CAWSES: Climate and Weather for Sun-Earth System– II http://www.cawses.org/CAWSES/Home.html
Task Group4 : What is the geospace response to variable inputs from the lower atmosphere?

TG4 Newsletter

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Article 1

The stratospheric warming event of 2010

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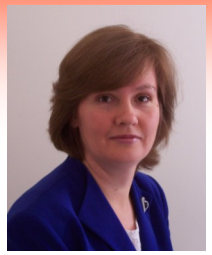

Larisa Goncharenko

It has been well known for several decades that stratospheric sudden warming (SSW) events dramatically disrupt circulation and temperature in the stratosphere and mesosphere. Recent experimental and modeling efforts present strong evidence of major variations at higher altitudes, from the lower thermosphere to the upper thermosphere and ionosphere, and across wide range of latitudes. These advances in understanding were possible due to the superposition of several factors: a series of strong SSW events in 2008 and 2009, prolonged unusually low levels of solar and geomagnetic activity, which allowed unambiguous determination of ionospheric effects related to lower atmosphere drivers, and a coordinated effort by the space physics community to collect and analyze data during the SSW events.

The winter of 2009-2010 was the third consecutive winter of such coordinated campaigns. It was marked by a significant stratospheric warming event peaking in the end of January 2010. Although this warming was not as strong as the SSW events of 2008 and 2009, it presents a perfect opportunity to study the coupling between different atmospheric regions under less extreme circum-

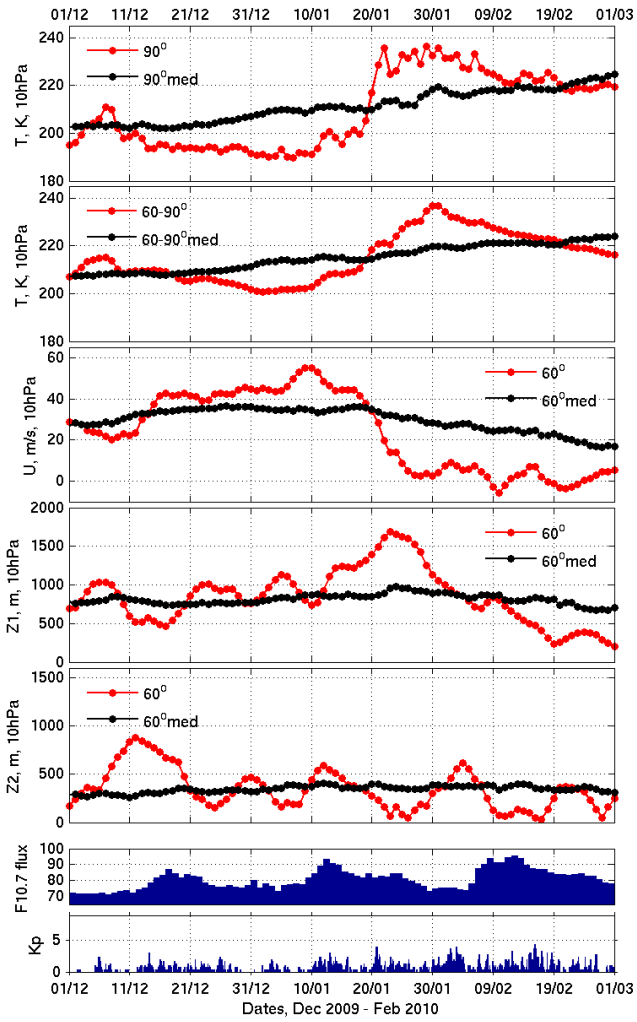

Figure 1. Summary of stratospheric and geomagnetic conditions for the winter of 2009-2010. Top to bottom: stratospheric temperature at 90°N and 10hPa (~32 km), zonal mean stratospheric temperature at 60-90°N, zonal mean zonal wind at 60°N, planetary wave 1 activity at 60°N and 10hPa, planetary wave 2 activity at 60°N and 10hPa, F10.7 index, Kp index. Black circles indicate 30-year means of stratospheric parameters, red circles indicate data for the winter of 2009-2010. Stratospheric data is provided by the National Center for Environmental Predictions (NCEP).

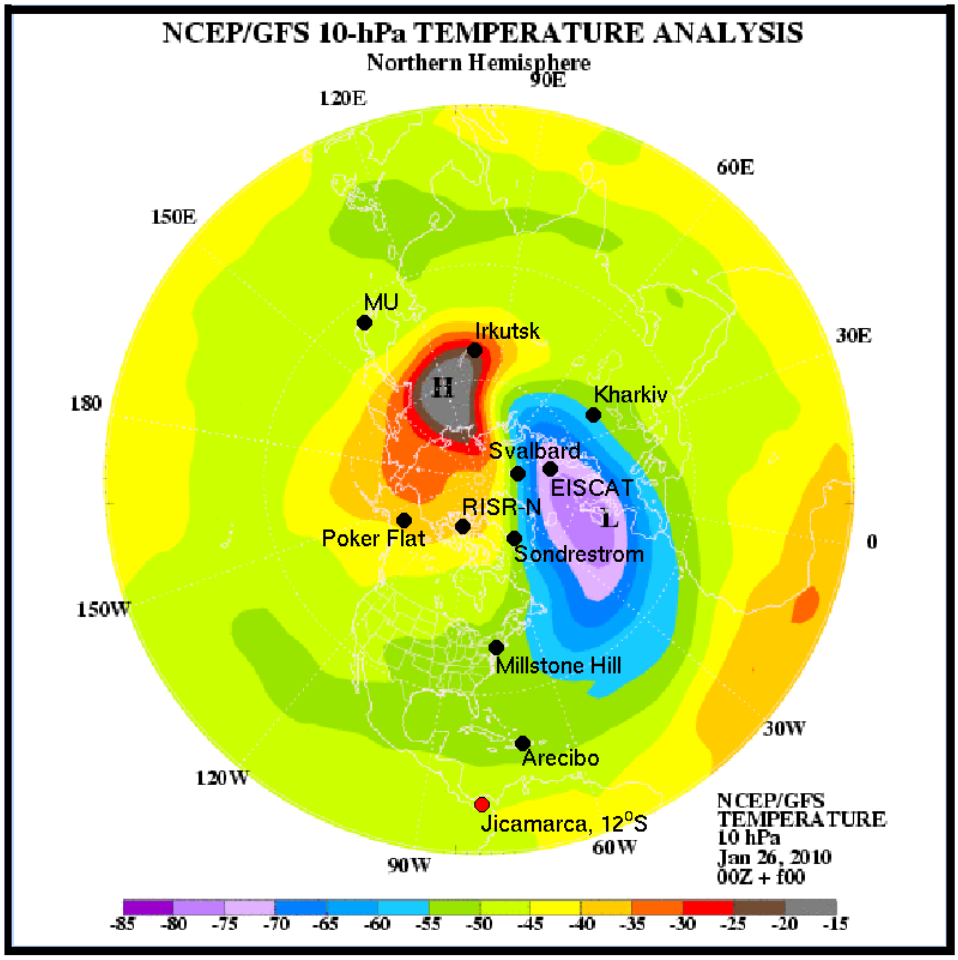

Figure 2. The map of temperature in the Northern Hemisphere at 10 hPa on January 26, 2010, during the stratospheric warming event. Black dots indicate locations of incoherent scatter radars participating in the experimental campaign. The Jicamarca ISR (red dot) is located at 12°S. The map is provided by the NCEP/ Climate Prediction Center.

stances.

Figure 1 summarizes stratospheric, solar and geomagnetic conditions during the period of December 1, 2009 – March 1, 2010. Peak stratospheric temperature at 90°N and 10hPa (~32 km) level was reached on 22 January, and temperature remained above the long-term mean for over two-week period. Strong abatement in the zonal mean zonal wind at 60°N was observed starting around January 10 and continuing well into March 2010, though wind changed the direction only for brief periods of time. The circulation was determined mostly by a planetary wave 1 (Figure 1, panel 4), while the activity of planetary wave 2 (Figure 1, panel 5) remained close to the long-term mean level. Maps of temperature in the Northern Hemisphere at 10-hPa level, presented in Figure 2, demonstrate that this was a vortex displacement event, with a warm cell forming between 90°E-180°E longitude and a cold cell forming between 30°E-60°W longitude. A coordinated World Day Incoherent Scatter Radar campaign was conducted during this period, with radars collecting information on ionospheric and thermospheric parameters in the ~90-700 km altitude range. Black dots indicate the locations of radars which were operating during this campaign. Jicamarca ISR is shown with a red dot as it is located in the Southern Hemisphere.

While detailed analysis of the collected data is underway, preliminary results indicate that disturbances in the upper atmosphere during the SSW event of 2010 are consistent with disturbances reported for other SSW cases. Both observations and numerical simulations point to the important roles of quasi-stationary planetary waves, which become strong prior to the stratospheric warmings. As these planetary waves propagate upward and equatorward, they interact non-linearly with tidal

modes, producing amplification in the amplitudes of migrating and non-migrating tides in the mesosphere-lower thermosphere region. The tidal winds can modulate electric fields through the ionospheric wind dynamo (at ~115 km). At low latitudes, these modulated electric fields map along magnetic field lines to higher altitudes and produce tidal variations in vertical ion drifts, electron density, and the equatorial electrojet.

There are significant uncertainties in our understanding of the manifestation of stratospheric sudden warmings on the middle and upper atmosphere, including relative roles of different types of planetary waves, gravity waves, solar and lunar tides, changes in the background circulation, and solar activity. They present an exciting challenge for the entire CAWSES community. It is our hope that members of the community will join the effort to examine available ground-based and satellite-based datasets collected during the winter of 2009-2010 to further our understanding of coupling processes between the lower and upper atmosphere.

Article 2

Observational chains of Indian Institute of Geomagnetism (IIG) – Instruments and science pursued to probe the dynamical and electrodynamical coupling of atmosphere-ionosphere system at low latitudes

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The Indian Institute of Geomagnetism (IIG), with its headquarters at Navi Mumbai and regional centers and observatories spread across the country, hosts a variety of instrument suites probing the near surface to near space environment. The magnetometer, optical airglow and ionospheric sounding (both passive and active) networks of IIG provide scientific data that are suited to address the main question of CAWSES-II Task Group (TG4), i.e., *What is the geospace response to variable inputs from the lower atmosphere?* Figure 1 depicts the atmospheric coupling processes of interest to scientists at IIG and the instrument suites that were deployed for this purpose.

The prime equatorial observatory, the Equatorial Geophysical Research Laboratory (EGRL), is located at Tirunelveli and is equipped with magnetometers, digital ionosonde, MF radar, GPS/VHF scintillation receivers and airglow instruments comprising of the multi-wavelength photometer, all-sky imager and Fabry-Perot interferometer. Studies pursued at EGRL have provided several insights of dynamical processes occurring in the mesosphere-lower thermosphere (MLT) region (80-98 km). The MF radar at Tirunelveli, one of the longest running middle atmospheric radars in the world, provided important information on the characteristics of large-scale atmospheric waves in this height region, as recent studies from this group demonstrated the role of lower atmospheric convective processes in driving variations in the atmospheric state at such intermediate altitudes. We have also brought out the relationship between the high latitude northern hemispheric major sudden stratospheric warming (SSW) events, the tidal winds in the low latitude MLT region and the reversal in the afternoon equatorial electrojet (EEJ). These findings have relevance to the understanding of upper atmospheric weather that has been gathering significant attention in recent years because of the impact it can produce on satellite communication and navigation systems and spacecraft operations.

Apart from studying the dynamics of the MLT region and how it couples to the plasma motions at E- and F-region heights, we are also involved in understanding the temporal and spatial variabilities of equatorial F-region irregularities driving the equatorial spread F (ESF) at various scale sizes using a chain of VHF spaced receivers located at Tirunelveli, Gadanki, Kol-

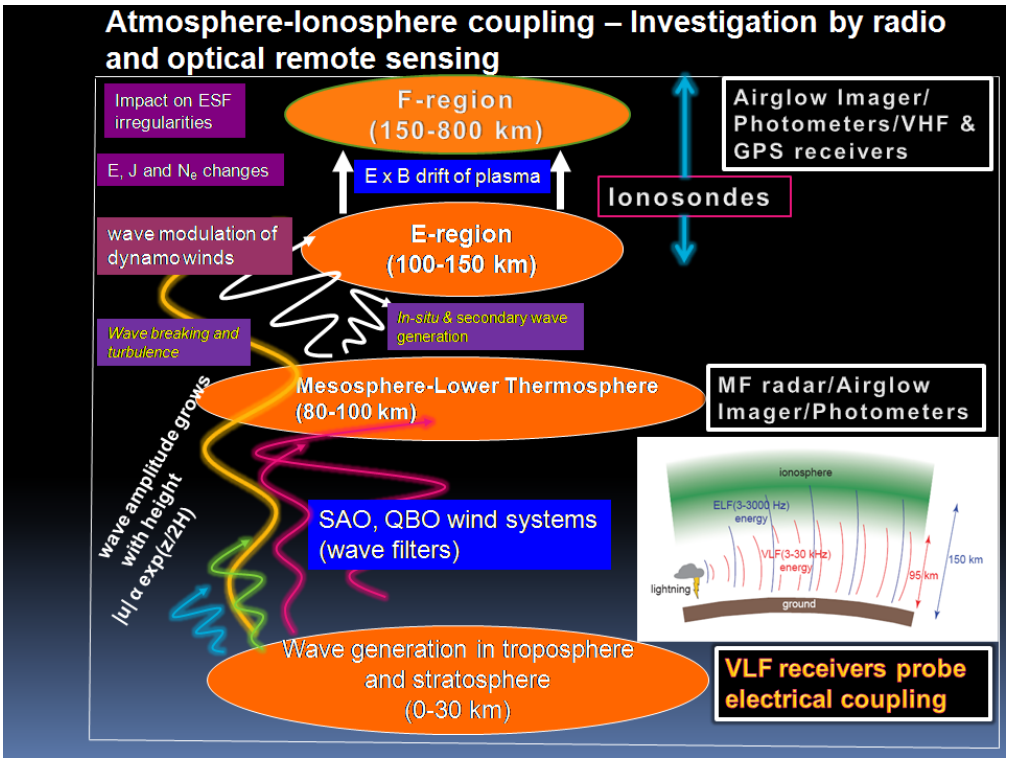

Figure 1. Schematic representing the Atmosphere-Ionosphere coupling studies pursued at IGG with a variety of instrument suites.

hapur, Rajkot and Allahabad along with digital ionosondes located at Tirunelveli and Allahabad (see Figure 2 for a map showing the locations of these sites). Studies carried out at IIG have used an approach that resolves whether the ESF irregularities detected by the MST-VHF backscatter radar at Gadanki are freshly generated or generated earlier at some location to the west of Gadanki and then simply drifted overhead at a later time. Other studies have investigated (i) the generation of ESF irregularities under varying geomagnetic conditions like those associated with disturbance dynamo and prompt penetration of high latitude electric fields, (ii) the morphological behavior of ESF irregularities using the amplitude scintillations on L1 frequency obtained by the GPS And Geo-Aided Navigation (GAGAN) project and (iii) the manifestations of the vertical coupling provided by planetary waves using a combination of GPS-TEC, TIMED-TIDI satellite observations of winds and CHAMP electron density observations.

Table 1. List of instruments and the observational sites of IIG hosting them

Instrument	Station
MF Radar	Tirunelveli and Kolhapur
Digital Ionosonde	Tirunelveli and Allahabad
VHF Spaced Receiver	Tirunelveli, Gadanki, Kolhapur, Rajkot and Allahabad
GPS-SCINDA Receiver	Tirunelveli and Rajkot
VLF Receiver (AWESOME)	Nainital, Varanasi and Allahabad
All-Sky Airglow Imager and Multi-Wavelength Airglow Photometer	Tirunelveli, Kolhapur and Allahabad
Fabry Perot Interferometer	Tirunelveli
Magnetometer	Tirunelveli, Alibag (data from these two stations used to compute EEJ strength) and nine others (not shown in the map)

Scientists from IIG have deployed VLF receivers at three sites in northern India, namely, Nainital, Varanasi and Allahabad, in collaboration with the STAR Laboratory, Stanford University under the AWESOME project, with the objective of understanding the temporal and spatial occurrence of the multifaceted VLF events originating from a variety of sources and the effects these events produce on the near Earth space environment.

To conclude, the scientific experiments pursued by IIG and other institutions in India have gathered momentum in recent years and the scientific community in India is now rightly poised to participate in the forthcoming campaigns of TG4.

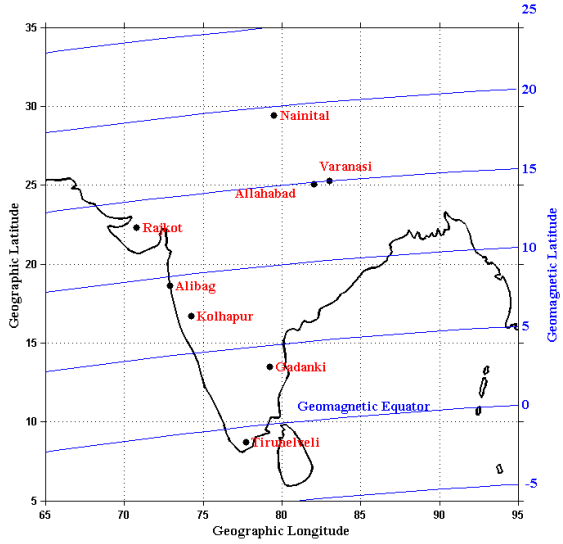

Figure 2. Map depicting the locations of various sites of IIG that are equipped with instrumentation suited for studies on MLT dynamics, EEJ, EIA, ESF and VLF events

Article 3

Tides and Coupling
The CAWSES 2 Global Tidal Campaign Project

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William Ward

Atmospheric tides are the dominant dynamical signature in the mesosphere and lower atmosphere. They are global oscillations whose dynamics involve variations in wind, temperature, pressure and density and extend from the ground to the thermosphere (see Fig 1). The dominant propagating components are migrating tides (at any given height these propagate westward with a phase velocity equal to the apparent velocity of the sun and with horizontal wavenumber equal to the frequency in days^{-1}) which are forced by solar heating wherever that occurs. Other tidal components (termed non-migrating) exist with other integer multiples of wavenumber and frequency (days^{-1}) and which are thought to be excited through latent heat release, deep convection and nonlinear interactions between global waves.

Since the solar forcing is regular with an annual variation in the latitude of maximum heating, it might appear that the tidal response should be equally regular. This however is not the case and significant variations in amplitude are observed from ground observations and in General Circulation Models (see Fig. 2). This variability is attributed to a variety of causes including variations in the sources, filtering effects of the background atmosphere, non-linear interactions and superposition effects between tidal components. This latter effect is of particular importance in comparisons between single station ground based observations where components with the same period cannot be distinguished and satellite observations where individual components are identified. During the CAWSES I Global tidal Campaign Project this effect was quantified [Ward et al., 2010] and found to be the main cause of differences between ground-based observations and satellite observations.

Another aspect of the superposition between components is that the resulting interference produces strong longitudinal variability in the strength of each frequency. This effect was also identified in the CAWSES 1 Tidal Campaign Project and is illustrated in Fig 3

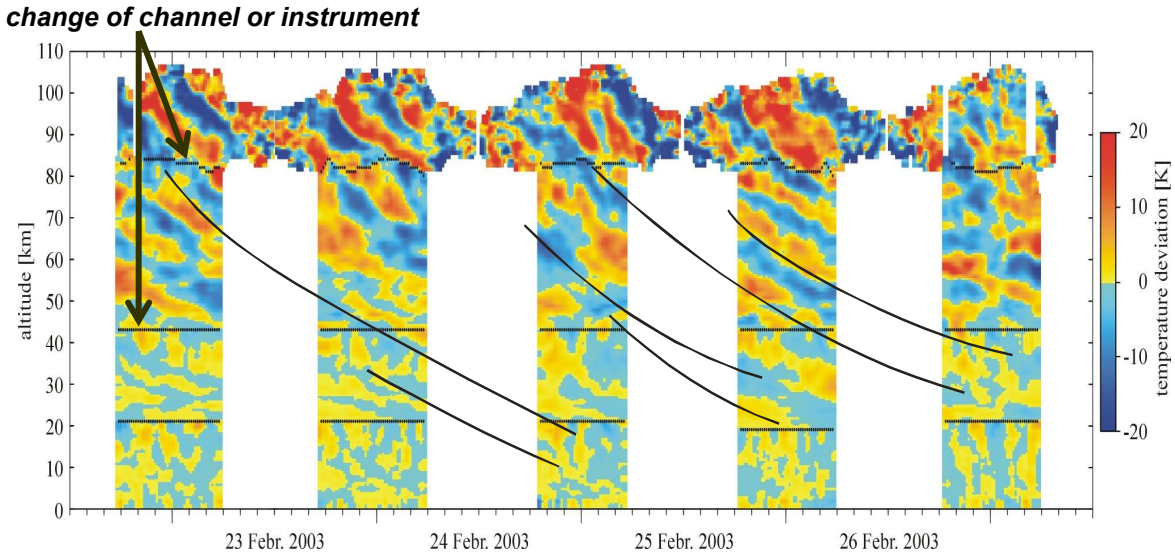

Figure 1: Temperature variations extending from the tropopause to the thermosphere observed using lidars at Kühlungsborn (54°N, 12°E). The plot is constructed by combining results from several different lidars. Thin lines indicate approximate phase fronts and thick brown arrows indicate the transition between observations from different lidars or different channels. Figure provided by M. Gerding, Leibniz Institute of Atmospheric Physics, Kuehlungsborn, Germany.

(again from the extended Canadian Middle Atmosphere Model (CMAM) – figure produced by D. Wang). While the model does not duplicate the actual longitudinal variability in detail the form of the variability with tidal amplitudes approaching zero at certain longitudes is consistent with observations.

Although the results from the CAWSES 1 Tidal Campaigns (to be moved from the current web site: http://www.unb.ca/fredericton/science/physics/CAWSES_GTC/ to the CAWSES 2 web site) have solved some of the issues associated with atmospheric tides, they also indicate that understanding these waves and their effects in the atmosphere is more complicated

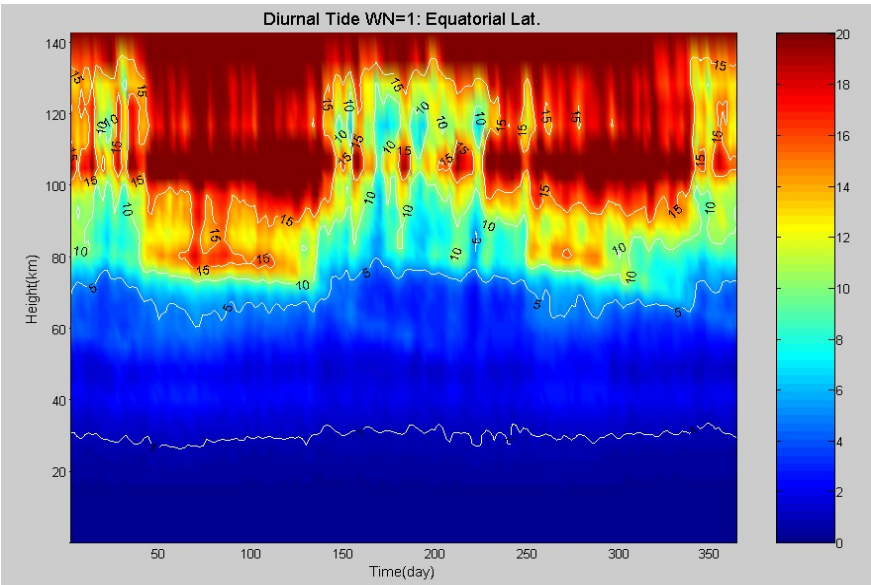

Figure 2. The annual cycle of temperature variations associated with the migrating diurnal tide as diagnosed from a run of the extended Canadian Middle Atmosphere Model. Of note is the significant week to week variability of this component. This type of variability is characteristic of most components.

than previously thought. The geographical variability associated with each tidal harmonic makes direct comparison between single station ground based observations and specific tidal components difficult since what is observed is the superposition of all the associated components (migrating and non-migrating). This geographical variability also applies to all secondary tidal effects (i.e. phenomena such as airglow, sporadic-E, noctilucent clouds, etc. which depend on the basic dynamical variables). This variability can be linked to the source distributions in time and space and the dissipation and filtering of various components. To date we have not been able to obtain a complete set of observations allowing the full "life cycle" of the tidal fields to be examined.

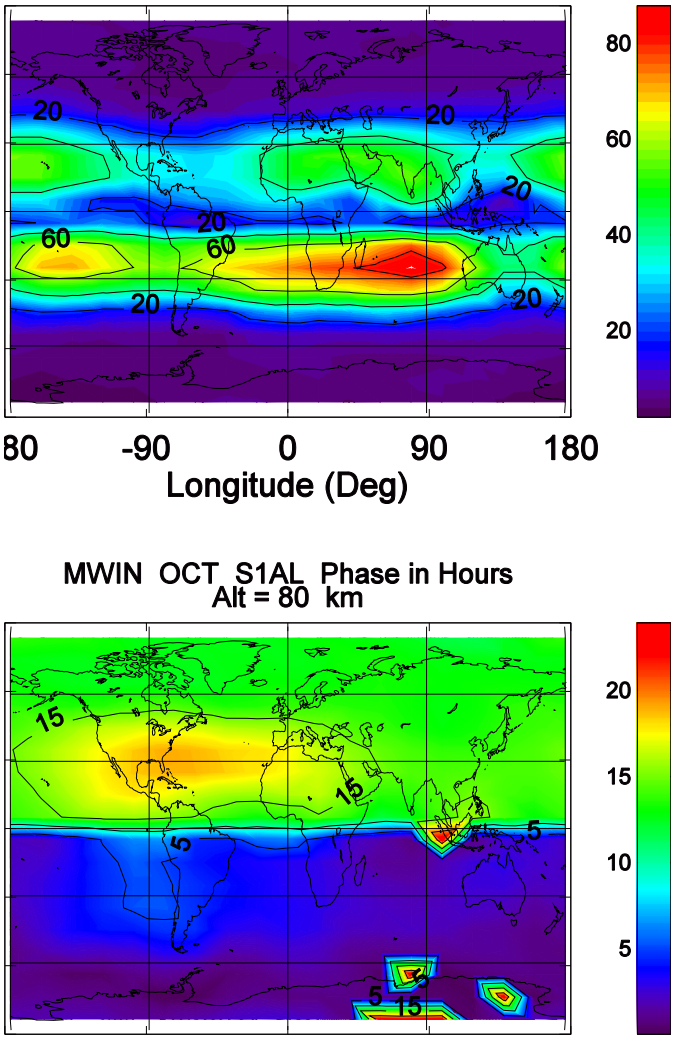

Figure 3. Variations in the local amplitude and phase of the diurnal tide as a result of the superposition of all diurnal components as modeled in the extended CMAM. Figure provided by D.Y. Wang.

The CAWSES 2 Tidal Campaign Project will continue basically along the same lines as the CAWSES 1 project. However, it will now serve two purposes: support for other field campaigns and scientific study of tides and their effects. We will time some tidal campaigns to coincide with other observing campaigns so that the tidal fields will be available to support the interpretation of whatever phenomena are being examined.

The scientific effort of these campaigns will be directed along several lines:

- To examine linkages between variations in source strengths and the observed tides in the mesosphere and lower thermosphere.
- To correlate the basic tidal variables with secondary tidal variability such as that observed in airglow or sporadic-E
- To correlate tidal signatures observed in the mesopause region with tidal phenomena observed in the thermosphere.
- To support the comparison of tidal effects simulated in models with those observed during the various tidal campaigns.

To support the maintenance of a web site supporting the tidal campaigns and the archiving of the associated data.

During CAWSES 2 there will be several campaigns. One will be directed towards relating airglow variability to tidal signatures in temperature and wind in order to confirm our current understanding of tidal effects on airglow. Another campaign will be collect observations allowing the relationship between tidal sources, the background filtering and the tides observed in the mesosphere and thermosphere to be explored. Other campaigns will be held to support other field campaigns in which coupling processes in the atmosphere and ionosphere are investigated.

The work to this point could not have taken place without the support of many scientists throughout the world. In particular, the leaders of the various observation types are to be thanked (Michael Gerding, Larisa Goncharenko, S. Gurubaran, Phillippe Keckhut, Dan Marsh, Jens Oberheide, Juergen Scheer and Werner Singer).

Article 4

CAWSES-II MLT Meeting ~ Singapore ~ 8 & 9 March 2010

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Iain Reid

The first Regional CAWSES-II MLT Radar Workshop was held in Singapore over the 8th and 9th of March 2010. It brought together scientists and their students working in research in the general area of the Mesosphere Lower Thermosphere and Ionosphere region of the atmosphere. The aim of the workshop was to begin discussions on the creation of a radar network in the East Asia-Oceania region. While there are a number of existing and new MF, meteor and VHF radars for studies of Mesosphere Lower Thermosphere region dynamics and lower ionospheric research in India, Indonesia, Thailand, China, Korea, Japan and Australia, the operation and coordination of studies using these radars has not been fully implemented. The purpose of the meeting was to present new results, describe plans for the future, and to coordinate future observations in the region.

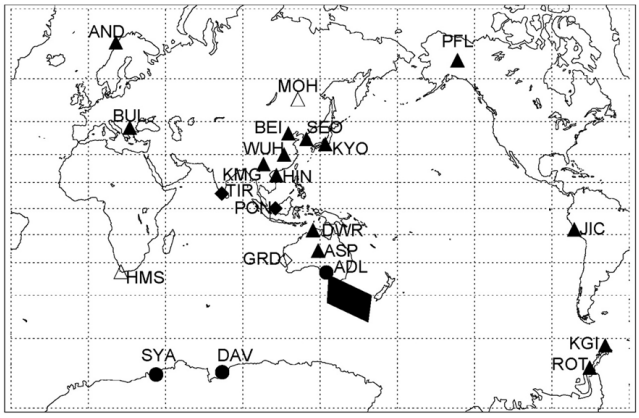

Figure 1. A selection of radars in the East Asia / Australian region. Open symbols indicate a pending installation; triangles indicate a meteor radar, diamonds an MF radar; the closed circles indicate a suite of instruments. The hachured area indicates the approximate coverage of the TIGER radars in the MLT region.

37 scientists and students attended the meeting from Australia, China, India, Indonesia, Japan, Korea, and the USA. 35 papers were presented and considerable discussion and interaction occurred. Highlights of the meeting included reports from Chinese colleagues involved in the Meridian Space Weather Monitoring Project (see http://english.cssar.cas.cn/op/mp/), and from Japanese colleagues developing the Inter-university atmosphere global observation NETwork – known as IUGONET (see http://www.iugonet.org/en/). Both of these projects aim to integrate and assimilate data from ground based networks of radars and other instruments to effectively form Virtual observatories of the MLTI region. The establishment of such 'ground based satellites' promises to further leverage excellent science from a variety of instruments.

Photo1. Workshop attendees at the Ngee Ann Adelaide Education Centre, Singapore.

The meeting was sponsored by, CAWSES-II, the Research Institute for Sustainable Humanosphere, Kyoto University, the University of Adelaide, the "Inter-university Upper atmosphere Global Observation NETwork (IUGONET)",which is supported by the Special Educational Research Budget from the Japanese Ministry of Education, Culture, Sport, Science, and Technology (MEXT), a Grant-in-Aid for Scientific Research (grant 19403009) by the Japanese Ministry of Education, Culture, Sport, Science, and Technology (MEXT), the Asia-Africa Science Platform Program, "Elucidation of ground-based atmosphere observation network in equatorial Asia", Japan Society for the Promotion of Science (JSPS), the Ngee Ann Adelaide Education Centre, ATRAD Pty Ltd, SCOSTEP, and the Adelaide Radar Research Centre.

The workshop was convened by Iain Reid of Adelaide University, and Toshitaka Tsuda of Kyoto University. The workshop objectives were met, and the general consensus was that the meeting should become an annual event. Another meeting is planned for February / March 2011 in Singapore.

Upcoming meetings related to CAWSES-II TG4

Conference	Date	Location	Contact Information
ISSI workshop	Sep. 27-Oct. 1, 2010	Bern, Switzerland	http://www.issibern.ch/workshops/earthplasma
CAWSES-II TG4 conference on "Vertical coupling from stratosphere to ionosphere" (IAGA/ICMA/CAWSES-II)	Feb. 14-18, 2011	Prague, Czech	http://www.ufa.cas.cz/html/conferences/workshop_2011/
AGU Chapman Conference on Modeling the Ionosphere/Thermosphere System	May 9-12, 2011	Charleston, South Carolina, USA	http://www.agu.org/meetings/chapman/2011/dcall/index.php
2011 Joint CEDAR-GEM Workshop	Jun. 26-Jul. 1, 2011	Santa Fe, New Mexico, USA	http://cedarweb.hao.ucar.edu.wiki/index.php/2011_Workshop:Main
IUGG General Assembly	Jun. 28-Jul. 7, 2011	Melbourne, Australia	http://www.iugg2011.com/
URSI General Assembly	Aug. 13-20, 2011	Istanbul, Turkey	http://www.ursigass2011.org/
ISEA-13	Mar. 12-17, 2012	Paracas, Peru	http://jro.igp.gob.pe/isea13/

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