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OPTICAL TURBULENCE PREDICTION USING WRF MODEL

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Abstract. The optical turbulence forecasting has become a necessary information for an optimal programmation of the astronomical observations, called "flexible scheduling". We propose the prediction of the optical turbulence by means of the Weather Research and Forecasting (WRF) model combined with an optical turbulence model. We performed a set of simulations to obtain a 24-hours period forecast for optical turbulence parameters above the Calern observatory. We present the results of our forecasting and comparisons with the CATS (Calern Atmospheric Turbulence Station) measurements.

Keywords: Atmospheric turbulence, turbulence prediction, flexible scheduling, astronomical observations

1 Introduction

In order to optimize the exploitation of the next generation of extremely large telescope (ELT), the prediction of atmospheric turbulence becomes necessary to schedule the observations and to choose the appropriate observing method with the appropriate instruments to be used at a specific time of the night. Thus, to have all the necessary informations about the optical turbulence several hours before the observation, we use a numerical weather prediction model to forecast the useful meteorological parameters relevant to the physics of the optical turbulence. In this study, we propose the use of WRF (Skamarock et al. 2019) model coupled with a turbulence model (Trinquet & Vernin 2006; Giordano 2014) above the Calern observatory. This site hosts a new generation station of atmospheric turbulence measurement (CATS) (Ziad et al. 2018) equipped with turbulence monitors. The PML (Profiler of Moon Limb) measures the vertical distribution of turbulence (profile of refractive index structure constant C_n^2) with high spatial and temporal resolution, 100 meters and 3minutes respectively. The G-DIMM (Generalized Differential Image Motion Monitor) measures the integrated parameters (seeing, outer scale, coherence time and isoplanatic angle) (see also `https://cats.oca.eu`). In this paper, we present our prediction method, the results of our forecasting and comparisons between the predictions and the CATS measurements.

2 Principle of the prediction

We use WRF to predict meteorological parameters (pressure, temperature, wind speed and direction, and relative humidity). WRF is a mesoscale numerical weather prediction system developped by a collaborative partnership (the National Center for Atmospheric Research (NCAR), the National Centers for Environmental Prediction (NCEP), and others institutes). The meteorological parameters predicted by WRF are injected into an optical turbulence model. Trinquet & Vernin (2006) have established a model to retrieve the temperature structure constant C_T^2 as a product of 3 quantities:

$$C_T^2 = \phi(z) \cdot \chi(z) \cdot S(z)^{1/2} \tag{2.1}$$

with $\chi(z)$ is the vertical gradient of the potential temperature, $S(z)$ is the wind shear and $\phi(z)$ is a vertical profil parameter deduced from a statistical analysis of radiosoundings balloons that we extended to CATS data. Then, C_T^2 is used to deduce the vertical distribution of optical turbulence described by the refractive index structure constant C_n^2 which is computed using the Gladestone's law:

$$C_n^2 = \left(\frac{80 \cdot 10^{-6} P}{T^2}\right)^2 \cdot C_T^2 \tag{2.2}$$

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where P is the atmospheric pressure in hPa and T is the air temperature in Kelvin.
Our approach is now to use local CATS statistics to constrain the function $\phi(z)$ of the equation (2.1) to better take into account the specificities of the Calern site.

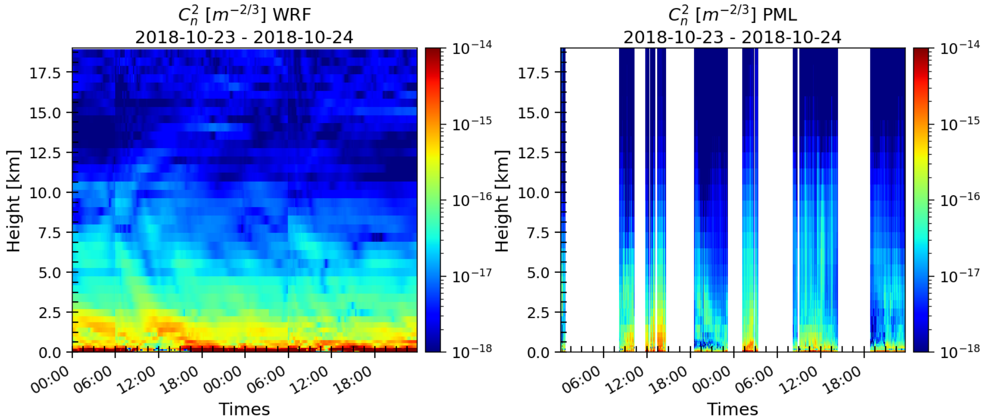

Fig. 1. Left: times series forecasting of C_n^2 by WRF. **Right:** times series of C_n^2 observed by PML.

3 Results

Fig. 1 (left) panel shows results of WRF forecast of C_n^2 profile for a 48h period. CATS measurements are shown on the right panel. We can notice that WRF provides a continuous temporal resolution and may complete missing data from turbulence monitors. One can see also that the turbulence is more intense in the planetary boundary layer. This is due to its direct interaction with the earth's surface. Fig. 2 shows a good agreement between 24h median profiles predicted by WRF and measured by the PML in the free atmosphere while differences remain in the boundary layer. This difference between the free atmosphere and the atmospheric boundary layer occurs because the meteorological parameters behave differently. For example, the near-surface temperature is characterized by diurnal variations, with maximum at local afternoon and minimum at local midnight. However, in the free atmosphere, the temperature shows a small diurnal variation.

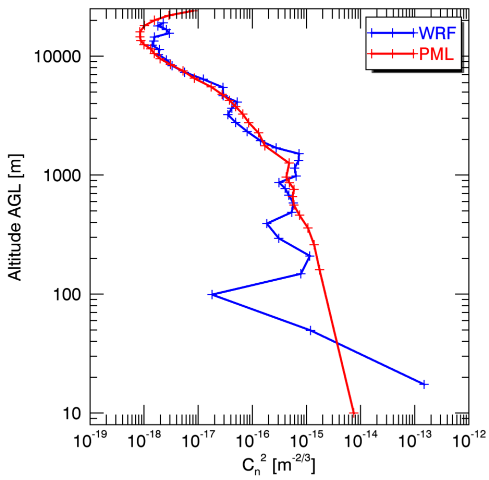

Fig. 2. Median profiles of C_n^2 on 2018/08/27

4 Conclusions

We have shown for a 24h forecasting, the capability of WRF model combined with an optical turbulence model to predict the vertical distribution of the optical turbulence above the Calern observatory. The predictions agree well with the PML measurements in the upper part of the planetary boundary layer and also in the free atmosphere. By contrast, there is a significant difference between WRF and PML results in the lower part of the boundary layer. As a perspective, a thorough study is required to find an optimal configuration of WRF by concentrating especially on the physical parameterization schemes and the use of a fine grid resolution to take into account the ground effects (topography, land use, surface heat flux, etc.) and properly represent the near-surface atmospheric processes that generate the optical turbulence.

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