

# Kelvin-Helmholtz Waves at Earth's Magnetopause: Statistics and Global Simulations

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## Statistics

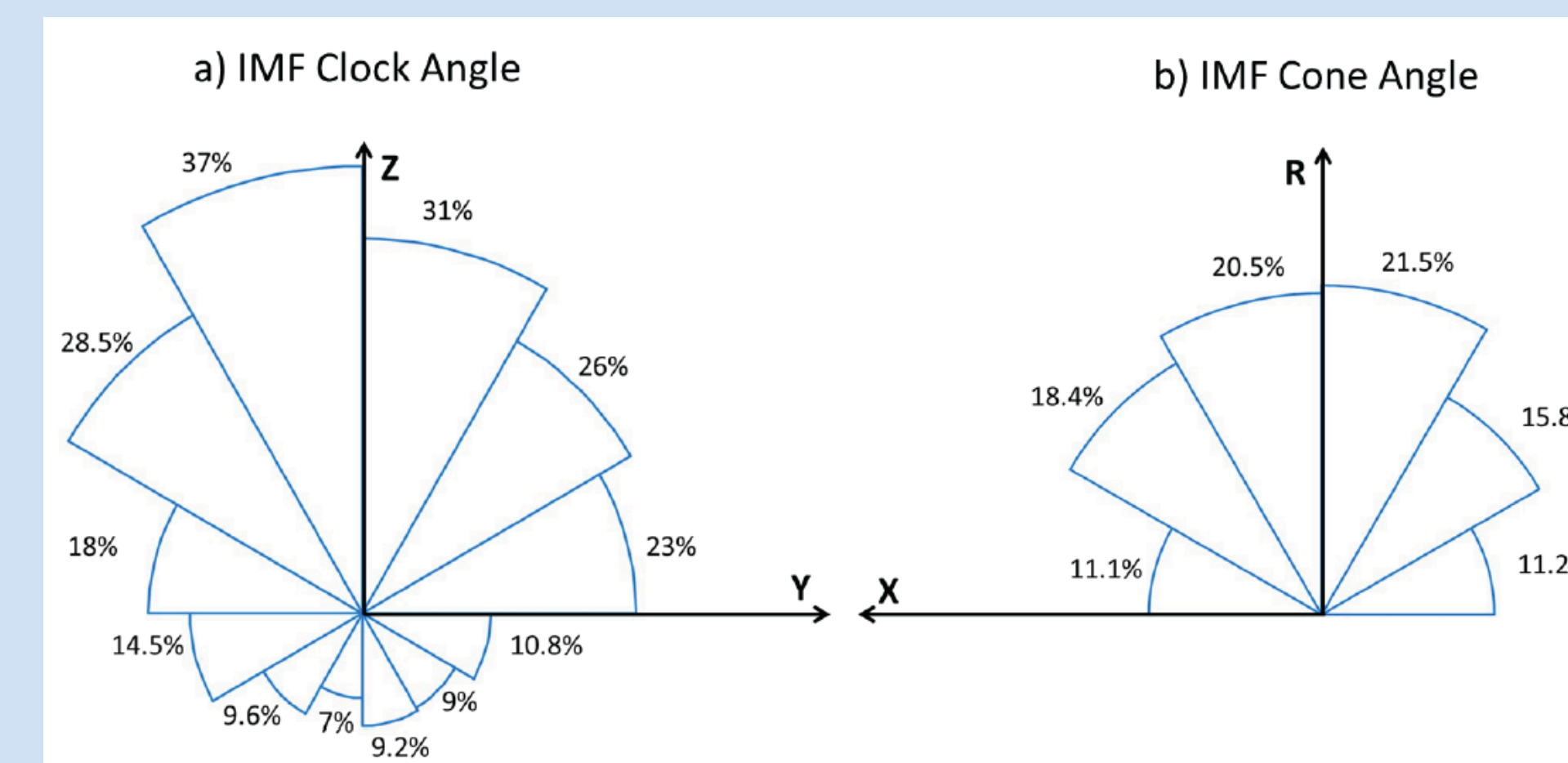
Although KH waves have been studied for some time, little was known how often they occur, and under which circumstances. The KH dispersion relation suggests that KH waves would be favored at the magnetopause flanks for north-south IMF direction, i.e., when the vectors of IMF, flow, and wave propagation are mutually orthogonal. Furthermore, the SW speed should be high, and during southward IMF reconnection may dominate over KH, although a few observations of KH during southward IMF have been reported.

The THEMIS mission provided the first opportunity to collect a large set of magnetopause crossings suitable for a statistical study. The apogees of the inner probes are around 10-12 RE, while the outer probes had apogees of 17 RE and 27 RE, respectively, before they were moved into orbits around the moon. We compiled a data base from 7 years of THEMIS observations and show that KH waves are much more common than previously thought.



THEMIS orbits during fall and spring seasons.

## IMF Dependence



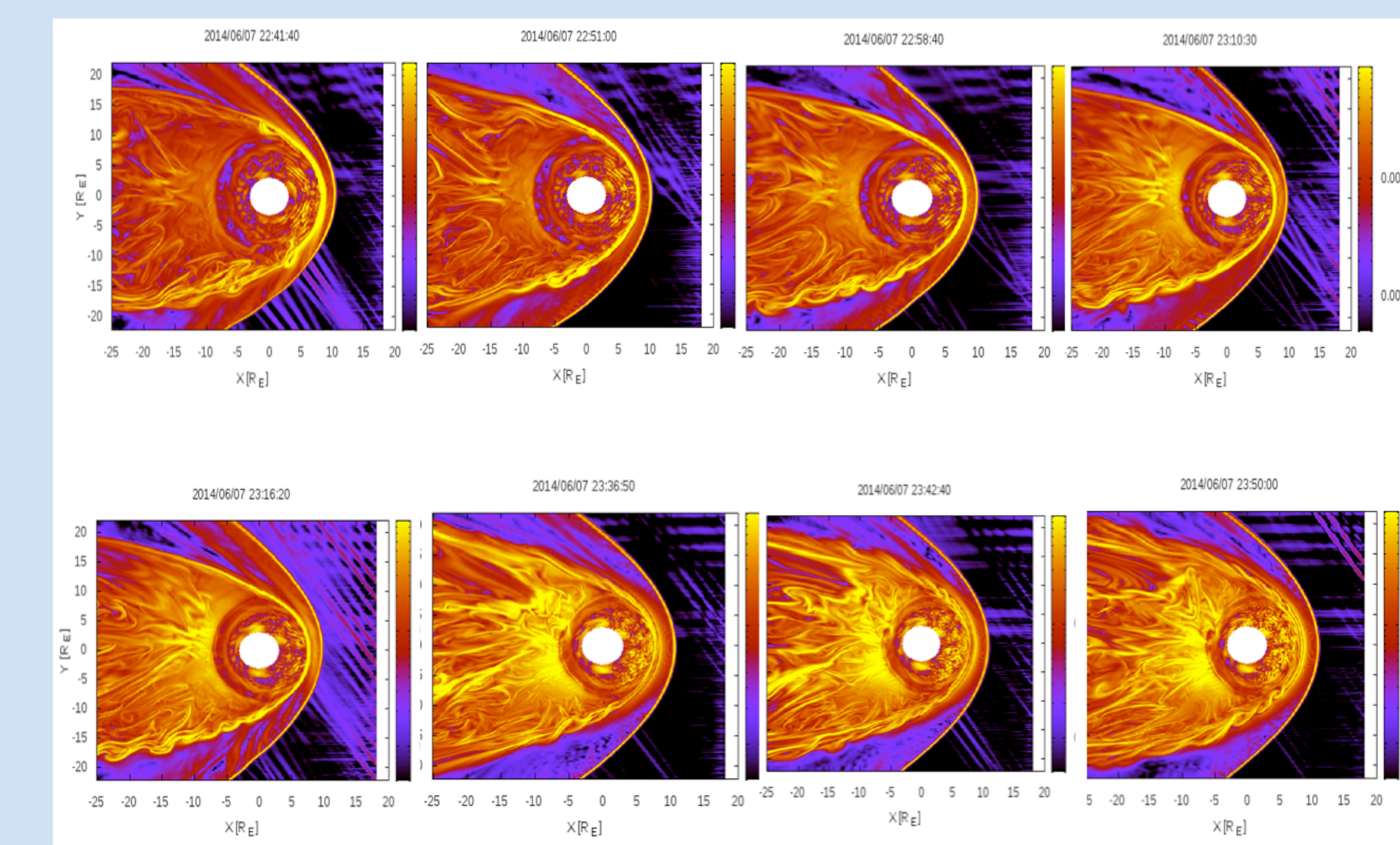
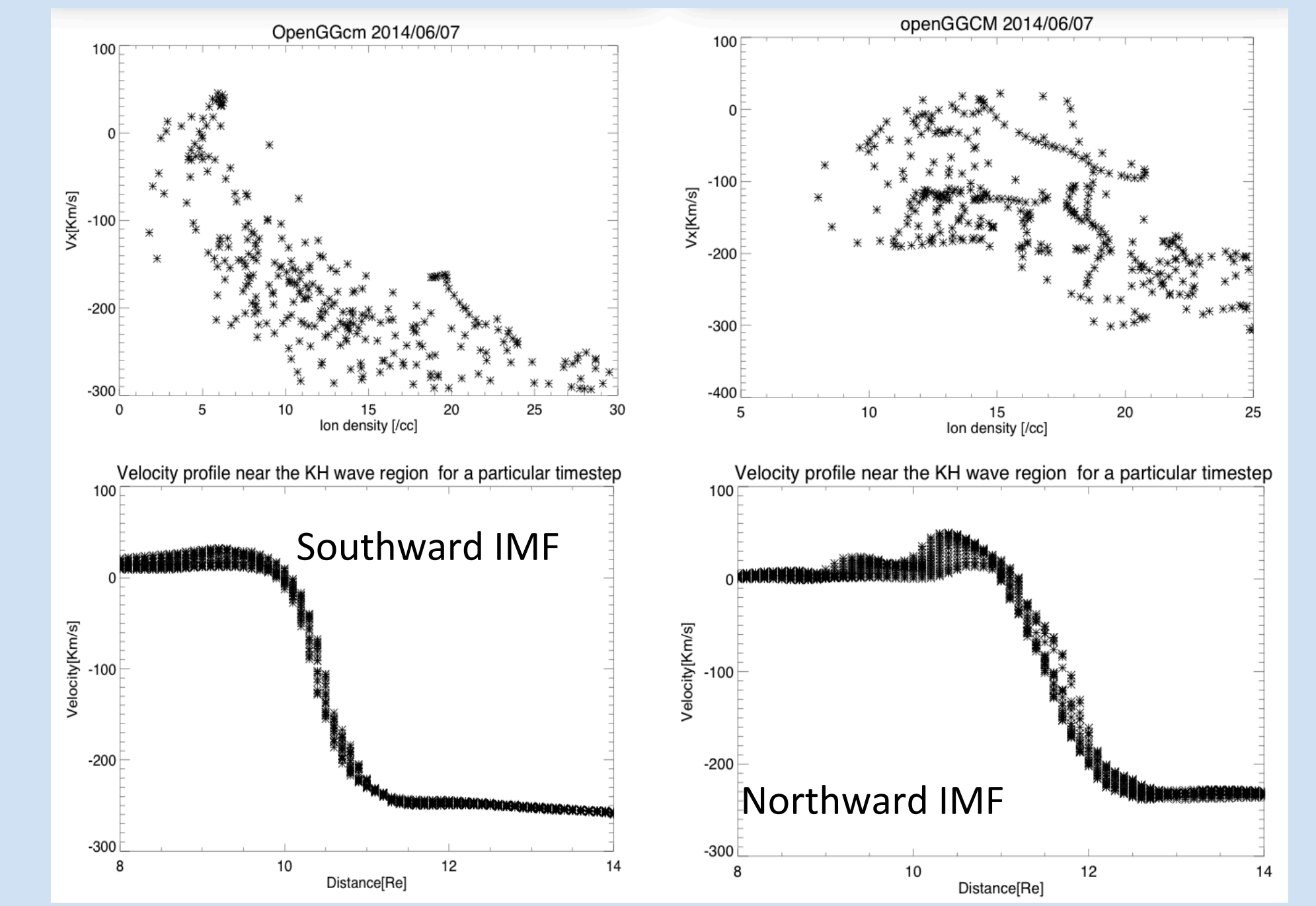
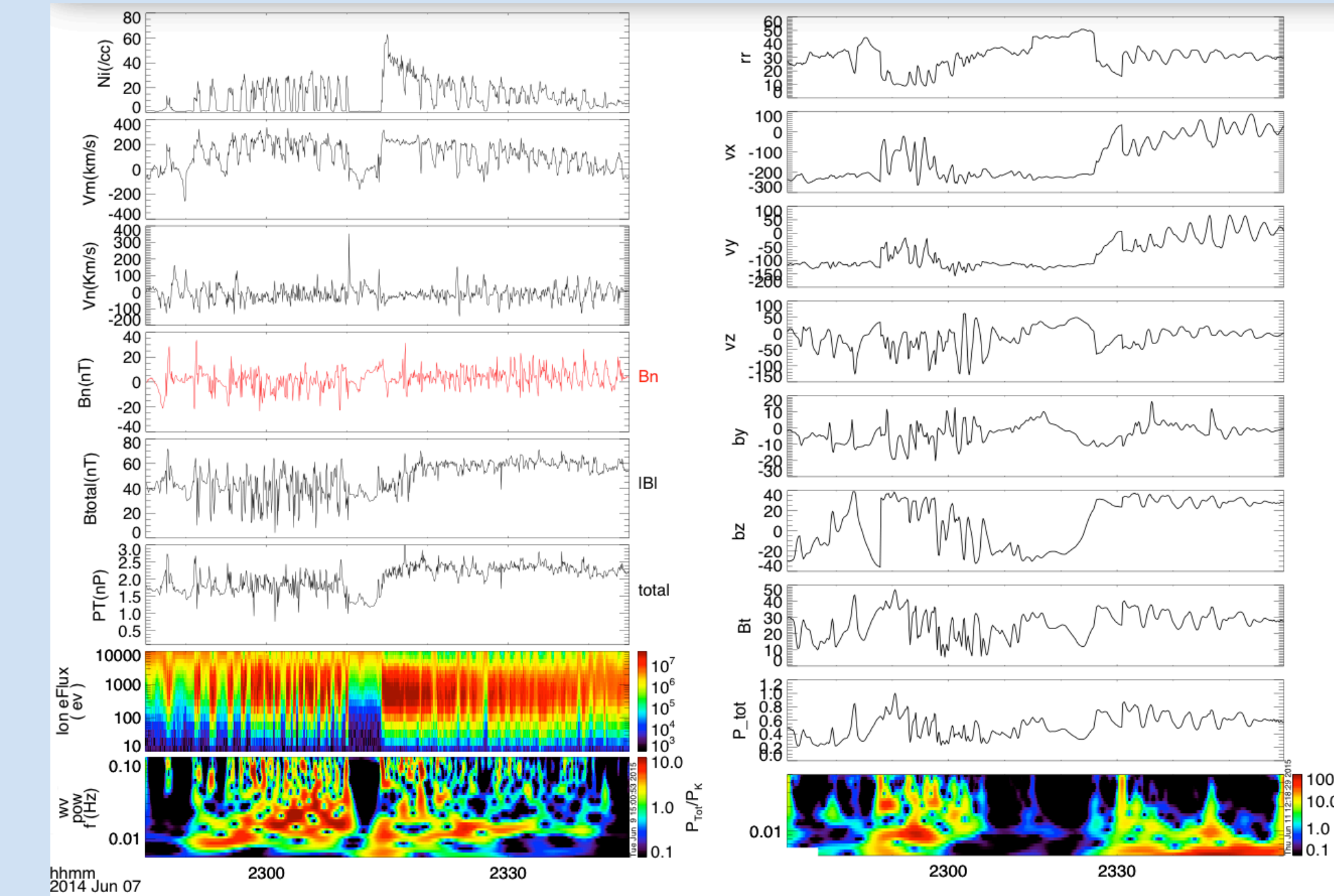
KH waves occur at all clock angles and at all cone angles. Wave occurrence maximizes at northward clock angle, as expected. However, there is a still significant rate at southward IMF. However, during southward IMF, KH intervals tend to be shorter.

The cone angle dependence is consistent with the dispersion relation, i.e., the magnetic field being largely perpendicular to the flow.

The overall occurrence frequency is ~19%.

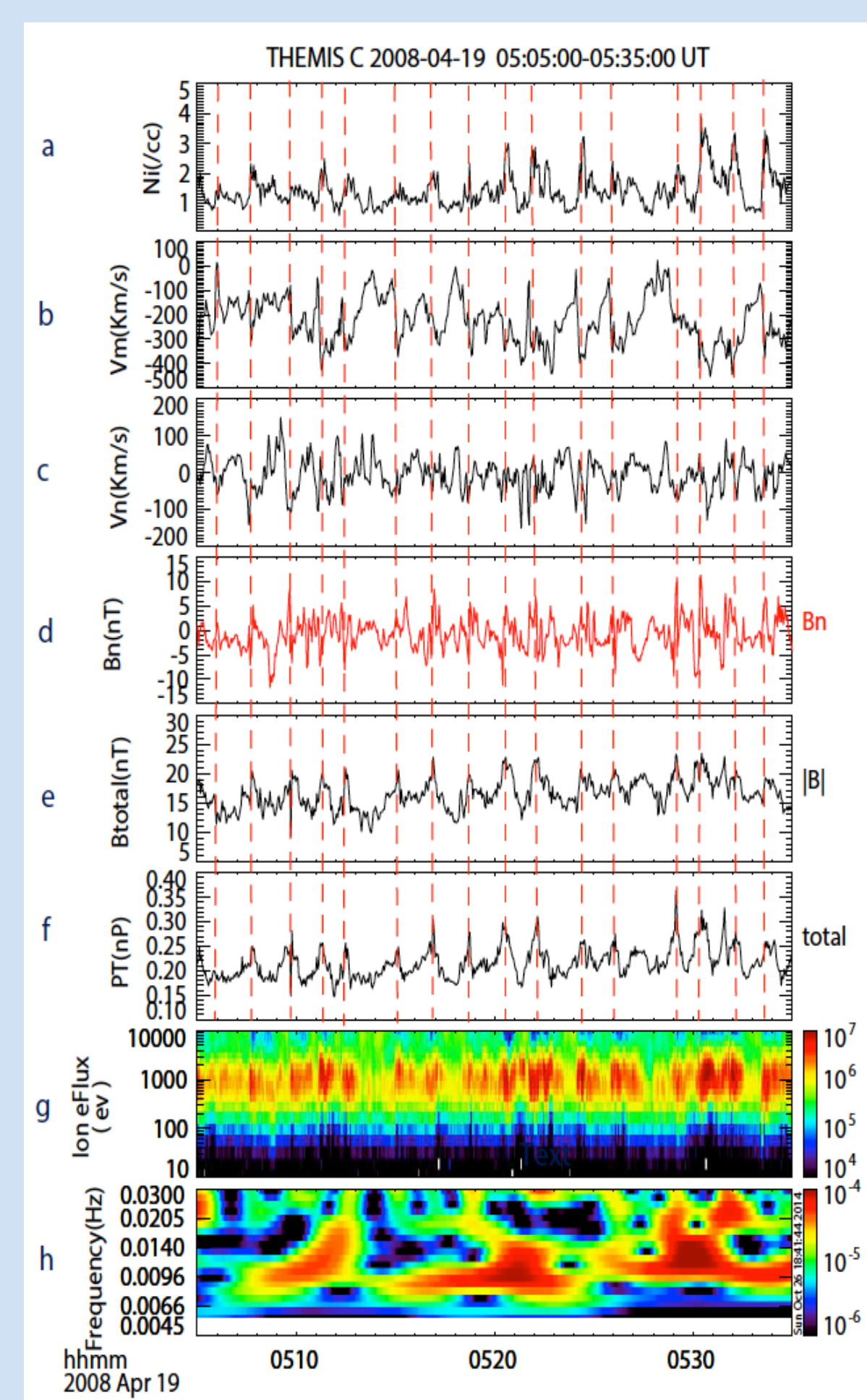
Kavosi, S., and J. Raeder, Ubiquity of Kelvin-Helmholtz waves at Earth's magnetopause, *Nature Comm.*, **6**, 1-6, DOI:10.1038/ncomms8019, 2015.

## OpenGGCM Simulations

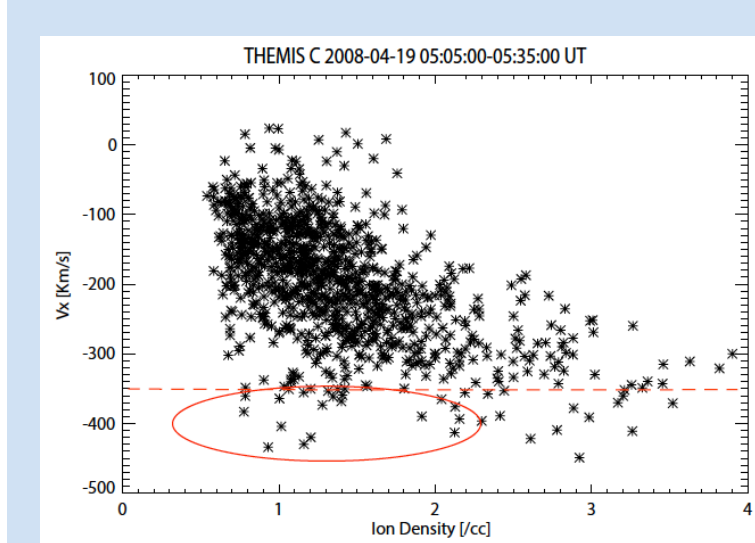


- During the June 7, 2014 event, KH first occurred during southward IMF, then the IMF turned northward and KH waves continued.
- OpenGGCM reproduces these waves, although the frequency is somewhat lower.
- In both data and simulation, waves are more irregular and the KH frequency is higher during southward IMF.
- This may be attributed to a thicker boundary layer during northward IMF conditions, consistent with finite width KH dispersion relations.

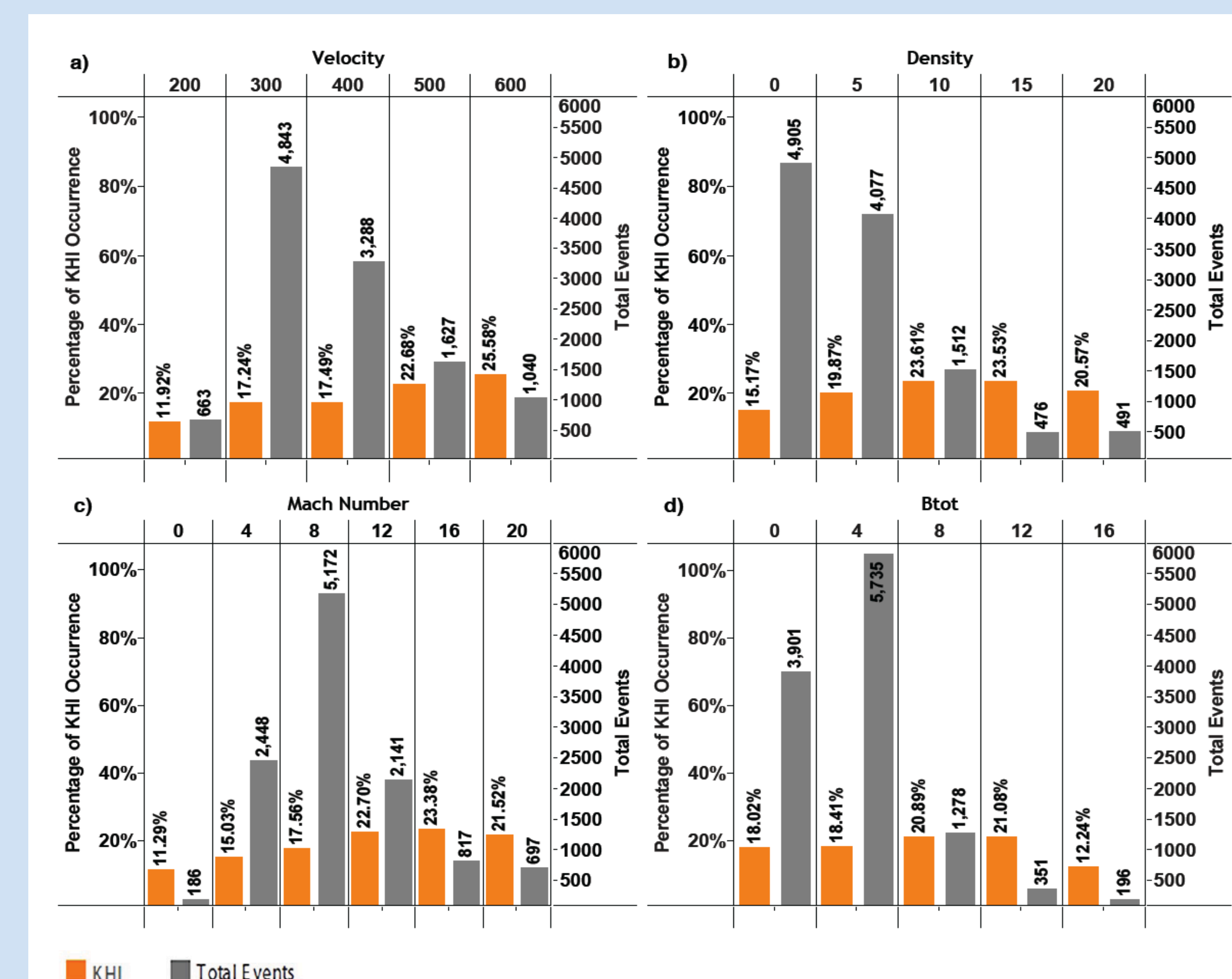
## Example



Example of a THEMIS KH event.



Both FTEs and KH waves have bipolar Bn signatures, but low density, high speed plasma indicates a breaking KH wave.



## Solar Wind Dependence

The orange bars show the percentage of KH occurrence in each bin, the grey bars show the total number of 5 min samples in that bin. The occurrence rate increases with solar wind velocity, as expected. There is little dependence on density and Mach number. There is also little dependence on the IMF magnitude, except that for large IMF values the occurrence rate noticeably drops.

## Summary

- KH waves are more common than previously thought, ~19% under all conditions.
- KH waves are most common for northward IMF (~40%), but still significant for southward IMF (~10%).
- Cone angle dependence is as expected, i.e., KH prefers N-S field.
- Dependence on SW parameters is weak.
- OpenGGCM reproduces KH waves under northward and under southward conditions.
- Under southward conditions the boundary layer is thinner, and KH has higher frequency and is polychromatic.

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