ESO

European Organisation for Astronomical Research in the Southern Hemisphere

Site Testing For The E-ELT: A Review

Marc Sarazin, ESO Garching, Germany

On behalf of …

The Teams

E-ELT ESO - *Sites: Armazones, Chajnantor, La Chira, La Silla, Paranal, Tolanchar, Ventarrones, Vicuna McKenna, Vizcachas*

- M. Sarazin (1), J. Argomedo, F. Char, F. Kerber, F. Gerlin, C. Gonzalez, R. Hinojosa, G. Lombardi, F. Luco, J. Melnick, J. Navarrete, A. Pizarro, F. Puech, D. Rabanus
- A. Tokovinin (9), Edison Bustos,
- V. Kornilov (10), S. Potanin, N. Shatsky, O. Votziakova
- R. Querel (7), R. Dahl, D. Naylor, R. Philips, G. Tompkins
- M. Cure (8), M. Caneo, A. Chacón, L. Cortes, O. Cuevas, C. Dougnac, A. Oyanadel, L. Illanes, J. Marín, D. Pozo
- R.Wilson (11), T. Butterley, J. Osborne
- E. Graham (12), A. Erasmus (13)

E-ELT FP6 - *Sites: Aklim, Izaña, Macon, ORM-DHV-MAGIC-Moradas*

- C. Muñoz-Tuñón (2), J. Castro-Almazán, J.M. Delgado, J.J. Fuensalida, B. García-Lorenzo, M. Reyes, A.M. Varela, H. Vázquez Ramió.
- D. García-Lambas (3), R. Arena, F. Bareilles, R. Bechler, V. Bertazzi, D. Ferreiro, H. Muriel, E. Lust, A. Otarola, P. Recabarren, V. Renzi, F. Stasyszyn, J. Viramonte, R. Vrech.
- Z. Benkhaldoun (4), A. Benhida, A. Bounhir, A.Habib, Y. Hach, A. Jabiri, M. Lazrek, A. Daassou, M. Sabil.
- J. Vernin (5), K. Ben Abdallah, A. Berdja, J. Borgnino, W. Dali Ali, J. Maire, F. Martin, H. Trinquet, A. Ziad.

TMT - *Sites: Armazones, Tolanchar, Vizcachas (under MOU with ESO)*

- M. Schöck (6), P. Gillett, A. Otárola, R. Riddle, W. Skidmore, T. Travouillon
- B. Blum (9), J. Araya, B. Gregory, S. Els, J. Seguel, D. Walker, J. Vasquez.

1. ESO, Garching, Germany
2. Instituto de Astrofísica de Canarias, Vía Láctea, E38205 - La Laguna (Tenerife). España
3. IATE, Observatorio Astronomico, Cordoba, Argentina
4. LPHEA, Faculté des Sciences Semlalia de Marrakech (FSSM), Marrakech, Moroco
5. UMR 6525 H. Fizeau, Université de Nice Sophia-Antipolis, CNRS, Observatoire de la Côte d'Azur, Parc Valrose 06108, Nice, France
6. TMT Observatory Corporation, 2632 E. Washington Blvd. Pasadena, CA 91107
7. University of Lethbridge, Department of Physics and Astronomy,4401 University Drive, Lethbridge, AB T1K 3M4, Canada
8. Grupo de Astrometeorología, Facultad de Ciencias, Universidad de Valparaiso, Av. Gran Bretana 1111, Casilla 5030, Valparaiso, Chile
9. Cerro Tololo Inter-American Observatory, Casilla 603 La Serena, Chile
10. Sternberg Institute Moscow, Russia
11. Durham Univerity, Durham, UK
12. University of Bern, Switzerland
13. SAAO, Cape Town, South Africa

Overview

- ESO and the E-ELT project
- Site Short listing
- Tools for Cloudiness Monitoring
- Tools for Cn2 Monitoring
- Open Questions
- Site Selection

An evolving organisation

The beginning...			Building up expertise...	Among world leaders	
1954	1962	1976	1989	1998	2008
ESO Declaration	ESO Convention	3.6-m Telescope	NTT	VLT	ALMA E-ELT ->

CERN

5 members

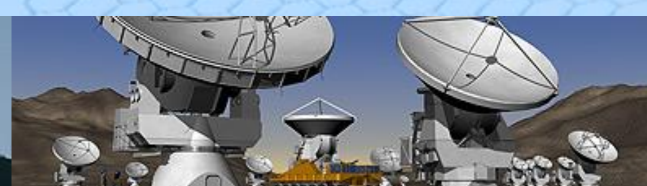
14 members, several others interested

US, Japan collaborations – A global world

769 staff (‘09)

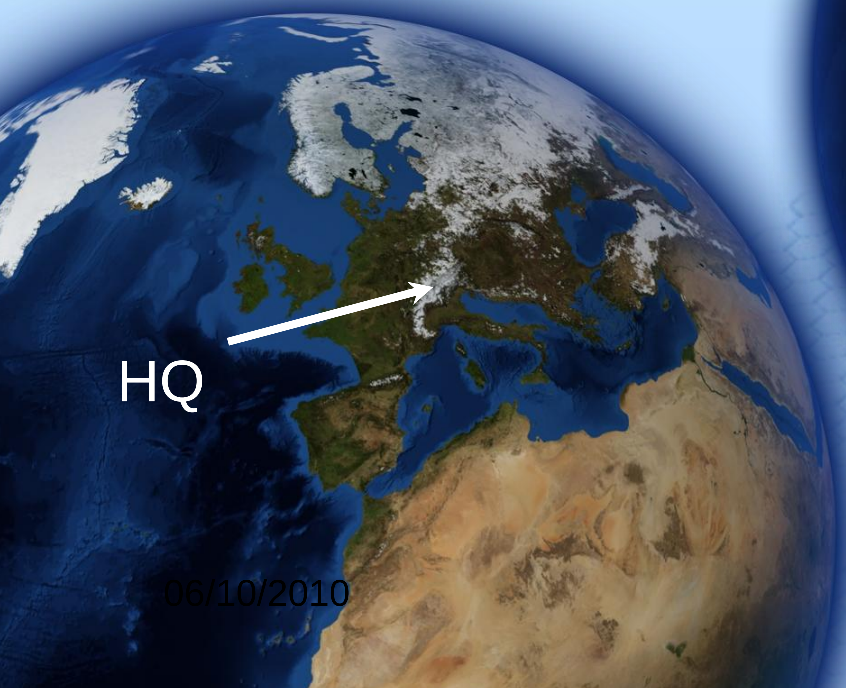
5 sites

Three Directorates


ESO’s observatory sites in Chile

- Paranal (2600 m)
- La Silla (2400 m)
- Chajnantor (5000 m)

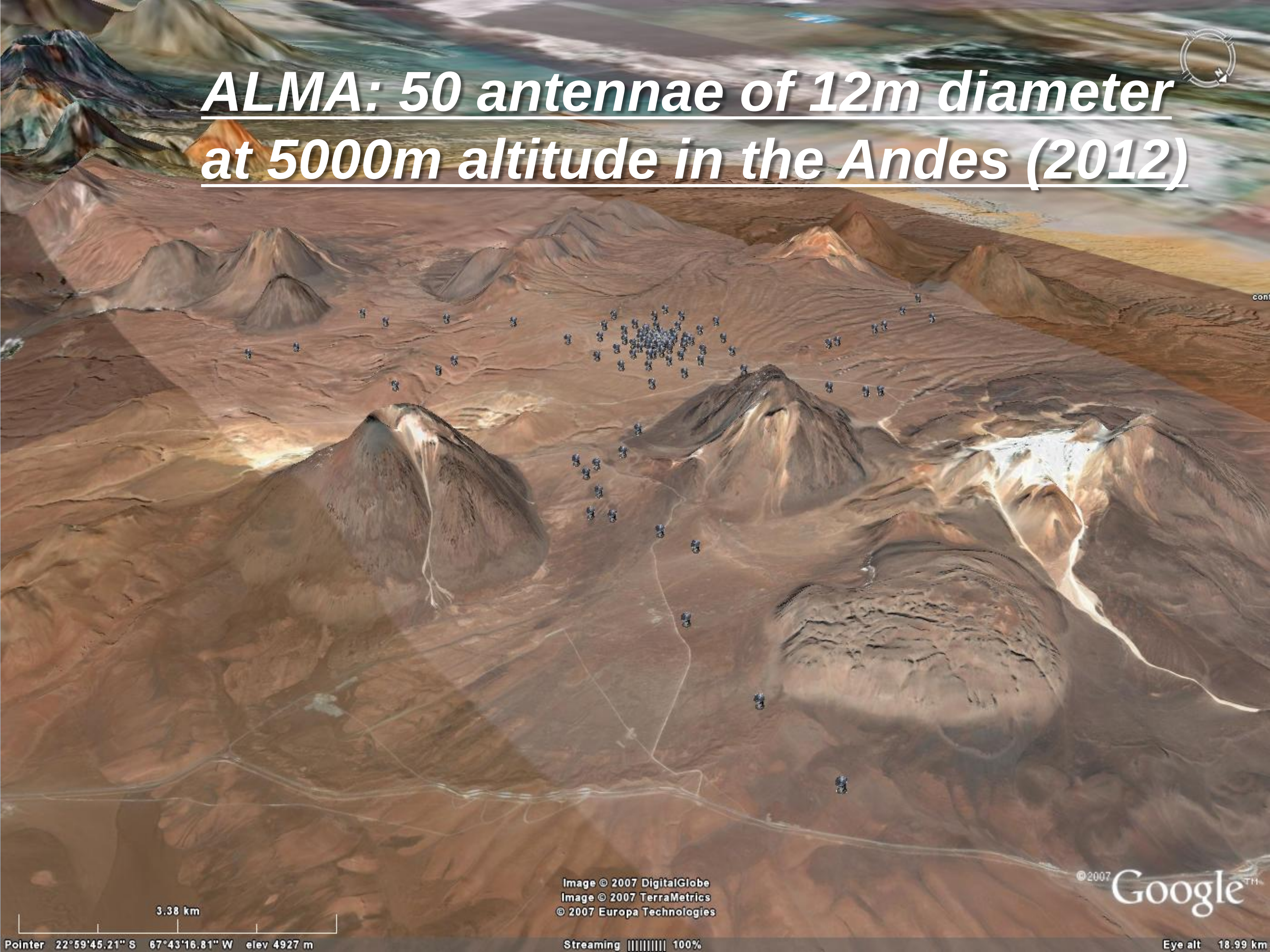


La Silla, ESO's first observatory site (1970)

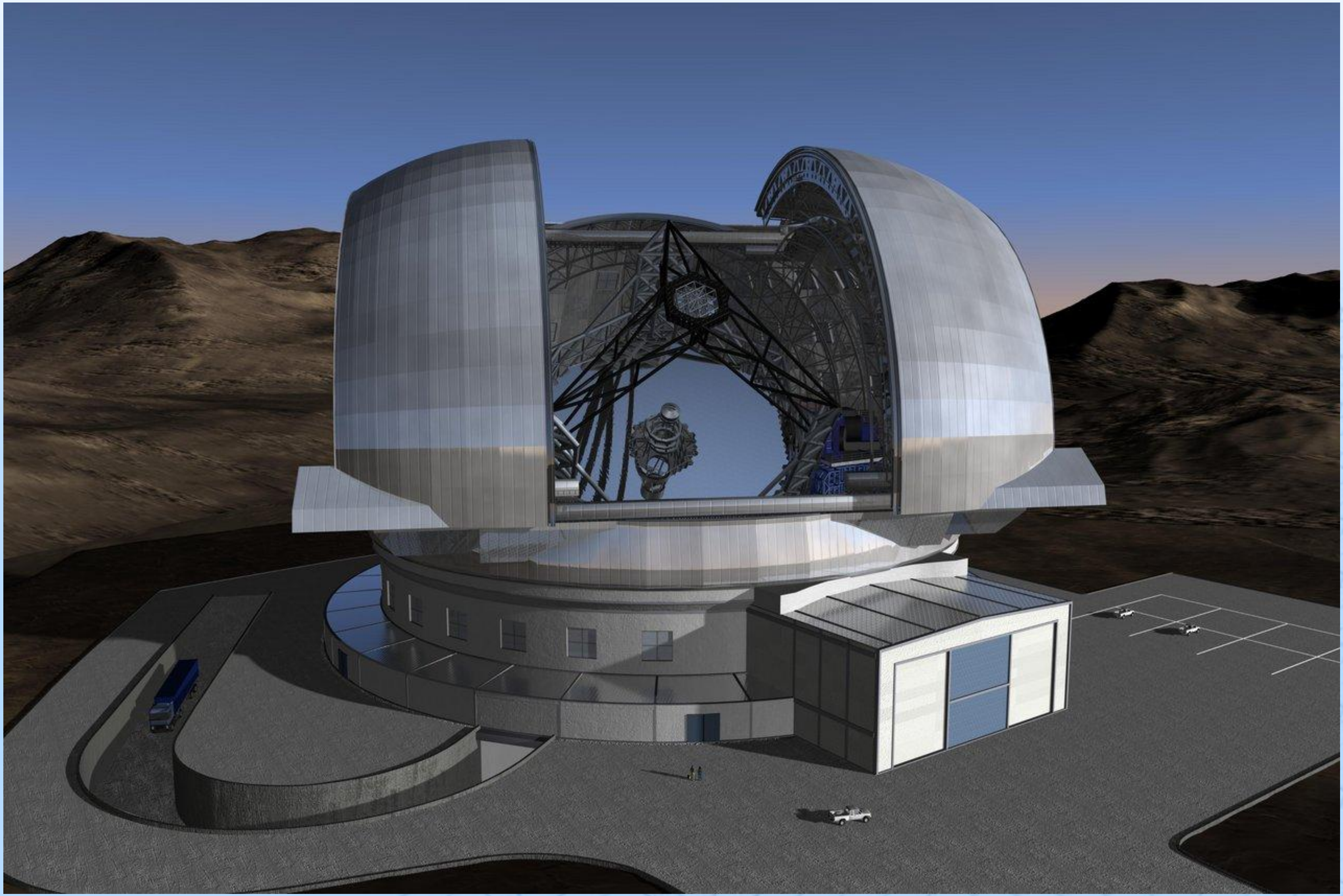
Paranal and the ESO Very Large Telescope (2000)

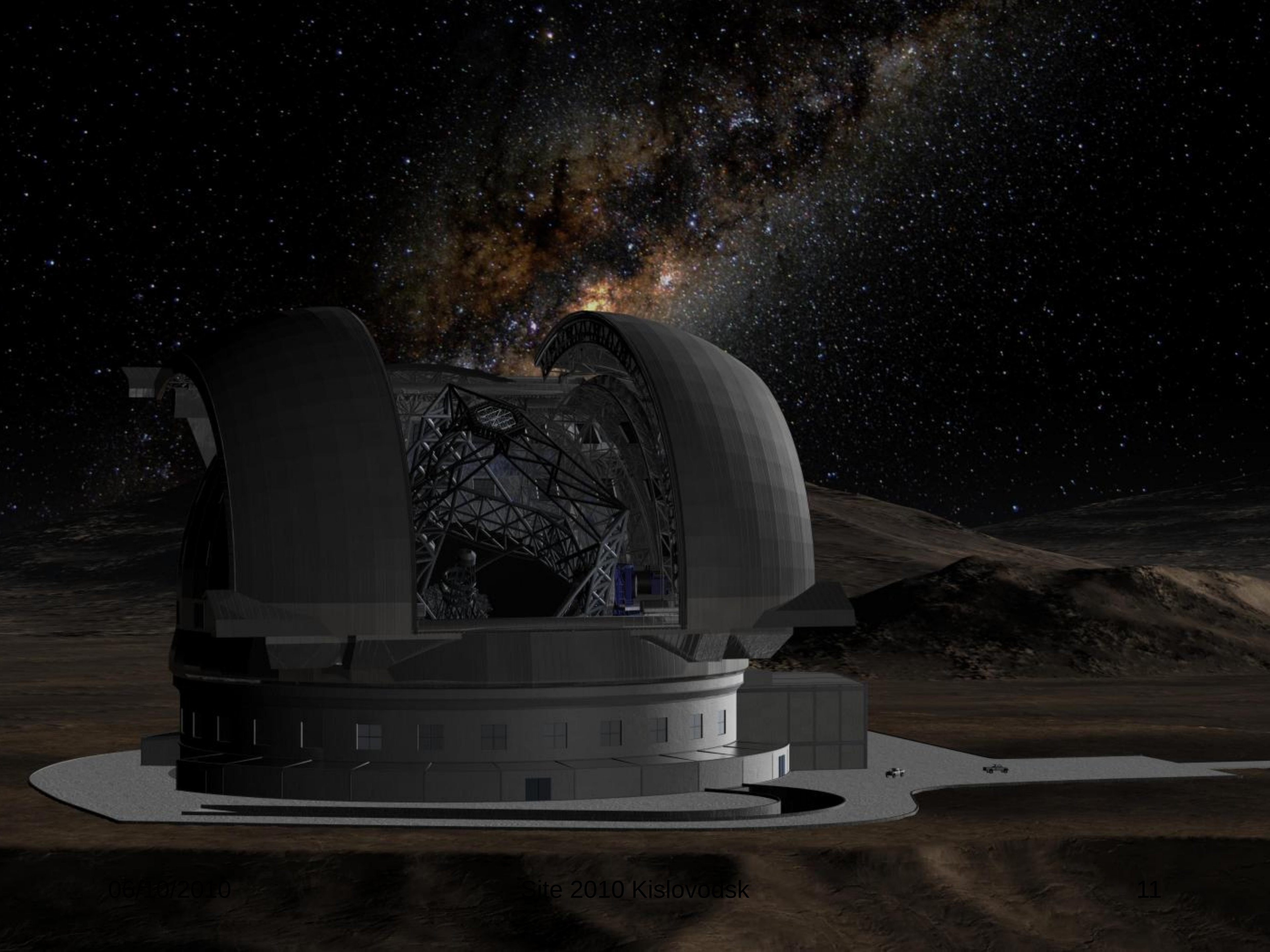
2600m in the Atacama Desert, the driest place on Earth.

ALMA: 50 antennae of 12m diameter at 5000m altitude in the Andes (2012)



European Extremely Large Telescope: E-ELT (2018)





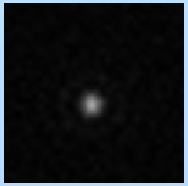
What will the E-ELT's vision be like?

Sites Short Listing

The need for a good telescope site: somewhere high and dry

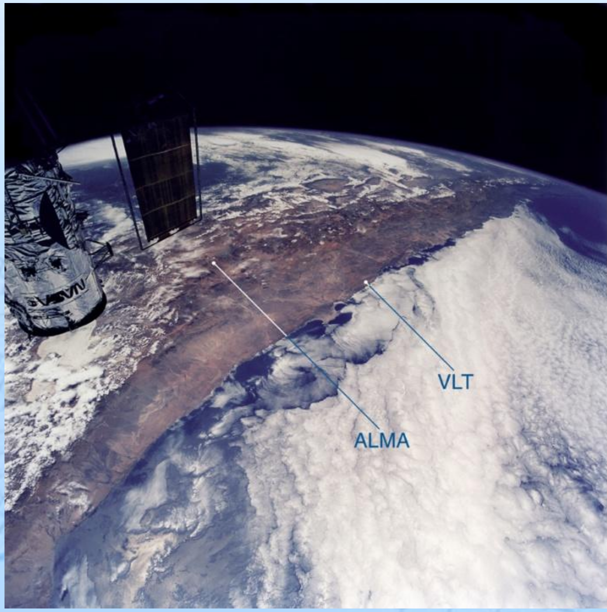
- Telescope observations are limited by turbulence in the atmosphere
- This is the same effect that makes stars "twinkle":

Poor site



Space

- It is extremely important to choose a good site for telescopes
- Typically a high, dry site with stable atmospheric conditions



Parameters for site selection

Atmosphere

- **Cloudiness**
- **Precipitable Water Vapour for IR**
- **Atmospheric Extinction**
- **Sky brightness**
- **Seeing or atmospheric coherence length, turbulence vertical profile**
- **Sodium layer density, for the laser guide star which is an artificial star used for Adaptive Optics correction**
- **Ground temperature, because of thermal IR radiation emitted by the telescope**
- **Wind speed on the ground; control of telescope problem**
- **Humidity, Precipitations (snow, rain, ice, fog);**

Site Characteristics

Soil properties, including typical stiffness,

- Seismicity
- Access to pre-existing infrastructures (roads, harbour, etc.); development costs
- local manpower costs.

Site evolution

- future potential light pollution
- long-term exposure to climate change
- potential long-term political stability.

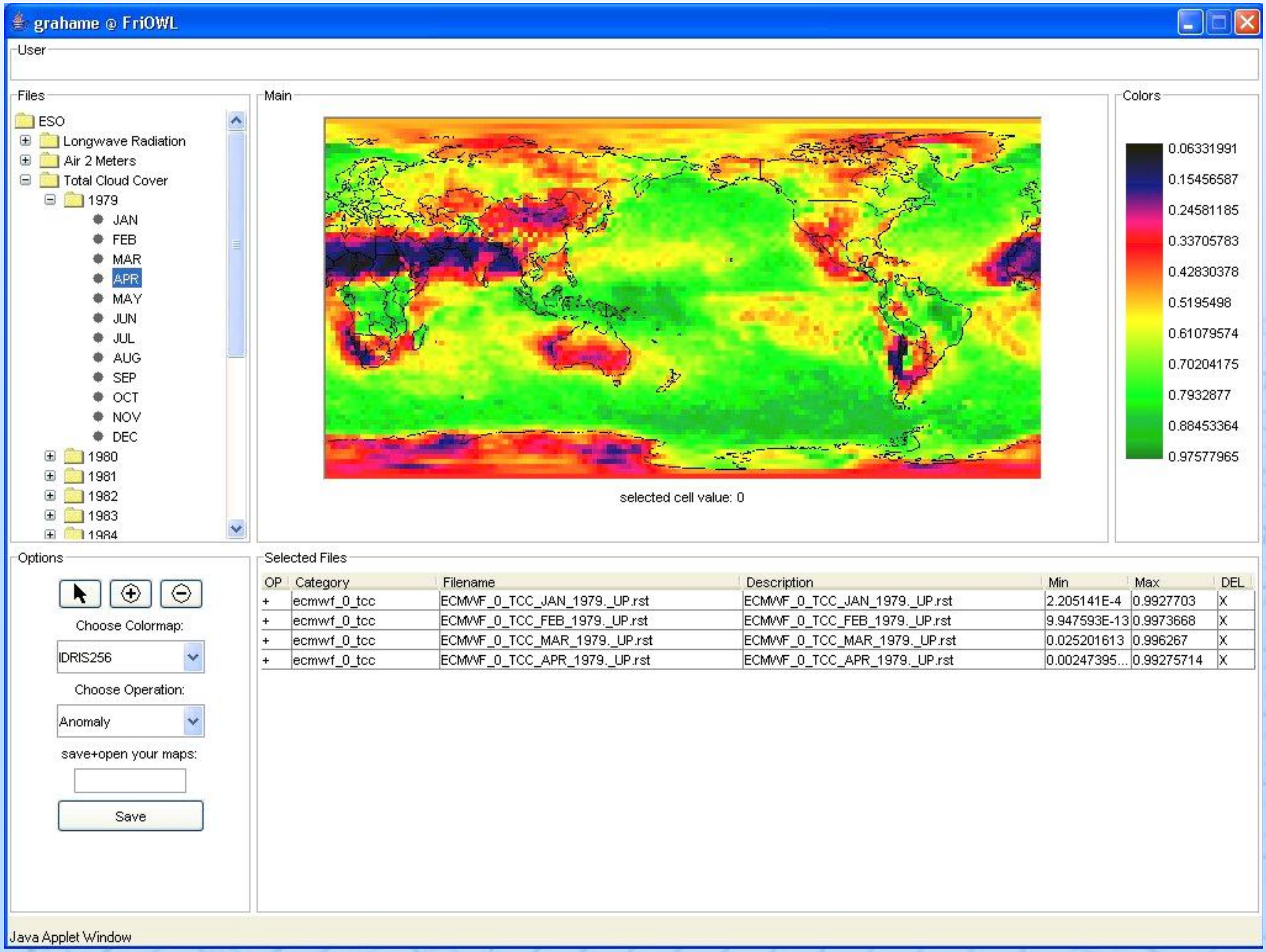
Possible Sites for Optical Astronomy

FRIOWL

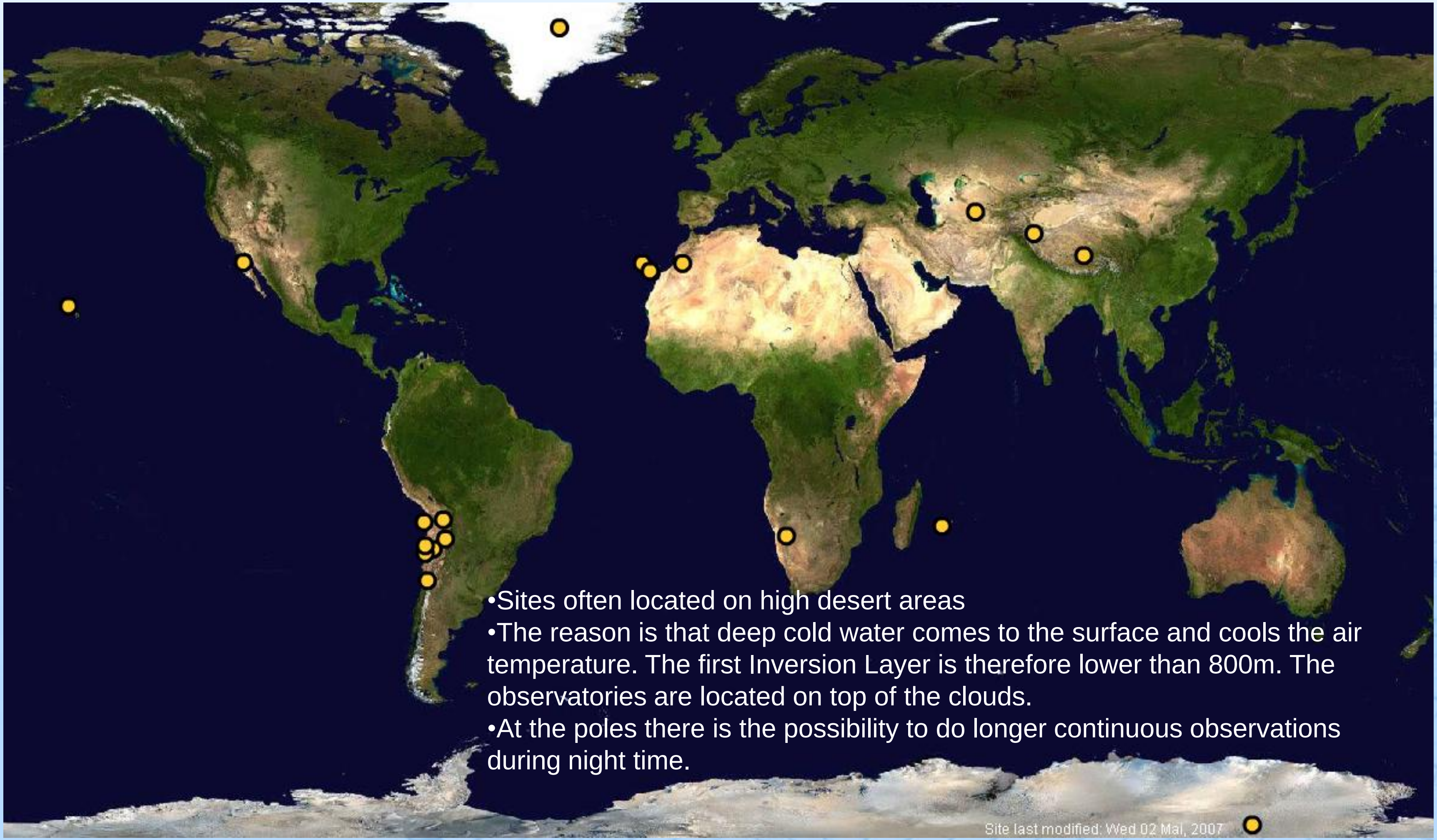
(E. Graham, PHD Thesis Fribourg-Bern Univ.)

A dedicated Geographic Information System

- Locate the most promising areas worldwide
- Analyze the variability of the relevant parameters
- Time span 15 years (45 years possible)
- Resolution Lat-Lon 2.5 degree, 300km



Possible Sites for Optical Astronomy

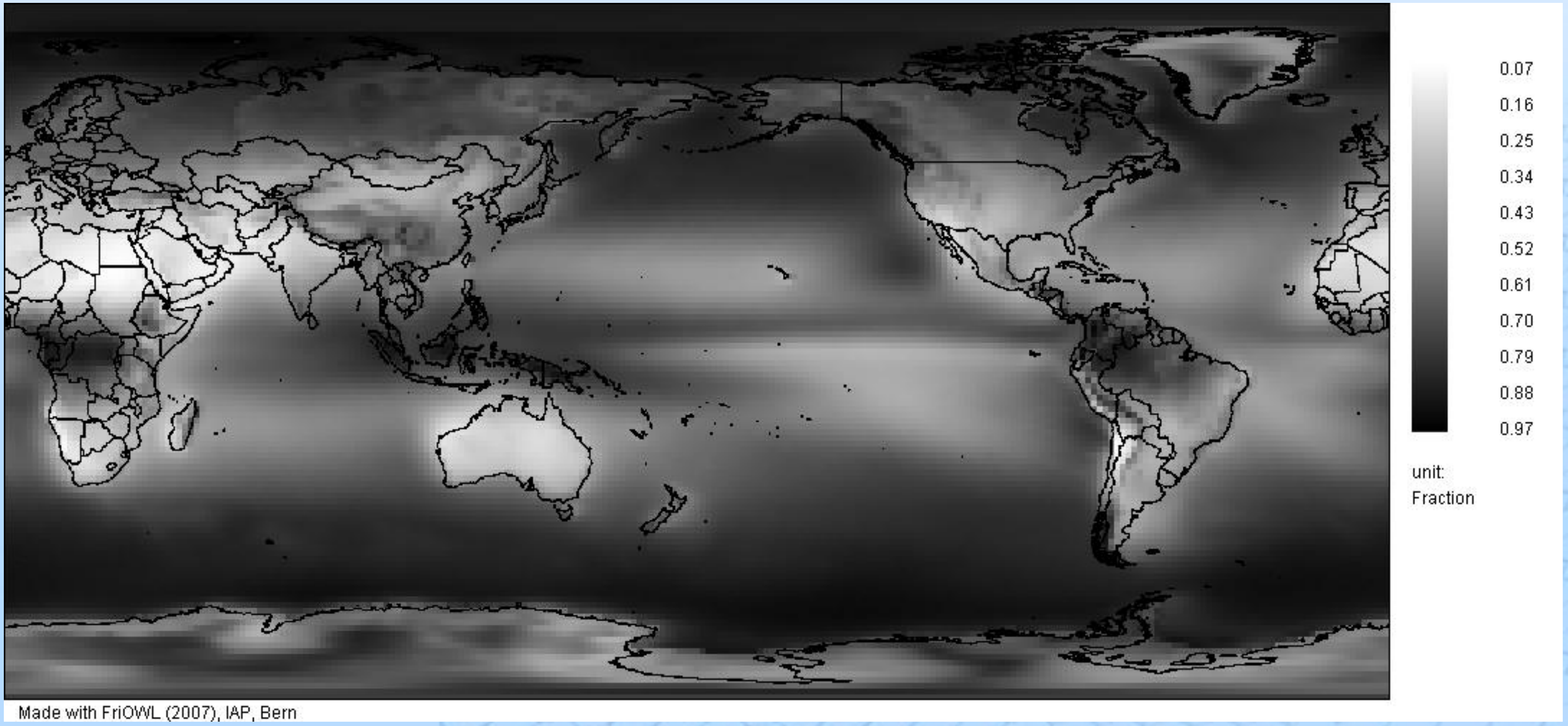


- Sites often located on high desert areas
- The reason is that deep cold water comes to the surface and cools the air temperature. The first Inversion Layer is therefore lower than 800m. The observatories are located on top of the clouds.
- At the poles there is the possibility to do longer continuous observations during night time.

Tools for Cloudiness Monitoring

(for PWV, see F. Kerber’s talk)

Total Cloud Cover from Global Models
ERA-Interim 1.5x1.5 degree
00&12 UTC, 1989-2009



Total Cloud Cover from Global Models
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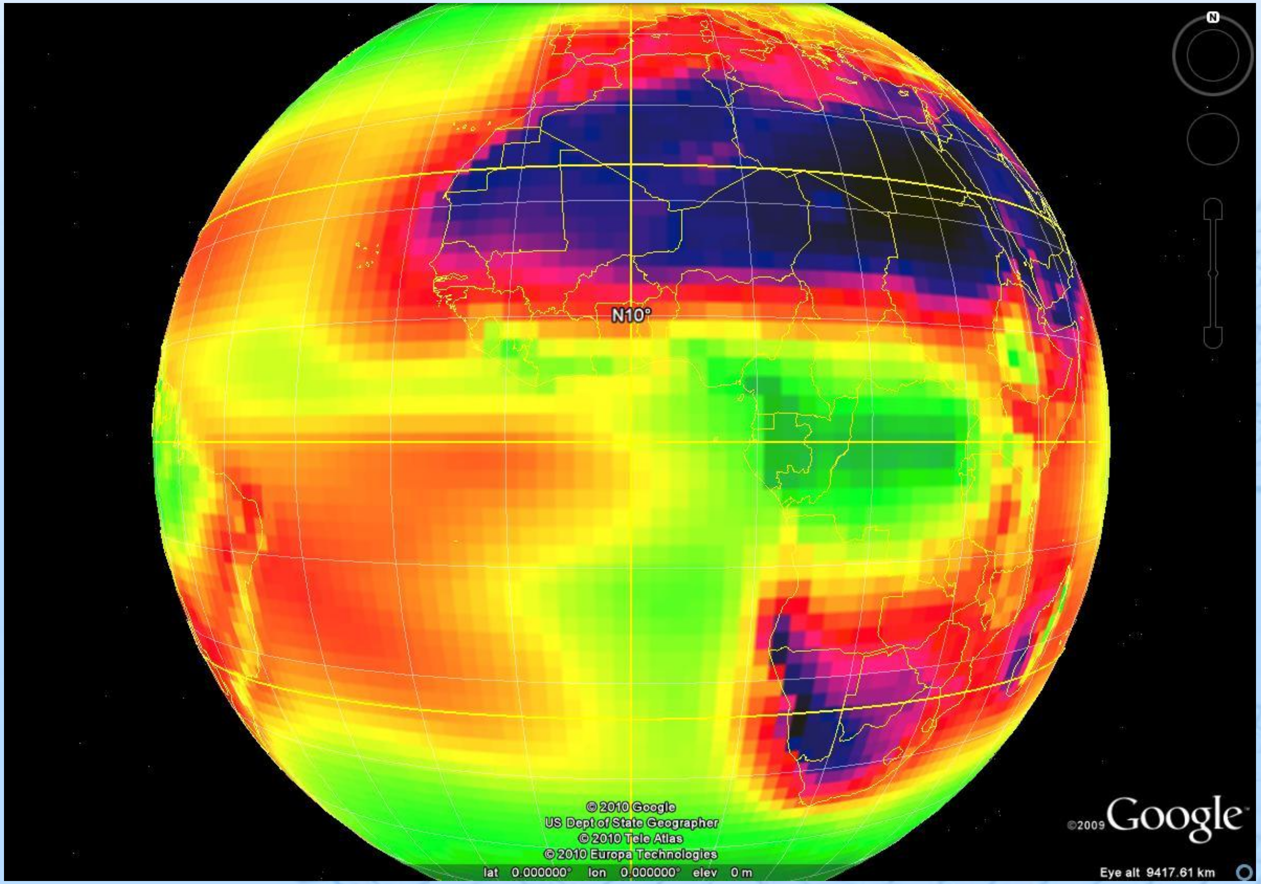

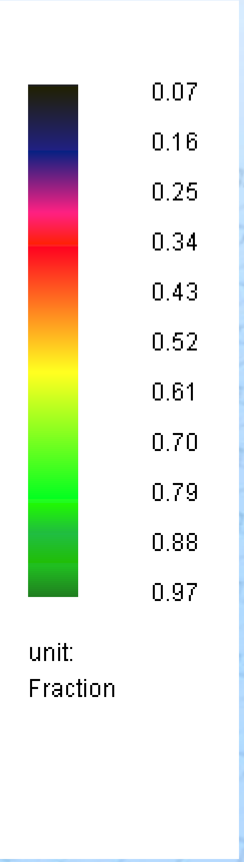

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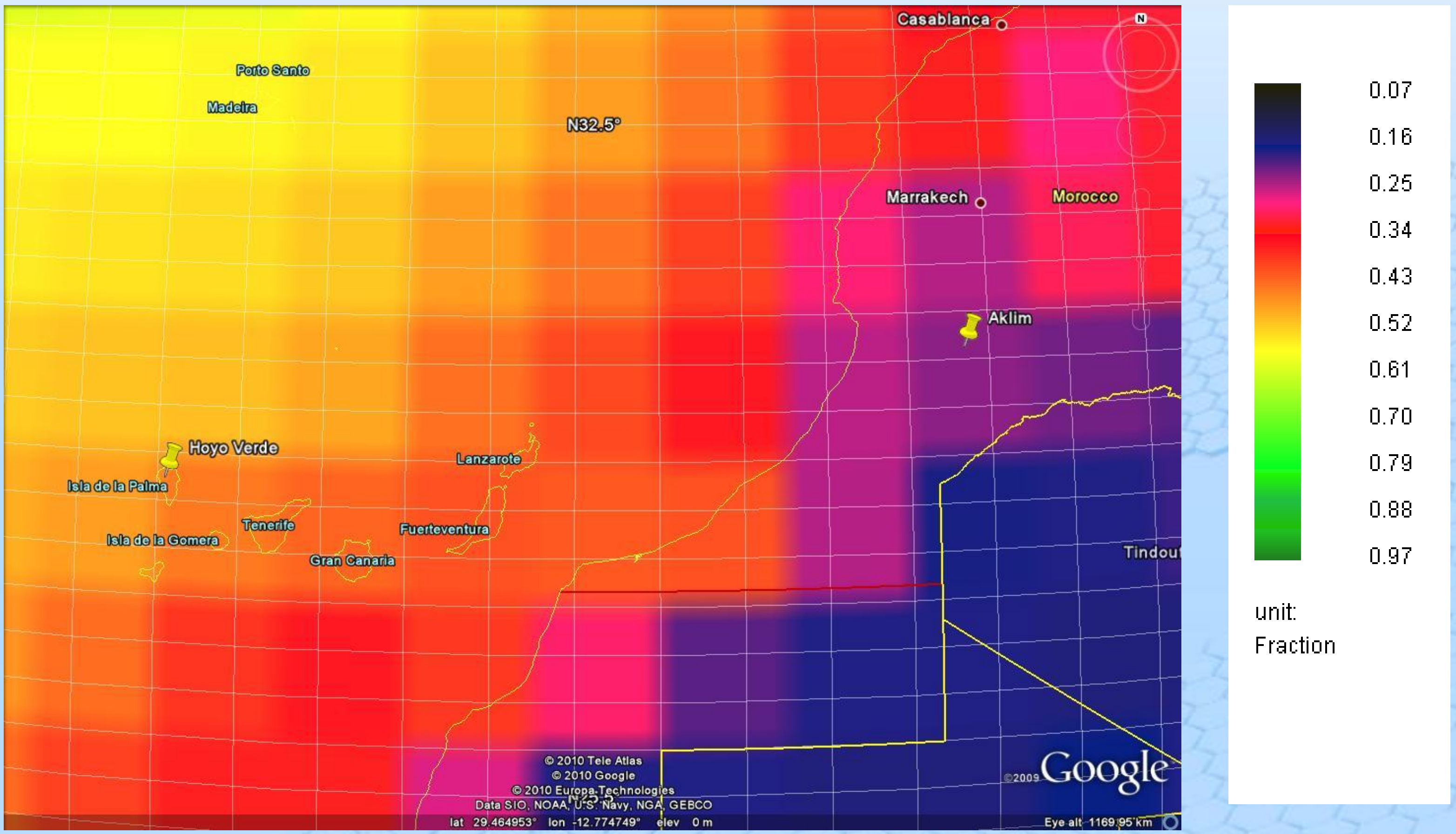
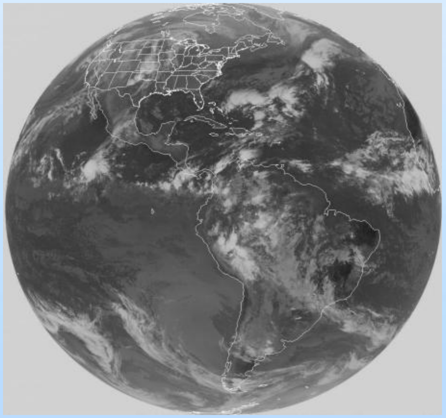
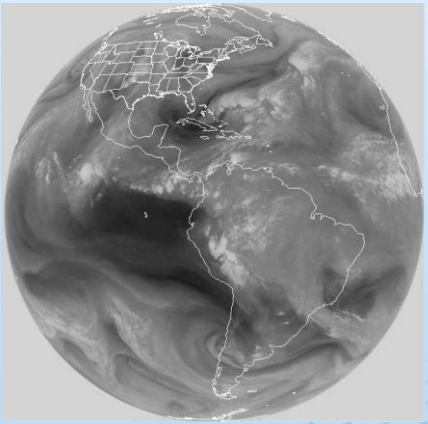


Nighttime Cloud Cover from GOES

Cloud and PWV extraction model developed by A. Erasmus, 1999-2002

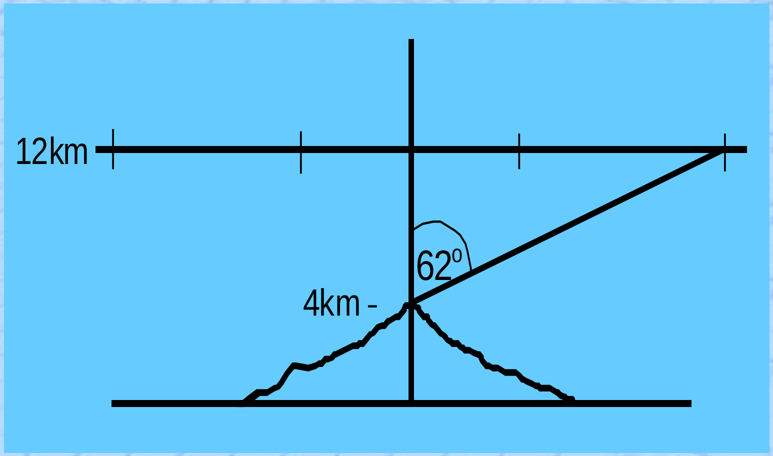
Infra-Red (10.7µm) & Water Vapor (6.7µm)





2	3	4
9	Site 1	5
8	7	6

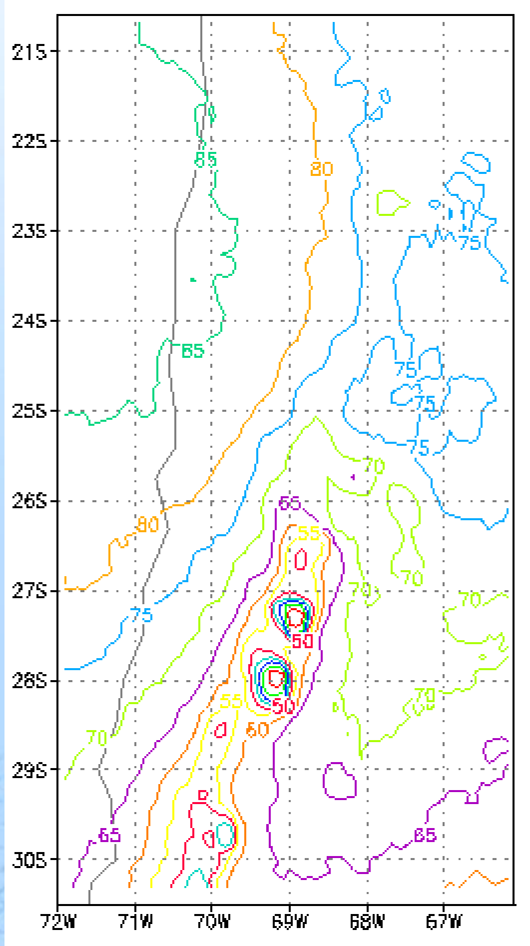
GOES
Meteorological
Satellites

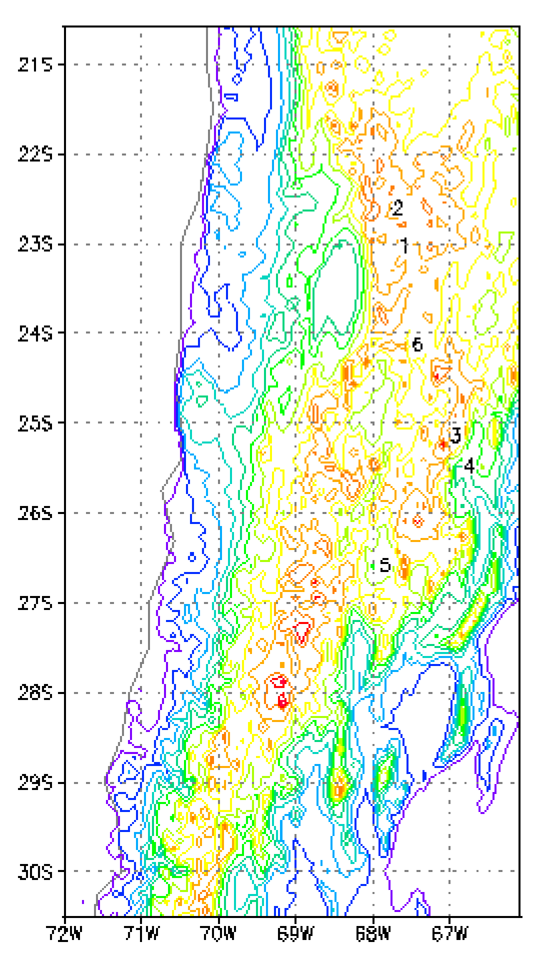


Nighttime Cloud Cover from GOES

4-years of GOES 3-hourly images analyzed by A. Erasmus in 2002

Period: July 1, 1993 to February 28, 1996 and June 1,1997 to August 31, 1999
(A. Erasmus, A Comparison Between Chajnantor (Chile), Chalviri (Bolivia) and Five Sites in Argentina using Satellite Data and a Verification of Satellite PWV measurements (ESO Report, Dec. 2002)





Argentina - Macon

ESO - Cordoba Observatory

Site Survey in Argentina

A MOU between ESO and the Observatory of Cordoba

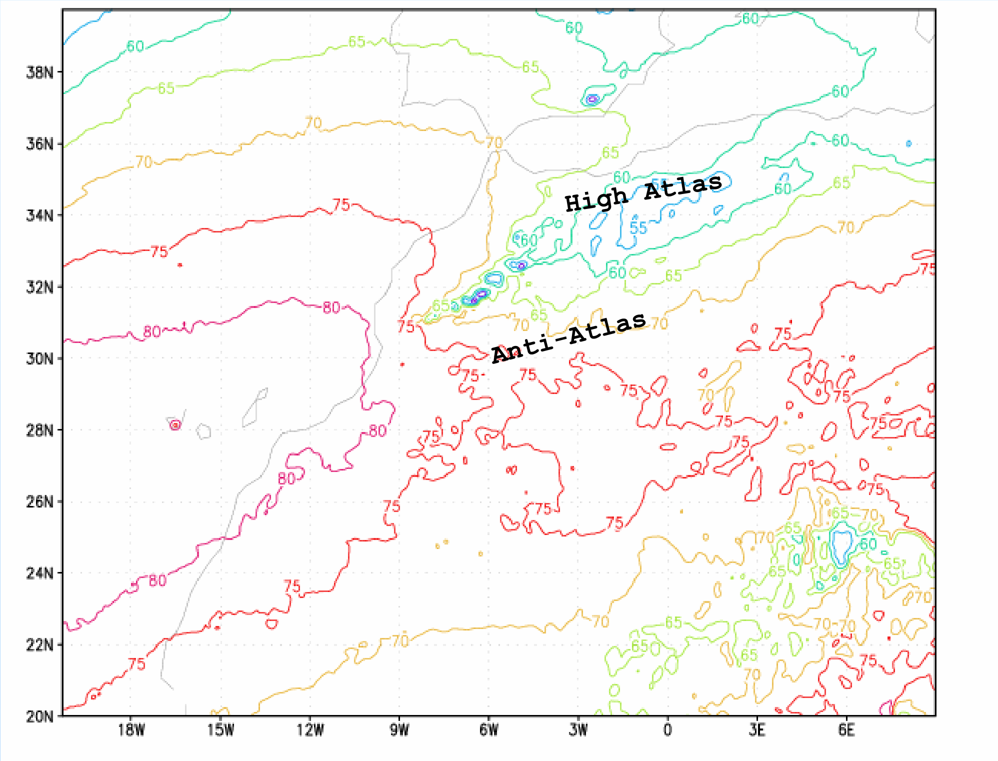
-step1:2002-2004
Select a candidate site

-step 2: 2004-2005
Monitor observing conditions

Credit: G. Hudepohl, ESO

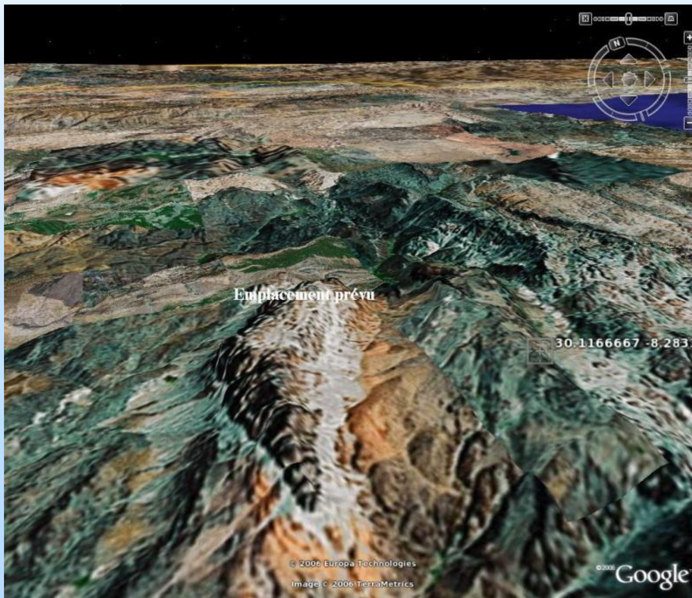
Nighttime Cloud Cover from METEOSAT

7-years of Meteosat 3-hourly images analyzed by A. Erasmus et al



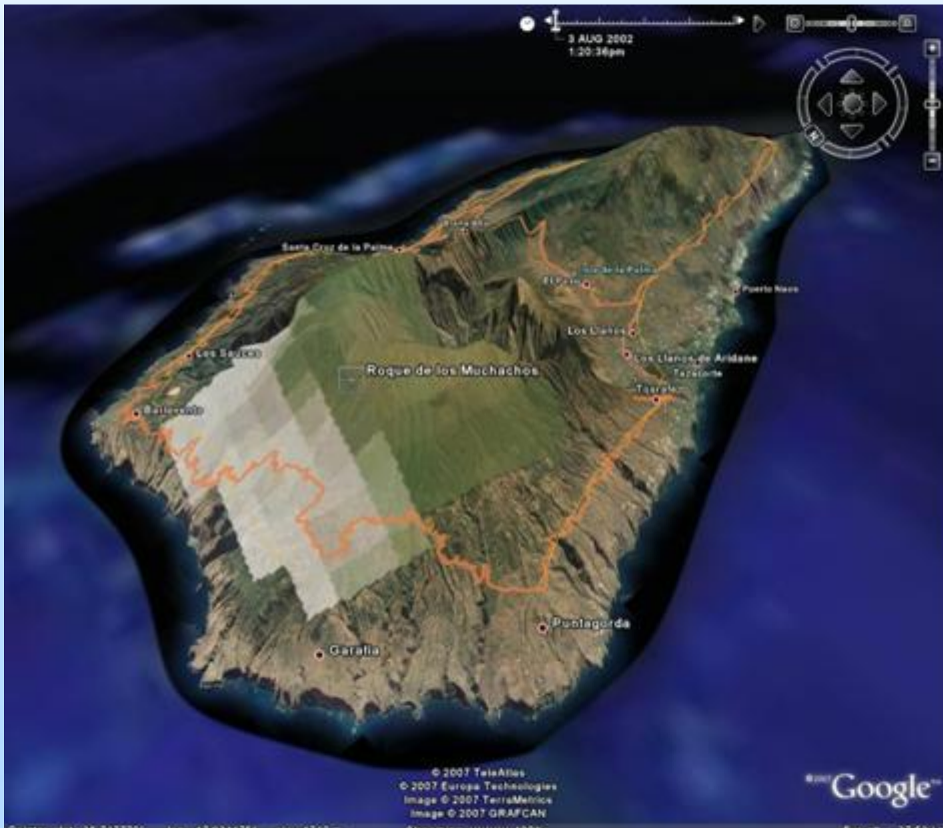
% of nighttime images that skies are clear for the years 1996 and 2002 over Canaries, NW Africa and Southern Spain (A. Erasmus, ESO final Report, Feb. 2006)

Aklim Mountain in Moroccan Anti-Atlas



Easy case:
No local sources of cloudiness

Daytime Cloud Cover with MERIS (ESRIN)

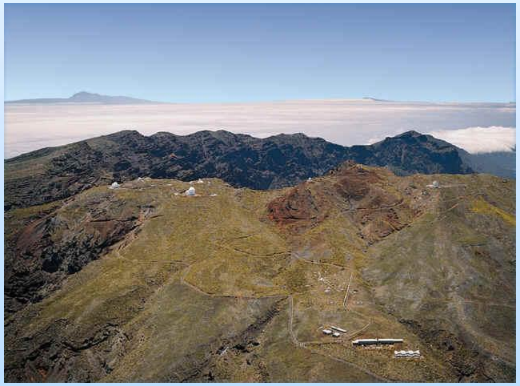


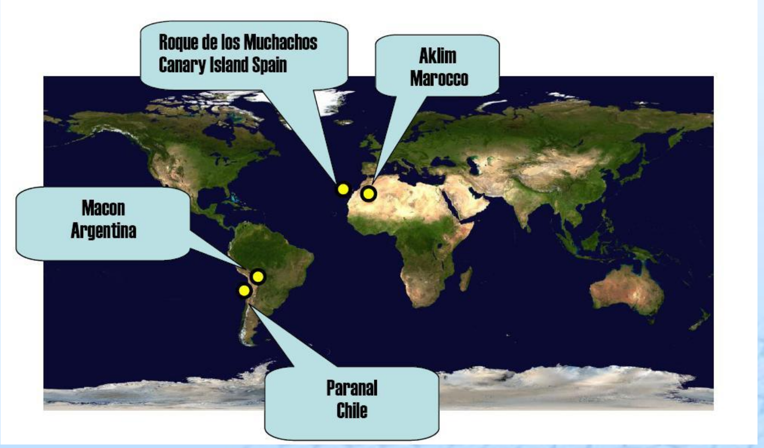

MERIS on board of ENVISAT

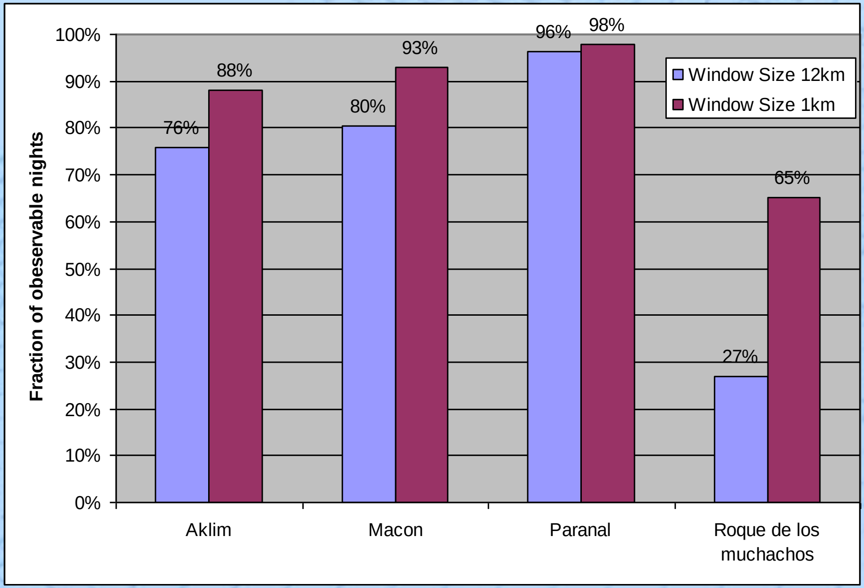
Analysis of the influence of spatial resolution:
La Palma is the most difficult case because of maritime inversion layer and caldera fog

SPIE6745-07, 2007
H. Kurlandczyk & M.Sarazin

Daytime Cloud Cover with MERIS (ESRIN)





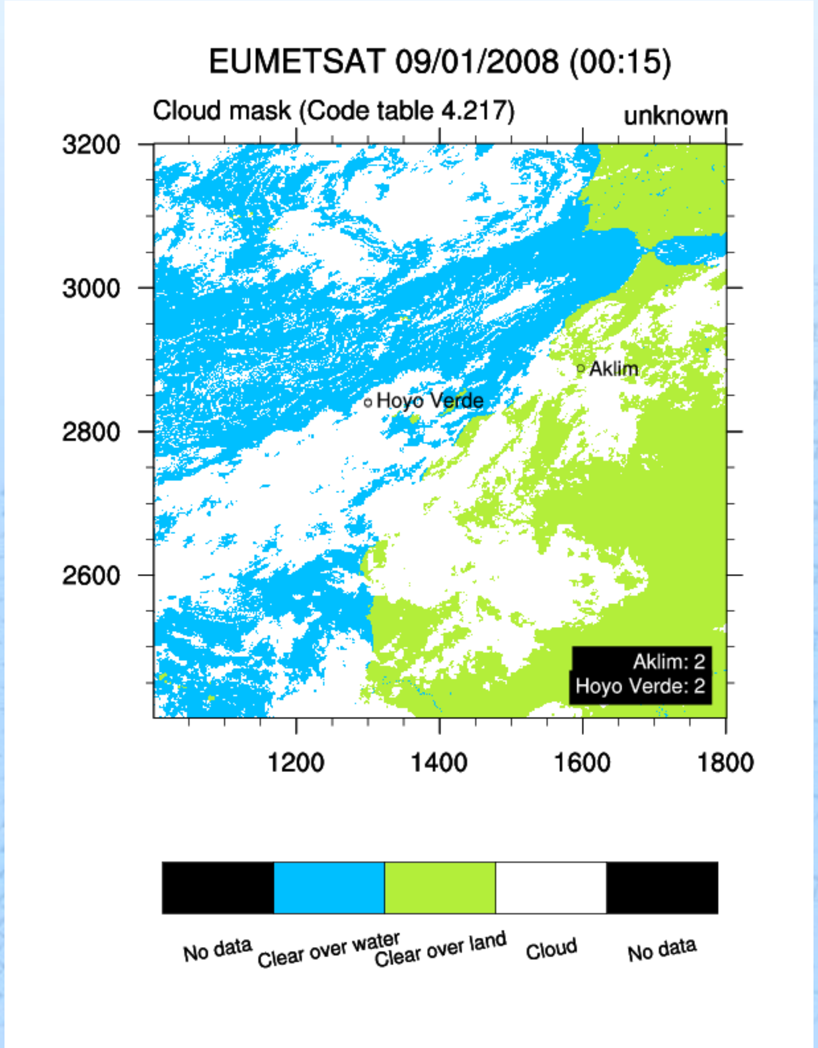


SPIE6745-07, 2007
H. Kurlandczyk & M.Sarazin

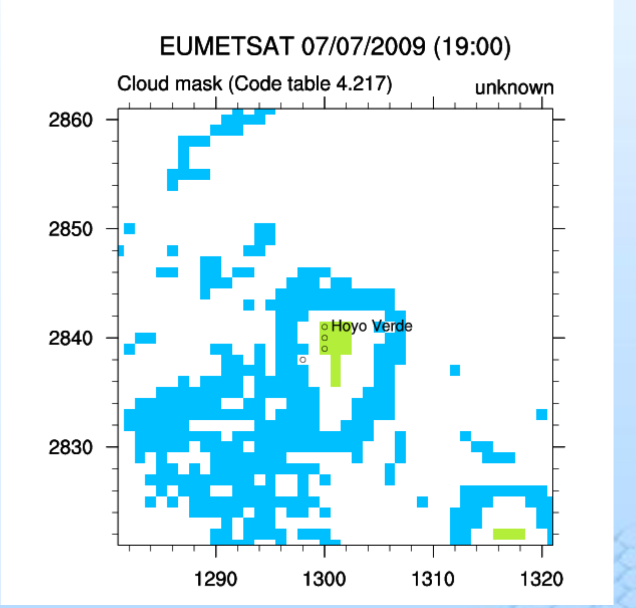
Nighttime Cloud Cover with METEOSAT II (EUMETSAT)

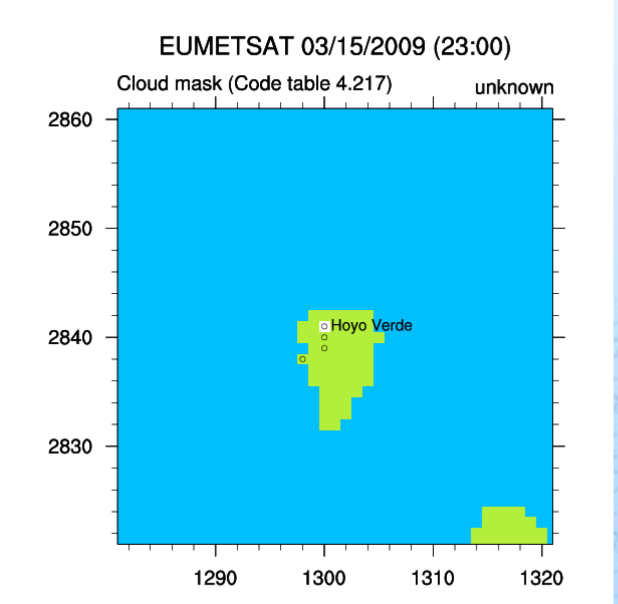
The current generation of geostationary Meteosat (Meteosat Second Generation – MSG-SEVIRI) has 12 channels with a horizontal resolution of 3 km at the sub-satellite point and an image repeat cycle of 15 minutes

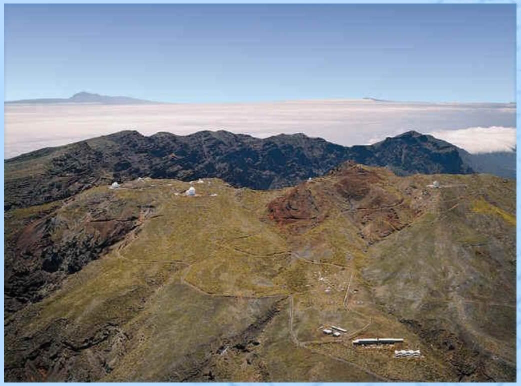
The EUMETSAT scenes analysis derives a cloud mask (cloud/no cloud decision) for each pixel



Nighttime Cloud Cover with METEOSAT II (EUMETSAT)

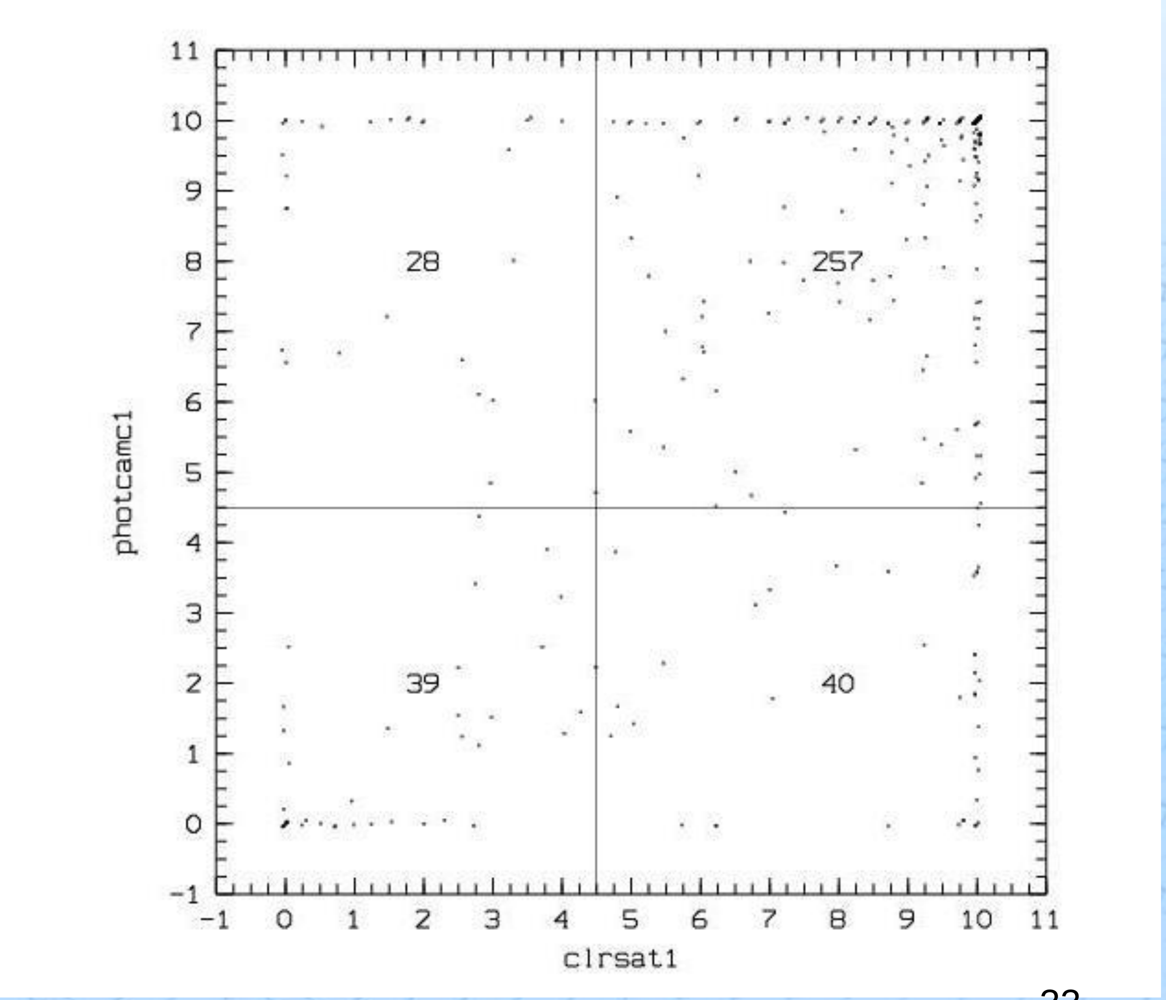






Nighttime Cloud Cover with METEOSAT II (EUMETSAT)

ORM: Comparison of the number of clear hours per night from CAMC ground based (vertical) and satellite (horizontal) observations in the period April 2008 to April 2009.



Clear night statistics: 81% agreement, 8% missed clouds and 11% false alarms

Working Together

The E-ELT Design Study

A technology development program funded by the European Community under its Framework Program 6

E-ELT Design Study
Site Characterization WP12000

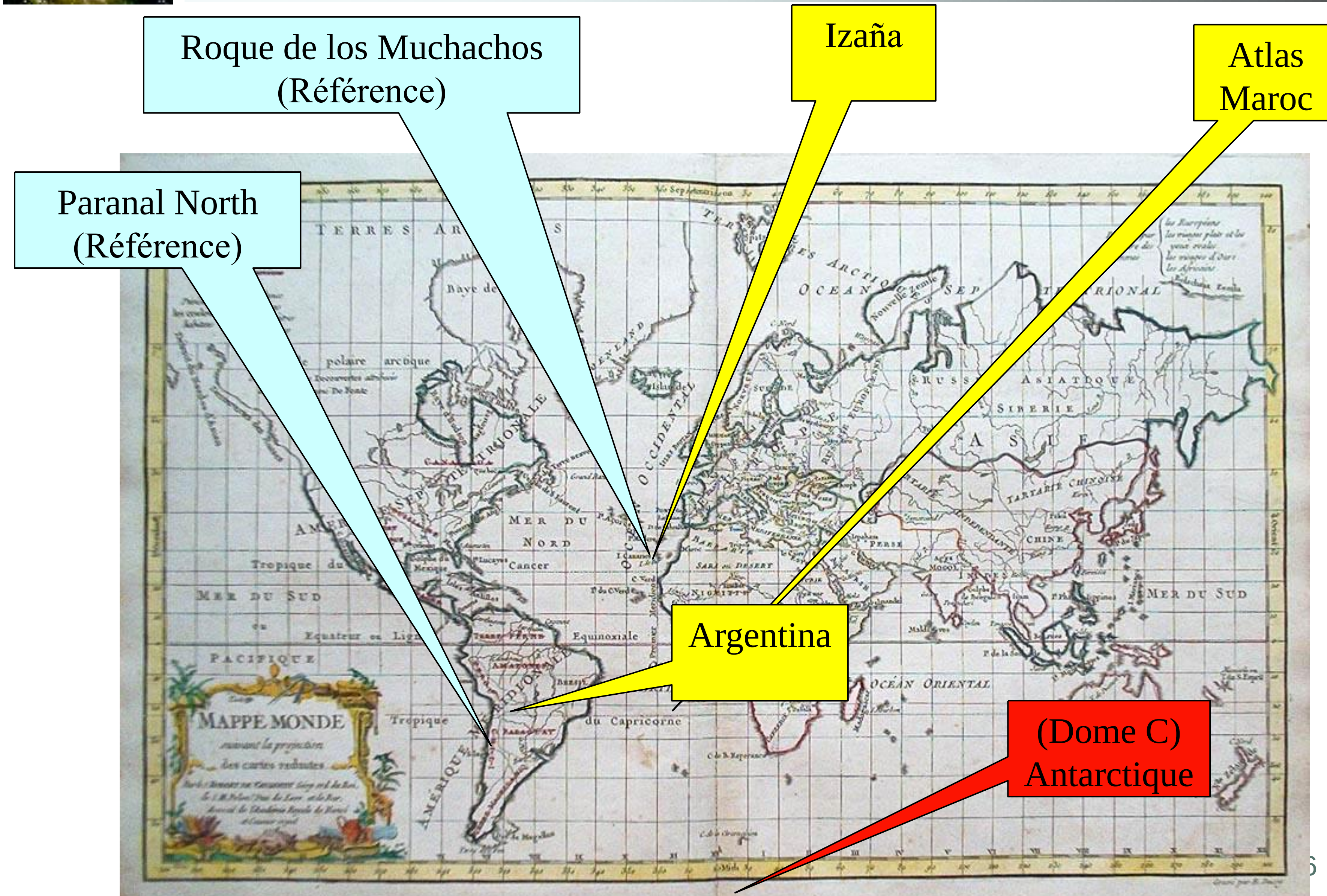
WM:Jean Vernin, WD:C.Muñoz-Tuñón, M.Sarazin 10/03/05

Summary from January 2005 to June 2009

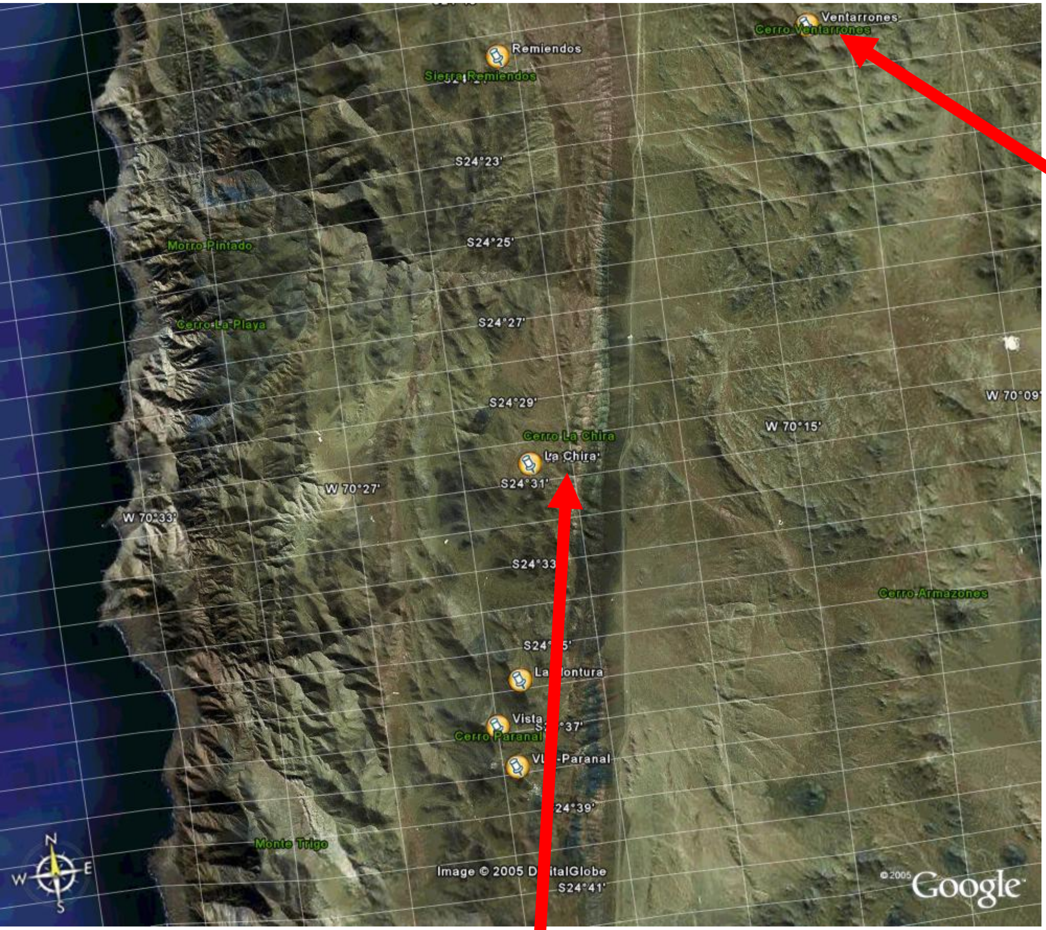
First brainstorming in Nice July 2003
Backaskog Meeting Sept. 2003 (CMT)
Various iterative proposals to PD
First progress meeting ESO 10 March 2005
First WP12000 Progress meeting Nice
First financing Sept. 2005
« Blue book »
First MASS-DIMM measurements April 2008
Last processed MASS-DIMM measurements May 2009
Final report « All site observations » June 2009

ELT Design Study – Contract No 011863
A technology development programme funded by the European Community under its Framework Programme 6

Site Selection Overall Philosophy



ParanalNorth:La Chira->Ventarrones



Cerro Ventarrones
24.24S-70.25W
2837m

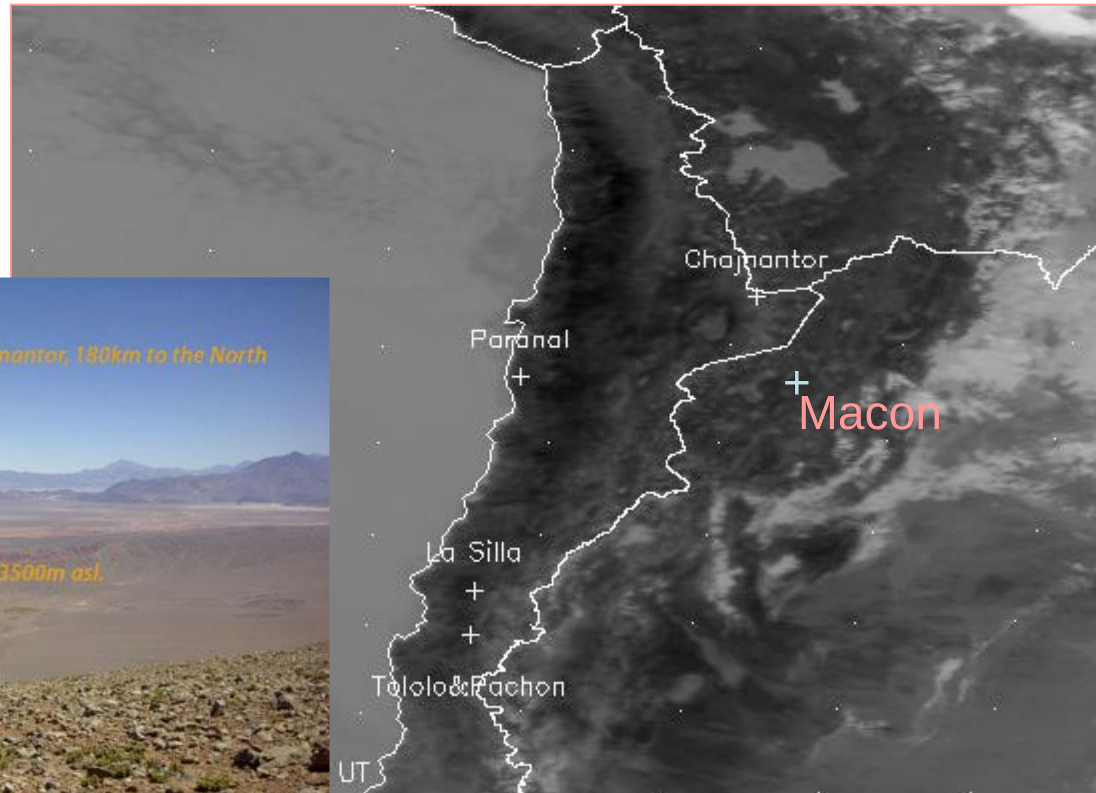
Cerro La Chira
24.5S-70.3W
2559m

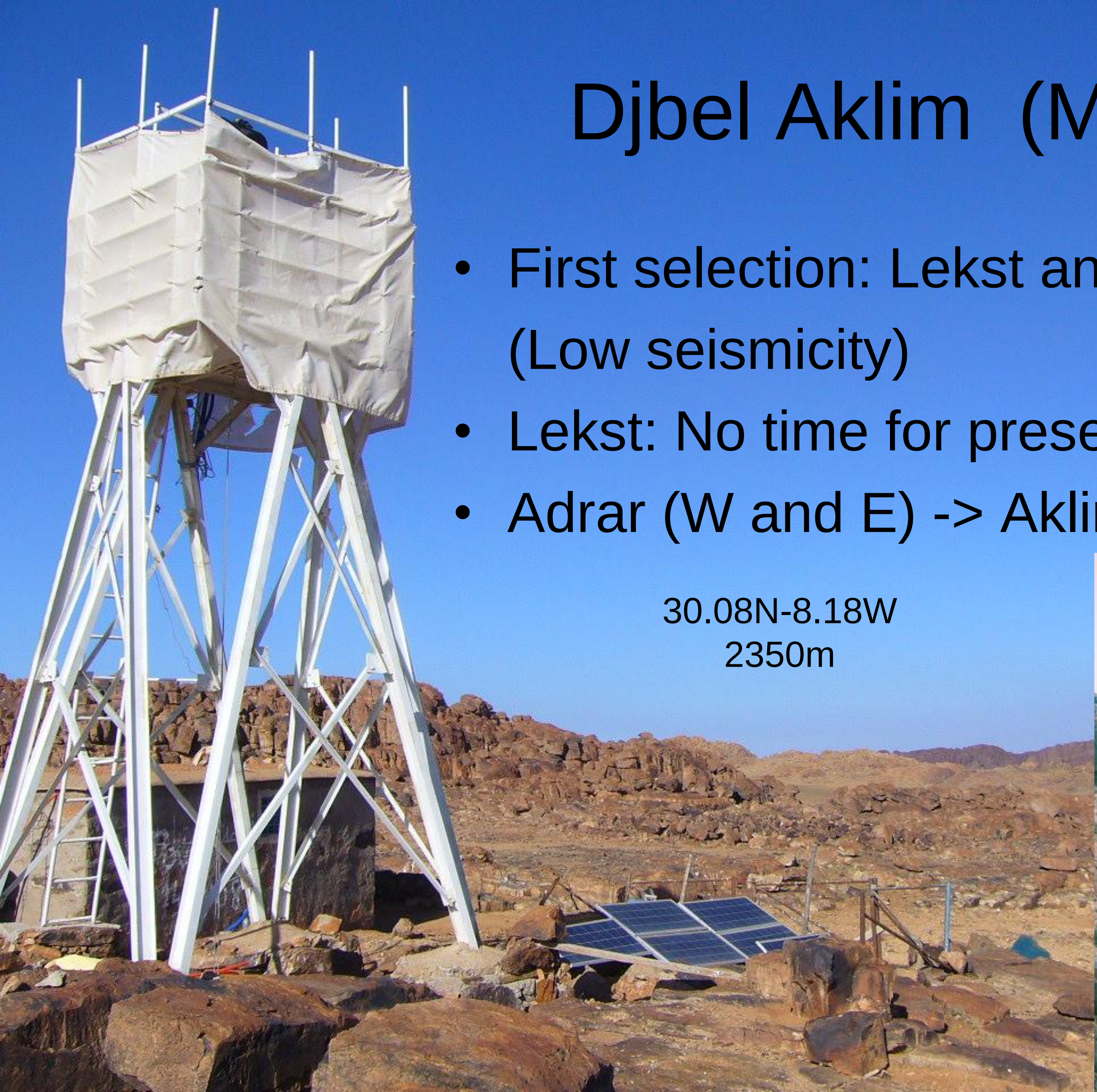
ORM: Degollo Hoyo Verde

ORM
28.45N-17.53W
2346m

Macon (Argentina)

Candidate site:
Macon Range (4500-5500m)
monitoring station, 4680m
24.5S-67.25W
Base Camp: Tolar Grande
150 ha





Djbel Aklim (Morroco)

- First selection: Lekst and Adrar (Low seismicity)
- Lekst: No time for preselection
- Adrar (W and E) -> Aklim West

30.08N-8.18W
2350m

Working Together

MOU ESO-TMT for sharing site data in Northern Chile

Cerro Armazones
&
Cerro Tolanchar

Working Together

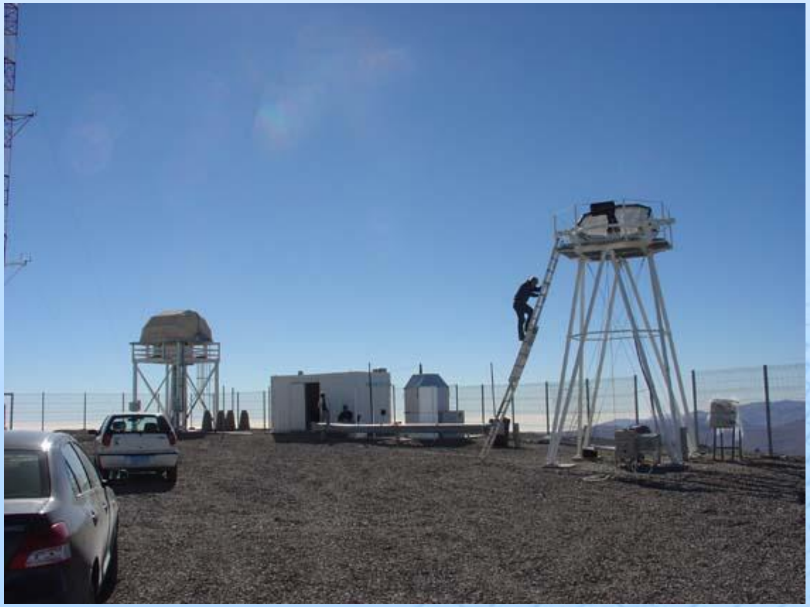
MOU ESO-TMT for operating a TMT station on an ESO site

Cerro Vizcachas (La Silla)

Cn2 measurements routine monitoring

MASS-DIMM

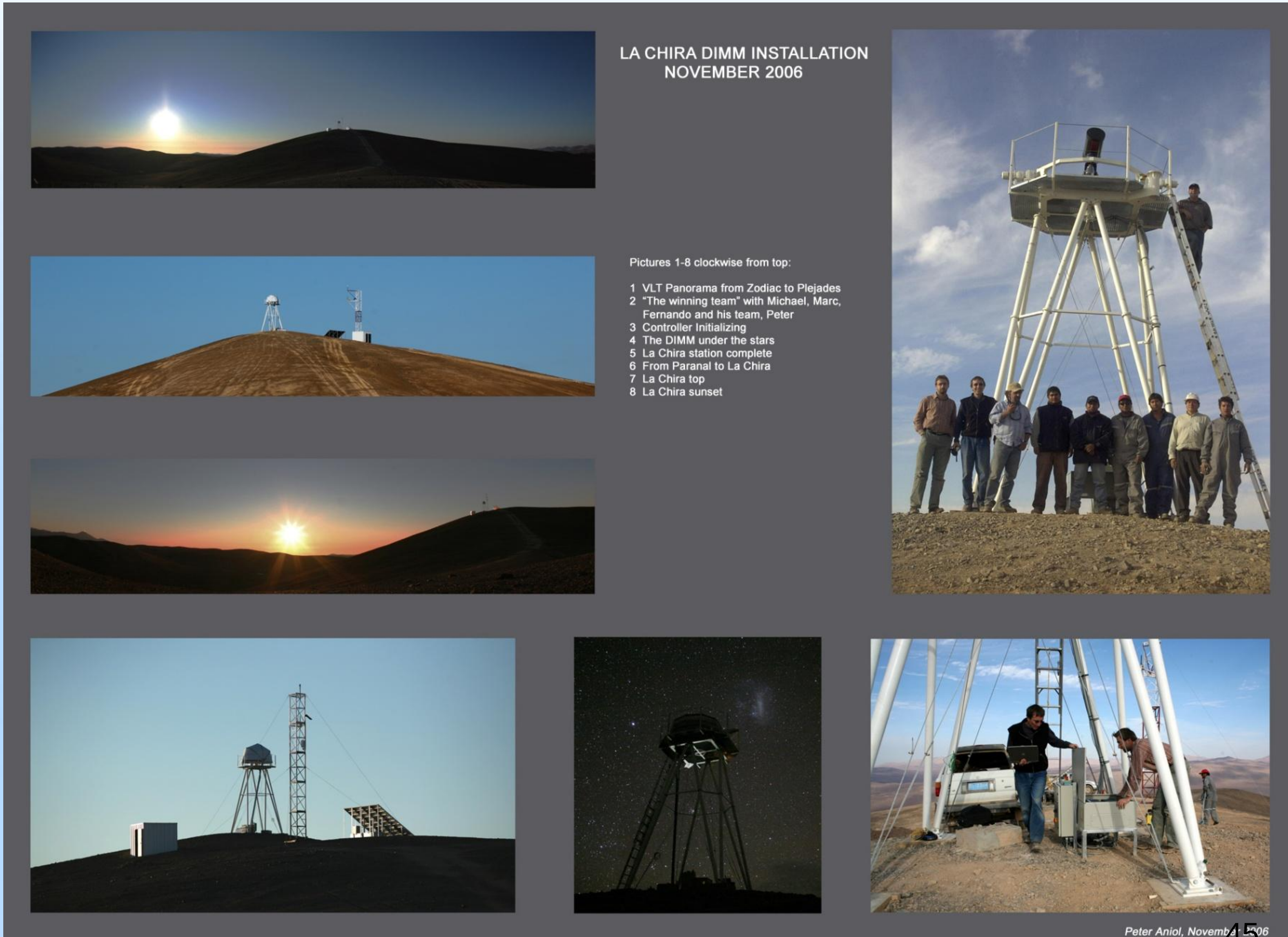
2006: instrumentation & infrastructure
2007: monitoring starts



Preparation of La Chira station: cross-comparison with Paranal ASM, July-October 2006

Victor Kornilov (Sternberg, Moscow) assembling the 4 ELT-DS MASS-DIMM instruments in June 2006

Standard Site Monitoring Station



Managing Diversity

4 different DIMM systems + 1 calibrator

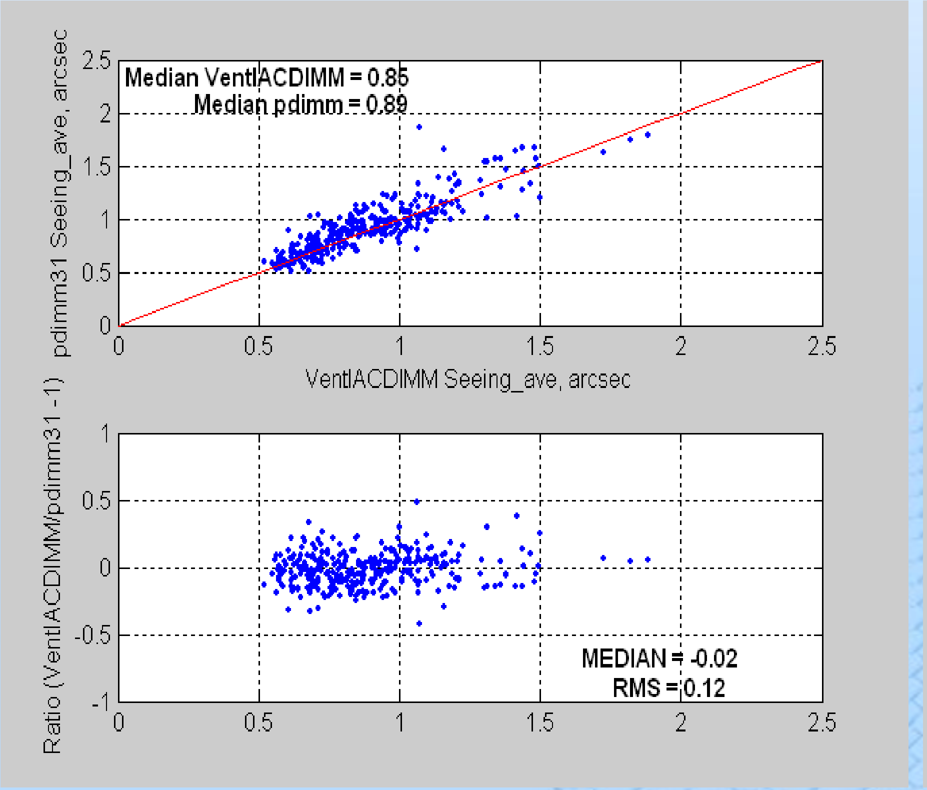
ASMDIMM	Paranal, La Silla
IACDIMM	ORM
FP6DIMM	Aklim, Macon, ORM, Ventarrones
TMTDIMM	Armazones, Tolonchar, Vizcachas
TURDIMM	mobile

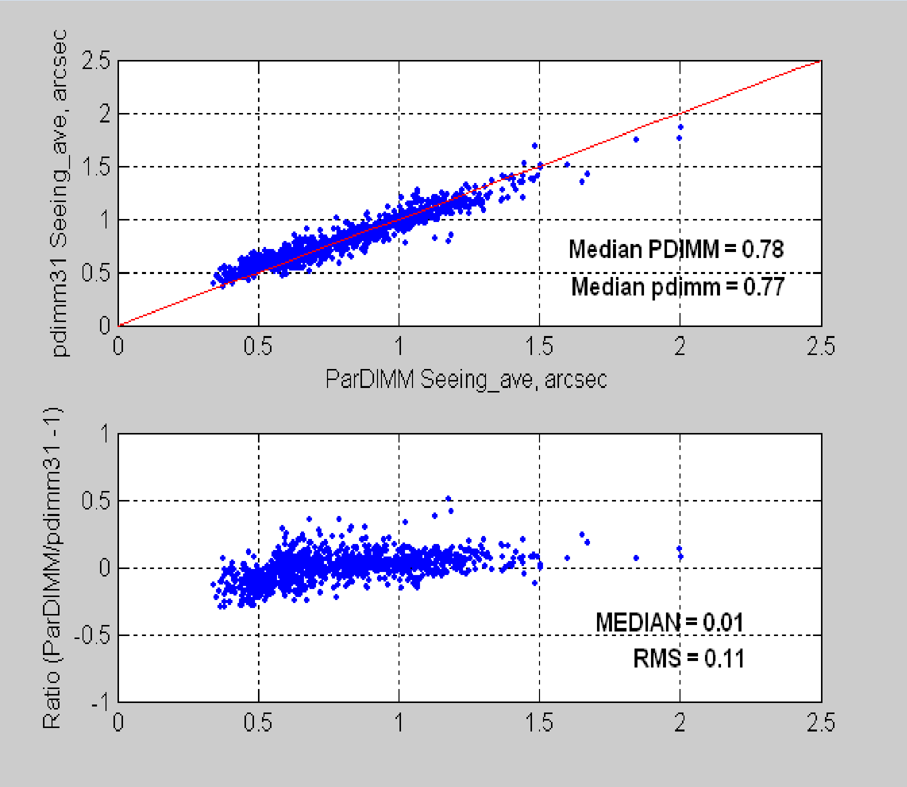
Plate scale (arcsec/pix)

DIMM (pixel size, mu)	C11+Mask	MASS_DIMM	ASM	C8+Mask
FP6DIMM (9.9)	0.71	0.87		
IACDIMM (7.4)				0.80
TURDIMM (7.5)	0.58	0.66		
TMTDIMM (9.0)		0.78		
ASMDIMM (22.0)			0.81	

Managing Diversity

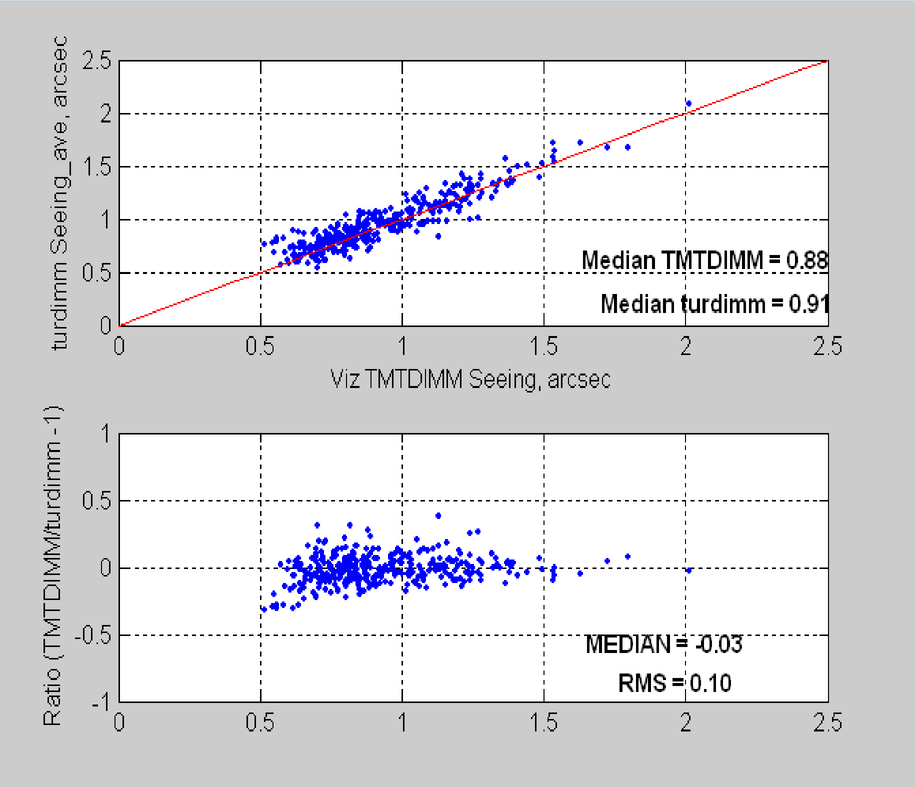
4 different DIMM systems + 1 calibrator

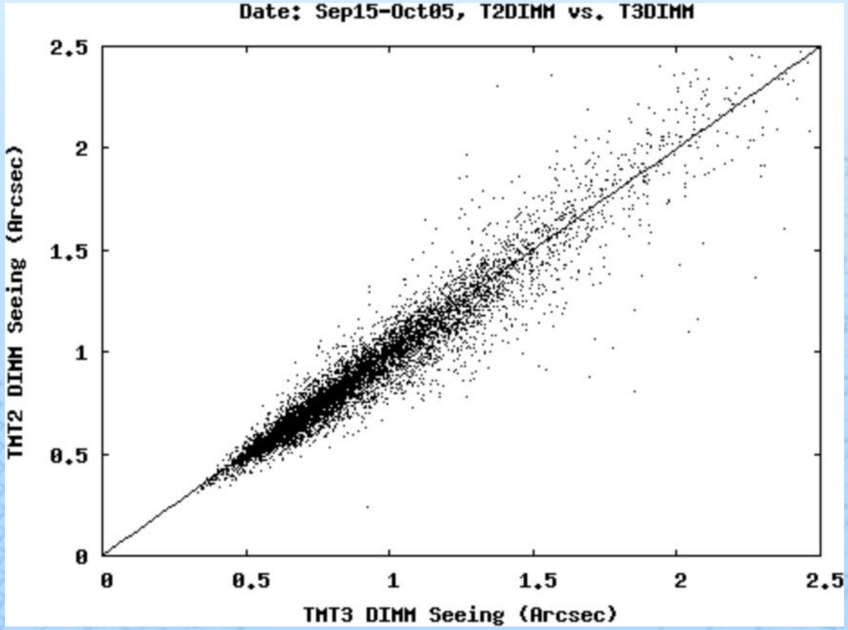




Managing Diversity

4 different DIMM systems + 1 calibrator





TMT-DIMM@Tololo: median difference 0.017+/-0.001)
Wang L. et al, APPLIED OPTICS Vol. 46, No. 25, 1 September 2007

Cn2 measurements campaign mode

Correction from ground (6m) to ELT (50-100m)

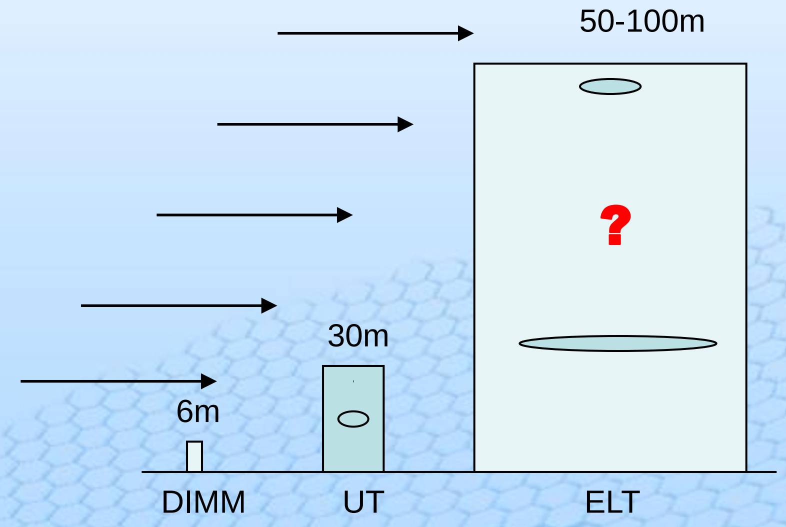
- Seeing conditions are monitored at lower height above ground
  - Direct measurement of the surface layer turbulence properties in the first 100m
  - Indirect estimations:

  UT-DIMM comparison

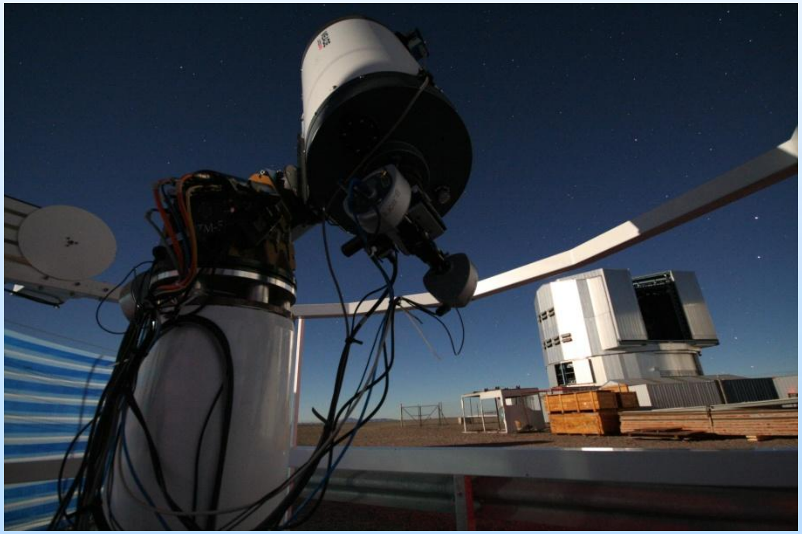
  MASS-DIMM comparison

  SLODAR-MASS-DIMM comparison

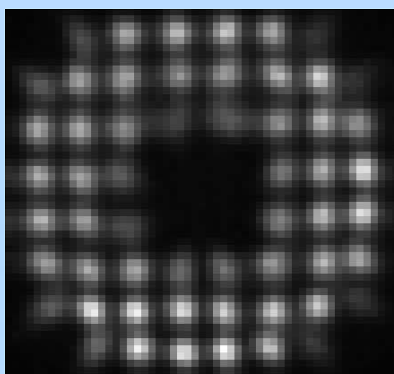
  LuSci-MASS-DIMM-GSM comparison



The Surface Layer Profilers



SLODAR
(Durham)



LuSci
(CTIO)

Wavefront Characterization Campaign at Paranal December 2007

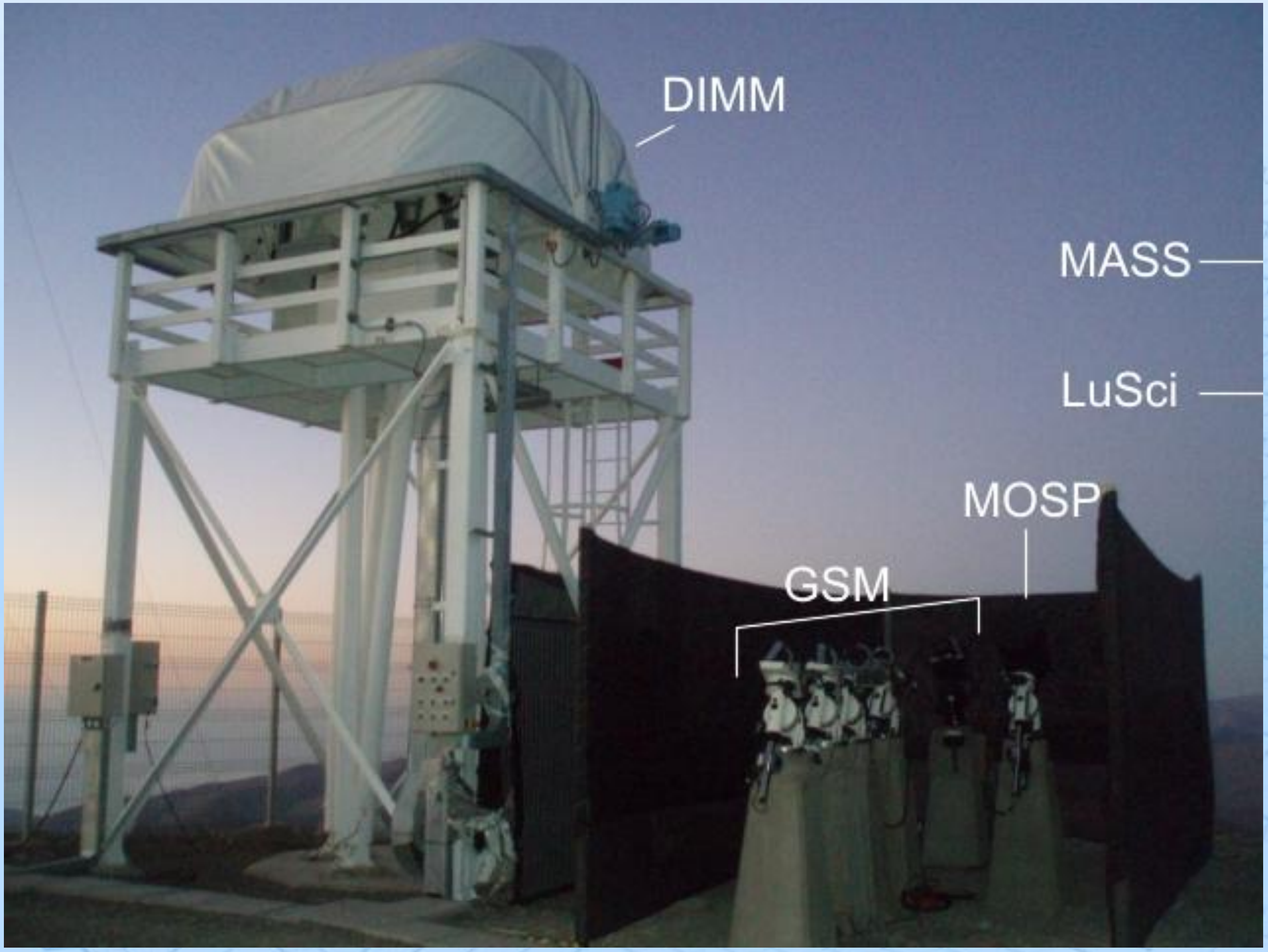
Instruments and expected parameters

MASS-DIMM ($C_N^2(h)$, ε_0, τ_0)
LUSCI ($C_N^2(h)$)
SCIDAR ($C_N^2(h)$, $v(h)$, ε_0, θ_0, τ_0)
MOSP ($L_0(h)$, $C_N^2(h)$, ε_0)
DIMM (ε_0, τ_0)
GSM (ε_0, L_0, θ_0, τ_0)
NACO (ε_0, L_0, τ_0)
AMBER (OPD, ε_0, L_0)

CN2 : structure constant
L0 : outer scale
V : wind speed
ε_0 : seeing
θ_0 : isoplanatic angle
τ_0 : coherence time

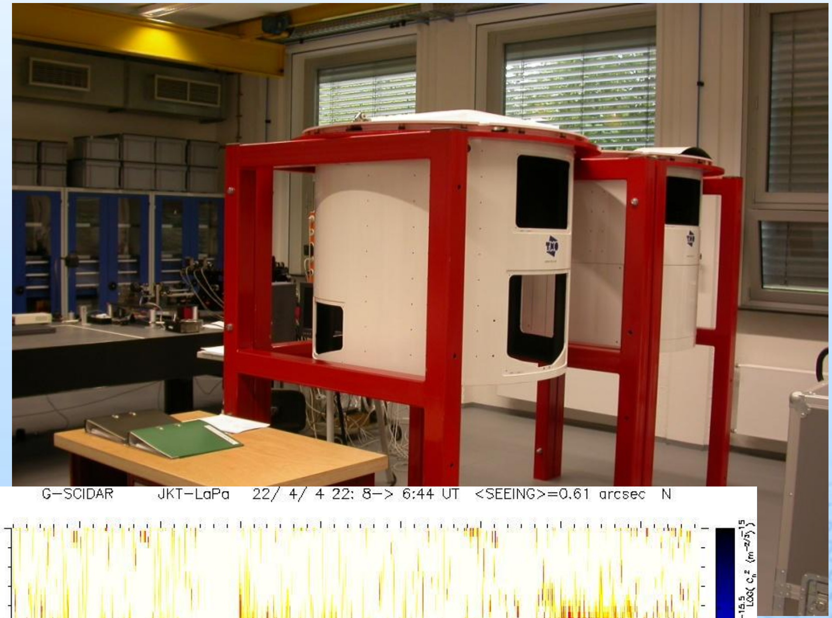
Wavefront Characterization Campaign at Paranal December 2007 Using DIMM-MASS-GSM-MOSP-LuSci & SCIDAR

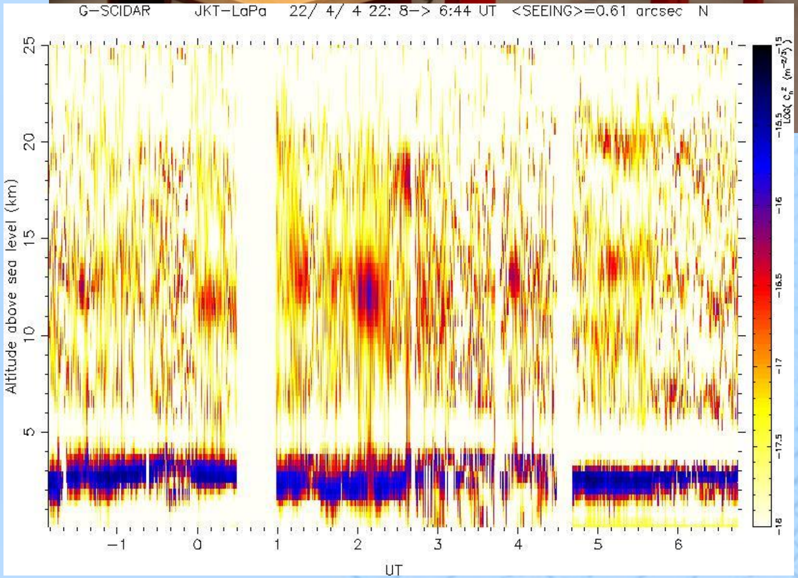
ESO/LUAN/IAC/CTIO
Joint effort



IAC – SCIDAR clone at Paranal VLTI-AT focus

Integration in AT-ROS planned
in July 2007
VLT-SOW-ESO-17416-4111
F. Derie, ESO

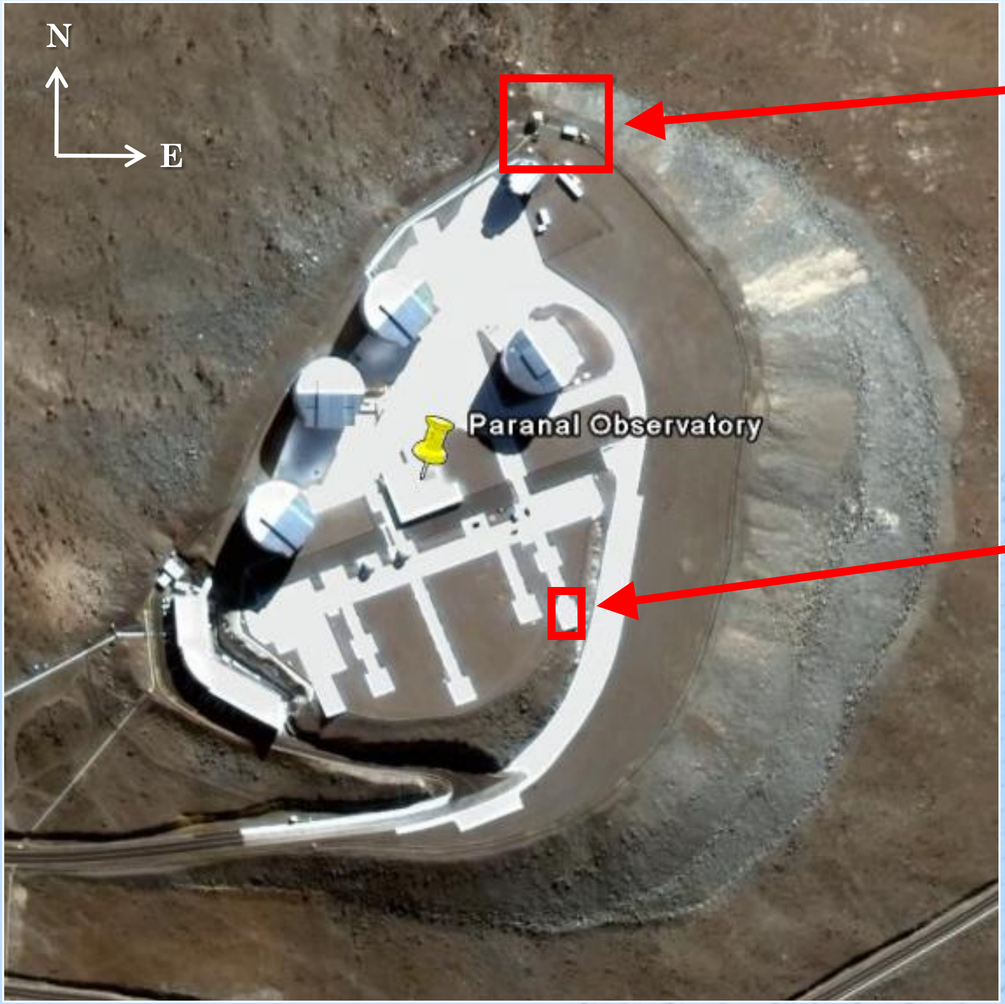




ROS interface at ESO Garching (top left)
Cute SCIDAR at ORM (above)
Cute SCIDAR output (left)

WHERE?

Cute-SCIDAR location at Paranal



The **Paranal Astronomical Site Monitor** is located on the platform, in a zone diametrically opposite to the Control Building, just behind the VST.

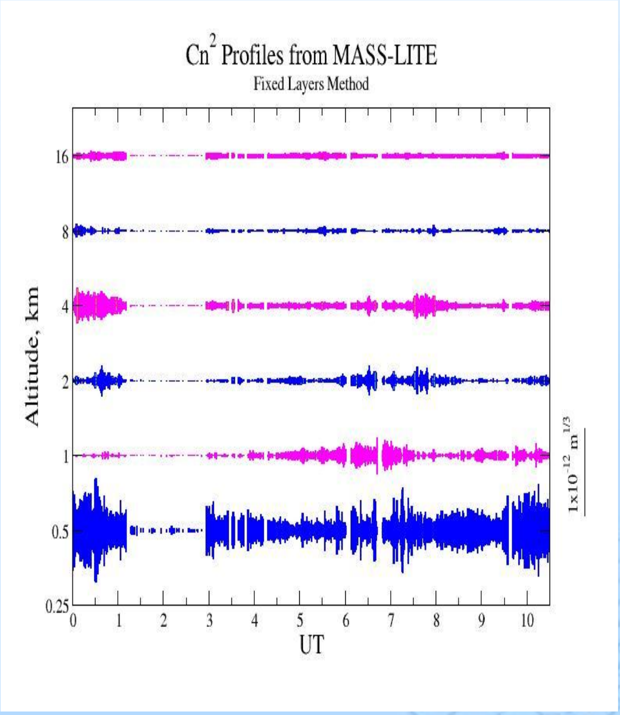
The **CUTE-SCIDAR@AT4** is located on the platform, in VLTI J2 Station.

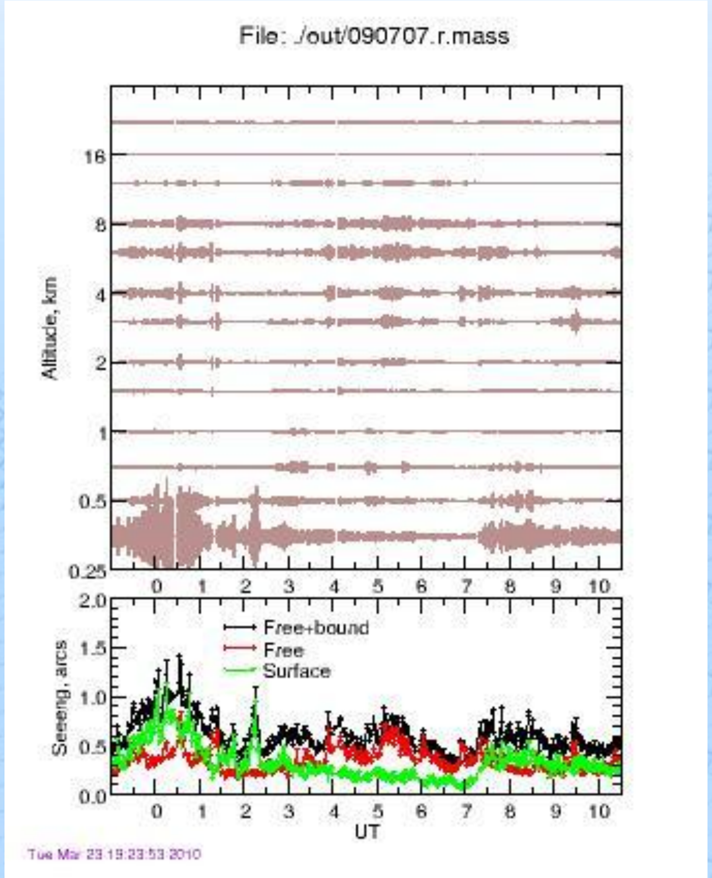
Pending Matters

- MASS and SCIDAR (see G. Lombardi)
- LuSCI and MASS-DIMM at low turbulence (see A. Tokovinin)
- Correction factor of MASS tau0

Correction Factor of MASS Tau0

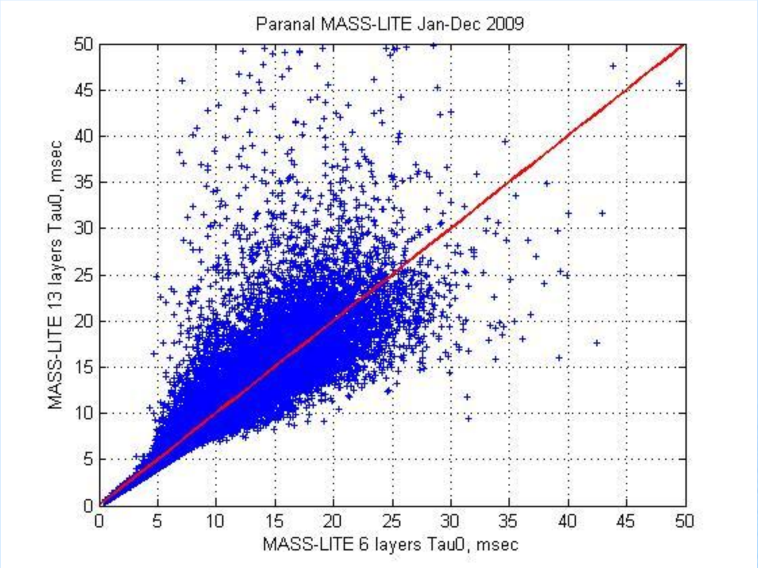
Using MASS in HD mode (see V. Kornilov)

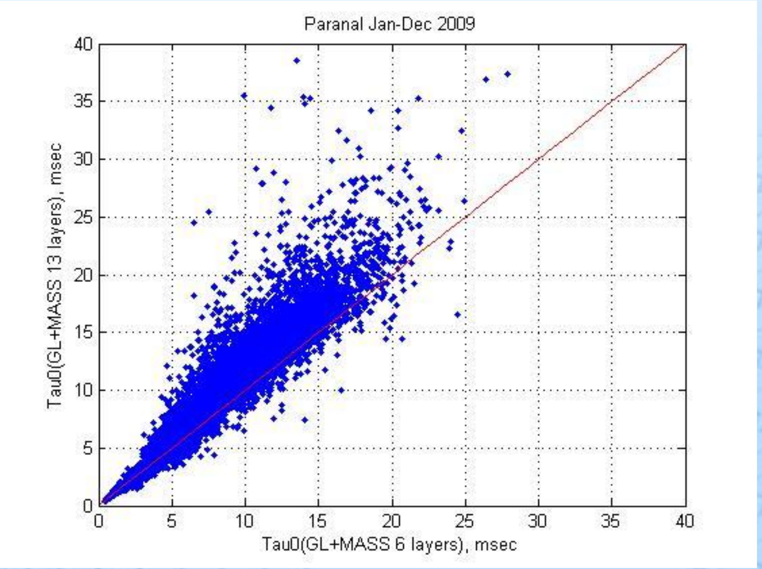




Correction Factor of MASS Tau0

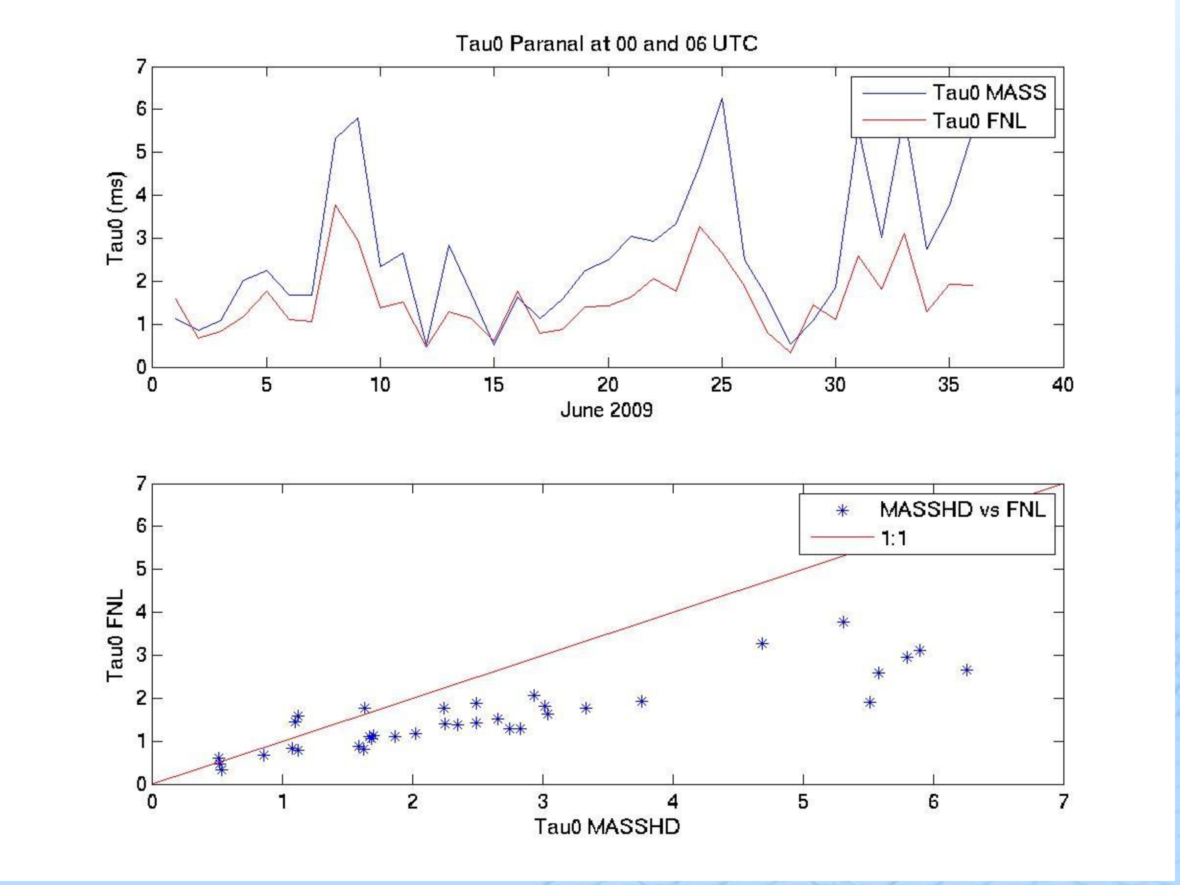
Using MASS MASS in HD mode





Tau0 MASS only (left) and including Ground Layer (right) -J. Navarrete

Correction Factor of MASS Tau0



Tau0 is computed following T. Travouillon et al, PASP 121, 2009

-Wind velocity from FNL global model: 26 vertical levels between 1000 and 10 Hpa

and

-13 layer Cn2 profile from MASS-LITE Paranal reprocessed in HD mode (see V. Kornilov)

Preliminary results by O. Cuevas (more in Valparaiso)

Site Selection: Merit Function (see J. Melnick)