Testing of a new gravity wave based clear-air turbulence diagnostic

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Introduction

The coincidence between gravity waves (GW) and clear-air turbulence (CAT) has been evident for a long time (e.g. Bekofsky and Liu, 1972). In recent years due to better data availability and improving understanding of GW dynamics possibilities of predicting CAT induced by GW are being researched (e.g. Kopec et al., 2011; Sharman et al., 2012; Knox et al., 2008). In the presented work we investigate application of an approach based on work by Haman (1962). This approach uses the amplitude evolution equation for slantwise propagating gravity waves to predict possible occurrences of Clear-Air Turbulence (CAT) near wave breaking regions.

Vertical Evolution of a Monochromatic GW Amplitude

• The idea by Haman (1962): shallow convection arises a spectrum of monochromatic GW immediately above cloud tops.
• The vertical evolution of the amplitude of a monochromatic GW (wavenumber k and phase speed c) is predicted using:
  \[ s^+ + \left( \frac{\omega}{c^+} \right) s + \left( \frac{\omega^2}{c^+} - k^2 \right) s = 0 \]
• Wave is expected to break into turbulence when either it encounters critical level or
  \[ K = \frac{1}{\omega} \left( \frac{k}{c} \right) \left( \frac{s}{\omega} \right) \]
  (Kopec et al., 2011)

Verification Procedure

• The index \( N_{\alpha} \) was tested for detection of moderate or greater turbulence
• The index was calculated for a set of 180 values of \( \Delta \) uniformly distributed in the interval (45m, 8995m)
• The indices for small \( \Delta \) results from the waves broken near the aircraft larger \( \Delta \) means less localized information
• The measure of skill was Area Under ROC Curve (AUC)
• Verification was conducted for all observations, 3 months separately and 8 11-day periods.

Verification Results

• Indices \( N_{\alpha} \) show chaotic behaviour possibly caused by lack of consideration of shallow convection which was assumed a GW forcing
• Indices \( N_{\alpha} \) usually bear relevant information about CAT but the most relevant \( \Delta \) changes with time thus they could be used as a member ensemble predictor but not as standalone index
• We have combined \( N_{\alpha} \) indices using random forest based method and the resulting ensembles display more predictable behaviour and show potential to be good short-time predictors.

Conclusion

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