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Site considerations for ELTs

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Abstract. The ESO strategy for short listing ELT candidate sites is reviewed: it uses a specially designed tool to allow the simultaneous use of existing databases with various relevant parameters.

Keywords. Instrumentation, methods and techniques: atmospheric effects, site testing.

1. Introduction

Several projects of ELTs have started a few years ago and prompted new site surveys worldwide. Among them the Thirty Meter Telescope (TMT) has certainly the most ambitious site testing campaign underway (Schoeck (2004)). Thanks to an excellent collaboration, TMT and ESO site characterization efforts are often complementary and a strong case is made for deploying similar, if not identical, instrumentation on the candidate sites. Moreover, any new instrument in development is systematically cross-compared to the existing standards. Thanks to a straightforward merging of the various databases, it is hoped that the candidates studied for both projects can be ultimately cross-compared. Because of the high cost of the site characterization instrumentation, the number of candidates has to be reduced to a few. Identifying potential candidates is however hardly a rational process and many factors others than science performance may sometimes blurr the picture. How to be sure that areas with strong potential have not been left over? To answer this question, a more systematic approach described in this paper has been attempted at ESO with the development of a dedicated geographical information tool.

2. Preliminary global analysis

A tool dedicated to tracking climatic trends, FRIOWL has been developped by the Department of Geography of the University of Fribourg (http://archive.eso.org/friowl, Graham *et al.* (2004)). This tool has also a first function of helping to locate the most promising areas worldwide on the basis of the long term average value of pre-selected parameters. FRIOWL is a geographical information system with a spatial resolution of 2.5^{o} (300 km), composed of several layers containing a minimum of 15 years of data stored as monthly averages. The study of the temporal variability of the layers gives later access to the seasonal and long term climatology of the areas containing selected sites. The nature of the layers have been chosen among the available material according to the expected sensitivity of ELT science to the various atmospheric parameters. In addition to topography, FRIOWL is currently composed of 11 layers among which total cloud cover and precipitable water vapour. Other layers are specific to observations like the high altitude wind speed (Fig. 1), related to the temporal coherence of the wavefront in adaptive optics (Sarazin & Tokovinin (2002)) and the aerosol index (Fig. 2) which is believed to be related to atmospheric extinction, however in a still debated way (Siher *et al.* (2004), Varela *et al.* (2004)).

It is possible to combine the layers with different weights such as to compose dedicated maps of suitability. An example is given in Fig. 3 where topography, PWV and cloudiness have been used as reference parameters for IR astronomy. It is easy to see that only a few regions on earth are suitable, which are however wide enough to provide many candidates which then are compared using the full parameter space. The wider the observation spectrum of the astronomical facility, the more layers must be added and the narrower the choice becomes. For instance in UV and V photometry, the central Saharian regions where the desert sand is pumped upwards before travelling to Europe, Brazil or to the Middle East depending on the seasons, have to be discarded for they high aerosol contamination.

In order to identify the best candidates within an area, the low spatial resolution information can be complemented by the direct use of satellite imagery. With a resolution about the size of the observable sky of a ground based facility, the technique developped by Erasmus (2006) has proven its usefulness.

3. Site short listing

Most existing observatories housing international facilities are high standards natural candidates for future projects unless they suffer from lack of space or environmental restriction. For this reason, several ELT sites surveys are currently conducted on well known places such as Las Campanas in Chile (Giant Magellan Telescope, GMT), San Pedro Martir in Mexico (TMT) and Roque de los Muchachos in Canary Islands (OWL). At Mauna Kea (Hawaii), second choice areas are compared to the summit ridge (TMT). At the VLT Observatory in Paranal (Chile), ESO plans to characterize a summit 20 km to the North (La Chira) for OWL, while TMT studies an earlier candidate of the VLT site survey (Armazones) 20 km further to the East.

Other existing observatories studied at the opportunity of earlier projects like the 8 m generation can be re-activated and short-listed. They must appear more attractive either because of the new science goals, additional technical constraints, or because earlier handicaps (e.g. political unstability, difficulty of access, etc.) have been reduced. This could be the case of Maidanak (Uzbekistan), known for its good seeing and very low wind at ground level, should wind load be considered as a major ELT telescope design driver.

Similarly entirely new sites can be introduced. However, the risk being higher, they have to present a well identified benefit for the project. This is the case of high elevation mountains studied by TMT in Chile for their low precipitable water vapor (PWV) content. This is also the case of the Macon ridge in NW Argentina studied by Cordoba Observatory and ESO which, in addition to low PWV, presents a twice lower seismic risk than Paranal. Note that we have considered until now only countries which have a long tradition in astronomy with a well developped scientific community. It is also possible, even recommended from the point of view of the dissemination of Science, to address the case of emerging countries. A few locally motivated individuals can indeed become reliable partners and provide the necessary logistics for a large scale site survey. A good example is Morroco, steadily moving since about a decade from a core of astronomers trained abroad, towards the construction of a national observing facility close to the University of Marrakech (Oukaimeden). On this basis, and with the perspective of a lower weather downtime than in the Canary Islands during Winter, the anti-Atlas mountain ridge is also considered for the siting of the European ELT.

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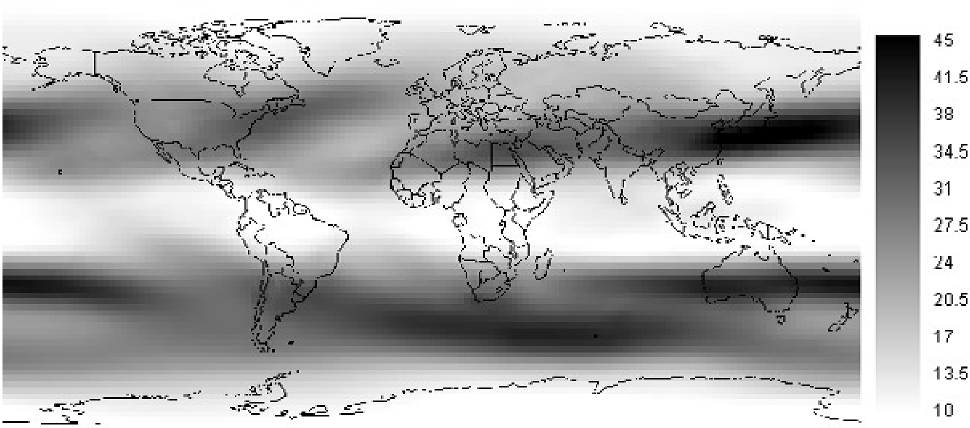

Figure 1. Mean Wind Speed at 200mB ($\approx$12 km a.s.l) in m s^{-1} for the period 1979-1993, with 2.5^0 square pixels.

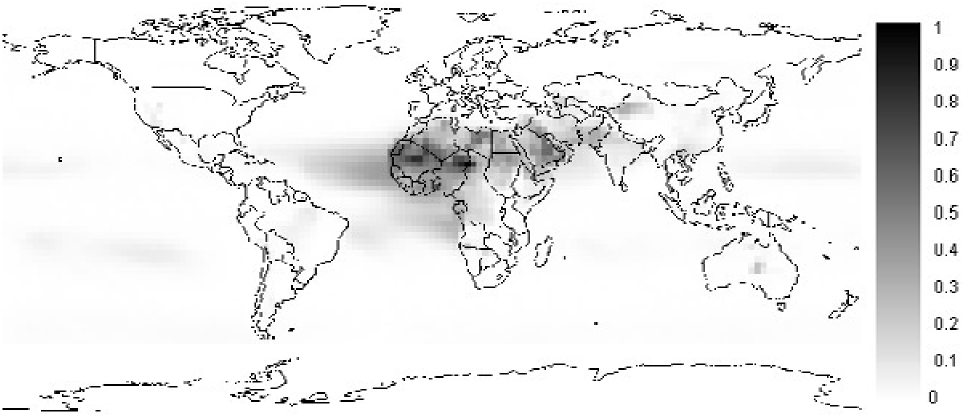

Figure 2. Mean aerosol index (arbitrary scale) as measured by the TOMS UV satellite for the period 1980-2002, with 2.5^o square pixels.

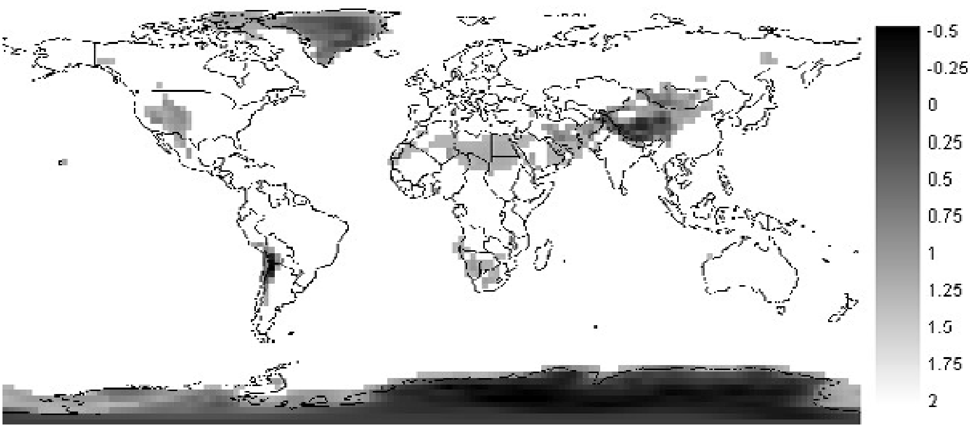

Figure 3. Overlay distinguishing areas providing both high summits and low cloudiness, as well as low PWV (arbitrary scale), with 2.5^0 square pixels.

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Finally, if justified by science, the extreme conditions are not anymore excluded for large facilities. The path was shown by ALMA, with the planned operation at 5000 m altitude of a highly sophisticated instrumentation fed by an array of 50 movable large size antennas. This is also the case of the new Antarctic scientific station of Concordia at Dome C, which could offer so favourable observing conditions that even a smaller ELT located there could become scientifically competitive. Dome C is the object of an intensive site testing activity led by Nice University (France), with the collaboration of many institutes worldwide, among them the University of New South Wales from Australia.

While the US projects are mostly privately funded, European astronomy is composed of a constellation of institutes which nevertheless managed to converge towards a single funding request to the European Commission FP6 framework program. This gave birth to The ELT Design Study, a technology development programme undertaken under ESO's lead by institutes and companies in Europe which will span over the 2005-2008 period. The study covers the development of enabling technologies and concepts required for the eventual design and construction of a European extremely large optical and infrared telescope, with a diameter in the 50- to 100-m range (see also Ardeberg *et al.* (2006)). Site characterization, exploratory instruments designs, and an assessment of the performance of a segmented aperture exposed to wind on a representative site are also included. Considering the available funds, the site characterization workpackage under the responsibility of Nice University (IAC and ESO as deputies) has been limited to 4 continental sites (Chile, Canary Islands, Argentina, Morocco) and Dome C in Antarctica. It also includes actions for a better understanding of the physics of the turbulence at large scales, proposed by Arcetri Observatory.

4. Conclusion

Considering a limited set of atmospheric parameters relevant for astronomy, it is easy to show that the potentially interesting areas on the planet are well identified. Moreover, not surprisingly, most of them are already the theater of professional astronomical observing. Finding new candidates is nevertheless possible when required by science or design constraints.

Within the next 3 years, more than 10 sites shall be characterized by the various ELT groups. And because much care was taken to use instruments which, if not always identical, are very similar and in any case repetedly cross-calibrated, the data accumulated can easily be merged and the sites cross compared for the benefit of all institutions.

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Discussion

Iye: Is there a prospect to establish a useful scheme to predict seeing for scheduling purposes ?

Sarazin: There is indeed work going on using meso-scale modelling to forecast observing conditions. It is a very challenging task to produce data which is reliable enough to be included into the routine operation scheme of the observatory. This status is not achieved yet in my view but the prospect exists.

Cui: Do you think the seeing measured by Shack-Hartmann is comparable with seeing instruments, such as DIMM? Is the result from Shack-Hartmann better than from DIMM because of the longer sampling period?

Sarazin: The image FWHM of long exposure Shack-Hartmann spots is a by-product of large telescope active optics systems. It provides the quality of the wavefront before it enters the instrument or adaptive optics stage. It includes the effect of atmospheric turbulence but also any degradation within the telescope enclosure or due to tracking errors and wind load. A DIMM can only properly sense turbulence which is isotropic and well developed, as exists in the atmosphere above the surface layer.

Dennefeld: With the global surveys now going on, are we sure that no interesting/viable site over the world is left unexplored?

Erasmus: In terms of atmospheric transparency the best locations have been identified. One area that remains to be quantified is Namibia. Local scale differences within the prime areas require further investigations and characterization.

McCaughrean: You mentioned the exceptional site testing results for Dome C at the beginning of your talk. Is there any formal collaboration between ESO and the teams working on Dome C in the context of ELT site testing in Antarctica?

Sarazin: ESO is following up closely the developments of site characterization at Dome C. ESO is funding a PhD student from Nice University for the comparative study of Chile and Antarctica high atmosphere turbulence. Finally, Dome C is part of the ELT-Design Study as a reference to which other candidates should be compared, depending on science goals.

Dennefeld: With current 8-10 m telescopes, the outer scale of turbulence L_0 is larger than the aperture. This is likely not to be the case anymore with ELTs. What will be the consequences for AO in particular?

Sarazin: This is an open question, we know rather well how the wavefront behaves within the initial range, but not further. That is why a specific experiment has been proposed by R Raggazoni, in the frame of the ELT-Design Study, aiming at sensing wavefront properties at scales larger than L_0.

Rouan: Did you try to use VLTI data to obtain information on the outer scale?

Quirrenbach: Comment: interferometers are indeed very well suited for measurements of the outer scale. The relevant information is contained in the temporal power spectrum of the optical path length difference between the interferometer arms. Simultaneous

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measurements of this quantity on baselines with lengths bracketing L_0 provide a direct and robust way to determine L_0. The VLTI is currently working on improving the robustness of fringe tracking. Once this is achieved, the VLTI will provide excellent measurements of the outer scale on Cerro Paranal.

SARAZIN: I agree, we shall use these data as soon as they are made available.