Influence of the Mt. Pinatubo Eruption on the Quasi-Biennial Oscillation

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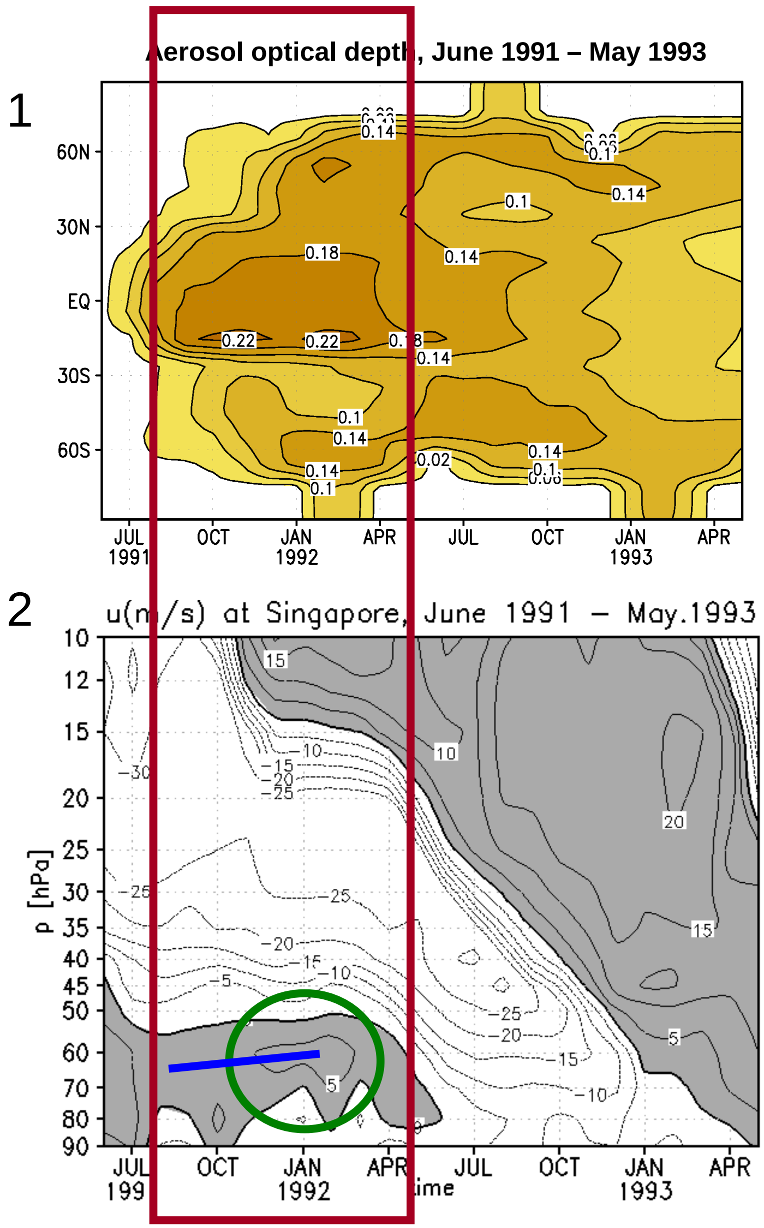
Can volcanic eruptions perturb the QBO?

- Naujokat (1986)
  - *Mt. Agung, March 1963:* unusually long westerly phase of 18 months, but also the following cycle has a long westerly phase.
  - *El Chichon, April 1982:* relatively short westerly phase of 10 months.
  - Both cases: E jet at 25 hPa above terminating westerly phase
- Seol and Yamazaki (1998)
  Intensified tropical upward mass flux at 100 hPa after the Mt. Pinatubo eruption in June 1991.
- Deushi and Shibata (P20/Friday 13.00)
  Effects of the eruption of Mt. Pinatubo on the quasi-biennial oscillation as revealed with MRI chemistry-climate model

Mt. Pinatubo erupton and the QBO in 1991-1993



1. Zonally averaged sulfate aerosol optical depth (AOD) at 0.55 µm from June 1991 to May 1993 (Stenchkov, priv. comm.)

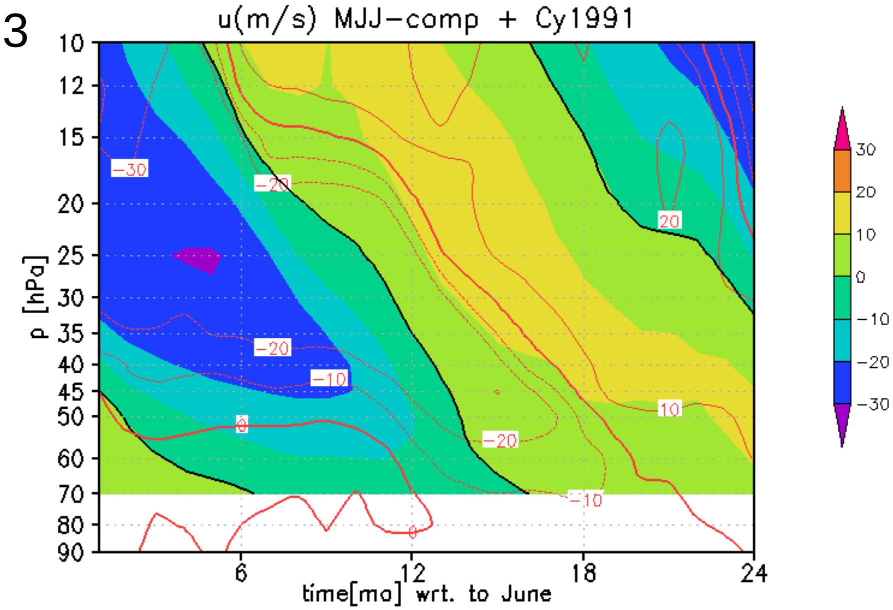
AOD=~0.2 from 09/91 – 04/93

2. QBO in zonal wind at Singapore from January 1991 to December 1993 (Naujokat, priv. comm.)

High tropical *aerosol loading* concurrent with lifting and strengthening of the westerly phase in winter 1991/1992.

How different was this cycle from the average cycle?

3



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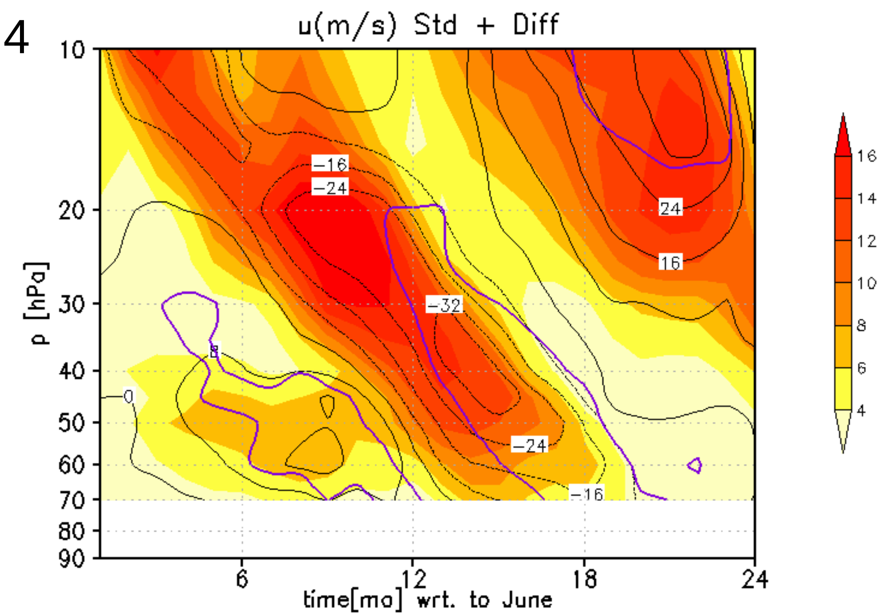


3. *Shaded:* Composite average of 11 QBO cycles with easterlies starting at 45 hPa in May/June/July of 1953-2005

Red cont.: Cycle of 1991-1993 is delayed by appr. 4 – 6 months compared to composite

4. *Shaded:* Composite standard deviation σ(U)

Black cont.: Difference between u(1991-1993) and U (ct. int.=8m/s)

Violet cont.: |Diff| = 2σ
The QBO cycle after June 1991 is an outlier wrt. the available data

Hypothesis

- Mt. Pinatubo eruption → SO_2 in stratosphere
  - sulfate aerosols forming in the tropical stratosphere
  - Radiative heating in near IR and thermal IR in tropics
  - Increased tropical upwelling / stronger BDC
  - Upward advection of QBO jets
  - Delayed QBO evolution

- Secondary effects:
  - Modified wave sources in troposphere? (suppressed in this study)

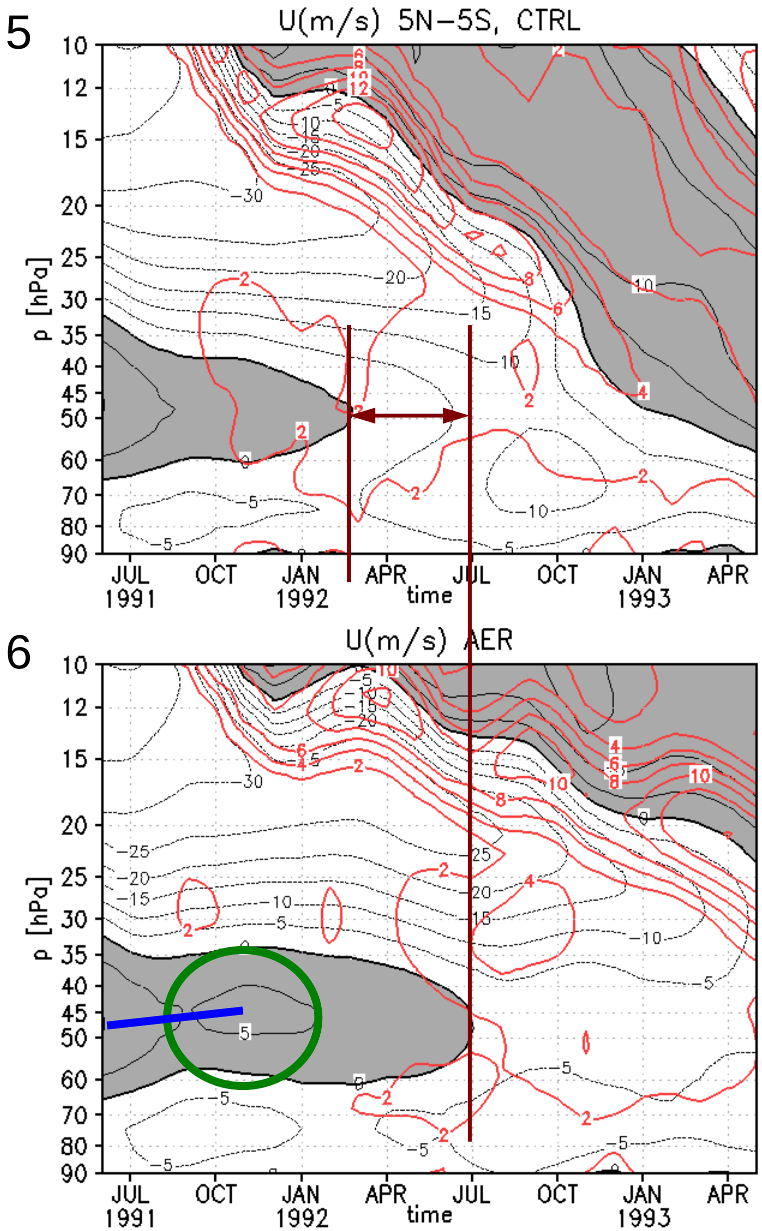
- Removal of stratopsheric sulfate aerosol
  - Return to normal upwelling and QBO evolution

Experimental design

- Compare 2 ensembles of QBO simulations
  - *Ctrl:* No volcanic forcing
  - *Aer:* Stratosph. sulfate aerosols following the Mt. Pinatubo eruption is prescribed by optical properties in SW and LW
  - *Aer* branches off from *Ctrl* in June 1991
  - Differences between simulations *Aer* and *Ctrl* are related to aerosol forcing in *Aer*, or internal variability
  - Use ensembles to increase signal to noise ratio, N=10

- Boundary conditions for SST+sea ice
  - Climatology of AMIP2 boundary conditions of 1979-1996
  - No Mt. Pinatubo or QBO signals in SST
- Initial conditions
  - Selected from a control run to resemble QBO phase of June 1991
  - Generate ensemble members by parameter modifications in 1st month
- Model:
  - MAECHAM5 at res. T42 L90 (Giorgetta et al., 2006)

Ensemble mean QBO in Ctrl and Aer



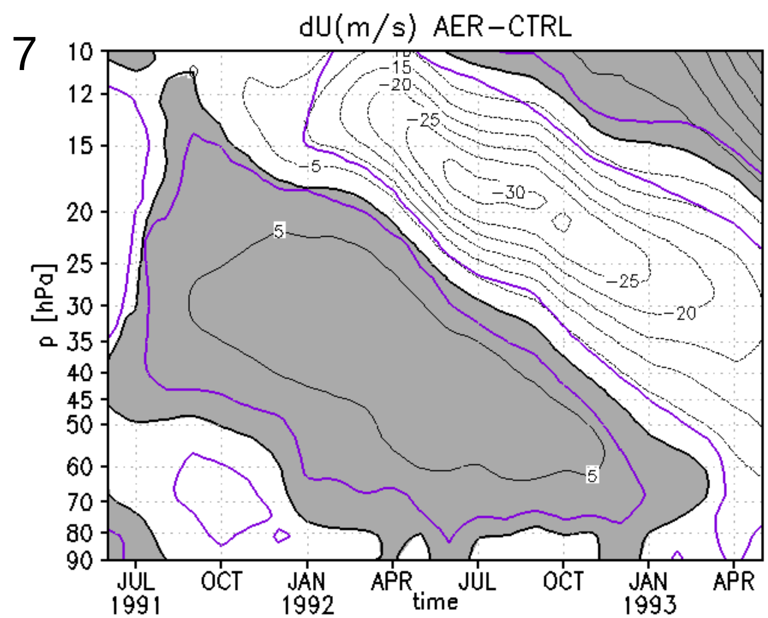
Shaded cont.: ensemble mean U

Red cont.: ensemble std.dev. in U

Violet cont.: t test at 95% sign.

Westerly phase lasts 4.5 months longer in AER than in CTR

Lifting and strengthening

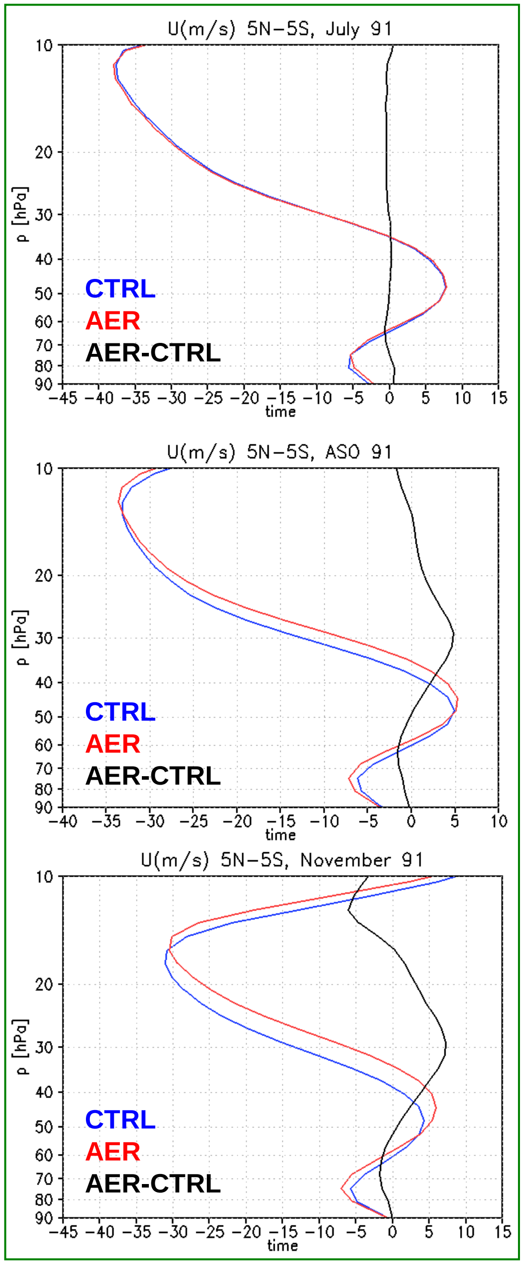


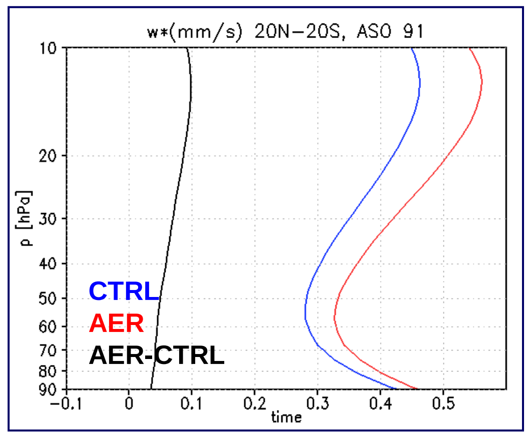
Tendencies dU/dt in August-October 1991

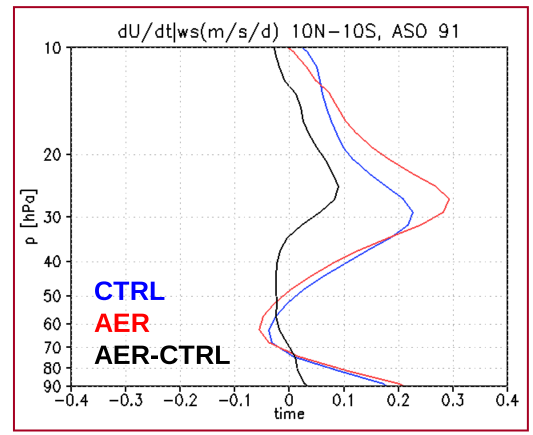
Left: Difference in U grows from July to Nov.

Middle: tropical upwelling stronger in *AER*

Right: dU/dt|w* is more westerly in *AER*
(dU/dt|divEP and dU/dt|vs change much less)







Conclusions

- The QBO cycle following the Mt. Pinatubo eruption was slower than normal
  - The westerly lasted 4 – 6 months longer than on average
  - The westerly jet was lifted and strengthened
  - The following easterly phase was delayed
- Model simulations reproduce these observed features inn response to the prescribed Mt. Pinatubo aerosol focing.
- Mechanism:
  - Volcanic aerosol radiative heating in tropical stratosphere
  - Stronger upwelling in tropical stratosphere
  - Increased upward advection of westerly wind above westerly jet
  - Delayed downward propagation of easterly jet
  - Prolonged westerly jet in lower stratosphere

Open questions

- What happened in years following tropical volcanic eruptions larger than that of Mt. Pinatubo, for instance after Krakatau or Toba or the eruption of 1258 of unknown origin?

- Are these results relevant for future climate change or strat. geo-engineering schemes?
  - Common: expected changes in tropical upwelling
  - Differences:
    - Climate change: rad. forcing + wave mean-flow inteaction
    - Strat. sulfate aerosol schemes: imitate volcanic effects
    - Both: longer time scale

END