Recent Temperature Microstructure Measurements From The Eurasian Basin

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Motivation:

The challenging nature of logistics in the Arctic Ocean have made it difficult to perform intensive microstructure experiments. The low levels of turbulence found away from the boundaries and topography and the prevalance of non-mechanical mixing regimes like double diffusion compound this issue.

Previous experiments, *Padman and Dillon* [1987], *Rainville and Winsor* [2008], *Sirevaag and Fer* [2012] have favored the calculation of ε, and because of this, profiled their instruments at speeds approaching 1 m/s. This has forced them, when calculating χ, to rely on fitting their data to theoretical turbulence spectra to resolve all of the variance, since ε is typically below the noise of level of most instruments below the pycnocline.

Meanwhile, our best estimates of the vertical heat flux from the Atlantic Water layer throughout the majority of the basin rely on laboratory derived flux laws. A parameterization can be applied anywhere a diffusive convective thermohaline staircase is present. While recent numerical studies have affirmed the laboratory flux laws, observational efforts are needed to attempt to verify these parameterizations in an oceanic regime.

This poster shows some preliminary results attempting to validate the 4/3rd laboratory flux law with heat flux calculated from temperature microstructure across double diffusive interfaces in an Eurasian Basin thermohaline staircase.

Data and Methodology:

As part of the NSF funded North Pole Environmental Observatory Project, a short temperature microstructure experiment was performed from the drifting Russian Ice Camp Barneo in April 2013.

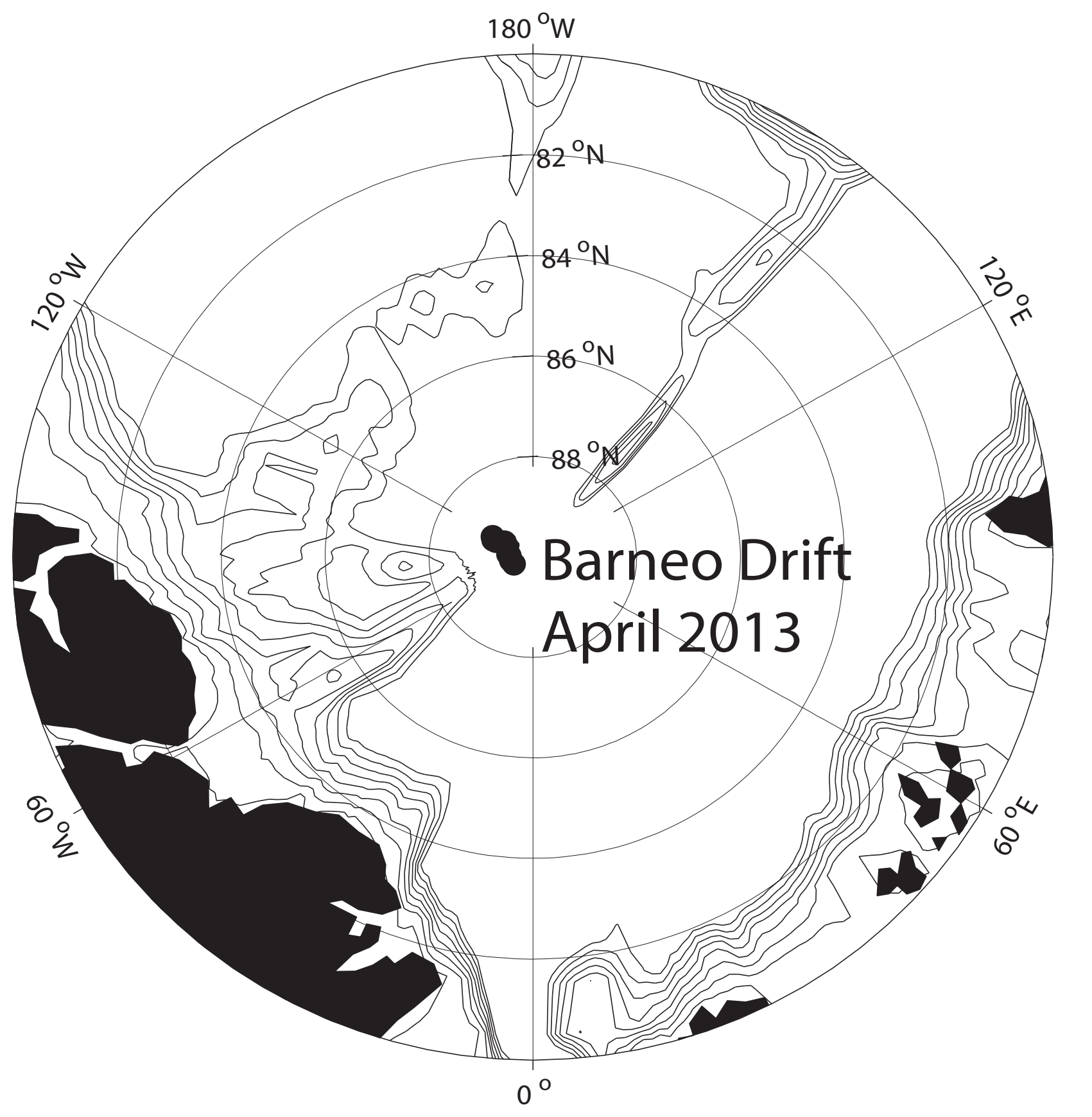

Fig. 1: Bathymetry map showing the location of the experiment drift in the Arctic Ocean.

An SBE 19+ CTD was affixed to an RSI Microrider and lowered through a hole in the sea ice. The Microrider had 2 shear probes and 2 FP07s but no microconductivity. The instrument package was lowered at a speed of between 20-25 cm/s in an attempt to capture all of the temperature gradient variance. From 4/11 - 4/19 a total of 42 casts down to 350 m were made. Interfaces were chosen visually and for two main criteria: thickness greater than 10 cm and free from other structures. Only 146 interfaces met this criteria as most were thinner or contained other structures. Heat flux is calculated three ways:

(1) 4/3rd Laboratory Flux Law

$$F_H = C(R_\rho)\rho c_p \left(\frac{g\kappa_T^2\alpha}{\nu}\right)^{1/3} (\Delta\theta)^{4/3}$$

(2) χ from FP07 temperature gradient spectra

$$\chi = 2\kappa_T \left\langle \left(\frac{\partial T'}{\partial z}\right)^2 \right\rangle \quad K_T = \frac{\chi}{2\langle \partial T/\partial z \rangle^2} \quad F_H = -\rho c_p K_T \langle \partial T/\partial z \rangle$$

(3) From molecular diffusivity

$$F_H = -\rho c_p \kappa_T \langle \partial T/\partial z \rangle$$

Sample Profile:

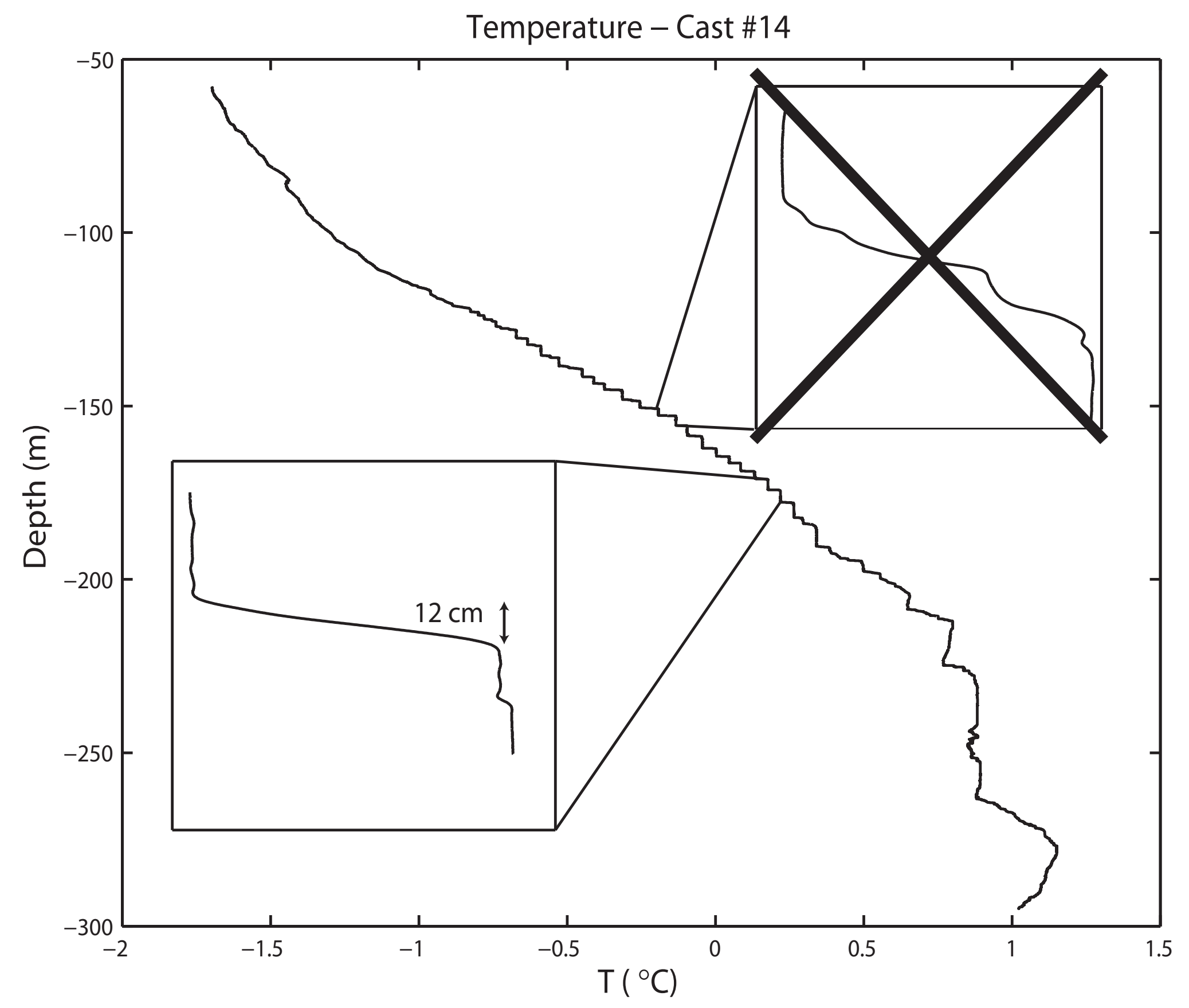

Fig. 2: Temperature profile from Cast #14. Insets are an example of two interfaces. The leftmost is included in the analysis while the rightmost is not.

Thermistor Comparison:

Unfortunately, acceptable data from both FP07s was only available in a handful of casts due to issues with the second themistor channel. Typically, two turbulence probes are used in the calculation of quantities.

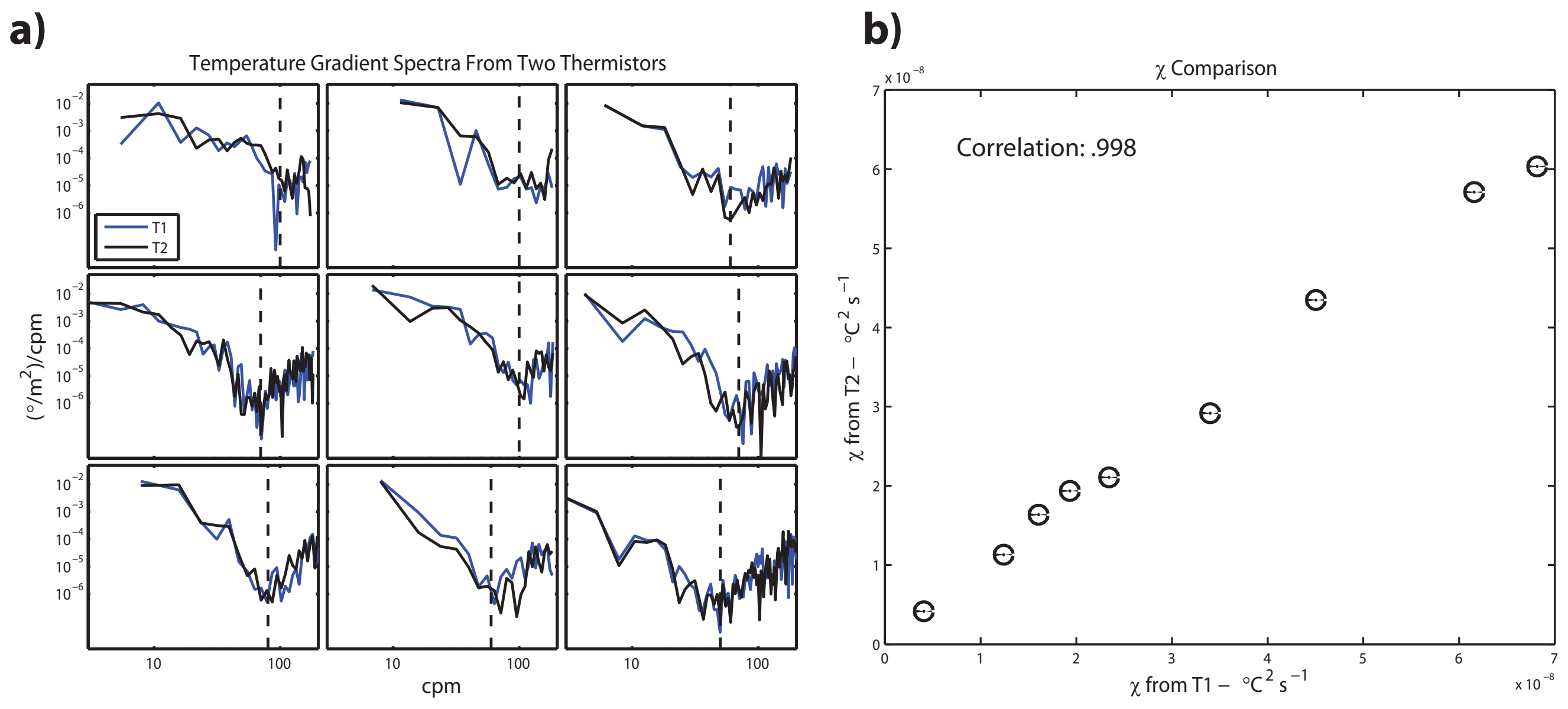

Fig. 3: (a) Comparison of Temperature Gradient Spectra from different thermistors across 9 interfaces from Cast #14. (b) Plot of χ calculated from the spectra in 3(a) for both thermistors.

Spectra - Interface vs. Layer:

χ values in the interfaces are an order of magnitude or more greater than χ in the layers. The interface/layer pair shown below were chosen at random. The interface is fit better with Kraichnan spectra while the layer is fit better with Batchelor spectra although there is deviation at low wavenumber.

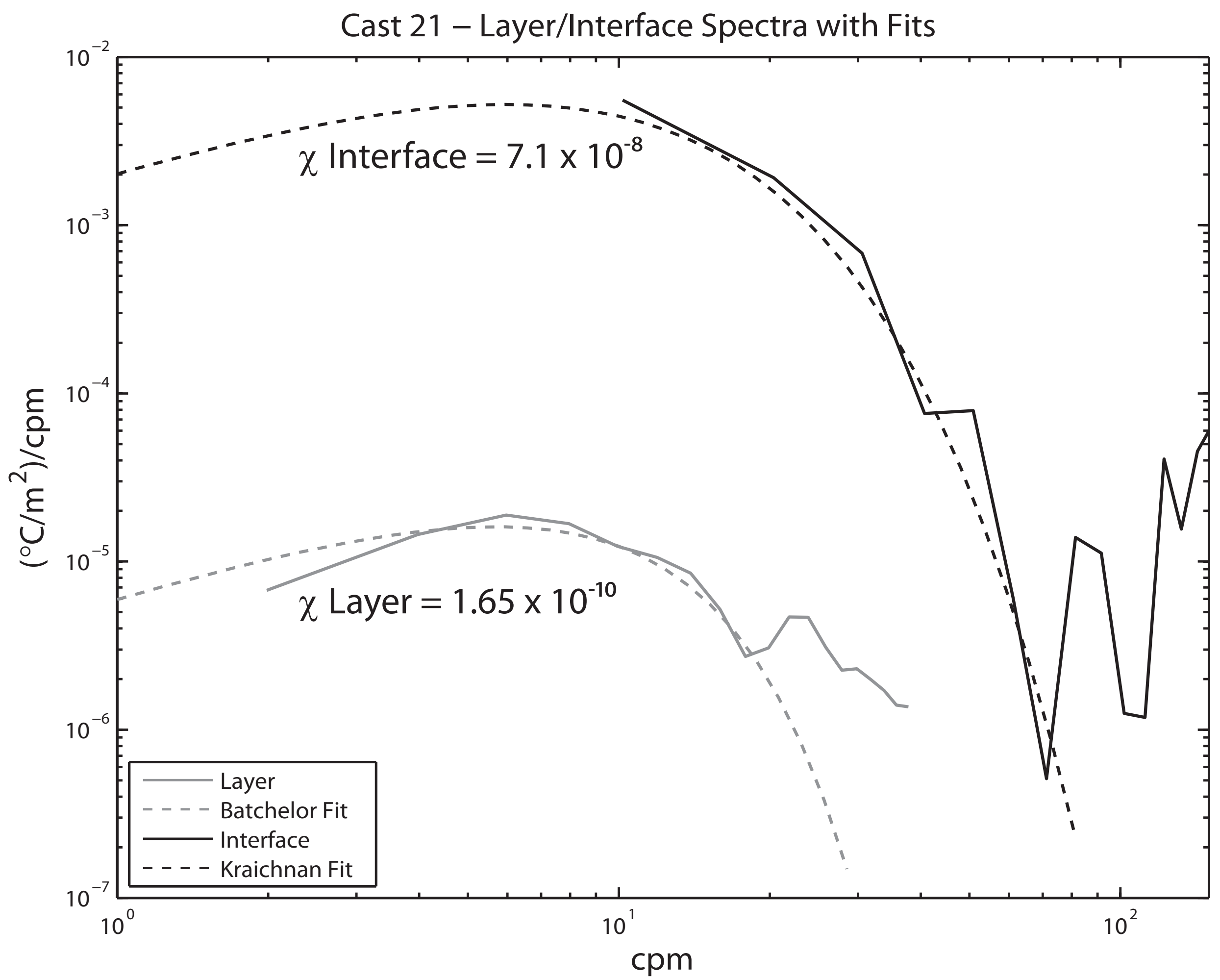

Fig. 4: Comparison of layer and interface spectra from Cast #21. Dotted lines are theoretical spectral fits.

Flux Law vs. Observations:

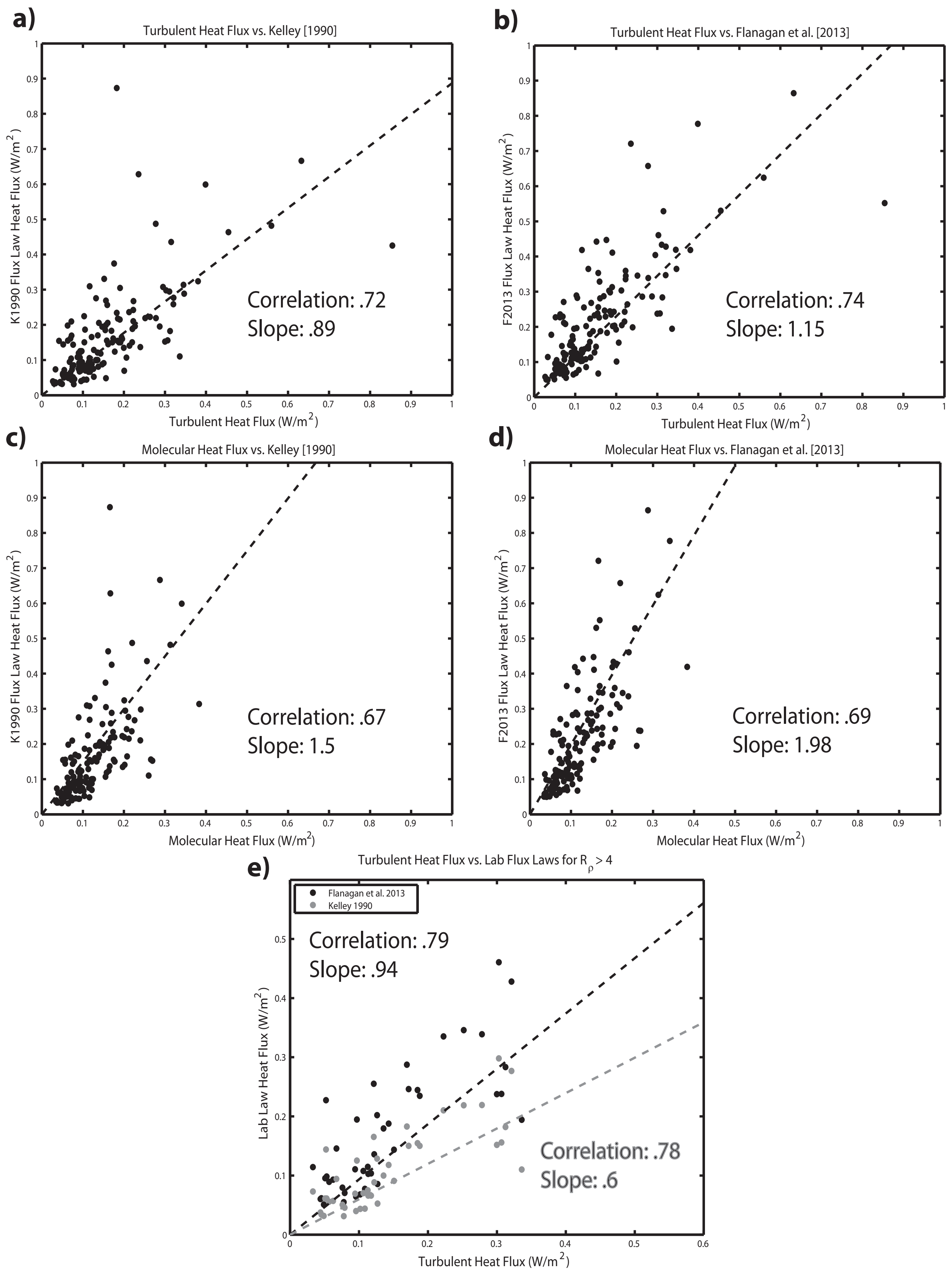

Fig. 5: Scatter Plots of Turbulent and Molecular Heat Flux vs. Laboratory Flux Laws with Correlations and Slopes. (a) Turbulent vs. *Kelley* [1990]. (b) Turbulent vs. *Flanagan et al.* [2013]. (c) Molecular vs. *Kelley* [1990]. (d) Molecular vs. *Flanagan et al.* [2013]. (e) All comparisons using only interfaces with density ratio greater than 4.

“mean” Interface Properties:

$$K_T = 1.73\times10^{-7}\, m^2 s^{-1}$$

$$\chi = 2.28\times10^{-8}\ {}^\circ C^2 s^{-1}$$

$$dt/dz = .22\ {}^\circ C m^{-1}$$

$$R_\rho = 3.5$$

$$F_{H\_Turb} = .16\ Wm^{-2}$$

$$F_{H\_Mol} = .12\ Wm^{-2}$$

$$F_{H\_K90} = .17\ Wm^{-2}$$

$$F_{H\_F2013} = .23\ Wm^{-2}$$

Conclusions:

Heat flux calculated from temperature gradient microstructure measurements agrees reasonably well with the laboratory flux laws.

“Eddy” diffusivity calculated across the interfaces appears only slightly (10-20%) higher than molecular diffusivity.

The magnitude of our heat flux values agree well with the *Flanagan et al.* [2013] formulation of the flux law for higher density ratios although both formulations are well correlated.

Acknowledgements:

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