An aerial photograph of a mountain range, likely the Sierra Nevada, with a large telescope dome visible in the distance. The sky is clear blue, and the mountains are covered in green vegetation and snow. The text is overlaid on the top half of the image.

Atmospheric Characterization of El Peñón: The Site of the Large Synoptic Survey Telescope

Mallory Young

Hendrix College

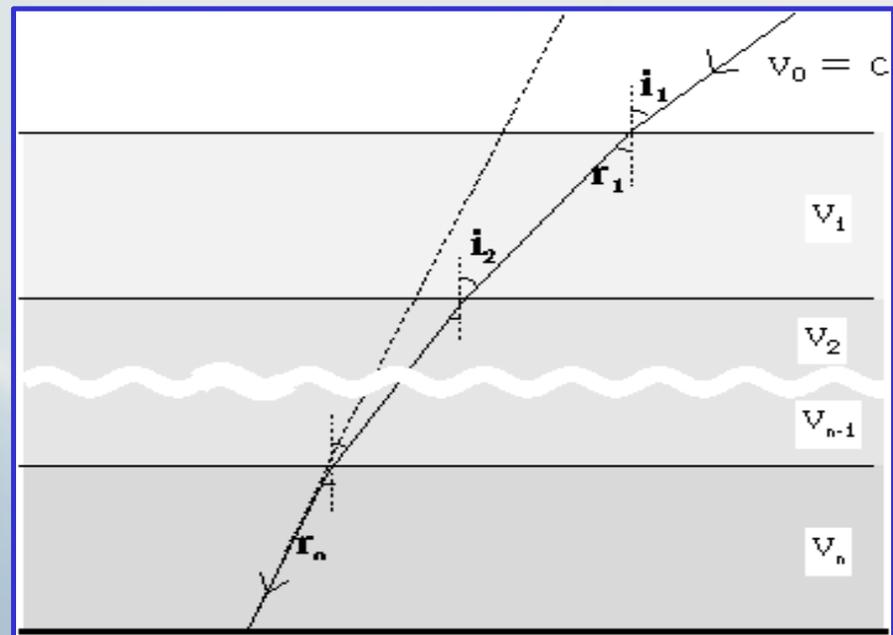
Advisor: Dr. John Peterson

Purdue University

25 July 2009

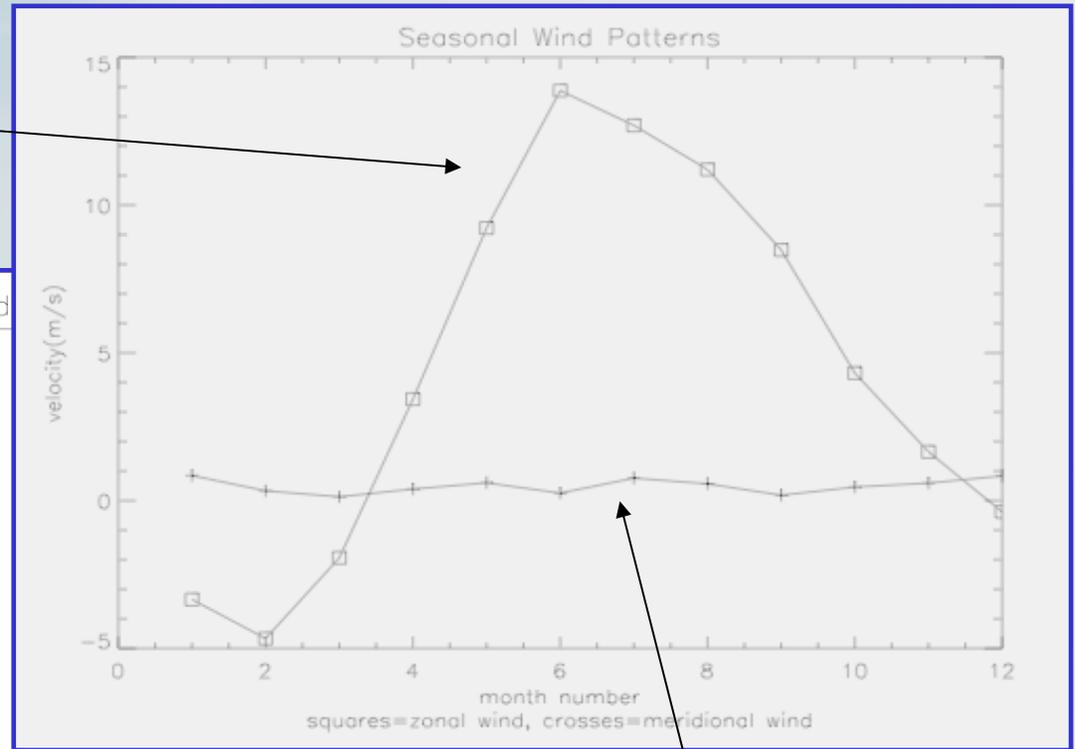
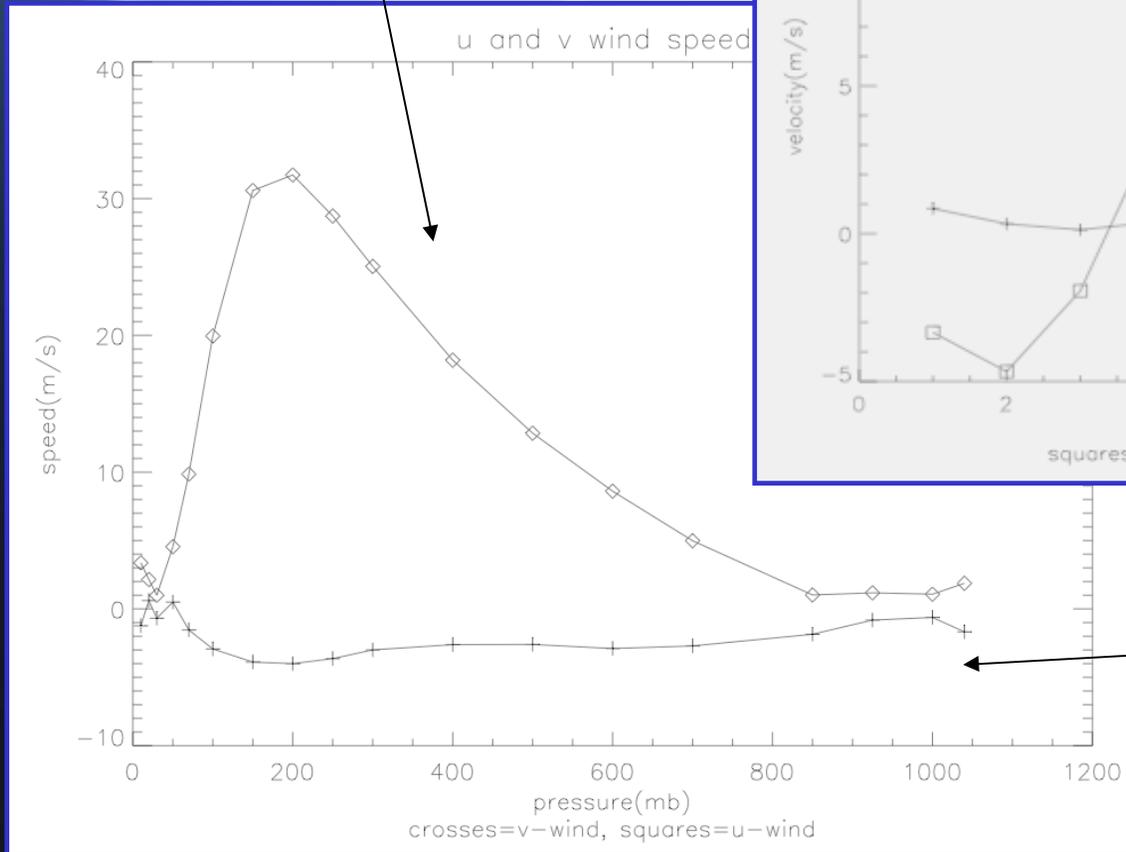
Overview

- LSST: most powerful telescope yet (2014)
- Site: Cerro Pachón, Chile
- Atmosphere: series of turbulence sheets
- Photons altered according to Snell's Law
- Defining parameters: wind speed, wind direction, and seeing
- Poor seeing \uparrow
distorted images



Wind Speed Characterization

Zonal winds display both seasonal and altitude dependence.



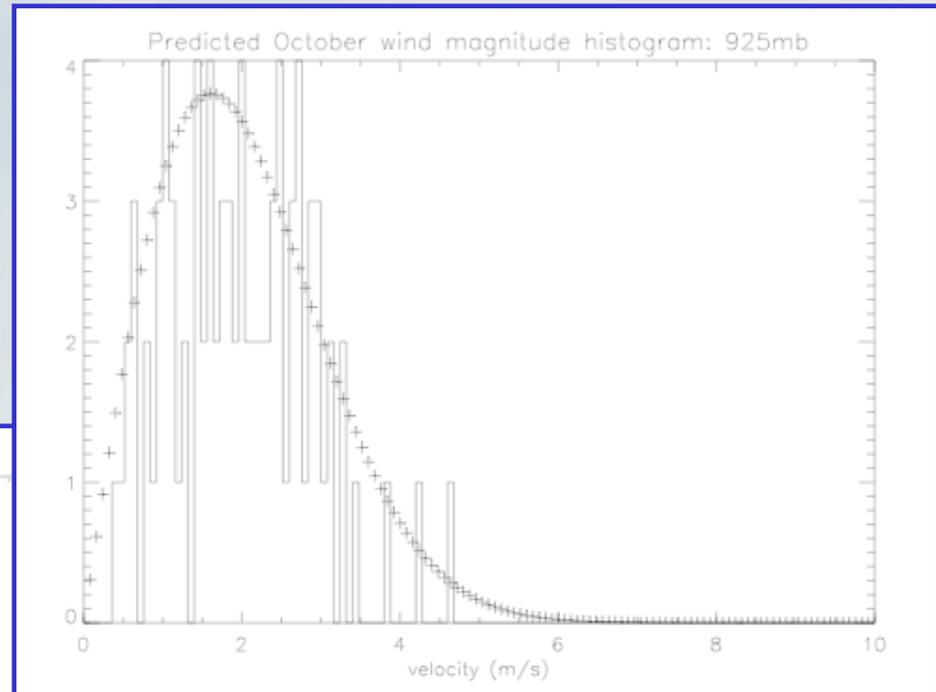
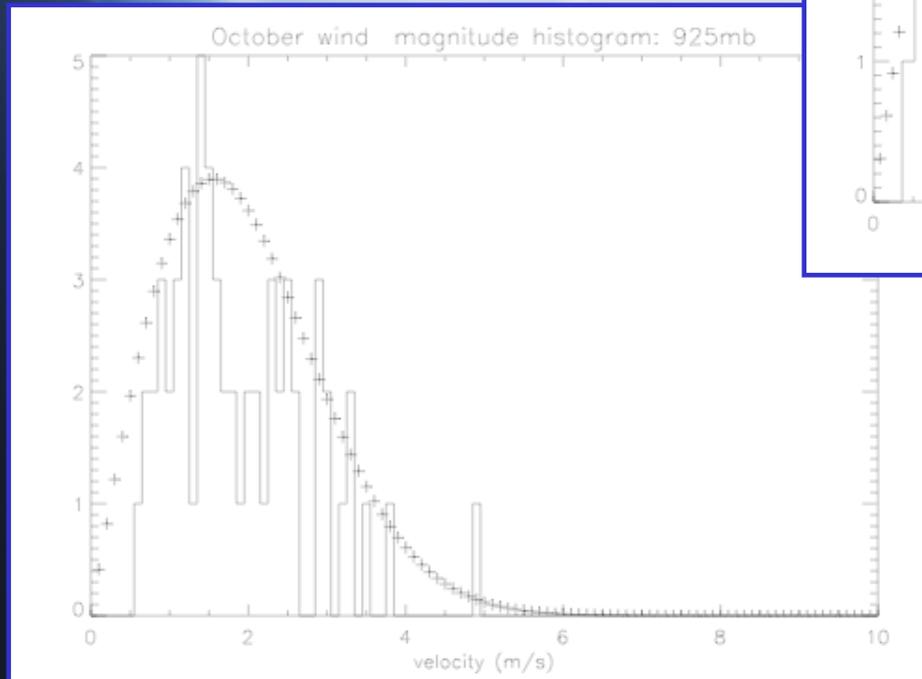
Meridional winds are roughly consistent for all months and altitudes.

Wind Speed Distribution

Rayleigh form of Weibull
distribution



Excellent model for wind
speeds



Random variate:

$$X = \sqrt{-2 \ln(U)}$$

where

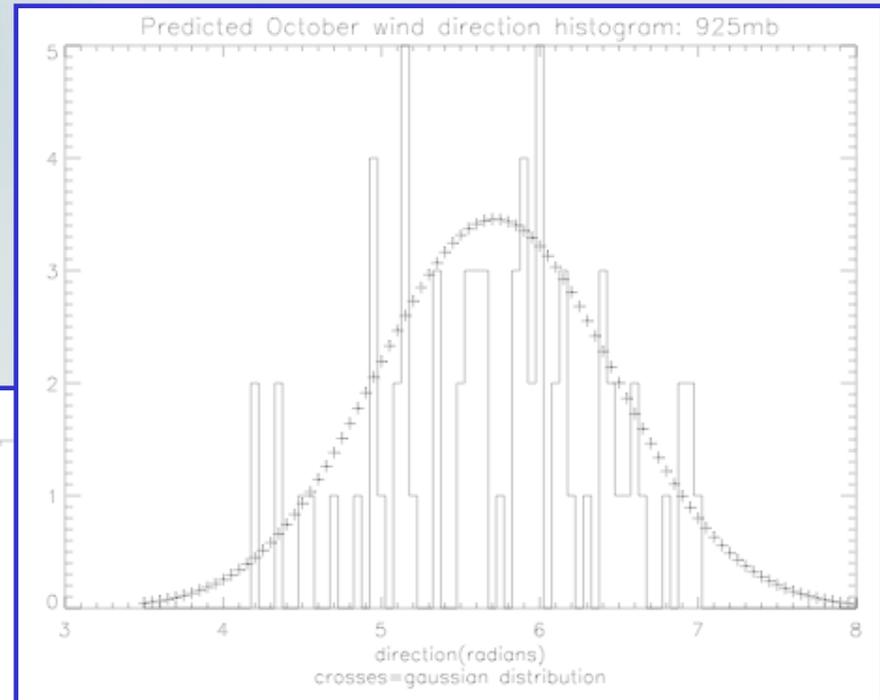
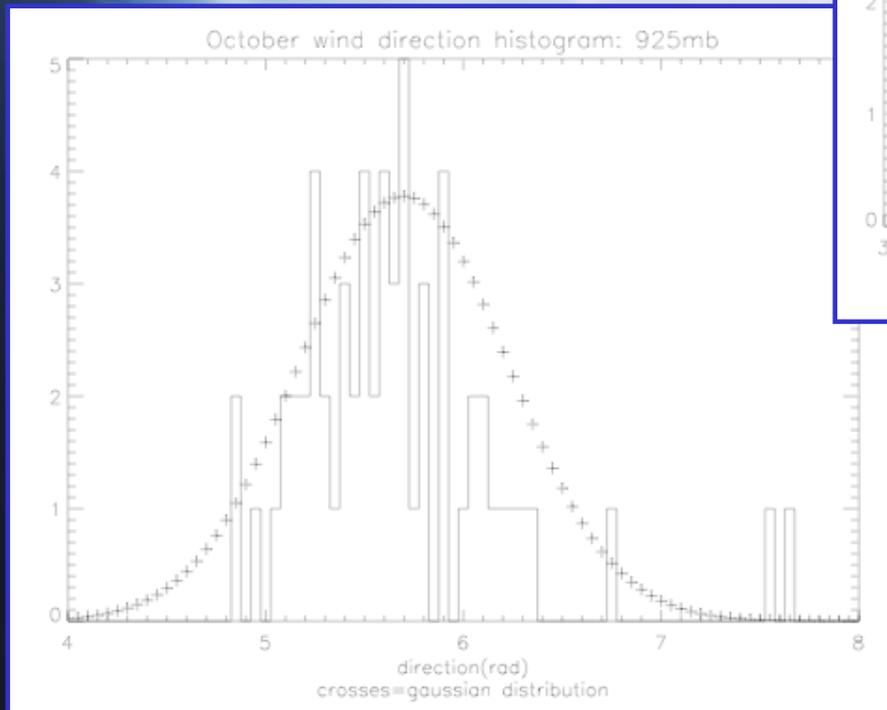
$$\sigma = \sqrt{\frac{1}{2N} \sum_{i=1}^N x_i^2}$$

Wind Direction Distribution

Gaussian Probability
Distribution Function



Excellent model for
wind directions



Random Variate:

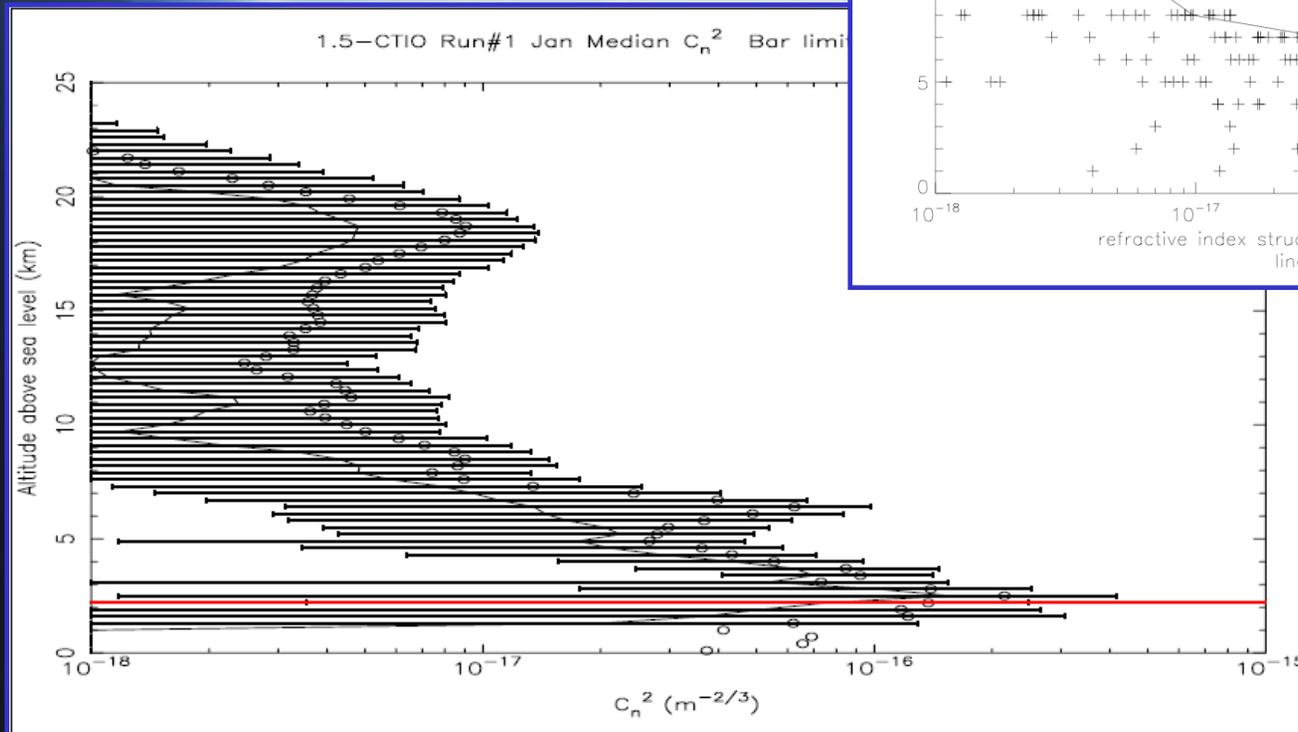
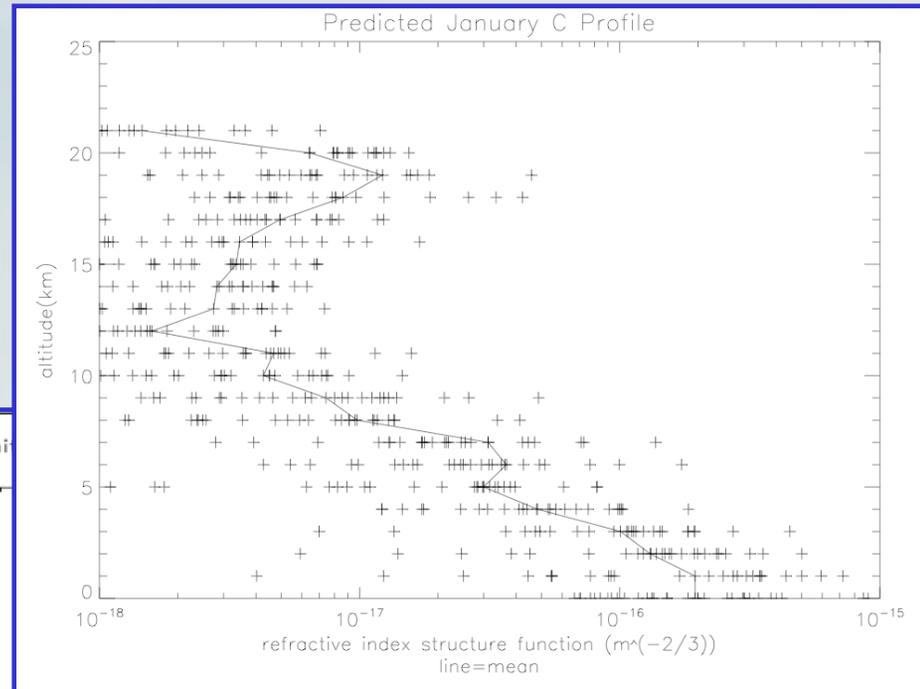
$$X \sim \mathcal{N}(\mu, \sigma^2)$$

Where μ = mean

σ = standard deviation

Seeing Characterization

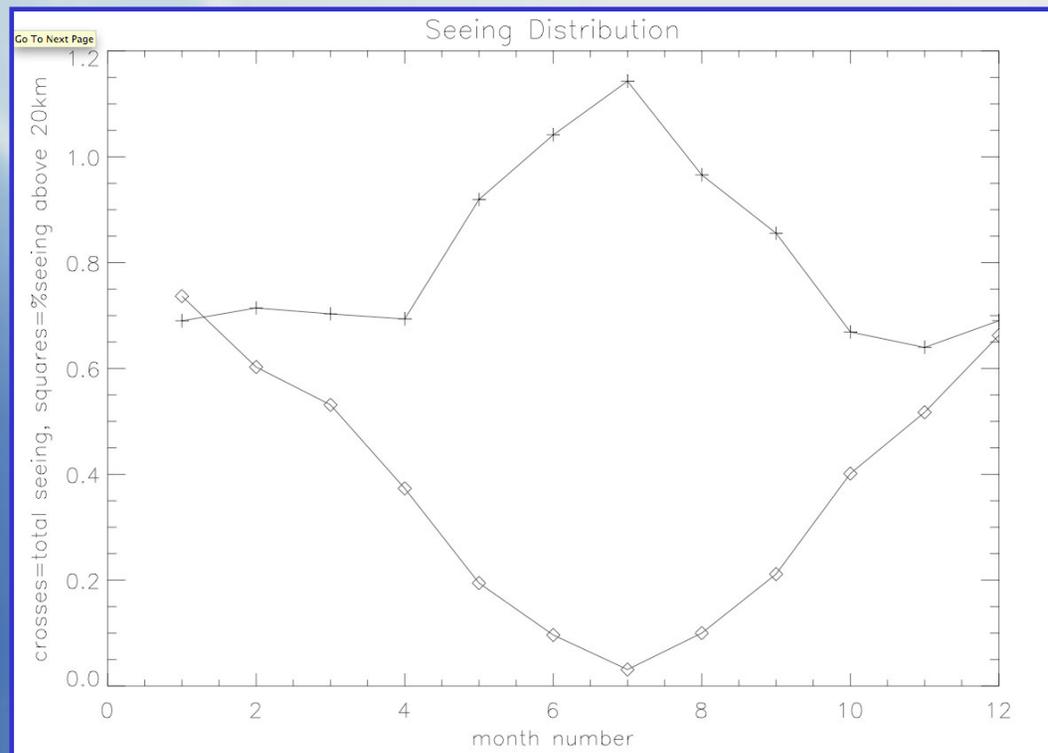
Refractive index structure
constant
↓
atmospheric seeing



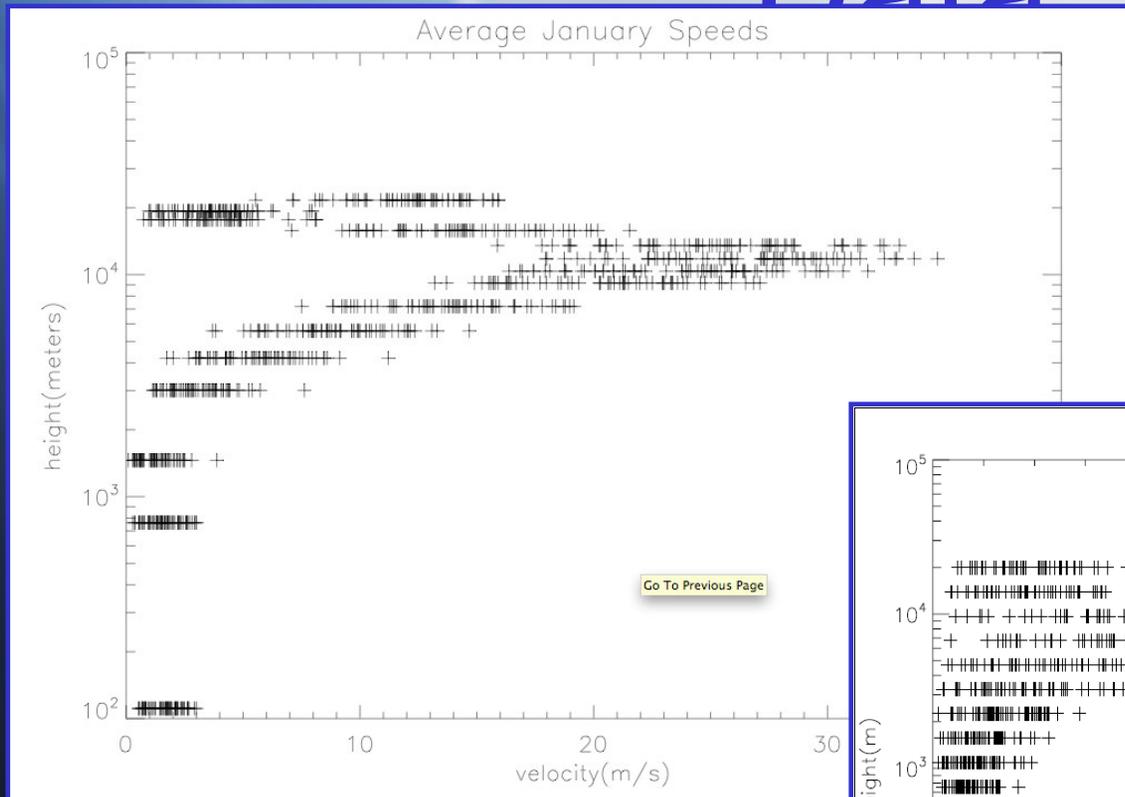
1998: Gemini Site
testing campaign on
Cerro Tololo yields
important
 C_n^2 data.

Cutoff Height

- No seeing = no effects on photons \Rightarrow no need for modelled turbulence sheet
- We can safely set the highest sheet at 20km

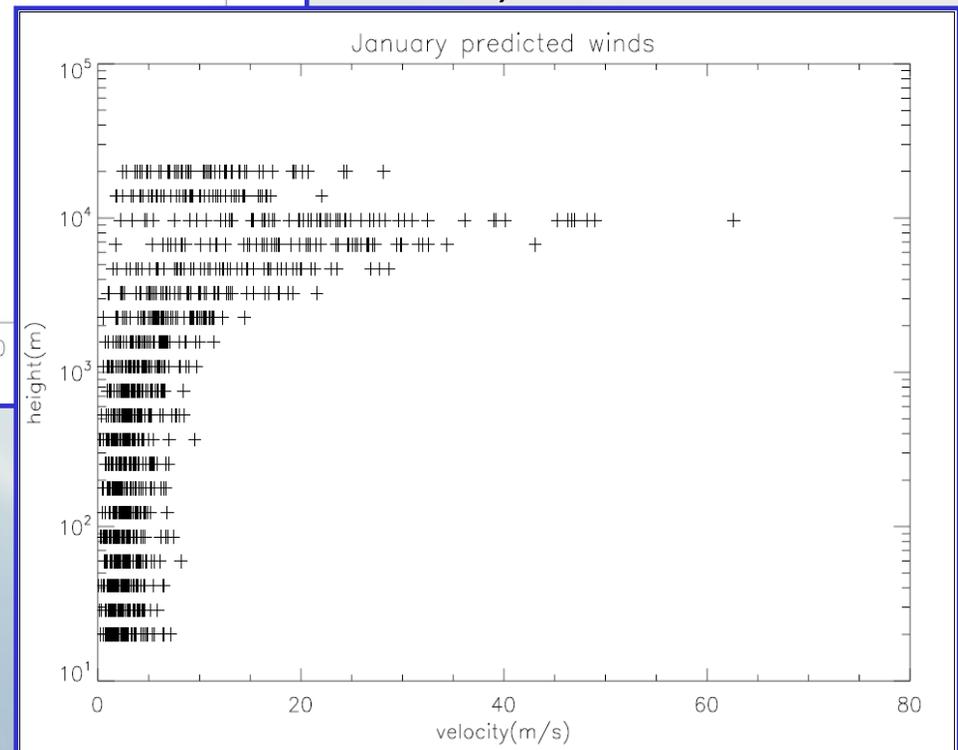


Predictions vs. Actual Data

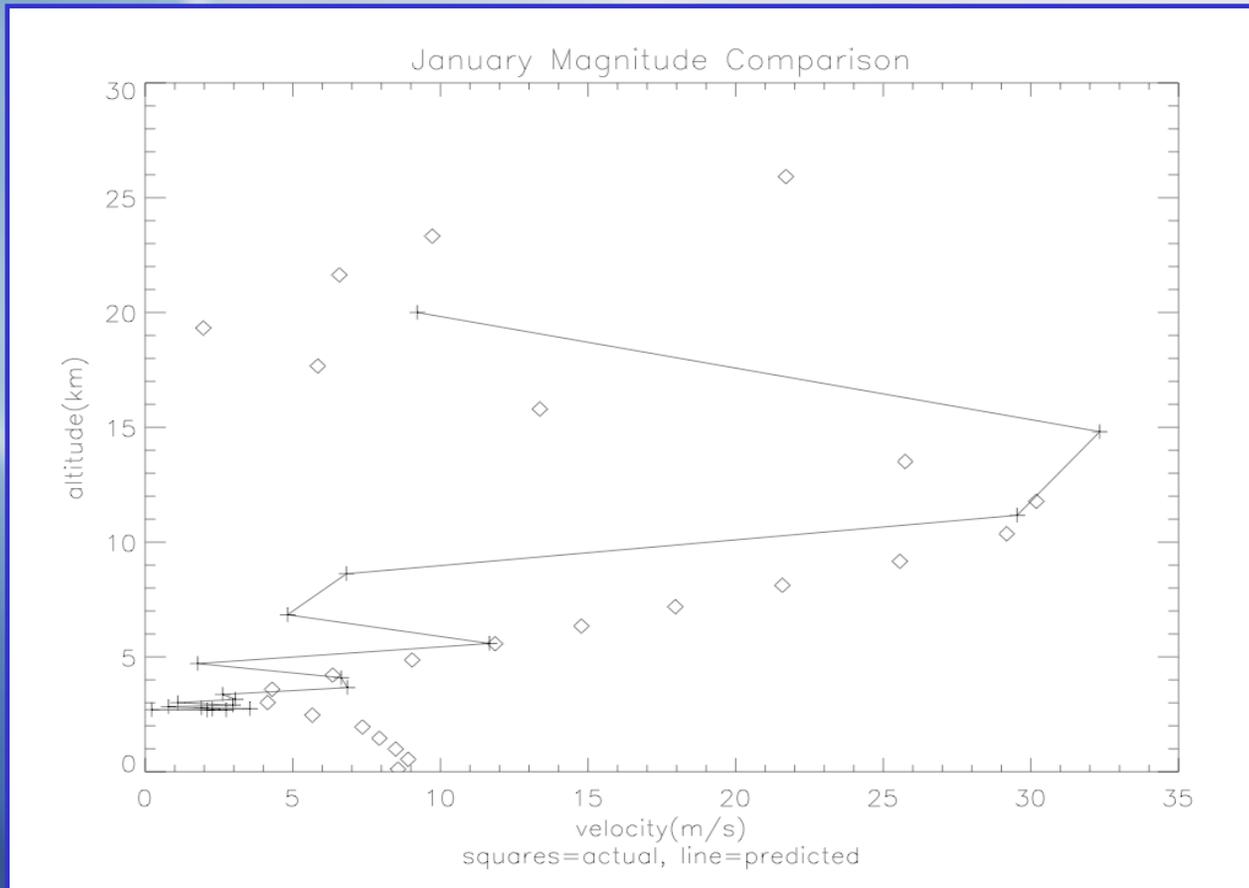


← Scatter plot of monthly averages taken from NCEP Reanalysis (1948-2008)

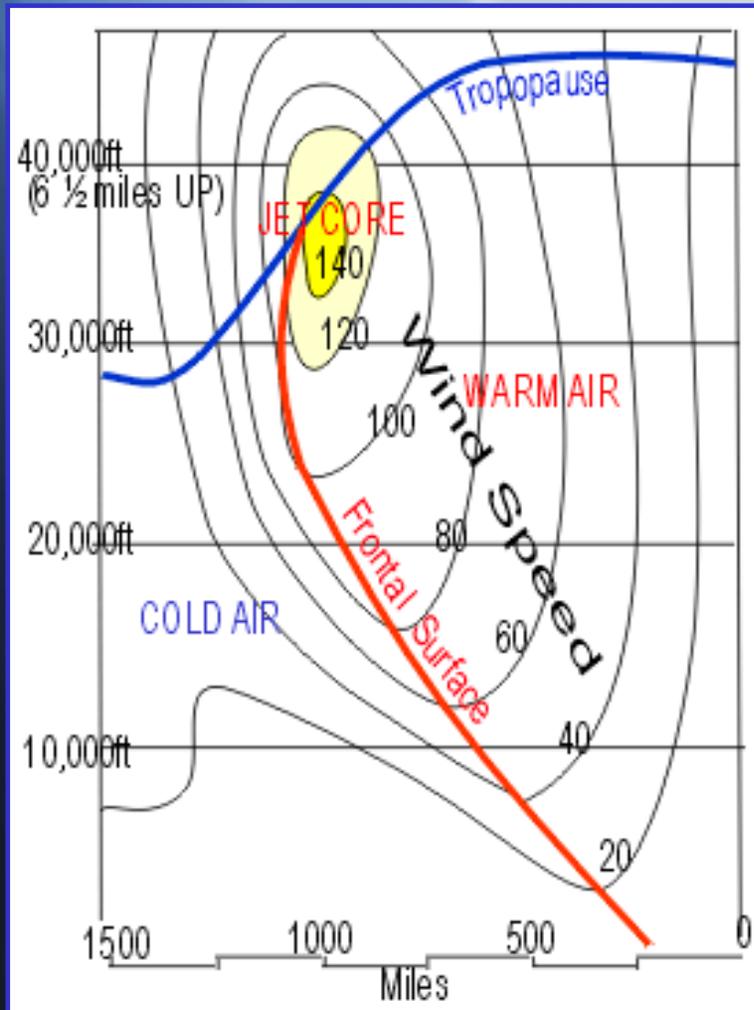
Scatter plot of predicted values from 61 runs of program (for January) →



Individual Instances



Vertical Wind Shear



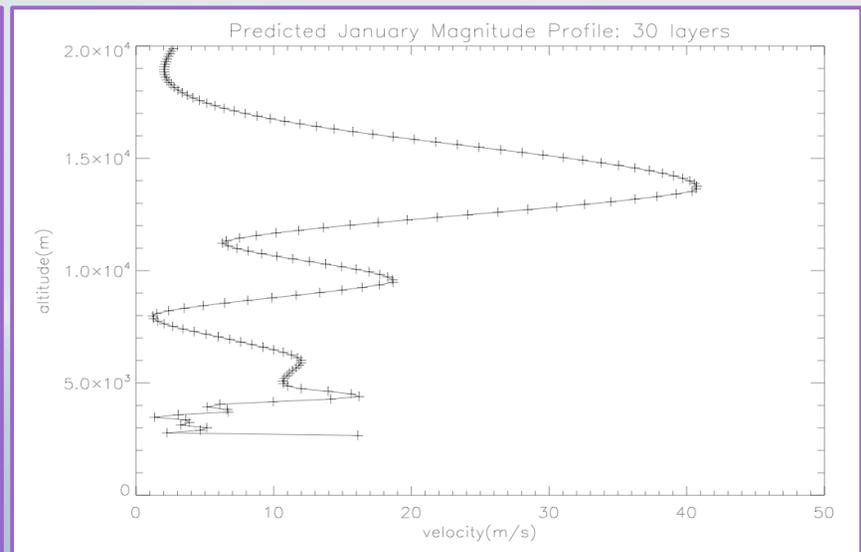
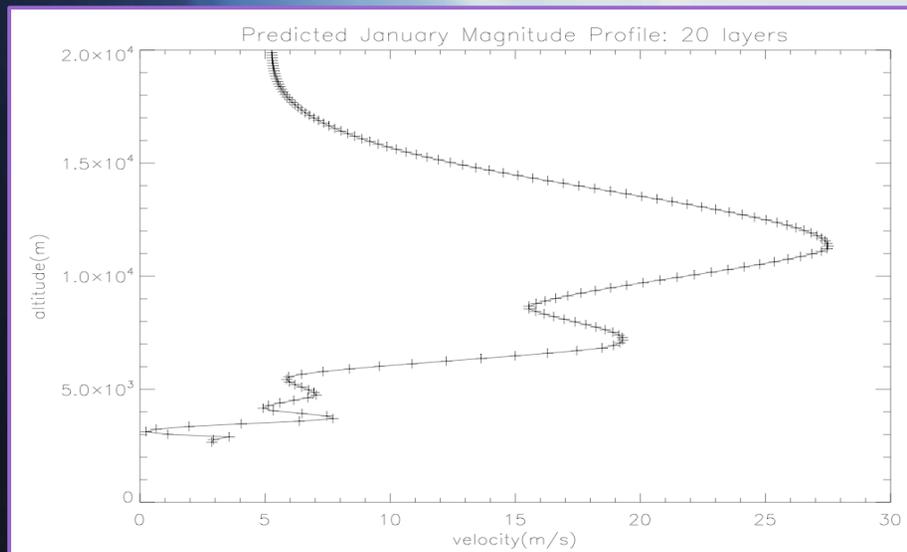
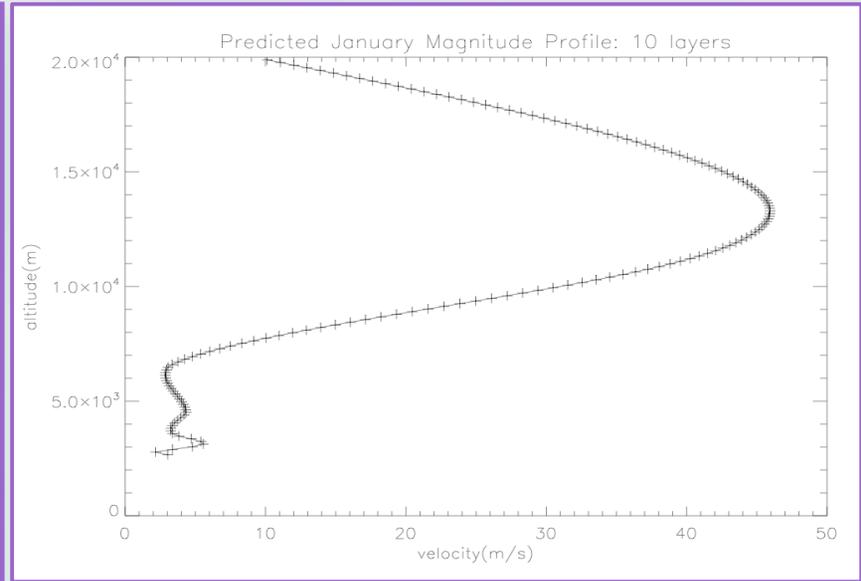
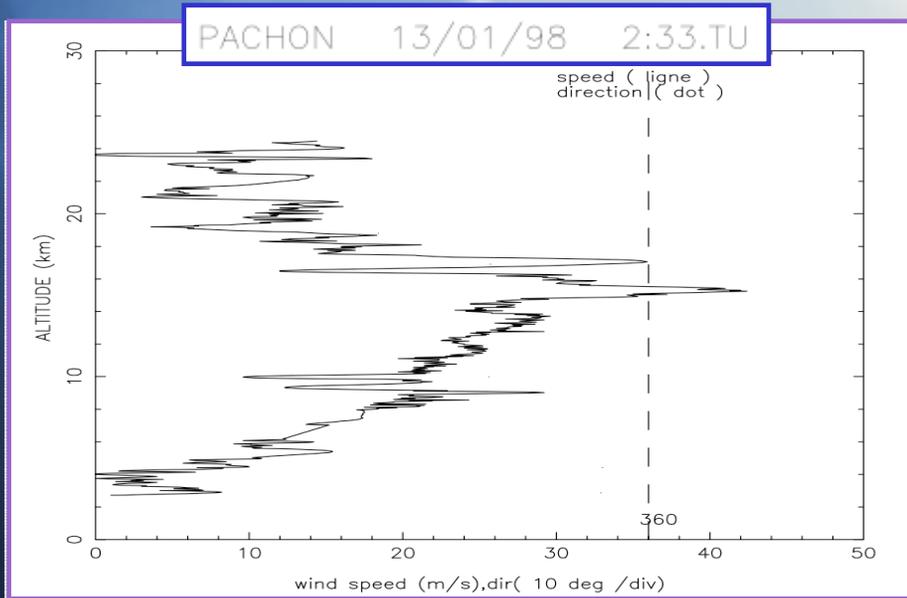
Definition: a change in wind speed over a relatively short altitude difference in the atmosphere.

Causes: jet streams and streaks, temperature and pressure changes, convection, mountainous terrain, storms...

Jet Stream Characteristics:

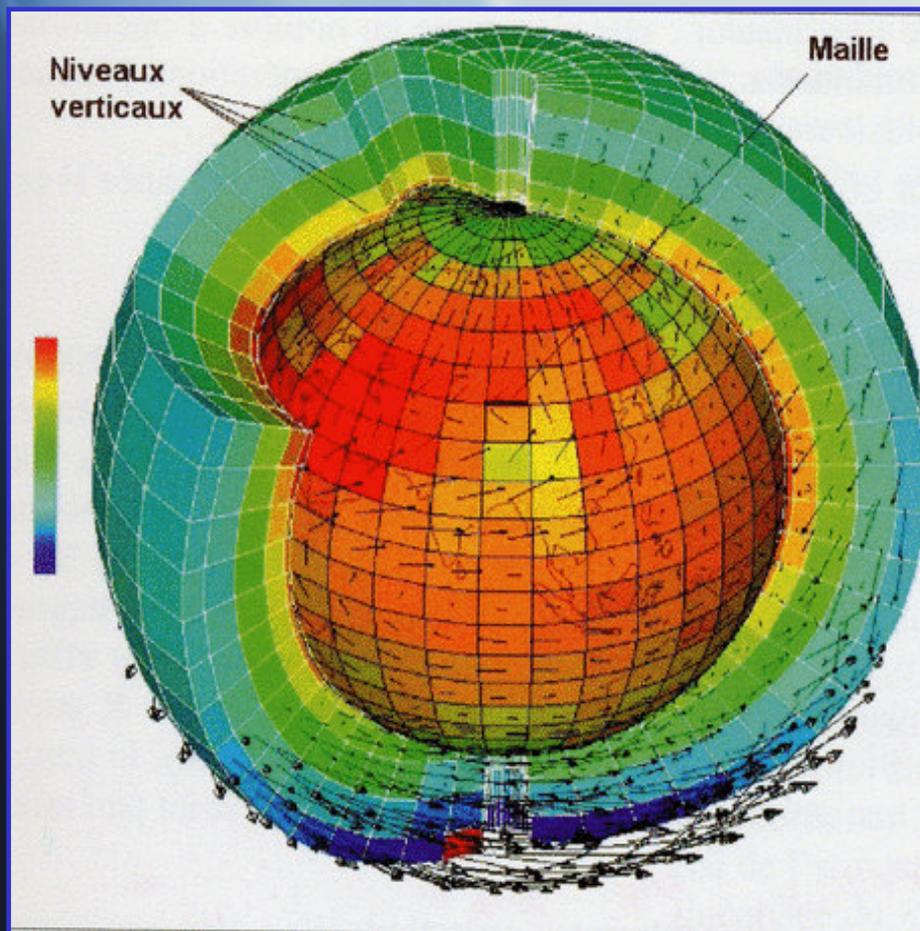
- Typically found between 200 and 300 mb (9 to 12km above sea level)
- Between 1.5 and 4km thick
- Follows wavelike path
- Not continuous

Effect on Wind Speed Profile



Cause of Smoothness?

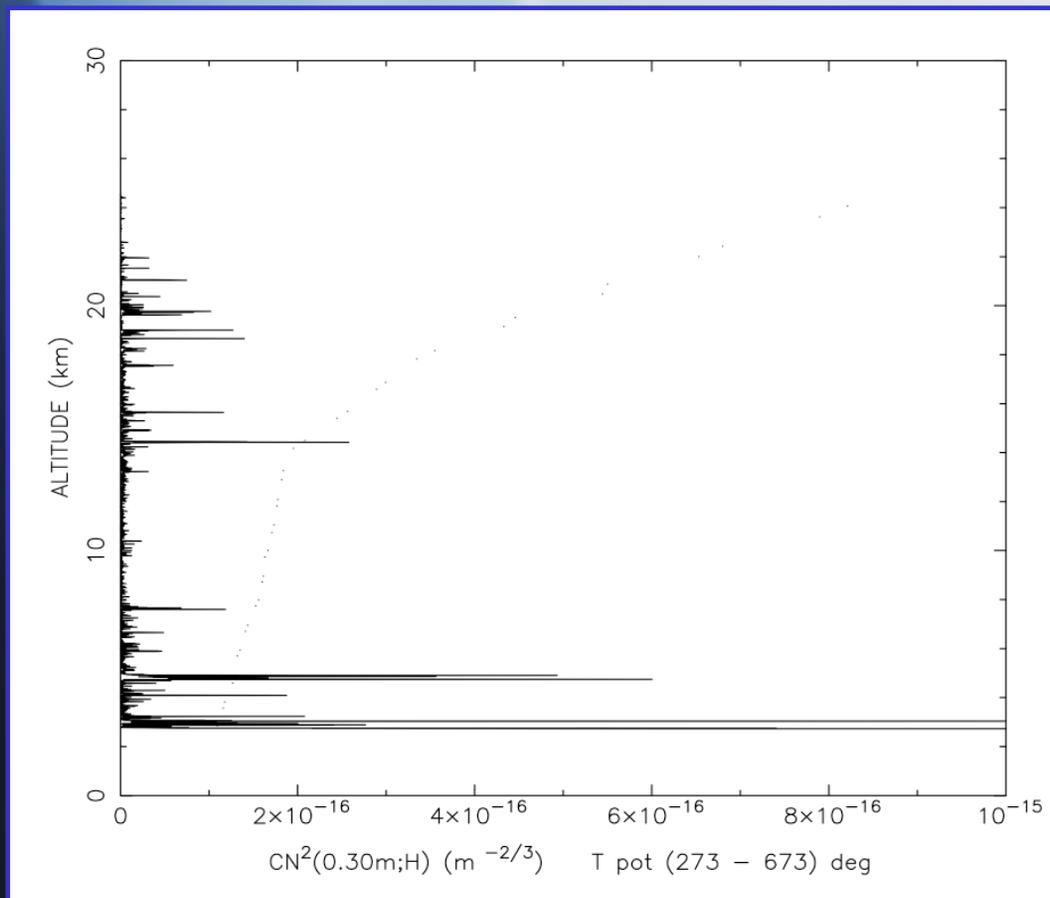
- 20th Century Reanalysis: wind data from 1908 to 1958.



- Surface pressure observations are combined with a short-term forecast from integrations of an NCEP numerical weather prediction model to estimate the complete state of the atmosphere.
- Averaged over 6-hour intervals
- Poor resolution (approx. $2.0^{\circ} \times 2.0^{\circ} \times 50\text{mb}$)

Same Goes for Seeing...

Gemini campaign balloon launched at 2:33am on January 13, 1998 reveals lack of smoothness.



Causes of Discontinuity:

- Gravity waves (vertical waves of air caused by mountainous terrain, thunderstorm updrafts,...)
- High temperature gradients
- Air moisture changes

Implementation

height	0	20.0000
wind	0	3.66568
winddir	0	315.762
Cn ²	0	1.24790e-16

height	1	79.6213
wind	1	3.71343
winddir	1	317.824
Cn ²	1	7.63503e-17

height	2	316.979
wind	2	4.94487
winddir	2	315.041
Cn ²	2	2.49666e-17

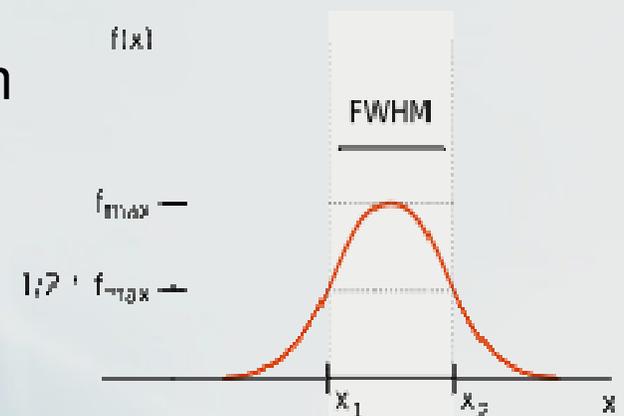
Height: given in meters above the telescope (sits at an altitude of 2660m above sea level)

Wind: magnitude of wind speed given in meters per second.

Winddir: wind direction given in degrees, where 0 points due east.

Cn²: in (m/s)^{-2/3}

Seeing: measurement in arcseconds of the full width at half maximum of the image point spread function.



Acknowledgements

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