$$\begin{cases} T(i,j,m) = \bar{T}_{obs}(i,j,m) + T_{sim}(i,j,m) - \bar{T}_{sim}(i,j,m) & \text{for temperature} \\ R(i,j,m) = \bar{R}_{obs}(i,j,m) R_{sim}(i,j,m) / \bar{R}_{sim}(i,j,m) & \text{for precipitation} \end{cases}$$

Future carbon stock changes of US forests with consideration of climate, atmospheric composition, disturbance and age effects

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Stand age and disturbances are recognized as important factors influencing the short- and long- term forest C dynamics. In addition to these factors, climate, CO_2 and nitrogen deposition have had significant direct and indirect effects on C dynamics of US forests. Future C dynamics will continue to be affected by these factors, which should be considered in developing optimum forest management policies. We used the Integrated Terrestrial Ecosystem Carbon Model to project how these factors will affect US forest C stocks under the IPCC A2 and B2 future climate scenarios and three disturbance scenarios: (1) forest stand ages are fixed in 2010 and no disturbances would occur after 2010 ($D_{fixedage}$), (2) forest stands are aging with no new disturbances after 2010 (D_{aging}), and (3) forest disturbed area increases at a fixed annual fraction (1%) and then forest regrowth starts in the second year ($D_{disturbed}$).

Methodology

The Integrated Terrestrial Carbon Cycle Model (InTEC) was designed for the purpose of investigating the effects of changing climate, atmospheric composition, disturbances, and forest recovery on the long-term C and N cycles in forest ecosystems (Chen et al., 2000a, b, c, 2003; Ju et al, 2007; Zhang et al., 2011a, b). The advantage of this model is that it integrates the effects of both non-disturbance (climate, CO_2 concentration, N deposition) and disturbance (i.e. direct C loss from harvest, fire and insect attacks, and subsequent forest recovery following disturbance events) on C dynamics.

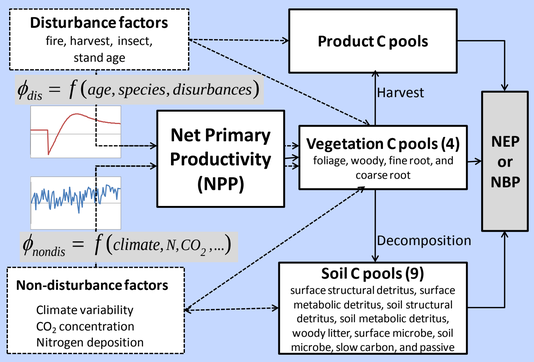


Fig. 1 The framework of Integrated Terrestrial Ecosystem Carbon Model (InTEC).

Assuming disturbances cause stand-replacement, and forests start to recover immediately in the year after disturbances. Forests experience a pulse of C losses in a disturbance year, the remaining biomass C is transferred to woody litter, surface metabolic detritus and surface structural detritus (Chen et al., 2003). After disturbances, forest stands start to regenerate immediately, net C change becomes more positive and reaches a peak as plants regenerate and soil detritus decays.

Future Projections

Three disturbance scenarios:

Scenario I: with fixed age and no disturbances
--------Forests will not be disturbed and keep stand age in 2010.

Scenario II : with age change and no disturbances
-------Forests will be aging without new disturbances until 2100.

Scenario III: with age change and disturbances
------Forests will be disturbed with new disturbances to 2100. Disturbance rate is 1% per year by regions. Disturbance occurred in oldest forests and followed by younger forests.

Two climate scenarios: GCGM2 A2 and B2

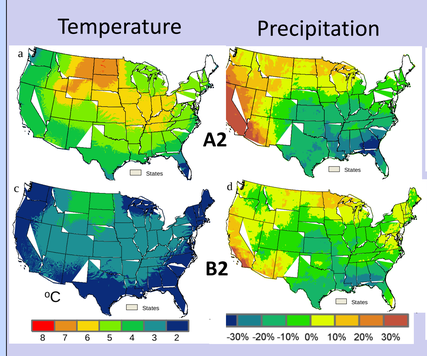


Fig. 2 Mean temperature and precipitation anomalies for the period of 2081-2100 relative to the period of 1991-2010.

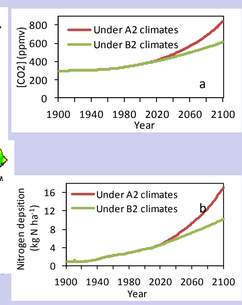


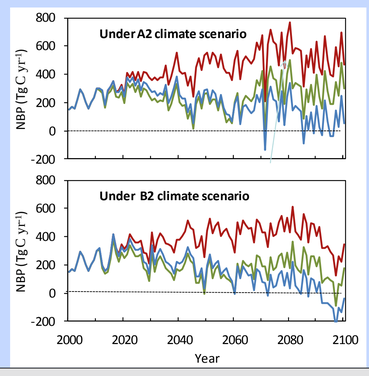
Fig. 3 Changes of atmospheric CO2 concentration and nitrogen deposition from 2011-2100.

Preliminary Results

Results showed that age and disturbance effects would continue to have important roles in determining changes of C stocks. Under both climate scenarios, US forests would be larger C sinks at the end of 21st century than the current level in the 2000s under the $D_{fixedage}$ and $D_{disturbed}$ scenarios. However, US forests would become a smaller C sink or a C source under the D_{aging} scenario. Increasing CO_2 and nitrogen deposition enhance the C sink regardless of disturbance scenarios. However, both of these effects would become saturated during the period of 2051-2100 under the $D_{fixedage}$ scenario. Disturbances and age effects have positive contributions to C accumulation during the period of 2011-2050 and negative contributions during the period of 2051-2100. These results indicate that managing forest stand age structures in appropriate ways could increase C stock accumulation.

Projections for future carbon sinks and sources

Fig. 4 Changes of carbon sinks and sources of conterminous US forests in response to two climate and three disturbance scenarios.



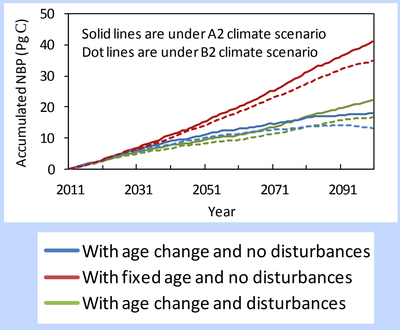


Fig. 5 Accumulated carbon sinks and sources of conterminous US forests in response to two climate and three disturbance scenarios

Accumulated NBP under A2 climate scenario (2011-2100)

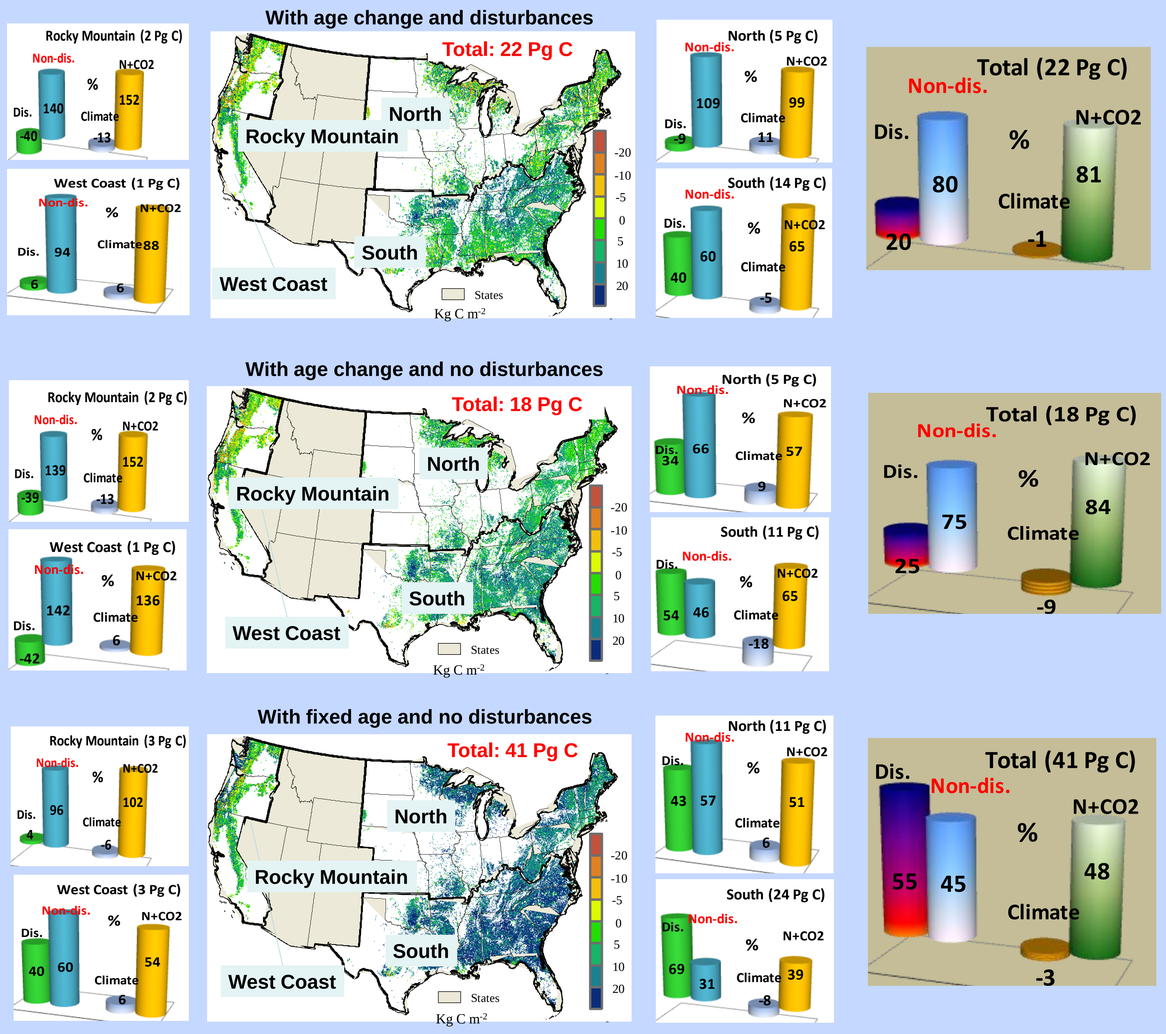


Fig. 6 Distributions of carbon accumulation conterminous US forests and percentages attributed to the separated effects of disturbance and non-disturbance factors in different regions during 2011-2100 under A2 climate scenarios and three disturbance scenarios.

Accumulated NBP under B2 climate scenario (2011-2100)

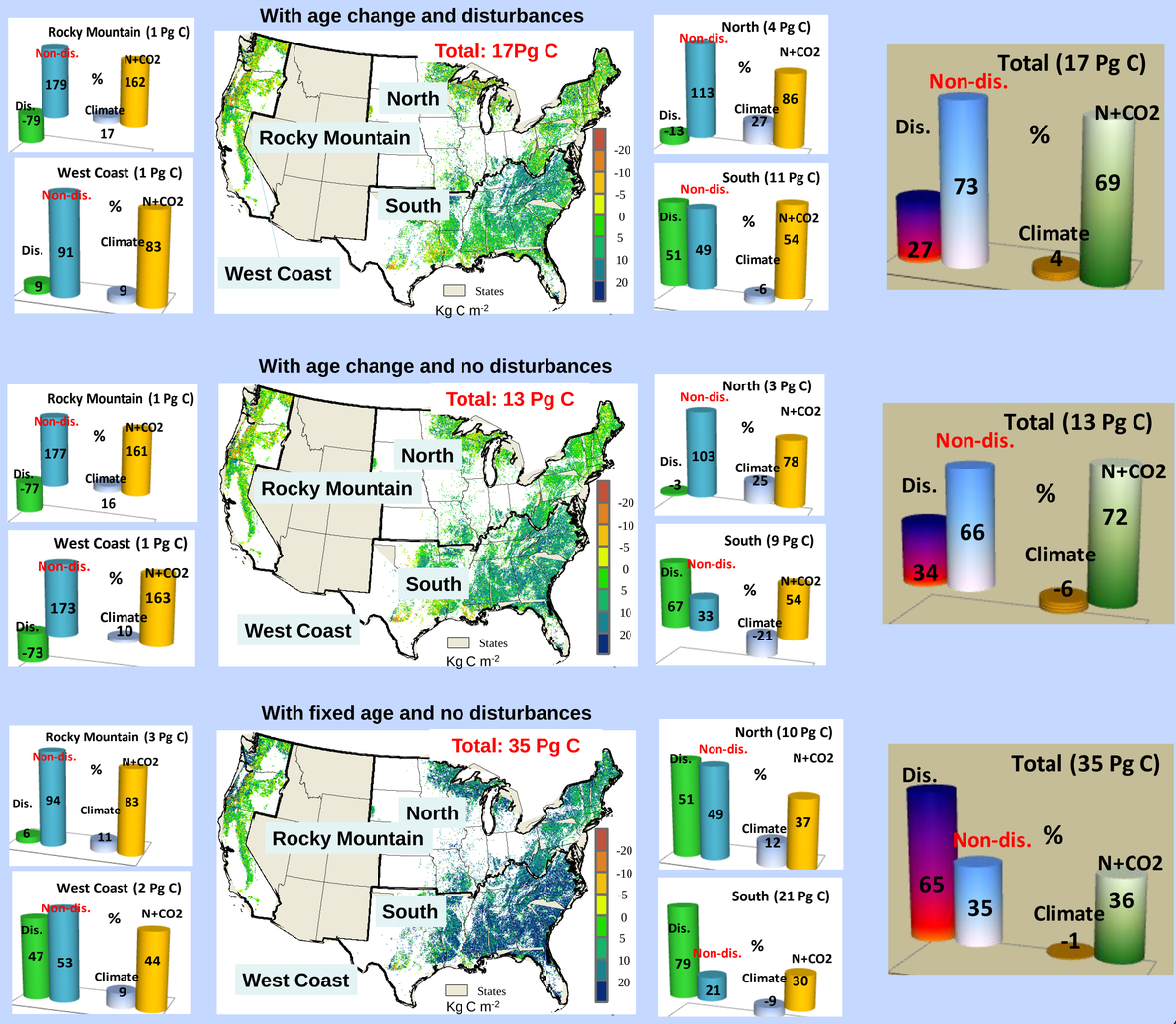


Fig. 7 Distributions of carbon accumulation conterminous US forests and percentages attributed to the separated effects of disturbance and non-disturbance factors in different regions during 2011-2100 under B2 climate scenarios and three disturbance scenarios.

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