**Atmospheric
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Interactive comment on "Tomographic retrieval approach for mesoscale gravity wave observations by the PREMIER Infrared Limb-Sounder" *by* J. Ungermann et al.

Anonymous Referee #2

Received and published: 17 December 2009

Referee Comments on Ungermann et al,

"Tomographic retrieval approach for mesoscale gravity wave observations by the PREMIER Infrared Limb Sounder"

Summary ——-

The paper describes simulated retrievals of idealised gravity waves from measurements made by the proposed infrared limb-sounder component of the PREMIER satellite instrument.

The set-up consists of simulated observations of a horizontally homogeneous atmo-

sphere with superimposed gravity waves of various horizontal and vertical wavelengths, which are then passed through a 2D (tomographic) retrieval system. Given the number of the measurements and retrieved points, this is in itself a major undertaking.

The authors show that these waves can be well-retrieved close to the Nyquist limits predicted by the the measurement grid, thanks to the low S/N of the instrument (only a single spectral point is used in this study).

They also demonstrate that a good approximation to the observational filter derived from such end-to-end simulations could also be constructed from just a linear analysis based on the averaging kernel matrix, and that a 1D retrieval using the same set of measurements produces significant distortions.

Comments ———

While I have only minor comments and questions on the methodology and results, my main criticism of this paper is that the authors do not adequately highlight the differences between this idealised case and the additional problems likely to be encountered in reality. There is a danger than non-experts might read this paper and cite it as evidence that gravity waves *will* be retrieved with high precision from such an instrument.

For example, only monochromatic gravity waves are considered with, effectively, infinite extent whereas in the real atmosphere the situation will be more complex, as evidenced by the fairly complex mathematical methods required to extract gravity wave signatures from CRISTA and HIRDLS data (ie not just simple fourier transforms).

Perhaps more importantly, only random errors (measurement and forward model) are assumed - in reality there would be some correlation in the Se matrix, at least due to the forward model errors. On p2824, line 16 this is dismissed: "other systematic errors can more readily be handled by detrending". But this seems to be based on the assumption that any systematic (or correlated) errors in the forward model simply map into the retrieved temperature as biases or linear trends. In reality, they are likely to trigger

oscillations in the retrieved profiles (due to the intrinsic anticorrelation between spatially adjacent retrieved points) which may well obscure some of the short-wavelength gravity wave structure and/or lead to false detection.

The retrieval itself, just the temperature profile, is a highly simplified version of what would be required in reality. For limb-sounders it is generally also necessary to re-trieve tangent pressure, possibly contaminant gases (Fig 1 shows a significant ozone contribution at the chosen spectral point) and continuum emission terms. These not only detract from the information available for a pure temperature retrieval but also pro-vide other degrees of freedom into which the gravity wave signal may be incorrectly assigned. This is, of course, just a simulation, but for the benefit of those readers unfa-miliar with the practicalities of limb-sounding, the authors should at least mention these extra considerations.

Finally, there has been significant recent, and relevant, work on detection of gravity waves using data from the HIRDLS instrument. There should be some acknowledge-ment and discussion of this.

Minor comments and suggestions ————————————

P2810, L2: "The main mission objective" - I assume this refers to PREMIER rather than the EE7 "mission" referred to in the previous sentence.

P2810, L6: Arguably, Aura was the first with TES as the limb imager (albeit 1D) and MLS as the microwave instrument.

P2814, L5: Here it says that there is "great flexibility" in spatial/spectral resolution, but on P2811 L23 it says that there are just two different operating modes (which does not imply any great flexibility).

P2814, L9: spectral sampling is "relaxed to 1.25cm-1". It would be helpful to say what it is relaxed from, ie the maximum sampling that could be obtained.

P2814, L13: you might as well add H2O to this list to match the molecules identified in

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Fig.1

P2814, L14: Here it says that the vertical coverage is 48km. However, on P2813 L18 it says "from 5-55km", which is 50km.

P2816, L15: "order of magnitude smaller than the forward model error itself". But you don't say what the "forward model error" is. Perhaps a comparison with the instrument noise would be more meaningful.

P2817, L1: "fast and accurate" are usually contradictory requirements. "fast" is probably more essential than "accurate" in the context of solving large inverse problems.

P2817, L9: Add "AIRS", the acronym by which this instrument is better known.

P2818, L16: "kernel functions" (section 4.2). P2813, L27: "weighting function", also section 5.2.1) P2821, L20: "Jacobian" Do these terms seem all mean the same thing?

P2819, Eq 1: This equation makes little sense - it seems that something has gone wrong in the typesetting of the second term inside the square brackets. Even with the correct equation, I think a diagram would help clarify things.

P2819, L14: "extent along the LOS". Is this really along the LOS or along the x-axis (assumed parallel to the earth's surface?).

P2820, L2: The reference to Hadamard 1902 is rather obscure, not helped by the title in the References section being in French and mistyped anyway (words such as "problmes" and "drives" seem to have lost the accented "e"s). I suggest omitting this reference altogether since the concepts are now well-established.

P2820, Eq(2): $F(x)$ is undefined.

P2820, L24: Give an approximate factor indicating by how much n exceeds m.

P2821, L6: Noise is given in (nW/(cm2...) but elsewhere (W/m2...) are used. (same applies to Fig 1 caption). Better to use same units throughout. And how does one

interpret "0.3% of radiance" in this context? (give approx range of values in radiance units for comparison with noise).

P2821, L14: Give some indication of size of sigma_i.

P2821, L17: Presumably the temperature retrieval above 55km is at the 2km grid spacing referred to on 2816,L9? Restate this here for clarity anyway.

P2821, L20 (and subsequently) Suggest using "K" rather than "F'(x)" since this is more standard (and since you define "F'(x)" as the "Kernel" matrix anyway).

P2821, Eq(4): First F(xi)T should be F'(xi)T

P2822, L5-15: Presumably the horizontally periodic structure in Fig 5d is due to some sort of "beating" effect between the horizontal wavelength and the measurement grid.

P2822 L18: Suggest changing this to "describes some of the characteristics" or "characterises the retrieval". (There are other retrieval characteristics, such as error covariance, which are not described by the averaging kernel).

P2823, L4: "area below the rows of the ... matrix" is confusing ("area" in conjunction with "matrix"). I think what you mean is "summing the elements in a row ...".

P2823, L26: I can see why the horizontal resolution should approach the measurement sampling but I don't know that it is valid directly to compare this with the 475-575km FWHM widths of the weighting functions which are presumably those measured along the LOS rather than the horizontal.

P2823, L28: PREMIER only exists as a concept at the moment, so change "PREMIER is" to "PREMIER would be".

P2824, L7-9: You mention "retrieval covariance matrix" but don't explain what this is. I assume it's the standard OE "m"-form: Sx = Sa - Sa KT (K Sa KT + Se) K Sa If the retrieval gets most of its information from the measurements (rather than the a priori) then this should be a reasonable approximation to G Se GT. However your comments

about not using the above form suggest that the a priori does contribute significantly. Is this actually the case?

P2824, L21: Isn't the horizontal wavelength equally important in defining the wave energy?

P2825, L19 (& Fig 8 caption): I didn't really understand the concept of "running to-wards" and "running away" from the instrument. Does this refer to the lines of constant phase (eg in Fig 5) tilting towards/away from the satellite with altitude (which I assume is to the left in Fig 5 given the slant of the tangent points). If so, which is the situation represented by Fig 5 - running towards or running away?. At the end of section 6.1 I think you're trying to explain the asymmetry between Fig 8a and 8b as due to the optical thickness of the atmosphere, but does the slope of the tangent points also contribute to this asymmetry?

P2830, L10-11: This sentence is a bit ambiguous. I think what you mean is: "for a homogeneously stratified background atmosphere, the 2D retrieval ...etc." although it could be read as ".. 1D retrievals (which assume a homogeneously stratified at-moshere)".

P2830, L18: It is stated that the 1D retrievals have a phase shift of 180deg compared with the "true" atmosphere. Is the reader supposed to be able to note this from Fig.11? (which doesn't actually show deviations from the true atmosphere). Perhaps add some lines to these plots showing locations of max/min amplitude in the "true" atmosphere.

P2833, L24: What is "equation system solving"?

Fig 2 caption: I assume that the satellite is on the left in this (and subsequent) figures. I don't understand what the last sentence means: "The across track ... centreline".

Typographical/Grammatical corrections ————————————————-

P2811, L5: "NIMBUS" should probably be "Nimbus" since it is not an acronym.

P2811, L9: Change "EGA" to "ESA"

P2811, L17: Change "PEMIER" to "PREMIER". Also the acronym should be expanded here, on its first use, rather than L22.

P2811, L20: remove comma after "necessary"

P2811, L24: remove "operating" (superfluous in context of this sentence).

P2812, L6: replace "assessed" with "accessed"

P2812, L9: no hyphen in "meso-scale"

p2812, L9: change "GW" to "GWs"

P2812, L10: Change "observations of GWs is" to "observations of GWs are"

P2812, L12: Suggest "They contribute about 50% to the driving..."

P2812, L18-20: "Currently ... at [the] present time" - remove one of these.

P2813, L1: Change "to accurately determine" to "to determine accurately"

P2813, L17: Suggest "provide about 10 000 simultaneous limb-views..."

P2815, L16: Rephrase as: "so as not to obscure"

P2815, L17: Change "capacities" to "capabilities"

P2815, L23: Change "line-of-sights" to "lines-of-sight"

P2815, L25: "viewed from multiple viewing angles" - suggest deleting "viewing".

P2815, L25/26: suggest rephrasing as "suggests a tomographic retrieval approach". Current wording implies that this situation presents a particular *difficulty* for tomographic retrievals.

P2816, L11: Change "other tracks" to "tracks other"

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P2816, L19/L20: Change to "as a priori" to "as the a priori".

P2817, L8: Change "applied on" to "applied to"

P2818, L1-2: Change "To sufficiently sample" to "To sample sufficiently"

P2818, L13: Change "two times as dense" to "twice as dense"

P2818, L14: Change "tangentpoints" to "tangent points"

P2819, L15: Move comma after "atmospheres" to after "thin".

P2819, L16: Change to "As a kind of ..."

P2820, L2: Change "with poses" to, eg, "presents"

P2821, L1: Change to "As an initial guess ..."

P2822, L3: Changes "profiles like described" to "profiles as described"

P2822, L6 & L11: Remove ")" after "5c)" and 5d)"

P2823, L13: Suggest rephrasing "... represents, as depicted in ..."

P2823, L14: "vertical respectively horizontal" - I don't know what this means.

P2827, L1: Insert comma after "Apparently"

P2829, L7: Change "well detectable" to "well detected" or "easily detectable".

P2928, L7: Change "computational" to "computationally"

P2831, L12: Change "GW with a ..." to "GWs with a ..."

P2831, L21: Change "length" to "lengths"

P2831, L27: Change "to inexpensively calculate" to "to calculate inexpensively"

P2832, L4: Change "GW" to "GWs"

P2832, L11: Change "will provide" to "should provide"

P2832, L25: Change "LIMB" and "NADIR" to "limb" and "nadir".

P2834, L3: Change "compute nodes" to "computer nodes"

Fig 3 Caption: Change "Line-of-sights" to "Lines-of-sight".

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Interactive comment on Atmos. Meas. Tech. Discuss., 2, 2809, 2009.

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