Investigating a Relationship Between Quasi-Periodic Meridional Clearing of Deep Clouds in Jupiter’s North Equatorial Belt and the Propagation of Zonal Waves in its Upper Tropospheric Haze: A Study of Near-Infrared Images

“Ride the Wave!”

Tyler Hackett, YIP, Norco College

Mentor: Dr. Glenn Orton

Jet Propulsion Laboratory
California Institute of Technology

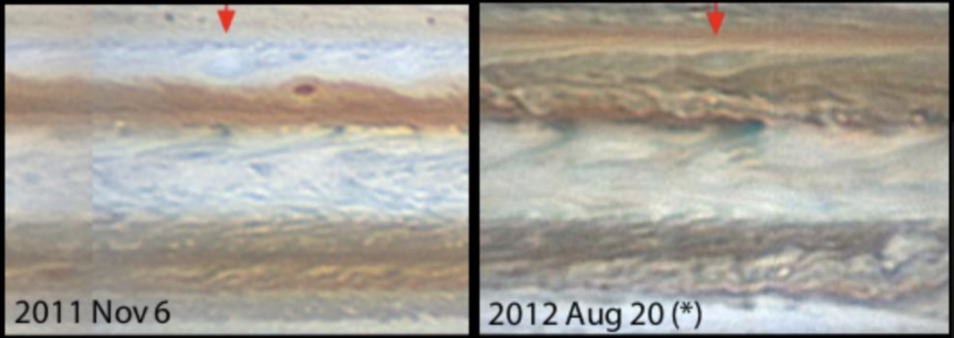
Routine Tasks

Jet Propulsion Laboratory
California Institute of Technology

Data Reduction & Archival of near-IR observations

- Reduce the latest near-infrared (1.58-μm to 5.10-μm) observations from IRTF SpeX
- Create flatfields and pixel masks when necessary
- Periodically collect, re-format, and upload batches of observations to the JSOC website
- Approximately 400 reduced observations in total (NSFCAM, NSFCAM2, and SpeX)

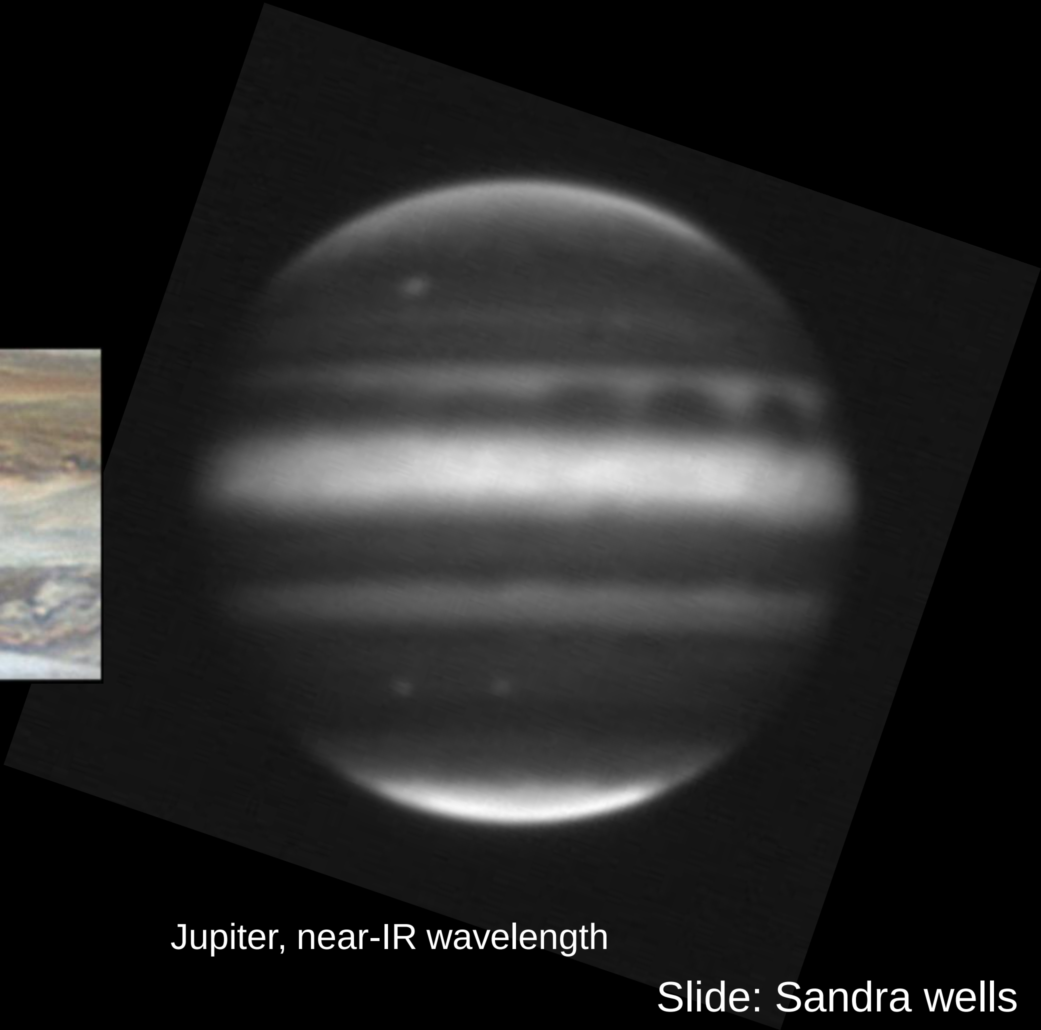
Introduction



Non-expanded NEB

Expanded NEB

Jupiter, visible wavelength



Jupiter, near-IR wavelength

Slide: Sandra wells

Analysis

Characterizing Upper Tropospheric Waves

Qualitative Approaches

Wave Types

Previous analysis by 2018 summer intern Sandra Wells

- Visual approach
- Two distinct types of waves (“intensity” and “width”)
- Both can be present simultaneously (“combination waves”)
- Low, Medium, and High strength
- Anomalous activity (isolated bright spots, waves, etc.)
- Overall, 14 different wave characterizations

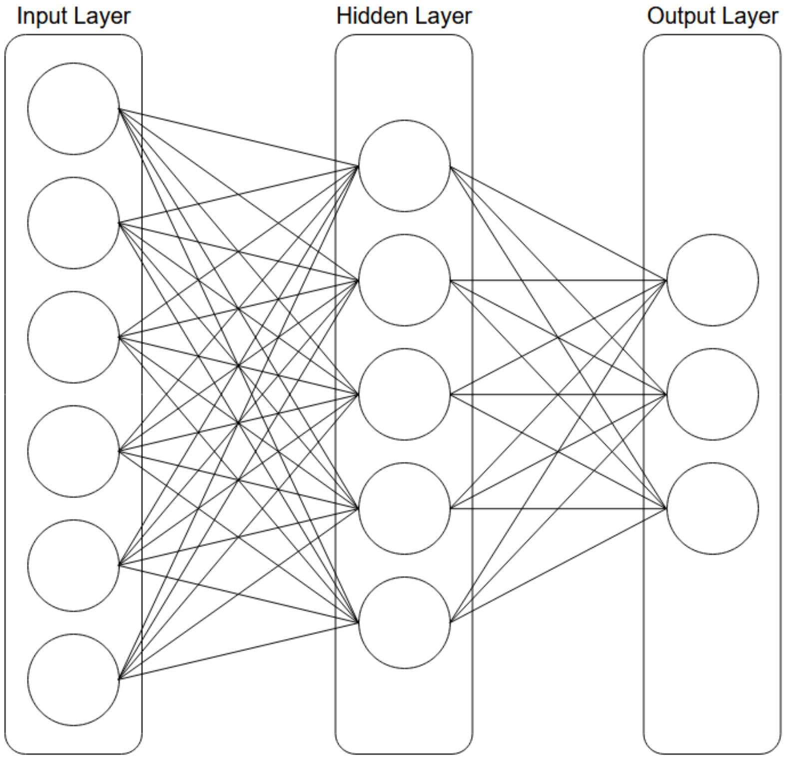
Experimenting with Neural Networks

Jet Propulsion Laboratory
California Institute of Technology

Neural Networks

A basic overview

- Robust pattern recognition model
- Training: attempts to find an optimal mapping between given inputs and outputs
- Handles noise and outliers effectively


Input Layer
Hidden Layer
Output Layer

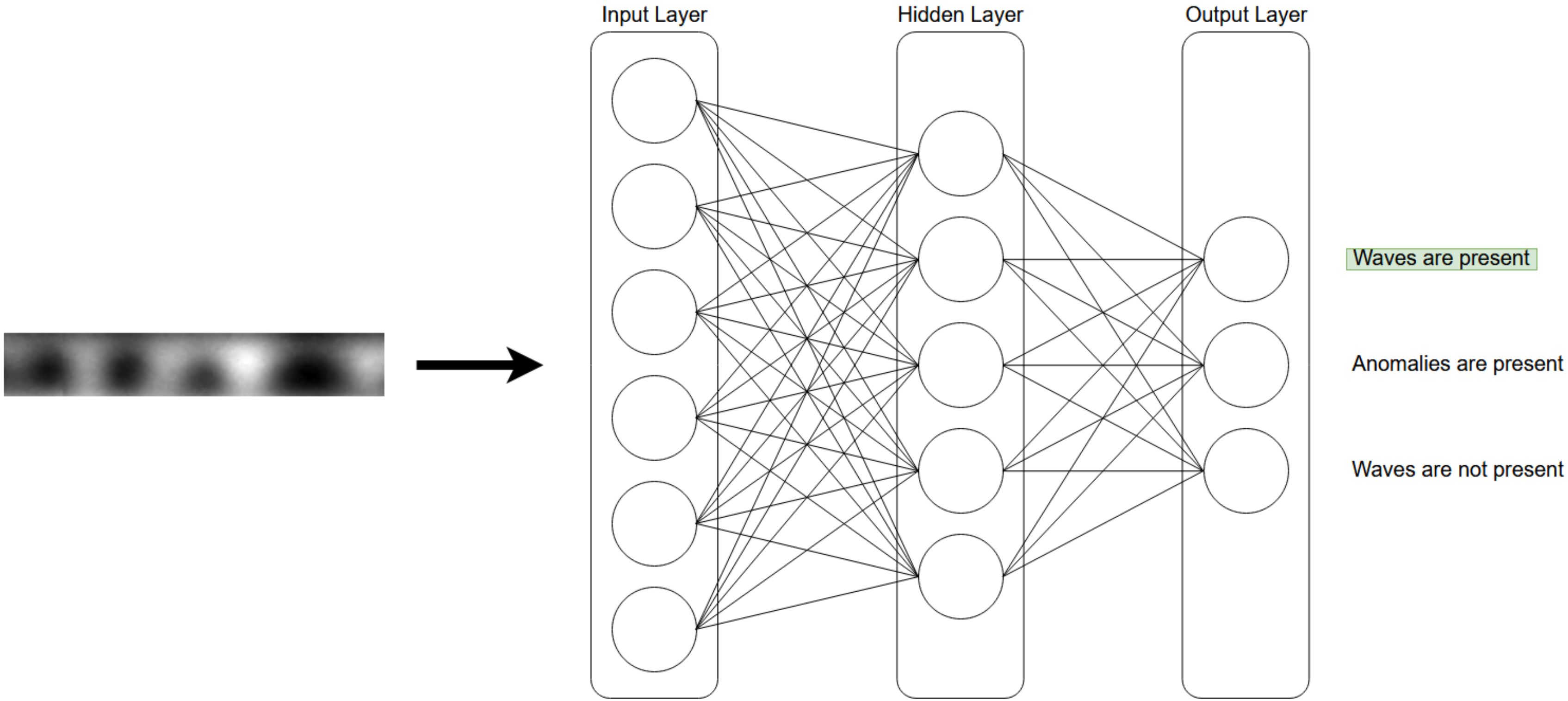
Neural Networks

Problems encountered

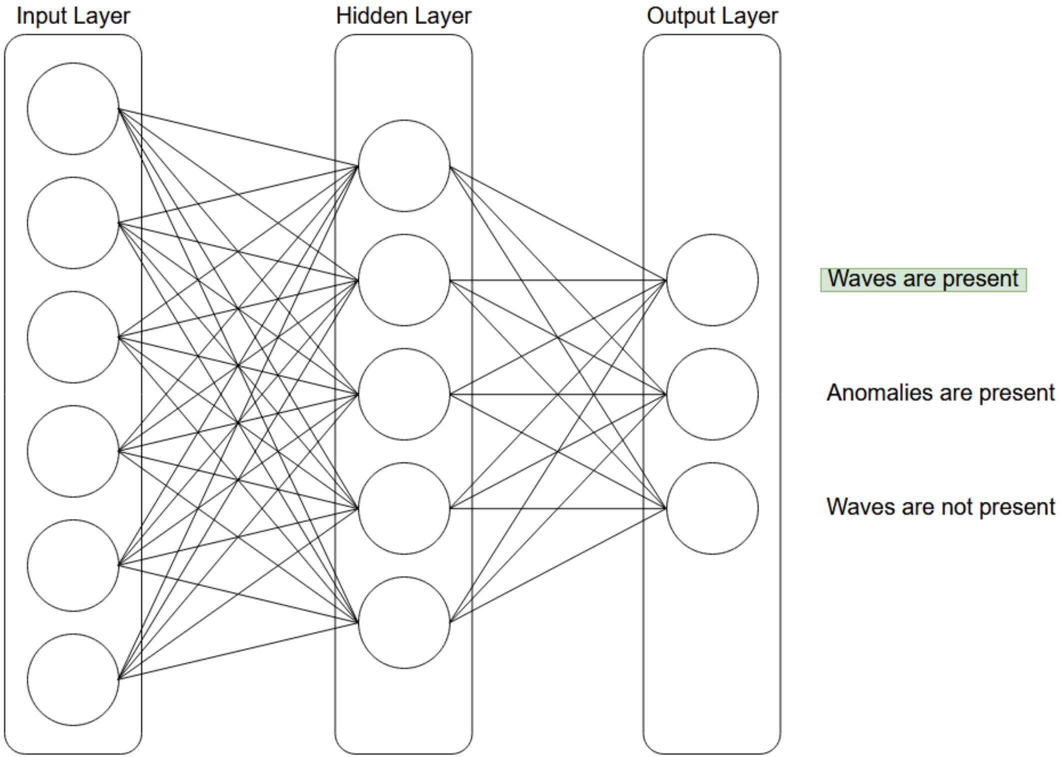
- Feed-forward architecture: many parameters to train
- Limited time to improve the model
- Dataset: too difficult to differentiate between wave types

Remedies

- Simplify the goal
- Three distinct labels: waves, no waves, and anomalies


Input Layer
Hidden Layer
Output Layer
Waves are present
Anomalies are present
Waves are not present

~82% prediction accuracy



Neural Networks

Example results from k-fold cross-validation set

60x5 angle-corrected, isolated NEB region

training examples: 785
k: 7

learnRate: 0.40
lambda: 0.15
epochs: 4500

Waves: W
No Waves: -
Anomalies: B

W W W W - W W W B W W W W W W B - W W W W W W - W W W - - W W W W W - W W W W W W W W B W - W -
W B W – W W B W - - W W B - - W W W W W W W - - W W - W W W B W W W W W W - W W - W W W W W W W
W W W W B W - W W W W W W W W W W - W W W W W W - W W W W W W W W

W W W W - W W W W W W W W W W B - W W W W W W B - W - - - W - W W W B W B - W W W W W B W - W -
W B W – W W W W W - W W - - - W W W W W W - - - W W - B - W B W W W W W W - W - - W W W W W - W
W W B W - W B W W W W W W W W W W - W W W W W W - W - B W - W W W

Prediction accuracy: 82.5%

Neural Networks

Future considerations

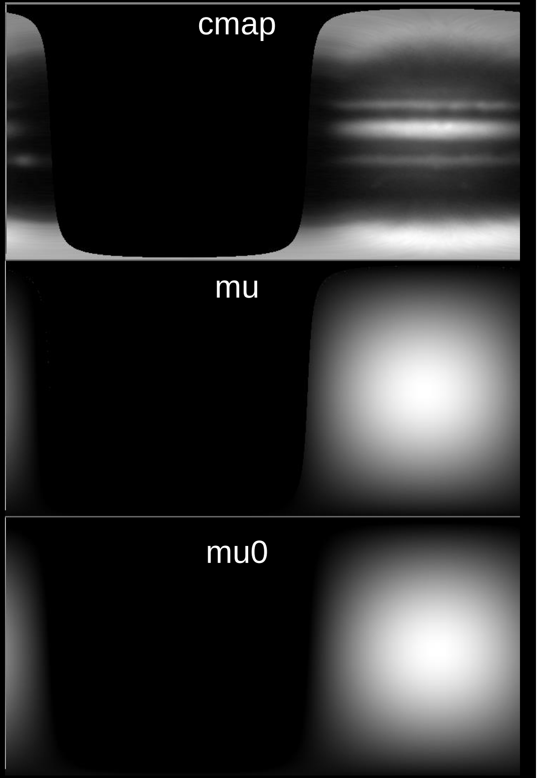
- Different architectures; convolutional neural networks
- Favor embeddings over one-hot encoded labels
- Data augmentation

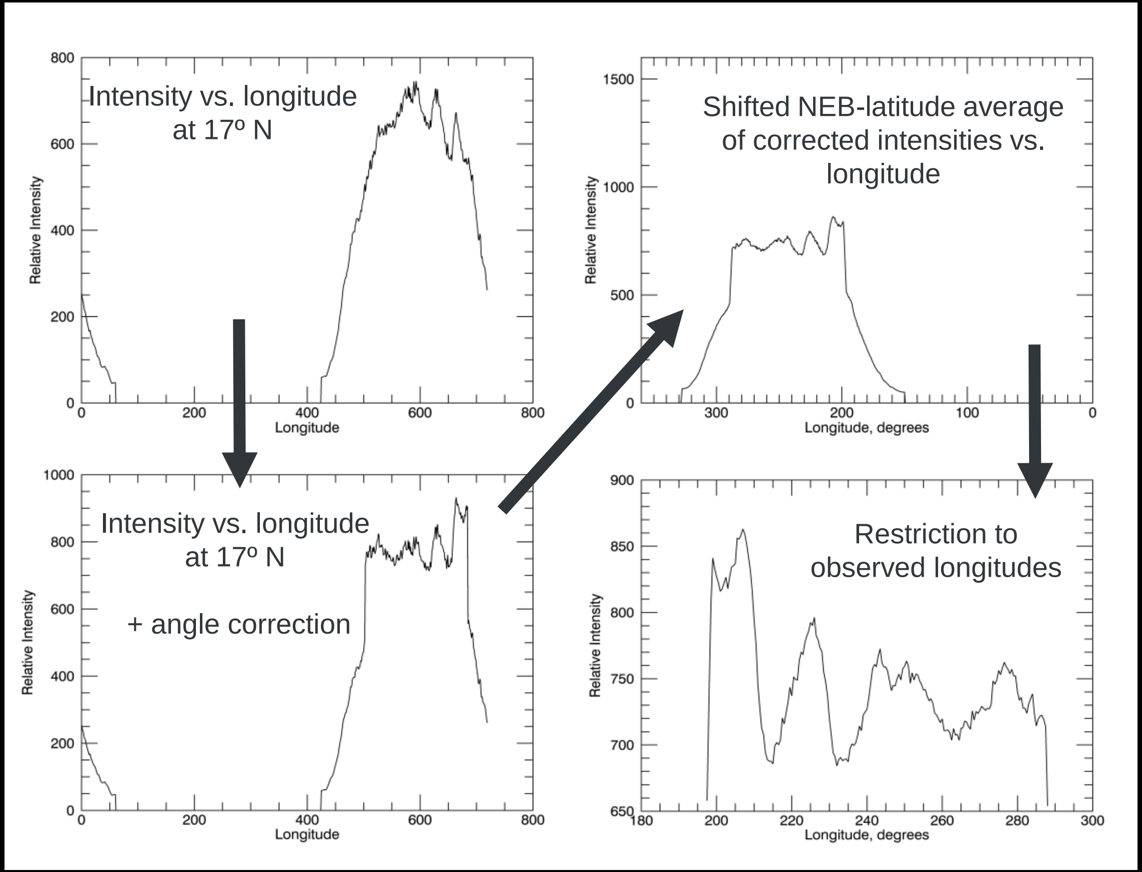
Quantitative Approaches

1. Variance Approach

Variance approach: analysis of a single image

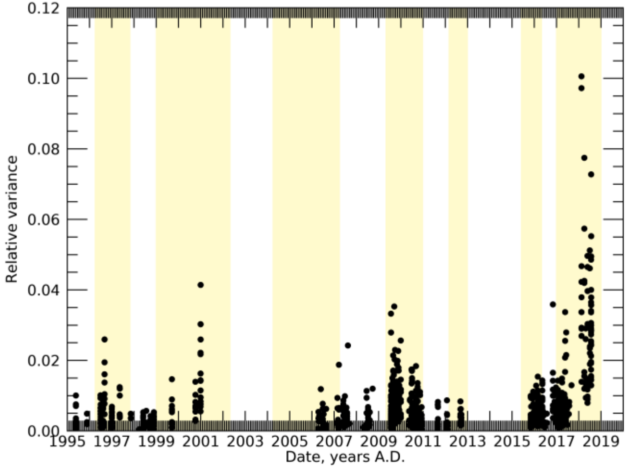
Sandra Wells, summer 2018





Automated Wave Characterization

Previous results (variance approach)



NEB Expansions

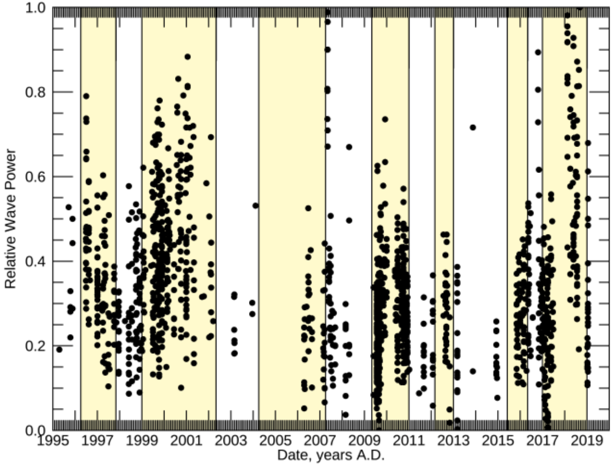
Fletcher, L. N., G. S. Orton, J. A. Sinclair, P. Donnelly, H. Melin, J. H. Rogers, T. K. Greathouse, Y. Kasaba, T. Fujiyoshi, T. M. Sato, J. Fernandes, P. G. J. Irwin, R. S. Giles. 2017. Thermal wave activity associated with the expansion of Jupiter’s North Equatorial Belt ahead of Juno’s arrival. *Geophys. Res. Lett.* **44**, 7140-7148.

Graph: Sandra Wells, summer 2018

2. “Relative Wave Power” Approach

Automated Wave Characterization

New Results (RMS approach)



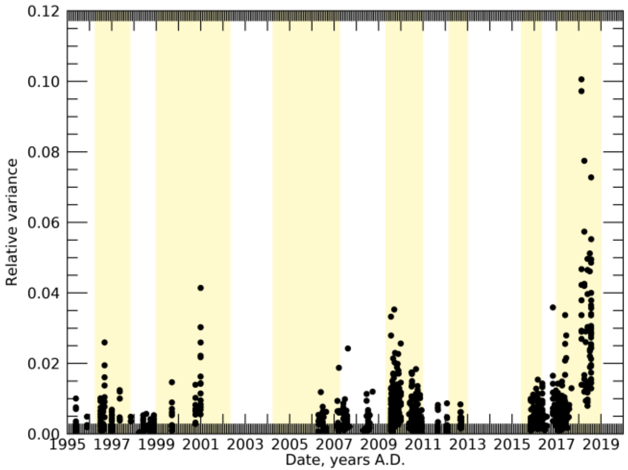
NEB Expansions

Fletcher, L. N., G. S. Orton, J. A. Sinclair, P. Donnelly, H. Melin, J. H. Rogers, T. K. Greathouse, Y. Kasaba, T. Fujiyoshi, T. M. Sato, J. Fernandes, P. G. J. Irwin, R. S. Giles. 2017. Thermal wave activity associated with the expansion of Jupiter's North Equatorial Belt ahead of Juno's arrival. *Geophys. Res. Lett.* **44**, 7140-7148.

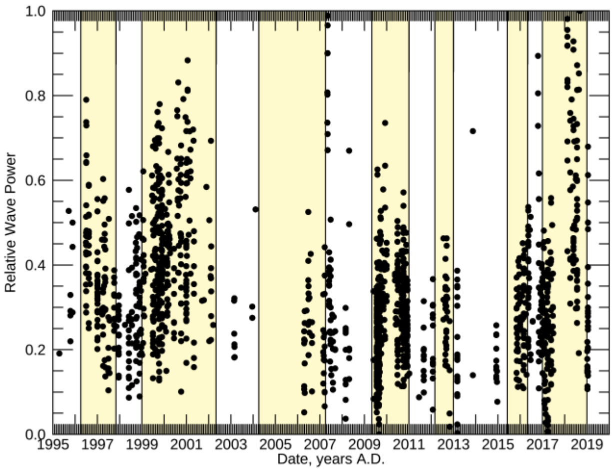
Automated Wave Characterization

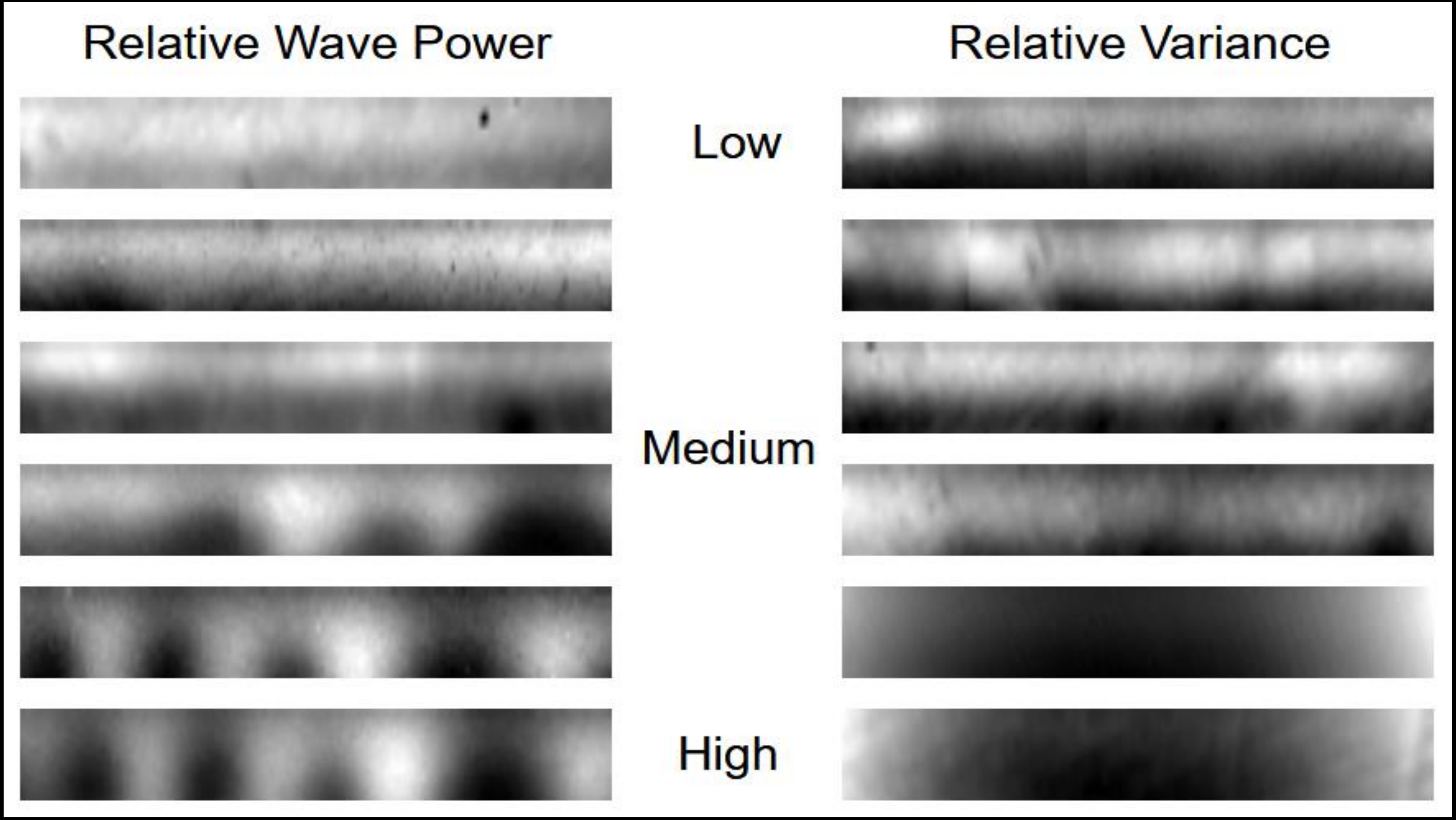
Side-by-side comparison

Variance



RMS





Relative Wave Power
Relative Variance
Low
Medium
High

Revisiting Wave Types

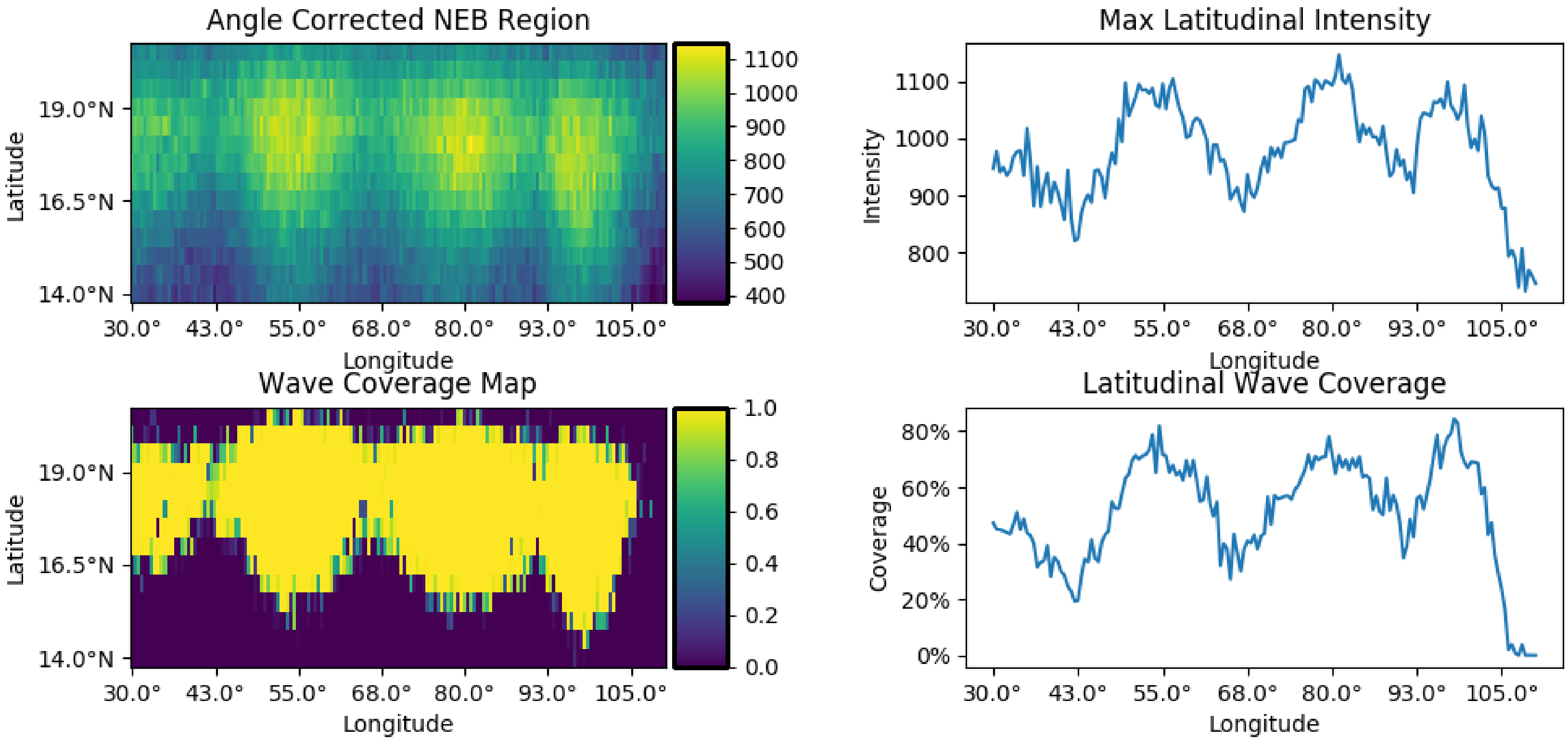
Revisiting Wave Types

Hypothesis:

Perceived differences between the intensity and width of waves may be caused by intensity scaling

Experiment:

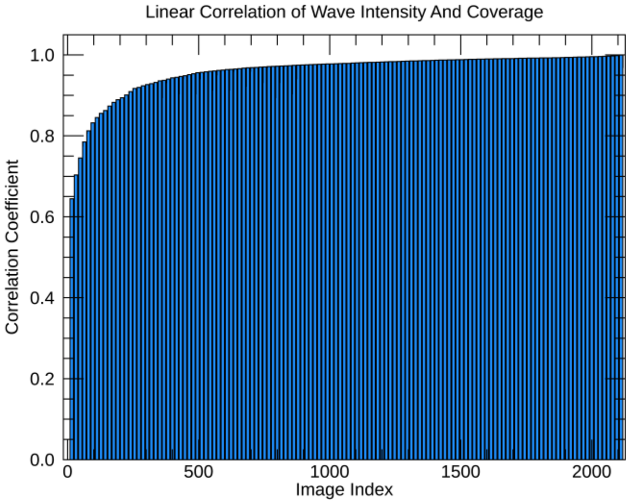
Determine if the intensity and width of observed waves are strongly correlated

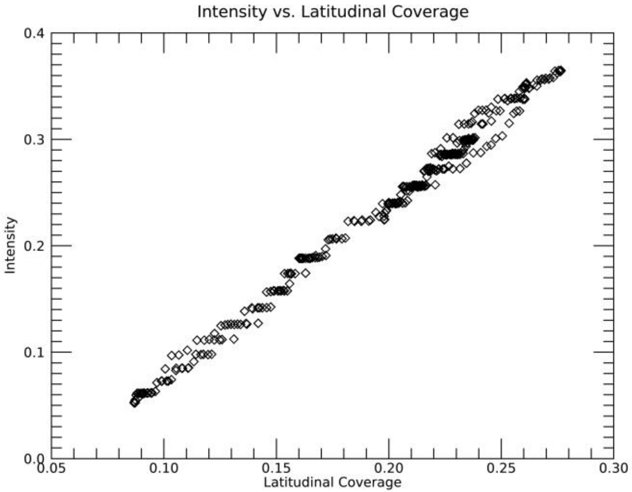


Angle Corrected NEB Region
Max Latitudinal Intensity
Wave Coverage Map
Latitudinal Wave Coverage
Latitude
Longitude
Intensity
Coverage
19.0°N
16.5°N
14.0°N
30.0°
43.0°
55.0°
68.0°
80.0°
93.0°
105.0°
1100
1000
900
800
700
600
500
400
1.0
0.8
0.6
0.4
0.2
0.0
80%
60%
40%
20%
0%

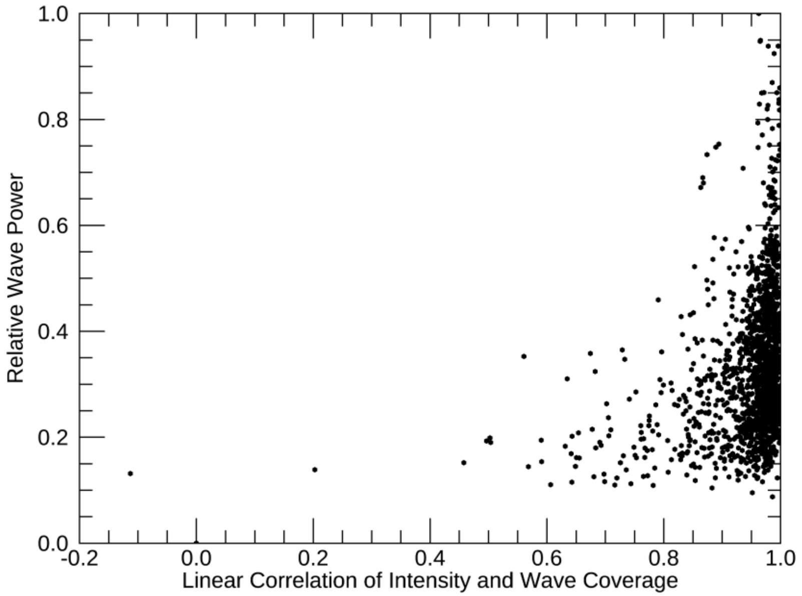
Revisiting Wave Types

Correlation between wave intensity and width





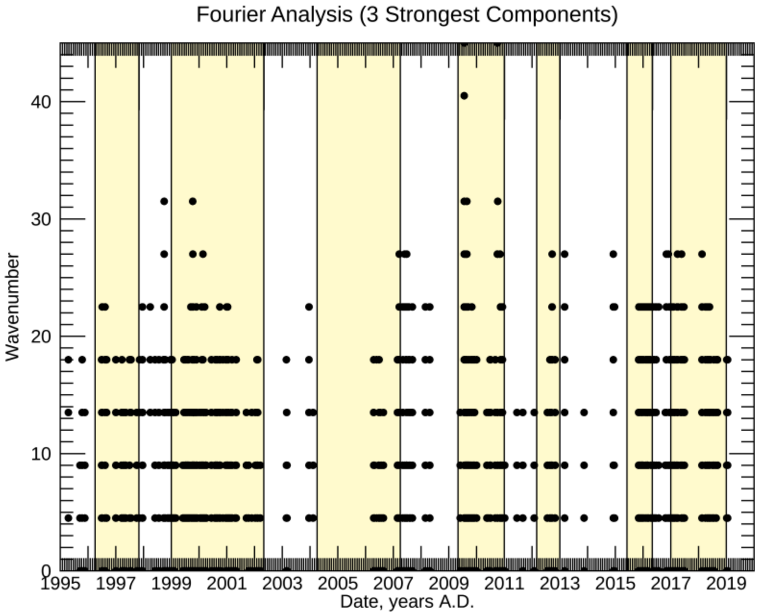
Revisiting Wave Types



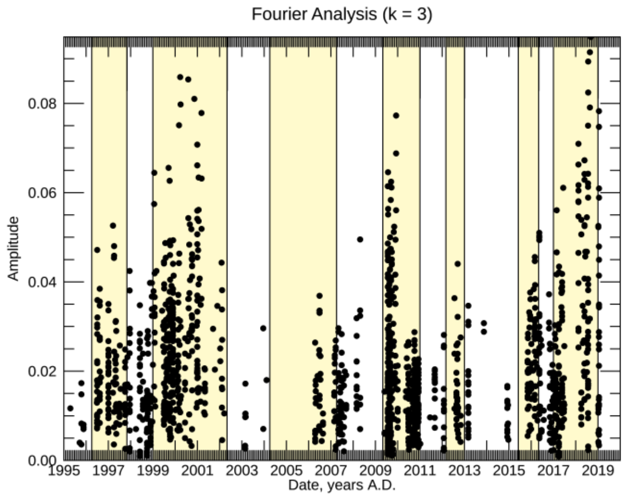
Fourier Analysis

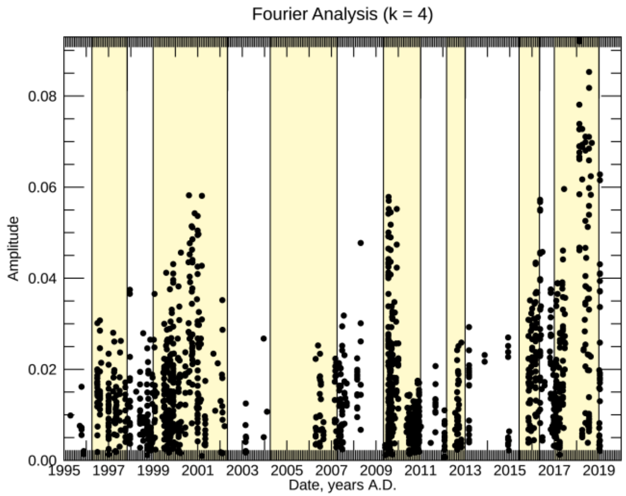
Fourier Analysis

Strongest sinusoidal components by wavenumber



Fourier Analysis





Conclusions

- Upper-tropospheric waves in the mid-NEB exhibit both intensity and latitudinal variation in most cases
- Anomalous (“breakout”) waves are common when intensity and latitudinal variations do not correlate well
- Quantitative analysis of wave activity supports the conclusion that waves are strongest during NEB expansions but are not unique to them

Conclusions

Future areas of research

- Stitch cylindrical maps together to reduce variations in the wave power scatterplots
- Stitched maps would also improve spectral resolution
- Investigate relationship between relative wave power and the intensity/width correlation coefficients

Acknowledgments

Glenn Orton
Tom Momary
Kevin Baines
Sandra Wells
JPL Education Office

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov