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How do environments affect the size of tropical cyclones?

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Along-standing issue on how environments affect the size of tropical cyclones is studied through a series of numerical experiments using the cloud-resolving tropical cyclone model, TCM4, and the global cloud-system-resolving model, NICAM. To first order, the primary circulation of a tropical cyclone can be considered as a warm-cored, quasi-axisymmetric vortex in gradient wind and hydrostatic balance. As a tropical cyclone evolves slowly while its primary circulation remains in gradient wind and hydrostatic balance, the secondary circulation (radial and vertical circulation) can be considered as a result of the response to both diabatic heating and momentum forcing including surface friction. The secondary circulation transports high absolute angular momentum inward to spin up the tropical cyclone primary circulation. This spin-up process can be well described by the Sawyer-Eliassen equation following the classic work of Eliassen (1952).

The balanced contribution to the intensification of a tropical cyclone simulated in TCM4, in particular the size of the cyclonic circulation, is investigated by solving the Sawyer-Eliassen equation and by computing terms in the azimuthal-mean tangential wind tendency equation. Results demonstrate that the azimuthal-mean secondary circulation and the spin-up of the mid-tropospheric outer circulation in the simulated tropical cyclone are well captured by balance dynamics. The mid-tropospheric inflow develops in response to diabatic heating in mid-upper tropospheric stratiform (anvil) clouds outside the eyewall in active spiral rainbands and transports absolute angular momentum inward to spin up the outer circulation. Although the azimuthal-mean diabatic heating rate in the eyewall is the largest, its contribution to radial winds and thus the spin-up of outer core circulation in the mid-troposphere is rather weak. This is because the high inertial stability in the inner core region resists the radial inflow in the mid-troposphere, limiting the inward transport of absolute angular momentum. The result thus suggests that diabatic heating in mid-upper tropospheric stratiform clouds is the key to the continued growth of the storm scale circulation.

The 7-km run using NICAM successfully simulated tropical cyclones that formed in three months from 1June to 31August 2004. A multi-scale interaction between tropical cyclones and environment has been investigated. It is clear that the size of tropical cyclones was sensitive to the environmental relative humidity. In a relatively moist environment, the tropical cyclone developed considerable precipitation (and thus diabatic heating) outside the core accompanied by significant outward expansion of the wind field and increase in size of tropical cyclones.

Keywords: tropical cyclone size, multi-scale interactions, NICAM, TCM4