Is there a feedback of the QBO to the tropical meteorology?

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The Role of the Stratosphere in Tropospheric Climate
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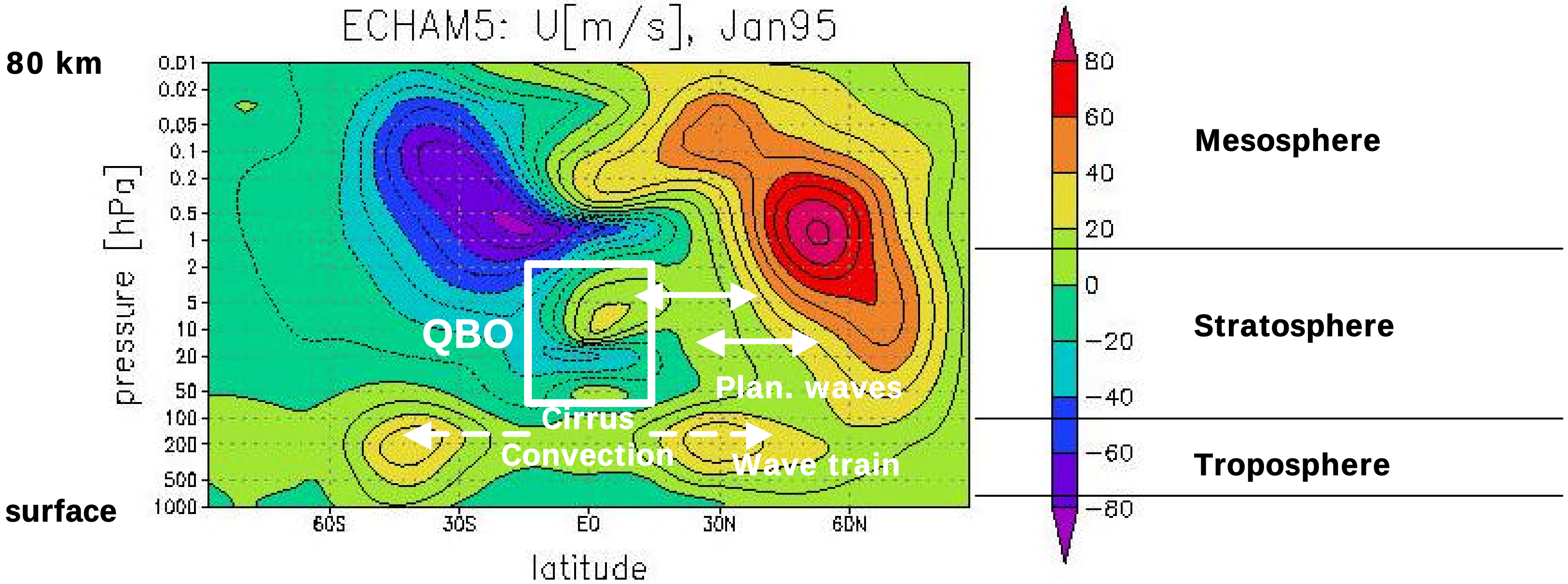
Domain of the QBO

•Zonally uniform jets in 12°N to 12°S

•Lateral interface+strat. trop. coupling: indirect link to troposphere

•Lower interface: direct link to troposphere



Example: Atlantic hurricane frequency

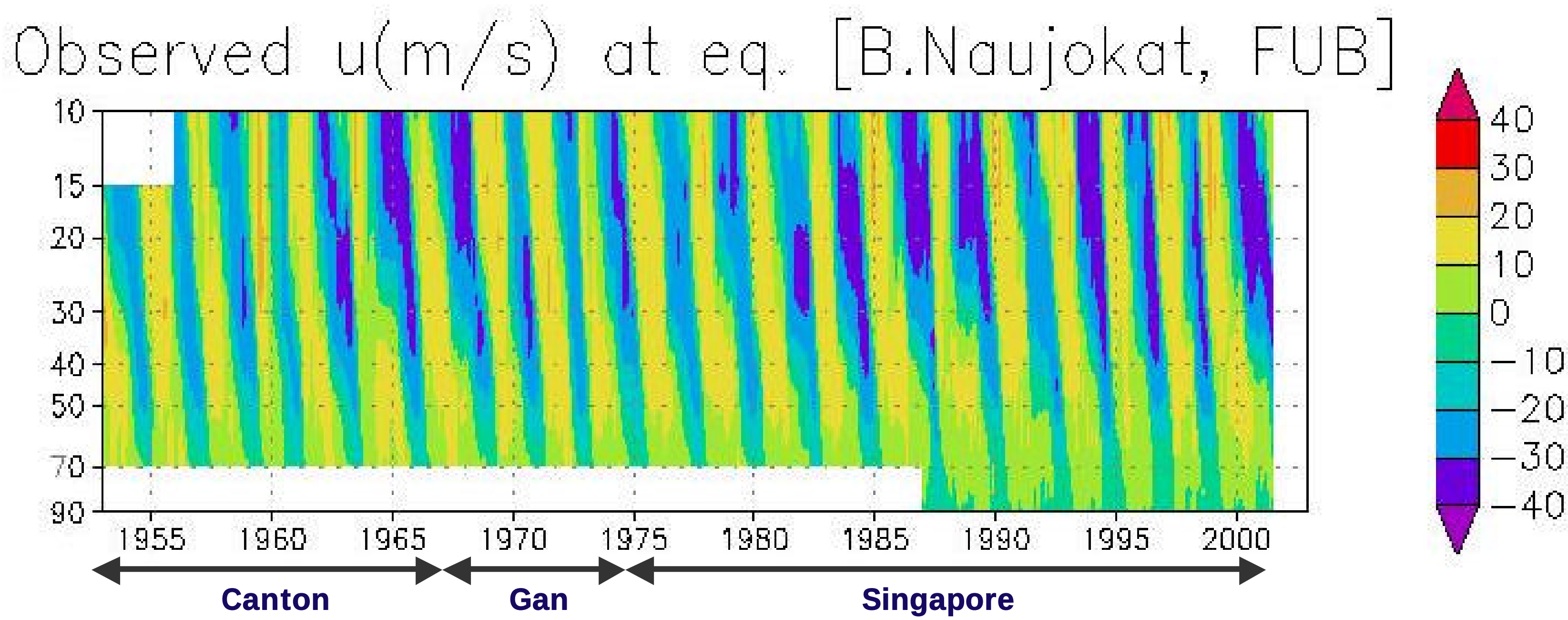
Gray et al., (1992):

- Years of eastward QBO phases at 50 hPa typically have
  50% more named storms
  60% more hurricanes, and
  200% more intense hurricanes
  than years of westward QBO phase.

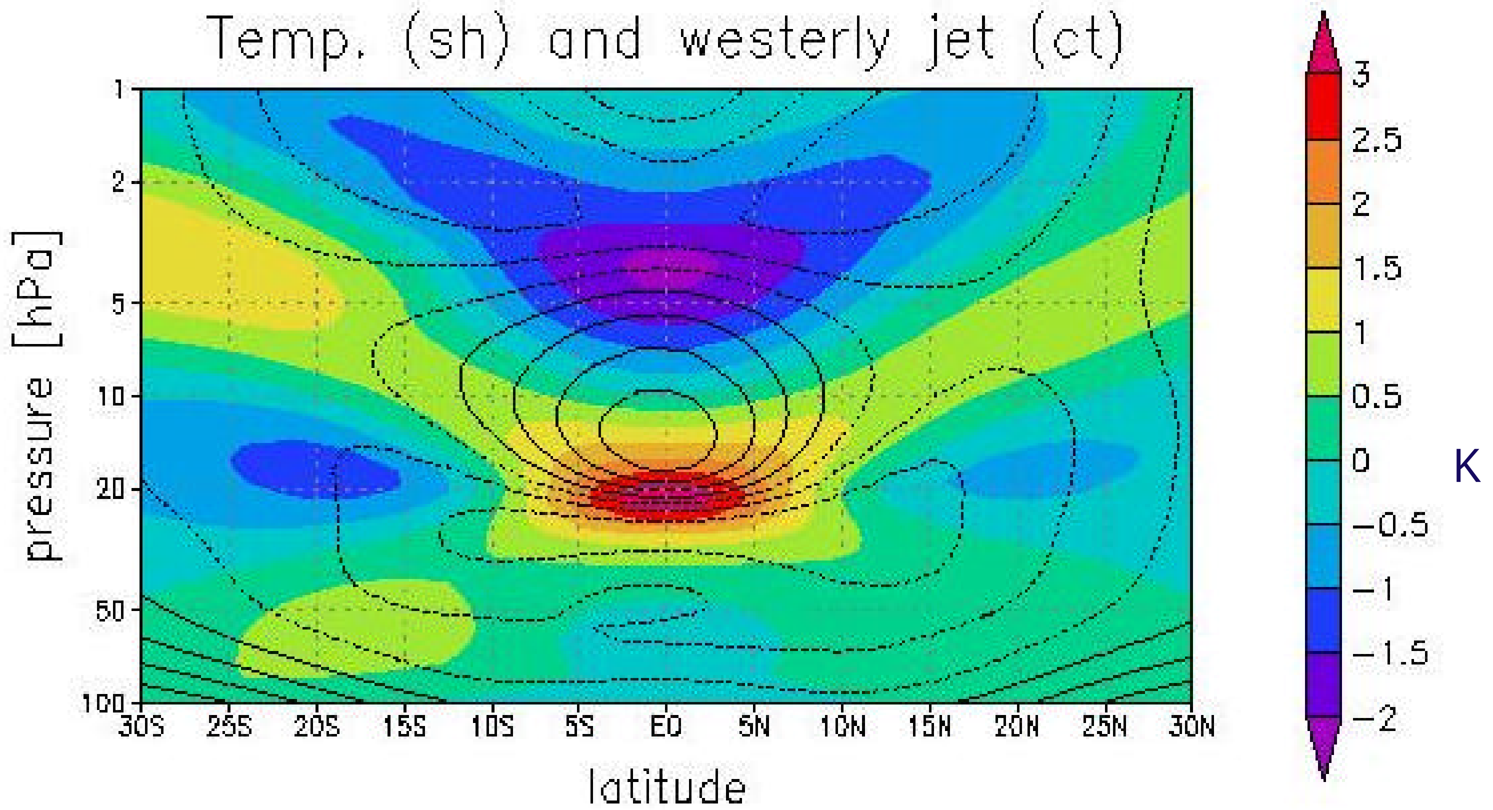
- Proposed mechanism:
  Cyclone genesis is suppressed by high vertical shear du/dz at tropical tropopause at 10N. Shear over Atlantic during hurricane season is larger when the QBO is in westward phase

The quasi-biennial oscillation (QBO)

- Cycle length: 22 to 34 months, average = 28 months
- Downward propagation from ~3hPa **to 90hPa** (40km-18km)



Secondary residual circulation of the QBO



ECHAM5: onset of westerlies at 20 hPa

QBO temperature signals are centred below and above the jets

Problem/Questions (1):

- QBO domain has interface to equatorial troposphere, but
  - QBO in zonal wind is weak at 90 hPa
  - Response in U to dynamical forcing is shallow
  - Tropical weather rarely reaches 100 hPa

- What makes tropical weather sensitive to the QBO in the equatorial stratosphere?

• Zonal wind u	residual circulation
• Wind shear du/dz	deep conv./hurricanes
• Stability dT/dz	deep convection
• Temperature T	sat. moisture, (subvis.) cirrus
• Upwelling w	(subvis.) cirrus

Problem/Questions (2):

- Which feedback mechanism(s) in the tropical troposphere amplify initial perturbations by the QBO?
- Do QBO modifications of tropical weather cause indirect QBO signals in the extratropical troposphere?

Plan:

- GCM experiments with/without assimilation of the QBO
- Specified QBO phase states to separate time scales of the QBO and the annual cycle
- Search for significant differences between monthly to seasonal climatologies of experiments W-QBO and E-QBO.

(Giorgetta et al. 1999)

Experimental design

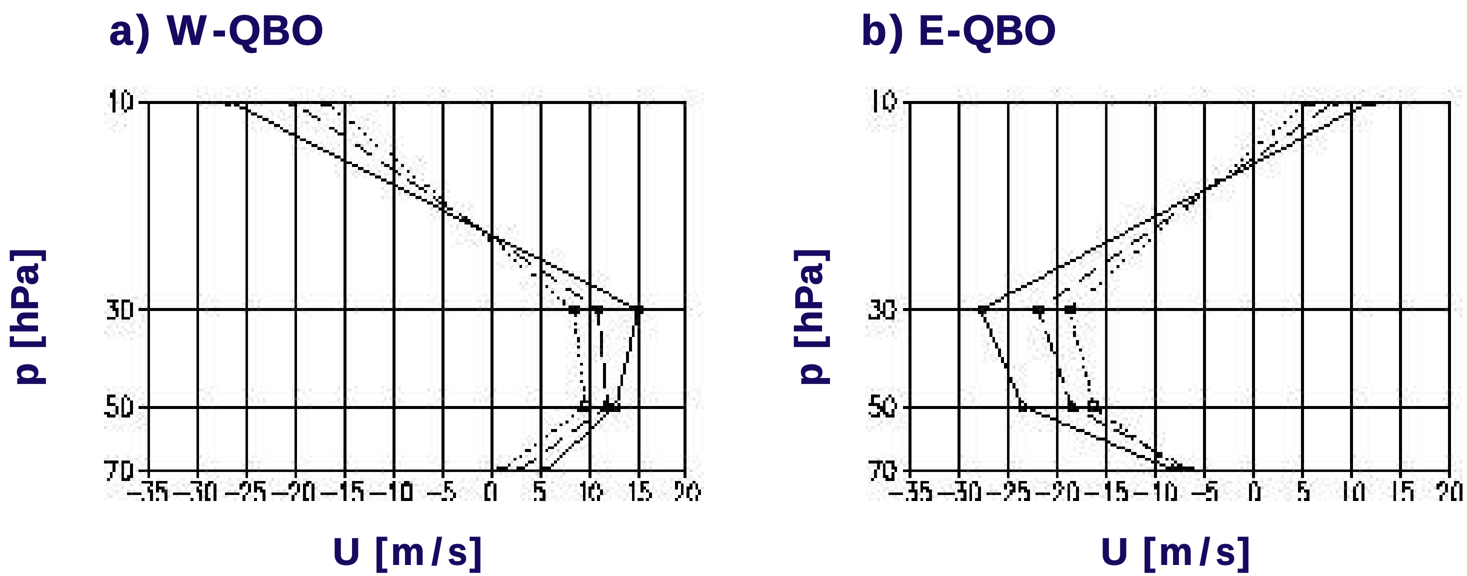
- Model: ECHAM4 T42 L19 + optional QBO assimilation
- QBO data: Singapore profiles [B. Naujokat, FUB]

- Experiments:
  test + confirm

	No QBO	Westerly QBO Feb.86	Easterly QBO Oct.84	Observed QBO 1979-1992
Clim. SST 10 y	CONTROL	**W-QBO**	**E-QBO**	-
Obs. SST 1979-1992	AMIP	-	-	AMIP&QBO

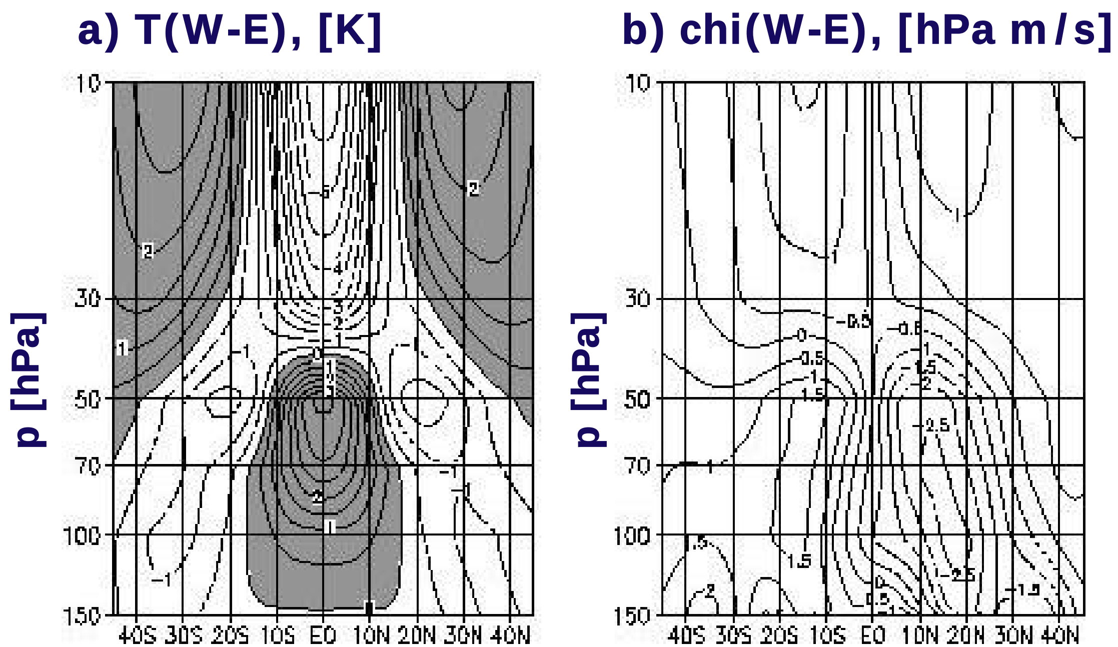
Assimilated QBO

- Full line: QBO at Singapore = zonal wind used for assimilation
- Dashed line: simulated zonal wind after assimilation, relaxation time scale = 10 days
- Dotted line: relaxation time scale = 20 days
- Assimilated QBO has appr. 75% amplitude



Secondary meridional circulation of QBO

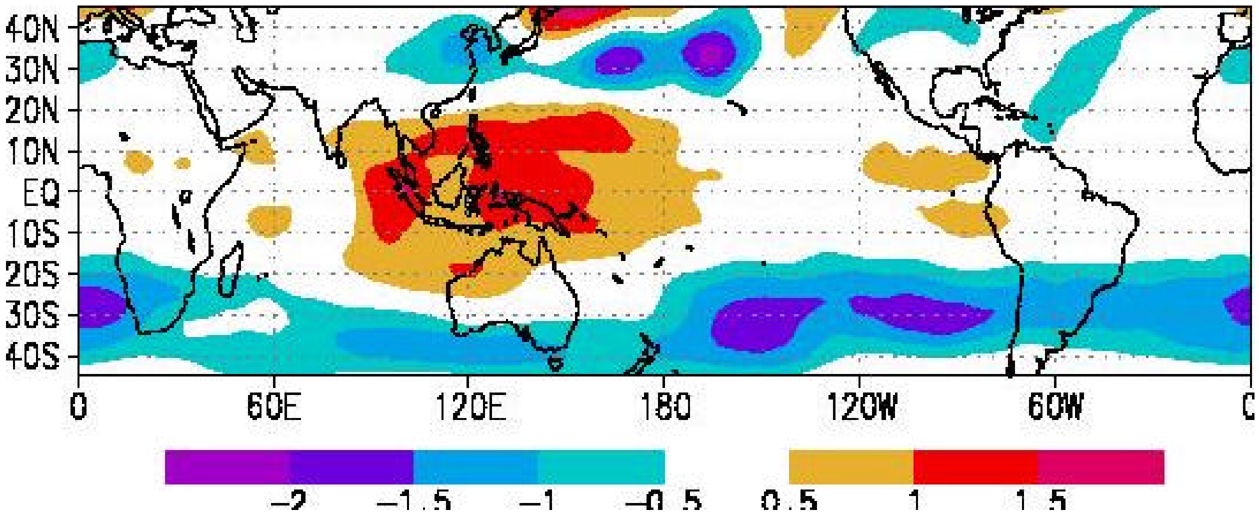
- Model dynamics generates secondary meridional circulation
- Climatological zonal mean difference of W-QBO and E-QBO at 100 hPa:
  Temperature: dT = 0.8 K Streamfunction: dchi = 4 hPa m/s



QBO signal in tropopause temperature

- Strongest signal along equator in areas with deep convection
- Longitudinally uniform in subtropics in winter hemisphere

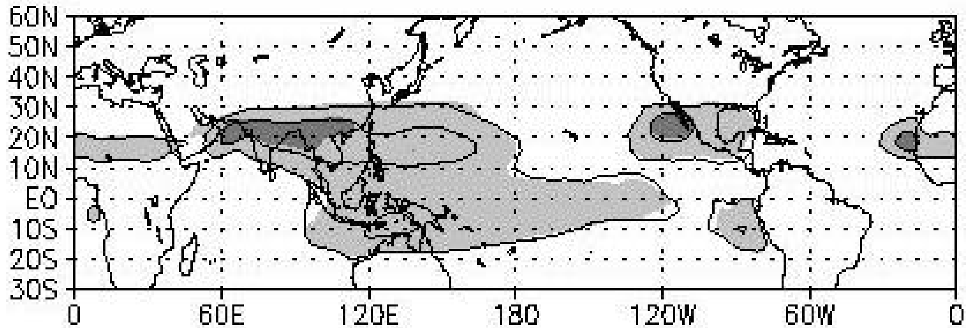
dT(W-E) at 100 hPa in August [K]



QBO signal in cirrus cover

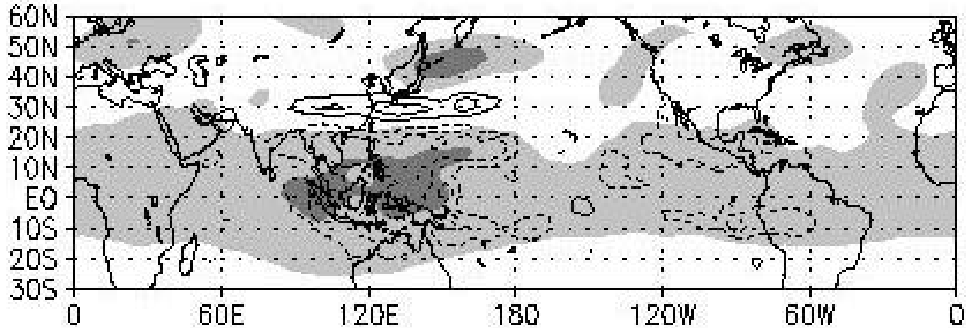
a) Extent of 20% and 40% cloudiness in August at 100 hPa

W-QBO: shaded
E-QBO: contour



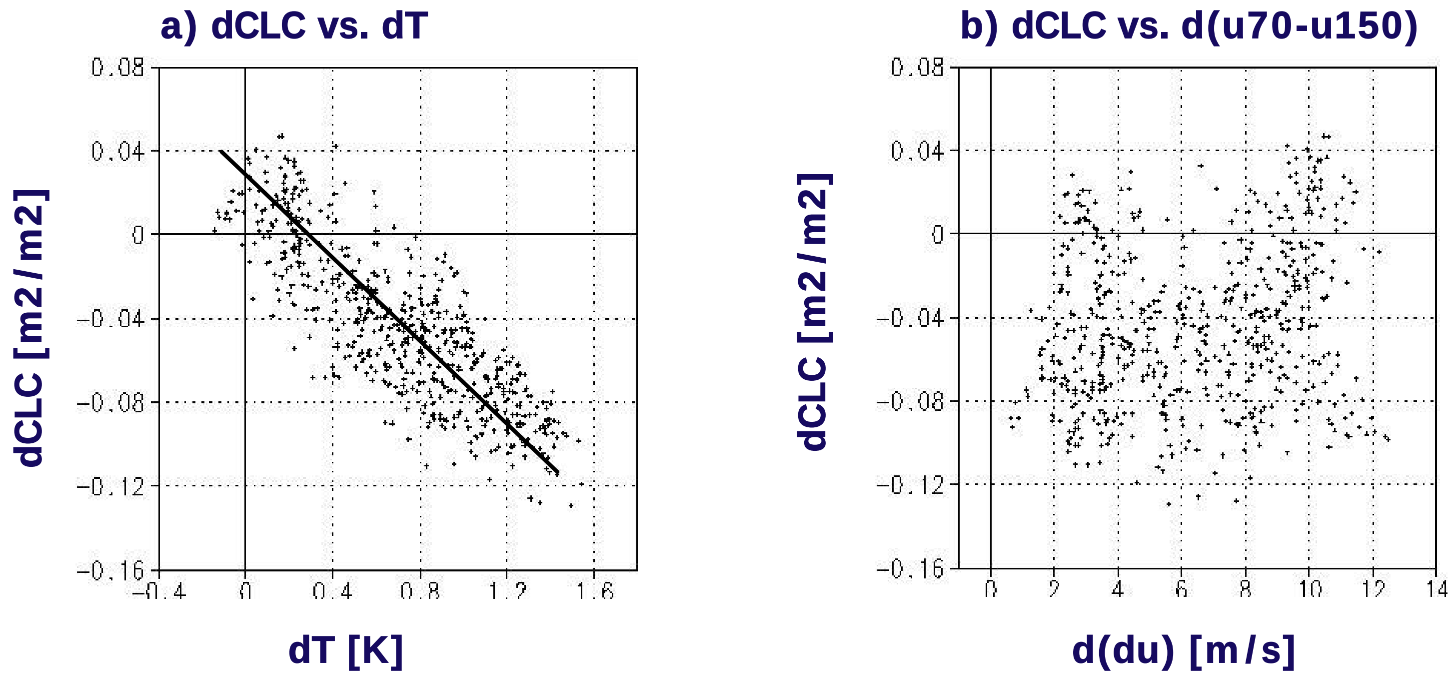
b) Cloudiness difference W-QBO – E-QBO in August at 100 hPa (contour, d=3%),

shaded where dT>0



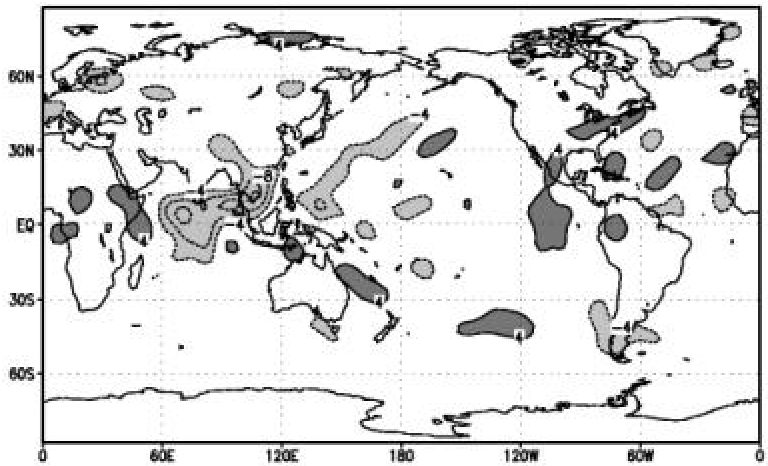
Changes in cirrus at 100 hPa vs. changes in by temperature and shear due to the QBO

- Consider tropical region with cirrus clouds in August
  - Area between 15N and 15S (exclude wave train region)
  - Area where mean cloudiness of W-QBO and E-QBO is 20% or more

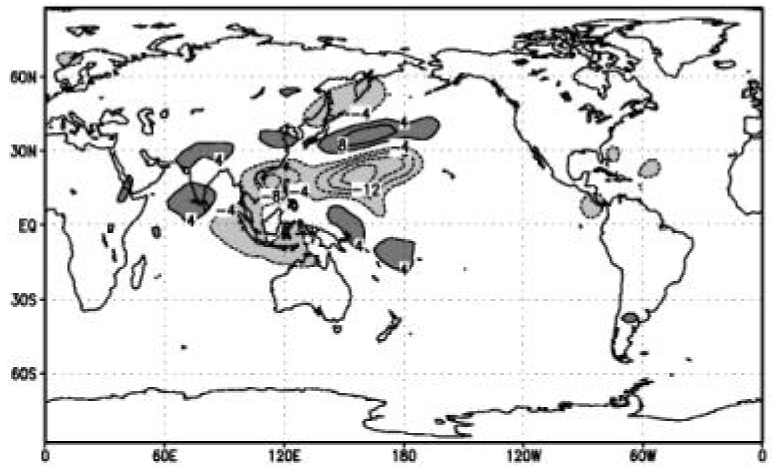


QBO signal in OLR, here E-W

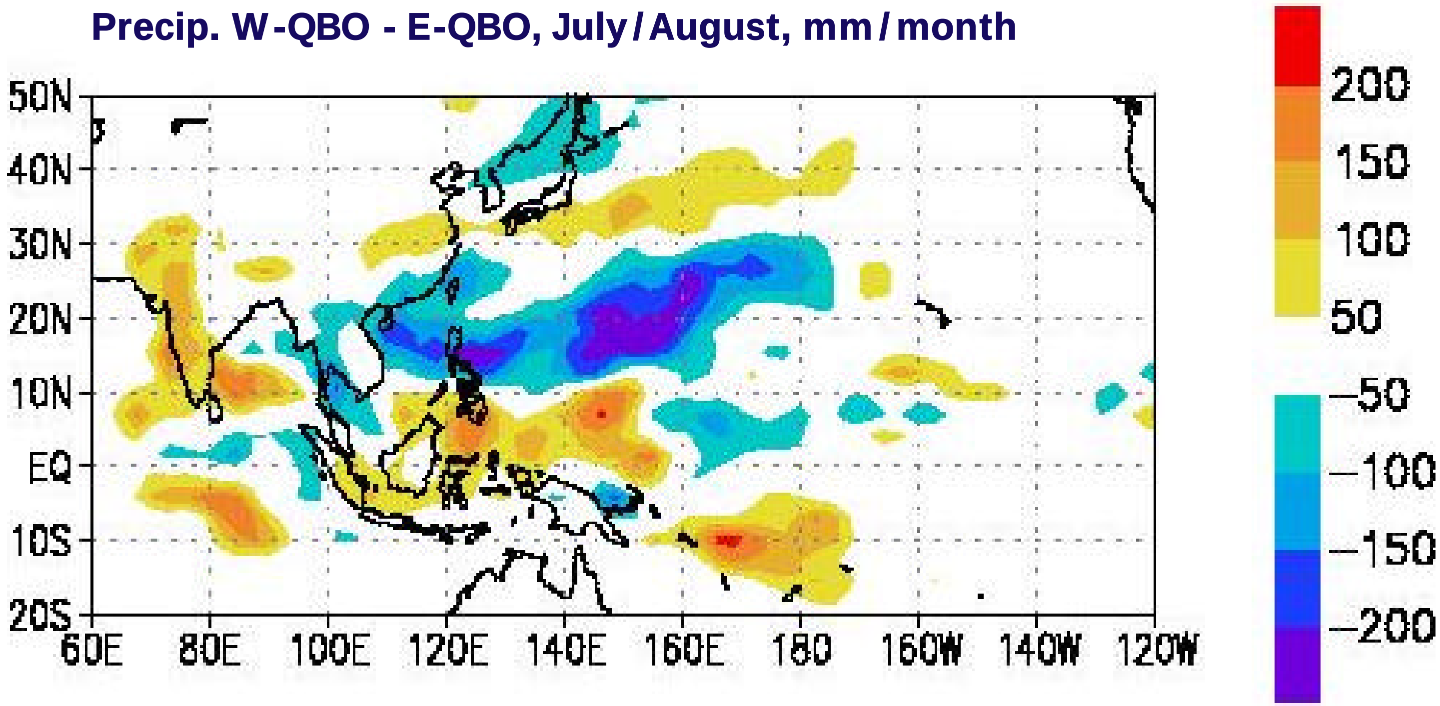
a) dOLR, E-W, June, ci=4W/m2



b) dOLR, E-W, Junly/August, ci=4W/m2



QBO signal in precipitation in July/August



Total change appr. 0
Positive signal in India, as in Mukherjee et al. (1985), Kane (1995)
See saw pattern in South China, as in Shen and Lau (1995)

QBO signal in zonal wind

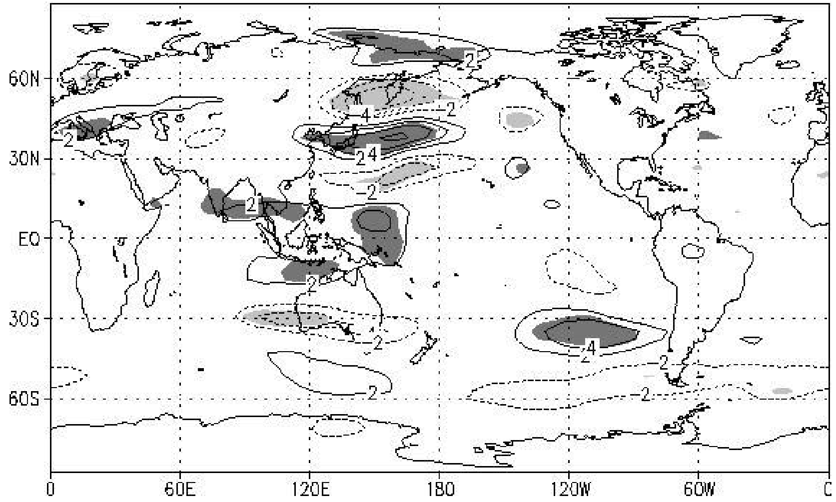
W-QBO – E-QBO in Juli/August

Light/dark shading for pos./neg. 95% significant diffs.

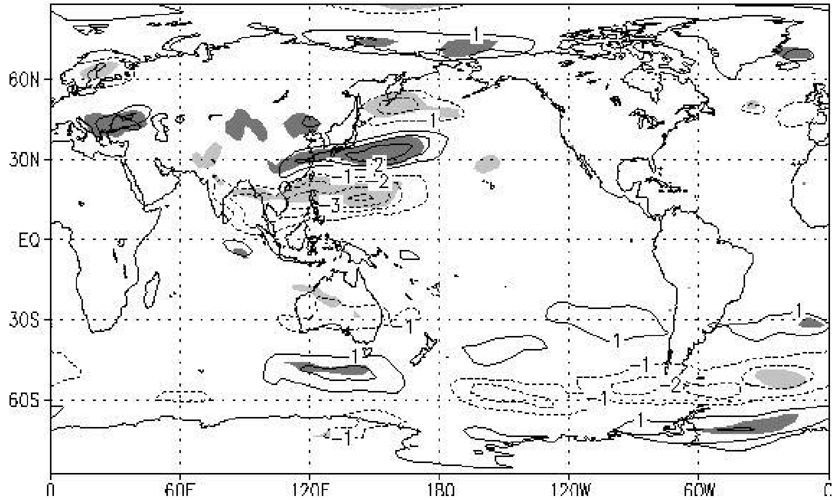
Monsoon circulation weaker

Barotropic wave train to mid latitudes

a) du at 200 hPa, contour int.=2m/s



b) du at 850 hPa, contour int.=1m/s



QBO signals in monsoon system

- W-QBO vs. E-QBO in lower stratosphere:
  - Higher temperature at equatorial tropopause
  - Shear du/dz more westerly
- Temperature signal is amplified in warm pool area
- Temperature signal in warm pool is co-located with change in cloud cover at 100 hPa (cirrus)
- Relocation of convection and precipitation in area with cirrus change
- Wave train radiating from the warm pool to mid latitudes

Hypothesis for QBO signals in monsoon circulation (1)

- QBO secondary meridional circulation modulates temperature at tropical tropopause:
  E-W → colder

- Cirrus amount in regions of deep convection is sensitive to temperature change:
  colder → more cirrus (at same detrainment)
- Long wave cloud radiative cooling at tropopause increases with amount of cirrus:
  more cirrus → colder

➢ Long wave cloud radiative forcing provider positive feedback for amplification of temperature signal in tropopause layer in areas of deep convection below the QBO

Hypothesis for QBO signals in monsoon circulation (2)

- Deep convection is sensitive to temperature changes at upper boundary:
  colder upper b.cond. → more intense convection
  more intense convection → more detrainment
  more detrainment → more cirrus

➢ Long wave cloud radiative forcing provides positive feedback for activity of deep convection in area of initial temperature perturbation

➢ Conditions for deep convection are improved at equator but degraded farther away

Hypothesis for QBO signals in monsoon circulation (3)

- Relocation of deep convection in warm pool area leads to shifts in the monsoon circulaton and latent heating:
  modification in precipitation pattern in tropics
  development of a wave train in circulation difference field

- Wave train is detected in the summer hemisphere, similar wave train may radiate towards the winter hemisphere

Conclusions

- GCM experiments with assimilated QBO and prescribed SST show:

- The QBO modifies the tropical deep convection
- Direct link of the QBO to the troposphere

- Coupling mechanisms depends on “physics”, not on “dynamics”:
  - Cloud radiative forcing of cirrus
  - Sensitivity of deep convection to stability in uppermost tropical troposphere

- Wave train causes secondary effects in extratropical troposphere