AEROCAN Workshop Report
Meeting held at MSC, Downsview on MARCH 7, 2001

General Goals of the workshop

The Meteorological Services of Canada (MSC) at Downsview hosted the second AEROCAN Workshop on Wednesday March 7, 2001. The technical program of the workshop was orchestrated by CARTEL (Centre d'applications et de recherches en télédétection) from the Université de Sherbrooke. AEROCAN is a national network of sunphotometers[1] sponsored by CCRS (Canada Centre for Remote Sensing) and supported by MSC as well as the AERONET group at NASA's Goddard Space Flight Center.

The general objectives of the workshop were threefold (i) to review the current operational status of AEROCAN and AERONET and the future directions of these networks, (ii) to review the climatological and science advances of scientists associated with these networks, and (iii) to discuss how best to demonstrate and promote the importance of this data to commercial and governmental interests.

[1] The principal product of the network is spectral aerosol optical depth and integrated water vapour content over a variety of sites representing different aerosol climatologies. Important derived outputs include aerosol particle size distribution, particulate refractive index and single scattering albedo. These parameters are generally acknowledged to be critical inputs as well as key validation elements for climatological studies, air quality monitoring and the atmospheric correction of surface remote sensing data. In the past few years the AEROCAN group in collaboration with AERONET has been developing a spatio-temporal statistical data base for aerosol properties over Canada.

Objectives of this report

The meeting was hosted by Bruce McArthur of MSC. A summary of the geneneral objectives of the workshop and the meeting agenda are included in the Appendix. The discussion below is limited to an overview of the presentations made at the workshop and recommendations for future work. Power point files from the presentations of Norm O'Neill, Alain Royer, Jim Freemantle and Phil Teillet are available on request. Occasionally I have inserted a comment (*terminated by my initials, NTO*) made at the time this report was written.
Norm O'Neill, June 5, 2001.

Overview of presentations

Morning session

Norm O'Neill presented an overview of the current status of AEROCAN. He showed that the network is doing well in terms of scientific publications (~ 10 AEROCAN related peer reviewed publications and 2 submitted from 1999 to the present) as well as in terms of conference participation. He indicated that the AEROCAN coordinator, Jim Freemantle, had made important strides in motivating, training and communicating with site managers and that this has produced an increase in the duty cycle of the network (see the summary of Jim Freemantle's presentation below). Although financing operational costs was always difficult, the in kind help of GSFC/NASA and Meteorological Services of Canada (through Brent Holben and Bruce McArthur respectively) was essential and very much appreciated. Recently CCRS, thanks largely to the initiative of Phil Teillet, had arranged a contract for AEROCAN outreach activities via ISSMAP (*In Situ* Sensor Measurement Assimilation Program). Norm briefly overviewed the current source of research funds which is the AEROCAN climatology strategic grant for which Alain Royer is PI. It was indicated that future sources of funding would be targeted towards the aerosol mapping project (AEROMAP) via another strategic grant and cloud studies at Egbert and Bratt's Lake via the CFCAS fund *(this has been carried out, NTO).*

Norm also gave an overview of some of the science results related to AEROCAN (other science results were reported by Alain Royer and are summarized below). These included the development of a spectral analysis technique based on the first and second spectral derivatives of the Angstrom coefficent and the fact that the size distribution is essentially bi-modal (work carried out largely with Tom Eck and Oleg Dubovik at GSFC). The theoretical framework developed for the spectral analysis led to a technique for extracting a modified Angstrom coefficient which represented the contribution of the fine mode Angstrom coefficient. A study of multi-year, multi-station data led to an empirical confirmation that the probability distribution for aerosol optical depth is log-normal rather than normal (i.e. that one should report the geometric mean and standard deviation rather than the arithmetic mean and standard deviation as is commonly done). Canadian forest fire smoke was analyzed from a climatological perspective as well as in terms of a specific series of events in 1998. Climatological results included a demonstration that the greater part of the optical depth variance at western sunphotometer sites was due to forest

fire smoke and that the fine-mode particle size of smoke increased with optical depth. The event analysis showed an increase of particle size versus distance between the smoke source and the sunphotometer station.

Alain Royer gave a brief presentation on the AEROCAN CD based climatology which had been largely put together by Amadou Bokoye. This database, which will be made available in an html type of presentation format represents statistical compilations of AEROCAN data from 1994 to the present. These CDs were to be made available shortly after the workshop (*this product is now ready to be mass produced, NTO*). Alain also reviewed a variety of other AEROCAN research activities which were being carried out at CARTEL. These included the POLDER AEROCAN/AERONET comparisons being carried out by Francois Vachon (MSc student at CARTEL), Amadou Bokoye's work on the validation of the CIMEL water vapour band using the GPS water vapour extraction methodology and some preliminary statistics on Arctic aerosols. The POLDER comparisons were marginal at best and we await word from the POLDER algorithm development team as to how to proceed (they claim the algorithm has since been improved). It is noted that comparisons of an $\alpha \times \tau_a$ (aerosol index) were marginally better (a parameter which combines concentration and size information and which appears to provide better continuity of POLDER inversions from land to water). The GPS water vapour extraction methodology looks like a promising technique especially when one considers that the basic equipment is a standard GPS receiver. The preliminary Arctic analyses showed, for example, that the AOD averages for Bonanza Creek and Churchill were appropriately low and comparable with earlier results by Shaw and Freud for Alaska, Inuvik and Alert.

Jim Freemantle gave a summary of the current AERCAN operations status. Jim highlighted the fact that a new site was started up at Churchill and that AEROCAN had taken over the responsability of the former BOREAS sites, Waskesiu Saskatchewan and Thompson Manitoba. He also showed some statistics which indicated that the number of measuring days as well as the number of observations per day at all stations had, in general, increased substantially over the four year period from 1997 to 2000. He briefly described some of the major operational problems encountered this year (battery and fuse problems with the VITEL transmitter, microswitch problems with the CIMEL robot and cable binding in general) and their solution. Jim underscored the importance of site visits and operator training and the need to check out calibrated CIMELs in Toronto before they are shipped off to the different sites.

Bruce McArthur gave an overview of MSC activities related to sunphotometry and shadow band radiometry. He underscored the fact that there were Brewer's at Bratt's Lake and Saturna Island and that PM measurements were made at Bratt's Lake. He pointed out that he had finally received a PFR (Precision Filter Radiometer[2]) sunphotometer from Davos Switzerland (a four channel sunphotometer which is being promoted as a standard for absolute calibration). A comparative experiment carried out between this instrument and other sunpotometers at Egbert showed excellent optical depth agreement to less than 0.01. However a comparative experiment carried out

[2] See, for example, http://www.pmodwrc.ch/worcc/worcc.html

between the MFRSR instrument and the CIMEL showed bad agreement with differences as large as 0.1 (he felt the MFRSR instrument was probably high). Bruce pointed out that David Halliwell at Bratt's Lake had discovered a fair number of problems with their CIMEL instrument. The most recent problem was intermittant robot pointing anomolies which caused inconsistancies in the zenith parking position (*Patrick Cliche at CARTEL, with the aid of CIMEL in Paris, has traced this to problems with the micro-switches which are used for the zenith and azimuth motors as positon references. In the process we obtained a less than well publicized procedure for checking out the values of the parameters which control these micro-switches, NTO*).

Phil Teillet presented an overview of his ISSMAP project and some ideas on how it might apply to AEROCAN. CCRS is becoming increasingly aware of the importance of in-situ measurements and is becoming sensitive to the concept of assimilation of measured data into geophysical models. The ISSMAP initiative is the result of this prioritization by CCRS. Phil showed a system wide ISSMAP flavoured concept which incorporated an assimilation scheme and an optical depth climatology of ground based sunphotometry (AEROCAN) as well as satellite based optical depth inversions. The overall goal of this scheme was the production of a centralized and readily downloadable national data archive (this really was a supporting argument for the AEROMAP concept presented in the afternoon). He also gave an overview of how such a database would fit into his scheme for operational surface reflectance retrieval. Finally Phil presented general transparencies on MODIS and its aerosol optical depth product (relevant to the objectives of Alain Royer's AEROCAN climatology strategic grant (Francois Vachon's thesis project as discussed below) and to the general AEROMAP concept.

Oleg Dubovik gave a good overview of AERONET operations and also reported on some of his latest optical inversion work. Highlights included the successful inversion of a tri-modal size distribution with a pronounced mode ~ 0.8 μm and Mexico City inversions where a strong coarse mode influenced the optical inversions. Jean Pierre Blanchet brought out an interesting perspective when he noted that the optical properties of the nucleation mode (which are weak and thus less amenable to optical inversion) was less critical from a strictly mechanical viewpoint given that the nucleation mode quickly coagulates into the accumulation mode.

Afternoon session

The afternoon session was devoted to applications of AEROCAN data.

Norm O'Neill gave an overview of the AEROMAP concept; a system for the production of aerosol maps anywhere over Canada. The proposed system would included at least four product levels which ranged from a climatological database to an assimilation system which rendered the predictions of an aerosol transport / chemistry coherent with available optical depth measurements from ground based and satellite data.

David Stanley of PCI gave a very encouraging heads up as to the preparedness of industry for the type of sysem represented by AEROMAP. He indicated that their

(PCIGeomatics) preference was a world wide aerosol mapping system since their custometers were world wide.

Jack McConnell from York University gave a brief overview of existing air quality models and touched on the relation between air quality and health. He presented some intriguing health cost-benefit analyses on the effects of reducing PM2.5 concentrations by different amounts (costs in terms of mortality rates and in terms of health care). The models included current Canadian air quality models such as AURAMS (the chemical transport model developed at MSC), the MC2AQ urban scale air quality model being developed at York University and GEM (Global Environment Model) derivative models at global and regional scales. He pointed out that the value of AEROCAN was in data validation of such models and in the data assimilation stage where vertically integrated measurements provide a valid and solid assimilation constraint.

Jean Pierre Blanchet from the Université du Québec à Montréal gave a brief overview of NARCM issues (the Mexican NARCM simulations carried out by Rodrigo Munoz Alpizar in particular). He pointed out that meteorogical scale phenomena do need measurements like those of AEROCAN since meteorological aerosol and pollution measurements are largely surface level measurements.

Alain Royer then gave a general overview of the status of the AEROCAN climatological project for which he is principal investigator (”Characterization of aerosol properties using data from a Canadian sunphotometer network: application to climate model and satellite retrieval validation”). The research work was reviewed above as part of Alain’s presentation (water vapour content validation using a GPS receiver, NARCM east coast validation using AEROCAN and POLDER data, the preliminary AEROCAN climatology). Currently this project employs Francois Vachon (MSc) and Rodrigo Munoz Alpizar (Ph.D.). Rodrigo’s project will be tied to nested NARCM simulations of forest fire smoke (using the Mexico City model) and comparisons with optical data. The AEROCAN strategic project enabled the hiring of a new postdoctoral fellow with a strong background in sunphotometry (S.Thulasiraman whom we call Raman). Raman reviewed some of his doctoral week which he did at the Department of Physics of Andhra University in Visakhapatnam India (south east India near the Bay of Bengal). The instrument employed in his study was the Multiwavelength Solar Radiometer (MWR) which was developed in India. Raman’s work on short term variations in coastal urban aerosols and constrained optical inversion results was published in the Indian Journal of Radio and Space Physics, Aerosol Science and Technology, and Tellus.

Future work

General comments were made on future initiatives, both in terms of research and operations. Bruce is moving ahead on the intercomparisons between the Swiss PFR instrument and the other sunphotometers / shadow band radiometer at Bratt’s Lake (CIMEL, MFRSR, Australian SP01A sunphotometers). Bruce will place a CIMEL near Brian Stock’s prescribed burning site in order to study the optics of fresh smoke (*Bruce is also trying to get some good measurements at Bratt’s Lake during the heavy string*

biomass burning season of this spring, NTO). Norm indicated that there will be an AEROCAN presence during the Pacific2001 experiment (the regular Saturna Island instrument and a loaner from Brent and AERONET). We at Sherbrooke hope to push ahead with an analyses of thin cloud influences on AOD in collaboration with Bruce at Bratt's Lake and Kevin Strawbridge at Egbert (*initial results to be presented at the IAMAS conference in Innsbruck Austria, NTO*). *We (primarily Raman) are also currently investigating the large Asian dust event which occurred this April (NTO).* Alain Royer will push ahead on a CIMEL at Resolute Bay (*an equipment grant for a new Resolute Bay CIMEL has been obtained by Alain, NTO*). It was suggested that we could learn a lot from the Barrow Alaska example in terms of measuring protocols for an Arctic or sub-Arctic station. Francois Vachon at CARTEL who was making comparisons between AEROCAN/AERONET instruments and POLDER data will continue this type of work by comparing the MODIS AOD product with AEROCAN sunphotometer data. Future NARCM studies (with AEROCAN as a validation element) will include the 1998 Great Bear Lake fire (which Norm's student Martin Aubé is currently employing to assimilate his aerosol model), the East coast POLDER data and Glen Lesins' GCM runs at Dalhousie University (Glen suggested that comparisons with our smoke paper might be interesting).

In terms of operations Bruce suggested that stronger links with NASA are required. He cited the example of the Bratt's Lake robot problem where there is a kind of disconnect between the AERONET technical team which declares everything to be working and the ultimate user who still finds the same recurring problem after the return from NASA. Jim Freemantle's solution to this problem was to plan for more case dependent checks at Toronto before the instrument was sent out to the site.

Operations protocol document

In response to comments prior to, during, and after the workshop we have finally put together an official operations protocol document. This is a draft and we fully expect changes to be made. It will be noted that we tried not to waste time with duplication and thus that references to existing AERONET documents are made when these exist. (NTO).

Appendix A – original invitation and agenda

The Meteorological Services of Canada (MSC) is hosting the second AEROCAN Workshop to be held in Downsview, Ontario, Canada (northern Toronto) at MSC, 4905 Dufferin Street, Wednesday March 7, 2001. The technical program of the workshop is being orchestrated by CARTEL (Centre d'applications et de recherches en télédétection) at the Universite de Sherbrooke. AEROCAN is a national network of sunphotometers* sponsored by CCRS (Canada Centre for Remote Sensing) and supported by MSC as well as the AERONET group at NASA's Goddard Space Flight Center.

The general objectives of the workshop are threefold (i) to review the current operational status of AEROCAN and AERONET and the future directions of these networks, (ii) to review the climatological and science advances of scientists associated with these

networks, and (iii) to encourage discussion of how best to demonstrate the importance of this data to commercial and governmental interests. We cordially invite all those who are involved in atmospheric science, climate studies or remote sensing to attend this unique workshop on aerosol sunphotometry and climatology.

*The principal product of the network is aerosol optical depth and integrated water vapour content. Important derived outputs include aerosol particle size distribution, particulate refractive index and single scattering albedo. These parameters are generally acknowledged to be critical inputs as well as key validation elements for climatological studies, air quality monitoring and the atmospheric correction of surface remote sensing data. In the past few years the AEROCAN group in collaboration with AERONET has been developing a spatio-temporal statistical data base for aerosol properties over Canada.

AGENDA

AEROCAN WORKSHOP MARCH 7, 2001, MSC TORONTO

** AM - AEROCAN operations and science **

0800 - 0820 AEROCAN status, CDROM database; Norm O'Neill & Alain Royer (CARTEL)
0820 - 0840 AEROCAN operations; Jim Freemantle (Crestech)
0840 - 0900 MSC related activities; Bruce McArthur (MSC)
0900 - 0930 AEROCAN science; Norm O'Neill, Bruce McArthur (MSC)
0930 - 0950 The new In Situ Sensor Measurement Assimilation Program (ISSMAP) at CCRS; Phil Teillet (CCRS)
0950 - 1010 AERONET inversion products; Oleg Dubovik (GSFC/NASA)
1010 -1030 coffee break
1030 - 1100 AERONET science with an emphasis on inversion algorithms Oleg Dubovik (GSFC/NASA)
1100 - 1200 round table discussion; technical and funding issues

LUNCH 1200 - 1330

** P.M. - AEROCAN applications **

Atmospheric corrections

1330 - 1340 concept of a central optical depth server Phil Teillet/Norm O'Neill/Alain Royer (CCRS/CARTEL)
1340 - 1350 commercial needs David Stanley (PCI Geomatics)
1350 - 1400 discussion

Air quality issues

1400 - 1420 PM2.5 and health issues, relation to ozone, composition, data-assimilation of ozone and aerosols; Jack McConnell (York University)
1420 - 1430 discussion

1430 - 1450 - NARCM* summary, Radiometric simulations project - Jean-Pierre Blanchet (UQAM)

1450 - 1500 coffee break

AEROCAN strategic project (Optical validation of NARCM)

1500 - 1520 project status; Alain Royer
1520 - 1540 new faces; short presentation of the Ph.D. sunphotometry work of S.Thulasiraman (CARTEL) and his project goals
1540 - 1600 MODIS/MISR/POLDER validation - Phil Teillet / Alain Royer (CCRS/CARTEL)
1600 - 1700 co-PI meeting

*Northern Aerosol Regional Climatological Model

Appendix B – attendees

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Appendix C - AEROCAN publications / presentations (1999 on)

Peer reviewed publications based on AEROCAN/AERONET data and with at least one member of AEROCAN as an author.

Peer reviewed (in press)

1. O'Neill, N. T., Dubovik, O., Eck, T. F., (2001), A modified Angstrom coefficient for the characterization of sub-micron aerosols, App. Opt., Vol. 40, No.15, pp. 2368-2374.
2. O'Neill, N. T. , Eck, T. F. , Holben, B. N. , Smirnov, A. , Dubovik, O. ,A. Royer, (2001), Bi-modal size distribution influences on the variation of Angstrom derivatives in spectral and optical depth space, J. Geophys. Res., vol. 106, 9787-9806.
3. Bokoye, A.I., A. Royer, N.T. O'Neill, P. Cliche, G. Fedosejevs, P.M. Teillet and B. McArthur (2001). Characterization of atmospheric aerosols accross Canada from a ground-based sunphotometer network : AEROCAN. *Atmosphere-Ocean* (accepté 04-2001).
4. B.N.Holben, D.Tanre, A.Smirnov, T.F.Eck, I.Slutsker, N. Abuhassan, W.W. Newcomb, J. Schafer, B Chatenet, F. Lavenue, Y.J.Kaufman, J. Vande, Castle, A.Setzer, B.Markham, D. Clark, R. Frouin, R. Halthore, A. Karnieli, N.T.O'Neill, C. Pietras, R.T. Pinker, K. Voss, G. Zibordi, (2000), An emerging ground-based aerosol climatology: Aerosol Optical Depth from AERONET, (accepted for publication in Jour. Geophys. Res.)
5. Eck, T. F., Holben, B. N., Ward, D. E., Dubovik, O., Reid, J. S., Smirnov, A., Mukelabai, M. M., Hsu, N. C., O'Neill, N. T., Slutsker, I., (2001), Characterization of the Optical Properties of Biomass Burning Aerosols in Zambia during the 1997 ZIBBEE experiment, Jour. Geophys. Res., Vol. 106, No. D4, pp. 3425-3448.
6. O'Neill, N. T., Ignatov, A., Holben, B. N., Eck, T. F.., (2000), The lognormal distribution as a reference for reporting aerosol optical depth statistics; empirical tests using multi-year, multi-site AERONET sunphotometer data, Geophy. Res. Lett., Vol. 27, pp. 3333-3336.
7. Fedosejevs, G., N.T. O'Neill, A. Royer, P.M. Teillet, A.I. Bokoye and L. J. B. McArthur (2000). Aerosol Optical Depth for Atmosheric Correction of AVHRR Composite Data, *Canadian Journal of Remote Sensing*. Vol. 26(4), 273-284.
8. Smirnov, A., Holben, B. N., Dubovik, O., O'Neill, N. T., Remer, L. A., (2000), Measurements of Atmospheric Optical Parameters on U.S. Atlantic Coast Sites, Ships and Bermuda during TARFOX, Jour. Geophys. Res. (Second Special TARFOX issue), Vol. 105, No. D8, pp. 9887-9901.
9. Eck, T.F., B.N.Holben, J.S.Reid, O.Dubovik, A.Smirnov, N.T.O'Neill, I.Slutsker, and S.Kinne, (1999), The wavelength dependence of the optical depth of biomass burning, urban and desert dust aerosols, J. Geophys. Res., 104, 31,333-31,350
10. Romanov, P., O'Neill, N. T., Royer, A., McArthur, B., (1999), Simultaneous Retrieval of Aerosol Refractive Index and Particle Size Distribution from Ground Based Measurements of Direct and Scattered Radiation, App. Opt., Vol.38, No. 2, pp. 7305-7320.

Peer reviewed (submitted)

1. O'Neill, N. T., Eck, T. F., Holben, B. N., Smirnov, A.A. Royer, Z. Li, (2000), Optical properties of Canadian Forest Fire Smoke Derived from Sunphotometry, (submitted to Jour. Geophys. Res.).
2. Smirnov, A., B.N.Holben, O.Dubovik, N.T.O'Neill, T.F.Eck, D.L.Westphal, A.K.Goroch, C.Pietras, I.Slutsker, (2000), Atmospheric aerosol optical properties in the Persian Gulf region, (submitted to Jour. Geophys. Res.).

Conference presentations / conference proceedings / technical notes

Conference proceedings and or presentations based on AEROCAN/AERONET data and with at least one member of AEROCAN as a contributor.

1. L. J. B. McArthur, J. R. Slusser, N. T. O'Neill, C. Wherli, D. H. Halliwell, and O. J. Neibergall, (2001), Comparison of Optical Depth Measurements at the Bratt's Lake Observatory, Saskatchewan, Canada, abstract submitted to the Global Aerosol Climatology Database Symposium, Portland, Oregon, October.
2. L. J. B. McArthur, R. L. Bello, J. V. Palala, I. Abboud, B. D. Beckett, N. T. O'Neill, A. Royer, Aerosol Optical Depth Measurements at Churchill, Canada, abstract submitted to the Regional Haze and Global Radiation Balance Conference, Air & Waste Management Association, October 2-5, 2001, Bend, Oregon.
3. Bokoye, A. I., A. Royer, N. T. O'Neill, L. J. B. McArthur, (2001), A north american arctic aerosol climatology using ground based sunphotometry, to be published in Arctic.
4. O'Neill, N.T., B. Holben, A. Smirnov, T. Eck A. Royer, Z. Li, (2000), Optical properties of Western Canadian forest fire smoke derived from the AERONET and AEROCAN sunphotometry networks, IRS2000 Conference, St. Petersburg, Russia, July 2000.
5. O'Neill, N.T., B. Holben, Aube, M., A. Royer, J.-P. Blanchet, L. Spacek, (1999), Comparisons between the the Northern Aerosol Regional Climatological Model (NARCM) and spatio-temporal measurements of passive aerosol optical parameters, Canadian Meteorological and Oceanographic Society, 33rd Annual CMOS Congress, Montréal
6. O'Neill, N.T., A. Smirnov, O. Dubovik, T. Eck A. Royer, A. Bokoye, Z. Li, J. Freemantle, (1999), Ground Based optical sensing of Western Canadian forest fire smoke near Toronto, Canadian Meteorological and Oceanographic Society, 33rd Annual CMOS Congress, Montréal
7. Toubbé, B., O'Neill, N. T., Royer, A., Bokoyé, A., McArthur, B., Teillet, P., Miller, J., Freemantle, J., (1999), Analyse des aérosols pour la validation des inversions satellitaires, Aerosols, ALPS'99, International Conference and Workshop, Radiation budget - Land surfaces - Ocean colour : the contribution of POLDER and new generation spaceborne sensors to global change studies, Miribel, France
8. N. T. O'Neill, B. Holben, E. Vermote, A. Smirnov, A. Royer, Martin Aube, J.-P. Blanchet, L. Spacek, (1999), Comparisons between the aerosol transport simulations of an RCM and spatio-temporal measurements of aerosol optical parameters, ALPS'99, Meribel France

9. N. T. O'Neill, B. Holben, A. Smirnov, A. Royer, A. Bokoye, P. Teillet, G. Fedosejevs, (1999), Canadian Sunphotometry Network for AerosolCharacterization, ALPS'99, Meribel France.