Review

Title: Fluctuations of radio occultation signals in sounding the Earth's atmosphere
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The authors investigate the dominant cause of fluctuation (scintillation) in Earth radio occultation data: clear air turbulence or internal gravity waves. Toward this end they assume empirical spectral forms for the turbulence (Kolmogorov) and for saturated (breaking) internal gravity waves (the "universal" spectrum). They apply a well known analytical method (Rytov approximation for weak scintillation) for relating the power spectra and cross spectrum of log-amplitude and phase scintillations as observed by a radio occultation receiver to the candidate power spectra of refractivity variations. The fundamental key to their test is that clear air turbulence is expected to be isotropic in space whereas gravity waves are anisotropic. If the former is true, the power spectra should depend only transverse motion at ray perigee; if the latter is true, the power spectra should depend solely on ray descent speed. Radio occultation data shows the latter to be true through most of the upper troposphere. The analysis approach of this work is based on a long tradition of radio scintillation analysis begun by Tatarskii, who developed a theory of wave propagation through random media, which is sound. This article should be published pending minor revision, which involves a modicum of additional analysis and justification of approach and significant improvements to grammar.

The authors should present a justification of the spectrum of internal gravity waves (IGW) that they incorporate. For Kolmogorov turbulence, description of its fluctuations by empirical power law is satisfactory. For gravity waves, the case for its description is more difficult. The "universal spectrum" of gravity waves is valid where gravity waves break, due to either Kelvin-Helmholtz or simple convective instability. Its power density spectrum follows a -3 power law in vertical wavenumber; however, its power density spectrum most assuredly does not follow a -3 power law in horizontal wavenumber as incorporated in this manuscript. The power density spectrum in the horizontal rather follows a form that is characteristic of the original source of the gravity waves. Moreover, IGWs break at different levels depending on the strength of their source: moist convection, orographic, jet stream breakdown. Even though it is probably discussed in the some of the papers they cite, the authors should nevertheless offer some justification for assuming the form of the power spectral density of the IGW in horizontal wavenumber as they did and why specifying IGW breaking parameters as a function of height the way they did.

The log-log plots of power spectra the authors present span only one and a half decades, meaning that there is only the slightest constraint on determination of the power law when significant spread between spectra is present. Such is the case in this manuscript. The authors must distinguish between a -3 power law characteristic of IGWs in the log-log plots and a -5/3 power law characteristic of Kolmogorov turbulence, which can be done easily by including a -5/3 line on the power spectral density plots.

Page 1, line 19: "stimulated"
Page 1, line 20: "Currently, RO sounding…"

Page 2, lines 1-3: “The stability of GPS signals, complemented with its global coverage and high vertical resolution, draws the attention of researchers to the study of inhomogeneities in atmospheric refractivity in addition to the retrieval of mean profiles.”
Page 2, line 10: “empirical”
Page 2, line 11: “component described”
Page 2, line 12: “the isotropic component as Kolmogorov turbulence”
Page 2, line 18ff: consider calling it “weak scintillation theory” rather than “weak fluctuation theory” throughout the manuscript.
Page 2, line 21-22: “about 30-35 km where residual ionospheric fluctuations and measurement noise become dominant.”
Page, line 23: “In the visible band,…” Throughout the text, call it the “visible” band rather than the “optical” band. “Optics” refers to a kind of signal dynamics that spans most frequency bands, including microwave, infrared, visible, and ultra-violet.
Lines 25-26: “In the radio band, the leading cause of the inhomogeneities is IGWs, whose spectra are characterized by a steep power spectral decrease with increasing wavenumber.”
Line 31: “dominate the radio signal…”
Line 32: “The aims of this paper are to clarify the role of the two inhomogeneity types and to evaluate their actual contributions…”
Page 3, line 2: “complicated dynamics of lower-tropospheric…”
Line 3: delete “the basic models and approximations”
Line 4: “screen approximation, the weak fluctuation/scintillation theory, and the approximations entailed. In Section 3 we apply these methods to derive…”
Line 17: “statistical average” should be better defined, most likely as “regional average”.
Line 17-18: “Refractivity fluctuations depend…”
Page 4, lines 7-8: “are wavevector parameters corresponding to the outer and inner scales, respectively.”
Page 4, line 10ff: The vertical wavenumber spectrum for saturated gravity waves is usually referred to as the “universal spectrum”. Be sure to cite the original work: Dewan and Good 1986.
Lines 15-27: The idea of “critical anisotropy” is new to me. To what phenomenon does it refer? Be clearer.
Lines 28-30: I’m not sure what this sentence means.
Page 5, line 3: “A = 0.033”
Page 6, equations 4, 5ff: Be clear about the “minus-plus” notation and why you use it. It took me a while to figure out.
Page 7, equation 7: When the thin screen approximation is itself in the small screen approximation with respect to the Earth’s curvature, I wouldn’t expect there to be any dependence on the Earth’s curvature in any equation. So why does the Earth’s radius occur in equation 7? Also, write out \bar{\Psi} explicitly.
Equation 8: Does this math also consider distortion of the Fresnel zones by the differential ray bending by the atmosphere’s vertical structure?
Page 8ff: Be sure to define precisely the angles \alpha, “occultation angle”, “obliquity angle”. I cannot tell what these angles are.
Page 8, line 14: “or grazing occultation”
Page 11, line 4: “Numerous radiosonde profiles and…”

Page 11, line 8: The value given for L_W is in fact highly variable throughout the global atmosphere. It should have been mentioned somewhere in the introduction that the intention is to qualify RO scintillations as due to turbulence or gravity waves in a gross, global sense.
Page 12, line 3-5: I do not understand this sentence.
Page 13, lines 1-2: "The variances of RO log-amplitude and phase fluctuations…do not contain direct information…" Why can't turbulence be anisotropic at its outer scales? Most of the atmosphere is stably stratified, resisting vertical motion, which means that turbulence would natural seek to extend in the horizontal rather than in the vertical.
Line 4-5: delete "to which the anisotropic…"
Line 5: "This information can be extracted from an ensemble of 1D spectra of RO signal fluctuations, when categorized according to frequency or to vertical wavenumber."
Line 8: What is the oblique movement velocity? Define. "they" should be "the"
Lines 9-10: "for a highly oblique occultation." Delete "due to the geometrical difference…" to the end of the sentence.
Line 16: What is the inclination angle?
Line 22: Linear trends in what? "Figures 2 and 3"
Line 33: "spectral window with variable width"
Line 33-34: Be clear about f. No need to write "Q-factor", a term more appropriate to prescriptions of oscillatory systems.
Page 14, line 1: "Figures 2 and 3"
Line 5ff: Be clear about what you mean when you write "isotropy hypothesis", "anisotropy hypothesis". I believe that the isotropy hypothesis is that the scintillations are caused by Kolmogorov turbulence and that the anisotropy hypothesis is that they are caused by breaking internal gravity waves. The text must be clear on this.
Lines 8-9: "frequency. With increasing occultation angle (???), the maxima systematically…"
Line 10: "all the spectra are peaked near wavenumber 1, which represents the first Fresnel zone…"
Lines 17-19: I don't understand this sentence.
Page 15, line 3: I suspect the "deep oscillations" are a reference to diffraction fringes.
Lines 3-4: "The slope of the spectrum at high frequencies agrees…"
Lines 6-7: This sentence needs clarification. What is \alpha, and what does it have to do with anisotropy?
Line 10: "they mostly exceed the theoretical..."
Line 11: "RMS values prove the validity…"
Line 14: The definition of "eikonal" should be moved much earlier in the document. Either that, or use term "phase" instead throughout the paper. It is a term much more commonly used in the RO community.
Lines 19-20: What are the "first approximation" and the "first term"?
Page 16, line 8: What is a Hann window? Give a reference.
Line 9: "Figures 4 and 5…"
Line 14: "These spectra are in fair agreement…"
Page 17, lines 2-3: "1) isotropic Kolmogorov turbulence, and 2) anisotropic saturated IGWs."
Line 4: "phase with empirical 3D…"
Page 18, line 5: What are "small altitudes"? The boundary layer?
Lines 8-9: "permit a diagnosis of wave activity…"
Line 18: "IGWs are additionally restrained…"

Line 23: Replace “close” with “similar”.
Lines 23-24: Remove the sentence. It is obvious.
Line 33: What are “occultation angles”?
Page 19, line 7: Estimates of what?
Line 8: Begin the sentence with “In the stratosphere and upper troposphere, …”
Line 14: “perturbations are sinusoidal.”
Line 16: What is “higher resolution”? Higher than what?
Page 20, line 2: “On the other hand, for quick estimates, …. The amplitude variance permits the …”