Some Unoriginal Thoughts on Thermal Gradients and Turbulence in Air

K. Hashemi
7 Feb 2000
ATLAS Week
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

\[ r \cdot d\theta \cdot n = (r+dr) d\theta (n+dn) \]
\[ r = -n \frac{dn}{dr} \]

For air: \( n \approx 1 + aT \)
\( n \approx 1.0003 \) at \( T = 200K \)
\[ \Rightarrow \frac{dn}{dr} \approx 10^{-6} \frac{dT}{dr} \]

So we have:
\[ r = -10^6 \frac{dT}{dr} \]
Ray Displacement

\[ dx = \frac{l^2}{2r} \]

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

for air:

\[ dx = -\frac{l^2}{2} \frac{dT}{dx} \cdot 0.5 \text{ mm} \]

\[ L = 4 \text{ m}, \quad \frac{dT}{dx} = 10 \text{ K/m} \Rightarrow dx = 80 \text{ mm} \]

\[ L = 10 \text{ m}, \quad \frac{dT}{dx} = 1 \text{ K/m} \Rightarrow dx = 50 \text{ mm} \]

Note: Sagitta error = \( dx / 4 \)
Sagitta Error

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

Sagitta Error

\[
\frac{dx}{4}
\]

\[
ds = l^2 \cdot \frac{dT}{dx} \cdot 0.7 \text{ mm K}^{-1}
\]
Stable Thermal Gradients

* need $1^\circ C/m$ transverse gradient along 10 m axis to give us 5-mm sagitta error

* need $100^\circ C/m$ along 1-m axis to give 5-mm sagitta error
1. **Horizontal**

Layers of air sit still. Get $dT/dy > 0.1 \degree C/m$ near surface and stable (observed Brandeis/MPI).

2. **Vertical**

The boundary layer breaks up and moves by convection. We have not yet tested this orientation.
* $dT/\text{dy}$ 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 H& DATCHA.