Proposed "Climatology/Meteorology" Exhibit

Summary of Documentary Research

The Biosphere Environment Museum • Environment Canada, January 25, 2012

Cover photo: “Cumulonimbus horizon paradise”, source: cepolina.com

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Introduction

This document presents a summary of the results of the documentary research conducted to provide form and content for the proposed exhibit temporarily entitled "Climatology/Meteorology". This new exhibit will be presented in Room 4 of the Biosphere, currently occupied by the exhibit "O.N.E. | Outfits from a New Era".

The results of the research will also be used to document educational and citizen science activities to be created and carried out by Biosphere staff.

It is agreed that the volume of information provided by the documentary research cannot all be included in the exhibit. Only key information will be included in the end.

The complete documentary research is available in electronic format and in hard copy (two binders).

A. Final research plan and classification, page 4

The documentary research was organized and collated based on a research plan approved by the Biosphere.

B. Summary sheets, page 7

Summary of the main chapters of the documentary research:

A. Final research plan and classification

Proposed “Climatology/Meteorology” exhibit at the Biosphere

Research plan

1 - Distinction between climatology and meteorology

Definitions, analogies

(Remember: Things that are not part of either, such as natural disasters like earthquakes, tsunamis and volcanoes, which people often confuse with weather phenomena)

2 - Meteorology

(a) Definitions
- Earth-atmosphere
- Solar energy / cycles (the influence of the sun, sunspots, seasons)
- Temperature
- Atmospheric humidity (condensation, clouds, stability, precipitation, the humidex factor, thunder and lightning)
- Atmospheric pressure (winds, atmospheric circulation, air fronts and masses, wind chill index)

(b) Extreme weather events
- What is “normality”?
- Records, striking examples

(c) Colours (blue sky, clouds, rainbows, sunsets)

(d) The ABC of weather predictions

3 - Climatology

(a) Definitions and classifications (that of Köppen and others)
- Around the world of climates
- Microclimates

(b) The past: paleoclimates (glaciations, etc.)

(c) The future and climate change

4 - The weather and us

(a) Meteorology/climatology and the planet
- Influence on biodiversity and landscape (e.g. seasonal flooding, etc.), general influence on the environment

(b) Meteorology/climatology each day
- The weather: the number one topic of conversation here

- Myths and reality: The weather influences our mood, our performance, etc.
- Beliefs and wives' tales for forecasting the weather: the Farmer's Almanac, arthritis, the flight of swallows, etc.: True or false? Is there any scientific basis?

(c) Meteorology/climatology and health
- Example of "vigilance" for air quality, pollens, etc.
- The spread of epidemics, e.g. H1N1, insect bites, West Nile virus, etc.
- Environmental emergencies (crisis management, spread of contaminants in the air or water, e.g. BP platform disaster, and the influence of weather and local disasters, role of EC)

(d) Meteorology/climatology and culture
- Influence on lifestyle (clothing, food, etc.)
- Urban planning (northern cities / southern cities)
- Breakdown of time (e.g. the six seasons of the Atikamekw, regions where there is "only one season", etc.)
- Myths and realities: living in a warm country makes people…; living in a cold country makes people…

(e) Meteorology/climatology and the economy
- Price of agricultural goods, economic crises and food emergencies, stock speculation
- Transportation of people (tourism) and goods (hydrology and tonnage of ships), etc.
- Infrastructure (e.g. snow removal operations, importance of being able to predict storms), etc.
- Influence of the temperature on energy demands (Hydro-Québec), etc.

5 - Understanding meteorological phenomena: history and evolution

(a) History of meteorology
- Meteorology in antiquity, beliefs, legends
- A history of international cooperation that even the cold war could not stop
- The evolution of technology (weather radar and satellites), data analysis, strength of computers, etc.

(b) History of the MSC

(c) Communication and dissemination of meteorological information
- The evolution of weather bulletins (radio, television, print media)
- How technology affects the evolution of communication of this information (satellite images, iPad applications, Environment Canada's Weatheradio, interactivity, etc.), new trends

(d) Increased accuracy of forecasts
- Evolution of technology and models (ref: CMC and MSC)

6 - Adaptation and mitigation measures

(a) Adaptation to extreme weather events
- Recurring events (e.g. monsoons, hurricane season, etc.)
- Non-recurring events (crisis management)

(b) Climate change and its influence on architecture, health, urban planning, population exodus, geopolitical tensions, etc.

(c) Geo-engineering and the climate war
- Cloud seeding (precipitation control)
- Fertilization of the oceans (CO2 capture)
- Etc.

(d) Inventions and anecdotes for adapting to cold and heat on a daily basis (e.g. Glider gloves for the use of cellular telephones, ref. David Philips)

7 - The future, methods and climate change

(a) Weather forecast models, climate models: new research trends

(b) Equations of fluid dynamics

8 - Citizen science

(a) Amateur meteorologists
- Citizen involvement in data collection
- Reconnection with nature
- Invitation to commit

B. Summary sheets for the documentation

Summary of the main chapters of the documentary research:

1. Differences between meteorology/climatology

Two very different ways of looking at “what it’s like out”

“The climate in which we live influences what we have in our wardrobe.
The weather influences the clothes we decide to wear in the morning.”
(Source: anonymous)

This witty definition summarizes well the difference between climate and weather. The corresponding disciplines can (almost) be summarized as follows: “Meteorology is about our daily life, while climatology is about our lifestyle."

However, although climate is of utmost importance in urban planning, for example, it is paradoxically of little concern in our daily lives, unlike meteorology, “in the same way that we only become aware of our heartbeat when it changes rhythm.” In addition:

• **Climate is predictable with its cycles. Weather is not.**

The first can be compared to the tides, the second to the waves.

• Weather does not create climate: Although data from climate models are based on weather data, it can be very difficult to extrapolate on one based on the other.

In short, they are two very different ways of looking at “what it’s like out”.

Different geographic durations and areas

Weather is the “here and now”: it concerns short-term measurements over a small geographic area (rapid variations – daily, seasonal, or at most annually). Climate is “general and sort of all over”: It evokes long-term averages over a large geographic area (variations over decades, centuries, even millions of years).




Climatology is a matter of long-term projections (which are extrapolations based on a given scenario), while meteorology refers to short-term projections, even though the term “long-term” is used to refer to a period of about ten days…

One source of overlap between the two concepts is therefore also a matter of vocabulary: climatologists and meteorologists use the same terms to refer to events that occur on very different scales. This is somewhat like history with a capital “H” (i.e. climate) vs. history with a small “h” (i.e. meteorology)…

In another sense, some would say that weather is concrete, while climate only exists in the form of a mathematical abstraction. In meteorology and in climatology, scenarios are developed. The former are a function of visible and very concrete atmospheric data, while the latter are extrapolated based on very different criteria: Earth radiation budget, solar cycles, greenhouse gas emissions caused by humans, etc. There are so many factors that, for common mortals, exist only in the form of concepts that are difficult to relate to reality. Moreover, given that climate is an average of meteorological conditions, the “transition” from meteorology to climatology is fairly intuitive. The reverse is not as true: if the average for a classroom of students is 70%, it is impossible to determine the mark for a specific student. That is why the issue of determining whether a new or unusual event (that is, at the outset, a weather event) is also a sign of climate change is more sensitive: we must wait to see if, “on average”, this type of thing will happen more often. Meteorology and climatology can therefore almost be seen as a snake that is eating its own tail.

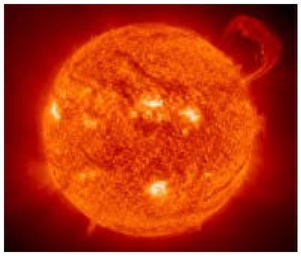
Natural disasters: Source often not meteorological or climatological

Finally, contrary to what may be incorrectly thought, not all major natural disasters are of a meteorological or climatological origin, such as earthquakes (and tsunamis), or volcanoes. However, recent research sometimes identifies a link between the two: storms that cause microseisms, melting of the permafrost that may cause earthquakes... not to mention weather events that are caused by volcanoes (volcanic winters, lightning and thunder) and that thus clearly contribute to blurring the lines between the two concepts.

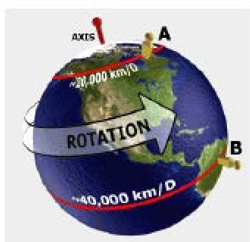
2. Meteorology

Understanding what meteorology is involves becoming familiar with a certain number of basic scientific concepts. To overly simplify, we can remember for example that:

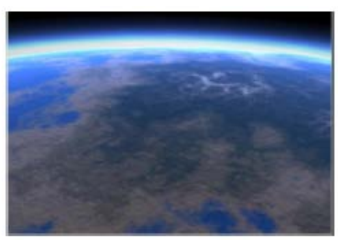
• **The sun provides energy that moves the atmospheric and oceanic masses.**




• The **rotation of the Earth** results in the alternation between day and night, as well as the **spinning of winds** around depressions and cyclones (Coriolis force), and the **cycle of seasons**.



• The atmosphere acts as a cover to protect us from the sun's rays, but also as a thermostat to regulate the temperature of the Earth's surface (which, without the atmosphere, would be minus 18 degrees).



• Water evaporated by the sun on the surface of the oceans creates clouds, where it condenses into droplets or crystals and returns to the planet's surface as rain or snow, before again feeding vegetation and rivers.



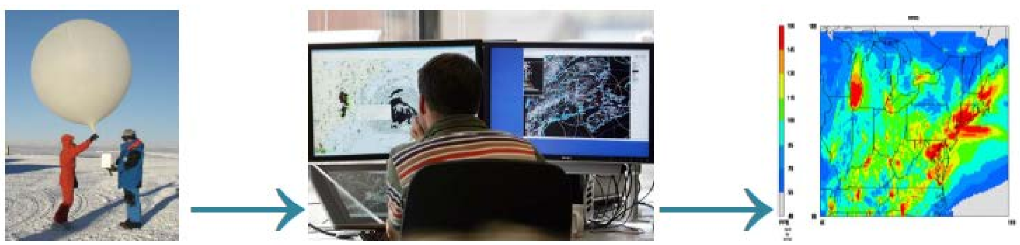
However, it must be noted that, **although some facts have been proven** (such as the 11-year duration of solar cycles, the fact that the type of precipitation depends on the temperature, or the role of the water cycle in forming clouds), **several atmospheric realities are still the subject of scientific research:** the specific causes of the variability of solar cycles, the formation of clouds, etc. This will be addressed in this section, and in section 7 of the research document (science and the future).

Predicting the weather

The weather in a given place and at a given time depends on atmospheric conditions in the surrounding area and above the area. For instance, there is wind if rapid movements occur, it is hot if the air mass is from tropical regions, the sky is cloudy if certain layers of the atmosphere are saturated with humidity and loaded with droplets of water, etc. **Predicting the weather in one place therefore consists of determining in advance the evolution of a series of physical variables that characterize that atmospheric parcel:**

- Pressure
- Temperature
- Humidity
- Wind
- Liquid water content

To this end, satellites, sounding balloons, weather stations, and other **weather buoys each send thousands of pieces of data to computer programs that analyze them using modeling.**



A model is a computer program that simulates the future evolution of the atmosphere. The result is thematic maps (winds, soil temperatures, humidity, pressure) for various timelines. Each simulation is replaced (updated) by another several times per day. Forecasters interpret the maps from the models to "translate" what could happen for the general public.

Although the accuracy of weather forecasts has greatly improved over the centuries (see section 5 of the research document), some **phenomena remain difficult to predict, particularly those that occur on small geographic scales.** This is also true for certain extreme phenomena (i.e. that occur outside their normal limitations for intensity for a given area), such as highly localized severe thunderstorms. In Canada, the following extreme weather conditions are severe weather events that immediately trigger weather alerts: tornadoes, severe thunderstorms, wind in excess of 90 km/h, and hail 2 cm or more in diameter.

Weather services in Canada have created several bodies for monitoring severe weather and its consequences, such as the Lightning Detection Network and the Canadian Hurricane

Centre (hurricanes, along with tornadoes, are always considered extreme weather events, regardless of where they occur), as well for scientific research and monitoring of ice, floods, forest fires, air quality, etc. (This will also be examined in section 5 of the documentary research.)



Finally, **not just disasters fall from the sky**. We also see the things of multi-colour dreams. Rainbows, red skies, or the mysterious green rays of the setting sun are all phenomena that can be explained by the diffraction of light, but that remain no less spectacular and fascinating.

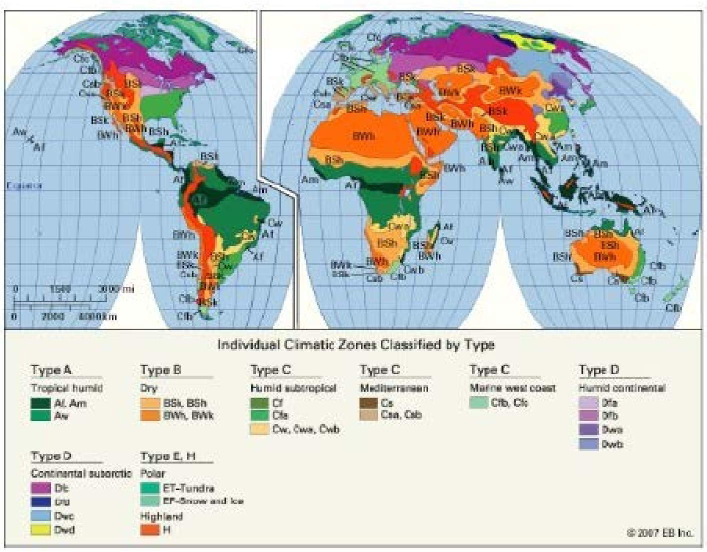
3. Climatology

Climate corresponds to the statistical distribution of atmospheric conditions in a given region over a given period of time. It is different from weather, which refers to conditions over the short term and in specific areas (see section 1).

Climate is determined using means established from annual and monthly statistical measurements of local atmospheric data:

Temperature • Precipitation • Sunshine • Humidity • Wind speed

There are several climate classification systems: some refer to latitudes, others consider dominant winds, rainfall, or altitude. The large variety of types of climates and the number of factors involved in their definition mean that any attempt at classification is necessarily imperfect. They are chosen based on the goals of the observers.



One of the most well-known is the **Köppen classification**, which divides the Earth based on rainfall regime and temperature variations, and considers the main families (temperate, tropical, dry, moist, polar)

The Earth's climate fluctuates. Some fluctuations, daily or annual, are random. Others are more systematic: **climate follows a cycle of about 100,000 years.**

About 2.3 billion years	First known glaciations, undoubtedly due to volcanic activity, a weakening of the greenhouse effect and a decrease in the intensity of light received from the sun. Ocean frozen to a depth of 800 to 1,000 metres.
2.3 billion to 950 million years	Dry and hot climate. The Earth seems to be free of ice despite low solar light and a reduced greenhouse effect. The existence of such a climate under such conditions remains a mystery.

950 to 570 million years	Three successive glaciations at low altitudes, each lasting about 100 million years. One cause that has been cited is the high obliquity of the ecliptic.
600 to 450 million years	Generally hot climate, continents flooded.
450 million years	Glacial push in the South, mild climate in the North.
420 to 300 million years	Mild climate, a lot of clouds. The coral reefs develop in the North, there is still ice in the South.
300 to 250 million years	Glacial push.
250 to 65 million years	Cool and damp climate, then rather hot and dry with the disappearance of the ice caps. The polar temperatures vary between 10°C and 20°C. Palm trees grow in Alaska, the sea level is 200 m higher than it is today.
65 million years	Brutal cooling, probably due to a meteorite shower or significant volcanic activity.
14 million years	The Antarctic ice cap forms.
8 million years	Asymmetric climate between the hemispheres. Europe is covered with tropical trees. The Antarctic ice cap reaches its current size.
2.4 million years	Falling temperatures. Glacial advance and drop of 100 metres in the sea level.
1.3 million to 900,000 yeas	Interglacial stage, climate comparable to the current climate.
600,000 to 540,000 years	Interglacial stage.
540,000 to 400,000 years	Glacial stage.
400,000 to 120,000 years	Interglacial stage.
120,000 to 10,000 years	Glacial stage, with a glacial maximum 18,000 years ago.

For 85,000 years, the temperature cooled very slowly until it reached a minimum. Then, in “only” 15,000 years, it progressively reheated to reach a maximum. During the last minimum, about 21,000 years ago, the average temperature on the Earth was 5 to 6 degrees lower than it is now; 6,000 years ago, it was 0.5 to 2 degrees more than in the 20th century. The mercury then began to fall. **In the next 30,000 years, a new ice age should begin and the next climate minimum should, in principle, occur in more than 70,000 years, if mankind does not derail everything by then.**

Numerical models are the only tool for estimating future climate evolution. They use the laws of physics, mechanics, chemistry, or biology to electronically reproduce the main functions of the climate system, i.e. the complex system made up of atmospheric and oceanic fluids, glaciers or the continental and marine biosphere. **Climate models are therefore a type of animated computer mock-up of the planet.**

The consequences of climate change are as numerous as they are complex. Section 6 of the research document details some of them for Quebec and Canada. The next section will look only at the repercussions of that **unbalance on the Arctic**, an area of the globe that is particularly sensitive and that has already begun to warm, and the **consequences of climate change on biodiversity** and the **spread of infectious diseases.**

4. Meteorology/Climatology and us

“Red in the morning, sailor’s warning”

Meteorology governs many aspects of our private lives and our societies. And that is nothing new: **proverbs and sayings regarding the weather are legion.** Some are bizarre, but most are based on proven observations: behaviour of animals, sequence of weather events, position of the stars, etc. Recent research has even looked at some of these and, **sometimes, science slowly makes progress thanks to popular wisdom.**

Psychological impact of the weather: biometeorology

In the Montréal area, violence increases as the temperature rises. For instance, an average of 64 assaults occur per day when the temperature is 30°C, compared to 55 when it is below 23°C.

The weather has become a subject of study for psychologists and sociologists, who are interested in its impact on our individual and collective behaviour.

Impact on health

From a medical perspective, weather and climate are important information in matters of **seasonal allergies, heat waves, or even the impact of UV rays.** One field of science, biometeorology, even specializes in this. The weather is also closely tied to the **spread of atmospheric pollutants:** it therefore remains a key element in this public health issue.

From a socio-cultural perspective, while the weather unquestionably guides our architecture and our habitat, it would seem that the very breakdown of time into seasons has in influence on our societies, and that the concept of the traditional four seasons is far from shared by everyone. Recent studies also confirm that climate variability may have influenced major historical events, such as the fall of the Roman Empire.

However, the weather has its greatest implications at the socio-economic level, as all areas of the economy are, to one degree or another, linked to atmospheric conditions. **It is even estimated that 80% to 85% of the North-American economy is tied to the weather.**

Farmers, for example, now have access to specialized weather sites that allow them to plan their activities.

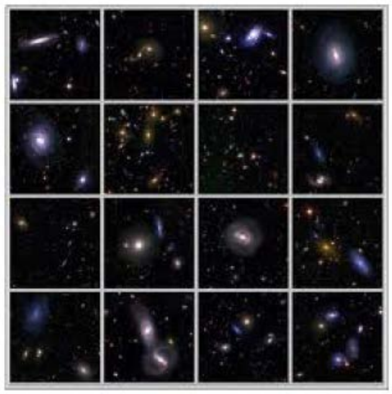
Regarding **air transport**, Environment Canada is an active partner in the aviation sector. The same is true for **maritime transport**, where organizations such as Canadian Ice Service provide resources that are indispensable to navigation. In the field of **urban infrastructure**, we need only consider the **collective cost associated with snow removal or heat waves** to be convinced of the importance of weather in our lives. The same is true for the economic issues that govern the **energy** sector. For instance, **the efficient production of hydroelectricity depends largely on the supply of water** in reservoirs and drainage basins, and the most important factor that influences that supply of water is the amount and type of precipitation.

Thus, while some scientists strive to improve numerical weather prediction models, others work to implement mechanisms to prepare the various sectors of the economy to deal with weather uncertainty. And some businesses see this as a **pretext to make a profit, through "weather derivatives", which make the risk associated with weather a new type of financial instrument.**

Finally, from an environmental standpoint, there are many links between weather (and climate) and "nature", but **research seems to be most active, and resources most plentiful, in the area of risk prevention and management (fires, floods, spread of pollutants).**

5. Understanding meteorological phenomena: history and evolution

The history of weather is marked by great discoveries that have their basis in the period of the emergence of scientific thought in **Ancient Greece and in the Eastern world (particularly regarding the movement of the stars and the dynamic of fluids)**, or during the time of the great technological advances at the dawn of the **Renaissance, up to the Industrial Revolution** (invention of **measurement instruments**, etc.).




Since the second half of the 20^{th} century, the history of weather has been particularly marked by:

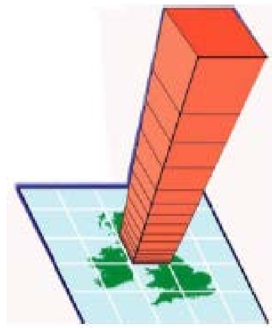
• The advent of weather satellites that made it possible, in the 1960s, to know weather conditions in remote areas, such as deserts, oceans or polar regions.

• The implementation and development of **numerical models** that made it possible not only to increase the accuracy of forecasts, but also to push them further and further, thus disproving the famous “butterfly effect”.

• **International cooperation**, which fostered the emergence of the **World Meteorological Organization.**

It was born of two imperatives: (1) atmospheric observation and modelling must be carried out at a global level; and (2) atmospheric observation by satellite requires major programs and investments that exceed the capacities of most countries.

All **current weather forecasts are based on atmospheric modelling, which is done by breaking down the atmosphere into cubes** (each cube having its share of the initial



parameters) and by modeling the evolution of those cubes based on the known initial positions – a method that was only made possible with the creation of the first computers in the early 1960s. **One of the consequences of international cooperation in meteorology is the advent of ensemble forecasts (e.g. Canada, United States, Mexico).**

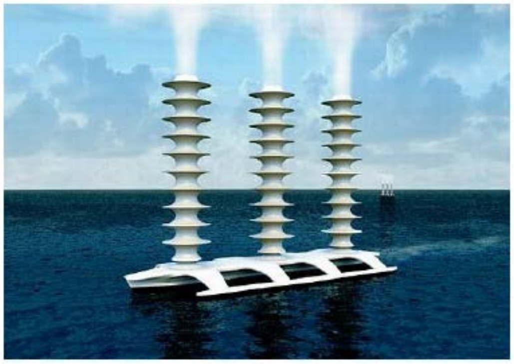
Moreover, each country or series of countries uses their own numerical model “concocted” from different equations, but that nonetheless all use the same physical principles that explain oceanic and atmospheric movements. Some models are even more suited than others to describing certain weather conditions, which is why, for example, Météo-France forecasts may be better for Montréal than those of Environment Canada (and vice versa) under certain conditions.

The various scientific advances have helped increase the accuracy of forecasts. In Canada, they are now at 90% for daily temperatures (i.e. the day of the forecast). **The means of communicating weather forecast has also greatly evolved.** There was a time when a bulletin contained only one line (“The weather is good / not good”!), while the accuracy of the information today results in increasingly complex and detailed bulletins. Each country has also adopted its own style. For instance, in the United States, they go as far as to cite a 50% risk of precipitation (in Canada, we begin at 60%). As well, other countries refer to a “confidence index”, which is not the case here.

The Meteorological Service of Canada has existed since 1871. It is now more active than ever on Twitter…

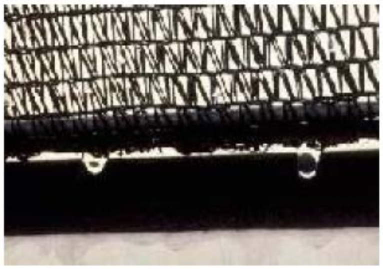
6. Adaptation and mitigation measures

Changing the weather is not a new idea, but advances in science and technology, coupled with the need to deal with global climate change, have made the climate fight a highly perfected fight: **from the seeding of oceans to increase their capacity to retain carbon…**



…to "whitening" clouds to better reflect the sun's rays, there are many ideas – some very controversial. We are a long ways from "canons that make it rain", when some dream of installing Venetian blinds in orbit...

Regardless, while the "heavy artillery" of **geo-engineering** have been written about extensively, measures on a more human scale are already in place around the world to try to adapt or **best benefit from a hostile climate.**



This is the case, for example, with fog nets used in rural communities in Chile, or simple and effective adaptation measures (**greening roofs**, for example) to fight the urban heat islands that flourish in large cities – including in Canada.

In Quebec, the **Ouranos Consortium**, which includes 250 scientists and professionals from various disciplines, is focusing its action on two main themes: Climate sciences and Impact & Adaptation. This globally recognized organization conducts research projects on the following climate-related subjects: agriculture, health, urban planning, recreation, the built environment, and water, forest and energy resources. For each of these themes, **Ouranos researchers propose status reports regarding climate change and possible solutions.**

On a lighter note, it must also be remembered that the climate is the mother of many inventions. While our harsh winters have influenced how we build dams, buildings, or even bridges, our climate has also led to ingenious inventions such as the snowmobile, winter fuels...

…**or the snow blower**, which, in the interest of history, was invented by one Arthur Sicard, who sold his first one to the municipality of Outremont in 1927.

In the same vein, technological innovations to make our lives easier in the event of bad weather or excessive heat literally rain down on specialized boutiques. From the **"backpack umbrella"** to the **air conditioned shirt** and **clothes that change colour in the sun**, there are now **a thousand and one ways to adapt, with humour, to the moods of the weather.**

7. The future, methods and climate change

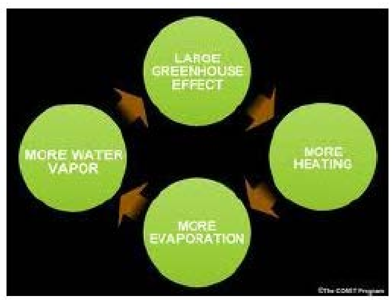
Scientific research in meteorology and climatology focuses on a few main areas that overlap and feed each other, including:

• Understanding of mechanisms at play in climate change
• Numerical modeling of the atmosphere
• Implementation of strategies to better understand, detect and predict extreme weather events (severe weather physics)
• Acquisition and assimilation of atmospheric data (particularly from satellites)
• Mitigation measures (see section 6)

Understanding the mechanisms at play in climate change is a long-distance race that involves specialists from several disciplines because the **interactions between atmosphere / Earth / ocean are incredibly complex. Topics that have, for the last few years, been particularly interesting to scientists include, to list but a few:**

• **Aerosols** (human and natural origin), fine suspended particles in the atmosphere that act directly and indirectly on the climate (aerosols absorb the sun's rays, but also change the amount of clouds in the atmosphere).

• **The "vicious circle" related to water vapour (the water vapour feedback loop):** A warmer planet will generate more humidity in the atmosphere, which in turn heats the planet…



• The links between the ozone layer and climate change

The performance of numerical models is also at the heart of the race – a high-speed race this time. When we consider the controversy surrounding the reliability of the climate models and the fact that a single simulation of the North American climate over 30 years, at a resolution of 45 km, takes more than 3 months to carry out and generates 2.5 terabytes of data (and the computers used are supercomputers, performing close to 2.5 billion mathematical operations per second!), we understand the importance of this issue. **The future construction of a mega scientific facility on the Panama Canal could one day help scientists perfect their modelling of the dynamic of fluids.**

The improved modelling of forecasts is also a constant concern for researchers. In Canada, research in meteorology is particularly focused on the numerical formulation and resolution of equations for all physical phenomena, the development of numerical algorithms, the improvement of short-term forecasts (less than 48 hours), the improvement of mid-term deterministic and ensemble forecasts (from 3 days to two weeks), the improvement of long-term forecasts, the development of new forecasting techniques and the improvement of current methods for the direct numerical forecasting of the weather.

As regards the **forecasting of extreme weather events, Canada is involved in the VORTEX2 project (storm chasers)**

and the ITOP project regarding the impact of typhoons in the Pacific.

Various Environment Canada departments are also involved in understanding and forecasting extreme weather events in the area (forecasting severe weather, hurricanes, etc., see section 5, Weather forecasting in Canada, who does what?)

Finally, given its vulnerability, **the impact of climate change on the Arctic and its populations** is a subject that is always of interest to the international scientific community in general, and Environment Canada researchers in particular.

8. Citizen science

Making observation of the weather a pastime by becoming an amateur meteorologist is an excellent way to **(re)connect with nature**, both for youth and adults.

In the United States, “**weather camps**” are very popular, while in France, there is instead a **growing number of amateur observer networks** that specialize in very specific regions and that, as needed, provide assistance to professional meteorologists.

In Quebec, a few awareness initiatives have been carried out by the **Association professionnelle des métrologistes amateurs** (Professional meteorologists association), particularly as part of the program “Les innovateurs à l’École” (Innovators at school) and the library of the Société pour la promotion de la science et de la technologie (Society for the promotion of science and technology), as well as the Conseil des loisirs scientifiques (Scientific recreation counsel).

These initiatives are intended for a school-aged audience. A contest entitled “meteorologist d’un jour” (meteorologist for a day) was also organized a few years ago.

Today, the group “**Les fous de météo**” (crazy about the weather) specializes in the observation and photography of weather phenomena, such as clouds, severe storms, lightning, etc.

Environment Canada also supports a program for volunteer weather observers recruited from among meteorology enthusiasts from across Canada. **They provide Environment Canada forecasters with the latest information regarding severe weather events**. The program ***Attention glace*** (IceWatch) is part of a series of Canadian projects for volunteer ecological monitoring.