5.1.2 SCIENTIFIC REASONS FOR A NETWORK OF ST RADARS AND COOPERATIVE CAMPAIGNS

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INTRODUCTION

Due to their capabilities of measuring wind profiles in the troposphere and stratosphere with a good time and height resolution whatever are the weather conditions, ST radars are well adapted to carry out atmospheric research in many fields as well as to fulfill the meteorological forecasting needs. That explains the development, all over the world, of such instruments.

The examples presented in this paper came from previous and future national or international campaigns planned in France. The VHF ST radar (Provence) from the LSEET participated in ALPEX 82, FRONTS 84 and MESO-GERS 84, and a network of ST radars will take part in the FRONTS 87 campaign.

ST RADAR NETWORK AND SCIENTIFIC CAMPAIGNS

Most of the scientific goals, which may be studied by ST radars, have been already mentioned (LARSEN, 1983; ROPER, 1983; FRITTS et al., 1984; GELLER, 1984). We may note:

-Even if a network of ST radars can operate by itself for dynamical studies, complementary data are usually necessary for most scientific investigations (radio soundings, microbarographs, precipitation radar, satellite images...). Most of them are available but generally not obtained at the same time or location.

-Even if one radar can contribute usefully to a campaign (cf FRONTS 84, MESO-GERS 84), a minimum of 3 radars is required for most of the spatio-temporal investigations (horizontal extent and variations of the phenomena, wave directional spectrum...).

So, the main difference between a research ST network working by itself and integrated in a specific campaign is essentially the duration of the experiment and the kind and number of instruments involved and working simultaneously.

Table 1 gives a list of some scientific topics which may be studied during specific campaigns involving the participation of other instruments in order to get a global and detailed view of the phenomena under study. In the next section, some examples of such campaigns are given.

These different topics impose the working characteristics of the ST radars and their relative position and spacing in the network. The time resolution is fixed by the expected time scales of the phenomena under study and the height resolution by their spatial scales and by the thickness of the turbulent layers (10 - 300 m). In connection with sodars for boundary layer observations, the lower altitude explored by the ST radar has to be less than 400 m; in connection with balloons for stratospheric observations, the upper altitude has to be higher than 12-15 km. The spacing of the radars acts as a filter in the

TABLE 1

	Boundary Layer	Free Atmosphere	Middle Atmosphere
Dynamics of precipitating clo ds	- Fair weather cloud birth - Dynamical properties of the clouds - Relation between turbulence and radiation at the top of the clouds		
Fronts	- Dynamical behaviour of the frontal flow - Mesoscale instability mechanisms and relationship with the precipitation processes - Waves and turbulence in the frontal zone - Boundary layer modification after precipitations		- Gravity waves - Interaction wave - turbulence
Deep Convection		- Convective burst and associated waves - Dynamical environment - Initiation conditions : mesoscale forcing.. - Convection dynamics - Waves and turbulence	
Mesoscale Flow	- Breeze phenomena (sea, valley..) - Nocturnal jets - Thermoconvective vortices		
Jet Stream Physics		- Waves and turbulence - Jet streaks	
Tropopause Dynamics and Topography		- Altitude, Foliation, Break, Stratospheric intrusion - Troposphere - Stratosphere exchange	
Stratospheric Turbulence			- Spatio-temporal structure of turbulence - interaction wave - turbulence

horizontal scales involved. In ALPEX 82, for small horizontal scale (50 km) studies the spacing was about 5 km, in FRONTS 87 for mesoscale studies, it will be about 100 km.

PREVIOUS EXPERIMENTS

In France, some experience has been acquired during the last 3 years concerning the integration of ST radar in scientific campaigns.

(1) During ALPEX 1982, 3 ST radars operated in the vertical mode in the Rhone Delta (ECKLUND et al., 1983) as a result of a collaborative effort between the Aeronomy Laboratory from NOAA and the LSEET (Toulon - France). The main objective of the ST radar experiment was the study of short scale gravity waves from vertical velocity measurements. These observations could also contribute to the ALPEX objectives on Genova gulf cyclogenesis (BRUN et al., 1985a) and local winds.

From this experiment, CARTER et al. (1984, 1985) determined the horizontal wavelength, the phase velocity and the propagation direction of waves. Some conclusions concerning this network are listed:

-The coherence between radar sites was very good while the coherence between heights separated by more than 2 km was generally quite poor. That does not permit a reasonable calculation of vertical wavelengths.

-With radar spacing of roughly 5 km, waves with horizontal wavelengths less than 10 km could be aliased and appear to have longer wavelengths. Since most observed waves had measured wavelengths around 10-20 km, it is possible that some of these are aliased.

-The fact that only vertical observations were made, limited the waves that could be detected to periods less than about 2 hr due to the weakness of the vertical wind induced by the waves of greater periods.

(2) During FRONTS 84, in the southwest of France, a ST radar was operating in the vertical mode during 2 months in coordination with other instruments (RONSARD cm radar, RABELAIS mm radar, balloons, airplane, radio-soundings, meteorological ground network,...). The observations have been focused in fronts and related phenomena, especially gravity waves, tropopause breaks and coordinated observations of clouds and their surroundings by different techniques.

Among all these instruments only the ST radar is able to provide continuously wind profiles with a good height and time resolution whatever the weather conditions (clouds or clear air, precipitation or not). In the experiment FRONTS 84, the ST radar has been useful:

-Inside the storm, to extend the other radar observations at altitudes higher than the ones observed with the precipitation radars;

-Outside the storm, to determine continuously the dynamical field and its perturbations as a function of time and altitude;

-Due to the capability of VHF radar to get large echoes from the tropopause level, to observe the behavior of the tropopause, its breaks... and to locate the breaks relative to the fronts (LARSEN and ROTTGER, 1982).

Sometimes, waves associated with a front have been detected. As an example, on June 3, 1985, a wave of about 40 min period is observed during several hours (BRUN, personal communication).

The comparison between these different sets of data has just begun.

(3) During MESO-GERS 84, with general objectives related to the boundary layer studies and orographic effects, the ST radar was operating in the vertical mode down to the altitude of 1.2 km to complement and extend sodar observations.

The main studies which will be carried out with the sodars and ST radar concern gravity waves and the relationship between surface stress and convergence or divergence effects associated with mesoscale systems. Particularly, with ST radar, it is possible to point out if the energy is propagating upward or downward and also to observe the entrainment effect associated with an inversion layer when it takes place at an altitude too high for sodars.

As the upper limit of the boundary layer has a diurnal variation and also varies with meteorological perturbations in the altitude range of 0.5 to 1 km, it will be suitable for a ST radar to be able to observe at least down to 400 m.

In this campaign, various interesting events occurred: "Hortense" hurricane, different kinds of frontal systems and fair weather conditions. ST radar data are needed to interpret them in a more complete way. This variety of phenomena is a good opportunity to estimate the contribution of ST radar to boundary layer physics.

(4) In 1984, two campaigns involving balloon experiments and ST radars took place. In the first one, which involved the 430-MHz radar of Arecibo, the payload consisted of a thermistor and a sonic anemometer (THOMAS et al., 1985, 1986). In the second experiment, which involved the VHF ST radar from LSEET during FRONTS 84, the payload consisted of a thermistor and an ionic anemometer (DALAUDIER et al., 1985, 1986).

In these cooperative experiments, the radar observations give the temporal variation of wind profiles and turbulent layers while balloon measurements provide the fine structure of wind and temperature profiles. These simultaneous in situ and remote experiments are important for a better description of the dynamical and thermal structure of the atmosphere (DALAUDIER et al., 1985, 1986; THOMAS et al., 1985, 1986) and also for a better understanding of the physical mechanisms producing the clear-air radar echoes (DALAUDIER et al., 1985, 1986).

(5) In conclusion, the preliminary results already obtained show the interest of ST radar in cooperative campaigns for a better understanding of some meteorological problems. Each of these experiments has been very instructive but none was really satisfactory: only the vertical wind was measured, only one radar was working during FRONTS 84 and MESO-GERS 84, and during ALPEX 82 the Rhone delta was not always documented by other techniques. Then taking into account all of these arguments, the use of ST radar will be optimized in other campaigns. A more comprehensive experiment is planned in 1987 with a network of 3 ST radars operating both on the vertical and horizontal components of the wind.

A PLANNED EXPERIMENT - FRONTS 87

FRONTS 87 is a French - U.K. campaign which will take place in France and U.K. on both sides of the Channel from October to December 1987. Its scientific goal is the study of active cold fronts in a nearly flat zone. The objectives are:

-To acquire mesoscale data sets concerning dynamics, thermodynamics and microphysics. The network of ST radars with a spacing of about 100 km will provide wind vector profiles, the altitude of the tropopause, the mesoscale flow, its horizontal gradient and divergence or convergence;

-To acquire continuous data sets in order to get the three-dimensional structure of the front and its environment under some stationary assumptions.

The instruments participating in this campaign will be: ground-based meteorological networks, radiosondes at 3-hr intervals, aircraft dropsondes to produce profiles of temperature, humidity and wind, aircraft in situ observations equipped to carry out dynamical, thermodynamical and microphysical measurements, cm and mm radars, Doppler acoustic radars, lidar...and also images from Meteosat and NOAA satellites.

The network of ST radars is one of the first priority of this experiment. For this purpose and future scientific campaigns, a network of ST radars are under study (PETITDIDIER et al., 1986).

CONCLUSION

These examples point out an evolution in the use of ST radars for dynamical studies. At first, they have been working by themselves with the adjunction of radiosonde data. Then networks have been built or under study and have been used to get horizontal parameters. From now, it appears that ST radar networks will be naturally included in cooperative campaigns. Only national or international scientific campaigns are able to conduct simultaneously all the experiments necessary to obtain an overview of a specific topic.

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