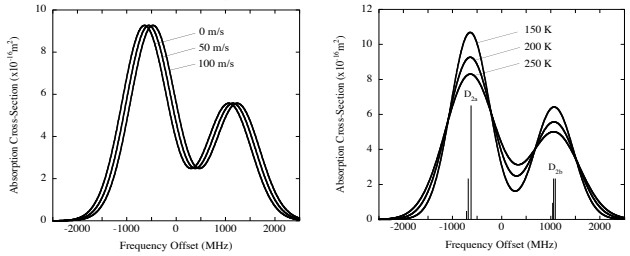
Na Doppler Lidar: Temperature and Vertical Wind

Principle of Lidar Measurement

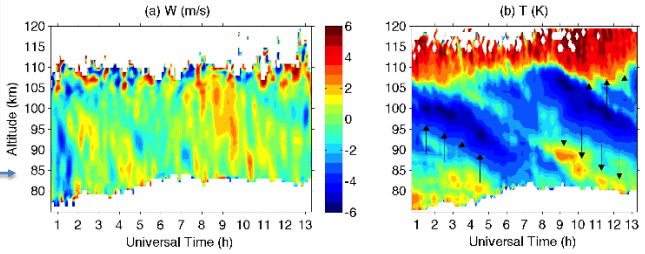
Doppler Shift: Vertical Wind (W)

Doppler Broadening: Temperature (T)



High-to-medium frequency mesoscale GWs

Semidiurnal Tide



[Lu et al., 2015]

Tidal signatures are also found in W, while higher-frequency GWs are found in T.

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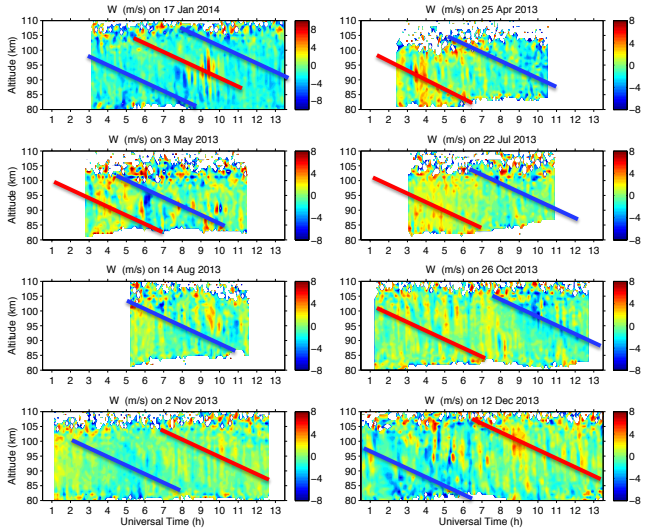
High-Resolution/Precision Na Doppler Lidar



[Lu et al., 2017]

In 2011, significant improvements of the receiver efficiency as described in *Smith and Chu* [2015] enabled this STAR lidar to obtain very high resolution data.

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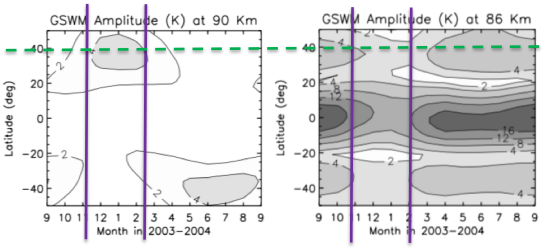
Data (Period) Selected

- Statistics of the STAR Na Doppler Lidar Data from November 2013 to January 2014.

	April	May	June	July	August	September	October	November	December	January	Total
Night	2	3	3	1	7	3	8	8	7	14	56
Hour(h)	15.9	18.5	12.9	6.9	42.2	23.0	73.1	73.6	69.2	125.5	460.8

Data Resolution: Δt=7.5 min, Δz=0.96 km

Semidiurnal Tide **Diurnal Tide**



Zhang et al., [2006]

Two Reasons to Choose this period:

- Good timing since semidiurnal tide reaches strongest and diurnal tide is the weakest.
- November – January: Winter-time in the NH, has the longest length of observations.

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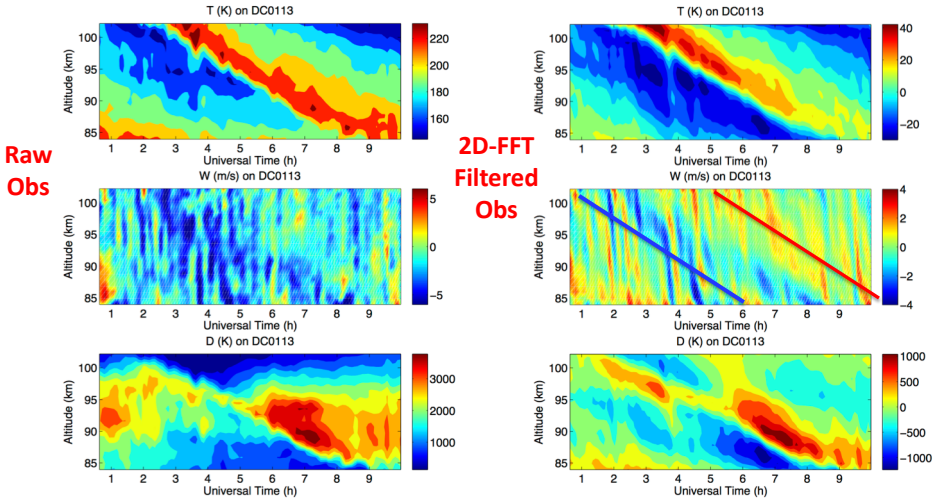
2D-FFT Filtering to Obtain Perturbations



From the raw measurements (without any post-processing), there is a positive correlation between T' and W' in term of a semidiurnal tidal period.

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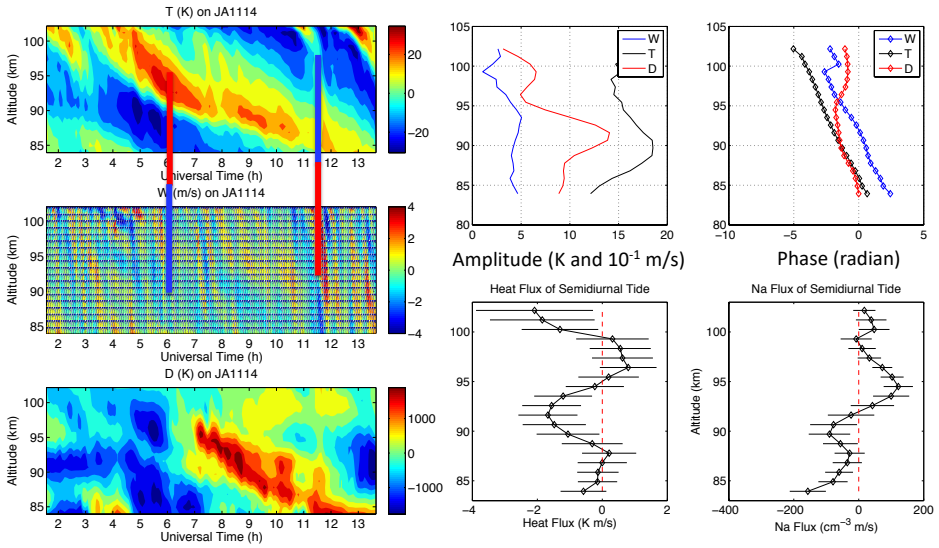
Example of Negative Heat Flux (01/11/2014)

Filtered Perturbations

Heat and Na Fluxes



A long dataset with salient semidiurnal tidal signature.

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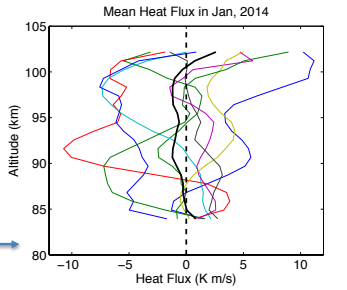
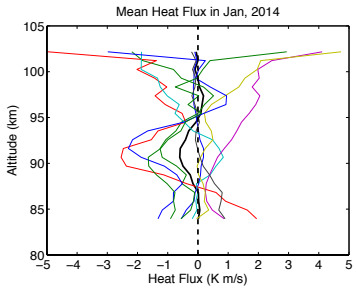
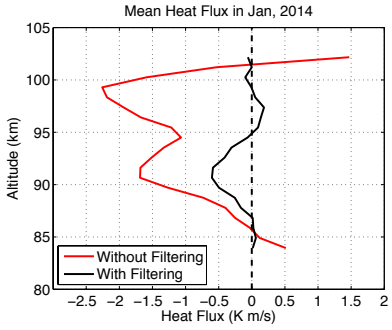
Day-to-day Variability and Mean Heat Fluxes

Without 2DFFT Filtering





With 2DFFT Filtering



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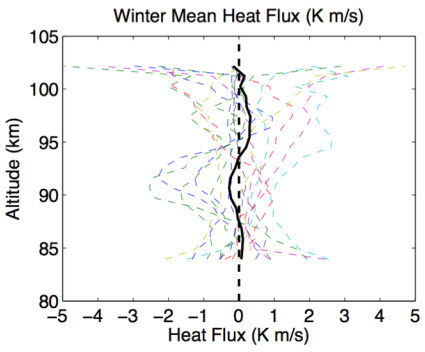
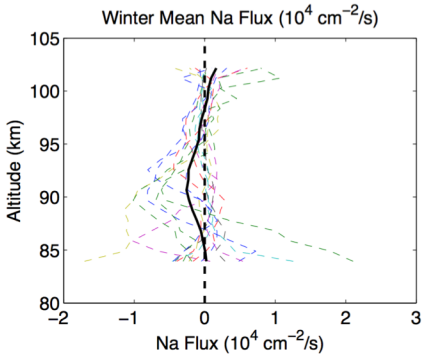
Day-to-day Variability and Winter Mean of Heat Fluxes





- **Both positive and negative heat fluxes are present (even can be seen from raw T and W).**
- **Day-to-day variability of the heat fluxes is significant.**
- **The mean heat flux is much smaller, but still non-negligible compared with contribution from gravity waves.**

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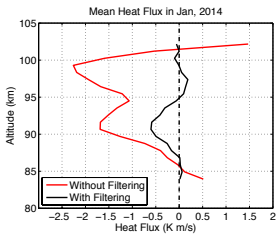
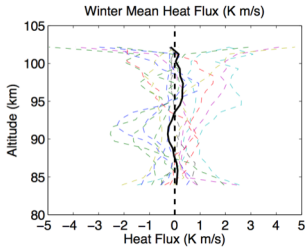
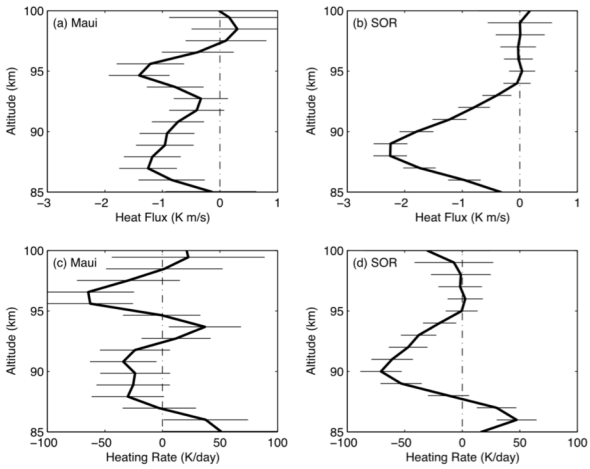
GW-induced heat fluxes

12-h Tide





Gravity Waves (A broad spectrum)



Liu and Gardner, 2005

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Summary

1. **Heat fluxes induced by monochromatic tidal waves are derived and both positive and negative fluxes are present.**

2. **There is a significant day-to-day variability. On day to day basis, semidiurnal tides can cause substantial heating locally.**

3. **The mean heat flux show net downward flux, which is about half of the heat fluxes induced by GWs.**

Open Questions

1. **What causes the large positive heat flux induced by the long-period waves (likely associated with semidiurnal tide)? *Waltersheid [1981] also suggested that for a single monochromatic wave, negative heat flux is not always the case.***

2. **Is the 12-h wave global-scale semidiurnal tide? Is it modulated by local processes (e.g., gravity wave drag)? Because GW drag can modulate tidal phases significantly.**

   If so, why GW drag can cause the phase difference between w' and T' shift from near 90° to either < 90° (positive flux) or >90° (negative flux)?

3. **Does wave-wave interactions play a role in the picture? The period of the apparent long-period oscillation is not exactly 12h, but more towards 11 h or even 10 h.**

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