地上気象擾乱の普遍周波数スペクトル

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Universal frequency spectra of surface meteorological fluctuations

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Statistical properties of meteorology are examined in terms of wavenumber and/or frequency spectra. It is known that in the free atmosphere, wavenumber (frequency) spectral shape is roughly proportional to a power of the wavenumber (frequency) (e.g. VanZandt, 1982; Nastrom and Gage, 1985). In addition, at the surface, temperature spectra tend to have a universal slope in the range of about 10-day period to a few-year period (Koscielny-Bunde et al. 1998). Sato and Hirasawa (2007, hereafter SH07) examined frequency spectra of surface meteorological parameters over a wide range of 2 hours to 20 years at Syowa Station in the Antarctic, and showed that the spectra have a shape proportional to two different powers of the frequency at the frequencies higher and lower than a transition frequency of (several days)$^{-1}$, as well as clear isolated peaks corresponding to annual and diurnal frequencies and their higher harmonics.

The purpose of this study is to confirm whether the characteristics of the frequency spectra of the surface meteorology shown by SH07 are universal. For this purpose, the analysis was extended to hourly surface meteorological data at 138 stations observed by Japan Meteorological Agency. The time series of the surface temperature, the sea level pressure (SLP), the zonal and meridional winds collected over the time period from 1 January 1961 to 31 December 2005 were used. Frequency spectra were estimated by the Maximum Entropy Method (MEM). Spectra of all physical quantities have similar characteristics as pointed out by SH07 at all stations. The spectral shape of the SLP was quantitatively estimated by the least squares fitting method in the low ((90 days)$^{-1}$ to (6 days)$^{-1}$) and high ((3 days)$^{-1}$ to (6 hours)$^{-1}$) frequency range to $S_L(\omega)=C_L\omega^{-\beta_L}$ and $S_L(\omega)=C_L\omega^{-\beta_L}$, respectively. Here $S_k(\omega)$ is the frequency spectrum, ω is the frequency, C_k is the coefficient, and β_k is the spectral slope, $k=L,H$. The variance for each spectral range v_k and the transition frequency ω_t are calculated analytically (Fig. 1). These parameters of the spectral shape clearly depend on the latitude (Fig. 2).

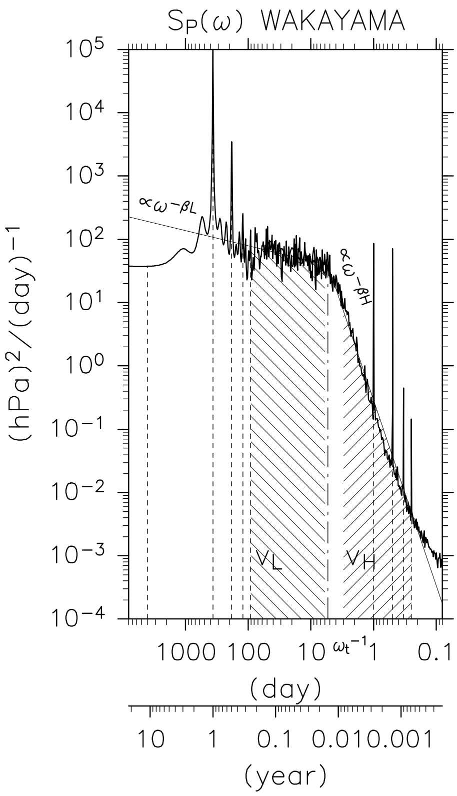

Fig. 1 Frequency spectra of the SLP and their shape parameters at Wakayama.

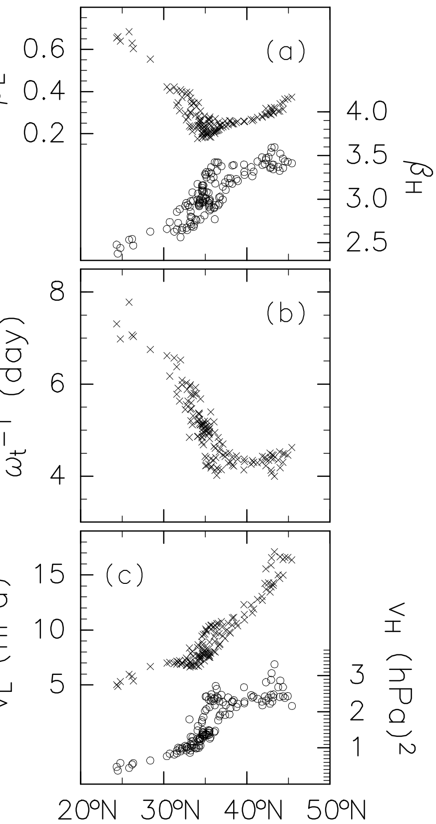

Fig. 2 Shape parameters as a function of the latitude.

Furthermore, to clarify the global distribution of the spectral shape, two simulation data (Miura et al. 2007; Noda et al., 2010) calculated using NICAM (Nonhydrostatic ICosahedral Atmospheric Model; Satoh et al., 2008) were used. Because of limited data period, spectral shape parameters in the high frequency range of the 2 m temperature, the surface pressure, the 10 m zonal and meridional winds were calculated. It is confirmed that the spectra from NICAM are surprisingly realistic in terms of the shape and amplitude. The spectral slope of all physical parameters varies depending on the latitude, and slightly on the geographical distribution. The variance in the high frequency range is large in the storm track region for the surface spectra (Fig. 3), on the continents for the 2 m temperature, on the ocean for the 10 m zonal and meridional winds, respectively.

It is indicated that energy source is the baroclinic instability. Because small Colioris term reduces the variance of SLP in the tropics, the rotation may be an important factor to determine the spectral shape. The distribution of ν_k of the temperature and the winds may be explained by the heat capacity and the roughness of the surface.

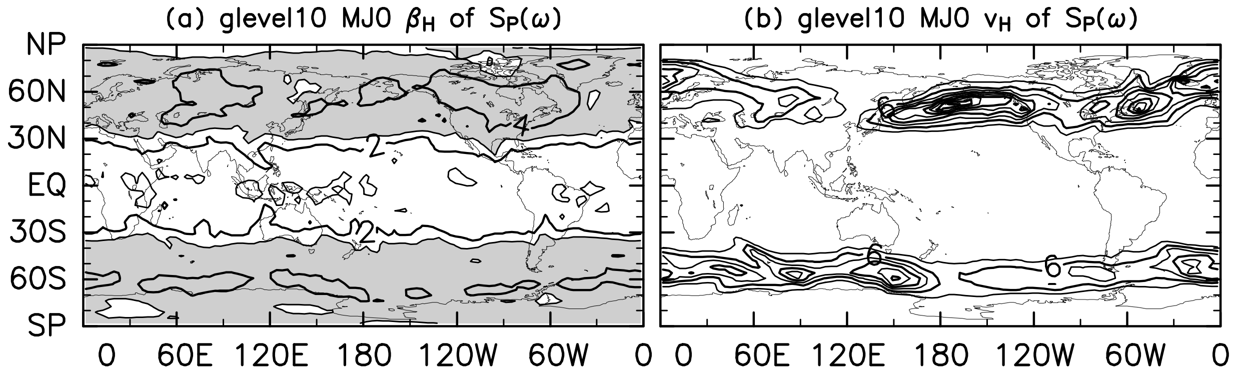

Fig. 3 Distributions of the slope and the variance in the spectral range of the surface pressure from 7-km mesh NICAM simulation (Miura et al., 2007) data.

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