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Editorial

A brief overview on the special issue on CAWSES-India Phase II program

1. Introduction

The Climate and Weather of the Sun Earth System (CAWSES) is a major international program initiated under the auspices of the Scientific Committee on Solar Terrestrial Physics (SCOSTEP). The CAWSES-India program was fully supported by the Indian Space Research Organization (ISRO) and both the CAWSES′ Phase I (2004–2009) and Phase II (2009–2014) programs have been quite successful with enthusiastic participation from researchers in various universities and national institutes across the country. The CAWSES-India Phase II was organized into three themes, namely, (1) solar influence on climate (0–100 km), (2) space weather and climate: science and applications, and (3) atmospheric coupling processes.

Each theme set off addressing a few focused questions, namely *(1.1) What are the linkages between the Indian Summer Monsoon (ISM) and solar variability? (1.2) How does solar variability influence tropical tropopause dynamics over long time scales? (1.3) What is the influence of solar variability on the tropical middle atmospheric chemical climate? (2.1) How well can we predict a geomagnetic storm? (2.2) What are the triggers for the generation of equatorial plasma irregularities? (2.3) How well can we nowcast/forecast scintillation occurrences? (2.4) How are the particle and electromagnetic energy inputs incident from the Sun distributed in various regions of the Earth′s atmosphere–ionosphere–magnetosphere system? (3.1) What is the role of Stratosphere–Troposphere Exchange processes in the long-term variabilities of trace gases like ozone and water vapor? (3.2) How does the tropical tropopause vary and what are the forcing mechanisms for the tropopause dynamics in the tropics? (3.3) What wave forcings drive the structure and dynamics of the middle atmospheric and lower thermospheric/ionospheric regions?*

Over 100 publications have emerged from the work carried out during Phase II, which have appeared in various peer reviewed journals. This special issue essentially gives a flavor of some of the results obtained in the recent past.

2. Solar influence on climate (0–100 km) (Theme 1)

2.1. Solar cycle effects on Indian summer monsoon

As the Indian Summer Monsoon (ISM) is due to modulations between warmer Asian continent and the cooler Indian Ocean, changes in the solar cycle are expected to influence the ISM characteristics. Among several elements of ISM, the Tropical Easterly Jet (TEJ), the Low Level Jet (LLJ), and rainfall are the important parameters to for investigations. An attempt has been made by Venkat Ratnam et al. (2014a) to investigate the role of solar cycle variability on these ISM features using re-analysis products. The ISM characteristics were studied during varying epochs of solar cycle, namely, solar activity maxima and minima, and increasing and decreasing levels of solar activity. TEJ revealed decreasing trend at the rate of 0.13 ms^{-1} up to the year 2000. An increasing trend was noticed, however, in the last decade. No perceptible trend was seen in LLJ at 850 hPa, but the jet speeds at 700 hPa level was marked with an increasing trend. TEJ speeds differed by $\sim 2\ ms^{-1}$ between solar maximum and minimum, whereas a difference of $\sim 5\ ms^{-1}$ was detected between the increasing and decreasing solar activity levels. On the whole, easterlies were observed to be stronger during solar maximum and increasing solar activity levels. No consistent relation was found between the ISM and solar cycle over the Indian region. These features are in accordance with our reasoning that the relation between the solar cycle and monsoon circulation is linear but there exists a non-linear relation between the solar cycle and rainfall activity.

2.2. Solar control on the cloud liquid water content and integrated water vapor associated with monsoon rainfall over India

By modulating galactic cosmic rays (GCR) and by controlling the nucleation of water droplets in the atmosphere, our Sun can influence clouds and the rainfall activity. There are two competitive processes that are active in determining the nature of the relationship. During the solar maxima, there is an increase in surface temperature which causes enhanced formation of water vapor and, as a result, an increased cloud Liquid Water vapor Content (LWC). It is known that the GCRs induce aerosols to form clouds. With the increase in the sun spot numbers (SSN), a suppression of GCR occurs and, consequently, the formation of clouds is reduced. Hence, during the maximum solar activity epoch, a reduced GCR activity will adversely affect the rainfall as well as LWC. Using data from nine different stations located in India, Maitra et al. (2014) reported a complex relationship between the solar activity and ISM rainfall and its associated parameters namely, LWC and integrated water vapor content in the atmospheric column. Both positive and negative correlations between SSN and ISM rainfall are observed in the tropical region. These assimilated facts indicate that there may be a connection between GCR and ISM on a global scale, resulting in a possible solar control on the underlying processes.

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2.3. Solar influence on the diurnal tide in the low-latitude troposphere and stratosphere

In general, tides observed in the middle atmosphere are believed to be generated due to the tropospheric water vapor, stratospheric ozone, and latent heat release associated with deep tropical convection with Sun as the ultimate source of energy. Tidal forcing due to these sources, in turn, depends on the solar conditions. It is expected that sea surface temperature (SST) is higher during solar maximum which increases overall convection in the tropics. This enhanced convection may lead to enhancement in the tidal amplitudes. Using long-termERA-Interim wind and temperature products available since 1979, Venkat Ratnam et al. (2014b) reported a long-term linear increasing trend in the convection and in the amplitude of the diurnal tide, which becomes prominent in the stratosphere suggesting that they are related. However, earlier studies have shown that increase in SST is not uniform across the globe during solar maximum conditions and is highly region dependent leading to La Nina-like (cooling) features in Pacific region and warming in the region extending from the Indian ocean to the maritime continent. Using modeling studies, these changes were attributed to changes in the Walker circulation and Inter Tropical Converging Zone (ITCZ) which intensify during solar maximum. Thus, it is meaningful to consider such changes in the convection also.

3. Space weather and climate: science and applications (Theme 2)

Investigations of equatorial and low-latitude electrodynamical phenomena and their inter-relationships have formed an important aspect of the results reported in this special issue.

The F-region of the ionosphere over magnetic equator (Thumba) in the Indian longitudes shows a characteristic pre-midnight rise in June solstices as obtained by systematic ground-based ionospheric measurements over the years. These measurements have also been verified by C/NOFS satellite based data confirming that this upward drift is electro-dynamical in nature. Formation of eastward electric fields in the night time during geomagnetic quiet times is unlikely and therefore this observational feature remained unexplained over the years. As the equatorial F-region vertical drifts during night time are controlled by E-region dynamo that is driven by tidal wind system, systematic wind measurements at upper mesospheric heights by an MF radar (at Tirunelveli) were analyzed, which revealed that the phases of both the meridional and zonal components of the diurnal tide regressed while the phase of the meridional component of the semidiurnal tide significantly advanced with decreasing solar activity with concomitant increases in amplitudes during the summer months. These observations suggest the possible semidiurnal tidal influence on the pre-midnight height rise over the Indian sector in the June solstice during low solar activity (Chakrabarty et al., 2014).

It is known that the plasma irregularities that get developed in the post-sunset hours, on occasions, move along the magnetic meridian and produce plasma scintillations at low-latitudes around the equatorial ionization anomaly (EIA) crest location. However, from a multi-station observational campaign using GPS TEC and S4 indices measurements from locations under (Calcutta) and around (Siliguri) the EIA crest region Das et al. (2014) reported cases wherein the plasma scintillations were first observed in the crest region of the EIA and were later observed to move equatorward. These observations indicate that post-midnight GPS amplitude scintillations are possibly associated with the interaction of traveling ionospheric disturbances from mid-latitudes towards the equator. These observations are obtained during deep solar minimum and in post-midnight hours. Such information on different levels of intensities of scintillation could provide useful information for trans-ionospheric satellite link design and Satellite-based Augmentation System (SBAS).

Using all-sky imaging observations of $O(^1D)$ 630.0 nm nightglow emissions from Kolhapur and Gadanki, detailed information about the characteristics of the equatorial plasma bubbles has been obtained. The plasma bubbles were found to be moving eastwards, wherein the east–west plasma drift velocity over Kolhapur and Gadanki varied from 124 ms^{-1} to182 ms^{-1} and 116 ms^{-1} to 160 ms^{-1}, respectively. These drifts derived were comparable with the zonal neutral wind velocities obtained from the Horizontal Wind Model-07 and an empirical drift model (Ghodpage et al., 2014).

A neural network based prediction of the Earth′s horizontal component of the magnetic field at various locations in the Indian sector has been reported by Unnikrishnan (2014). Through training procedure, solar flux (F10.7), latitude, longitude, day of the year, local time, Ap index, IMF Bz, and ion number density are identified as the optimum choice of input parameters. The predictions match well with the observations.

Whistler observations from multiple stations (Varanasi, Allahabad, and Lucknow) located in the Northern Hemisphere revealed that more than 50% of the causative sferics of whistlers matched closely with the times of WWLLN (World-wide lightning location network) detected lightning strikes. These lightning strikes originated from the Southern Hemisphere in a region conjugate to Varanasi and Allahabad. This shows that the whistlers have propagated in a ducted mode and the whole propagation path of whistlers lies in the ionosphere (Singh et al., 2014).

4. Atmospheric coupling processes (Theme 3)

4.1. Tropical Tropopause Dynamics and their impact on cirrus clouds

The studies of the tropical tropopause layer (TTL) and its dynamics have gathered significant attention in recent years because of the sensitivity of this layer to anthropogenic activities that lead to climate change. Convection in the tropics is known to play a key role in redistributing trace gases and aerosols in the Upper Troposphere-Lower Stratosphere (UTLS) region and the interaction between cloud dynamics, radiation and microphysics is of fundamental importance in these processes. A more comprehensive approach has been adopted by the Indian CAWSES community to address some outstanding issues on this topic.

Intensive observational campaigns under the theme 'Tropical Tropopause Dynamics (TTD)′ from Trivandrum and Gadanki were organized during Phase-II that involved launching of GPS radiosondes/ozonesondes at repeated intervals that yielded vertical profiles of temperature, relative humidity, zonal and meridional winds, and ozone density. In addition complementary experiments were carried out with the MST radar at Gadanki and the lidars both at Gadanki and Trivandrum. Venkat Ratnam et al. (2014c) presented an overview of the results obtained from one such experiment. Ravindrababu et al. (2014) compared the radar determined tropopause altitude with the cold point and lapse rate tropopause altitudes obtained from simultaneous radiosonde data at three hourly intervals during these campaigns. The smaller differences (0.1 ± 1 and 0.5 ± 1 km, respectively) between the two are attributed to the well-defined structure of the tropopause in the tropical latitudes.

The TTL region is very conductive for the formation of cirrus clouds. The TTD experiment provided an opportunity to understand (a) the association between upper tropospheric cirrus and the tropospheric convection, and (b) the role of atmospheric waves in modulating the thermal structure thereby accounting for the variabilities of cirrus occurrence characteristics. In this special issue, Pandit et al. (2014) examined the characteristics of tropical cirrus clouds observed over Gadanki during 1998–2013. Their occurrence characteristics during various seasons have been brought out in this work. It is shown that the cirrus top is located within the TTL (i.e., between cold point and convective outflow levels) on most of the occasions while the cirrus base is near the convective outflow level. The geometrical thickness of the cirrus cloud is found to be higher during monsoon season compared to winter and there exists a weak inverse relation with TTL thickness.

4.2. Stratospheric dehydration in the tropical lower stratosphere: Results from the water vapor analysis

A freeze-dry mechanism taking place in the cold tropopause region has been traditionally believed to dry up the lower stratospheric air. However, it is not known to what extent this mechanism operates over various convectively active regions. The tropical upwelling is part of the large-scale Brewer–Dobson circulation and contributes to the seasonal variation in temperature in the tropical upper troposphere and lower stratosphere. At the tropical tropopause layer, a complex interplay between circulation at various temporal and spatial scales, clouds associated with deep penetrating convective systems and radiation together drive a host of processes responsible for the stratospheric dehydration whose details are only beginning to be understood.

Jain et al. (2014) analyzed Aura Microwave Limb Sounder observations of water vapor mixing ratio (WVMR) in the tropical region. A close association between WVMR and temperatures at 100 hPa in the Indonesian–Australian western Pacific region is reported in this work. Several aspects were examined that are likely to contribute to the low 100 hPa temperatures and the subsequent freeze drying of the lower stratosphere in this region, namely, Brewer–Dobson circulation, convective activity, and low ozone mixing ratio near the tropopause level, wave activity of different temporal scales and anomalous sea surface temperature over the western Pacific region.

4.3. Thermal structure of the lower stratosphere

COSMIC/FORMOSAT-3 radio occultation measurements of atmospheric temperatures were used in the study by Kumar et al. (2014) to examine the occurrence characteristics of the coldest region in the stratosphere. Using vertical profiles of zonally averaged pole-to-pole temperature at every 5° latitude, it is shown that the coldest region occurs during winter in the high latitude stratosphere over a layer of vertical thickness of 20 km. Colder winter conditions prevail over a longer duration in the southern hemisphere when compared to the northern hemisphere. Such low temperature regions are seen to coexist with the jet streams prevalent in those regions. Another aspect investigated in this work is the sharpness of the tropical tropopause layer, which represents the stability of the region. During easterly phase of QBO, the stability of the tropopause is shown to increase.

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