Atmospheric QBO and ENSO indices with high vertical resolution from GNSS RO

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Outline

- Proxy for atmospheric temperature variability based on radio occultation temperature measurements (e.g. useful for regression).
- Two methods, M1 and M2
  - M1: PCA on monthly mean temperature anomalies
  - M2: PCA on monthly mean temperature anomalies
Outline

- Proxy for atmospheric temperature variability based on radio occultation temperature measurements (e.g. useful for regression).
- Two methods, M1 and M2
  - M1: PCA on monthly mean temperature anomalies
  - M2: PCA on monthly mean temperature anomalies
- Difference?
  - M1: The whole input field.
  - M2: Each altitude level separately
Atmospheric variability in the tropics

- Two main patterns
  - Quasi-Biennial Oscillation
    - “QBO” - stratosphere
  - El Niño Southern Oscillation
    - “ENSO” - troposphere
Commonly used indices

- Proxies for the variability
- QBO: Winds
- ENSO: Niño 3.4 SST index

Issues (e.g. when used in temperature regression analysis)
- An other physical variable – wind and sea surface temperature
- Account for timelag
- Cannot fully describe the vertical variability structure
Method: PCA

- “Principle Component Analysis”
- “Empirical Orthogonal Function” analysis
- Extracts the main variability from the input field
- Decomposed into a reduced set
  - Spatial component: “EOF”s.
    - WHERE.
  - Corresponding time components: “PC”s.
    - WHEN.
- Most of the variability is described by the first components.
Monthly mean temperature anomalies

Monthly mean temperatures from WEGC OPSv5.6

Resolution: 5° x 5° latitude / longitude grid, 200 m vertical resolution
Time: 2001-05 to 2017-02
Include: Latitude 30°S to 30°N, altitude: 2 km to 35 km
Monthly mean temperature anomaly @ 27.5°N
Monthly mean temperature anomaly @ 2.5ºN
M1

Performing the PCA on the whole input field
M1: EOFs (space) and PCs (time)

EOFs

PCs

Explained variance ratio

25%

20%

13%

7%
M1: EOFs @ 30 km

No longitudinal dependency
M1: EOFs @ 27 km

Node
M1: EOFs @ 25 km

Opposite pattern
M1: EOFs @ 22 km
M1: EOFs @ 20 km
M1: EOFs @ 17 km (~tropopause)
M1: EOFs @ 14 km

Node again
M1: EOFs @ 11 km

![EOF plots at 11 km depth](image)
M1: EOFs @ 8 km

[Images of EOF plots at 8 km for M1]
M1: PCs (indices)
M1: Cross correlations to known indices

PC1

PC2

PC3

PC4
Phase space diagram

Wind

RO temperature

Adapted from Wallace et. all. 1993
M2

Performing the PCA at each altitude level separately
M2: EOFs (space) and PCs (time)

EOFs

PCs

Explained variance ratio
M2: EOFs @ 30 km

No longitudinal dependency
M2: EOFs @ 27 km
M2: EOFs @ 25 km
M2: EOFs @ 22 km
M2: EOFs @ 20 km
M2: EOFs @ 17 km (~tropopause)

EOF2 adds information around the tropopause
M2: EOFs @ 14 km

Node again?
M2: EOFs @ 11 km

M2: EOF1 @ 11 km (56.7 %)

M2: EOF2 @ 11 km (9.9 %)
M2: EOFs @ 8 km
M2: PCs (indices)
M2: Cross correlations QBO winds @ 30 hPa
M2: Cross correlations QBO winds @ 50 hPa
M2: Cross correlations to Niño 3.4 SST index

3 month timelag

ENSO above the tropopause?
M2: Cross correlations Solar 10.7cm index
Some comparisons
M1: Reconstruction

Reconstruction using EOF1/PC1 and EOF2/PC2

Reconstruction using EOF3/PC3 and EOF4/PC4

QBO

ENSO
M1: Residual (anomalies - reconstruction)

Monthly mean temperature Anomalies (input field)

Reconstruction using all 4 EOFs and PCs
M1: Residual (anomalies - reconstruction)
M2: Reconstruction

Reconstruction using all the EOF1s/PC1s

Reconstruction using all the EOF2s/PC2s
M2: Residual (anomalies - reconstruction)

Monthly mean temperature
Anomalies (input field)

Reconstruction using all
EOF1s / PC1s and all EOF2s / PC2s
M2: Residual (anomalies - reconstruction)

Most of the variability explained by the two first PCs
M1: Temperature regression (2001-09 to 2017-02)

Notice the bump at the tropopause
M2: Temperature regression
(2001-09 to 2017-02)
Summary

- Derived proxies for atmospheric variabilities from GPS RO temperatures
- We did this with 2 methods
  - M1: Using the full input field
  - M2: The same as M1 but at each altitude level separately
- M2 describe the vertical structure better than M1