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14. ABSTRACT

This report results from a contract tasking University of Crete as follows: The contractor will investigate irregular plasma physical processes in the mid-latitude ionosphere. Proposed research will focus on four topics: 1) Formation and morphology of sporadic E layers (Es). 2) Plasma physics of instabilities and irregularities inside Es. 3) The role of unstable sporadic E in the generation of mid-latitude Spread F. 4) A new VLF experiment in Crete to perform measurements and studies of lightning-induced precipitation in the ionospheric D region over Europe.

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RADIO WAVE STUDIES OF IRREGULAR IONOSPHERIC PHENOMENA AT MIDLATITUDE

Final Progress Report

C. Haldoupis
Iraklion, December 31, 2004

A basic science proposal entitled "Radio wave studies of irregular ionospheric phenomena at midlatitude", was granted a special contract (SPC) award (F8655-03-1-3028) by the European Office of Aerospace Research and Development (EOARD). The contract was signed in May 2003 and its duration was set to be 20 months, that is, untill the end of December 2004. The present report summarizes the progress made during the entire period of the project.

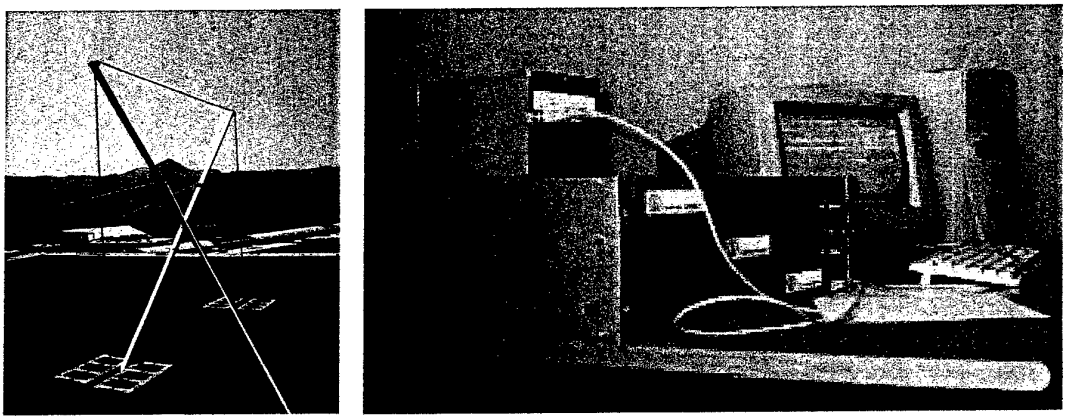
Summary of project objectives.

The scope of the original proposal was to carry out basic research on the plasma physics and electrodynamics of irregular ionospheric phenomena which are known to occur at midlatitudes. More specifically, it was proposed to study : 1) the properties and mechanisms relating to the formation and destabilazation of the midlatitude sporadic E layers (E_s) and the physical processes which define the effects of neutral atmospheric dynamics on plasma layering in the ionospheric E region, 2) the relationship between the unstable E_s and midlatitude spread F, and 3) the lower ionosphere effects on VLF (very low frequency) electromagnetic wave propagation during thunderstorm-related sprite activity and radiation belt electron precipitation events. Although the proposed research was mainly experimental it also included some theoretical work and numerical modeling.

The proposed topics were all within the research activities of the **Ionospheric Physics Laboratory** at the Department of Physics, **University of Crete** (IPL-UC), pursued also in collaboration with other groups from European Institutions (University of Bath, UK; University of Oulu, Finland; Universite de Rennes, France; Institute of Physics of the Earth, Russia), Canadian (Univeristy of Saskatchewan), and American Universities (University of Cornell and Stanford University). Since the main goal was to perform basic research, the effort focused on the production of new scientific knowledge and results of high quality and originality which can be disseminated to the scientific community though their publication in well known Journals and presentation in international conferences. The present EOARD contact turned out to be vital for the ionospheric research activities carried out at the University of Crete.

Experimental tasks.

Installation and operation of a multi-channel, narrow-band VLF receiver. A new VLF receiver station was established in Crete during July of 2003 as a joint project between the IPL-UC and the University of Stanford. The computer-controlled receiver and its operation software was provided by the University of Stanford whereas the personal computer and data acquisition card and the GPS time receiver was provided by the IPL-UC. The system monitors 6 VLF links, one from a transmitter in Puerto Rico and five from West European transmitters, and measures the amplitude and phase of the received signals with 20 ms time resolution. This VLF receiver station detects propagation "signatures" in the signal amplitude and/or phase caused by impulsive ionospheric changes in the nighttime D region plasma during conditions of atmospheric lightning.



The Crete VLF Receiver Station (Loop antenna and equipment)

Participation in the EuroSprite 2003 campaign. The Crete VLF receiver installation was completed in time in order to collect data in support of the summer 2003 European Sprite Detection Campaign in France (*EuroSprite* 2003). The receiver operated continuously since July 18, 2003 and thus accumulated a large and valuable data set, which are available for analysis to both partners, the IPL-UC and University of Stanford. Also, the last year or so, special software has been designed and implemented for the analysis of the Crete receiver VLF observations.

SESCAT Interferometry and high time resolution measurements. SESCAT (the Sporadic E Scatter (Doppler radar) experiment in Crete) operated for the summer 2003 in interferometer mode which allowed the collection of additional backscatter data. These data are presently analyzed in order to study the plasma instabilities and electrodynamics of unstable sporadic E layers. After about September 15, 2003 the SESCAT operation program was modified to allow the system to perform high time resolution measurements in an effort to detect transient ionospheric responses relating to atmospheric lightning and meteoric impacts into the atmosphere. We wish to stress that the maintenance and operation of SESCAT would not have been possible without the support of EOARD through the present SPC.

The Ionospheric SESCAT Doppler radar system in Crete, Greece

CADI measurements in Crete. A Canadian Advanced Digital Ionosonde (CADI) was set up briefly during August 2003 in order to test its operational state using a single dipole antenna that responds between 3 and 5 MHz. Unfortunately, soon afterwards, several hardware malfunctions occurred which did not allow the collection of observations for the proposed correlative studies between spread F and unstable sporadic E. The system remains out of function at present because the repairing costs are prohibitive.

ULF recordings in Crete. The EOARD funds helped to continue operation of a sensitive pulsation magnetometer in Eastern Crete (that belongs to the University of Oulu, Finland), which records electromagnetic noise in the 0.5 to 12 Hz range. These data can be used to supplement the VLF measurements for the purpose of studying lightning-produced impulsive electromagnetic emissions and the ionospheric response during sprite occurrences.

Summer 2004 joint SESCAT/digisonde data collection campaign. An observational campaign for E region backscatter measurements (using SESCAT) concurrently with Digisonde observations (made in Athens by Dr. A. Belehaki using the Athens National Observatory digital sounder) was undertaken from the beginning of June to the end of September, 2004. The purpose of these measurements was to correlate ionospheric E region backscatter with ionogram recordings in an effort to investigate the morphological properties and variability of sporadic E as well as issues of electrodynamic coupling between unstable E layers and midlatitude spread F. The observations are presently analyzed and studied.

Software development for interferometer data analysis. Over the years we have developed a rather versatile software analysis package of SESCAT observations. The last year, further work has been done which expanded the software options and capabilities. I particular a module was developed that allowed the computation of neutral winds from E region backscatter Doppler and interferometric observations.

Scientific progress and Publications.

With the support of the present EOARD contract, and in line with the proposed actions, our research effort continued over the last 20 months, also in collaboration with other groups. This resulted to several highly original papers which were submitted for publication in well known scientific journals, that is, Journal of Geophysical Research, Annalles Geophysicae, Journal of Atmospheric, Solar and Terrestrial Physics, and Geophysical Research Letters . From these papers, five (5) are already published, three (3) are accepted for publication, and two (2) are under review. Note that the present EOARD SPC award is acknowledged in all 10 papers, although work on two of these papers had started prior to the initiation of the present SPC. In addition, there have been three (3) short papers published in conference proceeding, in which the support of EOARD SPC is also acknowledged. A total of 10 papers were presented in international scientific conferences.

Next we provide a list of the resulting publications followed by a summary of their scientific contribution. More details can be found in the attached reprints and pre-prints of these papers.

1) ***Haldoupis C., M. C. Kelley, G. C. Hussey, and S. Shalimov, Role of unstable sporadic E layers in the generation of midlatitude spread F, Journal of Geophysical Research, Vol., 108(A12), 1446, doi: 10.1029/2003JA009956, 2003.***

There is growing experimental evidence to suggest that mesoscale spread F is linked to the occurrence of mid-latitude coherent backscatter from patchy sporadic-E layers, which are unstable to the gradient-drift and Farley-Buneman plasma instabilities. To validate this suggestion, we have compared E-region backscatter and spread-F ionosonde recordings from about a hundred days of joint operation during summer and found a one-to-one relation in the occurrence of both phenomena. Also, mid-latitude backscatter studies over the last few years have shown the existence of enhanced electric fields inside patchy sporadic E. These are believed to be polarization fields set up locally by neutral winds that transport the plasma patches horizontally, and by the relatively large Hall-to-Pedersen conductivity ratios at E-region altitudes. Moreover, mid-latitude echoes were found to be associated with mostly westward-drifting sporadic-E patches with typical scale lengths from 10 to more than 100 km and perturbed eastward electric fields from a few to maybe more than 10 to 15 millivolts per meter. We propose that the enhanced polarization fields set up inside unstable sporadic-E patches can easily map up the magnetic field lines to the F region and thus contribute to the formation of mid-latitude spread F. This new mechanism for spread-F generation is basically an image process that can account for key observational properties of the phenomenon. These include the rapid plasma upwelling and the abrupt changes in height (uplifts) of the F layer, as well as the scale sizes involved and morphological characteristics.

2) ***Kelley, M. C., C. Haldoupis, M. N. Nicolls, J. J. Makela, A. Belehaki, S. Shalimov, and V. K. Wong, Case studies between the E and F regions during unstable sporadic E conditions, Journal of Geophysical Research, Vol., 108(A12), 1447, doi: 10.1029/2003JA009955, 2003.***

Simultaneous F region airglow, E region coherent–scatter radar, and ionosonde observations made in Greece during summer sporadic E season in 2002. In this paper we report on two case studies during which patchy sporadic E layers were accompanied by midlatitude spread F, coherent VHF radar echoes (including two stream echoes), and travelling ionospheric disturbances registered by the airglow instrument. We argue that these events give strong evidence that polarization electric fields are built up in the E region and are mapped upward

to the F region, creating rising and falling regions in the bottomside plasma. The resulting structure creates conditions for midlatitude spread F, as detected by the ionosonde. This correlation between patchy sporadic E and midlatitude spread F is further supported in a companion paper. Upward coupling of this sort is particularly efficient in regions of F region plasma uplift and airglow depletion, since the F region Pedersen conductivity is low which reduces the electrical load on the E region generator.

3) ***Haldoupis, C., D. Pancheva, and N. J. Mitchell, A study of planetary wave periodicities present in midlatitude sporadic E layers, Journal of Geophysical Research, Vol., 109, A02302, doi: 10.1029/2003JA010253, 2004.***

The diurnal and semidiurnal atmospheric tides are known to be of fundamental importance in the formation of midlatitude sporadic E layers, acting through their vertical windshear forcing of the long-living metallic ions in the lower thermosphere. Also, recent studies suggested that planetary waves play a role on sporadic E generation as well, a fact that went unnoticed in the long-going research of sporadic layers. In this paper a methodology is employed to investigate the tidal and planetary wave periodicities imprinted onto sporadic E critical frequencies foEs. In this approach, standard analysis techniques used in neutral atmospheric dynamics are applied on foEs time series obtained during summertime when sporadic E occurrence is nearly continuous. It is shown that, besides the dominant and known 24- and 12-hour tidal periodicities in foEs there is often a weaker terdiurnal (8-hour) oscillation present as well. In addition, there are planetary wave periodicites in foEs with periods near the normal Rossby modes, that is, 2, 5, 10 and 16 days. It is also found that the tidal oscillations in foEs undergo a strong amplitude modulation with periods comparable to the dominant planetary wave periodicities present in the data. Our results are in line with recent findings based on a single event study which suggested that sporadic E layers are affected indirectly by planetary waves through their nonlinear interaction and modulation of the atmospheric tides at lower altitudes. The close relationship between neutral wave dynamics and midlatitude sporadic E periodicities suggests that the ionosonde data can be used as an alternative means of studying tidal and planetary wave characteristics and their climatology in the lower thermosphere.

4) ***Haldoupis, C., T. Neubert, U. S. Inan, A. Mika, T. H. Allin, and R. Marshall, Subionospheric early VLF signal perturbations observed in one-to-one association with sprites, Journal of Geophysical Research, Vol., 109, A10303, doi: 10.1029/ 2004JA010651, 2004.***

Observations on the night of July 21, 2003 of the ionospheric effects of a thunderstorm in Central France are reported. From 0200 to 0315 UT, a camera system in the Pyrenees Mountains captured 28 sprites, triggered by +CG lightning as observed by the French METEORAGE lightning detection system. A narrowband VLF receiver located on Crete, at about 2200 km southeast of the storm, observed subionospheric VLF signals from six ground-based transmitters. The amplitude of one of the VLF signals, originating at a transmitter located ~150 km west of the storm and passing through the storm region, exhibited rapid onset perturbations occurring in a nearly one-to-one relationship with the optical sprites. These "Early" VLF events are consistent with a process of narrow-angle forward scattering from a volume of enhanced ionization above the storm with lateral sizes larger than the VLF radio wavelength. The many +CG and -CG discharges that did not produce sprites, were also found to not be associated with detectable VLF amplitude perturbations, even though some of these discharges reached relatively large peak currents. The rapid onsets of several of the sprite-related VLF perturbations were followed by relatively long onset durations, ranging from about 0.5 to 2.5 s, indicating that these events were Early but not "fast". These "Early/slow" events may suggest a slow process of ionization build-up in the lower ionosphere, following intense lightning discharges that also lead to sprites. A limited number of Early VLF perturbation events were also associated with whistler-induced electron

precipitation events, or classic Trimpi perturbations, undoubtedly produced by the precipitation of electrons due to whistler-mode waves injected into the magnetosphere by the same lightning flash that led to the production of the sprite.

5) ***Hussey, G. C., C. Haldoupis, A. Bourdillon, J. Delloue, and J. T. Wientz, Midlatitude E region bulk motions inferred from digital ionosonde and HF radar measurements, Annales Geophysicae, 22, 3789, 2004.***

In the mid-latitude E region there is now evidence suggesting that neutral winds play a significant role in driving the local plasma instabilities and electrodynamics inside sporadic E layers. Neutral winds can be inferred from coherent radar backscatter measurements of the range-/azimuth- time-intensity (RTI/ATI) striations of quasi-periodic (QP) echoes, or from radar interferometer/imaging observations. In addition, neutral winds in the E region can be estimated from angle-of-arrival ionosonde measurements of sporadic-E layers. In the present paper we analyze concurrent Ionosonde and HF coherent backscatter observations obtained when a Canadian advanced digital ionosonde (CADI) was operated under a portion of the field-of-view of the Valensole high frequency (HF) radar. The Valensole radar, a mid-latitude radar located in the south of France with a large azimuthal scanning capability of 86° (26 ° E to 58 ° W), was used to deduce zonal bulk motions of QP echoing regions using ATI analysis. The CADI was used to measure angle-of-arrival information in two orthogonal horizontal directions and thus derive the motion of sporadic-E patches drifting with the neutral wind. This paper compares the neutral wind drifts of the unstable E patches as determined by the two instruments. The CADI measurements show a predominantly westward aligned motion, but the measured zonal drifts are underestimated relative to those observed with the Valensole radar.

6) ***Neubert, T. T. Allin, E. Blanc, T. Farges, C. Haldoupis, A. Mika, S. Soula, L. Knutsen, O. Van Velde, R. Marshall, U. Inan, J. Boer, and A. Hughes, Journal of Atmospheric and Solar-Terrestrial Physics, in Press, 2005.***

During the northern hemisphere summer of 2003 a sprite observation campaign was conducted from southern Europe and the magnetically conjugate region in South Africa. The campaign brought together a wide variety of instrumentation to investigate the effects of sprites on the mesosphere, and to search for signatures of the relativistic electron acceleration process in the magnetically conjugate hemisphere. Measurements in Europe included optical video imaging from a remote-controlled semi-automatic camera system located at the Observatoire du Pic du Midi in the Pyrenees mountains in southern France, infrasound observations in France, and ULF-HF electromagnetic observations from a number of locations in Europe. The measurements in South Africa included observations of optical emissions and VLF electromagnetic waves. The campaign was successful, with more than 100 sprites observed during 10 storms. The paper gives an overview of the campaign and some results. They include : (1) the fisr clear identification of infrasound from sprites, allowing independent (of optical observations) estimates of the energy input to the mesosphere, (2) the first observations suggesting sprites can be triggered by intracloud lightning, a result that underscores the need for considering the complete thunderstorm source field from both the cloud-to-ground discharges and the intacloud discharges feeding them, and (3) a clear one-to-one relationship with sprites and early VLF events, suggesting that VLF ground transmitter signals can be an important tool for estimating ionization and relaxation of ionised structures in sprites. No signatures of relativistic electrons were identified in the conjugate hemisphere.

7) ***Bourdillon, A., C. Haldoupis, C, Hanuise, Y. LeRoux, and J. Menard, Long duration meteor echoes charatcerized by Doppler spectrum bifurcation, Geophysical Research Letters, In Press, 2005.***

We report on a new category of long lasting meteor echoes observed occasionally with HF and VHF radars. These meteoric returns, which have lifetimes from many seconds to a few minutes, are characterized by a distinct Doppler spectral signature showing a pronounced Doppler bifurcation which includes narrow bands of discrete Doppler velocities, often of opposite polarity. The large signal to noise ratios and the narrowness of the spectra imply that Bragg scattering cannot be the generation mechanism, therefore these echoes do not associate with the long living meteor-induced backscatter (MIB) from the unstable lower E region. A reasonable interpretation needs to explain both the Doppler spectrum bifurcation and the long echo duration. As such, we propose the idea of a structured vertical wind shear in the lower E region which traps different fragments of a meteor trail plasma in the same way that sporadic E layers form. These trail parts inside the shear-related wind profile may act as relatively long-lasting meteoric reflectors moving with different Doppler velocities, also of opposite polarity.

8) ***Shalimov, S., and C. Haldoupis, E region wind-driven electrical coupling of patchy sporadic E and spread F at midlatitudes, Annales Gephysicae, under review, 2005.***

This paper investigates the role of neutral winds on the generation of relatively large polarization electric fields across patchy sporadic E layers, which then map upward to the F region to create conditions for medium-scale spread F. The calculations are based on an analytical model that uses the current continuity equation and field-aligned current closures to the F region in order to describe quantitatively a Hall polarization process inside sporadic E plasma patches during nighttime. In applying this model we use experimentally known values for E and F region conductances, the ambient electric fields and the prevailing neutral winds, in order to estimate the polarization fields that build up inside sporadic E. It is found that the relatively strong west-southwest neutral winds during summer nighttime, they can provide the free energy for the generation of sizable polarization electric fields which have comparable eastward and north-upward components and reach values of several mV/m. Given that the sporadic E patches have sizes from a few to several tens of kilometers, the polarization fields can map easily to the F region bottomside where they impact **E** x **B** plasma uplifts and westwards bulk motions, in line with key observational properties of medium-scale spread F. However, the present simple model needs further development to include also wind forcing of the F region plasma and possible polarization processes inside spread F.

9) ***Haldoupis, C., C. Meek, N. Christakis, D. Pancheva, and A. Bourdillon, Ionogram Height-Time-Intensity observations of descending sporadic E layers, Journal of Atmospheric and Solar-Terrestrial Physics, under review, 2005.***

A new methodology of ionosonde height-time intensity (HTI) analysis is introduced which allows the investigation of sporadic E layer (E_s) vertical motion and variability. This technique, which is useful in measuring descent rates and tidal periodicities of E_s, is applied on ionogram recordings made during a summer period from solstice to equinox. On the average, the ionogram HTI analysis revealed a pronounced semidiurnal periodicity in layer descent and occurrence. It is characterized by a daytime layer starting at 120 km near 06 hours LT and moving downwards to altitudes below 100 km by about 18 hours LT when a nighttime layer appears above at ~125 km. The latter moves also downward but at higher descent rates (1.6 to 2.2 km/h) than the daytime layer (0.8 to 1.5 km/h). The nighttime E_s is weaker in terms of critical sporadic E frequencies (*foEs*), has a shorter duration, and tends to occur less during times close to solstice. Here, a diurnal periodicity in E_s becomes dominant. The HTI plots often show the daytime and nighttime E_s connecting with weak traces in the upper E region which occur with a semidiurnal, and at times terdiurnal, periodicity. These, which are identified as upper E region descending intermediate layers (DIL), play an important role in initiating and reinforcing the sporadic E layers below 120-125 km. The observations are interpreted by considering the downward propagation of wind shear convergent nodes that associate with the $S_{2,3}$ semidiurnal tide in the upper E region and the

$S_{1,1}$ diurnal tide in the lower E region. The daytime sporadic E layer is attributed to the confluence of semidiurnal and diurnal convergent nodes, which may explain the well known pre-noon daily maximum observed in *foEs*. The nighttime layer is not well understood, although most likely it is associated with the intrusion of the daytime DIL into the lower E region due to vertical wind shear convergence nodes descending with the semidiurnal tide. Finally, the descent rates of sporadic E may not always represent the vertical phase velocities of the tides, especially in the nighttime layer.

10) Mika, A., C. Haldoupis, R. A. Marshall, T. Neubert, and U. S. Inan, Subionospheric VLF signatures and their association with sprites, observed during EuroSprite 2003, Journal of Atmospheric and Solar-Terrestrial Physics, In press, 2005.

In this study, VLF observations during *EuroSprite-2003* are analyzed in connection with many sprites observed above thunderstorms in central France. The sprites were detected with a sensitive camera from the Observatoire du Pic du Midi in the Pyrenees overlooking storms monitored by the French national lightning detection network. The VLF observations were made in Crete, Greece with a narrowband receiver, and in Nançay, France with a broadband receiver. The storms were in the vicinity of a VLF transmitter (HWV) whose signal was received on Crete, arriving over a great circle path that cut through the storms to the southeast. The Nançay broadband receiver was located near HWV to the northeast of the transmitter. This setup provided a unique observational set for investigation. The receiver in Crete observed early VLF perturbations in nearly one-to-one association with the sprites, which endorses the findings of earlier work based on *EuroSprite-2003* observations from a single storm. While part of the sprite-related VLF perturbations were of the early/fast type, many classified as "early/slow" having onset durations up to ~2 s and thus suggesting a new mechanism at work which may cause a slow build up of ionization after a sprite. The only elve in the data set was found to associate also with an early/fast VLF perturbation. Moreover, the analysis showed basically no early VLF events to occur in relation to the numerous ±CG discharges that did not lead to sprites. Bandpass filtering of the broadband VLF signal revealed that only about 5% of the sprites were escorted by early VLF perturbations, possibly due to backscatter, seen at Nançay concurrently with the much stronger Crete VLF events caused by forward scatter. Finally, by using all 131 sprites captured during *EuroSprite-2003,* the time lags of the sprites to the preceding +CG discharges were computed and analyzed. The time-lag distribution had a well defined tail suggesting that at least one third of the sprites observed were lagging the +CG discharges by more than 30 ms up to 300 ms. In addition these "long-delayed" sprites were not accompanied by any radio-sferics during the sprite observation period, in sharp contrast to the short-delayed sprites which were escorted nearly always by enhanced, burst-like, sferic activity. These observations endorse the notion of long delayed sprites reported in past studies, but also show that their occurrence is much more frequent than it was thought before.

Papers published in conference proceedings (EOARD is acknowledged).

1) The role of unstable sporadic E layers in the generation of midlatitude spread F, C. Haldoupis, M. C. Kelley, G. C. Hussey, and S. Shalimov, Proceedings of the 10th International workshop on technical and scientific aspects of MST radar, p. 86-89, Piura, Peru, May 13-20, 2003.

2) Continuous wave interferometer observations of midlatitude E region backscatter, C. Haldoupis, A. Bourdillon, A. Kamburelis, G. C. Hussey, and J. A. Koehler, Proceedings of the 10th International workshop on technical and scientific aspects of MST radar, p. 118-121, Piura, Peru, May 13-20, 2003.

3) Sporadic E layer Dependence on planetary waves. An event study showing an indirect relationship through modulated atmospheric tides, C. Haldoupis and D. Pancheva, Proceedings of the 10th International workshop on technical and scientific aspects of MST radar, p. 164-167, Piura, Peru, May 13-20, 2003.

Papers presented in international conferences the last 20 months

1.) The role of unstable sporadic E layers in the generation of midlatitude spread F, C. Haldoupis, M. C. Kelley, G. C. Hussey, and S. Shalimov, 10th International workshop on technical and scientific aspects of MST radar, Piura, Peru, May 13-20, 2003.

2.) Continuous wave interferometer observations of midlatitude E region backscatter, C. Haldoupis, A. Bourdillon, A. Kamburelis, G. C. Hussey, and J. A. Koehler, 10th International workshop on technical and scientific aspects of MST radar, Piura, Peru, May 13-20, 2003.

3.) Sporadic E layer Dependence on planetary waves. An event study showing an indirect relationship through modulated atmospheric tides, C. Haldoupis and D. Pancheva, 10th International workshop on technical and scientific aspects of MST radar, Piura, Peru, May 13-20, 2003.

4.) A survey of present knowledge of the unstable sporadic E layers at midlatitude, C. Haldoupis, (invited paper), XXIII General Assembly of the International Union of Geodesy and Geophysics, Sapporo, Japan, June 30 – July 11, 2003.

5.) VLF and ULF observations from Crete during sprite occurrences over a thunderstorm in southern France, C. Haldoupis, A. Mika, T. Bosinger, T. Neubert, U. Inan, and T. Wood, 1st European General Assembly of the European Geosciences Union, Nice, France, April 25-30, 2004.

6.) A mechanism for generation of the midlatitude spread F at the mesoscale, C. Haldoupis, 1st European General Assembly of the European Geosciences Union, Nice, France, April 25-30, 2004.

7.) ULF-response at a meridional chain of stations to lightning/sprite events, T. Bösinger, A. Mika, C. Haldoupis, 1st European General Assembly of the European Geosciences Union, Nice, France, April 25-30, 2004.

8.) Observations of VLF perturbations in relation with sprites, and implications, C. Haldoupis, A. Mika, T. Neubert, U. Inan, T. Bössinger, T. Allin, and T. Wood, 2nd IAGA/ICMA Workshop on Vertical coupling in the Atmosphere-Ionosphere System, Bath, UK, July 12-15, 2004.

9.) Tidal and planetary wave forcing of midlatitude sporadic E layers, C. Haldoupis (Invited paper), 2nd IAGA/ICMA Workshop on Vertical coupling in the Atmosphere-Ionosphere System, Bath, UK, July 12-15, 2004.

10.) The European spite 2003 Campaign, M. Rycroft, ... C. Haldoupis, 2nd IAGA/ICMA Workshop on Vertical coupling in the Atmosphere-Ionosphere System, Bath, UK, July 12-15, 2004.

Concluding Comment.

As seen from the present report, a good deal of basic research has been accomplished the last couple of years at the Ionospheric Physics Laboratory, University of Crete, also in collaboration with Universities in Europe and the United States. Besides of being basic, this ionospheric research is also of topical value for space weather issues and applications. We wish to point out that the support provided by EOARD, though its 25000 $US Special research Contract (8655-03-1-3028) award, was absolutely vital for the successful outcome of this work.

This progress report is submitted with the hope that this research effort will be appreciated and that EOARD will recognize the need for the continuation and promotion of the ionospheric research at the University of Crete, and thus continue providing its support. This is particularly important in view of the fact that funding for ionospheric science is basically nonexistent in Greece and even the European Union.