Professor Douw Steyn is exploring air pollution in the Lower Fraser Valley in his locality, British Columbia. In this illuminating interview, he discusses the importance of advanced statistical techniques, lessons learnt from past research and his hopes to influence policy in the region.

When did you become interested in advanced statistical and modelling techniques and what motivated you to continue along this path?

Before starting my PhD, I read a book on air pollution by Richard Scorer, and developed an interest in the subject. The technical challenges interested me, and the possibility of conducting research in an area of work that was societally relevant was inspiring.

Why was the Lower Fraser Valley (LFV) chosen as your study site?

This was a happy convergence of circumstances. The ozone pollution problems in the LFV are difficult, and involve the two areas of study I was interested in (boundary layer meteorology and mesoscale meteorology), and of course it is in my ‘backyard’.

How do you use experience from your prior studies in coastal regions with complex topography? Are geographical variables significant in the assessment of ozone concentrations?

The spatial and temporal variability of ozone pollution in the LFV is strongly dependent on particularities of geography and meteorology – valley, land/sea breezes and boundary layers in complex topography. My understanding of these phenomena has helped enormously in that I use my knowledge to constrain how I use the meteorological models that form the analytical core of my research into LFV ozone.

In order to properly capture the mesoscale meteorology in the LFV, I use a general atmospheric numerical model that is popular worldwide. While the model is general, it is capable of simulating atmospheric phenomena found in specific regions. This is achieved by the proper input of topography, surface properties, large-scale meteorological conditions and seasonal solar forcing. A hugely important part of this work is model evaluation; a statistical procedure in which model output is compared with actual measurements to ensure that the model has captured what actually happened on the day.

Why was cluster analysis used to determine decade-scale evolution of air pollution? How do you ensure your cluster analysis is replicable?

Cluster analysis is a well-established statistical technique that has allowed us to focus on the dominant meteorological regimes (clusters of weather types) during ozone episodes. Anyone repeating the cluster analysis with the weather data we used would come up with exactly the same results (clusters). We also performed a sensitivity analysis to ensure that the clusters were robustly defined.

Ground-based technologies, airborne instruments, or a combination of both are used to detect ozone concentrations. Has their evolution improved the accuracy of forecasting? What hurdles are there yet to overcome?

Data are of course crucial and we have various data collection platforms. I have used many in my research: balloon-borne sensors, fixed sensors, tower-mounted sensors, aircraft-borne sensors and remote sensors. All types of sensor have evolved enormously during my career. The major advances have been in miniaturisation, accuracy, precision and lowering cost. I think instruments on remotely controlled drones are a very exciting possibility.

What have you learnt from studying ambient ozone and emissions of ozone precursors so far?

All my research in the LFV has been directed towards understanding the link between emissions of precursors and ambient ozone concentration. I believe we have developed a comprehensive understanding of the link, and I hope that understanding will be used to develop the next generation of the LFV air quality management plan.

Could you explain the function of the steering committee and how it helps guide your focus?

The main function of the steering committee was to develop a set of research questions that were scientifically tractable and at the same time policy relevant. Too often, scientifically driven questions are policy irrelevant, and questions posed by policy makers are intractable. The committee was designed to reconcile the two imperatives (science and policy).

How important is collaboration to your work?

Collaboration is hugely important to my research. My collaborators and students form a research team, all members contributing different skills to the overall effort.
Observing the ozone

A study led by the University of British Columbia, Canada, is unravelling the processes of ozone air pollution with the aim of changing local, and perhaps even national, policy regarding air management.

OZONE’S PROPERTIES MAKE it a powerful oxidant, useful for industrial and consumer applications, but also a respiratory hazard and pollutant. Tropospheric ozone, created by the reaction of daylight ultraviolet (UV) rays on precursors emitted during the combustion of fossil fuels, can therefore damage the cells lining the airways and harm plant tissues, and as a major component of smog, seriously limits visibility.

Douw Steyn, Professor at the University of British Columbia (UBC), is studying the evolution of this deleterious process in the Lower Fraser Valley (LFV) as it provides a useful model in which to study the phenomenon. Straddling the Canada/US border, it is bounded by the Coast Mountains to the north and the Cascade Range to the southeast. This particular topography prevents the transport of air pollutants away from the region, and in the summer intensifies in the presence of more UV rays, causing severe air pollution and smog. Exacerbated by a growing population, declining air quality had become a real cause for concern in the area, creating a need for better air quality forecasts and management of industries during the sensitive summer months.

Collaborator profile: Dr Christian Reuten

Dr Christian Reuten is Technical Director of Air Quality at RWDI Air Inc., having worked as Research Associate at UBC from 2001-10. His investigations focus on atmospheric boundary layer processes in complex environments, including regional air-quality.

Reuten works with policy makers in the LFV to answer questions concerning ozone pollution, and with Steyn to conduct research on the atmospheric boundary layer in regions of complex topography and coastline.

In 2011, the two collaborated on a paper to assess another aspect of ozone pollution in the LFV – climate change. Based on present emissions and background concentrations of ozone, they investigated how large-scale weather changes could affect future episodes in the LFV. Using the Third Generation Coupled Global Climate Model (CGCM), they predicted significant increases in daily maximum temperatures in the valley. In turn, they expect this will more than double the number of ozone exceedance days per year – a startling prediction.

Starting in 1997, Steyn reported on a multi-agency field study carried out in the LFV in the summer of 1993. This field study, entitled ‘Pacific ’93’ obtained a comprehensive dataset of photochemical episodes in the valley. His analysis of the results significantly advanced understanding of the meteorology and chemistry of tropospheric ozone episodes in the region and supported more advanced modelling efforts.

Three years later, in collaboration with scientists now at the University of Birmingham in the UK, Steyn presented a numerical study of the meteorological conditions during Pacific ’93. Although several observational studies had been conducted, there was previously no 3D description of the temporally sensitive meteorological conditions for the whole valley. Steyn answered this call for a valley-wide assessment, employing a meso-scale model – the Regional Atmospheric Modelling System (RAMS) – to accurately forecast changes. The modelled results of meteorological variables for 1993 were broadly in line with observations and made for an interesting suggestion; that thermal plumes near mountain ridges may carry pollutants to higher levels before being transported, by the upper flows, back to the LFV.

SIMULATING THE PAST

More than 10 years later, Steyn went on to publish a new retrospective analysis of ozone formation in the LFV. This study was conducted using numerical models, and supplemented by observations and emission inventories, in an effort to understand the intricate relationships between reductions in local precursor emissions and ozone concentrations.

The large-scale project explored how ozone formation changed in the valley, using data from four key episodes during a 20-year period (1985-2005). Ozone formation was investigated using the Weather Research and Forecasting meteorological model, Sparse Matrix Operator Kernel Emission model and Community Multiscale Air Quality (WRF-SMOKE-CMAQ)
Collaborator profile: Annie Seagram

Graduate student Annie Seagram is a vital member of Steyn’s team. She works on meso-scale meteorology, conducting observational, scaling and numerical modelling studies of sea-breeze and slope flow dynamics.

Seagram recently contributed to a chapter in *Air Pollution Modeling and Its Application XXII*, presenting her findings on the modelled recirculation of pollutants during ozone episodes in the LFV, something often cited as a cause of poor air quality.

The study investigated recirculation using the Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT) to generate trajectories from the Weather Research and Forecasting (WRF) model. The model was applied to seven severe episodes, encompassing the main circulation regimes that are conducive to ozone episodes. Seagram found strong evidence of recirculation in the LFV, where the behaviour of the recirculation is strongly linked to diurnal wind changes and mesoscale circulations.

modelling system. For each episode, two simulations were performed, in order to isolate the effects of emission changes from those of meteorological changes; one was run with emissions levels observed during 1985, and the other from 2005.

Analysis revealed drastic differences in station readings around the LFV. Furthermore, as there seemed to be very little impact from precursor emissions upwind of the LFV, and because background concentrations of ozone are generally brought in from the North Pacific Ocean, and are generally quite low, Steyn suggested that summertime ozone formation in the area is primarily caused by local emissions.

**POLICY IMPLICATIONS**

Today, Steyn’s ongoing project will see him further study pollution trends in the LFV, using numerical modelling based on meteorological conditions observed during previous episodes, selected using criteria from meteorological cluster analysis. The modelling system chosen is responsive to emissions changes that have taken place previously and are likely to occur again in the future. To evaluate these models, the team will demonstrate its ability to capture the evolution of photochemical pollution over decadal time scales.

Steyn will also assess how pollution itself responds to emission changes, using chemical process analysis and spatiotemporal analysis of ozone plumes. In doing so, he will provide an unprecedented level of understanding on the complex relationship between ambient ozone and emissions of noxious precursors in the LFV.

Importantly, the project has been guided by a steering committee composed of stakeholders from policy, regulatory and scientific sectors. This has ensured that the questions asked are relevant. Moreover, the results are entirely scientifically credible, based on carefully selected methods to provide the robust scientific guidance Metro Vancouver and the FVRD needed to improve their air quality management plans.

Collaborator profile: Dr Bruce Ainslie

Dr Bruce Ainslie is Senior Air Quality Modeller at Environment Canada, and heavily involved with efforts to improve air visibility in the LFV.

Ainslie aims to address visibility with a triad of management, measurement and modelling. He uses photochemical transport models to simulate visibility loss due to emissions in the area and to determine which pollutant sources are the biggest contributors. He also performs policy modeling based on emission scenarios.

In collaboration with Steyn, Ainslie has been further investigating the polluted atmosphere in the LFV, conducting field measurement and numerical modelling studies, and playing a large part in the 2013 dynamical model evaluation work.

**INTELLIGENCE**

**DECADE SCALE EVOLUTION OF OZONE AIR POLLUTION IN THE LOWER FRASER VALLEY, BRITISH COLUMBIA**

**OBJECTIVE**

To provide a policy-relevant understanding of the relationship between ambient ozone and emissions of ozone precursors in the Lower Fraser Valley.

**KEY COLLABORATORS**

Recent graduate students: Bruce Ainslie, Christian Reuten, Annie Seagram • Professor Ian McKendry, University of British Columbia • Bruce Ainslie, Research Scientist, Environment Canada • Professor Peter Lawrence Jackson, University of Northern British Columbia

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is Professor of Atmospheric Science in the Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, and a member of the Institute for Applied Mathematics, the Institute for Resources, Environment and Sustainability, and the Liu Institute for Global Issues. He has served as Associate Dean (Research and Faculty Development) in the Faculty of Graduate Studies and Principal of the College for Interdisciplinary Studies. Steyn’s professional, teaching and research activities are in the field of air pollution meteorology, boundary layer meteorology, mesoscale meteorology, environmental science and interdisciplinary science. His research involves measurement and modelling studies of regional air pollution, especially in regions with complex terrain. Steyn has worked extensively on the statistics of air pollution, air pollution monitoring and monitoring network design. He is Chair of the scientific committee that leads the International Technical Meeting series on Air Pollution Modelling and its Application.