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DYNAMIC SCHEDULING: Selection criteria and evaluation

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ABSTRACT

We argue that a direct measurement of the atmospheric phase rms provides the best weather parameter for scheduling interferometers for high frequency observations. We evaluate the performance of a dynamic scheduling program under varying atmospheric phase conditions, and compare the simulated schedule with the results from actual observations.

1. Introduction

In order to make best use of the instrument we need to change the observing schedule according to the weather conditions. This is particularly important for an observing season which involves observations at multiple frequencies. A dynamic scheduling program needs some well defined parameter to decide if the weather is good enough for each project. If the weather is not good enough for the current project to succeed, then we make better use of the array by scheduling a project which can make use of the current conditions. In the following sections we explore various weather parameters, and evaluate the performance of a dynamic scheduling program.

2. Atmospheric parameters

Various weather parameters are possible as a selection criteria for observations: opacity, wind, humidity, turbulence, cloud coverage or temperature. For interferometer observations at high frequency, the atmospheric seeing is currently the limiting factor. Good atmospheric phase calibration might change this situation, but currently available techniques such as rapid switching between source and calibrator, at best, reduce the effects of seeing to an equivalent shorter baseline length given by $d = \sqrt{(h(s - s_0))^2 + (v\Delta T)^2}$, where h is the height of the turbulence in the direction of the source, v is the mean turbulent velocity, and ΔT is the switching time. Typical values $h = 1km$, and $v = 5 - 10m/s$ give equivalent baselines of 100 - 400 m, where the phase fluctuations are still large in poor seeing conditions. If the turbulence is too high, then it is not possible to calibrate the data, unless the source has strong and simple structure which can be used to self-calibrate on the short time scales of the fluctuations. In contrast, high opacity (high system temperature) increases the integration time required, but does not preclude a successful observation.

The weather conditions at a number of observatories are characterized by stable atmospheric conditions at night, with sharply increased turbulence in the afternoon. This can be understood as a direct result of turbulence deposited in the atmosphere by solar heating.

Satellite phase monitors currently provide the most direct measure of atmospheric phase noise. Interferometers monitoring geostationary satellites at 12 - 18 GHz have been installed at a number of observatories. The interferometer phase rms is sampled at 1 - 5 min intervals on 100 - 300 m baselines. Figure 1 shows the record for the OVRO phase monitor for 1996. The increased phase noise in the afternoon (0 UT) and during periods of poor weather is quite obvious. The rms phase from the satellite monitor and the rms phase measured with the OVRO interferometer at 3 and 1 mm are well correlated when the appropriate scaling ($\phi_{rms} \propto \nu$) is applied.

None of the other weather parameters which we investigated show a similar pattern. The solid line in Figure 1 shows the precipitable water at OVRO, which is not well correlated with the rms phase. Clearly the increased depth of the turbulent layer is not reflected in the calculated precipitable water. Atmospheric turbulence can change the scale height of the water component, introducing large errors into the calculation of precipitable water, which assumes a constant scale height. The rms phase is not well correlated with the opacity (Figure 2). The best correlation appears with the ambient temperature (Figure 3), but even this is a poor predictor of the seeing. Similar results were obtained at Hat Creek. Figure 4 shows the precipitable water at Hat Creek. This shows remarkably little variation over a 6 month period, in contrast with the actual seeing. Figure 5 shows that the temperature and relative humidity, from which the precipitable water is derived, have much larger diurnal variations, but result in a more uniform measure of precipitable water. Note also that the relative humidity often saturates at night in winter, even though these are usually the best observing conditions.

We conclude that a direct measure of the atmospheric phase rms provides the best parameter for scheduling observations at high frequency. A satellite phase monitor provides a uniform reference, independent of the astronomical observations, but lacking this we can measure the phase rms from systematic observations of strong calibrators.

3. Scheduling Program

The scheduling program, **TAC** sorts a prioritized list into an observing schedule using an atmospheric model or phase-monitor data to estimate the atmospheric fluctuations. The scheduling program monitors the atmospheric phase rms at intervals input by the user and switches projects if the seeing is no longer suitable for the current project.

The scheduling program maintains a list of the current status of the observations for each project, the integration time and HA range acquired. This status can be written out as a record of the current status, and read in as a starting point for continuing observations, or predicted future schedule.

A project can be terminated when it has met its requirements, or when it would exceed its maximum time allocation. The use of a single prioritized list ensures that the highest priority projects are completed, before starting lower priority projects which could be observed.

The scheduling program can be run off-line with the real system status replaced by model inputs and weather statistics. A template schedule such as is produced for a fixed queue assumes perfect weather. A more realistic schedule was simulated by using the phase monitor data from OVRO.

4. Evaluation of TAC performance

In order to evaluate the behavior of the scheduling program, we compared the simulated schedule with the results of actual observing schedules at BIMA and OVRO. Using the phase monitor data as a selection criteria, 1mm and 3mm observations were scheduled when the seeing was better than 1/10 wavelength (0.14 mm and 0.3 mm respectively). Using 2 hour scheduling periods, **TAC** produced almost identical results to the actual record of successful observations, using the criteria of completed projects over the time period considered. Using the scheduling program, no observations were acquired during unfavorable observing conditions; all the data acquired was good, in contrast to the actual observations.

The schedule is determined mainly by the project priority and atmospheric phase rms. High priority projects are completed if the weather is acceptable. The behaviour of the scheduling program can be modified using the minimum interval for which a project can be scheduled, and scheduling interval used to re-evaluate schedule. As a default these have been set to 1 hour and 2 hours respectively. Under unstable weather conditions, more efficient use of good weather may be obtained using shorter times. This behaviour can be modeled using the atmospheric time constant.

The behaviour of the scheduling program mimics our actual experience; as the schedule progresses the more difficult to aquire data (e.g. afternoons) remain incomplete, and the schedule becomes inefficient as larger blocks of unscheduled time appear at times of good seeing. Projects can be added to the schedule to fill these gaps.

5. Conclusions

* A direct measure of the atmospheric phase rms provides the best parameter for scheduling interferometer observations at high frequency.

* None of the weather parameters which we investigated was well correlated with the atmospheric phase rms.

* The atmospheric conditions should be monitored on a regular basis to provide the necessary data for the scheduling program.

* The scheduling program is a new piece of software which determines when to start and stop each project using the atmospheric phase rms as a selection criteria.

* The scheduling program maintains a list of the observations done. The current status can be and read in as a starting point for continuing observations, or predicted future schedule.

* The use of a single prioritized list ensures that the highest priority projects are completed, before starting lower priority projects which could be observed.

* Using the scheduling program, no observations are acquired during unfavorable observing conditions; all the data acquired are good.

* The scheduling program can be run off-line to produce a template schedule, this makes the job of the system manager easier. The grades given by the time allocation committee could be used to prioritize the list of projects.

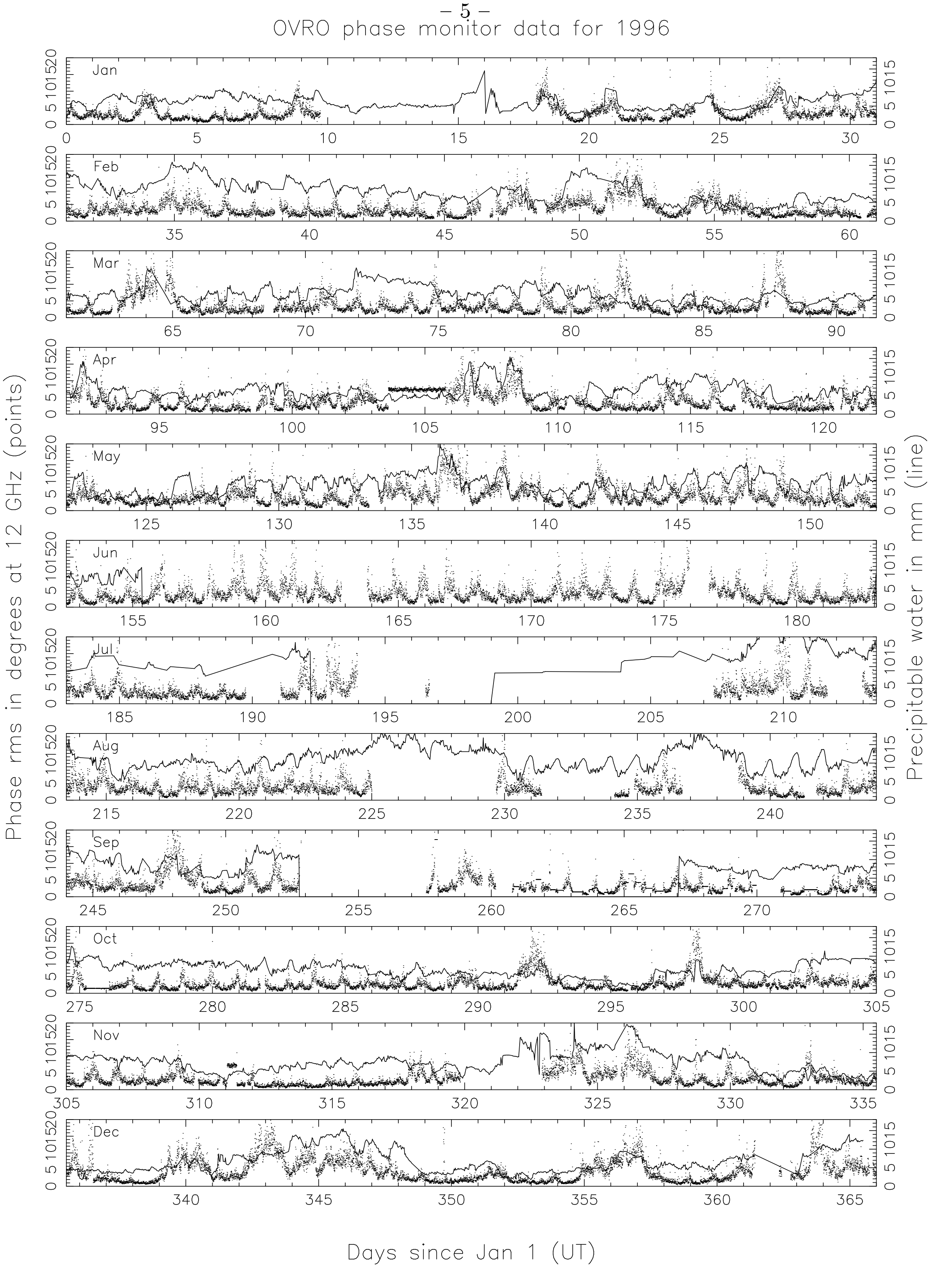

Fig. 1.— The phase monitor data from OVRO for 1996 (points) plotted against the precipitable water in millimeters (line). Anti-correlation between the phase and the water vapor can be seen at many times, particularly in the afternoon (approx 0 UT). A good example of this behavior is seen on days 40-45.

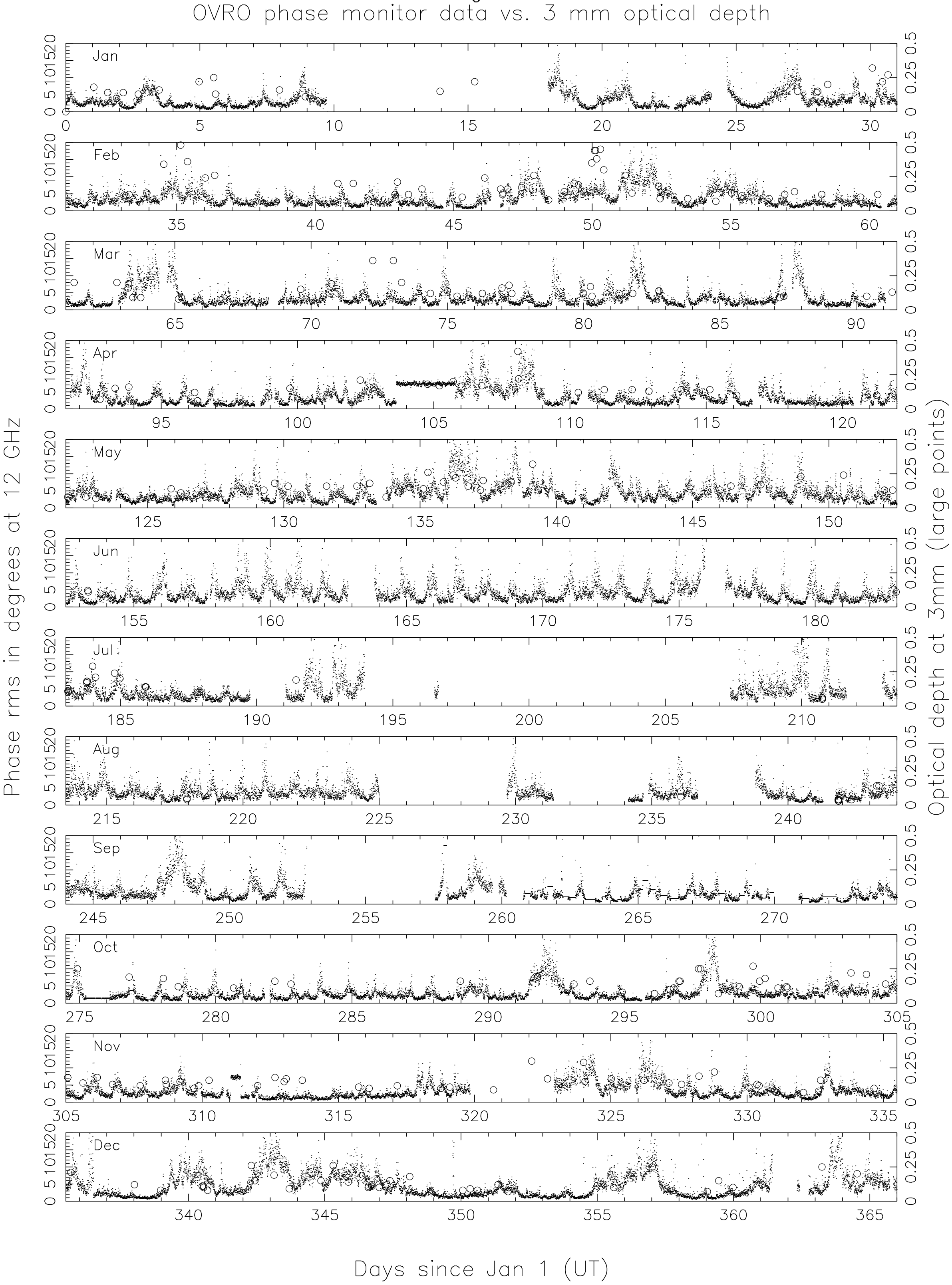

Fig. 2.— The phase monitor data from OVRO for 1996 (points) plotted against the optical depth measured by the interferometer at 3mm (large circles).

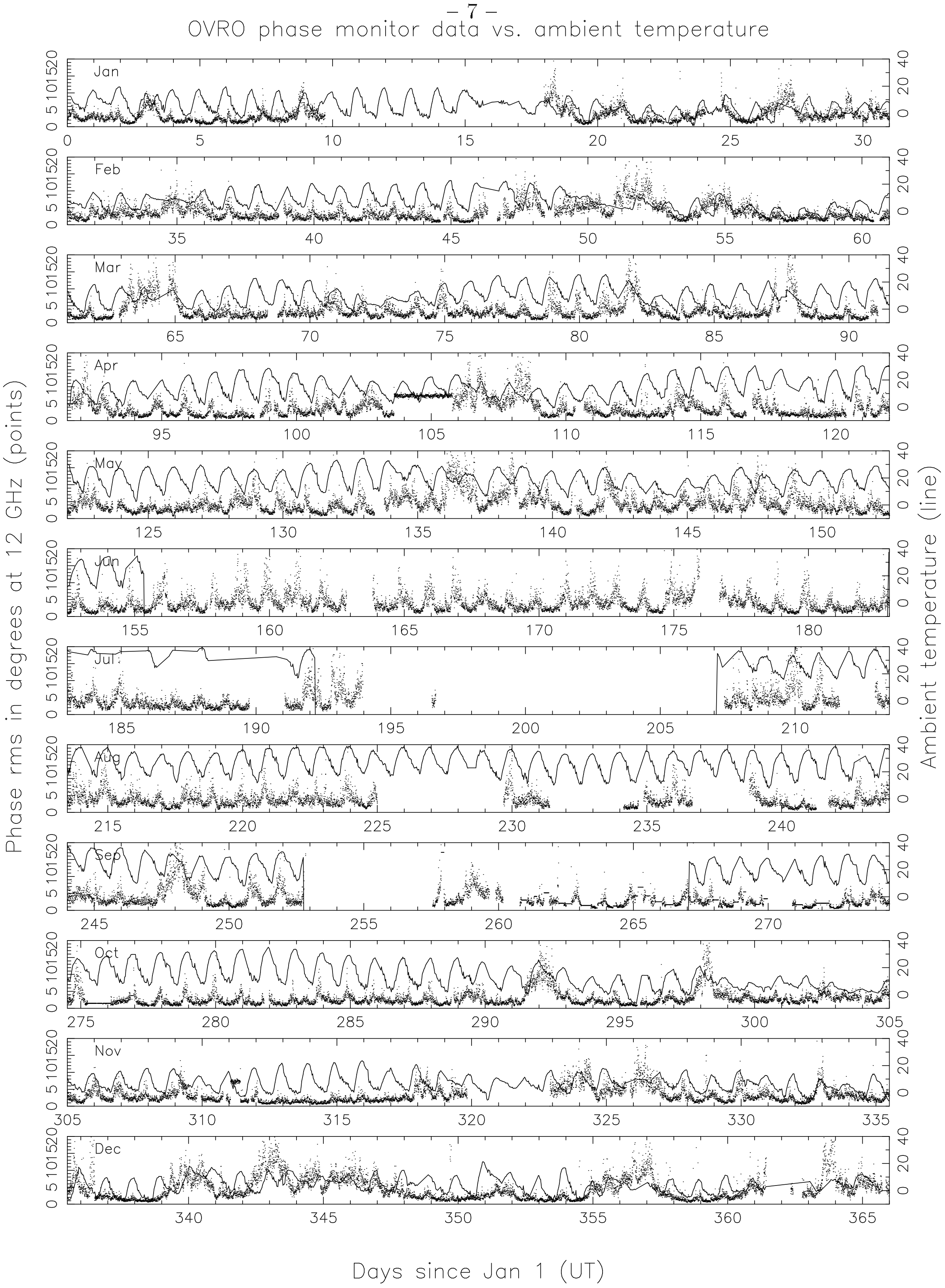

Fig. 3.— The phase monitor data from OVRO for 1996 (points) plotted against ambient temperature (line). While there is some correlation between the two, the temperature is not a good predictor of the rms phase.

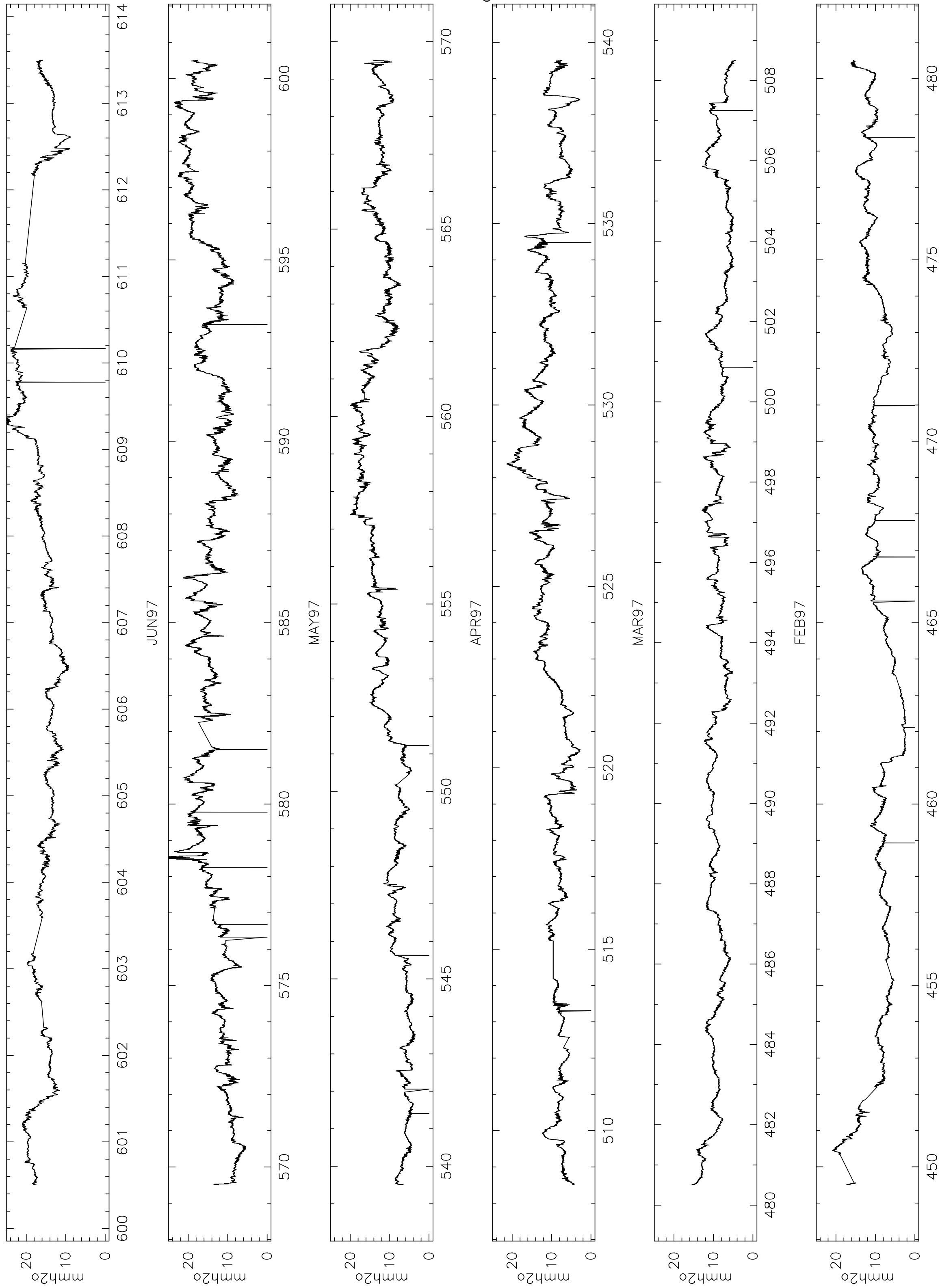

Fig. 4.— The precipitable water at Hat Creek shows remarkably little variation over a 6 month period, in contrast with the actual seeing.

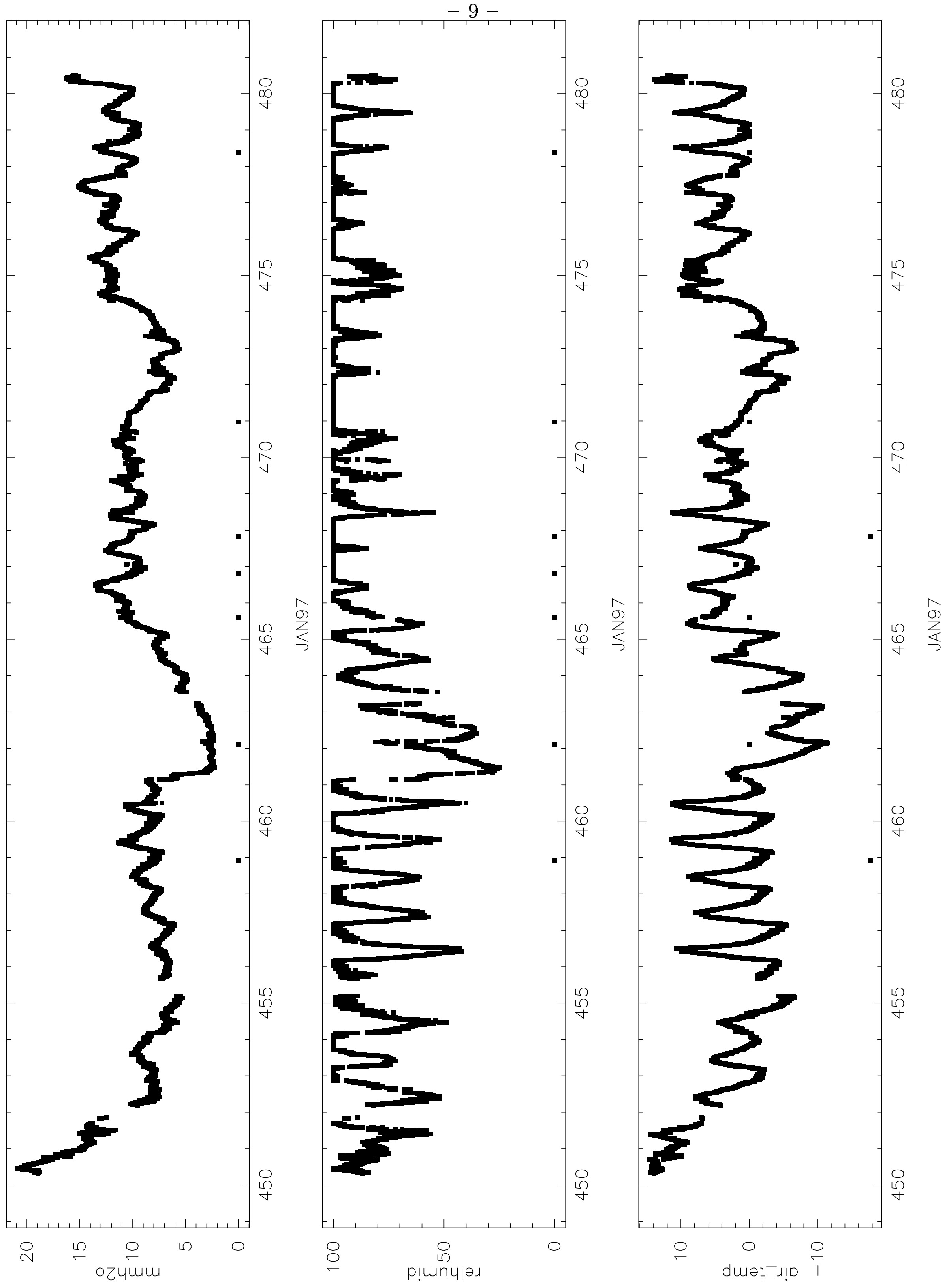

Fig. 5.— Measured Temperature and relative humidity at Hat Creek have much larger diurnal variations than the derived precipitable water