Forecasting for the Hat Creek Observatory

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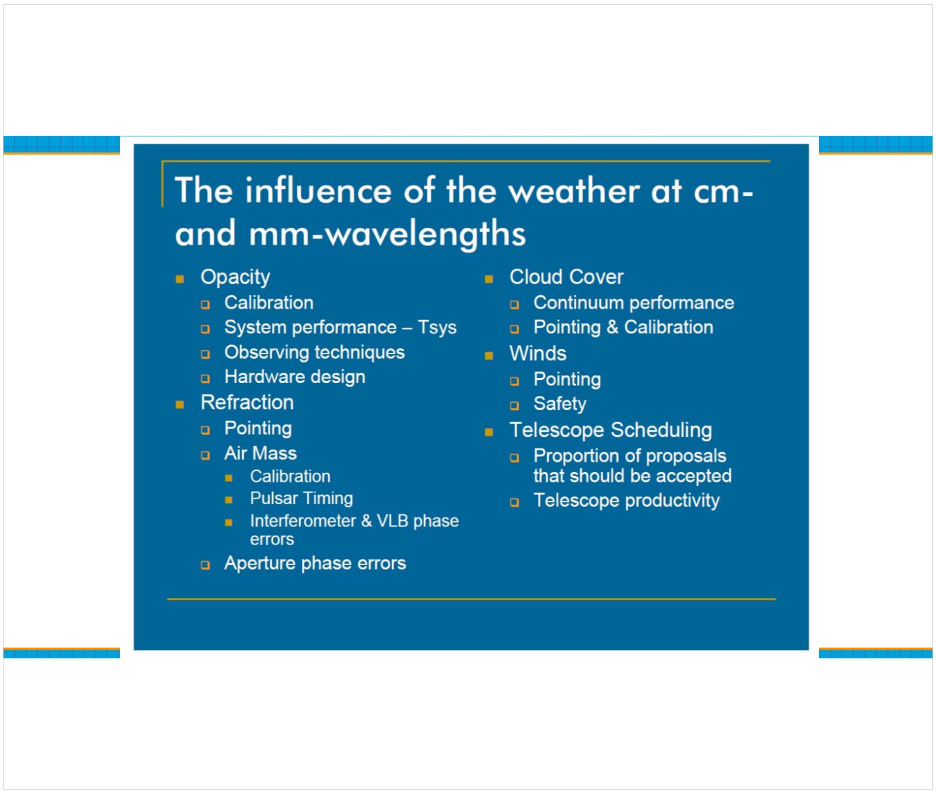
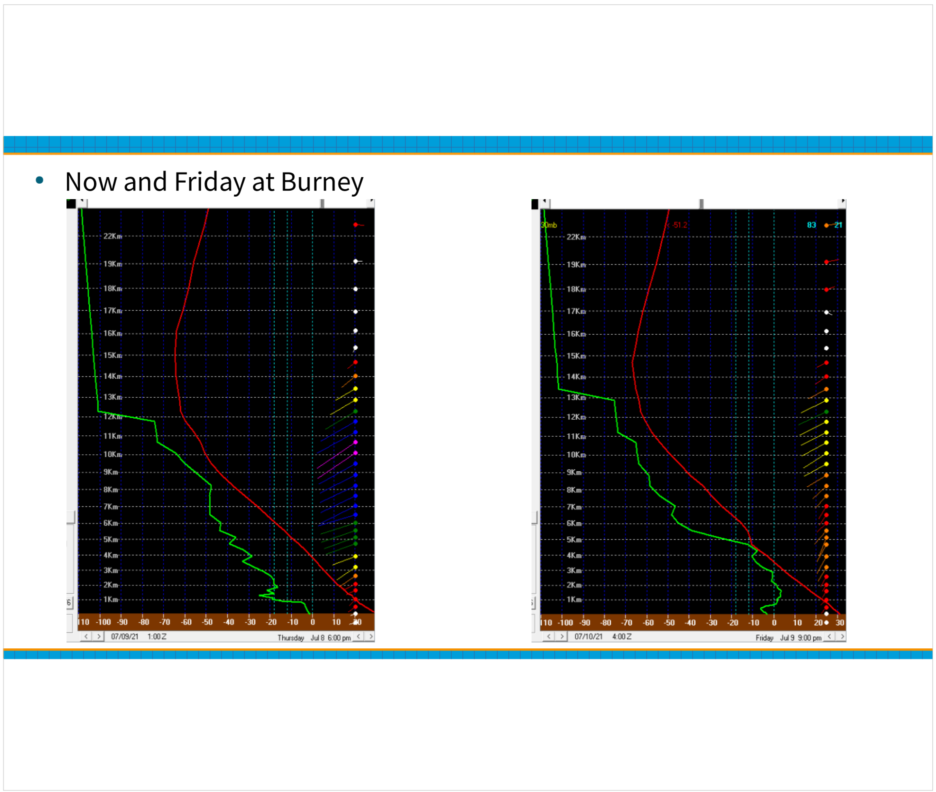
July 8, 2021



Various ways in which weather affects cm-wave radio astronomy

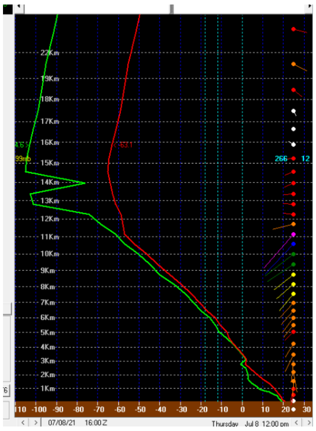
The standard products of the weather services (other than winds, cloud cover, and precipitation do not directly serve radio astronomy directly.

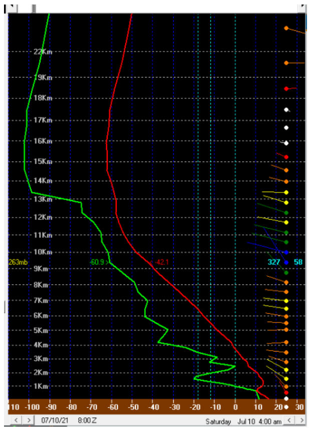
But, one can use vertical weather profiles to derive useful quantities



Vertical weather forecasts provide temperature, pressure, and dew point (humidity) at various heights above the observatory. Temp along x-axis, height along y. Red temperature, green dew point. Left profile shows dry conditions from the ground to well above the tropopause at ~ 10 km. The right shows dy at ground level but wet conditions at 4 km. Eventhough the ground level weather are almost identical, left has better high-frequency weather conditions.

- Noon today and Saturday at Hot Springs, VA





For Green Bank, left is terrible conditions for high frequency – wet from the ground to the tropopause. Right is much better. Again, both have about the same ground-level weather conditions.

Locations at which the National Weather Services provides these vertical weather products to the general public.

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)

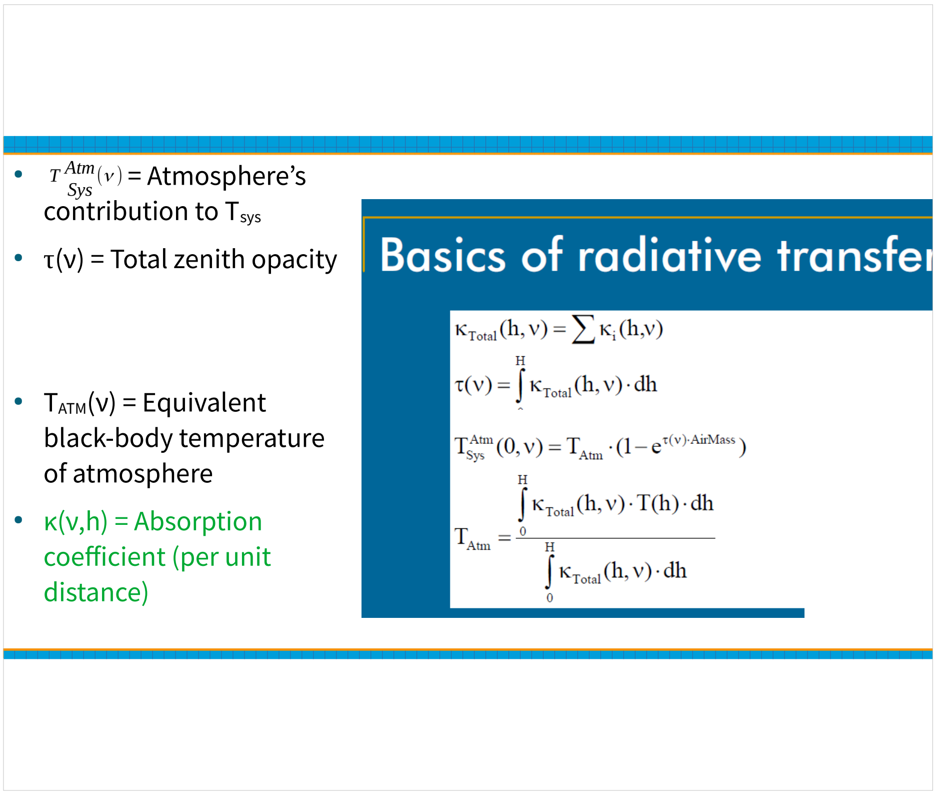
- 7.5-day (180 hrs) forecasts
- 35 km horizontal resolution
- 3 hour temporal resolution

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

Currently have anautomated system that downloads from the NWS forecasts which come from 2 different forecasting models.

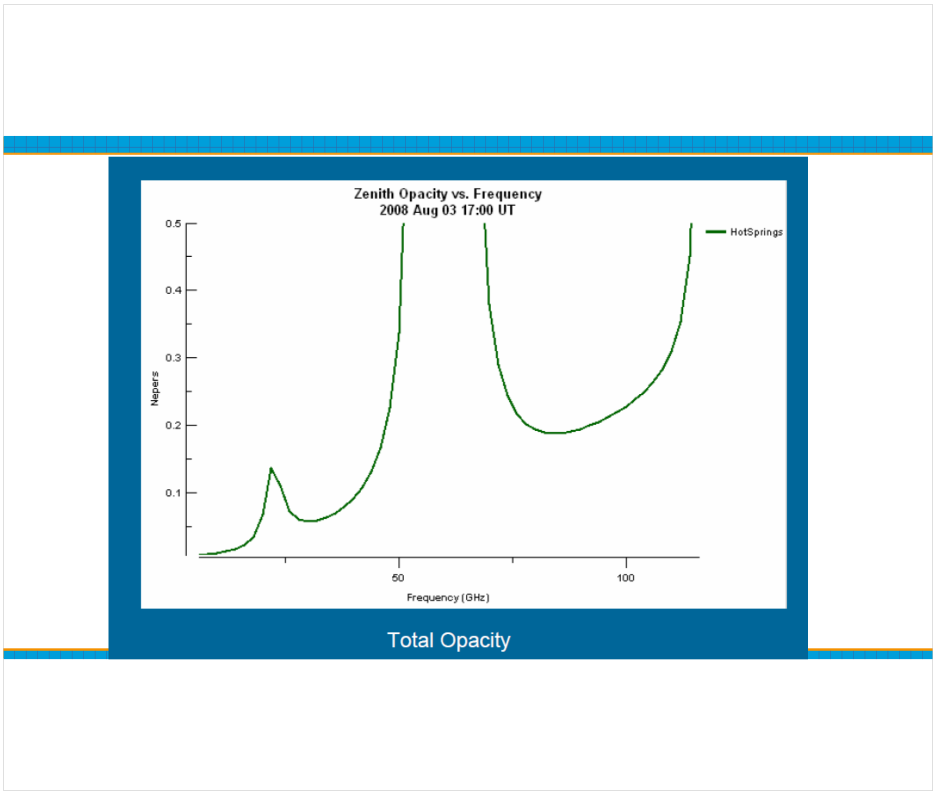
When weather.com, accuweather, etc report conditions for your localle, they are actually regurgitating the values from these same NAM forecasts or very similar products.



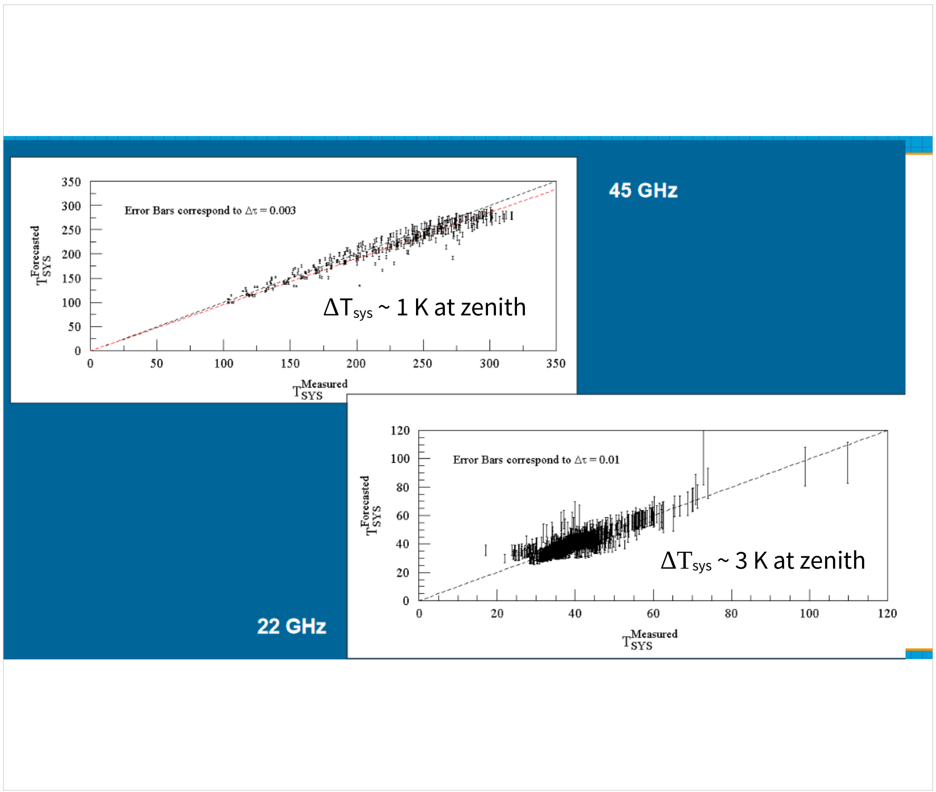
From models developed from labatory measurements, one can derive absortions coefficients as a function of observing frequency for atmospheric gases at all the range of temperatures, pressures, and humidity covered by vertical profiles. Thus, one can derive absorption coefficients, κ, as a function of height and frequency for every layer above the observatory. From κ and T in each layer, one can derive the total opacity and system temperature as a function of frequency using standard equations of radiative transfer.

- 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**

κ has six different sources, the first 4 of which are highly accurate. Since weather forecats cannot currently predict accurate sizes and densitions for water doplets (hydrools) in clouds, derived Tsys and opacities become less accurate under cloudy conditions. Models have an even harder time forecasting the size and density of rain drops, which results in inaccurate cm-wave astronomy forecasts when raining



Typical opacity vs frequency, showing water line at 22.2 Ghz, Oxygen lines at 60 and 120 Ghz. Water vapor, hydrosols, or rain produce an overall slope that goes as frequency squared (ie., like Mie scattering).



Comparison of measured Tsys and forecasted Tsys under many conditions (but not rain) and elevations at 22 and 43 Ghz. By careful analysis, these data showed that the highest uncertainties in both graphs is in the measured Tsys. Errors in forecasted zenith opacities cannot be determined but cannot be larger than 0.003 and 0.01 at 22 and 43 Ghz, respectively.

Useful References

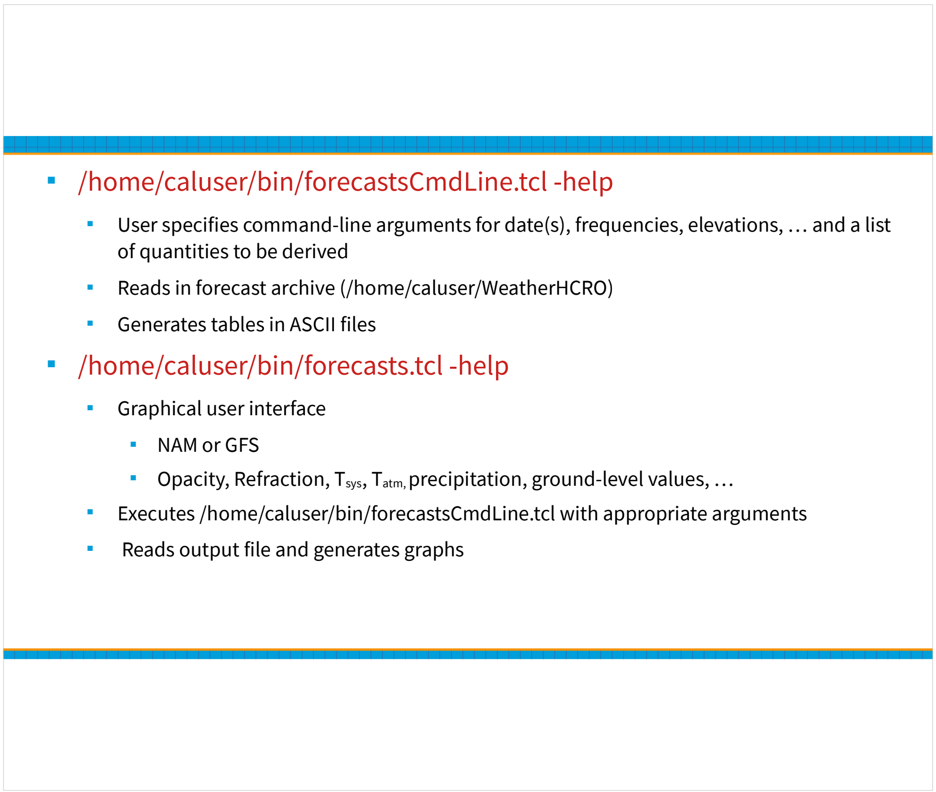
- www.gb.nrao.edu/~rmaddale/Weather/index.html
  - `Details` link provides outline of methods
  - Current results for the GBT
- www.gb.nrao.edu/~rmaddale/Research/WeatherForecastingForRadioAstronomy.pdf
  - Technical Seminar
- www.gb.nrao.edu/~rmaddale/Research/WeatherPosterAASJan2010Mod.pdf
  - Accuracy
- 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

Information on the cronjobs and prograns that are currently running on ATA computers that do the automated downloads.

One cron does the downloads every hour. The other, once a week fills in any holes caused by missed downloads (which would occur if the computer is down for more than 6 hours)

Data has been archived since Aug, 2020.



Utilities ATA staff can use directly, or called from within their own programs, that process archived data over any range of dates (since Aug 2020 and up to 10 days into the future) so as to produce desired weather-relared quantities.

The current calibration pipeline calls forecastCmdLine to obtain the necessary Tsys and opacities for its calculations.

Forecasts.tcl is a user-friendly GUI wrapper for forecastsCmdLine.