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Experiments on High Rayleigh number thermal convection in rapidly rotating hemispherical shell and the Earth's outer core

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Experiments on thermal convection in a rapidly rotating hemispherical shell were conducted at Ekman number of 5x10^-6 to understand the strongly non-linear convection in the Earth's outer core.The following 3 regimes were found.(1)Ra/Rac < 1:stably stratified state, (2)1 < Ra/Rac < 4: penetrative convection driven by cold plumes which form eastward spiralling cyclonic cells from the inner sphere. The cells are slowly advected westward by the zonal flow.(3) Ra/Rac > 4: dual convection driven by both cold and warm plumes. Warm plumes emanate inward from the outer sphere. The discrepancy in the wave number of these plumes results in turbulence. Our results suggest several new interpretations for the convection in planetary cores.

We report the results of laboratory experiments on non-linear thermal convection in a rotating hemispherical shell at Ekman number of 5x10^-6, in order to understand the strongly non-linear convection in the Earth's outer core. By rotating a hemispherical shell, we simulate the radial gravity by combined effect of centrifugal and laboratory gravities.Visualization and recording of the pattern and flow together with measurement of temperature time series are done to quantify the motions.We have studied the dependence of the convective pattern and temperature structure upon the Rayleigh number of up to 21 times critical.Three major regimes have been found; (i) Ra/Rac < 1 : stably stratified case absent of radial motion.(ii) 1 < Ra/Rac < 4 :penetrative convective mode driven by prograde spiralling cold plumes emanating from the inner core that drift retrograde. The cells are all cyclonic and are closely spaced.(iii) Ra/Rac > 4 : dual convective mode driven by both cold plumes from the ICB and warm plumes from the CMB resulting in very fine-scale geostrophic turbulence.A Reynolds stress driven retrograde flow fastest near the ICB was present.The transition of (ii) and (iii) occurs due to the difference in the wavenumber of the plumes emanating from the inner and outer boundaries, i.e., the cold plumes from ICB has smaller wave numbers (60) as compared to warm plumes from the CMB (108) which is due to differing bottom slopes.There was a geostrophic wall jet adjacent to CMB which was mostly retrograde except prograde at low latitudes, and existed irrespective of the Rayleigh number. Corresponding temperature measurement by thermister probes indicate oscillations of a typical period corresponding to the drift of columar structures and non-sinusoidal features originating from non-linearity.Heat transfer which is most pronounced in the equatorial region was found to increase at regime (ii) to (iii) transition. The experiments show that geostrophy predominates even if turbulence sets in, and that cyclones can predominate in the outer core. It also shows that drift of pattern arises from advection and not from wave motion.