Carbon Questions

There are two fundamental questions with regards aboveground biomass and carbon. Their requirements overlap in many ways but also differ significantly.

Question #1: How much carbon is stored in the (forest) ecosystems of the world, and what is the geographical distribution of forest carbon stocks?

A. The geographical distribution of biomass would serve as a baseline for future analyses of change.
B. The distribution of biomass would also allow more accurate assessments of carbon emissions from deforestation. Currently, the biomass of the forests being deforested (hence the carbon emissions from deforestation) is very uncertain.
C. The distribution of biomass (if young, regrowing forests could be distinguished from stunted, resource-limited forests) would also allow more accurate estimates of the carbon sinks attributable to forest growth (see Question, #2, below).

To answer Question #1 (what is the spatial distribution of forest carbon stocks), one would want as complete a map of biomass as possible (i.e., wall-to-wall). Sampling would generate a mean (and total) value of biomass, but it wouldn't address possible spatial covariation between biomass and deforestation (that is, systematic bias in the selection of non-average forests).

Spatial resolution should be at the scale of disturbance, 100 m or less.

Temporal resolution seems not to be an issue. On the one hand, it would be nice to have all the data collected at the same time (one season). On the other hand, time should best be used to cover as much of the land surface as possible. There may be priority areas considering B or C, above, but not for A (all forests need to be covered). A global assessment in the first year of the mission and, again, in the fifth year would be minimal (for Question #2, below).

An accuracy of 10% in biomass (or 10 MgC/ha) translates into an error of ~10% in estimated emissions from deforestation. Right now, biomass uncertainty contributes ~100% uncertainty to estimates of carbon emissions (i.e., a factor of two) (more, if biomass and land use covary).

Question #2: How much, where, and why are carbon stocks changing over the world's forest ecosystems?

This is one of the fundamental questions of the carbon cycle: What is the carbon balance of terrestrial ecosystems? Again, the *distribution* of sources and sinks is at least as important as a global estimate. Some ecosystems are losing carbon; some gaining it. 'Where' and 'how much' are questions of great interest for understanding the role of ecosystems in the current (and future) carbon balance. Many approaches for measuring terrestrial carbon fluxes, however, do not provide information about why the fluxes are occurring. Carbon science would be enhanced if we had a method that enabled broad categories of 'causes' to be distinguished. For example, what are the causes of carbon loss (deforestation, degradation through logging, grazing, fires, etc.), and what are the causes of carbon accumulation (regrowth following disturbance, regrowth as a function of age since disturbance)? [What attributes of a forest (1) might enable causes of change to be distinguished, and (2) might be observable from space?]

There is another reason for identifying whether or not a forest has been disturbed: the distinction would provide insight into whether other changes in carbon stocks, those not directly observable from space, are likely to have occurred (e.g., soil C, litter, CWD). Fire, for example, causes a different fraction of aboveground biomass to be emitted to the atmosphere than wood harvest.

Optical satellite data are good for measuring deforestation (and thus for calculating carbon sources). They are less good at seeing the accumulation of carbon in secondary forests once their canopies have closed. And most forests are probably gaining carbon as they recover from the last disturbance.

The annual rate of carbon accumulation in many (most?) forests may be so low as to be undetectable over the period of 3-5 years (or even 50). A worst case might assume that the global 'missing' carbon sink is distributed evenly over all forest ecosystems. The sink would be equivalent to ~1% of aboveground forest biomass (i.e., 1-3 MgC/ha) (see Houghton 2005). On the other hand, some areas are losing carbon (deforestation) and some areas are accumulating it rapidly (certain stages of recovery). So, many changes will be greater than 1%.

The world's forests may be divided into three categories : 1) those losing carbon through disturbance; 2) those accumulating carbon; and 3) those with little change in stocks. With regards accuracy and spatial resolution, the first choice would be to measure aboveground biomass to within 10 Mg/ha at 30-100m resolution (i.e., the scale of disturbance). [±1 MgC/ha would be even better, but….] At much lower accuracies and coarser resolutions, there is still much to be learned, however. Even if we learned only the fractions of forest area disturbed annually or recovering, knowing these fractions would advance our understanding of the dynamics of forests. Only a resolution so coarse that it failed to see any change in aboveground carbon stocks would be worthless.

Finally, an accuracy of 10 Mg/ha (and repeat measurements for change) may not be required if it were possible (with radar and or lidar) to distinguish between forests that are small because they are resource limited and those that are small because they are young (growing). The latter forests indicate a current and future accumulation of carbon that might be determined through modeling. A combination of modeling and satellite data might enable a calculation of changes in carbon stocks (as a result of age structure) that is more cost-effective than direct measurement of changes with satellite; i.e., there may be trade-offs between satellite accuracy and modeling. [Again, what attributes of a forest (1) might enable secondary forests to be identified and (2) might be observable from space?]

To answer questions pertaining to change in forest carbon stocks, repeat coverage of sampled areas is more important than wall-to-wall coverage. Some seasons might be better than others for obtaining aboveground biomass.

Spatial resolution should be the same: ideally at the scale of disturbance, 100 m or less.

Interannual variations in the strength of the terrestrial carbon sink result from interannual variations in the area of forest disturbed from fire and other causes, as well as from variations in carbon fluxes induced by climate variations. The relative importance of these two sources and sinks of carbon is poorly understood. To help quantify the importance of disturbance, annual estimates of disturbance and regrowth are required. First choice would be to have annual global coverage. If not possible, we should at least have samples of 1-year change, 2-year change, etc. for the entire lifetime of the satellite. As noted above (Question #1), global assessments in years 1 and 5 would provide an estimate of ‘long-term’ change (trend?), but would not be particularly good for characterizing annual disturbances.

An accuracy of 10% in biomass (or 10 MgC/ha) would yield a first estimate of the fractions of forest area disturbed, recovering, and unchanged in different regions of the earth and, thus, advance our understanding of forest dynamics.