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A northern-hemispheric climatology of indices for clear air turbulence in the tropopause region derived from ERA40 re-analysis

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A 44-year climatology (from 1958 to 2001) of indicators for clear air turbulence (CAT) is presented for the tropopause region based upon re-analysis data from the European Centre for Medium-Range Weather Forecasts (ECMWF). Small Richardson numbers (RI) were used as an indicator for Kelvin-Helmholtz instability, negative squared Brunt-Väisälä frequencies (N^2) for hydrostatic instability, negative potential vorticity values (PV) for symmetric instability. Additionally an empirical turbulence indicator (TI) is used. For all indicators there is a winter frequency maximum for CAT over the North American east and west coast. Other local maxima are found over the western part of the North Atlantic and North Pacific, the Himalayas, Central Europe and eastern China. TI and PV strongly and RI slightly depend on the jet position, contrarily to N^2, which has largest frequencies over land. There are differences in the frequency maxima relative to the jet positions for RI, TI and PV, with a maximum to the north for TI, a maximum to the south for PV and one for RI that is essentially along the jet axis. In summer the frequencies are smaller, except for N^2, and shifted polewards. For the considered 44 years pronounced non-linear trends could be identified with an increase of 40%-90% over the North Atlantic, US and European sector. The interannual variability of CAT is significant for TI and PV for the two phases of the North Atlantic Oscillation as well as for the Pacific / North American flow pattern, whereas the RI and especially the N^2 patterns are not markedly influenced by the jet streams variations during these phases.