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Inside this Issue

Article 1

EISCAT_3D: A European three-dimensional imaging radar for atmospheric and geospace research

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Esa Turunen

EISCAT_3D will be the next-generation incoherent scatter radar (ISR) for the study of the atmosphere and geospace. It will be a distributed phased-array facility with up to 100 000 individual antenna elements, located in northern Scandinavia in the auroral zone and at the edge of the polar vortex. The first Design Study of the technical concept was conducted in 2005-2009. Recently the EU granted 4.5 MEUR funding for the 4-year long Preparatory Phase action of EISCAT_3D, starting on 1st of October 2010. The aim of the Preparatory Phase is to ensure that the EISCAT_3D project will reach a sufficient level of maturity with respect to technical, legal and financial issues so that the construction of the radar system can begin in 2014-2015. The project calls for open communication with all interested institutes globally. More than 40 institutes have been offered to become Associate Partners. Open EISCAT_3D User Meetings will be held annually in order to discuss both the thematic science areas and applications of the new radar, as well as the over-

Figure 1. Artist image of the EISCAT_3D core site, with a back drop image of diffuse aurora and active sun. The EISCAT_3D Design Study 2005-2009 proposed a crossed Yagi antenna with a minimum directivity of about 7 dBi. The options for antenna design at core and remote sites will be revisited during the EISCAT_3D Preparatory Phase action in 2010-2014.

Figure 2. A small 224-MHz receive-only antenna array was constructed during the EISCAT_3D Design Study 2005-2009 at the Kiruna EISCAT site . The demonstrator array is a rectangular, 12x4 array of (6+6) element X-Yagis, with its major axis aligned in the Kiruna-Tromsø plane. Antennas operating in an Arctic environment will have their performance degraded significantly due to snow and hoarfrost sticking to the antennas. This aspect was among the topics investigated during the Design Study.

all development of the project. The 3rd EISCAT_3D User's Meeting will take place in Uppsala, Sweden, on 18-20 May, 2011.

EISCAT_3D will go beyond anything currently available in ISR technology, with multiple large phased-array antenna transmitters/receivers and multiple receiver sites, direct-sampling receivers and digital beam-forming and beam-steering. Five key attributes are combined in one radar: (1) volumetric imaging and tracking in spatially large geographic area, (2) aperture synthesis imaging for small scale structures down to metres, (3) multistatic configuration for calculation of vector velocities in the middle and upper atmosphere as well as for using adaptive Faraday rotation techniques, (4) by an order-of-magnitude improvement in sensitivity and (5) transmitter flexibility allowing arbitrary modulations.

EISCAT_3D will be capable of making continuous measurements from the middle atmosphere to the magnetosphere. Measuring the effects of man-made change and natural variability on the middle and upper atmosphere, and their potential contribution to global change, is a key objective for international science in the 21st century. Addressing the interactions between geospace and the atmosphere, as well as between the atmospheric layers themselves, EISCAT_3D offers a unique research opportunity to study the atmospheric energy budget and solar system influences, such as the effects of solar wind, meteors, dust, energetic particles and cosmic rays in the atmosphere.

The CAWSES community would benefit from the new measurement capability in their studies of upward energy flow from the stratosphere, to the mesosphere, and thermosphere, lower atmospheric tidal variability and interactions with the mean atmospheric circulation, gravity waves, planetary waves, and ionospheric variations, gravity wave excitation mechanisms, the implications of significant observed gravity wave geographical and temporal variability, and the impacts of stratospheric warming events on the ionosphere.

Major contributions to global societies, which today depend critically on the use of space, are expected in application areas such as improving space weather services and observing the increasing amount of space debris. Climate change is an area of vital concern to society. It has an impact on the upper layers of the atmosphere whose re-structuring can be measured continuously by EISCAT_3D.

In summary, EISCAT_3D will provide a thirty-year update to EISCAT's existing mainland facilities, exploiting recent advances in state-of-the-art electronics, networking, storage and computing. In doing so it, will outstrip the capabilities of any such radar operating in the world and become the centrepiece of the international network of instruments monitoring the Earth's upper atmosphere and space environment in the first half of the twenty-first century.

Figure 3. Geographical layout of the transmitter and receiver sites, as proposed in the EISCAT_3D Design Study 2005-2009. The dashed circle indicates the approximate extent of the common field-of-view at 300 km altitude. Options for locating the active and passive sites will be re-investigated during the Preparatory Phase action in 2010-2014. Several active sites are envisaged in the final configuration of the EISCAT_3D radar.

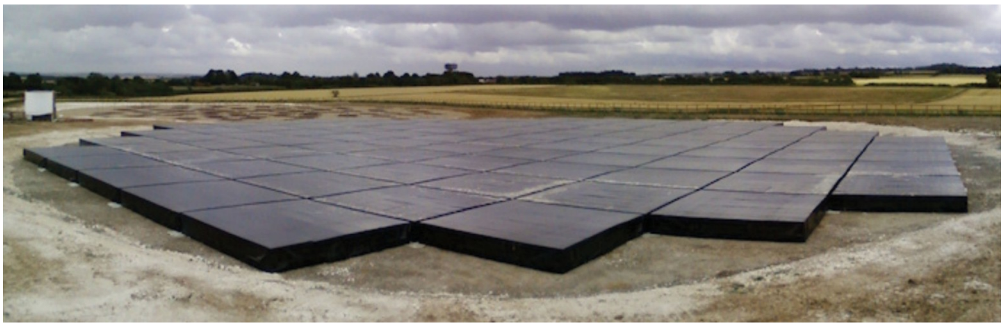

Figure 4. The Low Frequency Array (LOFAR) is an industrially produced multi-purpose sensor array concept for mainly radio astronomy at low frequencies below 250 MHz. Several sites have been constructed across Europe, the latest one being the LOFAR-UK Chilbolton site. The image shows the so-called High-Band Array (HBA) 120-250 MHZ. The antenna array consists of 96 element tiles, having altogether 3072 individual antenna elements. The HBA can be used as a receiver for the EISCAT_3D and the existing EISCAT VHF radars. During the Preparatory phase action, University of Oulu will install one LOFAR remote site with 48 HBA tiles at Kilpisjärvi in Finland. Prototyping of the EISCAT_3D beamforming will be tested in bi-static measurements using the current EISCAT VHF transmitter from autumn 2011.

References:

*Wannberg U.G. et al.: EISCAT_3D - A next-generation European radar system for upper atmosphere and geospace research, Radio Science Bulletin, No 332, 75-88, 2010.

*Turunen E. et al.: EISCAT 3D - European New Technology Atmospheric and Space Environment Radar Arrays, Proc. 19th ESA Symposium on European Rocket and Balloon Programmes and Related Research, Bad Reichenhall, Germany, 7–11 June 2009, ESA SP-671, September 2009.

*Web reference: http://www.eiscat3d.se/

Article 2

MIPAS temperature observations provide a global view of the atmosphere's thermal structure from the stratosphere up to the middle thermosphere

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B. Funke

Global temperature observations with full vertical coverage from the stratosphere to the thermosphere are of high value for advancing towards a better understanding of coupling processes between the lower and upper atmosphere. Satellite observations, however, are often limited to altitudes below approximately 110 km or to the upper thermosphere.

Recently, a new method has been developed for retrieving temperature profiles from 40 to 170 km from MIPAS/Envisat limb emission spectra taken in the upper atmospheric (UA) observation mode, thus filling the observational gap in the middle thermosphere. This method, employed by the IMK/IAA (Institut für Meteorologie und Klimaforschung/ Instituto de Astrofísica de Andalucía) scientific data processor, uses a two-step approach. First, temperature and pointing information is retrieved from CO_2 lines in the 12–15 µm spectral region up to 100 km under consideration of non-local thermodynamic equilibrium (non-LTE). In a second step, spectrally resolved thermospheric 5.3 µm NO emissions are used to retrieve simultaneously kinetic temperature and NO abundances from 100 to 170 km. Independent temperature information is obtained from the rotational and spin-orbit structure of the NO fundamental band taking into account vibrational, rotational, and spin-orbit non-LTE populations.

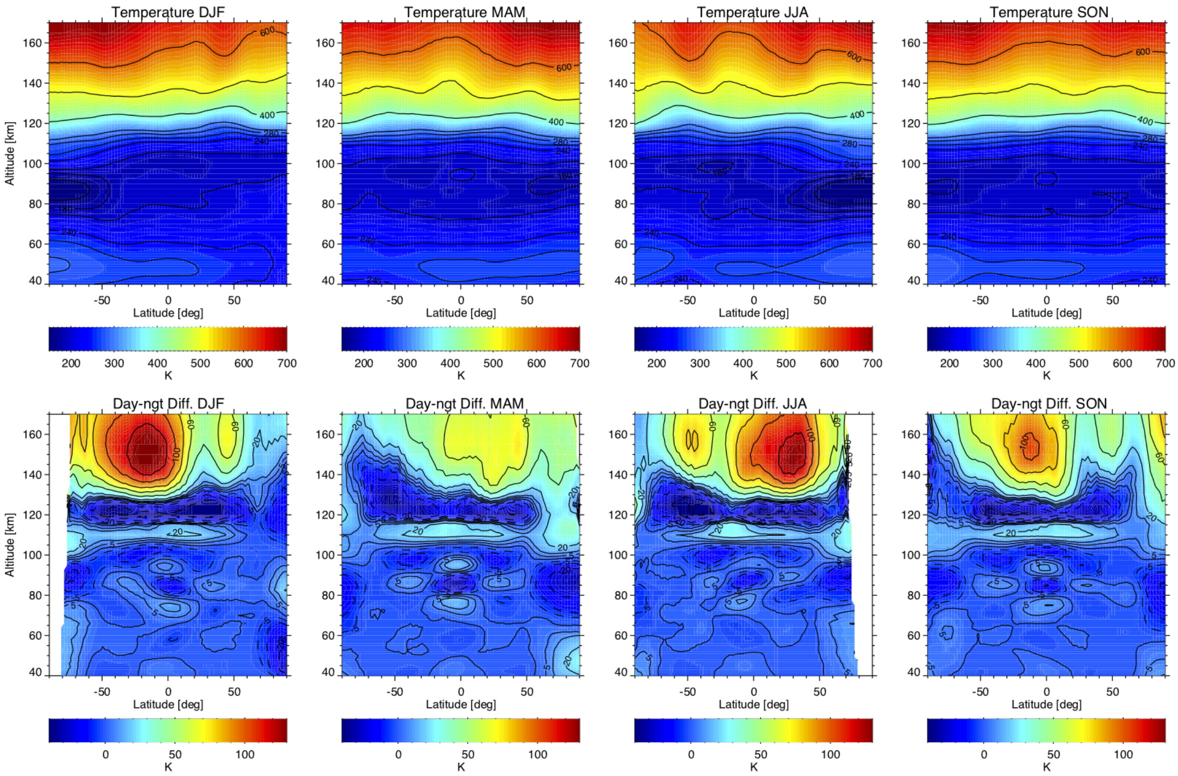


Figure 1. MIPAS zonal mean temperatures (top panels) and day-night differences (bottom panels) averaged over December-February (DJF), March-May (MAM), June-August (JJA), and September-November (SON) of 2007-2009.

MIPAS UA temperature observations have been first taken in January 2005 and are available on a regular basis (1 day out of 10) since 2007. Approximately 1000 temperature profiles are recorded per day at two different local times (10.00 am and 10.00 pm) with a global coverage. Figure 1 shows seasonal zonal mean temperature distributions obtained from MIPAS UA observations during 2007-2009. The sampling at fixed local times with 12h difference allows also for the analysis of diurnal variations and tidal effects (see Fig. 1, lower panels).

MIPAS temperature observations taken during the unprecedented stratospheric sudden warming (SSW) in January 2009 provide a confirmation of the classic mesospheric cooling response to SSWs (see Fig. 2). We have also observed a thermospheric warming of peaking at 120–140 km in concert with the stratospheric warming pulse. The thermospheric temperature increases of 15-20 K observed by MIPAS are consistent with the nighttime ion temperatures measured by the EISCAT UHF radar during the same period. These observations represent a confirmation of the thermospheric warming response to SSWs predicted by GCM simulations and provide the first experimental evidence of a dynamical coupling of the lower atmosphere and the thermosphere

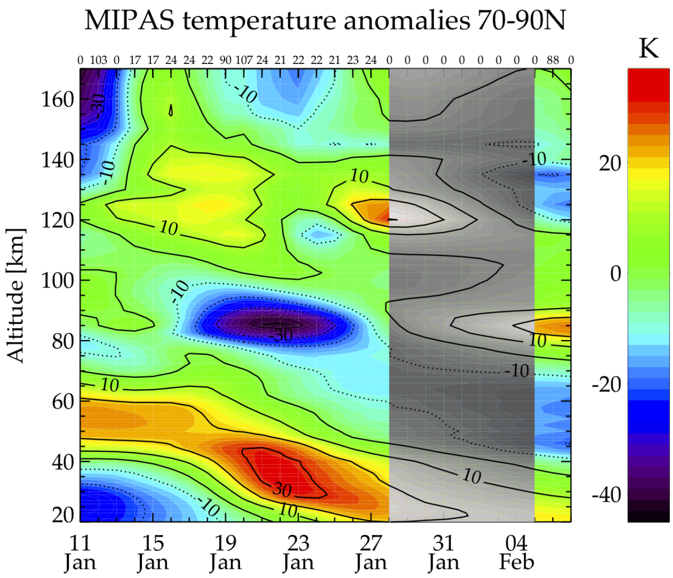
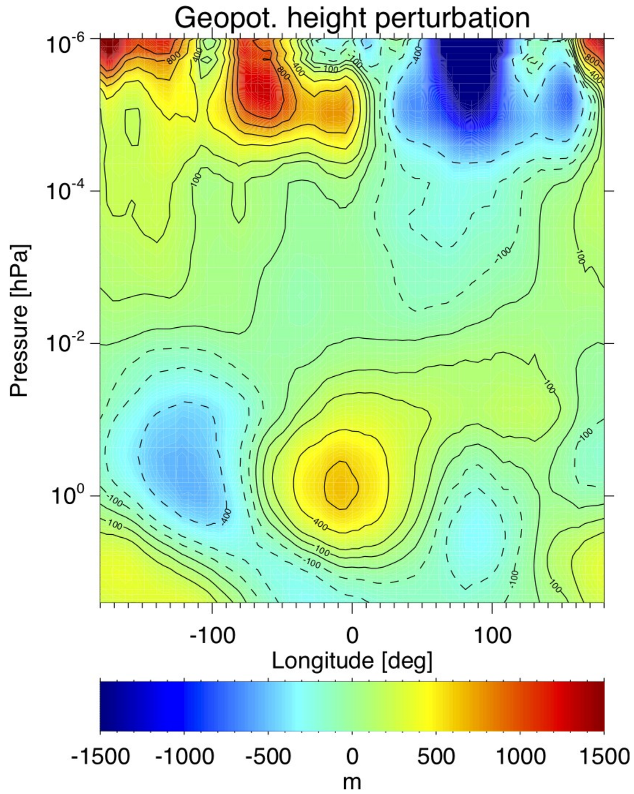


Figure2. Temporal evolution of zonally averaged MIPAS temperature anomalies (with respect to the temporal average) within 70–90°N. During the MIPAS data gap between 28 January and 5 February (grey-shaded) temperature anomalies are interpolated. Numbers at the top x-axis reflect the number of averaged observations.



in the 120–150 km range by means of satellite data.

From the analysis of the zonal temperature structure observed by MIPAS during this SSW a pronounced wave 1 pattern was found in the entire middle and upper atmosphere with maximum amplitudes around 10 hPa (~50 km) and 10^{-5} hPa (~140 km). In the mesosphere, the wave amplitude is significantly damped. The wave amplification above is most likely produced by in situ forced planetary waves in the MLT region due to zonally asymmetric gravity wave breaking. Further, a possible interaction between planetary waves and migrating tides causing the generation of non-migrating tides with increased variability in the lower thermospheric amplitude and phase cannot be ruled out.

These examples demonstrate the potential of MIPAS UA temperature observations to improve our understanding of lower and upper atmospheric coupling processes by covering the entire vertical range.

Figure 3. MIPAS geopotential height perturbations with respect to the zonal average over longitude for 19–20 January 2009 around 80°N.

Article 3

Coupling the Earth's Atmospheric and Plasma Envelopes

A Workshop held at the International Space Science Institute (ISSI) in Bern, Switzerland

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R. A. Treumann

The two constituents of the Earth's volatile gaseous envelope, atmosphere and plasma environment, seem to be completely independent. However, the dynamics of the atmosphere on various scales affects the dynamics of the ionospheric and magnetospheric plasmas, and the latter may affect the atmosphere. Energetically this coupling might rather be important only in upward direction (Table 1). For the purpose of collecting our contemporary view of these coupling processes, a Workshop was organised at ISSI in Bern, Switzerland from September 27 to October 1, 2010. [1]

[1]The papers presented at the workshop will lead to an issue of Space Science Reviews published in 2011 and simultaneously as a Springer book in the Space Science Series of ISSI, volume 40.

Table 1. Various energy inputs into Earth's atmosphere (courtesy Gang Lu).

Source	Energy Input ($W m^{-2}$)	Deposition Altitude (km)
Solar Radiation		
Total irradiance	1368	Surface
UV 200-300 nm	16	0-50
UV 120-200 nm	0.1	50-120
EUV	0.003	100-500
Particles		
Solar Energetic Particles (SEP)	0.002	30-90
Auroral Protons	0.001-0.006	100-130
Auroral Electrons	0.003-0.03	70-130
Galactic Cosmic Rays	0.000007	0-90
Joule Heating		
$E = 10 \sim 100$ mV/m, $S_P = 15$ mho	0.0015 ~ 0.15	100-500

Effects of Joule Heating on Upper Atmosphere

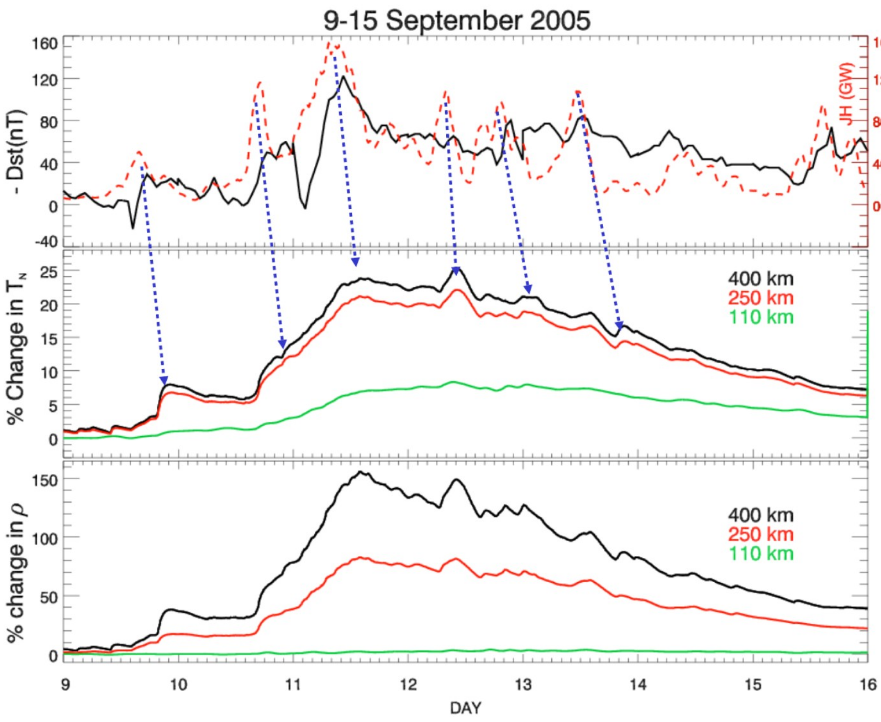

Figure 1. An example of the heating of the upper neutral atmosphere (seen in temperture T) by a major geomagnetic disturbance seen in Dst (upper panel) in September 2005. The arrows show the heating events related to the disturbance increases with consistent time delays. Density increases up to 150% at 400 km altitude are observed resulting from expansion of the atmosphere (courtesy Gang Lu).

Because of the dominance of the coupling from down to upward, the Workshop program was organised accordingly. Consideration of long-term trends and effects of solar cycle variations on the state of the atmosphere emphasising the transition between atmosphere and ionosphere (upward of 60 km) were followed by those of the various atmospheric wave modes and their role in changing ionospheric parameters. These included seasonal variations, tides, planetary and gravity waves in view of atmospheric heating up to the lower and middle thermosphere. Particular interest concerned tidal effects in the day-to-day valibility of the equatorial electrojet, where also gravity waves are important. Simulations confirm their evolution into turbulence at thermospheric altitudes, their dissipation and contribution to heating, expansion and winds. Instabilities leading to turbulence have been monitored observationally. In plasma, ion scale waves are excited by combination of plasma gradients, gravity and magnetic field. Near the equator they form plasma bubbles. Their turbulent decay affects neutrals and plasma predominantly by heating which causes travelling atmospheric disturbances (TADs), expansion (Figure 1) and mixing, local changes in collisional properties, changes in the ionisation and secondary

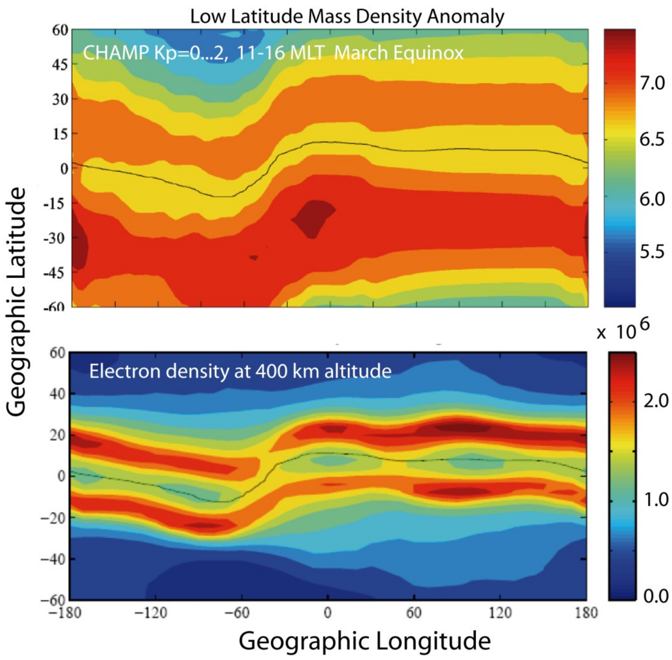

Figure 2. Atmospheric mass densities measured by the CHAMP spacecraft at geomagnetic quiescence. Of interest is the latitudinal bifurcation of the mass density with respect to the geomagnetic equator at maximum in the early afternoon, showing a so far not quite understood geomagnetic effect on the neutral atmosphere (courtesy Hermann Lühr).

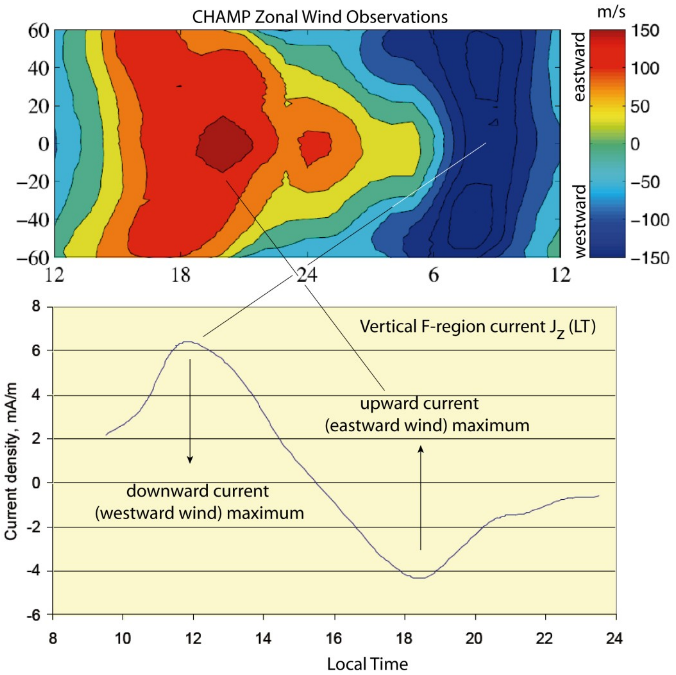

Figure 3. Zonal wind observations by the CHAMP spacecraft. The winds are westward at sunset and eastward at noon. The lower panel shows the corresponding vertical ionospheric electric currents Jz and their one-to-one correspondence to the directions of the zonal winds. Eastward winds cause upward currents, westward wind downward currents in the F-region (courtesy Hermann Lühr).

instabilities. The CHAMP spacecraft (Figures 2 and 3) observed such effects in situ.

Atmospheric chemistry occupied quite a bit of discussion because of its effects on ozone concentration. Through it the coupling between the Earth's plasma finds an important channel of affecting the state of the lower atmosphere. Even small local changes in temperature, ion and electron content during all kinds of heating events, in particular when precipation of charged particles takes place modify the chemical conditions by supporting or suppressing reactions, in particular of the atmospherically active NOx. Precipitation provides ionisation, heating and radiation. The penetration depth depends on particle energy and geographic/geomagnetic location. Energetic solar particles during rare violent events cause about isotropic effects down to the mesosphere. In the aftermath of strong magnetic storms energetic radiation belt particles causes similar effects in low latitudes. During substorms, medium energy particles precipitate in large numbers in subauroral and auroral latitudes just into the D-layer, but expansion of the neutral atmosphere leads to atmospheric mixing, turbulence and transport of products of chemical reactions (Figure 4). Small plasma effects may trigger atmospheric variations of global influence.

Lightnings, sprites, jets provide another channel of electrical, compositional, chemical, dynamical and radiational coupling, e.g. by generating electromagnetic waves that locally induce atmospherically triggered particle precipitation. Into this category fits also the formation of sporadic E-layers. They result from metallic meteoric ions but are expected to occur also from space debris.

Finally, electromagnetic wave disturbances are sensitive indicators of coupling. Observation of Schumann resonances at the high altitudes of the DEMETER spacecraft signal that the transparency of the ionosphere to such signals caused in the lower atmosphere is still badly understood, as is the possible transparency of the ionosphere to electromagnetic waves caused in the magnetosphere and propagating down to Earth. An example is the recent observation of leakage of auroral kilometric radiation to the Earth's surface.

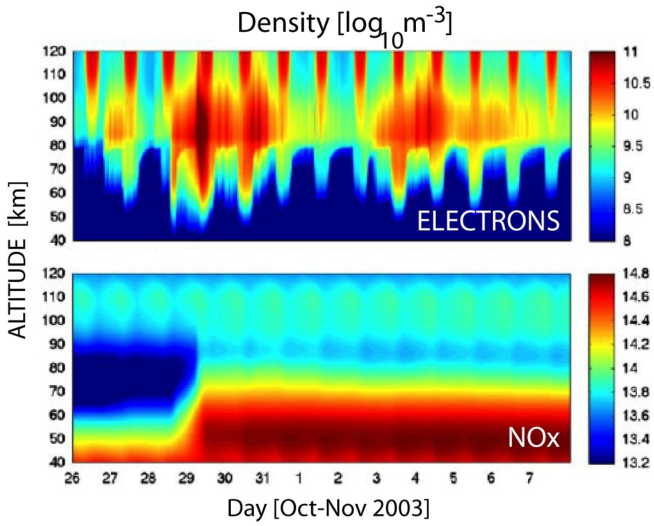

Figure 4. The generation of NOx from electron precipitation as calculated from a reaction model in atmospheric chemistry fort he period October-November 2003. The electron precipitation events (upper panel) cause an accumulation of NOx over a longer period with maximum around ~40 km altitude, an altitude tht is crucial for interaction with ozone (courtesy Esa Turunen).

Highlights on young scientists

Following atmospheric tides from the ground to space

Scott England
Space Sceiences Laboratory, University of California Berkeley, CA, USA

Scott England

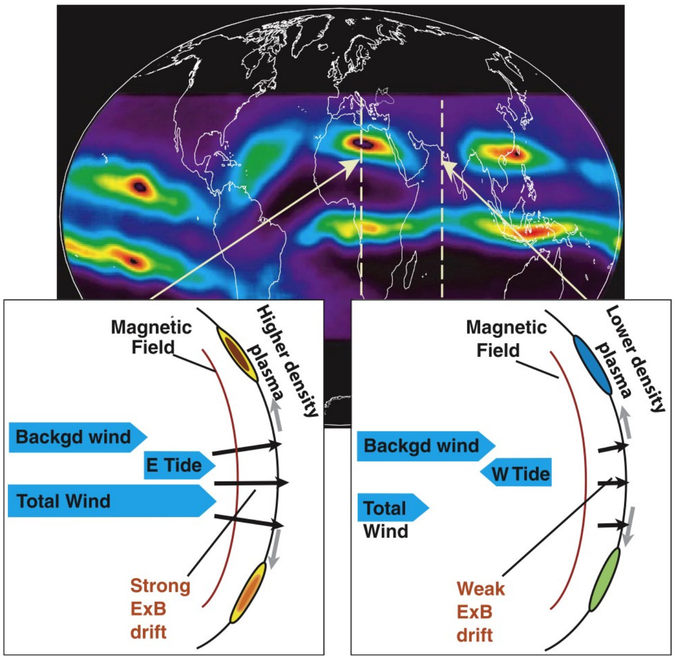

Figure 1. The non-migrating tide—E-region dynamo mechanism originally proposed to explain the wavenumber-four structure seen in the ionosphere.

I arrived at Berkeley in 2005 when Eiichi Sagawa and Thomas Immel made their now well-known discovery of the wavenumber-four signature in the equatorial ionosphere. This was observed as a persistent variation in the equatorial ionospheric anomaly (EIA), with four peaks in longitude when considered in a fixed local time frame.

The 90º longitudinal scale and persistence of this feature pointed to an internal driver, rather than magnetospheric or solar influences. The explanation we proposed was that an atmospheric tide could modify the E-region dynamo. This would then modify the uplift of plasma near the equator and hence modify the EIA (Figure 1). If true, this would represent a coupling from the lower atmosphere tidal source to the near-earth space environment.

I had the privilege to work on the early characterization of the ionospheric response using the IMAGE and TIMED satellites, the first detection of the change in the E-region daynamo, the plasma uplift near the equator and linking these to the observed tides. I have also been working on modeling the coupling between tides and the ionosphere via a variety of mechanisms – dynamic, electro-dynamic and photochemical – across a wide range of altitudes (Figure 2).

The emerging picture is one of a closely coupled atmosphere-ionosphere system, the net effect of which is the wavenumber-four signature. This not only produces this striking feature, but provides us with a stringent test of our understanding of all the communication pathways between the atmosphere and ionosphere.

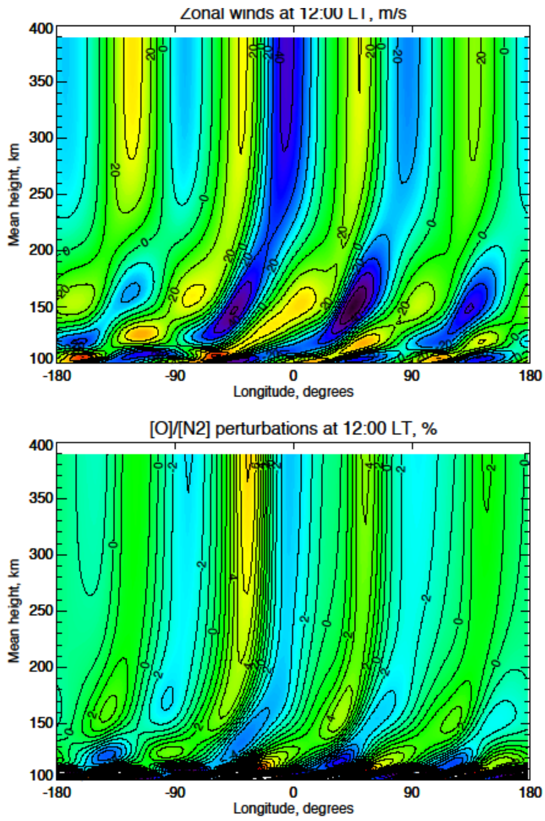

Figure 2. The impact of non-migrating tides on thermospheric winds and composition may extend throughout the entire thermosphere as simulated by the TIME-GCM.

Short News 1

TG4 New Project “Thunderstorms and Geospace”

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In the past two decades the understanding of atmospheric electricity made a great progress by regional and global mappings of lightning discharge with ground-based and spaceborne instruments and by discoveries of unrecognized phenomena, such as TLEs and TGFs. Here we focused the following topics to connect different altitudes both via electromagnetic processes and via dynamic processes relating to discharges.

1) Investigate dynamical effect of thunderstorm activity in the middle and upper atmosphere, including WAVE-4 structures.
2) Investigate the effect of electrical discharges on ion/electron density in the ionosphere and atmospheric constituents.
3) Establish the global electric circuit model, covering the surface, atmosphere, ionosphere and magnetosphere.
4) Investigate the relationship between high energy particles and thunderstorms.
5) Investigate the relationship between thunderstorm and solar activities. (collaborating with TG1)

Short News 2

Announcement; World Day Campaign

Scott England
Space Sciences Laboratory, UC Berkeley, CA, USA

Recent studies have demonstrated that the global-scale low-latitude ionosphere exhibits spatial and temporal periodicities that match planetary wave and tidal forcing in the thermosphere. To investigate this, we are planning a campaign to study wave forcing simultaneously with the day-to-day variability of the ionosphere. A major commitment has been made by URSI-ISWG through their World Day program. The Arecibo, Jicamarca and Millstone radars will operate from 1st • 10th August 2011 in support of our effort. We hope to combine these with other observations for a full diagnosis of the driver and response. Further details can be found at
http://sprg.ssl.berkeley.edu/~england/worldday.html.

Upcoming meetings related to CAWSES-II TG4

Conference	Date	Location	Contact Information
The 4th IAGA/ICMA/CAWSES-II TG4 Workshop on Vertical Coupling in the Atmosphere-Ionosphere System	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/
AOGS2011	Aug. 8-12, 2011	Taipei, Taiwan	http://www.asiaoceania.org/
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/

The purpose of this newsletter is to make more communications among scientists related to the CAWSES-II Task Group 4 (particularly between those of the atmosphere and the ionosphere). **The editors would like to invite you to submit the following articles to the TG4 newsletter.**

Our newsletter has four categories of the articles:

1. Articles— ~500 words and four figures (maximum)
   on campaign, ground observations, satellite observations, modeling, workshop/conference/symposium report, etc
2. Highlights on young scientists— ~200 words and two figures
   on the young scientist's own work related to CAWSES-TG4
3. Short news— ~100 words
   announcements of campaign, workshop, etc
4. List of planned workshop

Category 2 (Highlights on young scientists) starts from this issue. This helps both young scientists and TG4 members to know each other. Please contact the editors for recommendation of young scientists who are willing to write an article on this category.

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This newsletter is also available on the web at
http://www.cawses.org/wiki/index.php/Task_4