Geophysical Research Abstracts
Vol. 13, EGU2011-6668, 2011
EGU General Assembly 2011

Super-rotation over tidally-locked exoplanets

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Over the past fifteen years, a variety of planet-search initiatives have led to the discoveries of over 500 exoplanets. Recent high-precision radial-velocity surveys indicate that a large fraction of, perhaps most, nearby stars have super-Earths with periods less than 2 months and masses more than five times that of the Earth. These exoplanets, discovered with current techniques, are mainly within relatively short distances to their parent stars. Therefore, these planets are tidally locked due to strong gravity and thus have synchronous rotation. That is, one side of these exoplanets always faces their parent stars, and the other side remains dark, just like the Earth's Moon whose one side always faces the Earth.
Using a modified Earth-atmospheric GCM, we carry out simulations for Earth-like tidally-locked exoplants. Stellar radiation and atmospheric compositions are nearly the same as Earth's. The exoplanet is assumed an aqua-planet, with a 50-meter slab ocean. Simulations show strong super-rotation, i.e. westerly winds over the equator. For fast rotation (1 day), the maximum zonal wind speed is up to 90 ms-1 over the night-side. As rotation becomes slower, westerly winds decrease. Super rotation also slows down as stellar insolation becomes weaker. It is worth to point out that most Earth-GCMs cannot generate westerly winds over the equator. However, it readily generates super-rotation for tidally-locked exoplanets. Diagnostics demonstrates that the strong super-rotation is forced due to eddy-flux convergence by poleward-propagating tropical Rossby waves. The wave pattern resembles the Gill solution, but showing differences. It is found that Kelvin waves are largely damped out.

Refernce:Hu, Y., and F. Ding, 2011: Radiative constraints on the habitability of exoplanets Gliese 581c and d. Astronomy & Astrophysics, in press.