Multi-point Satellite Measurements in the Ionosphere-Thermosphere System Enabled by New Technologies

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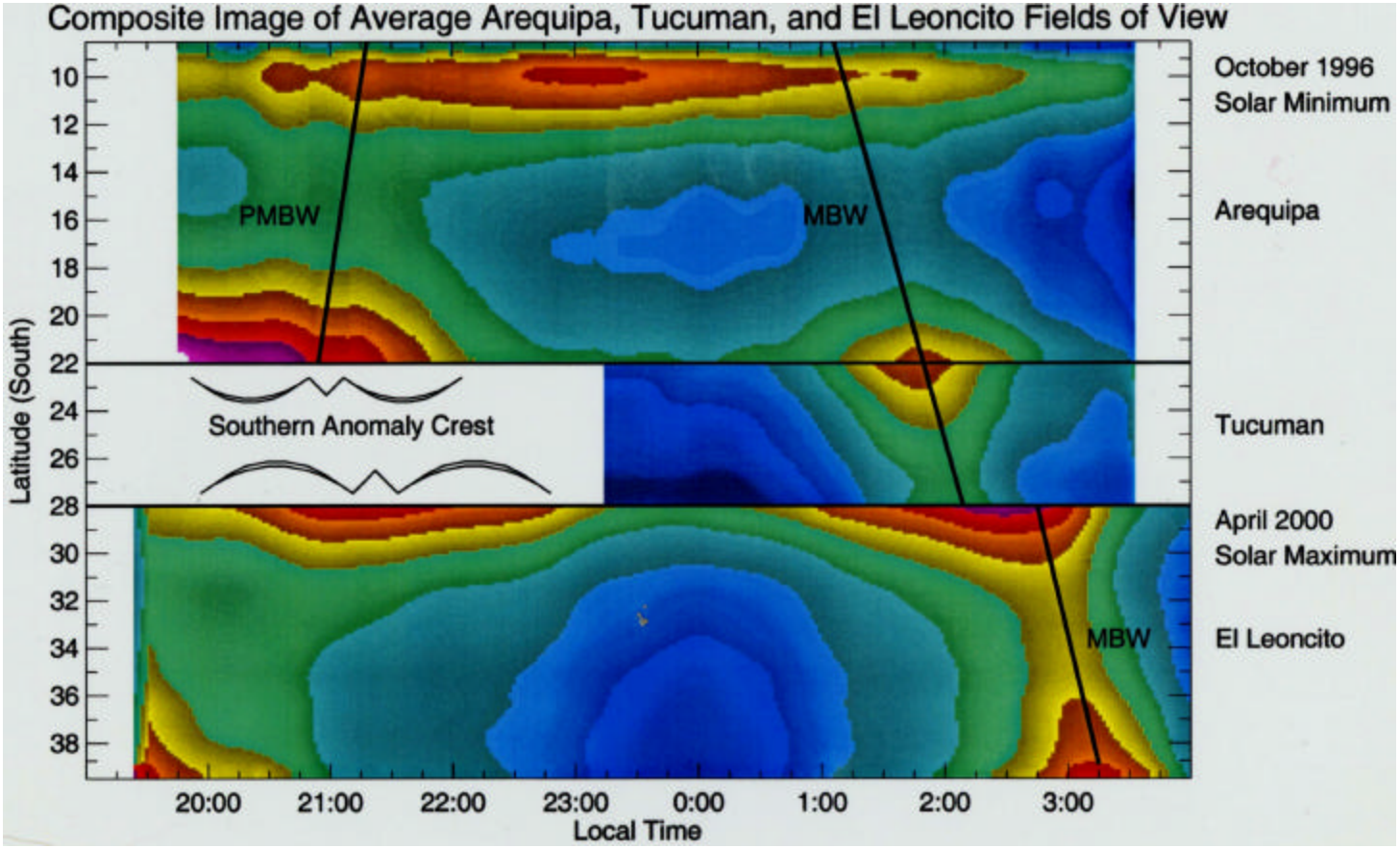
Ionosphere-Thermosphere Science

Open questions on latitude extent and amplitude of the Midnight Temperature Maximum: Brightness waves

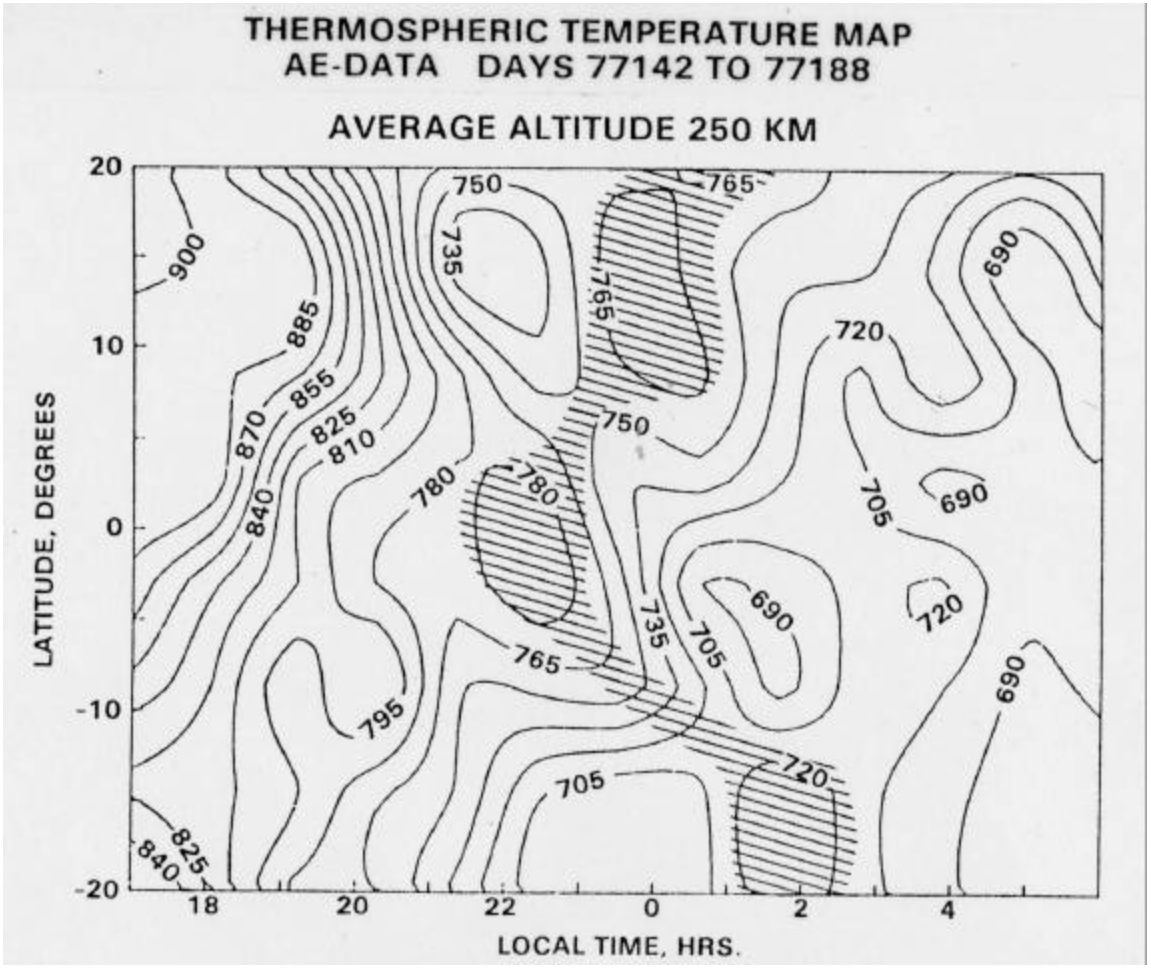
Mendillo and Colerico, 2000



Ionosphere-Thermosphere Science

Predicted model amplitudes are low for temperatures and winds

Herrero and Spencer, 1982



Ionosphere-Thermosphere Science

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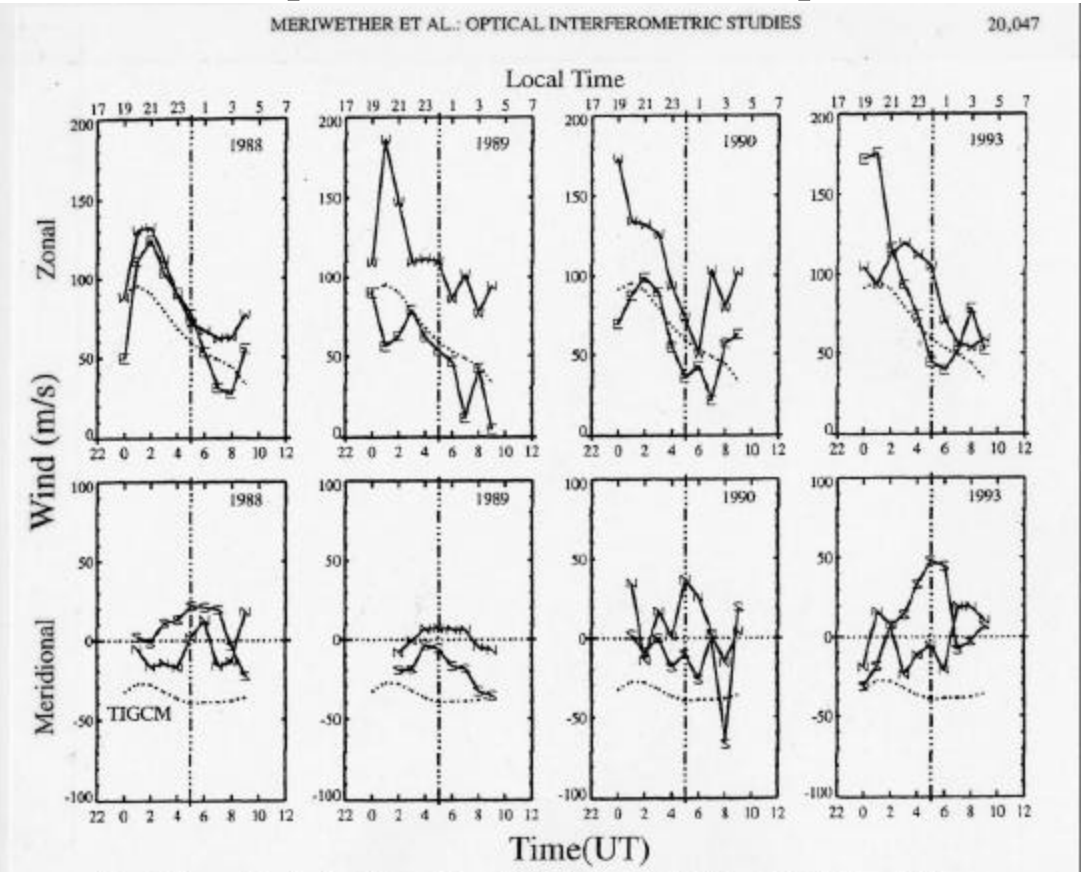

Figure 5. Averaged nocturnal variations of the zonal (E/W) and meridional (N/S) winds for the interval of days 120-140 (local fall season) for each of the 4 years 1988, 1989, 1990, and 1993. The dotted lines represent the predicted winds from the NCAR/TIGCM calculations for $F_{10.7} = 195$

Ionosphere-Thermosphere Science

Vertical average structures from San Marco III/V show interference effects, standing wave patterns.

Arduini et al, GRL 24, 377-380, 1997

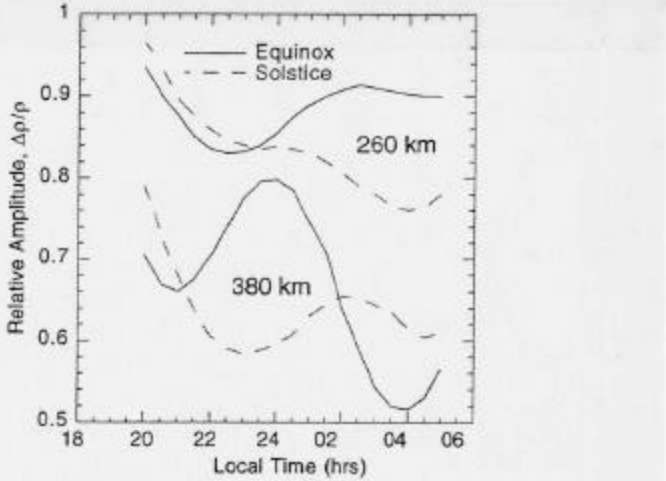

Figure 2. Two examples of the midnight density maximum (MDM) at different altitudes and seasons (SM5 data base).

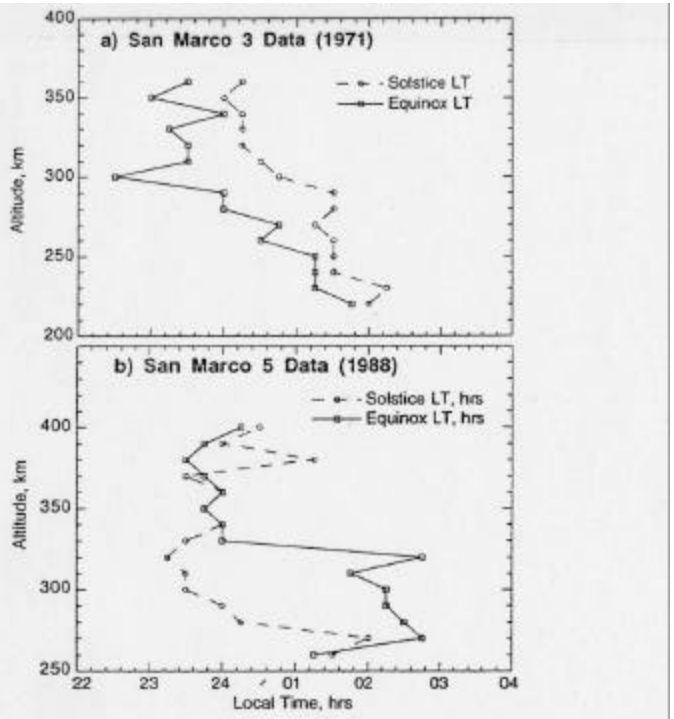

Figure 3. Altitude progression of MDM, solstice and equinox a) SM3 data. b) SM5 data.

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Arduini et al, GRL 24, 377-380, 1997

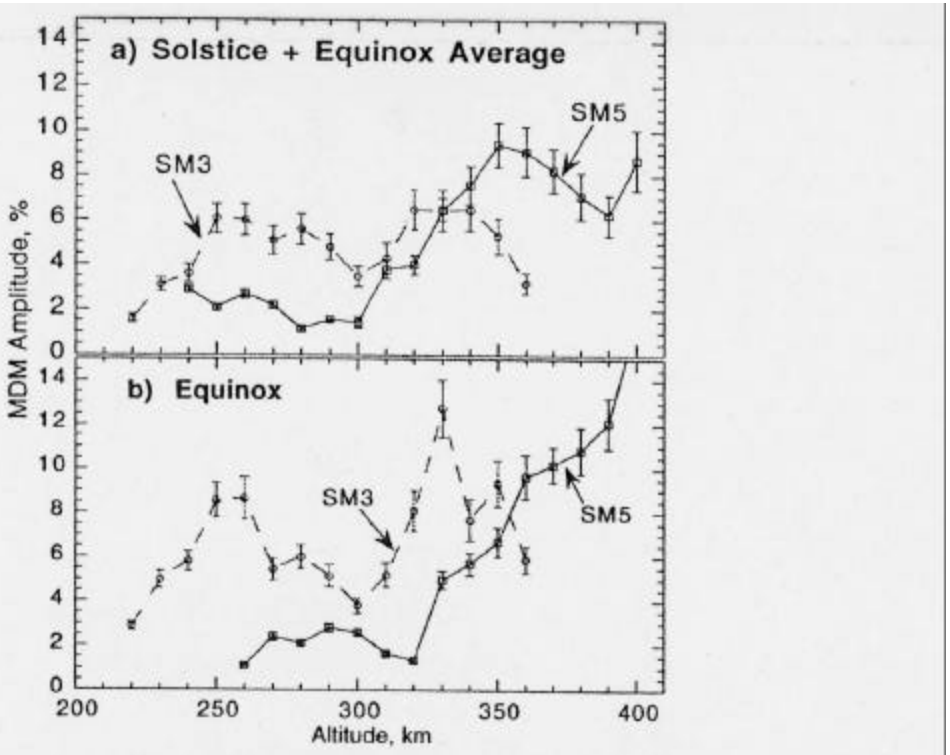


Figure 4. SM3 and SM5 MDM amplitude ($\Delta\rho/\overline{\rho}$)variation with altitude. See text for details.

Our models are proper. Yet cannot account for MTM/MDM dynamics. Nightside dynamics closely coupled to dayside:

Temperature amplitudes predicted: about 10°-20°K, but 50°-150°K observed.

Meridional and zonal wind amplitude disparity.

Need 24 hr coverage with latitudes to about ±40°, perhaps further and multiple altitudes sampled closely in time.

Now possible to conceive a multi-satellite mission:

Mass of each satellite < 5 kg

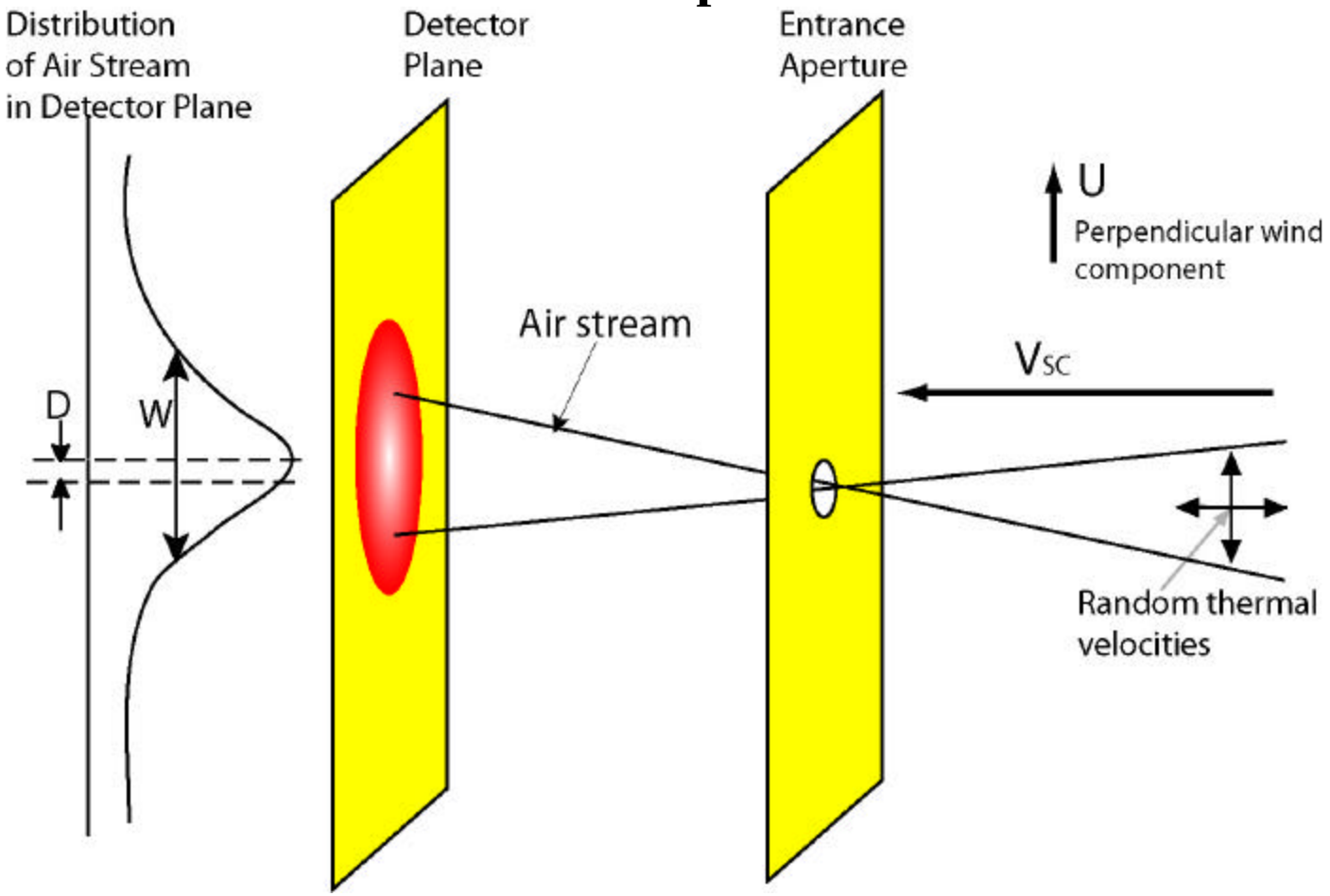
Fully instrumented: n, $\mathbf{U}$, T_n; n_i, $\mathbf{V}_i$, T_i, n_e, $\mathbf{B}$, perhaps composition

Launched 5 or 6 at a time from the Space Shuttle or other launch opportunity.

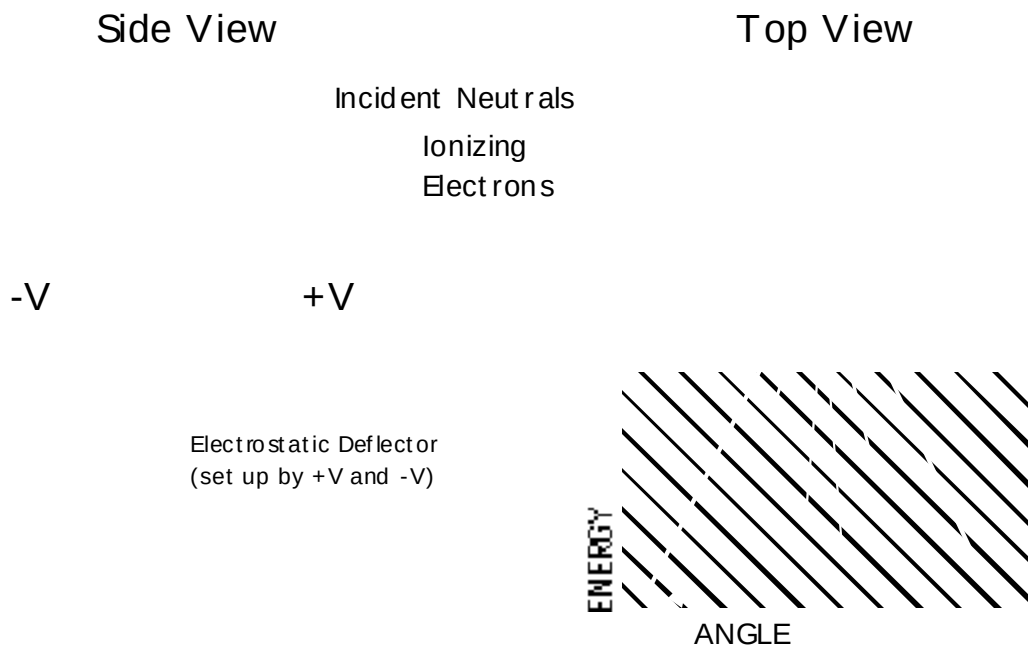
Drag differentially to provide multi-altitude sampling with time difference < 45 minutes.

Short mission life days to months without orbit maintenance thrusters.

Experiment to measure neutral winds, ion-drifts and their temperatures



Miniaturized position sensitive detectors enable small charged-particle spectrometers for neutral wind and ion drift and temperatures.

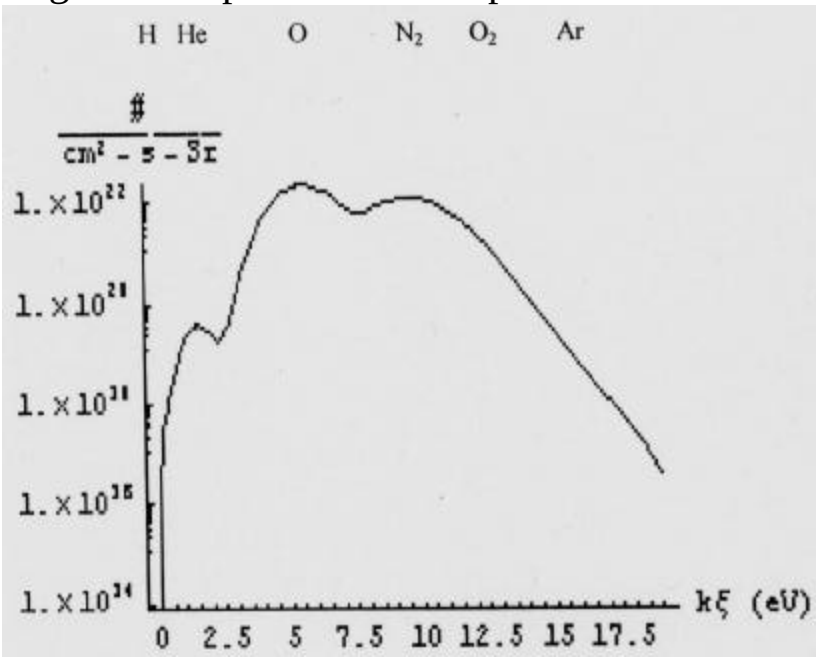


Mass and Power: less than 300gm/300mW using Carbon nanotube cathodes for electron impact ionization of neutral air stream.

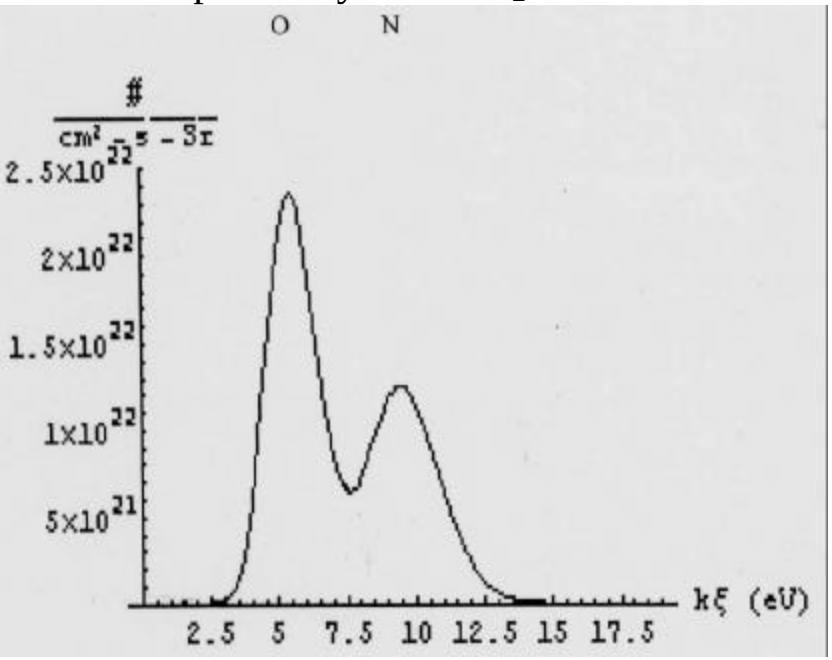
Simulation of Measured Energy Spectra for In-track Neutral Wind Component and Temperature at 250 km Altitude

Ambient Thermospheric Neutrals Temperature of 975K/Satellite speed: 8 km/s.

Logarithmic plot shows all species



Linear plot: only O and N_2 discernible



The technology exists to build and operate fully instrumented satellites with total mass less than 10 kg. Multiple-altitude measurements of the I-T region from a set of small satellites operating simultaneously are enabled by new detector technologies. In addition to large reductions in mass and power, the new technologies enable direct measurements of energy distributions to yield the full neutral wind vector from a single platform. The satellites described address the scientific questions posed above including measurements of the neutral wind vector, temperature and density, ion-drift vector, ion temperature and densities, and vertical distribution of the atomic oxygen ion.

Orbit Decay and Differential Drag for a Multiple Altitude Mission

Estimates of the radial velocity due to air drag for a satellite in circular orbit with drag coefficient C_D, cross sectional area A, and mass M follow from

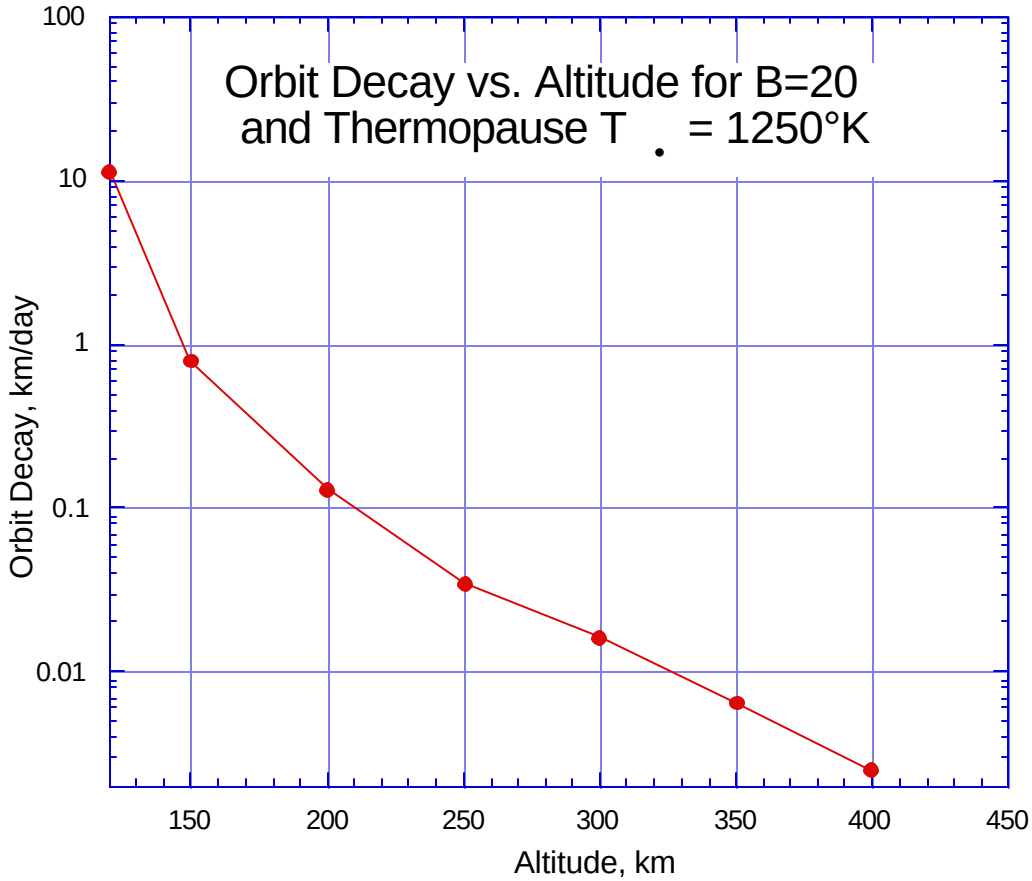
$$\frac{dr}{dt} = -r(r)C_D\left(\frac{A}{M}\right)Vr \ ,$$

where the orbit radius $r = R_E + h$ is the sum of the earth's radius R_E and the altitude h. R_E is the atmospheric mass density and V the satellite velocity.

The ratio A/M, the inverse of the ballistic coefficient $B = M/A$, is between 10 and 20 for nanosatellites like SNAP-1 and others contemplated here. Alternative designs exist to that increase the ballistic coefficient to higher values.

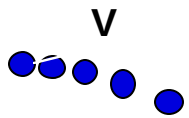
Large satellites typically have ballistic coefficients exceeding 100.

Orbit Decay Estimates

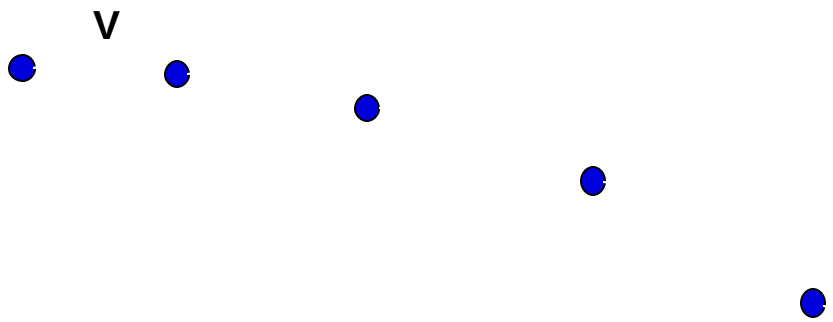


Multi-altitude NanoSatellites

Shortly after deployment



Long after deployment



Multi-point measurements with Small Satellites

Drawing shows five small satellites differentially dragged to different altitudes