

A VHF WINDPROFILER NETWORK IN ONTARIO AND QUEBEC, CANADA: DESIGN DETAILS AND CAPABILITIES

Wayne Hocking¹, P. A. Taylor², P. S. Argall¹, I. Zawadzki³, F. Fabry³, G. Mcbean¹, R. Sica¹, H. Hangan¹, G. Klaassen², J. Barron¹, and R. Mercer¹

1. University of Western Ontario, London, Ont., Canada, N6A 3K7
2. York University, Toronto, Canada
3. McGill University, Montreal, Qc., Canada

1. INTRODUCTION

A new network of VHF windprofiler radars (40-55 MHz) is now under development in Ontario and Quebec, Canada¹. It will cover the latitude region 42N to 50N, and the longitude region from 74W to 85W. Two radars are currently complete. The network is unique in several ways. First, it is the first such network in Canada. Second, we concentrate on the VHF (Very High Frequency) band, using frequencies in the range 40 to 55 MHz. This will help avoid the problems related to signal contamination due to birds and insects, and will also reduce the contamination which can occur due to precipitation. In addition to supplying three components of the wind, the radars also present some new parameters. For example, we present scatterer anisotropy as a routine parameter. This parameter is a good indicator about the convective state of the atmosphere, and on some occasions has been correlated with precipitation (Hocking and Hocking, 2007). In addition, tropopause heights are reported on an hourly basis, and this has proved useful in studies of ozone exchange between the stratosphere and troposphere, and indeed for general studies of STE (stratosphere-troposphere exchange). Turbulence strengths are also reported as functions of height and time on at least an hourly basis, and this useful for aircraft safety as well as for studies of STE.

Traditionally frequencies around 50 MHz have been avoided for such networks due to the difficulties in obtaining low altitude winds (below 1.5 km), but recent developments by various groups have shown that with the right choice of antennas, and the correct method, measurements as low as 400 m altitude are possible. These new developments are

integrated into our network. In addition a series of calibrations using balloons and instrumented aircraft are currently under way, and the radars are already participating in pollution transport studies in Canada.

The network is in a meteorologically interesting area, close to the Great Lakes. The Meteorological Research Branch (MRB) of the Meteorological Service of Canada plans to collaborate on applications Research and Development projects related to assimilation of the windprofiler data into NWP (Numerical Weather Prediction) models, model validation, and severe weather studies.

2. NETWORK DISTRIBUTION AND RADAR DESIGN.

The proposed radar locations are shown in fig. 1. An additional radar at McGill University in Montreal will also work with the other radars, although it was built prior to the availability of funding for this network. At the time of presentation of this abstract, the radars at Walsingham and Harrow were complete. Others are under construction, with the biggest hurdle to production being legal issues associated with land leases and ownership.

Figs. 2 and 3 show some photographs of some VHF windprofiler radars in the network. All radars in the network will have one of two main designs, although frequencies will vary, depending on allocation by Industry Canada. All frequencies will be between 40 and 55 MHz, and generally in the range 40 to 50 MHz. Fig. 4 shows the main two antennas designs, and the corresponding polar diagrams. The two different arrangements are designed to allow greater flexibility when adapting to local terrain.

¹ Corresponding author address: Wayne K. Hocking, Dept. of Physics and Astronomy, P&A Building, University of Western Ontario, London, Ont., N6A 3K7, Canada. Email: whocking@uwo.ca

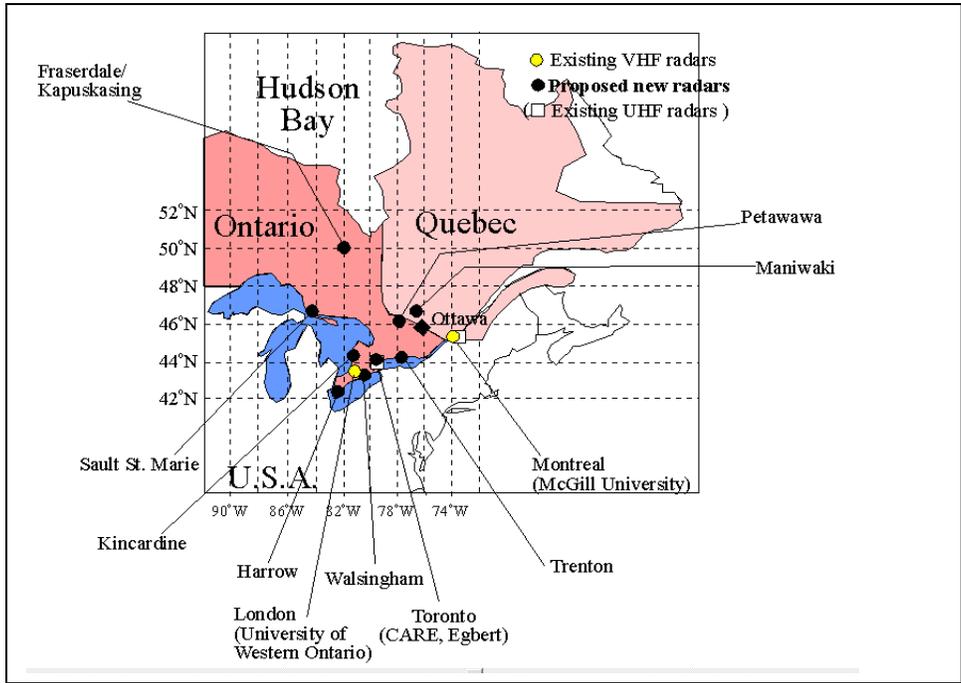


Fig. 1. Geographical distribution of the O-QNet radar network in Canada.

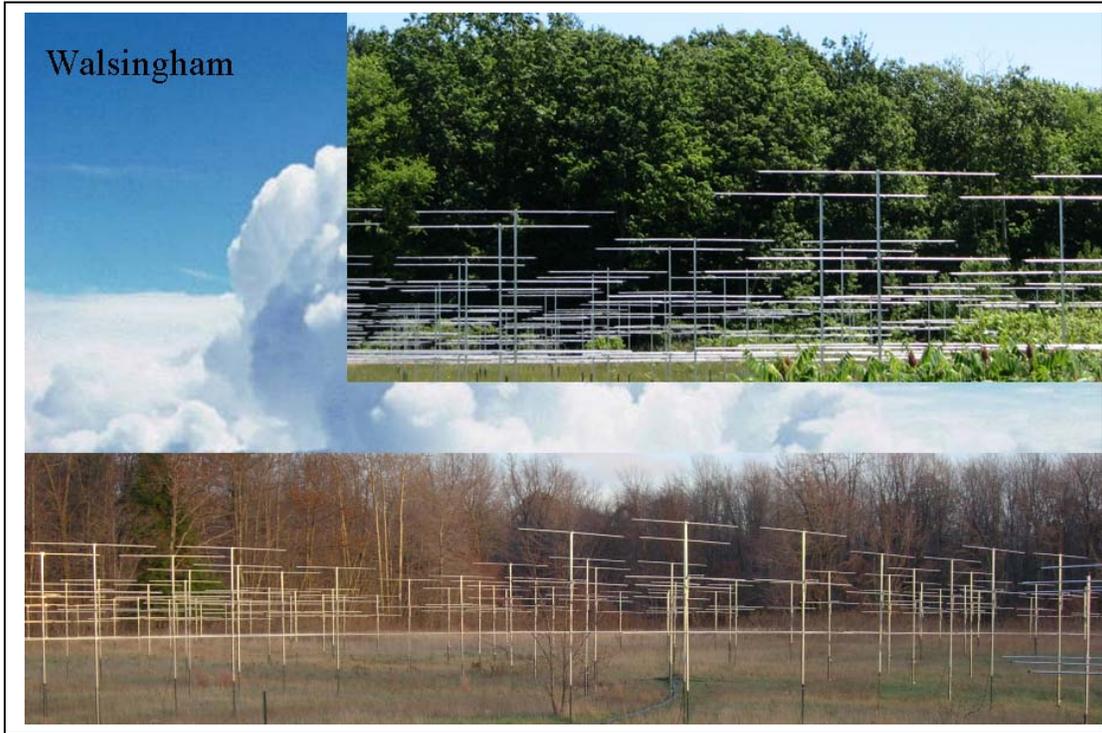


Fig. 2. Photographs of antennas at the Walsingham radar.

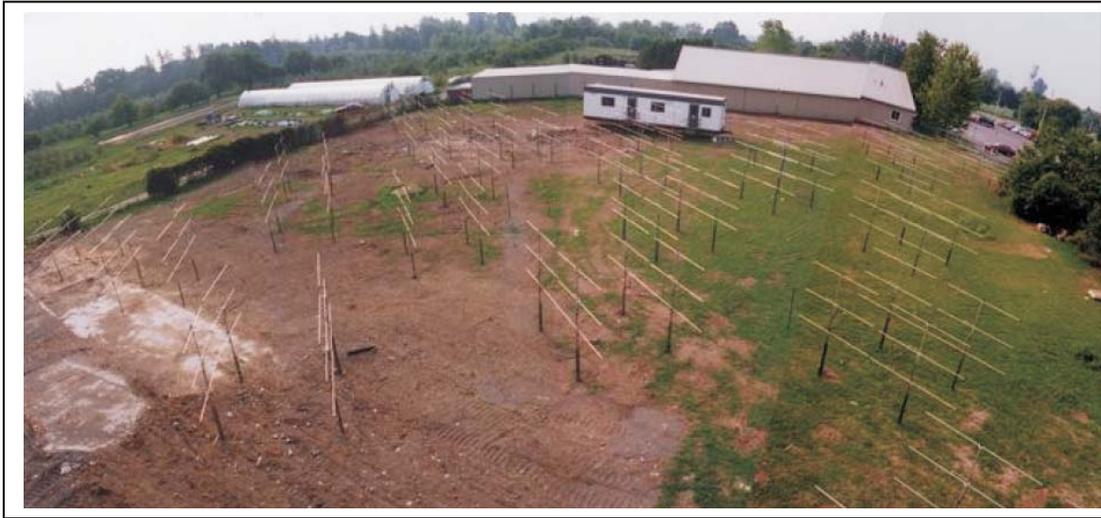


Fig. 3. Aerial view of the McGill radar during construction

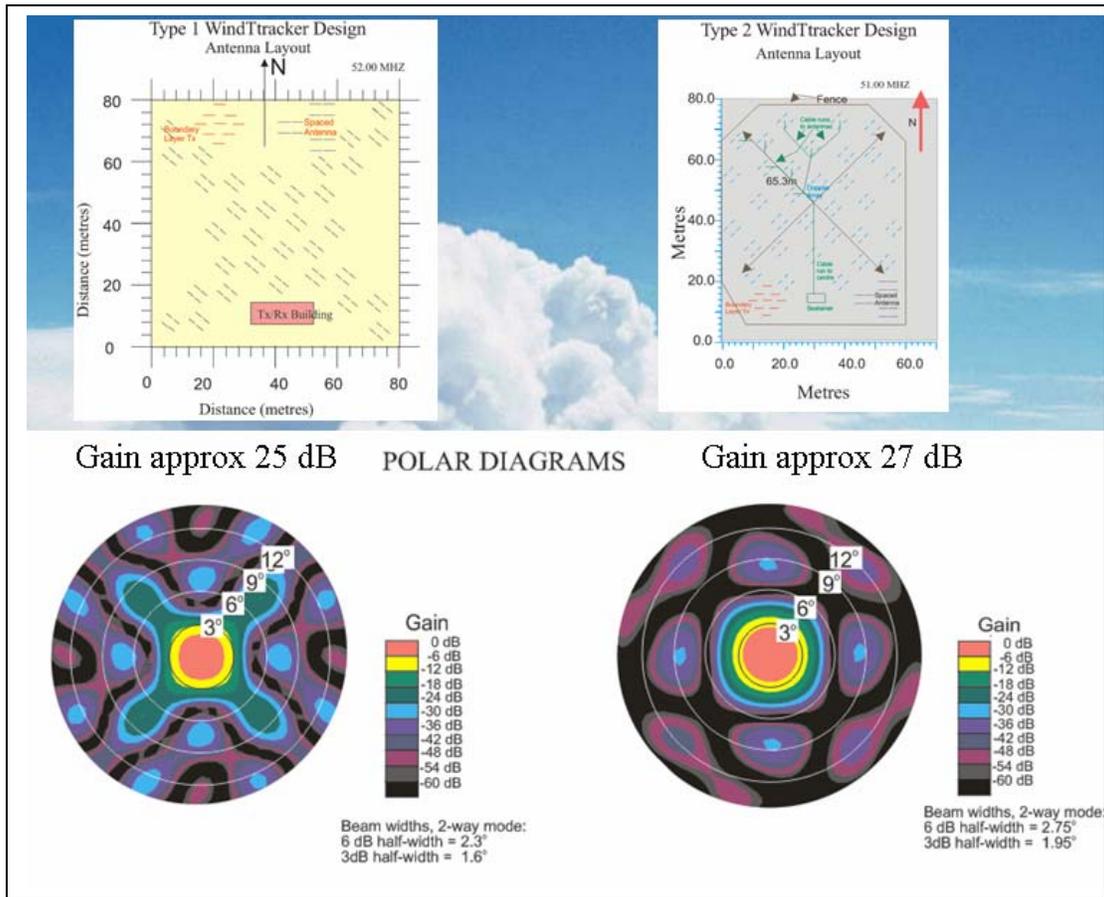


Fig. 4. Antenna layout and associated polar diagrams for the two main radar designs.

The first antenna layout uses a cross-like structure for the antenna pattern, while the second is more tightly clustered. The first requires more land, but produces a narrower main lobe of the polar diagram, and higher gain. It also produces stronger sidelobes, but these are not a serious contaminant as long as suitable software spectral processing (e.g. Hocking, 1997) is used. Despite the higher sidelobes, the higher gain of this system allows measurements to greater altitudes. The second configuration is designed to be used when land availability is limited. The design has a slightly wider main beam than the first, and slightly lower gain. However, the quasi-irregular spacing of the quartets results in excellent sidelobe suppression, as can be seen in the polar diagram.

The first option is used at McGill and Walsingham, the second is used at Harrow. A third option, similar to option 2 but with even closer spacing between antennas, will be used at the next radar (Negro Creek) due to the very severe space limitations at that site.

3. VALUE OF NETWORKS, COMPARISONS WITH OTHER NETWORKS.

The technology behind windprofiler radars is now relatively mature, and they have been used in experimental modes for the last 15-20 years.

However, their capabilities are best realized when used as networks, and especially when used in conjunction with numerical weather prediction (NWP) computer models. While attempts have been made to integrate them into such NWP schemes, their potential is still largely untapped. One reason for this is that NWP models are not quite yet capable of fully utilizing the large amounts of data available from these radars. This capability will only occur with the development of new four-dimensional variational analysis computer models running on computers with massive data-handling capabilities, and it is only now that such machines are becoming available. Most major weather centers, including the Meteorological Service of Canada, are working to develop such schemes.

Within the USA, a network of profilers has been established by NOAA (National Oceanic and Atmospheric Administration), using a frequency in the 400-500 MHz band. However, this choice

of frequency leads to contamination from other scattering targets like birds and insects, and can on occasion lead to incorrect interpretation of wind motions.

Within Europe, another network (CWINDE) has been established, but it is designed on a "contribution basis only". Various researcher organizations there have agreed to contribute data from their own radars to a larger data base, and these radars have a wide variety of operating parameters.

Examples from the NOAA site in the USA can be seen at the web site www.profiler.noaa.gov/npn/profiler.jsp, and from the European network at <http://www.metoffice.com/research/index.html>.

The new network will be the first of its kind in Canada. Before the network was proposed, there were two existing VHF windprofilers which were capable of regularly measuring winds above 2 km altitude; one at London, Ontario, and one at Resolute Bay (Nunavut). In addition there were a small number of modest UHF-band profilers which could perform studies in the region below about 2-3 km altitude, and a couple of sonar-based instruments. However, the new network will represent a major advance for Canadian windprofiler studies. It is especially concentrated around the most populous areas of Ontario and Quebec. Some of the key project objectives are discussed in the next section.

4. Project Objectives.

Our overall objective in this proposal is to establish a network of windprofiler radars within Ontario and Quebec, with the intention to use it to demonstrate the usefulness of such a network for weather forecasting and atmospheric science in the Canadian context. The network will be closely linked through the internet, with frequent updates of data supply to a central server for access by all relevant researchers. Preliminary sites have been found as shown in the map in fig. 1, although further adjustments may take place before the project is finished. In addition we will be able to employ the existing sites at London and Montreal. Our network design is also arranged so that the existing UHF profilers can contribute to the network in a complementary manner.

Our network will differ in several ways compared to those discussed in section 3.

Of course it will produce both horizontal and vertical winds, as do all windprofilers, and an example is shown in fig. 5. It is important to note that no interpolation was used in producing these plots – the data are purely raw values recorded by the radars. In the following sections we will concentrate on some of the more unique aspects of our network.

First, we wish to concentrate on the VHF (Very High Frequency) band, using frequencies in the range 40 to 55 MHz. This will largely avoid the problems related to signal contamination due to birds and insects which have affected higher frequency profilers, and will also reduce the contamination which can occur due to precipitation. In the past VHF radars were avoided because they could not normally measure below about 1.5 km altitude, but recent developments have shown that with the right choice of antennas, and the correct method, measurements as low as 400 m altitude are possible (Vincent et al., 1997; Hocking, 2006a, b).

Secondly, our network will not only produce wind motions (both horizontal and vertical), but will also routinely measure the strengths of turbulence. This feature is not normally implemented in a network of this type. This will be important for studies of atmospheric diffusive transport at these upper levels, and also from the perspective of air traffic safety. This latter issue will be discussed shortly.

Thirdly, our network will be somewhat more tightly clustered than the others (and much more tightly clustered than the existing radiosonde network), and will be sited in a geographically and meteorologically fascinating area, near the Great Lakes of North America. (Tornadoes, for example, are more common here than most other places in Canada, and lake breezes have very important effects on local meteorology).

Fourthly, we will work closely with the airlines of Canada, to examine the capabilities of these radars for improvement of airline safety (reduction of encounters with clear air turbulences) and for reduction in fuel costs by utilizing better flight planning strategies based on better knowledge of upper level winds.

Encounters with turbulence still represents an important problem for the airline industry, both from the perspective of aircraft damage, and injuries to staff and passengers. Associated with high levels of injury are high insurance premiums, so a better understanding of turbulence can reduce these overheads to the airline industry, resulting (we would hope) in reduced airfares.

Fifthly, we will work closely with other organizations such as fire-fighters, forestry officials and local forecasters to make the data accessible for their own particular applications. Fire fighting is one example of possible important applications of these data. Often knowledge about wind motions at heights of 1000 to 1500 metres is inadequate during periods of fire activity, and this makes it hard to determine where the smoke and sparks from the fires is likely to drift. Windprofilers can provide this knowledge if one happens to be located nearby.

Sixthly, we are keen to examine the potential for improvements by incorporating the data from this network into new computer models which take advantage of the latest advances in computer speed, parallel processing and storage capability. These models will cover a variety of grid scales, from eddy-scale simulations (which will take advantage of the high time resolution of these radars) to mesoscale models and beyond. We will especially be looking at the roles of gravity wave processes in these models, and once again the high temporal resolution will be important here.

We will also expand our studies to include topics like troposphere-stratosphere ozone and pollutant transport, in order to investigate upper atmosphere phenomena related to, among other things, global warming. Furthermore, knowledge of the upper level wind field will also be important for long-term studies of long-lived pollution transport and even for tracking radionuclear contaminants which might be produced, for example, in the (hopefully unlikely) event of a nuclear incident.

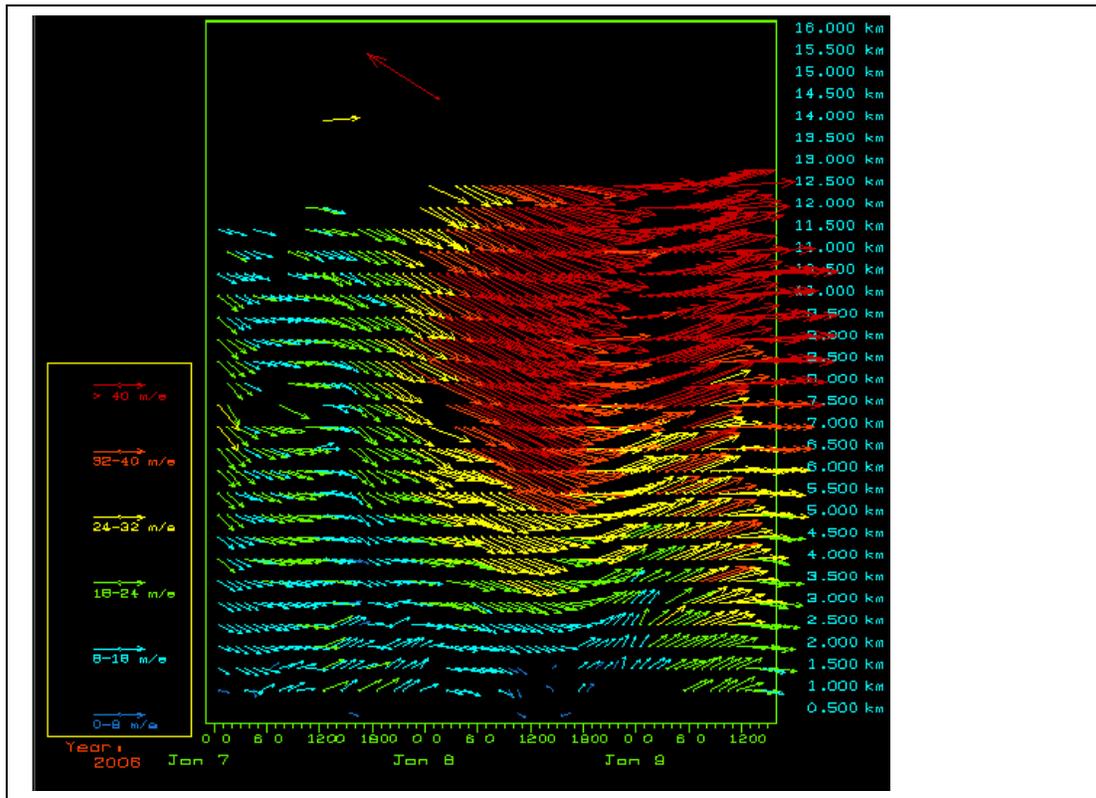


Fig. 5. Typical winds measured over a 2-day period with the Walsingham radar. No interpolation is used, and these results are very typical of measurements recorded with the network radars.

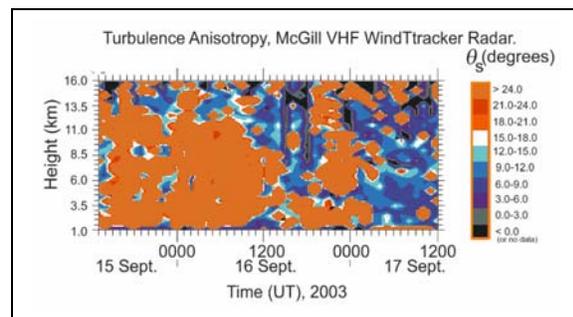
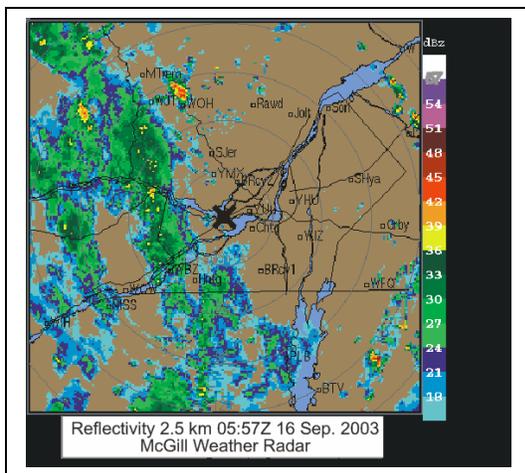


Fig. 6. Precipitation map recorded with an S-band radar (left), and height-time plot of isotropy index as a function of time during the occurrence of this precipitation event (right). In the second figure, the orange/brown colors represent more isotropic scatter, and studies show that stronger isotropy is common during precipitation events in Montreal (Hocking and Hocking, 2007).

There are several other interesting aspects to this program. For example, fig. 6 shows how turbulence anisotropy, as measured with one of our winprofilers, correlates with precipitation in Montreal in non-winter months. More details can be found in Hocking and Hocking (2007).

Another proposed study includes investigations of bird migration, using X- and S-band radars for studies of bird motions, complemented by meteorological parameters obtained from the O-QNet. Other projects will no doubt arise as the project evolves.

References

- Hocking, A., and W.K. Hocking, "Turbulence Anisotropy Determined by Windprofiler Radar and Its Correlation with Rain Events in Montreal, Canada", *J. Atmos. Oceanic Technology*, 24, 40-51, 2007.
- Hocking, W.K., "System design, signal processing procedures and preliminary results for the Canadian (London, Ontario) VHF Atmospheric Radar", *Radio Sci.*, **32**, 687-706, 1997.
- Hocking, W.K., "Boundary Layer Winds with 50 MHz radars - comparison of different approaches", Paper I.3-18, MST11, the 11th International Workshop on Technical and Scientific aspects of Mesosphere-Stratosphere-Troposphere Radars, Gadanki/Tirupati, India, Dec 11-15, 2006a.
- Hocking, W.K., "Comparison of IDI and FCA analyses for Boundary Layer VHF wind measurements", Paper I.3-27, MST11, the 11th International Workshop on Technical and Scientific aspects of Mesosphere-Stratosphere-Troposphere Radars, Gadanki/Tirupati, India, Dec 11-15, 2006b.
- Vincent, R.A., S. Dullaway, A. D. MacKinnon, I. M. Reid, F. Zink., P. T. May, and B.H. Johnson, "A VHF boundary layer radar: First Results", *Radio Science*, 33(4), 845- 860, 1998.

5. CONCLUSIONS

We have presented plans and progress associated with the O-QNet, currently under construction in Canada. Unique features include the use of the VHF frequency band, and world-wide-web displays of turbulence strengths, scatterer anisotropy, and tropopause heights, among others. Plans for presenting and analyzing the data within a unified framework have been discussed, and integration into NWP models has been considered.