Solving the Atmosphere: Case Study of Tropical Storm Vamei

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The atmosphere, like any other fluid, is governed by a few fundamental physical principles: the conservation of mass, the First Law of Thermodynamics and Newton's Second Law. Thus, one can easily write down a set of partial differential equations for the atmosphere and hope to solve for the atmosphere's behaviour from there. Or can one?

Apart from the general mathematical problems associated with solving the hydrodynamical equations, additional challenges to solving the atmosphere arise from: (1) the discretization of the problem in numerical solutions, hence demanding unresolved processes to be parameterized; and (2) from the representation of sources and sinks for mass, heat and momentum in the atmosphere and on the Earth's surface. Moreover, because of the chaotic nature of atmospheric dynamics, meteorological observations need to be assimilated into the numerical solutions to keep them from diverging too much from reality. We shall explain the theory and the practice of solving the atmosphere through the realistic simulation of a case of extreme weather in Southeast Asia.

On 27 Dec 2001, tropical cyclone Vamei landed on the southern tip of the Malayan Peninsula, bringing heavy rain and widespread flooding in the southern Malaysian state of Johor and nearby Singapore. While tropical cyclones or typhoons are no strangers in some countries in Southeast Asia, e.g. the Philippines, the occurrence of Vamei at the very low latitude of 1.5 degrees north is virtually unheard of before (Chang et al. 2003).

The Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS®) was used to make a high-resolution simulation of the regional weather for the period 17 – 29 Dec 2001. Navy Operational Global Atmosphere Prediction System (NOGAPS) outputs were used to initialize and to provide boundary conditions for the model run. A host of observational data was assimilated every 12 hours. Description of the COAMPS model can be found in Hodur (1997).

A tropical cyclone was successfully spun up in the COAMPS model simulation. To verify the simulated track of the cyclone, we apply an objective criterion to identify the centre of circulation in the lower troposphere, essentially following the same principle as in Power and Davis (2002). The cyclone track so derived is compared to published best-track data of Vamei from the Joint Typhoon Warning Center in Hawaii. This gives us a quantitative assessment of how good our numerical solution of the partial differential equations for the atmosphere is in this case.

References

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