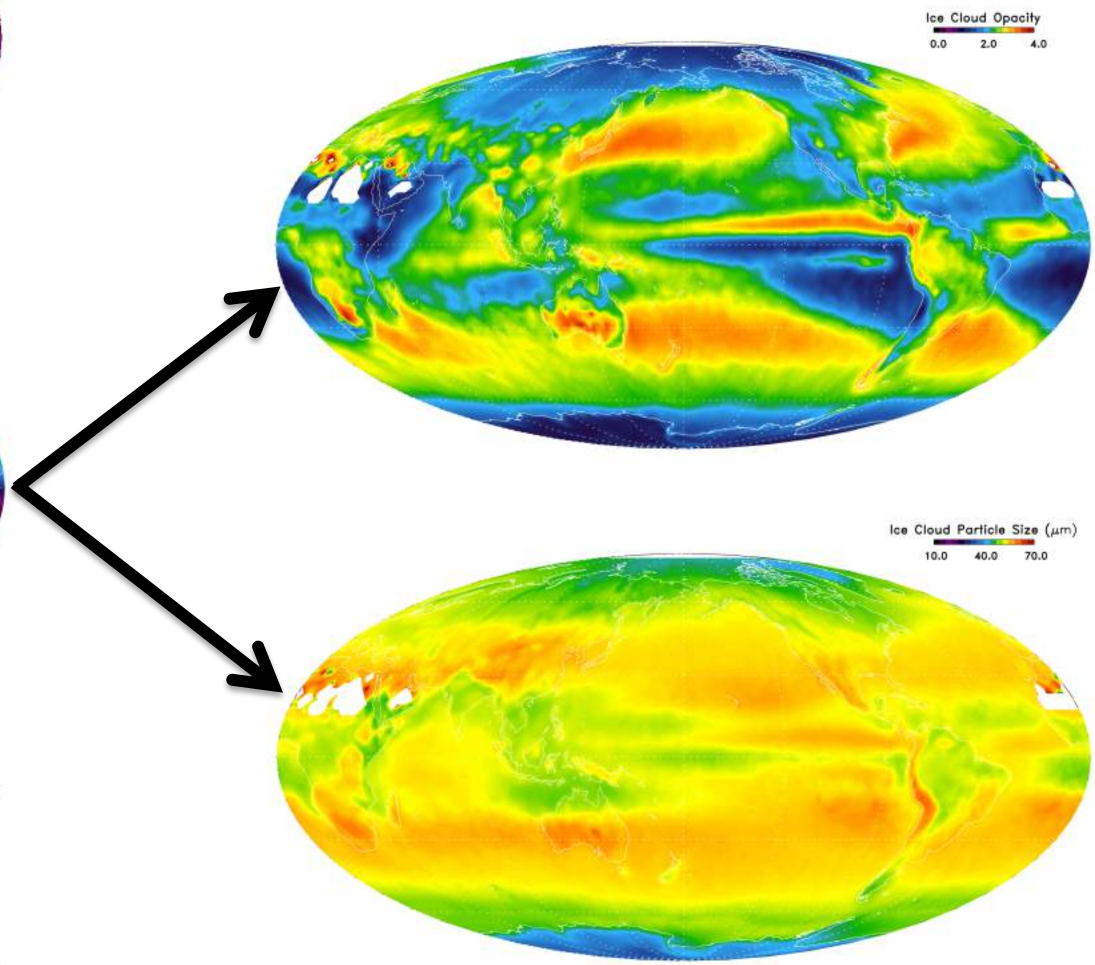
Low-latitude cloud variability and tropical waves

14-year trends in cloud properties

Six minute AIRS granule on September 6, 2002



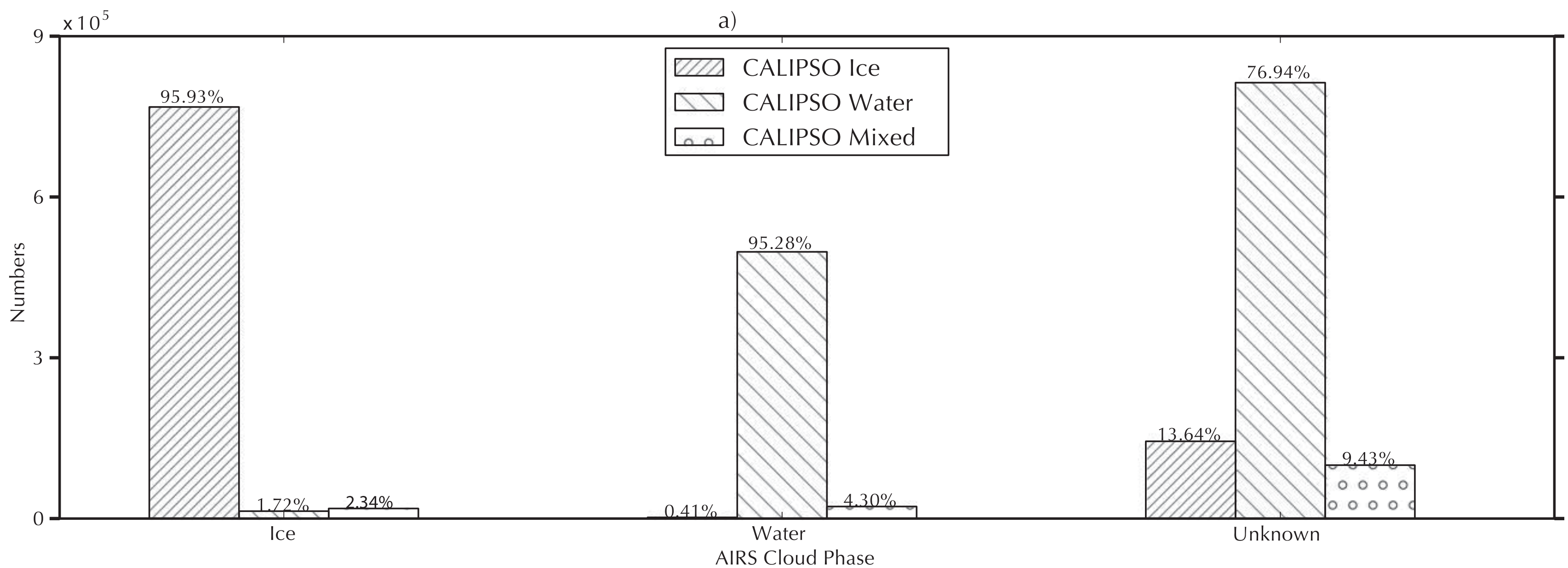




Kahn et al., 2014, Atmos. Chem. Phys.

CALIOP versus AIRS thermodynamic phase estimates

CALIOP ice (liq) when 3x as much ice (liq) as liq (ice) in AIRS FOV



Jin and Nasiri, 2014, J. Appl. Meteor. Climatol.

The single-layered phase comparisons are really promising

(With some issues over mountainous/a few land regions)

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Multi-layered clouds have a somewhat higher rate of disagreement

Opportunity to attempt two-layer (or more) phase retrieval in AIRS

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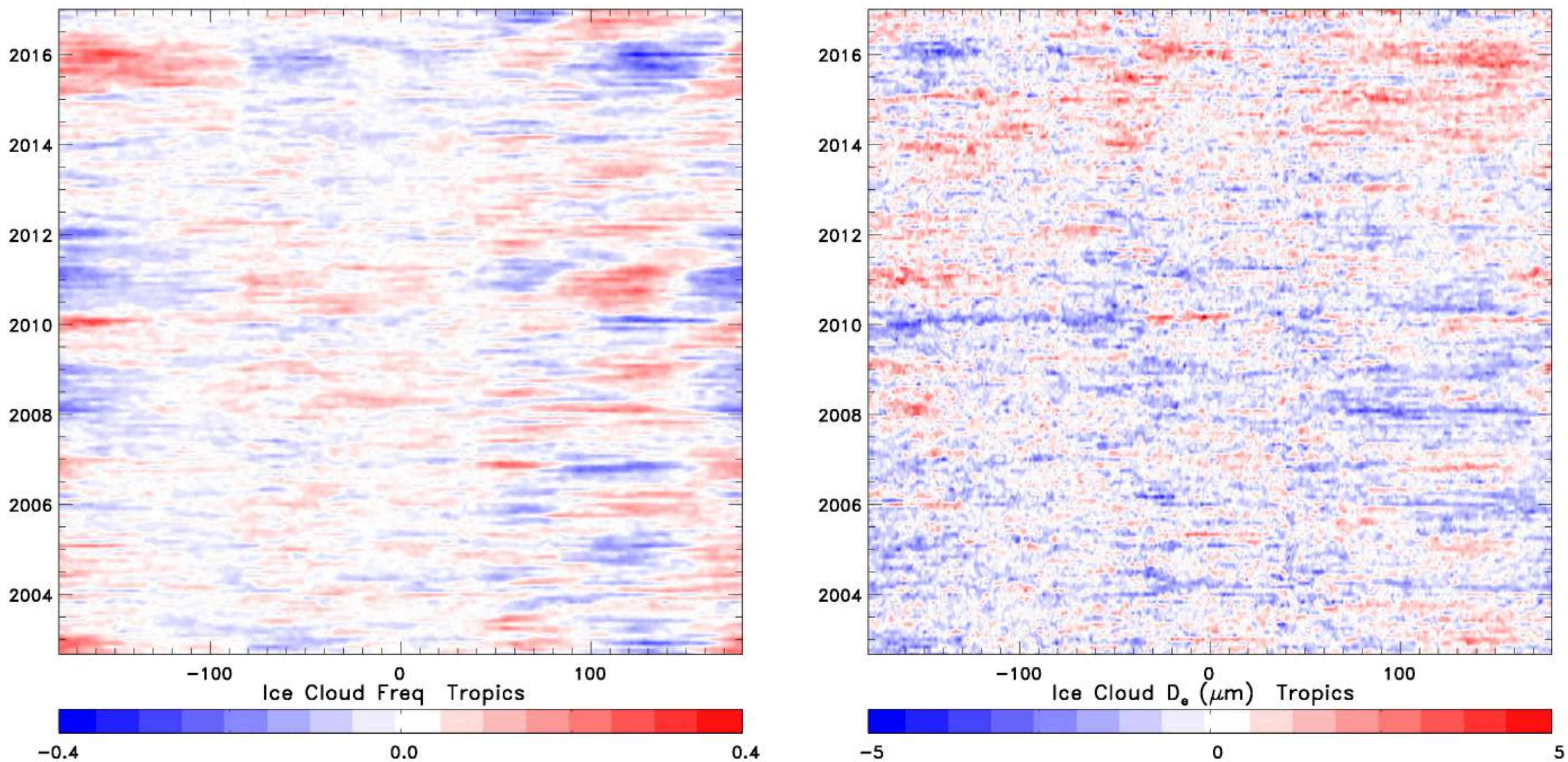
Supercooled liquid indices of refraction must be exploited

2760 *J. Phys. Chem. A* **2005,** *109,* 2760−2764

Frequency Dependent Complex Refractive Indices of Supercooled Liquid Water and Ice Determined from Aerosol Extinction Spectra

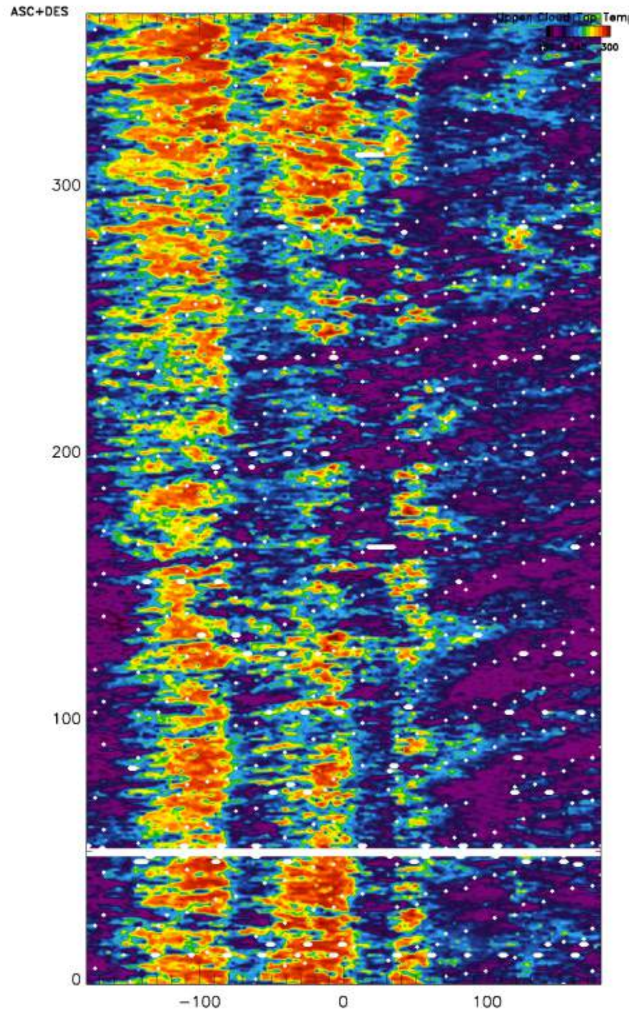
A. Y. Zasetsky,* A. F. Khalizov, M. E. Earle, and J. J. Sloan

Hovmöller diagrams of ice cloud frequency and effective diameter anomalies (18°S-18°N)



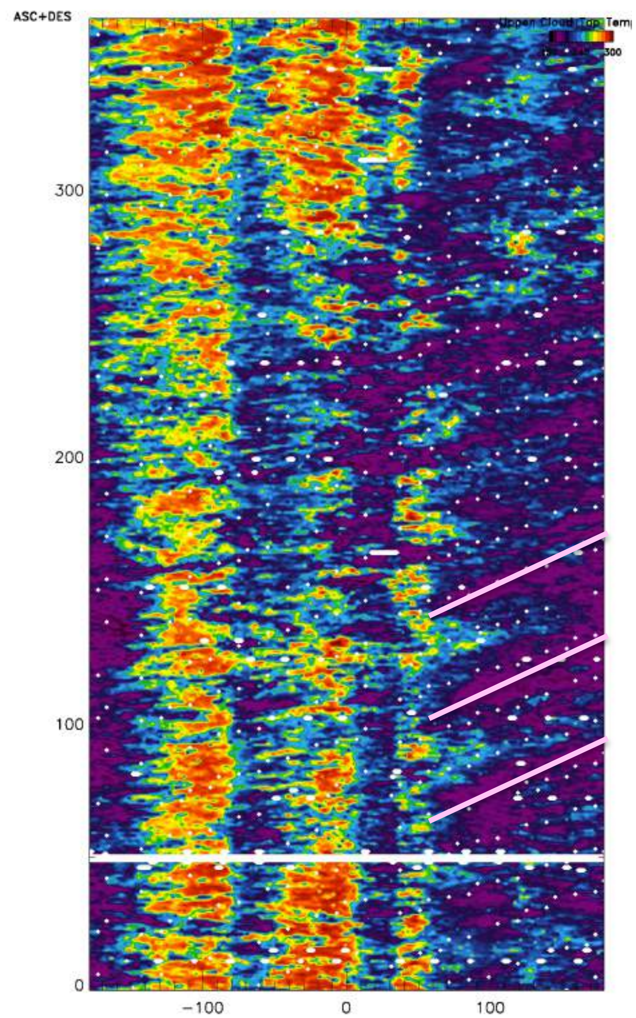
Lots of eastward and westward convectively coupled equatorial waves (CCEWs)

Cloud top temperature



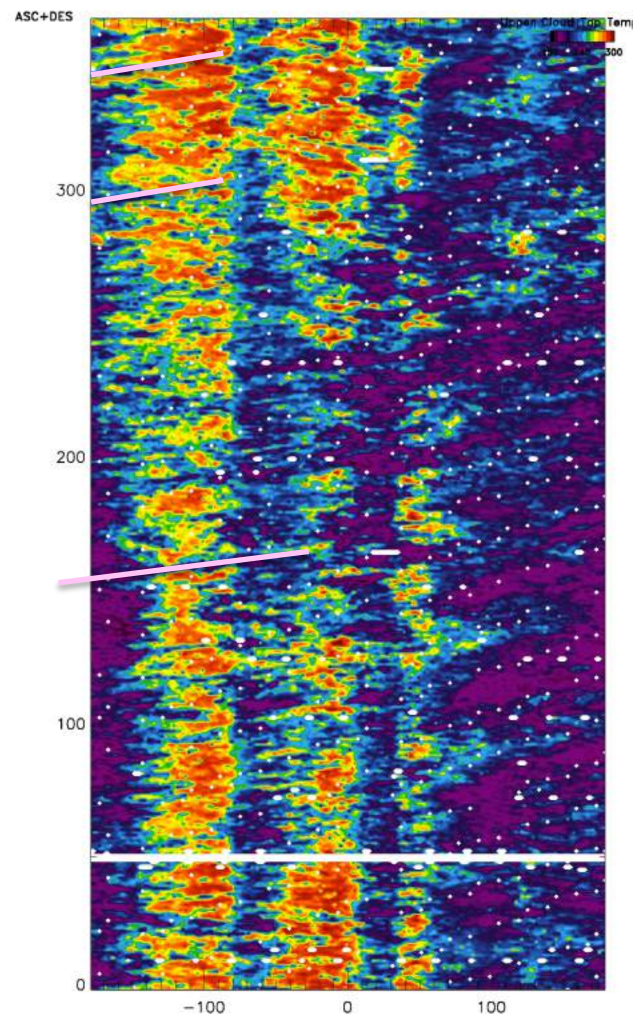
Madden-Julian Oscillation (MJO)

Cloud top temperature



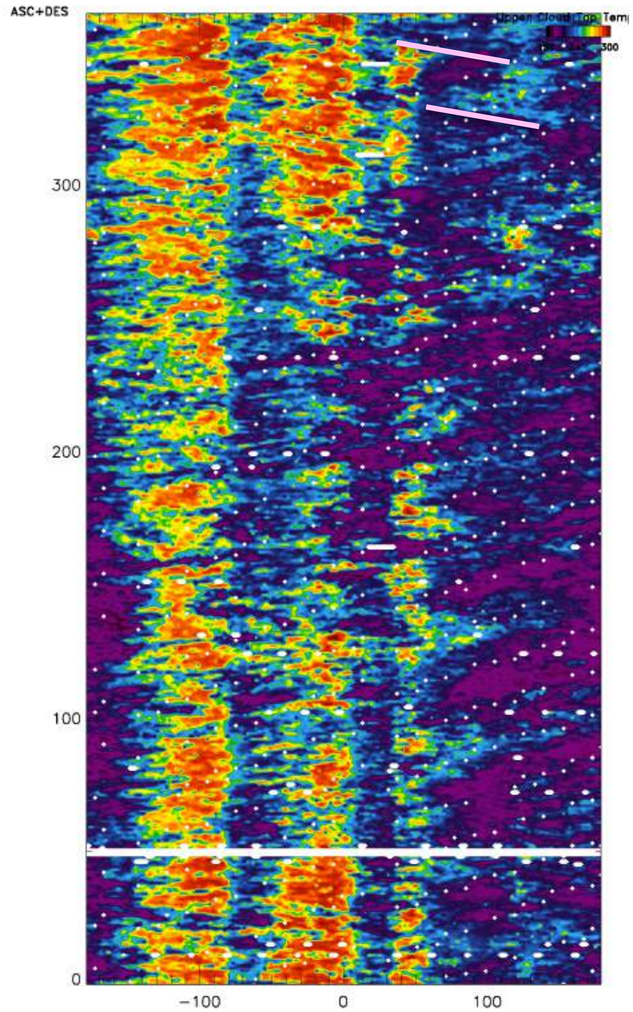
Kelvin waves

Cloud top temperature



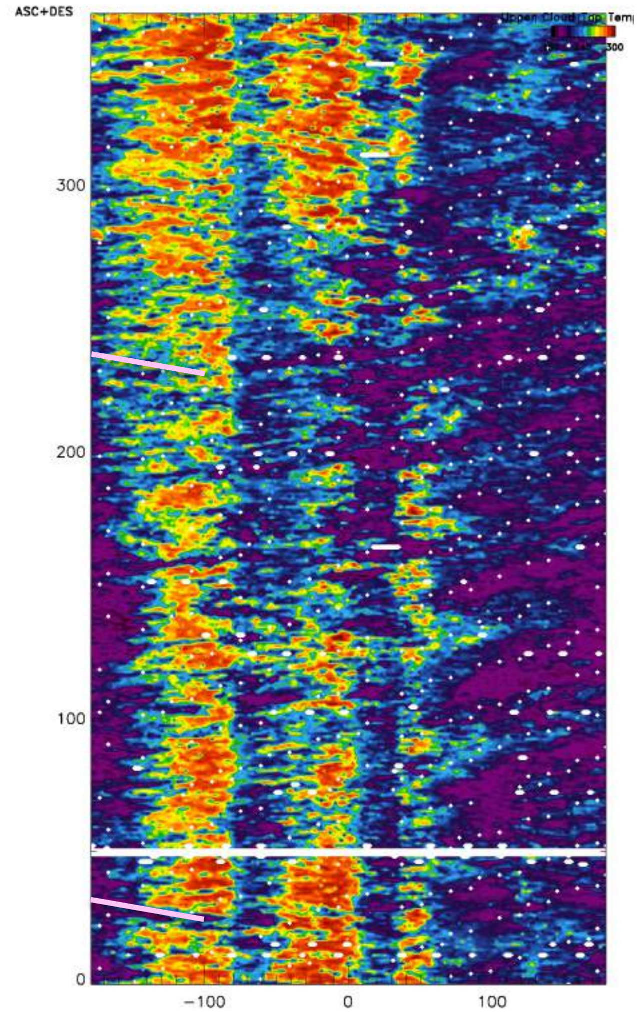
Equatorial Rossby waves (?)

Cloud top temperature



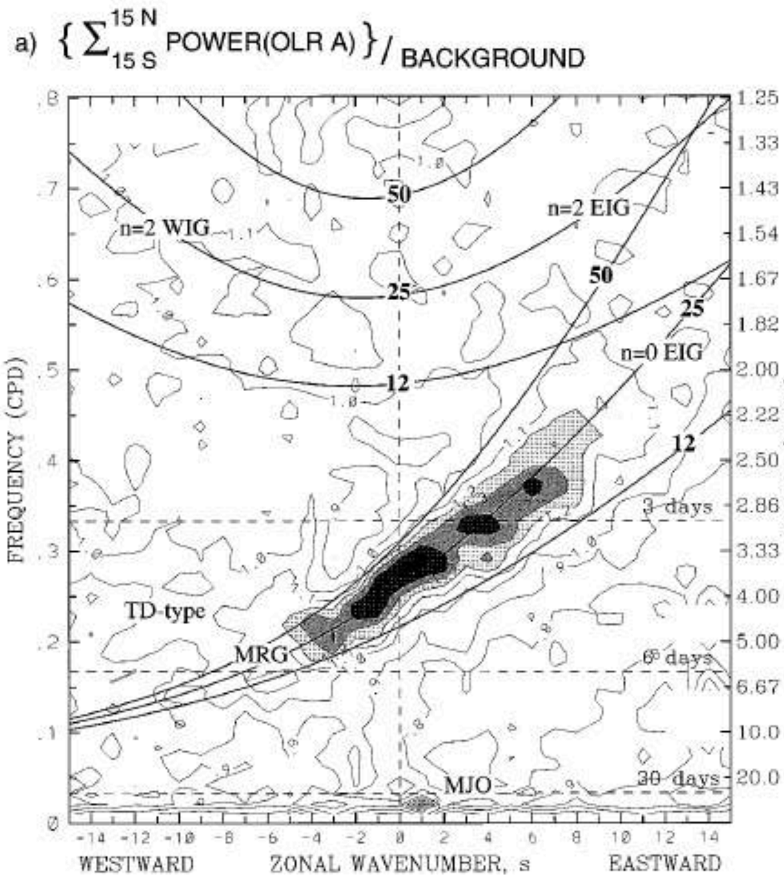
Mixed Rossby-gravity waves (?)

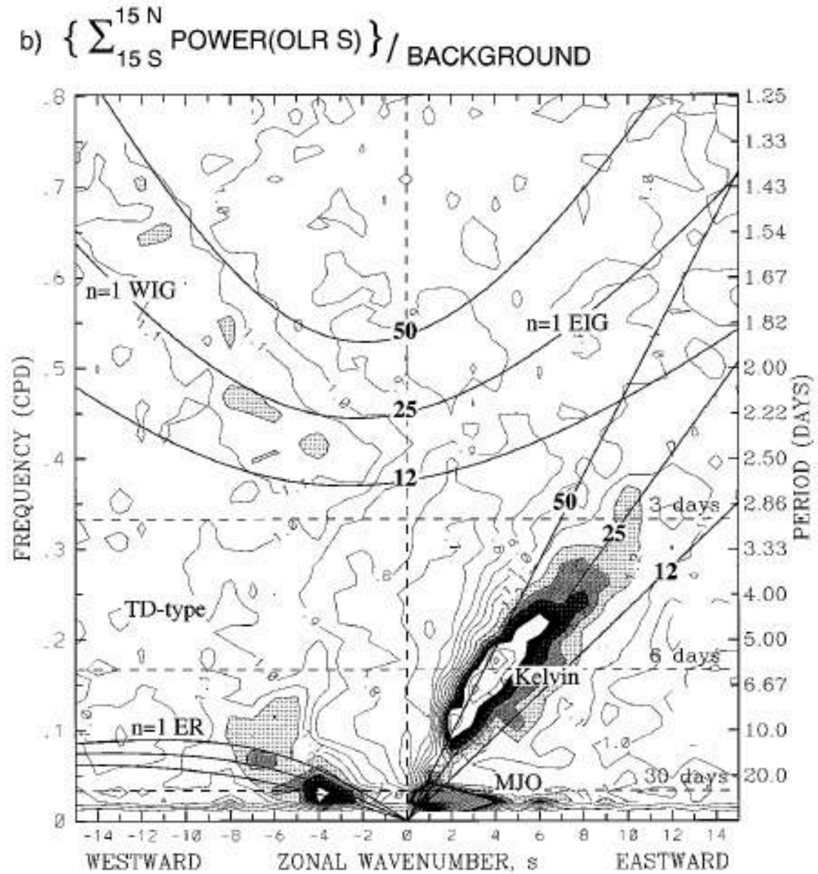
Cloud top temperature



Wheeler-Kiladis (W-K) diagrams for OLR

Waves can be symmetric or antisymmetric about equator

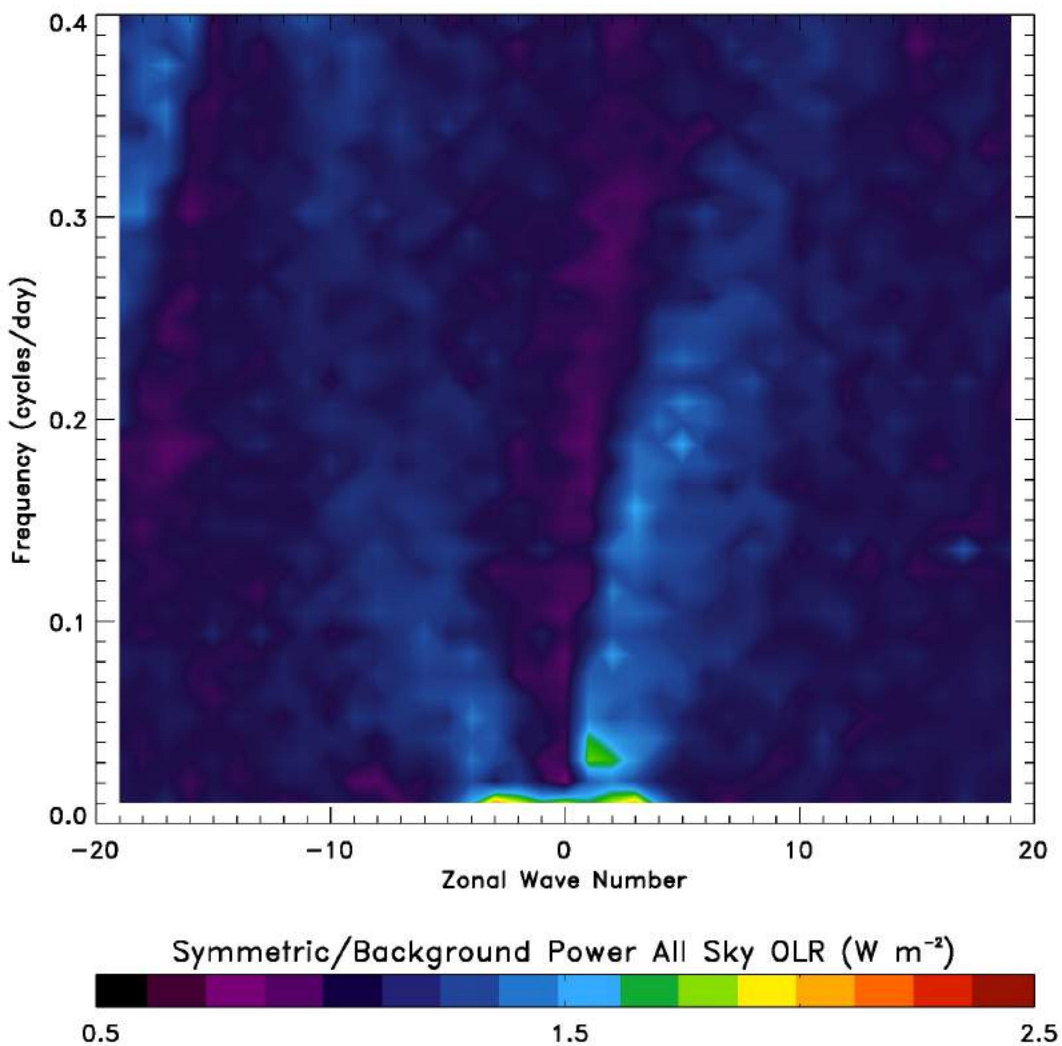




Wheeler and Kiladis, 1999, J. Atmos. Sci.

Symmetric W-K diagram for AIRS all-sky OLR

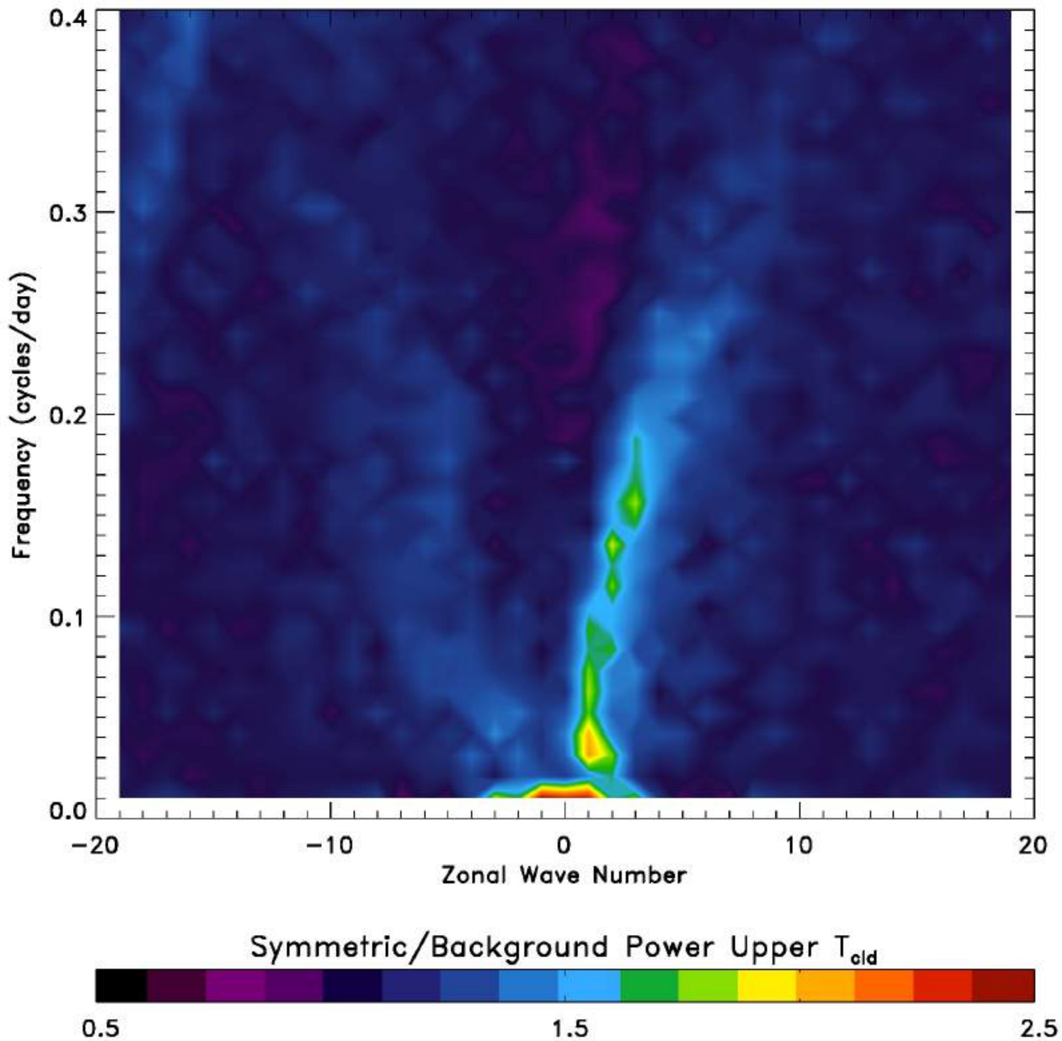
Slight shift in frequency compared to OLR



Kahn, Dorrestijn, et al., in preparation

Cloud top temperature

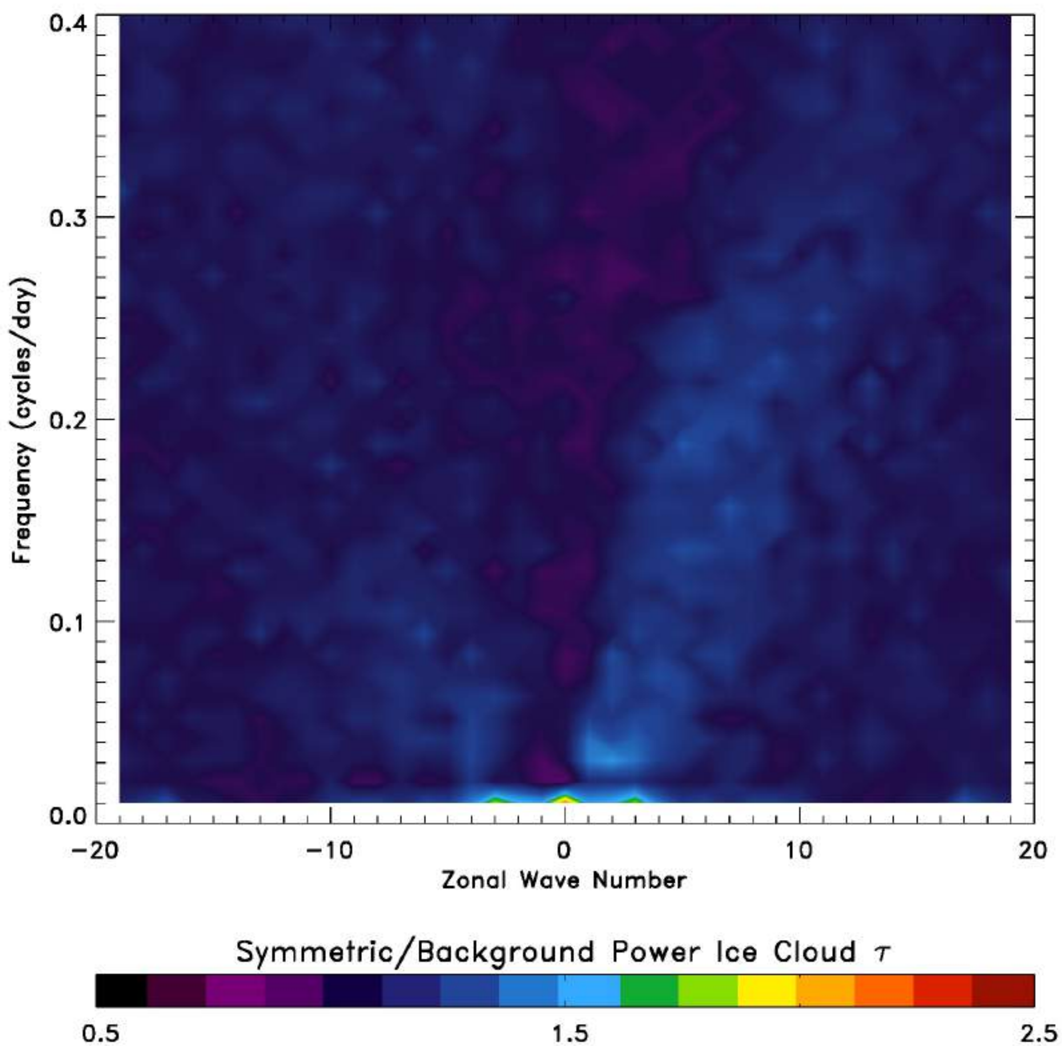
Smaller zonal number – controlled by tropopause-level Kelvin waves?



Kahn, Dorrestijn, et al., in preparation

Ice cloud optical thickness

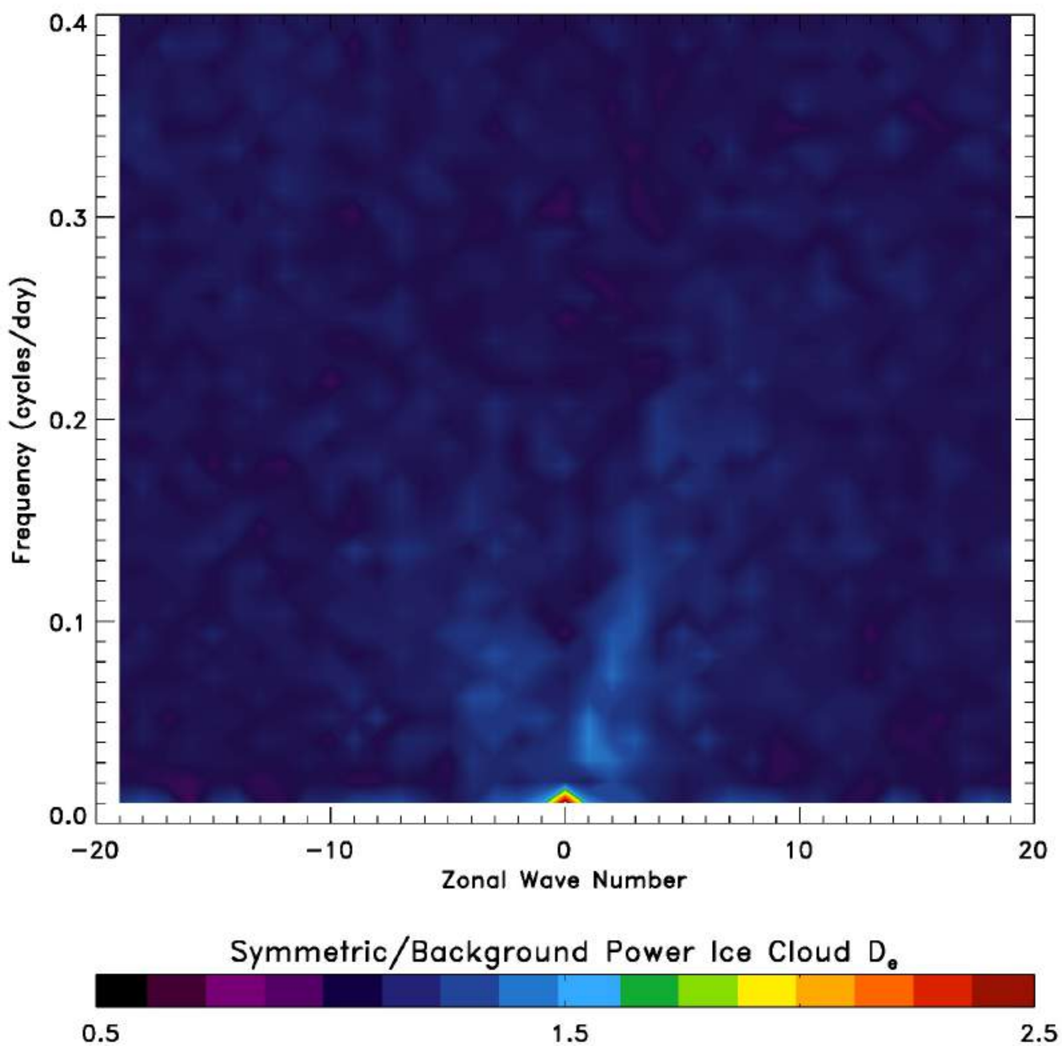
Dispersed energy at higher wave number consistent with convection



Kahn, Dorrestijn, et al., in preparation

Ice cloud effective diameter

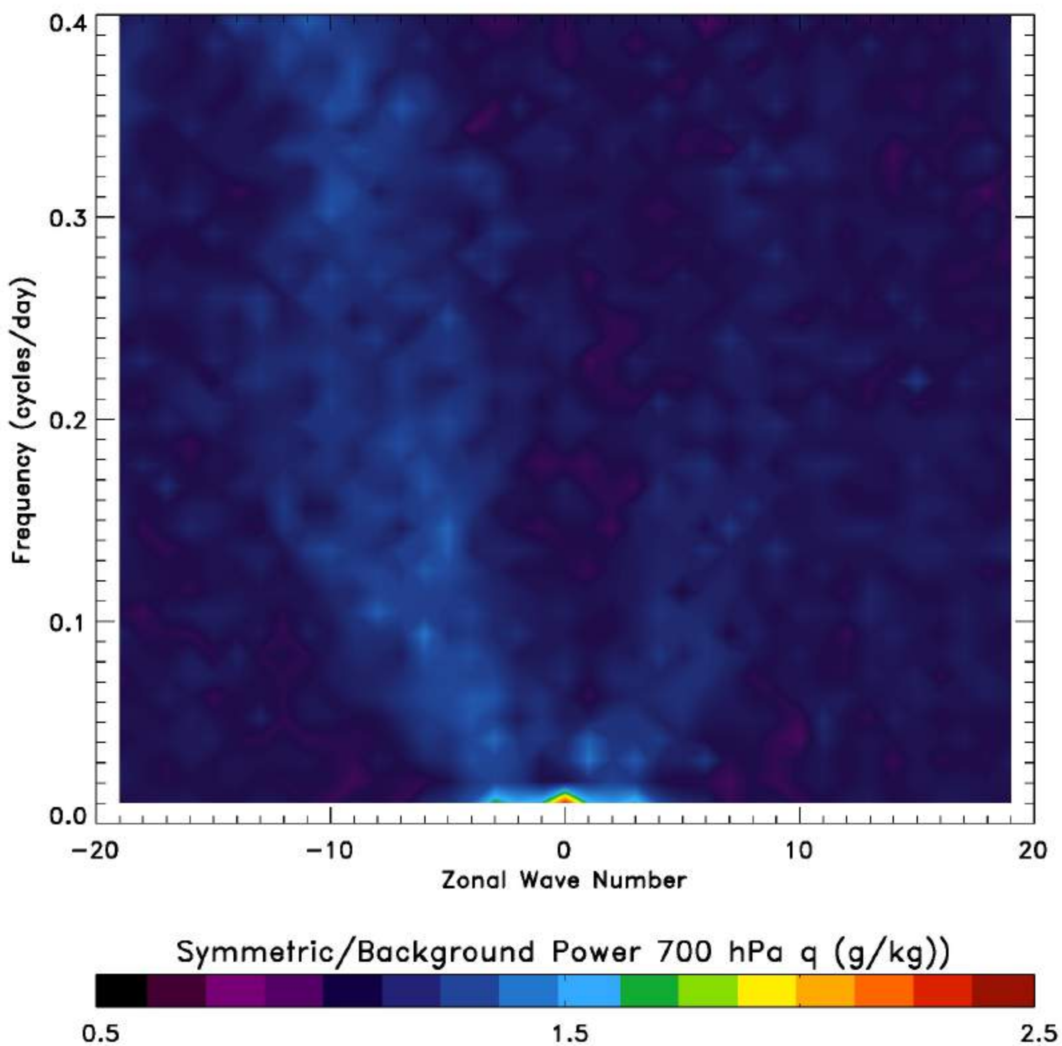
Less energy with focus at low frequency and wave number



Kahn, Dorrestijn, et al., in preparation

Specific humidity at 700 hPa

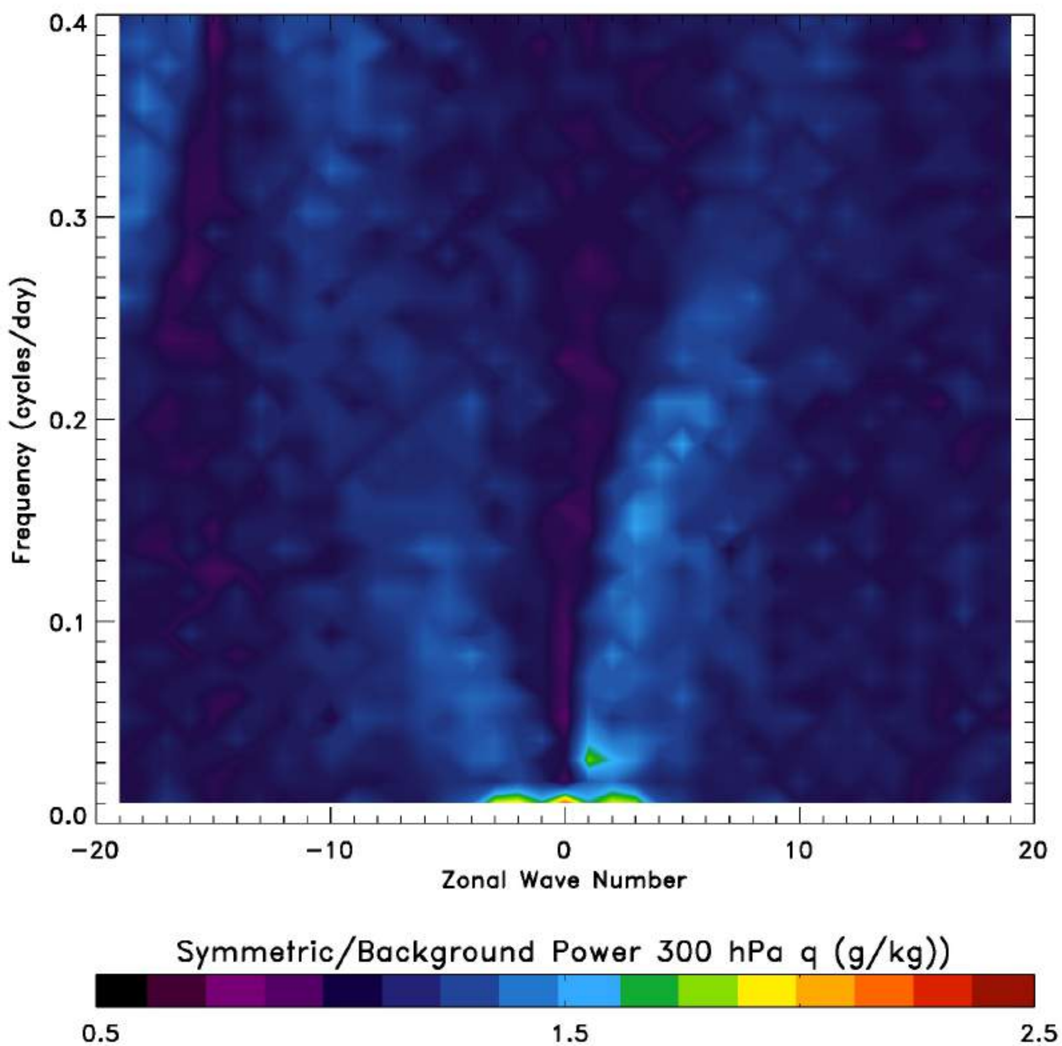
More wave energy in equatorial Rossby waves in lower/mid troposphere



Kahn, Dorrestijn, et al., in preparation

Specific humidity at 300 hPa

More wave energy in Kelvin waves in upper troposphere



Kahn, Dorrestijn, et al., in preparation

Tropical cloud property variability strongly related to classic view of CCEWs

More to the story with T/q and antisymmetric

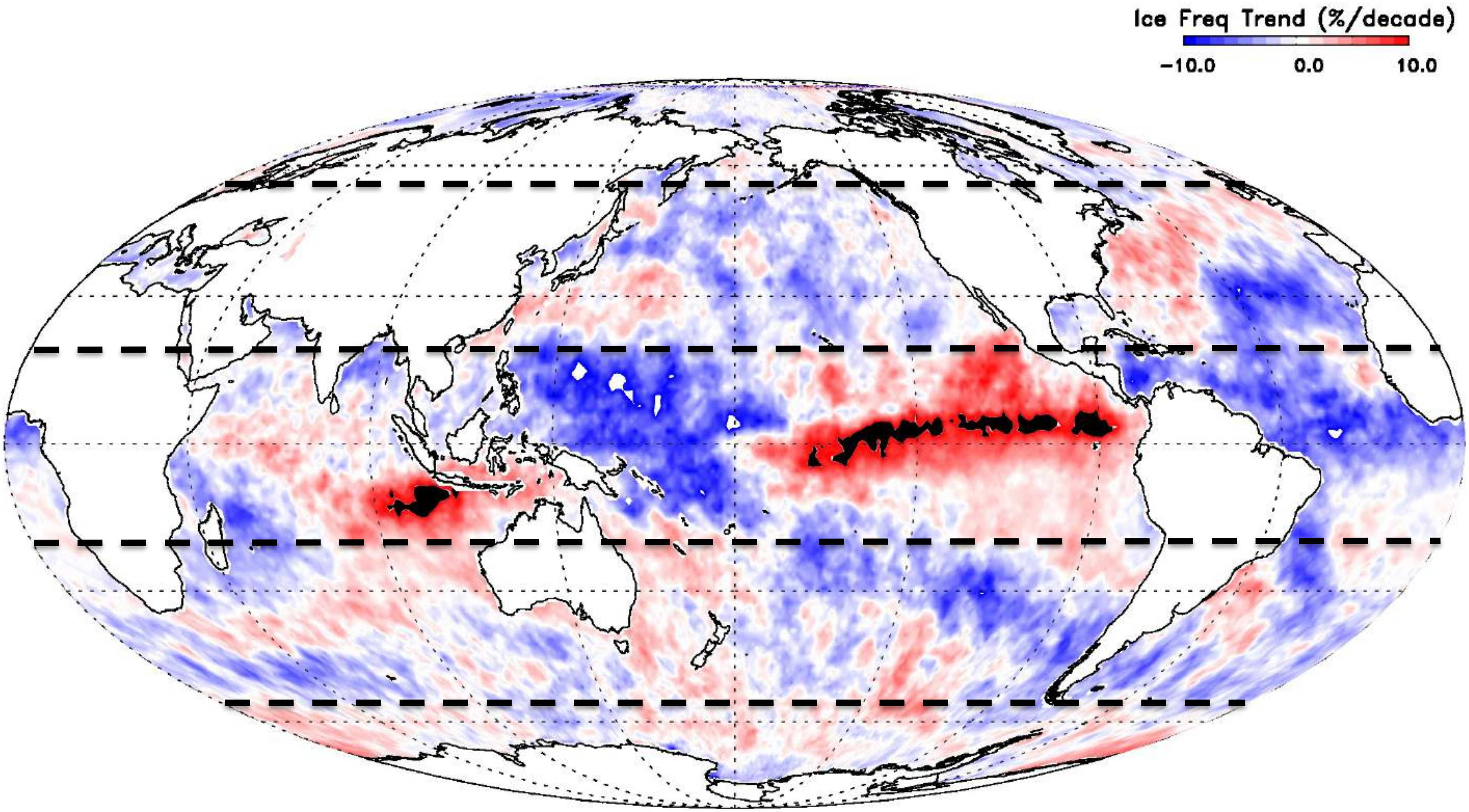
OLR does not reveal full complexity of cloud variability within CCEWs

New flavor of climate GCM test?

What about trends in the AIRS clouds?

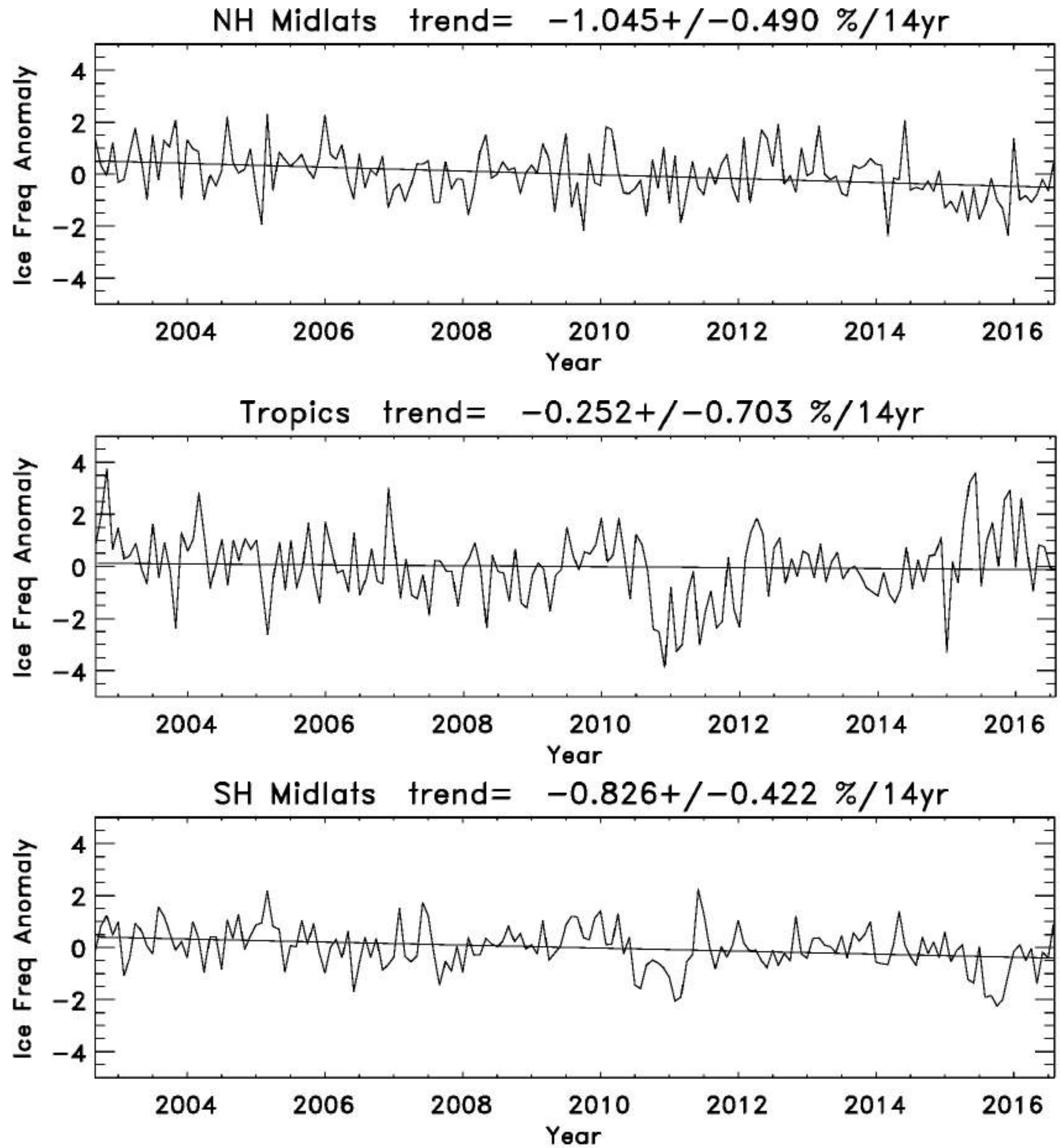
Dominant regional ice cloud trends in tropics

Trends more subtle in extratropics



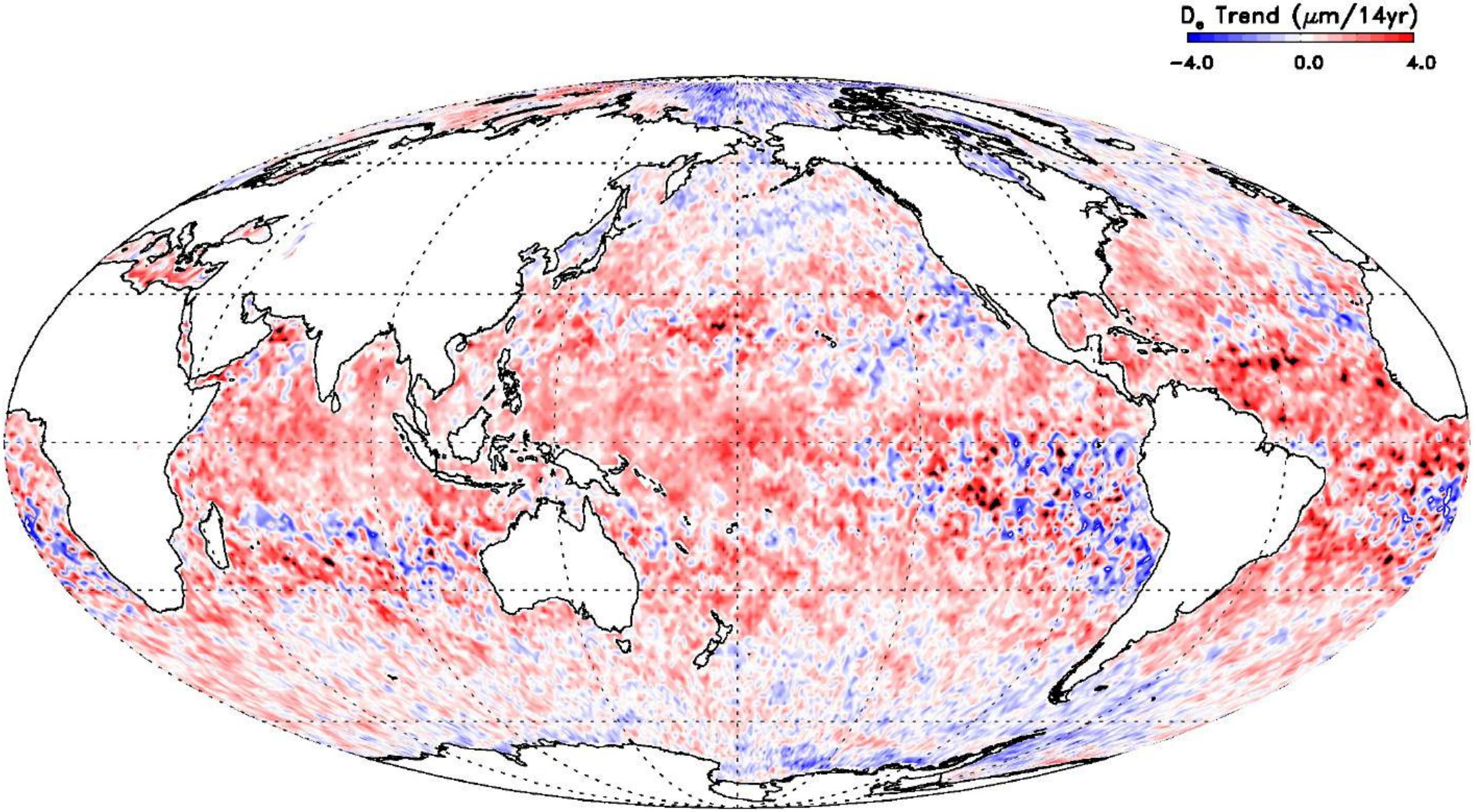
Trends with respect to <u>total counts</u> of AIRS fields of view

Statistically significant decrease in ice in SH/NH



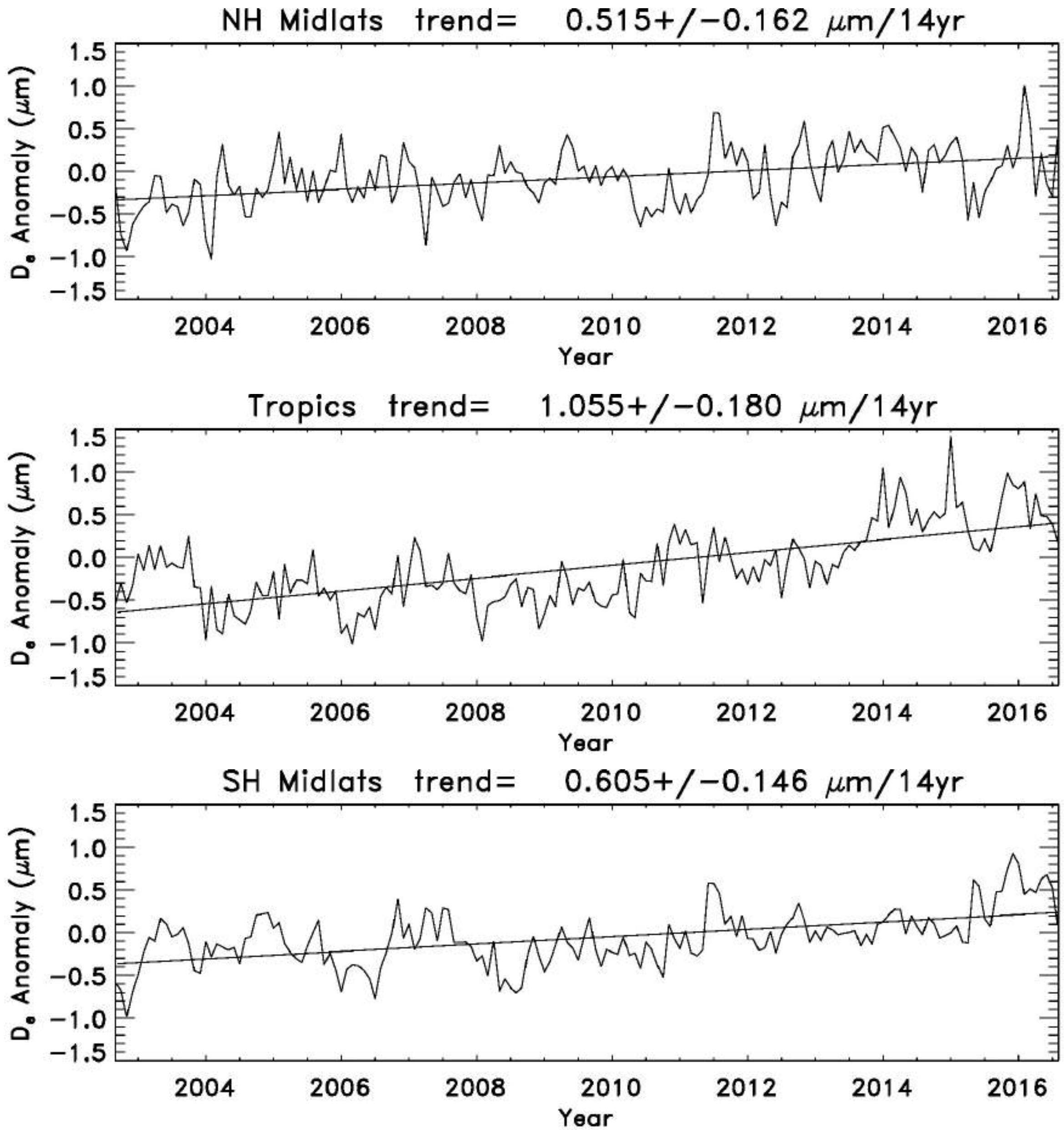
Widespread increase in D_e over most of globe

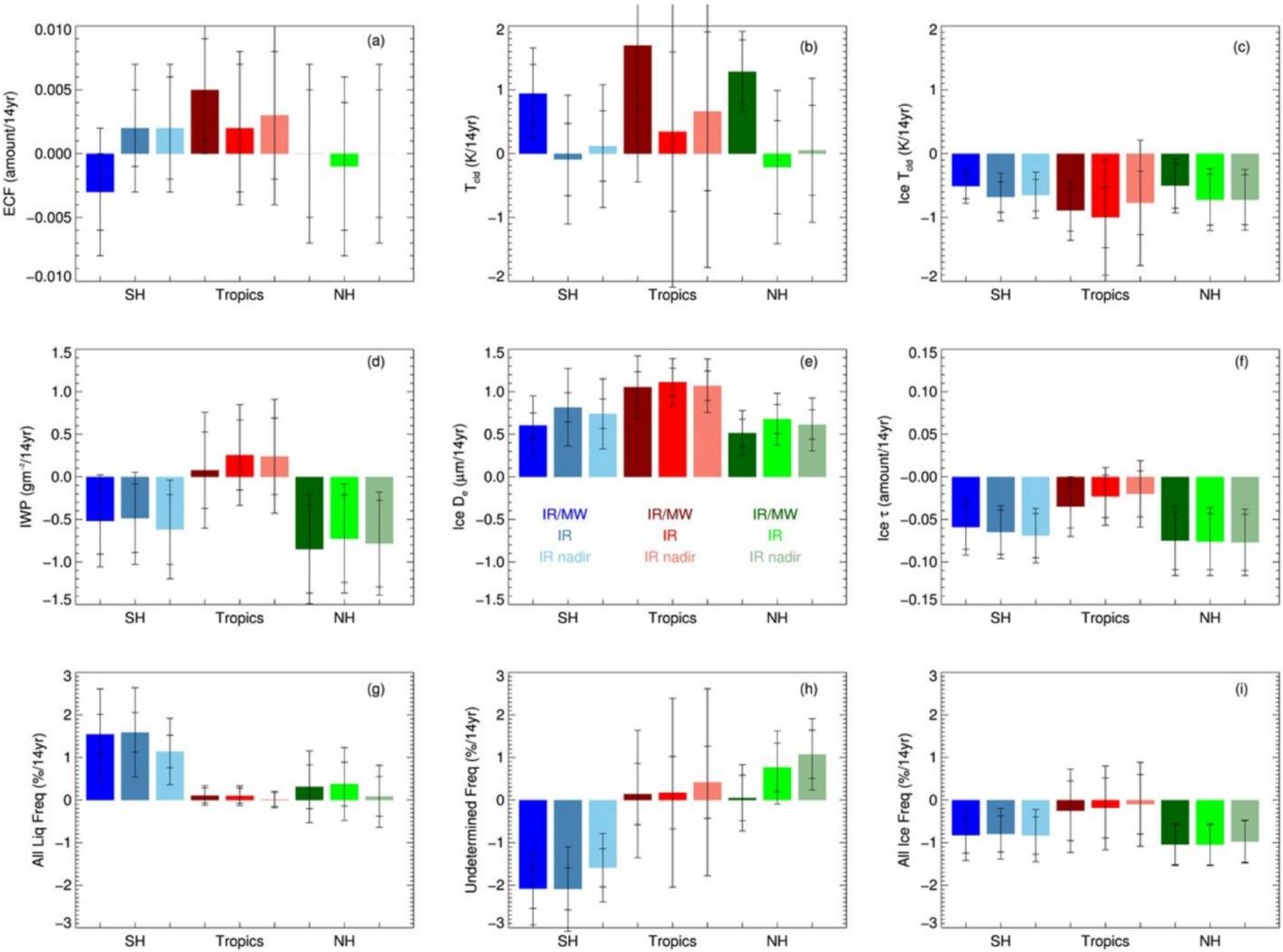
Strongest trends appear to be in Tropics



Kahn et al., in preparation

“Jump” in Tropics and steady trend in SH/NH





(a)
ECF (amount/14yr)
0.010
0.005
0.000
−0.005
−0.010
(b)
T_{cld} (K/14yr)
(c)
Ice T_{cld} (K/14yr)
(d)
IWP (gm^{-2}/14yr)
(e)
Ice D_e (μm/14yr)
IR/MW
IR
IR nadir
IR/MW
IR
IR nadir
IR/MW
IR
IR nadir
(f)
Ice τ (amount/14yr)
(g)
All Liq Freq (%/14yr)
(h)
Undetermined Freq (%/14yr)
(i)
All Ice Freq (%/14yr)
SH
Tropics
NH

Backup Slides

Cloud thermodynamic phase tests

Table 1. Breakdown of the Individual Ice Phase Tests That Are Summed Into a Single Value for the "Phase Test" (+1 to +4) Presented in This Work[a]

Description	Channels and Thresholds	Features	Value
Cold ice cloud test	T_b 960 cm^{-1} < 235 K	Cold and opaque ice cloud detection	+1
Particle scattering test	ΔT_b 1231–960 cm^{-1} > 0.0 K	Ice and liquid discrimination	+1
Thin cirrus test	ΔT_b 1231–930 cm^{-1} > 1.75 K	Thin cirrus identification	+1
Water vapor line test	ΔT_b 1227–960 cm^{-1} > -0.5 K	Discriminate cirrus from water vapor	+1

[a]There is no relationship between the number of positive ice phase tests triggered and the definition of the four heterogeneity categories defined in Table 2.

Liquid water test #1	ΔT 1231-960 cm^{-1} $<$ -1.0 K	Probable liquid water	-1
Liquid water test #2	ΔT 1231-930 cm^{-1} $<$ -0.6 K	Less stringent liquid water	-1

Kahn et al., 2014, Atmos. Chem. Phys.; Kahn et al., 2015, J. Geophys. Res.

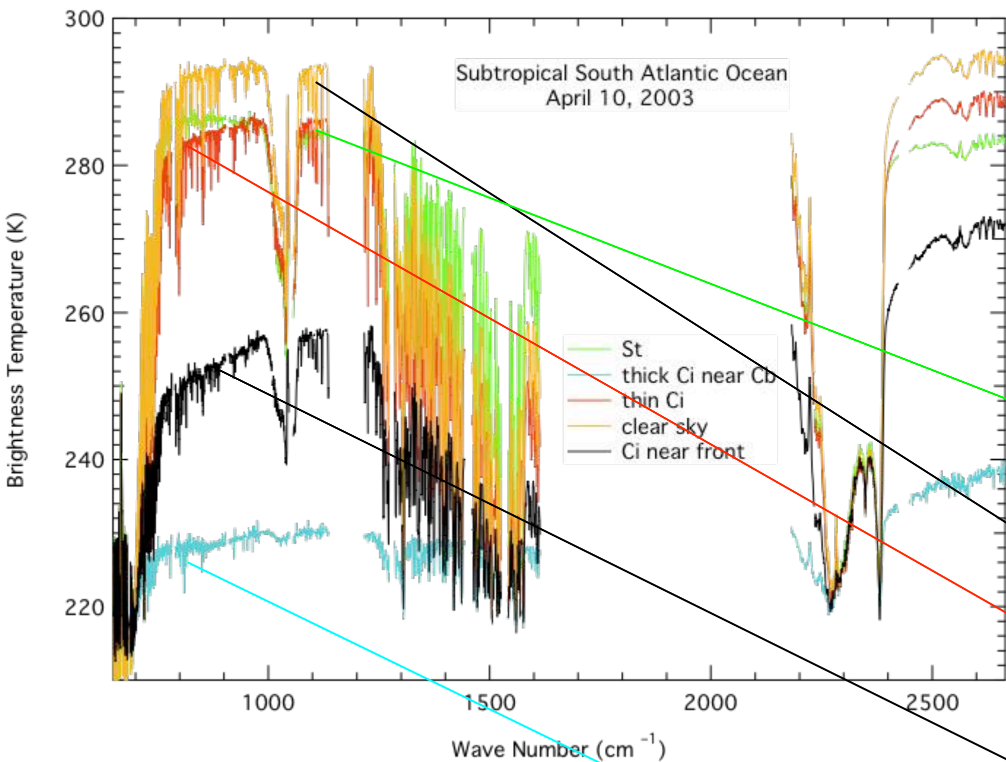
The radiometric calibration of AIRS is very stable

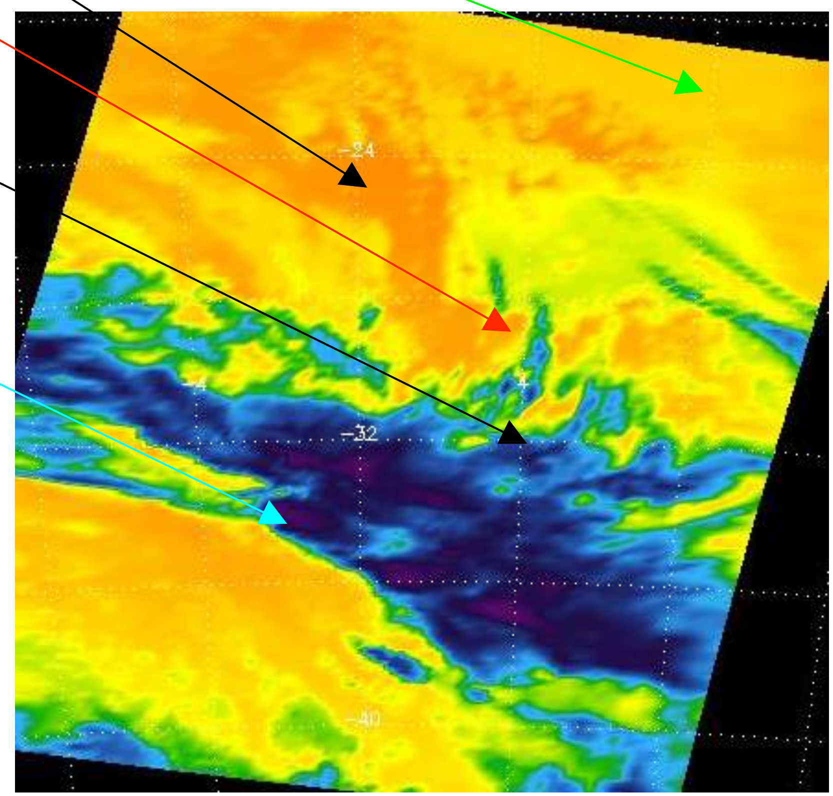
Can use clear sky mask and compare to SSTs over tropical oceans
Or calculate from surface emissivity, T/q from numerical models

Stable to within ±0.3-0.4 mK/yr

Window channels such as 1231 and 2616 cm^{-1}

e.g., Pagano et al., 2012, Proc. SPIE



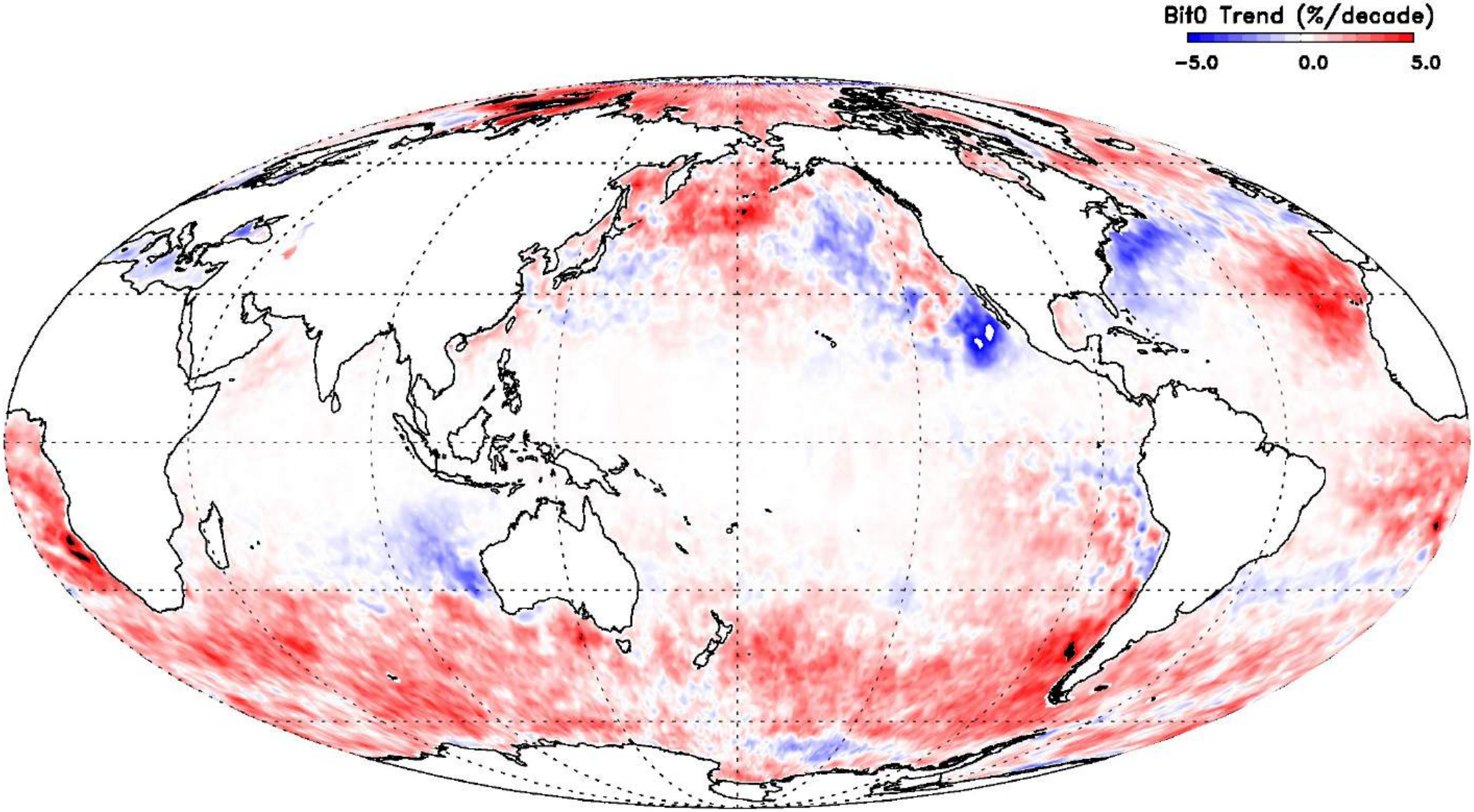


Ups and downs caused by optical thickness and cloud top temperature

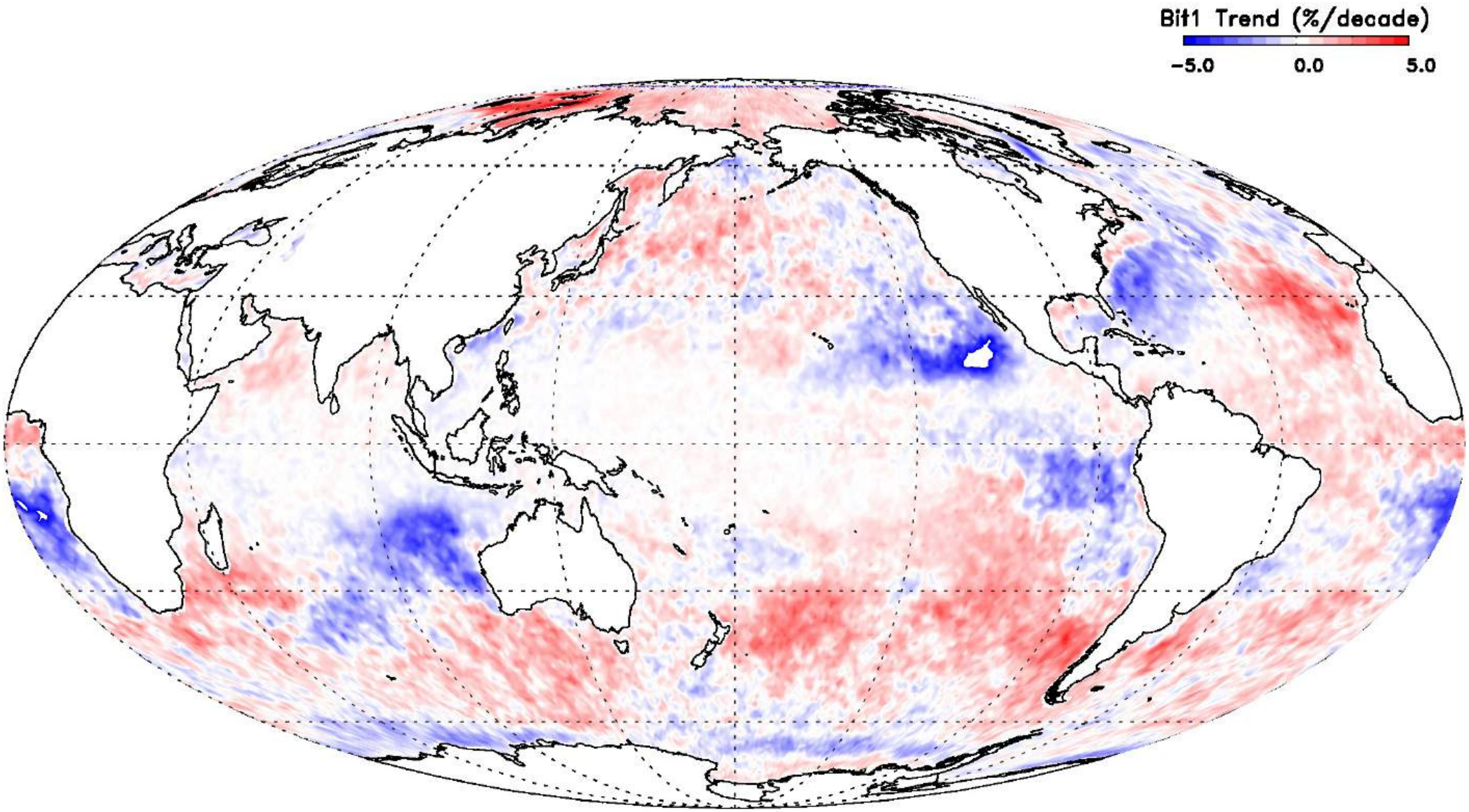
Slope in 8-12 µm window caused by ice cloud particle size and cloud phase

Uniform increase for two liquid tests in SH

Regional trends of opposite sign in NH

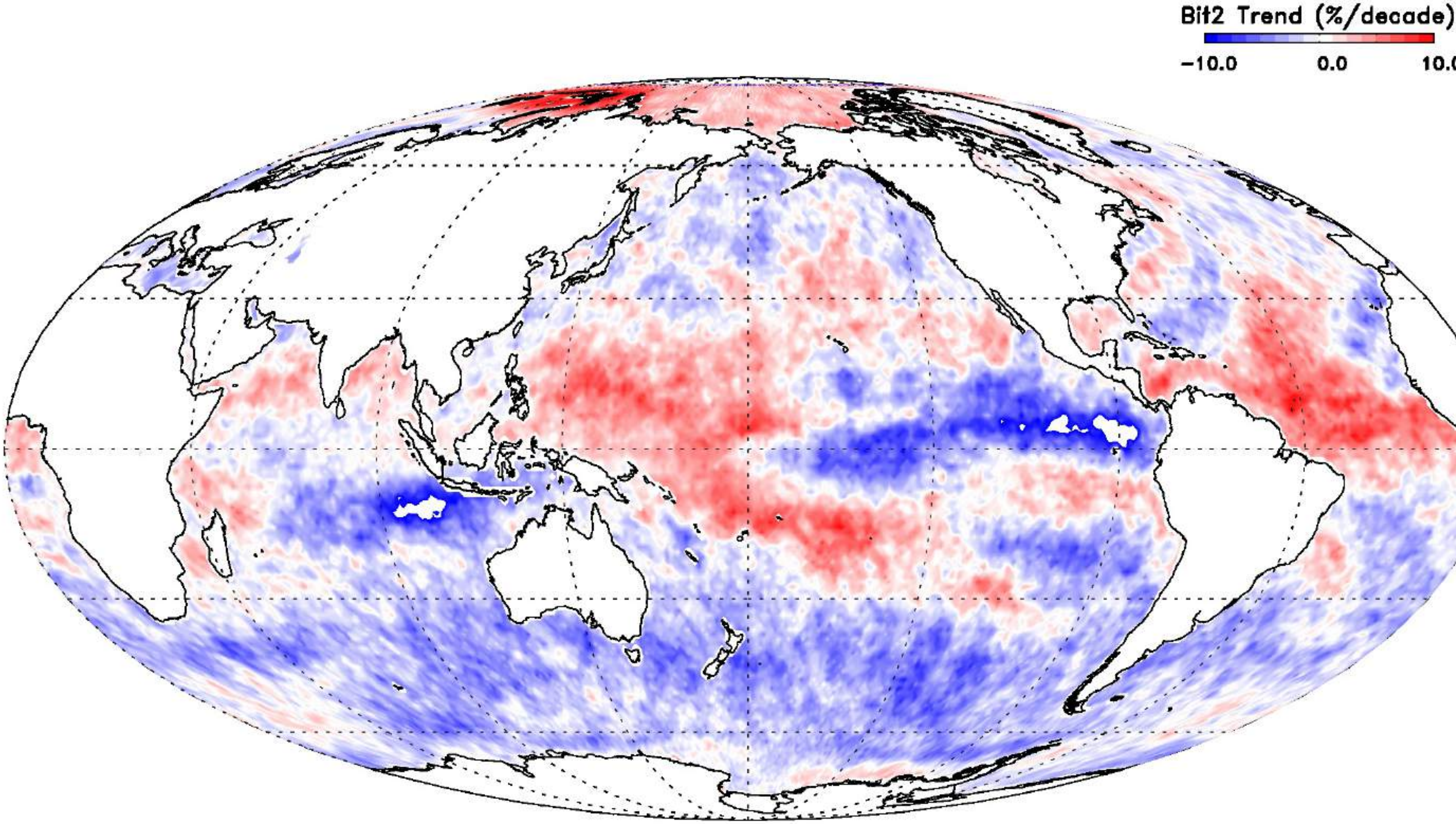


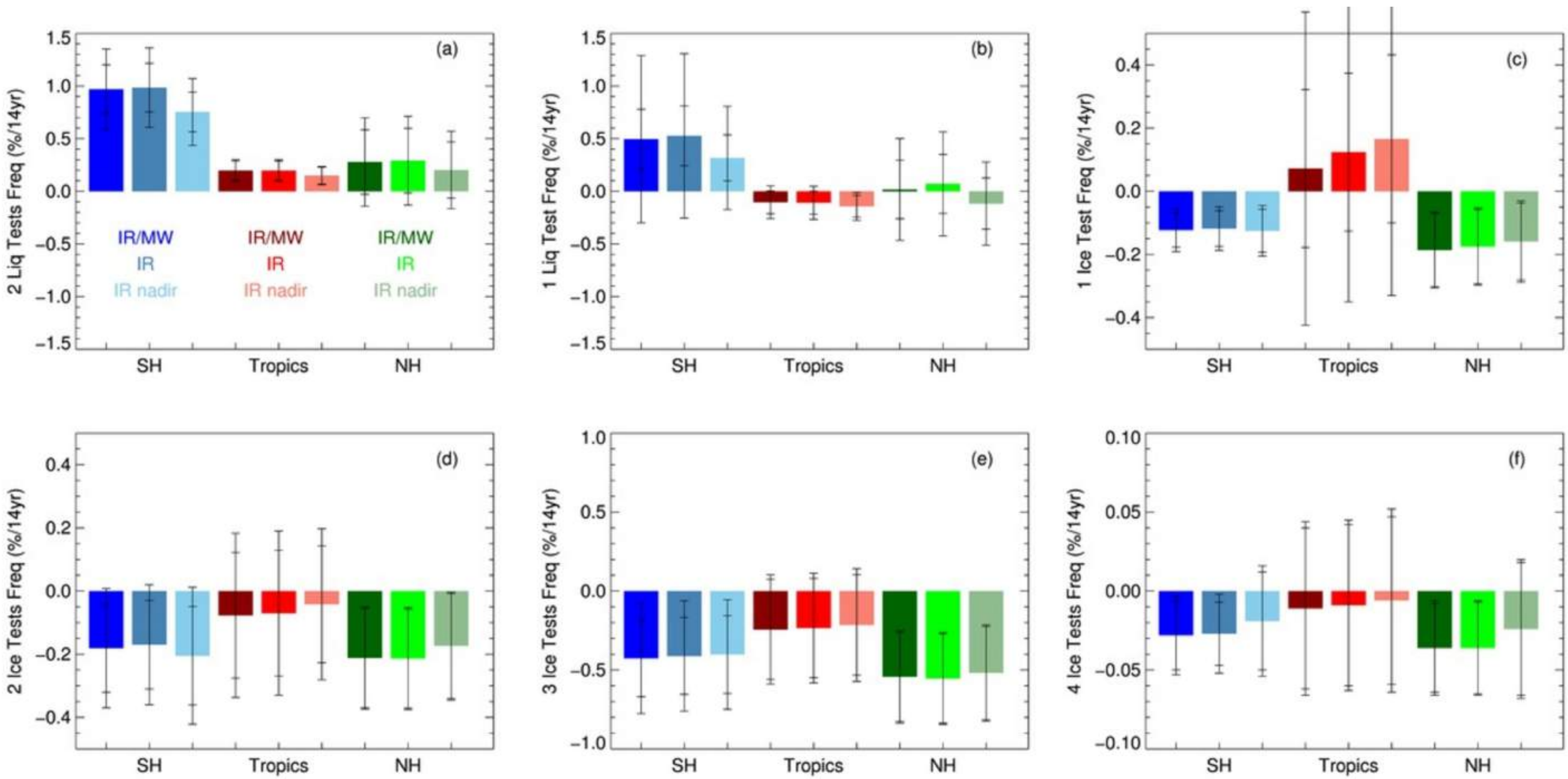
Similar yet less uniform increase for one test



Uniform decrease for undetermined in SH

Notable increase for all non-ice categories in Arctic

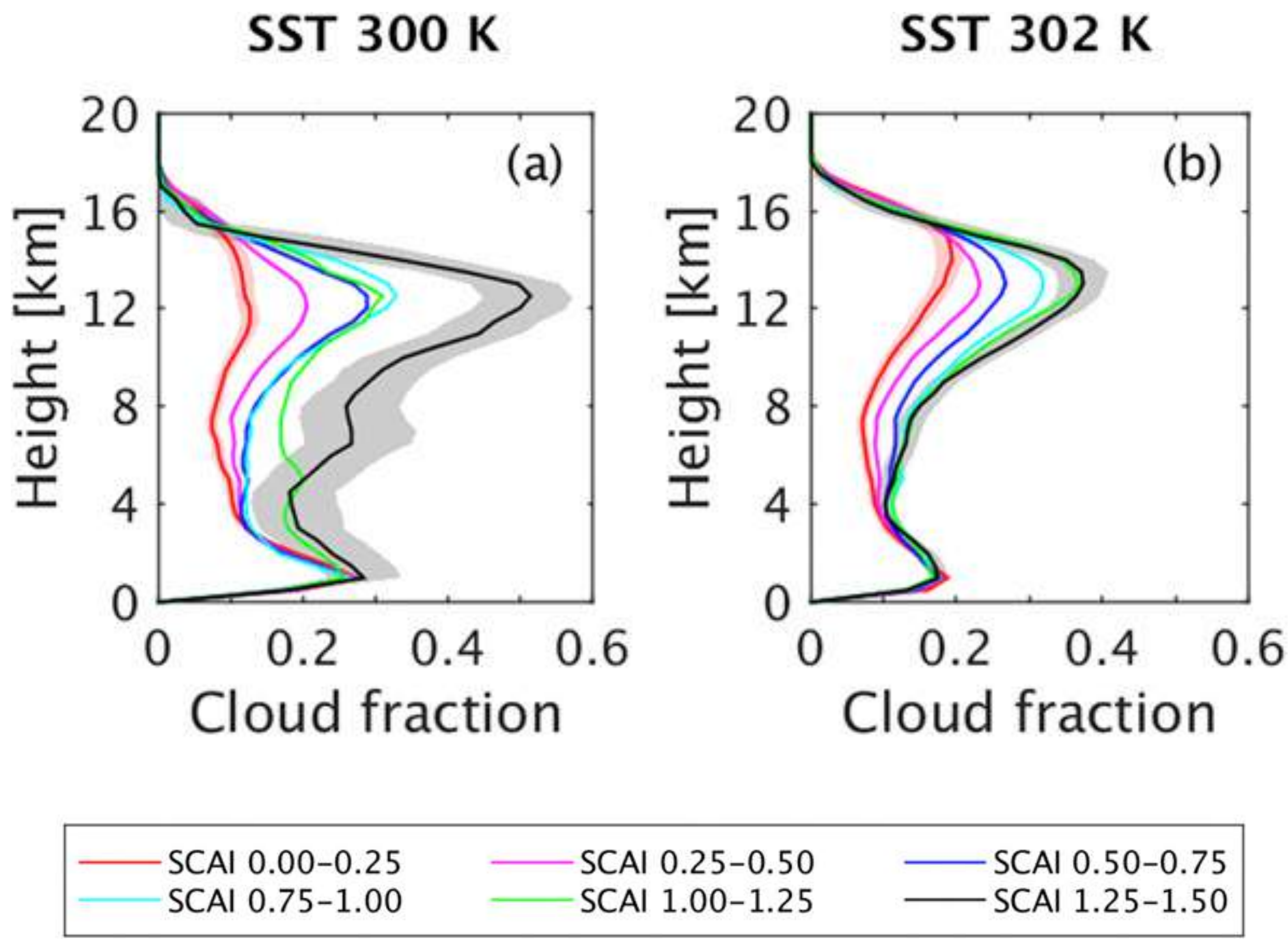




(a)
2 Liq Tests Freq (%/14yr)
IR/MW
IR
IR nadir
IR/MW
IR
IR nadir
IR/MW
IR
IR nadir
SH
Tropics
NH
(b)
1 Liq Test Freq (%/14yr)
(c)
1 Ice Test Freq (%/14yr)
(d)
2 Ice Tests Freq (%/14yr)
(e)
3 Ice Tests Freq (%/14yr)
(f)
4 Ice Tests Freq (%/14yr)

Convective clustering increases at higher SSTs

Derived from CloudSat/CALIPSO

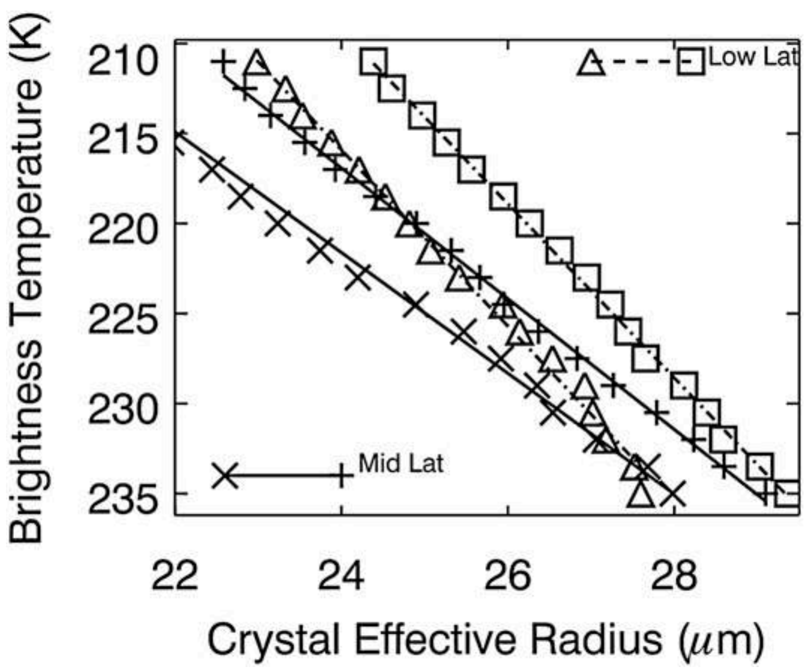


Stein et al., 2017, J. Climate

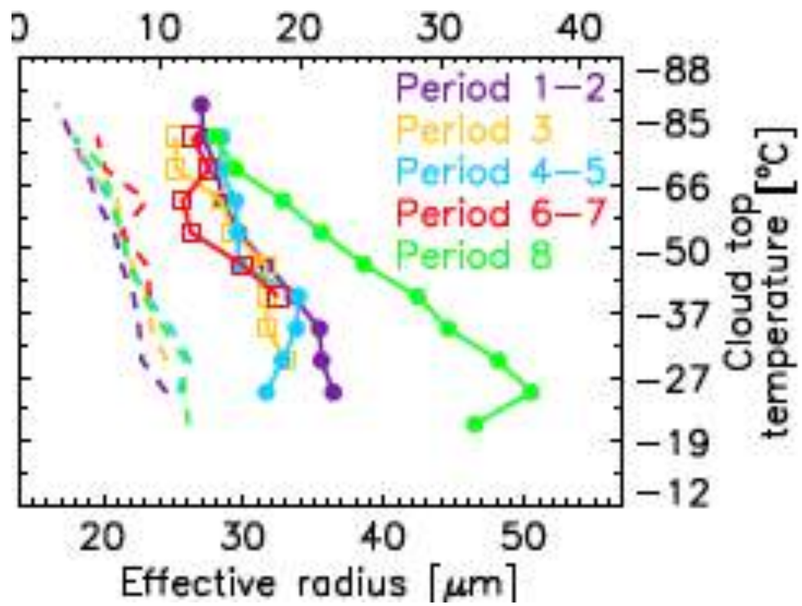
Stronger convective cloud tops have larger particle sizes

Observed in MODIS (left) and MODIS+POLDER (right)

Observed at surface Darwin ARM site (Protat et al., 2011, ACP)



Yuan and Li, 2010, J. Climate



Strong Convection=**purple**, **blue**, **green**

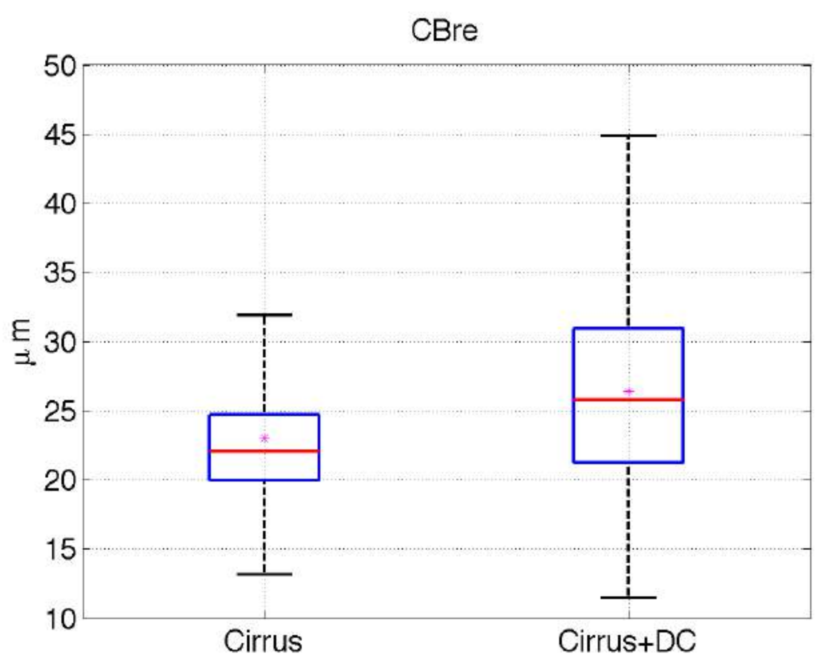
Weak Convection=**yellow**, **red**

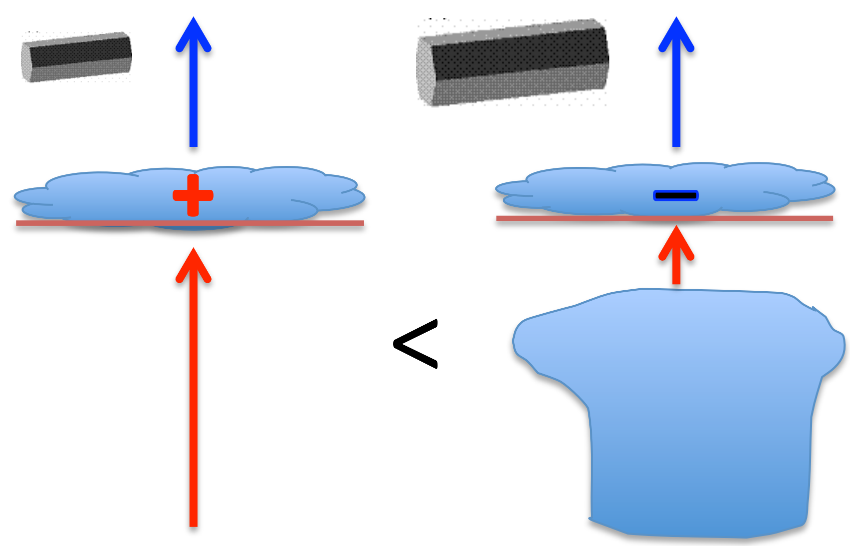
Van Diedenhoven et al., 2014, J. Geophys. Res.

Enhanced radiative cooling in multilayer ice cloud

Leads to ice particle growth in overlying cirrus

Increased convective clustering lead to more of these clouds?





Theoretical basis in Stephens, 1983, J. Atmos. Sci.

Courtesy of Hanii Takahashi