WHITE PAPERS

FOR SCOSTEP SCIENTIFIC PROGRAM(S)
2014 – 2018

The nine proposals, submitted to the SCOSTEP Secretariat are given in alphabetical order according to the first author's name.

These proposals are released only to the members of the ISSI/SCOSTEP panel members for consideration in preparation for the ISSI/SCOSTEP Forum to be held on May 7 – 8, 2013 in Bern, Switzerland.

Dr. Marianna Shepherd
SCOSTEP Scientific Secretary

March 31, 2013

Project Title: Coronal Heating and the Acceleration of the Solar Wind

I. Proposed Research

In our proposed research we will seek to answer the following question:
What are the physical processes that heat the corona and accelerate the solar wind?

It has long been assumed that the solar corona is heated by dissipation of magnetic disturbances that propagate up from the Sun's convection zone (Alfvén 1947). Convective flows interacting with magnetic flux elements in the photosphere can produce Magnetohydrodynamic (MHD) waves that propagate up along the flux tubes and dissipate their energy in the corona. In closed magnetic structures the random motions of photospheric footpoints can lead to twisting and braiding of the coronal field lines, and to the formation of thin current sheets in the corona (Parker 1972, 1983, Priest et al. 2002).

Observations suggest that Alfvén waves exist in the lower solar atmosphere and can carry enough power to heat the corona and accelerate the solar wind (e.g., Cranmer & van Ballegooijen 2005, De Pontieu et al. 2007).

An important factor in understanding the heating of the corona is the plasma dynamics occurring within the structures of closed and open field lines. The cooling and heating events predicted by the Alfvén wave turbulence model should produce plasma flows. These flows would appear as Doppler shifts or line broadening depending on a range of factors.

The detailed physical processes by which the corona is heated and accelerated are not yet fully understood. Firm constraints on the plasma properties near the Sun and in the heliosphere are key to understand the relevant processes.

Recently we (van Ballegooijen et al 2011) developed a three dimensional (3D) MHD model describing the propagation and dissipation of Alfvén waves in active region loops. The model includes a detailed description of Alfvén waves in the coronal part of the loop, as well as in the lower atmosphere at the two ends of the loop.

The aim of this project is to significantly improve the existing 3D MHD modeling of the coronal heating by Alfvén wave turbulence and to develop a better understanding of the solar wind considering that it originates in the solar corona.

II. Main Goals

The intellectual merit of our project is to solve the longstanding problem of coronal heating and the role that Alfvén waves play in the heating of the chromosphere and corona, and in driving the atmospheric oscillations that result in the acceleration of the solar wind. In order to achieve this goal, we will be conducting comprehensive studies of generation and dissipation of Alfvén waves in the solar atmosphere in observed open and closed field lines by using state-of-the-art analytical and numerical tools. In addition to developing a theoretical basis for understanding the coronal heating, and the formation of the solar wind, another aim of our project is to interpret observations and compare them to our modeling results.

In our current modeling we consider the closed loops in which both footpoints of the field line are anchored on the photosphere (Asgari-Targhi & van Ballegooijen 2012). For this research project we will be applying our 3D MHD modeling to both the closed and the open field lines in the solar corona where the solar wind originates.

Our theoretical results will be used to interpret the current observational data as well as future observations. We will compare our results with the signatures of Alfvén waves that are observed by the Extreme ultraviolet Imaging Spectrometer (EIS) instrument on Hinode. EIS has enabled spectral information to be obtained for field lines in active regions. We will be using EIS spectral lines to calculate the relationship between nonthermal velocities, Doppler outflows, and intensities in the open and closed field lines in the boundary region between the coronal hole and the active region. In addition the SDO/AIA imaging data will be used to trace the field lines.

The observational data in the corona will be complemented with measurements of the associated solar wind streams observed by Inter-Planetary Scintillation (IPS) and in situ instruments for the coronal target regions. Previous studies suggest that one source of the slow solar wind may be the boundary region between the coronal hole and the active region (e.g., Ko et al. 2006). Using the coronal data, our code (Miralles et al. 2011) will track the solar wind streams from the solar surface to few solar radii (IPS, data) to ~1 AU (in situ data, ACE and STEREO spacecraft).

Our theoretical analysis of Alfvén wave turbulence in closed and open field lines and hence the generation of solar wind, and the comparison of these results with the observations will allow us to first validate our theoretical modeling, and also to develop an understanding of the mechanisms behind the heating of the corona and the structure of the solar wind. The observations will provide constraints on the understanding of the origin and nature of these waves in the solar corona.

III. Research plan

Our research will be conducted in the following steps:

We will calculate analytically and numerically the generation and dissipation of Alfvén waves in the solar corona, considering open and closed field lines. We will investigate the mode coupling between the Alfvén waves and the magnetoacoustic waves. This is what we are determined to include in our theoretical modeling. Using the above results we will look for observational signatures of Alfvén waves in the solar corona based mainly on data from the EIS instrument as well as solar wind data from IPS and in situ.

Year 1

We will be focusing on improving our numerical methods in solving the differential equations that are used to model the Alfvén waves in the open and closed coronal field lines. We will select a few active regions observed by AIA on Solar Dynamics Observatory and EIS on Hinode. The observations will be reduced, cleaned from instrumental effects and calibrated. In particular the AIA and EIS data will be spatially coaligned in order to identify structures in both instruments.

In addition to working on the analytical and numerical solutions to the Alfvén wave turbulence modeling, we will be using the expertise of Dr. Alexander Voss from St. Andrews University to develop the computational scientific software with effective Software Engineering solutions to perform our numerical simulations.

In order for computational modeling to help validate the theoretical models, it is of crucial importance that the latter are translated into code accurately and in a way that allows the resulting programs to be executed effectively on modern computer architectures such as multicore or GPGPU systems. Effective exploitation of such lower-level parallelism is also a prerequisite for scaling up the computational models to levels where they can benefit from high-performance computing resources (Post & Votta 2005). In order to develop the software required for our work, we aim to adopt sound software engineering approaches such as continuous testing methods for code verification and routine cloud-based simulation runs for validation of the theory and its translation into simulation code against observational data.

Year 2
We will be working with our partners on improving our analytical and numerical calculations of the propagation and dissipation of Alfvén waves in the open and closed coronal field lines. Our main focus would be in including the coupling between Alfvén waves and fast and slow magnetoacoustic waves. This will be done in parallel with looking for observational signatures of Alfvén waves in both open and closed coronal field lines as well as analyzing the observations of solar wind structures.

Year 3 and Year 4
The results we have obtained from our numerical methods will be used to provide the theoretical interpretations of the coronal data available from EIS and solar wind data from IPS and in situ.
We will compare the theoretical analysis of Alfvén wave turbulence in closed and open field lines and the generation of solar wind with the observations. This will allow us to first validate our theoretical modeling, and also to develop an understanding of the mechanisms behind the heating of the corona and the structure of solar wind.

This research will improve our understanding of the origin and nature of the waves in heating of the solar corona and the role they play in the acceleration of solar wind.

Final results of the investigations will be made available, published in peer-reviewed journals, and disseminated in international talks and seminars at conferences, universities and other research institutes.

IV. Our Team of Scientists

The personnel for this project are from the United States, the United Kingdom, and Japan.

Drs. Mahboubeh Asgari-Targhi and **Mari Paz Miralles** are from the Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, USA.

These scientists will provide observational and theoretical expertise in coronal and solar wind heating and acceleration.

Prof. Kanya Kusano and **Dr. Shinsuke Imada** are from STEL (Solar-Terrestrial Environment Laboratory), Nagoya University, Japan. STEL is an international center of solar wind research where the IPS solar wind database resides. The collaboration with STEL will greatly improve the application of the coronal heating study to the solar wind. These scientists will provide expertise on EIS and IPS measurements.

Dr. Alexander Voss is from St. Andrews University, United Kingdom. This scientist provides expertise in scientific software development and supporting software engineering practices.

Asgari-Targhi and Voss have previously collaborated on the Elastic Virtual Research Infrastructure for Research Applications (ELVIRA) project funded by the Engineering and Physical Sciences Research Council (EPSRC) in the UK. They made use of cloud resources for performing the numerical calculations by making use of multiple research sites in addressing the coronal heating problem (Asgari-Targhi & van Ballegooijen 2012). Outcomes from this project such as OpenMP parallelized simulation code will be utilized in this proposed collaboration.

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SCOSTEP-FUTURE:

A WHITE PAPER BY ATMOSPHERIC "TRENDS" SCIENTIFIC COMMUNITY

Scientific Associations:

(1) "IAGA/ICMA/SCOSTEP -Working Group II-F: Long-term Trends in the Mesosphere, Thermosphere and Ionosphere)

(2) CAWSES Task Group-2 on "How will Geo-space Respond to a Changing Climate?"

Contribution /Compilation by:

TREND-Working Group:

Gufran Beig (India)-Chair and Jan Lastovicka (Czech Republic) -co-chair

Task Group-2 of CAWSES -Co-leaders:

Jan Lastovicka (Czech Republic); Dan Marsh (USA); and Gufran Beig (India).

A brainstorming session was dedicated to discuss about the scientific issues and future of SCOSTEP program after CAWSES in the TREND-2012 workshop held at Bunes Aires, Argentina, organized by the Working group on " Long Term Changes and Trends in the mesosphere, thermosphere and ionosphere" of IAGA /ICMA and SCOSTEP. Thereafter further ideas and opinions were invited by the members of trend community under "IAGA/ICMA/SCOSTEP -Working Group II-F: Long-term Trends in the Mesosphere, Thermosphere and Ionosphere) and CAWSES Task Group-2 on "How will Geo-space Respond to a Changing Climate?" This report is based on the outcome of the above deliberations. Hereafter we will refer the opinion of above deliberation as "TC-WG" in rest of this paper. The TC-WG passes the following resolution in their workshop session as Bunes Aires, Argentina (September' 2012):

Quote *"The TC-WG community under the umbrella of a joint working groups of IAGA/ICMA and CAWSES on long term changes and trends in the atmosphere-ionosphere actively works toward enhancing the scientific message in this area and meet every year since 1999 through specialized workshops and/or arranged sessions in each IAGA/IUGG assemblies. It is successfully publishing the special volume of the workshop proceedings in the form of book /Journal (JASTP, JGR, PCE, Ann. Geophysicae, etc). Members of the Trend WGs recently participated in the 7th international workshop of the series at Bunes Aires during September 11-14, 2012 and expressed strong interest in terms of a resolution in continuation of a CAWSES-like activity of SCOSTEP due to their close scientific linkages of TRENDS related research. WGs decided to come up with a white paper highlighting key scientific question which we wish to address in coming years and which is anticipated to form a basis of new program of SCOSTEP after 2013."* **Unquote.**

It has been unanimously decided that by very nature of fundamental scientific core area of trend community, there is no doubt that a close scientific linkages need to continue with SCOSTEP and that a new program should emerge beyond doubt. It is now time that we need to consider entire atmosphere as a whole system that responds not only to direct solar influences, but also to internal variations and changes of both natural and anthropogenic origin. TC-WGs strongly feel that "trends' should feature prominently in the next SCOSTEP activity and it should be the focus to determine the changing state of atmospheric and space parameters and their impacts.

- There is a general agreement of our WG that can we adopt a unified title to the next SCOSTEP project like "**GEOSPACE CLIMATE CHANGE**". In the new project the focus should be on how the thermosphere /ionosphere responds to variations in both solar & geomagnetic output and influences from below. Under the above theme, the list of topics given below would unify.

- There is a general agreement of our WG that for a trend community (like us), an ambitious program under the broad title "**Realizing Climate change signals in the Upper atmosphere**" could be one of the options.

- From the perspective of earlier task group 2 of CAWSES under SCOSPTEP and to carry the science to next level, the question is how does the long-term average (i.e. its climate) of geospace (here meant to be the thermosphere /ionosphere) change. This is an extension of CAWSES II TG, which was more related to changing climate effects of Geospace, where climate meant mostly tropospheric climate.

The following specific scientific issues and points have emerged:

(1) The key open question of long -term changes and trends in the middle and upper atmosphere and the ionosphere are changes /trends in circulation /dynamics & particularly in wave forcing (atmospheric waves) and resulting impacts – HERE PROGRESS IS SLOW.

(2) Practical impact of such studies are:

a) Changes of orbital lifetime of satellites and particularly of dangerous space debris in response to cooling and contracting thermosphere.

b) Long-term changes in TEC and gravity wave activity could have impact on ionospheric influence on GNSS (GPS, GALILEO, GLONASS etc.) signal propagation + ionospheric corrections and signal stability.

c) Changes in space weather and space climate effects via changes of background conditions.

(3) Importance of Ozone recovery in the upper atmosphere? It is likely to be one of the biggest drivers over the next few decades and need attention of upper atmospheric community to establish the linkages.

(4) The continuous measurement systems beyond a solar cycle are sparse so far. Large temporal gaps between missions and the scarcity of data from previous solar cycles impose serious obstacles to the understanding and attribution of geospace climate. Hence, instead of short-lived (less than a solar cycle), and sporadic monitoring set-up. Community should think of dedicated long term monitoring system like that of Earth Science community.

(5) DIRECT (local CO_2 cooling / solar & geomagnetic effects) and INDIRECT (wave propagation, e.g., tides, SSWs, GW filtering & sinking of the whole atmosphere) forcing of geo-space.

(6) A focussed effort to understand long-term variability of these drivers would be a good unifying goal.

(7) Distinguishing between anthropogenic, solar and other natural causes of climate change and variability from the point of view of long-term trends, and in view of the possible weaker solar activity.

(8) Response of the Geo-space to changing /increasing anthropogenic forcing and long-term changes of solar/geomagnetic activity is of high importance

for climatic change of human's environment, which now includes also nearby space sued for satellite technologies, which are becoming more and more important for our everyday life.

(9) Better quantitative comparisons between observed trends and the effects predicted for different drivers of trends by model simulations. The goal is to attach percentages to the contributions of different drivers (CO2 increase, magnetic field changes, solar activity trends, influences from the lower atmosphere, etc.) to the observed trends.

(10) Of course, the above percentages are likely to be different for different variables, and will also probably depend on season and local time. Hence, these seasonal and local time dependencies should be studied in further detail as well, and could in fact be a very useful aid in distinguishing between the effects of different drivers.

A strong commitment through SCOSTEP program dedicated to geospace climate research should contribute to two of the most important scientific questions facing the solar and space physics community. First, it would elucidate the intricate systematic interplay between solar and lower atmospheric influences on the near-Earth space environment. Second, it would address the natural upward extension of one of the most compelling science questions of our time: How are humans altering the climate of Earth and Eco-system?

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White paper to the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) on the 2014-2018 Science Program

TITLE: Specification and Prediction of the Coupled Inner Magnetospheric Environment (SPeCIMEN).

Submission led by Jacob Bortnik (USA) and Craig J. Rodger (New Zealand) on behalf a wider team listed below.

OBJECTIVE: Prediction and specification of the Earth's inner magnetospheric environment to high accuracy, based on inputs from the sun and solar wind, employing a combination of physical and statistical predictive modeling.

BACKGROUND: The Earth's inner magnetosphere is an exceedingly complex, coupled system that is driven by fluctuations in the solar wind, ultimately reflecting conditions in the Sun's corona. This inner magnetospheric environment is host to a variety of particle species (including electrons and heavy ions) that cover a broad range of energies from sub-eV to tens of MeV, and plasma waves that cover essentially the entire frequency spectrum. Incoming energy from the solar wind is processed through the system and results in a variety of effects such as the energization of electrons and protons to MeV energies (i.e., the formation of the radiation belts), and the precipitation of particles into the dense upper atmosphere resulting in bright auroral displays, modifications to the distribution of ionospheric conductivities, and a slew of chemical reactions that propagate through the Earth's atmosphere and may couple to surface climate. These effects also act as feedback processes to inner magnetospheric dynamics, throttling rates of reconnection or convection, modifying the pattern of the global electric field and hence wave excitation (which, in turn, affect the higher energy particles), and loading or unloading the system's mass dynamics via substorms, flows, and related effects.

The inner magnetospheric system is not only the key link between the Sun/solar-wind input and atmospheric output, but also acts as the environment within which the vast majority of all Earth-orbiting spacecraft (i.e.., military, scientific, or commercial) are immersed, and this environment is known to degrade or destroy such spacecraft through a variety of mechanisms.

AIM AND RELEVANCE: Given this context of fertile scientific ground, and a pressing societal need, we propose a science program that is aimed specifically at the specification and prediction of the inner magnetospheric environment. This includes the dynamics of the thermal (~eV), energetic (100's of eV to 100's of keV), and relativistic (~MeV) particle populations, the plasma wave environment (specifically focusing on the key waves that contribute to inner magnetospheric dynamics, such as ULF and VLF waves), and the system outputs in the form of precipitation flux into the Earth's upper atmosphere, as a function of particle species, energy, location, and time.

SCIENTIFIC QUESTION: The scientific question can be stated simply: Can the state of the Earth's inner magnetosphere be specified and predicted to high accuracy, based on inputs from the sun and solar wind?

DATASETS AND APPROACH: We believe that we are currently on the verge of answering the scientific question in the affirmative, but this cannot be done without a coordinated and sustained scientific effort that involves a large participation of the international scientific community. This is truly a "Manhattan type problem" and has never been attempted before on a grand scale. It is interdisciplinary and international, and will involve scientists in a variety of fields. While not requiring the financial backing at Manhattan project-levels, it will be only be solved by the combination of a wide range of experimental datasets, new experimental observations, and modeling techniques. We are fortunate that much of the puzzle pieces already exist in different parts of the world, such that a coordinated international programme will most likely bring successful closure.

We currently enjoy an unprecedented quantity of data that describes the inner magnetosphere, solar wind, Sun's surface, and ionosphere. A recent example is the twin Van Allen Probes mission (formerly known as Radiation Belt Storm Probes) which has been launched in August 2012 and will operate for 2-4 years, collecting data on the particle and wave environment in the critical solar max and declining phase period beyond 2012. This dataset has spurred great interest in inner magnetospheric physics, and forms a complement to existing missions such as THEMIS, CLUSTER, Double Star, and context for upcoming missions such as MMS, DSX, BARREL, RESONANCE, ERG and others.

This is also an area where ground-based observatories can make significant contributions and enhance the understanding gained from the space-based missions. This provides opportunities for a wide range of international partners, and is thus not restricted to researchers from the primary space-faring countries. Indeed, some of the experimental techniques, such as observations of high-latitude VLF waves or mid- and high-latitude narrowband or riometer observations are comparatively cheap. As an example of strong scientific value from ground-based arrays, consider the THEMIS all-sky imager network which is able to do real-time imaging of the whistler-mode chorus wave field in space, through its signature pulsating auroral precipitation.

There are presently a range of models that describe inner magnetospheric dynamics, each of which has its own strengths and weaknesses. For instance, physics-based models (e.g., particle drift codes, or diffusion-based modeling) provide deep understanding but often cannot include all the relevant processes that drive dynamics. On the other hand, data-driven predictive models (e.g., data assimilative, or regressive models) can capture phenomena but do not necessarily provide insight into the physical processes involved.

MODELLING COLLABORATIONS: We propose a large-scale collaboration between physical and predictive modelers, and observationalists (using both space- and ground-based instrumentation). The collaborative effort is divided roughly into 4 phases, which would roughly coincide with the 4 years of the science program, but also involve a great deal of feedback and iteration. The phases are as follows:

Phase 1: Improvement of predictive modeling and parallel development of theoretical models: Currently, a few numerical data-based models have shown great promise in being able to model and predict the distribution and variability of equatorial plasma waves (i.e., chorus and plasmaspheric hiss, using a multi-regressive model; Stanford University), and separately radiation belt fluxes on a daily cadence (geosynchronous orbit, NARMAX model, Sheffield University). In phase 1, these models will be extended to cover the full space swept out by the parameters L (a measure of radial distance), Magnetic Local T, and latitude (or distance along the field line). The models will also incorporate a few types of magnetospheric plasma waves, cold, energetic and suprathermal particles. Simultaneously, physical models will be extended and improved, for instance ray tracing or full-wave models that reproduce wave spectral properties, or diffusion-based radiation belt models that accept wave fields as their input.

Phase 2: fusion of predictive and physical models: In phase 2, physical models will be used to amend the predictive model results. For example, a fully characterized wave field will be available in 'real time', driven only by solar wind inputs. This wave field will be fed into radiation belt models that will use it to calculate the diffusion coefficient matrix and solve the Fokker-Plank equation. Other physical models (e.g., cold or suprathermal plasma) will be used to similarly amend data-driven predictive models, and incorporated into radiation-belt or ring-current codes.

Phase 3: Comparison and incorporation of multiple data streams: At this stage, a fully functional, 'first-generation' model will be available, and multiple data streams will be used as a comparison to its predicted outputs. These data streams could be either ground- or space-based, and measure essentially any predicted quantity of the model such as precipitation fluxes and their spatio-temporal distribution, radiation-belt fluxes and their dynamics, cold plasma or suprathermal particles.

Phase 4: Feedback and refinement: Following directly from phase 3, a comparison to as many data streams as possible will quickly reveal areas where the model/s underperform. Identification of these key areas is critical and will help the modeling community to understand where physical processes are possibly missing, and the experimental community to know which key measurements need to be performed.

In reality, the feedback and refinement process will likely be occurring at every stage along the process, but will be most important when an entire data/physics-driven model is available to make specific predictions that can be directly compared to observations.

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SIGNIFICANCE TO WIDER SCOSTEP EFFORTS: The scientific programme suggested here is likely to be complementary to other proposed SCOSTEP activities. We expect there to be a white paper suggesting a focus on how high energy particle precipitation alters polar atmospheric chemistry, affecting dynamics and coupling to climate. That community has struggled to include radiation belt electron precipitation, which may be included as a loss term in the predictive model outlined in this proposal. There is also synergy with scientific efforts to understand the dynamics of the Sun; solar wind speeds and the impact of coronal mass ejections are both known to strongly affect the radiation belts. One can imagine other likely SCOSTEP synergies in such a strongly intercoupled system, with proposals focused on the substorms, the technological impacts of space weather events, long terms changes in the geomagnetic field, and so on.

Data Assimilation for the Thermosphere and Ionosphere

Motivation: The future of space weather products and services for the ionosphere and thermosphere (IT) is in the development of global data assimilation schemes using coupled thermosphere ionosphere models and large amounts of diverse data. This is the same path that troposphere weather prediction has taken a few years back. Data assimilation in the IT system is required because of the impossibility to measure the forcing of the system with the necessary spatial and temporal resolution. The thermosphere and ionosphere are coupled so tightly that successful modeling of one is not possible without the other. A data assimilation scheme that makes use of both thermosphere and ionosphere measurements would provide great potential for better ionospheric specification and forecast and equally importantly, better interpretation of model data comparisons for better knowledge of the physics. At the same time it would open the way for specification and forecast of total neutral mass density and neutral winds which are necessary for tracking the ever increasing number of satellites and pieces of space debris and for calculating reentry orbits.

A successful data assimilation scheme for the thermosphere ionosphere system requires a well tested and validated coupled thermosphere ionosphere model and large amounts of data with known uncertainty (error) estimates. Ideally, the testing and validation process for the model and the data sets would take place in a near-operational environment.

There are several well tested coupled models of the thermosphere ionosphere system. The models have been used for more than 20 years and their capabilities and limitations are well known. With access to an ever increasing amount of real-time measurements one can develop testbeds for evaluating not just the models but in the future also the measurement biases of different instruments.

Schemes to automatically run the models in real-time using near-operational data bases, produce relevant plots, and display them in a web page for community comments and suggestions already exist.

What is needed:

1. Improve the present schemes to run models in real-time and provide real-time results to both the research community and to operational forecast centers.

2. Develop on the fly independent evaluation and verification procedures for models and data. Compare model results from different research assimilation schemes with global data sets and other available measurements.

3. Develop an operational data assimilation capability for the IT system. This is an important effort that will have to be eventually applied to all domains from the Sun to the bottom of the oceans. However, as opposed to the troposphere system which is chaotic and requires precise specification of the initial condition, the IT system is externally strongly forced by variations in the total energy input and its spatial distribution. Proper knowledge of the system inputs over a few days can make the initial condition irrelevant in terms of the induced uncertainty in the final state. This difference may make the optimum data assimilation schemes for forced systems very different from those developed for chaotic systems.

Proposal to SCOSTEP Program
Abnormal PhEnomena and Cycles in Sun-Earth System (APECSES)

We suggest that CAWSES should be succeeded by the program **Abnormal PhEnomena and Cycled in Sun-Earth System (APECSES).** When formulating our proposal, we tried to define the scientific task as broad as possible so that all aspects of solar-terrestrial physics were represented. There is no doubt that various processes are most intensively studied nowadays in different fields of the solar-terrestrial physics. Undoubtedly, the results of these studies will be called for both in the related fields of science and in various aspects of the human activity. Considerable progress was made in the past decade towards the understanding of the fundamental processes of solar-terrestrial physics. We have a good idea of the general scenario of solar events and their impact on the Earth. However, there are many phenomena that do not fit this scenario differing either by their parameters or by unpredictable occurrence. We suggest that the next program be devoted to the solution of these problems.

The main leads of the "Solar-Terrestrial Processes in the Past, Present and Future" Program can be provisionally formulated as follows:

1. 11-year and longer-period cycles, progress in the dynamo studies, helioseismology. The problem of very large and very small solar cycles. Contrastive analysis of solar-terrestrial events in the past and present and predictability of Sun-Earth system's behaviour in the future. The statistical database built up in the past can be used in these studies. One of the topical questions is the problem of the forthcoming Cycle 25. Are there any real indications that a long period of low solar activity is in store? Is the theory able to specify the parameters responsible for the “grand minima”? On the other hand, is it possible in principle that solar cycles might be much higher than those observed in the past 200 years? Why did such extreme phenomena as the Carrington event and the 1921 magnetic superstorm occur in the activity cycles of less than medium amplitude?
2. Coronal heating, generation and acceleration of solar wind, the role of coronal holes. Why do the solar wind parameters calculated from solar data sometimes disagree with observations? What is the relative contribution of the wave and flare mechanisms to the heating of various objects in the corona? Are there long-term structural variations in the corona?
3. Solar flares, CMEs and their impact on the heliosphere and near-Earth space. Are there possibilities of very strong flares? The maximum energy of the flares yet observed is estimated to be 10^{32} erg. Might a flare of energy 2-3 orders higher than that possibly occur and what effect would it cause on the Earth and heliosphere?
4. Small-scale dynamics of the solar atmosphere; reconnection and its role in the dynamic pattern of the solar atmosphere. In particular, can we identify direct signatures of the reconnection preceding immediately a flare of CME? Why does a flare sometimes fail to occur in spite of all signatures of pre-flare situation present? Is it possible to predict the direction of a mass ejection?
5. Oscillations in solar structures and diagnostics of solar processes. Do the oscillations trigger nonstationary processes? What is the frequency range in which the oscillations are most efficient? What is the origin of oscillations in the solar wind? Do they bear a direct relation to oscillations in the Sun?
6. Coronal and interplanetary shock waves. Analysis of the fine structure of space plasmas. The fine structure of the sector boundaries. Acceleration and propagation of solar cosmic rays.
7. Interaction of the solar wind and magnetic clouds with the Earth’s magnetosphere; magnetospheric, ionospheric and atmospheric effects of solar activity Relative contribution of natural and anthropogenic factors to climate variations on the Earth.

The study of these problems will be carried out using spacecraft observations (SDO, Hinode, STEREO), ground-based geomagnetic, ionospheric and cosmic ray measurements, the results of analysis of Arctic ice, etc. Many aspects of the **APECSES** project are associated with the observation programs of the future solar-heliospheric missions, such as the Solar Orbiter, Interhelioprobe, Solar-C and Solar Probe+, which will stimulate their refinement.

Vladimir Kuznetsov
Vladimir Obridko

Role **O**f the **MI**ddle Atmosphere/Lower Thermosphere in **C**limate (ROMIC)

White paper for SCOSTEP's new program (2014-2018)

Franz-Josef Lübken, IAP Kühlungsborn, Germany

18 March 2013

1 Summary

The main aim of this proposal is to study the role of the middle atmosphere/lower thermosphere (MALT[1)]) in climate. This includes two major topics:

- How do climate change and solar variability affect the MALT ?
- How do processes in the MALT affect the troposphere ?

Trends in the MALT are generally much larger then in the troposphere, but, unfortunately, the reasons for these trends and the relative contribution of anthropogenic and natural (solar) impact are only poorly understood. The direct impact of increasing greenhouse gases (GHG) due to radiative transfer is fairly well represented in models. However, indirect effects, such as amplification of the solar signal and feed back mechanisms between radiation, composition, and circulation, are presumably equally important but are more complicated and less explored.

In the atmosphere, coupling by planetary waves, gravity waves, and tides, is extremely important. For example, gravity waves can drive the thermal state of the atmosphere away from radiative equilibrium by up to 100 Kelvin. These waves therefore contribute significantly to the interaction of circulation, distribution of GHG, and radiation, and thereby influence the thermal and dynamical structure of the atmosphere. Unfortunately, a major part of this dynamical coupling is only poorly represented in models and shall therefore be studied in ROMIC.

Climate change occurs in the MALT and evidently couples down to troposphere, as is know since only recently. The MALT is therefore also relevant for climate change on Earth's surface. Some long term evolution in the troposphere can be modeled adequately only if upper atmosphere layers are taken into account.

As is shown below, ROMIC addresses various open questions in a wide range of scientific disciplines, including solar physics, atmospheric physics and chemistry, dynamics, climate research etc. ROMIC includes several topics from solar and terrestrial physics and is therefore in line with SCOSTEP's general mission. Obviously, there is some overlap with other programs (SPARC etc.). ROMIC should not be viewed as being in competition but rather in synergy with these programs.

2 Main Scientific Topics

a. Solar forcing

Absorption of solar radiation in the atmosphere directly affects composition (e. g. ozone, water vapor etc.) but also temperatures and circulation. The unusual UV solar irradiance during solar cycle 23 has triggered studies which demonstrate direct consequences for the MALT. Solar impact

[1)] here: approximately from 10 to some hundred km by composition changes is more complicated when photochemically active species, being created in the lower thermosphere, are transported to lower altitudes. Although the effect has been studied experimentally and theoretically with models in recent years, there are still many open questions, in particular regarding the role of transport processes and details of photochemistry. More general, we need a better understanding of the spectral variability of solar radiation and its effect in the MALT.

Low solar activity is commonly made responsible for low temperatures being observed during the Maunder Minimum but the mechanisms are not fully explored, partly because too little is known about changes in the MALT. The current solar cycle allows to study low solar activity effects in the entire atmosphere and its impact on climate.

b. Coupling mechanisms

Strong coupling within the atmosphere is provided by planetary waves (PW), gravity waves (GW), and tides which, for example, can modify circulation, transport of trace gases, as well as momentum and energy deposition over large distances. For example, the summer mesopause at polar latitudes is the coldest region on Earth despite permanent sunshine which is due to a residual circulation driven by GW. Propagation of waves is modified by background winds but also by the existence of other waves (example: absorption of GW by PW). The stratosphere may heat drastically within a few days (sudden stratospheric warmings, SSW) and the normal general circulation at middle and polar latitudes reverses. SSW are related to strong planetary wave activity and impact the entire MALT. Circulation changes may propagate from the MALT into the troposphere and affect weather conditions. It is known that the occurrence of SSW has gradually increased in recent decades and that SSW are modulated by solar cycle, but the mechanisms are still not explored. Various uncertainties exist regarding these waves as far as generation mechanisms, propagation, absorption, importance for tracer transport as well as momentum and energy deposition is concerned.

Tides are waves of specific importance in this context since solar radiation is the main driver, but other mechanisms are also important, e. g. latent heat release in the tropics. Although studied since many years, our knowledge is limited due to complicated generation and propagation mechanisms involved. For example, large thermal tides were recently observed in the polar mesopause region during summer where most models predict very low amplitudes. Furthermore, tides were observed in the thermosphere which, surprisingly, were linked to tropospheric sources. Tides interact with other waves and circulation and can thereby strongly modify background conditions.

Atmospheric layers are also coupled by transport of greenhouse gases, for example carbon dioxide, ozone, and water vapor. Therefore, modifying photochemically active constituents in one part of the atmosphere may cause changes in an entirely different part with unexpected feedback mechanisms. For example, it has recently been shown that decadal changes in stratospheric water vapor have the potential to affect global climate through radiative transfer. The reason for this decadal changes of water vapor and details of dynamical coupling are not yet understood.

Coupling from above to below obviously occurs through circulation patterns, represented by indices such as NAM[2)]. This pattern propagates from the MALT down into the troposphere and is known to have increased in the last decades. Cause and effects are not yet fully explored. We note that oceanographic processes can also have an important impact on the troposphere (e.g. El Nino Southern Oscillation), which (through the coupling mechanisms mentioned above) may propagate into the MALT.

The aim of ROMIC is to study these coupling mechanisms, including their variation with solar and anthropogenic activity, and their potential role in climate change in the MALT and at the Earth's surface.

c. Trends in the MALT and relevance for climate

Several trends are observed in the MALT, some of which are much larger compared to the troposphere. Temperatures in the mesosphere have dropped by up to 10-12 K since the late 19th century, much more than typical trends in the troposphere and stratosphere. The summer mesopause region is

2) Northern Annular Mode

of particular importance in this context since observations of ice layers known as 'noctilucent clouds' exist since more then 120 years and can be used to better understand long term variations. Trends in the stratosphere are mainly due to long term composition change (CO_2, O_3, H_2O). Again, complicated feed back mechanisms exist, for example between GHG cooling and subsequent modification of photochemical processes affecting, for example, ozone concentration.

Trends in waves and circulation patterns are observed, but not yet understood. For example, planetary wave activity is observed to increase in recent decades which is not well represented in models. This points to some deficits in our knowledge of the feedback mechanisms between chemistry and transport. Very recently, trends in GW activity are observed but not yet explained satisfactorily. Climate change is expected to affect coupling mechanisms, for example by an intensification of the Brewer-Dobson (BD) circulation. This should lead to an increase of GW activity. Unfortunately, some observations of age-of-air are not consistent with an enhanced BD circulation which points to some deficits in our understanding of this important coupling mechanism.

The MALT has long been thought to be of little importance for the troposphere. This view has changed during the last years since there is considerable evidence that the MALT plays an active role in the troposphere and even for surface weather. There is increasing evidence for an influence of the Sun on trends in the MALT and also on tropospheric climate, but the mechanisms are not yet fully understood, despite all the progress being made in programs like CAWSES.

In ROMIC, trends in the MALT shall be studied which includes an investigation of the relative importance of anthropogenic and natural (solar, vulcanic) forcing.

3 Interested scientists (examples)

Some examples of scientists who have explicitly expressed their interest in the research topics of ROMIC (in alphabetical order):

USA/Canada: Rashid Akmaev (Univ. of Colorado), Joan Alexander (CORA), Mark Baldwin (NRA), Rich Collins (Univ. of Alaska), Jeff Forbes (Univ. of Colorado), Ronaldo Garcia (NCAR), Marv Geller (State Univ. of New York), Charles McLandress (Univ. of Toronto), Marty Mlyncak (NASA Langley), Jens Oberheide (Clemson Univ.), Cora Randall (Univ. of Colorado), Jim Russel (NASA Langley), Stan Solomon (NCAR), Richard Walterscheid (NOAA) William Ward (Univ. of New Brunswick)

Russia/Asia/Australia: Hye-Yeong Chun (Yonsei Univ., Seoul), Kaoru Sato (Univ. of Tokyo), Bob Vincent (Univ. of Adelaide), Vladimir Yushkov (CAO, Moscow), ??? (Peking, EISCAT)

Europe: ROMIC-community in Germany (e. g. Ulrich Achatz (Univ. Frankfurt), John Burrows (Univ. Bremen), Katja Matthes (Helmholtz Center Kiel) Sami Solanki (MPS), etc.)
Thierry Dudok de Wit (Univ. of Orleans) Alain Hauchecorne (CNRS, Paris), Jörg Gumbel (Univ. Stockholm), Joanna Haigh (Imperial College London), Manuel Lopes-Puertas (Astrphys. Inst. Granada), Joeran Moen (Univ. Oslo), Adam Scaife (UK met office)

... and potentially authors from other white papers.

Solar-Terrestrial Evolution & Climate Connections

A White Paper for the SCOSTEP Scientific Program

Scientific Motivation

We propose an international effort to study the Sun-Climate Connection on timescales much longer than typical space-weather events and spanning over solar-planetary evolutionary timescales. The motivation for this project is that as the warming Earth has entered a global temperature level for which we have no parallel in written history a thorough knowledge of paleoclimate, some of which was much warmer than the recorded climate of the last millennia, is a crucial component in understanding and predicting the Earth's climate regime of the future. Climate change is one of the key challenges for humankind in the 21st century and probably beyond, and hence all aspects of it need o be thoroughly studied. The Sun, while certainly not driving the current changes in climate, nevertheless remains an important influence on the Earth's biosphere. Hence a thorough knowledge of that influence over the entire evolution of the Sun-Earth system is an indispensable component in understanding the evolution of the Earth's biosphere, both in the near future and in the remote past.

4-Year Goal

Develop a time-line and a comprehensive narrative for the evolution of the Sun's radiative output and mass loss from the time that the Earth formed until the present. The radiative output includes the solar irradiance that is governed by the equations for stellar evolution, as well as, perhaps, influenced by episodes of large mass loss early on in the evolution of the Sun. Solar radiation in the UV, EUV, and X-rays is governed by the magnetic activity of the Sun, which was almost certainly much more vigorous in the young Sun. Knowledge of the magnetism and mass loss of the young Sun can be derived from dynamo simulations in regimes rather different than that of the present day Sun, while a reality check on the results can be obtained from observations of solar analogs much earlier in their lifespan. We note that these studies all have particular relevance to the "Faint Young Sun" paradox as well. Specifically, we will focus on the following questions:

- How has the Sun’s magnetic, radiative and particular output varied over its lifetime?
- How has evolving solar variability changed the heliospheric environment?
- How do these changing conditions in space affect the Earth’s environment?
- How has the Earth’s climate and biosphere evolved in response to solar evolution?
- How will future solar changes in the long-term impact our climate?

Interdisciplinary Character

This project requires expertise ranging over the following subjects:

- Stellar evolution
- Dynamo theory and simulations
- Solar and stellar winds, both magnetically and thermally driven
- Solar and stellar surface magnetism, from the photosphere to the corona
- “Faint Young Sun Paradox”, which requires understanding all of the above
- Paleoclimatology and Climate Science

Our projects include both data analysis and modeling and will focus on confronting theory with observations. Datasets that will play an important role will include but not be limited to, solar and stellar radiative variability, paleoclimate data, and stellar wind data. Theory and simulations will target solar magnetic field, solar wind and heliospheric field evolution.

International Character

As a first attempt to assemble experts from the relevant disciplines we list prospective team members below. This membership is by no means intended to be comprehensive and certainly not exclusive, and we will seek additional team members as the project develops.

Elements of the Program

Again, this list of research elements is not comprehensive nor exclusive. Specific research projects that we envisage are:

- Dynamo simulations in the parameter range of a younger Sun.
- Stellar Evolution calculations that take into acount the mass loss and spin-down of the Sun during its evolution.
- Calculation and simulation of the Sun’s output over its spectrum resulting from the dynamo action simulated above.
- Comparison of the results above with data from Sun-like stars obtained by various space missions and ground based observatories: those include the radiative output in various spectral regimes, and the thermal and magnetically driven solar wind.
- Modeling of the Cosmic Ray flux received at Earth as modulated by the solar wind and solar magnetic activity over the lifespan of the Earth.
- Comparison of the simulation results above, with any data that are obtained from the geophysical record, such as Cosmic Ray intensity, perhaps high energy radiation and particles from the Sun.
- Simulations of the evolution of the Earth’s magnetosphere in response to the evolving output from the Sun.
- Paleoclimate simulations based upon the younger Sun’s spectral data, Cosmic Ray results, and solar wind evolution obtained above.
- Analysis of the various hypotheses brought forward to resolve the “Faint Young Sun Paradox” in the light of the results above.

Anticipated Outcome

As mentioned above, we intend to deliver a time-line and a comprehensive narrative for the evolution of the Sun's radiative output and mass loss from the time that the Earth formed until the present. Modelers of the Earth’s paleoclimate, and current and future climate, will be able to use these inputs in their simulations, nd compare their results

Team Leaders

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Proposal for new program from Japanese SCOSTEP committee

Tatsuki Ogino,
Chair of Japanese SCOSTEP committee, Science Council of Japan

Members: Toshitaka Tsuda, Kazunari Shibata, Yoshiharu Omura, Kan-ya Kusano, Taro Sakao, Kazuo Shiokawa, Iku Shinohara, Yukihiro Takahashi, Naoki Terada, Takuji NakamuraTsutomu Nagatsuma, Toshihiko Hirooka, Masahiro Hoshino, Mamoru Yamamoto,
Toshifumi Shimizu (*guest member*), Nozomu Nishitani (*guest member*)

Scientific motivation

The current CAWSES-II program has been of great success in both pursuing individual themes of Task-Groups and interdisciplinary researches between Task-Groups for atmospheric, ionospheric, magnetospheric, and heliospheric studies. However, in order to achieve a better understanding of the whole solar-terrestrial system further experimental, modeling and theoretical investigations are and will be of great importance. As the CAWSES model has proven to be very successful in providing context and support for these activities it is proposed that the current activities of the CAWSES-II program be continued although with more emphasis on (1) climate, weather and impact and (2) extreme/severe space weather (storms) as a new topic to be studied. Thus the new program will build on the organizational and scientific heritage of CAWSES (but under a different name) and will expand that research into areas of increasing current and future significance. Based on the experience from the two CAWSES programs it is proposed that the duration of the new program should be 5 years.

Topics for the new program

The following are topics which the Japanese SCOSTEP community suggests to be included in the new program.

1. SOLAR VARIABILITY
   - Earth-affecting solar transients (see Appendix)
   - Extreme events in the solar-terrestrial system
   - Solar maximum and declining phase (e.g. 2014-18 will be the maximum and declining phase of solar activity)
   - Discrimination of global trends and solar activity

2. COUPLINGS
    - Latitudinal coupling in atmosphere and geospace
        - e.g. energy transfer from high to low latitude during geomagnetic storms
        - Coupling between equatorial and mid-latitude/polar ionosphere
        - Atmospheric coupling between different latitudes and hemispheres
    - Whole atmosphere and geospace coupling
        - Expansion of TG-4/CAWSES-II to global scale and into geospace
        - Effect of geospace disturbance to the atmosphere
    - Teleconnections in the Earth system
3. OTHER IMPORTANT ISSUES
    - Turbulence/small scale processes in solar-terrestrial phenomena
        - A new issue arising from high-resolution observation and modeling
    - Combination of observation and modeling (in space weather)
        - Data assimilation for precise forecasting
    - Atmospheric dynamics for ground-ionosphere electric current
4. INFRASTRUCTURE
    - Capacity Building
    - Informatics including big data.

Should the structure of CAWSES II be adopted for the new program items 1 to 4 could form new Task Groups.

Related Activities in Japan in 2014 – 2018

The following activities/projects related to solar-terrestrial physics and the proposed program will be carried out in Japan during 2014-2018.

- Solar Telescope (Kyoto Univ.)
- ERG satellite for investigation of radiation belts (launch: 2015)
- Hinode satellite will continue its operation
- IUGONET (Inter-university Upper atmosphere Global Observation NETwork: database development activity)
- PANSY radar will be in full operation in Syowa station, Antarctica
- EISCAT-3D will be in operation (international collaboration)
- Equatorial atmosphere radar (Equatorial MU radar) is newly proposed.
- Multi-point ground network will expand to sub-auroral latitudes and over Asia and Africa
- International school activity will be kept by Kyoto Univ. and Kyushu Univ.

Appendix:

International Study for Earth-Affecting Solar Transients (ISEST)

SOC Members: Jie Zhang (USA), B. Vr?nak (Co-Chair, Croatia), A. Asai (Japan), P.Gallagher (Ireland), A. Lara (Mexico), N. Lugaz (USA), C. Mostl (Austria), A. Rouillard (France), N. Srivastav (India), Y. Yermolaev (Russia), Y.-M. Wang (China), D. Webb (USA)

An international effort including observations, data analysis, modeling, and transition from science to prediction operation. The ISEST tasks are:

(1) Create a comprehensive database of Earth-affecting solar and heliospheric transient events
(2) Characterize and quantify the kinematic and morphological properties of transient events
(3) Develop advanced theoretical models of the propagation and evolution of heliospheric transients
(4) Develop advanced 3D numerical models of prediction of ICME arrival and the expected strength of space weather impact
(5) Prediction tool development
(6) Public outreach and education

ROLE OF SOLAR VARIABILITY IN CLIMATE

WHITE PAPER FOR SCOSTEP SCIENTIFIC PROGRAM 2014-2018

Monday, December 31, 2012

Understanding the Earth's climate system and how it responds to both external and internal changes is one of the largest challenges faced by society. Being able to understand past climate and to predict how the Earth's climate will change in the future requires good understanding of both natural sources of climate variability and anthropogenic climate forcing. In the Fourth Assessment report the Intergovernmental Panel for Climate Change (IPCC) writes *"The Earth's global mean climate is determined by incoming energy from the Sun and by the properties of the Earth and its atmosphere, namely the reflection, absorption and emission of energy within the atmosphere and at the surface. Although changes in received solar energy (caused e.g. by variations in the Earth's orbit around the Sun) inevitably affect the Earth's energy budget, the properties of the atmosphere and surface are also important and these may be affected by climate feedbacks."*

The observed changes in global temperatures in the past decades have motivated a significant effort put towards observing, modeling and predicting the effect of human activity on the atmosphere and through that to the current climate. While anthropogenic forcing has driven significant changes in the climate since the mid 20th century, the Sun was the main controller of the Earth's climate and it's variation throughout and prior to the Holocene, and remains the one energy source for driving climate in the first place. Based on present understanding, solar variability has a role in the observed climate change. About 8% of the recent global climate change could be attributed to solar variability. However, this number has a large uncertainty as several aspects of solar forcing and the mechanisms coupling solar variability to the Earth's climate system remain poorly understood. With increasing complexity and sophistication of atmospheric and climate models, and the need for increased accuracy on future predictions, it is important that we are able to include a complete picture of the solar forcing in the models.

Current understanding

Sources of solar forcing can be generally divided into radiatively driven and particle driven components. The scientific focus for the well established radiatively driven solar forcing has in the recent years shifted from global responses to Total Solar Irradiance (TSI) variations to regional responses driven by Solar Spectral Irradiance (SSI) variations. Many questions still remain on the nature of the SSI variations, how they should be implemented to models, and how they will change in future. It has become clear that there is great need for continuation of space based observations of SSI variations, with a particular interest in what will happen in the future if the Sun moves away from the current "Grand maximum" of solar activity and towards a new Maunder Minimum. The importance of the top-down stratospheric UV (SSI) mechanism is accepted and has been confirmed in model and observational studies. The bottom-up effect involving atmosphere-ocean coupling is working in combination with the top-down although details have to be confirmed with chemistry climate models including an interactive ocean. The particle driven component is further divided into Energetic Particle Precipitation (EPP) and Comic Ray (CR) effects. It is important that these are separated, not only because their sources are different, but because the CR affect the lower atmosphere directly, while the EPP effect is initially in the upper-stratosphere-lower thermosphere region. Understanding of the influences from the EPP component is maturing. The chemical effects of EPP on the atmosphere are now well understood, but there is a call to improve our understanding of further dynamical effects, as well as the potential mechanisms and magnitudes of any EPP influences on climate. Currently a significant uncertainty remains in understanding some of the sources for EPP, with new missions such as NASA's Van Allen Probes helping to address this question. The potential EPP effect on climate is a new research area, becoming more timely as climate models are starting to extend to higher altitudes. EPP provides one of the key pathways linking the lower thermosphere to the stratosphere and further down to troposphere via stratosphere-troposphere coupling in the polar regions. The CR driven component is currently considered to be the least matured of the sources of solar forcing, in terms of scientific understanding. A dedicated ongoing international research effort is working on the topic. This includes using large resources within the CERN CLOUD experiment to examine the potential coupling of CR and aerosol nucleation. Recent results have suggested that although CR may stimulate aerosol nucleation, these effects are not large globally.

Need for continuation and increased interdisciplinary collaborations - Role of SCOSTEP

In the current CAWSES-II program, task group one is dedicated to solar influences on climate. In the past few years the interest in the role of solar variations as a source for climate variability has grown, particularly after the first observations suggesting SSI variations are larger than expected, and radiative components may contribute significantly too. Task group one has been instrumental in bringing together communities that work on various aspects of the Sun-climate system and unveiling specific aspects of the problem. Today there is a clear need for increasing that momentum by pursuing the effort that has already led to many important results. For that reason, the continuation of a program dedicated to solar influences on climate is our highest priority.

Such a program should have a double objective. The first one is to truly assess the role of Sun as a source for climate variability, also responding to requirements from climate models and future climate predictions. Particular attention should be paid to the couplings between individual layers. The second objective is to provide a structural improvement, by focusing on those issues for which a multidisciplinary effort is the best way forward for making solid progress.

Currently the EU COST Action TOSCA (Towards a more complete assessment of the impact of solar variability on the Earth's climate) is working to coordinate the research efforts taking place in Europe and the SOLARIS-HEPPA SPARC activity is bringing together the solar irradiance and EPP communities, but wider international links remain vital. More direct collaboration should be encouraged across the wider solar-terrestrial community to bring together the atmospheric communities in SCOSTEP and the solar and magnetospheric physicists, more traditionally associated with COSPAR. These could be carried out as an independent SCOSTEP program alongside other programs.

Timeliness

We have recently witnessed a golden age, as an unprecedented large number of satellites and ground instruments have been monitoring the state of the solar-terrestrial system. The last solar cycle has provided us with the best coverage of observations ever. Unfortunately, this will not continue to the current solar cycle, as many satellites have been lost (e.g., Envisat, SAMPEX), or are not expected to last for significantly longer (e.g., SORCE, ACE, SoHO). Most satellites are unlikely to be replaced, at least not in the near future. Therefore, it is crucial to properly exploit now the synergy between these missions, in direct relation with ongoing modeling efforts. The timeliness of this effort is also supported by the unusual state of activity of the Sun, which is slowly emerging from a prolonged period of very low activity (timed with SCOSTEP Max13/MiniMax24). This state raises many questions on how our present understanding of the Sun-climate connection may help us constrain past solar variations and their impact on climate. These are additional motivations for building on the achievements of CAWSES-II, while staying focused on the last solar cycle and the present one.

This document was written on behalf of CAWSES-II Task Group 1, SOLARIS-HEPPA - Solar Influences for SPARC, and COST action ES1005, by

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