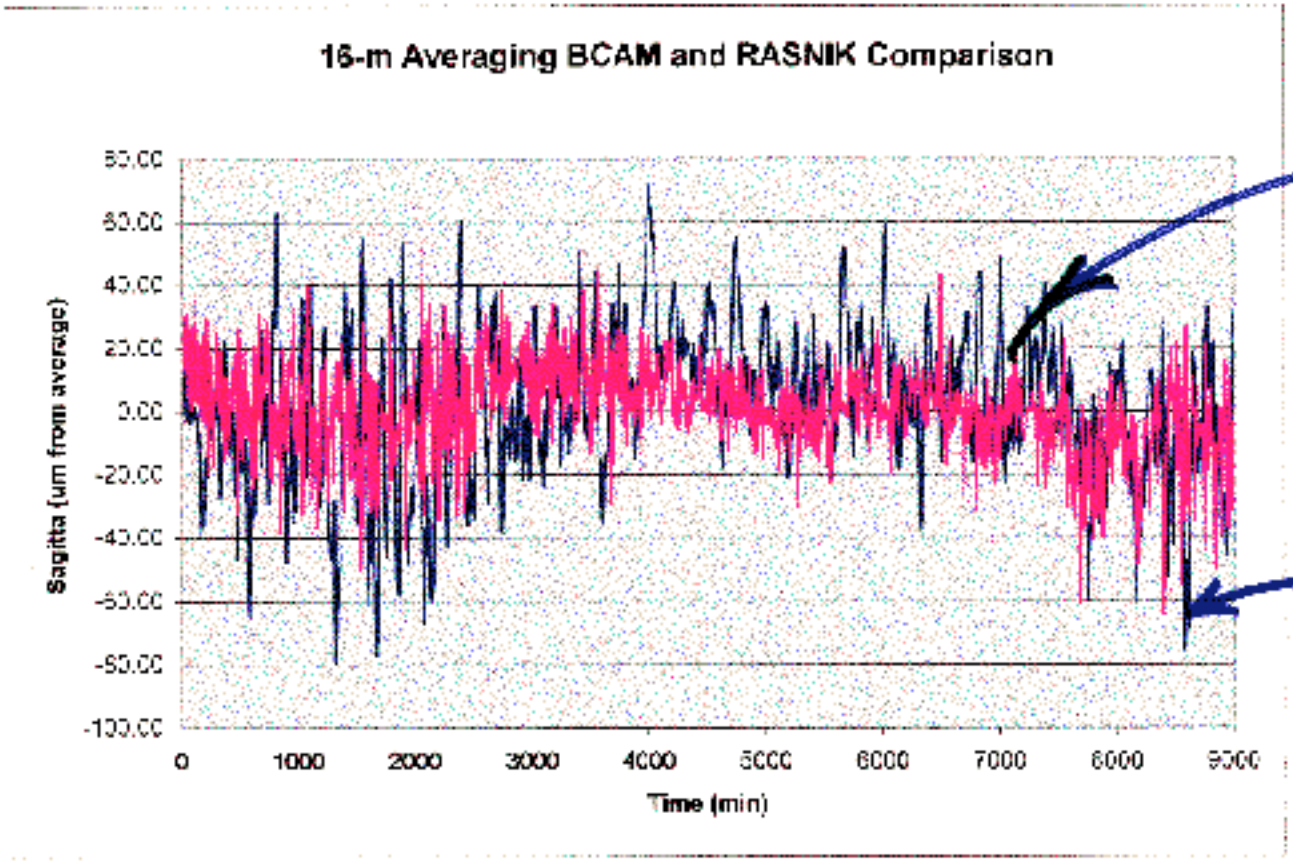
Some Unoriginal Thoughts on Thermal Gradients and Turbulence in Air

K. Hashemi

7 Feb 2000

ATLAS Week



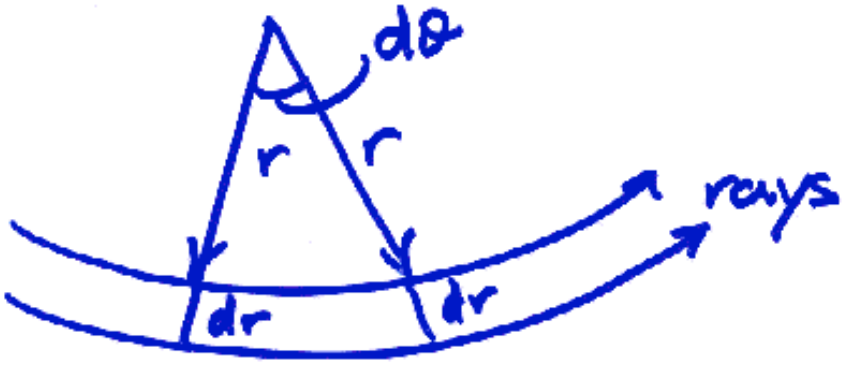
RASNIK Single samples (pink)

BCAM 4-sample running average (blue)

Turbulence

* If you wait long enough between measurements, errors due to turbulence are stochastic.
* Our experience is that one minute is long enough.
* With 16-m BCAM three-point monitor, obtained sagitta St. dev. 45 μm over five days, and 25 μm when we used 4-sample running average
* Corresponding RASNIK st. dev was 15 μm.
* Conclude that turbulence is not a problem because we can take averages

Ray Curvature



$$r \cdot d\theta \cdot n = (r+dr)\,d\theta\,(n+dn)$$

$$r = -n \Big/ \frac{dn}{dr}$$

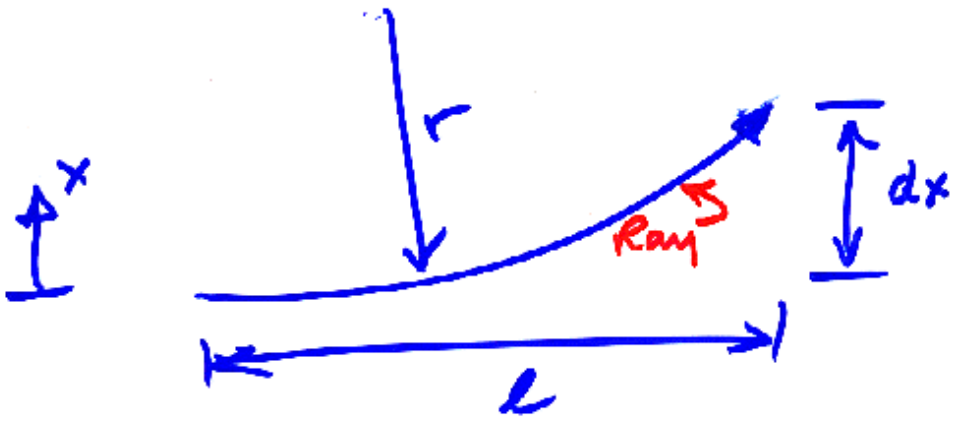
for air: $n \simeq 1 + aT$

$n \simeq 1.0003$ at $T = 300K$

$$\Rightarrow \frac{dn}{dr} \simeq 10^{-6}\, dT/dr$$

so we have: $\boxed{r = -10^{6} \Big/ \frac{dT}{dr}}$

Ray Displacement



$$dx = l^2 / 2r$$

$$= -\frac{l^2}{2n}\frac{dn}{dx}$$

for air:

$$dx = -l^2 \frac{dT}{dx} \cdot 0.5\,\mu m\,K^{-1}$$

$l = 4\,m$ $dT/dx = 10\,K/m \Rightarrow dx = 80\,\mu m$

$l = 10\,m$ $dT/dx = 1\,K/m \Rightarrow dx = 50\,\mu m$

NOTE: Sagitta error = $dx/4$

Sagitta Error

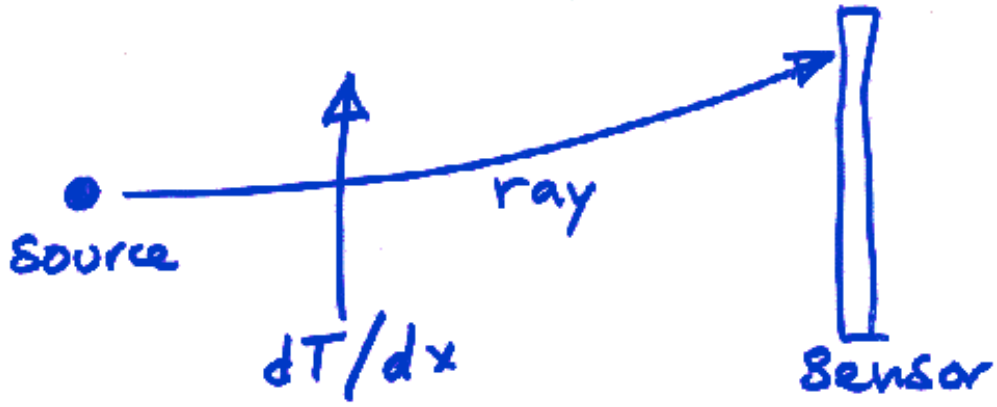
Claim: Sagitta error caused by ray curvature is same for all 3-point monitors (STAMP, ALMY, BCAM, RASNIK)

Sagitta Error

$$= \frac{dx}{4}$$

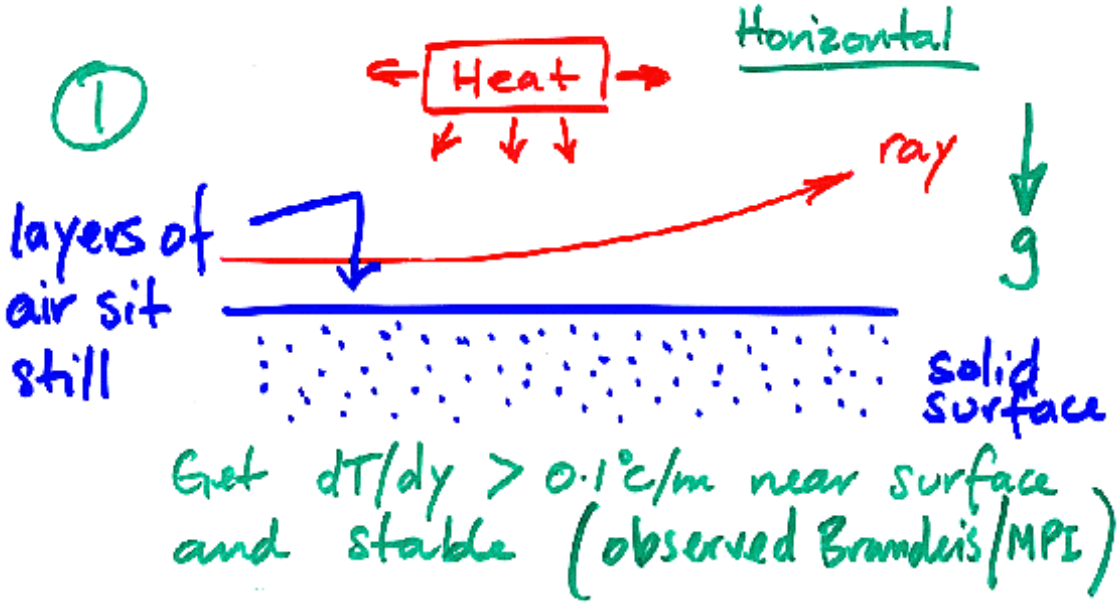
$$ds = \ell^2 \frac{dT}{dx} \, 0.1 \mu m \, K^{-1}$$

Stable Thermal Gradients

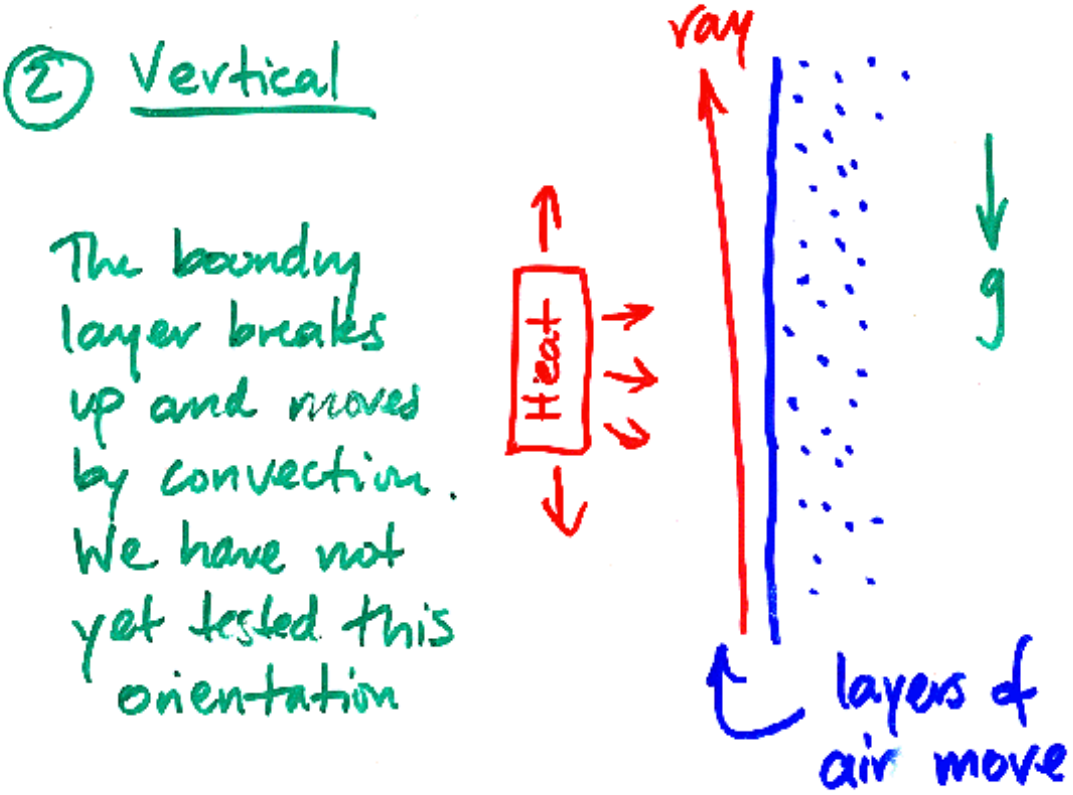


* need 1°C/m transverse gradient along 10 m axis to give us 5-mm sagitta error

* need 100°C/m along 1-m axis to give 5-mm sagitta error

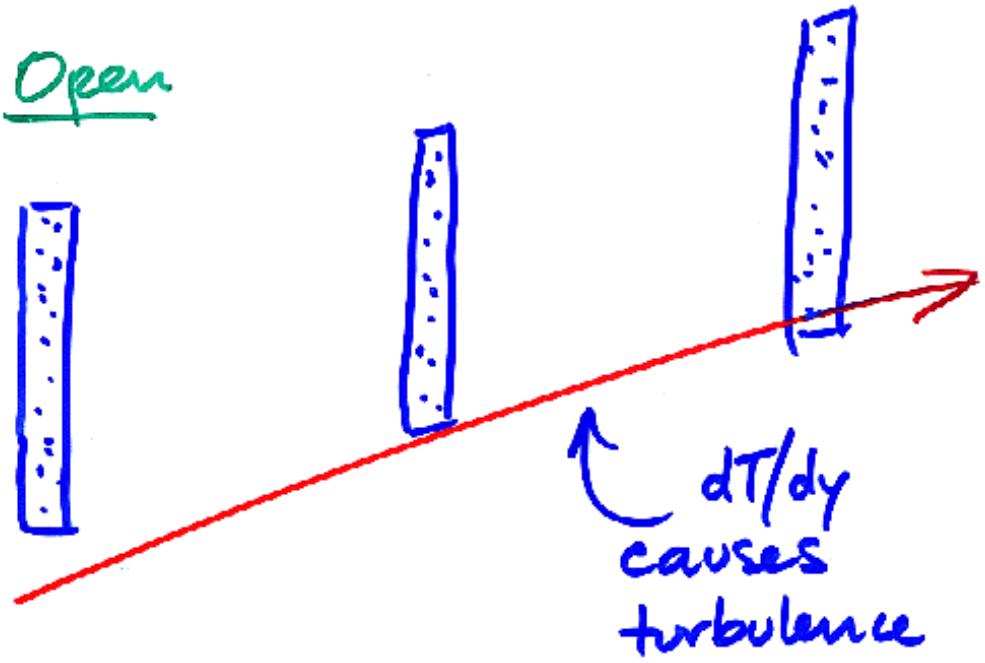


Get $dT/dy > 0.1°C/m$ near surface and stable (observed Brandeis/MPI)



The boundry layer breaks up and moves by convection. We have not yet tested this orientation

③ Open



* dT/dy small, since strata are unstable.
* Hard to make absolute measurement of systematic ray displacement
* Harry's idea to use two-color images.
* INVESTIGATE at H8 DATCHA

Conclude

* Protective tubes are a layout disaster.
* Assume we can operate without them in the end-cap.
* Test at H8 DATCHA.