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7.6A INTERPOLATION PROBLEMS IN METEOR RADAR ANALYSIS

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Meteor echoes come from random points in the observation volume, and are irregularly spaced in time. This precludes the use of FFT techniques on the raw data to give the spectrum of waves that are present. One way around this obstacle is to restrict our interest to a particular class of waves, and fit a corresponding model to the raw data. Tides can be determined this way, since we *a priori* know the periods: 24 and 12 hours, by definition. Even here we have to make assumptions about the spatial structure of the tides; it may be reasonable to assume that there is no horizontal variation across the observation volume, but in the vertical this is certainly not the case. If, in addition, we are interested in other types of waves which may be present and whose periods are unknown, then examining the raw line-of-sight velocities does not tell us how to modify the model, since the line-of-sight direction is not fixed. This then is the motivation for interpolation.

Interpolation takes a temporal series of line-of-sight velocities, and transforms it to a temporal series of wind velocities for each orthogonal direction, i.e. north, east, and vertical. The velocities along a given direction can then be examined readily for any waves in addition to tides.

There are different approaches to interpolation, each method having its advantages (and disadvantages). One method is to assume that the wind is constant during some fixed height/time interval, and use regression on all echoes occurring in that interval to determine the (model) constant wind. In another method, the wind is assumed to vary, in time, as a polynomial of specified degree. As before, the regression only uses echoes within a fixed time/height region. In both cases an equally spaced grid in time and height, each grid point having an associated wind vector, is obtained by marching the "interpolation region" in both time and height. The resulting grid is then ready for FFT analysis.

Another method is to regress only on clusters of echoes that are reasonably correlated. This avoids unreliable wind estimates, particularly when there are few echoes in the interpolation region, but the resulting winds are irregularly spaced in time and height.

The implicit assumption, in all the methods mentioned, is that the errors, that is, the residuals in the regression, are uncorrelated and normally distributed. This is the underlying assumption in least-squares regression, and implies that the interpolation region must be much smaller than the shortest period wavelength that we expect to see. The residuals are then attributed to instrumental error and random turbulence.

One problem with decreasing the size of the interpolation region is that fewer echoes are available for the regression and consequently the precision suffers. If the region is too large, so that it encompasses many cycles (either temporal or spatial wavelength), then we can still model the errors as uncorrelated, because the point of occurrence within the observation volume is random. In this case, however, information is lost since we have essentially filtered out the high-frequency contact. So the problem is to choose an interpolation region small enough so as not to filter out the waves that are of interest, yet not too small as to have too few echoes for a reliable estimate.

If we are trying to interpolate the wind when there are too few echoes, then there are two options. The first is to not interpolate at that point, thus leaving a gap in the time-series. If these winds are to be Fourier transformed, then the gaps must somehow be filled, preferably in such a way as not to distort the true spectrum. The second option is to increase the interpolation region so as to increase the number of echoes. This may lead to excessive smoothing, as mentioned before. So the problem is: Do we always try to interpolate a wind, resulting in a time-series with no missing values, or do we set a lowest acceptable "reliability" and treat the missing-value problem as a separate issue?

The last problem has to do with correlated errors. If there is a steady vertical shear, or, say, a trend produced by a long-period planetary wave, then the errors will always be correlated, no matter how small we choose the interpolation region. What is the effect on our estimate of the (model) wind and thus on our estimate of the tides?

To see what effect correlated errors have on the accuracy of the interpolation procedure, we have simulated a meteor radar, randomly picking the observed parameters of height, elevation, azimuth, and time of arrival. A specified wind was then projected onto the line-of-sight directions. The height, elevation, azimuth, and hourly echo rate distributions correspond to those of real echoes. Twelve hundred echoes/day were generated. Following GROVES (1959) the horizontal winds at (t_0, h_0) were computed using an interpolation box centered on (t_0, h_0) with a time width of 2 hours and a height width of 5 km. The echoes in the box were weighted inversely by the distance to the center of the box. The tidal components were then determined using a least squares curve fit.

Figure 1 is a harmonic dial showing the semidiurnal tide (at a given altitude) computed daily from 30 days of simulated meteor echoes. The specified meridional wind in this case consisted of a semidiurnal tide with a vertical wavelength of 80 km, a 3-hour gravity wave with a vertical wavelength of 5.5 km, and gaussian white noise with zero mean and a standard deviation of 25. The zonal wind was zero. For the cloud of tidal estimates shown in this figure, an error ellipse and 2-dimensional standard deviation about the true value was computed (BARTELS, 1932). This calculation was performed at all heights and the standard deviation was then plotted as a function of height as shown in Figure 2.

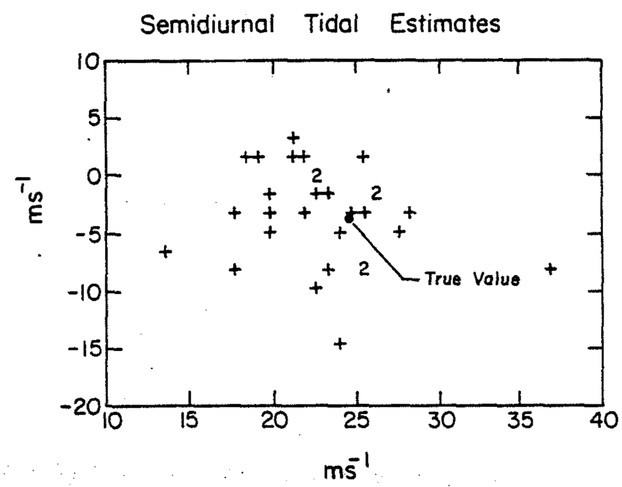

Figure 1. Harmonic dial of semidiurnal tidal estimates (Case D).

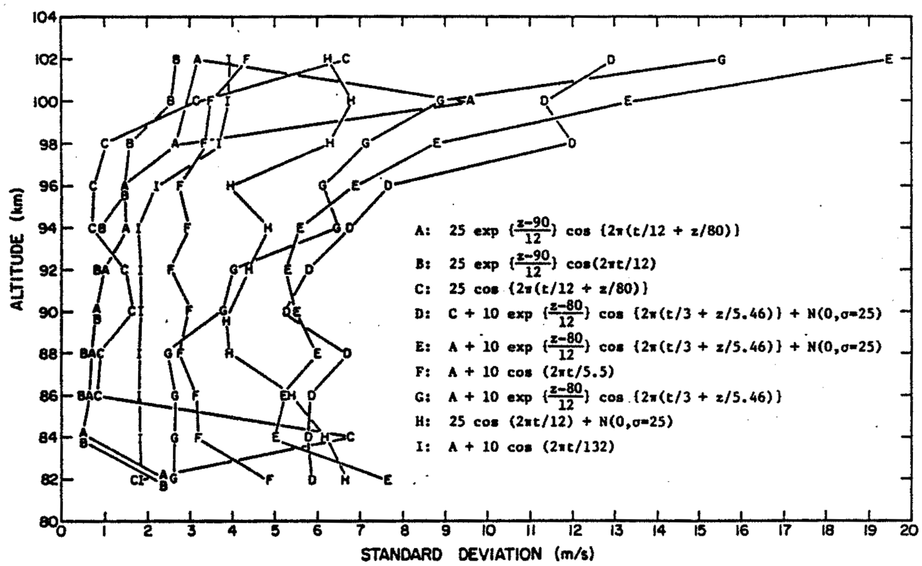

Figure 2. Standard deviation of tidal estimates for different wind fields.

From Figure 2 we can conclude that the variance of the tidal estimate will depend on the nature of the noise (correlated or uncorrelated). In the case of uncorrelated noise, the tidal variance decreases with increasing echo rate. With correlated noise (the presence of wind shears), the tidal variance is governed more by the magnitude of the wind shears. The presence of long-term trends such as planetary waves contributes less to tidal variance than gravity-wave-induced wind shears.

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