Session Summary: Mesosphere Summer Echoes, Meteor Echoes, and Ionosphere Echoes

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This session was comprised of three topics that are quite distinct and separate; they are not closely related except from the viewpoint that all occur in the upper altitude regime of MST radar observational capability. Therefore, I will not attempt to synthesize everything in one summary, but will put forth my subjective views on the key issues of each topic separately. Also, because the plurality of the presentations were on mesosphere summer echoes, and since my own expertise lies in this area, I will discuss this topic more analytically than the others. My apologies to the presenters whose papers do not get as thorough a coverage.

Mesosphere Summer Echoes (MSE)

The most striking thing about this session was that out of the ten MSE presentations (the *Pan et al.* paper was withdrawn), none put forth new ideas for the physical mechanism(s) that produces MSE. I think the reason for this lack of theoretical development is that there is already a "backlog" of theories that have been proposed. The problem is that we have not been able to conclusively prove or disprove these theories. And because all the theories depend crucially on charged aerosols (ice, dust, large cluster ions), we will never be able to test them simply by radar observations. We will need to use our full arsenal of instruments in conjunction with radars to measure the aerosol number density, size and charge distribution, spatial inhomogeneities, and their interaction with the surrounding plasma inside an MSE layer. New, innovative rocket probes will have to be designed to accomplish this task. And collocated lidars can certainly give us excellent simultaneous data on the largest particles (noctilucent clouds) as we saw in the "Combined MST Radar and Optical Measurements" session.

Another observation I made at this workshop was the recent proliferation of radars at sites suitable for MSE work. Early results from the ALOMAR-SOUSY [*Singer et al.*] and Machu Picchu [*Woodman et al.*] radars were presented in this session, while construction reports of the Esrange and Resolute Bay radars were given in other sessions. Together with other existing radars (Aberystwyth, EISCAT, Sondrestrom, and SOUSY), we will have better means in the future to keep track of the geographical morphology, the long-term variability (a possible indicator of global atmospheric change), and the interesting asymmetry between the northern and southern hemispheres recently discovered [*Balsley and Woodman*].

To make full use of the radars we need to implement the latest interferometry techniques to study small-scale scattering structures [*Röttger and Pan*], and to observe at different frequencies simultaneously to probe the scattering mechanism at various length scales [*Meek et al.*].

For dynamicists, MSE is a fortuitous tool in that a region normally inaccessible by small VHF radars can be observed due to the greatly enhanced scattering cross sections. Turbulence, waves, and the wind field can be observed through MSE [*Czechowsky et al.*], but let me remind readers that strong turbulence is absent most of the time and that the scattering is usually not isotropic. There is evidence, however, that isotropy and the incidence of turbulence increases with height [*Hooper and Thomas; Huaman and Balsley*]. Plasma fluctuation spectra derived from rocket measurements also indicate that MSE occurring at different heights can correspond to spectral characteristics consistent with both turbulent and non-turbulent states [*Ulwick*]. The same rocket plasma data can be used to estimate the level of Fresnel scatter assuming horizontally coherent sheets [*Alcala et al.*].

Meteor Echoes

Meteor echoes are useful. They can be used for robust long-distance communication and for measuring mesospheric winds; operational systems have been set up around the globe for these purposes. Lately, powerful multi-purpose research radars have been used to measure other atmospheric parameters using meteor echoes.

Of course, one has to be careful in using a radar not specifically designed for one's particular purpose. For example, pinpointing exactly where the meteor echo is coming from is not a simple task given the ambiguity of sidelobes and various aliasing phenomena. Solving such problems, *Chilson et al.* used the SOUSY radar to calculate the height profile of ambipolar diffusivity in the mesosphere, while *Fisher and Kingsley* investigated turbulent structures with precise altitude location. (An interesting aside: Could the diffusion measurement be used to test the reduced-diffusion theory of MSE?)

Most meteor studies are conducted in the VHF band, where the strongest scattering takes place perpendicular to the trail. *Zhou* discovered, however, that the powerful Arecibo 430-MHz radar mainly detects meteors that are traveling parallel to the radar beam, raising some questions about the validity of the classical theory for his observations.

Ionosphere Echoes

A wide range of topics were gathered under this heading.

E region

Wang and Chu used the interferometric capability of the Chung-Li radar to resolve range/altitude ambiguities of multiple sporadic E layers.

Choudhary et al. studied E-region field-aligned irregularities (FAIs) with the Indian MST radar. Nighttime echoes tended to be continuous and layered, while daytime echoes occurred within a narrow range and descended with time.

Schlegel and Haldoupis presented morphological data of E-region coherent echoes from the new SESCAT radar on Crete. They noticed a strong correlation between the drift pattern and mesospheric winds. Furthermore, since more than 90% of the echoes occurred in the summer, they speculated that there may be some indirect connection with MSE conditions.

Brown et al. observed E-region FAIs using high-resolution (150-m) interferometry with the MU radar. They saw fine structures down to the resolution limit, and also noticed a north-south (away from/towards the radar) asymmetry in the angular spread and Doppler spectra of the FAIs.

Viswanathan et al. compared E-region echoes observed by the magnetic-equatorial Trivandrum radar and the off-equatorial Indian MST radar. The backscatter observed by both radars appeared to be Type II.

Rao et al., 2 recorded upper E-region FAIs with the Indian MST radar. They noted that these echoes were mostly observed between 2000 and 2400 LT in contrast to the largely daytime occurrence over Jicamarca.

E and F regions

Yamamoto and Fukao took FAI data throughout the E and F regions simultaneously with the MU radar, using the a real-time data processing system. They noticed that F-region echoes were associated with spread-F events, and that the intensity of F-region backscattering correlated with the activeness of the E-region echoes.

F region

Rao et al., 1 looked at the characteristics of spread-F with the Indian MST radar. They observed large vertical velocities in both directions, and they interpreted the strongest downdraft regions to be plasma depletions.

Coupling effects

Fejer concluded that equatorial thermospheric plasma drift measurements are significantly affected by lower atmospheric processes during low solar flux conditions.

Kirkwood and Röttger warned that, if a single linear polarization is used with a VHF MST radar, Faraday rotation can make the apparent backscattered signal vary with the total electron density. This effect is expected to be significant during disturbed conditions above the mesopause, and even during undisturbed times for lower-thermosphere meteor radar measurements at solar maximum.