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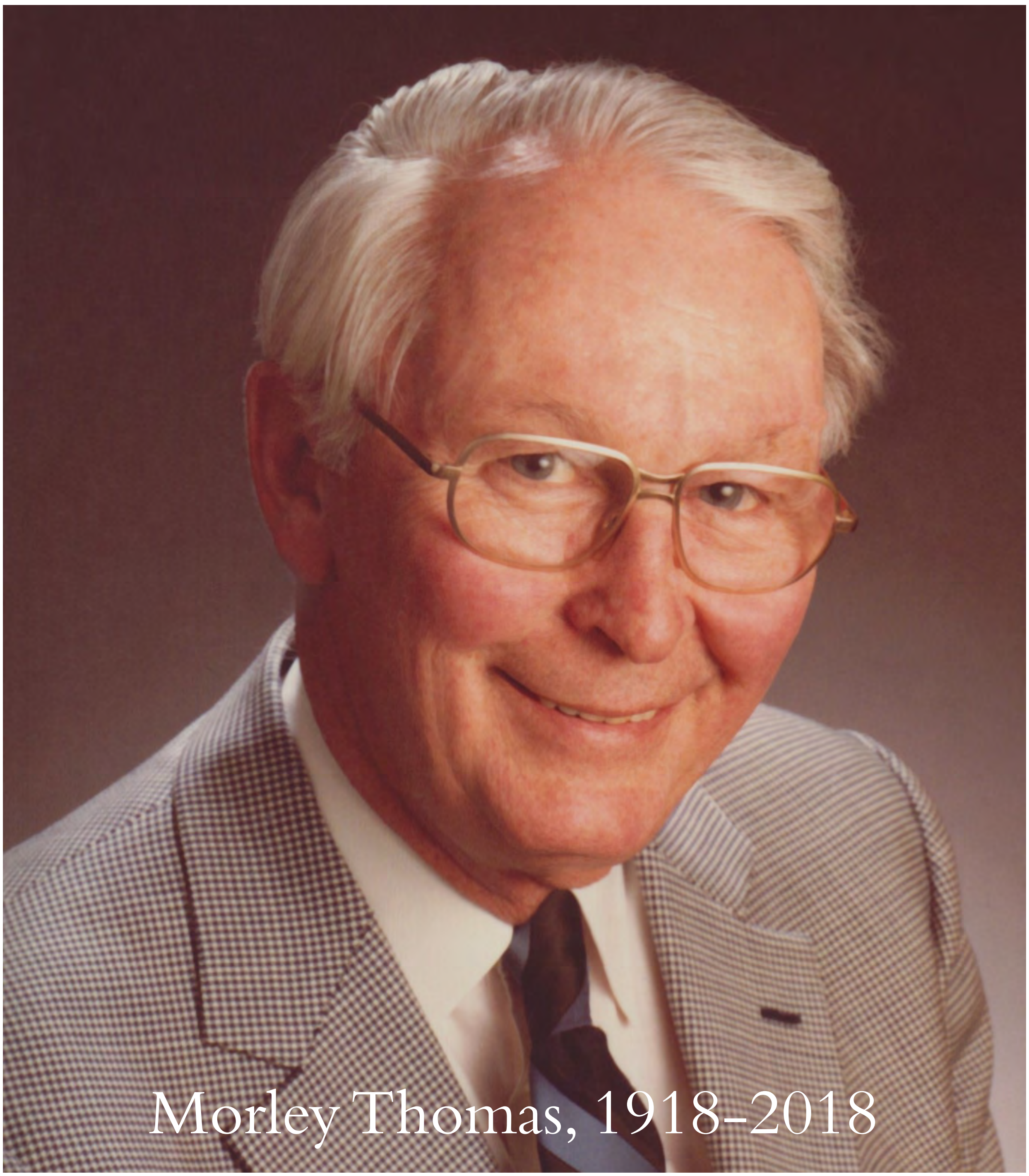
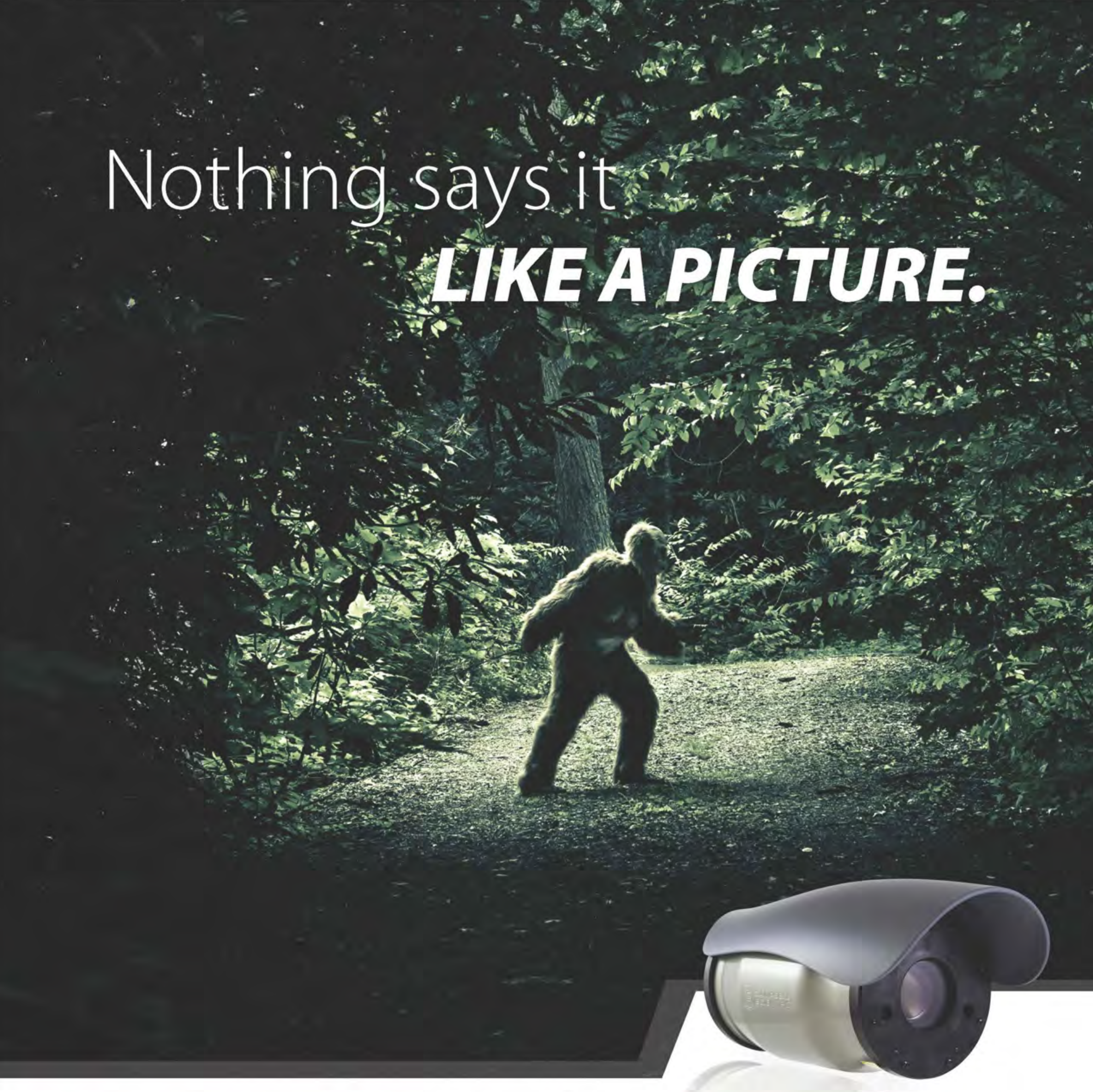


Photo courtesy of Steve Thomas and family. Tribute to Morley's scientific life and career, page 16.


Nothing says it
LIKE A PICTURE.

CMOS Bulletin SCMO
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CMOS Bulletin SCMO
"at the service of its members / au service de ses membres"

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CMOS exists for the advancement of meteorology and oceanography in Canada.

Le but de la SCMO est de promouvoir l'avancement de la météorologie et l'océanographie au Canada.

Words from the President

Past-President Wayne Richardson (right) passes the torch to Paul Kushner (left) at the 2018 congress in Halifax.

This month I'm thinking back on the 2018 CMOS Congress in Halifax, a great gathering for our community that featured excellent plenaries and sessions, smooth organization, superb facilities, and a welcoming spirit throughout the week. My sincere thanks go out to the Halifax Congress's volunteer team, under the leadership of Dave Wartman's Local Arrangements Committee and Clark Richards' Scientific Organizing Committee. Their tremendous effort shows what can happen when foresight, hard work, dedication, and team spirit come together in support of a complex undertaking.

Thinking about CMOS Halifax 2018 brings me back to one of our primary themes of stewardship this year – strengthening CMOS's financial position. As previously pointed out by Past Presidents Martin Taillefer and Wayne Richardson, our yearly fiscal deficits ($28,254 in 2016 and $59,712 in 2017, see the Annual Review for 2017) continue a trend that is draining our reserves and limiting our work to keep CMOS relevant. Wayne told you last year about tightening up CMOS's operations, and this year we're reviewing the financing of the annual congress, which is one of our main revenue sources. Going beyond finances, we need to address how the congresses operate and how we measure success. Our working group will come back with recommendations for CMOS Council in the coming months. We need your feedback on the future of CMOS Congresses and welcome your input.

(Speaking about congresses: don't forget to plan for the IUGG Congress in Montréal, July 8-18 2019! CMOS, with CGU, will be co-hosting the meeting, is counting on a good revenue stream from it, and will be holding key annual activities like the banquet there. Save the date!)

In the coming months I'd like to talk to you about the other themes of stewardship we're focusing on this year. First, we're working on CMOS's advocacy for our research community. To get the conversation started, take a look at Evidence for Democracy's submission to the Parliamentary Finance Committee in advance of the 2019 federal budget, which included input from the CMOS Special Interest Group on Atmosphere Related Research in Canadian Universities (CMOS ARRCU-SIG). Second, we're thinking about how CMOS might address sustainability issues around anthropogenic global warming. We'll be talking about opportunities that society has missed, serious impacts we're starting to see, and future opportunities for addressing global warming. I'd love to hear your thoughts!

As always, feel free to contact me at president@cmos.ca.

Sincerely,

Paul Kushner

CMOS President and Professor, Department of Physics, University of Toronto
Email: president@cmos.ca
Tel: 416-946-3683

Mot du président

Wayne Richardson, Président sortant (sur la droite), et Paul Kushner au Congrès de Halifax.

Ce mois, je contemple le Congrès de la SCMO 2018 qui a eu lieu à Halifax. Ce fut un rassemblement important pour notre communauté, un rassemblent doté de sessions et plénières excellentes, d'une organisation souple, ayant lieu dans de superbes installations, le tout baignant dans un esprit des plus accueillants qui était en évidence tout le long de la semaine. Je remercie sincèrement l'équipe de bénévoles du Congrès d'Halifax, sous le leadership du Comité local des Préparatifs de Dave Wartman et du Comité organisateur scientifique de Clark Richards. Leurs efforts considérables sont preuve de ce qui peut être accompli lorsque prévoyance, travail ardu, dévouement, et un bon esprit d'équipe sont réunis pour appuyer un projet complexe.

Ma réflexion sur le Congrès de la SCMO 2018 (Halifax) m'a porté à une considération particulière d'un de nos thèmes d'intendance les plus fondamentaux – le renforcement de la position financière de la SCMO. Tel que souligné précédemment par les anciens présidents Martin Taillefer et Wayne Richardson, nos déficits annuels croissants (de 28 254 $ en 2016 et de 59 712 $ en 2017 -- veuillez consulter l'Examen annuel pour l'an 2017) doivent être adressés, faute de quoi non seulement seront épuisés nos réserves, mais aussi notre effort pour assurer la pertinence de la SCMO se retrouvera limité. L'an dernier, Wayne a porté à votre attention le besoin de resserrer les opérations de la SCMO. Cette année, nous révisons le financement de notre congrès annuel, une de nos sources de revenus les plus importantes. Au-delà des finances, nous devons aussi adresser la façon dont les congrès opèrent ainsi que la façon dont on évalue ce qui constitue un succès. Notre groupe de travail fera rapport, dans les mois prochains, de ses recommandations pour le Conseil de la SCMO. Ainsi, nous vous consultons car nous avons grandement besoin, et sommes donc à la recherche, de votre rétroaction sur l'avenir des congrès de la SCMO.

(En parlant de congrès… N'oubliez pas d'inscrire à vos calendriers le Congrès de l'UGGI qui aura lieu à Montréal du 8 au 18 juillet 2019 ! La SCMO, avec l'UGC, partageront le rôle d'hôte de cette réunion et nous espérons qu'elle sera aussi génératrice de revenus importants. Qui plus est, plusieurs activités annuelles principales, telles le banquet, y seront tenues ! Inscrivez les dates à l'encre !)

Dans les mois qui viendront, j'ai l'intention de vous entretenir sur d'autres thèmes d'intendance sur lesquels nous concentrerons notre attention. D'abord, nous travaillerons sur la mobilisation de la SCMO pour notre communauté de recherche. Pour amorcer la conversation, veuillez consulter la soumission au Comité parlementaire sur les finances, préparée par Evidence for Democracy, en anticipation de l'exercice budgétaire fédéral de 2019 -- la soumission comprend l'avis du Groupe d'intérêt spécial de la SCMO sur la Recherche au sein d'institutions universitaires canadiennes reliée à l'atmosphère (CMOS ARRCU-SIG). Ensuite, nous réfléchirons sur la manière dont la SCMO pourrait adresser les questions relatives au développement durable pertinentes au réchauffement anthropique de la planète. Nous discuterons d'opportunités ratées par la société, des impacts considérables que nous commençons à observer, et de voies d'avenir pour adresser le réchauffement planétaire. Il me fera plaisir que vous me fassiez part de votre façon de penser sur ces sujets.

Et pour ce faire, n'hésitez point à me joindre à president@cmos.ca.

Paul Kushner

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The Lunar Atmosphere: a surface-bounded exosphere that builds a record of delivery of water to the Earth's oceans

By Paul Godin, Jacob Kloos, Tue Giang Nguyen, Jasmeer Sangha, and John Moores, Department of Earth and Space Science and Engineering, York University

The moon has been and still is an area of great interest in the field of planetary sciences. Because its atmosphere is extremely thin (typically, you will find no more than one million molecules per cubic centimeter, whereas on Earth the density at sea level is typically twelve orders of magnitude greater), the moon was once widely regarded as having no atmosphere at all. However, thanks to the Apollo missions and the subsequent Lunar Reconnaissance Orbiter (LRO) and Lunar Atmosphere and Dust Environment Explorer (LADEE) missions, we have a much greater understanding of the composition of the lunar atmosphere. Earth-based telescopes have detected traces of sodium, argon and potassium atoms in the atmosphere while measurements from the Apollo missions detected other gases such as oxygen, carbon dioxide and nitrogen. There is also an extensive dust atmosphere resulting from the constant bombardment of micrometeorites. The LRO along with its companion the Lunar CRater Observation and Sensing Satellite (LCROSS) later discovered water deposits at the poles hinting at a possible water cycle on the surface of the moon [Dunbar, 2013].

With such a low density, the lunar atmosphere is technically a "surface boundary exosphere". Indeed, the conditions near the surface of the moon are very comparable to the outermost layer of the Earth's atmosphere. The difference between the bulk of the terrestrial atmosphere below the exobase (the boundary between the thermosphere and the exosphere) and the exosphere above lies in the way molecules interact with one another through collisions. Below the exobase, atmospheric molecules are constantly colliding, evening out temperature and compositional properties. However, in the much thinner exosphere, molecules are extremely unlikely to collide, and their trajectories are constrained only by incoming solar energy and gravity giving rise to ballistic motion. Molecules that have gained a lot of energy from the sun may even find themselves escaping the gravity of earth completely (Jeans escape) and fly off into space never to be seen again [UCAR, 2011].

Ultimately, the exosphere is the boundary between the atmosphere and space. Understanding the exosphere is therefore very important for understanding the dynamics of volatiles on the moon, in particular: water. Our group, the Planetary Volatiles Laboratory at York University, is very interested in how water molecules migrate ballistically across the surface and how that movement can be detected. Additionally, understanding the dynamics of the lunar surface-bound exosphere allows for greater insight into the processes that affect other planetary bodies with a similar atmosphere including Mercury, large asteroids, and the moons of the giant gas planets.

Another open question is from which source did the Moon's water originate? Possible sources include delivery directly by impacts or recombined hydrogen implanted from the solar wind [e.g. Sunshine et al., 2009; Dyar et al., 2010; McCord et al., 2011]. All of these sources also impact the water inventory on the Earth and, as such, reservoirs of ice on the moon may preserve a record of bulk water delivered to the Earth-Moon system by cometary impactors. Perhaps as much as 1014 kg could have accumulated over the past 2 Ga [Arnold, 1979]. Another exciting possible source is that the moon could have retained some water sourced from the Earth following the giant impact which formed the satellite. Analysis of the isotopic composition of hydrogen from ancient lunar highlands samples and water reservoirs on Earth show remarkable consistency, strongly suggesting a shared origin between lunar and Earth water [Barnes et al., 2014].

For exploration, this water ice offers a potential readily available source of hydrogen and oxygen that can be used to sustain exploration activities. The water itself can be used by astronauts directly as potable water, the oxygen can be used to manufacture breathable air and the hydrogen can be used as a feedstock to produce fuel for operations and eventual return to the Earth. Knowledge of ice deposit locations and reservoir inventories would be an important factor when deciding where to build a potential lunar base. In short, the water deposits on the moon have high scientific and exploration value.

Ballistic Motion

The transport of volatiles is fundamentally different on the moon compared to within collisional planetary atmospheres. Take for example the water cycle; on Earth, water in liquid form can evaporate into the atmosphere where it may ultimately condense and fall back to Earth; may it be in liquid or solid form. Due to the low atmospheric pressure (3×10-15 bar) on the Moon, water is never in liquid form thus must go through different processes to migrate to different regions.

For particles to leave the lunar surface they must sublimate. Once the Sun sufficiently heats the surface, approximately 150 K, the ice molecules will enter a gaseous state and unbind from the lunar regolith. Due to the thin atmosphere, atmospheric interactions are extremely unlikely, and these molecules convert the newly acquired thermal energy to kinetic energy as they undergo ballistic motion (i.e projectile motion). Once airborne, the molecules will undergo one of four possible outcomes:

1. A high energy UV photon from the Sun hits the molecule and photodissociation of the water molecule occurs. The energy absorbed needs to be high enough to cleave apart the molecule by exceeding bond energies between its constituents.
2. The water molecule gains enough kinetic energy from the initial sublimation interaction to completely escape the Moon's gravitational pull and is lost to space.
3. The particle completes its ballistic trajectory and lands back on the surface where it gives up its energy, waiting for the next photon sublimation interaction to hop again.
4. The particle completes its ballistic trajectory at a region of permanent shadow which protects it from further sublimation.

On the Moon, using typical solar activity levels, water has a photodissociation rate of 1.26 x 10-5 mol/s, which results in approximately 90-95% of particles photo-dissociating while hopping along the lunar surface before reaching a region of permanent shadow, thus the eventual fate of most water is outcome #1. However, the probability of any individual molecule being photo-dissociated on any single hop is very low. Furthermore, only a small number of molecules (<1%) on the long tail of the Maxwell Boltzmann distribution of sublimation energies gain enough kinetic energy to exceed the Moon's escape velocity, 2.38 km/s and suffer outcome #2. That leaves the 5-10% that will eventually make it all the way to the permanently shadowed regions near the lunar poles.

As a result of the relatively low number of molecules that are dissociated in a single hop or escape on any particular hop, molecules spend most of their time making large jumps near the equator. As they proceed towards the poles, they make smaller jumps, as shown in Figure 1. It is important to note that night time temperatures can plummet to 100 K (Figure 2), meaning particles that land on the night-side of the moon will lay dormant until sunrise. Most of the lunar surface is unstable in terms of temperature, though there are small cold regions near the poles that remain in shadow yearlong allowing for particles to be trapped for long periods of time. These regions are known as permanently shadowed regions (PSRs) and can function as traps for volatiles on the moon.

The Search for Lunar Water Ice Deposits

The potential for the PSRs of the Moon to preserve water has been recognized for over 60 years [Urey, 1951]. Spacecraft have observed hydrogen signals consistent with significant deposits of water ice at these PSRs [Mitrofanov et al., 2010; 2012]. Observations made by the Neutron Spectrometers onboard the Lunar Prospector orbiter in the late 1990s [Feldman et al., 1998], later confirmed by the Lunar Exploration Neutron Detector (LEND) experiment onboard the LRO [Mitrofanov et al., 2010; 2012), clearly show the hydrogen signal. Additionally, ultraviolet Lyman-α (121.6 nm) reflectivity [Gladstone et al., 2012] suggest that some of this water may be exposed at the surface.

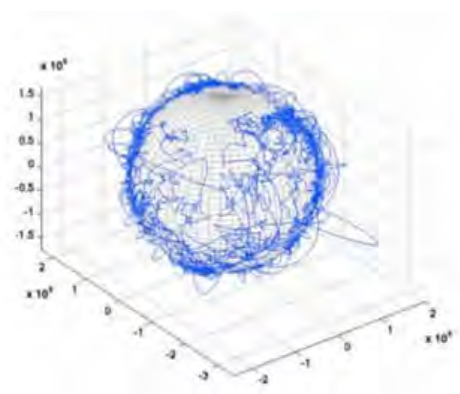


Figure 1: A simulation of a single water particle undergoing ballistic transportation on the lunar surface with the probability of photodissociation being zero starting at the equator. After 5049 hops the particles arrives within 5o of the South Pole. [Moores, 2016]

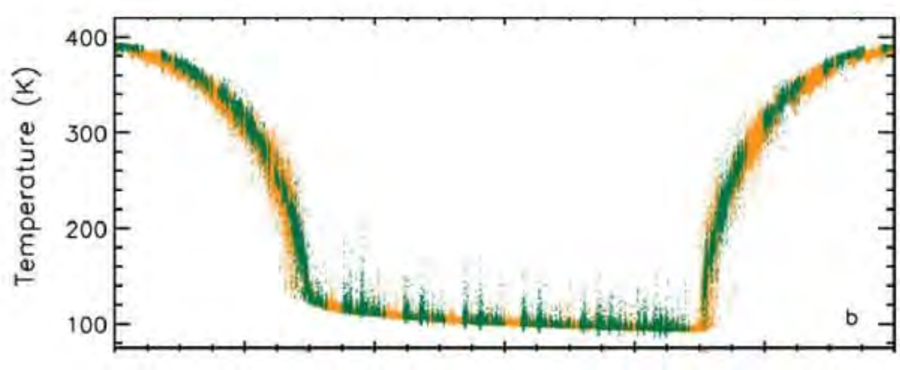


Figure 2: Surface temperature across the lunar equator with the time of day along the x-axis. The peak temperature occurs at noon, and the almost flat section is the night time temperature on the other side of the Moon. [Vasavada et al., 2012]

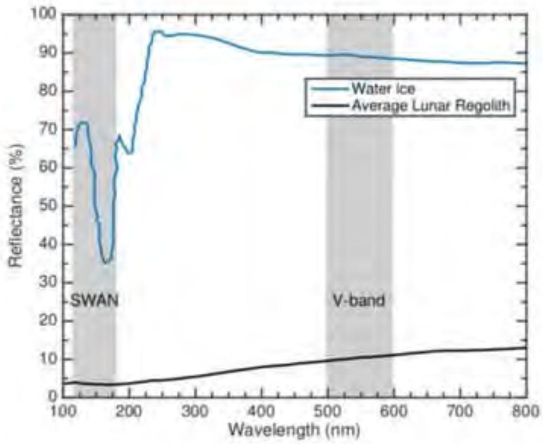


Figure 3: Reflectivites of ice and lunar regolith samples. The shaded regions show the bandpasses of the SWAN instrument on board the SOHO spacecraft and the astronomical V-band [Wagner et al., 1987]

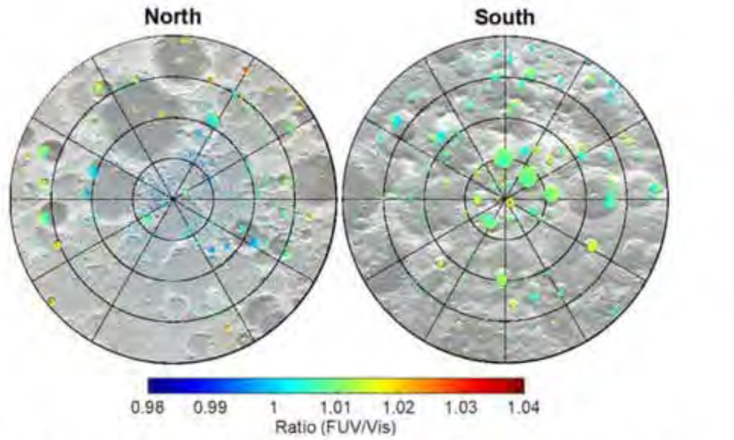


Figure 4: Ratio of FUV/Visible illumination at the PSRs of the North and South Poles of the Moon.

Better understanding of the distribution of lunar water ice is still needed. In some places this ice is observed as frost directly on the surfaces of the PSRs, while in other locations more extensive deposits are inferred below the surface. For the surficial component, distinguishing ice from lunar regolith can be achieved by their different reflectivity at different wavelengths as shown in Figure 3. Since the reflectivity of ice changes significantly going from UV to IR, while regolith reflectivity changes only a little bit, the ratio of images taken at different wavelengths filters can reveal the location of ice.

Both NASA and ESA have planned satellite missions to map lunar ice distribution. Both missions will use active remote sensing, using visible and IR light sources carried on board. In our research we have recently been examining a passive remote sensing approach, using far-UV (FUV) and visible light from the background starfield.

Illumination Conditions at the Poles

To investigate the ice in the PSRs remotely, some photons are needed. As luck would have it, PSRs aren't so shadowed after all – they can see the stars. One of the brightest wavelengths for peering into these dark places is therefore in the Lyman-α portion of the FUV where hydrogen atoms emit light. Quantifying the FUV and visible photon flux within PSRs is important in determining the viability of in-situ passive remote imaging.

The precise photon flux reaching the PSR surfaces can be determined using astronomical data sets that map the entire sky in FUV and visible bands. For FUV, the Solar Wind Anisotropies (SWAN) instrument on board the Solar Heliospheric Observatory spacecraft acquires background maps the entire sky in FUV light (115 – 180 nm). To model the visible photon flux within lunar PSRs, we utilize the Color All-Sky Panorama Image of the Milky Way from Mellinger [2009]. Additionally, the visible photon flux reaching the PSRs will also be contributed by scattered sunlight from the crater walls, which has been shown to be significant by Mazarico et al., [2011].

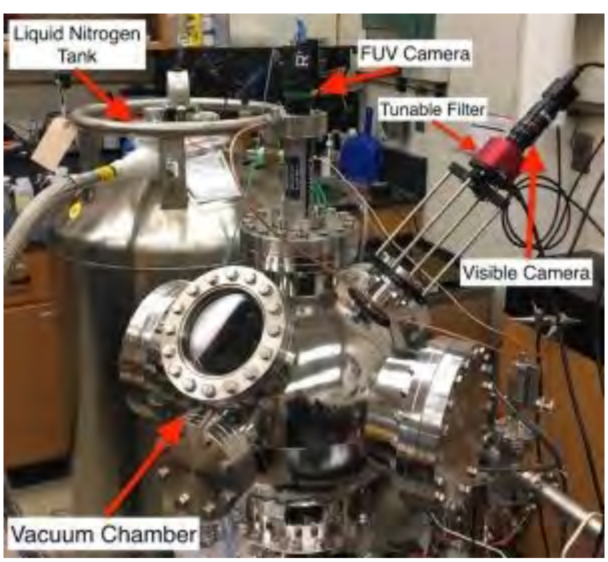


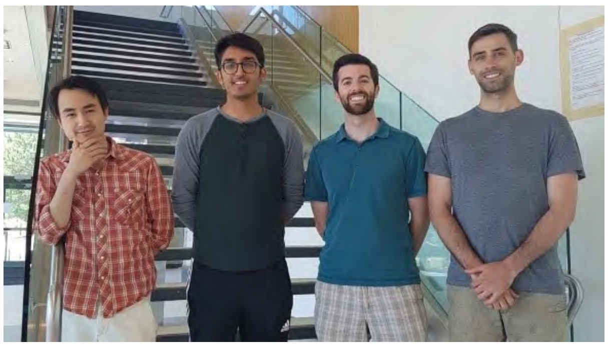
Figure 5: Experimental set-up for studying UV/Vis reflectivity of ice and regolith.

The results from this work, shown in Figure 4, are presented in the form a map for the north and south pole showing the ratio of FUV/Visible light reaching the PSRs. All areas of color represent a PSR (as determined from the work of Mazarico et al., [2011]). These maps reveal that there are approximately equal amounts of FUV and visible light that reach the PSRs, and little geographic variation is observed at large or small-scales.

This theoretical work has been complimented with experimental studies that have been performed using a cryo-vacuum chamber within the Planetary Volatiles Laboratory at York University. This chamber will be used to simulate the thermal and radiation environment of the lunar PSRs. To simulate the diffuse light sources that illuminate the lunar PSRs, the ice/regolith samples will be irradiated with FUV and visible radiation sources. Two cameras were interfaced with vacuum chamber to perform the imaging experiments: a VIS/NIR imager and a FUV imager (see Figure 5), thus allowing wavelength characterization of the samples.

Lunar regolith simulant (JSC-1A) and ice samples were held in a small cylindrical copper container located in the center of the chamber. The samples used in our study consisted of: (1) a completely "dry" sample, consisting of pure regolith simulant; (2) an intimate mixture of (roughly) equal parts water ice and regolith; (3) water ice added on top of regolith simulant and (4) pure water ice. These samples were imaged with the FUV and Visible imagers. From these experiments, we can confirm that the reflectivity ratio of regolith changes very little, while as we increase the amount of water ice, the ratio decreases significantly corresponding to less reflection of the ice in the FUV.

In summary, the lunar atmosphere is far more than just the vacuum of space. Volatiles hop around the surface following ballistic trajectories, eventually settling in PSRs. Determining the distribution and size of these deposits and can tell us much about the atmospheric cycles on the moon. Several future lunar missions are planned to investigate the distribution of water deposits on the Moon, taking advantage of the changes in reflectivity of ice and regolith at different wavelengths. Simulation work done in our lab shows that this detection can be done passively, using FUV and visible radiation. Since the Earth and moon share a common origin for water, analyzing water samples from these deposits can also yield insights about the history of our own oceans.



The Authors, From Left to Right: Tue Giang Nguyen, Jasmeer Sangha, Paul Godin and Jacob Kloos

References

Dunbar, B. (2013, June 08). Is There an Atmosphere on the Moon? Retrieved from https://www.nasa.gov/mission_pages/LADEE/news/lunar-atmosphere.html

UCAR. (2011). Exosphere – Overview. Retrieved from https://scied.ucar.edu/shortcontent/exosphere-overview

Moores, J. E. (2016), Lunar water migration in the interval between large impacts: Heterogeneous delivery to Permanently Shadowed Regions, fractionation, and diffusive barriers, J. Geophys. Res. Planets, 121,46–60, doi:10.1002/2015JE004929.

Vasavada, A., et al. Lunar equatorial surface temperatures and regolith properties from the Diviner Lunar Radiometer Experiment. Journal of Geophysical Research, 117, 2012.

Urey, H.C. (1951) The Planets, their origin and development. Yale University Press, New Haven, Connecticut.

Mitrofanov, I. and 28 co-authors (2010) Hydrogen Mapping of the Lunar South Pole Using the LRO Neutron Detector Experiment LEND. Science 330 (6003) pp. 483- doi: 10.1126/science.1185696

Mitrofanov, I. and 23 co-authors (2012) Testing polar spots of water-rich permafrost on the Moon: LEND observations onboard LRO. J. Geophys Res. 117 E00H27 doi: 10.1029/2011JE003956

Feldman, W.C., S. Maurice, A.B. Binder, B.L. Barraclough, R.C. Elphic and D.J. Lawrence (1998) Fluxes of Fast and Epi-thermal Neutrons from Lunar Prospector: Evidence for Water Ice at the Lunar Poles. Science 281 (5382) pp.1496-1500

Gladstone, G.R. and 19 co-authors (2012) Far-ultraviolet reflectance properties of the Moon's permanently shadowed regions. J. Geophys. Res. 117 (E00H04) doi: 10.1029/2011JE003913

Sunshine, J.M., T.L. Farnham, L.M. Feaga, O. Groussin, F. Merlin, R.E. Milliken and M.F. A'Hearn (2009) Temporal and Spatial Variability of Lunar Hydration As Observed by the Deep Impact Spacecraft. Science 326 (5952) pp. 565-68.

Dyar, M.D., C.A. Hibbitts and T.M. Orlando (2011) Mechanisms for incorporation of hydrogen in and on terrestrial planetary surfaces. Icarus 208 (1) p. 425-437.

McCord, T.B., L.A. Taylor, J.-P. Combe, G. Kramer, C.M. Pieters, J.M. Sunshine and R.N. Clark (2011) Sources and physical processes responsible for OH/H2O in the lunar soil as revealed by the Moon Mineralogy Mapper (M3). J. Geophys. Res. 116 E00G05 doi: 10.1029/2010JE003711

Arnold, J.R. (1979) Ice in the lunar polar regions. J. Geophys Res 84(B10) 5659-5667

Jessica J. Barnes, Romain Tartèse, Mahesh Anand, Francis M. McCubbin, Ian A. Franchi, Natalie A. Starkey, and Sara S. Russell (2014), The origin of water in the primitive Moon as revealed by the lunar highlands samples, Earth and Planetary Science Letters, Volume 390, p.244-252

Mellinger, A. (2009), A Color All-Sky Panorama Image of the Milky Way. Publications of the Astronomical Society of the Pacific, 121:1180–1187

Mazarico, E., G. A. Neumann, D. E. Smith, M. T. Zuber, and M. H. Torrence (2011), Illumination conditions of the lunar polar regions using LOLA topography, Icarus, 211, 1066–1081

Article: Comparison of Wind Forecasts and Observations

Comparaison des prévisions et des observations de vent au lac-St-Charles, Québec / Comparison of wind forecasts and observations at Lake Saint-Charles, Quebec

Richard Leduc and Maude Chartrand, Geography Department, Université Laval

*Lake Saint-Charles is the main source of drinking water for nearly 300,000 citizens of Quebec City's and other municipalities. For several years obvious signs of accelerated aging of the water body were noticed, one of the symptoms of which is the appearance and recurrence (since 2006) of episodes of potentially toxic cyanobacterial water blooms. The "**Association for the Protection of the Environment of Lake Saint-Charles and Northern Marshes (APEL)**" has the mission to ensure the sustainability and quality of this drinking water. For monitoring purposes and studies, the City of Quebec has installed a meteorological tower whose observations serve, among other things, as inputs to an empirical model developed by the APEL to model the development of cyanobacteria. The tower has been in operation since December 2016.*

*Predicted meteorological data (particularly wind speed and direction) can also be used as inputs to this model to predict the development of cyanobacteria. Predicted values from **Environment and Climate Change Canada's High Resolution Deterministic Prediction System (HRDPS)** are used to drive the CALMET diagnostic model set up in a domain (20 km by 20 km) centered on Lake St. Charles with a resolution of 100 m by 100 m. In this study, observed and predicted wind for 273 days in 2017 are compared. It can be seen that the tower at Lac St-Charles has a lower average speed by about 34% compared to that predicted (i.e. calculated by CALMET with forecasts from HRDPS) – respectively 1.67 m/s and 2.53 m/s. The frequency of CALM (<0.4 m / s) observed is about 16% compared to about 1% for that predicted. There is also a much higher observed frequency for the NNE and NE directions than those obtained by CALMET. There are also significant differences on the east and west side. CALMET significantly adjusts the directions of the last quadrant where the NNW direction, in the direction of the lake, becomes predominant. At the tower the directions NE and NNE are important at night where-as at this moment, CALMET gives a direction NNW, probably associated with a katabatic flow which is channeled in the direction of the lake. The correlation between the measured and predicted speeds is 0.544 (for one year). Depending on the forecast period (00 h to 42 h), the correlations between the measured and predicted speeds vary between 0.45 and 0.66 while the vector correlation is between 0.76 and 1.16. Observations and forecasts for 2018 will be used for further comparisons at Lake St-Charles and elsewhere.*

Introduction

Le lac Saint-Charles constitue le principal réservoir d'alimentation en eau potable pour près de 300 000 citoyens des villes de Québec et de L'Ancienne-Lorette, de la municipalité de Saint-Gabriel-de-Valcartier et de la réserve autochtone de Wendake. Alors que l'urbanisation ne cesse de s'intensifier dans le bassin versant du lac Saint-Charles, on remarque depuis plusieurs années des signes évidents de vieillissement accéléré du plan d'eau. L'un des symptômes révélateurs de cette eutrophisation est l'apparition et la récurrence depuis 2006 d'épisodes de fleurs d'eau de cyanobactéries potentiellement toxiques.

L'Association pour la protection de l'environnement du lac Saint-Charles et des Marais du Nord (APEL) est un organisme à but non lucratif ayant pour mission la protection et la mise en valeur du riche patrimoine écologique du bassin versant de la rivière Saint-Charles, dans le but d'y promouvoir, d'une part, un milieu de vie harmonieux aux humains qui l'habitent et, d'autre part, la pérennité et la qualité de l'eau. À l'aide d'une équipe de spécialistes, l'APEL travaille à:

- assurer la pérennité et la qualité de l'eau ;
- mobiliser la population dans la recherche d'un milieu de vie de qualité tout en assurant la protection de l'environnement ;
- favoriser la mise en valeur du riche patrimoine écologique ;
- maintenir et améliorer la qualité reconnue des travaux de recherches et de suivi du milieu en collaboration avec des nombreux partenaires ;
- maintenir et améliorer en continu la gestion de l'organisation.

L'APEL publie régulièrement les résultats des échantillonnages et des rapports relatifs à la qualité de l'eau dans le bassin versant et disponibles sur le site internet (par exemple, APEL, 2014).

Pour les fins de suivi et des études relatives au lac Saint-Charles, la Ville de Québec a installé une tour météorologique dont les observations servent, entre autres, d'intrants à un modèle empirique de développement des cyanobactéries en collaboration avec AirMet Science Inc., l'Université Laval et l'APEL. La tour météorologique est en opération depuis décembre 2016.

De plus, l'APEL a manifesté l'intérêt d'obtenir des données météorologiques prévues (particulièrement la vitesse et la direction du vent) pouvant aussi servir d'intrants dans son modèle afin de prévoir le développement des cyanobactéries.

L'objectif de ce texte est de présenter des résultats préliminaires comparant les vents mesurés à la tour et ceux prévus par le modèle diagnostique CALMET basé sur le système à haute résolution de prévision déterministe (SHRPD) d'Environnement et Changement climatique Canada (Milbrandt et al., 2016).

Données

La Figure 1 esquisse la topographie locale et le relief de part et d'autre du lac qui fait environ 5 km par environ 700 m dans sa partie la plus large. La topographie montagneuse de cette région pourrait canaliser le vent dans le sens du lac et favoriser le transport de cyanobactéries vers le barrage situé dans la section la plus au sud.

La tour météorologique (10 m) a été installée par une firme spécialisée dans le montage et l'opération d'équipements météorologiques et selon les normes en vigueur; sa localisation est illustrée par le carré noir de la Figure 1 aux coordonnées UTM 19T (319991 m, 5199212 m) et son élévation au-dessus de la mer est de 156 m. Elle comprend, outre un anémomètre et une girouette (de type turbine), les sondes de mesure de la température et de l'humidité, un pluviomètre totalisateur et une mesure du rayonnement ultra-violet. La validation des données a été confiée par la Ville de Québec à une autre firme spécialisée.

En ce qui concerne les données météorologiques prévues, les prévisions du système à haute résolution de prévision déterministe (SHRPD) dont la résolution est de 2.5 km ont été acquises (et le sont encore) à tous les jours depuis le début janvier 2017 pour le sous-domaine EST. On peut consulter le site meteo.gc.ca/grib/grib2_HRDPS_HR_f.html pour une description du système et des sous-domaines. Notons néanmoins, que le sous-domaine est s'étend de l'ouest des Grands-Lacs jusqu'à l'est de la ville Québec et du sud des Grands-Lacs à la baie de James. Les données prévues pour les prochaines 48 heures du SHRPD sont disponibles quatre fois par jour à 00 TUC, 06 TUC, 12 TUC et 18 TUC.; ce sont celles de 06 TUC qui sont acquises.

Afin d'effectuer un ajustement aux conditions locales autour du Lac St-Charles, on utilise le modèle météorologique diagnostique CALMET qui permet de simuler des effets locaux (écoulement catabatique, canalisation, effets côtiers, etc.). Le modèle CALMET est le modèle météorologique qui fournit des données d'entrée au modèle de dispersion CALPUFF, modèle qui fait partie de la suite de modèles recommandées par le US-EPA (www.epa.gov/scram). Une description du modèle CALMET est présentée par Scire et al. (2000); le

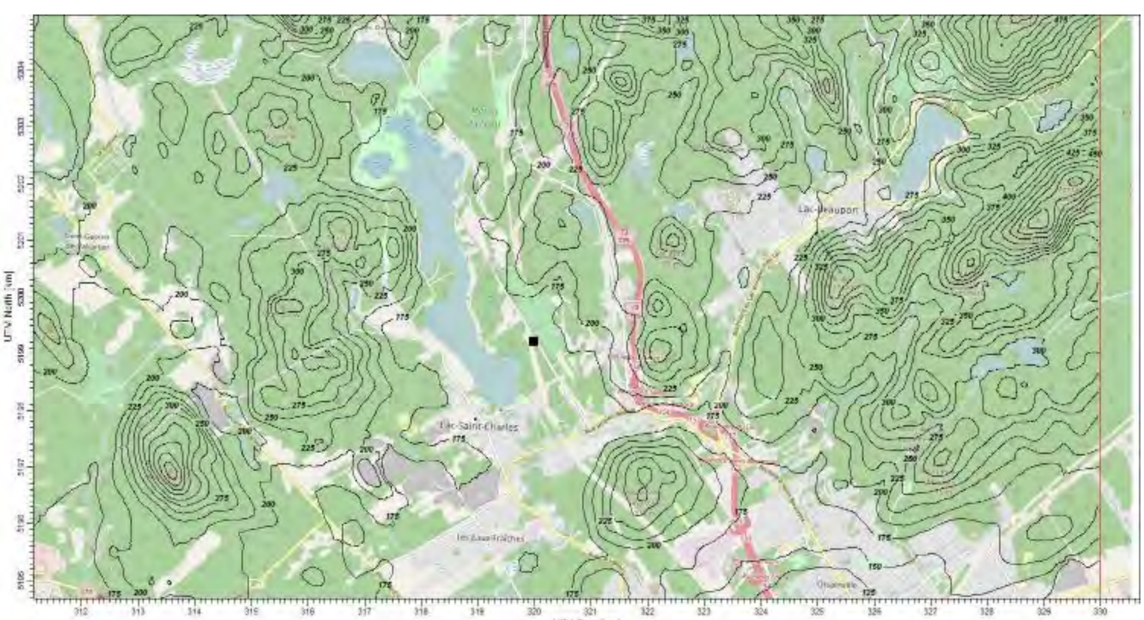


Figure 1. Localisation de la tour et topographie sur le domaine de calcul

modèle CALPUFF (et CALMET) est largement utilisé au Canada, au Québec et ailleurs dans le monde pour des études de dispersion. Le modèle CALMET (et CALPUFF) est public et peut être obtenu sur le site de la firme Exponent (www.src.com/ ou via celui cité précédemment) et chez Lakes Environmental. Outre des données d'observations, le modèle CALMET peut aussi recevoir comme intrant des données prévues par des modèles méso-météorologiques tels le MM5 et le WRF (par exemple, Lee et al., 2014) et il est couramment utilisé de cette manière.

Pour l'usage de CALMET, on a défini un domaine de 20 km par 20 km centré sur le Lac St-Charles avec une résolution de 100 m par 100 m, ce qui permet d'avoir plusieurs points de calcul sur le lac et autour. On obtient les prévisions de 48 h de diverses variables aux points de grille du SHRPD inclus dans le domaine de calcul de CALMET; celles-ci comprennent, jusqu'à 500 mb, les hauteurs des niveaux de pression, et à chacun de ceux-ci, la température, l'humidité, la vitesse et la direction du vent, etc. et qui servent d'intrants à CALMET (les valeurs dites prévues sont celles ajustées par CALMET, à moins d'indication contraire). On obtient par la suite la valeur calculée par CALMET au point de grille associée à la tour météorologique et on peut ainsi comparer les mesures aux valeurs prévues pour les diverses échéances des prévisions.

Les données des prévisions ne couvrent pas l'année complète compte tenu de divers problèmes techniques, comme par exemple une coupure de courant, des problèmes de connections ou de gestion des informations, etc. Au total, on dispose de 273 jours de prévisions.

Résultats

Vitesse du vent

Variable (m/s)	Prévue	Mesurée à la tour	Aéroport de Québec
Moyenne	2.53	1.67	2.83
Nombre	6462	6462	6462
Écart-type	1.31	1.45	1.99
Médiane	2.41	1.28	2.50
Maximum	8.41	8.57	15.83

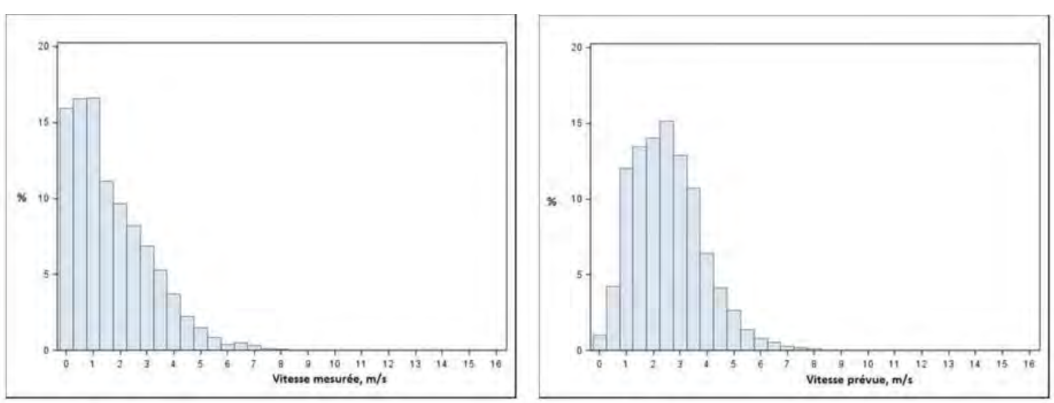
Tableau 1. Statistiques descriptives des vitesses prévues et mesurées

Au Tableau 1 on présente les statistiques descriptives pour les heures communes; les données prévues dans ce cas sont les prévisions des échéances 00 h à 23 h de chaque jour. La tour au lac St-Charles a une vitesse moyenne inférieure d'environ 34% par rapport à celle prévue (i.e. calculée par CALMET avec les prévisions), soit respectivement 1.67 m/s et 2.53 m/s. Le régime éolien au Lac St-Charles diffère passablement de celui de l'aéroport Jean-Lesage de Québec (environ 14 km au sud), situé dans un environnement plat et dégagé, avec une moyenne de 2.83 m/s; les directions dominantes y sont WSW et ENE avec une fréquence d'environ 17% et 12% respectivement et 4.75% de CALME.

Les histogrammes des vitesses (m/s) mesurées à la tour et prévues (Figure 2) montrent aussi une différence entre les deux séries de données, les valeurs calculées par le modèle étant distribuées de manière plus continue et une fréquence de CALME mesurée beaucoup plus grande, tel que discuté à la section suivante. La corrélation entre les valeurs mesurées et prévues est de 0.54.

Rose des vents

Les roses des vents sont illustrées à la Figure 3; on y trouve aussi les directions individuelles observées et prévues à la tour. Les données prévues sont également celles des échéances 00 h à 23 h de chaque jour. Des résultats semblables sont aussi disponibles pour diverses échéances des prévisions.



a: vitesses mesurées b: vitesses prévues

Figure 2. Histogramme des vitesses mesurées (m/s) et prévues à la tour du Lac St-Charles

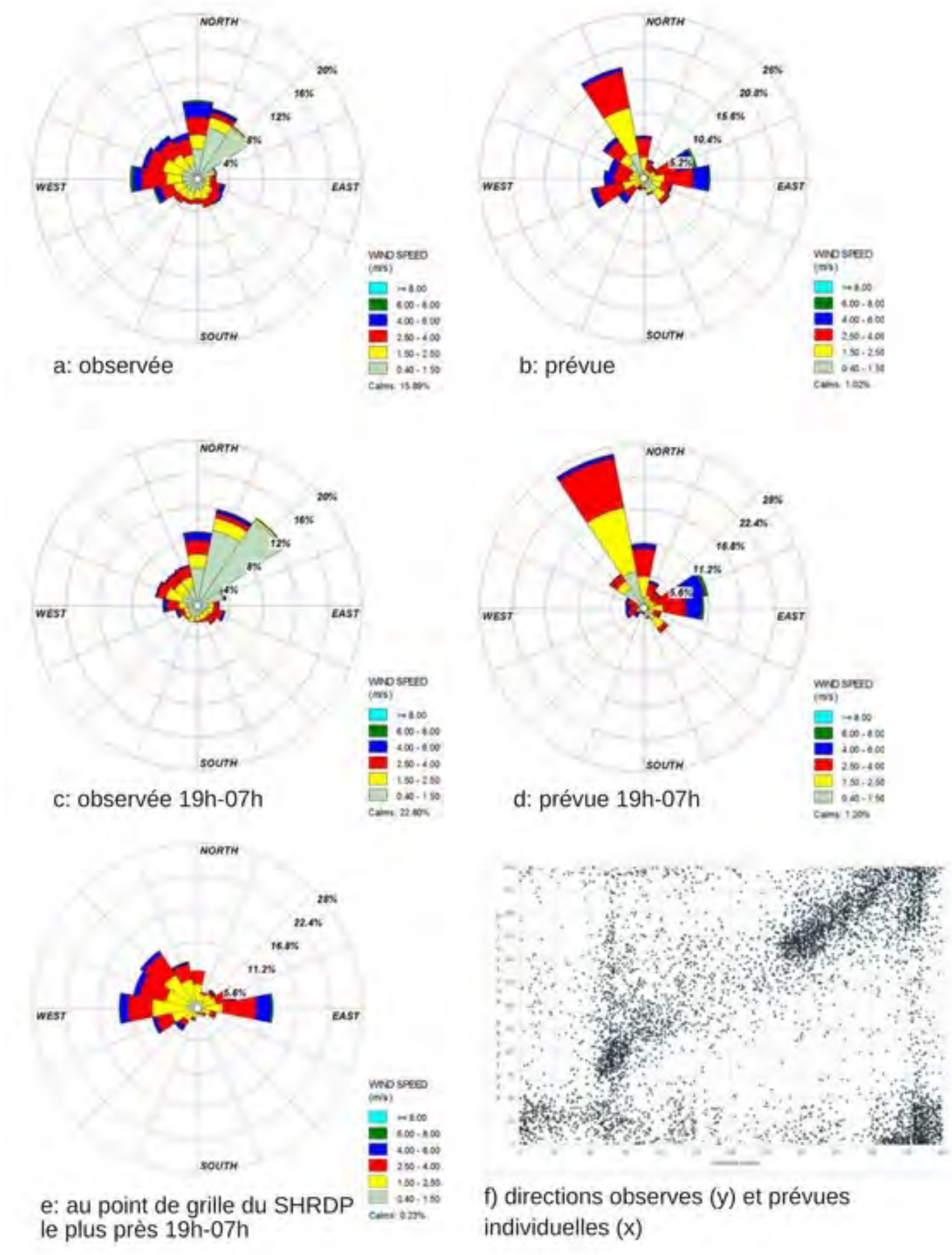


Figure 3. Rose des vents a: observée; b: prévue; c: observée 19h à 07 h; d: prévue 19h à 07 h; e: prévue 19h à 07 h au point de grille du SHRPD le plus près; f: directions observées et prévues individuelles

On note une fréquence de CALME (< 0.4 m/s) élevée à la tour à environ 16% comparativement à environ 1% pour celle prévue.

On constate une fréquence observée beaucoup plus élevée pour les directions N, NNE et NE que celles obtenues par CALMET (Figure 3 a et b). Il y a aussi des différences importantes du côté EST et OUEST. CALMET ajuste de manière significative les directions du dernier quadrant où la direction NNW, dans le sens du lac, devient prédominante.

La Figure 3 f illustre la distribution des directions respectives; le tableau de contingence n'est pas présenté mais est disponible. On note que les directions observées du N (349° à 11°) à l'ENE (57° à 78°) sont le plus fréquemment associées à une direction prévue du NNW (327° à 348°). Les directions observées de l'ESE (102° à 123°) au SW (214° à 236°) sont le plus souvent associées à la direction prévue de l'E (79° à 101°); par ailleurs dans le cas de la direction SW observée, la fréquence de 0.48% de la direction prévue de l'E est semblable à celle prévue du SW à 0.43%, deux directions qui ne sont pas voisines. À partir de la direction observée WSW (237° à 258°), les directions prévues les plus fréquentes sont décalées et les prévues peuvent aussi couvrir quelques directions avoisinantes. À la direction CALME observée, s'associe le plus fréquemment la direction NNW prévue (4.15%). D'ailleurs, le test fait avec la variable Wr proposé par Fisher (1995, section 5.3.6) donne une différence significative entre les deux séries de directions.

On note par ailleurs que les vitesses sont faibles pour les directions NNE et NE à la tour; ces directions sont importantes la nuit entre 19 h et 7 h (Figure 3 c). Par contre, on note que la direction prévue la plus fréquente à ce moment est le NNW (Figure 3 d) probablement associée à un écoulement (catabatique) en provenance des sommets au nord et nord-est et qui se canalise dans le sens du lac.

Les données brutes du SHRPD extraites au point de grille le plus près (320005 m, 5198809 m) localisée à environ 400 m au sud de la tour montrent une composante EST de nuit que l'on retrouve aussi dans celles ajustées par CALMET mais pas la dominante du NNW ni celle de l'ENE. CALMET ajuste ainsi les directions prévues dans le sens du lac mais l'écoulement catabatique est probablement moins important que celui observé à cause de cette composante EST initiale du SHRPD.

Corrélations

En ce qui concerne les vitesses, on présente au Tableau 2 les coefficients de corrélation pour diverses échéances de prévision entre les valeurs calculées par CALMET et les observations; on y donne aussi le coefficient de corrélation vectorielle (ρ2). Les faibles valeurs de la corrélation de Pearson ou vectorielle peuvent s'expliquer compte tenu des différences déjà exposées.

Échéance	Corrélation Pearson vitesse	Corrélation vectorielle (ρ^2) vitesse-direction
00	0.50	0.84
06	0.62	0.80
12	0.66	1.14
18	0.46	0.86
24	0.45	0.76
36	0.66	1.16
42	0.45	0.79
00-23	0.54	0.92

Tableau 2. Coefficients de corrélation

Conclusion

Des essais préliminaires de prévisions basées sur le système SHRPD et ajustées localement avec le modèle diagnostique CALMET ont été réalisés pour une période de 273 jours en 2017 dans un domaine centrée sur le Lac St-Charles au nord de la ville de Québec. Les mesures de la vitesse et de la direction du vent obtenues sur une tour météorologique sont disponibles et ont été comparées aux valeurs prévues. On constate que le modèle CALMET ajuste des directions prévues par le SHRPD dans le sens du lac mais que les écoulements catabatiques (de nuit) des directions NNE et NE qui y sont importants ne sont pas bien reproduits.

On procédera à une comparaison sur une période plus longue avec les mêmes données qui sont acquises en 2018; le système SHRPD-CALMET est opérationnel sur d'autres domaines (ville de Québec, La Malbaie et Cap-Chat) et sera aussi comparé à d'autres observations de vent de tours météorologiques locales.

Les données prévues sur le sous-domaine EST du SHRPD depuis janvier 2017 dont nous disposons peuvent être fournies gracieusement à toute personne intéressée.

Remerciements

Nos remerciements s'adressent à Philippe Barnéoud (ECC Canada) pour ses commentaires et suggestions de même qu'à Environnement et Changement climatique Canada qui rend ces données disponibles aux usagers. Nous remercions aussi la Ville de Québec et l'APEL qui ont rendus les données d'observations disponibles.

Références

APEL, 2014: Rapport sur l'état du lac Saint-Charles en 2014, http://apel-maraisdunord.org/apel/assets/Etat_lac_saintcharles_2014_vfinale_web_20161125.pdf.

Breaker, L. C., Gemmill, W. H., & Crosby, D. S. (1994). The application of a technique for vector correlation to problems in meteorology and oceanography. Journal of Applied Meteorology, 33(11), 1354-1365.

Fisher, N.I, 1995: Statistical analysis of circular data. Cambridge University Press, 277 p.

Lee, J.K., J. C. Kim, K. J. Lee, M. Belorid, P.A. Beeley, J. Yun, 2014: Assessment of wind characteristics and atmospheric dispersion modeling of 137cs on the Barakah NPP area in the UAE. Nuclear Engineering and Technology, vol. 46, no, 4 August 2014, p 557.

Milbrandt, J.A., S. Bélair, M. Faucher, M. Vallée, M. L. Carrera, A. Glazer, 2016: The Pan-Canadian High Resolution (2.5km) Deterministic Prediction System. Weather and Forecasting, décembre 2016, vol. 31, p 1791.

Scire, J., F. R. Robe, M. E. Fernau, R. J. Yamartino, 2000: A User's Guide for the CALMET Meteorological Model. Earth Tech, January 2000, 332 p.

À propos des auteurs

Richard Leduc a débuté sa carrière en 1972 à Downsview. En 1979, il a rejoint Environnement-Québec où il a travaillé durant 28 ans en qualité de l'air (modélisation et applications des réseaux de mesures). Il est Professeur-associé (bénévole) à l'Université Laval. Depuis 12 ans, il travaille chez AirMet Science Inc.

Maude Chartrand réalise présentement une maîtrise en Sciences géographiques à l'Université Laval et portant sur les changements climatiques. Ses champs d'intérêt sont variés, allant de la géographique environnementale à la géographie sociale, et elle applique et adapte des méthodes d'analyse spatiale, quantitatives ou qualitatives pour la réalisation de ses travaux de recherche.

In Memoriam: Morley Thomas, 1918-2018

The Passing of Morley Thomas, 1918-2018

David Phillips, Climatologist and Author

Morley Thomas, affectionately known as Canada's Mr. Climatology, died on March 31, 2018 in Watford, ON, a few weeks after a fall and successful surgery on a broken hip. International meteorology lost a leader and skillful diplomat; Canadian meteorology lost a staunch and vigorous supporter over 65 years; and I lost a dear friend and remarkably generous mentor.

Traditionally, climatologists think over centuries of time, so it's only fitting that Morley lived in his 100th year. He was born in Talbotville, ON. Sadly, his father died six weeks later from the Spanish flu pandemic that killed 50 million people around the world. His loving mother, grandparents and many aunts and uncles raised him in a farm community near St. Thomas. He deeply knew and loved southwestern Ontario where he returned to live in retirement. Morley would always let you know the height of the corn and hay in Elgin and Middlesex counties. He was schooled and home-schooled and entered St. Thomas Collegiate Institute where he excelled at mathematics and sciences and football. After high school he contemplated civil engineering at Queens University, but was dissuaded by a teacher who claimed that to be a "dead end". After all he said, "All the railways and bridges in Canada have been built". He entered the University of Western Ontario on scholarship to study mathematics with a focus on actuarial sciences and a "major" in football. His love of the gridiron culminated in Western winning the Yates Cup (Senior Inter-Collegiate championship) in 1939 during an era of leather helmets and no face guards. On graduation in 1941, he tried insurance with London Life for four months but with the war underway and having trained as a sergeant in the artillery with the Canadian Officers Training Corps, he patriotically joined the Royal Canadian Air Force as a civilian meteorologist. Following a 15-week course he was posted to a RCAF Service Flying Training School in Dauphin, MB, then Dunnville and Kingston ON. As a "metman" Morley analyzed weather maps, wrote and issued weather forecasts and briefed student pilots and aircrew in the British Commonwealth Air Training Plan. Following the war in 1945, Morley requested and accepted a posting in climatology at meteorological headquarters in Toronto under the tutelage of Clarence Boughner. Climatology was a surprise choice given that most meteorologists saw climatology a dull, boring terminal subject. Instead, Morley saw it as fascinating and an exciting opportunity, although he never lost his love for analyzing daily weather maps. In 1949, he earned his master's degree in physics (meteorology) from the University of Toronto and returned to climatology.

Morley The Climatologist

From 1951 to 1953, he was seconded to the National Research Council's Division of Building Research in Ottawa, where he produced the first Climatological Atlas of Canada and provided practical climate guidance and advice to those in building and construction, thus beginning regular climatological inputs and updates to the National Building Code. Following his stint at Building Research, Morley devoted his energies to the

Left: MSC Climatological Section Christmas Pary, Toronto – 1947
Right: Morley Thomas, Celebrating his last day as MSC Historian - Downsview 21 November 2007. Morley was the MSC Historian from 1983 until 2007. In the photo, from left: Tom Agnew, Morley Thomas, David Phillips, Sheila Osborne.

development of operational climatology – expanding observational networks and experimenting with machine processing. He worked tirelessly and often anonymously to ensure that weather observations, comprising billions of data from thousands of observing sites, were properly quality controlled and housed in an archive for easy retrieval. Morley knew well that the observational record was the lifeblood of a climatologist and the foundation of all climate services and sciences and one of the principal responsibilities of a national weather service.

Over the next two decades and more, Morley rose through the various senior positions in the Canadian weather service. As Director-General of Central Services he was responsible for computing services, instrumentation, training and ice services. He was a major force behind the Canadian Climate Program – a comprehensive national initiative bringing together all levels of government, the universities and the private sector to make the best use of climatic information. And while not the founding director of the Canadian Climate Centre, he probably should have been, he was its principal architect. In 1979, he became DG of the Canadian Climate Centre – the focal point for climate applications, services, monitoring and research in Canada and from which he retired in 1983.

International Activities

His work as a climatologist took him around the world. At least a dozen foreign governments including Nigeria, Caribbean nations, Mexico, and Bulgaria, sought his advice in setting up a progressive climate service. He gave long and distinguished service to the various World Meteorological Organization technical commissions, boards and committees, especially those related to climatology. He represented Canada at six sessions of the WMO Climate Commission and served for 10 years as Chairman of the Working Group on Climatic Atlases and Technical Regulations.

1978 was a pivotal year for Morley. Owing to reorganization of the weather service, he no longer had responsibility for climatology. He was contemplating retirement. And in April, he headed to Europe as the Canadian principal delegate to the Commission for Climatology (CCl) expecting this would be his last international meeting on the Commission. There was serious consideration in WMO for ending the Commission and distributing its terms of reference amongst the other commissions. In Geneva, delegates spoke of their demise. In backrooms, a ground swell formed to draft Morley as President. He resisted but delegates from every WMO region persisted. Impelled by an unconstrainable sense of duty, he agreed and was elected unanimously. Morley went to work to save climatology internationally even though he had no responsibilities for climatology at home. Soon the World Climate Conference took place and the World Climate Programme was launched. Through his leadership and quiet charm, he returned the Commission to its important place in the history and life of WMO. He was an exceptional and much beloved president providing vigorous leadership and diplomacy at a critical time. The distinguished American climatologist Helmut Landsberg described Morley's leadership in international meteorology as "a model for the cooperative efforts needed in multinational organizations". Climatology was coming to the fore and being increasingly

Left: Fourth CMS Congress, Winnipeg MB - 18 June 1970. At the head table, from left were: Paul Kowal (Chairman Winnipeg Centre), Pat McTaggart Cowan (guest speaker), Morley Thomas (retiring president), Don McMullen (incoming president), Clarence Boughner (Acting Director, Meteorological Branch).
Right: WMO Meetings, Geneva Switzerland – 1971. From left: Fred Page, Morley K Thomas, JRH Noble

recognized by those outside climatology/. Morley would never say he saved climatology but there is no question he kept it alive until others discovered and developed the important environmental and global issue it was to become.

A second term as President was almost automatic, but Morley shocked delegates at CCI-IX in Washington when he declined the presidency. Morley had other things in mind – retirement and writing the history of Canadian meteorology − something he had been anxiously looking forward to for 30 years.

Honours

Numerous awards have recognized Morley's contributions. He was awarded the Patterson Medal in 1981, Canada's highest meteorological award. In 1985, Morley was selected as the Massey Medalist by The Royal Canadian Geographical Society in recognition of his "substantial personal contributions to the advancement of Canadian climatology and his leadership in international meteorology". Morley stood astride climatology and geography. Geographers always thought him as one of them. Geographers especially admired his work delimiting the regional climates of Canada. For 20 years, he taught geography and climatology to Canadian meteorologists-in-training. He had hoped to attract meteorologists into climatology not as an opportunity to avoid shift work, but as he saw it − a sense of duty and devotion. The Massey Medal was presented to Morley by The Rt. Hon Jeanne Sauvé, former Minister of the Environment, and Canada's Governor General at a formal ceremony at Rideau Hall. On his retirement in 1983, Morley was the first recipient of the Morley K. Thomas Long Service Award for continuous volunteer weather observing over 30 years or more. It was only fitting because for 32 years he took daily weather readings at Toronto-Sunnybrook — the remarkable little weather station in the Thomas' backyard on Lewes Avenue. In 2016, Morley was present in Downsview at a ceremony when MSC's special collection and hard copy history archives was named the Morley Thomas Meteorology History Archives.

Morley's service to CMS and CMOS:

Canadian Meteorological Society (CMS)

- Treasurer, 1950-51
- Secretary, 1964-1966
- Vice President, 1966-1968
- President, 1968-1970

Canadian Meteorological and Oceanographic Society (CMOS)

- Archivist , 1979-2006

Morley was a vigorous supporter of Canadian meteorology both as a member and frequent guest speaker at the Canadian Branch of the Royal Meteorological Society, the Canadian Meteorological Society (CMS), and Canadian Meteorological and Oceanographic Society (CMOS). He served on their executives and committees including President of CMS from 1968 to 1970. He was the first Life Member and Fellow of CMOS. He was also a fellow of several organizations including the American and Royal meteorological societies, the Royal Canadian Geographical Society, the Canadian Association of Geographers and the Canadian Society of Agro-Meteorology. While he appreciated the recognition, he was uncomfortable discussing it, only when the contribution of others was included.

Morley The Historian

Morley "retired" as a paid public servant on Monday January 31, 1983. On Tuesday morning, he set up shop in the Downsview library as the Service's unofficial historian and began in earnest his labour of love researching and writing the history of the Canadian weather service. He remained in that volunteer role for over 25 years. At about the same time, he was named the CMOS archivist and continued to write articles on the history of the Society.

Morley always had a deep appreciation for history. His interest in service history began in the 1970s when he noticed that the department was about to toss some century-old correspondence. Realizing their historic value, he salvaged the documents. But before he could put pen to paper, he methodically began the painstaking work of compiling, organizing, documenting, appending and cataloging two centuries of historical documents including thousands of pieces of correspondence dating back to pre-Confederation and through two world wars. Also part of the paper archives were the annual record of operations, diaries, data logs, financial ledgers, personal records of employees, acts from parliament, position papers, oral histories, internal memos, minutes of meetings, organizational charts, maps, blueprints, photographs, newspaper clippings, and much more. No emails or tweets, but everything else.

Once having organized the written record he set out to write the first volumes of the weather service story. Morley told it brilliantly in three wonderful, highly acclaimed volumes. Jim Bruce called them fascinating. When one peruses his works, one is so impressed with the rigour and the meticulous care in which he documented the past record. Morley's gift for language and love for history permeated his writings – scientific, popular and bureaucratic – and in his conversations too. He was a wonderful storyteller and very insightful man. We were mesmerized at coffee break by his stories, and the only time you would interrupt him was when he said, "Back in '88 – and you'd interject was that in 1888 or 1988. And he would continue.

In addition, Morley authored several other books in retirement, including a volume on the development of climate observing in Canada for the National Museum of Science and Technology, and a book on the history of the Commission for Climatology for WMO. Further, he published books on local histories on his home town and counties, a modest autobiography "Well Weathered: My Sixty-five Years in Meteorology" and volumes on his family and his wife's.

Morley Thomas was Canada's foremost authority on climatology spanning a paid and volunteer career of 65 years. He was held in very high esteem in Canada for his many contributions by people who had never met him. He authored more than 100 publications including articles and reports, books and atlases and three volumes of the Bibliography of Canadian Climate, essays, and magazine articles on different aspects of Canada's climate. He co-authored Climate Canada with Kenneth Hare, a textbook widely used in high schools and universities. His writing was never dull and more reflected his enthusiasm and the importance of the subject.

Morley contributed to the advancement of the science and services in climatology in several ways, nationally and internationally. He helped transform climatology from its classic, bookkeeping function to one based firmly on physical scientific principles. Through his lucid descriptive climatographies, he defined Canada's many climates for all to appreciate and understand. He promoted climatology as an applied discipline for the betterment of society. He understood the enormous potential of yesterday's "spent" weather observation as a way of transferring data into information and in doing so he furthered the practical side of climatology making life safer, more secure and more comfortable for all. He popularized climate change beyond the realm of academia by making others see it as one of the most important environmental issues that human kind has ever faced. Through his efforts in establishing the Canadian Climate Program and the World Climate Programme, he ensured that world leaders, albeit all but one, would be compelled to discuss the implications and necessary remedial actions to a changing atmosphere. And lastly, he carefully documented the history of Canadian meteorology and told the remarkable story of a fine organization with dedicated people − one of Canada's oldest and most respected governmental scientific organizations, one with a very proud history, clear purpose and many remarkable achievements. A story that had to be told. And Morley Thomas told it – brilliantly and proudly.

It was only fitting that in 2015, the federal government changed the name of the Department that Morley helped create and organize and retire from, to Environment and Climate Change Canada. He lived to see that happen. It must have given him enormous satisfaction, if not delightful revenge.

On a more personal note, I knew Morley for over 50 years. He was a wonderful person. He was tall with barely a pause in his giant stride, and with a bouncing laugh that would fill a room. He had a Jean Beliveau-like personality always encouraging never judging. He always had time to read what you had written and return it promptly with encouraging words. That Morley Thomas was a superb climatologist and serious historian, there is no question. But just as importantly, he was a caring, gentle and modest man and a decent and sensitive human being. I will forever remember him that way.

More on Morley Thomas, in the following obituaries:

http://v1.theglobeandmail.com/servlet/story/Deaths.20180406.93400684/BDAStory/BDA/deaths
https://strathroyfuneralhome.com/tribute/details/4507/Morley-Thomas/obituary.html

In case you missed it...

From CMOS Bulletin Volume 46, Number 3:

EON-ROSE: Integrating Climate Science and Earth Science
by K.J.E., Boggs, P., Audet, D.W., Eaton, M. Fayek, J.T., Freymueller, R.D., Hyndman, T. James, P.J., Kushner, P. Myers, M.G., Sideris, P. Sullivan, and M. Ulmi

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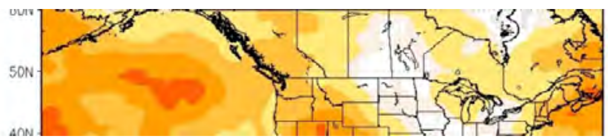
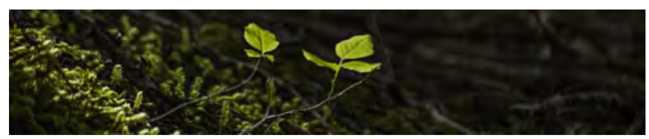
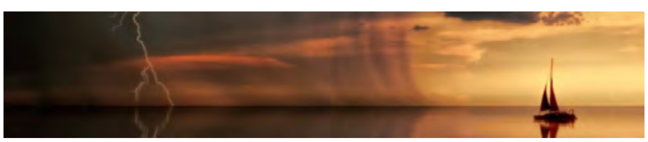


Seasonal Outlook for Summer (JJA) Based on the CanSIPS Forecast Issued on the 31st May 2018
by Marko Markovic and Kevin Gauthier

Message from the CMOS President: Tightening Up, Speaking Up, and Greening Up
by Paul Kushner





WMO Presents Top Scientific Prize to CMOS' Gordon McBean
Sourced from public.wmo.int

Polar Knowledge Canada 2018-2019 Funding Announced
by Marko Markovic and Kevin Gauthier

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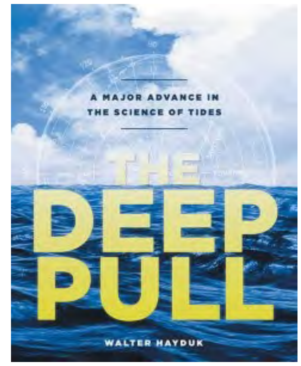
CMOS News

New Book Available for Review



The Deep Pull: A Major Advance in the Science of Ocean Tides.
By Walter Hayduk, FriesenPress, ISBN 9781525518706 (hardcover) $35.49, 9781525518713 (softcover) $27.49, 9781525517820 (eBook) $11.99, 251 pages. More information available at www.walterhayduk.com. (2018-7)

Other recent titles still available for review by a CMOS member:

Eustasy, High-Frequency Sea-Level Cycles and Habitat Heterogeneity, 2017. By Mu Ramkumar and David Menier, Elsevier Inc, ISBN 978-0-12-812720-9, Paperback, 102 pages, US$60 (2017-3)

Minding the Weather: How Expert Forecasters Think, 2017. By Robert R. Hoffman, Daphne S. LaDue, H. Michael Mogil, Paul J. Roebber, and Gregory Trafton, The MIT Press, ISBN 978-0-262-03606-1, Hardcover, 469 pages, $66.69 (2017-4)

Risk Modelling for Hazards and Disasters, 2017. By Gero Michel, Elsevier, ISBN 9780128040713, paperback, 338 pages, US$100.00 (2017-5)

Introduction to Satellite Remote Sensing; Atmosphere, Ocean and Land Applications, 2017. By William Emery and Adriano Camps, Elsevier, ISBN 9780128092545, 860 pages, US$130.00 (2017-6)

Remote Sensing of Aerosols, Clouds and Precipitation, 2017. By Tanvir Islam, Yongxiang Hu, Alexander Kokhanovsky and Jun Wang, Elsevier, ISBN 9780128104378, 364 pages, US$120.00 (2017-7)

Mixed-Phase Clouds: Observations and Modeling, 2017. By Constantin Andronache, Elsevier, ISBN 9780128105498, 300 pages, US$89.95 (2017-8)

Synoptic Analysis and Forecasting, An Introductory Toolkit, 2017. By Shawn Milrad, Elsevier, ISBN 9780128092477, 246 pages, US$125.00 (2018-1)

Ice Caves, 2017. Edited by Aurel Persoiu, Elsevier, ISBN 9780128117392, 752 pages, $225.00 (2018-2)

Sea Ice Analysis and Forecasting: Towards an Increased Reliance on Automated Prediction Systems, 2017. Edited by Tom Carrieres, Mark Buehner, Jean-François Lemieux and Leif Toudal Pedersen, Cambridge University Press, ISBN 9781108417426, 236 pages, $143.95 (2018-3)

Rainbows: Nature and Culture, 2018. By Daniel MacCannell, The University of Chicago Press and Reaktion Books Ltd, ISBN 9781780239200, 208 pages, US$24.95 (2018-4)

Verner Suomi: The Life and Work of the Founder of Satellite Meteorology, 2018. By John M. Lewis, The University of Chicago Press and the American Meteorological Society, ISBN 9781944970222, paperback,168 pages, US$30.00. (2018-5)

Never reviewed a book before? No problem!

Check out some of these past reviews for ideas: Weather in the Courtroom; Convenient Mistruths: A Novel of Intrigue, Danger and Global Warming; Weather, A Very Short Introduction; Nonlinear and Stochastic Climate Dynamics.

If you a review a book it is yours to keep! Contact the Editor to get involved.

CMOS Gets Tweeting with Christine Leclerc

Please welcome our new Twitter volunteer, Christine Leclerc.

Christine holds a certificate in Web Design from a US college and an MFA in Creative Writing from UBC. Previously, she served as a Communications Director in the non-profit sector and currently volunteers as Treasurer with the student-led sustainability leadership non-profit Embark and as a Member-at-Large on the board of Sierra Club BC. Christine is lifelong learner who is fascinated by environmental issues and is studying Physical Geography at SFU to enter a career in climate science. If you're tweeting about meteorology, oceanography, or a related topic that may be of interest to the CMOS-SCMO membership, don't forget to tag us using the @CMOS_SCMO Twitter handle so Christine can retweet you!

Many thanks to Kevin Bowley for all of his work as Tweet Master these past few years, and best of luck to him in his new role at Penn State University.

Other News

Weather Enterprise Conference, Oct 11-12, Amsterdam

The Global Weather Enterprise will be hosting a two-day Weather Enterprise conference in parallel with this year's CIMO TECO-2018, which is being held alongside Meteorological Technology World Expo 2018 on October 9-11, in Amsterdam. The conference, which will be held on October 11-12, has been organized by the WMO in cooperation with the World Bank, GFDRR and the Association of HydroMeteorological Equipment Industry (HMEI). It will focus on two key themes: data and business models. More on the GWE in a recent article in Meteorological Technology International.

IABM AGM, September 4th, Budapest

The 21st Annual General Meeting of the International Association of Broadcast Meteorology (IABM) will be held on Tuesday September 4th, 2018, at the Corvinus University of Budapest, Hungary. It will be held during the EMS Annual Meeting & European Conference on Applied Climatology (ECAC).

The full agenda for the IABM AGM is available here.

DATA, MODELS AND ANALYSIS

The Highest Impact Articles in *Atmosphere-Ocean*

CMOS
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Edited by
GUOQI HAN, HAI LIN and DOUW STEYN

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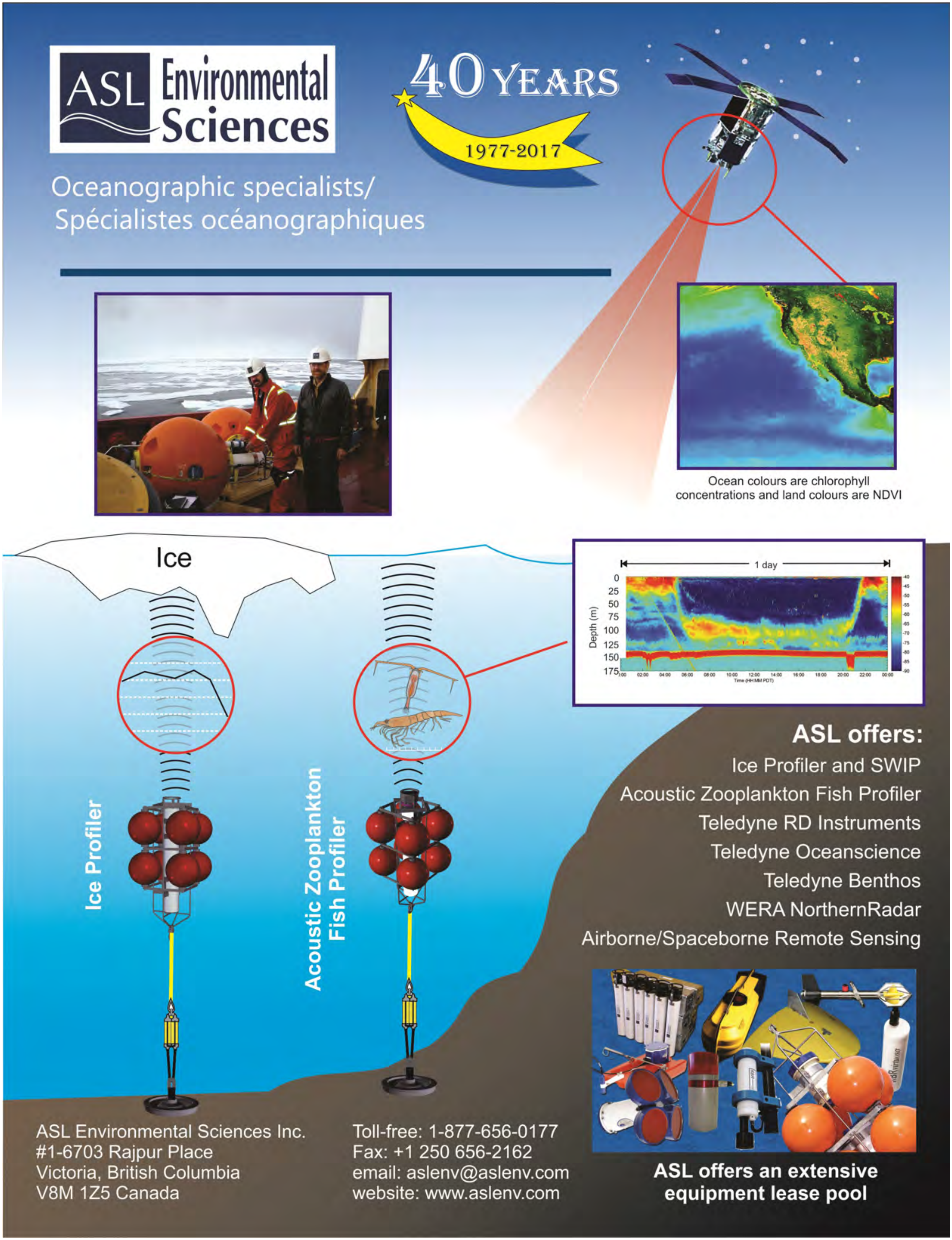
Le *Bulletin de la SCMO* se trouve maintenant en ligne à http://bulletin.scmo.ca/. N'hésitez pas à soumettre notes, rapports d'atelier et nouvelles à l'adresse bulletin@scmo.ca. Nous accepterons, réviserons et publierons vos contenus sur une base continue.

Cette publication est produite sous la responsabilité de la Société canadienne de météorologie et d'océanographie. À moins d'avis contraire, les opinions exprimées sont celles des auteurs et ne reflètent pas nécessairement celles de la Société.

Thank you to Bob Jones and Paul-André Bolduc, for their continued editorial assistance and guidance.



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