Some Information for the CAESAR Discussion

Al Cooper - 21 Sept 2020

THE PROBLEM RE SENSIBLE-HEAT FLUX

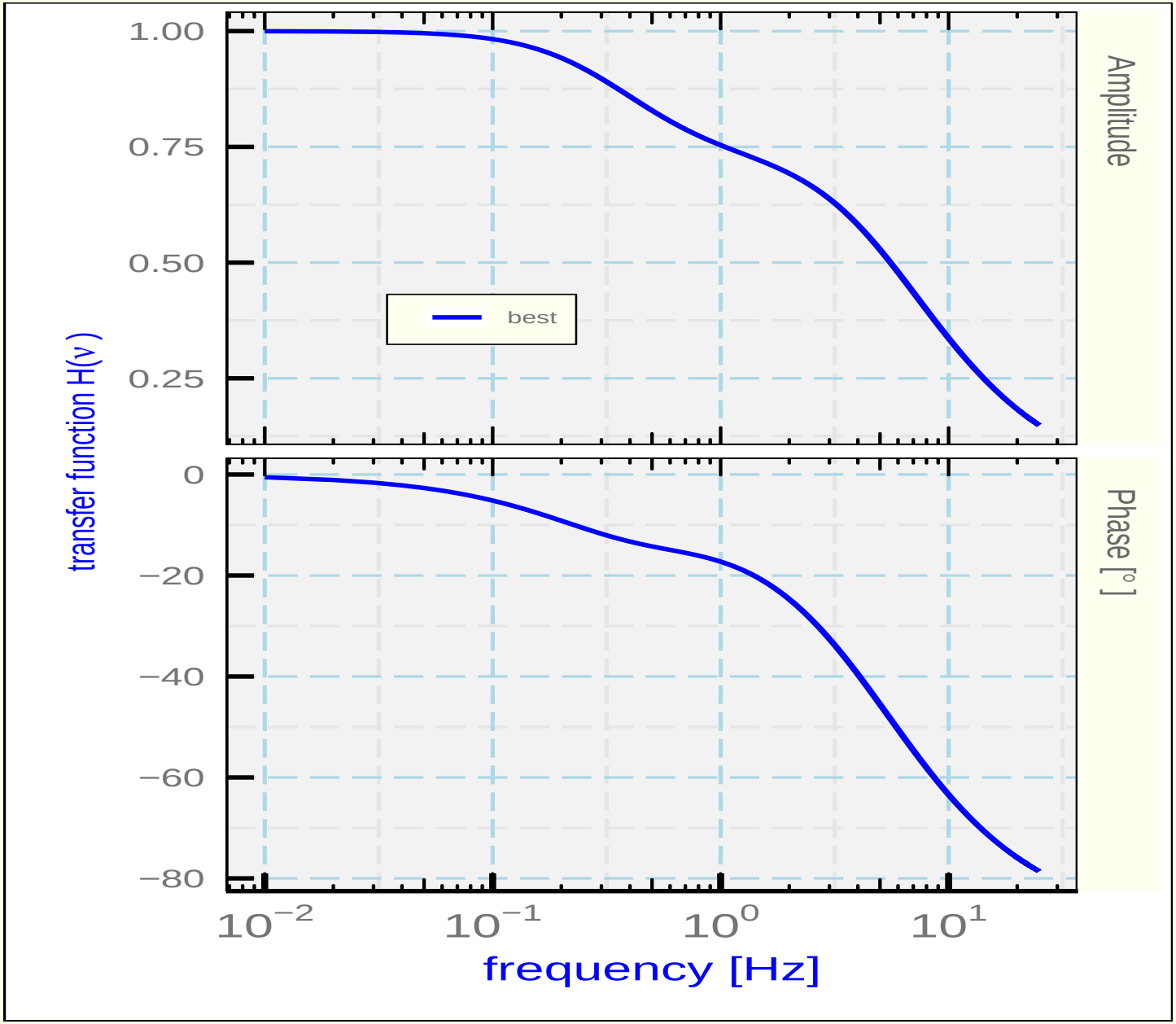
The Response Time of a Thermometer Affects the Measurement

- Desirable: measure at frequencies above 1 Hz (10 Hz?).
- The standard sensor, the Rosemount 102E4A2, doesn't respond fast enough and so misses part of the flux.
- The response also introduces a phase shift, potentially giving a wrong-sign contribution for some frequencies.

Recent Work

- The frequency-domain transfer function was determined for the sensor.
  $H(\nu) =$ sensor output) / (measurand input)
  $H(\nu)$ has both amplitude (gain) and phase.
- The transfer function was found by using the known input provided by dynamic heating.

THE TRANSFER FUNCTION (best fit from observations)



CALCULATING SENSIBLE-HEAT FLUX F_s

Eddy Correlation:
Simultaneously measure temperature and updraft

$$F_s = \rho\, C_p \left\langle w' T' \right\rangle$$

Express in terms of the cospectrum:

$$F_s = \mathrm{Re}\left(\int \rho\, C_p \hat{w}^*(\nu)\, \hat{T}(\nu) d\nu \right)$$

$(\hat{})$ denotes Fourier transform, * complex conjugation

Then use $\hat{T}_m(\nu) = H(\nu)\, \hat{T}(\nu)$ where:

$H(\nu)$ is the complex transfer function (gain and phase)

T_m is the uncorrected measurement

The corrected cospectrum:

$$F_s = \mathrm{Re}\left(\int \rho\, C_p \hat{w}^*(\nu) (\hat{T}_m(\nu)/H(\nu)) d\nu \right)$$

CORRECTIONS ARE TYPICALLY 30-35%. Examples:

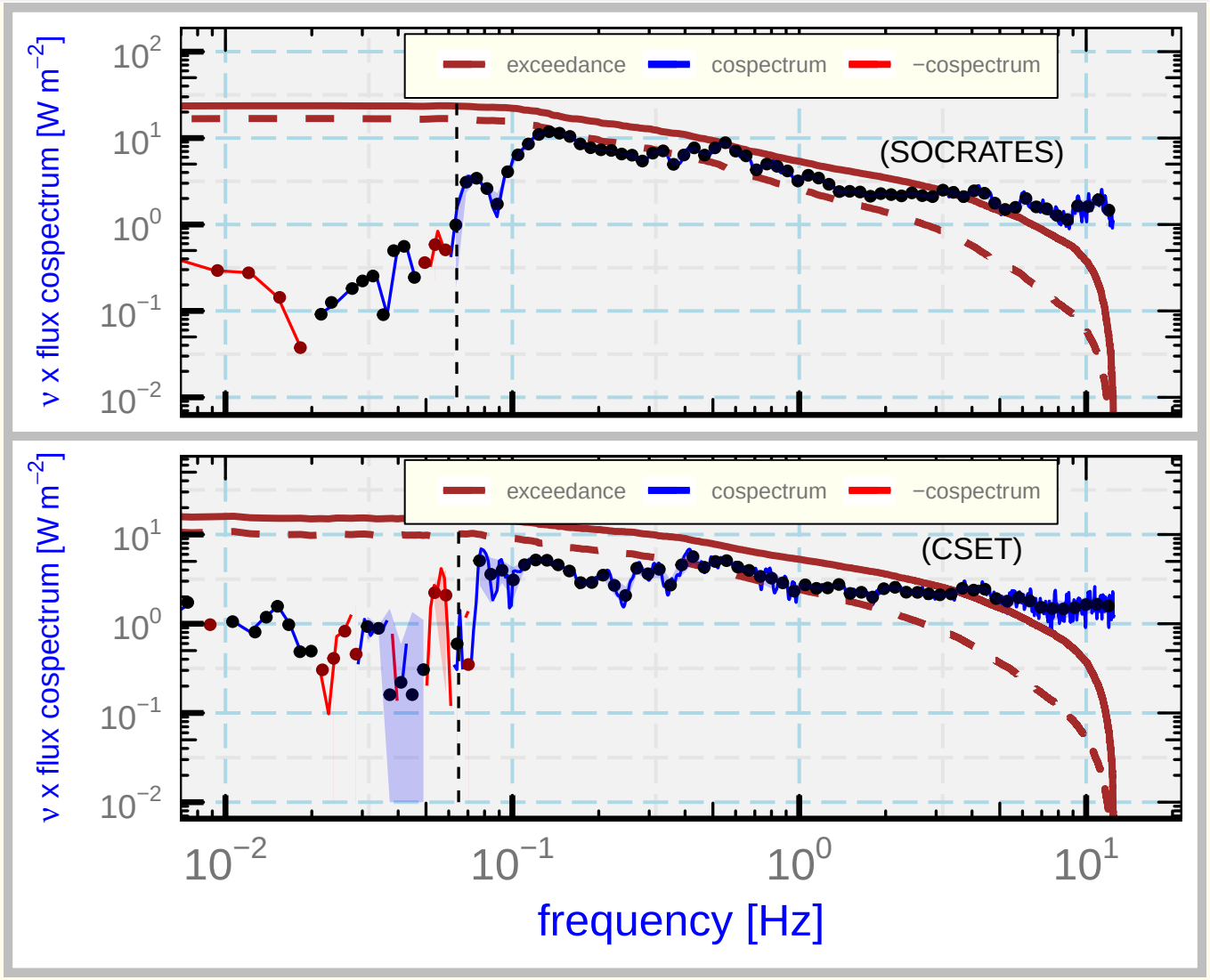


Figure: Corrected cospectra (blue line, black dots). The brown line is the "exceedance" (flux contributed by frequencies above the plotted value); the dashed brown line is the same for the uncorrected cospectrum.

SUGGESTED ASSESSMENT, NSF/NCAR C-130:

Sensible-heat flux:

- Defensible measurements are possible with the proposed correction, which removes an otherwise significant error.
- Remaining uncertainty from sensor response: 5% or less.
- To limit other aspects of the uncertainty, long-enough legs in relatively homogeneous conditions are needed. Cf. Lenschow references. Simulations can provide additional guidance.

The situation is less studied for latent-heat flux:

- There are several candidate sensors for water vapor:
  - VCSEL – the standard sensor on RAF aircraft, but a recent change to improve instrument resolution needs study.
  - UV Hygrometer – has provided good measurements, but it has not been studied as much as other sensors.
  - Picarro – needs study for flux applications. Uses sample tubing.