A Simple Model to Simulate the Assimilation of Vertical Motion from Cloudy Satellite Imagery

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Satellite infra-red sounders are invaluable tools for revealing information on the structure of the atmosphere. They provide much of the information used to initialise atmospheric models, especially in regions that do not have extensive ground-based observations, such as oceans. However, in the presence of cloud, much of this information must be discarded, as the cloud layer is opaque to infra-red radiation. This means that in those situations where information is most desired (such as a developing weather system), it is also very limited in coverage.

A study into the feasibility of retrieving vertical atmospheric motion from sequences of infra-red geostationary satellite images has been undertaken. A single-column model of the atmosphere simulates cloud development with vertical motion, allowing the characteristics of a 2D-Var data assimilation system using a single simulated infra-red satellite observation to be studied. The adjoint method is sufficient for producing an accurate gradient for the cost function, but the non-linear nature of cloud formation causes the minimisation to be very poorly conditioned. The conditioning varies very strongly with the atmospheric variables. Minimisation is achieved using preconditioned conjugate gradients.

The model was provided with a background with values for humidity (with error of 10%) and temperature (with error of 1K). Assimilating simulated infra-red radiances every 15 minutes over an observation window of 6 hours allows vertical motion to be retrieved with an error of half a centimetre per second in some conditions. Moreover, evaluating the Hessian of the cost function at the minimum provides an estimate of the reliability of the retrieval. This allows atmospheric states that do not provide sufficient information for retrieval to be rejected (such as a cloudless atmosphere or a non-moving opaque cloud layer in the upper troposphere). Retrieval is most accurate with a small upwards motion, with error increasing slowly with larger upward motion and increasing rapidly with downwards motion.