Reducing optical turbulence profiler data to a representative set for GLAO

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Abstract

A table of model Cn2 profiles is a popular way of representing the variety of vertical distributions of Cn2(h) that can exist over an astronomical site. The variety over long time scales is usually most important to planning the long term performance of an adaptive telescope. We check that the cumulative distribution of the integral of Cn2(h) of each profile, from the large sample measured at Mt Graham, can be represented by just three statistical model profiles. We test them with a simple ground-layer adaptive optics (GLAO) filter that simulates some residual ground-layer (GL) and free-atmosphere (FA) turbulence.

Group selection

The regions of higher probability (black) in the following 2-d histogram represent periods, sometimes several sequential nights, when the proportion of GL turbulence strength (x axis) to FA strength (y axis) was steady. Forecasting when they will occur will be very rewarding to GLAO telescopes. Note that the turbulence strength (y axis) was steady. Forecasting when the proportion of GL turbulence strength (x axis) to FA turbulence will be 20% the turbulence at intermediate heights. The filtered turbulence strength is proportional to residual phase variance.

In the present sample, the most prominent feature is that the turbulence strength at the ground and the free-atmosphere go hand-in-hand. We will define our three groups in terms of J_{(total)}=J_{(GL)}+J_{(FA)}.

The groups are 8% wide and centered at the 20th, 50th, and 80th percentile (good, typical, and bad turbulence conditions). It will be illustrative in the next section to include a worst group centered at 95% that will complete the cumulative distribution of the model profiles.

In summary, three model profiles can mark the critical points on a cumulative distribution of GLAO residual phase variance and from these points it is possible to interpolate all percentiles in between. Cumulative distributions of other image quality metrics are generally smooth functions in the context of planning the long term performance of an adaptive telescope. For this reason we propose that the curvature of the cumulative distribution can also be understood and modeled with the aid of a large sample of J_{(GL)} and J_{(FA)}.

Group combination

Since the individual profiles included in each group may be measured on an arbitrary grid of heights, or even with different measurement techniques, it is mathematically convenient to compute the average profile in each group. Both the average J(h) and average h can be computed on a new grid, with grid spacing suited to the purpose of the model profiles. In the figure below, the J_{(total)} of the full sample (dotted curve) and the model J_{(total)} (squares) match well by definition.

A simple GLAO filter on the full sample of profiles gives the solid “truth” curve while the filtered model profiles (asterisks) do an acceptable job of finding the critical locations on the curve. The GLAO filter used here simulates a system that corrects 70% of the J_{(GL)} turbulence and corrects 20% the turbulence at intermediate heights. The filtered turbulence strength is proportional to residual phase variance.

Discussion

It is also useful to bring together profile measurements from different periods of observation or types of profilers, optimized to measure complimentary heights above the same site (e.g. Ref.[2,3]). The plot below and to the left shows that we still get a good match when we separately group J_{(GL)} and J_{(FA)} then bring them back together in three composite good;good, typical;typical, and bad;bad profiles. Since the present measurements were actually simultaneous we can also show where they lie in the 2-d histogram.

References:

Optical Turbulence, Astronomy meets Meteorology, Sept 15-18, 2008

This work is funded by a Marie Curie Excellence Grant (FOROT) MEXT-CT-2005-023878, FP6 Program.