Space-time Interpolation of Satellite Winds in the Tropics

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1. Introduction

Many meteorological and climatological applications rely on the
computation of mean wind fields of vorticity and divergence, from weekly to yearly time scales. With the ever increasing availability of satellite measurements, it is desirable to compute such mean fields from satellite wind observations alone. Due to the uneven sampling of the ocean in space and time, however, most averaging techniques are known to produce poor results, in particular banded structures that resemble the satellite swaths and artificial peaks in the energy spectra (e.g., Zeng and Levy 1995). Here, we propose to compute average fields of vorticity and divergence in the Tropics from SeaWinds-on-QuikSCAT (QS) wind measurements by using the space-time interpolation method developed by Zeng and Levy (1995). The temporal and spatial scales used in the interpolator will be determined by matching the subgrid scale variability in time and space (Levy and Vickers 1999), as determined from QS and TAO buoy wind measurements.

2. Methodology

The method consists in interpolating optimally at each grid point by substituting temporal information when spatial information is missing:

$$u = \frac{\sum w_k u_k}{\sum w_k}$$

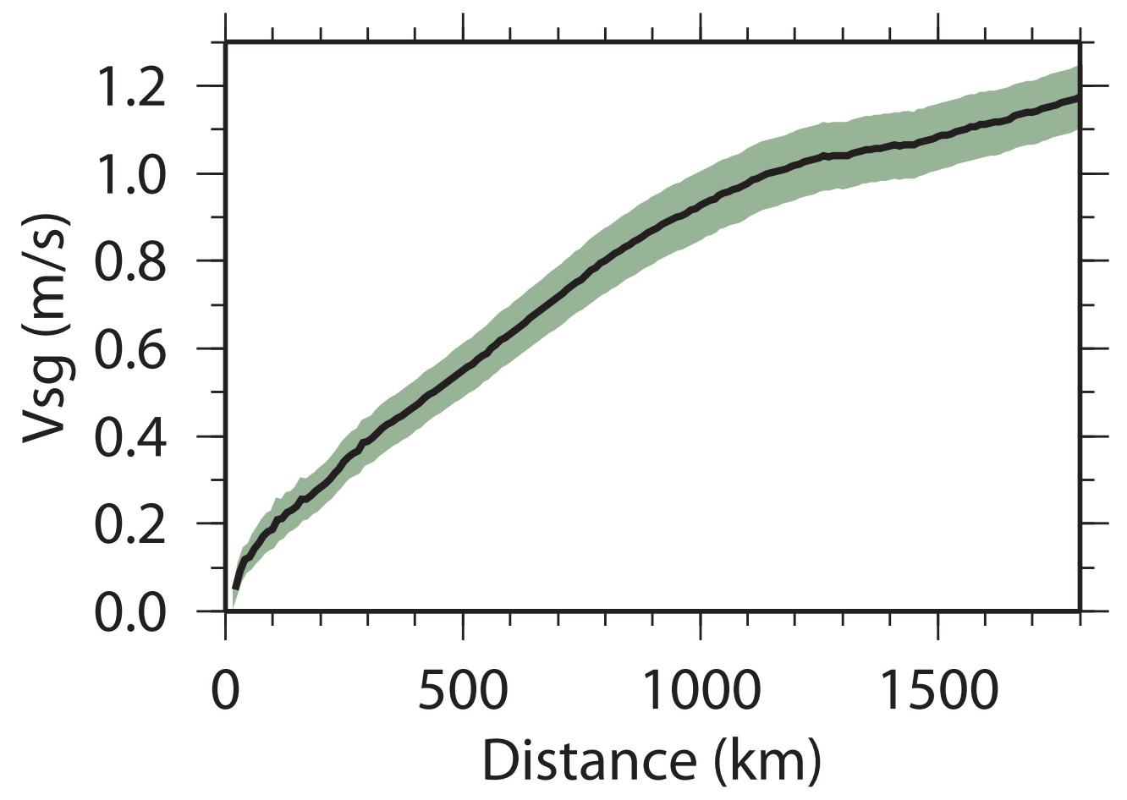
where u_k is the variable to be interpolated at (x_0,y_0,t_0) (wind, pressure, vorticity, divergence, etc.) and w_k is a weight function:

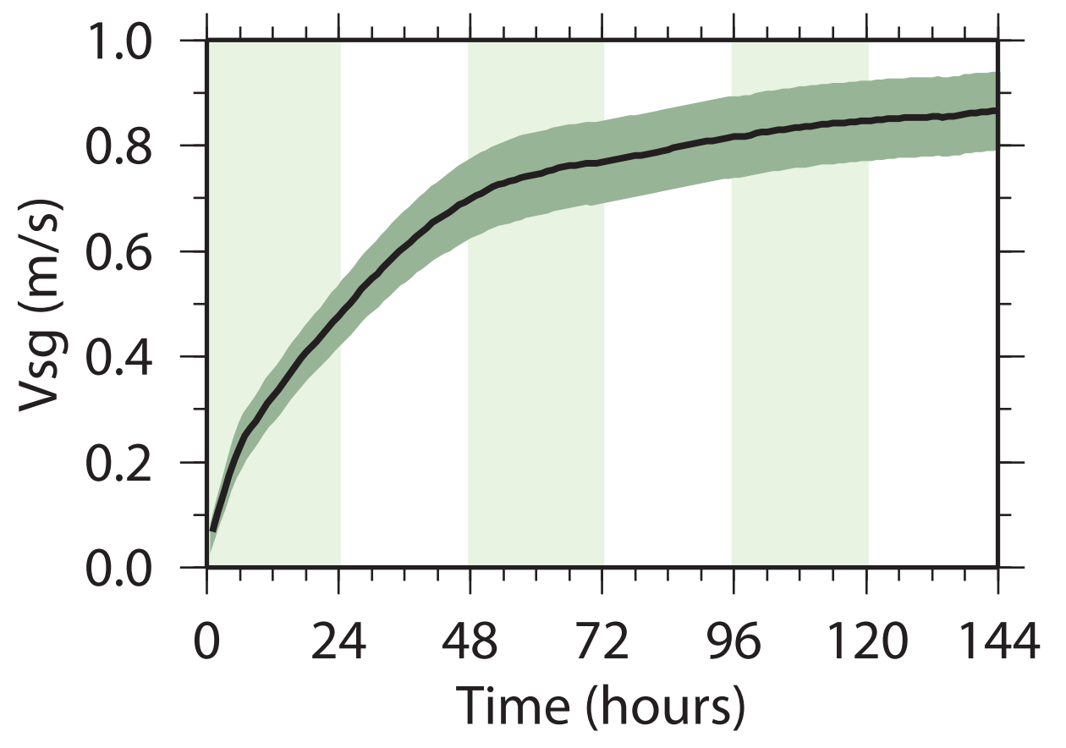
$$w_k = \frac{2-\left[\frac{(x_k-x_0)^2+(y_k-y_0)^2}{D^2}+\frac{(t_k-t_0)^2}{T^2}\right]}{2+\left[\frac{(x_k-x_0)^2+(y_k-y_0)^2}{D^2}+\frac{(t_k-t_0)^2}{T^2}\right]}$$

D and T are determined by characterizing the subgrid velocity scale due to unresolved spatial variability when averaging satellite data over increasingly larger radii, and matching it with the temporal velocity scale due to unresolved temporal variability when averaging buoy data over increasingly longer time windows. For each QS swath overlapping a TAO buoy, the QS surface wind vector is averaged over increasingly larger circular areas of radius R and the subgrid velocity scale for each radius is defined as:

$$U_{sg} = \overline{(u^2+v^2)}^{1/2} - (\overline{u}^2+\overline{v}^2)^{1/2}$$

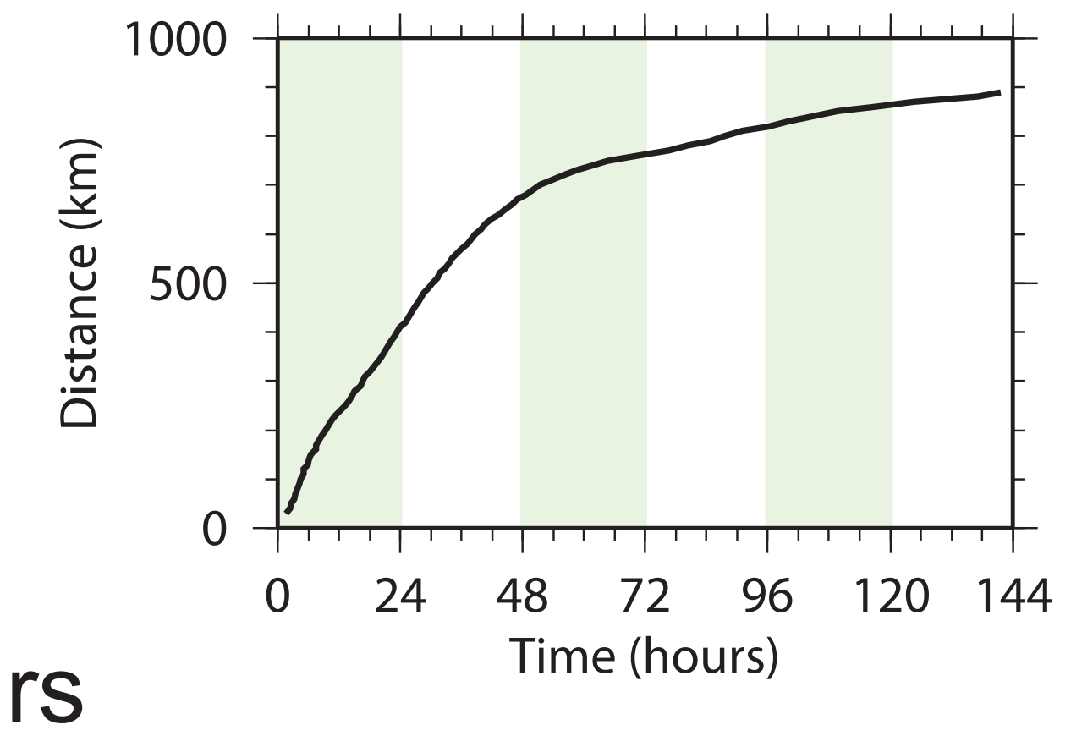
which yields the figure on the right.





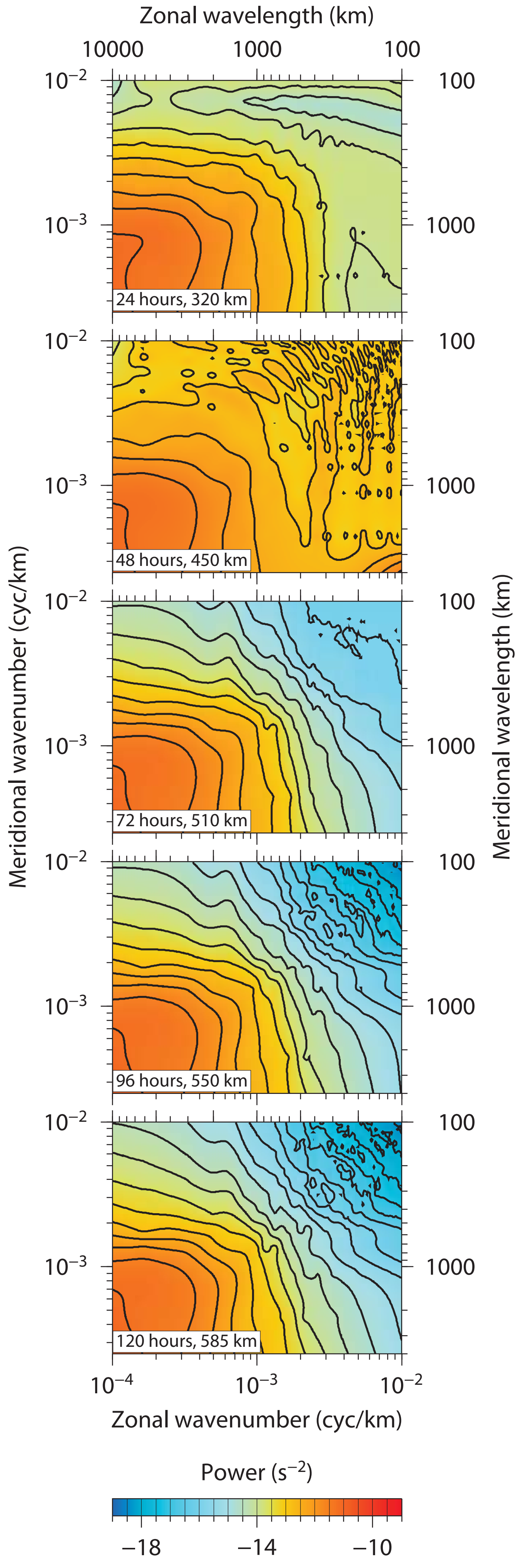
Similarly, the TAO buoy winds are averaged over increasingly longer time windows and the temporal velocity scale is calculated in each case, which yields the figure on the left for TAO buoy 2N165W.

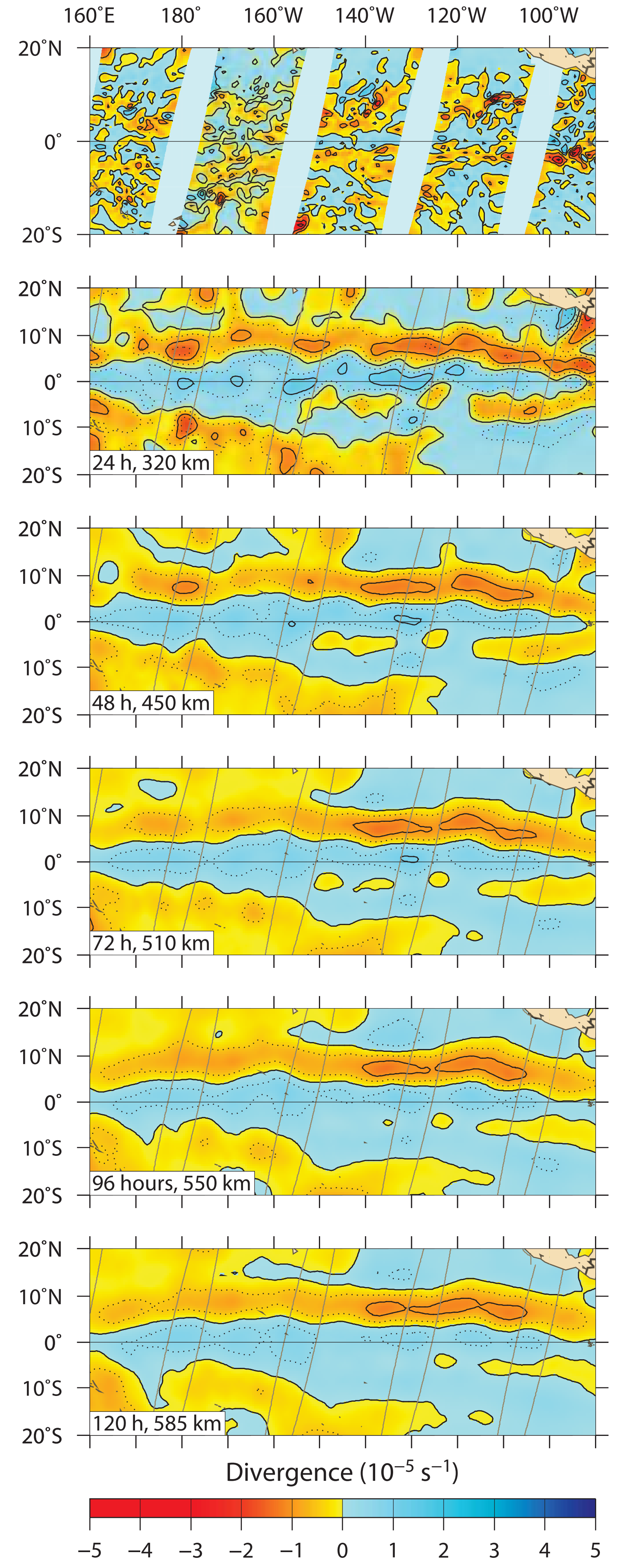
By matching the spatial and temporal scales yielding identical subgrid velocity, the following correspondence is obtained:



which provides an equivalent D when T is known, and vice versa. The previous calculations are repeated for all available TAO buoys and averaged to produce a unique relationship that yields the possible pairs of spatial and temporal ranges (D,T) that we could use in our space-time interpolator. The next figure shows different interpolated divergence fields for April 15, 2000 at 06 UTC based on 5 possible pairs (D,T) where T increases from 1 to 5 days.
In the (24 h, 320 km) interpolated field, one can notice a number of suspicious minima and maxima in the vicinity of the swath edges. As we increase the interpolation windows, these extrema disappear and the divergence field becomes more homogeneous.

We determine the optimal pair of ranges by performing a 2D spectral analysis of the interpolated fields for each pair, as shown below. In the first two spectra, unphysically high energy levels can be observed, due to aliasing and the projection of artificial features onto the spectrum at specific scales and their harmonics.





At 72 h and 510 km, these spurious extrema mostly disappear and interpolating at larger spatial and temporal scales does not further improve the spectrum significantly. This suggests that satellite-derived divergence and vorticity can be interpolated with a 3-day time window, i.e., much better than the 8-day Nyquist frequency suggested by the return period.

Patoux (2012)