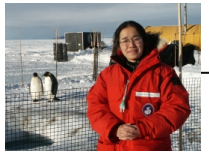
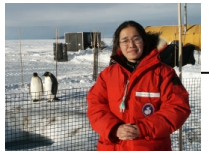


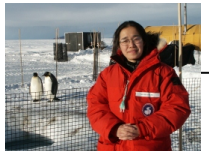
ASEN-6519 LIDAR REMOTE SENSING



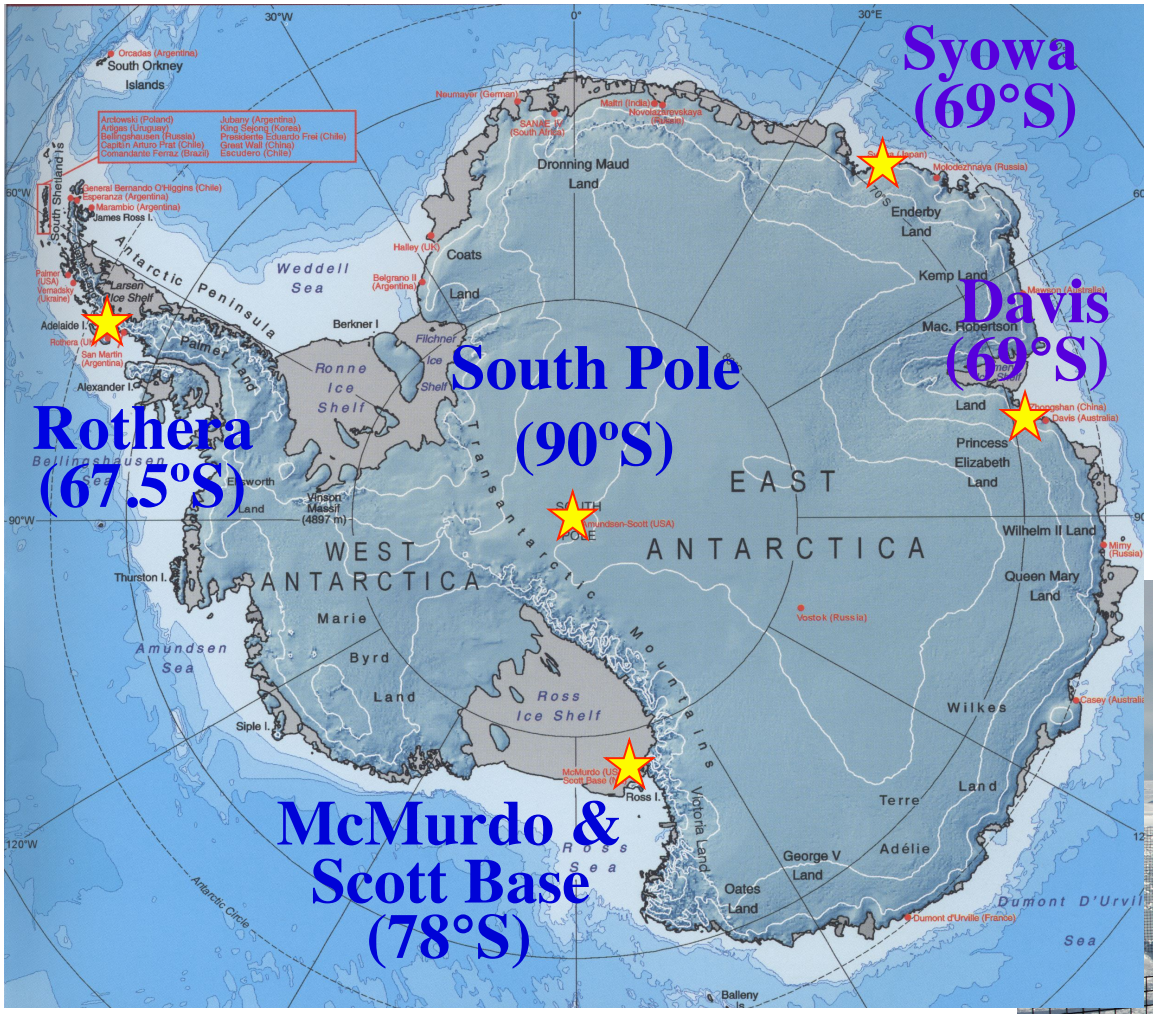
Lecture 01
Introduction to LIDAR Course

Xinzhao Chu

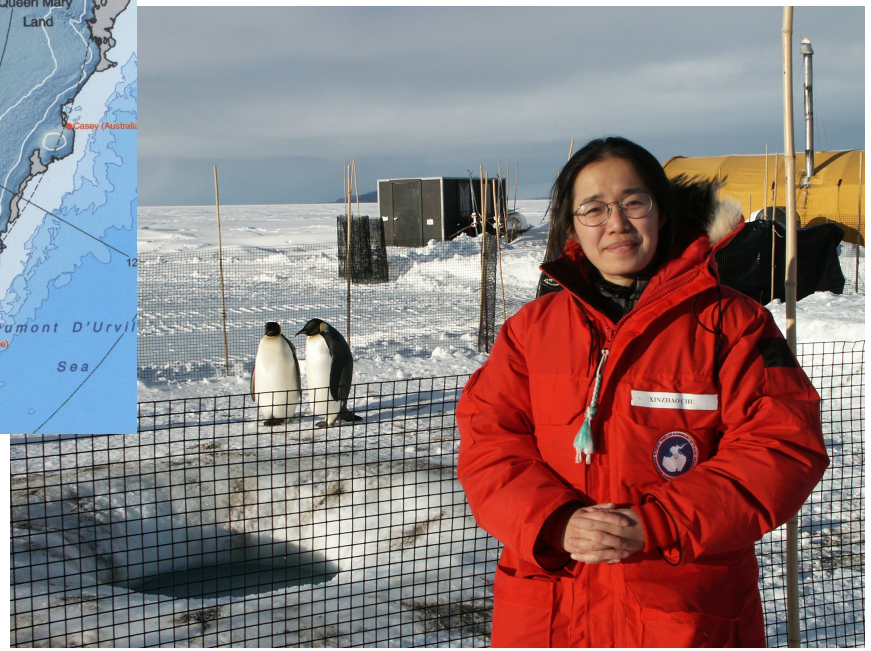
University of Colorado at Boulder



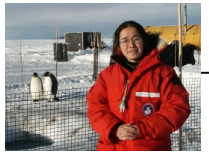
Lidar Campaign @ McMurdo



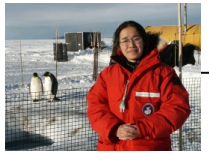
"Three Penguins"



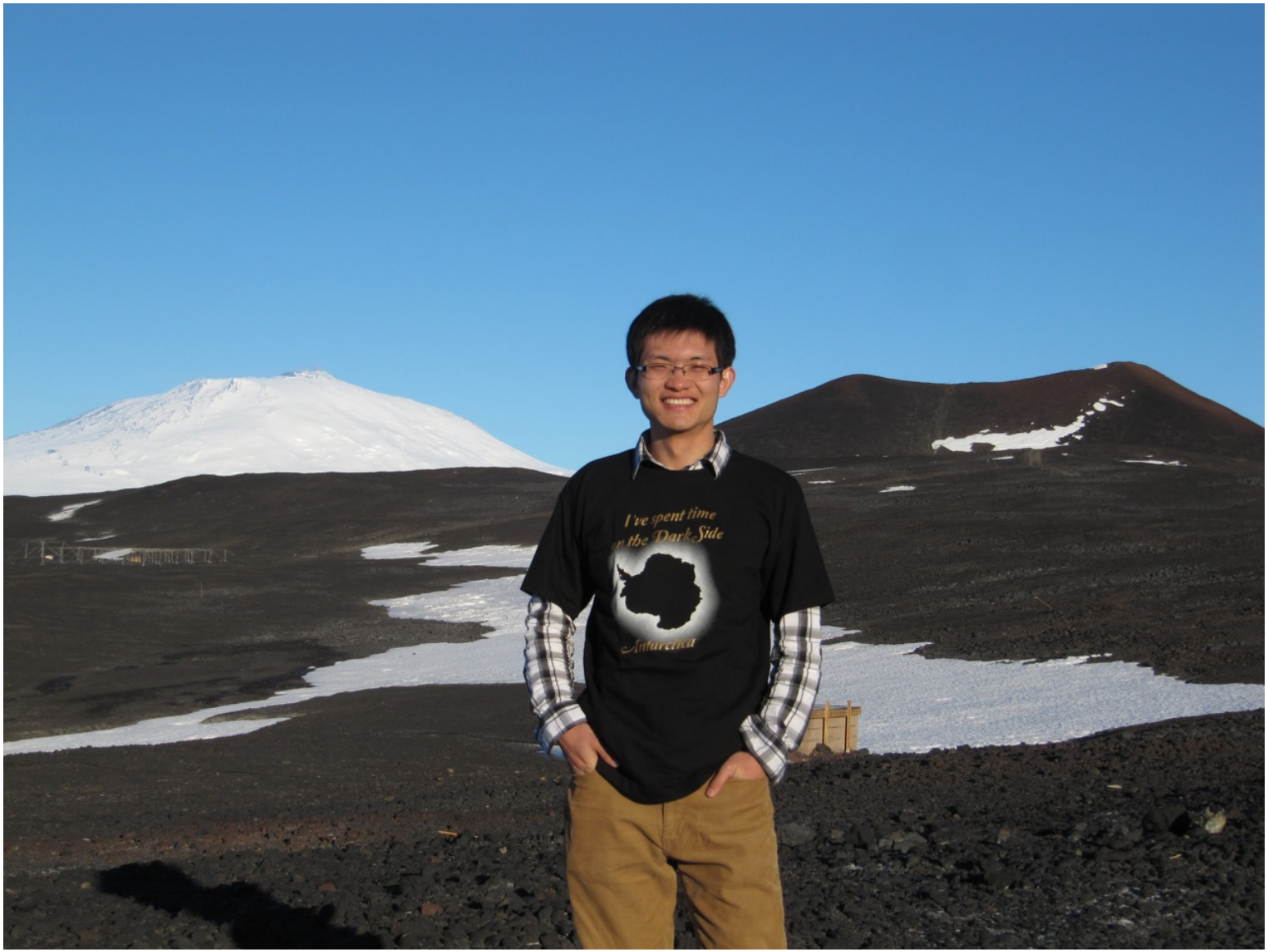
To complete an observational chain for Antarctica by filling in an important gap

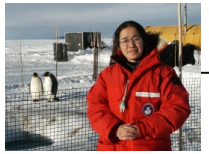


Greetings from McMurdo, Antarctica

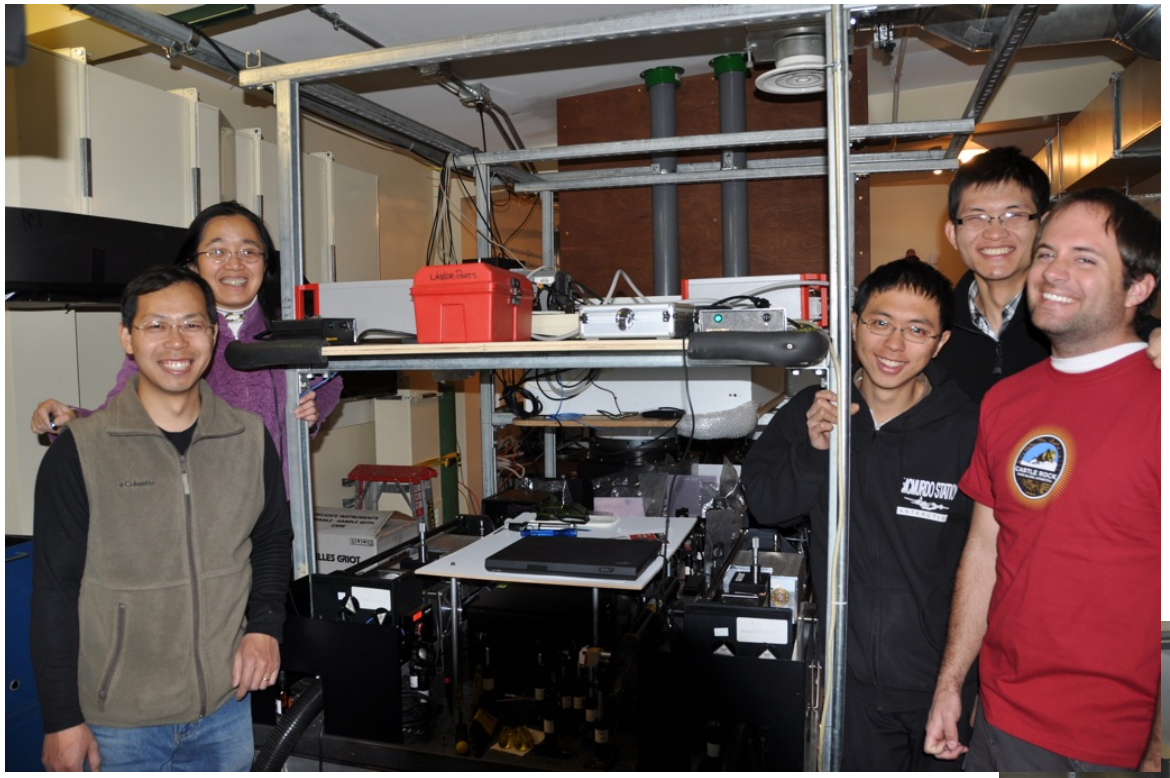


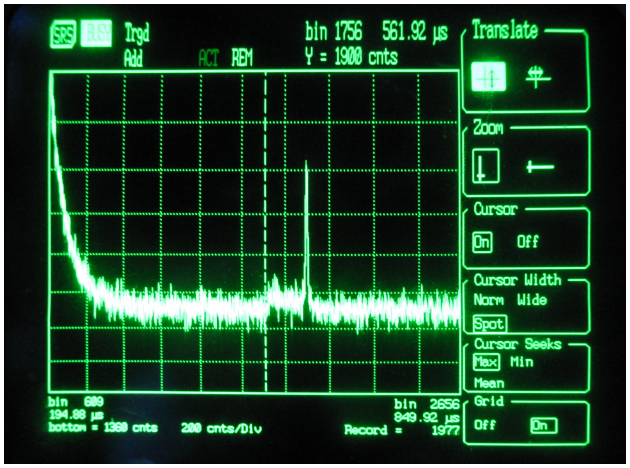
Greetings from Antarctica

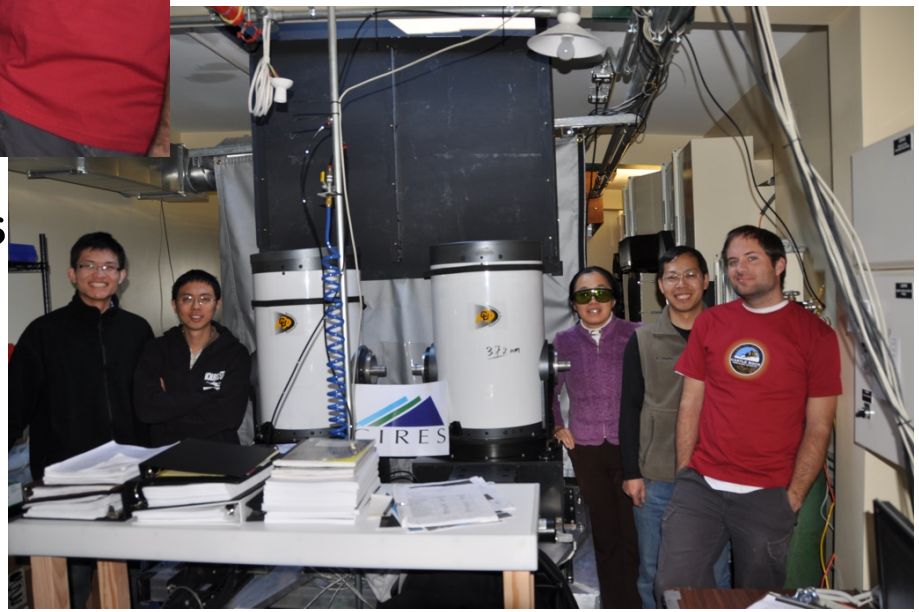




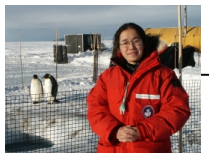
Greetings from Antarctica







12/13/2010 First lidar lit off Arr. Heights
12/14/2010 First good Rayleigh signals
12/16/2010 First 372nm Fe signals
12/18/2010 First >24-hr lidar run
12/20-22/2010 First 48-hr lidar run
12/24-26/2010 First PMC signals

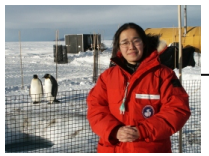


LIDAR: What and Why?

LIDAR stands for Light Detection and Ranging, commonly known as Laser Radar.

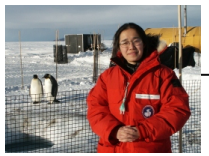
Lidar is not only replacing conventional sensors, but also creating new methods with unique properties that could not be achieved before.

Lidar is extremely useful in atmospheric and environmental research as well as space exploration. It also has wide applications in industry, defense, and military.

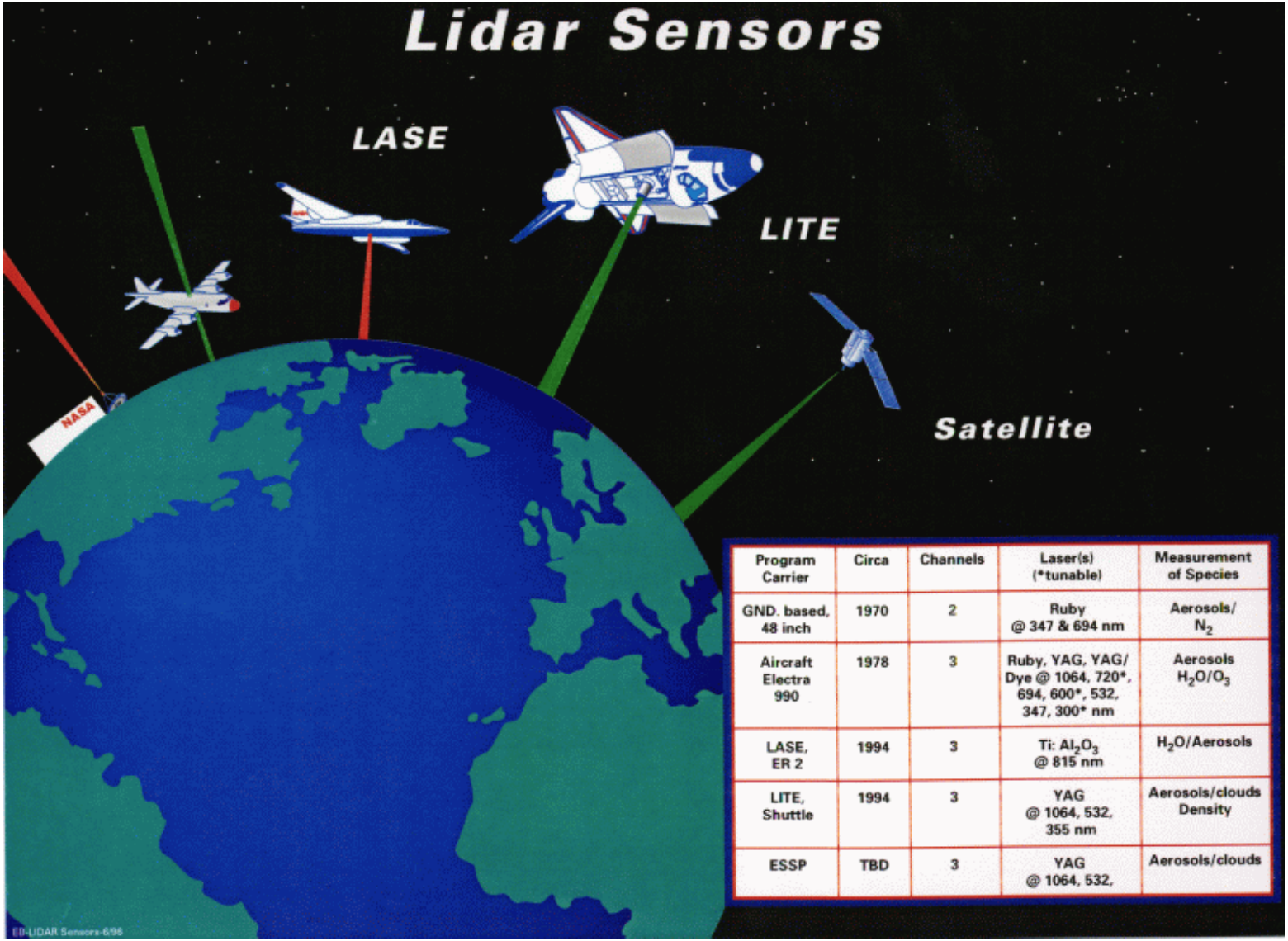


LIDAR: Light Detection And Ranging

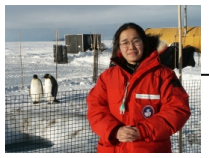
- Send light to the atmosphere
- Record light scattered by the atmosphere as function of time
- Convert time of flight to distance
  (1 ms ~ 150 km)



Lidar from Ground to Space

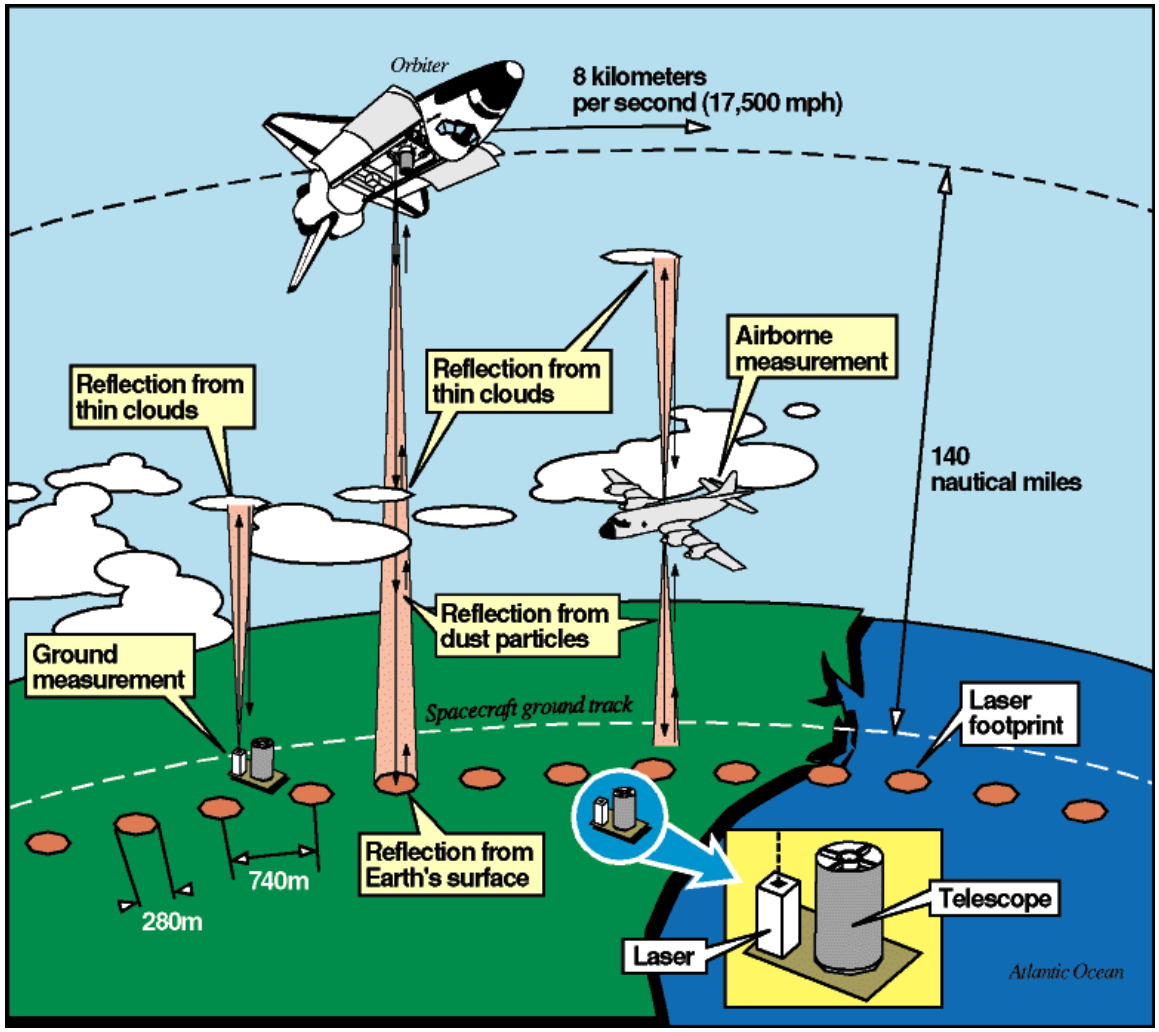


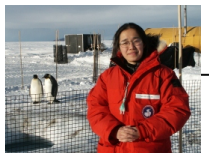
Program Carrier	Circa	Channels	Laser(s) (*tunable)	Measurement of Species
GND. based, 48 inch	1970	2	Ruby @ 347 & 694 nm	Aerosols/ N_2
Aircraft Electra 990	1978	3	Ruby, YAG, YAG/ Dye @ 1064, 720*, 694, 600*, 532, 347, 300* nm	Aerosols H_2O/O_3
LASE, ER 2	1994	3	Ti: Al_2O_3 @ 815 nm	H_2O/Aerosols
LITE, Shuttle	1994	3	YAG @ 1064, 532, 355 nm	Aerosols/clouds Density
ESSP	TBD	3	YAG @ 1064, 532,	Aerosols/clouds



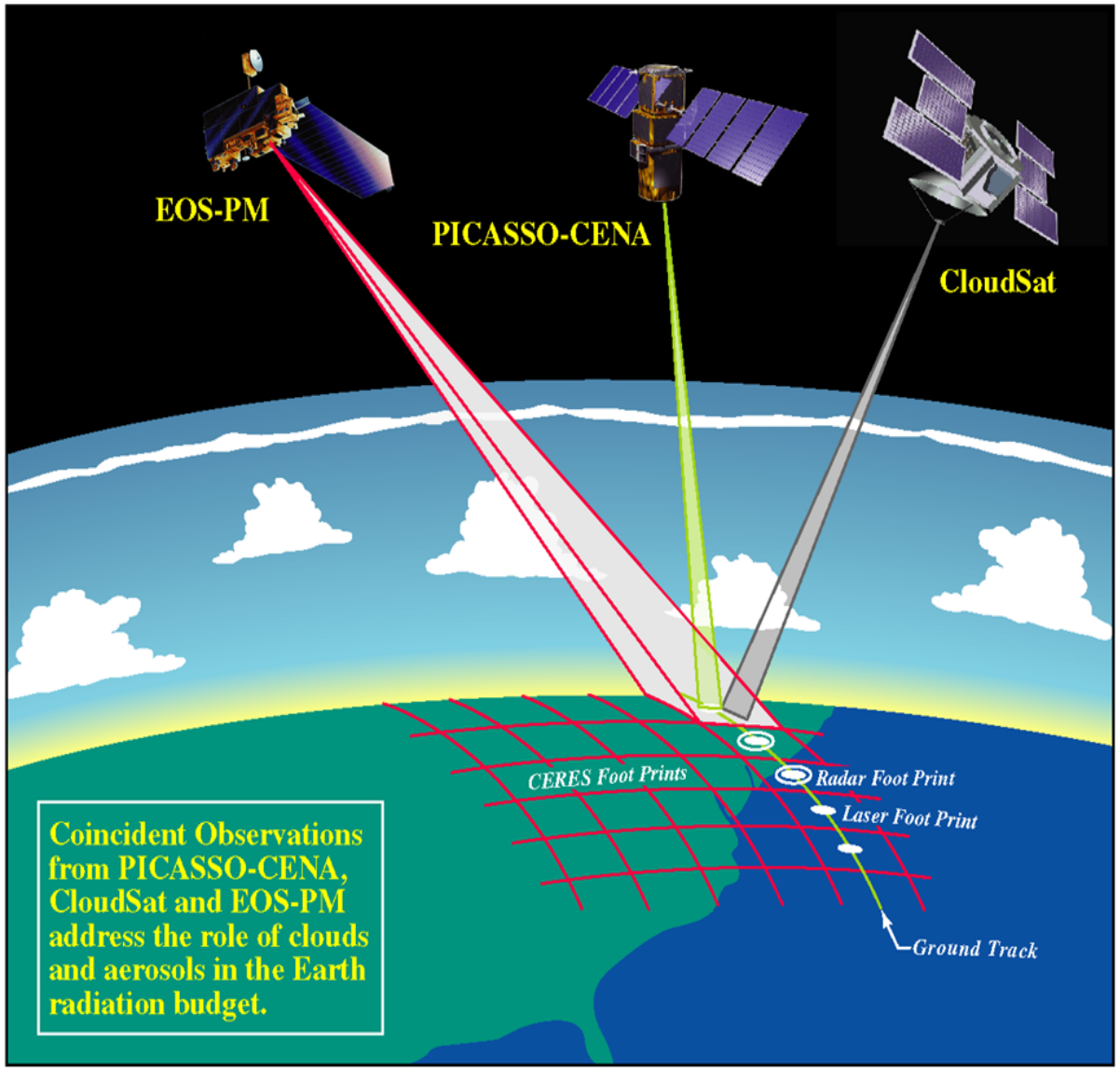
NASA LITE Mission

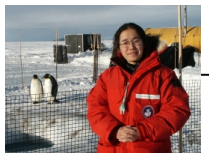
Lidar aboard Space Shuttle Discovery



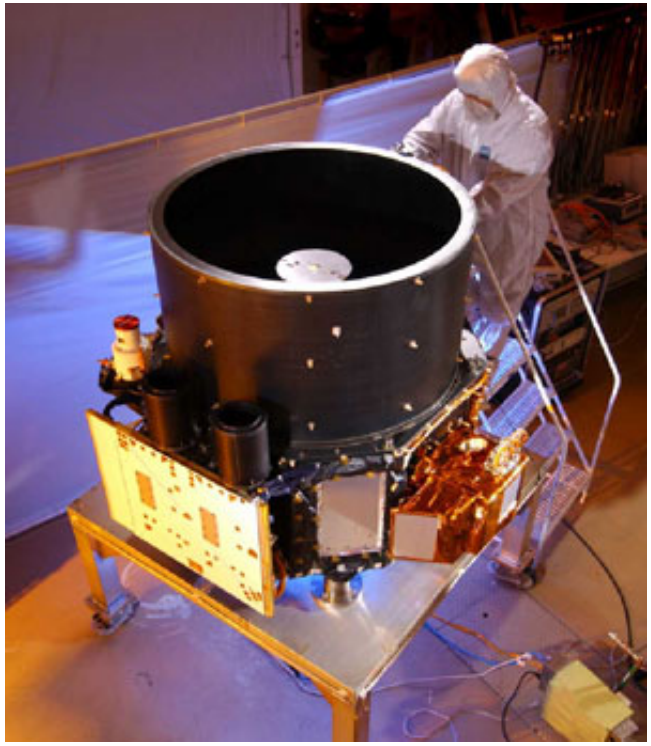


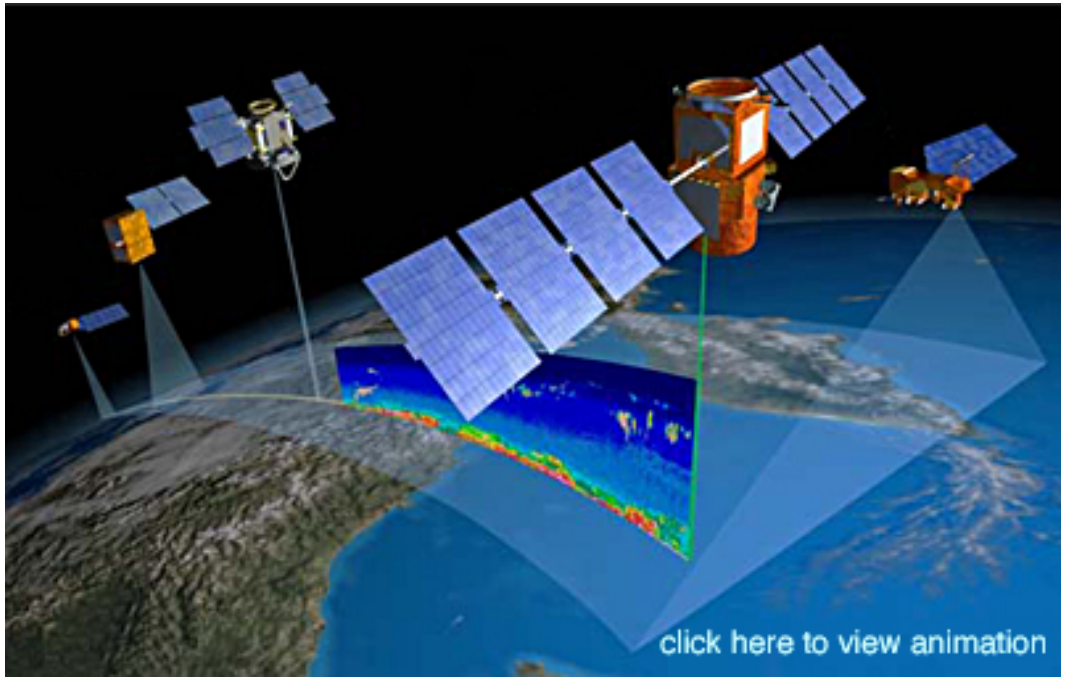
Lidar aboard Satellites



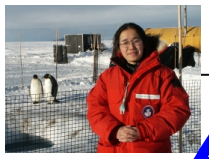


CALIPSO: Lidar on Satellite

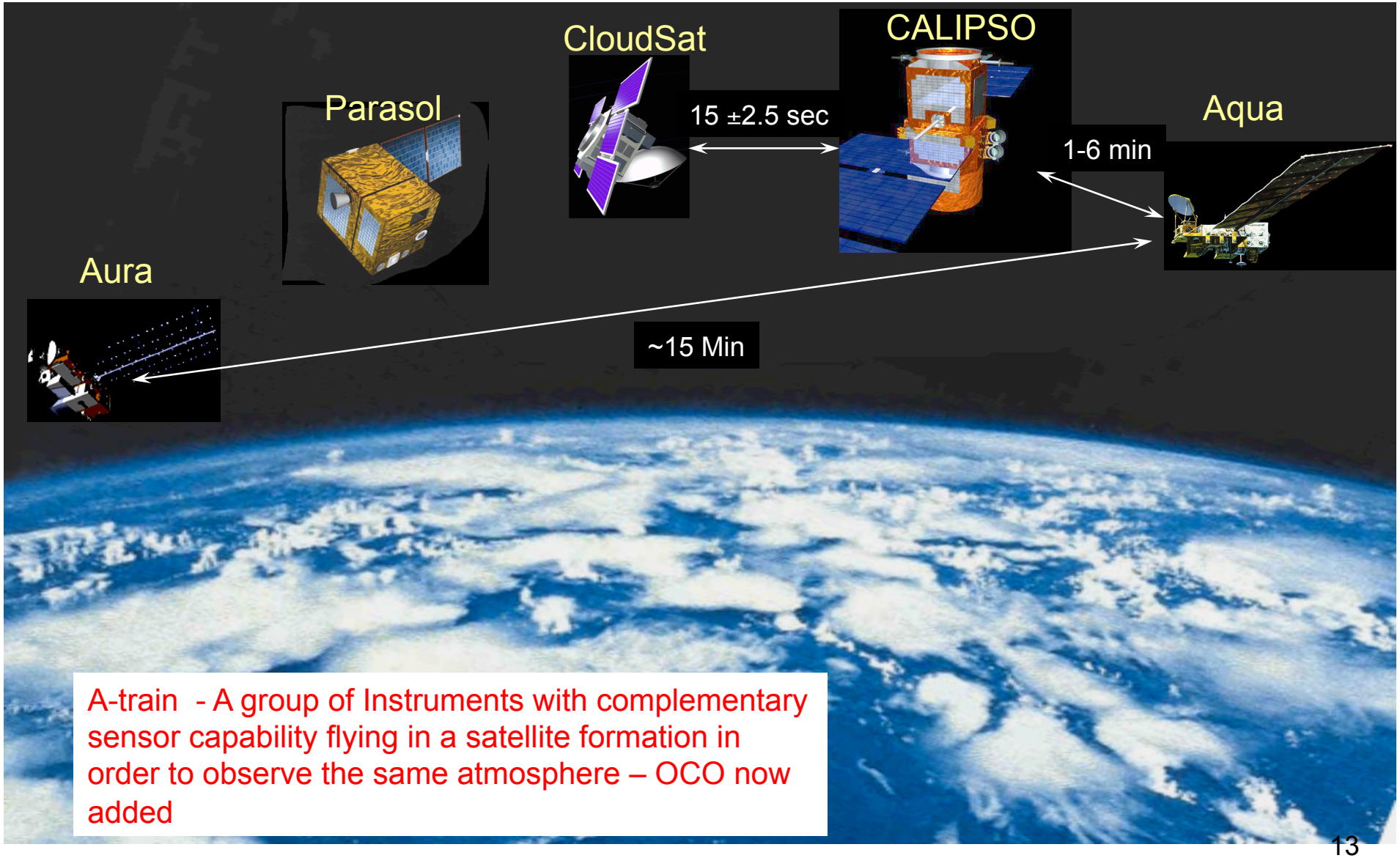




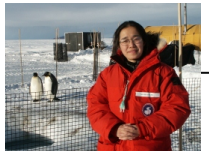
http://www-calipso.larc.nasa.gov/



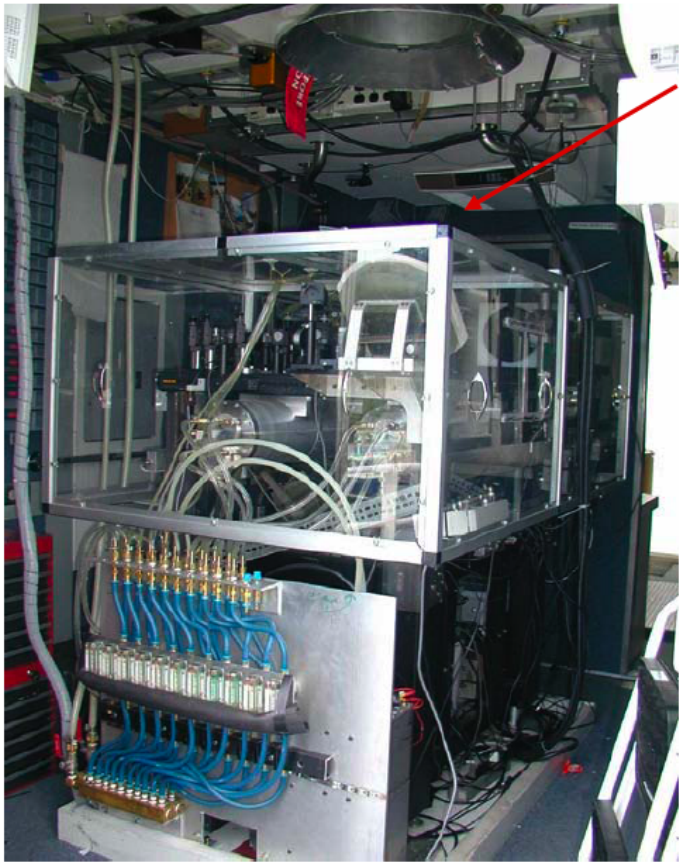
Aqua (A) Train for Multiple Observations



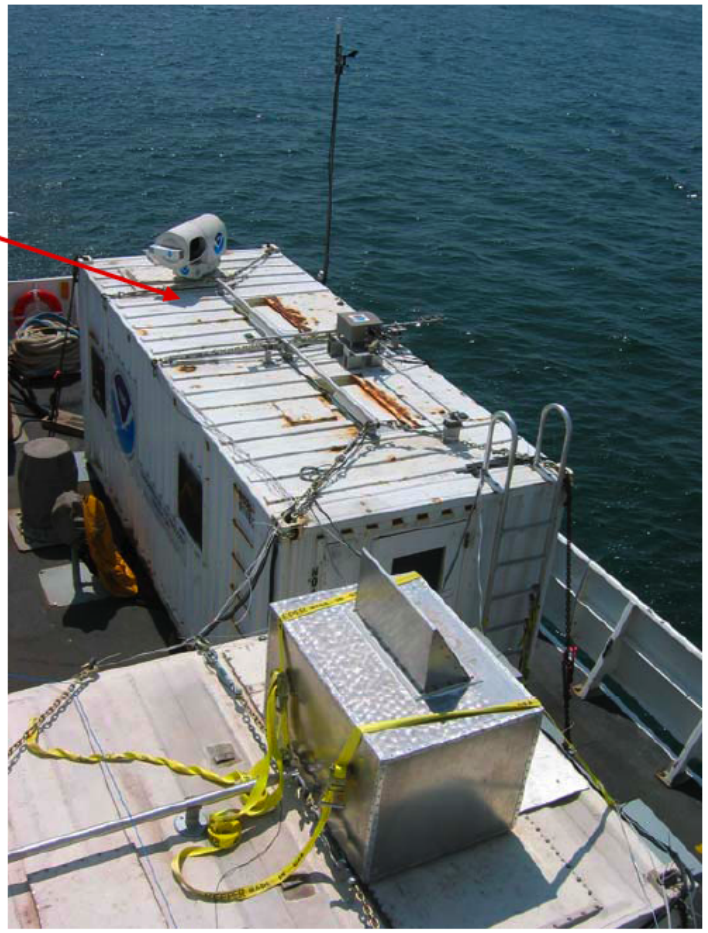
A-train - A group of Instruments with complementary sensor capability flying in a satellite formation in order to observe the same atmosphere – OCO now added



NOAA ESRL Lidars on Ocean



- Mini-MOPA
- HRDL
- OPAL
- TOPAZ
- DABUL
- Fish Lidars
- TUV
- CODI
- TEAC0
- ABAeL



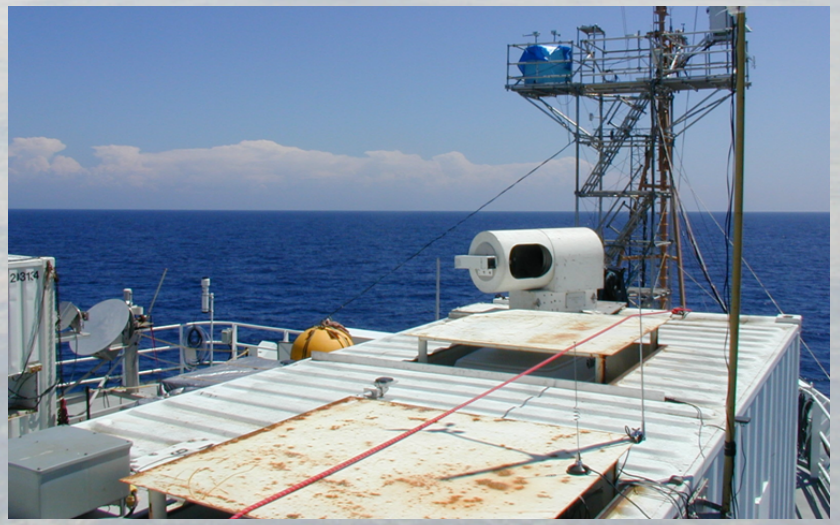
Basic Lidar measurements

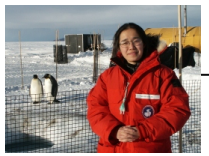
- Chemical distributions (ozone, water vapor, NH3, CO2)
- Cloud properties
- Aerosol measurements
- Low level mean winds
- Residual winds
- Turbulence, general dynamics

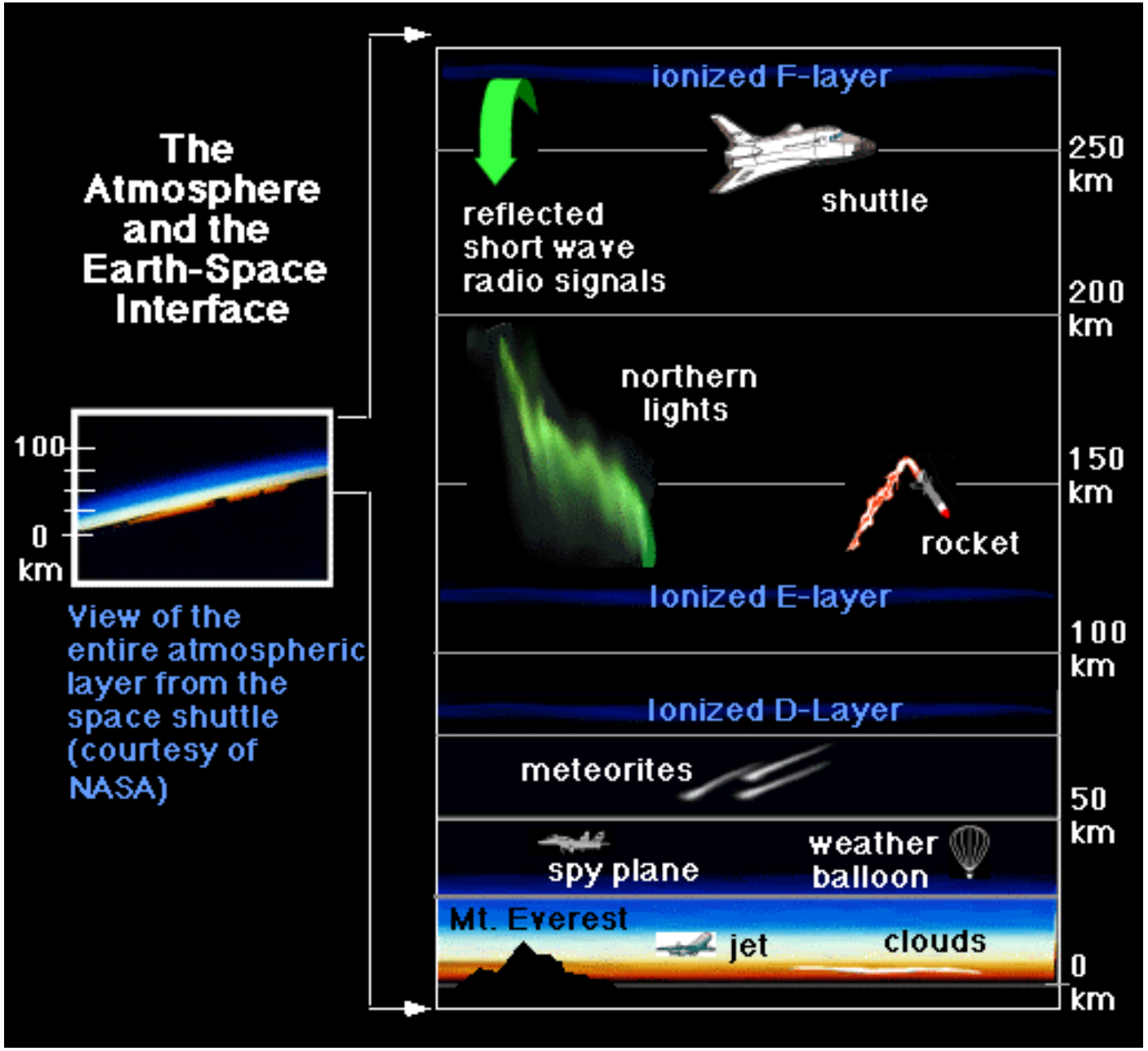
Instruments have been mounted on research ships for sea based operation

Challenges include:

- Sea salt corrosive environment
- High vibration
- Platform motion & orientation
- Low frequency accelerations – stability issues
- Big waves and leaky seatainers



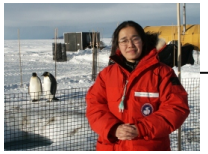


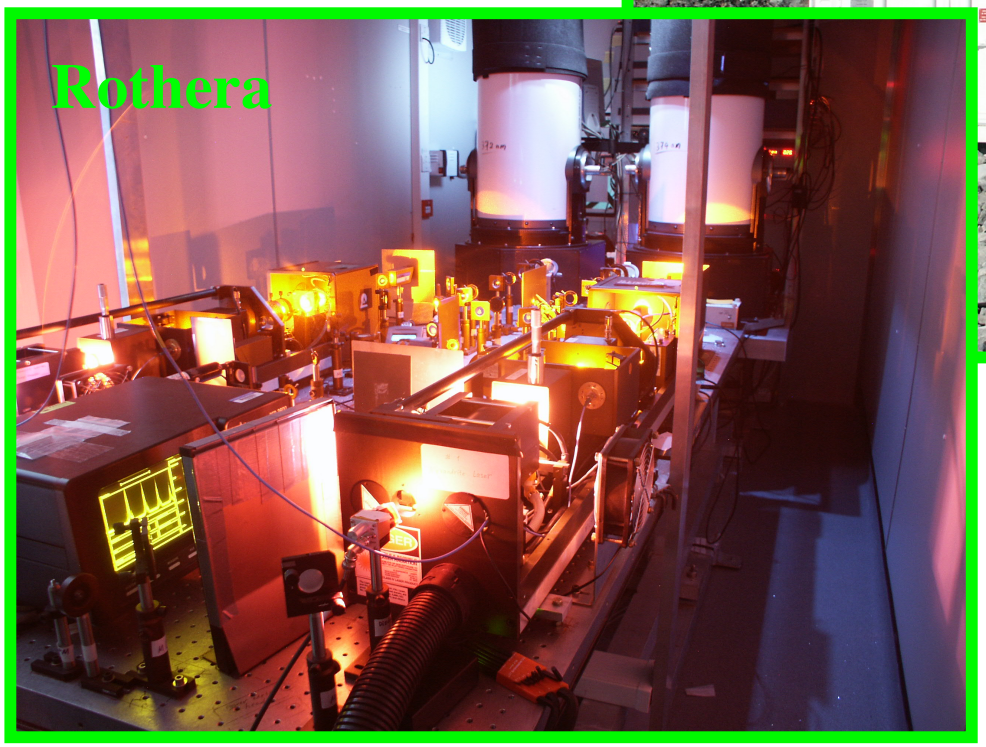

The Atmosphere and the Earth-Space Interface
100
0
km
View of the entire atmospheric layer from the space shuttle (courtesy of NASA)
ionized F-layer
reflected short wave radio signals
shuttle
250 km
200 km
northern lights
150 km
rocket
Ionized E-layer
100 km
Ionized D-Layer
meteorites
50 km
spy plane
weather balloon
Mt. Everest
jet
clouds
0 km

NSF/NCAR Electra Aircraft

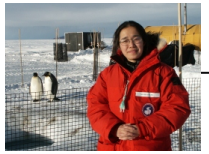
Airborne Fe Boltzmann Lidar

Groundbased Lidar at the South Pole

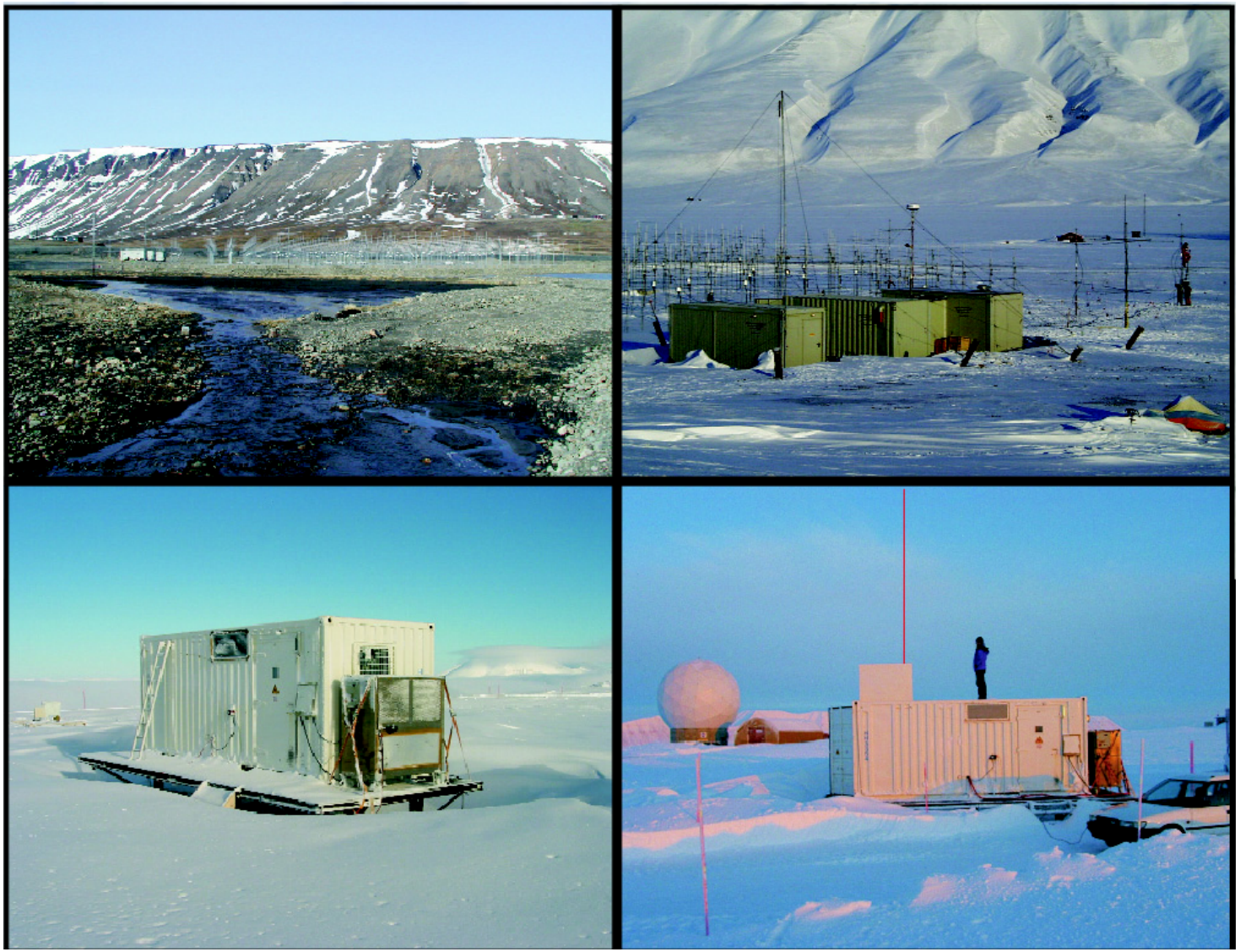


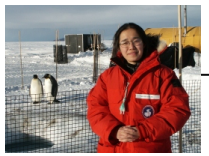


Containerized Lidar at Rothera, Antarctica

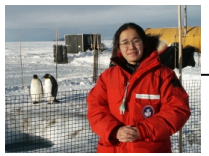


Containerized Lidar at Svalbard

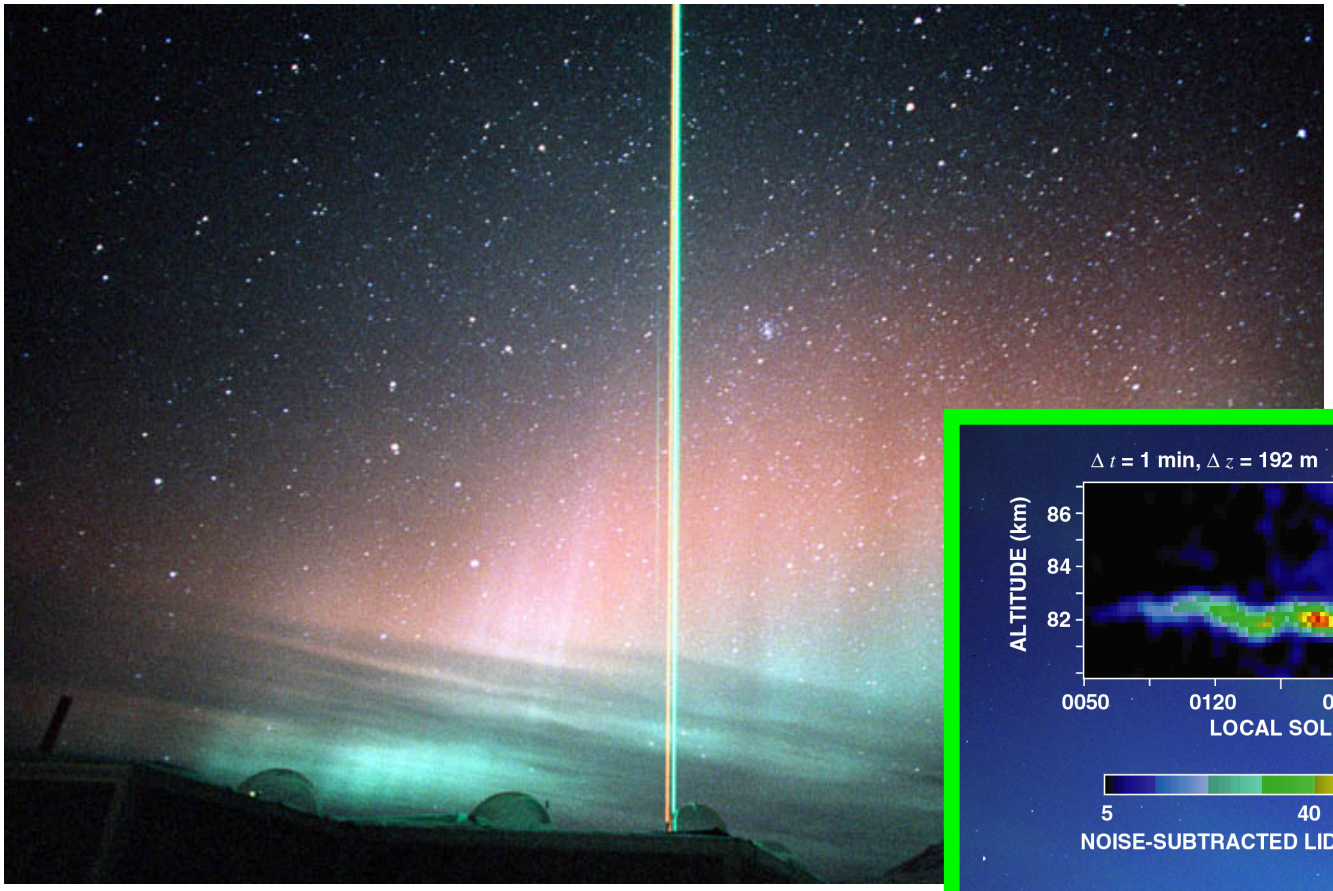


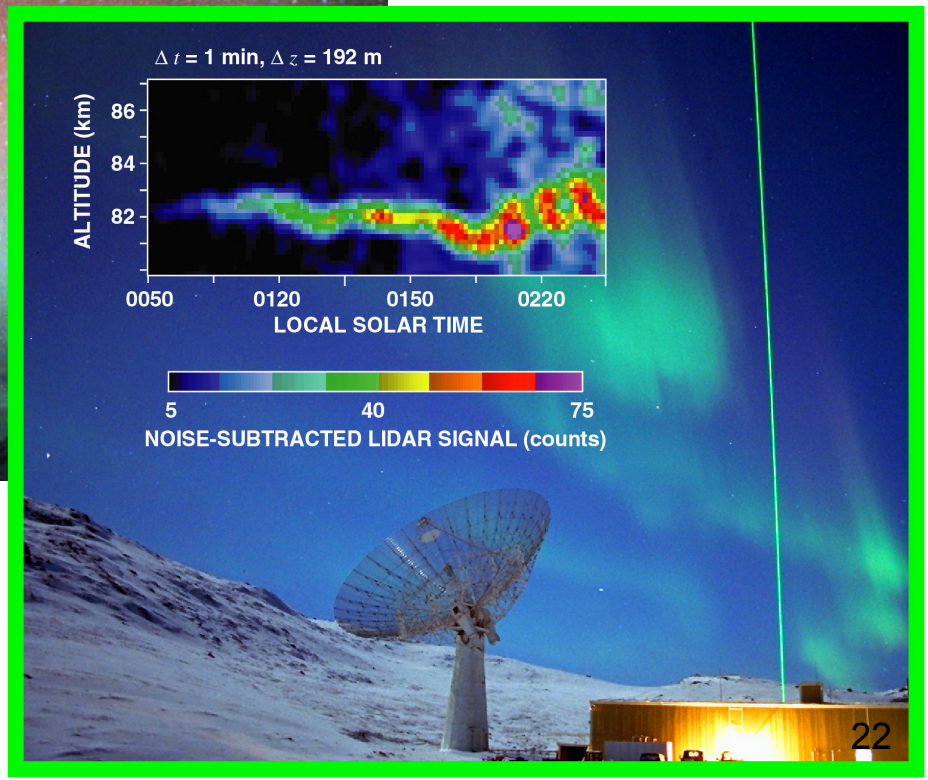


Andoya Rayleigh & Na Lidars

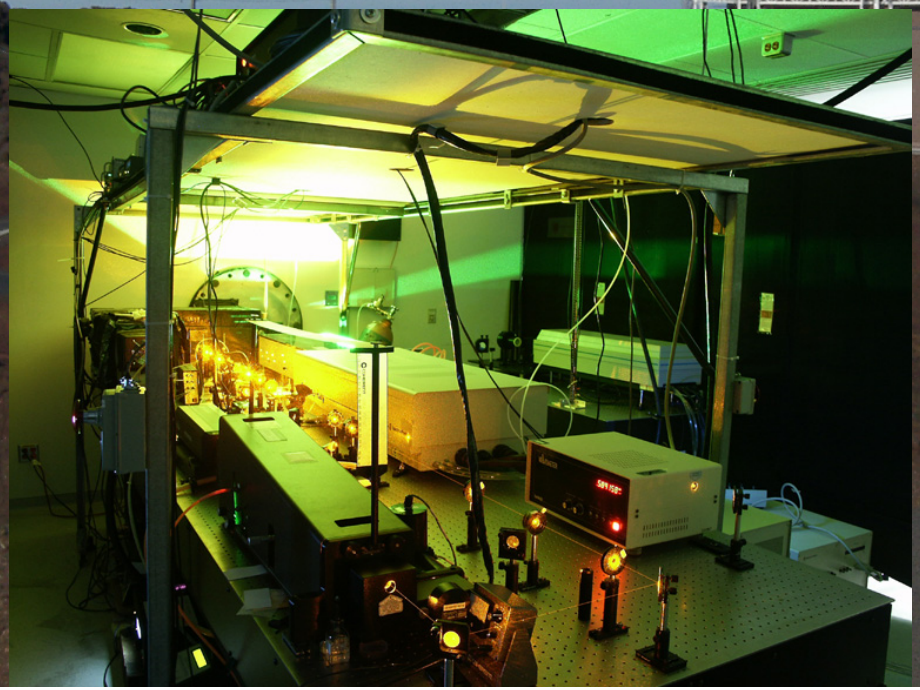


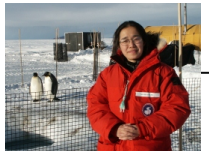
Sondrestrom Rayleigh Lidar



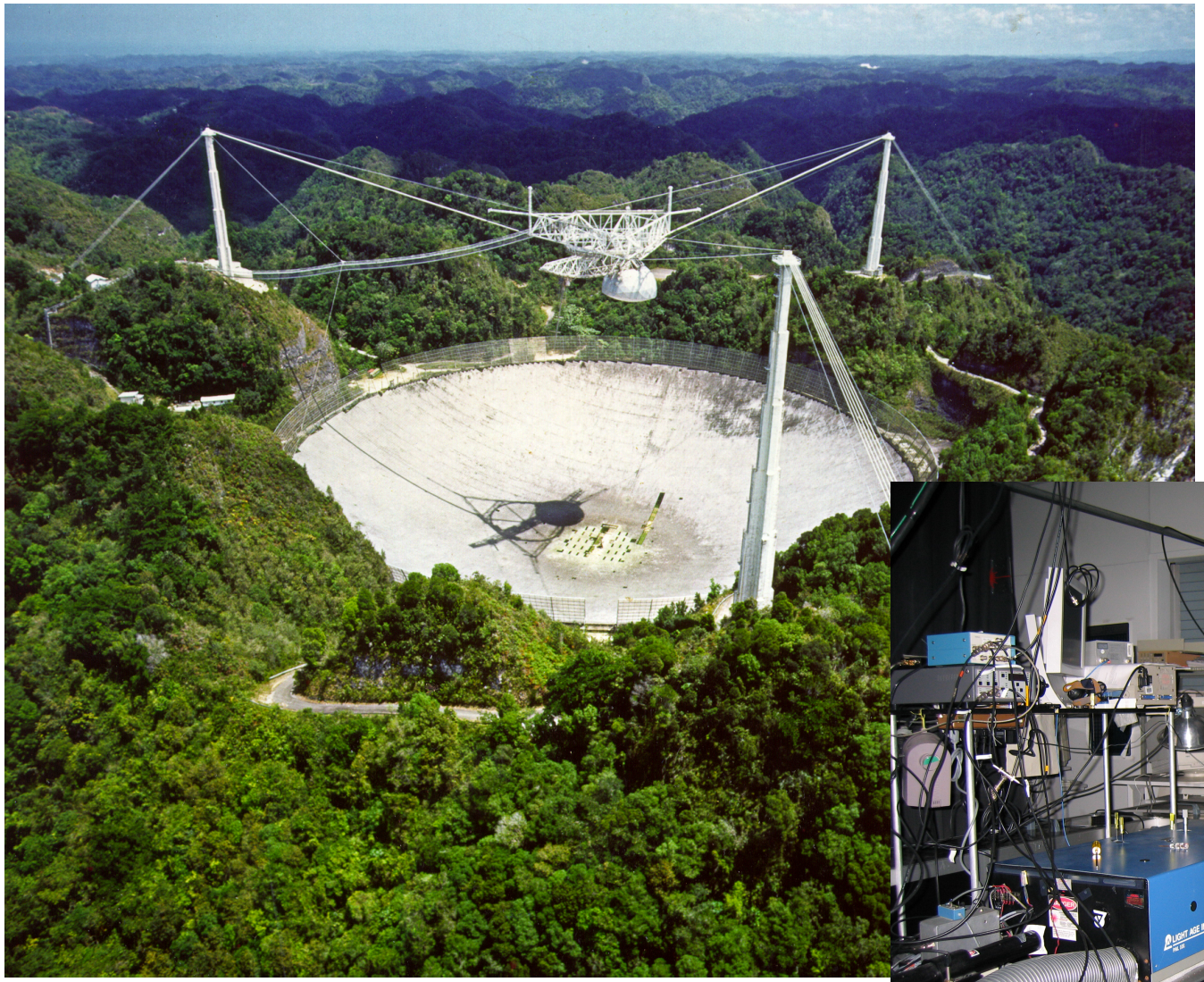


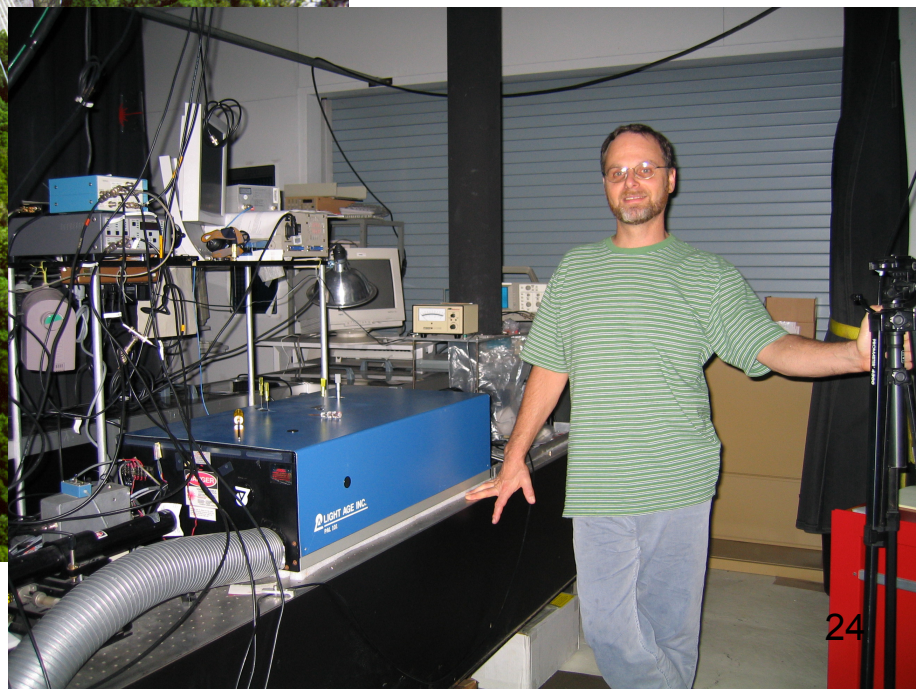
Large-Aperture Na Doppler Lidar at SOR, NM and Maui, HI

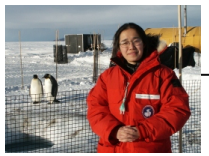




Arecibo Observatory K Doppler Lidar





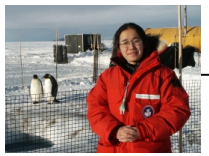


Lidar Course Objectives

1. A comprehensive, yet easily understandable, up-to-date overview of lidar principles, technologies, and applications;

2. Approaches for lidar simulation, lidar sensitivity and error analysis, lidar data retrieval, and lidar system design to quantitatively analyze lidar system performance and measurement errors;

3. Opportunities to see and possibly operate the real state-of-the-art lidar systems and make connections to lidar experts in the nation and world.



Textbook and Reading Materials

Textbook:

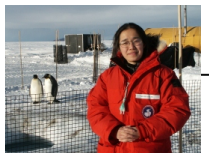
"Laser Remote Sensing" (2005)
edited by Fujii and Fukuchi

Major Reference Books:

"Lidar" (2005) edited by C. Weitkamp
"Laser Remote Sensing: Fundamentals & Applications" (1984)
by Raymond Measures

Other References:

"Proceedings of 24th and 25th ILRC" and other journal papers



Course Format

1. PPT presentation in classroom

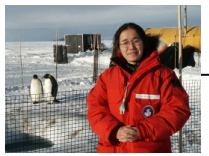
2. Lecture notes posted at the class webpage:

http://cires.colorado.edu/science/groups/chu/classes/

3. Homework Reading Reports over reading materials

4. Homework Projects of lidar simulation and data retrieval

5. Final project integrating reading, design, and simulation together, with class presentation and final written report



Grading Policy

20% Homework Reading Reports: your understanding to lidar principles, technologies, and applications

60% Homework Projects:

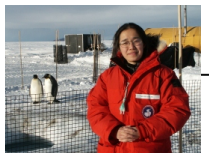
(1) Lidar simulations (e.g., range-resolved or non-range-resolved lidar photon counts, error analysis)

(2) Lidar data retrieval and error analysis (e.g., Na density, Doppler temp and wind, Boltzmann and Rayleigh temperature, coherent wind, HSRL aerosol, DIAL, or Raman lidar data)

(3) Lidar design and performance analysis

20% Final Project: Select one type of lidars and go through principle, design, simulation, error analysis, application

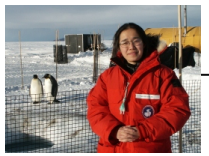
100-point grading system for reports and projects



Potential Final Projects

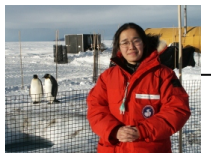
1) Resonance Fluorescence Doppler lidar
2) High-spectral-resolution lidar
3) Direction-detection wind lidar (or with edge filters)
4) Coherent Doppler lidar
5) Laser altimeter (including fish lidar)
6) Raman lidar
7) Differential absorption lidar (DIAL)
8) Polarization lidar
9) Rayleigh/Mie lidar
10) Fluorescence lidar ……

- Overview of principles, history, and current status
- Design of a lidar system
- Simulation of expected lidar signals
- Sensitivity or error analysis
- Applications

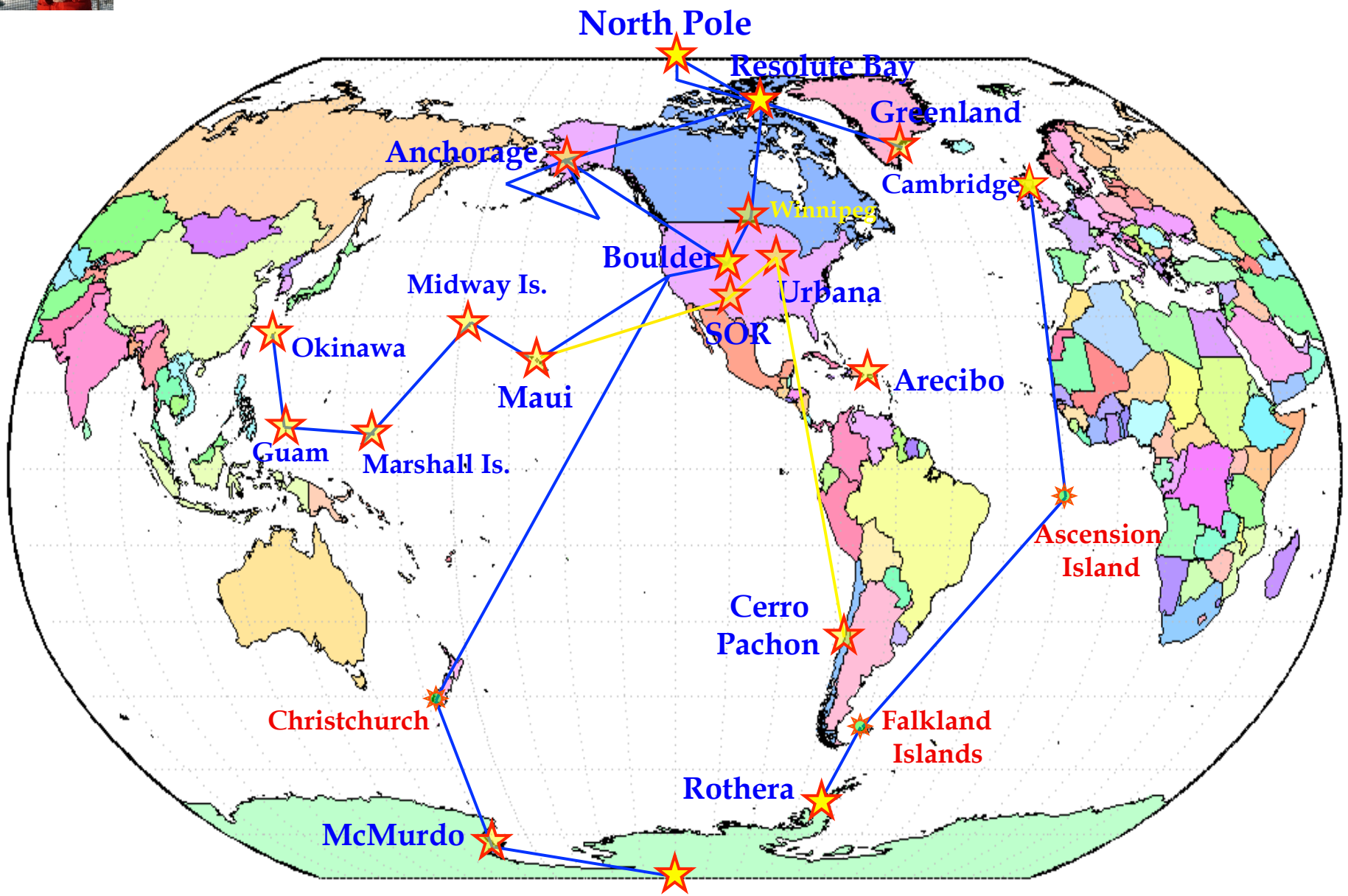


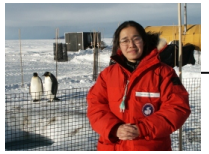
How to study this course?

1. Read books and lecture notes prior to classes, especially if lack of background
2. Listen to the lectures and try to understand the most in classes
3. Review lecture notes and read books and materials
4. Do projects to apply learned skills and check concepts
5. Discuss with the instructor, TA, and classmates to get clear concepts
6. Visit instructor's research group to look at real instruments and real applications



LIDAR Expeditions over the World



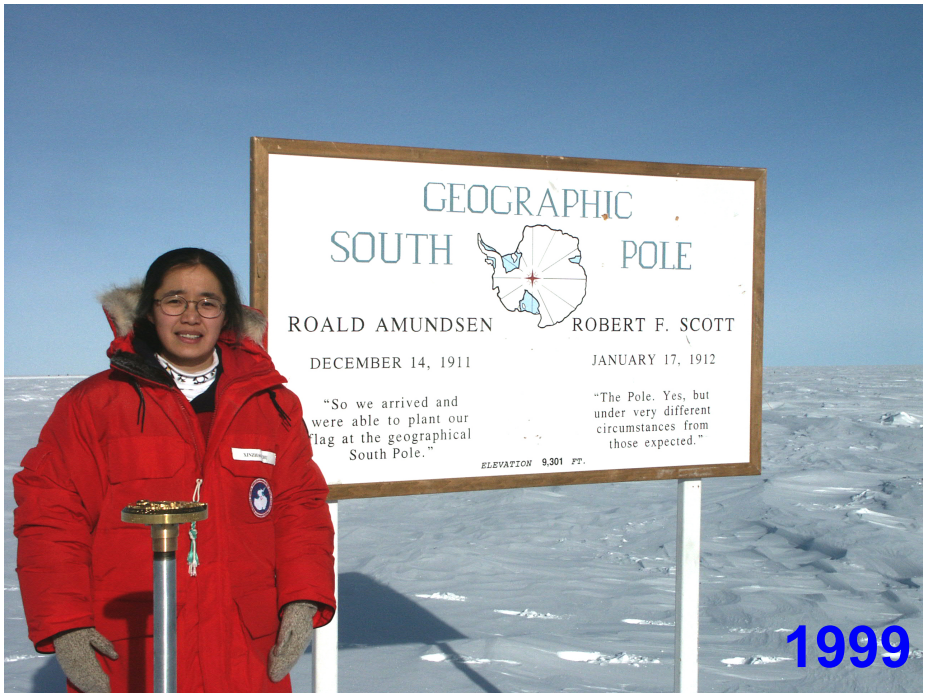


Pole-to-Pole Lidar Observations

Applied Optics
Lasers, Photonics, and Environmental Optics
ISSN: 0003-6935
20 July 2002
OSA Optical Society of America

North Pole

South Pole



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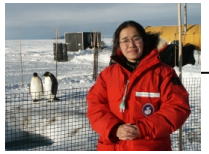
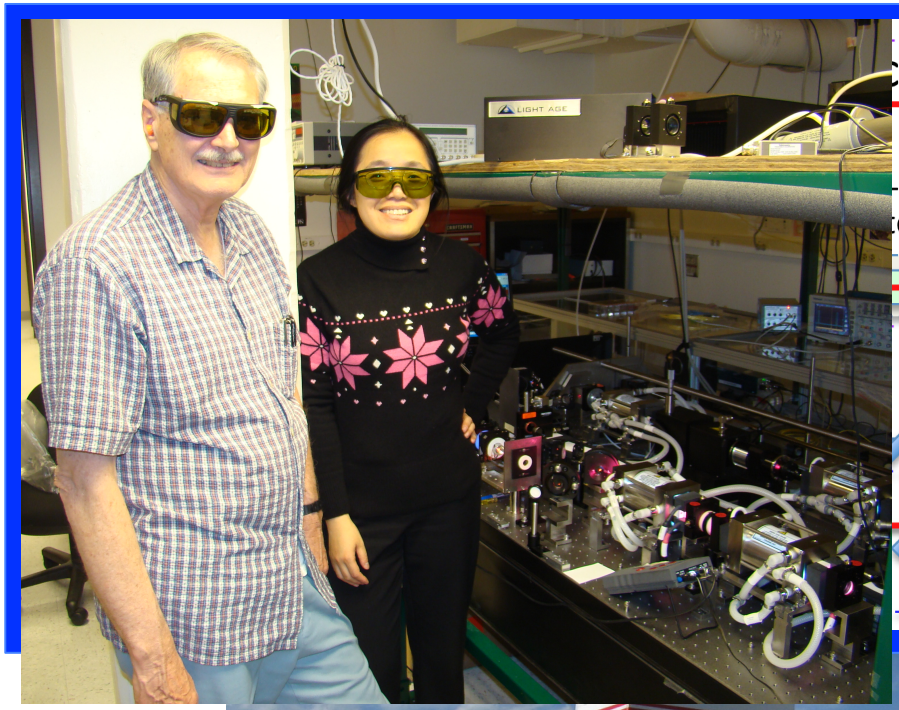
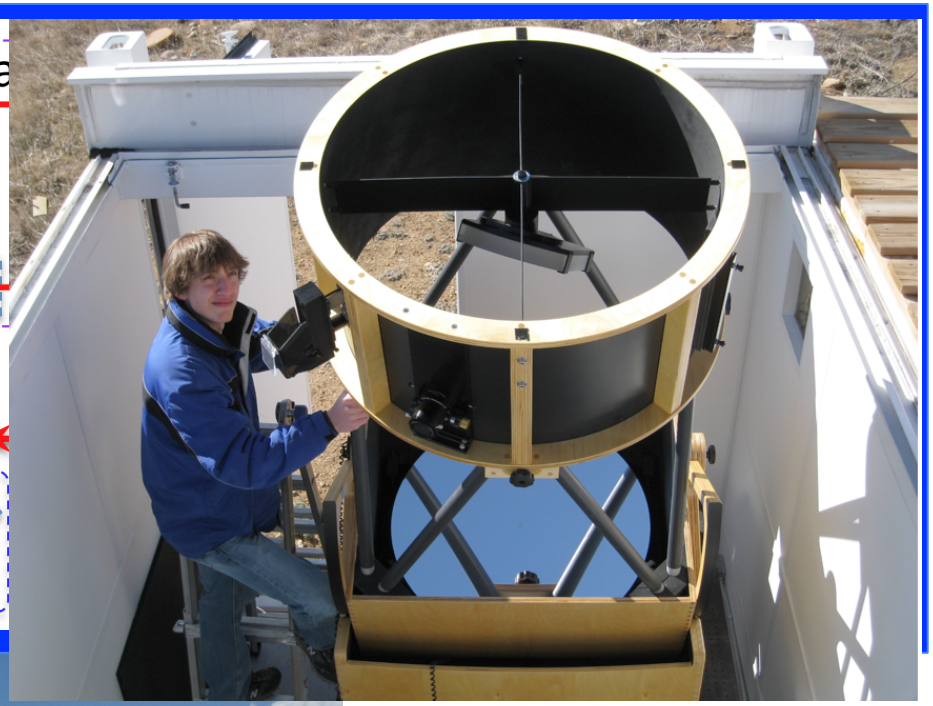
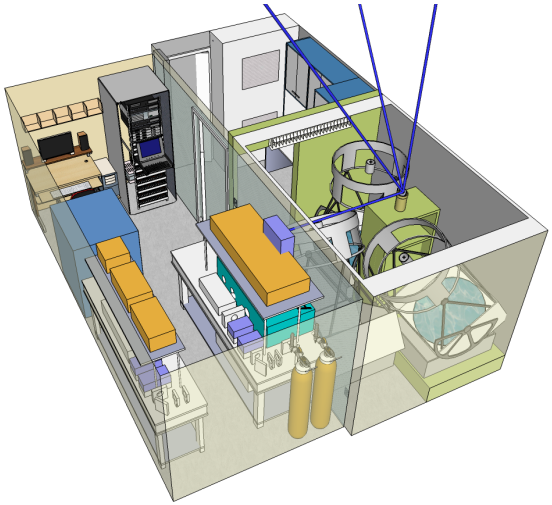
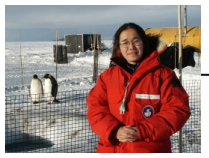


Mobile MRI Fe Doppler Lidar

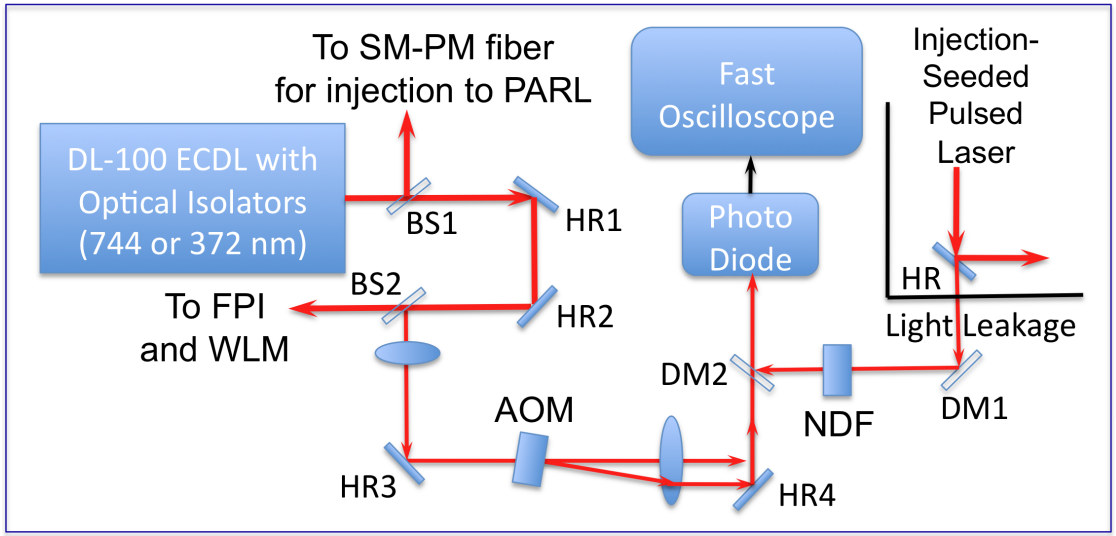


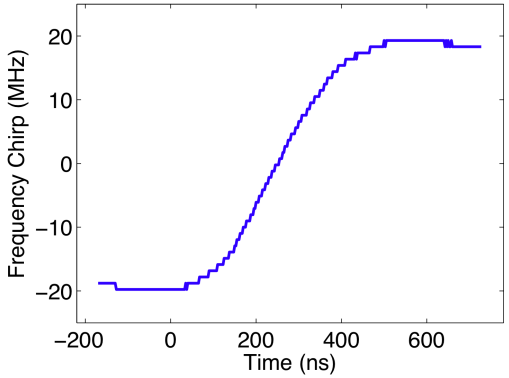


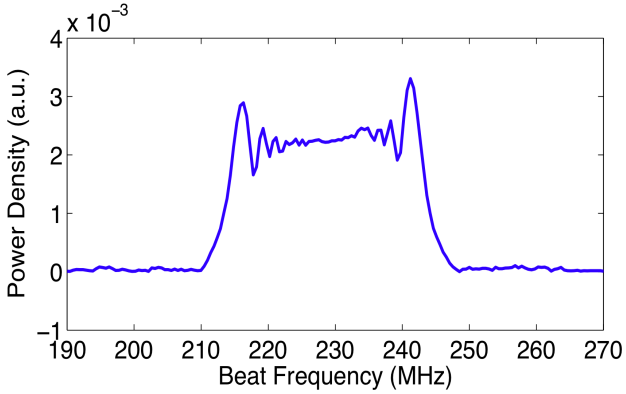


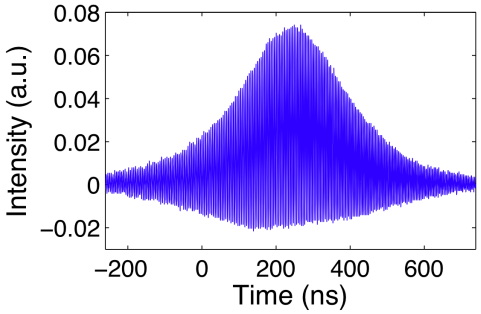


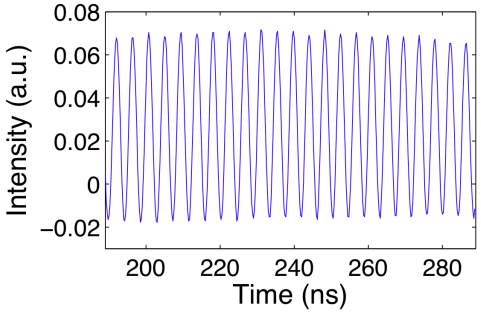
Optical Heterodyne Detection of Laser Pulse

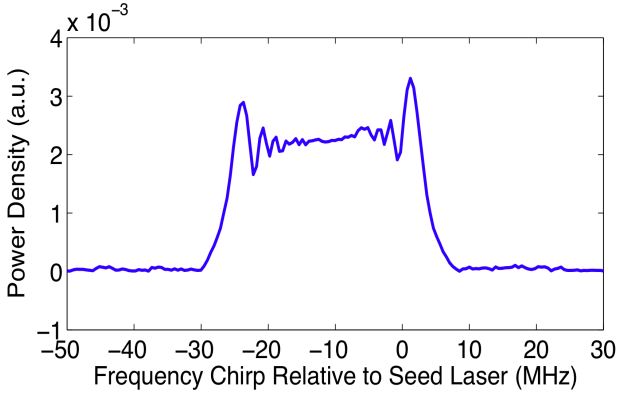


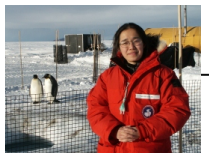












Summary

We expect an exciting adventure through the wonderful "lidar remote sensing" field …

Hope you will stay with us in the journey …

Let us work together to make advancement and contributions to lidar science and technology …

Reference Reading Materials
Chapter 1 of "Laser Remote Sensing" textbook
IntroRemoteSensing.pdf and IntroLidar.pdf (at website)