Geophysical Research Abstracts
Vol. 13, EGU2011-9872, 2011
EGU General Assembly 2011

GNSS Radio Occultation Trend Patterns for Atmospheric Climate Change Detection With a Fingerprinting Method

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The detection of climate change signals in rather short satellite datasets is a challenging task in climate research and requires high quality data with good error characterization. Global Navigation Satellite System (GNSS) radio occultation (RO) provides a novel record of high quality measurements of atmospheric parameters of the upper troposphere-lower stratosphere (UTLS) region. Due to characteristics such as long-term stability, self-calibration, and a very good height-resolution, RO data are well suited to investigate atmospheric climate change. We present a study investigating whether the multi-satellite RO record shows evidence of a forced climate change signal by using an optimal-fingerprint detection technique. This technique relies on data from observations (RO record), which are represented as the sum of a scaled forced climate change pattern and an estimate for internal climate variability. The latter two are estimated from simulations of three climate models (GCMs) of the IPCC 4th Assessment Report. RO refractivity, geopotential height, and temperature within two trend periods (1995–2010 intermittently and 2001–2010) are investigated. The UTLS variability is mainly influenced by two atmospheric patterns, the quasi-biennial oscillation (QBO) and the El Niño-Southern Oscillation (ENSO). Originating in the tropics, they also impact mid-latitudes. A multiple linear regression model was employed to estimate the share of the patterns in UTLS variability for RO data and to remove the ENSO signal from GCMs and RO and the QBO signal from RO (it is not contained in the GCMs) in order to get a cleaner climate signal. Results show that for the given intermittent 15 year period and the continuous 9 year period, the multi-satellite RO records show an emerging climate change signal, which is consistent with the projections of the GCMs. The trend signal of the shorter 2001 to 2010 period is still masked by natural variability, even though consistency between RO and GCM trend patterns is given. Concerning the longer period, climate change can be detected at a 90 % confidence level for refractivity and geopotential height. Lower confidence levels are achieved for the temperature record when only large-scale aspects of the pattern are resolved. When resolving smaller-scale aspects RO temperature trends appear more than two times stronger than GCM projected trends, the difference stemming mainly from the tropical lower stratosphere, allowing for climate change detection at a 95 % confidence level. Putting the detected change signal into context with natural changes (solar and volcanic), those processes can be considered to provide minor contribution only for the period discussed, suggesting that this change has been mainly caused by anthropogenic influence on climate.