Forecasting for the Hat Creek Observatory

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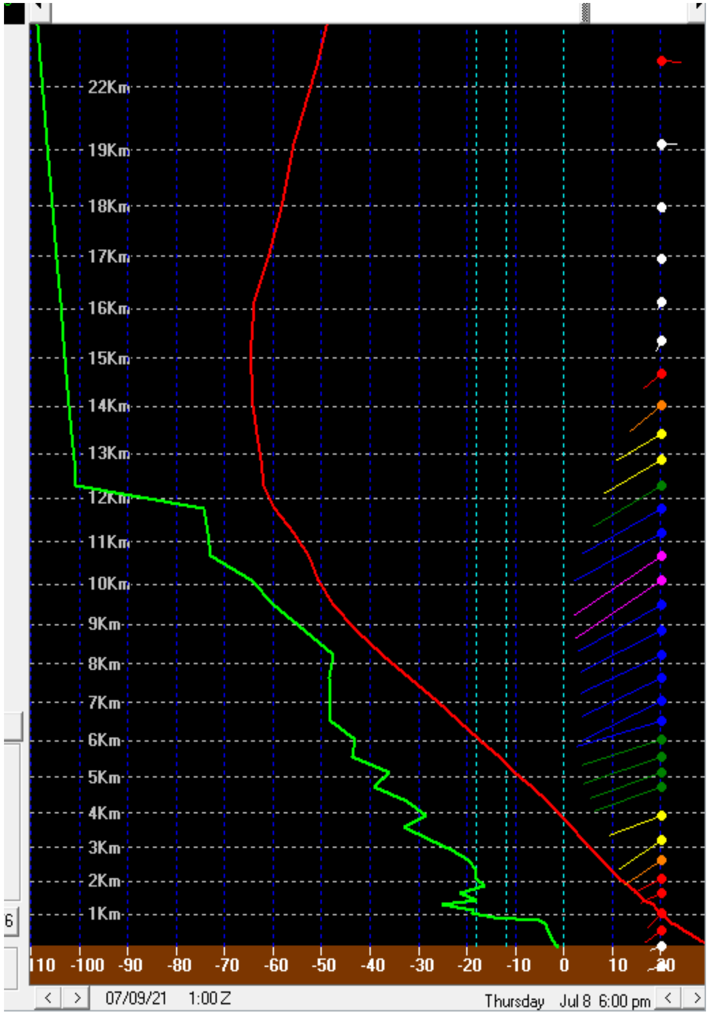
The influence of the weather at cm- and mm-wavelengths

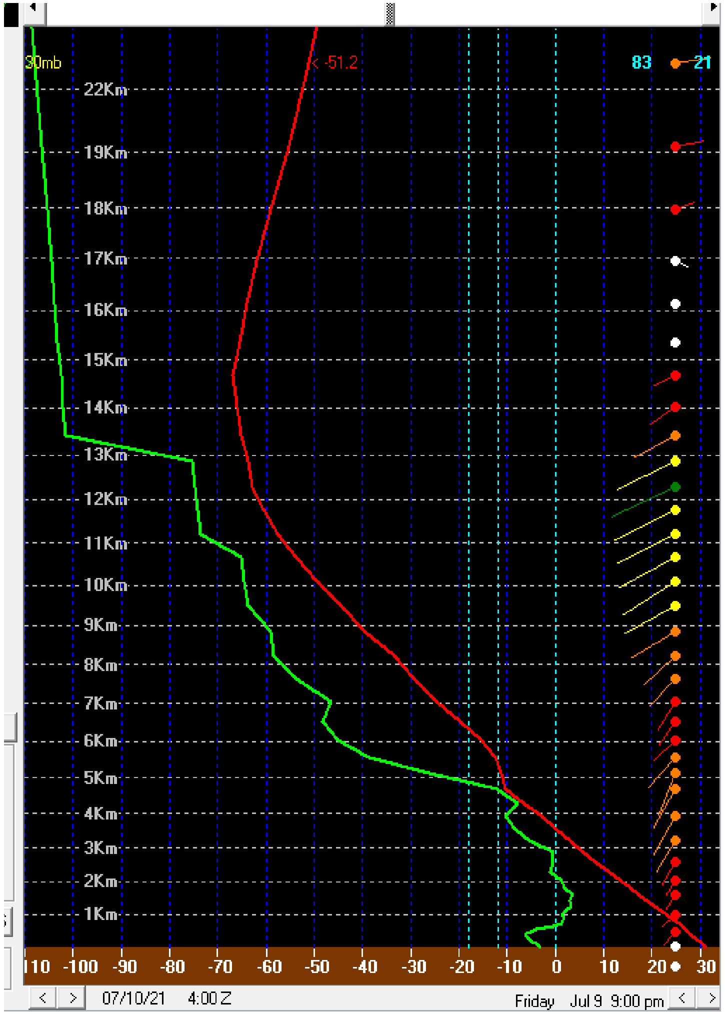
- Opacity
  - Calibration
  - System performance – Tsys
  - Observing techniques
  - Hardware design
- Refraction
  - Pointing
  - Air Mass
    - Calibration
    - Pulsar Timing
    - Interferometer & VLB phase errors
  - Aperture phase errors
- Cloud Cover
  - Continuum performance
  - Pointing & Calibration
- Winds
  - Pointing
  - Safety
- Telescope Scheduling
  - Proportion of proposals that should be accepted
  - Telescope productivity

The standard products of the weather services (other than winds, cloud cover, and precipitation do not directly serve radio astronomy directly.

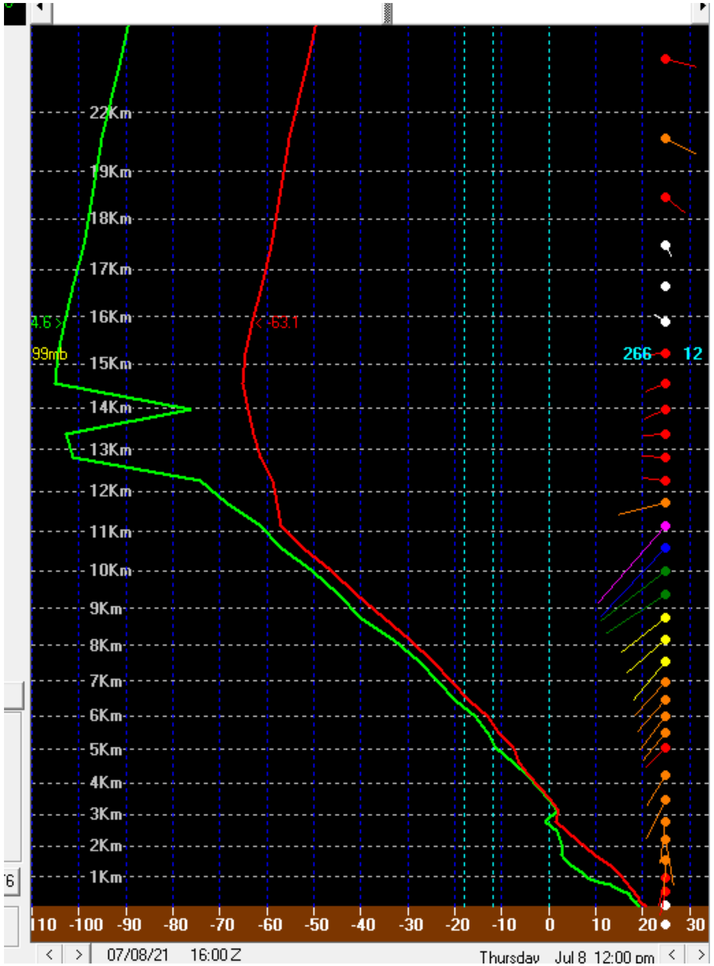
But, one can use vertical weather profiles to derive useful quantities

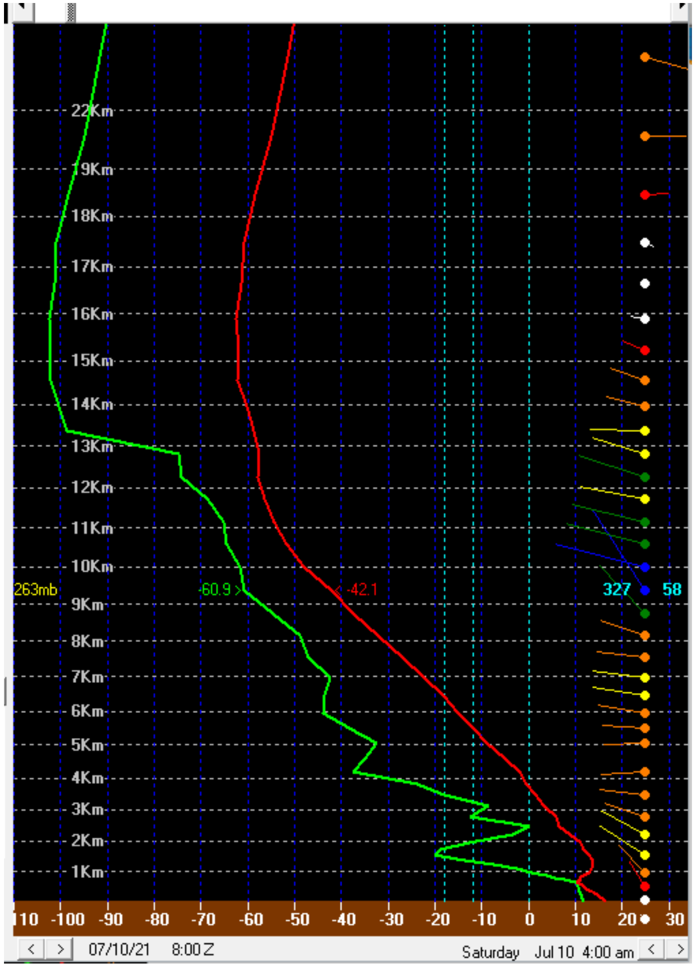
- Now and Friday at Burney





- Noon today and Saturday at Hot Springs, VA





Bufkit files available for “Standard Stations”

North American Mesoscale (NAM)

- The 3.5 day (84 hours) forecasts
- Updated 4-times a day
- 12 km horizontal resolution
- 1 hour temporal resolution

Global Forecast System (GFS)

- 7.5-day (180 hrs) forecasts
- 35 km horizontal resolution
- 3 hour temporal resolution

65 layers from ground level to 30 km (i.e., Stratosphere)

Layers finely spaced (~40 m) at the lower heights, wider spaced in the stratosphere

- $T^{Atm}_{Sys}(\nu)$ = Atmosphere's contribution to T_{sys}
- $\tau(\nu)$ = Total zenith opacity
- $T_{ATM}(\nu)$ = Equivalent black-body temperature of atmosphere
- $\kappa(\nu,h)$ = Absorption coefficient (per unit distance)

Basics of radiative transfer

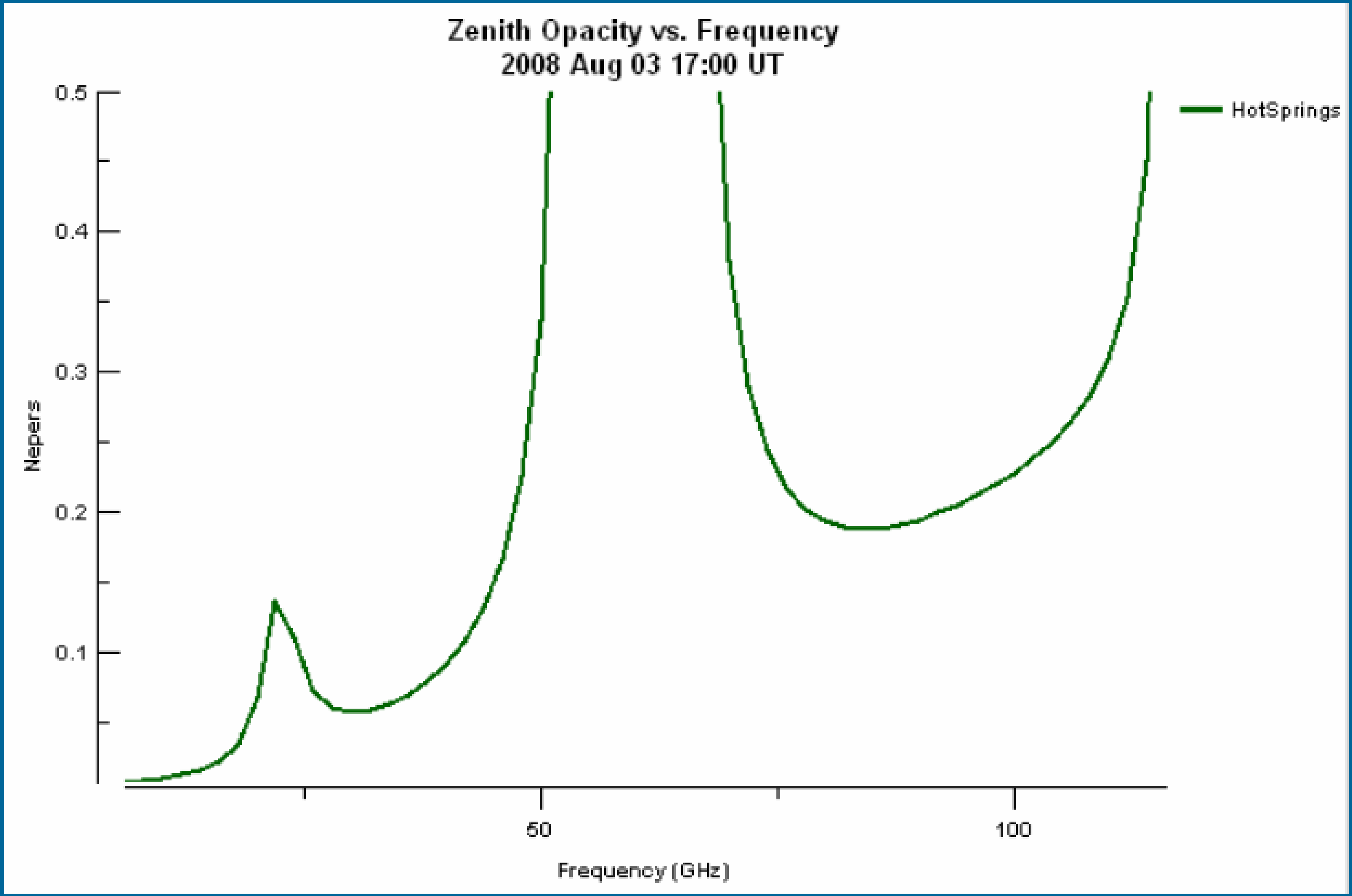
$$\kappa_{Total}(h,\nu) = \sum \kappa_i(h,\nu)$$

$$\tau(\nu) = \int_0^H \kappa_{Total}(h,\nu) \cdot dh$$

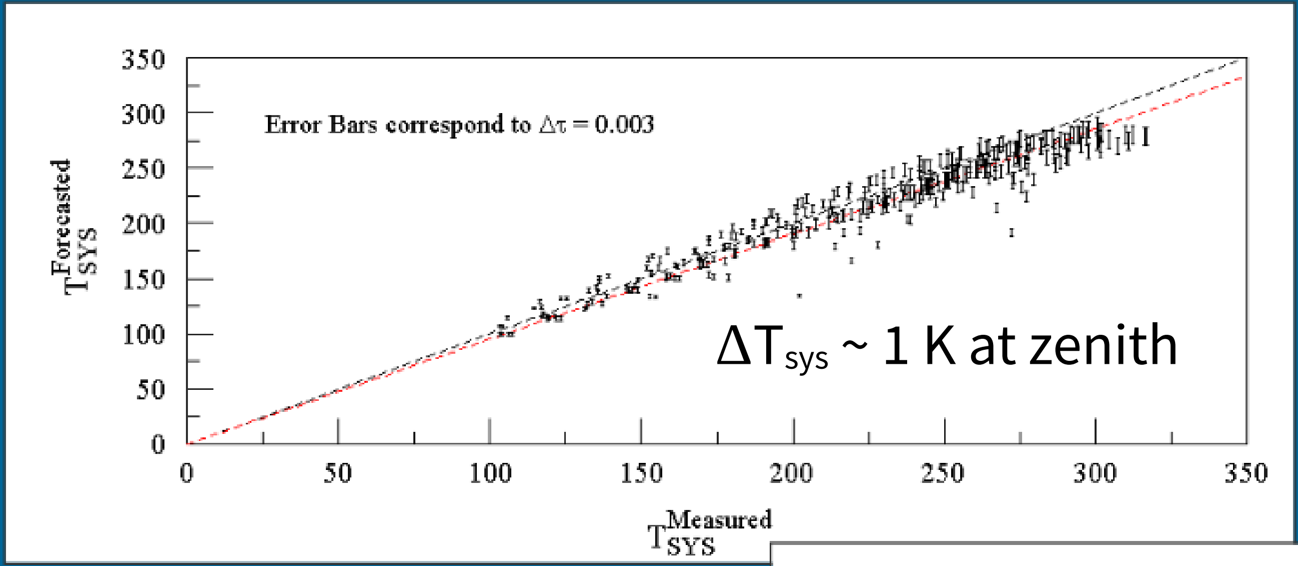
$$T^{Atm}_{Sys}(0,\nu) = T_{Atm} \cdot (1 - e^{\tau(\nu)\cdot AirMass})$$

$$T_{Atm} = \frac{\int_0^H \kappa_{Total}(h,\nu) \cdot T(h) \cdot dh}{\int_0^H \kappa_{Total}(h,\nu) \cdot dh}$$

- κ modeled as arising from six components of the atmosphere (see Liebe in references)
  - Dry air continuum: Non-resonant Debye spectrum of O_2 below 100 Ghz
  - Water vapor rotational lines: 22.2, 67.8 & 120.0 Ghz
  - Water vapor continuum
  - Oxygen spin rotation resonance lines 51.5 – 67.9 Ghz
  - Hydrosols (Clouds) – Mie approximation of Rayleigh scattering from water droplets
  - **Rain**

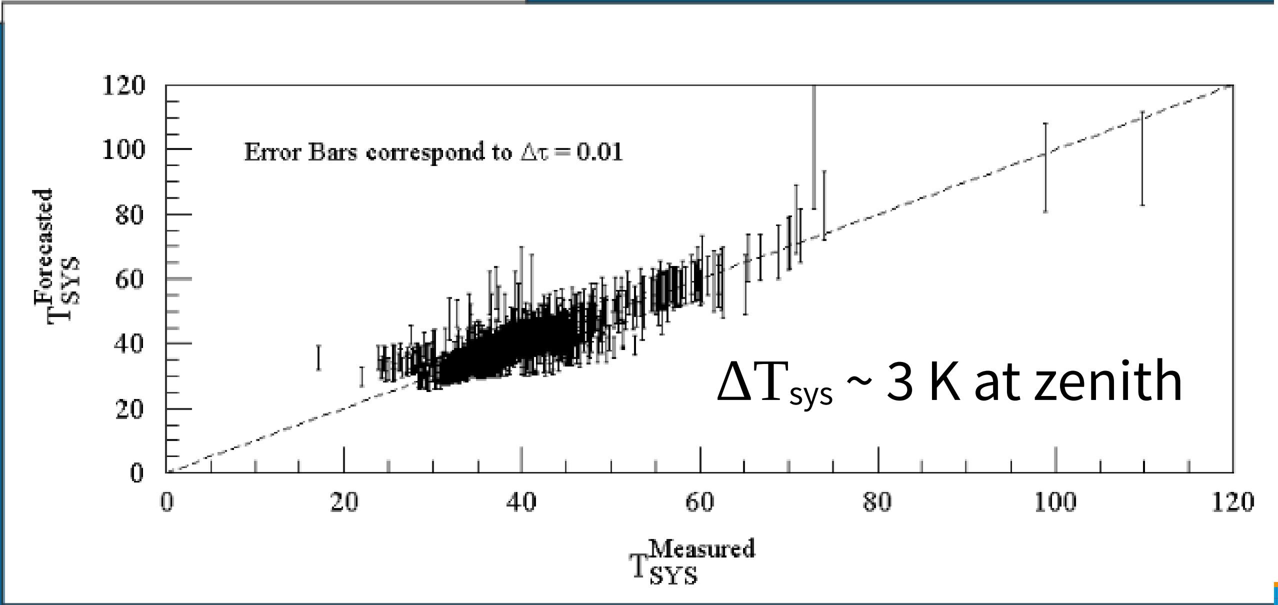


Total Opacity



Error Bars correspond to Δτ = 0.003
ΔT_{sys} ~ 1 K at zenith
$T_{SYS}^{Forecasted}$
$T_{SYS}^{Measured}$
0
50
100
150
200
250
300
350

45 GHz



Error Bars correspond to Δτ = 0.01
ΔT_{sys} ~ 3 K at zenith
$T_{SYS}^{Forecasted}$
$T_{SYS}^{Measured}$
0
20
40
60
80
100
120

22 GHz

Useful References

- www.gb.nrao.edu/~rmaddale/Weather/index.html
  - `Details` link provides outline of methods
  - Current results for the GBT
- www.gb.nrao.edu/~rmaddale/Research/WeatherForecastingForRadioAstronomy.pdf
  - Technical Seminar
- www.gb.nrao.edu/~rmaddale/Research/WeatherPosterAASJan2010Mod.pdf
  - Accuracy
- https://training.weather.gov/wdtd/tools/BUFKIT/
  - Details and instructional material on NWS vertical profiles
- **H.J. Liebe, "An Updated model for millimeter wave propagation in moist air", 1985, *Radio Science*, 20, 1069**
  - **The underlying physics**

- Retrieving NWS Forecasts
  - /home/caluser/WeatherHCRO contains
    - Downloaded NWS BUFKIT files
    - Logfile
    - Programs run by crontab for
      - Downloading NWS files
      - Backfilling missed downloads
  - Crontab entries:
    - 30 * * * *   /home/caluser/bin/tclsh /home/caluser/WeatherHCRO/TestSource/downloadBufkitFiles.tclsh
    - 22 0 * * SUN /home/caluser/bin/tclsh /home/caluser/WeatherHCRO/TestSource/backfillBufkit.tclsh -weekly

- /home/caluser/bin/forecastsCmdLine.tcl -help
  - User specifies command-line arguments for date(s), frequencies, elevations, … and a list of quantities to be derived
  - Reads in forecast archive (/home/caluser/WeatherHCRO)
  - Generates tables in ASCII files
- /home/caluser/bin/forecasts.tcl -help
  - Graphical user interface
    - NAM or GFS
    - Opacity, Refraction, T_{sys}, T_{atm}, precipitation, ground-level values, …
  - Executes /home/caluser/bin/forecastsCmdLine.tcl with appropriate arguments
  - Reads output file and generates graphs