GEOPHYSICS, NATURAL SELECTION, and HYDROLOGICAL FORECASTING

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Over the last 30 years hydrology has evolved from a field focused on engineering problems of rainfall-runoff and irrigation scheduling at the scale of the small watershed to a field struggling with global-scale issues which demand a geophysical perspective. This shift of perspective, while it emphasizes the geosciences, is essential both to achieving an understanding of the environmental consequences of climate change, and to developing the practical tools for long-range forecasting of water availability.

The key to understanding the fundamental difference between the hydrological system at small geographical scale and that at large geographical scale lies in the sensitivity of the precipitation to the feedback of moisture and heat from the land surface. At small geographic scale, the input precipitation may be assumed to be independent of these land surface fluxes, and the rainfall-runoff system collapses to a simple cascade. This was the standard hydrological model at mid-century. At large geographical scale however, the feedback fluxes are important determinants of the precipitation, and the system may be highly non-linear. The large spatial scales at which this feedback is most important dictate correspondingly large dominant time scales with their attendant potential for long-range forecasting. Several such hydrological 'teleconnections' have been empirically recognized for some time, while regional- and global- scale numerical models of the coupled land surface, atmosphere, and ocean are now providing their geophysical justification.

In these large scale numerical models, the hydrological states and fluxes at the land surface are necessary boundary conditions to the fluid and thermodynamical equations governing the atmospheric physics. At vegetated land surfaces these boundary conditions involve biological states and fluxes which are not determined by the familiar conservation equations of fluid dynamics, and the geometrical structure of the plant canopy modulates the biophysical interaction of the atmosphere-plant-soil system. Our research suggests that we can formulate in physical terms the natural selection processes that determine the canopy configuration and that fix the average vegetal fluxes under equilibrium conditions. These additional equations should facilitate writing an approximate dynamic landsurface boundary condition in which the canopy structure is not pre-specified but is instead determined by the climate and soil in a truly interactive process. Such capability is needed in order to deal realistically with climate change.