SUMMARY OF RESEARCH REPORT
NASA GRANT # NAG5-10252
(1/14/2001-1/14/2005)
Lower Thermospheric Composition Studies in the Auoral Zone

by

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b. Introduction

This TIMED/CEDAR grant had two major objectives. The GUVI instrument on TIMED should routinely produces maps of the flux of energetic particles and their average energy. However, while those data will be available soon there were no plans to routinely produce the O/N2 ratio in the auroral. Ground-based photometric techniques have been available for years which routinely measure all three quantities in the auroral zone. The first objective of the previous proposal was to use these ground-based techniques to provide some validation for the routine measure of average energy. The second objective was to use the ground-based to data to validate GUVI algorithms for the measure of O/N2 in the auroral zone.

We have made some progress to these goals while we await the release of the properly precessed GUVI data. For now these objectives are being addressed by making use of algorithms by one of us (Doug Strickland of CPI) that are being used for specific GUVI level 1B data sets that contain data coincident with the ground-based measurements. Also we have collected ground-based data from two Alaska sites and they are available on our web site and on the CEDAR website. The details of the progress we have made are discussed below.

CoIs on this proposal were Mark Conde, then at the Univeristy of Alaska, Gray Swenson of the Univeristy of Illinois, and Doug Stricklamd of Computational Physics Inc.

2. Experimental Technique

Photometric instruments have been located at three sites in the auroral zone. Two of the instruments were developed at Aerospace and are nearly identical. They are located at Poker Flat (65.7N,147.4W), and Fort Yukon (66.6N,145.3W) observatories which are separated by a little over 100 km. Each photometer has four channels: the permitted N2+(427.8 nm) first negative group (1NG) 0,1 molecular

band emission also referred to as either the 4278 or the blue emission, the forbidden OI (630.0 nm) atomic oxygen emission line also referred to as the red emission, the permitted O I (844.6 nm) atomic oxygen emission line also referred to as the eight emission, and the permitted N2 (871.0 nm) first positive group (1PG) 2,1 molecular band emission also referred to as the 8710 emission. All four filters are typically sampled every 10 seconds and the integration time on each filter is typically about 1 second. The photometers are looking up the local magnetic zenith and run automatically from dusk to dawn. The procedure for using these data is described in detail in Hecht et al. (1999). All emissions were corrected for backgrounds by subtracting emissions measured during periods of no aurora and by using the data from filters which measured auroral free emission regions. All sky cameras and meridional scanning photometers operated by the University of Alaska are used to help determine cloud free periods and provide a measure of H alpha which can be used to infer the presence of proton aurora. The third site has a similar suite of filters, developed by the University of Illinois, operating at Sondrestrom, Greenland (66N, 56 W). Auxiliary instruments at that site can also be used to infer cloud free periods.

Using techniques developed by CPI and Aerospace and described in Hecht et al. (1999) we use the 8710/blue ratio to correct for atmospheric scattering and then use red/blue vs. 8446/blue to derive the average energy, E, of the precipitating particles and fo, the scale factor which indicates how the atomic oxygen profile in a model atmosphere is scaled. An fo of 1 indicates no composition change while a factor less than 1 indicates depletion of atomic oxygen relative to molecular nitrogen. The 4278 data can be used to infer Q, the particle energy flux.

3. Results

a. Data Availability

The two Alaska photometers became operational in late September of 2001, well before the TIMED launch. Nominally, they operate every night from dusk to dawn. However, a few nights are not available due to instrument problems. Information on the configuration of these instruments is available at

http://gedds.pfrr.alaska.edu/aerospace/installation/index.html

Data are sent nightly to a web site operated by the University of Alaska. Almost a the Poker Flat and Fort Yukon data are available at either

http://gedds.pfrr.alaska.edu/aerospace/pokerflatdata/

or

http://gedds.pfrr.alaska.edu/aerospace/fortyukondata/

or go to

http://gedds.pfrr.alaska.edu/aerospace/

and click on either Poker Flat or Fort Yukon Data sets

Once at either data site one sees the following for example.

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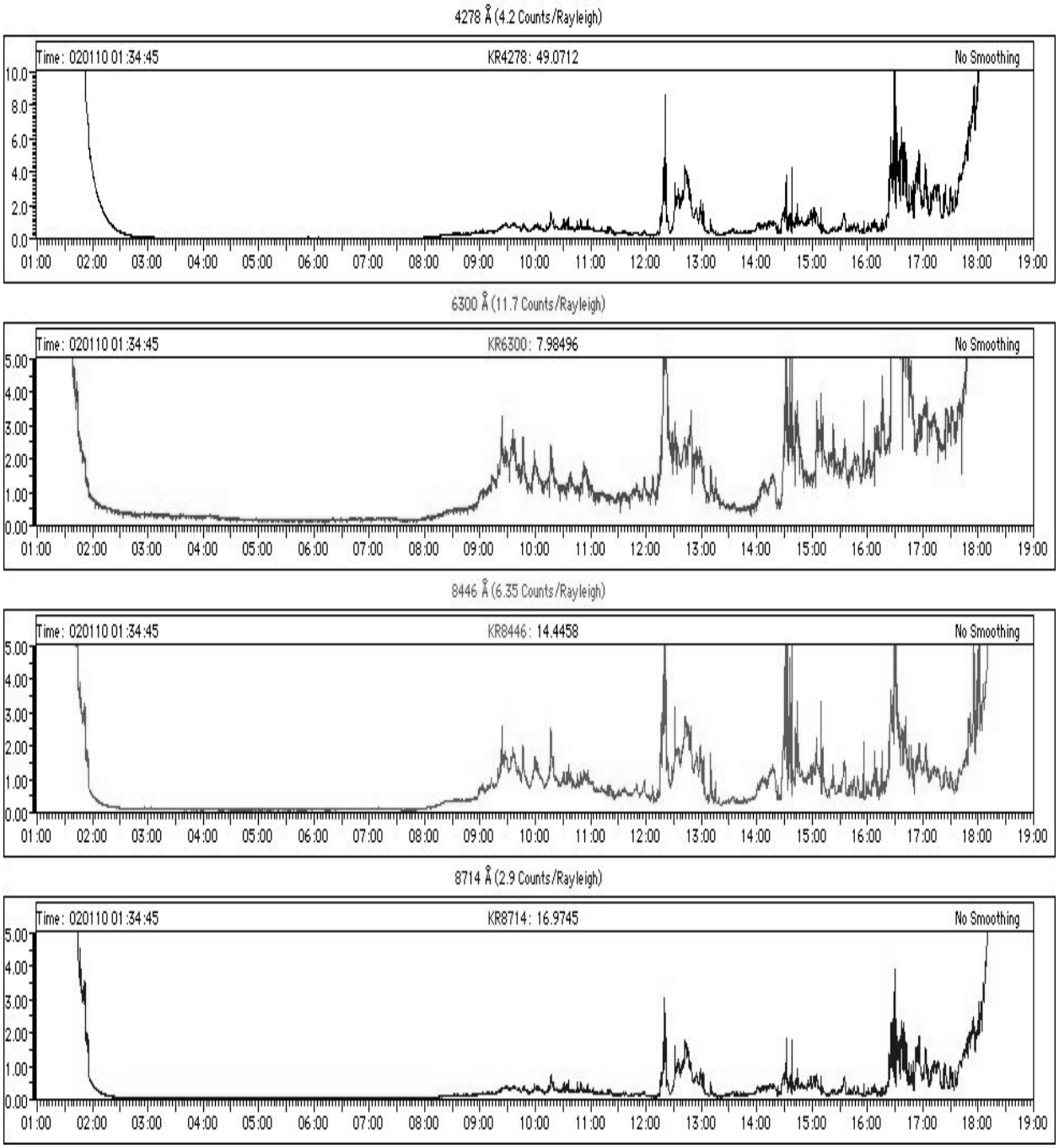
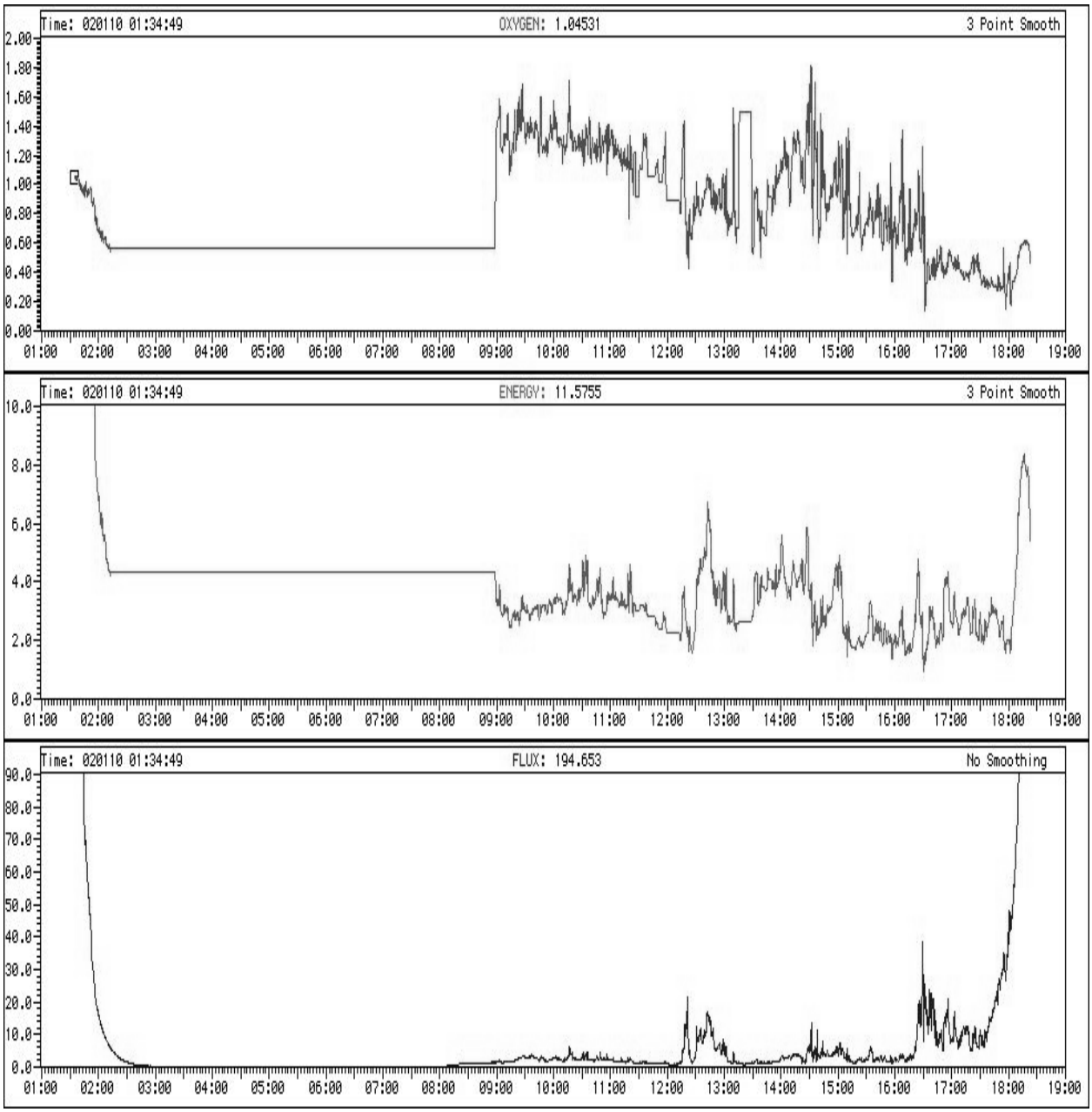
Thursday, April 01, 2004 10:43 PM        <dir> 200403291421
Thursday, April 01, 2004 10:43 PM        <dir> 200403301418
Thursday, April 01, 2004 10:43 PM        <dir> 200403311413
Wednesday, October 27, 2004  4:29 PM     <dir> 200410271627
Thursday, October 28, 2004  4:36 PM      <dir> 200410281635
Friday, October 29, 2004  4:35 PM        <dir> 200410291633
```

Data prior to Apriol 1 2004 has that date because of a change in the data network. After that date the day the data were taken is listed. The last entry is a code which gives the date (yearmonthdaytime) when the data were sent to the website. That date gives the day of year (in UT) when the data were taken. Clicking on that gives a list of files. Clicking on index.html then brings up all the summary plots.



This figure above shows the summary plots for 4278, 6300, 8446, and 8714 from top to bottom respectively. The very steep increases and decreases are sunset and sunrise and those data and the subsequent analysis at those times should be ignored. The figure below shows the result of our standard analysis. The three plots show fo, the average energy, and flux as a function of time for this night.



These are the quick look data. For the purposes of analysis a standard background correction is applied. We have also reprocessed much of the data from 1/02 to 4/02 for Poker Flat using backgrounds appropriate for each night. Nights that are very cloudy or have moonlight contamination are generally excluded. These reprocessed data are available on the CEDAR database at.

http://cedarweb.hao.ucar.edu/instr/p4p.html

Included in this website is a more complete description of the data reduction technique. Summary plots of the reprocessed data are available. The data plots indicate when the sun is below 12 degree solar depression angle, the optimal period for analysis.

The data from Fort Yukon from 1/02 to 4/02 are nearly reprocessed and should be submitted to the CEDAR database shortly. However, on request to james.hecht@aero.org any night of interest for which data are available can be reprocessed.

Data from Sondrestrom with respect to Q are available for much of the last auroral season. This year the fifth filter (8710) was installed and thus similar data to those obtained at Poker and Fort Yukon are available upon request. These requests should be sent to swenson1@uiuc.edu and james.hecht@aero.org

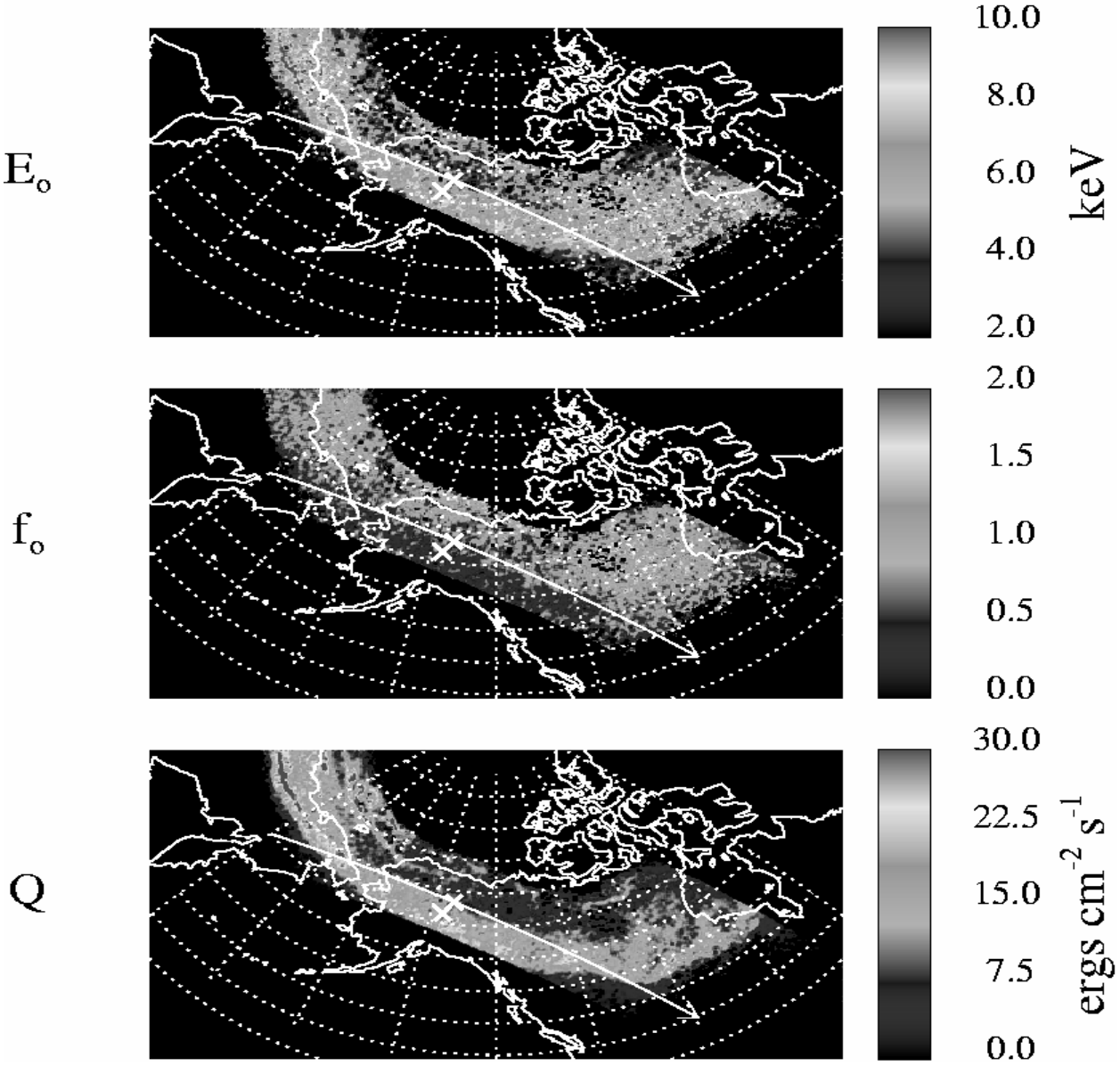
Data for Sondrestrom for the 5 channels (427.8, 557.7, 630.0, 844.6, and 871.5) have been acquired routinely since August, 02. The data summaries are expected to be available on the web site at http://eosl.csl.uiuc.edu under 'Data' and 'Sondrestrom by 2/15/03. Also under Sondrestrom, an allsky OH airglow imager at (6-2) band will be archived, for this same period. The general sky conditions are frequently 'cloudy', but the instruments have been operating routinely. The allsky OH data are being processed as keograms, just as the data from Maui and Socorro are, on the same site for Professors Swenson's other TIMED/CEDAR project. A glance at keograms can be used to define sky clarity by the star fields. There is some photometer data available from the spring, 02, but it is of low quality as the power supply had problems and the counts are uncalibrated. If there is a specific day of interest, email should be sent to swenson1@uiuc.edu.

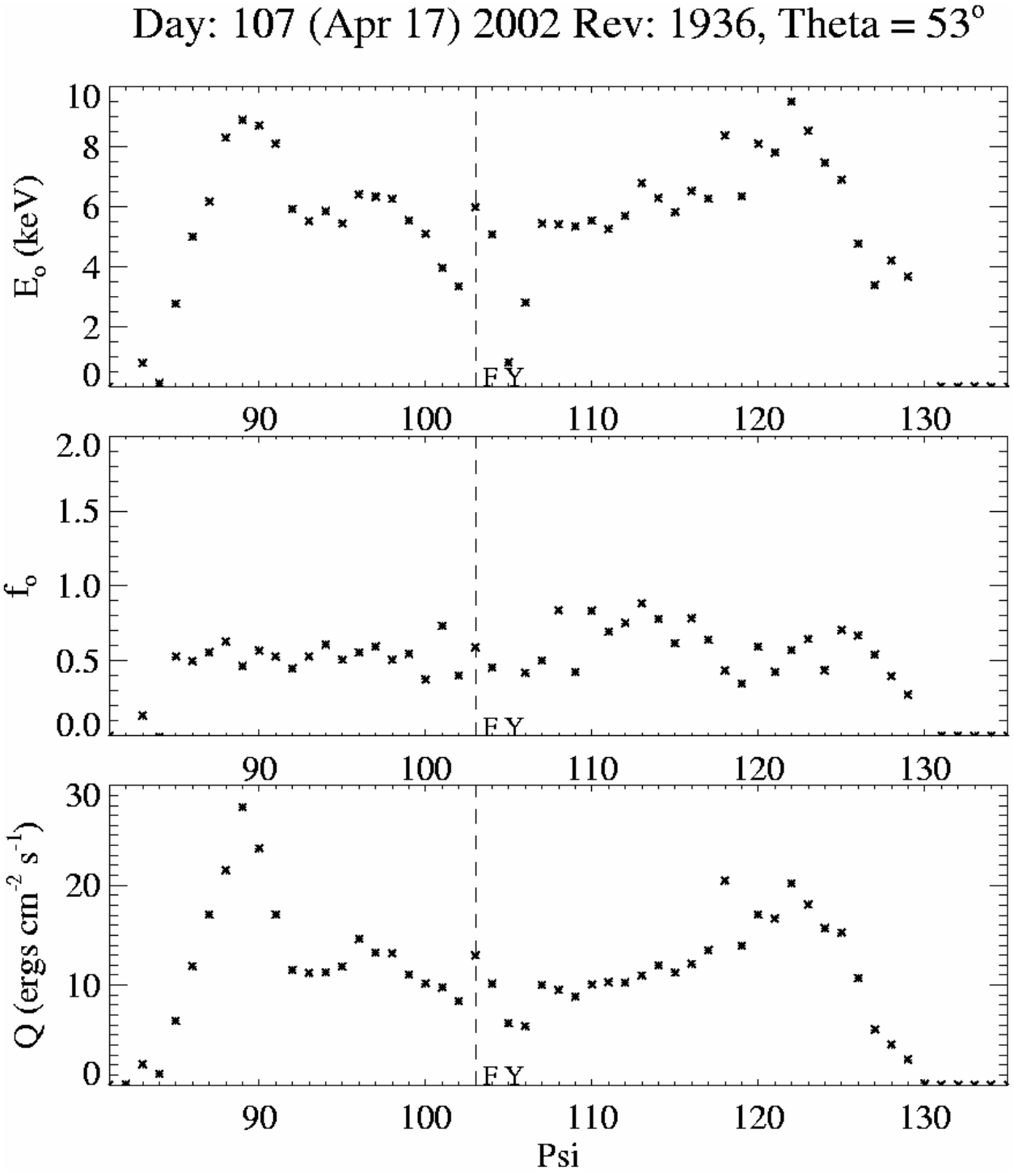
b. GUVI auroral image capability

Recently, CPI had developed the ability to analyze GUVI auroral data and display these results in a way that comparisons can be made with the ground-based data. Here E0 is the characteristic energy of a Gaussian distribution.The next figure shows three product images of the characteristic energy, oxygen scaling factor, and the flux. Two Xs mark the ground-sites. The one without the line through it is at Poker Flat. The one with the line through it is at Fort Yukon. The line plots of these values along the line is shown in the following figure with the position of Fort Yukon marked. A similar plot was constructed for Poker data but is not shown.

Day 107 (Apr 17) 2002, Rev 1936

Coincident GUVI/Ground-based measurements at 11:20 UT

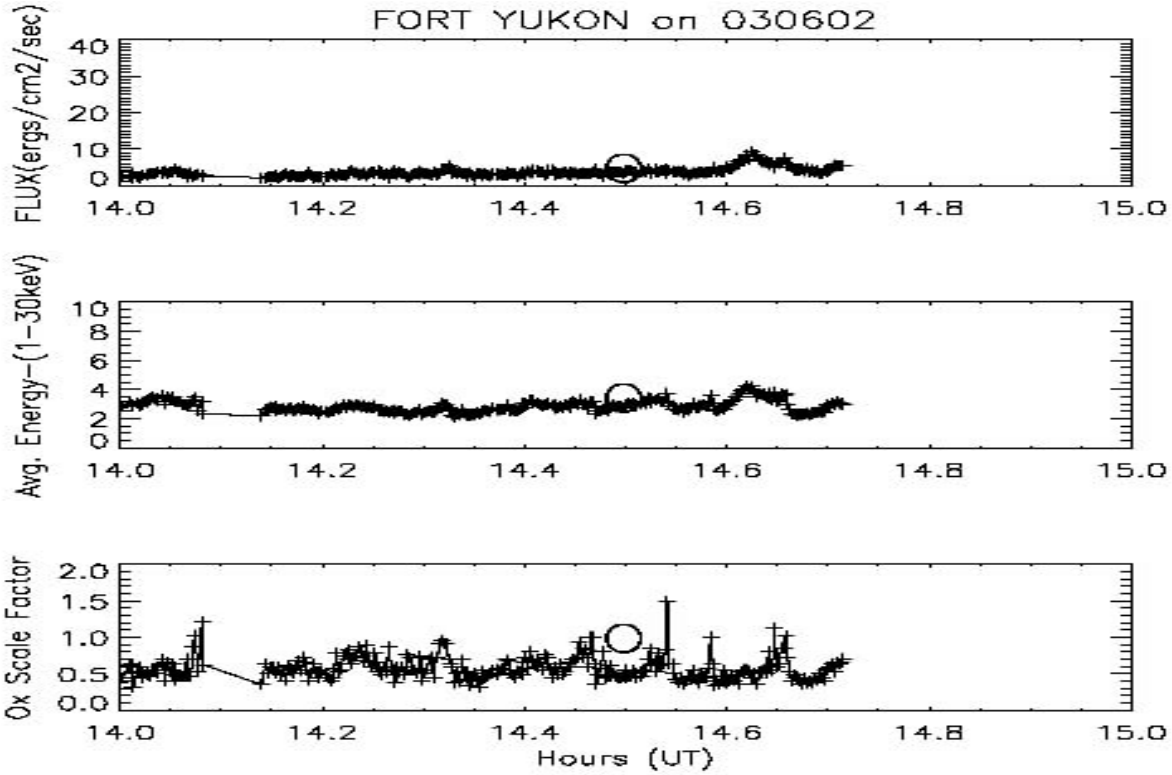


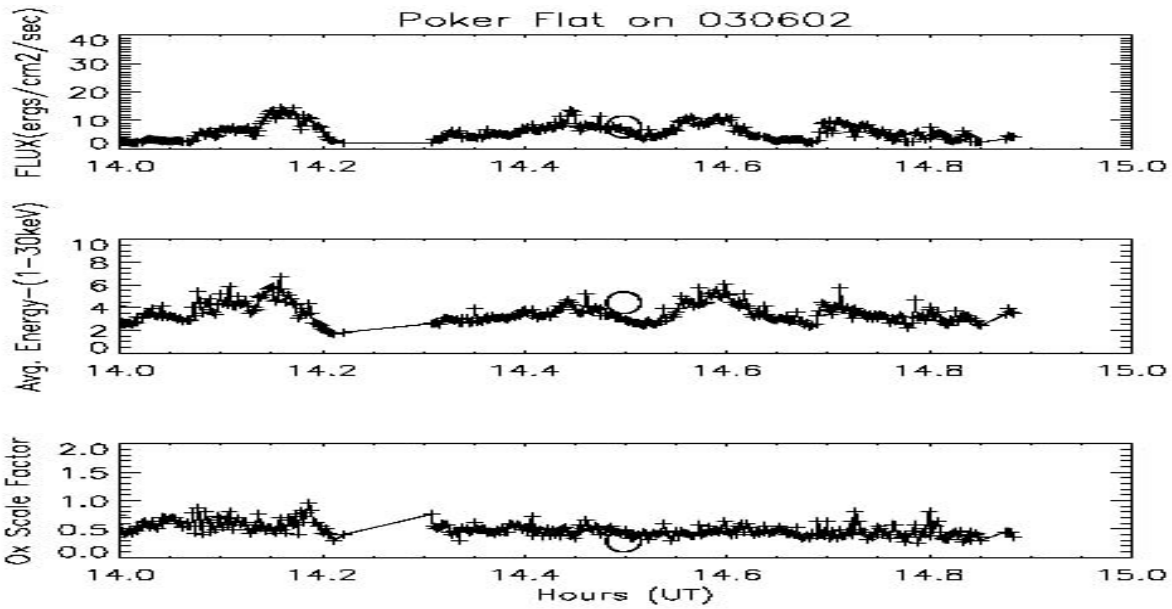


The spatial resolution of the color plots is approximately 30 x 30 km. However, for the line plots some smoothing has occurred and the individual points are separated by about 100 km.

c. Science Results from ground-based and GUVI data

The major results to date were presented at the Fall AGU in December 2002. The presentation was a poster entitled "Composition Changes in the Lower Thermosphere over Alaska from TIMED Ground-Based and GUVI Observations" by J. H. Hecht, D. J. Strickland, and M. G. Conde. Considerable help in reducing the GUVI was provided by M. D. Morrison of the GUVI team who will participate more formally in future presentations of these results. In this effort we compared Q, Eo, and fo from the data obtained from Fort Yukon and Poker for a variety of auroral conditions with an emphasis on periods when there were GUVI overpasses. Unfortunately, due to rather weak aurora for much of Jan-April 2002 and the near twilight orbit of GUVI during the latter half of this period coincidences were sparser than expected. Nevertheless the comparisons are encouraging at this point. The figure below shows one set of comparisons for the early March period. The circle represents the results of the GUVI analysis presented in December. For that analysis averages over combined GUVI pixels (20 by 100 km) were shown.

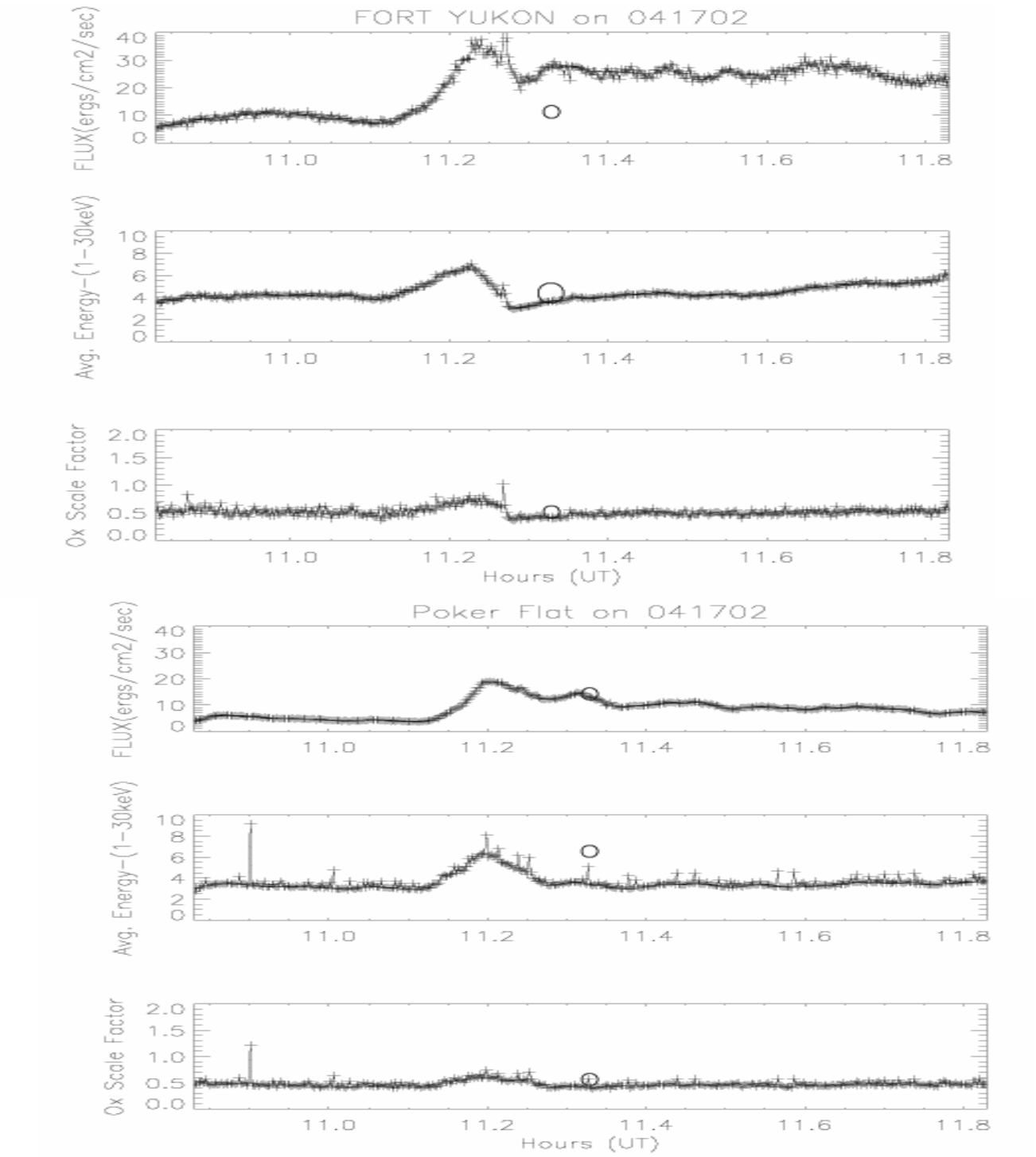




Some of the problems inherent in this initial GUVI analysis can be seen in the analysis of the entire March 5-7th period. The Ap values for March 5-7 were 21, 17, and 9 respectively. The most active period was on March 5th. On that date both sites show fo values close to 1 consistent with the modest activity, which is sporadic at both locations. On the 6th the auroral activity at both sites is more sustained, especially at Fort Yukon. In particular, Fort Yukon shows a significant decrease in fo from above 1 to close to .5 at the end of the night. Poker shows a similar decline. These results suggest that auroral heating is causing significant local composition change associated with substorm activity. On the 7th similar composition changes occur at both sites although recovery of fo towards 1 is occurring at Fort Yukon by 15 UT. One GUVI overpass occurred on the 6th as shown above. The data are in relatively good agreement for the fo at Fort Yukon. However, the ground-based data suggest significant gradients, and thus the data from the large pixel size of GUVI may be subject to those effects.

The use of the new CPI capability is shown in the next example during the April storm day of 4/17 when the Ap value was 62. The storm started at midday on the 17th and continued for several days. The fo values are low, close to 0,5 at both sites on that date. The GUVI overpass data are available only on the 17th. They indicate a larger decrease in fo than in the ground-based data. Only data from the 17th around the GUVI overpass are shown. These comparisons are shown below for both Poker and Fort Yukon. The GUVI data are averaged over three points on the line plots for Fort Yukon (shown above) and Poker (not shown). The height of the circles represents roughly the extremes for the three averaged points. Both the fluxes and the average energy show some differences from the ground-based data. This is not surprising considering that the ground-based field of view is 1 degree (equivalent to about 2 km) while even the smallest GUVI pixel is an order of magnitude larger. Thus, if the aurora is not diffuse and does not completely and uniformly fill the pixel

there will be differences especially in the flux. However, one might expect the oxygen scaling factor to be much closer even with non uniform aurora and indeed those comparisons are promising.



The following are the conclusions from the study presented at AGU supplemented by the recent CPI results. The data presented show a variety of composition changes with respect to the O/N2 ratio in the auroral zone in the lower thermosphere. The results from Poker and Fort Yukon suggest that the scale sizes for composition change due to substorm activity are greater than 100 km as similar results are seen at both stations. Some local differences are seen and need to be investigated. Geomagnetic storm effects also appear to be larger than the 100 km separation of the sites. In a qualitative sense the GUVI and ground-based data are in reasonable agreement. There is some indication of a larger energy being measured by GUVI although this is somewhat biased since we have used the characteristic energy from the GUVI analysis which should be reduced by about 10% to match the definition used in the ground-based analysis. However, more comparisons need to be made. As more data are being obtained this winter it is hoped that such a comparison will be forthcoming.

During the last year of this investigation CPI and Aerospace have worked closely in comparing Q, E, and f0 values between GUVI and the ground-based sites over the 2002 to 2005 period. Suprisingly less than 20 such coincidences occurred over each site. This is due to the constraints of the ground-based sites being cloud free, the Moon being down and aurora present during a GUVI overpass. Fron the UVI perspective large aurora (Q above 10 ergs) are desirable. This comparison is in progress and results should be available shortly during the followon grant to this work.

Dr. Strickland, Dr. Conde and myself also collaborated with Dr. D. Morrsion of APL on comparing GUVI and ground-based photometer results during the period around the large magnetic storm of November 20th 2003. This work showed that the GUVI technique is superior in deriving the effects of auroral precipitation in the E region but can underestimate effects in the F region which can occur if large low energy precipitation events occur. This work was presented at the Fall 2004 AGU as “Composition Change in the Lower Thermosphere during the Great Magnetic Storm of November 20 2003 from TIMED Ground-Based and GUVI Observations” by J. H. Hecht, D. J. Strickland, M. G. Conde, and M. D. Morrison.

Finally, a review article was prepared and is currently in the review process on the application of ground-based remote sensing techniques to inferring auroral energy deposition. This review includes results from the Poker Flat and Fort Yukon systems. This paper is entitled The Application of Ground-based Optical Techniques for Inferring Electron Energy Deposition and Composition Change during Auroral Precipitation Events, by J. H. Hecht, D. J. Strickland, and M. G. Conde. The paper is submitted to JASTP.

4. References Cited

A more complete set will be found on the CEDAR data web page

http://cedarweb.hao.ucar.edu/instr/p4p.html

Hecht, J. H., A. B. Christensen, D. J. Strickland,T. Majeed, R. L. Gattinger and A. Vallance Jones,A Comparison Between Auroral Particle Characteristics and Atmospheric Composition Inferred from Analyzing Optical Emission Measurements Alone and in Combination with Incoherent Scatter Radar Measurements J. Geophys. Res.,104 ,33-44, 1999.

Hecht, J. H., D. L. McKenzie, A. B. Christensen, D. J. Strickland, J. P. Thayer and J. Watermann, Simultaneous observations of lower thermospheric composition change during moderate auroral activity from Kangerlussuaq and Narsarsuaq, Greenland, J. Geophys. Res., 105, 27,109-27,118, 2000.