

First continuous ground-based observations of long period oscillations in strato-/mesospheric wind profiles

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This paper outlines the first science results from an opportunistic network of novel ground-based Doppler radiometers. The potential to record continuous wind measurements in the upper stratosphere and mesosphere is quite unique to this instrument type and could well complement the existing ground-based, air-borne/in situ and satellite observing networks, where direct wind measurements are limited to balloons, airplanes, lidar and meteor radar. The authors do well to analyze (admittedly) short time series from the small number sites operating this instrument and report evidence for planetary waves and middle atmosphere wind seasonality. The paper highlights good agreement with ECMWF Operational Analyses within the stratosphere but with important differences above the stratopause. The latter is thought to be due to the paucity of observations assimilated by ECMWF during the times of the WIRA campaign.

This is a good first science paper but does suffer from the short WIRA record. Nonetheless it would appear to highlight the potential for a wider use of these profilers which would also benefit centres such as the ECMWF in producing more accurate weather and climate products of the upper atmosphere. Pending due consideration of the comments below, I would recommend publication.

Comments:

The authors make use of the Lomb-Scargle method to reconstruct periodograms used in the analysis of wave-types. As seen in the Supplementary Text, the unaltered ECMWF OA periodograms seem to show weaker spectral power in the mesosphere as compared to the data which is sampled as WIRA (i.e. excluding data poor times). The weaker signals are more like the WIRA data. The authors cite previously published deficiencies in the ECMWF data to explain this bias, but does sampling play a role here too.

Can one use a resampling procedure (with replacement) to reconstruct confidence intervals in the ECMWF data, sampled as WIRA. The existing ECMWF data seems overly, "significant", so it might be worthwhile to check against a non-parametric approach like this.

Specific Comments: I leave it to the discretion of the editor and authors just show many of the suggested grammatical corrections are adopted. However, the authors would do well to address the use of language throughout the text

(Title) I would replace "strato-/mesospheric" with "stratosphere-mesosphere" or even "middle atmosphere"

(35036, L5) "...measurements of tracers..." -> "...tracer measurements..."

(L11) suggesting removing the word "model"

(L15) suggest removing "As shown by current research", i.e. "An accurate representation of middle atmosphere dynamics can..."

(L17) What is meant by long time scales in this context? Seasonal?

(L18) "validation"

(L20) The last sentence does not make sense, please rephrase.

(L24) Suggest, "For studying long period oscillations long and continuous measurements are required."

(35037, L1) "non-existent" and remove "so far"

(L5) Suggest, "...have been previously used to retrieve vertical profiles of horizontal wind...of providing long and continuous measurements for the analysis..."

(L10) "Presently available lidar data are too short for long-period spectral analysis, whereas"

(L13) "Wind data from rocket soundings..."

(L16) "Horizontal wind oscillations..."; remove "region"; "...have been extensively studied..."; "In the upper stratosphere and lower mesosphere, analyses of long period oscillations in trace gas concentrations, such as ozone and water vapour, have been reported..."

(35038, L3) "The Doppler Wind...is a novel ground-based...used for continuous observation of horizontal wind profiles, which is a unique strength of this instrument."

(L12) "However, as indicated by Rodgers (2000), features vertically spaced..."

(L17) "A strength of microwave radiometers is their ability to take measurements day and night and under overcast conditions. This strength, compared with low operation costs, allows for the generation of long and continuous time series."

(L26) "...comprise both zonal and meridional components."; "untrustable"->"untrustworthy" perhaps (also Figure 1 caption).

(35039, L1) It is stated that a strength of the instrument is that it can "see" through overcast conditions, but it is nonetheless adversely affected by tropospheric water. Can the authors expand a little more on this. Also, "The altitude range sensitivity largely depends on the signal-to-noise ratio of the receiver as well as on the tropospheric conditions, especially the water content. The sensitivity was significantly improved by an instrument upgrade in autumn 2012."

(L6...) How about, "The European Centre for Medium-Range Weather Forecasts (ECMWF) is a major service provider of weather and climate data products. The Operational Analysis data used in this study combines meteorological data from a variety of different observing platforms with a continually updated climate model". I am not sure the 6-hourly output is relevant here. You might like another sentence describing how the Operational Analyses differ from reanalyses (i.e. underscore the model is receiving updates in the former and not the latter), and also what observations are being assimilated at the heights relevant for WIRA. That is are you effectively comparing against a model (i.e. very few observations are being assimilated)?

(L8) "measurement data"-> "observations"

(L23-25) "...with periods ranging from 5-50 days are intermittent, showing little phase preference"

(35040, L3) "and the use of a Hamming windowing function to help minimise spectral leakage."

(L9...) I would suggest simply referring to a single reference, such as Press et al ("Numerical Recipes") for the Lomb(-Scargle) description, only referring in text to departures from the standard treatment or to the particular application of the statistical tests used here.

(35042, L1) "Spectral analyses have been performed on daily-averaged wind data from WIRA and ECMWF Operational Analysis."

(L8) Remove the words "The results for the", i.e. "Analysis of the unaltered ECMWF time series is shown in Figs. S2 and S3 of the Supplement Material."

(L14) "cause trustable" - not a good phrase. How about "less significant" or some other.

(L16) I think "seasonal averages" is not the right phrase to use here. The profile-spectra simply apply to a time window having length 7 or >12 months, depending on data set used. Also altitude dependent temporally averaged periodogram does not sound right either, how about profile-time periodograms? Just a thought.

(L18) "lower"->"lesser"

(L20) Perhaps the authors can comment on the phase of the solar cycle during the measurement campaigns (i.e. during solar max there is a conspicuous 27-day rotation period which is largely absent at other times). Also, in the stratosphere, at least, conspicuous 20-30 days oscillations can be seen in annular mode (AM) data, and has been linked with the shouldering of AM autocorrelation function in tropospheric and stratospheric data (e.g. Ambaum and Hoskins, 2002).

(35043, L1), "if existing"->"if present" or "at best"

(L8) "measured average periodogram": can the authors think about rephrasing instances of this throughout the text please.

(L10) Presumably the authors refer to the Nyquist limit for diagnosing the 2-day (planetary) wave in the "daily averaged" data? Also use 2-day, 5-day notation for describing these particular planetary wave types.

(L11) I do not see the 5-day feature the authors refer to in the text. Well perhaps so in the Provence data, but not so in Sodankyla nor Bern.

(L14) "Oscillations". Also probably start next sentence with "Evidence for the 16-day wave...", as no independent evidence has been provided that the wave should be seen here.

(L20) High wind speeds can also be seen in figure 1. The authors need to weaken their statements of high interannual variability inferred from data covering effectively 2 winter seasons and different monitoring equipment and locations. Please simply reference an independent paper here (there are plenty!).

(L28) "Analysis of the ECMWF data which has been similarly sampled to that of the WIRA data...". The remainder of the sentence should be rephrased: you are validating the WIRA data against the ECMWF Operational Analysis data not the other way around! To reiterate from a previous comment: it will be good to know what observations are being assimilated by the ECMWF OA (are you seeing model or observations?). One might also check to see if the ECMWF forward model, used in the development cycles mentioned, employ a (spectral) gravity wave parameterisation suitable for the

upper stratosphere and mesosphere. If they do not, and there are little to no observations at upper levels, this would be consistent with the overly strong winds seen in the analysis data.

(35044, L10...) Re: previous comment, you indirectly mention the issues I raise, but specific details of mesospheric observations and gravity wave parameterisations would be good to include here.

(35045, L2) "Atmospheric waves can be intermittent in nature (i.e. wave-packets). Accordingly, the temporal evolution of waves were examined."

(L9...) "...and is consistent with the absence of measurement noise." Also, please relax statements about seasonality in the text. Features seen in figures 4 and 5 may very well be due to seasonal differences in variability, but the length of your time series are not long enough to show this. However, if you were to add the caveat of looking at an extended time series of ECMWF OA data, statements to this effect could be added.

(35046, L22...) "...with the wave features showing pronounced temporal intermittency" The analysis and comment here about signatures for a solar signal is not very strong, as the data length is small (even for the 27-day rotational period) and there are no hypotheses about how the forcing might manifest within the short time record of winds ("...however solar forcing might influence the atmospheric wave pattern in an indirect way.").

Sentence starting, "An augmented presence..." does not read well and should be rephrased.

Sentence following this one describes the low frequency variability as a wave. It has not been established whether this longer period variability (20-50 days) is wave-like and not just part of a broader spectrum of variability.

Care must be taken in making overly assertive statements of strong seasonality. Two of the stations are close to one another, one is in a sub-tropical location and there is 5 months to a about a years worth of data between the separate radars. Seasonality is to be expected, but please first place this in the broader literature.

(35047, L7) How about, "In addition, the ECMWF Operational Analysis data shows reduced variability (<10 days) as compared with the WIRA data."

(L11) Is there a better reference to use for the EU ARISE project?

(L16) "...used in WIRA's retrieval algorithm as described in Rüfenacht et al. (2014)"