

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 2013		2. REPORT TYPE		3. DATES COVERED 00-00-2013 to 00-00-2013	
4. TITLE AND SUBTITLE Observation and modeling of tsunami-generated gravity waves in the earth's upper atmosphere				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) NWRA/CoRA,3380 S. Mitchell Lane,Boulder,CO,80301				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 3	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Observation and modeling of tsunami-generated gravity waves in the earth's upper atmosphere

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LONG-TERM GOALS

To determine the response of the 630 nm airglow in the thermosphere to gravity waves excited by ocean tsunami.

OBJECTIVES

To build a compatible set of models which 1) calculate the atmospheric gravity waves (GWs) excited by a tsunami, 2) propagate these GWs into the thermosphere, and 3) reconstruct the GW field in the thermosphere (e.g., neutral wind, density and temperature perturbations caused by the GWs) as a function of space and time. These perturbations will then be given to Dr. Makela's group in order to calculate the 630 nm airglow response to these GWs.

APPROACH

Dr. Vadas has already built a similar set of models for GWs excited by deep convective plumes previously. However, these models cannot be simply applied here, because

- 1) the GWs excited by deep convective plumes require a different analytic model (plane wave versus a single "impulse" for convective plumes), and
- 2) convective plumes are pinpoint sources, unlike tsunamis.

Our approach is to first derive analytically the Fourier-Laplace compressible solutions to GWs excited by a plane wave. (A tsunami can be decomposed as a sum of plane waves.) These solutions are in spectral space. We will then "sprinkle" these GWs in x,y space (regular or random). We will then ray trace these GWs into the thermosphere, and reconstruct the GW field there. Note: this latter model is the same as that for the convective plumes, and is therefore "done".

WORK COMPLETED

Before beginning work on deriving the GW solutions, we first needed to perform a literature search in order to understand what was done previously. We have now fully completed this task. In doing so, we determined what we would like to include in our models that was not included previously. For example, one model only solved the Boussinesq equations in a non-viscous thermosphere. We decided that it would be better to solve the compressible equations, because the phase speeds of the excited GWs were near the speed of sound in the atmosphere, and therefore errors would like occur if only calculating the Boussinesq solutions. Additionally, our ray trace model automatically takes into account the extremely important effect of viscous dissipation in the thermosphere. Another model solved the steady state solutions. But a tsunami is a transient source. We are therefore using a ray trace model which solves wave packet (not steady state) solutions.

We then set up our equation set, which is the compressible, Navier Stokes equations in the presence of a plane wave vertical force. This force models the displacement of the air directly above the moving ocean tsunami. We then linearized these equations, and solved them using Fourier-Laplace techniques. These are the same techniques we used previously (Vadas, JGR, 2013). We checked that these solutions were correct by plugging them back into the original linearized equations. These solutions were presented at our recent CoRA/NWRA site review.

RESULTS

The Fourier-Laplace analysis shows that there are “two” GW solutions. One is GWs which have the same wave period as the tsunami (i.e., “forced” waves). The other is “free” GWs which have a spectrum of different wave periods and scales. These second set of GWs have not been modeled previously, because previous models were more heuristically-based. Because GWs with periods that do not match the tsunami period have been observed in the 630 nm layer, it is possible that these second set of GWs may be able to better explain these observations. Thus, they may be quite important for understanding the complexity of the observations.

IMPACT/APPLICATIONS

Because we are building a more realistic set of GW excitation and propagation models, our GW solutions may provide for a much better understanding of how tsunamis affect the 630 nm airglow layer. This would greatly enhance our ability to detect tsunamis in the 630 nm airglow layer and in the ionosphere in general.

RELATED PROJECTS

Not at this time.