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SSC
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CTA Candidate site in Chile

Introduction

This is a report about a possible Chilean site for CTA-South. It was re-initialized by the 1st report of the Site Review Committee stating:

...missing the opportunity to build CTA at a significantly better site, for which there is no host country interest. For example, it has been noted that there are no proposed sites in Chile, while Chile is known for having some of the best astronomical sites in the world. ...

Disclaimer: This is not a “Chilean Site Proposal” along the same lines as the proposals received in the response of the call.

Specifically: I cannot and do not speak for Chile, the Chilean community, Chilean organisations, or organisations based in or operative in Chile!

Any assessments are based upon measurements and data reported or made available by others. This is a CTA effort.

Following approval by the CTA consortium an agreement with ESO for the deployment of instruments for meteorological studies was signed. The CTA site work package started testing the conformity and complementarity of its own assessments for comparison.

Introduction

In > 60 yrs of site studies for astrophysics Chilean sites have been repeatedly reported to provide the largest number of clear hours in the southern hemisphere.

Excellent historic experience.

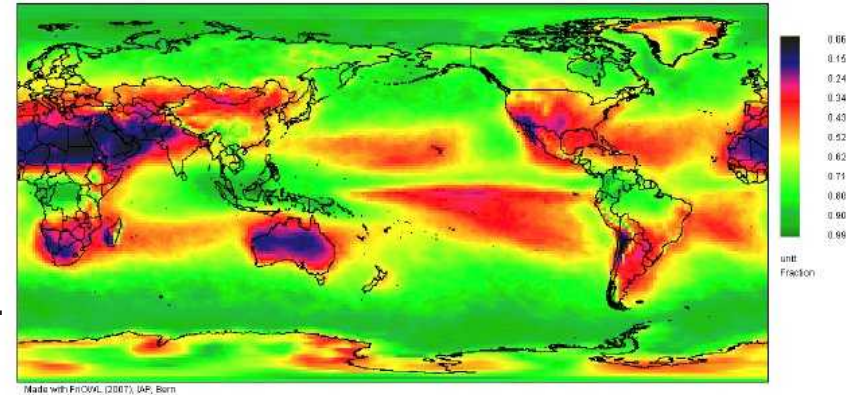
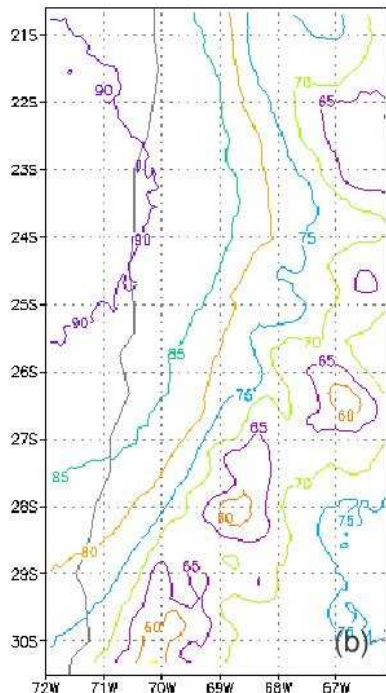


Figure 1: Average total cloud cover for the period 1989-2009 compiled with FRIOWL geographic information system¹ from monthly averages of ERA-INTERIM re-analyzes four times per day (00, 06, 12, 18h UT)

From A. Erasmus, 2002, Report to ESO 66814/ODG/02/6419 Sarazin et al., Proc. SPIE 7827-03-1

The area suitable for CTA covers many 1000 square-km, mostly in regions II, III, and IV (up to 95% cloud-free). Given the large overlap in CTA and ESO communities it is suggestive to consider sites in the vicinity of ESO to allow for synergies.

Chilean sites offer optimum MWL coverage for simultaneous work (ALMA, APEX, VLT, EELT, LSST, La Silla, Campanas, ...)



Site Location II



Implantation of CTA array on site straightforward, full conformity with CTA requirements



Site Location III



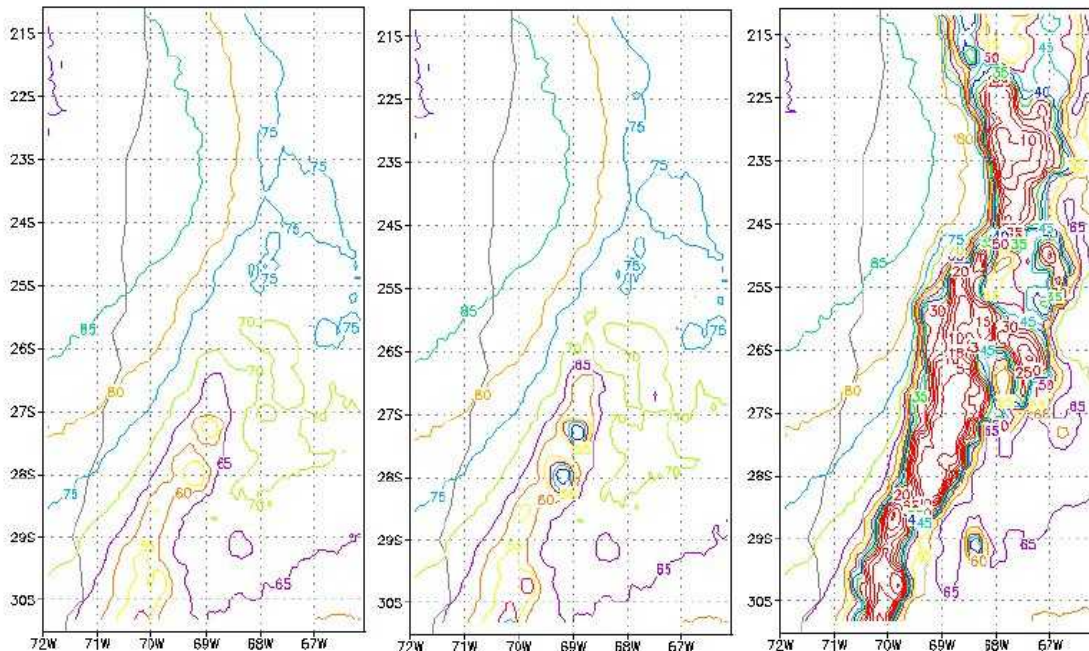
Geotechnical conditions:
Absence of vegetation implies
longterm absence of rain/snow.
One of the driest deserts on Earth.

The soil is made of
coarse sand up to
m-sized boulders.
Trucks can be driven in.
Infrastructure work for
nearby observatory
(PAO) 'easy'.



Weather Conditions I : Cloud cover

- Percentage of completely clear nights (0% cloud cover): about 80%
Different long-term studies based on satellite data (FRIOWL data base) report up to 90% cloud-free skies, Logs at Paranal report 78% photometric nights. Satellite-based studies report 75% - 88% (different studies, satellites, time intervals) of 'clear nights'.
- Percentage of partially clear nights (<20% cloud cover): about 10 %
Observatory logs report 92% 'usable nights', 10% fraction of cloudy skies in satellite studies.



From A. Erasmus, 2002,
Report to ESO
66814/ODG/02/6419

Weather Condition II: Wind

- Average wind speeds ontop of Paranal/Armazones = 6 m/s (20 km/h)
- Wind preferentially from North (shielded for site 1)
- Probability >100 km/hr: Never recorded during EELT site testing

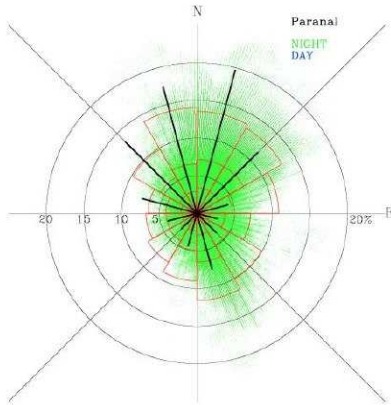


Figure 5: (left) The wind-rose of Paranal at 10m for night-time (red lines show at intervals of 30° the 15%, 50%, and 90% percentil

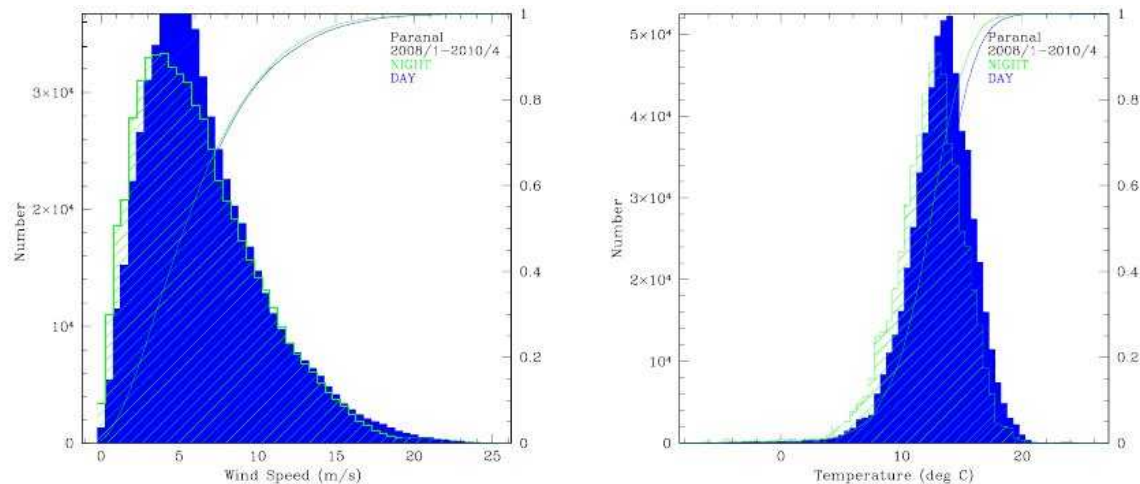
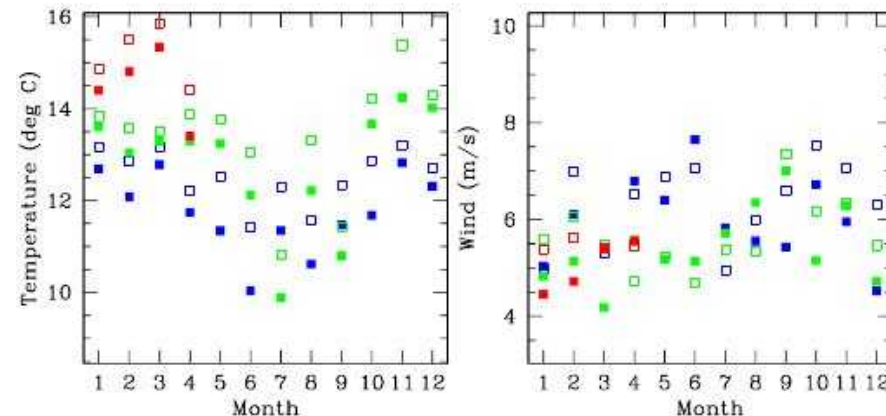


Figure 6: Statistics of wind speed and temperature for Paranal.

	Temperature [°K]			Wind Speed [m/s]		
	Median	25%	75%	Median	25%	75%
Day	13.4	11.7	15.0	5.8	3.8	8.7
Night	12.5	10.7	14.2	5.6	8.6	3.3

	Temperature [°K]			Wind Speed [m/s]		
	Median	25%	75%	Median	25%	75%
Day	11.2	8.4	13.7	7.4	4.3	11.1
Night	7.0	4.9	8.8	6.5	10.3	3.7



Weather Conditions III: T, RH, precipitation

- Percentage of time temperature and humidity within operation range: 100%
- Percentage of night with snow on ground: 99.9%
- Conformity with extreme temperature, humidity and precipitation survival requirements: complete conformity.

Table 4: Weather downtime due to dust

Site	All data f_D	Dust+Humidity ($> 85\%$)	Dust+Wind ($> 18ms^{-1}$)
Paranal	99.8%	0.0%	0.0%
Ventarrones	—	—	—
Armazones	98.8%	0.5%	0.0%

- (E-SPE-ESO-313-0111_5.pdf) and ESO E-ELT report

Table 7: UBVRI extinction at existing observatories

Observatory	k_U	k_B	k_V	k_R	k_I	Source
Paranal	0.46	0.24	0.14	0.09	0.06	QC1 database for FORS1 & FORS2

Night Sky Background

- Quantitative numbers:

Many detailed studies during site tests, see reports by ESO, e.g. Petat, A&A, 2003 and references therein, <http://www.eso.org/~fpatat/science/skybright/>

Summary natural brightness: Negligible contribution from artificial light, natural background varies by factor 2, presumably in phase with solar irradiance.

→ limits non-simultaneous comparisons.

Artificial lights: No cities within 80 km, Taltal [21000] , 95 km, Antofagasta [250 000], 130 km los (north), shielded, B-750 (local) and new Panamericana (20km) shielded



Natural Hazard Risks

- Earthquakes: Highest natural risk, fault line close to potential site. Chile in general and Atacama region in particular suffered from several strong earthquakes in last century
- Hail storms: None (according to reports by observatories)
- Sand storms: Negligible
- Bush Fires: None (no grass, no wood, no fuel – stones do not burn)
- Snow: In the past 20 years 5 snowfalls have been recorded. The snow reached the ground to a height of up to about 25mm and evaporated within at most six hours. Density (weight load) was not measured but is expected to be very low.
- Volcanic activity: Low risk at sites in the vicinity of Armazones
- Wildlife: None (no water – no food)
- Thunderstorms: Very low risk according to reports by observatories

Social/Political Risks

- Political stability of country: Very high; Chile has been run as a democracy since WWII with only one exception (stable military government) . In the past 23 years several peaceful and smooth transitions of power following democratic elections. Political stability is ensured also by stable economic growth.
- Crime: FBI and various other statistics report very low rates of violent crime, property crime, drug threat, gang threat, terrorism and financial institution fraud.
- Import regulations: Information provided by APEC, Chile allows duty-free imports for ESO (possibly a role model).
- Any other important consideration: Very low rate of corruption by international standards, 'result-oriented' unions, appreciation of contributions to the scientific profile due to international scientific research infrastructures.

Infrastructure

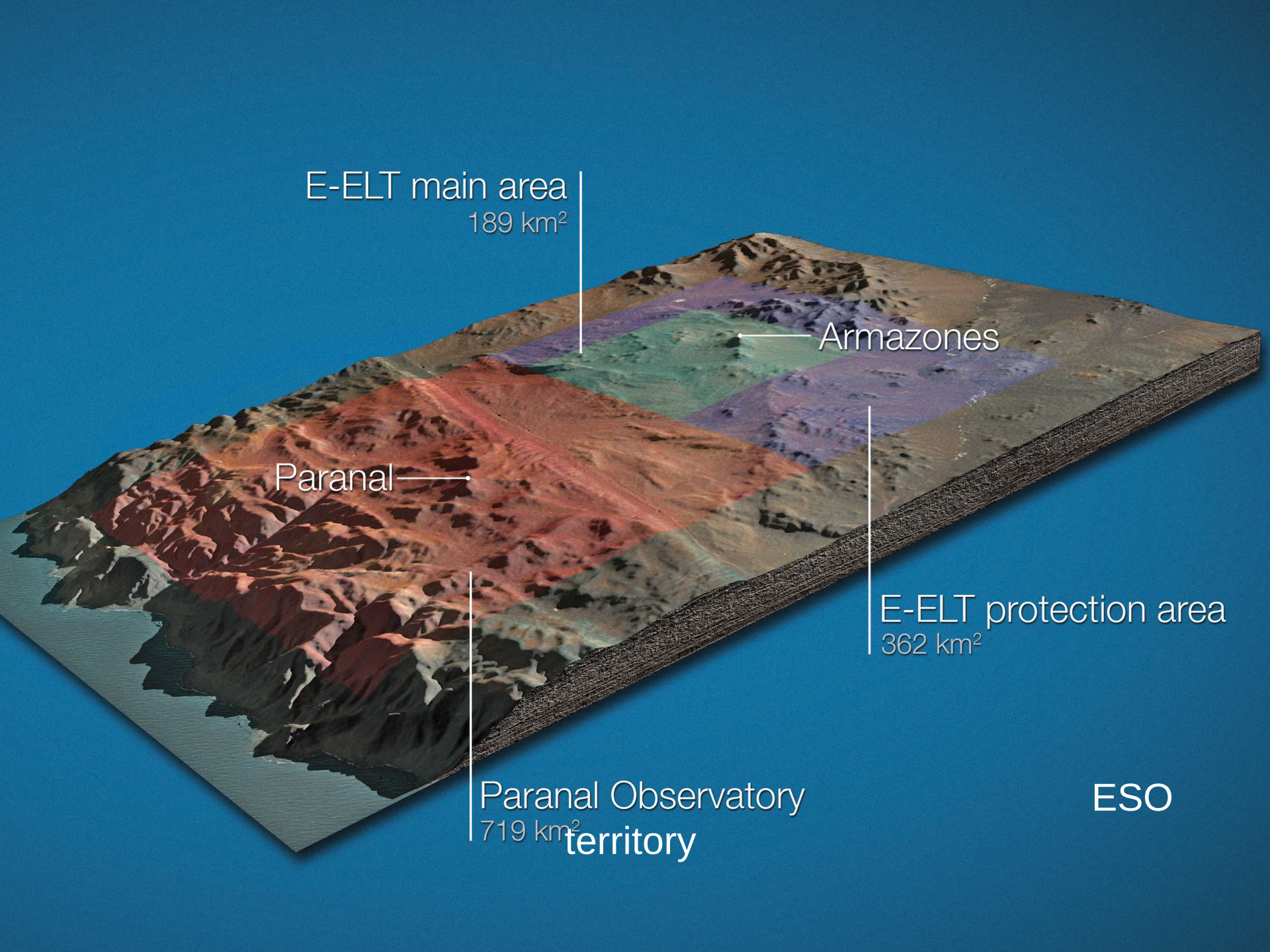
- Roads: Roads have been or will be built as part of the VLT and EELT projects, a local road has been tarred. The planned road for the EELT will pass at the edge of the proposed site of the array. Existing roads have been used to transport the VLT components (8.2m main mirror, etc.) → no concerns, no additional costs.
- Electricity: ESO operates multi-fuel turbines on site with average and peak powers that exceed CTA requirements (copies are possible and logistically manageable). Bids for connecting the PAO to the Chilean grid have been placed.
- Buildings: No installation available for re-use, ESO experience in civil engineering, companies, costs. Possibilities for synergies should be explored.
- Data network: in 2011 EVALSO (FP7-funded program) to link the PAO with GEANT established a 10 gigabit/s connection.
- Water: ESO trucks water to the observatory. ESO water consumption exceed CTA requirements by > factor 10

Accessibility

- Distance to airport: 150 km
Cerro Moreno International Airport serves >1 million passengers/yr.
- Nearest town to live: Taltal (95 km) is closest, but irrelevant (no intl. Schools, ...)
Antofagasta (300.000) is 130 km distance (mostly mining, but intl. schools)
- Nearest Port: Antofagasta is a major container harbor on the Pacific coast.
Easy, fast and reliable connection of all goods transported on ship.
- Hospital: Medical Rescue at Paranal, Helicopter and runway for transportation to Antofagasta.
- Antofagasta, its harbor and its airport are connected by roads to the Paranal-Armazones area. These roads were used to transport all goods, telescopes and infrastructure to the Paranal observatory - including the 8.2m sized main VLT-mirrors - right to the mountaintop (and potential CTA sites).

Site Ownership

- The largest land-owner in regions II, III, and IV is the state.
- A national 'astronomy law' has been established, which provides a framework for establishing observatories on government land.
- The area around Paranal and Armazones has been given to ESO, with a surrounding area not legally owned by ESO but subject to government ensured protection for ESO facilities.
- Establishing future astronomical facilities which do not harm the astrophysical exploitation of the area by ESO are in principle possible in the vicinity of the Paranal/Armazones region.
- Various possibilities exist: Within ESO territory, in 'protected area', outside the 'protected' area. Preferred location (technical, meteorological suitability) is included in first options. Cost/benefit estimates for minor relocations not conducted.
- ESO is open to site studies within EELT area and supports CTA in site exploration. In case CTA is interested, ESO offered support in discussion with Chilean state.



E-ELT main area
189 km²

Armazones

Paranal

E-ELT protection area
362 km²

Paranal Observatory
719 km²
territory

ESO

Political support of Host Country



Recognizing the meteorological advantages of Chilean sites, noting the benefits of cooperation with existing large-scale astronomical facilities and appreciating cost-savings from possible synergies CTA concentrated its studies on sites in the Paranal-Armazones region which hosts the ESO flagships.



ESO has been established in Chile 50 years ago.

ESO supported the growth of Chilean astronomy.

ESO enjoys excellent relationships with the Chilean authorities.

ESO is highly respected throughout South America.

ESO and its role in Chile are recognized by all governments funding ESO (which make up a large share of CTA member states)



Conclusion

Optical astronomy conducted serious site reviews in the Southern hemisphere during the last 50 years. These reviews considered southern America, southern Africa and Australia.

Almost all major facilities since then have been placed in Chile. Almost all exceptions driven by political desire (AAO, SALT, TMT).

Some organisations conducted several assessments and repeatedly confirmed the excellent conditions (Weather, hazards, engineering, economic stability, ...)

Among other areas, the vicinity of Paranal-Armazones observatory fulfills all basic requirements and provides very long-term meteorological studies.

Man-made disadvantages (tarred local road, LGS, mining) not at critical level.

Chile offers excellent meteorological conditions and superd opportunities for MWL cooperations. A CTA location in the vicinity of ESO operated observatories offers opportunities for synergies.

Chile experiences significant seismicity.