NJIT

"Packed with lots of useless information!"
-- Flunked Undergrad Student

"Rayleigh/Mie" LIDAR

FOR ... UMMM...

Really Cool Smart Folks That Want to Learn Stuff Because They Have Too Much Free Time?

A Reference for the Rest of Us!

by Andrew J. Gerrard

First: A Pet Peeve of Mine…

The terms “Rayleigh” and “Mie” are [theoretical] scattering processes. “Rayleigh” is elastic scattering governed by classical/quantized EM, and “Mie” is for a homogeneous collection of perfectly spherical particles of uniform composition.

I prefer “molecular/aerosol” lidar.

Outline

1) Some basics and a bit of CEDAR molecular/aerosol history

2) “Simple”, incoherent molecular/aerosol lidar (i.e., photon counting).

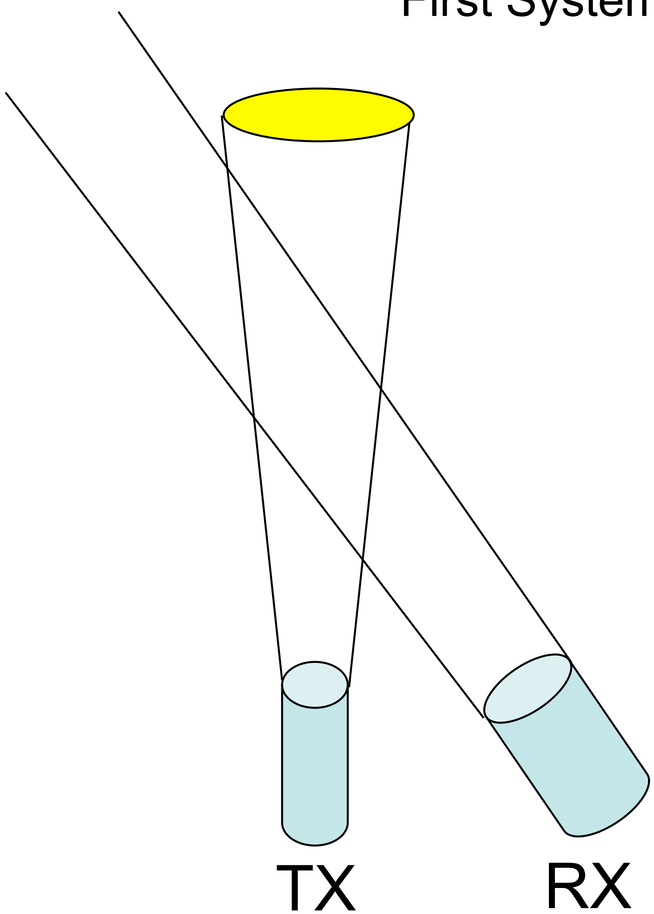
3) What can be done with simple molecular/aerosol lidar?

4) Challenges of “simple” molecular/aerosol lidar

5) Making it more complex

Early Molecular/Aerosol Lidar Systems

First Systems: Searchlights! [Hulburt, 1937]



Scatter off molecules and aerosols

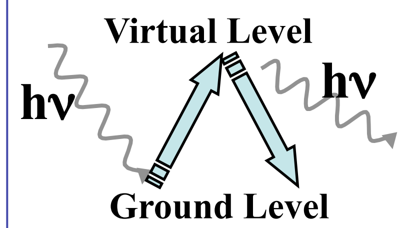
The Lidar Equation

$$N(r,t) = \left[\eta \cdot T_A^2\right] \cdot \left[\frac{P_L \cdot \tau}{hc/\lambda}\right] \cdot \left[\sigma_{eff} \cdot \rho(r,t) \cdot \Delta r\right] \cdot \left[\frac{A_R}{4\pi r^2}\right] + N_B(r,t,\tau,\Delta r)$$

Now, you'd think…

1) Lots of $\rho(r,t)$
2) r^2 is "kinda close"
3) Can get BIG P_L because CO_2 and/or Nd:YAG have big powers available!

Rayleigh/Elastic

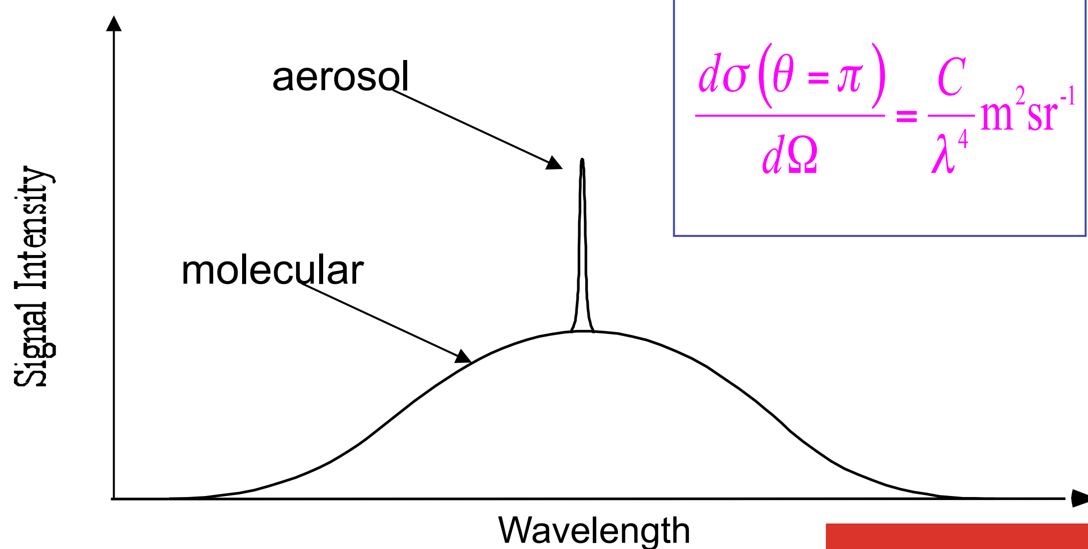


$$\frac{d\sigma(\theta = \pi)}{d\Omega} = \frac{C}{\lambda^4} \mathrm{m^2 sr^{-1}}$$

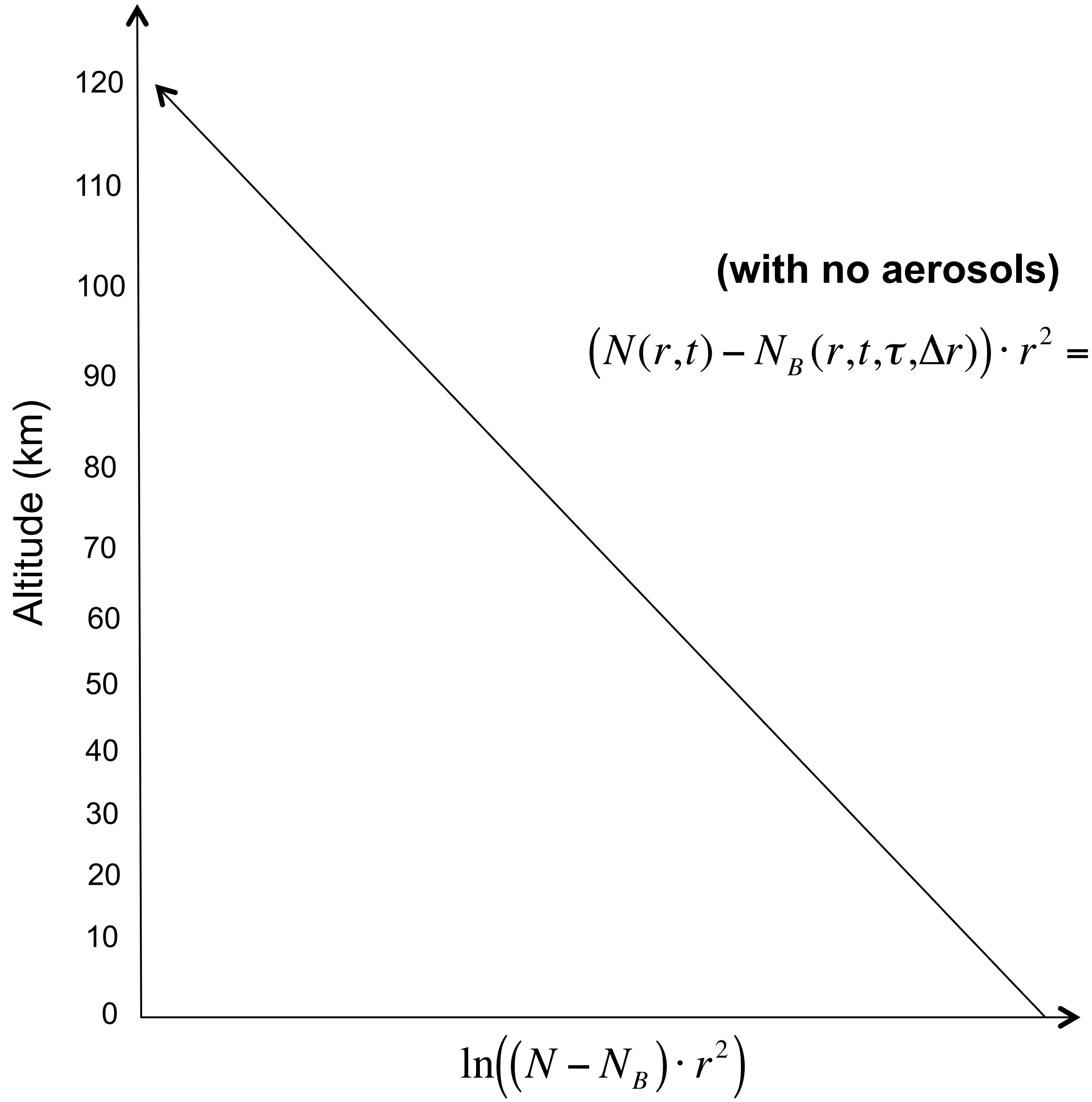
BUT

σ_{eff}, for molecular scattering, is very small (i.e., ~10^{-32} m^2 compared to resonance methods, which are ~10^{-16} m^2)

Therein lies the kicker…



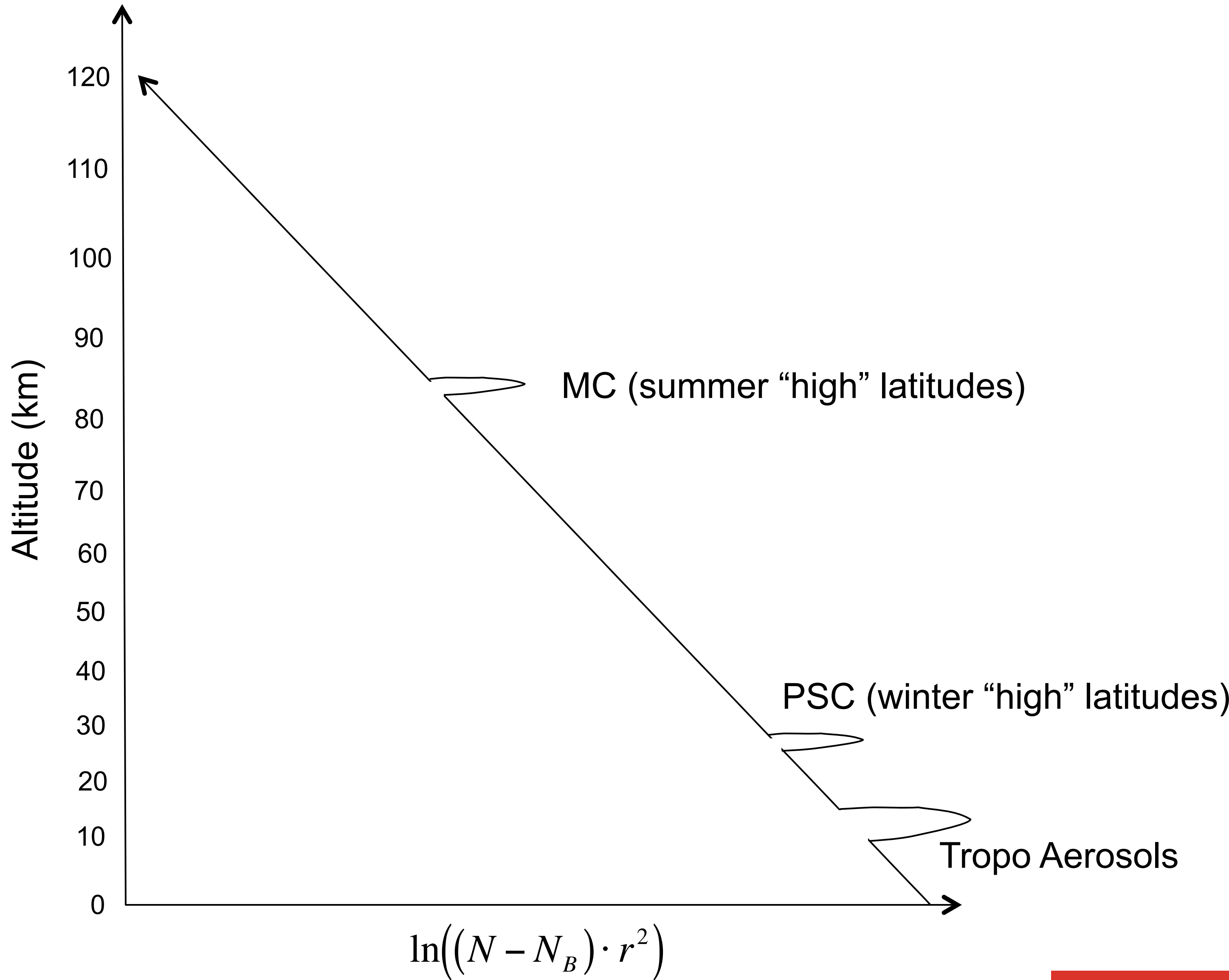
With Uber Laser!



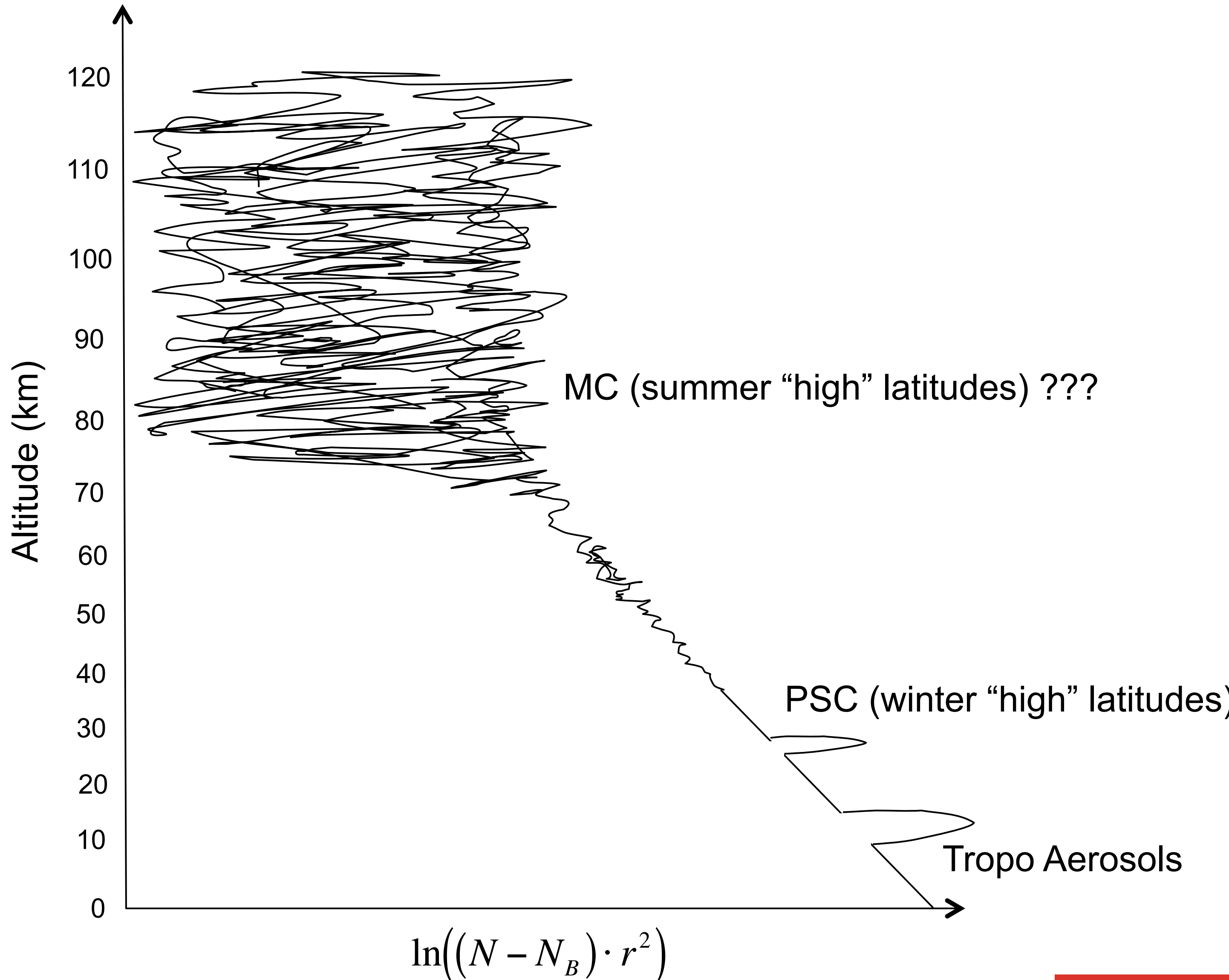
(with no aerosols)

$$\left(N(r,t) - N_B(r,t,\tau,\Delta r)\right) \cdot r^2 = C \cdot \rho\left(r,t\right)$$

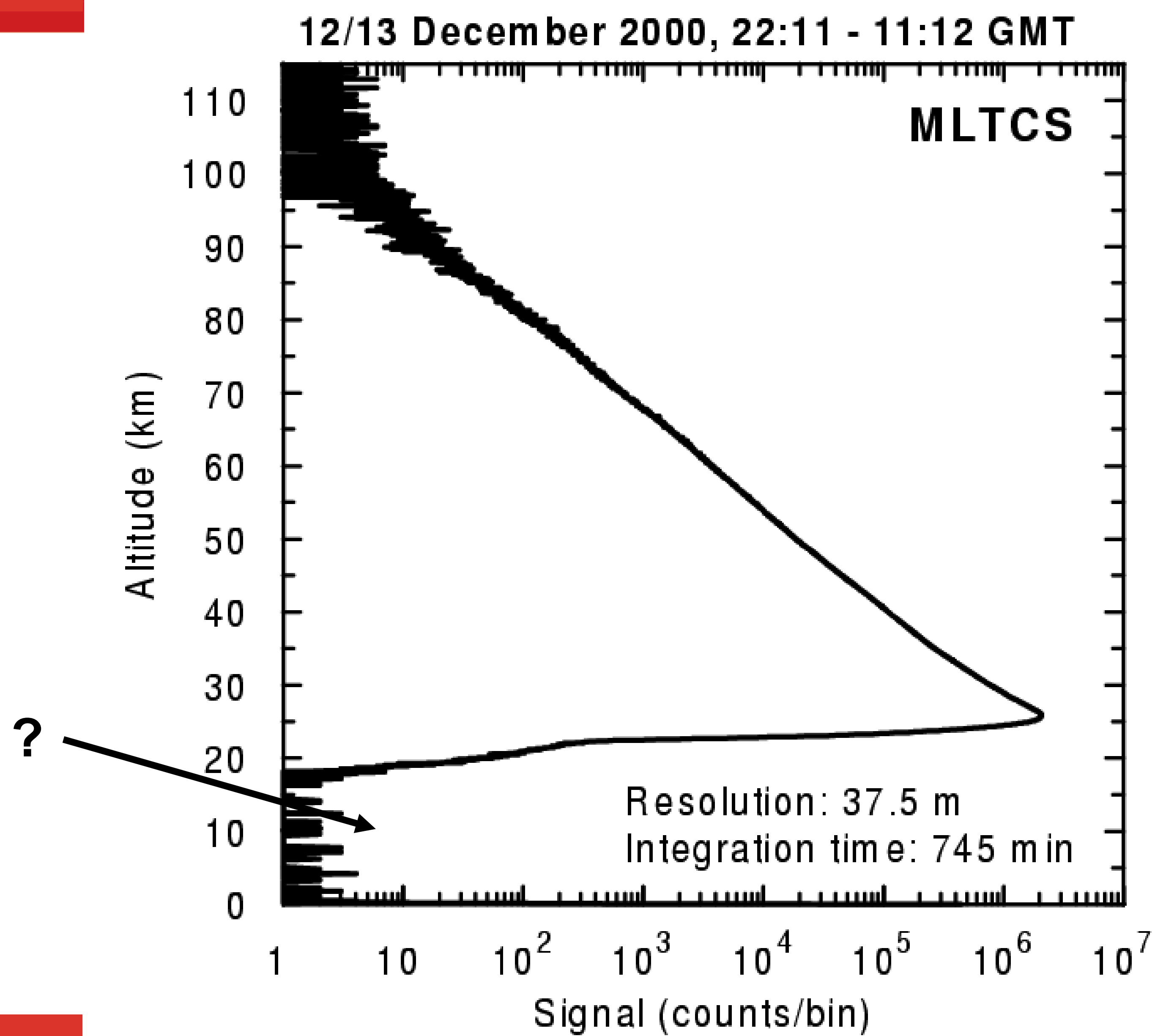
With Uber Laser!



With REAL Laser…



So is this "CEDAR Science?"


12/13 December 2000, 22:11 - 11:12 GMT
MLTCS
Altitude (km)
110
100
90
80
70
60
50
40
30
20
10
0
1
10
10^2
10^3
10^4
10^5
10^6
10^7
Signal (counts/bin)
Resolution: 37.5 m
Integration time: 745 min
?

Some Molecular/Aerosol Lidars in CEDAR

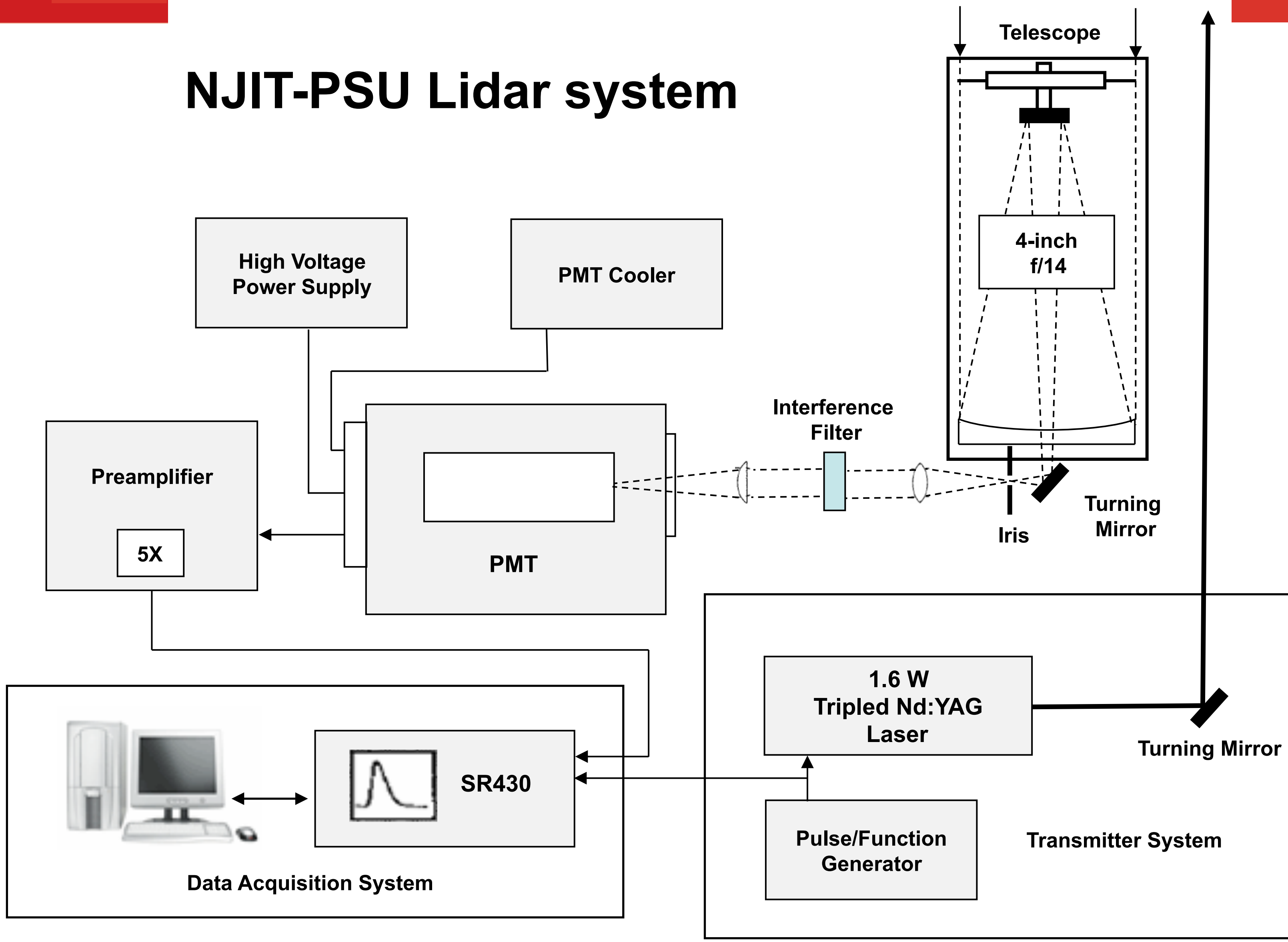
Late 1980's and early 1990's: University of Illinois at Urbana-Champaign

Late 1980's and throughout the 1990's: Arecibo Lidar Observatory

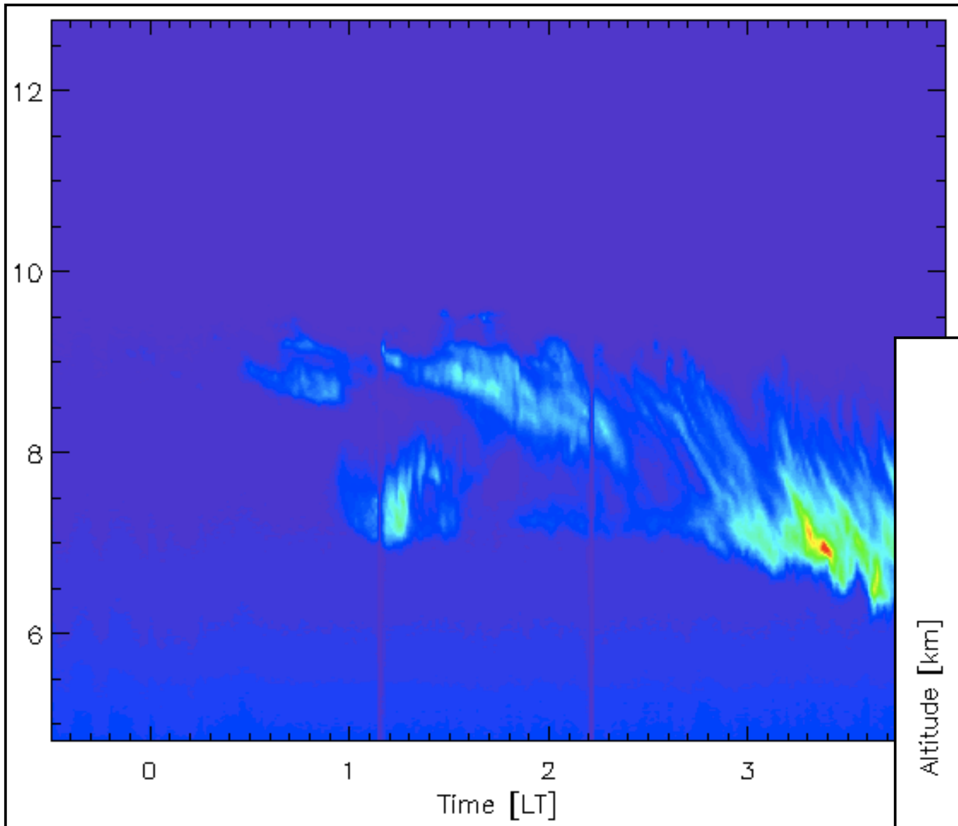
<u>Today</u>
Utah State
Sondrestrom ARCLITE
UAF/Poker Flat

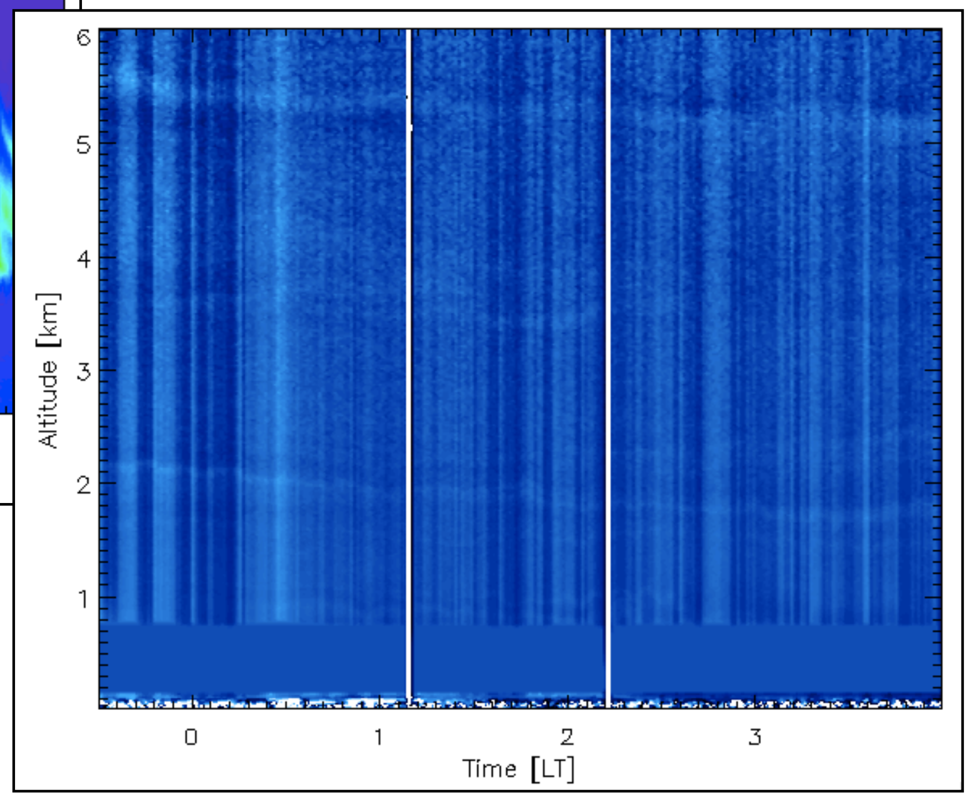
BUT…
More coming online in the past year!

NJIT-PSU Lidar system

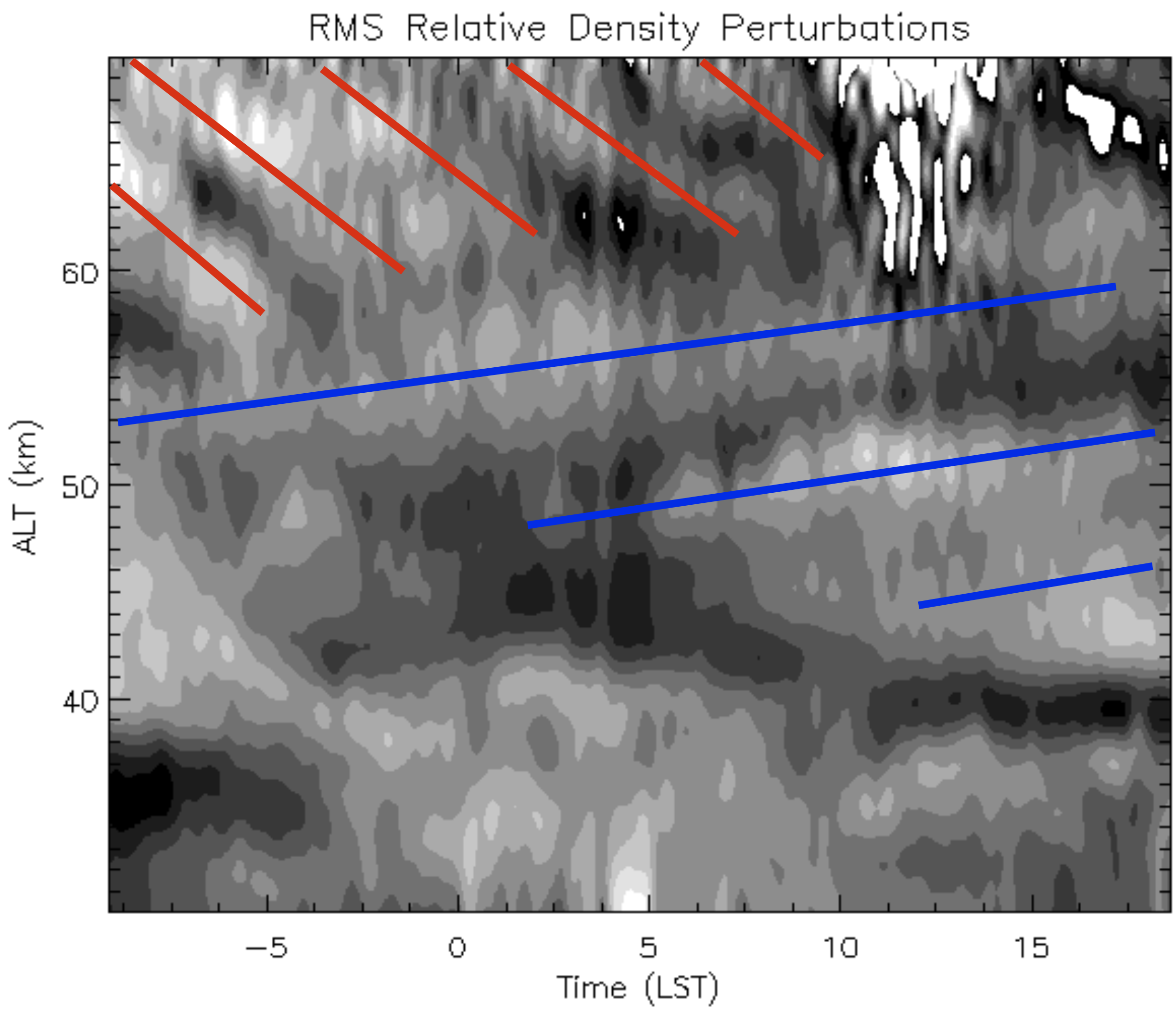


Example Lidar Data





Relative Density Perturbations



$$r(z,t) = \frac{\rho(z,t) - \overline{\rho(z)}}{\overline{\rho(z)}}$$

Fun with gravity waves!

$$PE = \frac{1}{2}\rho_0 \left(\frac{g}{N}\right)^2 \left\langle \frac{\Delta\rho}{\rho_0} \right\rangle^2$$

Absolute Temperatures

Hauchecorne and Chanin [GRL, 1980]

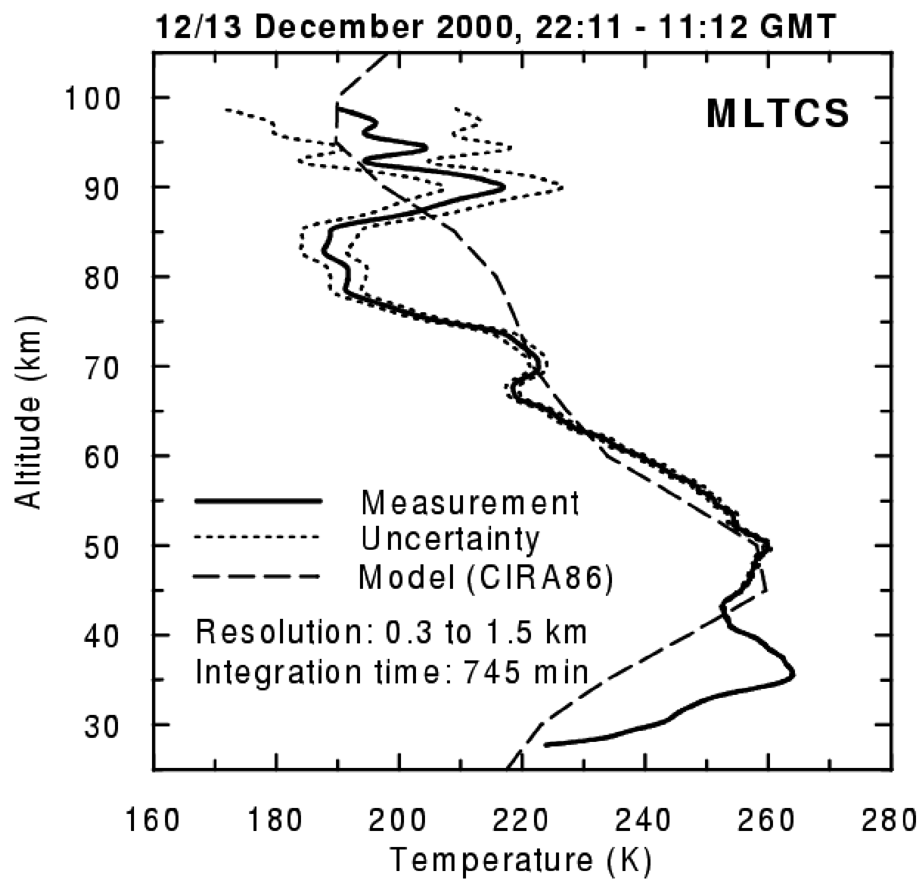
Ideal Gas Law

Hydrostatic Balance

Equation for the Temperature

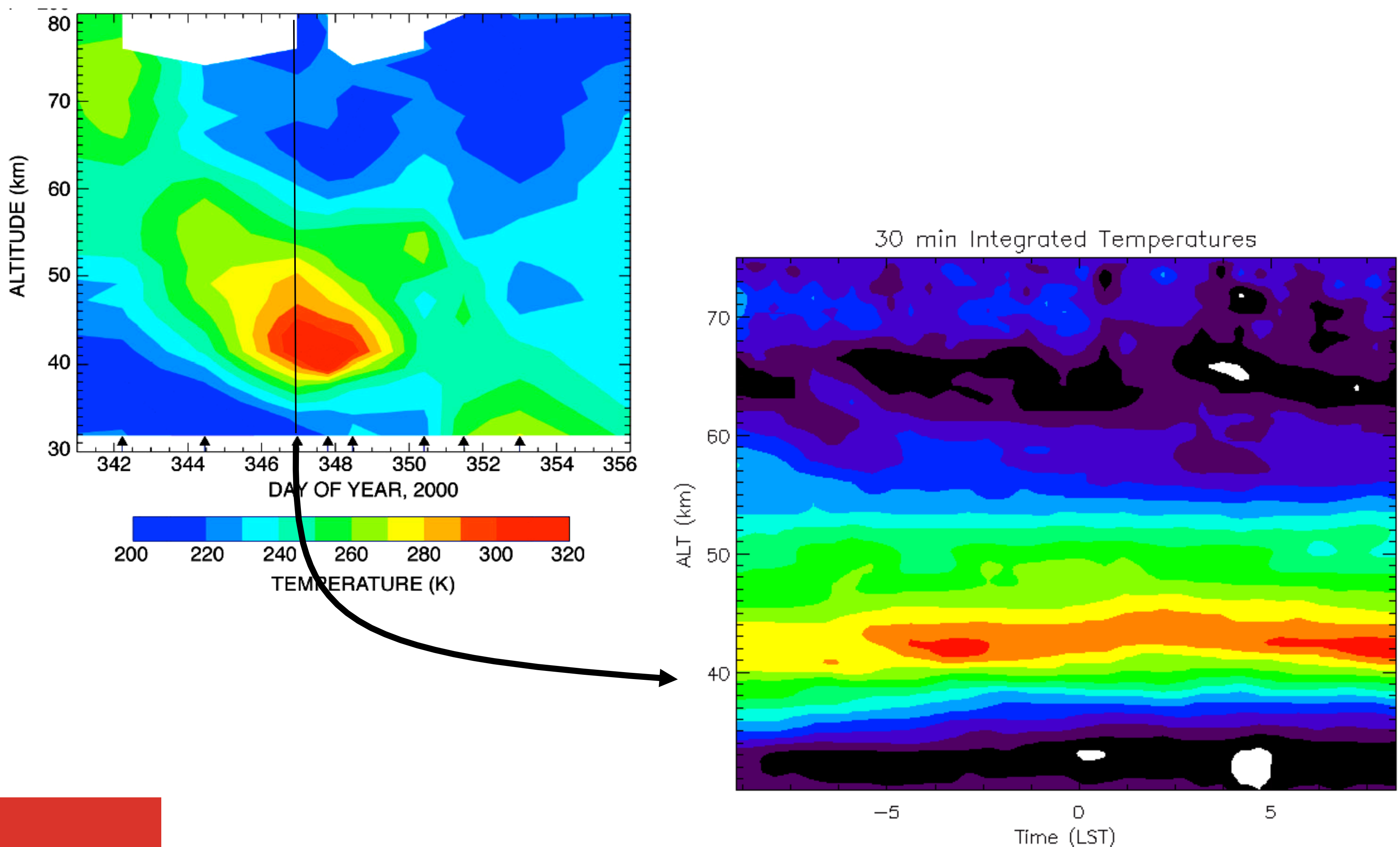
Requires:

1) Seed temperature atop
2) Remove top ~10 km



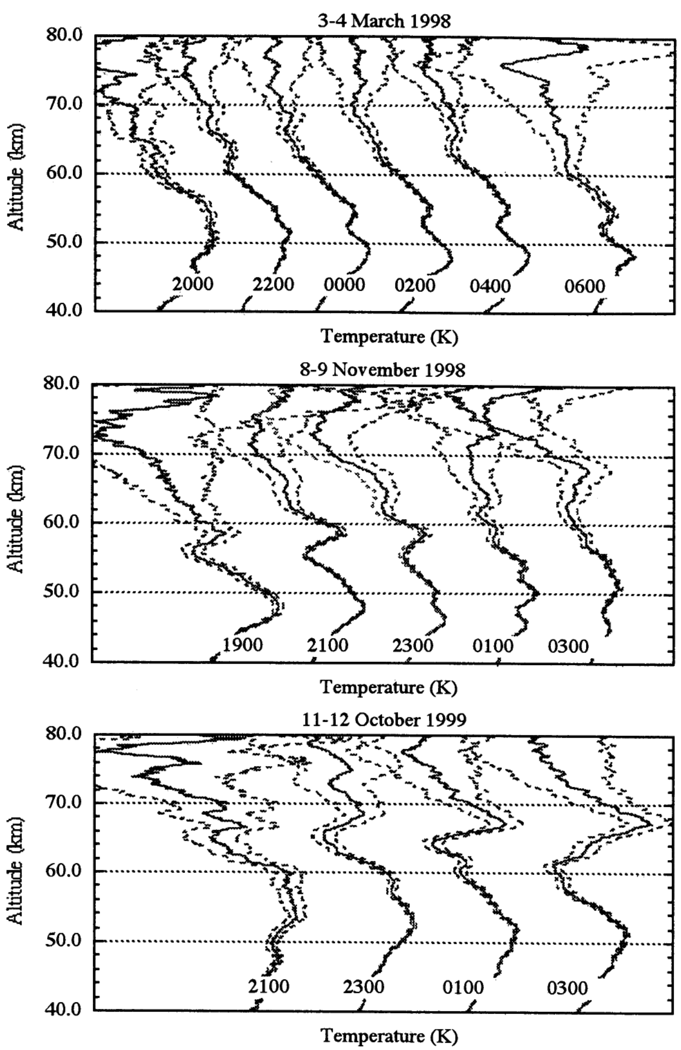
Note: Beware the “other” approach!

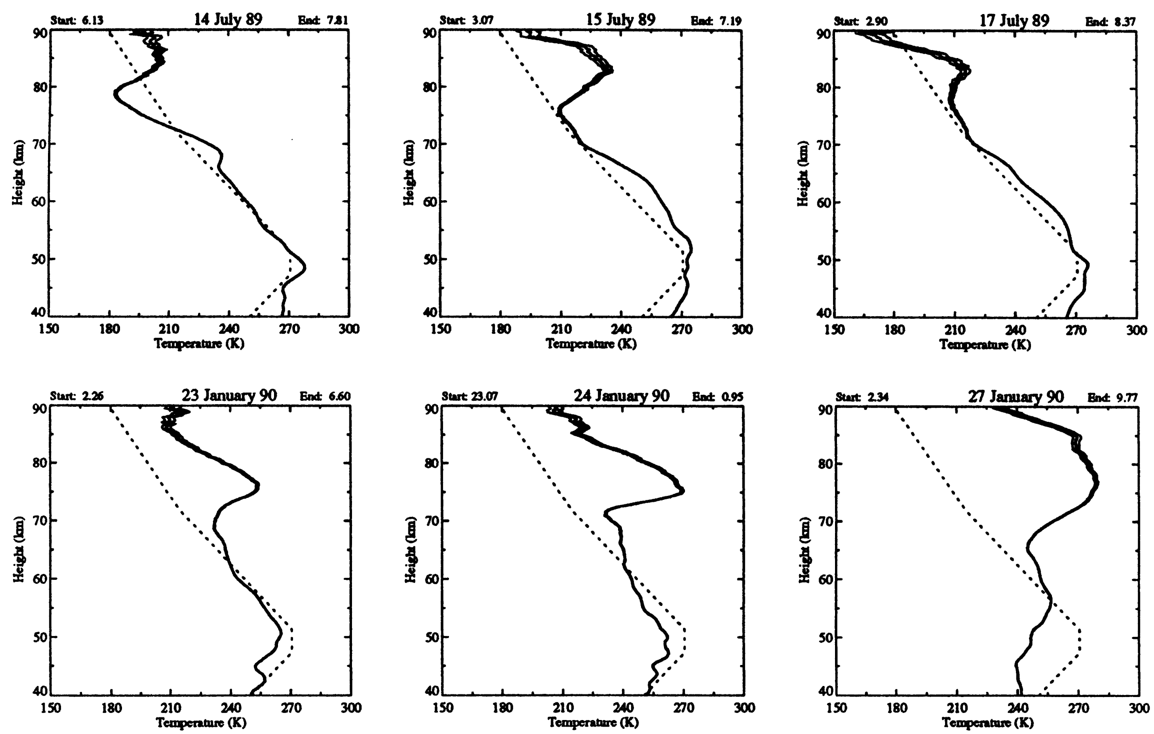
Absolute Temperatures

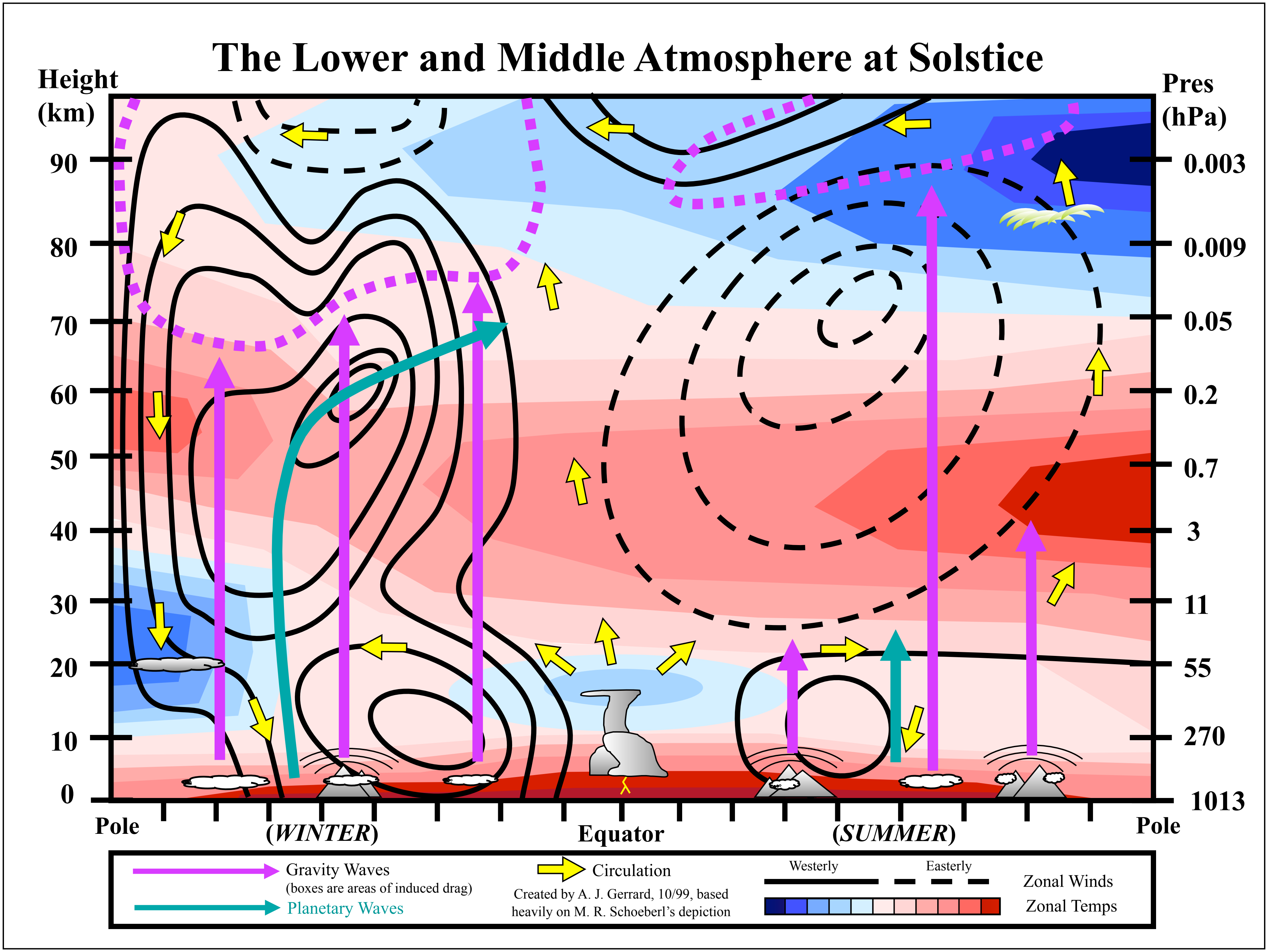


Now… LOTS of Measurements!

- NDSC
- MILs, QBO, SAO, Tides, Planetary waves, Polar vortex
- Etc. etc. etc.





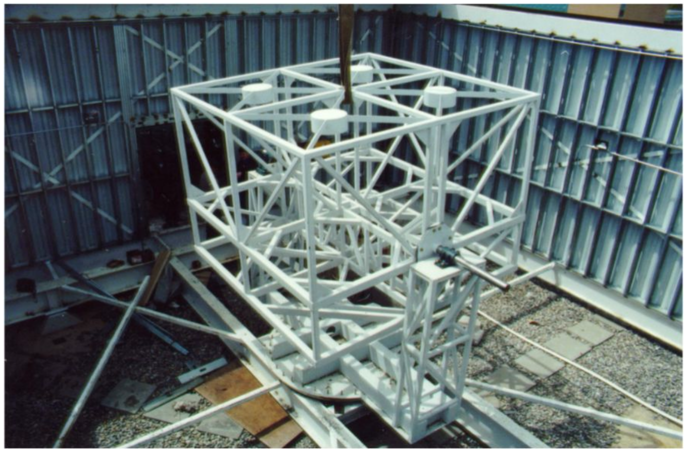


The Lower and Middle Atmosphere at Solstice
Height (km)
90
80
70
60
50
40
30
20
10
0
Pres (hPa)
0.003
0.009
0.05
0.2
0.7
3
11
55
270
1013
Pole
(WINTER)
Equator
(SUMMER)
Pole
Gravity Waves
(boxes are areas of induced drag)
Planetary Waves
Circulation
Created by A. J. Gerrard, 10/99, based heavily on M. R. Schoeberl's depiction
Westerly
Easterly
Zonal Winds
Zonal Temps

Challenges [in MA Molecular/Aerosol Lidar]

1) Getting enough photons
   - BIG telescopes

2) Daytime observations
   - Low rep rates
   - Cross polarization methods
   - Fabry-Perot/narrow-band filters



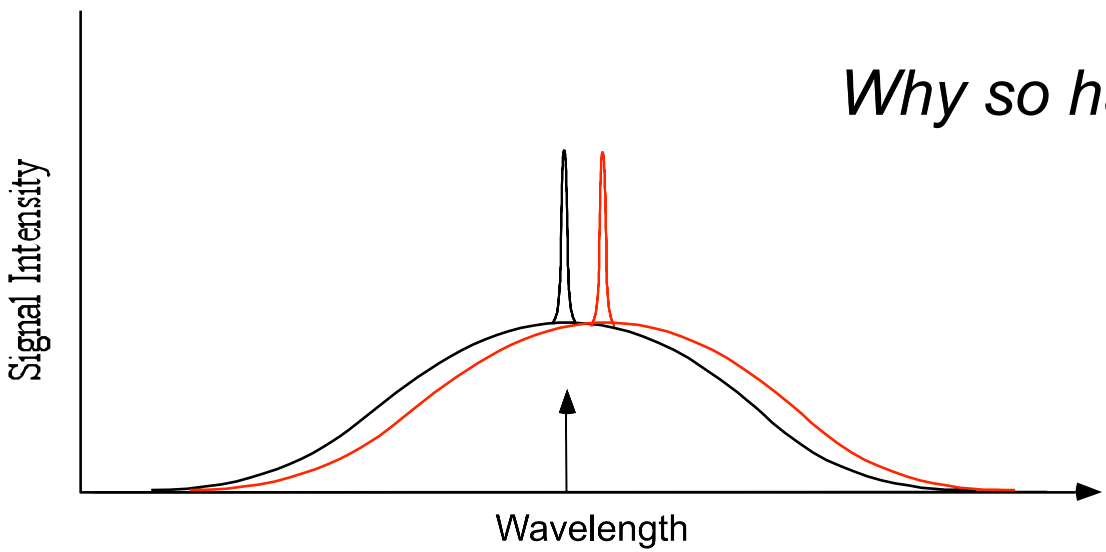
Make the System More Complicated!

- Multi-wavelength
  - Aerosol size distribution
  - Aerosol composition
- Dual-polarization
  - Aerosol shape

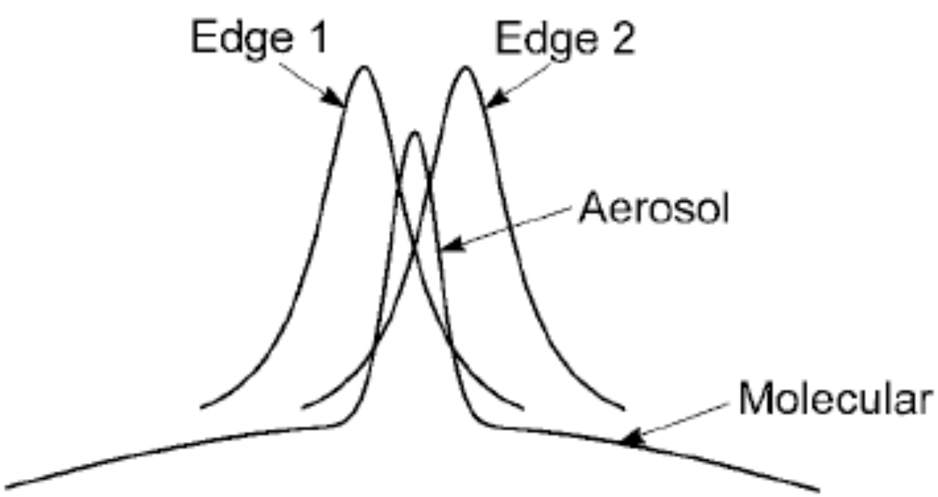
} *MC and PSC*

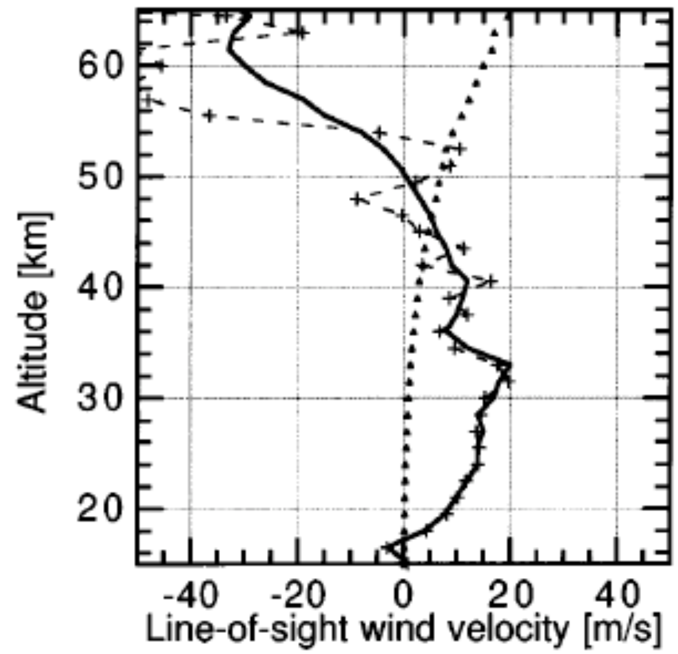
- Neutral Winds… Holy Grail of Molecular/Aerosol Lidar!

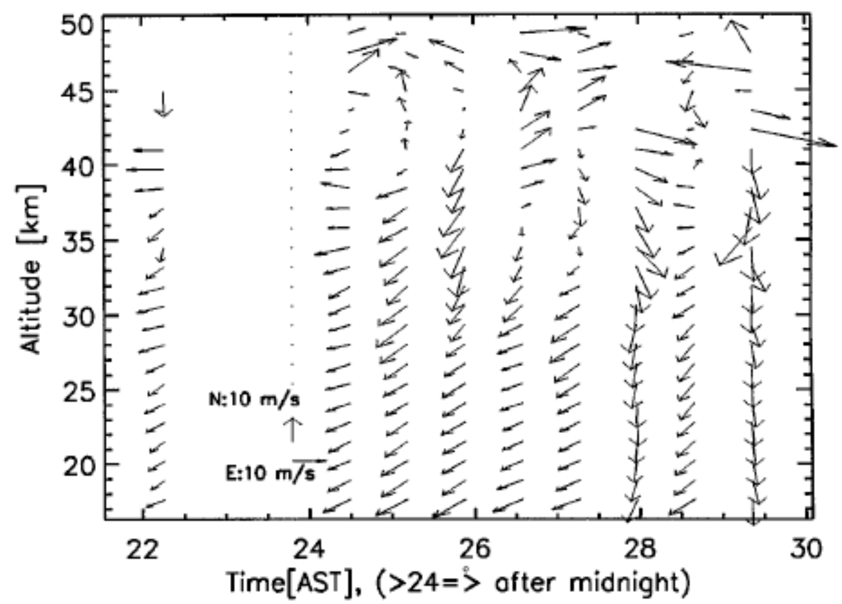
Why so hard?



"EDGE" Technique

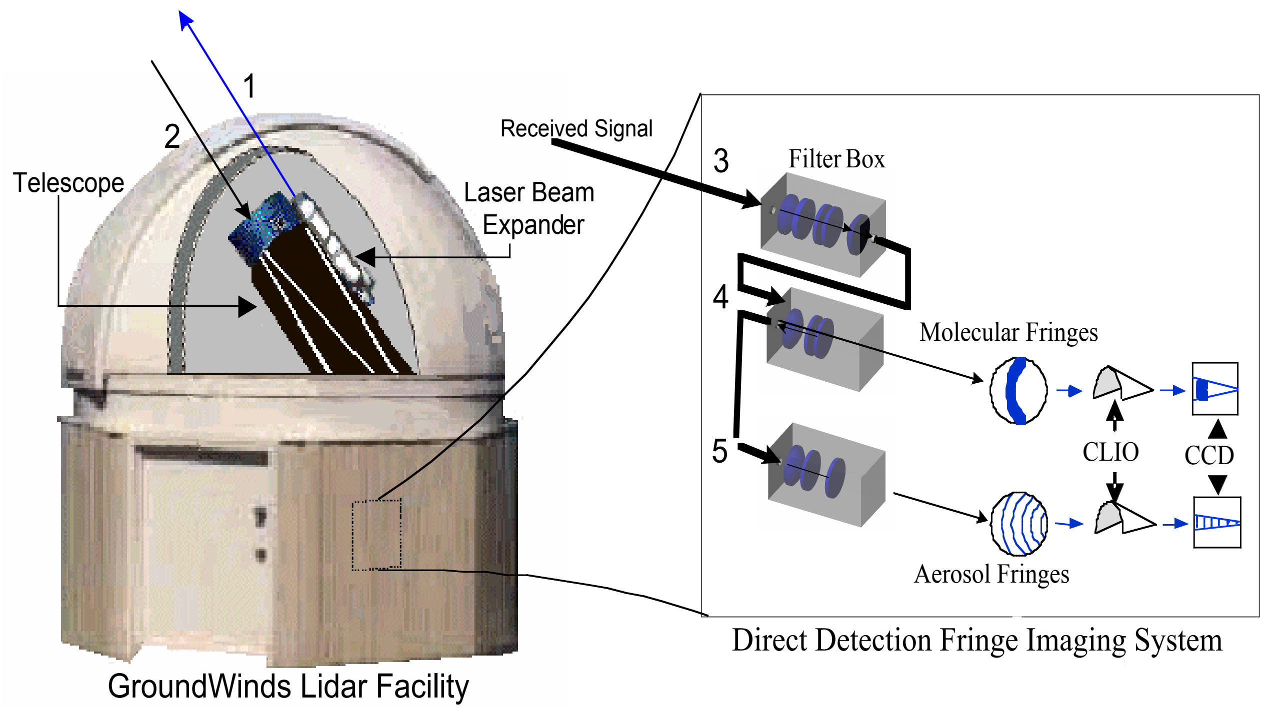


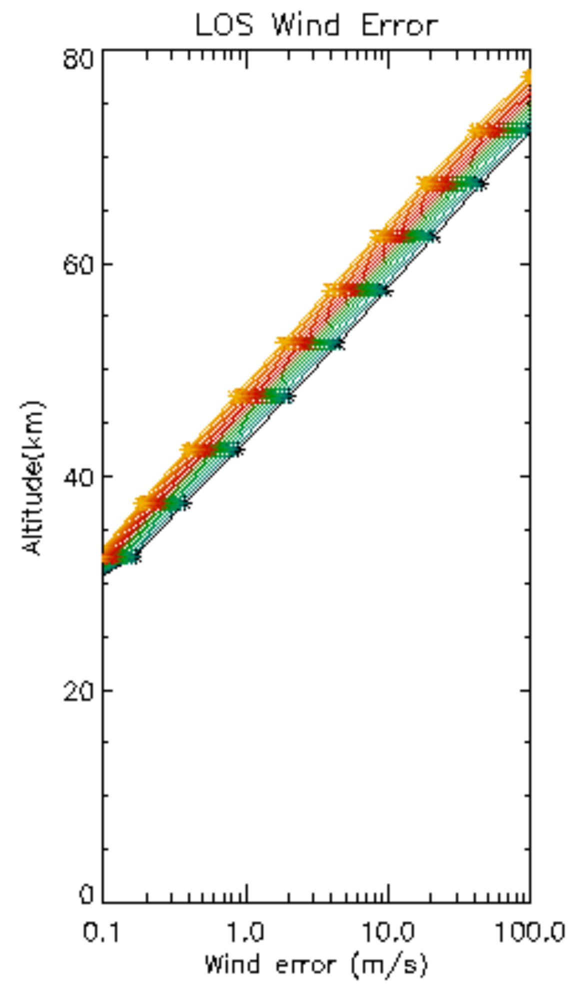




Error Issues?

Spectrally Scanning Receiver





Error Issues?

Conclusions/Thoughts

- I have skipped A LOT of tropospheric molecular/aerosol issues. For example:
  - coherent detection
  - composition measurements
  - hard-target lidar
  - ocean/underwater lidar

- I have skipped A LOT of the molecular/aerosol development done by the "non-NSF-supported" community, namely "the Germans and the French."

- The big development in molecular/aerosol lidar for the CEDAR community must be: Get the winds!

- CEDAR lidar systems are currently "governed" by CRRL.

- Where do molecular/aerosol lidar systems belong at NSF?