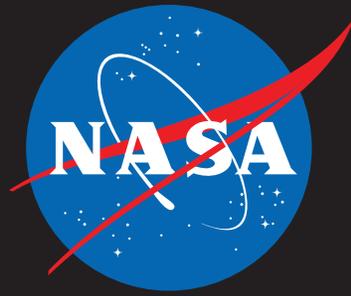


National Aeronautical and
Space Administration



A Multi-Sensor Perspective on the Interannual Variability of Tropical Temperature and Water Vapor

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Annmarie Eldering, Andrew Gettelman, Biajun Tian,
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A-Train Symposium

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Motivation

To better characterize the controls on the tropical upper tropospheric/lower stratospheric (UTLS) temperature and humidity.

Stratosphere

~50hPa

~100hPa

~200hPa

~1000hPa

Tropopause

TTL

$Q_{\text{clear}}=0$

Cold

Warm

Troposphere

Warm
Moist
Upward Motion

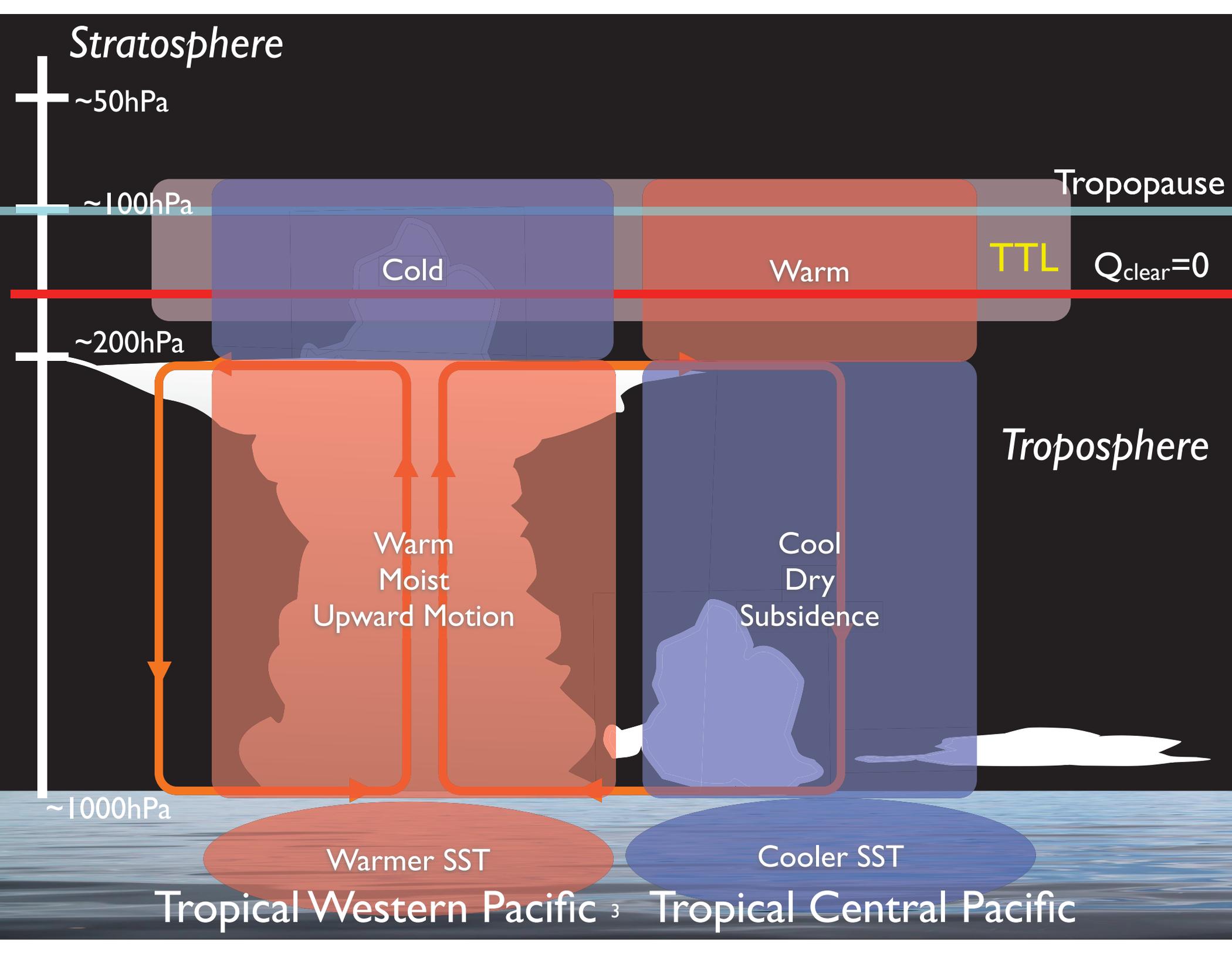
Cool
Dry
Subsidence

Warmer SST

Cooler SST

Tropical Western Pacific

Tropical Central Pacific



Stratosphere

Quasi-Biennial
Oscillation (QBO)
Baldwin, RG, 1999

~50hPa

~100hPa

~200hPa

~1000hPa

Tropopause

Cold

Warm

TTL

$Q_{\text{clear}}=0$

Warm
Moist
Upward Motion

Cool
Dry
Subsidence

Troposphere

El Niño Southern
Oscillation (ENSO)
Trenberth, AMS, 1997

Warmer SST

Cooler SST

TWP

TCP

Stratosphere

~50hPa

Quasi-Biennial
Oscillation (QBO)
Baldwin, RG, 1999

TTL T & H₂O

~100hPa

Cold

Warm

Tropopause

TTL

$Q_{clear}=0$

~200hPa

Warm
Moist
Upward Motion

Cool
Dry
Subsidence

Troposphere

El Niño Southern
Oscillation (ENSO)
Trenberth, AMS, 1997

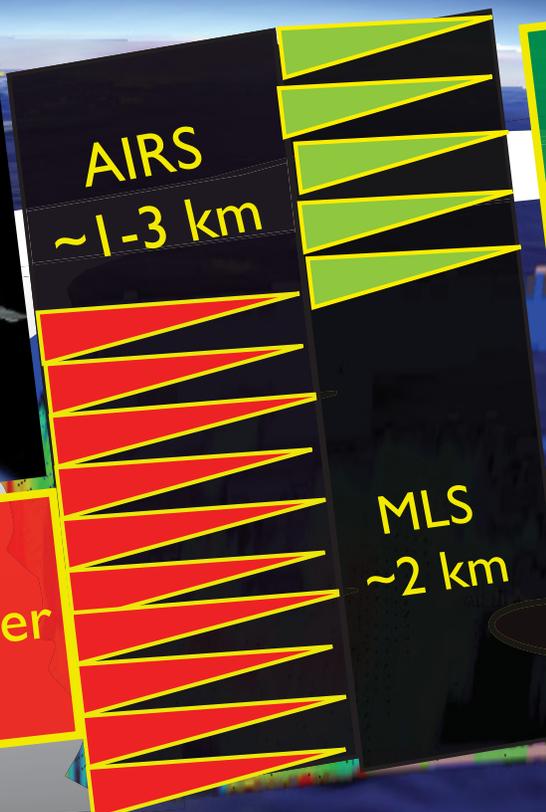
~1000hPa

Warmer SST
TWP

Cooler SST
TCP



Atmospheric Infrared Sounder (AIRS)



Microwave Limb Sounder (MLS)

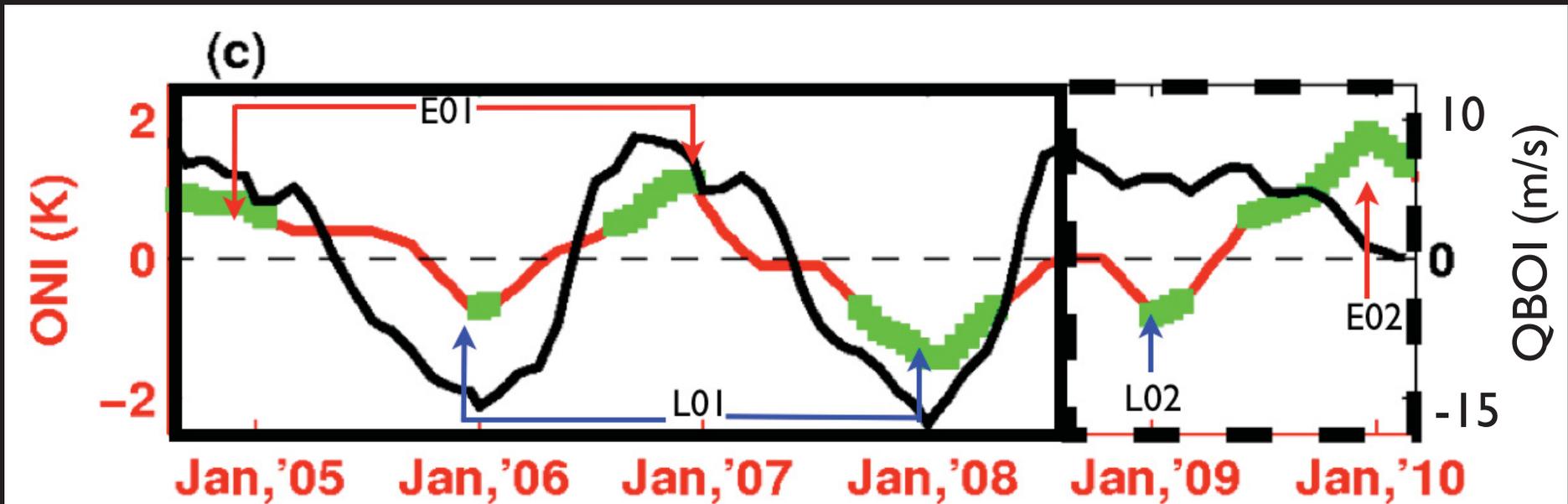


Datasets:

- (1) Temperature (AIRS)
(Accuracy $\leq \sim 0.5K$)
- (2) Combined H₂O (AIRS,MLS)
(Liang, et.al, AMT (2010), manuscript in review)
- (3) Lat: 8S-8N, Lon: 180E-180W

AIRS		MLS	
P (hPa)	Accuracy (%)	P (hPa)	Accuracy (%)
150	25	83	7
200	25	100	8
250	20	121	12
300	15	147	15
400	10	178	17
500	5	215	25

ENSO and QBO Indices



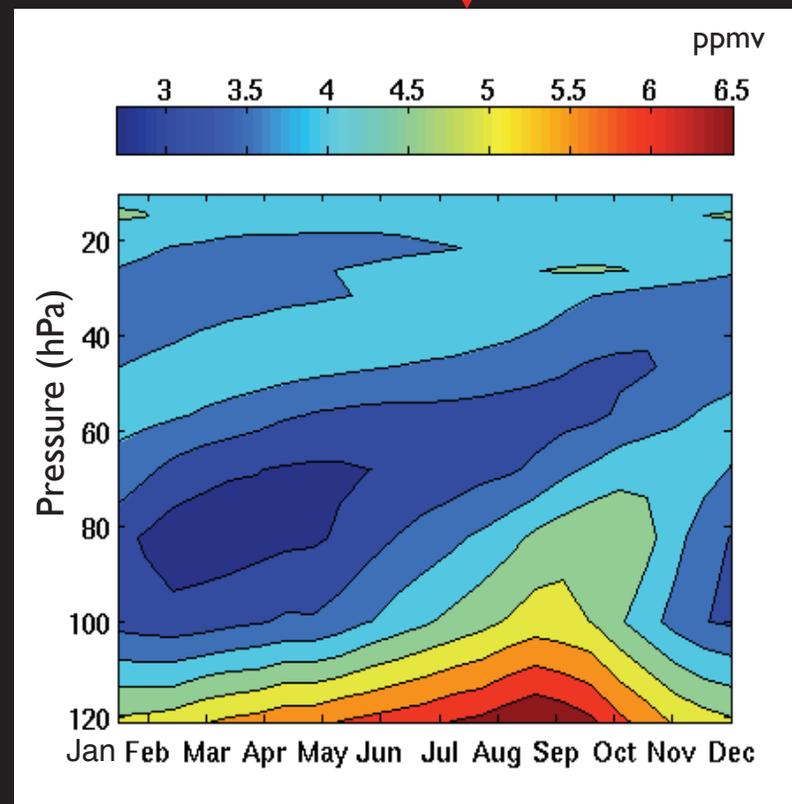
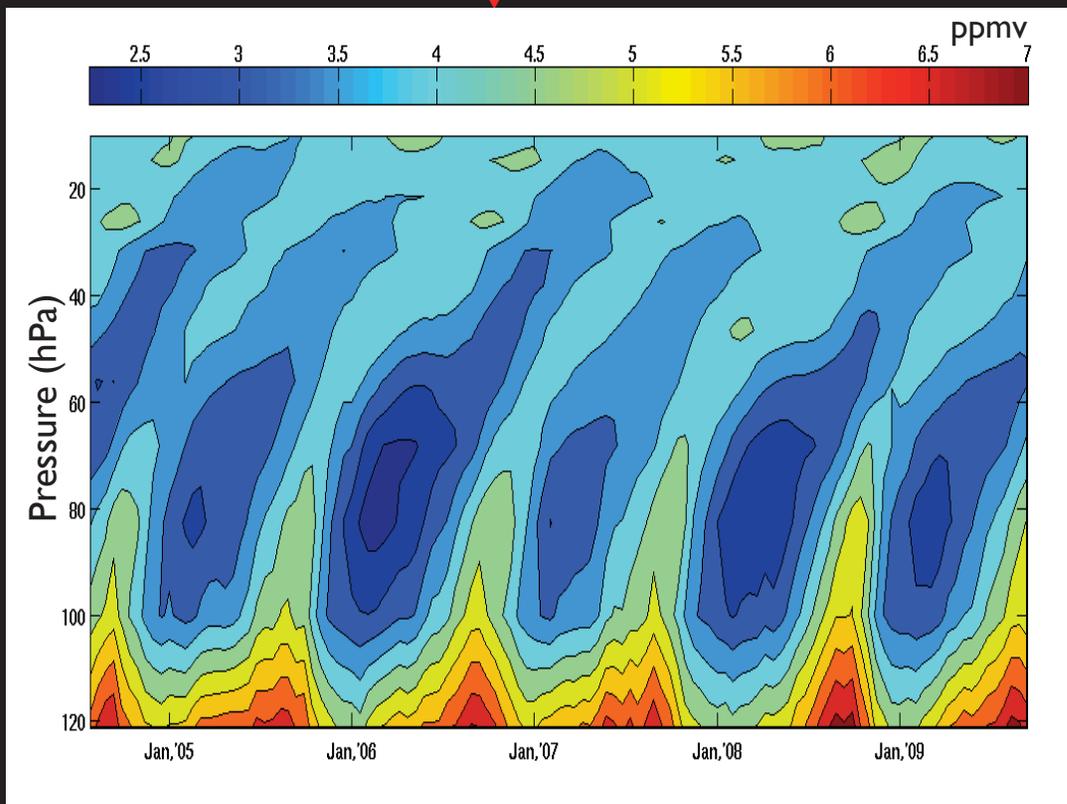
- Ocean Niño Index (ONI) in the Niño3.4 region (5S-5N, 120W-170W) (*Source: NOAA CPC, in-situ measurements*)
- QBOI represent zonal mean zonal wind anomalies at 50 hPa (*Source: NCAR/NCEP reanalysis*). Anomalies in thermal wind balance with lower stratospheric temperatures (*Randel et.al, JGR, 2000*)

Seasonal and Annual Cycle of H₂O

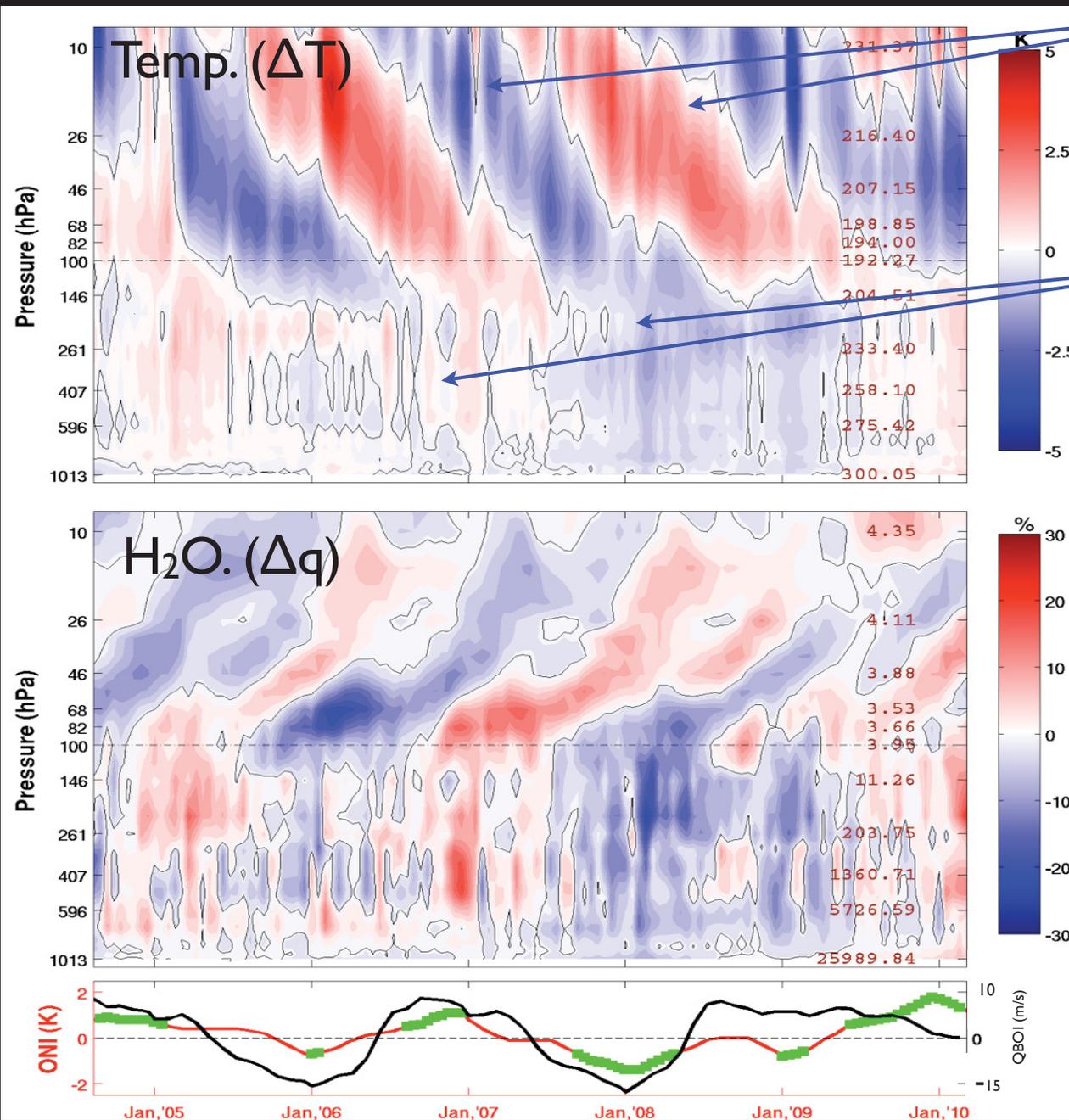
AIRS/MLS Time Series

minus

Annual Cycle



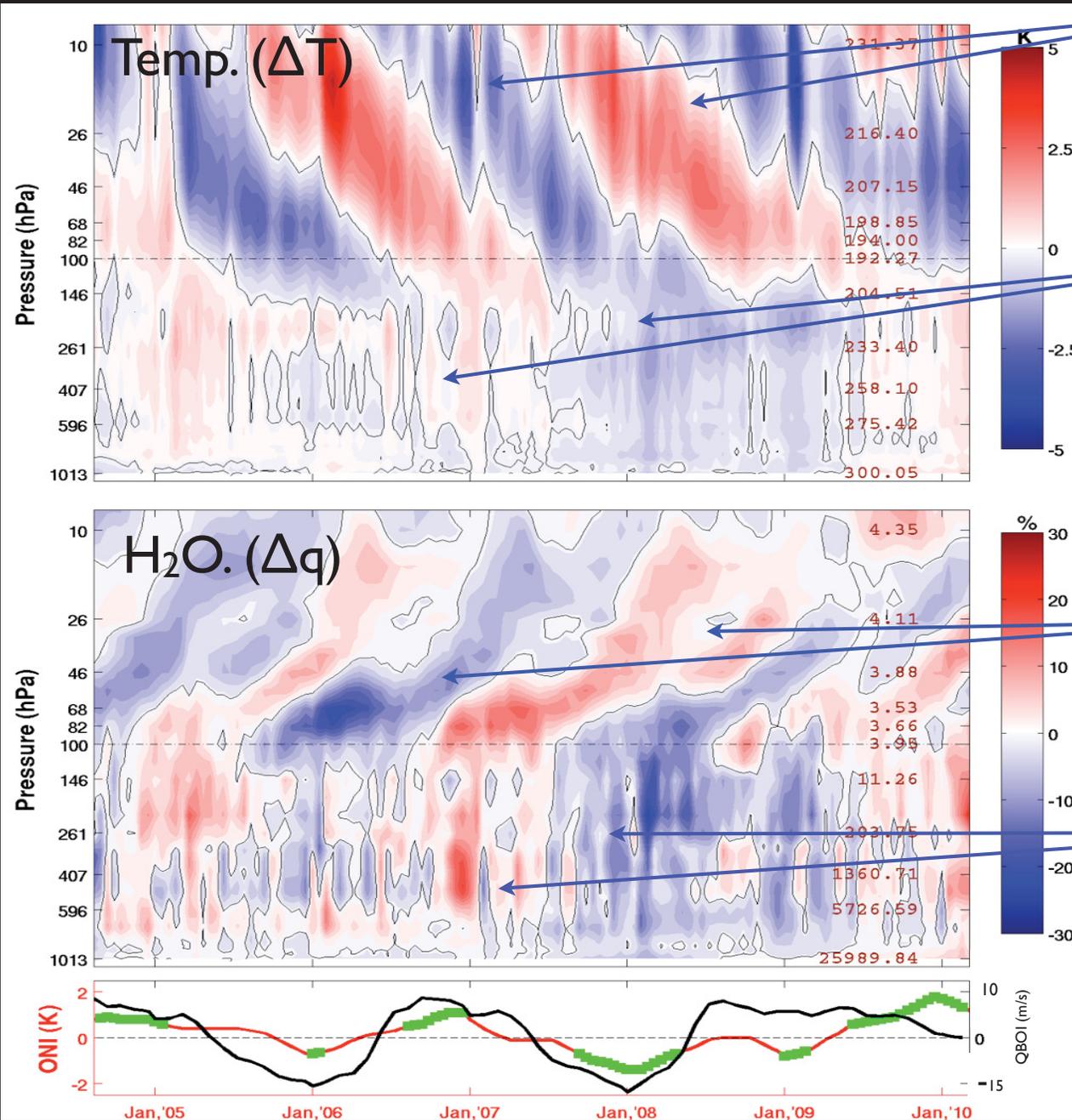
Surface to Stratosphere Interannual Variability of T and H₂O



Quasi-biennial Oscillation (QBO) for T with period ~28 months

ENSO

Surface to Stratosphere Interannual Variability of T and H₂O



Quasi-biennial Oscillation (QBO) for T with period ~28 months

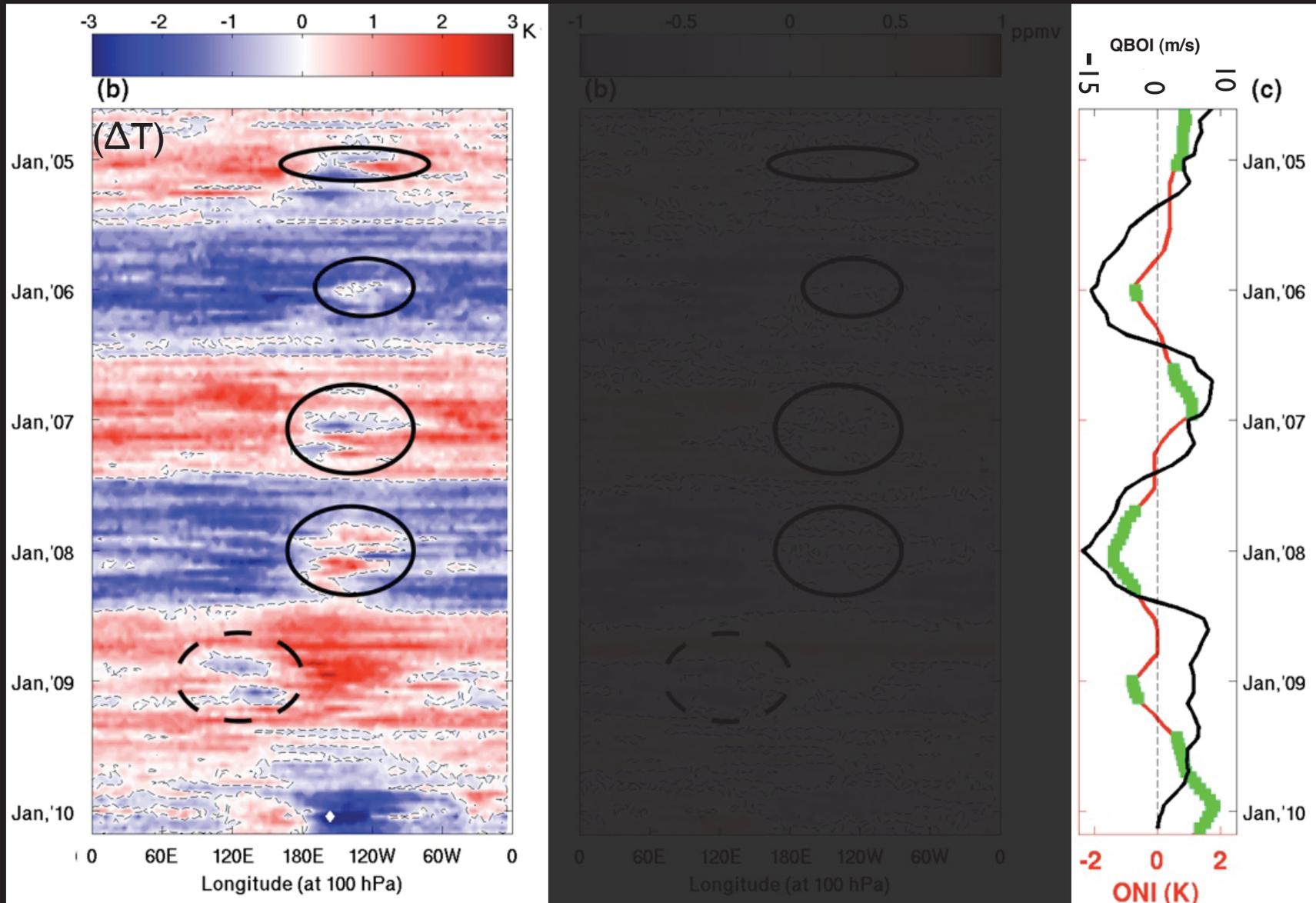
ENSO

Interannual Variability of tape recorder
(Randel, et. al., JAS, 1998, Gellar, et. al., JAS, 2002)

ENSO

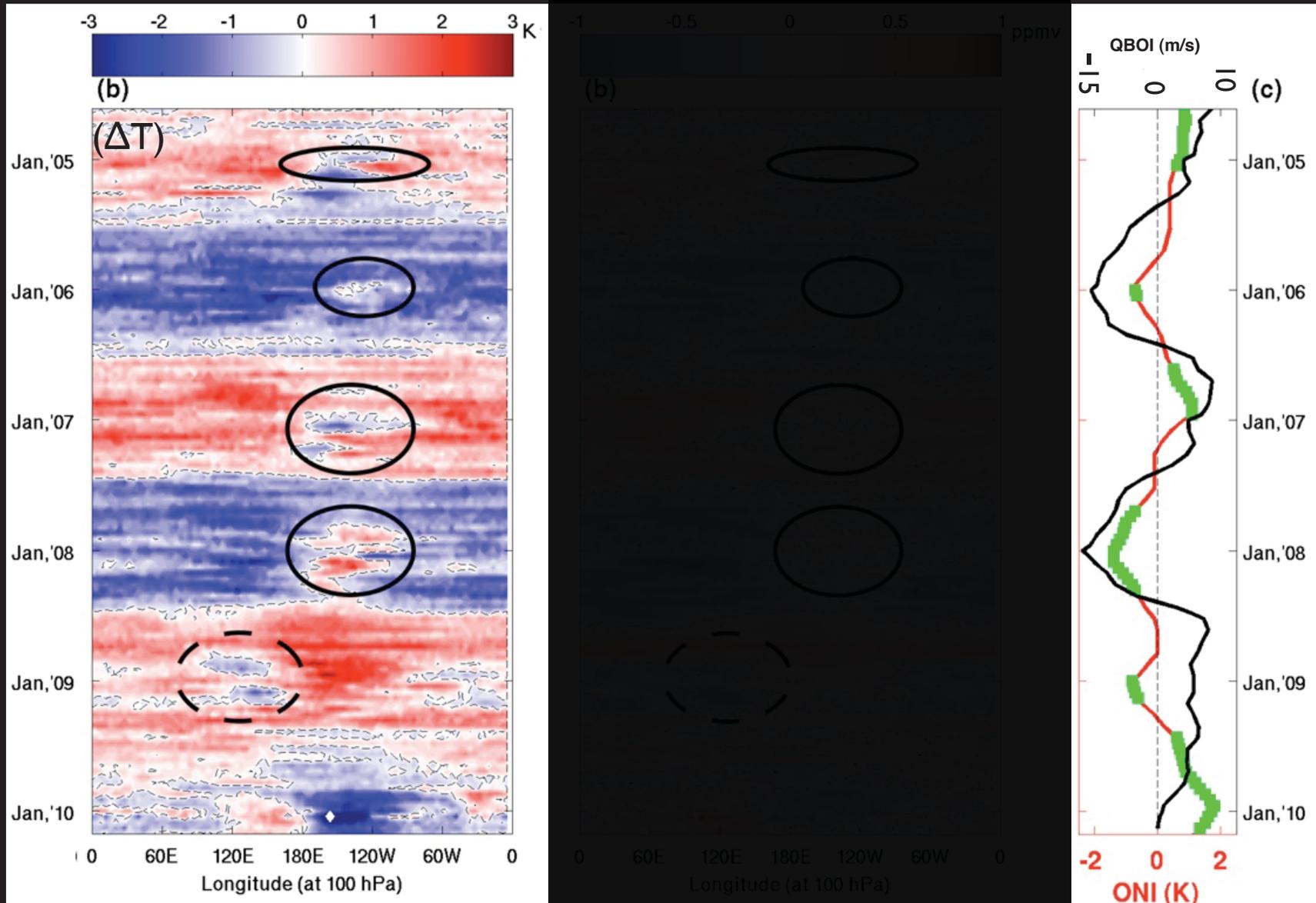
New vertical picture of H₂O

Zonal Structure of ΔT and Δq

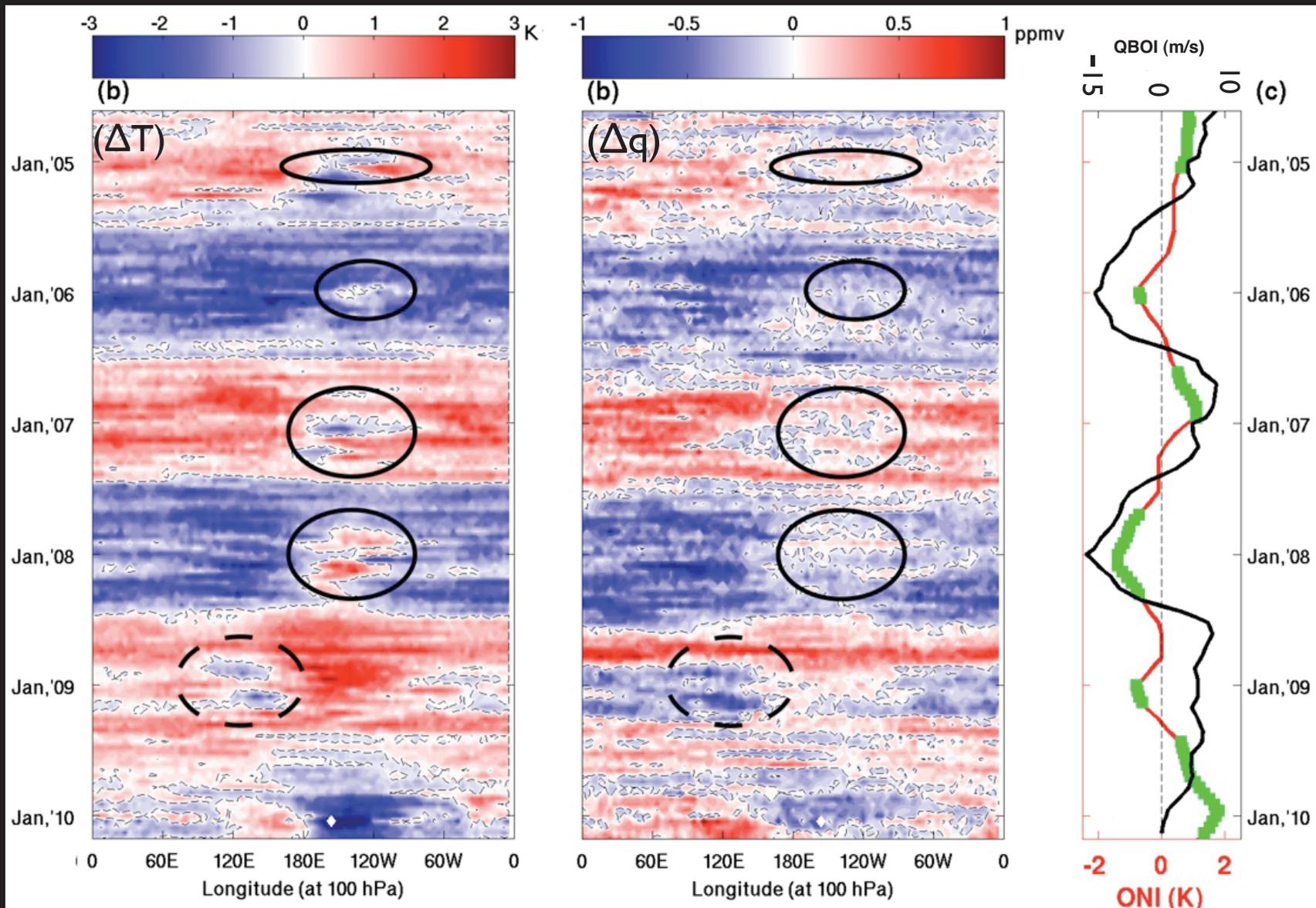


Zonal Structure of ΔT and Δq

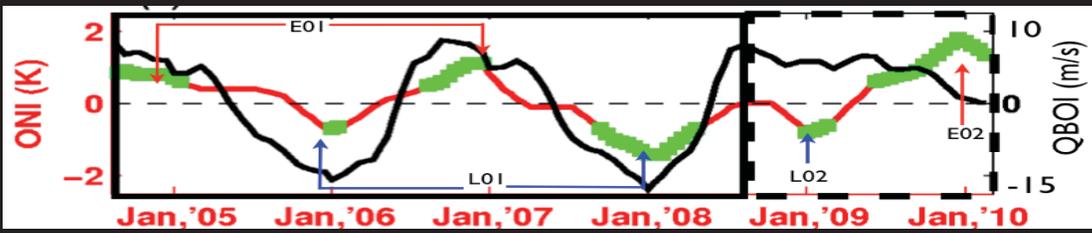
Correlation between ΔT and QBO: $R=0.86$



ΔT and Δq mainly driven by QBO ([Randel, et.al, 1998](#)) but with some zonal asymmetries



Composites of ENSO events



ENSO Phase

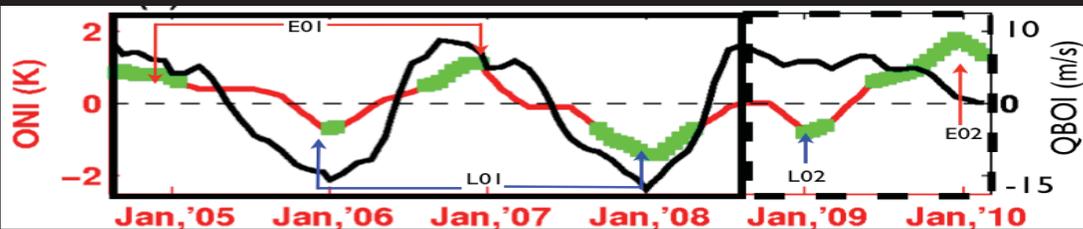
E+ = El Niño

E- = La Niña

QBO Phase

Q+ = Westerly

Q- = Easterly



ENSO Phase

QBO Phase

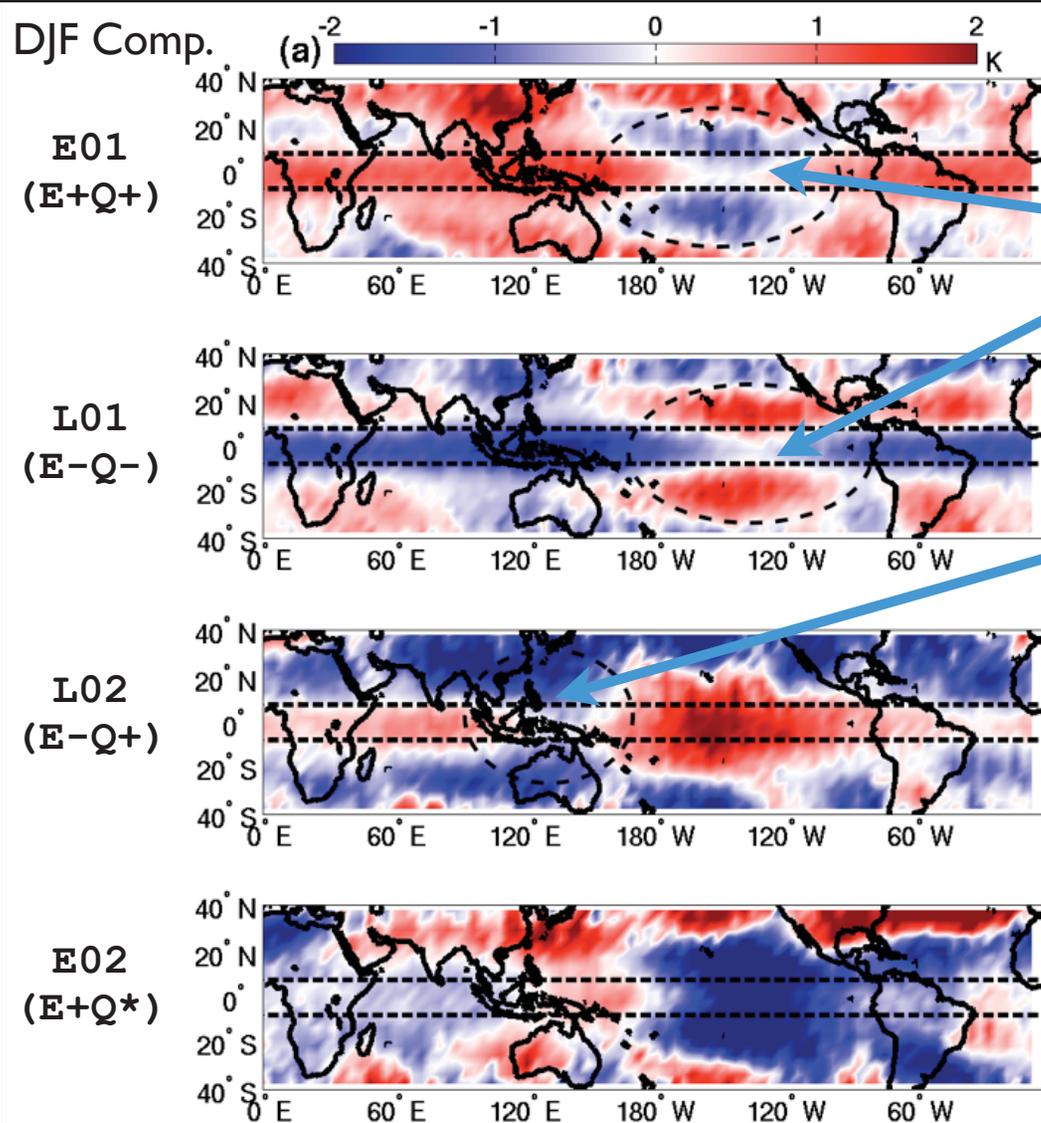
E+ = El Niño

Q+ = Westerly

E- = La Niña

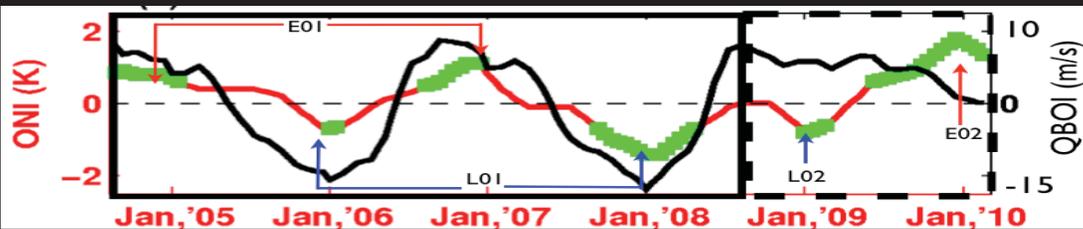
Q- = Easterly

ΔT (100 hPa)



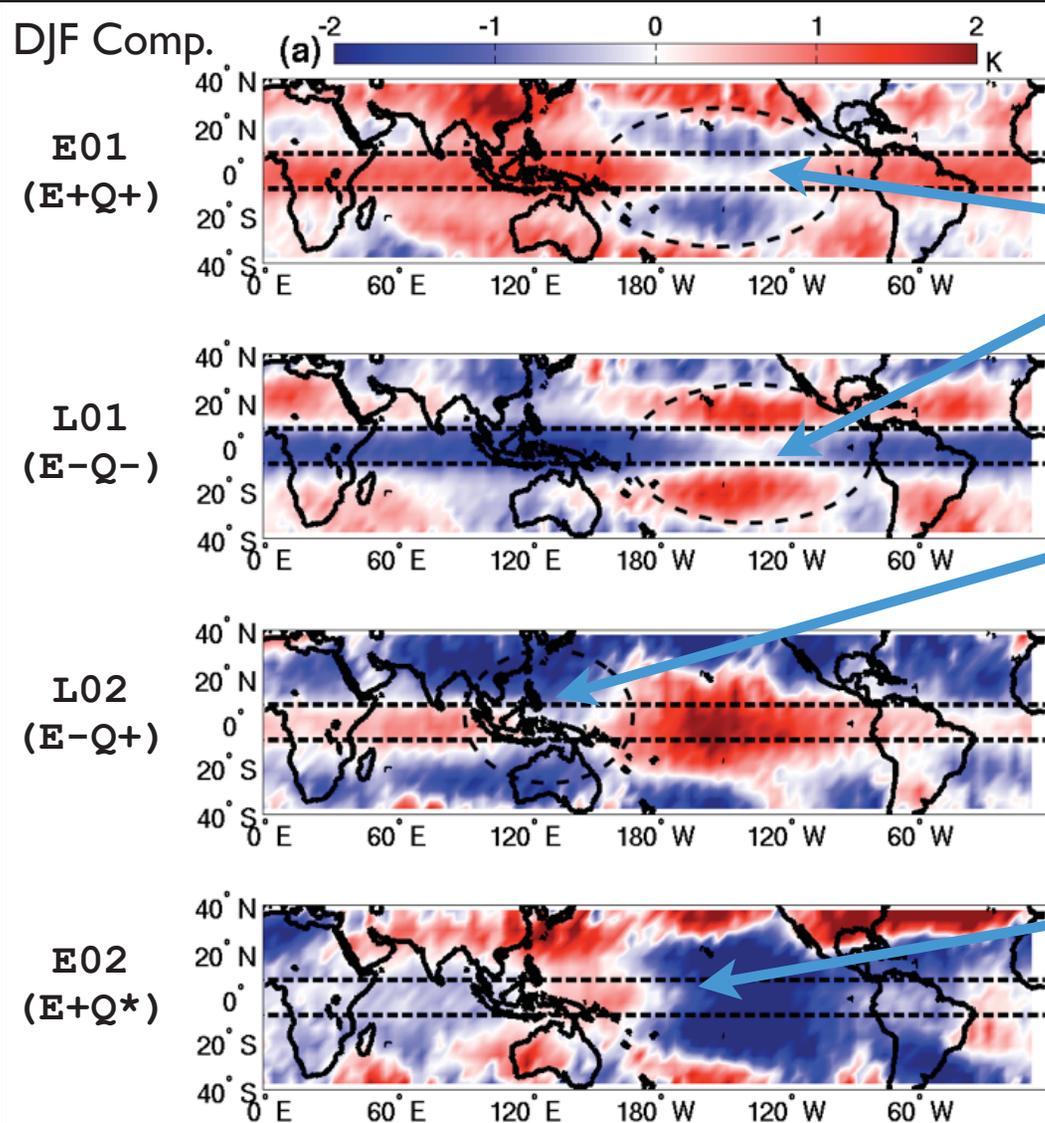
- Zonal break over TCP when QBO and ENSO in phase

- TWP experiences zonal break when ENSO and QBO out of phase

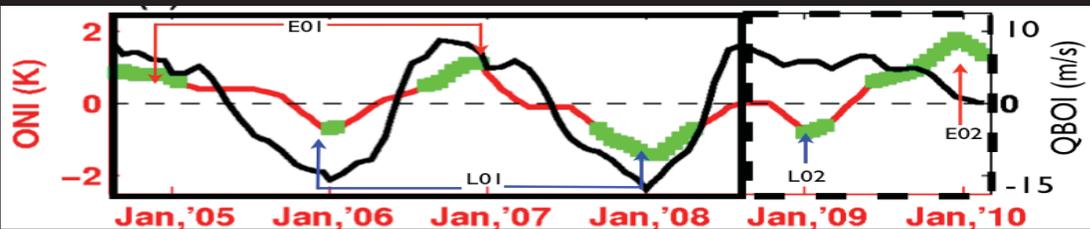


ENSO Phase **QBO Phase**
E+ = El Niño **Q+ = Westerly**
E- = La Niña **Q- = Easterly**

ΔT (100 hPa)



- Zonal break over TCP when QBO and ENSO in phase
- TWP experiences zonal break when ENSO and QBO out of phase
- E02 event primarily an ENSO signal; QBO in transition



ENSO Phase

QBO Phase

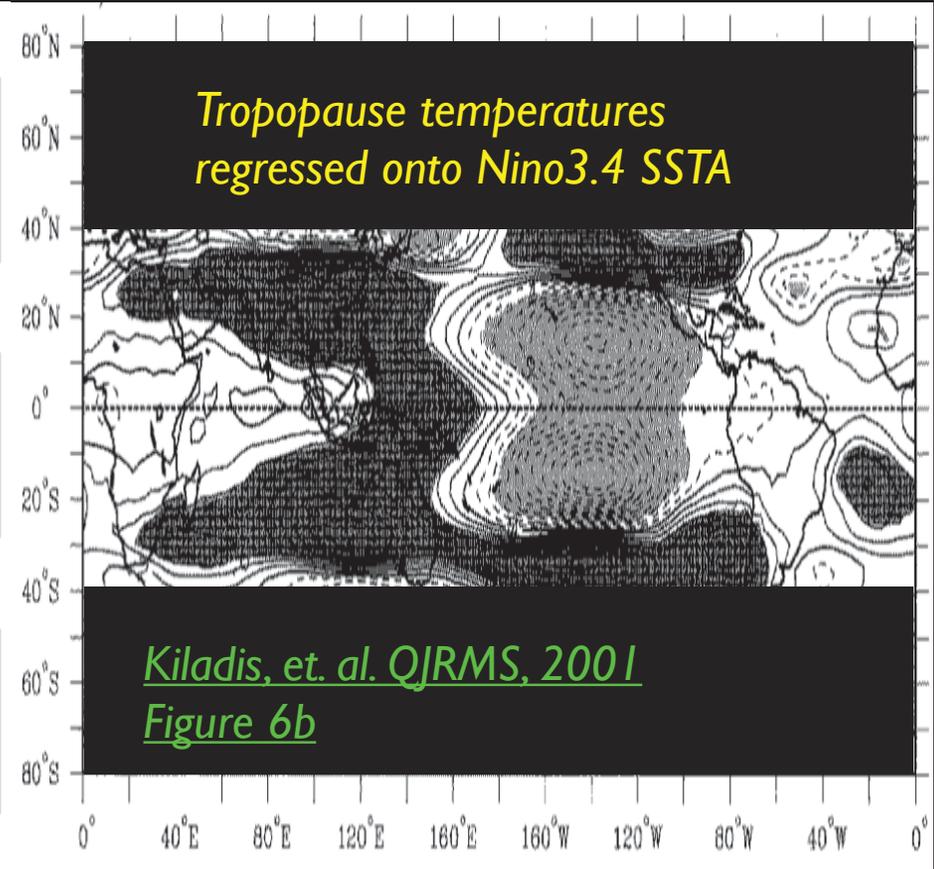
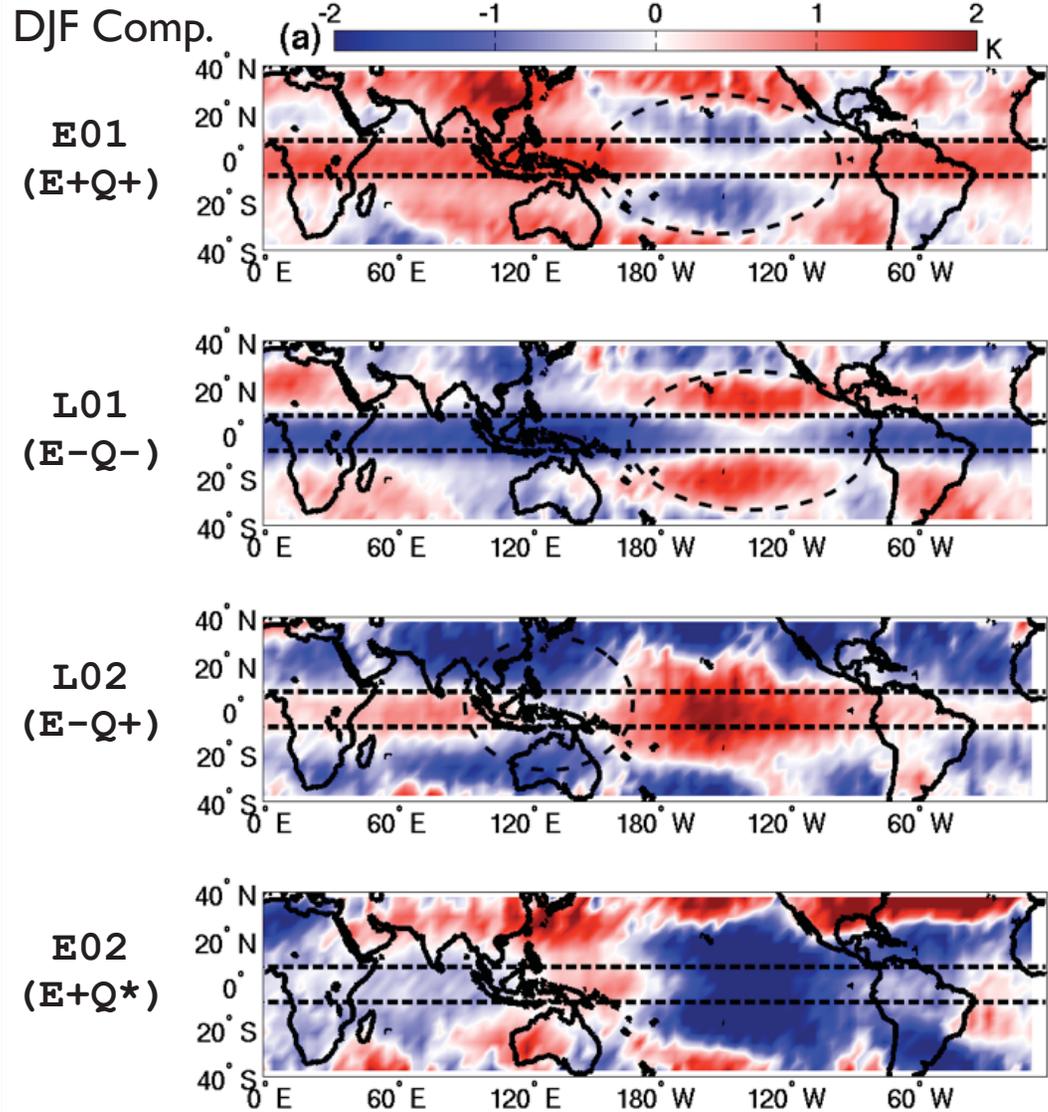
E+ = El Niño

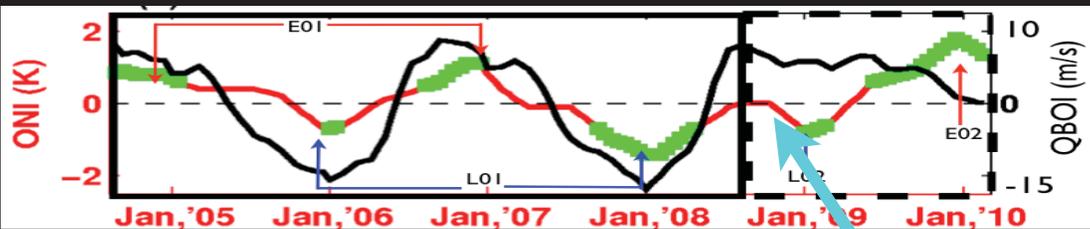
Q+ = Westerly

E- = La Niña

Q- = Easterly

ΔT (100 hPa)





ENSO Phase

E+ = El Niño

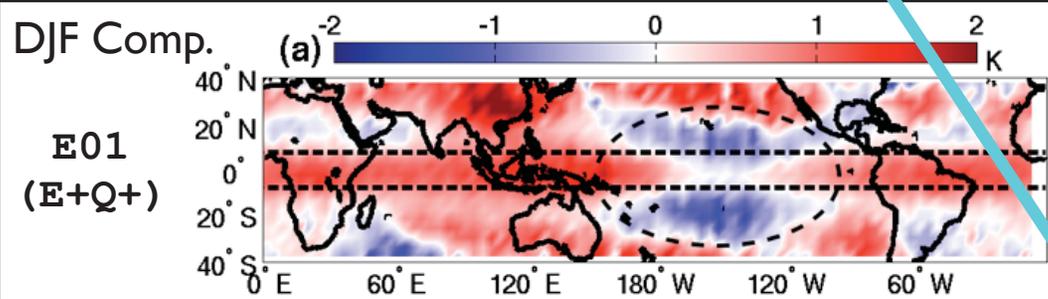
E- = La Niña

QBO Phase

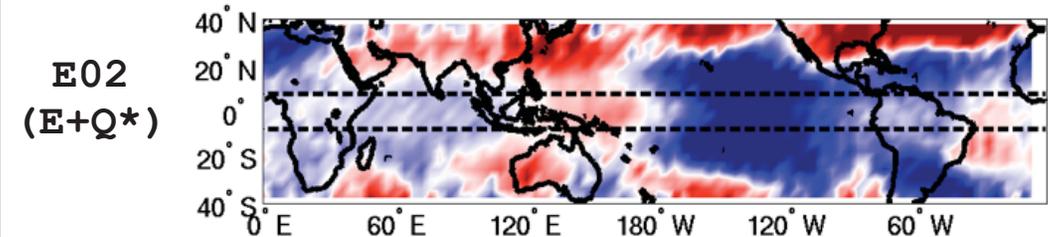
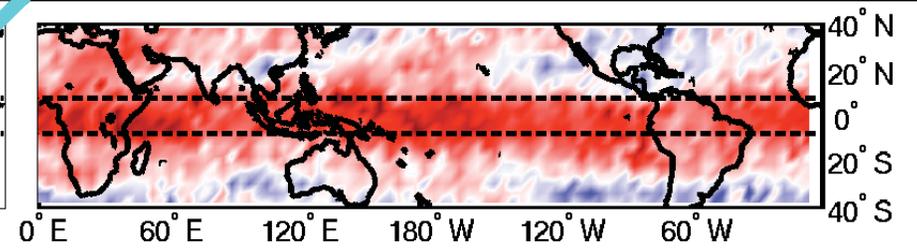
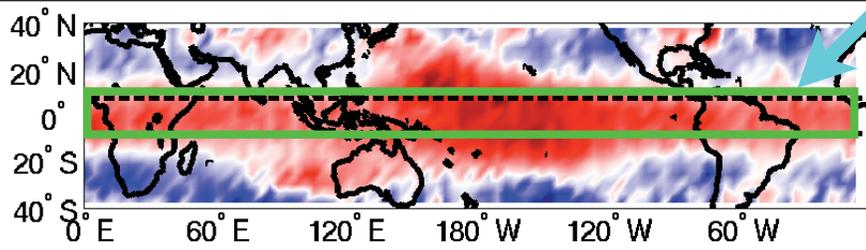
Q+ = Westerly

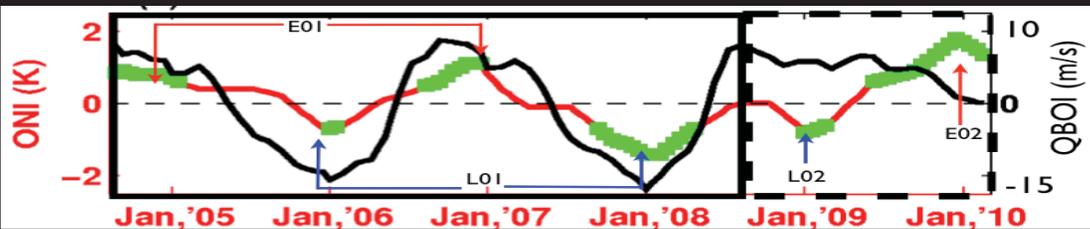
Q- = Easterly

ΔT (100 hPa)



For ONI ~ 0 (~Fall of 2008), and +QBOI we see the zonal symmetry of the QBO





ENSO Phase

QBO Phase

E+ = El Niño

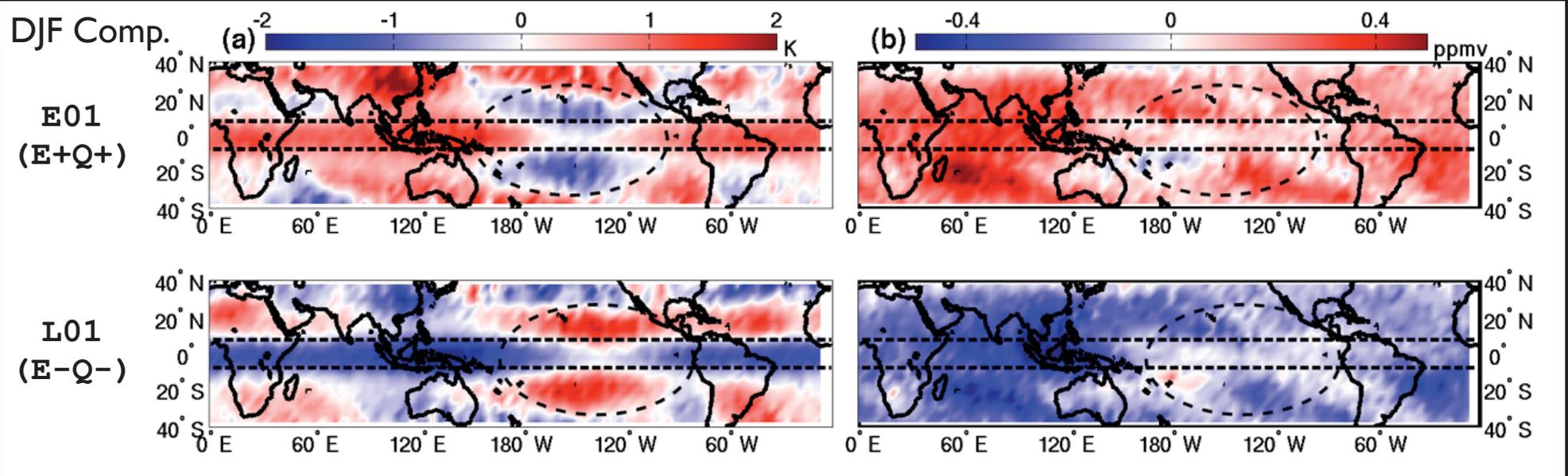
Q+ = Westerly

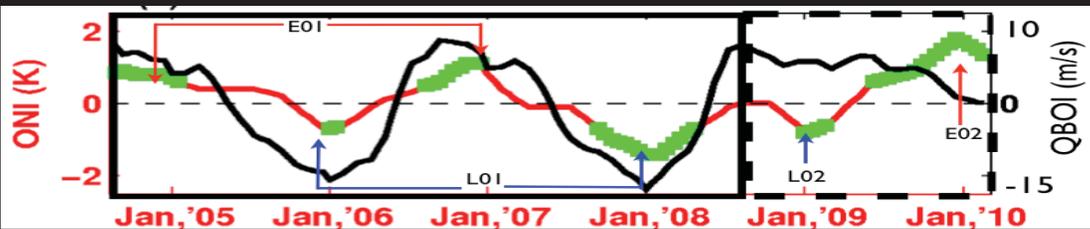
E- = La Niña

Q- = Easterly

ΔT (100 hPa)

Δq (100 hPa)





ENSO Phase

E+ = El Niño

E- = La Niña

QBO Phase

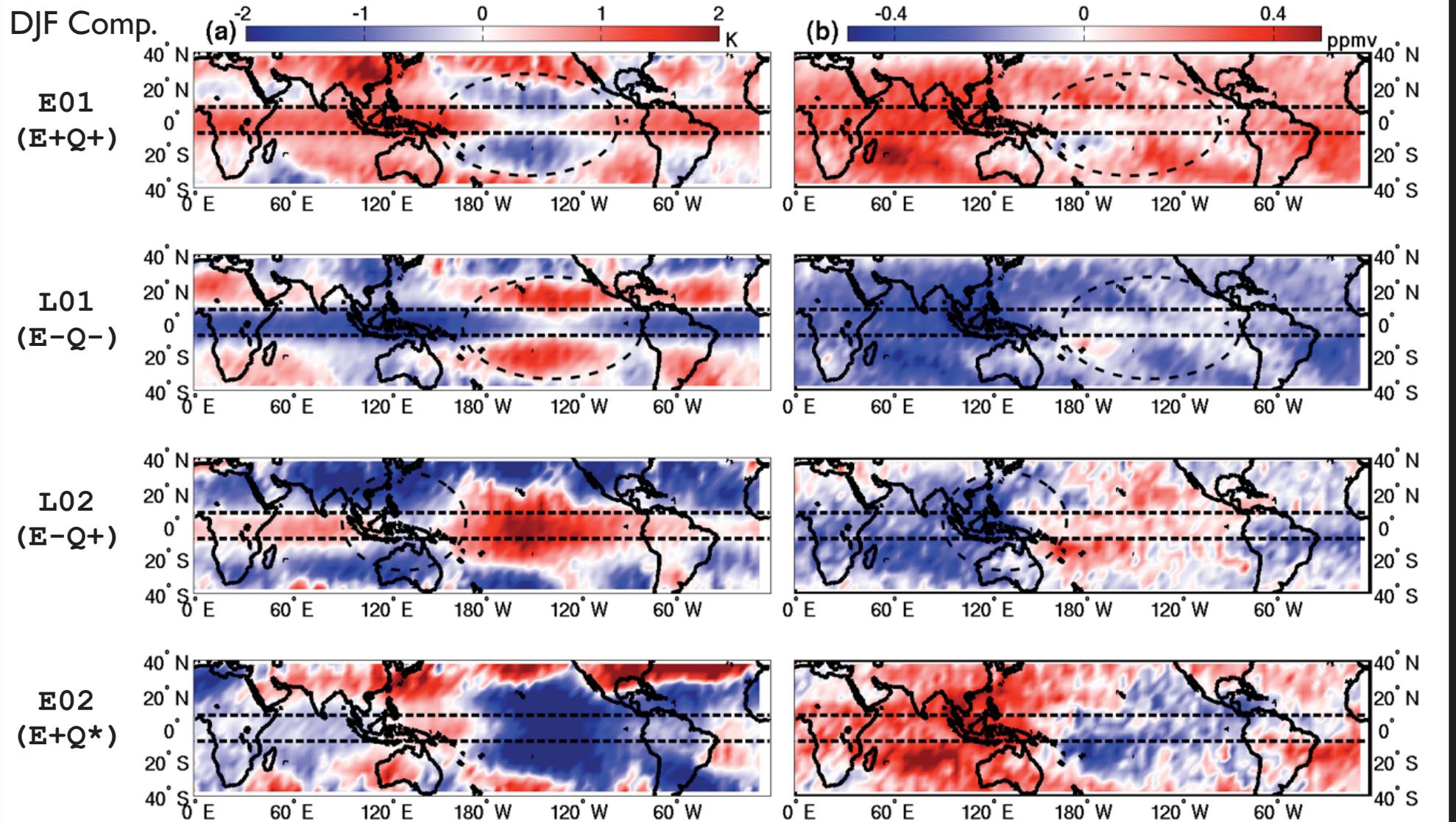
Q+ = Westerly

Q- = Easterly

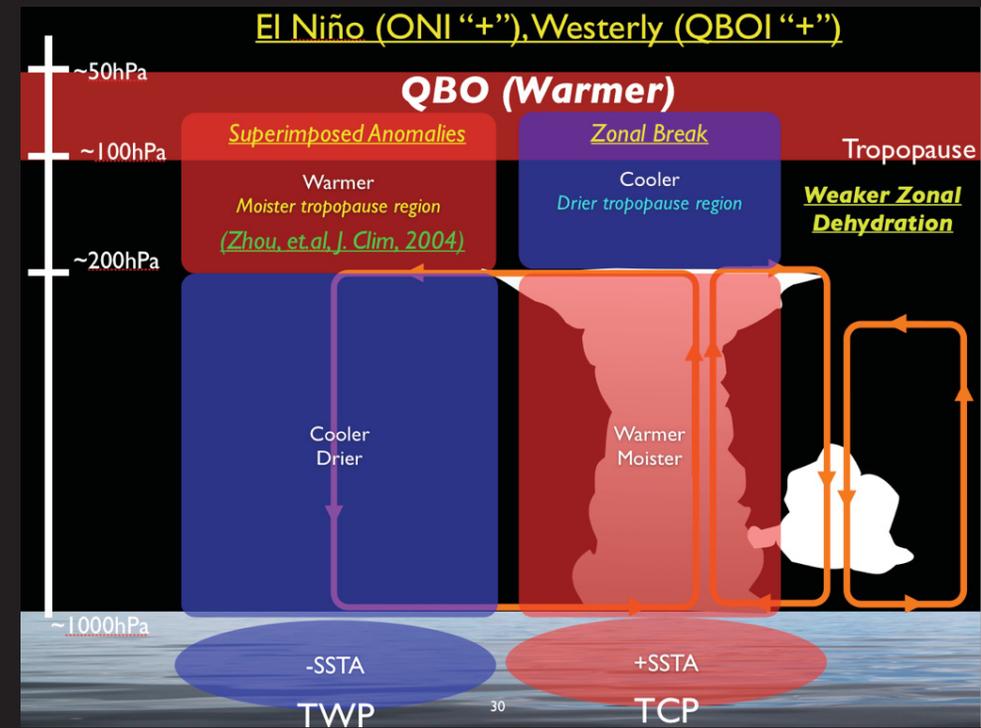
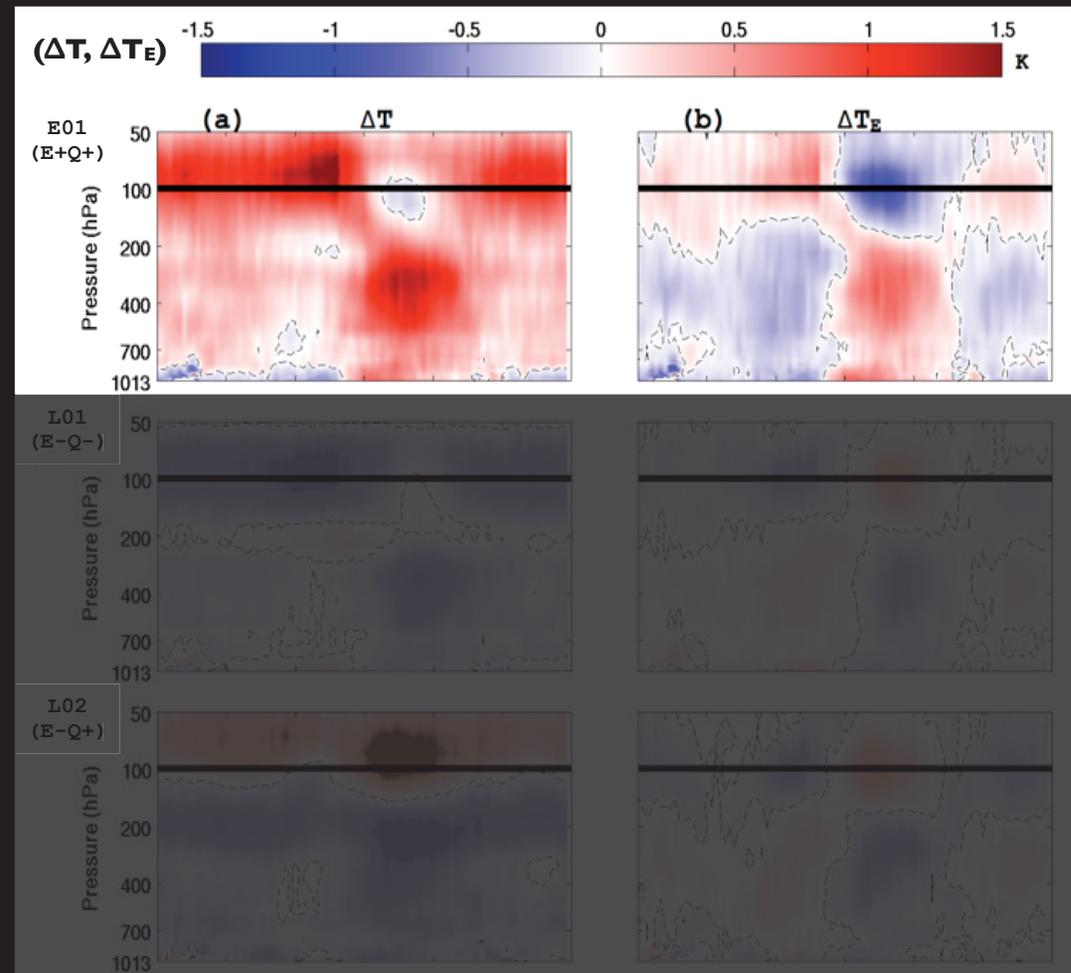
ΔT (100 hPa)

Δq (100 hPa)

DJF Comp.

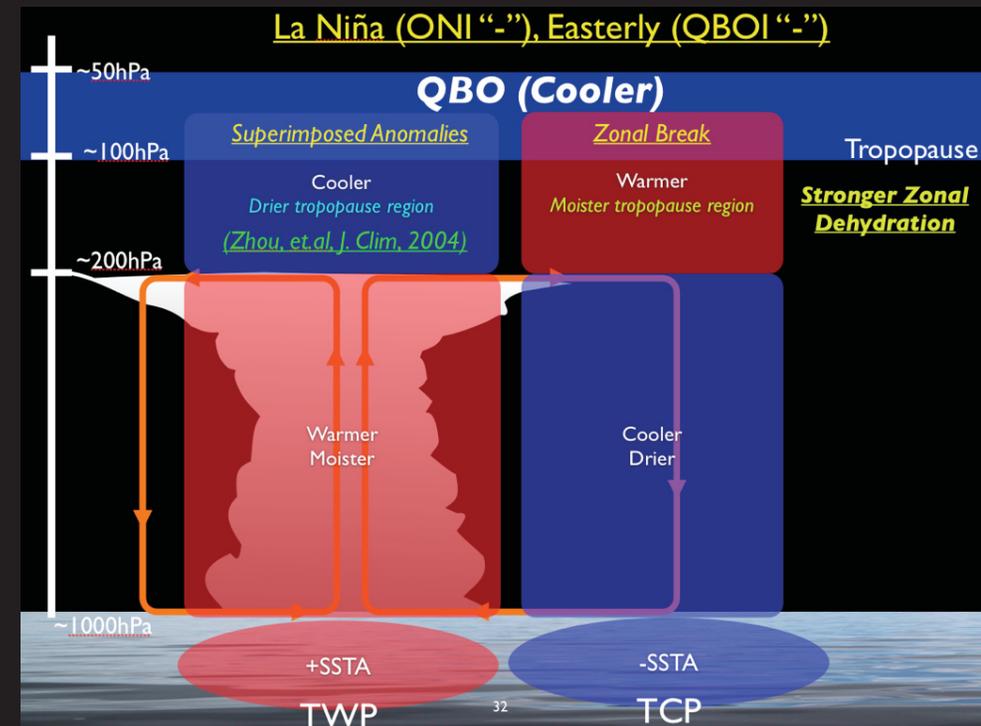
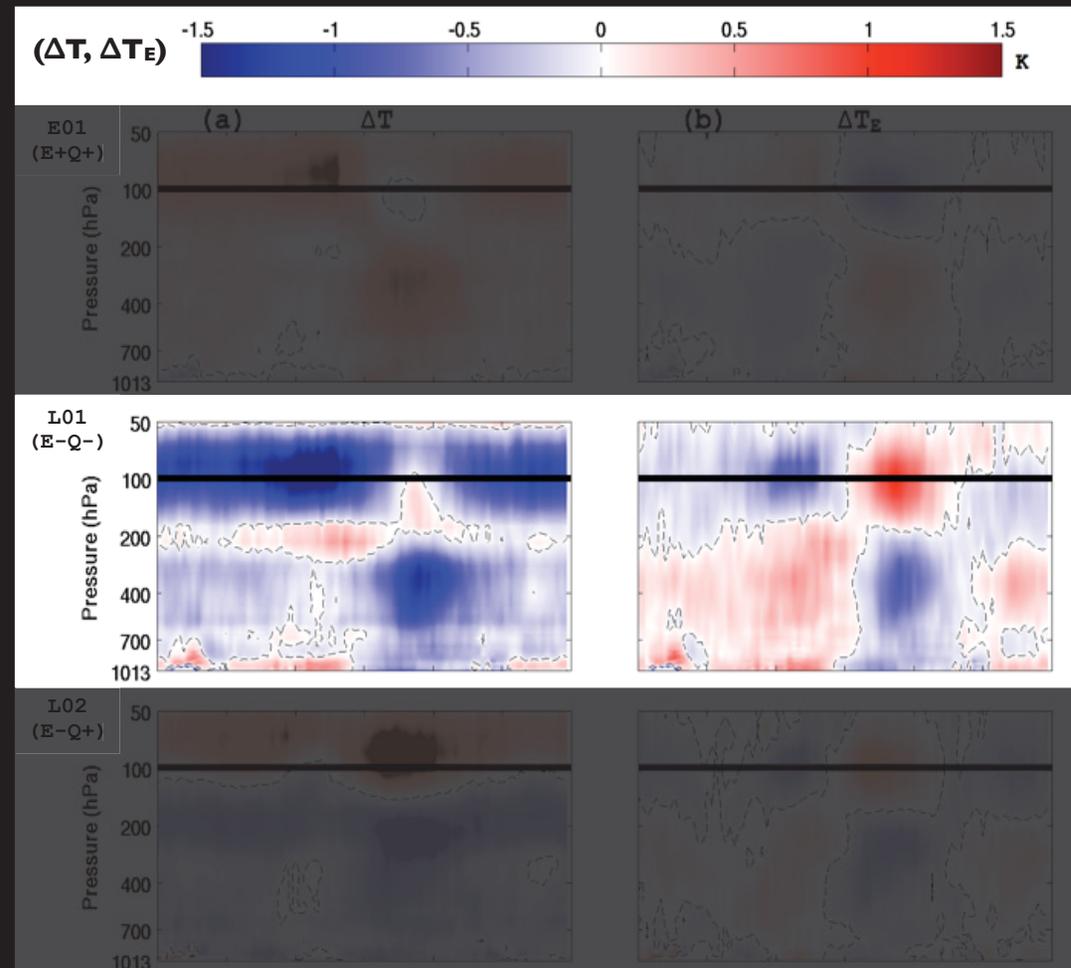


Vertical and Zonal Structure of ΔT and ΔT_E



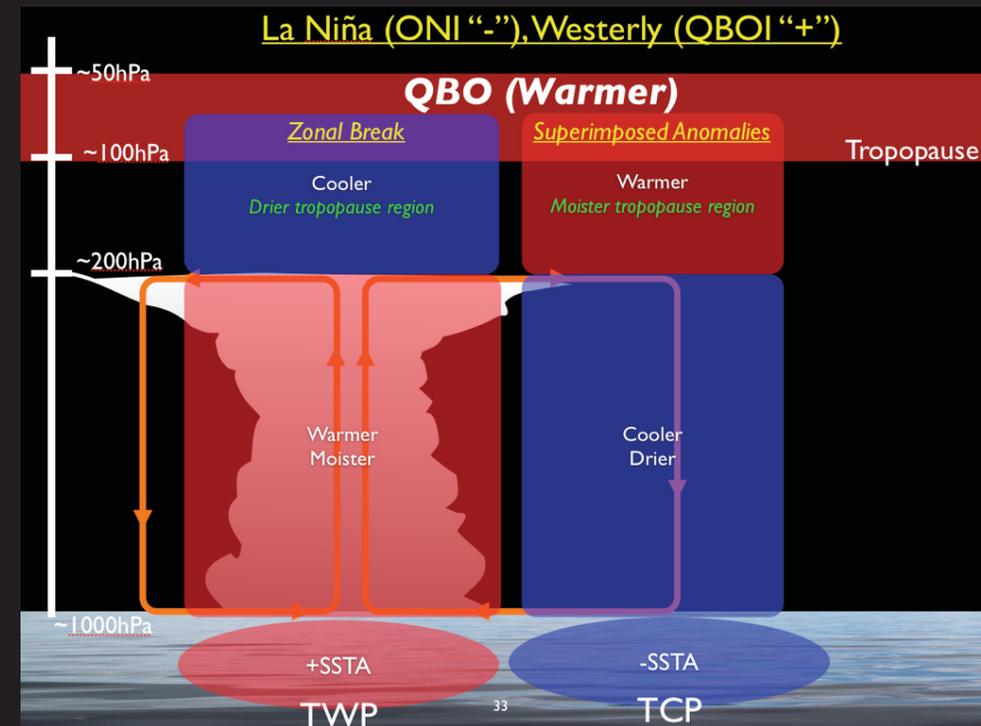
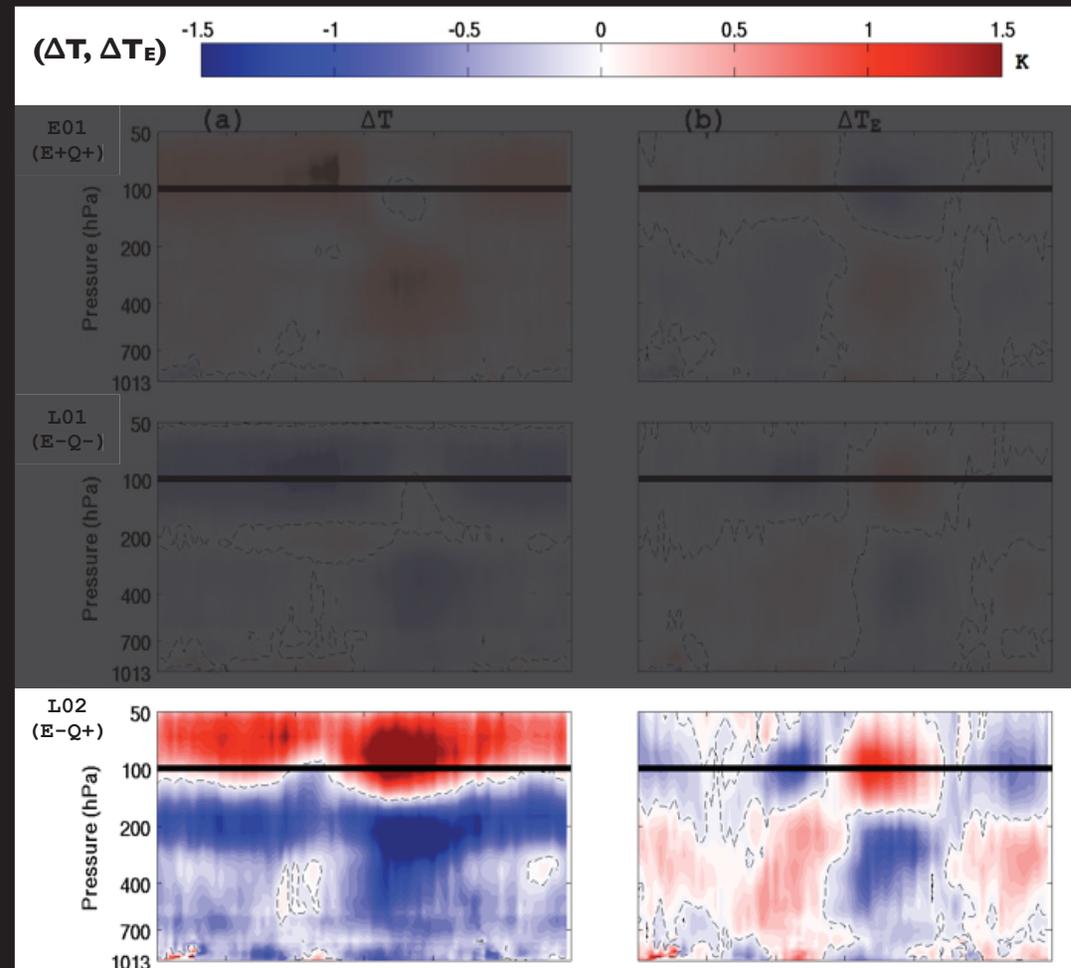
- Zonal break in QBO signal is due to ENSO induces changes in convection
- ΔT_E shows quadrupole structure between TCP and TWP.

Vertical and Zonal Structure of ΔT and Δq



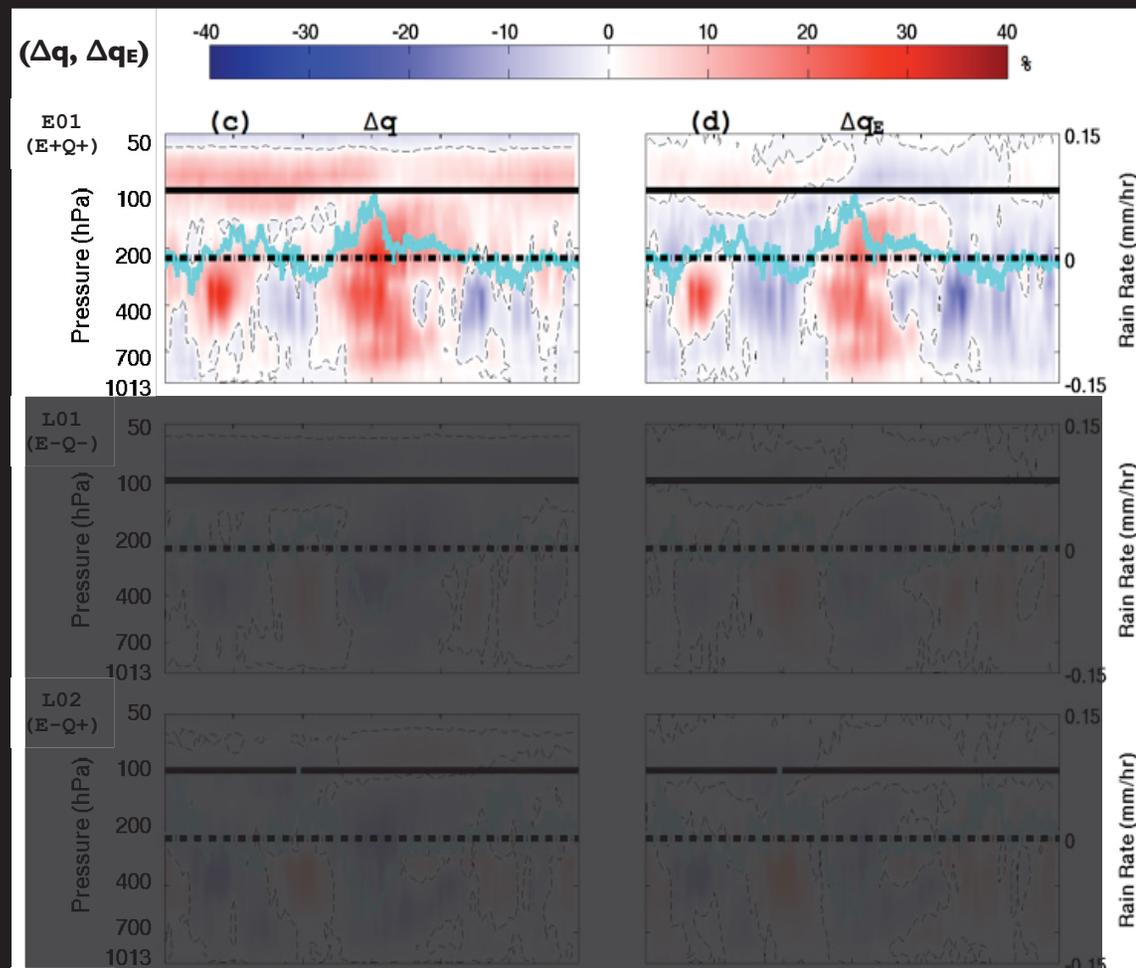
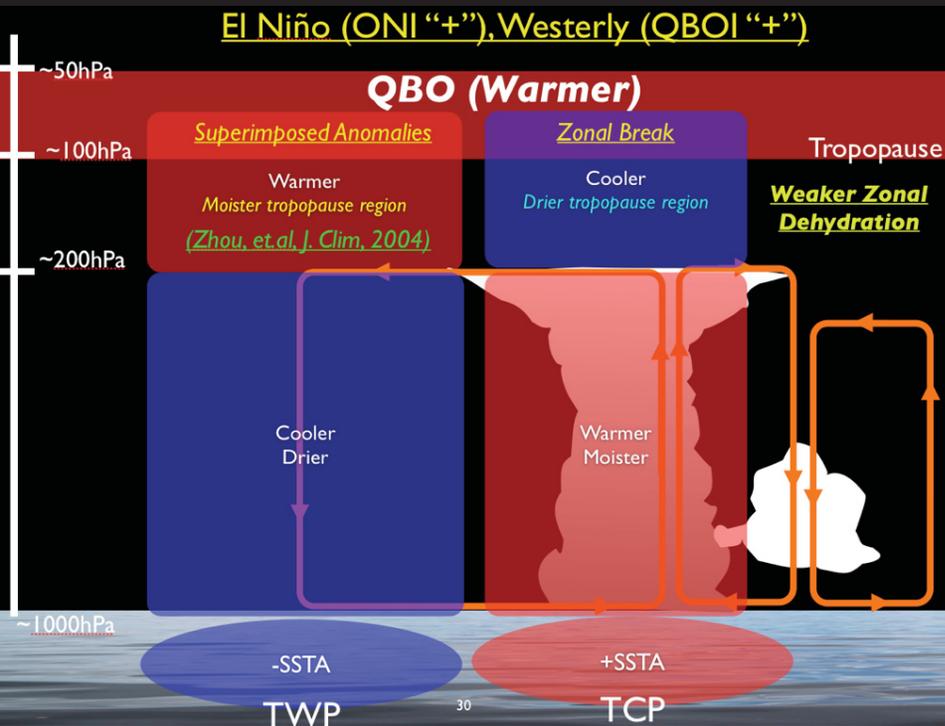
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Vertical and Zonal Structure of ΔT and Δq



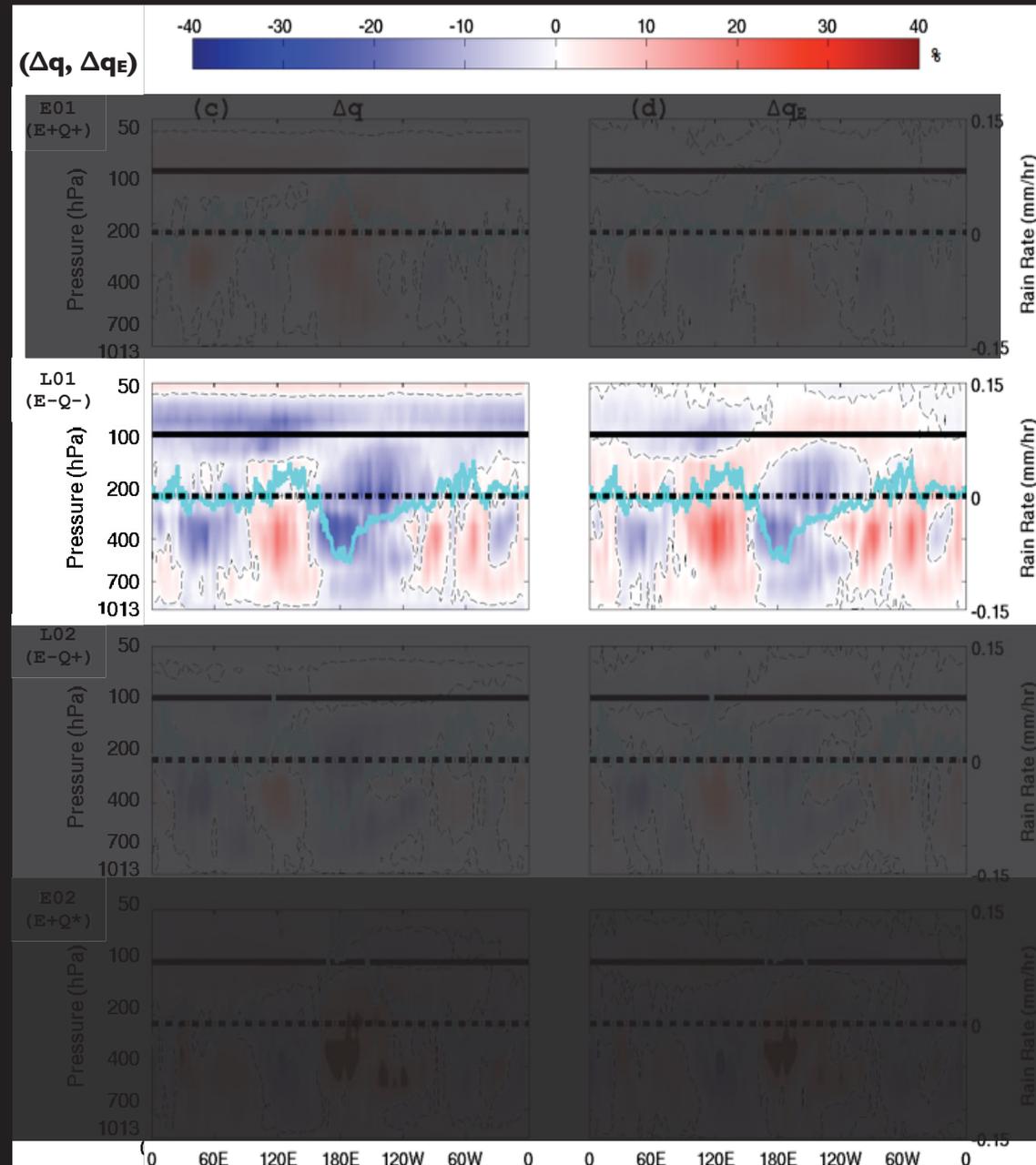
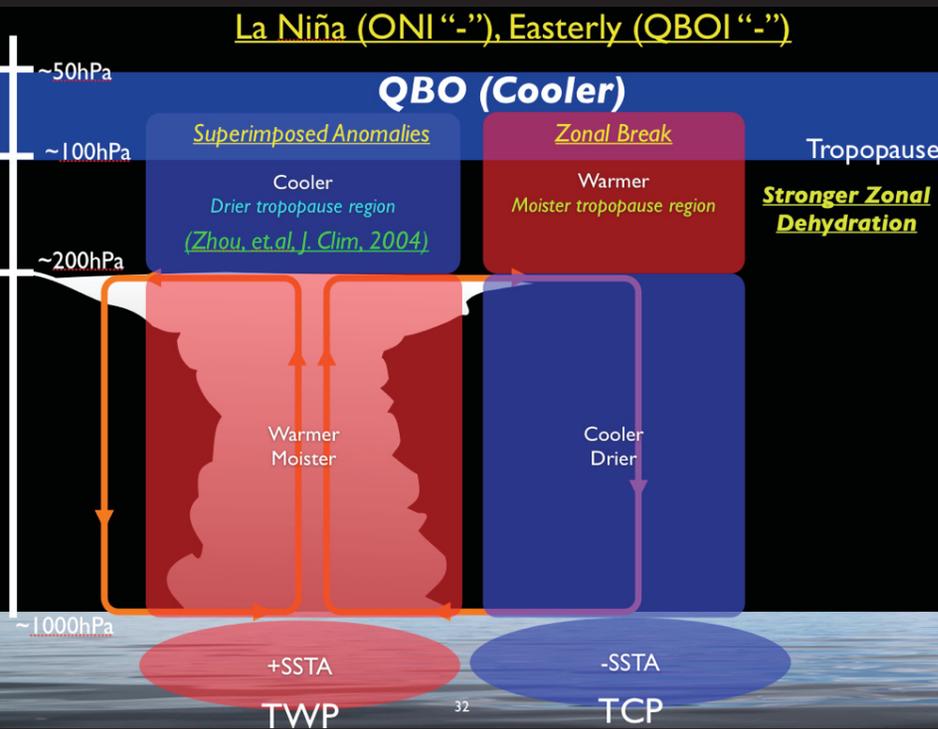
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Vertical and Zonal Structure of ΔT and Δq



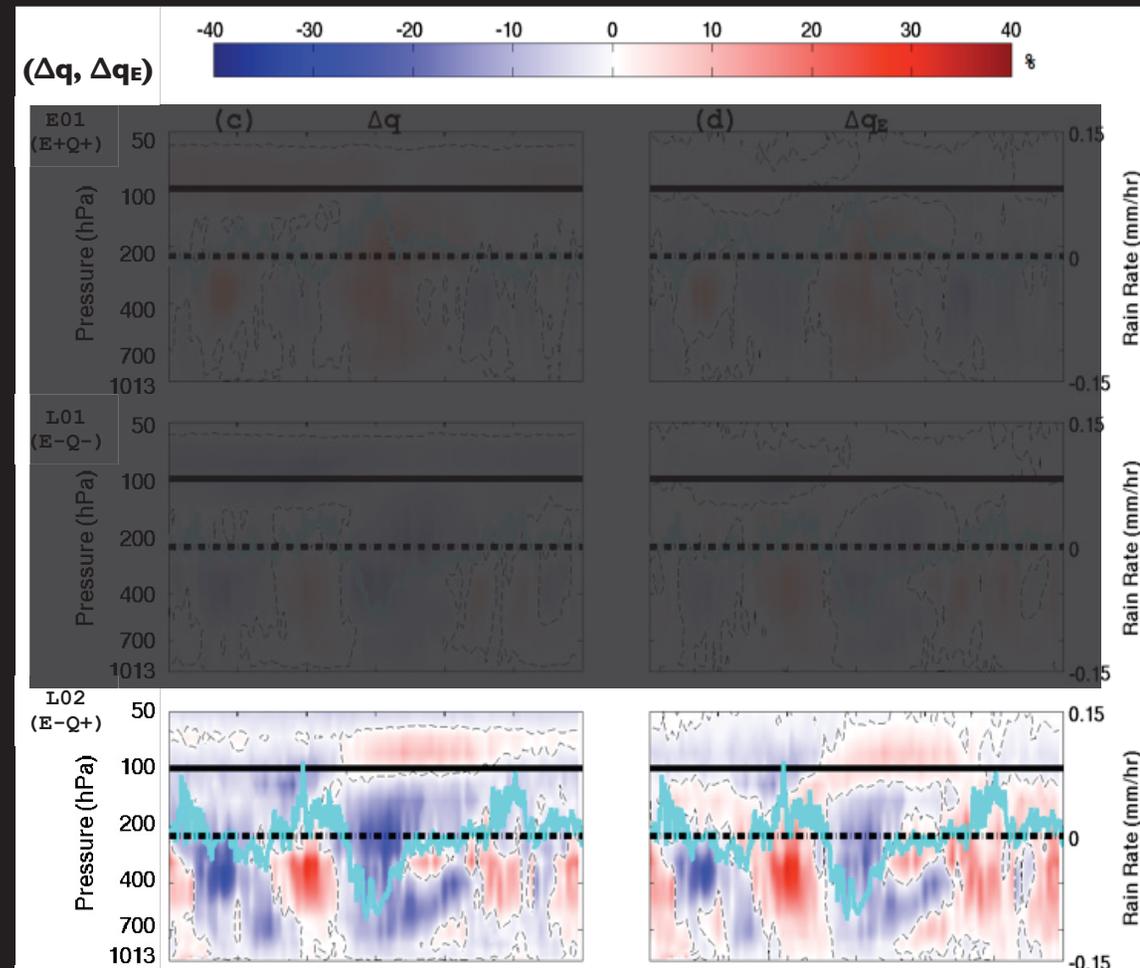
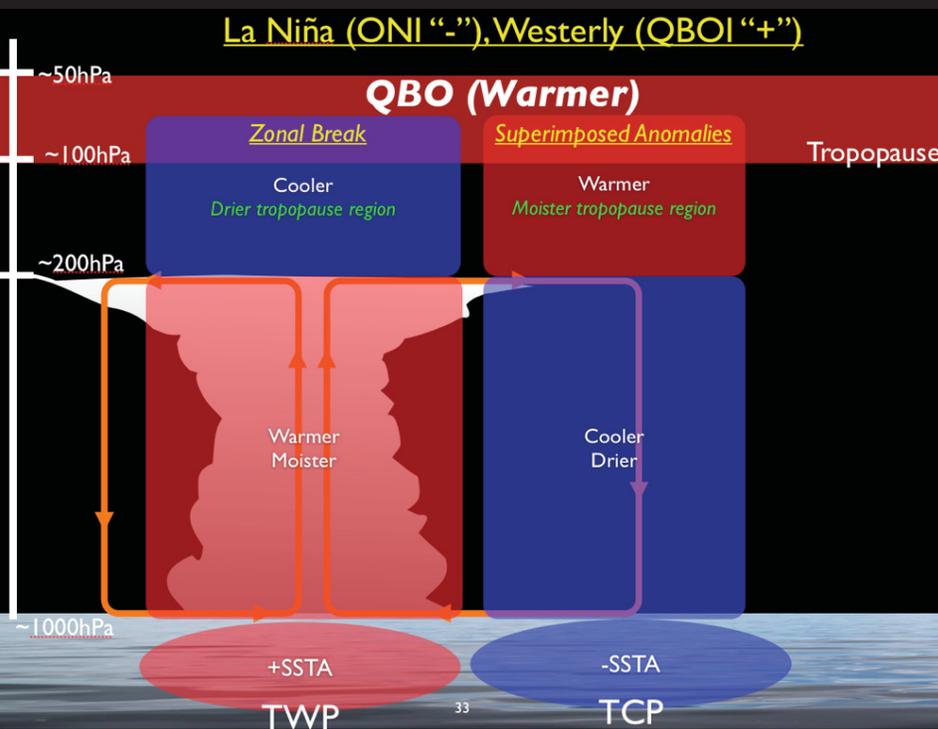
- Moisture and rain rate (TRMM) anomalies track each other
- Δq_E shows moisture also has quadrupole feature like ΔT_E but with different vertical extent

Vertical and Zonal Structure of ΔT and Δq



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Vertical and Zonal Structure of ΔT and Δq



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Conclusion

- ◆ TTL T and H₂O anomalies show a location dependent zonal break depending on the relative phase of the ENSO and QBO.
- ◆ Changes in Walker Circulation, i.e. deep convection, is one of the main mechanisms
- ◆ Evidence of joint ENSO and QBO impact on zonal water vapor distribution; TCP might play a role.
- ◆ *Multi-sensor A-Train measurements allows us to characterize tropical UTLS T and H₂O structure*
- ◆ *Next step: Integrate CloudSat and CALIPSO measurements to connect interannual changes in T and H₂O to cloudiness*

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- ◆ ***Multi-sensor A-Train measurements allows us to characterize tropical UTLS T and H₂O structure***
- ◆ ***Next step: Integrate CloudSat and CALIPSO measurements to connect interannual changes in T and H₂O to cloudiness***

Thank You!!!

Vertical and Zonal Structure of ΔT and Δq

