# SECTION III

## Introduction to Spatial Scaling and Spatial/Temporal Modeling

IN SECTION II we developed an appreciation of how ecosystems operate in the temporal dimension and presented an array of models developed to predict their behavior into the future. In Section III, we extend this analysis to the spatial dimension. Most forested landscapes are extremely heterogeneous in both physical and biological characteristics. In this section we introduce ways to quantify the physical heterogeneity of topography, climate, and soils. We further extend the analysis of heterogeneity to include biological features of forests, primarily through the application of remote sensing techniques. Finally we demonstrate how heterogeneous spatial data may be incorporated into simulation models that quantify ecosystem responses across landscapes and project changes in forest structure and composition forward in time (Fig. III.1). These ecosystem models can provide land managers a visual image of how the landscape may change in the future under the range of alternatives being considered today.

Critical to the success of these spatially explicit models is a judicious choice of variables that can be measured and compared over landscapes and regions. In most cases the appropriate variables are derived by simplifying the analysis of

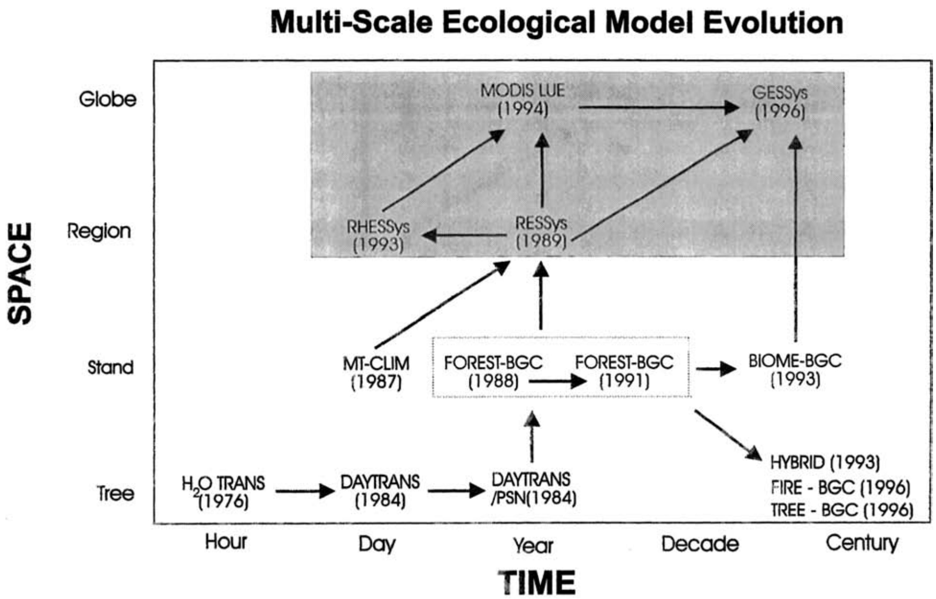


**FIGURE III.1.** Evolution of a family of related ecosystem simulation models for a range of space/time applications, referenced by the model name and initial publication date. Model development shows a progression from an earlier precursor with a smaller temporal or spatial scale. Reference papers for stand-level seasonal models include H2OTRANS (Waring and Running, 1976), DAYTRANS (Running, 1984a), DAYTRANS/PSN (Running, 1984b), and FOREST-BGC (Running and Coughlan, 1988). Extensions of forest dynamics through a stand life cycle are represented by FOREST-BGC (Running and Gower, 1991), HYBRID (Friend *et al.*, 1993), BIOME-BGC (Running and Hunt, 1993), FIRE-BGC (Keane *et al.*, 1996a,b), and TREE-BGC (Korol *et al.*, 1995).

In this section, a number of georeferenced models that extrapolate across increasingly large areas are introduced. They include MT-CLIM (Running *et al.*, 1987), RESSys (Running *et al.*, 1989), RHESSys (Band *et al.*, 1993), MODIS-LUE (Running *et al.*, 1994), and GESSys (Hunt *et al.*, 1996). Together these models provide a means of extrapolating climate, hydrology, net primary production, and ecosystem gas exchange across the entire surface of Earth.

individual stands as discussed in Section III (Fig. III.2). Because direct validation at regional to global scales is extremely difficult, our relative confidence in any prediction is heavily weighted toward models that incorporate principles that have been thoroughly tested at smaller spatial scales where direct measurements were possible.

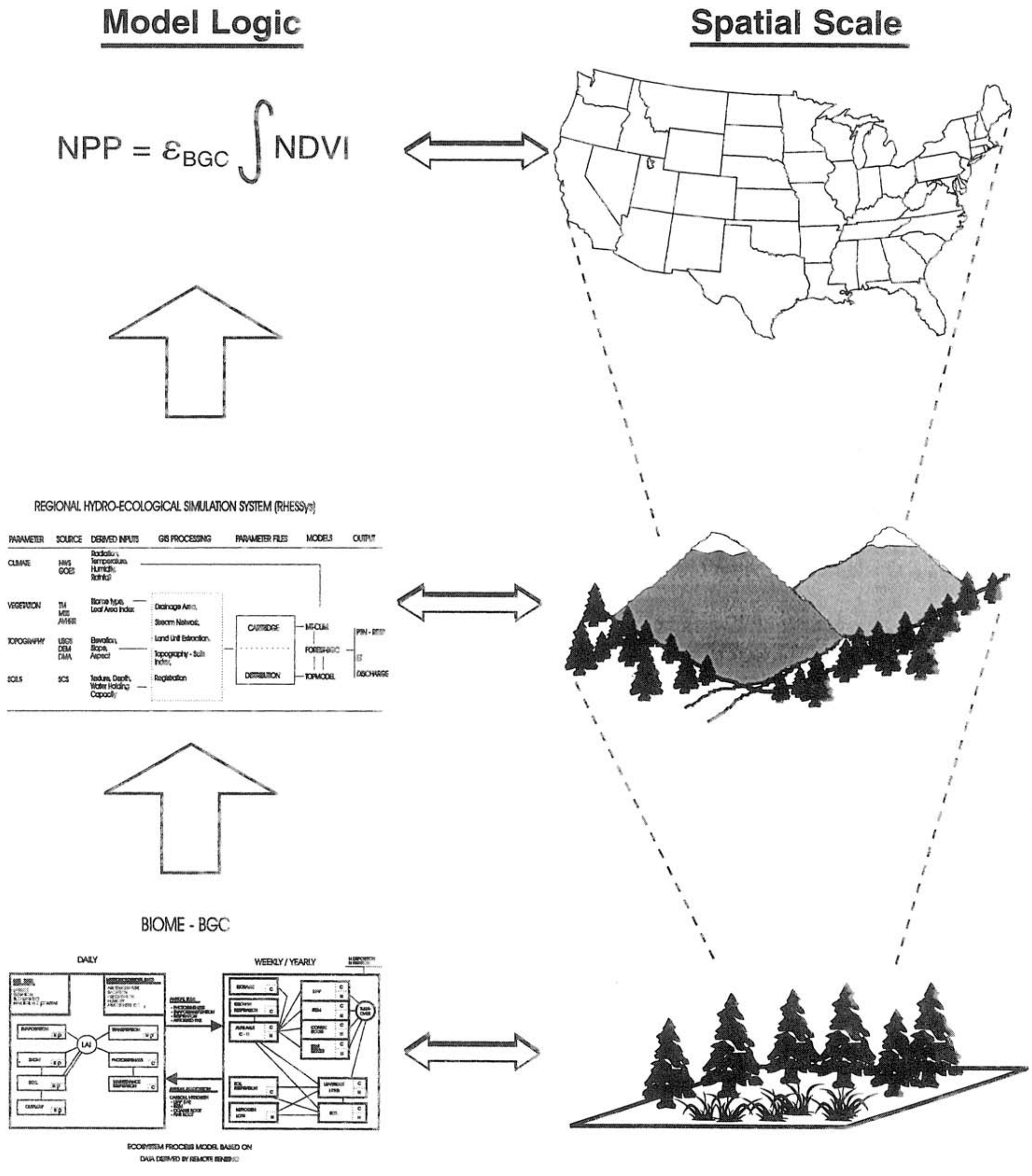


**FIGURE III.2.** Example of the simplifications required in shifting from local to regional to global scale ecosystem analyses. When computing NPP at the stand level, FOREST-BGC includes over 70 variables to define site and stand conditions. At the regional level, the RHESSys model requires only 20 variables. At the global scale, simple models compute NPP with only three variables: time-integrated satelite estimates of vegetation greenness (NDVI), incoming solar radiation ($I_s$), and biome-specific light conversion efficiencies ($\varepsilon$). These conversion efficiencies are derived from the more refined models such as FOREST-BGC.