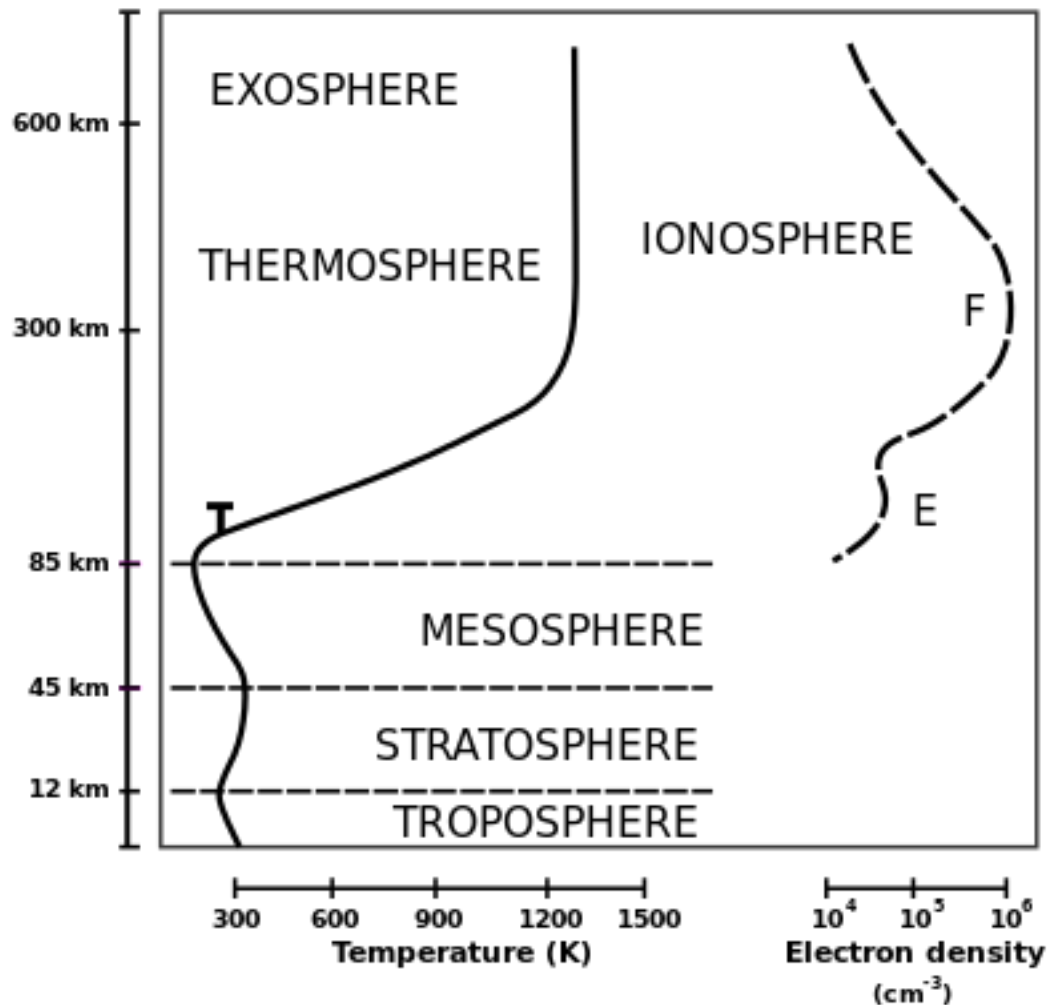


The Effects of the Atmosphere on Radio Astronomy Observations

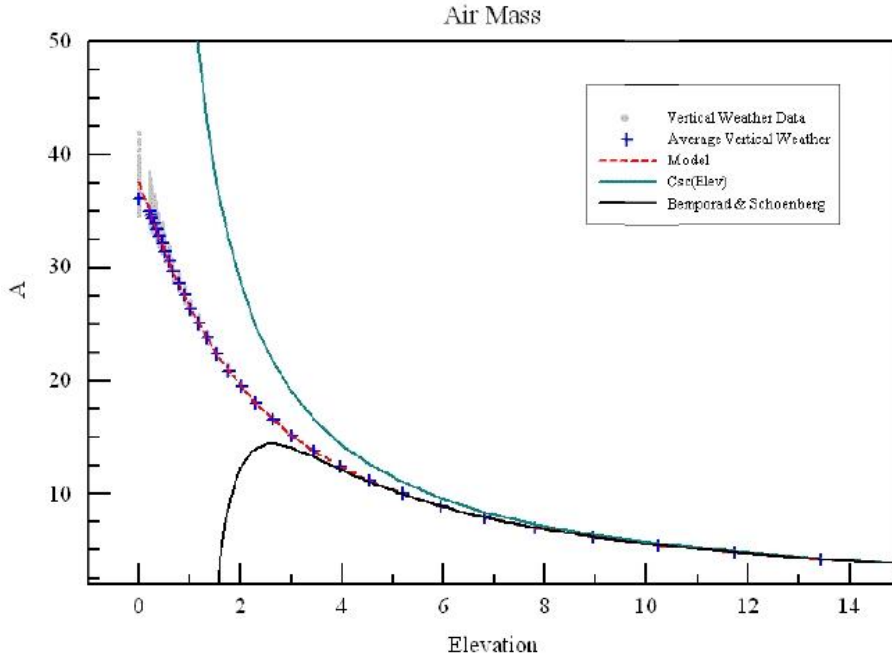
Dana S. Balser



The Effects of the Atmosphere on the Radio Signal



Atmospheric Refraction



$$R = E_o - E_t$$

Plane Parallel

$$n_o \cos(E_o) = \cos(E_t)$$

$$R \sim (n_o - 1) \cot(E_o)$$

Maddalena & Johnson (2006)

Spherical

$$R = r_o n_o \sin(z_o) \int_1^{n_o} \frac{dn}{n(r^2 n^2 - r_o^2 n_o^2 \sin^2(z_o))^{1/2}}$$

Green (1985)

Anomalous Refraction (Seeing)

$$m_{50} = \frac{f}{100 \text{ GHz}} \left(\frac{D}{50 \text{ m}} \right)^{5/6}$$

= 0.4 at 10 GHz for Arecibo

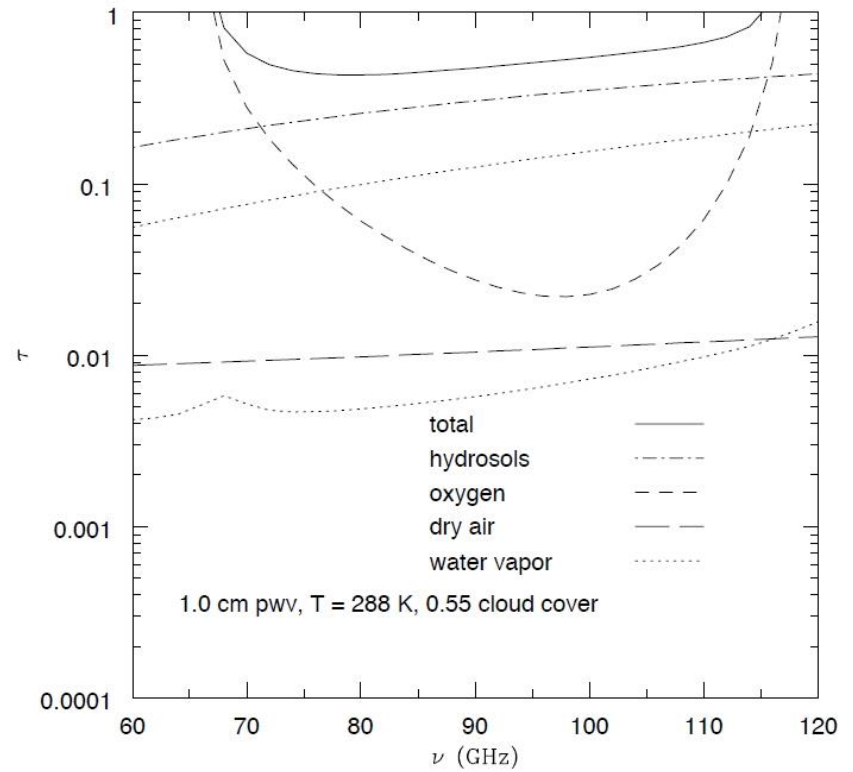
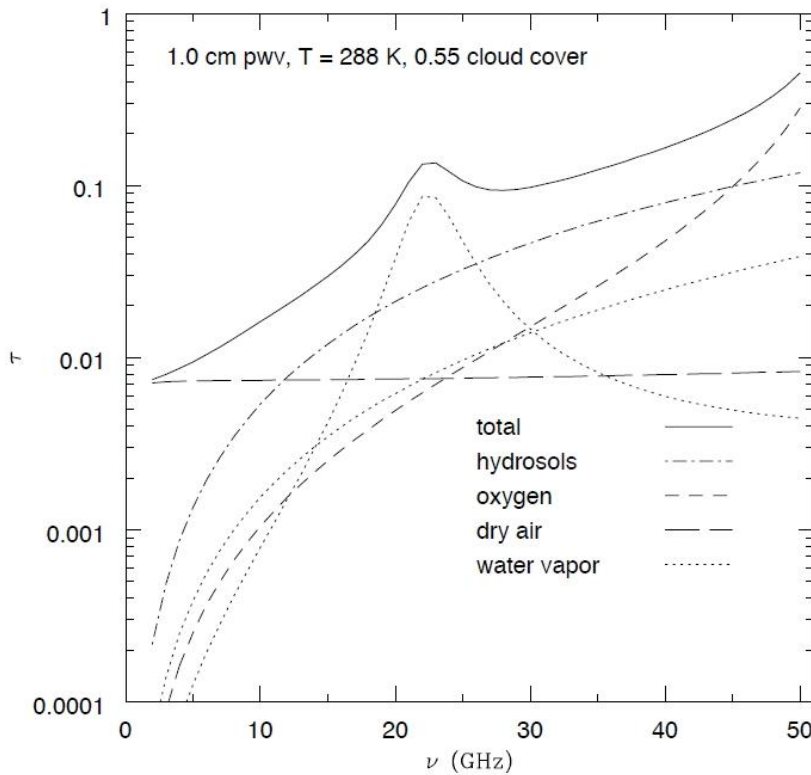
= 1.8 at 100 GHz for the GBT

= 3.0 at 300 GHz for the LMT

Important when $m_{50} > 1$

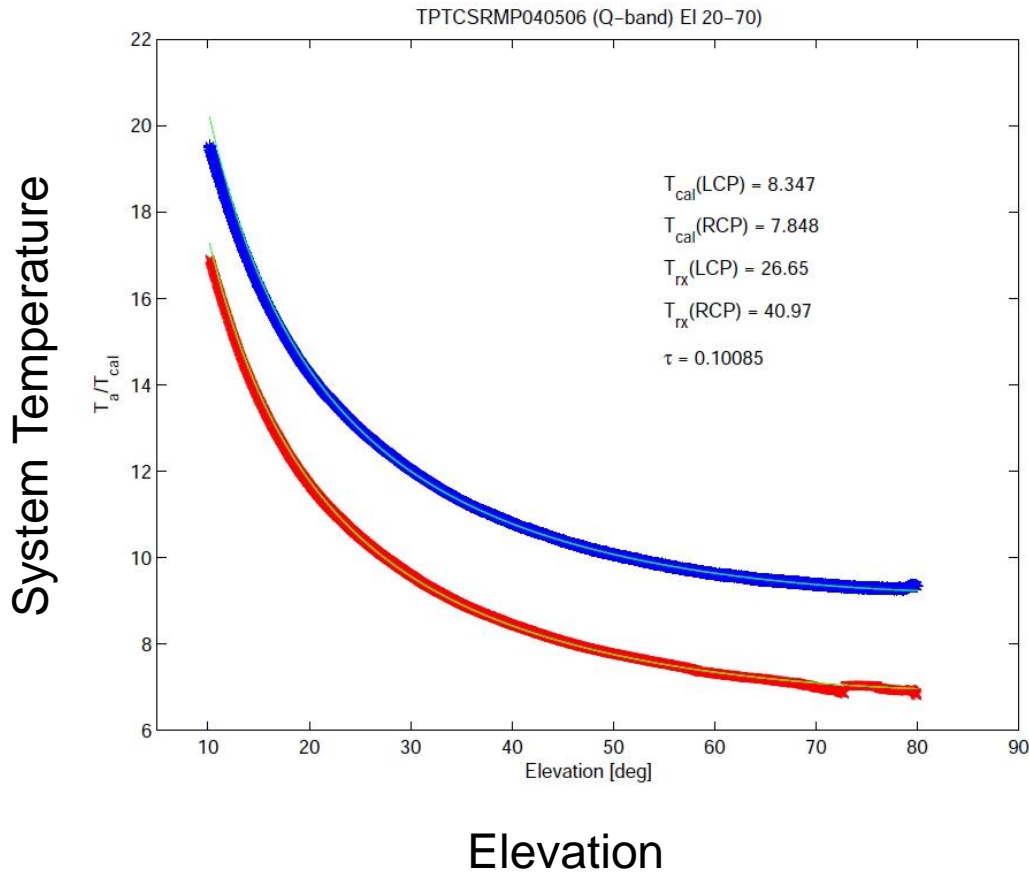
Atmospheric Absorption

$$T_A \propto e^{-\tau}$$



Condon (2007)

Atmospheric Emission (Noise)



$$T_{sys} = T_o + T_b$$

$$T_o \sim T_{rcvr} + T_{src} + T_{grd} + T_{cmb}$$

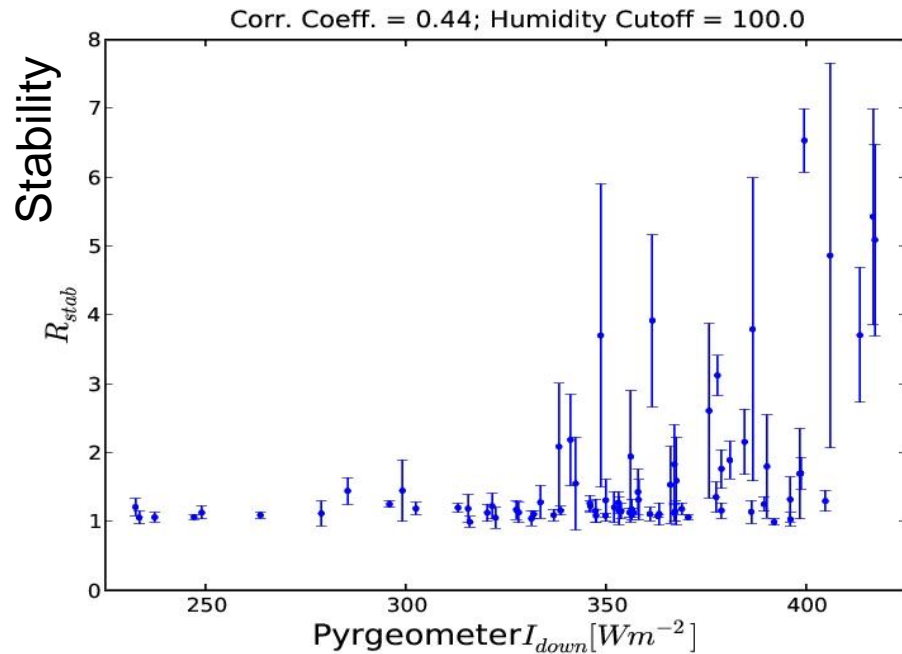
$$\sim T_{rcvr} + 6K$$

$$T_b = T_k(1 - e^{-\tau})$$

Condon (2007)
Balser (2004)

Atmospheric Stability

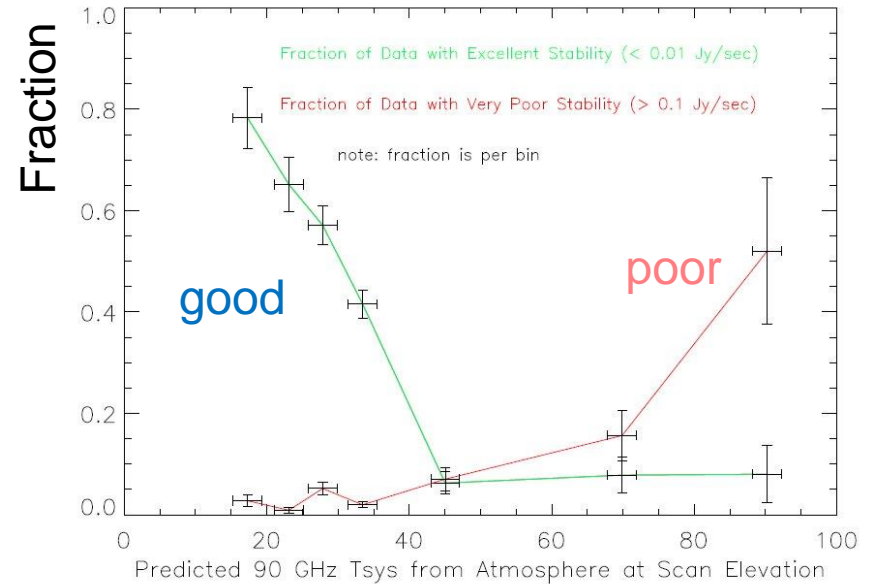
9 GHz



IR Irradiance

Balser (2011)

90 GHz



Tsys (90GHz)

Mason & Perera (2011)

The Effects of the Atmosphere on the Telescope

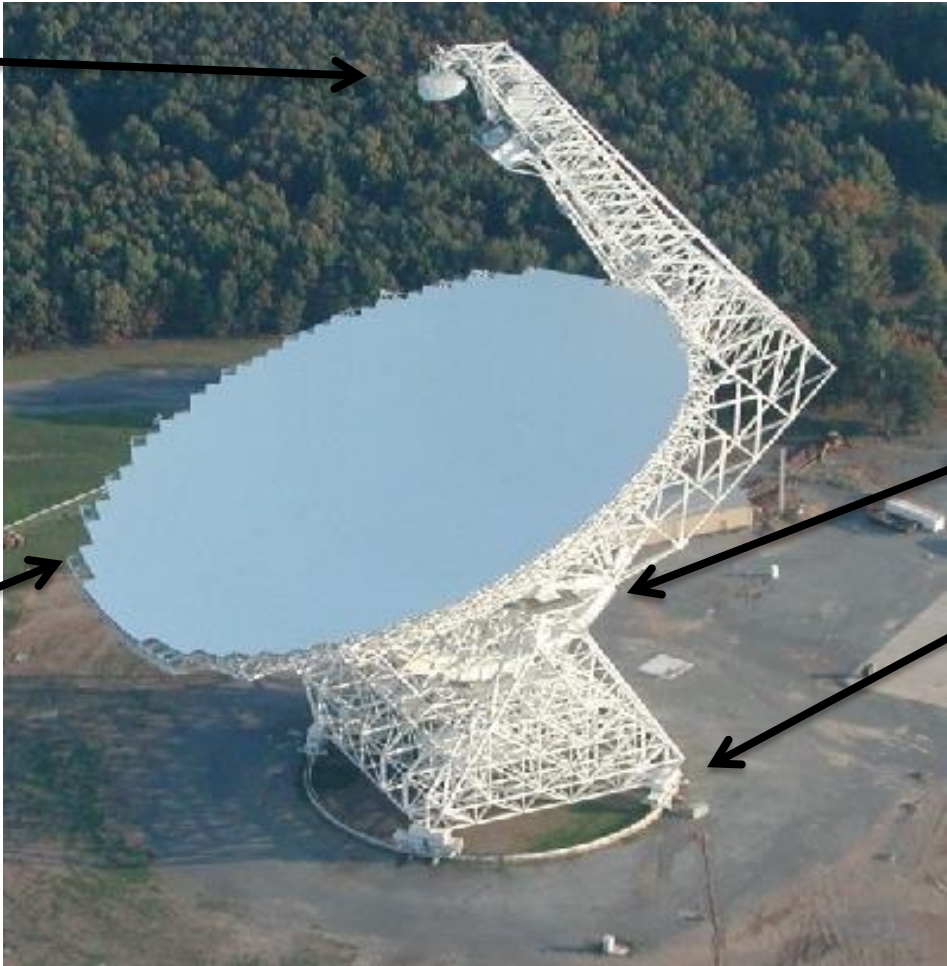


Repeatable Errors:
Gravity
→ Static Corrections

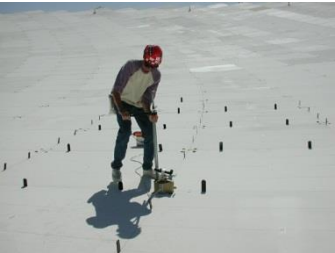
Non-repeatable Errors:
Thermal (slow)
Wind (fast)
→ Dynamic Corrections

Telescope Adjustments

Focus



Surface



Pointing



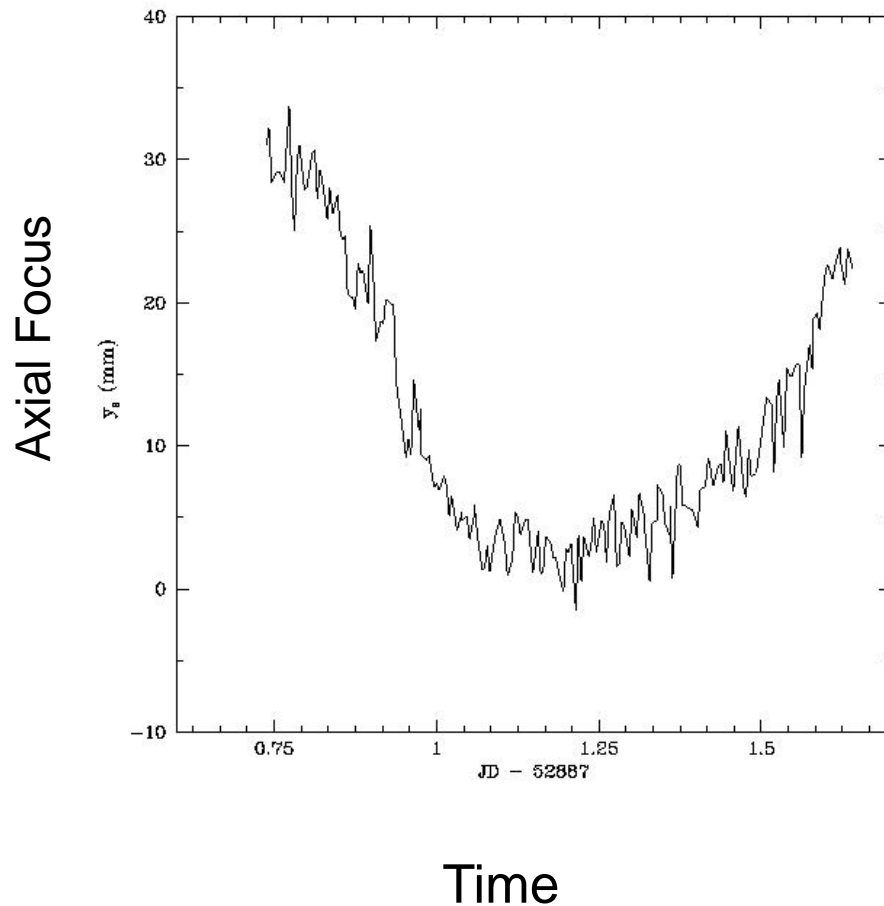
Telescope Performance

Pointing : $\sigma_s = 10\% \rightarrow \frac{\sigma_2}{\theta} \approx 0.20$

Focus : $g_a > 0.95 \rightarrow \Delta y_s < \lambda / 2$

Surface : $\eta_s \approx 0.37 \rightarrow \varepsilon < \lambda / 4\pi$

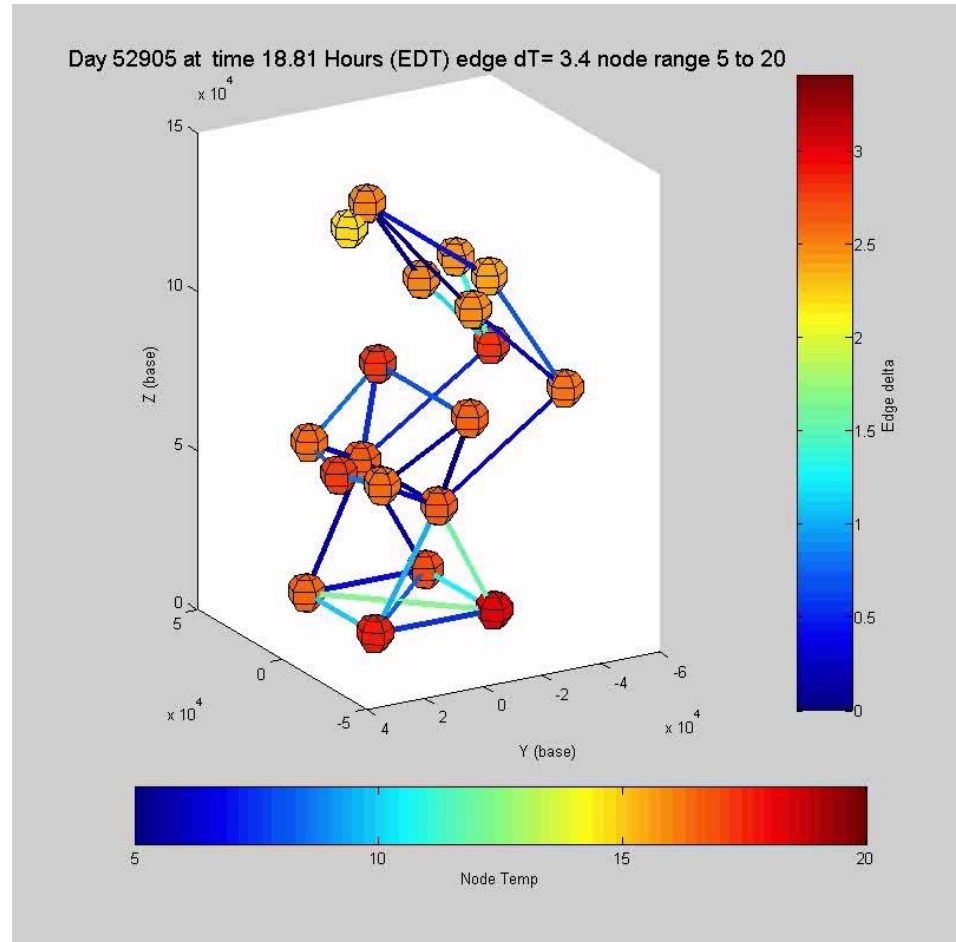
Thermal Effects: pointing, focus, surface shape



30 mm $\rightarrow \lambda/3$ at $\nu = 3$ GHz

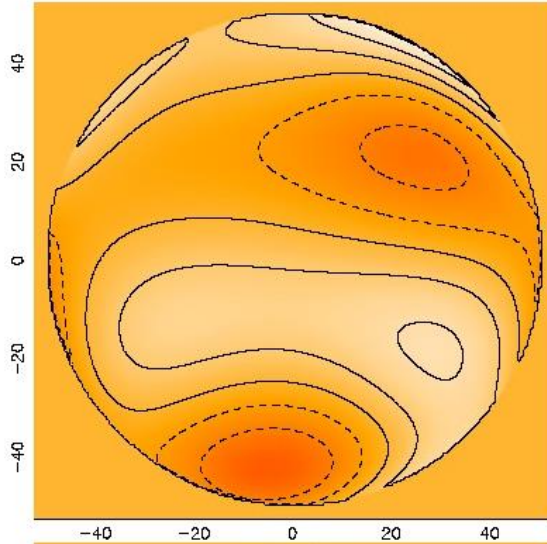
30 mm $\rightarrow 3\lambda$ at $\nu = 30$ GHz

Telescope Pointing and Focus: thermal model

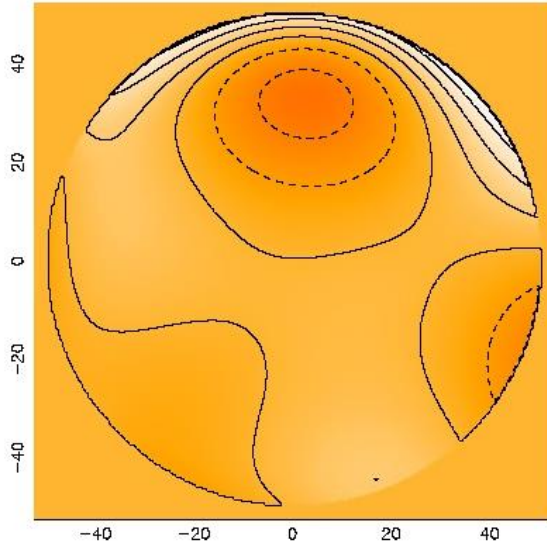


Constantikes (2007)

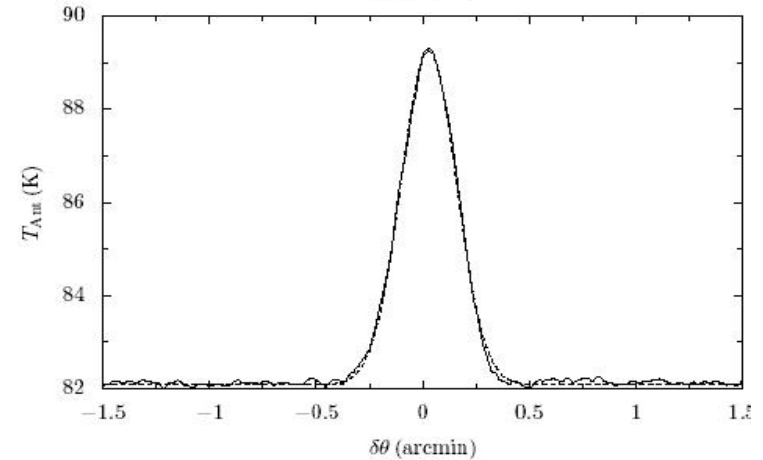
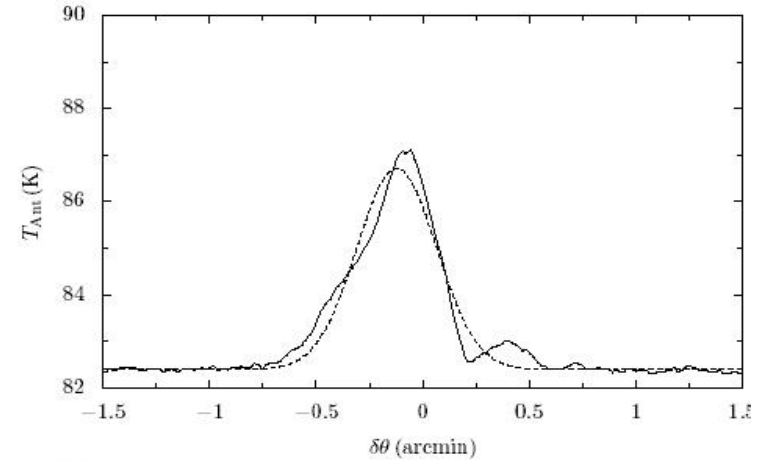
Telescope Surface: OOF Holography



$$rms = 330\mu m$$

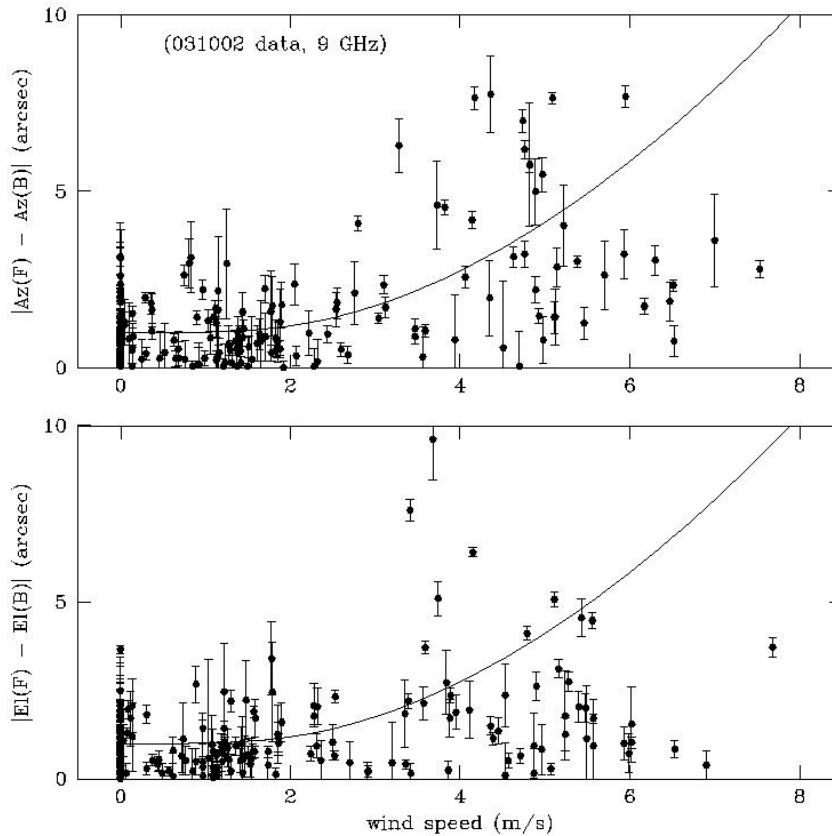


$$rms = 220\mu m$$



Nikolic et al. (2007)

Wind Effects: pointing



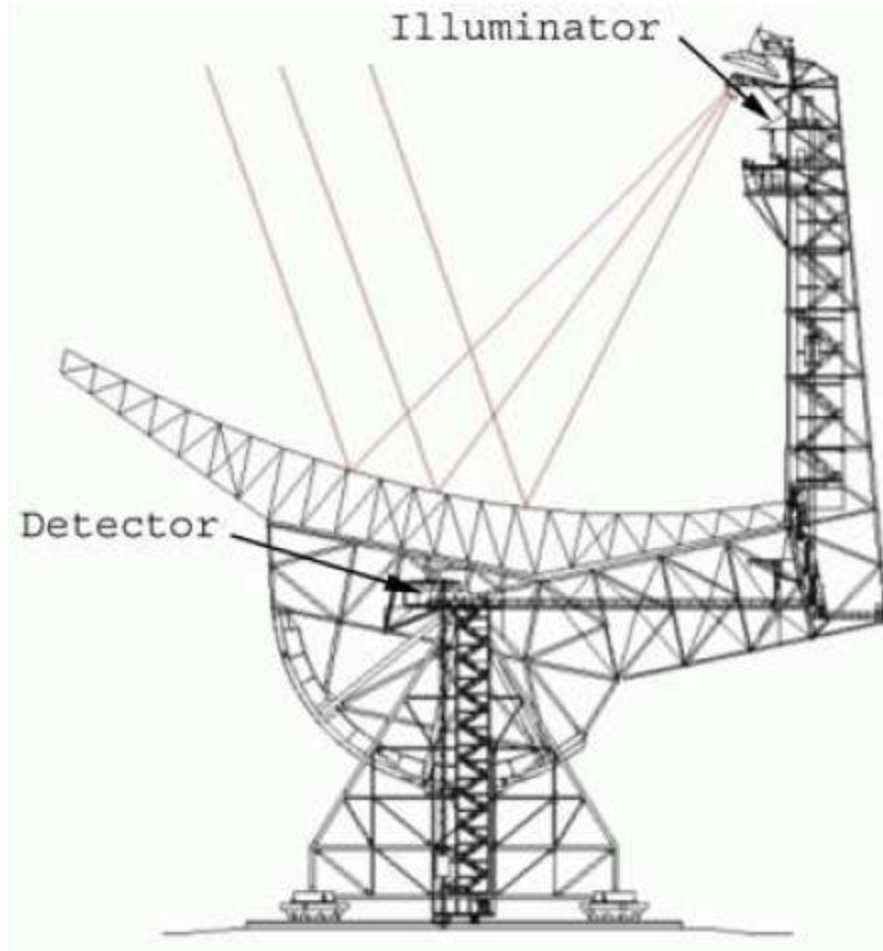
Hooke's Law

$$\sigma_1(\text{wind}) \approx 0.16 \left[\frac{s}{m \ s^{-1}} \right]^2 \text{ arc sec}$$

$$\sigma_2(\text{wind}) \approx \sqrt{2} \sigma_1(\text{wind})$$
$$\approx 8'' \text{ at } s = 6 \text{ m s}^{-1}$$

Condon (2003)

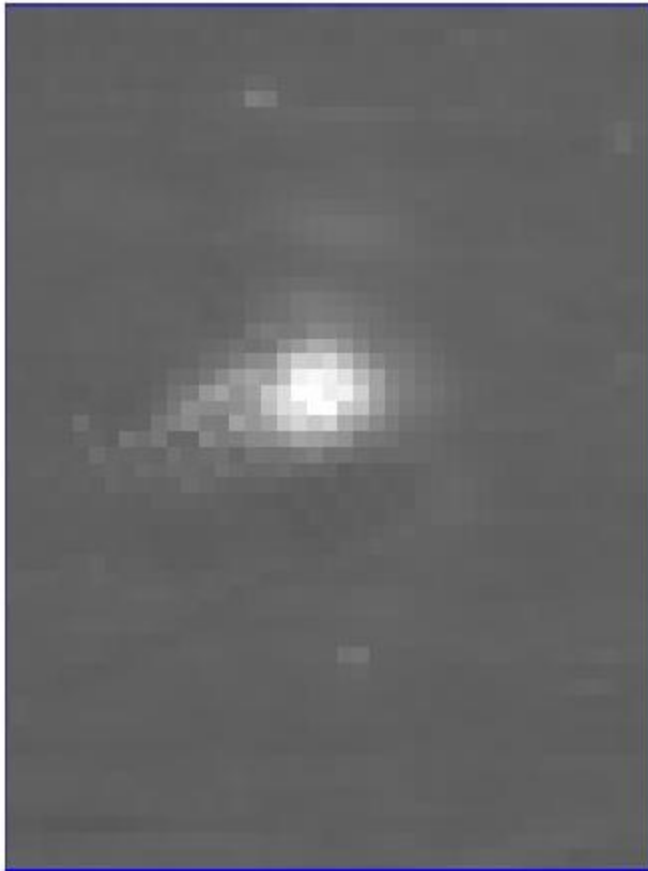
Quadrant Detector



- Flag bad data
- Correct maps from arrays
- Real-time corrections

Map Corrections

Before



After



Ries et al. (2009)

Fini

