SUN-WEATHER RELATIONSHIPS

Background

"Sun-weather" studies are defined as investigations of possible processes in the lower atmosphere of the Earth that are initiated or controlled by changes in the output of the Sun. These changes can include solar variation in radiation (as in the solar constant, or in specific wavelength regions), in particles (as in physical properties of the solar wind, or in solar cosmic rays, or solar-modulated galactic cosmic rays), and in the extended magnetic field of the Sun (as in circumstances of the passage of interplanetary sector boundaries). Changes of short term (in the "weather") as well as long term (in regional or global "climate") are considered, although mechanisms involved in the two time scales may be quite different.

It is clear that studies of Sun-weather relationships are not an independent discipline. As a practical, interdisciplinary area, Sun-weather study relies on solar physics, magnetospheric physics, and atmospheric physics. Thus, programs in Sun-weather relationships envisioned here for the STO lean heavily on more fundamental programs in these other three areas. Instruments to carry out specific Sun-weather investigations will be a part of the working arsenal of equipment dedicated to solar physics, atmospheric physics, and magnetospheric physics. Indeed, while specific Sun-weather investigations should be an essential part of programs planned for the STO, major advances in our understanding of the Sun's influence on weather can also be expected from the broad advances anticipated from STO in each of the three more basic areas.

In anticipating possible programs for the STO in the Sun-weather area, it is recognized that there is less than complete understanding of the range of possible processes and mechanisms that could be involved. Some seem now to be obvious contenders that must be included, such as changes in the bulk radiation of the Sun or in specific spectral components that have known effects on the chemistry of the upper atmosphere. But there are many others, such as induced changes in the Earth's electric potential or a host of possible cloud formation mechanisms, that may be more important. The field of Sun-weather study is not sufficiently advanced, in 1977, to predict which theories or mechanisms will be the most likely contenders for study a decade from now. Thus, the approach is taken here of outlining broad areas rather than specific ones and of utilizing a varied and comprehensive list of equipment that might be needed in studying Sun-weather connections in 1985, hoping in this way to cover the widest range of possible important mechanisms.

This topic is approached recognizing that a number of recent developments show that a solar effect on weather is statistically established; the problem now is to determine the magnitude or importance of its impact on weather and climate and to understand its mechanism. In this regard the proposed schedule of a Space Station seems timely. It comes at a time when the world asks for tests and hard facts in the area of Sun-weather relationships, and the STO seems, for the reasons stated in preceding sections, almost uniquely qualified to provide these tests and facts.

Advantages of an STO

The proposed STO offers substantial advantages that may provide new and needed information in the study of solar influence on weather. These are:

(1) the capability to monitor the various outputs of the Sun in a laboratory environment, with the possibility of in-orbit cross-calibration, instrument replacement, and the use of on-board, controlled secondary standards;

(2) the capability of real-time observations of specific solar effects on the terrestrial atmosphere, requiring simultaneous or time-correlated observations of both Sun and Earth;

(3) the possibility of testing specific hypotheses of Sun-weather connections, through the availability of high-capability atmospheric, magnetospheric and solar observing equipment, and the ability to concentrate on specific geographic areas of interest.

Of all the aspects of an STO, the solar-weather objectives are most interdisciplinary and demand the greatest real-time, innovative reaction by the staff of the Observatory. The very nature of these objectives asks for recognition of relationships between members of a complex sequence of events stretching from the Sun to the surface of the Earth. The ensemble of instruments and data displays on the STO will allow the Observatory scientists to focus on specific relationships and to follow them as they unfold and evolve. Complete automation to follow these varied relationships seems virtually impossible. Further, the real-time pattern recognition and correlative capabilities of the human mind may catch significant relations that could easily elude notice during subsequent processing of recorded data at a ground site.

Near-real-time and extended analyses of data by a team of specialists on the ground are also essential. The former will provide information for baseline observation plans that can be transmitted to the STO. However, such baseline plans will be most effectively carried out and reinforced through the innovations of the on-board STO scientific staff.

Program of Investigations

Table 3 lists a program of potential investigations that follow from our current understanding of solar-weather connections. The left-hand column contains a brief statement of investigations with a statement of purpose. The middle column gives the advantages to be gained by conducting this investigation from a manned space station. In some instances the investigation will draw support from relevant unmanned spacecraft. The last column recommends the appropriate orbit for the STO.

The investigations are necessarily general, since at this stage a comprehensive attack is what seems to be most needed. Some suggestions are more specific than others, but pinpointing specific mechanisms for trial is avoided. Moreover, the possible mechanisms and solar-weather

TABLE 3. POTENTIAL INVESTIGATIONS OF SUN-WEATHER RELATIONSHIPS

	Investigation	Advantage of Space Station	Orbit
1.	Measure the solar constant $S = \int_0^\infty S_\lambda d_\lambda$ on a continuous basis. Accuracy ~ 0.1 percent. Purpose: To establish whether and by how much the total solar output varies over time scales of days to months.	Allows maintenance of calibration under "laboratory conditions" with ability to check, replace.	Any.
2.	Measure the ultraviolet and soft X-ray spectral irradiance of the full solar disk, with correlated measurements of terrestrial atmospheric composition and ionization. Purpose: To diagnose solar-induced change in atmospheric composition at times of solar activity.	Capability of simultaneous "up" and "down" looks, and advantage of being on station as solar activity occurs and develops.	LEO (middle to high inclination) for first investigation. GEO for more extensive coverage.
3.	Collect visible-light images of the entire globe and of specific selected areas at times of solar changes. Coverage of terrestrial areas should include cirrus coverage, cloud patterns, ice cover, albedo, Doppler wind velocities, temperatures. Examples of areas of specific interest are the Gulf of Alaska or specific regions of the tropics. Purpose: To allow a broad attack on questions of weather change related to solar change, with capability of examining specific hypotheses and specific events.	Flexibility, comprehensive coverage. Ability to check on suspected mechanisms in specific areas. Ability to observe real-time events.	LEO. Prefer high-inclination orbit for pilot study. GEO with two free-flyers for total Earth coverage.
4.	Monitor atmospheric temperature distribution and wind velocities as function of height over globe, with capability to concentrate on geographic regions of interest. Purpose: To improve the definition of day-to-day weather change and weather systems.	Flexibility; ability to examine specific regions.	LEO (middle to high inclination) for pilot study; then GEO.
5.	Measure high-latitude atmospheric responses to cosmic ray flux modulation, particle precipitation, and aurorae by monitoring these fluxes and events with concurrent measurement of cloud cover, atmospheric composition, temperature, and velocities. Purpose: Examine possible direct responses in specific selected regions such as the auroral oval.	Flexibility; ability to concentrate on specific areas to test specific theories; on-board availability of many diagnostic tools.	LEO (high inclination) for preliminary study; then GEO.

TABLE 3 (Concluded)

	Investigation	Advantage of Space Station	Orbit
6.	Monitor lightning frequency and intensity and their spatial and temporal distribution over the Earth. Purpose: To examine temporal and spatial variation in the Earth's electric field generator as a possible link between solar variability and weather.	Permit flexibility and an intelligent search. Capability of studying targets of opportunity such as extensive thunderstorms.	LEO (equatorial orbit) for preliminary study. GEO for more extensive coverage.
7.	Monitor the dust veil of the atmosphere (globally), with capability to follow specific disturbances such as volcanic eruptions. Purpose: To complete overall diagnosis of weather change and climate change.	Flexibility to zoom in and to follow targets of opportunity. Availability of a large platform for complex equipment.	LEO.
	Related Experiments		
8.	Continuous monitoring of solar wind velocity, density, magnetic field to identify effects of coronal holes, high-speed streams, crossing of magnetic sector boundaries on the Earth's magnetosphere and atmosphere (must be done from other spacecraft or free-flyers outside the magnetosphere).		
9.	Thermal mapping of ocean temperature and currents (longer time scale changes).		
10.	In-orbit measurement of brightness of outer planets throughout spectrum should the current anomaly of planetary brightness variations persist; orbital measurement should allow accuracy improvement.		

effects considered are recognized as being incomplete.

Almost all of the experiments proposed here involve apparatus which will serve other areas of research on board the Space Station: solar physics, magnetospheric physics, and atmospheric physics. The specific equipment is listed in the preceding sections.

The observational capabilities given in Table 3 provide a typical set of tools to investigate the class of scenarios suggested currently for the solar influence on weather. For example, the option that any appreciable variation of solar radiation could have a fairly direct influence on the Earth's atmosphere is addressed by items 1 through 4. Similarly, the thought that solar modulation of ionizing particles reaching the atmosphere may influence cloud mechanics, and hence weather, can be investigated by a combination of items 3, 4, and 5. Likewise, the idea that solar-induced changes of electrical conditions in the ionosphere interact with meteorology is addressed in items 3, 5, and 6. The concept that solar particle radiation filtered by the Earth's magnetosphere may change ozone concentrations in northwestern North America, resulting in the formation of cold anticyclones that propagate across the continent, can be investigated by items 2, 3, and 4. These are examples drawn from contemporary literature.

Even more important, however, is the encompassing ability of the instrumentation complement, when it is finally selected, to test refined and still-to-be-proposed scenarios that will surely come forward between now and the advent of the STO. In actual STO operations, a specific observation plan could be tailored to each of the prime candidate mechanisms for solar influence on weather and climate. At the present time, the observations to be made must be discussed in general terms as above. Ultimately the observing campaigns must be quite specific. This is the feature that distinguishes the STO from the traditional monitoring observations.