LIDAR and Atmosphere Remote Sensing

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YUNIBESITHI YA PRETORIA

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National Space Science and Technology Strategy, 14 April 2009

Remote Sensing of the Atmosphere

Remote sensing is a technique for measuring, observing, or monitoring a process or object without physically touching the object under observation. Optical and radio telescopes, cameras, radars, lidars etc., are various types of remote sensing devices.

Two types of remote sensors.

(a) Active remote sensors

Energy Source included in the measurement.

The observer can control the source

Eg. Radar, Lidar, Sodar, Sonar etc.

(b) Passive remote sensors.

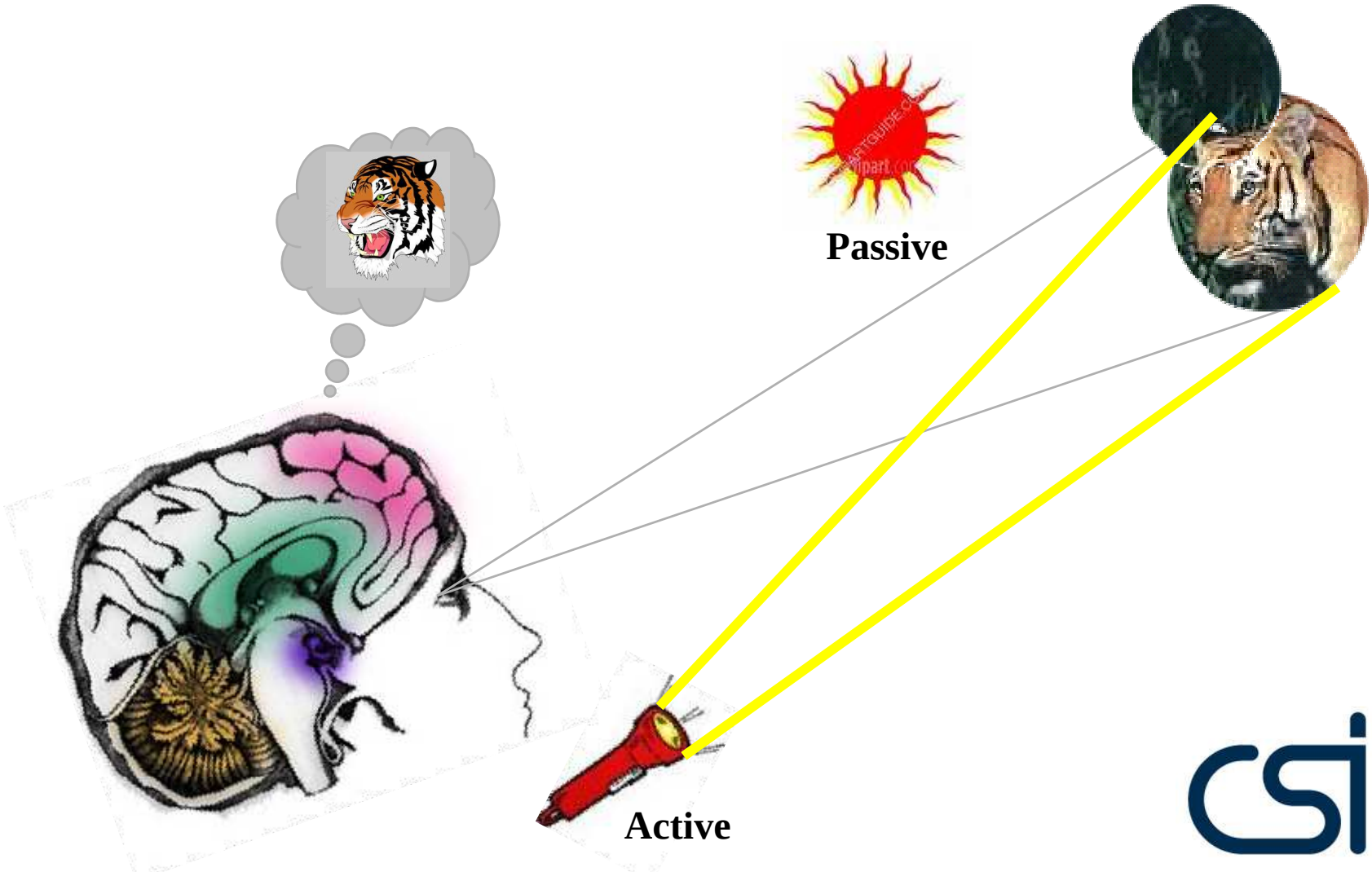
Energy source is not included in the measurement.

They rely on the external source which is beyond the control of the observer

Eg. Optical and Radio telescopes, Radiometers, Photometers, Spectrometers etc.

The Eye as a Remote Sensing Instrument

- Eyes are scanning the environment with up to 60 frames per second

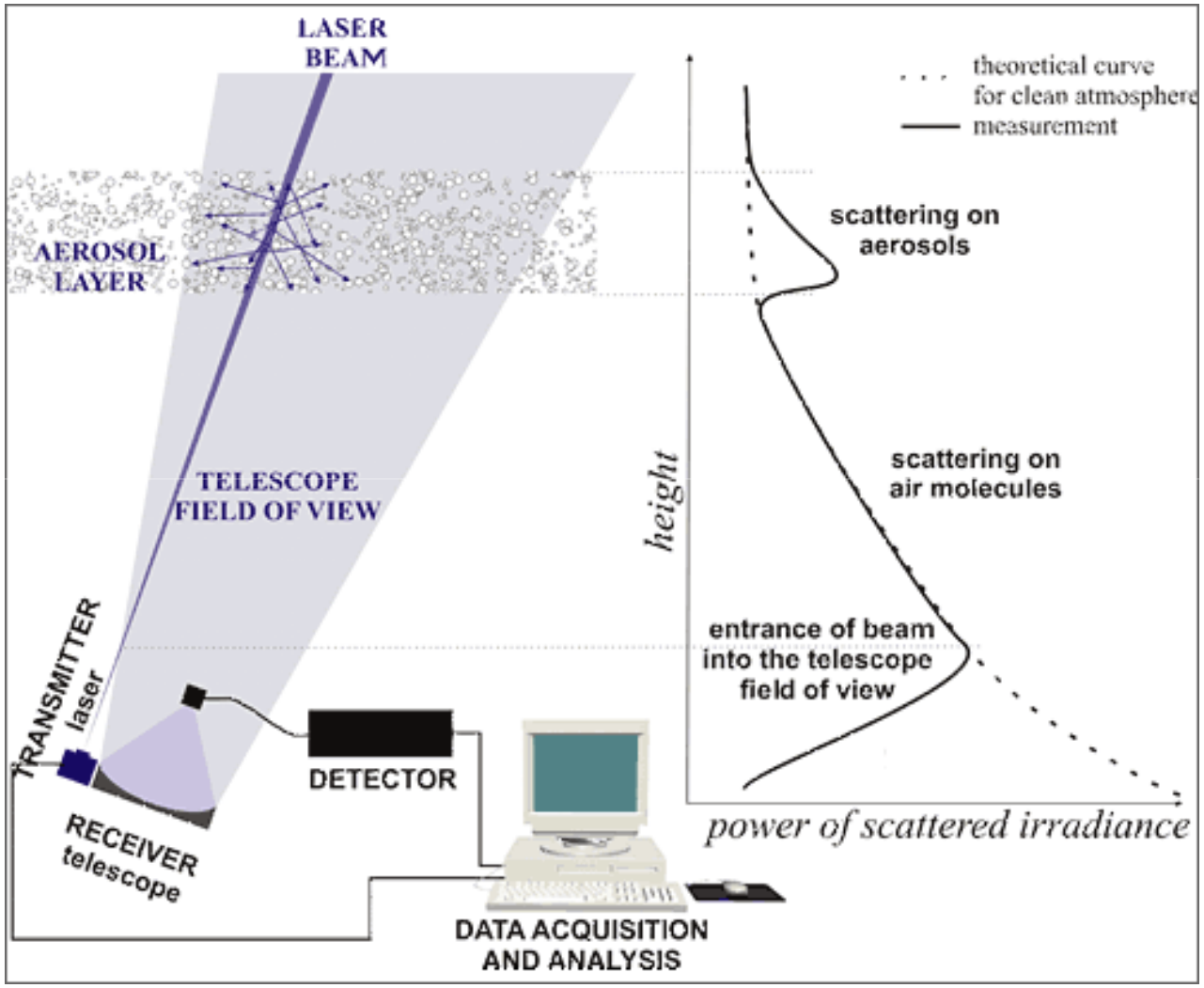


LiDAR Principle

- LIDAR (Light Detection and Ranging)
- LiDAR employs a laser as a source of pulsed energy
- Lasers are advantageous because –
  - ✓ Monochromatic
  - ✓ Highly coherent, high collimated
  - ✓ Short pulse duration, high pulse energy

- Transmitted laser beam passing through the atmosphere causes scattering.
- Absorbtion by gases and particles attenuates the beam as it propagates
- Fraction of energy is backscattered in the direction of the LiDAR system and is available for detection.

…LiDAR Principle



Centre for Atmospheric Research, University of Nova Gorica

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…LiDAR Principle

Atmospheric backscattering depends upon -

(a) the wavelength of the laser energy used,

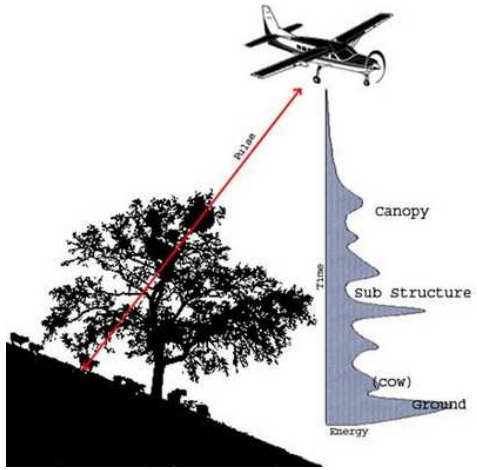
(b) the size, shape and refractive properties of the particles

(c) Backscattering increases with scatterers concentrations.

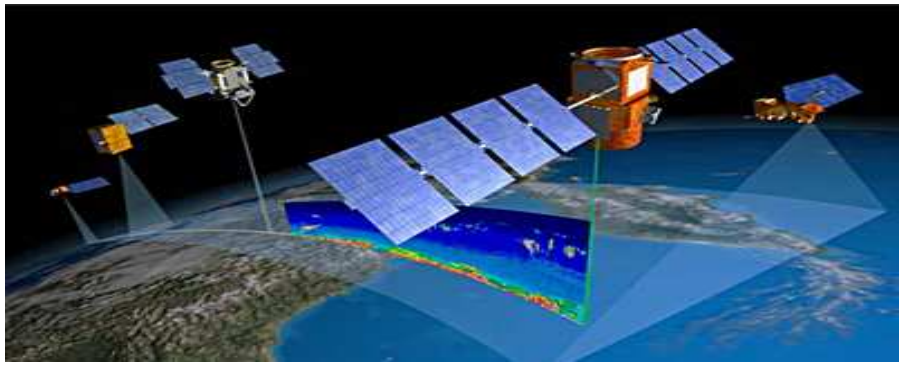
Advantages of LiDAR over Radar

- Shorter wavelengths allow the imaging of smaller particles.
- Narrow beam allows high resolution data to be obtained.

LiDAR Platforms



Airborne

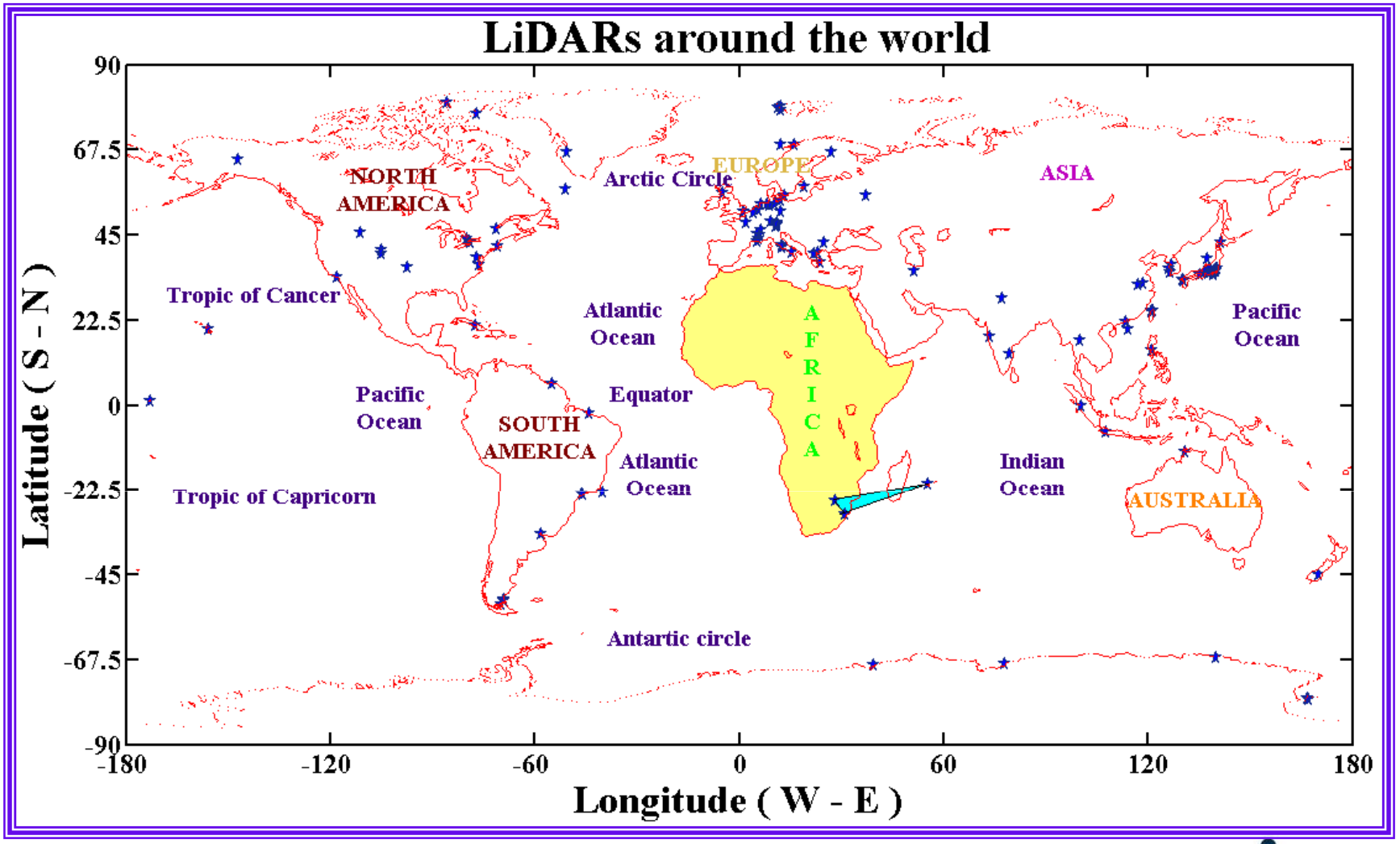


Satellite

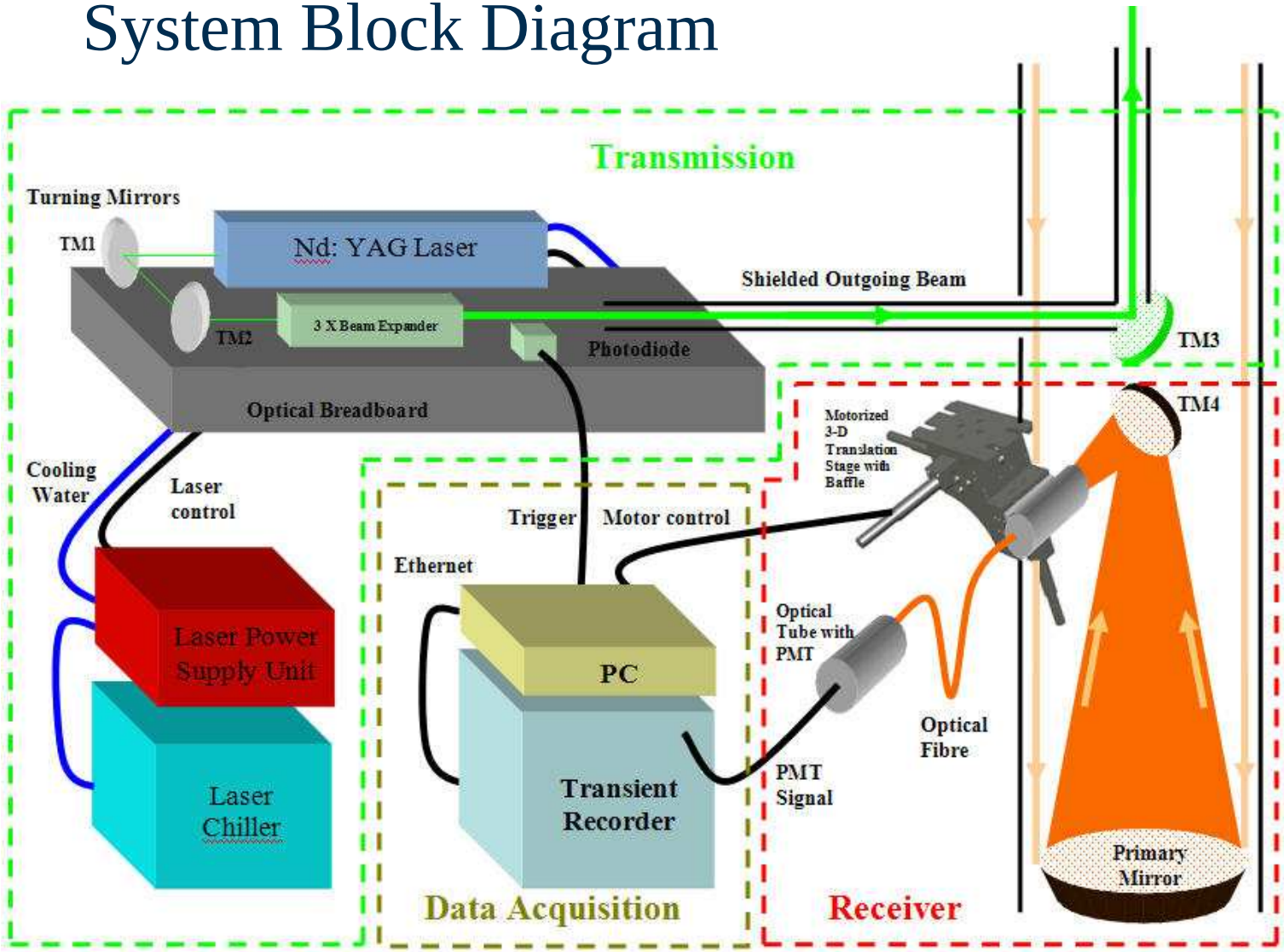
Mobile

Ground-based

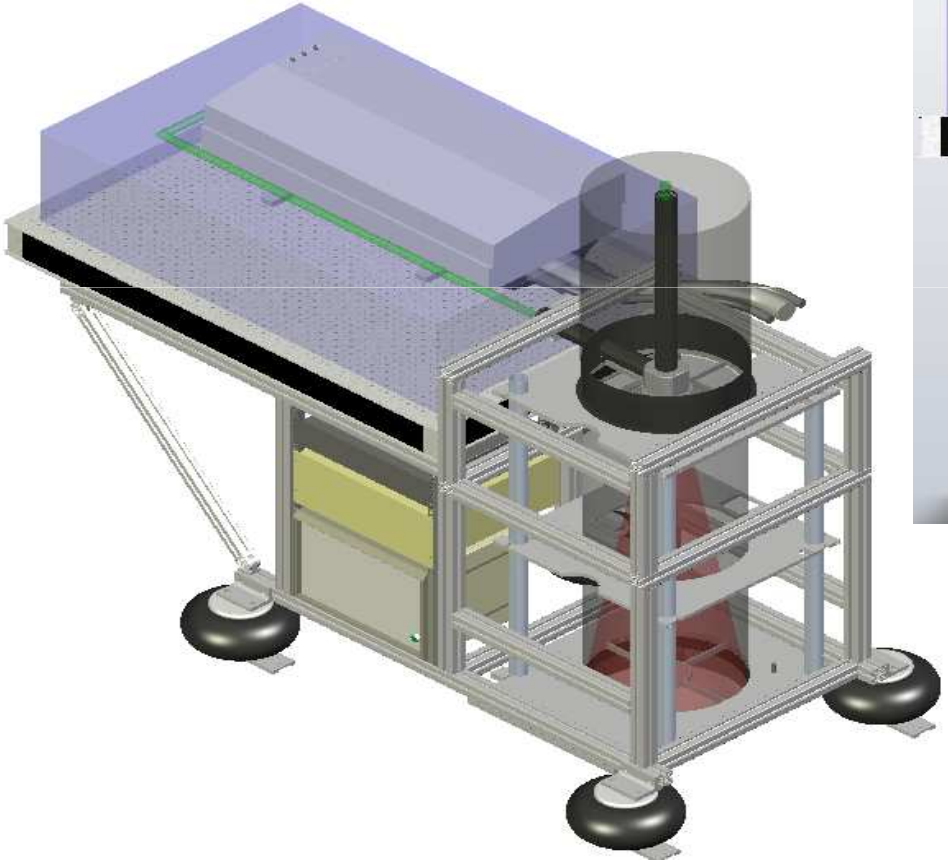
Phoenix Mars Mission

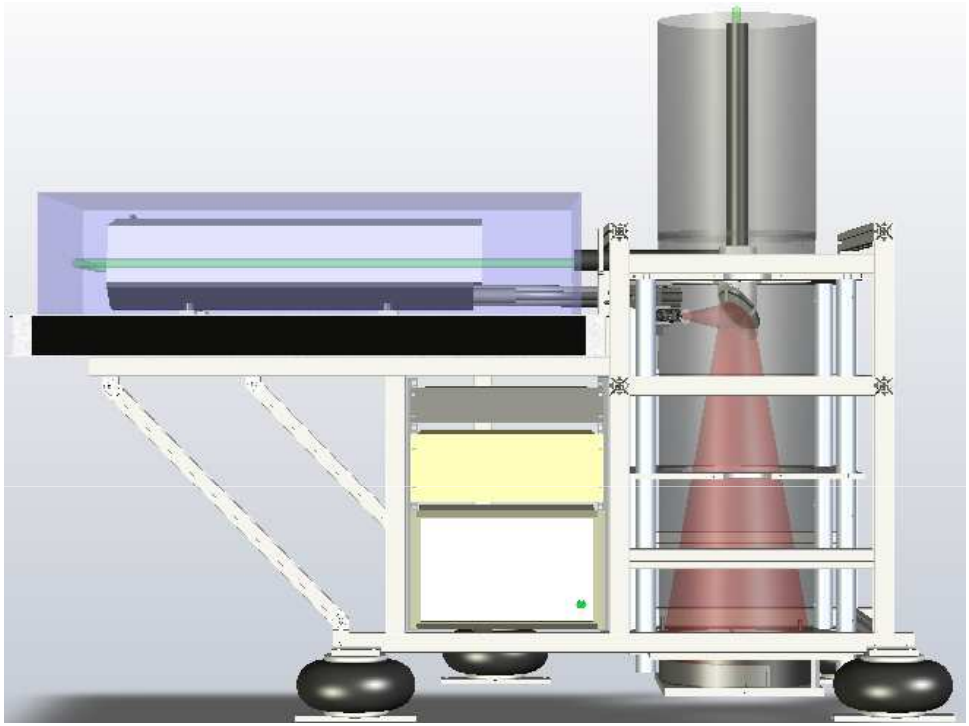


System Block Diagram



System 3-D View





SOUTH AFRICAN
CIVIL AVIATION AUTHORITY

Ref: Special Use of Airspace
Enq: Magda Smith
Tel: 011 545 1064

18/02/2008

CSIR

012 841 3327 Fax: 012 841 3152 asharma@csir.co.za

ATTENTION: Ameeth Sharma

Green Laser Beam **141**

CSIR, Brummeria, Pretoria

Coordinates South: 25 45 32
Coordinates East: 028 16 44
Height: unk
Date: 18/02/2008 -05/03/2008

The CAA has no objection to the use of airspace as detailed above, but subject to any necessary approval by local authorities and any other applicable regulations not falling within the ambit of the CAA's responsibility.

ATC Requirements: *Operator to contact AFB WKLF OPS Room @ (012) 672 3439 prior to operations every day. The officer at the OPS Room will advice CSIR whether there is flying or not in the WKLF CTR. In which case the CSIR will not be permitted to continue during that period of time. If otherwise it can be proven that the beam will not affect any flying crew. Also call Radar Planner 30 min before Tel: 011 928 6448, to advise them of your operations. At no point may the laser beam be pointed to an aircraft and the skies must also be clear as there could be an aircraft in the cloud.*

The Commissioner reserves the right to withdraw this approval in the public interest.

CAA to take NOTAM action.

Yours faithfully,

FOR CIVIL AVIATION AUTHORITY

CAUTION

PILOT !!!

There is a

GREEN LASER BEAM

co.za

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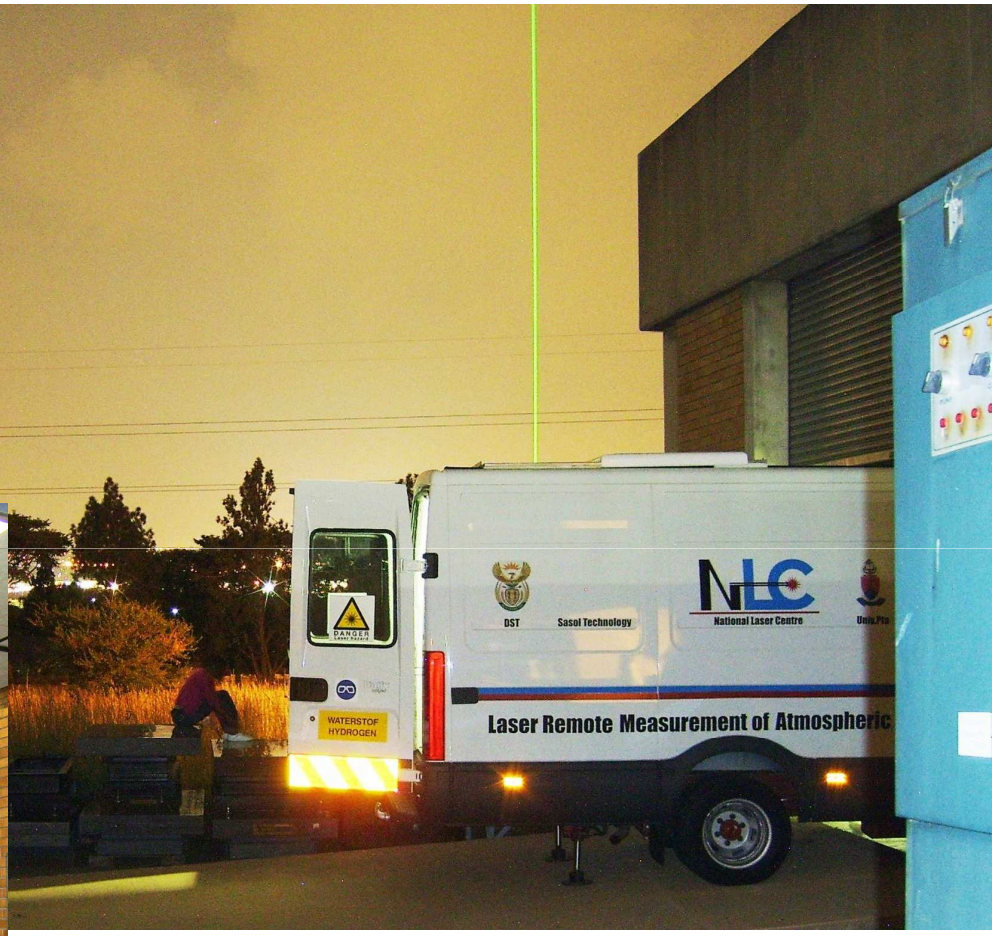
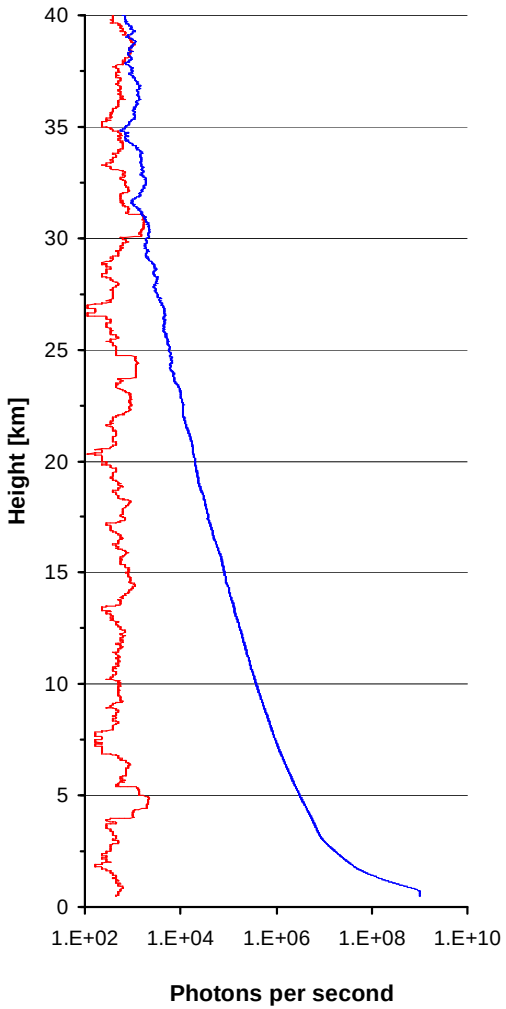
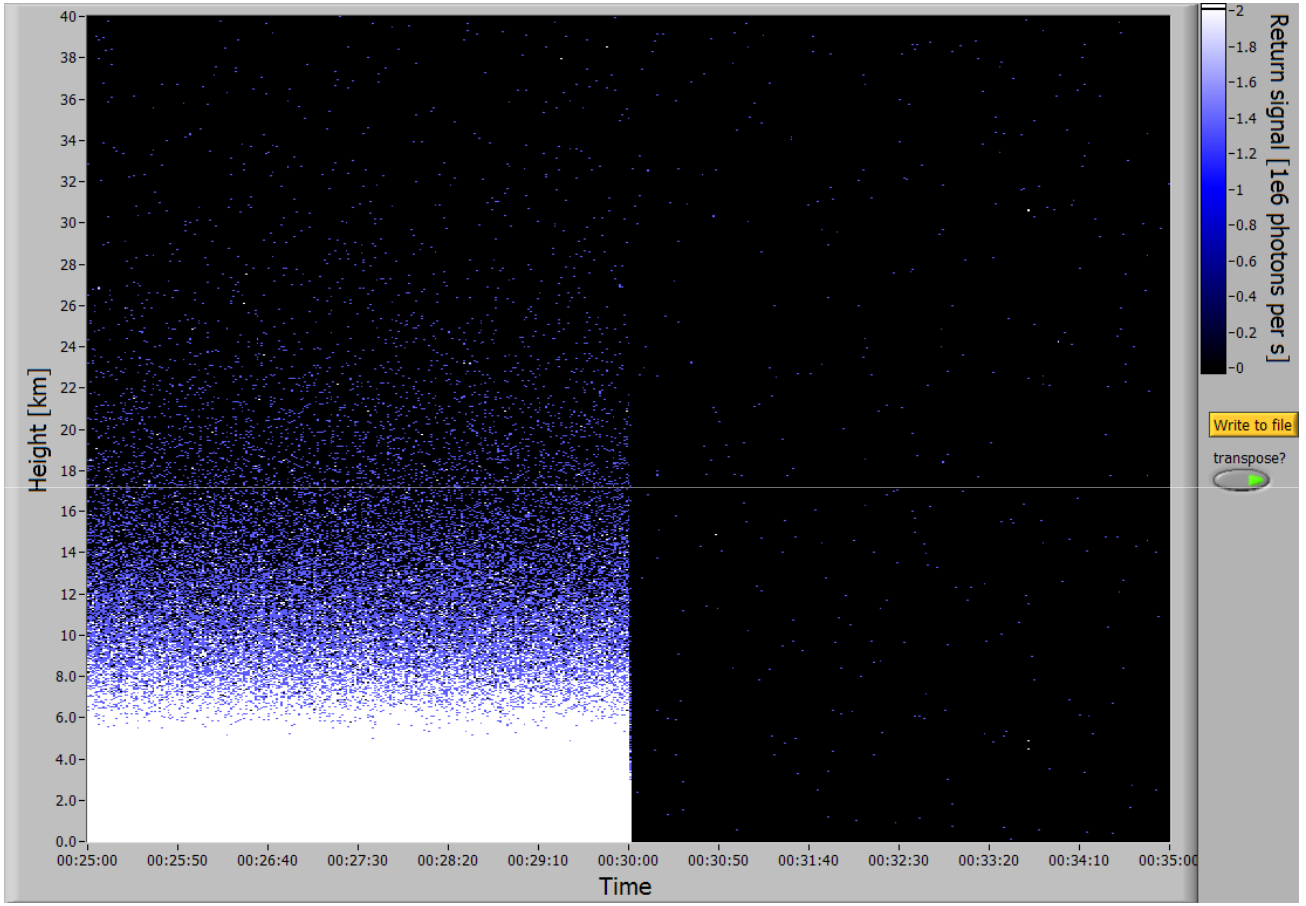
Initial Tests



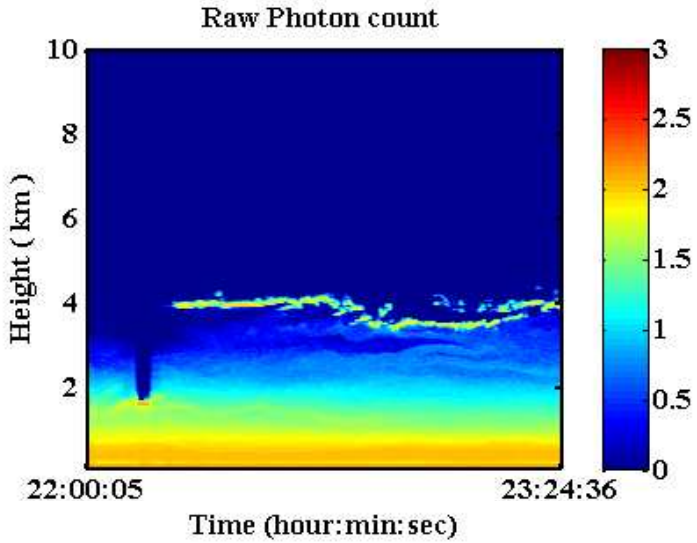
Signal to Noise Performance

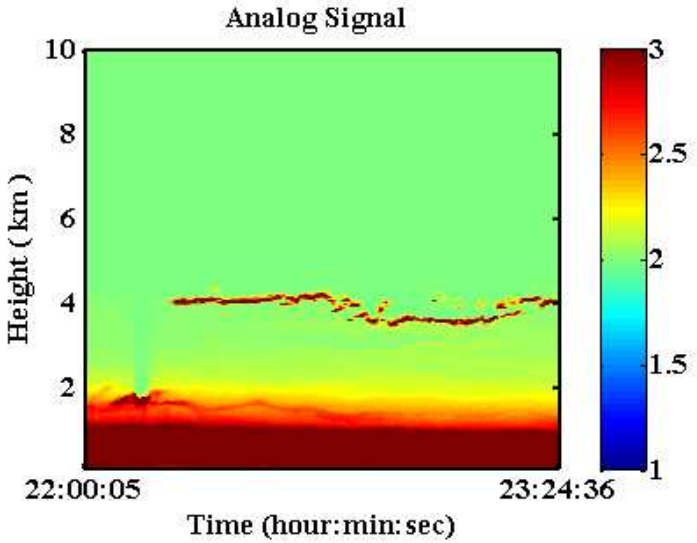


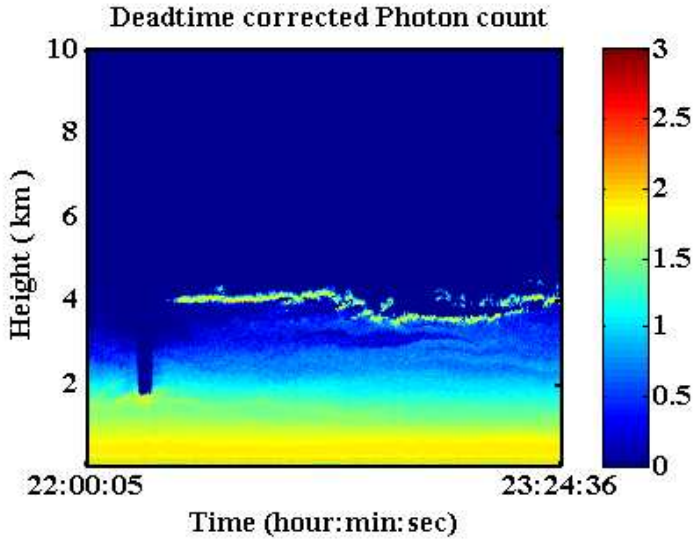


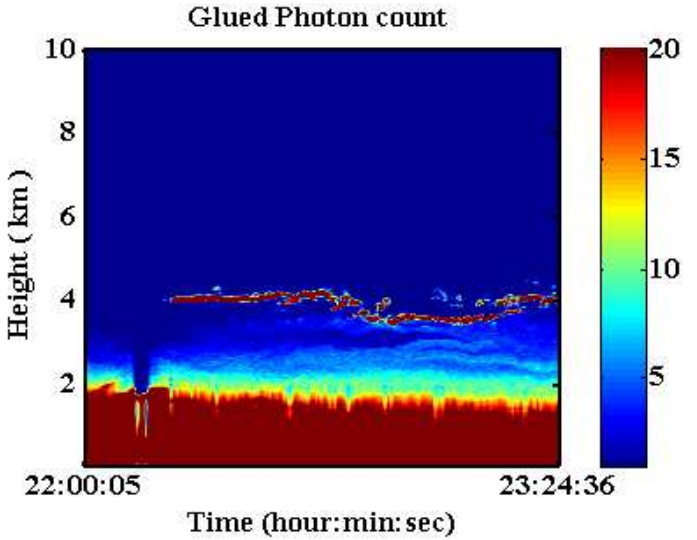
Preliminary Results

23 Feb 2008



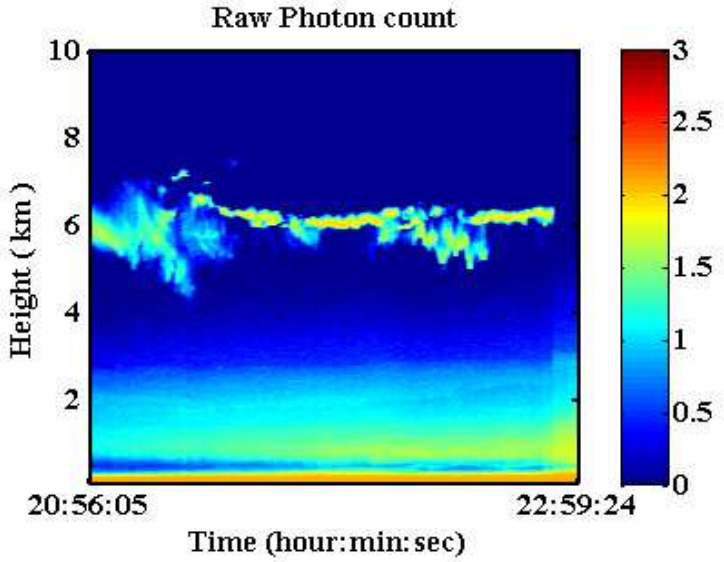


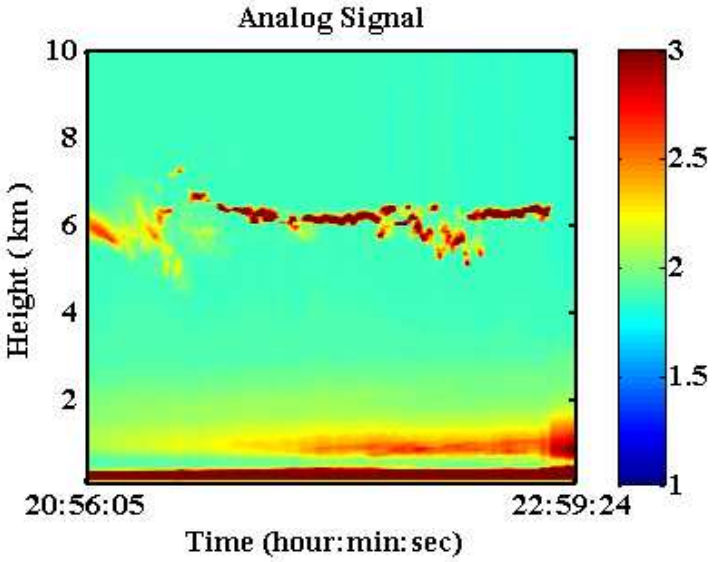


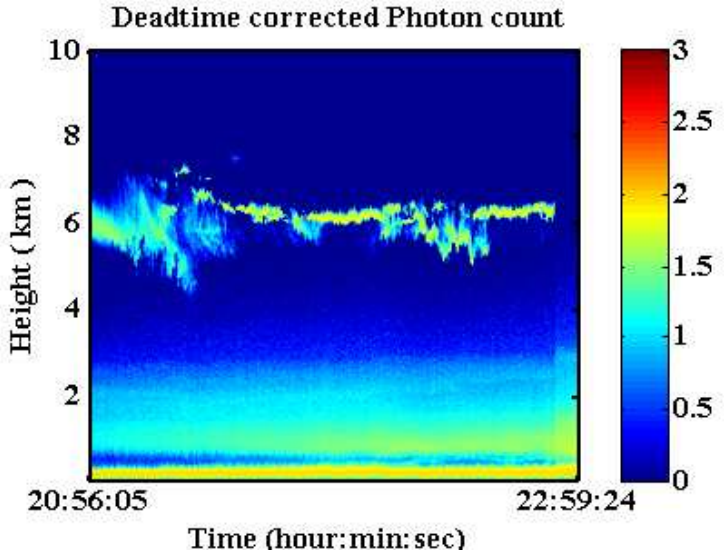


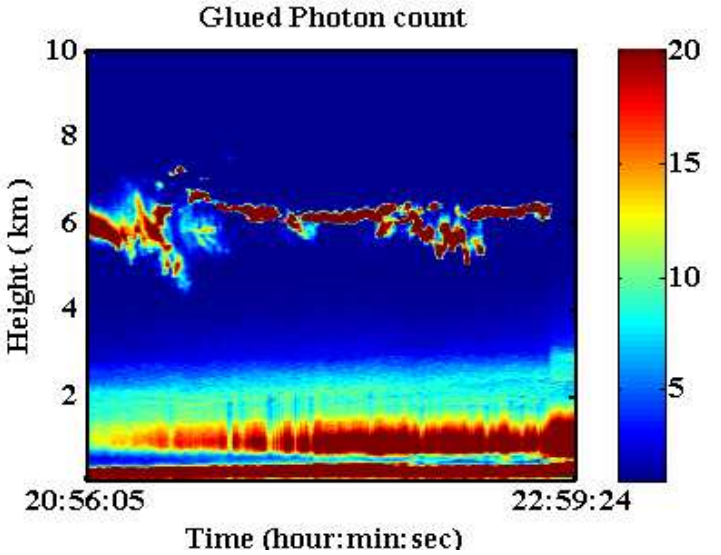
Preliminary Results

18 April 2008

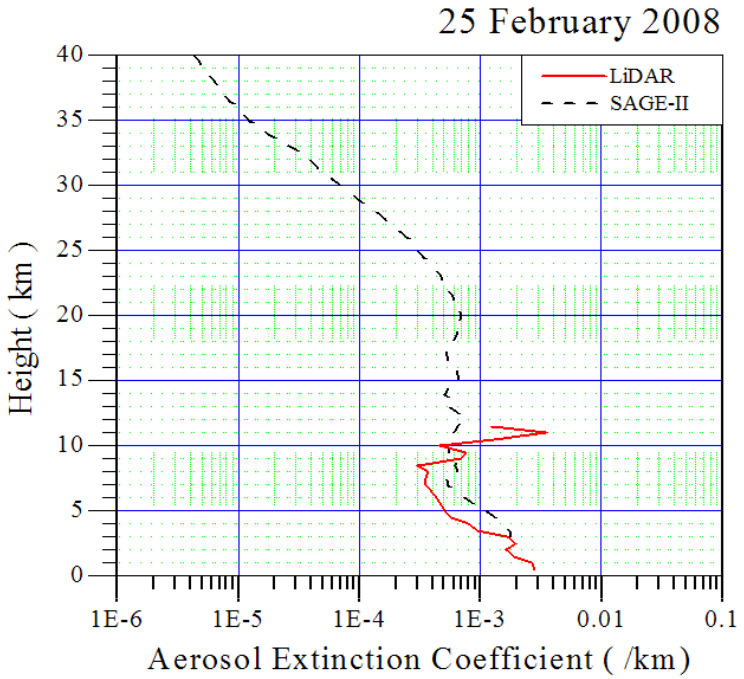


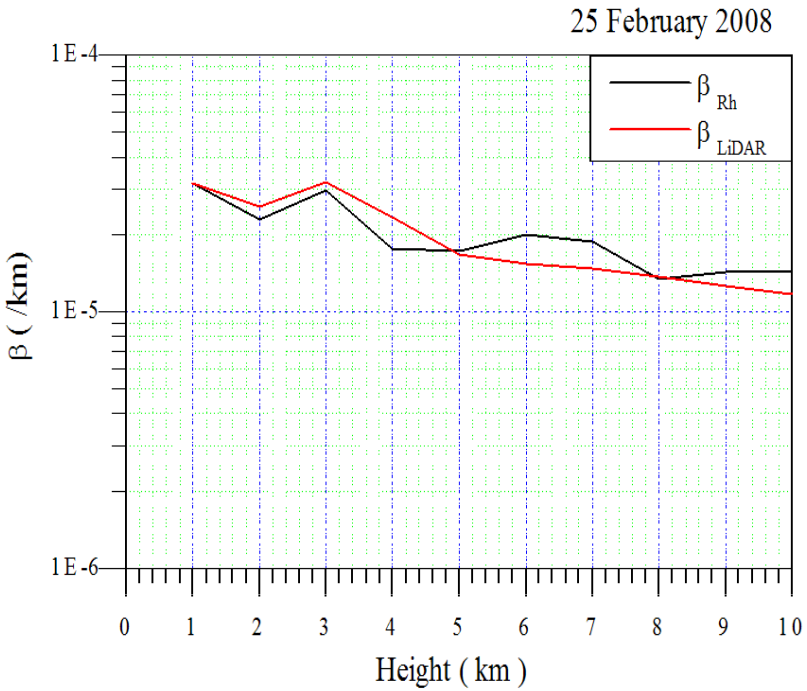


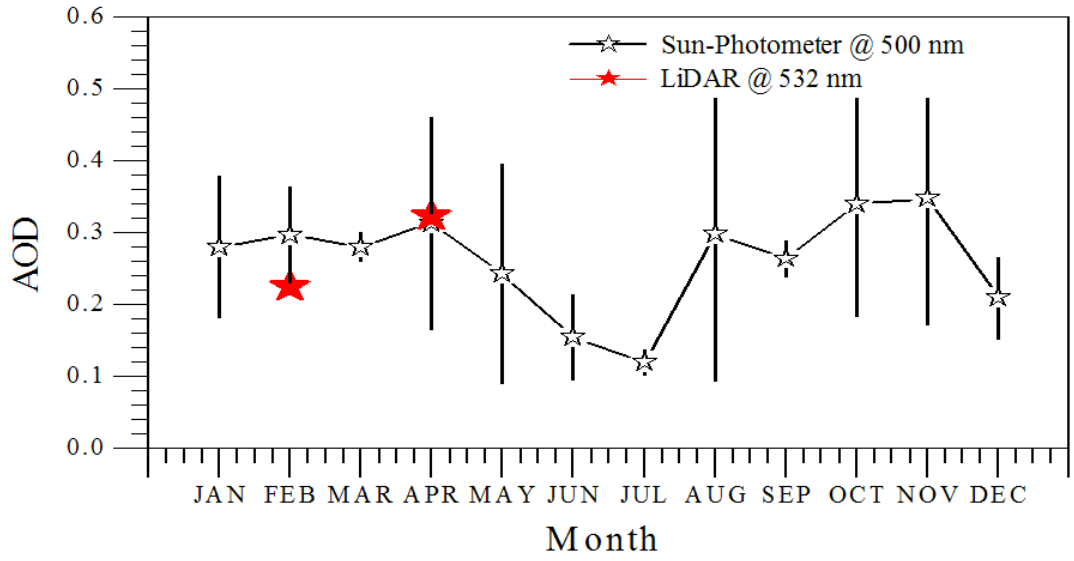




Validation/Comparison







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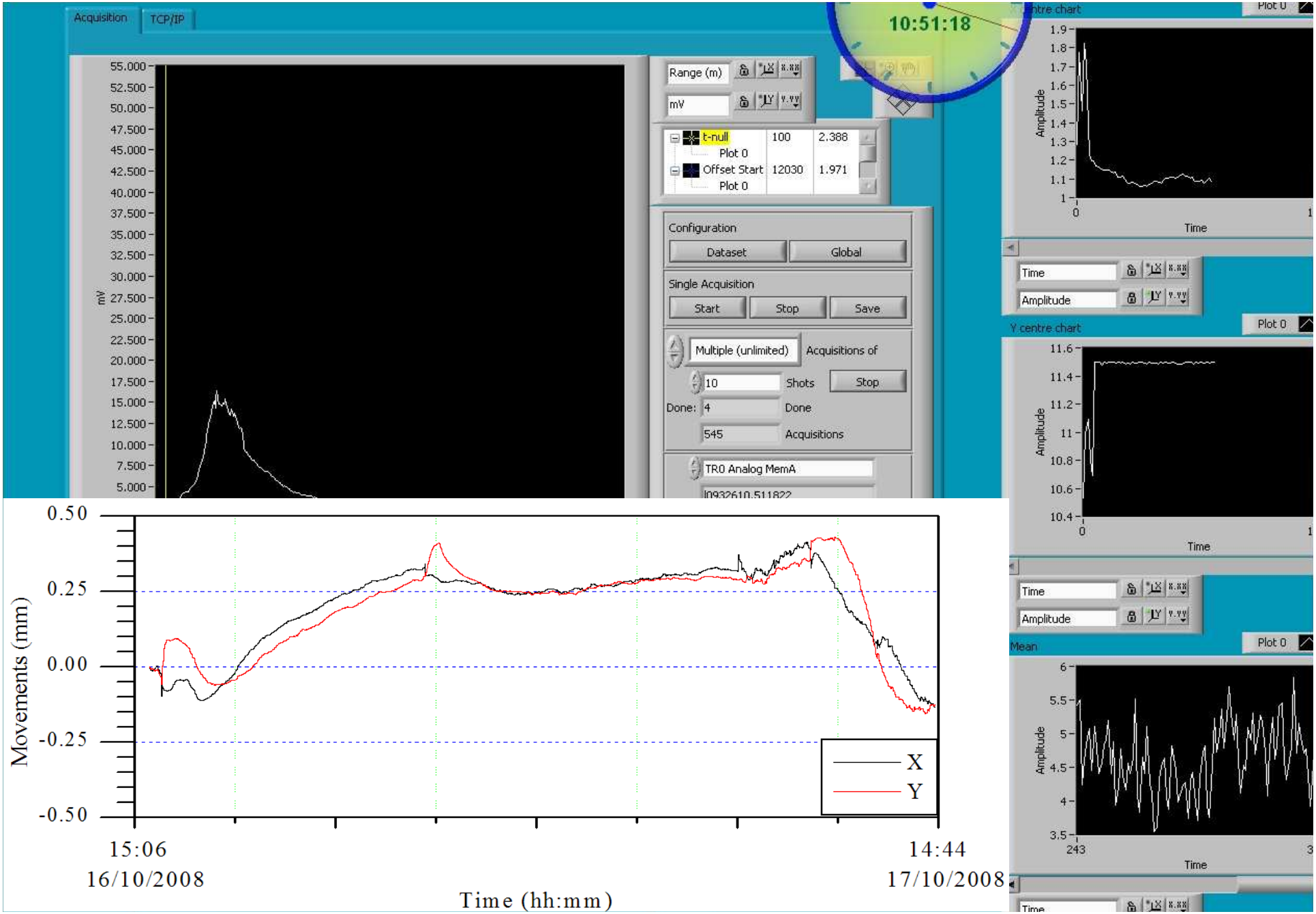
Fibre Auto-Alignment



Demonstrations - HEI

University of Pretoria
CSIR – Natural Resources Environment
CSIR – Meraka Institute (Remote Sensing)
Portland Cement Factory
Boiler Industry
ESKOM

Human Capital Development

2- Master degree students – 2007 & 2008
(3 months on internship from Addis Ababa University)

1- Ph.D degree student (full time) + 2 Ph.D (Partially)
(continuing from 2008, expected to be awarded by end of 2010)

Trainee + Honour degree students

6-Articles

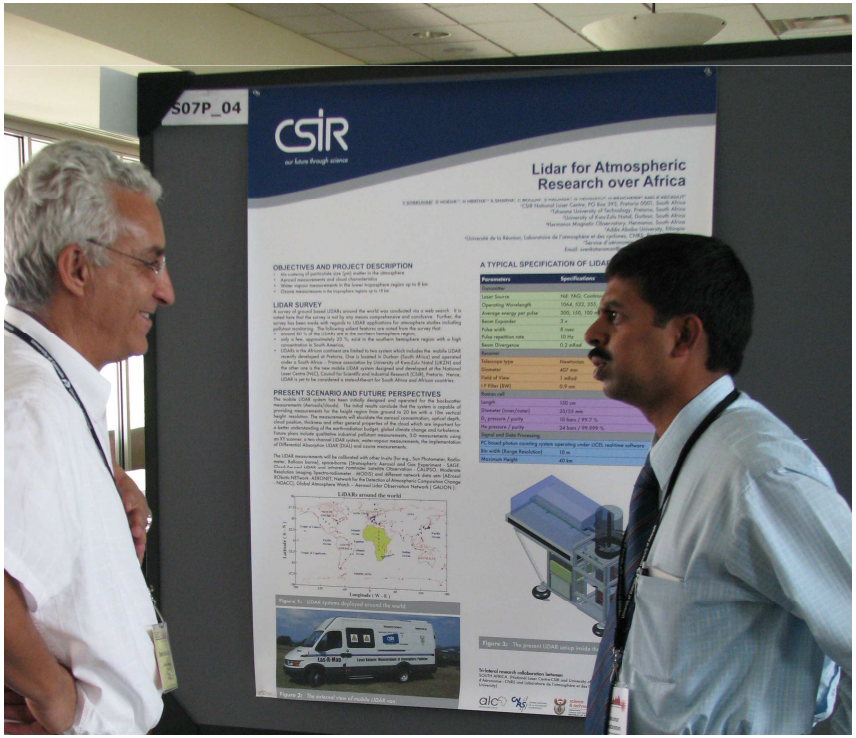
(1 Book Chapter and 2 articles are accepted for publications)

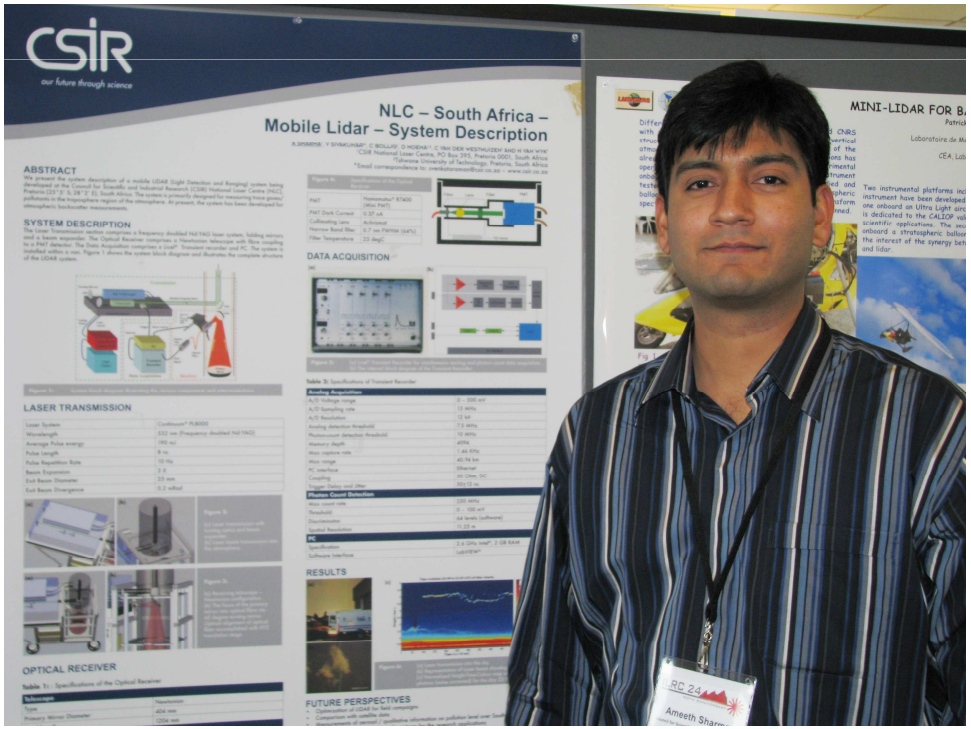
5-Peer reviewed conference proceedings with ISBN

5-Popular articles

17-conference presentations

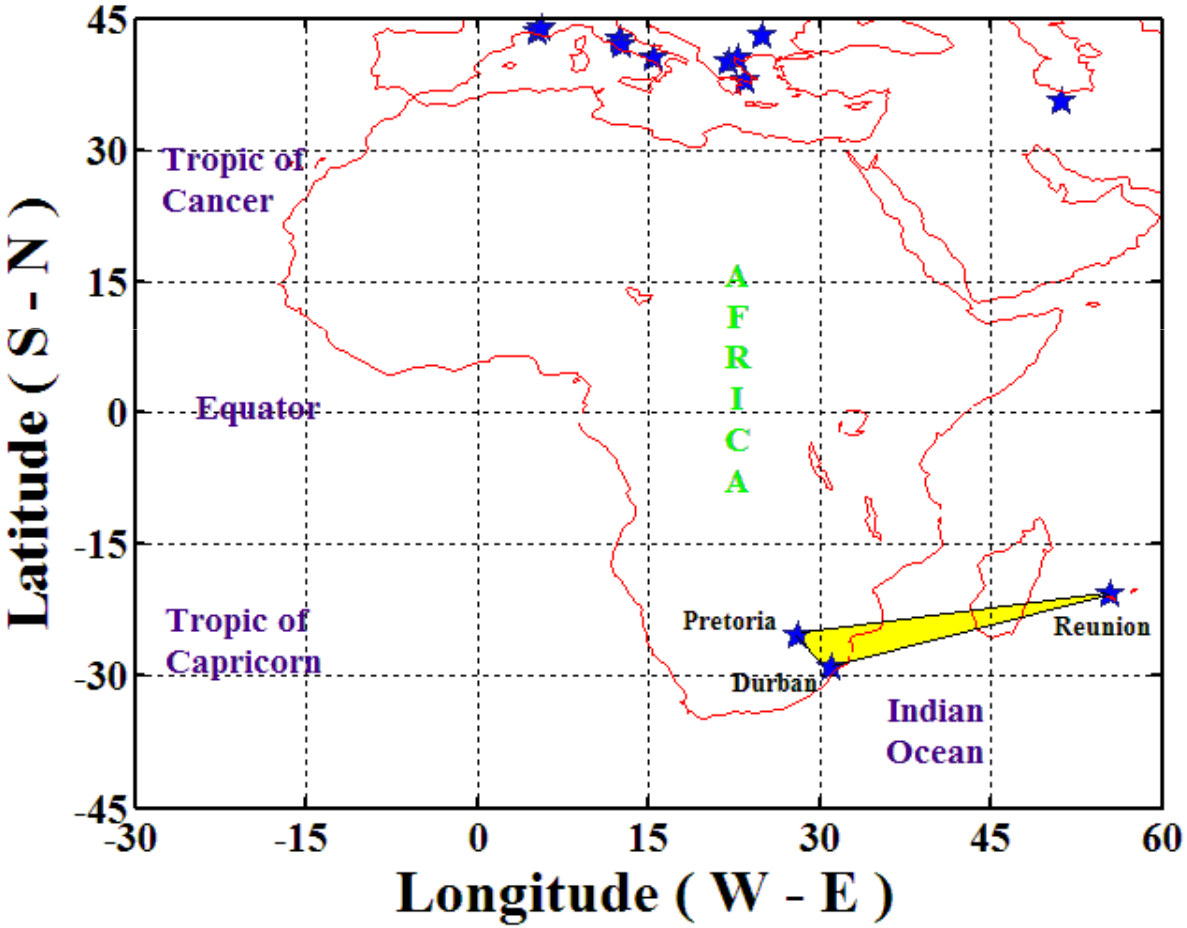
13-Scientific reports





New Initiatives

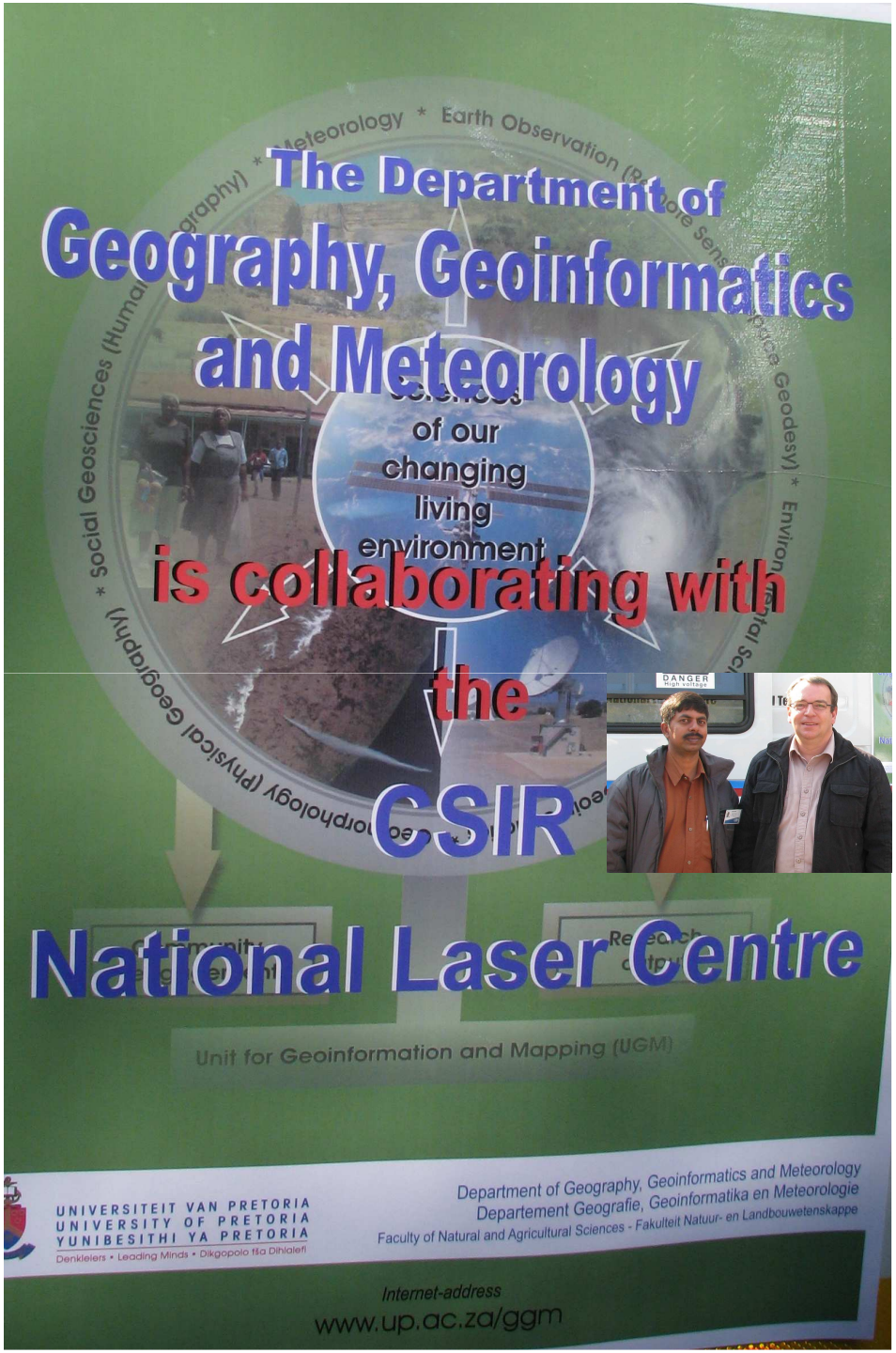
South-African French LiDAR (SAFiR) network for study of upper troposphere and lower stratosphere aerosol distributions and dynamics



SERA CSIR-UP

A combined research and academic training activity between the Council for Scientific and Industrial Research (CSIR) National Laser Centre (NLC) and the Department of Geography, Geoinformatics and Meteorology (GGM) at the University of Pretoria (UP)

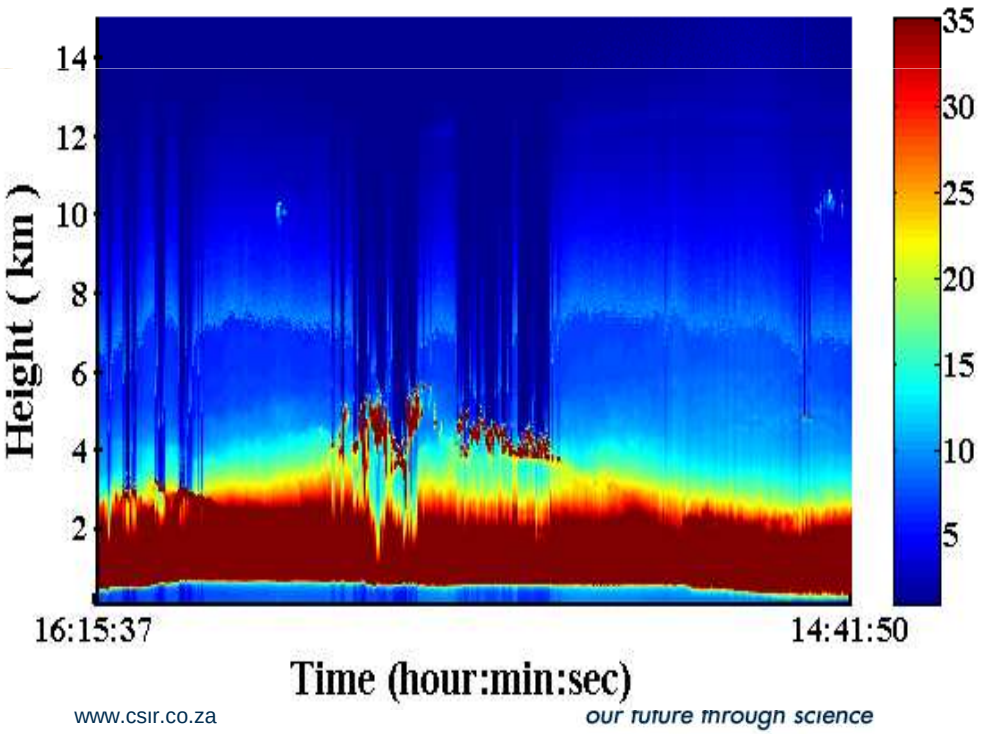
on ATMOSPHERIC REMOTE SENSING using state of the art Light Detection And Ranging (LiDAR) instrumentation and other active and passive remote sensing tools.

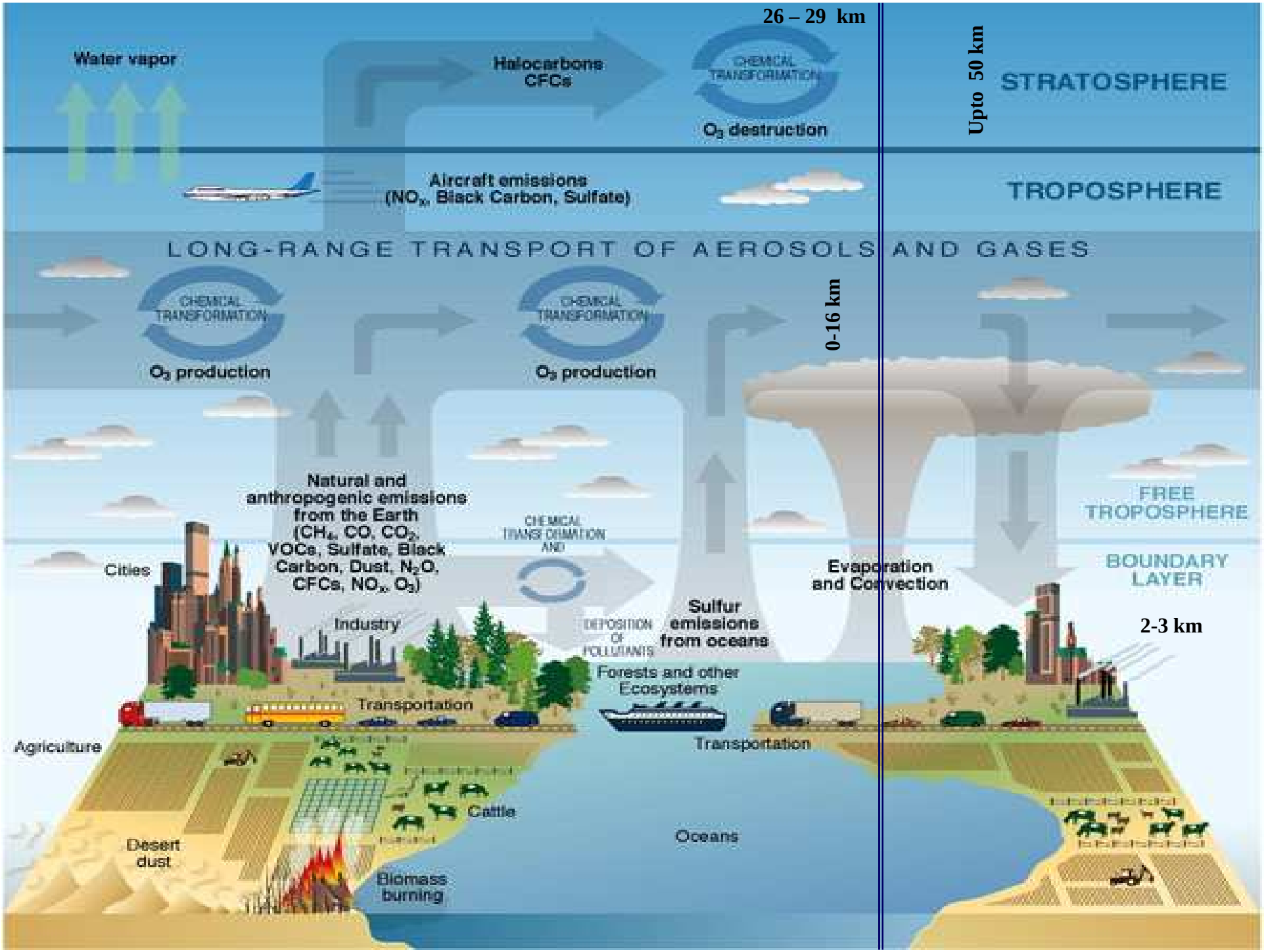


Last year, there were 35 students enrolled for bachelor degree programme and benefited.

First "Lidar Field Campaign"

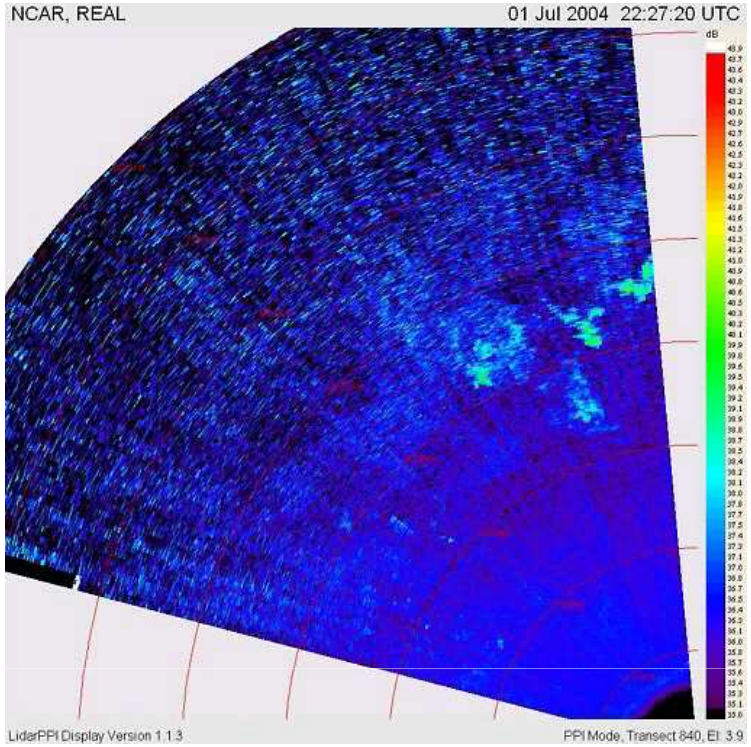
- 2-day measurement campaign at University of Pretoria
- First 23-hour continuous measurement

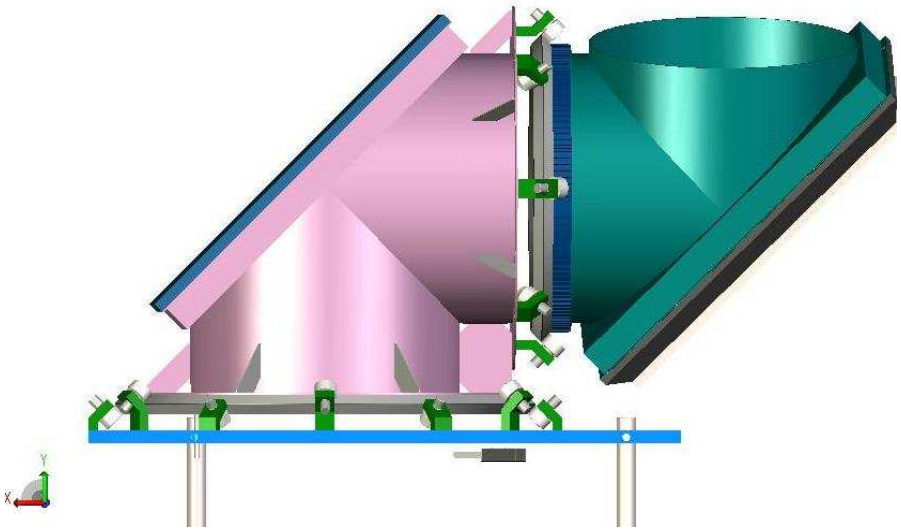



26 – 29 km
Upto 50 km
STRATOSPHERE
Water vapor
Halocarbons
CFCs
CHEMICAL TRANSFORMATION
O_3 destruction
Aircraft emissions
(NO_x, Black Carbon, Sulfate)
TROPOSPHERE
LONG-RANGE TRANSPORT OF AEROSOLS AND GASES
0-16 km
CHEMICAL TRANSFORMATION
O_3 production
CHEMICAL TRANSFORMATION
O_3 production
Natural and anthropogenic emissions from the Earth (CH_4, CO, CO_2, VOCs, Sulfate, Black Carbon, Dust, N_2O, CFCs, NO_x, O_3)
CHEMICAL TRANSFORMATION AND
DEPOSITION OF POLLUTANTS
Evaporation and Convection
FREE TROPOSPHERE
BOUNDARY LAYER
2-3 km
Cities
Industry
Sulfur emissions from oceans
Forests and other Ecosystems
Transportation
Transportation
Agriculture
Cattle
Oceans
Desert dust
Biomass burning

Where does it go ?

How does it impact ?





Adopted from NCAR site

Based on our earlier survey, there are no multi-channel LIDAR systems employed for atmosphere research in South Africa and African countries and X-Y dimensional mapping of the atmosphere have not been explored (except few countries around the world)


OUR
CHANGING
PLANET
"Aerosols"

DST Ten-Year Plan for South Africa

Expanding the limits of space science and technology

*Space science and technology – South Africa should become a key contributor to global space science and technology, with a National Space Agency, a growing satellite industry, and a range of innovations in space sciences, **earth observation**, communications , navigation and engineering.*

Earth observation involves all activities connected with the collection of information on the earth's surface or atmosphere. Such information underpins virtually all public policy decisions, from public health to water resource management, to protection of the ecosystem.

In search of energy security

Science and technology in response to global change

Climate change science and responses

Important changes are taking place in the global climate, but there is still great uncertainty about how earth systems operate.

***Global climate change** science with a focus on climate change – South Africa's geographic position enables us to play a leading role in climate change science. Mitigating climate change also provides an economic opportunity for South Africa; therefore the country needs to develop a strategy to take advantage of the so called "Green Economy".*

DST National Space Science and Technology Strategy

KEY PRIORITY AREAS

4.1 Environment and Resource Management

Environmental and geospatial monitoring

Hydrological monitoring

Climate change mitigation and adaptation

Meteorological monitoring

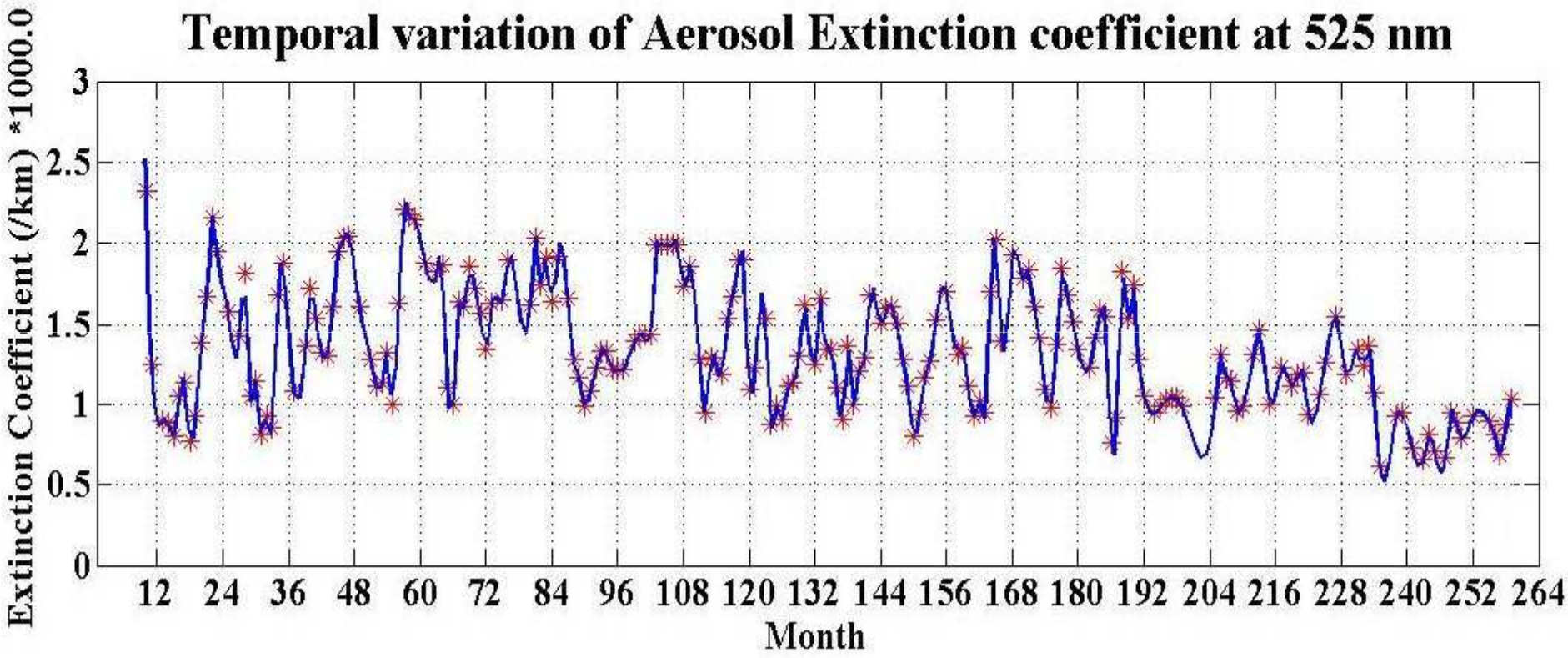
4.2 Health, Safety and Security

Disease Surveillance and Health risk

Earth Observation

Space science and exploration

SAGE – II – AEROSOL EXTINCTION 525 nm OVER SOUTH AFRICA



National Collaborators

Prof. Prince Ngobeni, Tshwane, University of Technology, Pretoria.

Prof. Hannes Rautenbach, University of Pretoria, Pretoria.

Prof. Stuart Piketh, University of Witwatersrand, Johannesburg.

Lidar Scientist…., University of KwaZulu Natal, Durban.

Dr. Mark Alexander Tadross, University of capetown, Capetown.

Dr. Sandile Malinga, Hermanus Magnetic Observatory, Capetown.

Dr Deon Terblanche, South African Weather Service Department

International Collaborators

Dr. Gizaw Mengistu, Addis Ababa University, Addis Ababa, Ethiopia.

Prof. Hassan Bencherif, CNRS-UMR 8105, Reunion University, Reunion, France.

Dr. Philippe Keckhut, Service d'Aéronomie, CNRS-UMR 7620, Paris, France.

Funding Agency / Organizations

- **Department of Science and Technology, South Africa**
- **Council for Scientific and Industrial Research**

  National Laser Centre
- **National Research Foundation**
- **Centre National de la Recherché Scientifique**
- **African Laser Centre**

Laser Design: Lunar Laser Ranger

Lunar Laser Ranging uses laser pulses to accurately determine the distance between the Earth and Moon, up to a level of 3 mm.

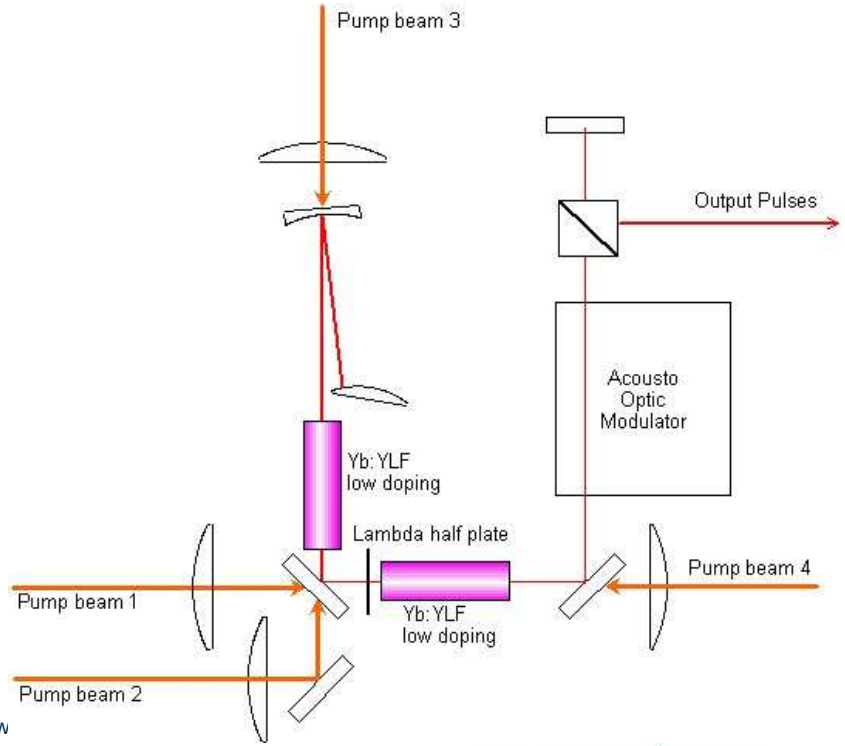
There are only 3 other international stations that have this capability.

SA is developing a new concept Lunar Laser Ranger, at
The Space Geodesy Programme of HartRAO (NRF Facility)

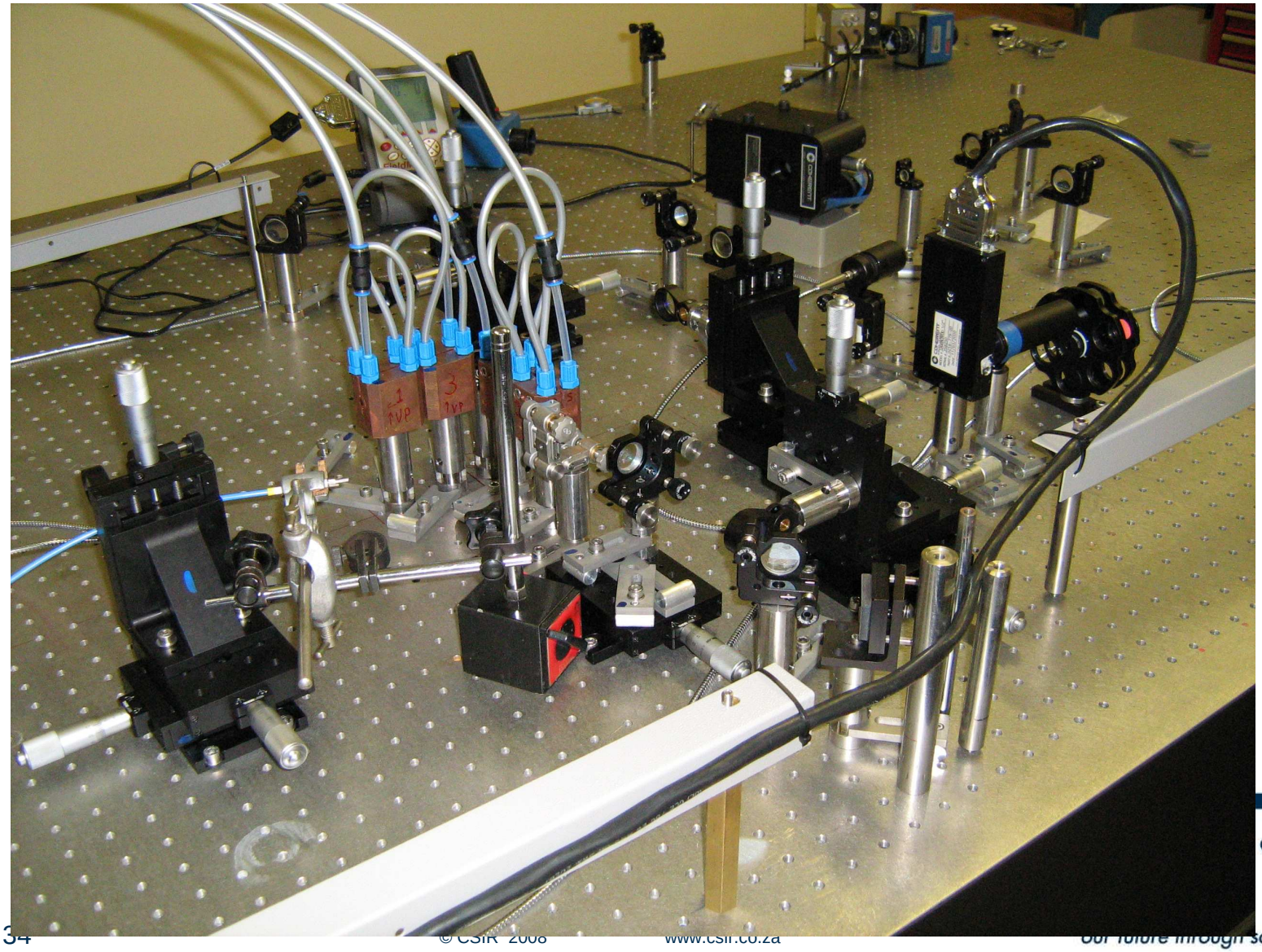
The National Laser Centre collaborates on this in assisting with the development of a new type of laser with better characteristics than available commercially

For LLR laser we would like:

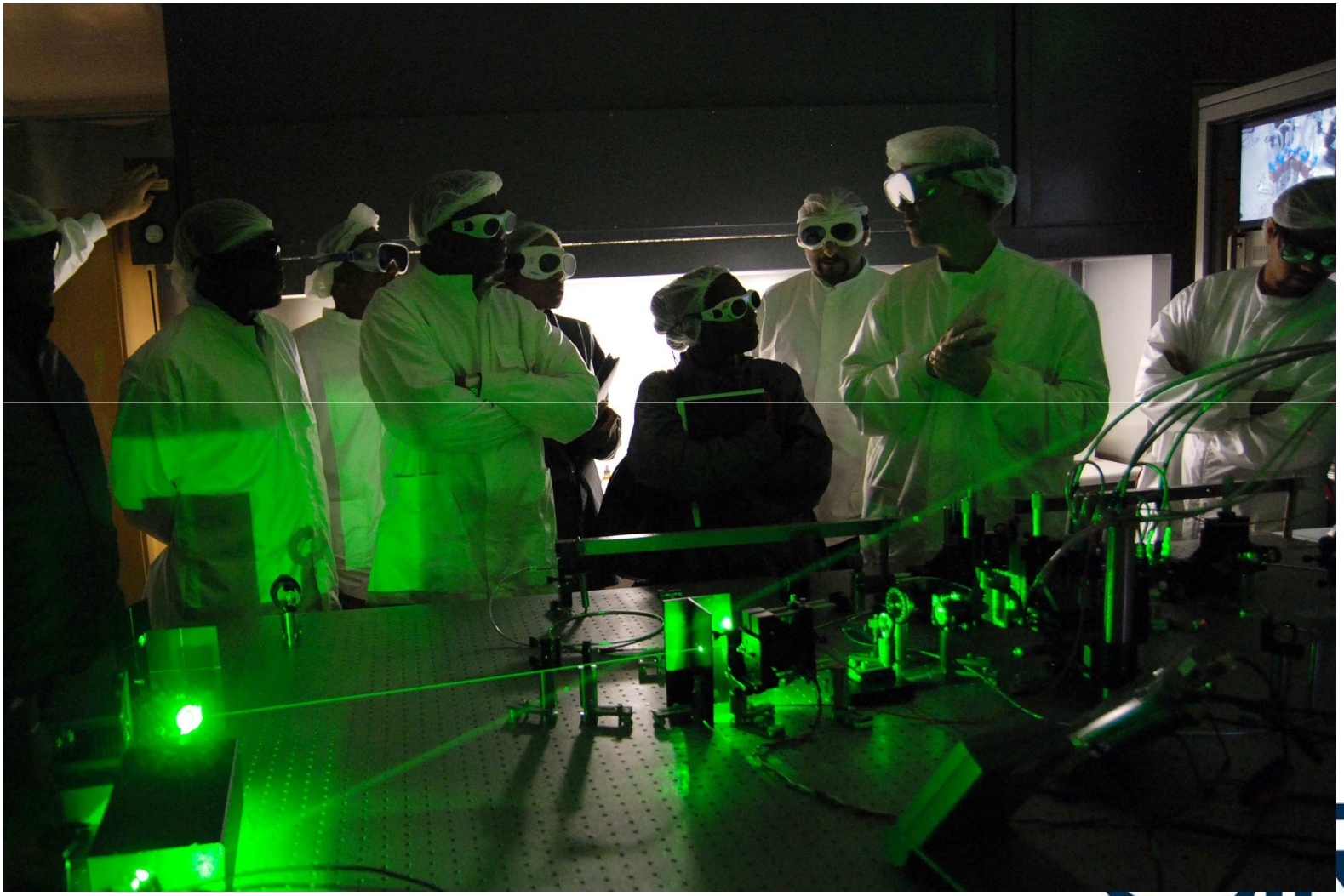
- ~ 500-540 nm wavelength
- < 50 ps pulse length (FWHM)
- M^2 close to 1
- 200 – 400 mJ per pulse
- Pulse Repetition Rate: up to 1000 Hz



Laser Design: Lunar Laser Ranger



Laser Design: Lunar Laser Ranger



After climbing a great hill,

one

only finds that there are many more hills to climb.

--

Nelson Mandela