6.9 *IN SITU* SCIENCE FROM GLOBAL NETWORKS OF STRATOSPHERIC SATELLITES

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1. INTRODUCTION

Global Aerospace Corporation is developing, under NASA Institute of Advanced Concepts funding, a revolutionary concept for a low-cost adaptive observing system comprising a global constellation and network of perhaps tens to hundreds of stratospheric superpressure satellites (StratoSat™ platforms). StratoSat™ platforms float in the stratospheric winds at 35 km altitude, fly for up to 10 years after launch, have some maneuvering capabilities and can perform a multitude of tasks, such as monitoring global weather and climate, tracking hurricanes, validation of satellite observations, and hazard detection or disaster monitoring. **Figure 1** illustrates the constellation concept.

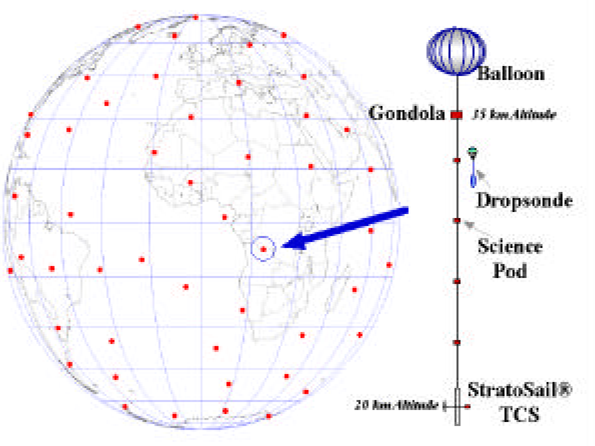

Figure 1 Global Constellation of StratoSat™ Platforms

StratoSat™ platforms can carry a payload of at least 250 kg using a smaller, advanced version of the NASA Ultra Long Duration Balloon (ULDB). StratoSat™ platforms are guided by a Trajectory Control System (TCS). The TCS is a suspended vertical wing that uses the natural difference in wind speed and direction at different altitudes in the atmosphere to drag the balloon across the relative wind. The TCS enables individual balloons to be maneuvered and a network of StratoSat™ platforms to be configured for high frequency observations over specific target areas, such as hurricane tracks or regions of initial condition sensitivity for weather forecasts. In addition to simultaneously providing hundreds of high-resolution GPS dropsonde profiles through the stratosphere and troposphere, a constellation of StratoSat™ platforms could provide continuous *in situ* and remote sensing measurements with a suite of instruments positioned in the gondola, along the tether and on the TCS. The science pods positioned along the tether are small, autonomous, self-contained instruments relaying data to the gondola. The detailed description of the concept can be found in Heun (2001) or at http://www.gaerospace-.com/publicPages/projectPages/StratCon/index.html.

Here we describe potential atmospheric science missions and possible payloads for global and regional networks of StratoSat™ platforms. We present selected *in situ* science mission scenarios: ozone loss monitoring and related stratospheric chemistry, vertical profiling of atmospheric constituents in the troposphere and stratosphere, cloud particle measurements, and global circulation monitoring through measurements of tracers of stratospheric transport. Other potential applications of the StratoSat™ platform network may include hurricane tracking, weather forecasting, global radiation budget monitoring and disaster monitoring. These example concepts have been developed based on our current understanding of Earth science priorities and the extrapolations of technological developments in measurement capabilities.

2. EXAMPLE MISSION SCENARIOS

Within the context of the areas of global change that are being addressed by the NASA Earth Science Enterprise (ESE) strategic plan (NASA 1998), the recommendation of the Pathways report (NRC 1999) and the monograph, *Atmospheric Sciences entering the 21st century* (NRC 1998), and the specific areas of research/ scientific questions to be answered within the context of environmental global change, we enumerate here a set of scientific observations from a network of tethered balloon platforms. This can in no means be thought of as a comprehensive set, but rather as one representative of the types of observations that can be made, the flexibility of this approach in terms of the ability to reposition platforms to observe specific seasonal or geographical environmental issues. Because, as evidenced by our experience with ozone depletion, the planned network would be in position to observe the unpredicted events as they happen.

It is important to understand that because of the nature of the instrumentation proposed on the balloon platforms, calibration and long-term accuracy are a critical part of this plan. There is currently skepticism on the part of atmospheric researchers on the ability of instruments to make some of the key abundance measurements with the necessary accuracy and precision either remotely or by *in situ* methods, and to maintain calibration for months to years. Instruments with proven pedigree are seen as necessary. In principle, with technological advances over the next decade, this could be accomplished for applications in the lower stratosphere.

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2.1 *Mid-latitude Ozone Loss*

The recent Stratospheric Processes and their Role in Climate (SPARC) report (WMO 1998) on ozone showed that during the past ten years mid-latitude ozone in the lower mid-latitude stratosphere from about 12 to 15 km has decreased by about 1%/year. Solomon et al. (1998) have postulated that *in situ* heterogeneous chemistry on thin cirrus could be responsible for this decline. Alternatively, transport of low ozone air from the tropics or from the polar region has also been suggested as a possibility. It has also been suggested that variability of tropopause height could be the cause. The ambiguity results in large part from the fact that neither measurements of chlorine monoxide nor any additional tracers of atmospheric transport accompanied the ozone measurements. Because of the high resolution required by these measurements, with measurements above (carefully distinguished from those below) the local tropopause, satellite instrumentation cannot address this problem, which requires continuous monitoring, alone.

The payload would provide simultaneous measurements of ozone, water vapor, and nitrous oxide at intervals in the tropopause region, as well as a temperature profile to locate the exact position of the local tropopause. For this payload, three highly accurate *in situ* multipass absorption instruments can be positioned at 1-km intervals above the TCS, with an additional one close to the TCS. A microwave temperature profiler, alternately upward and downward looking, will be used to locate the tropopause. To provide adequate coverage for this experiment will require approximately 10 StratoSat™ platforms stationed in northern mid–latitudes.

2.2 *Polar Ozone Loss*

Data has shown that the potential for polar ozone depletion is prevalent, depending on the length of time the vortex holds together and how long the temperatures in the vortex remain cold enough for polar stratospheric clouds to form. Ozone depletion has been observed in the poles but quantification is difficult. Air in the vortex is continually descending and being mixed with air external to the vortex. Quantifying ozone loss requires the ability to calculate the fraction of air mixed into the vortex and what is the character of that air.

StratoSat™ platform payloads similar to those flown during the NASA SOLVE mission in the Arctic in 1999-2000 and capable of maintaining their position throughout the fall winter and spring would provide critical information during years with and without significant ozone depletion. Two StratoSat™ platform payloads with proven instrumentation are proposed here. The remote sensing payload with a Fourier Transform Infrared Radiometer (FTIR) making absorption measurements with 2 km altitude resolution in the limb-scanning mode at the gondola would provide detailed information about vortex formation and breakup, transport across the boundary, and mixing of descending vortex air with mid-latitude air from below by measuring H_2O, CH_4, N_2O, CFC-11, CFC-12, SF_6, O_3, CO_2, CO, NO, NO_2, HNO_3, HCl, HF, CF_4. In addition to the FTIR, a Submillimeterwave Limb Sounder (SLS) would be flown. This instrument would specifically be used to measure reactive species responsible for ozone loss. These include chlorine monoxide (ClO), bromine monoxide (BrO), and key radicals responsible for ozone destruction. The *in situ* payload would be used for high accuracy, high precision, sub-kilometer altitude resolution measurements of ozone loss, denitrification, dehydration, and the presence of polar stratospheric clouds. Together the two payloads would provide the means of quantitatively analyzing ozone destruction in the entire vortex.

The combination of payloads in and near the Arctic vortex is as follows: the remote sensing payload is as described containing the FTIR and SLS instruments at the gondola. The *in situ* payload contains instruments on the tether, positioned specifically at intervals where maximum ozone loss is expected to occur. That payload will contain two instrument suites. One, a tracer suite, will measure ozone, H_2O, CH_4, N_2O, CO_2, pressure and temperature. This will provide detailed information on the transport of air in a region. The other, measuring HCl, and particles will be used to provide information on the detailed calculation of ozone loss. This payload could be used to follow an air mass to do two exciting experiments, one to monitor ozone destruction, the other to follow the formation of polar stratospheric clouds. Such a mission concept can be accomplished with a constellation of 10-20 StratoSat™ platforms each operating in a region from 60° to the pole.

2.3 *Global Distribution of Ozone*

This constellation concept addresses global ozone distribution; tropospheric monitoring for trends in rural areas as well as in outflow region from large emission areas; global determination of stratospheric-tropospheric exchange.

Monitoring ozone concentrations both by satellite and using ozone sondes has provided a means of determination of variations or trends in ozone both in the stratospheric and in the troposphere. While satellite based instrumentation provides worldwide coverage of the stratosphere, they are of limited value in the troposphere. The sondes can only be launched from land or in special instances from ships. This means that there are large remote areas, especially in and near the tropics, where there is no coverage. There are a number of areas of research that could benefit from the measurements of ozone profiles in remote areas. In the region of the tropopause, understanding the mass flux from the stratosphere into the troposphere is required to understand the sources of ozone in the troposphere. Making these measurements on a regular basis in the context of various meteorological conditions would allow for a statistical determination of this mass flux. To do this properly, it would be very valuable to simultaneously measure water vapor and temperature on the sonde. Additionally, because these sondes would be dropped from about 35 km, adding the measurement of nitrous oxide or methane would provide invaluable information on transport of air in the stratosphere as well. New infrared measurement techniques are currently under development, which can be extended from water vapor to N_2O and/or methane and potentially result in a powerful experiment, monitoring tropospheric ozone, investigating stratospheric tropospheric exchange, and supplementing the radiosonde network, especially in the tropics where it is severely lacking. It is especially important to monitor tropospheric ozone in remote rural regions far from pollution sources because this represents a worldwide background level of pollution and is important to measure when considering the magnitude of pollution sources in urban areas. **Figure 2** illustrates this constellation and payload concept.

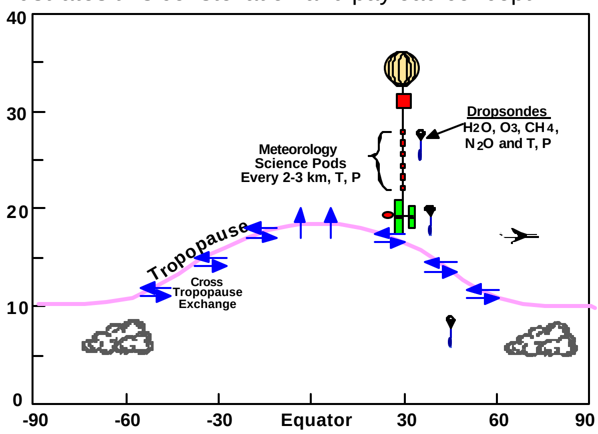

Figure 2 Global ozone distribution experiment

This payload would contain dropsondes to measure the suite of molecules described above. With the advances in technology currently being proposed for a water vapor sonde extended to ozone and methane or N_2O a sonde package of about 0.25 kg is projected. Accordingly, for 100 kg dropsonde allowance per platform 400 sondes could be carried.

Additionally, whether it is monitoring pollution from the Asian continent, the United States, or biomass burning regions in South America, quantifying these significant pollution sources is critical in understanding their contribution to global pollution levels. A nadir looking FTIR on the gondola monitoring thermal emission can provide the continuous operation necessary for this experiment. Transport of these pollution events typically occurs in filaments within a narrow altitude band and satellite instrumentation does not have the resolution to properly these pollution events. These instruments, looking at thermal emission, can make simultaneous measurements of ozone, water vapor, carbon monoxide, and nitric oxide.

2.4 *Water Vapor and Tropical Circulation*

It is currently understood that air enters the stratosphere in the tropics from where it slowly rises and heads poleward. The cold tropical tropopause limits stratospheric humidity. Key issues regarding global change involve the water vapor mixing ratio in the upper troposphere, the mechanism that controls the water vapor mixing ratio entering the stratosphere, and the rate in which the air and that water vapor mixing ratio is transported poleward. Questions of ascent velocities in the tropical stratosphere are critical in understanding the general circulation. Stratospheric models need data on these velocities on an ongoing basis. Current approaches have relied either on aircraft and balloon-borne CO_2 profiles or radiative transfer calculations to determine ascent velocities. Both carbon dioxide and water vapor exhibit seasonal cycles with water vapor ranging from a 3 ppmv minimum Northern Hemisphere (NH) winter to 6 ppmv in the summer. CO_2 varies by about 3 ppmv with its maximum in NH fall and minimum in spring. Measurements of carbon dioxide at the surface and at the tropical tropopause have served to characterize its variability very well. The phasing of the water vapor signal is well understood from satellite measurements and *in situ* measurements have started to provide accurate quantitative information on its seasonal cycle. Measurements of CO_2 and water vapor have already been used to give ascent velocity information but the data is sparse. The availability of continuously measured water vapor and CO_2 profiles from the tropopause up into the middle stratosphere would provide invaluable information for stratospheric circulation and would help provide better understanding of the overall lifetime of atmospheric species. These data would also provide the first picture of the interannual variability of atmospheric circulation. It would address issues involving our understanding of how much water enters the stratosphere on an annual basis and provide a basis for our understanding trends or variability in stratospheric water which have been observed by satellites and sonde data.

Accurate high-resolution measurements of upper tropospheric water are critical for our understanding of global warming. Water vapor is the principle greenhouse gas and measurement of its concentration in the upper tropical troposphere, along with concurrent ozone and temperature measurements from about 12 to 18 kilometers is critical. Satellite-based measurements can provide neither the resolution nor the accuracy needed in the tropopause region where ozone and water vapor mixing ratios vary significantly with altitude. For example, the vertical resolution of satellite sensors is of the order of several kilometers (1-5 km) and the accuracy of the water vapor measurements is of the order of 10-20% on average. Balloon measurements in the upper troposphere indicate that the water vapor mixing ratio changes at a rate of about 20%/km (1 ppmv/km). Consequently, the satellite measurements can differ from the in situ measurements by as much as 40% (WMO, 2000).

Two different science objectives can be considered for the understanding of global circulation in the tropics. One objective relates to the monitoring and quantitative understanding of the circulation in the tropical stratosphere and the other objective relates to the mechanistic control of the transfer of air from the troposphere to the stratosphere. The first objective requires *in situ* sampling in the region from 15-km altitude and up, while *in situ* sampling upwards from 20 km could satisfy the second objective. While conducting remote sampling below 20 km, as technology allows, might provide some insight into mechanistic issues, we currently believe that *in situ* measurements are critical.

We would envision 35-50 platforms from 15° S to 15° N latitude for this mission. This coverage will map out the seasonal, latitudinal and longitudinal dependence of the flux into the lower tropical stratosphere. **Figure 3** illustrates the fixed-science approach that utilizes instruments for remote measurements from the gondola and an array of *in situ* instruments along the tether along with *in situ* and remote sensing instruments at the TCS. The payload consists of a microwave temperature profiler at the TCS, water vapor and ozone LIDAR instruments at the gondola, and *in situ* water vapor, ozone and CO_2 instruments on the tether and on the sail. A new *in situ* absorption technique called cavity ringdown laser absorption spectroscopy using a multipass cell will provide high accuracy. For CO_2, where 0.1-ppmv accuracy is the goal, a small gas addition system will be used to periodically calibrate the instrument.

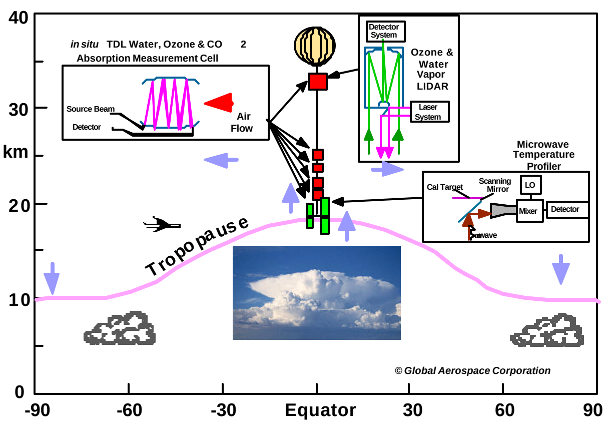

Figure 3 Tropical dynamics experiment

An alternate approach to multiple stationary instruments along the tether is to apply the “reel-down” technique for a set of instruments that can make measurements during controlled descent on a tether independent from the tether used for the trajectory control sail. Potentially, the duty cycle of the trajectory control tether would be on the order of 85-90% and allow for a reel-up and reel-down sequence about once every 12 hours. This would then allow measurements down to 15 km with timing controlled to prevent interference with aircraft operations.

A hybrid option exists that could satisfy both objectives with less complexity, but with assumptions on technological advance. This option is to have the fixed configuration of sensors as in the baseline case but with an additional 5 km of tether that could be reeled down periodically to make measurements below 20 km. For example, the entire TCS and science pod configuration could be reeled down an additional 5 km once every 12 hours for an hour or so for collection of tropospheric measurements. This would enable critical science measurements to be made in the upper troposphere. This option would reduce the time any system element was below 20 km thus reducing its exposure to “controlled aerospace”. This option also eliminates the necessity for two tether and two reeling systems, one for the TCS and one for the science, and thus reduce system complexity. The hybrid option does assume that technology advance will enable high accuracy measurements of CO_2 and other gases from small self-contained science pods along the tether. The determination of which approach to take will depend upon the relative rates of instrument development and technology for tandem or multipurpose tether reel up and reel down systems.

2.5 *Radiative Studies in the Tropics: CRYSTAL*

Issues of global warming and how to determine whether we are experiencing it or not have been a focus of serious debate within both the scientific and political communities. It is well understood that much of the infrared radiation that escapes the earth does so in the dry or downwelling regions of the tropics, where the relative humidity is low enough. Monitoring the emitted radiation of the atmosphere from the near to far infrared in the tropics with an accurately calibrated FTIR will provide invaluable information on climate change.

High-level clouds dominate the cloud radiative forcing signal in the tropics and a variety of modeling and theoretical studies suggest that the response of these clouds to external forcing might have a controlling effect on global climate sensitivity. Aerosols have been found to play both a direct and indirect role in climate change. Calculations show that the direct contribution of aerosols has a cooling effect of on average about -2.5 W/m^2, which is significant relative to greenhouse gases. Currently, satellite instruments are planned for monitoring cloud cover, its radiative properties and their particle microphysical properties, such as ice water path length. Understanding the details of aerosols and their radiative properties requires simultaneous measurements of their size distribution and particle density as well as their radiative effects. The study of the radiative properties of aerosols has been severely limited because or the difficulty of doing such an experiment. While there are *in situ* measurements from aircraft instrumentation and sondes of aerosol properties as well as from satellites (SAGE) and radiative measurements from satellites there is little if any data linking the two, especially in the tropics.

The CRYSTAL (NASA 2000) study project is being organized to provide a coordinated effort for aircraft *in situ* cloud measurements along with radiative measurements for satellite validation. A tropical mission like this requires significant resources and planning (2-3 years) and then provides a limited 2-4 week opportunity for completing the science objectives. The scope of the science goals suggests solutions are decades rather than years away. The combination of radiative and *in situ* cloud particle measurements, as well as water vapor and other atmospheric tracers suggest strongly that controlled balloon-borne instrumentation could provide a significant cost-effective method of attacking this critical problem. This problem can be approached using constellations of a few (1-5) or several (6-10) platforms. While projected satellite based instrumentation will provide a global picture, resolution from a satellite often is insufficient to clearly isolate homogeneous regions. However, balloon-borne instruments have a small enough "footprint" to do just that.

At this time, further analysis is necessary to analyze which approach is most cost effective. This analysis must consider the need to cover various geographic areas in the tropics, how trajectories can maintain coverage of those areas, and what the cost-effectiveness is of multiple instrument production and calibration. Specific interest lies in the potential for a sparse network in the tropics to also provide calibration and validation data for a satellite radiometer observations.

The payload could consist of Cloud LIDAR, and FTIR instruments at the gondola, both providing remote measurements of the air column below. The FTIR would take highly resolved infrared emission spectra. The LIDAR instrument with the same footprint as FTIR will determine radiative feedback properties of optically thick and thin cirrus clouds through verification of clear sky as well as through the measurement of change in emission in the presence of clouds at specific altitudes. Measurement of clouds at certain altitudes can be used to trigger the dropping of sondes from the gondola to measure water vapor, ozone, particle size distribution in the clouds, as well as pressure and temperature. The ozone and water vapor measurements can be used to compare with the FTIR measurements. This payload could also benefit from a reel down technique for cloud particle measurements in the upper troposphere. Additionally, because the emission measurement will provide a reasonably accurate measurement of ozone and water vapor, the primary absorbers of infrared radiation, a full radiative heating rate calculation can be made on the air below the gondola, providing an independent determination of ascent rates in the stratosphere. This combination of experiments focused on a localized air mass cannot be accomplished by satellite-based instrumentation.

2.6 *Global Circulation and Age of Air*

All models that integrate transport and chemistry depend on their ability to model the transport of air. Currently models have difficulty with transport times in the stratosphere. Also, there are predictions that that there might be a relationship between global warming, ozone depletion, and changes in the global circulation. Monitoring the age of stratospheric air would provide significant help in understanding global change. This stratospheric monitoring on a continuous basis global circulation can be best accomplished by continuous *in situ* measurement of tracers of stratospheric transport, CO_2, N_2O, H_2O, CH_4, temperature, and pressure, at 2-3 km intervals along the tether. The most significant challenge to this experiment involves measuring CO_2 with sufficient accuracy under severe weight restrictions. This payload will require significant technical innovation to provide a calibration system adequate for the enumerated science goals. An accuracy of 1-ppmv for CO_2 will provide one level of information, yielding the mean age of an air mass. An accuracy of 0.1-ppmv will reveal the age spectrum of the air, meaning how old are all the individual air parcels that make up the sampled air mass. A lightweight calibration system is required for this experiment.

2.7 *Hurricane Tracking and Weather Forecasting*

More accurate prediction of a hurricane track and its size may result in significant reduction in evacuation costs and in the saving of lives. There are three complementary areas that need to be addressed in improving hurricane forecasting:

- Accurate high-resolution atmospheric pressure, temperature, and wind data;
- Ocean temperatures in the vicinity of the hurricane; and
- The physics in the models that use this data for forecasting the track and growth of the hurricane.

The winds in the vicinity of the hurricane are important for predicting where the hurricane is going. The winds outside the hurricane are important for estimation of intensity of the hurricane. Both wind measurements are needed. Currently, satellites provide low-resolution atmospheric data, buoys provide surface wind, pressure, air and ocean temperature, and manned aircraft fly into the storm to supplement the wind, pressure and temperature data around the storm. While this network of information has continued to improve hurricane forecasting, more high quality, high resolution *in situ* data is needed.

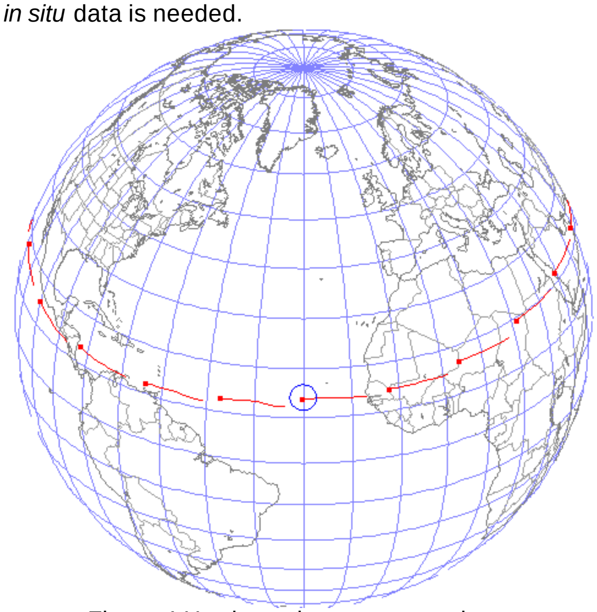

Figure 4 Hurricane intercept experiment

A constellation of platforms could be used to address this problem. Stationed in the Atlantic (and Pacific) they could carry dropsondes to measure wind, temperature and pressure in the vicinity of the hurricane. This added information would provide significant data increase input into the models. With a projected sonde mass in ten years of 10 to 25 grams, each balloon payload could have more than 1000 sondes for this experiment that provides profiles from balloon altitude to the surface. In addition to the dropsondes, Precipitation Radar may be an important instrument on such a payload due to its ability to provide additional data on storm intensity. The possible candidate instruments for a hurricane-focused regional constellation may include:

- Meteorological dropsondes
- High-resolution wind LIDAR
- GPS reflection sea-state
- Precipitation radar
- Low-resolution imager

Figure 4 illustrates the hurricane intercept experiment. A string-like constellation of StratoSat™ platforms (indicated by dots with "tails", representing 24-hour trajectories) intercept a hurricane (a large circle just above the equator) in equatorial Atlantic.

Because this constellation of platforms could be useful for weather forecasting as well as hurricane tracking, there should be temperature, pressure, and horizontal wind measurements on the tether, at approximately 3 km intervals. These data could be used for input into assimilated weather forecasting models. Over the last few decades improvements in weather forecasting have been limited more by computing capability than by the lack of physical data. We have reached the stage that the bottleneck for improving weather forecasting is higher resolution data. Satellite data sets have helped to fill in regions where radiosondes are lacking. However, *in situ* measurements will provide climatology far more accurate data than that given by a satellite-based system. Additionally, this network will supplement the global radiosonde network, which has very limited coverage in remote areas.

2.8 *Global Radiation Balance*

As part of NASA's directive to detect long-term climate change, a simultaneous measurement of the total energy entering and leaving the atmosphere has been undertaken in an effort to determine whether the atmosphere is warming. Because this requires global coverage, the approach has been to use satellite-based radiometry to make this measurement. The program uses filter radiometers on satellites in morning, afternoon, and inclined orbits to measure the Earth's radiation balance. However, because the satellite is in orbit at approximately 800 km, far above that part of the Earth's atmosphere that has a significant role in radiative balance, models must be used to convert the measured radiance to a flux at the top of the atmosphere to compare with the measurement of solar flux. This conversion significantly limits the accuracy of the radiation balance determination. Additionally, the footprint of a satellite-based instrument is often too large to provide a homogeneous radiative field. Radiation measurements will often be from a mixed clear air and cloud-filled region, thus making interpretation of the data significantly more complicated.

A constellation of platforms can be used to position radiometers globally in the stratosphere for a direct radiation balance determination. The radiation must be measured from the ultraviolet (0.2 microns) through the infrared (100 microns), using filters to divide this full region into about 5 regions so that changes can be isolated to specific physical causes. This can be accomplished by positioning a pyranometer and a pyrgeometer on the platform, which would allow to measure both solar short-wave (SW) and terrestrial long-wave (LW) upwelling radiant fluxes. These radiometers will be mounted on a flipping instrument bench allowing for frequent in-flight calibration by exposing pyranometers to direct solar radiation and pyrgeometers to a blackbody calibration source of known temperature. **Figure 5** illustrates calibration procedure.

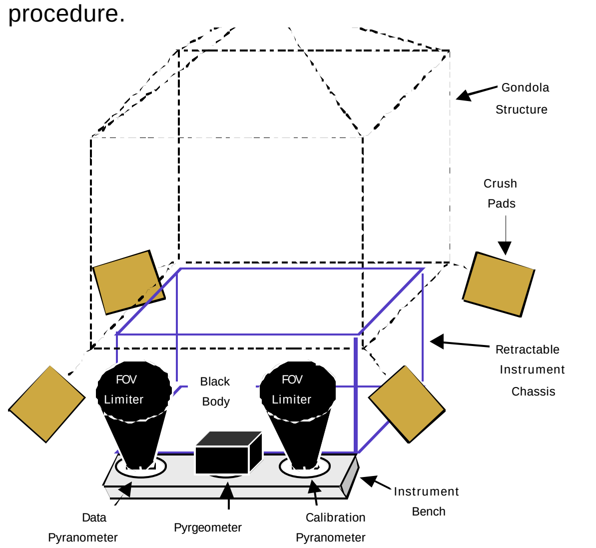

Figure 5 Instrument bench in calibration position

Because the ability to interpret the data is related to the effects of cloud cover, we include a cloud LIDAR instrument at the balloon gondola as well. Additionally, it is currently believed that using an FTIR would be the most accurate way to do this experiment. While it may be prohibitively expensive to plan for an FTIR on every balloon platform, this global monitoring approach lends itself to cross calibration in the infrared with one or more platforms with FTIRs specifically flying for reference measurements. Together these options show the advantages of making these measurements using a constellation of balloon-borne payloads. Example payload that addresses the ERB measurements can include the following instruments:

- Pyronometers
- 4 instruments of different types
- Hemispheric FOV
- Short-wave (0.3-3 ì m)

- Pyrgeometers
- 2 instruments of different types
- Hemispheric FOV
- Long-wave (4-40 ì m)
- Instruments located on optical benches
- Calibration system

There are two applications of stratospheric constellation in support of Earth Radiation Balance (ERB) measurements. One application assumes that a sparse network is deployed around the world to act as calibration/validation for orbital radiometers. A second application is a dense network that makes the primary measurement and carries out self-calibration. There has been considerable discussion regarding the advantages and disadvantages of balloon-borne radiometers for directly measuring the broadband flux. Some of the advantages are:

- Radiative flux measured directly at 35 km (commonly accepted top of the atmosphere (TOA) to which satellite measured radiance is extrapolated)
- High spatial resolution measurements
- No angular modeling needed
- 90% of the irradiance is within a 200 km footprint (70° field of view (FOV))
- Less than 0.5% of effective FOV is exposed to space
- Complete diurnal coverage (no diurnal model required, the leading source of uncertainty in daily and monthly flux averages)
- No Sun angle bias (Sun synchronous orbits, except ERBE/ERBS and CERES/TRMM)
- Global Synoptic coverage allows actual dynamics of ERB to be seen (including horizontal fluxes); never before possible

Some researchers feel that a sparse network could be of high value in calibrating and validating satellite measurements (e.g. for CERES). For calibration it is important to make coincident measurements at a variety of geographic locations across the globe. After a dense network of calibration points has been achieved, the balloon network is of little further value unless there are new satellites with new measurements to be calibrated. Others believe there is a potential continuous role for a global network in making the direct flux measurements but only if the issue of instrument calibration could be solved.

3. CONCLUSIONS

Global and regional networks of StratoSat™ platforms would provide a unique opportunity to perform a number of crucial Earth science experiments within the context of global environmental change. Advances in balloon technology and unique maneuvering capabilities allow for a revolutionary low-cost approach to the problems of ozone loss monitoring, global circulation, hurricane tracking, weather prediction and others. Technical challenges facing balloon systems include development of calibration techniques and logistical management of the balloons in the network.

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