MODEL FOR AIRGLOW PERTURBATIONS DUE TO IGW

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Abstract

Airglow 630 nm emission is localized around 250 km height and it allows the detection of Internal Gravity Waves (IGW) through perturbation in its intensity. Along with activity related to ionosphere dynamics, gravity waves triggered by lower atmosphere or ocean phenomena can be observed. The recent tsunami event of 11 March 2011 allowed the first airglow observation tsunami-driven IGW in Hawaii. We present here airglow modeling results of IGW excited by a realistic tsunami propagating through the Pacific ocean. The model includes the propagation of the gravity wave in the atmosphere, the coupling between neutral and charged particles in the ionosphere and the emission of the 630.0 nm airglow. Synthetic all-sky images are calculated by integrating the emission along rays from the camera location to the airglow layer.

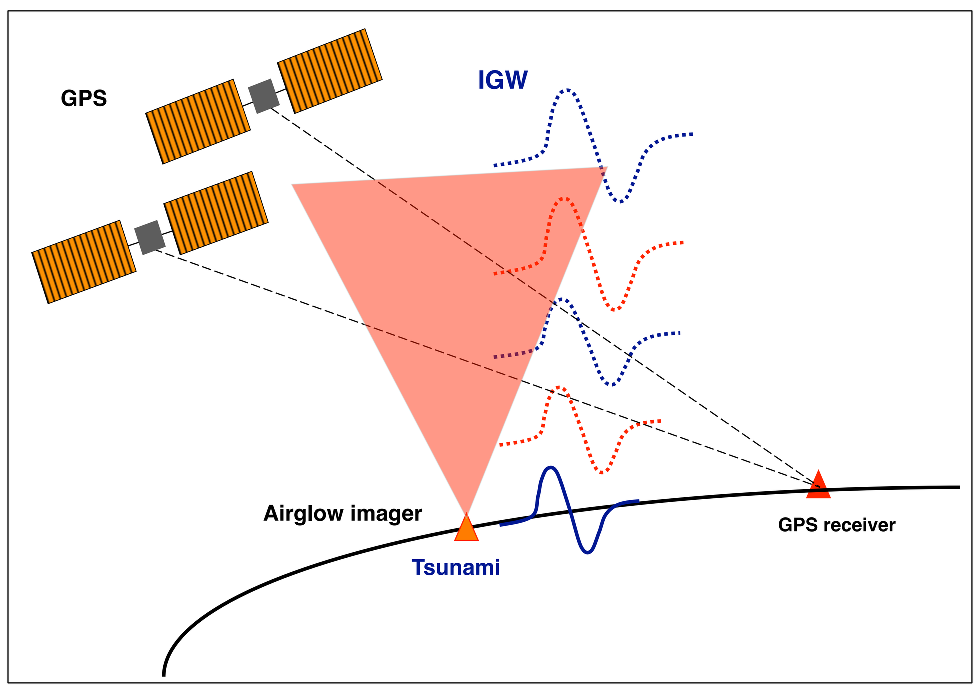

Figure 1: Representation of tsunami-driven IGW detection by GPS and airglow.

Tsunami propagation

- Finite-difference model of whole ocean propagation using USGS eartquake source to excite tsunami (Hébert et al. 2007).

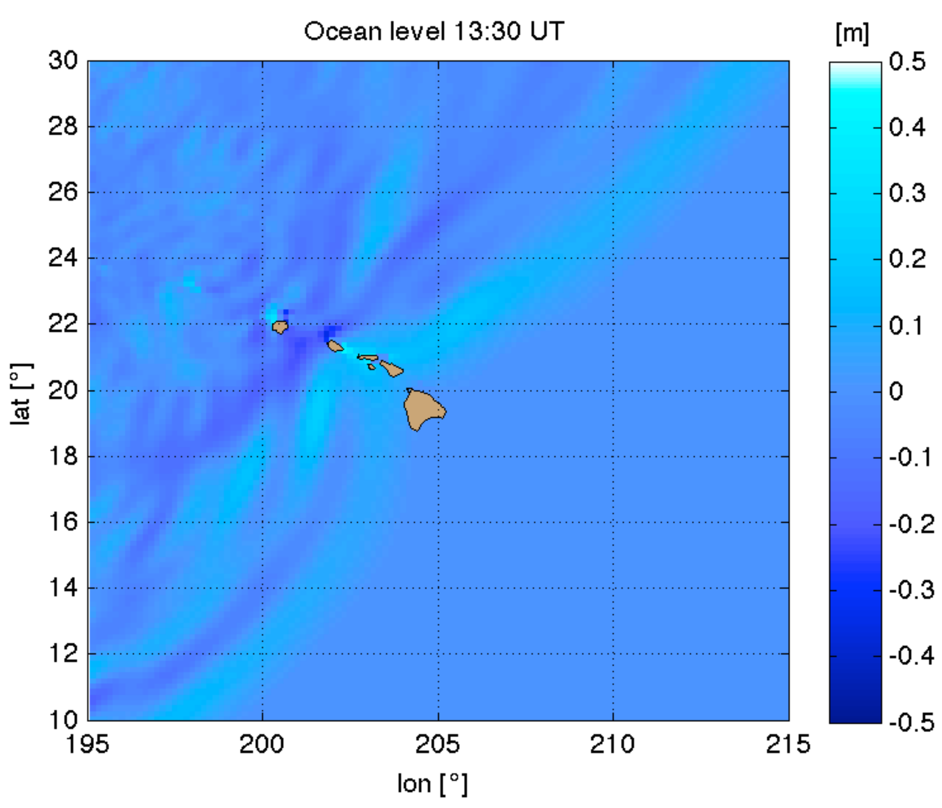

Figure 2: Tsunami passing near Hawaii: ocean displacement force a gravity wave in the overlaying atmosphere. Note the effect of the bathymetry on the wave front.

References

- Hébert et al. 2007, Numerical Modeling of the Great 2004 Indian Ocean Tsunami: Focus on the Mascarene Islands, Bulletin of the Seismological Society of America, 97(1A):S208–222.
- Link and Cogger (1988), A reexamination of the O I 6300-Å nightglow. JGR, 93(A9):9883– 9892.
- Makela et al. (2011), Imaging and modeling the ionospheric airglow response over hawaii to the tsunami generated by the tohoku earthquake of 11 march 2011, GRL 38(13), L00G02.
- Occhipinti et al. (2008), Geomagnetic dependence of ionospheric disturbances induced by tsunamigenic internal gravity waves. GJI, 173(3):753–756.
- Occhipinti, G. et al. (2011), Three-dimensional numerical modeling of tsunami- related internal gravity waves in the Hawaiian atmosphere, EPS, 63(7), 847–851.

630 nm airglow emission

- Maximum at 250 km height, ionosphere F2 layer.

Charge exchange	$O_2 + O^+$	$\longrightarrow$	$O_2^+ + O$
Dissociative recombination	$O_2^+ + e^-$	$\longrightarrow$	$O + O(^1D)$
Airglow emission	$O(^1D)$	$\longrightarrow$	$O(^3P) + h\nu$

Hawaii observation

- All-sky imager on Haleakala Volcano (Hawaii) observed gravity waves at 250 km with azimuth, speed and period coherent with tsunami propagation

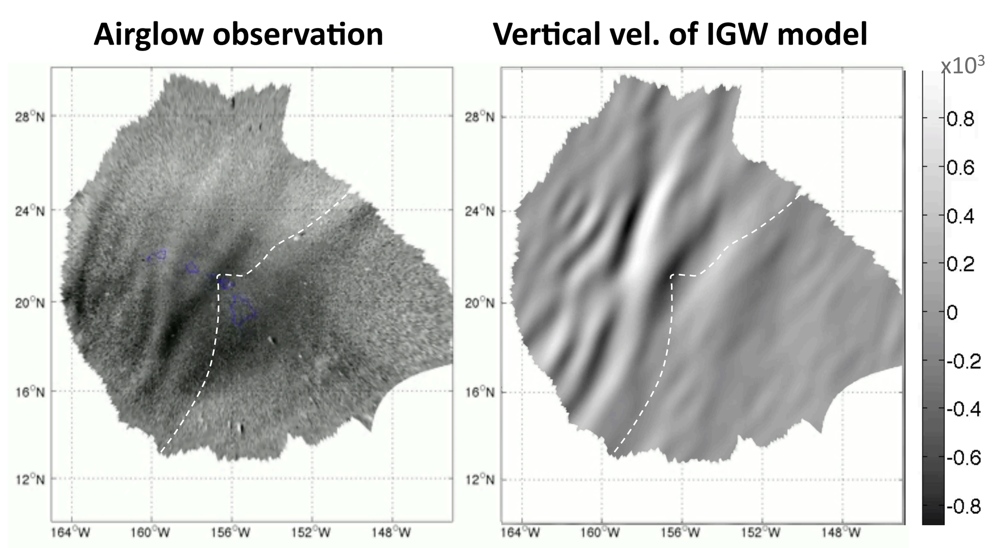

Figure 3: Airglow observation of tsunami-driven observation in Hawaii [Occhipinti et al. 2011].

Gravity waves model

- IGW forced by the vertical displacement of the ocean is computed in a realistic atmosphere (MSISE), through a pseudo-spectral propagator (Occhipinti et al. 2008).

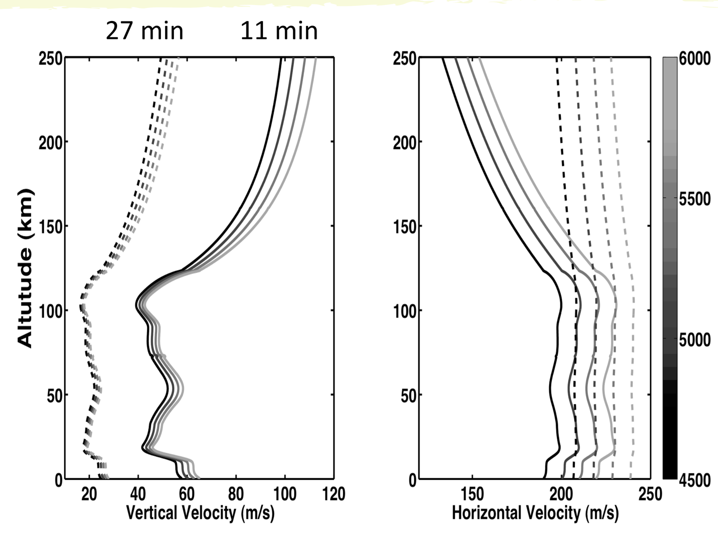

Figure 4: Vertical and horizontal velocity of IGW for 2 wave periods and 4 ocean depths [Occhipinti et al. 2011].

Neutral-plasma coupling

- Neutral IGW is coupled to the charged ions through collision model based on parameters computed by empirical models (MSISE, IRI, SAMI, HWM)

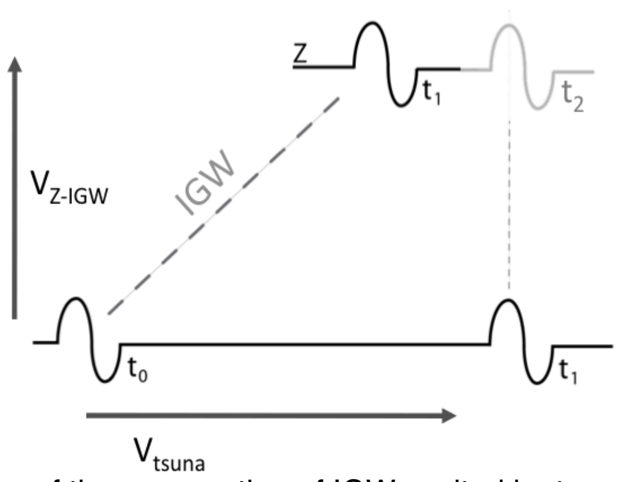

Figure 5: Scheme of the propagation of IGW excited by tsunami displacement [Occhipinti et al. 2011].

Acknowledgment

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Airglow model

- Volume Emission Rate of 630 nm airglow is calculated from the densities of the species involved (Link and Cogger 1988).

$$\mathrm{VER} = \frac{A_{630} f(^1D) k_1 [O_2][O^+]}{A_{^1D} + k_3[N_2] + k_4[O_2] + k_5[e^-]}$$

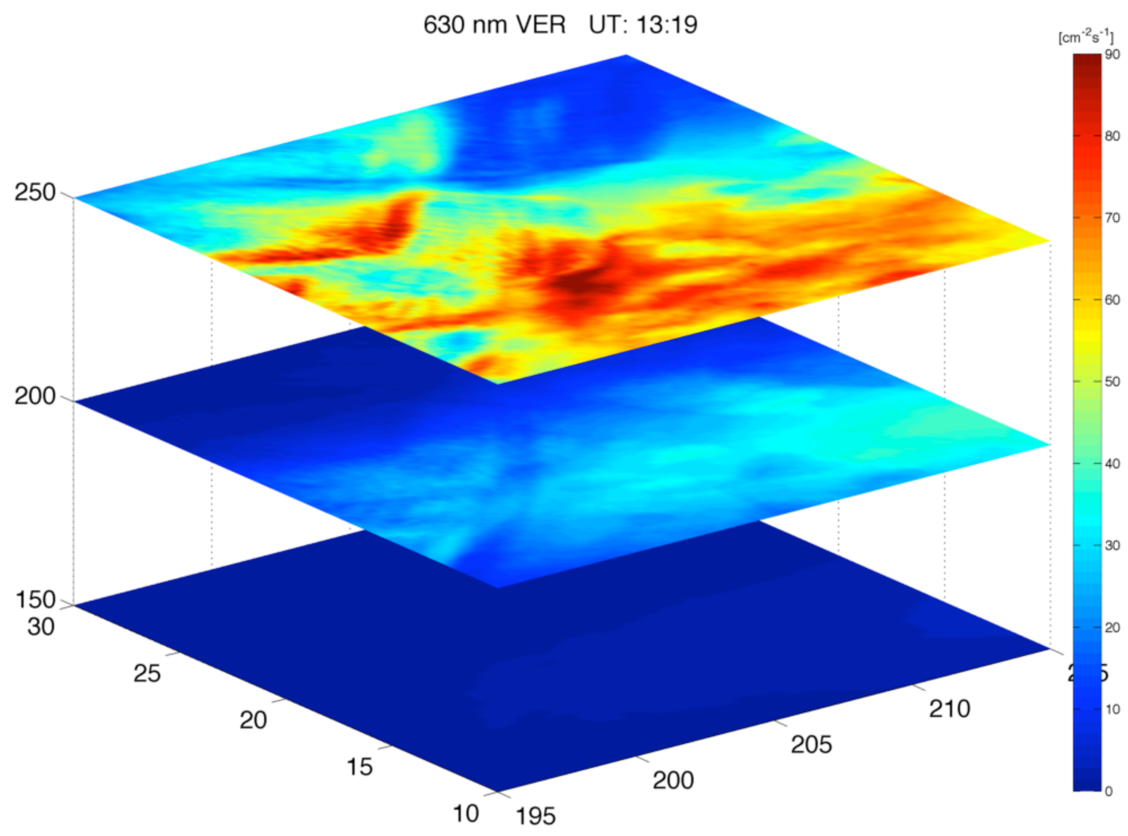

Figure 5: Airglow VER model in the region of Hawaii during the tsunami propagation.

Synthetic airglow

- VER is integrated to have the total emission.
- To highlight the components of the IGW and the tsunami effect a passband filter is applyed.

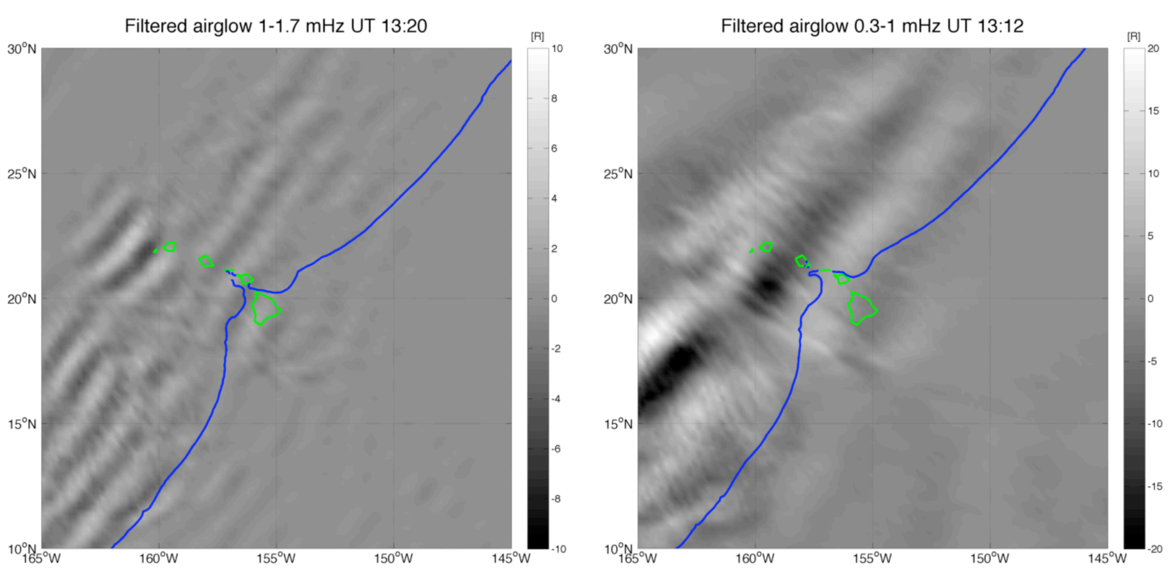

Figure 6: Synthetic observation of aiglow filtered for the two main components of the tsunami wave. IGW overtakes the tsunami near the islands.

Conclusions

- The first airglow observation of tsunami-driven gravity wave has been validated by model
- The model include: tsunami on the ocean surface
  - Gravity Wave in the atmosphere
  - Neautral-ions coupling
  - Airglow production
  - Instrument observation
- Both dominant periods of tsunami are found in the airglow signature

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