Briefing Note on Climate Change 2021: The Physical Science Basis

"In August 2021, the International Panel on Climate Change released its Sixth Assessment Report. Among its authors are several Canadian climate scientists. The report has important applications for disaster and emergency management policy in Canada, and naturally foreshadows the work that practitioners will be doing in the coming years. The Canadian Journal of Emergency Management's operations section has produced a briefing note summarizing the Sixth Assessment Report's Summary for Policy Makers, which is in itself an extensive white paper. This briefing note was produced by operations staff Kaitlyn Boudreau, Melanie Robinson, and Zahrah Farooqi, and was approved for publication by a member of the Editorial Board."

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Part A – The current state of the climate

Human influences have warmed the atmosphere, ocean, and land; ultimately resulting in widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere. Over the last four decades, each has been successively warmer than the previous. Further, global mean sea levels have increased by 0.20 meters (1.3mm annually from 1901-1971, 1.9mm annually from 1971-2006, and 3.7mm annually from 2006-2018). Human influences that have resulted in these changes have included increases in well-mixed greenhouse gas concentrations, aerosols, and ozone and land development. Solar and volcanic drivers and internal climate variability have also played a factor. Table 1.0 depicts the changes that have been seen and are predicted.

Table 1.0

Likely	- Human-caused global surface temperatures increase from 1850-1900 to 2010-2019 is 0.8-1.3 degrees - Well-mixed GHGs contributed a warming of 1.0-2.0 - Increased global average precipitation has increase since 1950, with a faster rate of increase since the 1980s - Human influence contributed to the pattern of observed precipitation changes since the mid-20th century - Mid-latitude storm tracks have shifted poleward in both hemispheres since the 1980s - Global proportion of major tropical cyclone occurrence has increased over the last four decades - Human influence has increased the change of compound extreme events since the 1950s

Very likely	- Well-mixed GHGs were the main driver of tropospheric warming since 1979 - Human influence contributed to the poleward shift of the closely related extratropical jet in austral summer in the Southern Hemisphere - Human-influence is the main driver of the global retreat of glaciers since the 1990s - Human influence is the main driver of the decrease in arctic sea ice area between 1979-1988 and 2010-2019 - Human influence contributed to the decrease in Northern Hemisphere spring snow cover since 1950 - Human influence has contributed to the observed surface melting of the Greenland ice Sheet over the past two decades - Human influence is the main driver of the global mean sea level increases since at least 1971 - Human influence contributed to marine heatwaves doubling in frequency since at least 2006
Extremely likely	- Human-caused stratospheric ozone depletion was the main driver of lower stratosphere cooling since the implementation of The Montreal Protocol in 1979 until the mid-1990s - Human influence contributed to the pattern of observed changes in the usage of near-surface salinity (such as using salt to clear roadways in colder climates) - Human influence has been the main driver of the warming of the upper ocean since the 1970s

No significant trend or evidence	- Antarctic sea ice area from 1979-2020 due to the regionally opposing trends and large internal variability - Human influence on the Antarctic Ice Sheet mass loss
Virtually certain or high confidence	- The global upper ocean (0-700m) has warmed since the 1970s - Human-caused CO2 emissions are the main driver of current global acidification of the surface open ocean - Oxygen levels have dropped in many upper ocean regions since the mid-20th century - Changes in the land biosphere since 1970 are consistent with global warming - In 2019, atmospheric Co2 concentrations were higher than any time in the last 2 million years - Concentrations of CH4 and N2) are higher that anytime in the last 800,000 years - Global surface temperatures have increased fast since 1970 than in any other 50-7ear period over the last 2000 years - In 2011-2020, annual average Arctic Sea ice area reached its lowest level since at least 1850 - Global mean sea level has risen faster since 1900 than over any preceding century in at least the last 3000 years - Hot extremes (including heatwaves) have become more frequent and more intense across most land regions since the 1950s - human-induced

	- Cold extremes (including cold waves) have become less frequent and less severe - human-induced - Marine heatwaves have approximately doubled in frequency since the 1980s - Frequency and intensity of heavy precipitation events have increased since the 1950s over most land area

Part B – Possible Climate Futures

Five emissions scenarios are considered to compare climate response to greenhouse gases (GHG), land use and air pollutant futures than assessed in AR5. Results over the 21st century is provided for the future terms (2021-2040), (2041-2060) and (2081-2100).

Box SPM.1: Scenarios, Climate Models and Projections

SPM 1.1	➢ Assesses the climate response to 5 scenarios that covers the possible future development of anthropogenic drivers of climate change; ➢ Starts in 2015; ➢ Emissions vary depending on socio-economic assumptions, levels of climate change mitigation and air pollution controls; ➢ Scenarios include high and very high GHG levels and CO2 emissions that double by 2100 and 2050.
SPM 1.2	➢ Assesses climate models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6) of the World Climate Research Programme; ➢ Models include newer representation of physical, chemical and biological processes;

	➢ Historical CMIP6 simulations resemble mean global surface temperature change within 0.2°C – warming is within the *very likely* range; ➢ Other CMIP6 models simulate either above or below the *very likely* warming range.
SPM 1.3	➢ CMIP6 climate sensitivity values are higher compared to CMIP5; ➢ Higher sensitivity values are resulting from amplified cloud feedback – larger in CMIP6 by 20%.
SPM 1.4	➢ Future changes in global surface temperature, ocean warming, and sea levels are constructed; ➢ Assessment constructed from multi-model projections with observational constraints. ➢ Based on past simulated warming and the AR6 assessment of climate sensitivity.

With every increase of global warming, changes become greater in temperatures, precipitation and soil moisture resulting in larger extremes. Land surface will continue to warm more than the ocean surface while it is very likely that heavy precipitation will increase and become more recurrent in most areas.

An intensified global water cycle together with its variability, global monsoon, precipitation and the severity of wet and dry events are anticipated from continuous global warming. Ocean and land carbon sinks are expected to be less effective at slowing the growth of CO2 in the atmosphere under the circumstances with increased CO emissions.

Numerous changes due to past and future greenhouse gas emissions are permanent for centuries to millennia, particularly changes in the ocean, ice sheets and global sea levels. Past GHG emissions have committed the global ocean to future warming since 1750 while mountain and polar glaciers are expected to continue melting for decades to centuries.

Global mean sea level is determined to continue to rise over the 21st century. Sea levels are estimated to rise for centuries to millennia due to continued deep ocean warming and ice sheet melt while remaining elevated for thousands of years. Human activities affect all major climate system components.

Part C – Climate information for risk assessment and regional adaptation

Knowledge regarding the climate response and the range of possible outcomes can help inform climate services, the assessment of climate-related risks, and adaptation planning. Decadal variability has enhanced and masked underlying human-caused long-term changes, and this variability is very likely to continue in the future. As such, all continents are projected to experience further increases in climate impact drivers (CIDs). CIDs are physical climate conditions (means, events, extremes) that affect and elements of our society and/or ecosystems. They can be determinantal, beneficial, neutral, or a mixture of each, across interacting system elements and regions. CIDS are grouped into seven types: heat and cold, wet and dry, wing, snow and ice, coastal, open ocean, and others. Table 2.0 shows some projections.

Table 2.0

Medium confidence	- Based on paleoclimate and historical evidence, it is likely that at least one large explosive volcanic eruption would occur during the 21st century - this would reduce global surface temperature and precipitation, especially over land for 1-3 years

High confidence	- At 1.5-degree increase, heavy precipitation and associated flooding are projected to intensify and be more frequent in most regions in Africa and Asia, Norther America and Europe - More frequent and/or severe agricultural and ecological droughts are projected in a few regions in all continents except Asia compared to 1850-1900 - If global warming exceeds or reaches 2 degrees, the magnitude of the change in events will increase across the globe - Regional mean relative sea level rise will continue throughout the 21st century - Many regions are projected to experience an increase in the probability of compounds events. Ex) concurrent heatwaves and droughts are likely to become more frequent

Part D – Limiting future climate change

Limiting human-induced global warming to a specific level requires limiting cumulative CO2 emissions, reaching at least new zero CO2 emissions, along with significant reductions in other greenhouse gas emissions. Strong, rapid, and sustained reductions in CH4 emissions would also limit the warming effect pollution and would improve air quality. Further, if global net negative CO2 emissions were achieved and sustained, the global CO2-induced surface temperature increase would be gradually reversed. Still, other climate changes would continue in their current direction for decades to millennia. By the end of the century, scenarios with very low and low GHG emissions would strongly limit the change of several CIDs.

Finally, it was noted that emissions reductions were seen in 2020 due to measures taken to reduce the spread of COVID-19. These effects were temporary but had a detectible impact on air pollution.