**Executive Summary**

The goal of FLAGG-MD is to produce quantitative measurements of sources, sinks, and fluxes of CO2, CH4, CO (C-gases, called hereafter GHGs), complete with determination of uncertainty, for the Baltimore/Washington metropolitan area. We will advance the *measurement science for GHGs* to develop internationally recognized methodologies and technologies through a balanced approach of observations and numerical simulations. The results will improve the measurement technology available to regulatory agencies including the Maryland Department of the Environment and the USEPA and *increase the accuracy of climate science measurements*. We will coordinate with and learn from advances made in NIST-supported INFLUX. FLAGG-MD consists of three components: Observations, C-cycle and meteorological modeling, and Climatology. Observations will include surface and airborne field measurements of trace gases and meteorological variables, and a harmonizing of all extant and planned observations with NIST/NOAA standards and methods. The C-cycle modeling relies on an initial estimate of emissions, dispersion driven by high-resolution WRF-Urban and WRF-Chem meteorological analyses (runs with assimilated weather data), assimilation of chemical observations for the inverse model, and refinement of emissions. The purpose of climatology is to determine the optimal conditions for flux determination and to provide insight into any bias inherent in sampling under those select conditions. WRF-Urban will be developed to run in forecast mode for flight planning. Results will be employed to evaluate and enhance NASA satellite observations of CO, CO2, and CH4. The outcome will be improved understanding of GHG inventories and transport in the atmosphere in larger more meteorologically and geographically complex cities and megacities of the American east coast.

 The UMD Cessna 402B has been used with great success to determine, meteorological variables, as well as trace gas and aerosol concentrations in the Baltimore/Washington area. We will augment the instrument package with a Picarro CO2/CH4/CO analyzer and NOAA/NIST calibration equipment as well as whole air sample canisters. In the summer or fall of 2014 we will bring the Cessna to Indiana for comparisons to Prof. Shepson’s Beechcraft Duchess (ALAR) INFLUX project to verify that the trace gases and winds are in agreement, and then to develop synchronized flight patterns to better determine horizontal flux. In the winter of 2014/15 we will coordinate with both ALAR and the NCAR C130 during WINTER in the Baltimore area. Circulation patterns and air traffic control over Maryland are substantially more complex than over Indiana, and several options for flight pattern are discussed in the body of the proposal. Parallel efforts to identify and forecast characteristic flow patterns will be conducted under the climatology effort. Remotely sensed data and methods will be evaluated to augment in situ measurements. Other observational efforts include identifying, in coordination with MDE, DNR, the NPS, NOAA/ARL and NASA/GSFC, all existing meteorological and trace gas monitoring in and near the Baltimore/Washington domain as well as identify and evaluate towers for instrumentation. We will evaluate the suitability of those measurements (including cross calibrations as necessary) for the goals of FLAGG-MD.

 At the heart of FLAGG-MD lies the C-cycle model, VEGAS. Although horizontal flux can be estimated from *in situ* observations alone, a quantitative evaluation of biogenic and anthropogenic emissions of GHGs requires the inversion of the C-cycle model. The model requires high-resolution meteorological analyses from WRF-Urban, used successfully for studying the Urban Heat Island effect of this area. This model has been run for multiday episodes with resolution as fine as 0.5 km and resolves subtleties such as the Chesapeake Bay breeze and nocturnal low-level jet. WRF-Chem will be modified to ingest WRF-Urban fields. Initial emissions of CO2 and CH4 will be obtained from Prof. Kevin Gurney (funded separately); emissions of CO are available from our runs for CMAQ (funded by MDE) and from future WRF-Chem runs that will account for CO from VOC oxidation. Both chemical data described above, and meteorological data described below, will be assimilated into WRF-Urban and VEGAS using Ensemble Kalman Filter methods. Assimilation techniques will also be employed to determine the optimum sampling strategy – balancing precision of measurements with spatial coverage. The result will be an inverse model providing *a posteriori* emissions estimates leading to refinements of the model system and precision of GHG emissions.

 A climatology of meteorological observations can provide insight into the optimal weather conditions for flux measurement. Especially important are winds aloft and planetary boundary layer depths. As part of the first year’s efforts we will compile and evaluate data from the three wind profilers in the FLAGG-MD area as well as from several Lidars operated by NASA, UMBC, and Howard University. There are numerous monitors for CO and some observations CO2 and CH4 in the area. These will be evaluated and harmonized with NIST calibration procedures where possible. Flow patterns can be visualized with ensembles or clusters of back and forward trajectories. Ideal conditions for flux measurements are when the families of trajectories travel as a stream of moderate velocity. To generate such an analysis, we will begin a 3-year climatology with WRF and use HYSPLIT or FLEXPART and Lagrangian trajectories to trace the flow from known sources of CO2. Sources of CH4 are less well known and must be identified from observations. Mesoscale circulation generally falls into a limited number of characteristic patterns that vary with season. We will perform a Lagrangian analysis of the WRF fields and identify these patterns. The insight obtained from these studies will guide future flights to improve emissions and flux measurements in future years.

FLAGG-MD will produce policy-relevant science. The goal of providing improved quantification of anthropogenic GHG emissions to the scientific community and to regulatory agencies such as MDE, RGGI, and USEPA, will be met through direct analysis of ambient and remote measurements as well as through model inversion.