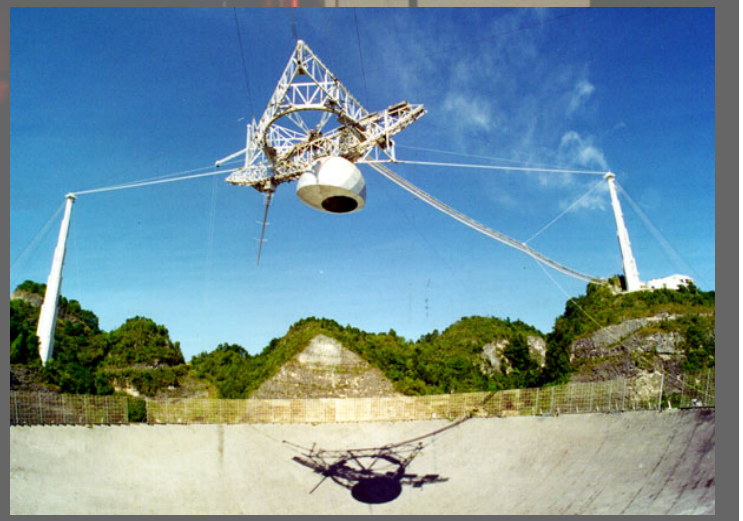
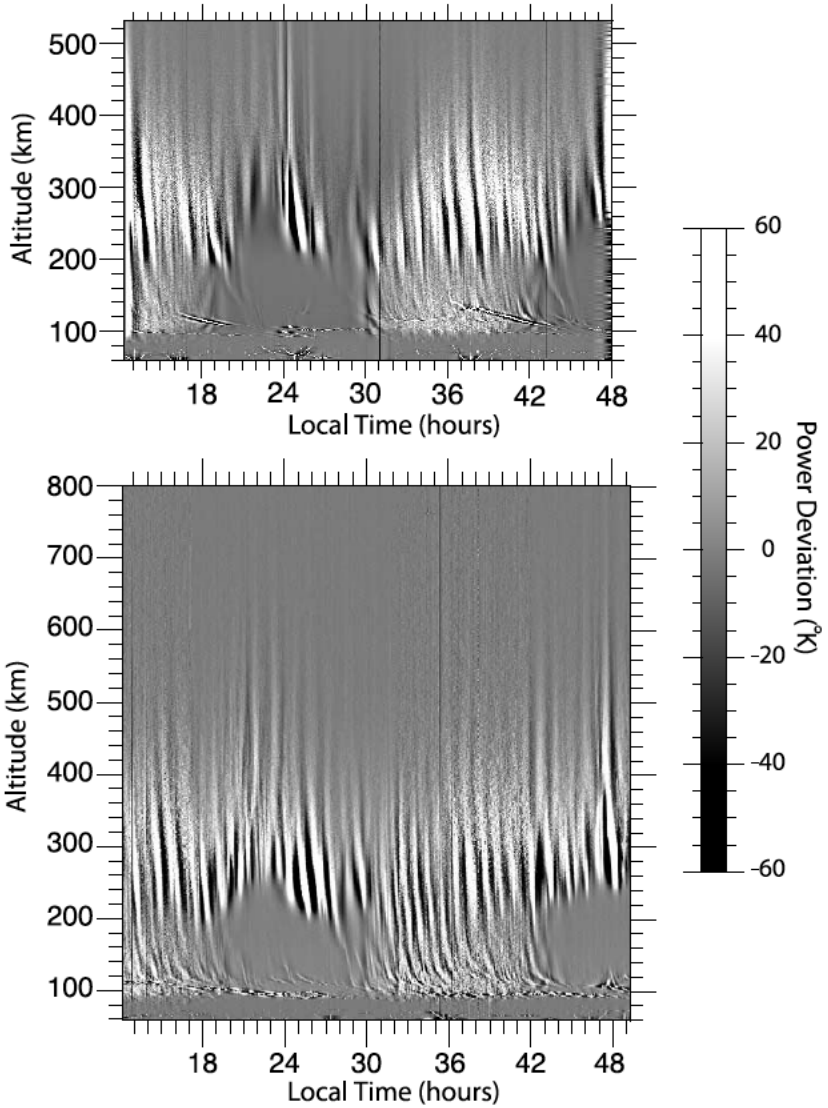
E-region studies using radio and optical techniques at Arecibo

One of the greatest strengths of the Arecibo Observatory that houses the world's most sensitive incoherent scatter radar is the multiple optical instruments that are co-located at the site. These includes three resonance lidars, imagers, photometers and Fabry-Perot systems.

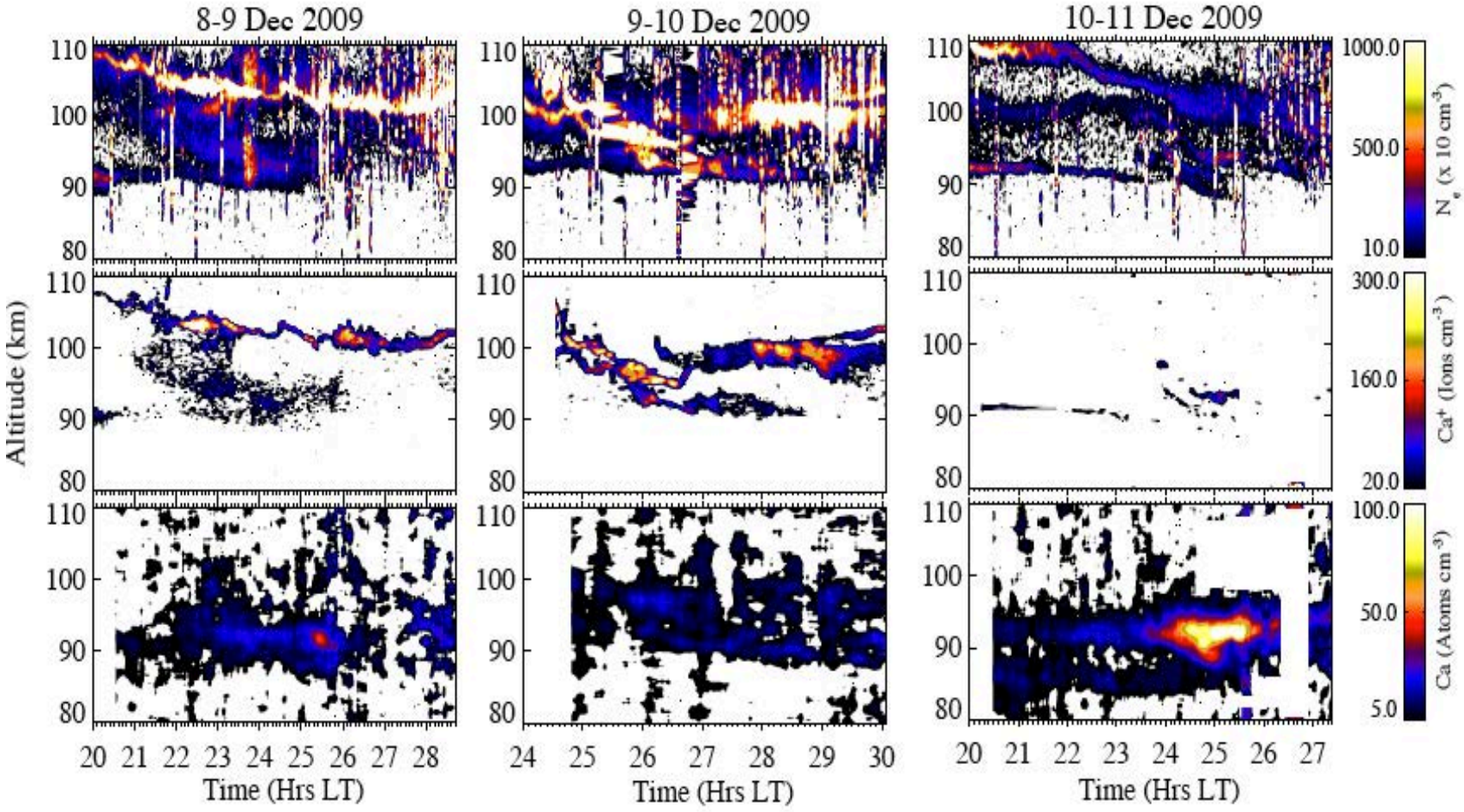


Evidence of Quasi-periodic structures in the E- and F region



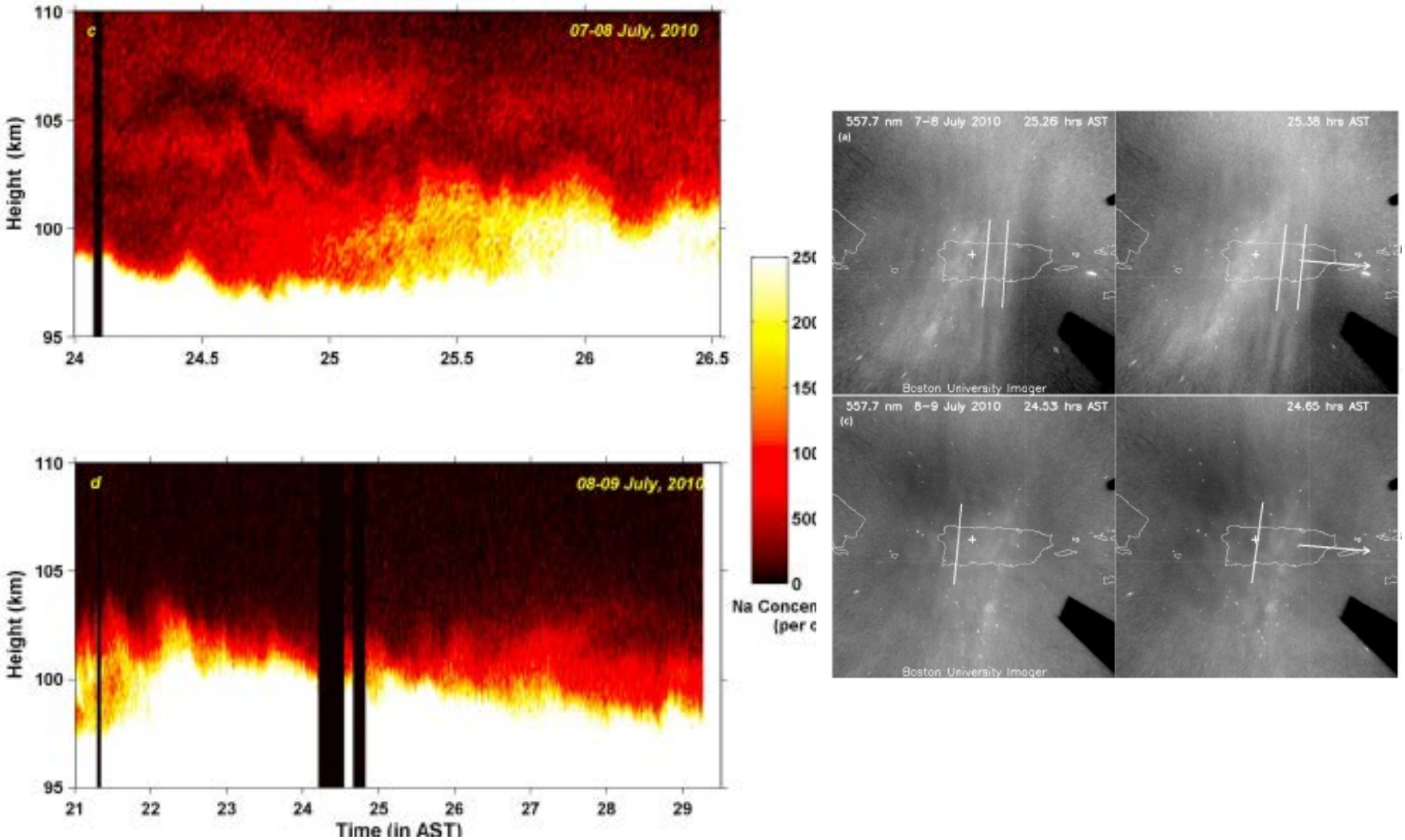
RTI maps of high-pass filtered ISR data in terms of signal power without range square correction and illustrates the waves with quasi-periods ~ 1 hour. More details can be found in *Livneh et al., JGR, 2007*.

Evidence of ion-electron-neutral coupling using simultaneous ISR and lidar Observations



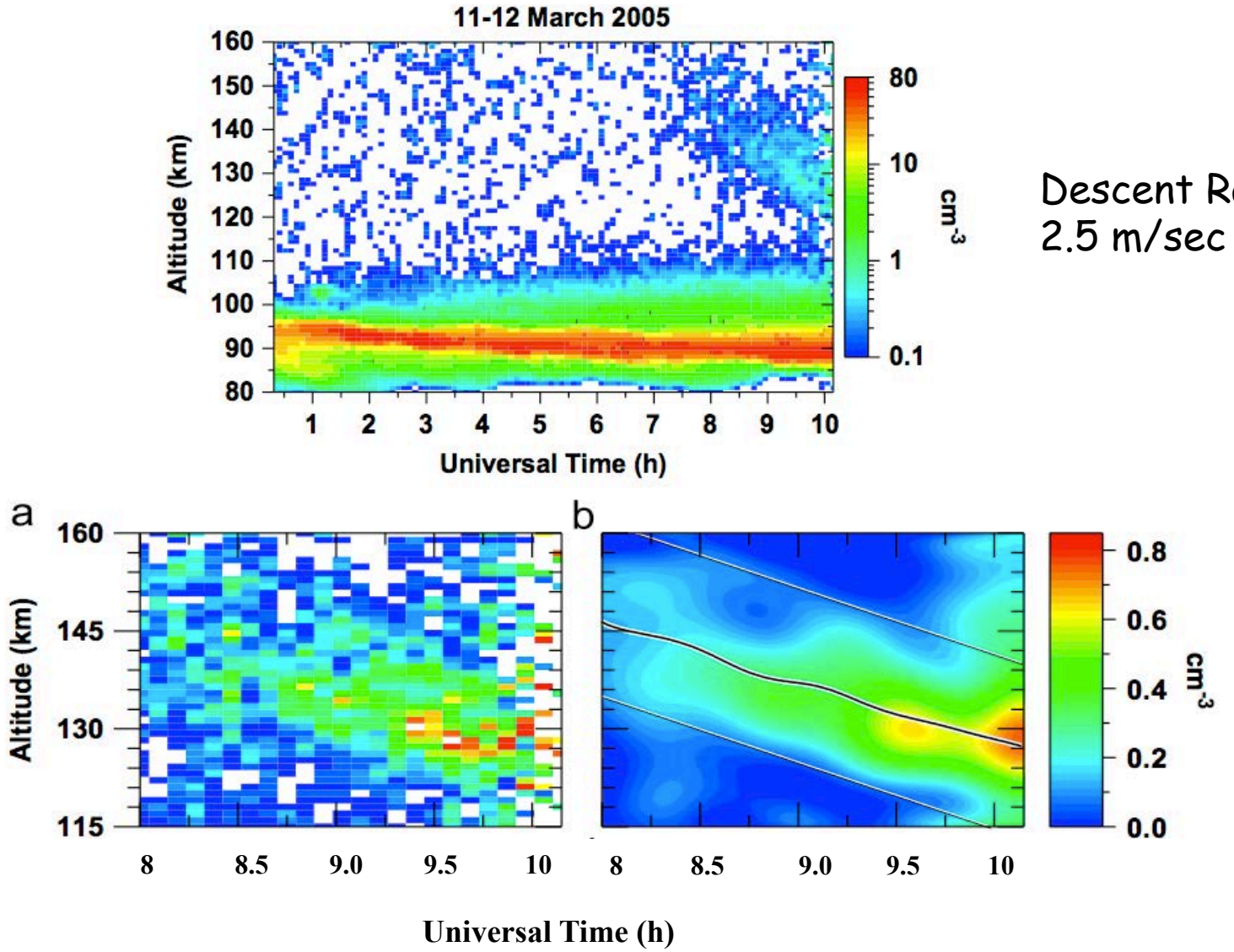
Coordinated measurements electron concentrations (upper), Ca^+ (middle) and Ca (lower) facilitate understanding of mesospheric chemistry and ion-neutral interactions [*Raizada et al., GRL, 2011*].

Influence of dynamical instabilities on the Na layer over Arecibo



The left panel shows HTC maps of Na densities on two consecutive nights. Billows were observed on the first night accompanied by a strong wave activity, which can be seen in the 557.7 nm airglow images in the right panel [*Sarkhel et al, JGR, 2012*].

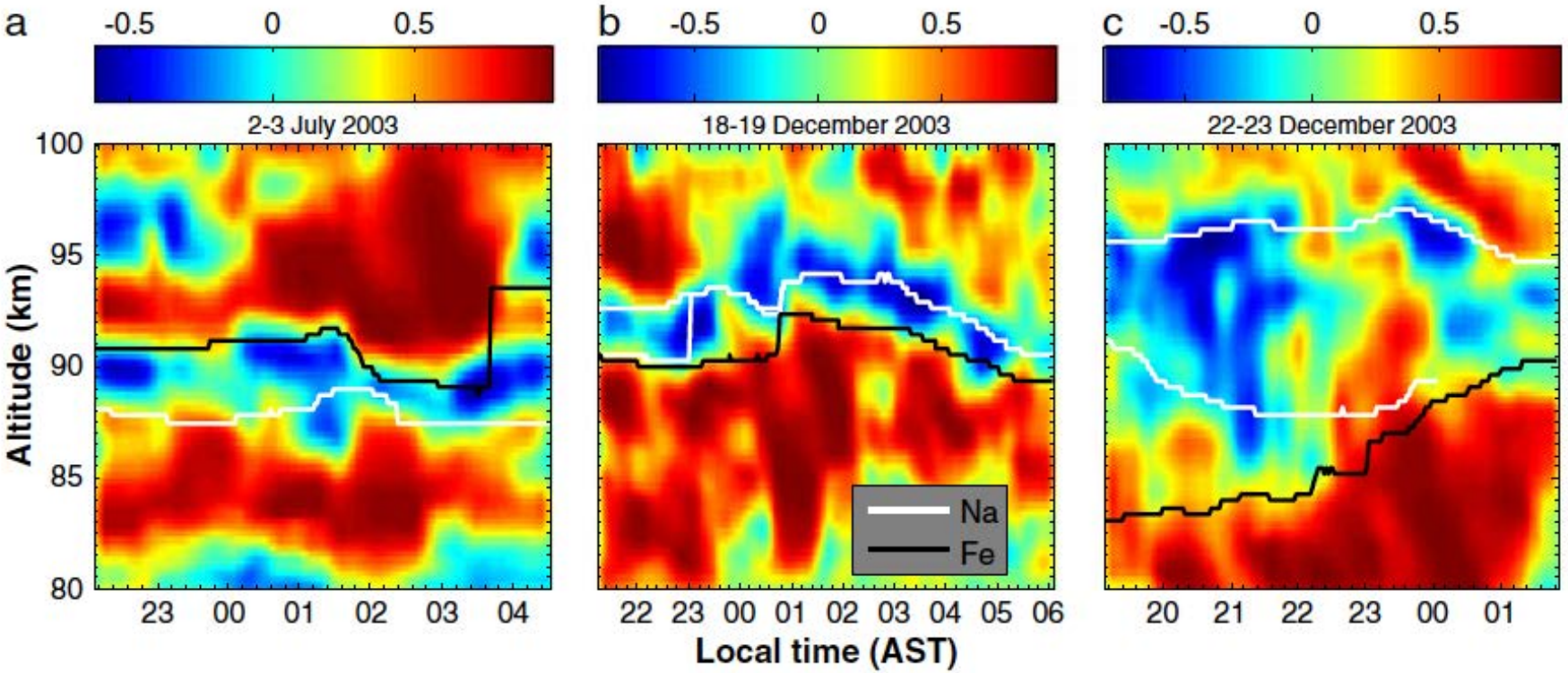
Thermospheric Layers as observed by lidars from Arecibo



Descent Rate :
2.5 m/sec

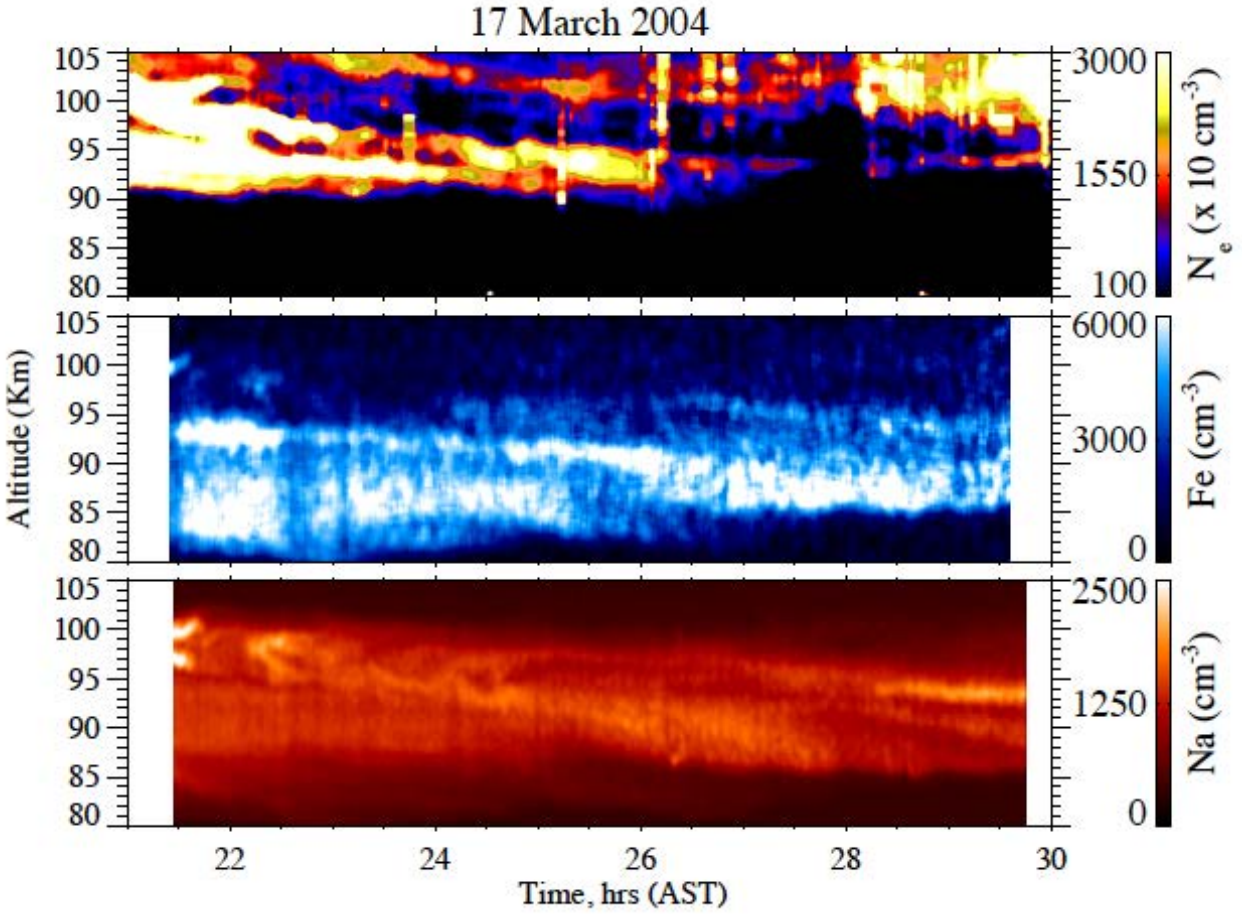
Evidence of high altitude thermospheric K neutral layers as observed using a resonance lidar. Even though the layer is weak, it descends at a rate of a semi-diurnal tide [*Friedman et al., JASTP, 2013*].

Correlative studies between Na and Fe from Arecibo



This figure shows the temporal variation of correlation between Na and Fe with altitude, which was calculated by using a sliding window of 1 hour at each time. Red indicates high correlation while blue represents negative values. Thus, the region where anti-correlation exists is bounded by these two regions with positive correlation and this varies in width and altitude during each night. This behavior has been attributed to gravity wave induced density fluctuations. The superimposed lines represent the altitudes of (a) local minima, and (b & c) local maxima of Na (white) and Fe (black line) densities [*Yue et al., 2013*].

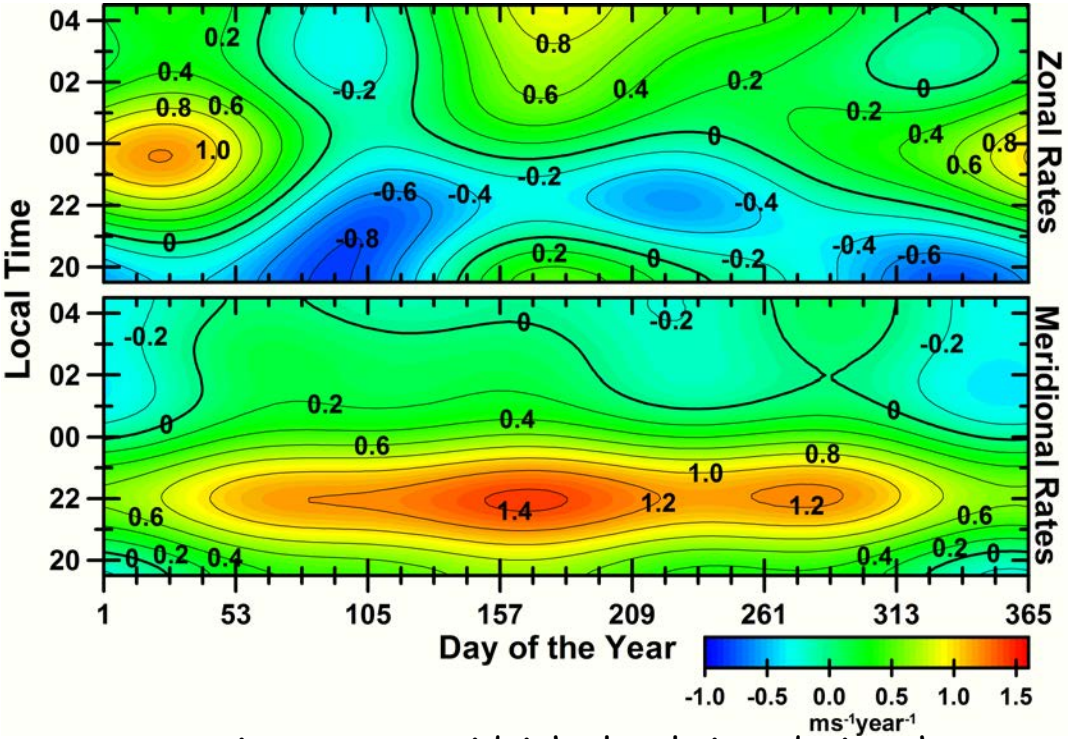
Influence of Sporadic E on the neutral Na and Fe layers at Arecibo



Altitudinal and temopral variations of electrons (top panel), Fe (middle panel), and Na (lower panel) on 17-18 March 2004. Descending C shaped structures are strong in both Na and Ne, but weaker in the case of Fe. This is most likely due to longer lifetimes of Fe^+ as compared to Na, an alkali metal.

Trends in the thermospheric neutral winds (TNW) - 1

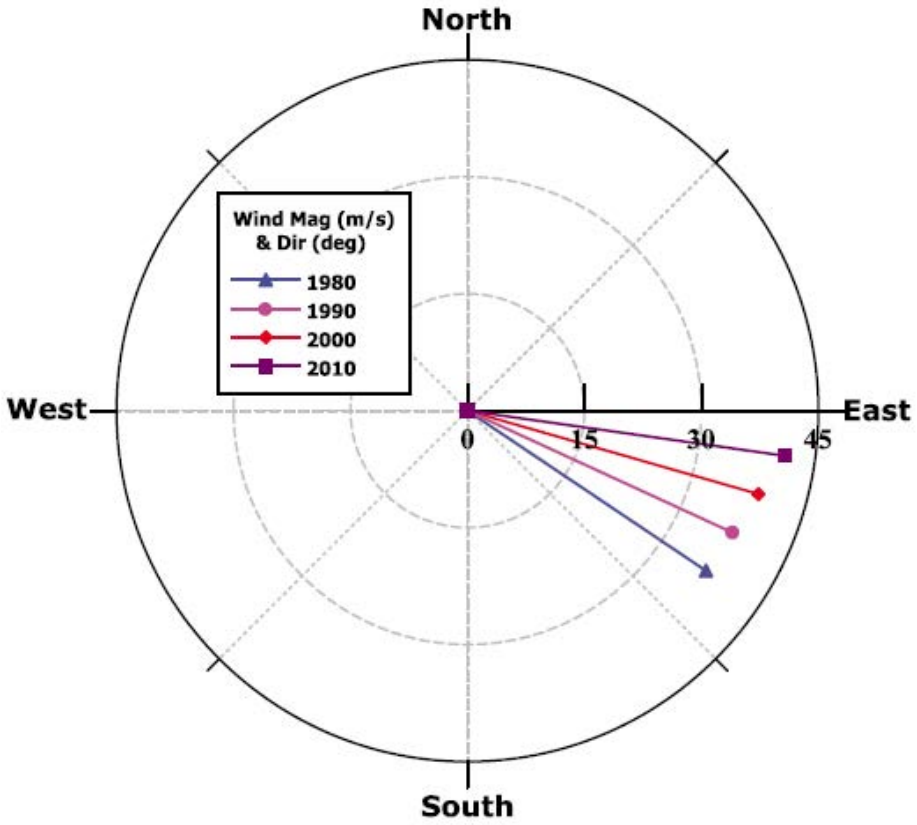
Based on 30 years of Fabry-Perot, Brum et a. (2012) reported that the neutral wind trends over Arecibo are strongly dependent (even as to sign) on the day of year and the time of night.



The figure on the left shows TNW component long-term trend rates arranged by DOY versus LT. During the last 30 years it was detected an increase in the northward component's absolute value, mostly before 01:00–02:00 LT, and with an intensity that is dependent on season. The larger variation before midnight was detected during the summer. During the winter we detected a tendency of the meridional wind to be more southward after midnight local time during the last 30 years The zonal component showed a substantial dependence with season for the long-term variation during the last 30 years. It was found a decrease in the eastward value during the equinoxes before midnight and a strong increase at midnight local time during the summer period.

Brum et al., JGR, 2012

Trends in the thermospheric neutral winds (TNW) – 2
Variation in the Neutral Wind Vector (1980-2010)

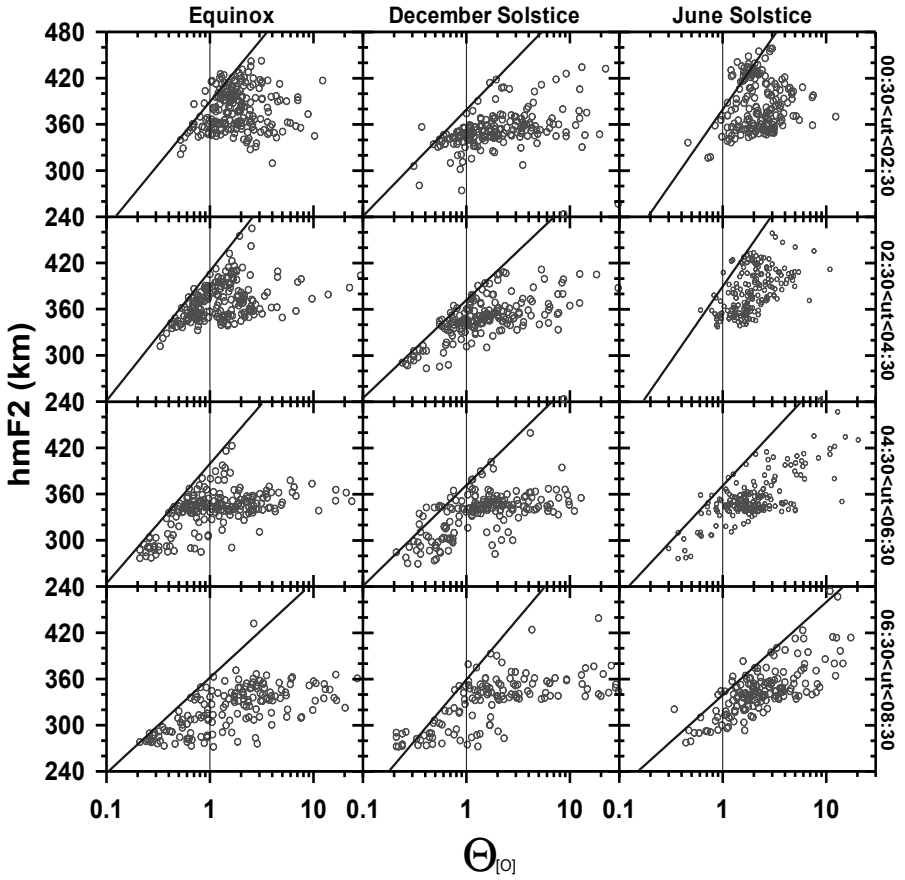


The figure on the left shows de variation of the vector component of the thermospheric neutral wind derived from the trends over 30 years, the vector direction has rotated counterclockwise by approximately 26° while its magnitude has only slightly increased, maintaining an average value of roughly 40 m/s (Tepley et al., 2011).

Tepley et al., 2012

Oxygen densities derived from Arecibo ISR (or MSIS vs. Burnsider Factor and alternative hypothesis for the $O\text{-}O^{+}$ cross section adjustment)

Ion-momentum studied using incoherent scatter radar (ISR) data involves the estimation of neutral density and/or theoretical collision cross section. The current results presents the computed Burnside factor based on ISR data and a neutral wind empirical model based on local Fabry-Perot data. As result, a remarkable dependency of the Burnside factor (or Oxygen densities rate - $\Theta_{[O]}$) with season and altitude were found (on going reserch).



Work in Progress

References

- Livneh, D. J., I. Seker, F. T. Djuth, and J. D. Mathew, Continuous quasiperiodic thermospheric waves over Arecibo, J. Geophys. Res.,, VOL. 112, A07313, doi: 10.1029/2006JA012225, 2007.
- Tepley, C. A.; Robles, E.; Garcia, R.; Santos, P. T.; Brum, C. M. & Burnside, R. G. Directional trends in thermospheric neutral winds observed at Arecibo during the past three solar cycles *Journal of Geophysical Research: Space Physics, 116*, PP.A00H06. DOI: 10.1029/2010JA016172, 2011.
- S. Raizada, C. A. Tepley, N. A. Aponte and E. Cabassa, Characteristics of neutral Calcium, Ca^+ and their relationship to sporadic Ion/Electron Layers at Arecibo, *Geophys. Res. Letts.*, Vol. 38, l09103, doi:10.1029/2011GL047327, 2011.
- Brum C.G.M, Tepley C.A, Fentzke J.T., Robles E, dos Santos P.T. and Gonzalez SA, Long-term changes in the thermospheric neutral winds over Arecibo: Climatology based on over three decades of Fabry-Perot observations, Journal of Geophysical Research: Space Physics. Vol. 117(A2), pp. A00H14. DOI: 10.1029/2011JA016458, 2012.
- S. Sarkhel, S. Raizada, J. D. Mathews, S. Smith, C. A. Tepley, Francisco Rivera, S. A. Gonzalez, Identification of large scale billows-like structure in the neutral Na layer over Arecibo, , J. Geophys. Res., Vol. 117, A10301, doi: 10.1029/2012JA017891, 2012.

References

- S. Raizada, C. A. Tepley, B. P. Williams, R. Garcia, Summer to winter variability in mesospheric calcium ion distribution and its dependence on Sporadic E at Arecibo, *J. Geophys. Res.*, Vol. 117, A02303, doi:10.1029/2011JA016953, 2012.

- Friedman J. S., X. Chu, C. G. M. Brum, X. Lu, Observation of a thermospheric descending layer of neutral K over Arecibo, J. A. Sol-Terrs. Phys., 104, 253–259, 2013.
- Yue., X., Q. Zhou, S. Raizada, C.A. Tepley, and J. F. Friedman, Relationship between mesospheric Na and Fe layers from simultaneous and common-volume lidar observations at Arecibo, *J. Geophys. Res* DOI: 10.1002/jgrd.50148, 2013.

Collaborators/Users

- Asti Bhatt (asti.bhatt@sri.com)
- Alok Taori (alok.taori@gmail.com)
- Abdu M., (abdu@dae.inpe.br)
- Bifford Williams (b.p.williams@gats-inc.com)
- Christiano Brum (cbrum@naic.edu)
- Carlos Martinez (??)
- David Hysell (david.hysell@cornell.edu)
- David Fritts (dave@gats-inc.com)
- Diego Janches (diego.janches@nasa.gov)
- Frank Djuth (fdjuth@geospace-research.com)
- I. S. Batista (??)
- Irina Strelnikova (strelnikova@iap-kborn.de)
- John Plane (J.M.C.Plane@leeds.ac.uk)
- Jorge Gonzalez (gonzalez@me.ccny.cuny.edu)

Collaborators/Users

- John D. Mathews (jdm9@psu.edu)
- John Noto (noto@sci-sol.com)
- Jonathan Friedman (jonathan@naic.edu)
- Josef Hoeffner (Hoeffner@iap-kborn.de)
- Larisa P Goncharenko (lpg@haystack.mit.edu)
- Markus Rapp (
- Michael Nicolls (michael.nicolls@sri.com)
- Michael P. Sulzer (sulzer@naic.edu)
- Nestor Aponte (aponte@naic.edu)
- Olga Mayol (omayol@ites.upr.edu)
- Paulo Faugundes (fagundes@univap.br)
- Pedrina Terra Santos (pterra@naic.edu)
- R. L. Watersheid (
- Robert Kerr (robert.kerr@sri.com)
- Ruben Delgado (delgado@umbc.edu)

Collaborators/Users

- Steve Smith (smsm@bu.edu)
- Sumanta Sarkhel (sarkhel.fph@iitr.ac.in)
- Shikha Raizada (shikha@naic.edu)
- Qihou Zhou (zhouq@miamioh.edu)
- Xinzhao.Chu (Xinzhao.Chu@colorado.edu)
- Y. T. Morton ()