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Investigating sensitivity to Saharan dust in tropical cyclone formation using NASA's adjoint model

Daniel Holdaway (1,2)

(1) Global Modeling and Assimilation Office, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA, (2) Goddard Earth Sciences Technology and Research, Universities Space Research Association, Columbia, Maryland, USA

As tropical cyclones develop from easterly waves coming off the coast of Africa they interact with dust from the Sahara desert. There is a long standing debate over whether this dust inhibits or advances the developing storm and how much influence it has. Dust can surround the storm and absorb incoming solar radiation, cooling the air below. As a result an energy source for the system is potentially diminished, inhibiting growth of the storm. Alternatively dust may interact with clouds through micro-physical processes, for example by causing more moisture to condense, potentially increasing the strength. As a result of climate change, concentrations and amount of dust in the atmosphere will likely change. It it is important to properly understand its effect on tropical storm formation.

The adjoint of an atmospheric general circulation model provides a very powerful tool for investigating sensitivity to initial conditions. The National Aeronautics and Space Administration (NASA) has recently developed an adjoint version of the Goddard Earth Observing System version 5 (GEOS-5) dynamical core, convection scheme, cloud model and radiation schemes. This is extended so that the interaction between dust and radiation is also accounted for in the adjoint model. This provides a framework for examining the sensitivity to dust in the initial conditions. Specifically the set up allows for an investigation into the extent to which dust affects cyclone strength through absorption of radiation.

In this work we investigate the validity of using an adjoint model for examining sensitivity to dust in hurricane formation. We present sensitivity results for a number of systems that developed during the Atlantic hurricane season of 2006. During this period there was a significant outbreak of Saharan dust and it is has been argued that this outbreak was responsible for the relatively calm season. This period was also covered by an extensive observation campaign. It is shown that the adjoint can provide insight into the sensitivity and reveals a relatively low sensitivity to dust compared to, for example, the thermodynamic variables. However a secondary sensitivity though moisture is seen. If dust dries the air it can significantly reduce the cyclone intensity through the moisture.