**Working Group Question:** What **systematic observations** are needed to reduce uncertainty in **direct and indirect** forcing [including thermodynamic effects]?

**Working Group Goal:** Outline key attributes of a systematic observation program for the next 10 years. The observation program needs to:

- Test modeled forcing (especially cloud effects, including latent heating and precipitation)
- Observe key links between aerosol sources and ultimate effects
- Be able to address regional as well as global effects, surface as well as TOA forcing (including resulting gradients), and effects on hydrology
- Be able to produce results differentiated by the important regimes, e.g.,
  - properties and effects of different kinds of aerosols,
  - properties and effects over land vs. ocean, etc.

**Definition of systematic observations (scope of Working Group):** We included measurements from satellites and from long-term surface stations, as well as regular aircraft measurements to get information within the atmospheric column (e.g., the regular flights by NOAA at the DOE-ARM SGP site). We excluded intensive campaigns that typically last for two months or less (while typically getting much more complete information than is possible with systematic observations). Affordability of regular measurements was a key consideration in our discussions.

Thus, the scope of this Working Group partially overlapped with the scope of Working Groups 2 (direct effect) and 3 (indirect effect). Those working groups included the intensive campaigns that were excluded from our discussions. Our scope also partially overlapped with that of Working Groups 5 (GCM calculations) and 1 (emission inventories). That is, we addressed the question of how systematic observations could best contribute to the goals of those working groups.

**Strategies vs. Observations:** Before listing present and future needed observations, we discussed the strategies those observations needed to support. Considerations included

- The need to distinguish correlation (e.g., between AOD and cloud properties) from cause
- The spatial scales where correlations are important for the indirect effect
- The most effective enhancements to current networks (e.g., for AOD, SSA, ΔF, …)

**Systematic Observations: Available Today and Needed Enhancements:** We made a table outlining the systematic observations relevant to NACIP that are available today, needed enhancements in the near term (1-3 years, or in space missions already defined), and needed
enhancements in the long term (3-10 years, including a new space mission). The table follows. The dedicated space mission, listed under “Needed Enhancements—Long Term,” would be unique in combining polarization measurements (to define aerosol fine-mode size and refractive index) with spectral, angular, glint/off-glint, lidar, and flux retrievals. If such a mission is to fly by 2008, it needs to be advocated today.

Not included in the table, but emphasized by the group, were:

- The need to more regularly use today’s and future systematic measurements in assimilation/tracer models, transitioning to climate models.
- The need for cloud-aerosol interaction models for cumulus and cumulonimbus, with simulation of spectral radiances (as measured by satellite) and precipitation processes.
Table 1. Systematic Observations for NACIP

<table>
<thead>
<tr>
<th>Space</th>
<th>Surface (regular measurements)</th>
<th>Aircraft (regular flights)</th>
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<tbody>
<tr>
<td>Radiance $\rightarrow$ Rad flux ($\Delta \lambda_1$, $\Delta \lambda_2$, ...)&lt;br&gt;Surface albedo&lt;br&gt;AOD($\lambda$) [small vs large particles]&lt;br&gt;SSA(UV)&lt;br&gt;By cloud type: Cloud albedo +/-&lt;br&gt;Precipitation&lt;br&gt;Cloud top height&lt;br&gt;Cloud fraction&lt;br&gt;Drop size (as fcn of top height)</td>
<td>AOD($\lambda$)&lt;br&gt;SSA(2$\lambda$)&lt;br&gt;P($\Theta, \lambda$)&lt;br&gt;Size distribution&lt;br&gt;Rad flux ($\Delta \lambda_1$, $\Delta \lambda_2$, ...)&lt;br&gt;Surface albedo, BRDF [1 or few sites]&lt;br&gt;Scattering (D&lt;$\lambda$1µm, &lt;10 µm)&lt;br&gt;Absorption&lt;br&gt;Chemical composition (size resolved)&lt;br&gt;Backscatter(z) [lidar]</td>
<td>Scattering (neph; D&lt;1µm, &lt;10 µm)&lt;br&gt;Absorption (PSAP, filter-based)&lt;br&gt;Size distribution&lt;br&gt;Some chemistry (filter)&lt;br&gt;</td>
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**Needed Enhancements—Near Term (~1-3 Years, or in space missions already approved)**

| Validation & improvement of all above products (including new versions of existing products as necessary)<br>Better absorption, SSA($\lambda$) [OMI, Glint/off-glint<br>Better cloud albedo (add models, MISR ...)<br>Chemical composition (or aerosol type)<br>Add cloud imager to Global Precip Mission<br>Simultaneity (e.g., precipitation with others above)<br>Models to get height of aerosol (in today's space data)<br>New analyses of MODIS, MISR, ...<br>GLAS, CALIPSO aerosol AOD(z) | Cloud radar (expensive?) with lidar<br>Existing VHF radar to get $v_z$ with aerosol from satellite<br>Better coordination among existing sites (intercalibration, central data archive like AERONET)<br>Check BSRN for coordination, enhancements<br>Better collocation of existing measurements<br>Add longer $\lambda$ & polarization to AERONET<br>Expand lidar networks to include key AERONET sites<br>Rain measurements<br>Synch all above with satellite overpasses to increase value for correlative studies and cal/val | As above, but more systematic (e.g., sync with satellite overpasses [e.g., Terra, Aqua, GLAS, CALIPSO, CloudSat, PARASOL])<br>Rad flux (including divergence $\rightarrow$ absorption)<br>Better chemistry (including size resolved)<br>Scattering($\Theta, \lambda$)<br>|

**Needed Enhancements—Long Term (~3-10 Years, including a new space mission)**

| Fine mode size, refrac. index: Polarization<br>Dedicated mission to derive aerosols, clouds, radiation & precip simultaneously (spectral x angular x polarization x glint/off-glint + lidar + flux)<br>Coordination with EARTHCARE (Japanese-European mission with hi-res lidar, doppler cloud radar, FTS nadir, broadband radiometer [CERES-like])<br>Try to get chemical comp(z) | Cloud radar (expensive?) with lidar<br>Existing VHF radar to get $v_z$ with aerosol from satellite<br>Better coordination among existing sites (intercalibration, central data archive like AERONET)<br>Check BSRN for coordination, enhancements<br>Better collocation of existing measurements<br>Add longer $\lambda$ & polarization to AERONET<br>Expand lidar networks to include key AERONET sites<br>Rain measurements<br>Synch all above with satellite overpasses to increase value for correlative studies and cal/val | Extend "CCN" + giant nuclei measurements from intensive campaigns to regular flights<br>