The NJIT-UACNJ-PSU Collaborative:
A spatially scanning middle atmospheric lidar system in northwest New Jersey

NJIT New Jersey's Science & Technology University

We present an overview of a new middle and upper atmospheric observatory located in northwest New Jersey; focusing specifically on the 355-nm lidar system deployed in summer-early fall 2008. The lidar system uses a 2.2 W 355-nm laser system attached to a 1.2 meter, fully steerable optical telescope to measure a host of lower and middle atmospheric parameters, including a) lower and middle atmospheric gravity wave structures, b) lower atmospheric cloud/aerosol formations, and c) frontal systems as progenitors of gravity waves. These topics of interest are studied using 4D volume visualization methods often used in tropospheric Doppler radar systems.

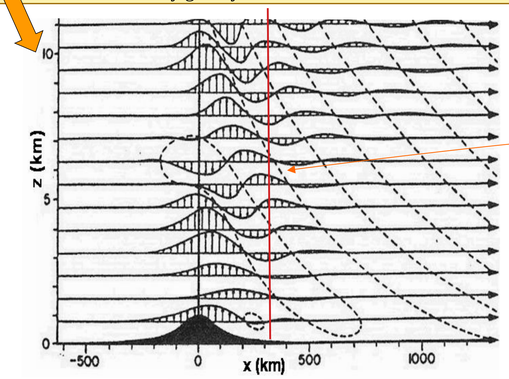
Stationary Gravity Waves

These are the waves generated in a fluid medium and have gravity as their restoring force

In the atmosphere, they exist due to the stable density stratification of atmosphere under gravity

As an illustration, a mountain ridge acts as an obstruction to the wind flow and causes perturbations in the air above it, thus exciting stationary gravity waves

The resultant wave pattern due to varying density atmospheric layers is called the stationary gravity wave



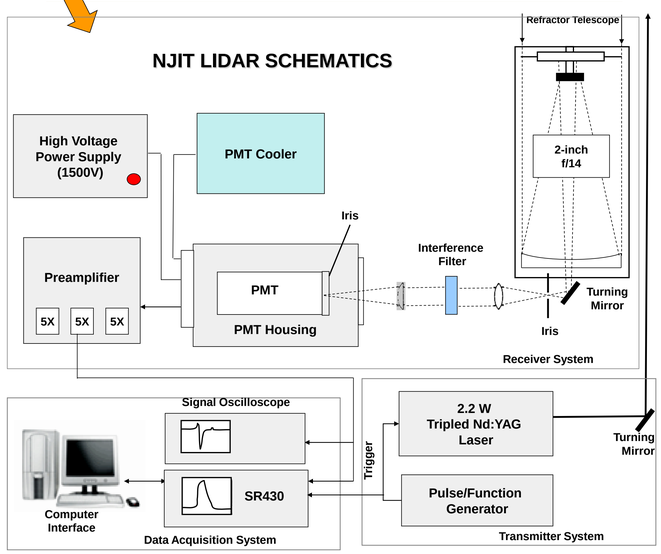
Urban Heat Island Effect

Urban areas tend to stay warmer than surroundings due to large amounts of heat-absorbing materials (asphalt)

This results is the urban-rural convective circulation known as Urban Heat Island Effect, UHI, thus creates a heat reservoir or "dome", comprising urban areas, and acts similarly to mountain ranges producing stationary gravity waves

NJIT LIDAR SYSTEM

System Specs:
- Optical Assembly of filters and lenses
- PMT Housing, Cooler
- High Voltage Power Supply
- Home Computer System
- Multichannel Scalar SR 430
- Pulse Function Generator
- Pre-Amplifier
- Oscilloscope
- 2.2W Laser (Projected Up)



System's Working

- The system is used to essentially sample the reflected laser energy from air molecules/ aerosols over 5~20 km altitude range
- The amount of photon-counts received over the altitude array would determine atmospheric density at each altitude
- It would allow us to obtain high temporal & spatial resolution observations of relative air density above the Newark-New York City metropolitan hub
- We would analyze the altitude, time & relative density indices to observe the stationary gravity wave structures and activity

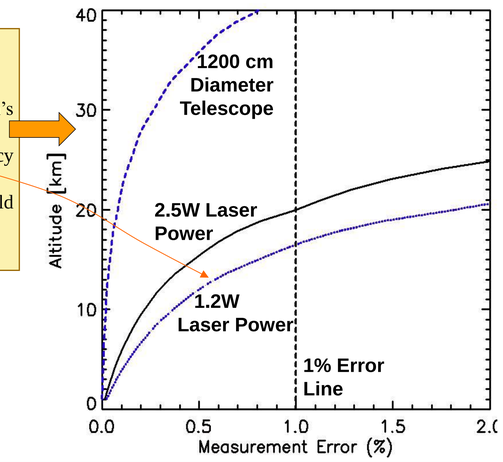
Crucial Aspects of Research

Stationary Gravity waves:
- Generate turbulence patches above urban areas, which are hazardous for aviation safety. Thus their evaluation of their characteristics could help in determining the locations of these patches
- Form long-lasting cold packets of air like lee clouds. This promotes the processing of airborne contaminants which could transported to the middle atmosphere and across the globe through global atmospheric circulation
- Propagate to middle & upper atmosphere, where they break down and lose momentum, which affects global circulation

- Global Climate Models do not currently treat forcing from such gravity waves from urban areas thus:
  - POTENTIAL IMPACT ON THE CLIMATE IS STILL UNCERTAIN!
- Observation and characterization of these waves would help in incorporating them in Global climate models to enhance numerical climate modeling.

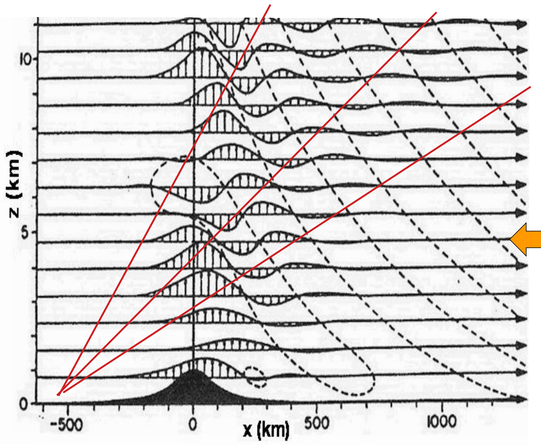
Altitude-Error Analysis

- We quantified error in return photo-count and estimated our system's performance using Poisson's statistics
- A 1.2W laser was found to give our lidar system a data acquisition accuracy with under 1% error up to an altitude level of 17 km.
- Tradeoff analysis helped us pick 1.2W even though a 2.5W laser could extend the range of our system to about 20 km.



ITEK TELESCOPE

- The U.S. Air force grant of over $1.1M in the form of fully steer-able 1.2 m diameter coude-focus telescope (48" lens)
- The plot above shows that the data accuracy of 99% can be achieved with this telescope over an altitude range of ~43 km
- This telescope will allow us to swiftly carry out stratospheric and lower-middle atmospheric wind analyses.
- Future lidar data will be collected at the Jenny Jump Park, NJ, where observatory is nearing completion



Future Prospects

- Bigger Telescope= Higher resolution data
- Steer-ability= volume scanning
- We can now perform 3D wave analysis as shown on the figure on the left
- Finding Stationary Gravity Wave characteristics observed over urban areas:
  - Horizontal, Vertical Wavelengths
  - Trace Speeds, Intrinsic Frequencies
- We would pursue stratospheric & ground wind analysis

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