Engineers Canada

Infrastructure Resilience Professional Program

Climate Science for Engineers

Draft Syllabus

July 2017

(15 hours of lectures + assignments + evaluation)

Overall knowledge:
Understanding of the principles of climate science and their relation to the development and application of engineering design parameters and incorporation into professional practice

Proposed topics:
- Climatology and climate science principles
- Climate and weather impacts on infrastructure
- Evolution of climate and climate change science
- Climate data: acquisition, interpretation and manipulation
- Climate change projections - models and scenarios
- Climate data availability
- Climate and hydrology
- Translating climate data into engineering design parameters
- Engineering professional practice principles and applications to infrastructure

Proposed textbook:
None identified at this time however there is relevant educational material from the American Meteorological Society (AMS) and more recently the Canada Centre for Climate Services.

Proposed Outline
1. Basic climatology and climate science principles (2 hours) –

   Objective: Provide an overview of basic concepts and terminology in climatology and climate science with a description of the main processes governing the climate system.

   1.1. Differences between climatology and meteorology
   1.2. Climatic system component
      1.2.1. Atmosphere
         1.2.1.1. Greenhouse effect
         1.2.1.2. Circulation
      1.2.2. Hydroshere
   1.3. Descriptive and relational climatology (Spatial distribution of temperatures, precipitation, and snow cover and relationships between climate parameters)
   1.4. Climate variability at various temporal scales

1.4.1. Paleoclimatology (including)

1.4.1.1. relationship between CO_2 and global temperature

1.4.2. Interdecadal (NAO, AO, PDO, etc.)

1.4.3. Internannual (e.g. El Niño, La Niña)

2. Climate evolution and climate change science (1 hour)

<u>Objective</u>: Provide an overview of basic concepts and terminology related to climate evolution and climate change science. Cover observed historical trends, GHG loadings and impacts on natural habitats and built infrastructure.

- 2.1. A brief history of climate change including
  - 2.1.1. Main scientific understanding
  - 2.1.2. Climate-scepticism
  - 2.1.3. Politics
- 2.2. Chemistry
  - 2.2.1. Different green house gases
  - 2.2.2. Ocean acidification
- 2.3. Historical trends (temperature, precipitation, sea levels, etc.) and detection of climate change
- 2.4. GHG atmospheric loadings – past, present and future
- 2.5. What changes climate shifts induce in the natural and built environment

3. Climate models, emission scenarios, and projections (2 hours)

<u>Objective</u>: Provide an overview of basic concepts and terminology related to climate models and discuss of the available emission scenarios and projections.

- 3.1. Climate modelling
  - 3.1.1. Prevision, projection, and prediction (including description of)
    - 3.1.1.1. Forecast model, reanalysis and climate model
  - 3.1.2. General principles
  - 3.1.3. A brief history
  - 3.1.4. Physical basis
  - 3.1.5. Model evaluation
- 3.2. Global and regional models
  - 3.2.1. Motivation
  - 3.2.2. Characteristics
  - 3.2.3. Downscaling considerations and options
- 3.3. Climatic projections
  - 3.3.1. Principles
  - 3.3.2. Emission scenarios (equilibrium, IS92A, SRES, RCPs)
  - 3.3.3. Coupled Model Intercomparison Project (CMIP3 and CMIP5)

3.3.4.Coordinated Regional Downscaling Experiment (CORDEX)

3.4. Uncertainties

3.4.1.Natural and internal variability

3.4.2.Structural (or model) uncertainties

3.4.3.Emission scenarios

3.5. Available climatic projections

3.5.1.Global (IPCC5)

3.5.2.Canada

4. Climate data: acquisition, interpretation and manipulation (2 hours)

<u>Objective</u>: Provide an overview of basic concepts and terminology related to climatic data acquisition, measurement instruments and their uncertainties, available datasets and their main characteristics.

4.1. An historical overview of the development of meteorological instruments

4.1.1.Meteorological stations and networks

4.1.2.Radar

4.1.3.Satellite

4.1.4.Other types of instruments

4.2. Available observational datasets

4.2.1.Raw data

4.2.2.Interpolated datasets

4.2.3.Homogenized datasets

4.2.4.Derived datasets

4.2.5.Prevailing data formats and analysis tools

4.3. Reanalyses

4.3.1.What is a reanalysis?

4.3.2.History of reanalysis development

4.3.3.ERA-Interim, JRA-55, MERRA, CFSR, 20CR reanalysis

4.3.4.Reanalyses comparison

4.4. Climate models

4.4.1.Coupled Model Intercomparison Project (CMIP)

4.4.2.Coordinated Regional Downscaling Experiment (CORDEX)

4.4.3.Canadian Regional Climate Model (CRCM)

4.4.4.Other ensembles

4.4.5.Example: extraction and treatment of model climatic ensemble

4.5. Climate information portals and services

4.5.1 Canada Centre for Climate Services

4.5.2 Pacific Climate Impacts Consortium

4.5.3 OURANOS

4.5.4 Prairie Regional Adaptation Collaborative (URegina)

4.5.6 Engineers and Geoscientists BC Climate Portal

4.5.6 RSI CCHIP Portal
4.5.7 Other Portals Under Development

5. Using climate scenarios in engineering work considering climate change (4 hours) –

   Objective: Provide an overview of best practices in the development climate change scenarios and discuss the benefits and challenges associated with their use in climate change work.

   5.1. Introduction
      5.1.1. Where should an engineer start?
      5.1.2. What are climate scenarios?
      5.1.3. What is the use of climate scenarios for engineering?
   5.2. Types of climate scenarios
      5.2.1. Incremental scenarios (synthetic scenarios)
      5.2.2. Spatio-temporal analogues
      5.2.3. Temporal series from climate model simulations
   5.3. General considerations for the use of climate scenarios
      5.3.1. Spatio-temporal issues
      5.3.2. Types of variables
      5.3.3. Uncertainties
      5.3.4. Critical climate thresholds for key infrastructure categories
   5.4. Post-treatment methods
      5.4.1. Definition, motivation, and basic principles
      5.4.2. Post-treatment methods
      5.4.3. Advantages and drawbacks
   5.5. Ways to present climate scenarios to engineers
   5.6. Projected changes in main climatological variables across Canada (by sector and/or by region)
      5.6.1. Temperature, precipitation and other key climate indices
      5.6.2. Projected changes in extremes
   5.7. Projected changes in hydrological regimes
   5.8. Infrastructure design-life future time horizons for climate projection data

6. Engineering practice adapting to climate and weather impacts on infrastructures in Canada (5 hours)

   Objective: Provide an overview of the impacts of climate change on different Canadian infrastructures relevant to the engineering practices, and discuss how to incorporate climate principles into infrastructure design and engineering professional practice

   6.1. Principles of climate adaptation and mitigation in engineering professional practice
   6.2. The need for climate adaptation and integrated design

6.3. Impacts of climate change on design and operation of different types of built infrastructure across Canada
6.4. Climate parameters within infrastructure design codes and standards
6.5. Engineering applications of climate change principles and associated tools for adapting infrastructure
    6.5.1. Conventional infrastructure design
    6.5.2. Integrated infrastructure design
6.6. Examples of applying climate change and adaptation principles into infrastructure design
6.7. Case studies
    6.7.1. Examples of best practices (things that worked)
    6.7.2. Examples of what not to do (things that did not work)