AURA New Initiatives Office (NIO)
Working Towards a 30-Meter Giant Segmented Mirror Telescope

The site testing for the Thirty Meter Telescope

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New Initiatives Office

* Why we do it
* Where we do it
* What we do
* How we do it
* What's currently going on

The Thirty Meter Telescope

TMT is the result of joining

- CELT (Caltech, UC)
- VLOT (ACURA)

...

into a single project with the goal to build and operate a 30m optical/IR telescope by mid of the 2nd decade of the 21st century

TMT and AURA are conducting an extensive site testing campaign in order to identify the most suitable site for such an ELT

Where to build a 30m telescope

The future ELTs will be expensive -> observing time is very valuable
* Requirement: high observing efficiency

=> no (low) cloud coverage
=> low (reasonable) windspeed (but not too low!?)
=> low humidity, dust

ELTs will make heavy use of adaptive optics (AO)
* Requirement: atmosphere above the observatory has to be "usable" for AO

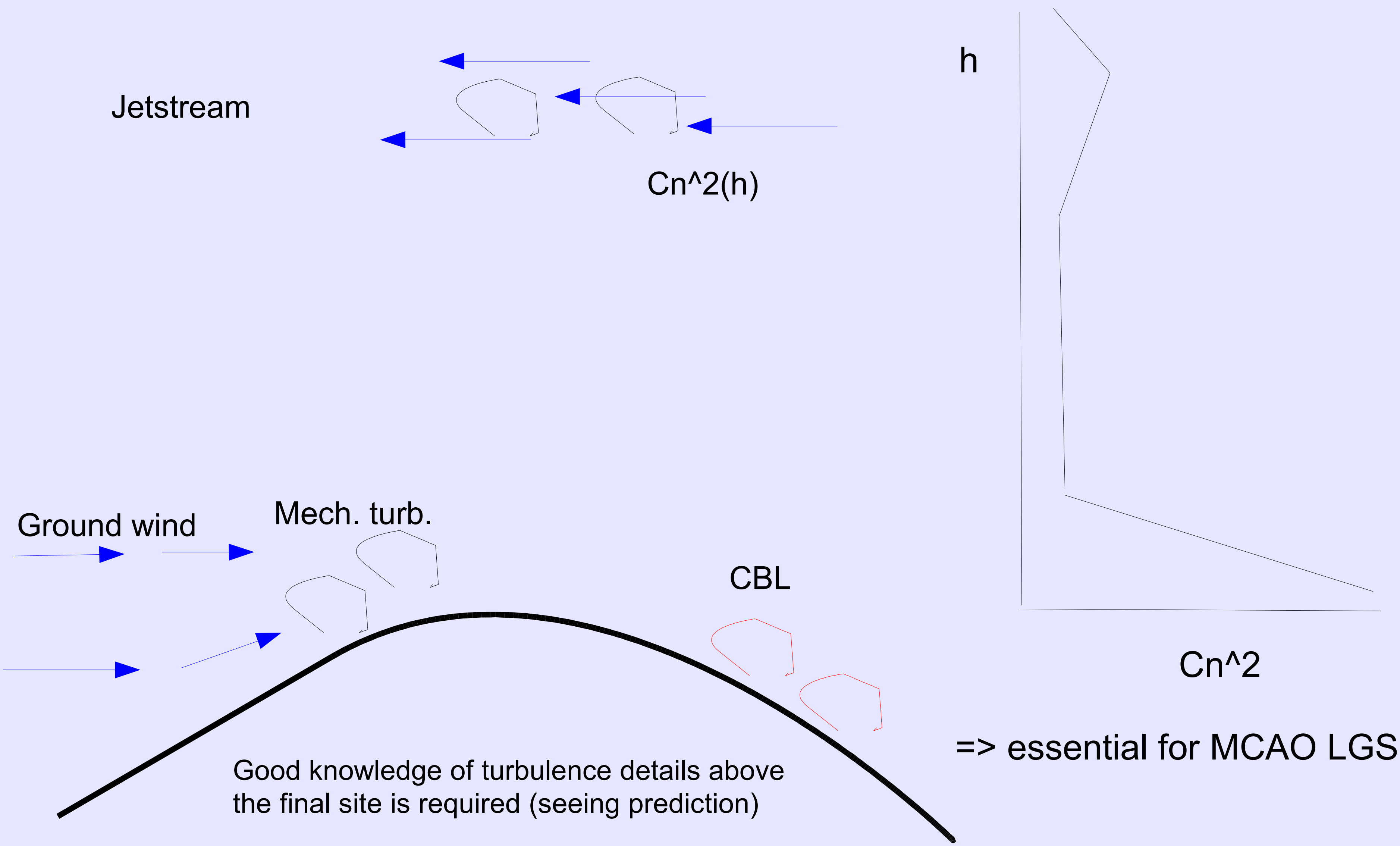
=> low seeing (r0)
=> long coherence time (tau0)
=> "well behaved" / well known Cn^2(h) profiles
=> known outer scale L0

* ELTs will have big domes, design requires knowledge of

=> wind speeds and temperatures

Project goal:
Monitor a sample of sites using well calibrated and identical equipment for at least two annual cycles for their atmospheric properties.

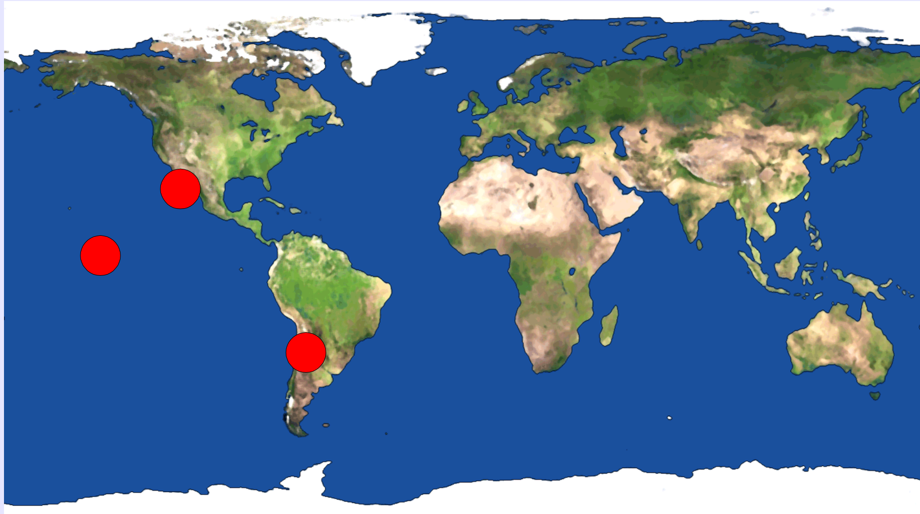
Turbulence profiles – more about seeing



=> essential for MCAO LGS

Good knowledge of turbulence details above the final site is required (seeing prediction)

Where we are testing



Based on an analysis of satallite data, regions were identified which show

- low cloud coverage
- low precipitible water vapur
  (*Erasmus* studies)

Other factors for preselection

- existing astronomical data
- accessability
- political stability

After visits of a number of mountains and obtaining permissions, site testing equipment has been setup on 5 mountains located in the northern and southern hemisphere.

A brief history of site evaluation in Chile

- *The selection of any site in the Southern hemisphere...is more or less a leap in the dark.*

- *... an unexampled opportunity for an authoritative “seeing survey” prelimenary to site selection.*

- *... I believe one or two thousand dollars could well be spent in such a survey.*

From
“Reports on astronomical conditions in the Region about Copiapo” (1909)

=> criteria for good astronomical sites defined since 100yrs
=> “seeing survey” !

Zurhellen, Ristenpart, Prager,
Curtis, Moor, Paddock
(Shane Archives)

Todays knowledge of southern sites (South America, Chile) is much improved by site testings

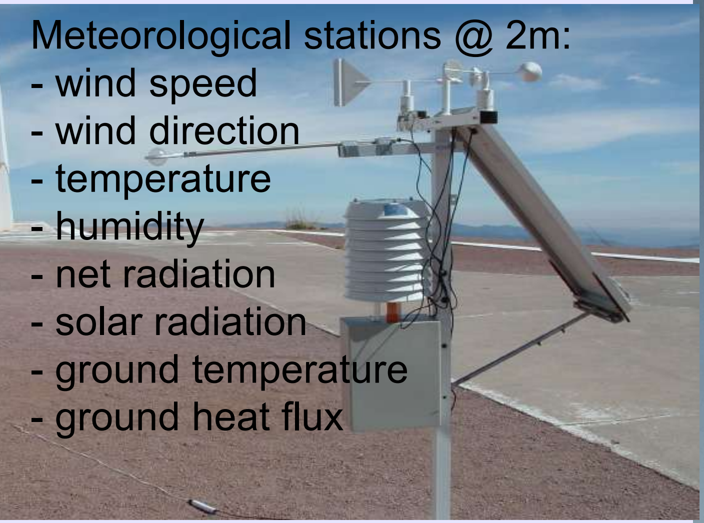
- site testings for Cerro Tololo Interamerican Observatory (1960ies, J. Stock)

- site testing for Las Campanas Observatory (1960ies)

- ESOs Very Large Telescope, Paranal (1980ies, M. Sarazin)

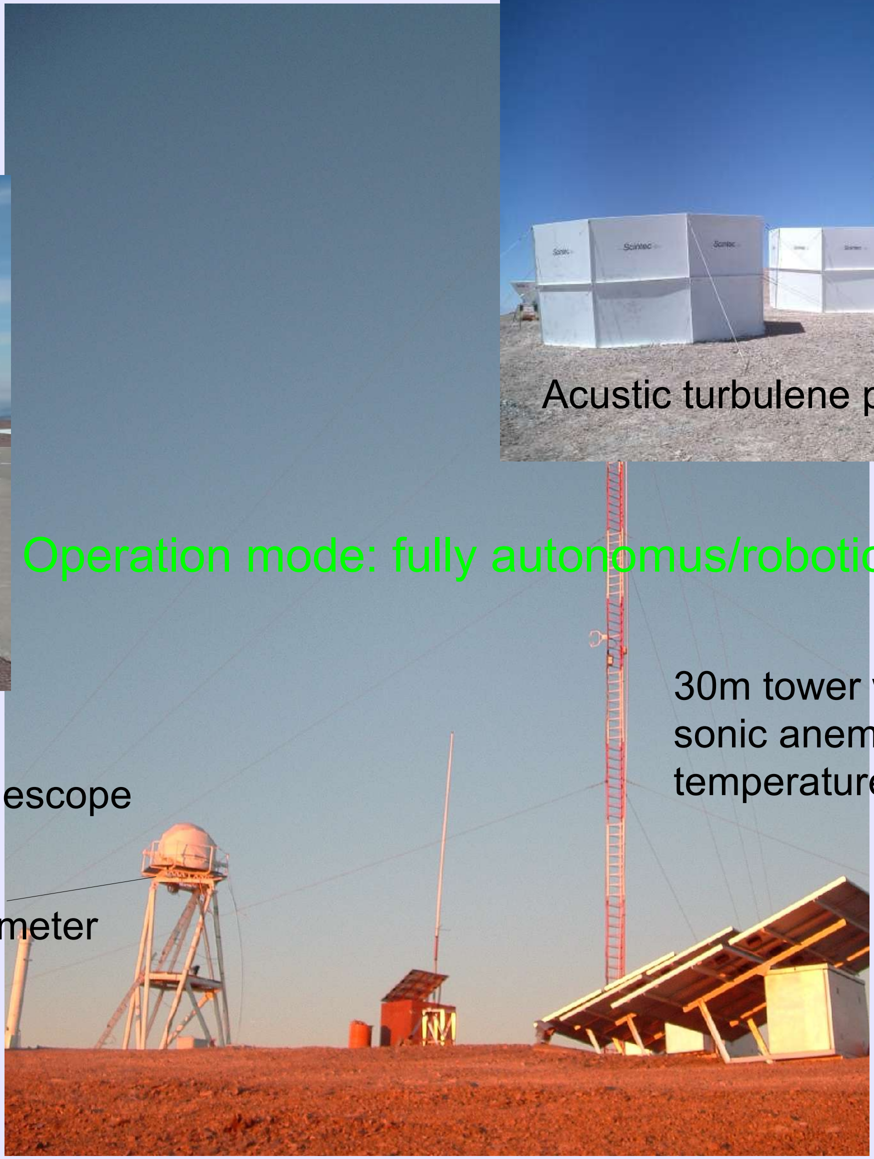
TMT site testing equipment - Overview

Under development:
20mu pwv monitor IRMA



Meteorological stations @ 2m:
- wind speed
- wind direction
- temperature
- humidity
- net radiation
- solar radiation
- ground temperature
- ground heat flux

Acustic turbulene profiler SODAR



Operation mode: fully autonomus/robotic !

30m tower with
sonic anemometers
temperature probes

7m tower with 35cm site testing telescope
with MASS-DIMM

Dust sensor
Sonic anemometer

All Sky Camera (ASCA)

Solar power system

Riddle et al. (2006)

How to get all this on a remote mountain

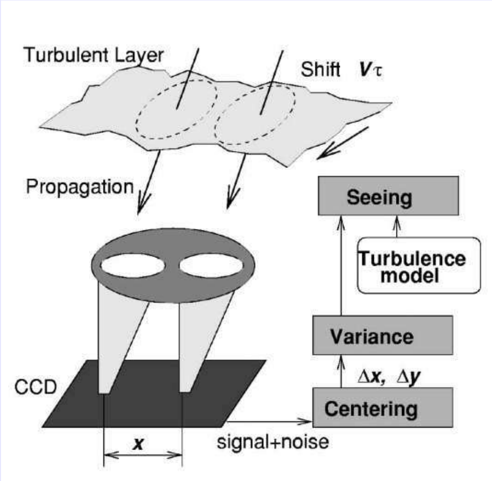
“And another day in the office”

Setting up the 30m tower

Site Testing Instrumentation: Combined MASS-DIMM unit

Differential Image Motion Monitor DIMM
Stock&Keller(1960), Sarazin&Roddier(1990)...

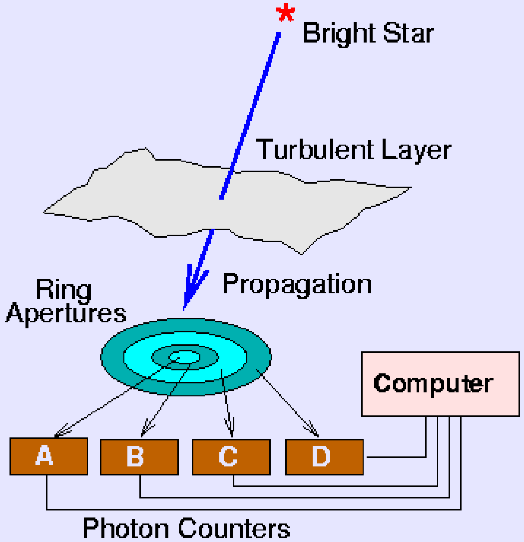
-> variance of image motion ~ r_0
=> integral seeing from the ground to infinity



From Tokovinin(2002)

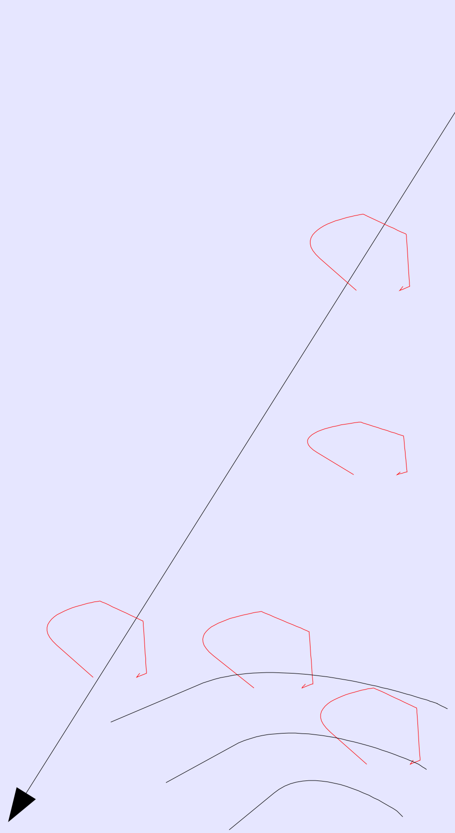
Multi Aperture Scintillation Sensor MASS
Tokovinin et al. (2003), Ochs (1976)

-> scintillations on the ground show spatial structure
-> structure depends on propagation length
=> low resolution turbulence profiles Cn^2(h)dh



35cm site testing telescope with MD

Site Testing Instrumentation: MASS-DIMM, SODAR, sonic anemometer



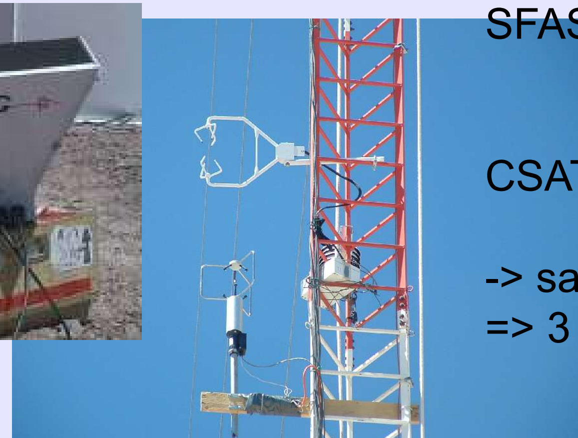
MASS delivers Cn^2dh at
h = 0.5, 1, 2, 4, 8, 16 km

DIMM delivers Cn^2 integrated
from h = 0 – inf.

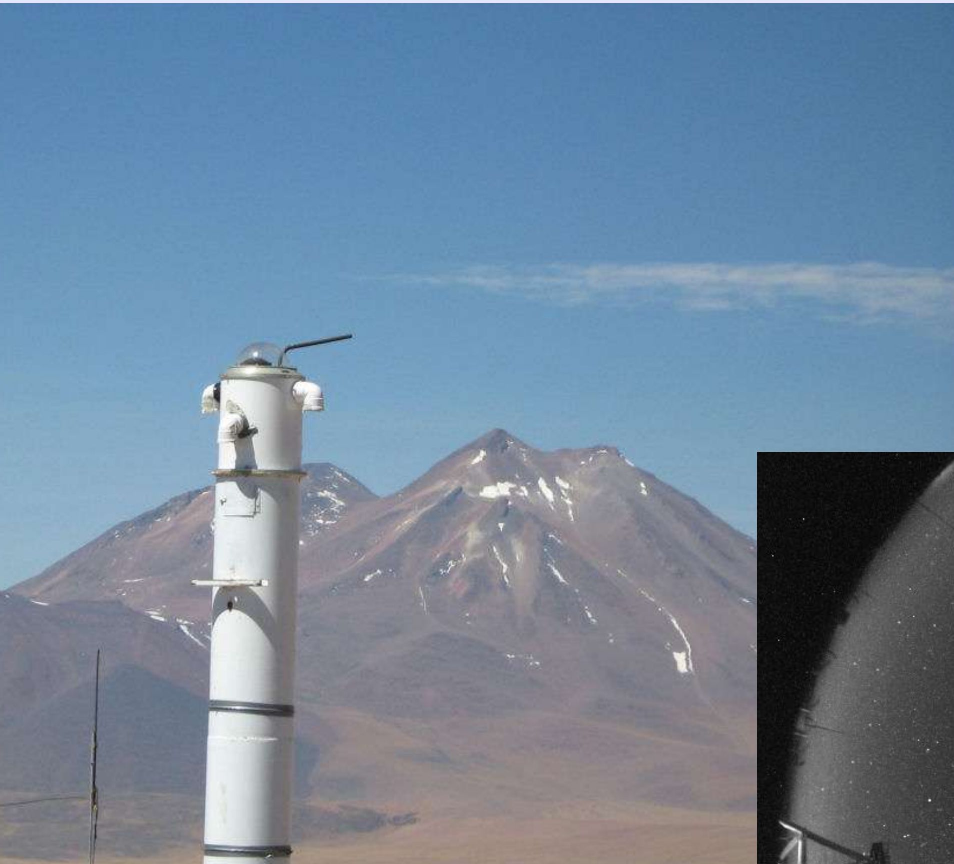
DIMM-MASS -> Cn^2 integrated
from h = 0 – 0.5 km

SODAR
XFAS: Cn^2 @ h = 50...800m
SFAS: Cn^2 @ h = 20...200m

CSAT-3 sonic anemometer f=60Hz
h = 7m / 10m, 20m, 30m
-> sampling slow for Cn2
=> 3 D wind speed



Site Testing Instrumentation: All Sky Cameras ASCA



Fisheye lense equipped with 1k x 1k CCD
B, R, Y, Z filter
images of entire sky every 2min in each filter

=> cloud coverage
=> OH glow
=> air traffic

Walker et al., 2006, SPIE

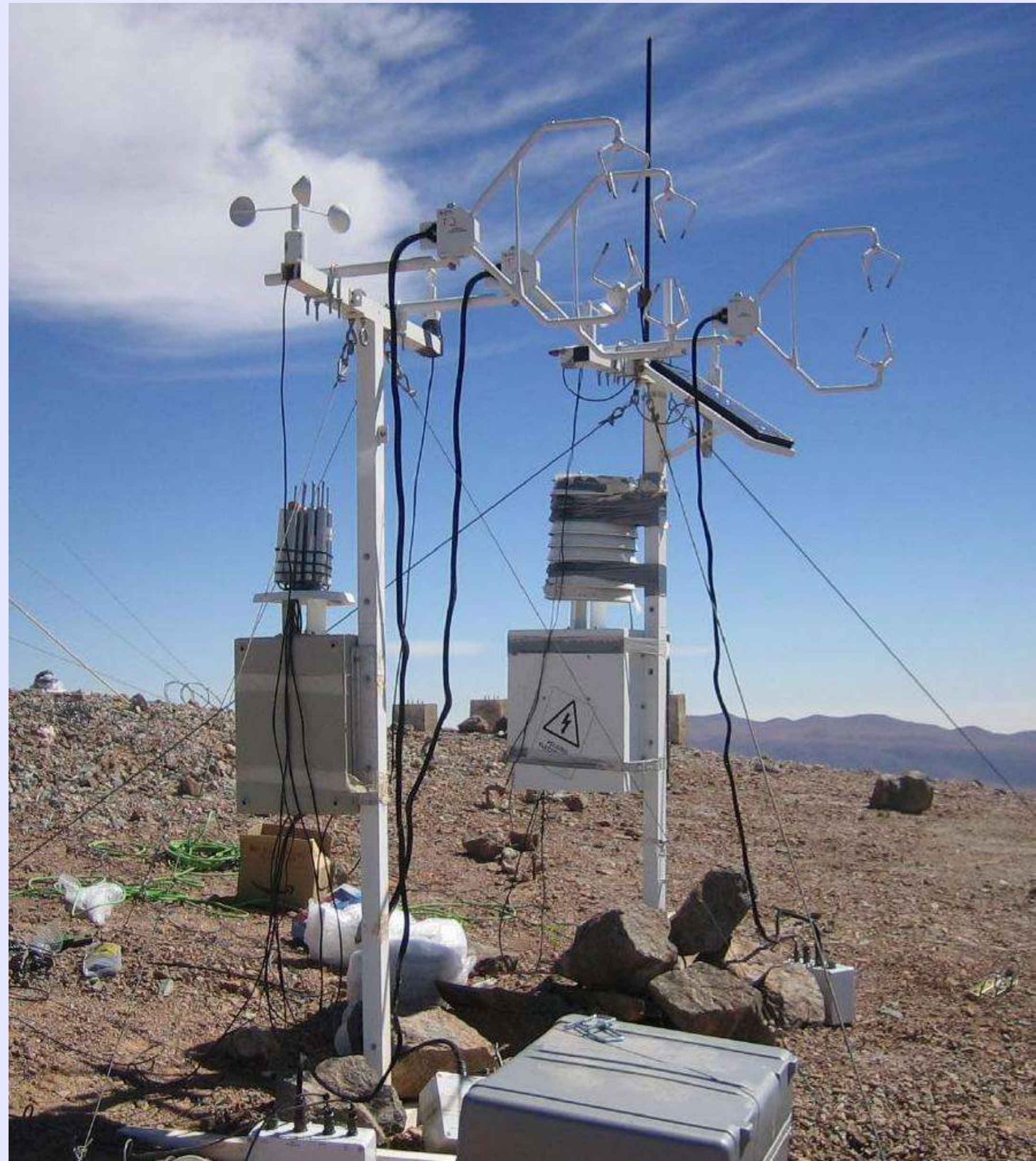
"...well calibrated equipment"

* MASS-DIMM calibration campaign on Cerro Tololo

Wan & Schoeck (2006)

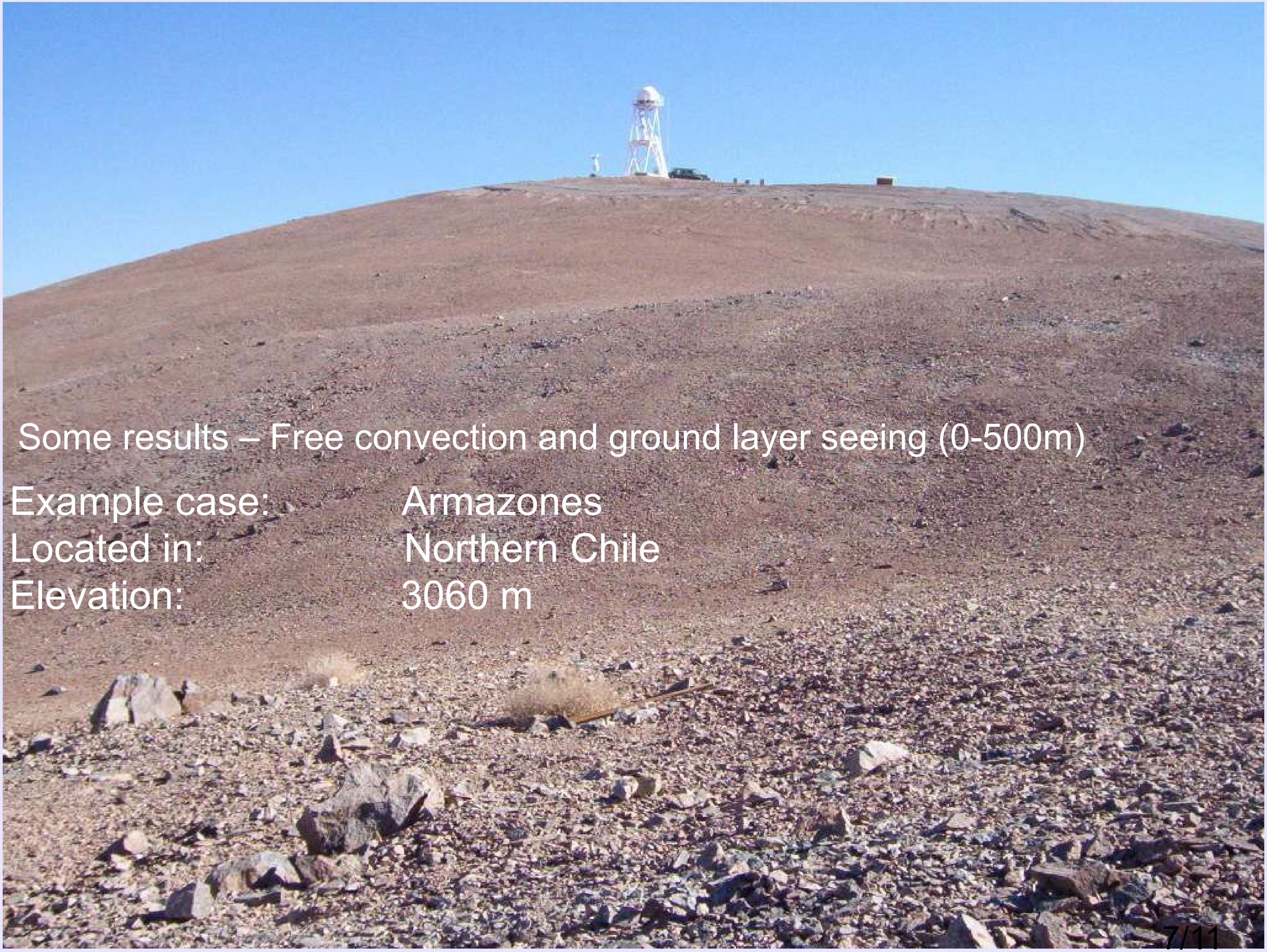
* calibration campaign of thermoprobes and CSAT-3 sonic anemometers

Skidmore et al. (2006)



* calibration campaign of SODARs

Travoullion (2006)

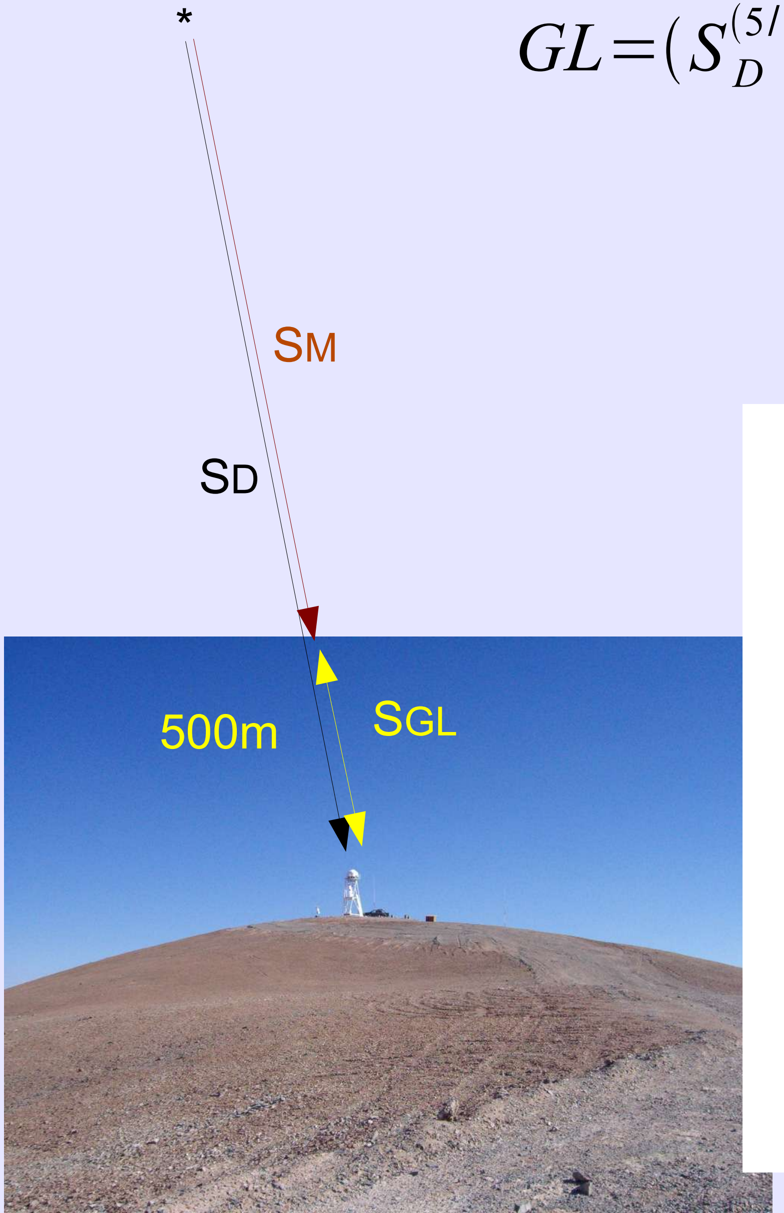


Some results – Free convection and ground layer seeing (0-500m)

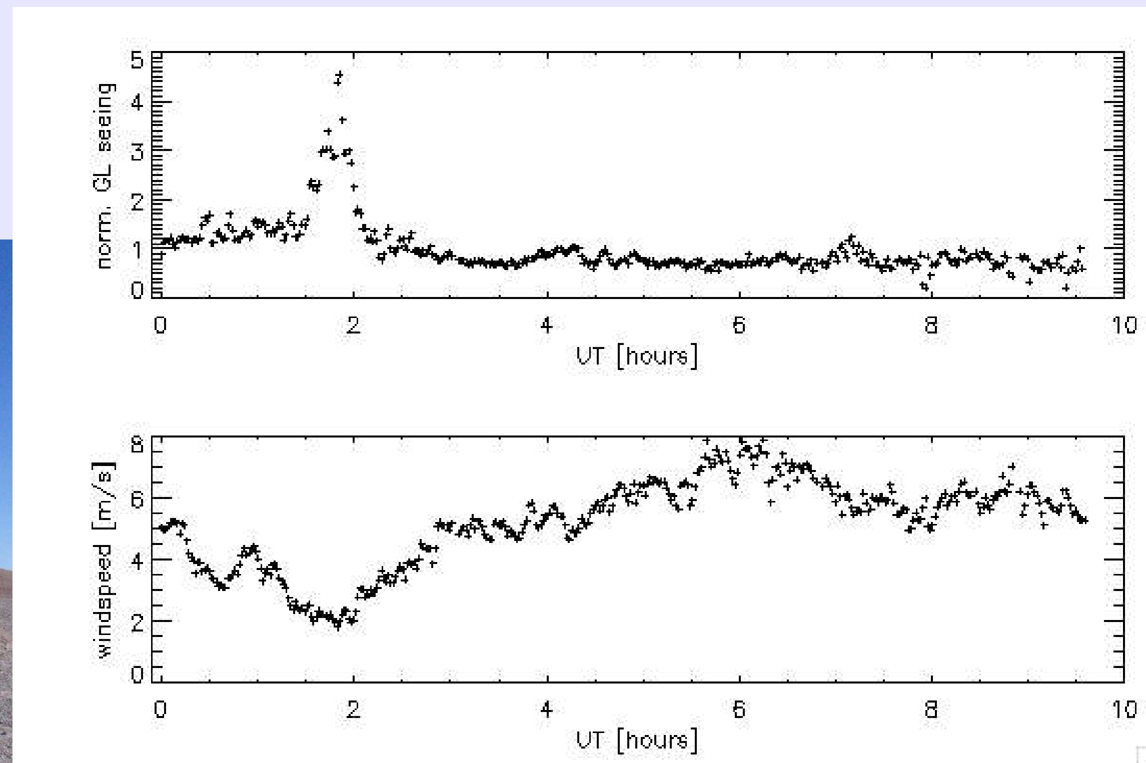
Example case:	Armazones
Located in:	Northern Chile
Elevation:	3060 m

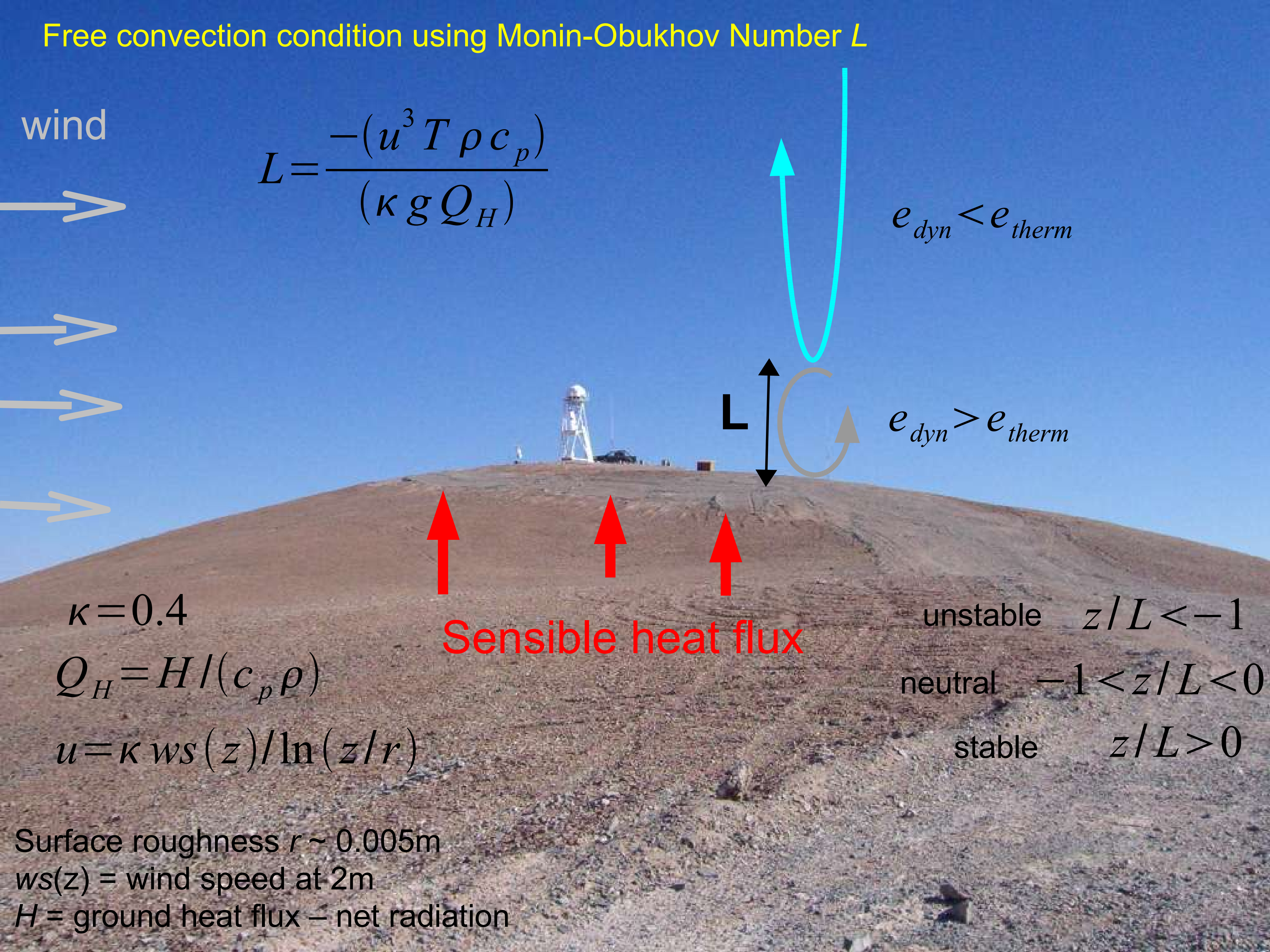
Ground layer seeing from MASS DIMM seeing data

$$GL = (S_D^{(5/3)} - S_M^{(5/3)})^{(3/5)}$$



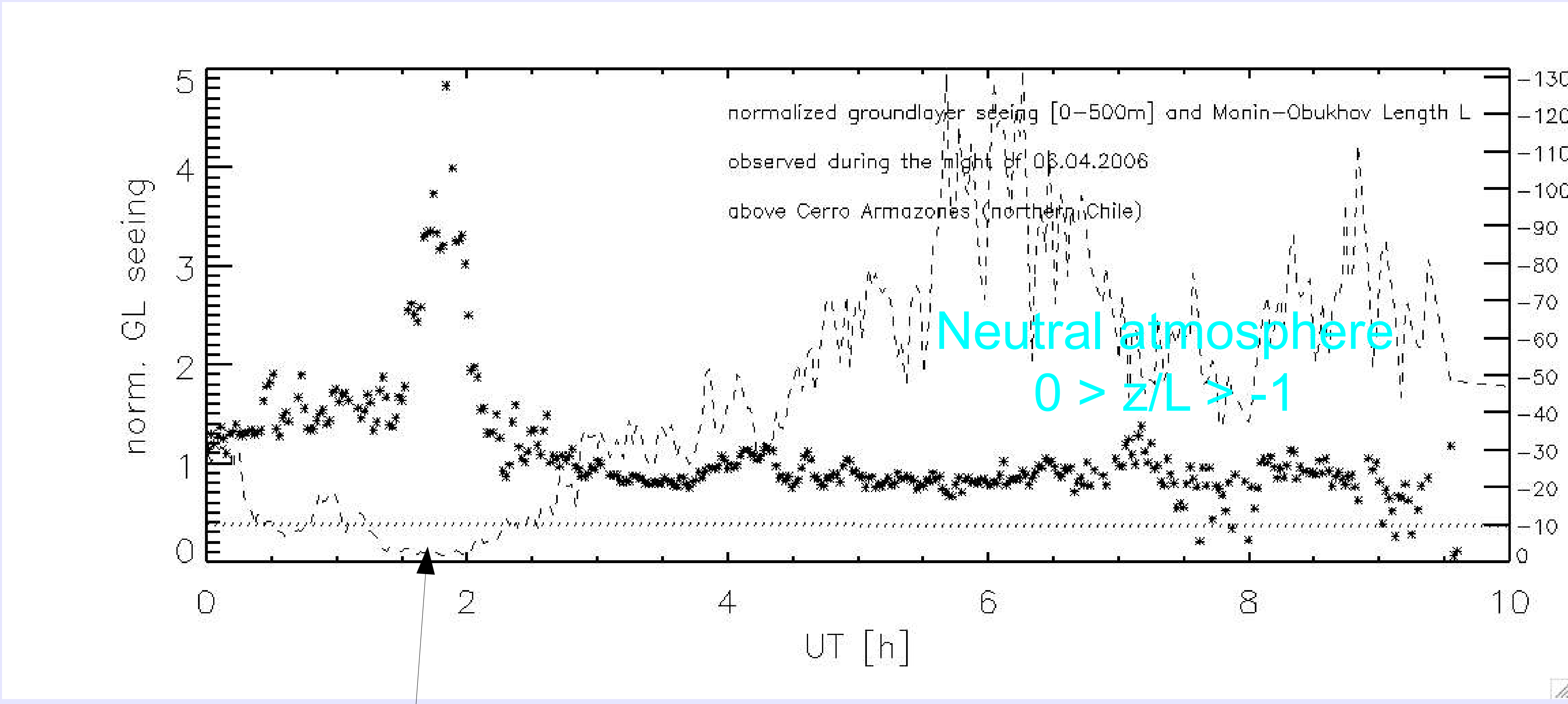
Night of April 6, 2006 above Armazones





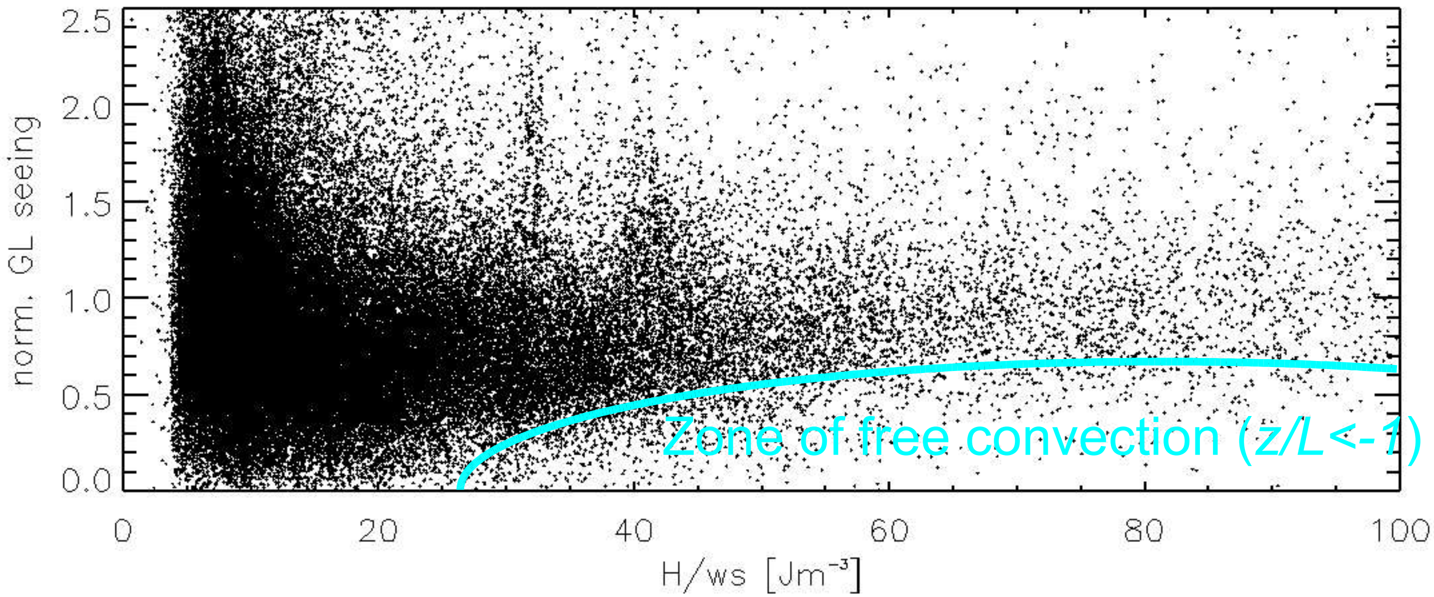
Free convection condition using Monin-Obukhov Number L
wind
$L = \frac{-(u^3 T \rho c_p)}{(\kappa g Q_H)}$
$e_{dyn} < e_{therm}$
L
$e_{dyn} > e_{therm}$
$\kappa = 0.4$
$Q_H = H / (c_p \rho)$
$u = \kappa ws(z) / \ln(z/r)$
Sensible heat flux
unstable $z/L < -1$
neutral $-1 < z/L < 0$
stable $z/L > 0$
Surface roughness r ~ 0.005m
$ws(z)$ = wind speed at 2m
H = ground heat flux – net radiation

Night of 06.04.2006

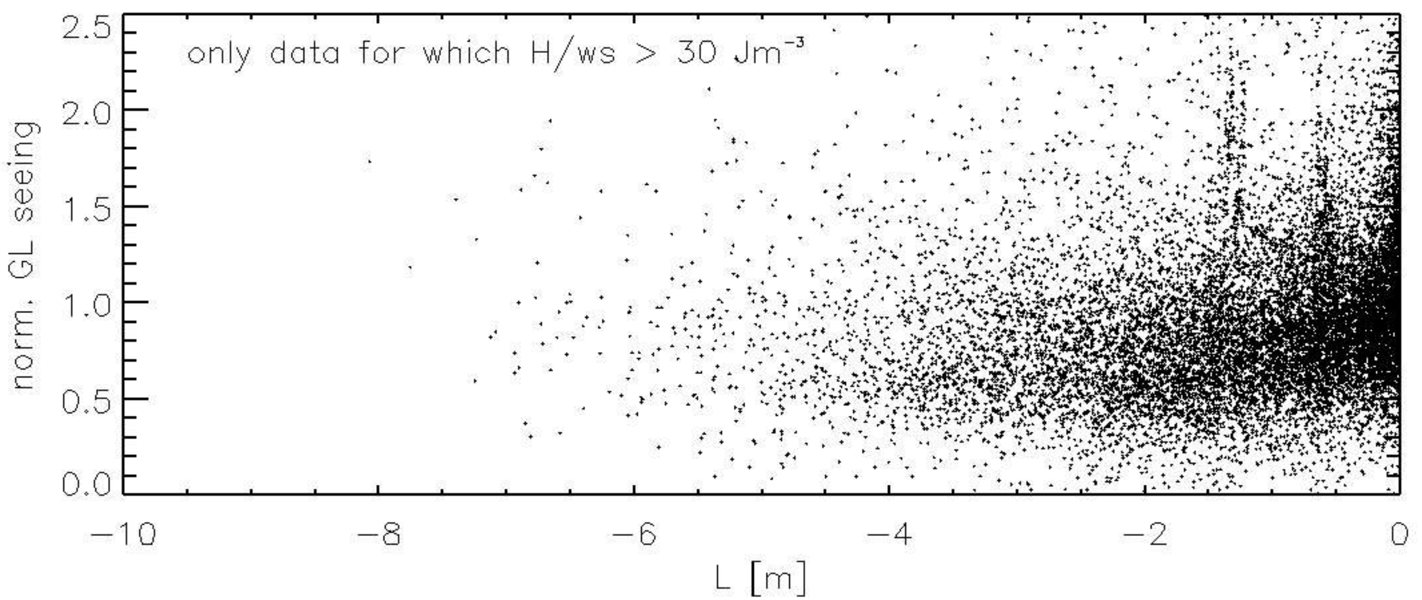


Unstable atmosphere z/L < -1

General dependence of the GL seeing on the ground sensible heat flux and wind speed



Sensible heat flux devided by wind speed H/ws



H/ws > 30J/m^3
=> |L| < ~5 m

Els & Vogiatzis (2006)
Els & Vogiatzis (2007)

Summary

* The site testing for a Thirty Meter Telescope is in full swing

* Identical and well calibrated sets of instrumentation have been deployed on five sites

* Instrumentation is cross calibrated -> quality control

* Robotic operation -> high observing efficiency -> lots of data -> basis for right decision

* Data from most mountains already 2+ yrs

* Apart from comparing sites, we are getting more and more insight into the physics of the atmosphere above the sites
  > future aim: seeing prediction/forecasting