Advancing and Applying Aerospace Technology to Protect the Global Environment:  
An AIAA Information Paper

Abstract

Significant global changes in climate patterns in recent decades are evident, appearing both as gradual and abrupt phenomena. Accumulating “greenhouse gases,” including from human activity are likely contributors to these changes. Since natural effects couple with the human-induced effects through intertwined feedback mechanisms, an understanding of the dynamics of Global Climate Change (GCC) requires an extensive, global observation program. Dedicated orbital science platforms are being deployed to gather data regarding specific factors that may impact GCC. However, a more comprehensive, and sustained observation program is needed, that includes means to achieve stable measurement calibration across the globe that is sustainable over many decades. An evolving, detailed knowledge of climate-change-drivers will enable formulation of trans-national climate-change-mitigation protocols. However, for such protocols to be effective, technical means will have to be provided to verify compliance. Current and new aerospace technology is central to all these GCC-monitoring activities.

Background

Escalating consumption of fossil fuels and deforestation is rapidly increasing the atmospheric levels of Carbon Dioxide (CO$_2$), a greenhouse gas. Annual human-driven CO$_2$ emissions have almost doubled since the 1970s, while forest coverage around the world is rapidly being destroyed to support other uses of the land. Eleven of the twelve years between 1995 and 2006 are among the twelve warmest recorded globally (based on records kept since 1850) [Ref.1]. The Greenland ice sheet has been experiencing major, annual mass loss [Ref.2]. There is an on-going thawing of large tracts of permafrost in high northern latitudes that had been continuously frozen for many millennia. That thawing also releases large amounts of methane (CH$_4$) into the atmosphere which was previously trapped in the form of solid clathrates within the permafrost. CH$_4$ is an even more powerful infrared radiation trapping greenhouse gas for a given concentration than CO$_2$. Evidence that global temperatures are rising at least near the poles is also seen in unprecedented summer gaps in the northern polar ice cap, and episodic breakup of sizable ice-shelf sections along the Antarctic coasts. Near surface temperatures of the Gulf of Mexico have also risen in recent years, enabling tropical storms to intensify more quickly into strong hurricanes. All these circumstances are likely indicators of GCC, with a probable major contribution from the human-driven emissions.

The Obama Administration stated goals during the 2008 presidential campaign to better understand GCC and to limit its effects [Ref.3], but to mitigate GCC, it is necessary first to better understand the factors that contribute to the problem. Developing an initial scientific understanding of GCC is benefitting from distinct, one-of-a-kind research platforms as defined in the National Research Council’s Decadal Survey [Ref.4], but a complete understanding of the factors driving on-going trends in environment behavior shifts necessitates continuous, long-term, global observation across the observable spectrum. To this end there is considerable interest in the Global Earth Observation System of Systems (GEOSS) program, which would provide an international cooperative path to achieving these goals. However, to date US support and involvement in GEOSS has been limited.
Aerospace technology is uniquely capable of enabling GCC monitoring by providing orbital and aerial observational platforms that can collectively carry a broad set of sensitive and broadband atmospheric, surface, and geophysical monitoring instrumentation suites. Application of existing platforms and sensor technologies is enabling specific GCC factors to be addressed on a case-by-case basis. This work is facilitating initial identification of the combination of human-driven and natural factors contributing to GCC as well as initial characterization of how they couple. However, further investment in new capabilities and associated technologies is necessary to facilitate more accurate tracking of GCC trends, to enable fuller understanding of the integrated effects of coupled GCC phenomena, and ultimately, to construct as well as monitor international protocols that would mitigate GCC.

**Some Significant Issues**

While on-going and planned GCC observational efforts will make significant progress in understating the causes of climate change, the following important issues must be addressed to assure the necessary level of success.

- To date, government sponsored GCC monitoring has focused on dedicated, one-of-a-kind missions to investigate specific GCC phenomena. These missions provide invaluable scientific data and insight. Even so, they have not yet covered the full range of measurements deemed essential for a scientific GCC understanding, as reflected in the National Research Council’s Decadal Survey [Ref. 4]. Also, results of these missions are sometimes held within Principal Investigator “silos” that are not fully accessible or easily used by other scientists.

- Means are needed for very stable, sustained calibration of GCC observations. Calibration standards that remain valid for very long time spans (at least many decades) must be applied to collected climate change data. Fully valid bases for comparison of different instruments or results from different looking conditions must be established. “Ground truth” is needed for large regions where calibration data collection is lacking (i.e., the oceans, Africa, and Central Asia).

- A coordinated approach is needed across the GCC monitoring enterprise to enable a fuller understanding of the many interdependent factors. Sensor scheduling methods, more advanced data reduction algorithms, and data fusion strategies need to be addressed. Also, collected GCC data must be properly tagged, made sharable, and efficiently disseminated by means of user-friendly media. A holistic, GCC-enterprise-level view of these issues is needed to facilitate rapid climate change science progress.

- Long-term GCC observational goals need assessment. If international GCC mitigation protocol monitoring becomes an objective, then dedicated platforms with on-demand tasking capability will be needed.

- Some specific observational technologies could be further developed to achieve additional GCC-monitoring capabilities. Occultation methods based on pervasive radio emissions such as GPS or Iridium satellite L-band emissions could provide an effective means for determining atmospheric water vapor content, but new, low-cost observation platforms would be needed to get on-going global coverage. Emitters of additional frequency bands would be needed in addition for occultation observations of atmospheric water vapor to be fully decoupled from the effects of atmospheric density variation. Also, while space-based gravimetry has already proven it use for monitoring loss of ground-based ice coverage, further sensitivity capability improvements could enable strategically
important measurements such as ground water supply levels. However, domestic investment in the required gravimeter technologies is lacking.

**Recommendations**

Pursuing the following recommendations regarding application of existing and new aerospace technology will enable more rapid advancement of GCC science, formulation of GCC mitigation strategies, and monitoring of compliance with GCC mitigation protocols.

- Establish a comprehensive and sustained space, air, ground, and sea-based climate monitoring system that both facilitates better understanding of GCC and enables assessment of global compliance with GCC mitigation protocols.
- Develop small, globally place-able land and sea-based calibration systems that work interactively with space and air-based GCC observational platforms.
- Implement GCC mission planning tools that can coordinate observations across multiple, varied, and asynchronous observation systems.
- Standardize GCC data storage protocols and data formats, making the resulting databases both widely acceptable and user friendly.
- Authorize on-going technology and capability development to advance GCC observational sensitivity including in the areas of occultation observations and gravimetry/gradimetry.
- Implement means for accurate GCC protocol compliance monitoring.
- Expand and provide increased funding to NASA and NOAA to initiate these recommendations.
- Leverage US investments in GCC observational capabilities by becoming a full participant in GEOSS.

**References**