QBO and ENSO indices from GPS Radio Occultation to describe atmospheric variability

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A R S C l i S y s

Introduction

The GPS Radio Occultation (RO) satellite technique provides 15 years (since 2001) of high quality measurements with global coverage and high vertical resolution. These properties make RO a valuable dataset for the characterization of atmospheric variability.

Atmospheric variability arises from different physical processes and manifests itself on different time-scales. In this study, we focus on inter-annual atmospheric variability of the tropical troposphere and stratosphere, which mainly results from El Niño-Southern Oscillation (ENSO) and the Quasi Biennial Oscillation (QBO). To describe these modes of variability proxies (so called indices) are used (Fig. 1).

We perform a principle component analysis (PCA) of the RO temperature record to identify dominating variability modes and to provide vertically resolved atmospheric indices.

Input data

Wegener Center OPSv5.6 RO record.
Monthly mean temperature field.
Time: May 2001 to October 2016
Altitude range: 2 km to 35 km, 100 m vertical resolution
Latitude range: 30°S to 30°N
Horizontal grid: 5° x 5° in longitude and latitude

Data preparation:
Bilinear interpolation of missing data
Computation of **temperature anomalies.**
Temporal smoothing with a 1-2-1 running mean.
Detrended (Fig. 2).

Conclusions and outlook

We investigated the use of RO temperature time series for the computation of atmospheric variability indices. In method 1 we performed a PCA for the full 4-dimensional temperature field. We find that the first four principle components are needed to resolve atmospheric variability, PC 1 and PC 2 represent the QBO, PC3 and PC4 represent the ENSO. In method 2 we performed a PCA at each altitude level. Here, most of the atmospheric variability in the troposphere and stratosphere due to ENSO and QBO is explained by the first PC. In addition, PC2 captures some variability in the troposphere region and in the stratosphere.

In a next step we will test the performance of the provided indices over conventional indices in a multiple linear regression analysis. Especially for the computation of height-resolved atmospheric trends it is essential to account for height-varying variability patterns to properly remove their contribution in trend detection.

QBO indices

ENSO SST index

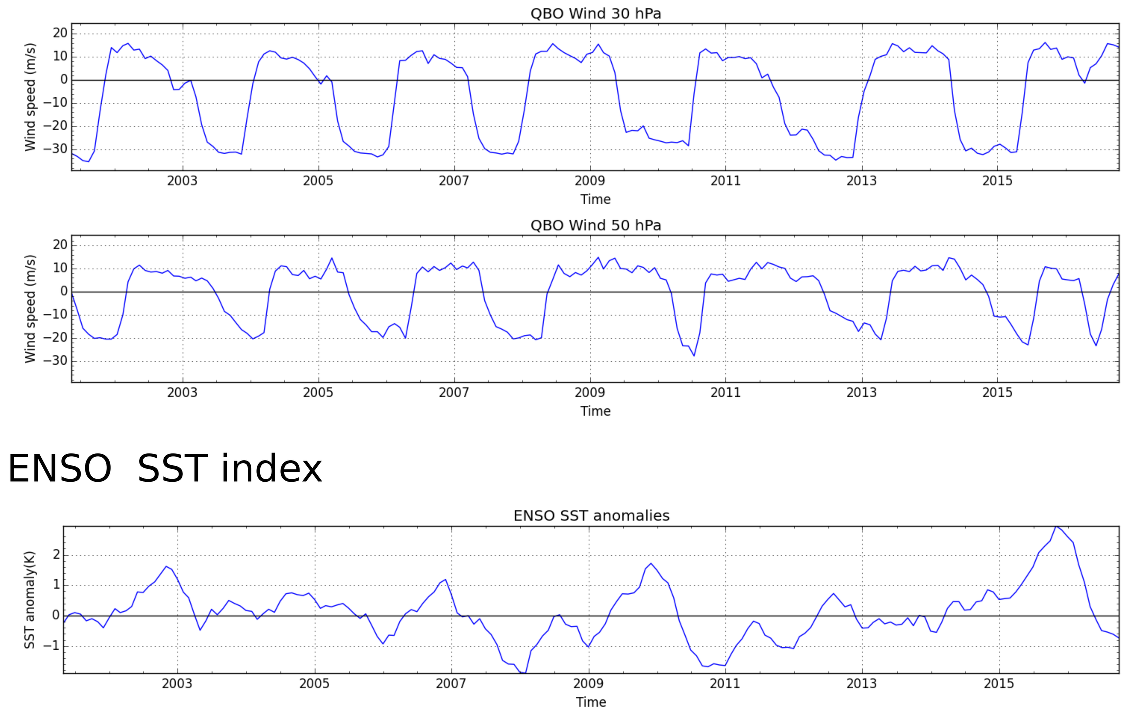


Fig. 1: Conventional QBO wind indices at 30 hPa (top) and 50 hPa (middle) and ENSO sea surface temperature (SST) index (bottom).

Method 1, M1

A space-time matrix is constructed. Latitude, longitude and altitude are stringed along one axis to reduce the dataset to two dimensions: time and space [altitude + latitude + longitude]. A PCA is performed on the whole dataset.

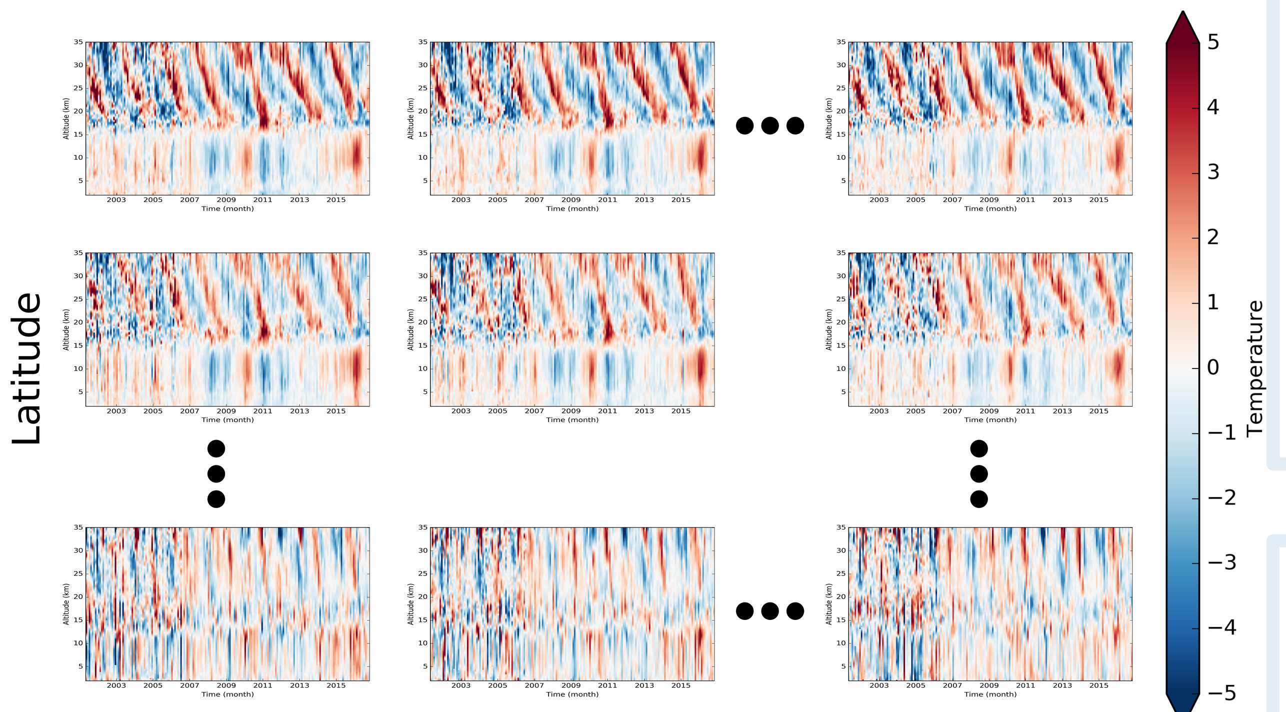
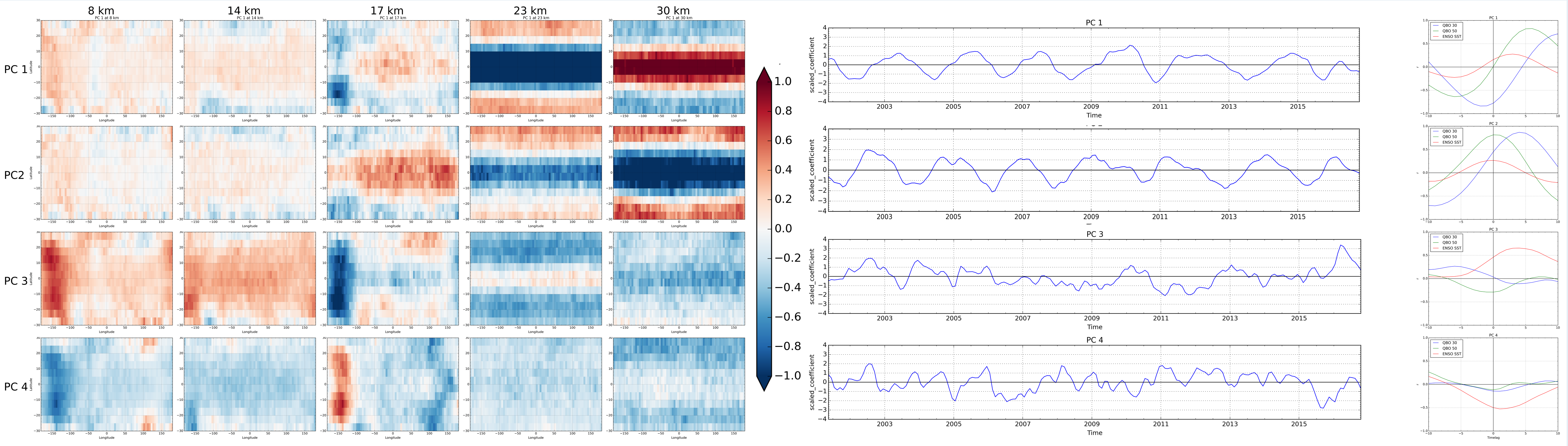


Fig. 2: Temperature anomalies as function of time and height for different locations of a 5° latitude x 5° longitude grid.

EOFs

Timeseries

Correlations



Explained variance ratio

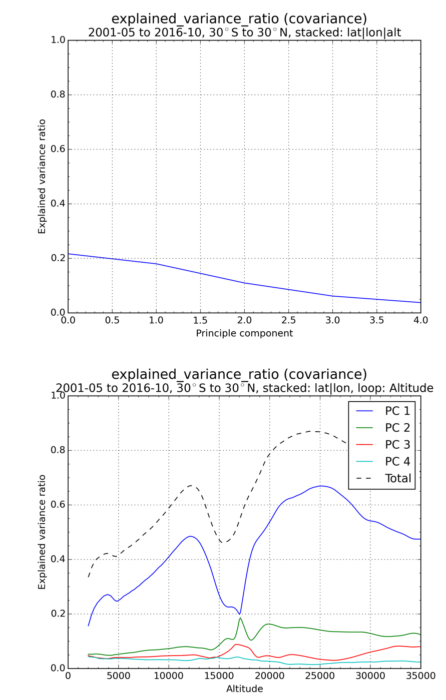


Fig. 6: Explained variance ratio for the PCs of M1 (top) and M2 (bottom).

Method 2, M2

A space-time matrix is constructed for each altitude level. Only latitude and longitude are stringed along one axis, leaving the dataset with three dimensions: time, altitude, and [latitude + longitude]. A PCA is performed at each altitude level.

EOFs

Timeseries

Correlations

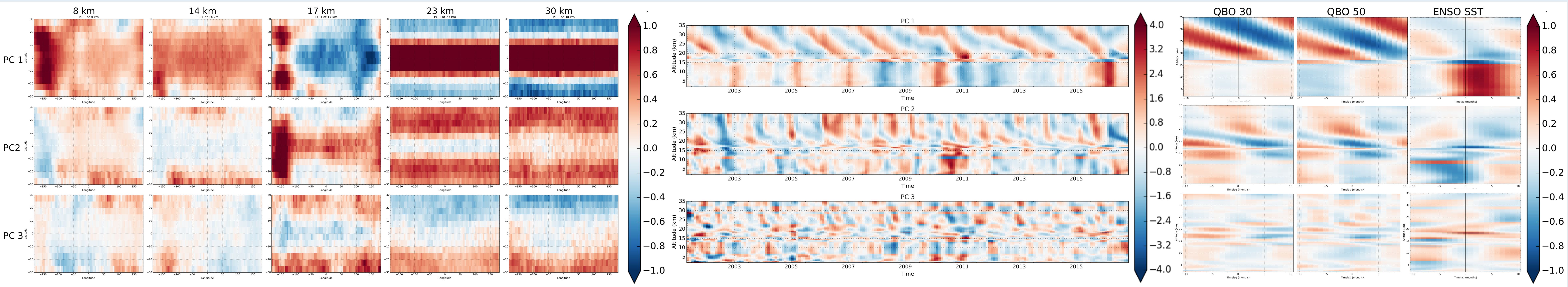


Fig. 3: Empirical Orthogonal Functions (EOFs, scaled eigenvectors) at selected altitudes (8 km, 14 km, 17 km, 23 km, 30 km). For M1 (upper panels), there is only one EOF for each Principal Component (PC). For M2 (lower panels), there is one independent EOF at each altitude.

Fig. 4: The PC time series that correspond to the EOFs are shown. For M1 (upper panels), there is only one timeseries per PC which represents all altitude levels. For M2 (lower panels), there is one time series for each altitude level.

Fig. 5: Correlation of RO-based PC time series to QBO wind indices and ENSO SST index for M1 (upper panel) and M2 (lower panel).

Acknowledgments
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