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ELEMENTS OF A SITE SURVEY STRATEGY FOR AN EXTREMELY LARGE TELESCOPE

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Abstract. The site survey for an Extremely Large Telescope (ELT) requires an entirely new strategy. It is indeed not anymore possible to select the best known site on the basis of cloudiness and seeing only, and to set the design specifications of the telescope accordingly. Some particularities of giant structures as well as the continuous use of adaptive optics could impose new requirements on particular environmental parameters such as wind or seismicity which many of the best current observatories worldwide do not fulfill. Plans for a global search for potential sites are outlined which make extensive use of recently available databases and related software tools. To operate a pre-selection, it is proposed to implement a dedicated geographical information system (GIS) handling the wealth of available remote sensing data worldwide. When focusing onto particular summits, the GIS should then be complemented by mesoscale modeling of the local flow.

1 Introduction

The site survey for OWL poses the challenge of defining a long term strategy which shall be able to evolve with the developments of the engineering concepts. It is indeed not possible, as in past projects, to select the best available site on the basis of cloudiness and seeing only, and to set the design specifications of the telescope in accordance. Some particularities of gigantic structures as well as the continuous use of adaptive optics impose new dramatic requirements, in particular the sensitivity to seismic hazard of the telescope structure in survival mode could eliminate many of the existing top-level observatories. Similarly the limiting operational wind speed for the telescope mechanics and optics shall be a major selection criterion (Dierickx 2002). Finally, the performance, and in some cases even the feasibility, of an adaptive optics system for an ELT is linked to the temporal coherence of the atmosphere, a highly location dependent parameter,

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simulations currently undertaken shall set the requirements for the site. After a thorough review of the regional climatology worldwide, a consistent database shall be assembled into a dedicated geographical information system (GIS) with a higher resolution on the areas of interest. The locations satisfying the engineering requirements shall be compared and ranked in terms of science throughput. It is also proposed to make intensive use of mesoscale models to provide a detailed analysis of the wind flow over selected areas: a study is underway to assess the accuracy of such models, comparing meteorological measurements and modeled data of the wind speed and direction at the VLT observatory of Paranal and searching for links to global climate change. Finally, as in any site survey, field measurements have to be conducted on selected candidates. Automated autonomous monitors have to be developed for that purpose on the model of the VLT ASM (VLT Astronomical Site Monitor). Such monitors shall be equipped with traditional meteorological equipment, as well as with dedicated instruments for monitoring seeing, sky photometric quality, isoplanatic angle and coherence time. In addition, single stars turbulence profilers (MASS: Multi-Aperture Scintillation Sensor) has been introduced by Tokovinin 2002 to hopefully replace the very accurate, but hardly transportable, traditional SCIDAR (SCintillation Detection and Ranging). It is also hoped that a thorough initial climatic and meteorological analysis described in the next sections allows to shorten the duration of the field campaigns, which in any case could never cover all climatic cycles, some of them being multi-decadal.

2 Tropospheric flow as a new parameter for ELT sites

Adaptive optics techniques are sensitive to the rate of change of the optical wave front high spatial frequency structures due to atmospheric turbulence. The subtropical jet stream acts as circulation engine which drags lower layers of the atmosphere in its infernal rotation around the earth. It is thus realistic to assume that whatever their altitude, the velocity of all turbulence layers is somehow linked the 200 mb global circulation. A method described by Sarazin 2001 permits to estimate the wave front coherence time from a combination of ground based seeing measurements and general circulation data. An excellent agreement was found with VLT interferometer atmospheric phase fluctuations (di Folco 2002). The data summarized in Table 1 show that the ratio between existing observatories and a reference site in Costa Rica belonging the inter tropical belt where no jet stream is present is about 2 on average and up to 5 on some months. Even better conditions are to be expected in Antarctica with an annual mean tropospheric wind velocity below 10 m/s at dome C (Storey 2002).

3 Geographical Information Systems

A contract for appropriate site selection, using a GIS-based (Geographical Information System) decision making tool, has been appointed to the Department of Geosciences, University of Fribourg, Switzerland. It will consist of a robust user

Site Country	Chirripo Costa Rica	M. Kea Hi, USA	Gamsberg Namibia	Paranal Chile	ORM Canary, Sp	Maidanak Uz.
June	17.8	19.5	32.0	34.5	24.0	27.1
Dec.	10.3	24.7	20.0	22.2	42.6	49.6
Yearly	13.6	24.1	26.6	27.5	32.4	33.7

Table 1. Comparison of the mean 1980-1995 200 mb wind velocity in m/s at various sites for the months of June, December and for the full year (from the 2.5 degree resolution NOAA Global Gridded Upper Air database).

interface allowing interrogation of combined climatological, topographical and geological databases. This will be achieved by using a combination of Visual Basic computing language and GIS software (e.g. IDRISI).

There are many different climatological and meteorological parameters that will need to be considered in the decision-making process. Those of primary importance include air temperature, humidity (precipitable water content), surface wind speed and direction, synoptic isobaric flow (at standard levels) and cloud cover. Layers for each of these parameters will be created in the global climatological database at a grid resolution of 2.5 degree or greater, using NCEP/NCAR Global Re-analyses data (http://www.cdc.noaa.gov/cdc/data.nmc.reanalysis.html) covering from 1948 to the present, or the ECWMF Global Re-analyses, ERA-15, the fifteen year reanalysis dataset between 1979 and 1993, and a new reanalysis project called ERA-40 covering from mid-1957 to 2001 expected in early 2003.

A Digital Elevation Model (DEM) at a resolution of 0.08 degree lat/lon grid ($\approx$ 1 km) will be used by the user interface. The DEM is available from NOAA GLOBE Project in IDRISI compatible raster format. This layer will be of direct benefit in the calculation of an upwind terrain roughness parameter (UTRP), an empirical index which will give an indication of the suitability of a potential site, given local wind turbulence. It consists of an index attached to each land pixel resulting from the combination of two subsets:

- Roughness maps (R): the standard deviation of the altitude of neighboring pixels (normalized by distance from pixel) is computed for each pixel for 8, 45 degree sectors. The distribution obtained is then normalized and truncated to twice the median so that R stays between 0 and 1.

- Upwind maps (U): map of frequency of occurrence of given wind direction (wind rose) in 45 degree steps. U is between 0 and 1 (100%), the sum of R over the eight sectors is equal to 1.

An appropriate land cover map and world vector format map will also be used. At a later stage, it will be necessary to include seismic potential maps, in order to locate regions of maximum and minimum probability of earth tremors.

4 Mesoscale Modelling

A contract for the analysis of the performance of mesoscale modeling of the surface wind flow at the VLT site has been awarded to the Meteorological Institute of Munich at Ludwig Maximilian University. The project aims at estimating the efficiency of the public mesoscale model MM5 in modeling the flow above the Paranal area in view of forecasting the occurrence of bad observing conditions (bad seeing) linked to a particular (NE) wind direction. This study is in the line of pioneering work done at the University of Nice using a similar model (MesoNh) developed at CNRM, Toulouse (Masciadri 1999). MM5 is driven by ECMWF data from 00 UTC, 6 UTC etc., linearly interpolated in between. First a 'classification' of 500 hPa patterns was conducted for the period 1998-2001, in the Paranal area. 11 typical patterns were identified. It was found that these synoptic situations did not have a clear influence on observing conditions at Paranal. It was concluded that there is no significant correlation between the behavior of the flow at Paranal (and therefore 'seeing') and the 500 hPa patterns, thus demonstrating the mesoscale nature of the problem.

A minimum of 20, twenty-four hour simulation for Paranal will be performed, including 10 cases where the wind turned from northwest to northeast during the night and ten others where it did not. The results from an inter comparison will give a fairly good indication of the usefulness of such forecasts. A success of the study could lead to an operational forecast of the risk of bad seeing occurrence at the observatory. In such an operational application, the runs should start at 6UT after reception of the ECMWF 00UT data set to forecast the conditions of the next night (a night is defined as 0UT-10UT) in steps of 1 hour. As the complete forecast should be available at the beginning of the night, the model should run twice faster than real time.

The further application of this work to ELT site surveys is straightforward: the MM5 output for typical synoptic situations shall be used to refine the computation of the upwind terrain roughness parameter (UTRP) described in the previous section.

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