National Committee for Space Science

Decadal Plan

National Committee Space Science

Sun to Earth Working Group

Chair: C.L. Waters

1. Summary

The Sun to Earth Working Group has the responsibility of identifying relevant space science questions and topics to be addressed in Australia over the period 2007-2016. The pursuit of science motivated purely by a quest for knowledge is often moderated by the reality of funding constraints. While a national funding agenda might emphasize practical outcomes, it is important to appreciate that near-Earth space science research is an international endeavor. Research outcomes published in the international literature must be internationally competitive and sensitive to international priorities. Australia does not have any funding agency focused on space science (eg. NASA). Therefore, it can be argued that funding for space science in Australia is more competitive, compared with countries that have space science focused funding agencies. Australia does benefit from space science applications derived from research funded off shore. There are also examples where Australian space science research has significantly impacted and altered the focus of international efforts. However, the stress on space science funding possibly contributed by no clear national priority for space related research, the diverse space science related overseas opportunities that provide difficulties in engaging younger academics for Australian universities indicate future difficulties for Australia's participation in space research on the international scene.

One further point that needs to be addressed in the Decadal plan is the space science program at the Australian Antarctic Division and recent trends to curb these activities. Space science for "Australia" must include Australian responsibilities in Antarctica and associated sun-Antarctic islands. The Space and Atmospheric Sciences section at the Australian Antarctic Division have developed strategic plans for their programs. Some of that material has been included here, provided by Dr R.J. Morris and the AAD web site.

Why should Australia participate in space science? (Why use a car rather than a horse and cart?) Is it simply a matter of participating in technology at the international level?
The motivation for participating in space science might be bounded by two extreme positions:

(i) We involve Australian space scientists in the international scene purely for identifying and developing applications that (a) will generate money (b) are relevant only to Australia

(ii) We pursue space science purely for knowledge sake, participating in international science regardless if the study is directly relevant to Australia.

Where on the continuum between these two positions should Australian space science funding aim?

This report provides an overview of space science research in Australia as it relates to the effects of solar processes at Earth. Many of these efforts tend toward the "pursuit of knowledge for knowledge sake" end of the motivation scale even though most research groups may be able to indicate "possible applications with further development". The science questions gleaned for the Decadal Plan have not been sorted by motivation. Rather, these science questions and aims are the logical extension of present Australian research. Balancing pure research with local applications of that research will be an important goal of the Decadal plan.

Space science research considered in this report covers space and atmospheric physics, including the science of space weather. The regions of interest are:

- Troposphere (0-10 km) ?
- Stratosphere (10-50 km)
- Mesosphere (50 - 90 km)
- Thermosphere (90 - 500 km)
- Ionosphere (110 - 500) km
- Plasmasphere (500 km to ~5Re)
- Magnetosphere
- Solar Wind
- Heliosphere

2. What Sun to Earth space science questions are presently being addressed by Australian scientists

The Sun and Heliosphere
Solar radio bursts
Plasma waves and instabilities;

- The role of turbulence
- Interactions with particles and particle acceleration, stochastic, linear and nonlinear, critical and self-organised phenomena

Multi-scale studies; small-scale physics, effects for initial conditions, boundaries, multi-stage acceleration processes

2.a. The Terrestrial Magnetosphere

Energy transfer near the magnetopause: magnetic reconnection
Plasma waves and instabilities;

- Turbulence
- Interactions with particles and particle acceleration, stochastic, linear and nonlinear, critical and self-organised phenomena
- Mechanisms for energy transfer through the magnetosphere

Multi-scale studies; small-scale physics, effects for initial conditions, boundaries, multi-stage acceleration processes
ULF waves

- Understanding propagation and generation mechanisms
- Remote sensing plasma mass dynamics in the magnetosphere
- Using remote sensing of cold plasma to monitor energy reserves for radiation belt dynamics
- Location of magnetospheric boundaries using ULF wave data

Radiation belt and cosmic ray studies; impacts on space technology and aircraft operations

Energisation and dynamics of the Region 2 Birkeland current system

2.b. The Terrestrial Ionosphere

Large-scale electric fields in the magnetosphere driving small-scale plasma instabilities and large-scale plasma convection in the ionosphere
Methods for estimating the global, high latitude distribution of the height integrated ionosphere conductivities.
Quantification of the Birkeland current system in terms of Poynting flux dump into the ionosphere and thermosphere (using Iridium, SuperDARN and TIMED)
Dynamics of ionosphere plasma convection at sub-auroral latitudes
TEC variations in the low latitude ionosphere
Relationship(s) between the equatorial and mid-latitude variations in TEC
Properties of the Weddell Sea TEC anomaly and high latitude plasma irregularities
Toward more global measurements of TEC
Physics of partially ionized plasmas

2.c. The Atmosphere

Measurement of winds (60-100 km) and temperature around 90 km. Temperature variations in the mesosphere between summer and winter and the role of vertical winds
MFSA radar studies of Polar Mesosphere Summer Echoes (PMSEs), noctilucent clouds and methane dynamics
Role of gravity waves in dumping energy into the mesosphere
Stratospheric aerosol loading and temporal properties (LIDAR)
Mesosphere temperatures measured using the OH spectrometer
Can 'greenhouse gas' warming be monitored by the temperature around 85 km altitude?
Ozone concentration measurements

2. Science topics and questions for the Decadal Plan

Broad Sun to Earth science objectives
To identify the major inputs/variables in each region (e.g. radiation, matter, chemical, biological)
To quantify the energy pathways from the Sun to the ground
To identify and quantify coupling mechanisms between each region (solar wind <-> magnetosphere <-> ionosphere <-> thermosphere)
What, if any, are the effects of solar variations on the climate near the Earth surface?
What are the consequences of small scale structures on larger-scale systems?
To understand the Sun and its connections to Earth, including space weather, effects on atmosphere dynamics and climate, and effects on human society

Effects of cosmic ray radiation (aircraft crews)

2.d. The Sun and Heliosphere

What causes coronal mass ejections (CMEs)?
Improve the monitoring and prediction of CME events
How can we accurately predict effects of CMEs on the terrestrial environment ?

2.e. The Terrestrial Magnetosphere

What are the mechanisms for energy transfer from the solar wind to the magnetosphere?
How much solar winds energy is 'captured' by the magnetosphere?
What observations/model parameters do we need in order to predict the magnetosphere environment and its dynamics?

2.f. The Terrestrial Ionosphere

Electrodynamic coupling between the magnetosphere and ionosphere, causes and effects
What are the elements and important parameters in the global magnetosphere-ionosphere electric circuit?
What is the spatial distribution of energy transfer between the ionosphere and thermosphere?

What are the relevant coupling mechanisms between the ionosphere layers and their effects?
Storm-time effects on currents, ionosphere dynamics and disturbances
Particle precipitation; dynamics, triggers and ionosphere effects
How can we improve the currently available ionospheric models such as IRI and PIM to reproduce the southern hemisphere ionosphere?
Equatorial region:

- What is the trigger mechanism of the reversal of the forward plasma fountain?
- What is the blocking mechanism of the reversal of the forward plasma fountain?
- Can we predict the event of pre-reversal enhancement? If yes, how accurately?
- Is it possible to design local warning systems (for the northern shores of Australia)?
- How do the events of equatorial evening variations damage the GPS/GALILEO signals?
- What are the exact effects of the evening variations of the equatorial ionosphere on JORN? How can we improve the operation of JORN?

How are the low- and mid-latitude ionospheric regions associated?
High Latitudes:

- How do the high latitude plasma irregularities such as plasma patches and blobs affect GPS/GALILEO signals?
- What is the response of the Weddell Sea Anomaly to geomagnetic storms?
- Does the Weddell Sea Anomaly affect the development of the mid-latitude trough?
- If there is an effect, how does it vary in time and space?

2.g. The Atmosphere

Understand the role of Antarctica in global climate (from the Strategic plan provided by Ray Morris, AAD)

- What is the climatology of the stratosphere and mesosphere regions of the Antarctic atmosphere?
- What are the structures and dynamics of the stratospheric ozone layer?
- What are the annual and decadal trends in temperature, winds, and densities throughout the stratosphere and mesosphere? What can these data tell about global climate change?
- Is the formation of polar stratospheric and mesospheric clouds evidence of climate change?
- How is momentum transferred from the lower atmosphere to the mesosphere? What is the role of turbulence
- What is the role of the atmospheric electric field in sun-weather coupling?
- What concentrations and with what time lag do atmospheric emissions appear in the stratosphere, mesosphere, thermosphere?

Identify the coupling mechanisms between various atmosphere layers
Model thermosphere expansion variables for predicting LEO satellite drag
The role of atmospheric aerosols in climate change:

- What is the concentration at various aerosol sizes
- What is the spatial distribution
- What are the radiative transfer processes?

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