Natural Resources Canada | Ressources naturelles Canada

National dialogue on groundwater (NDGW)

Dialogue national sur les eaux souterraines (DNES)

January 19, 2021

Canada

Overview

1. Greetings (Éric Boisvert) – 5 minutes
2. Breaking News or New development (all) – 5 minutes
3. Presentation – 30 minutes (15 minutes each)
   - **Geneviève Bordeleau** - Long-term monitoring of methane concentrations in a shale aquifer using total dissolved gas pressure (PTDG) probes: comparison with data from groundwater samples
   - **Andre R. Erler** - High-resolution Climate Projections for Integrated Hydrologic Modeling
4. Questions (all) – 10 minutes
5. Wrap-up and next meeting on April 6, 2022, from 1 to 2 p.m.(ET)

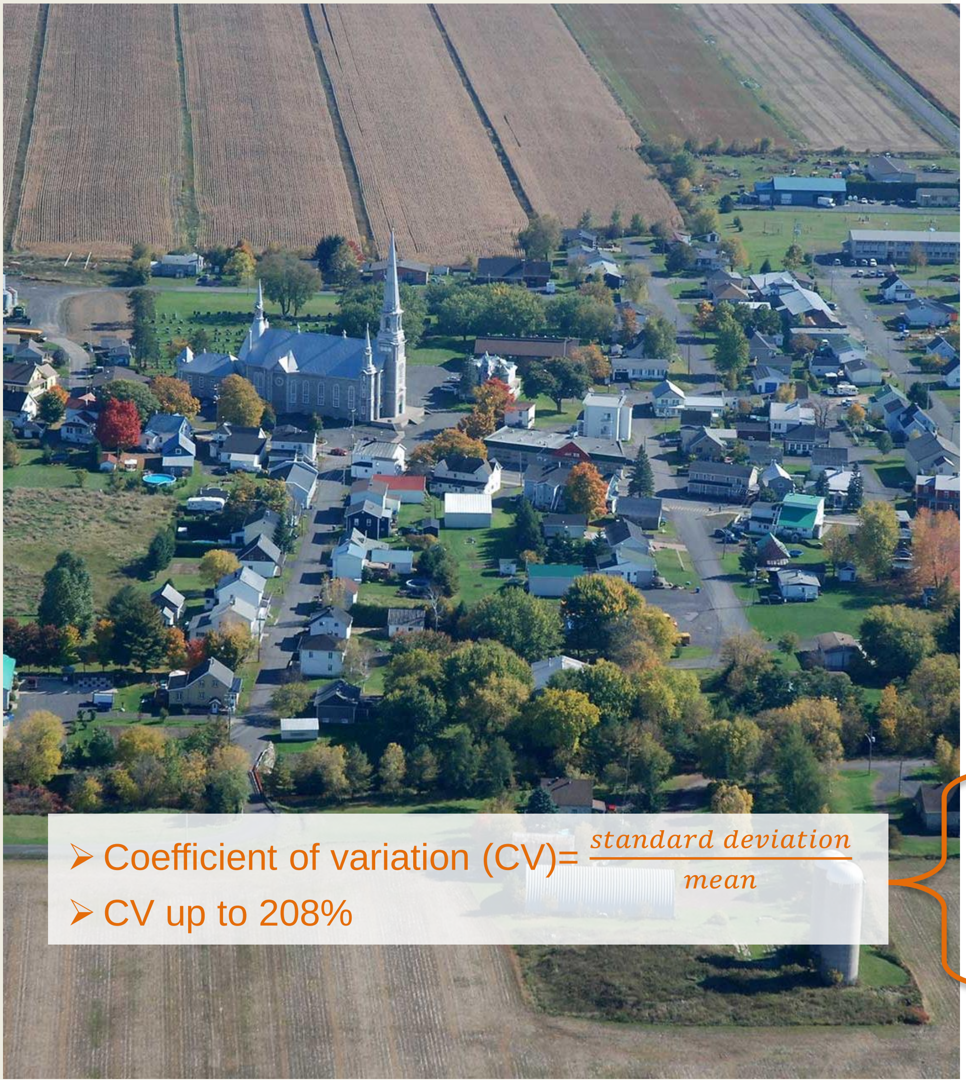
LONG-TERM MONITORING OF METHANE CONCENTRATIONS IN A SHALE AQUIFER USING TOTAL DISSOLVED GAS PRESSURE (P_{TDG}) PROBES: COMPARISON WITH DATA FROM GROUNDWATER SAMPLES

Geneviève Bordeleau – Institut national de la recherche scientifique (INRS)
Jim Roy – Environment and Climate Change Canada (ECCC)
Christine Rivard – Geological Survey of Canada (GSC)
Cathryn Ryan – University of Calgary

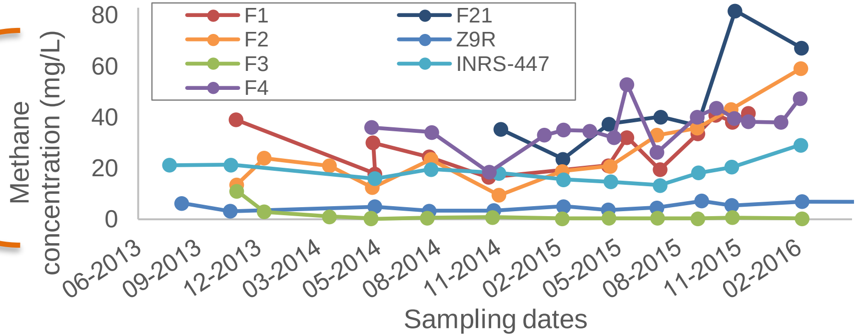
Institut national de la recherche scientifique

The St-Édouard project

- 2 exploration shale gas wells (1 vert., 1 hz)
- No commercial O&G production
- 2013-2016: methane baseline study
- GW from 30 residential wells and 14 monitoring wells
- Methane conc. between <0.006 mg/L and 82 mg/L

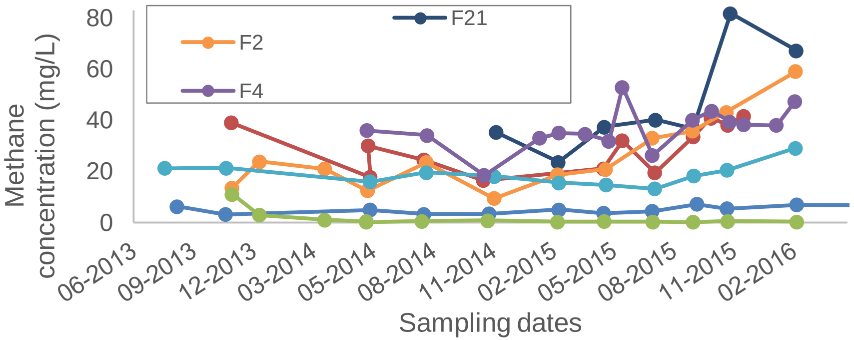


- Coefficient of variation (CV)= $\frac{standard\ deviation}{mean}$
- CV up to 208%



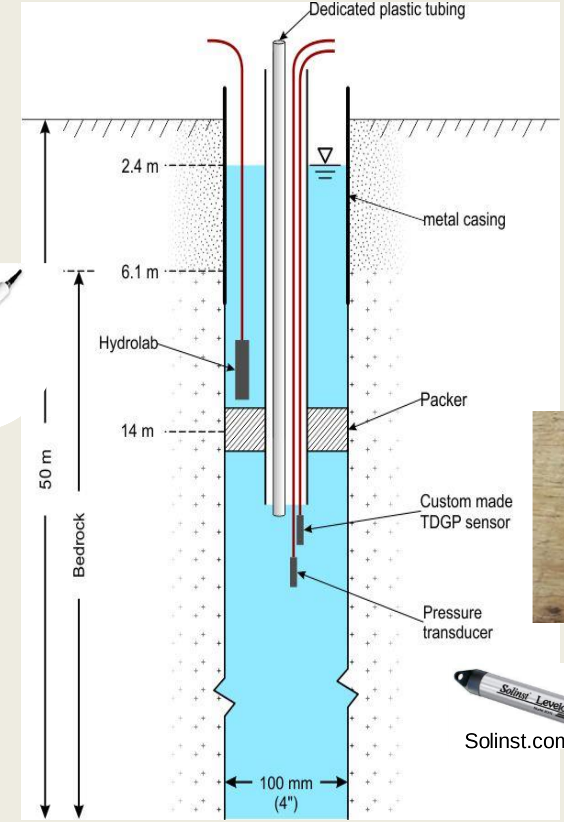
Sampling protocol

- ❖ Same type of sampling device
- ❖ Same sampling depth (where flowing fractures were previously identified using borehole geophysical methods)
- ❖ Low-flow (< 500 mL/min), minimal drawdown (ideally <10 cm)
- ❖ Submerged bucket method, results averaged over 3 vials



- ✓ Gas-charged (>10 mg/L CH_4)
- ✓ Accessible year-round
- ✓ Different hydrogeological context (bedrock formation, depth)
- ✓ Methane largely dominant (>85%) over other gases

Field set-up



- P_{TDG} probes: gas-permeable, water-impermeable silicon membrane that isolates a gas-filled chamber containing a pressure transducer
  - Custom-made probe with external datalogger (C. Ryan)
  - Hydrolab MS5 probe with internal datalogger (F2)
- Packers: to prevent in-well degassing
- Levellogger: measuring water pressure and temperature
- Measurements: every 15 to 60 min
- Water sampling: dedicated tubing stays in place
- Data download and water sample collection: approximately every 2 months over a period of 2 years

Data interpretation

Bubbling pressure (P_{BUB})

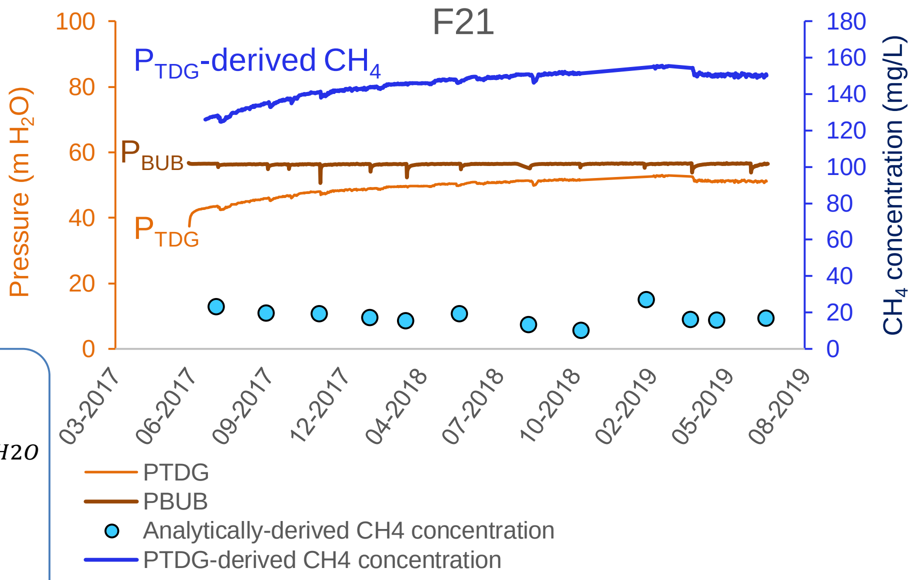
- $P_{BUB} = P_{water} + P_{atm}$ →from levellogger

Analytically-derived CH_4 concentration (GW samples)

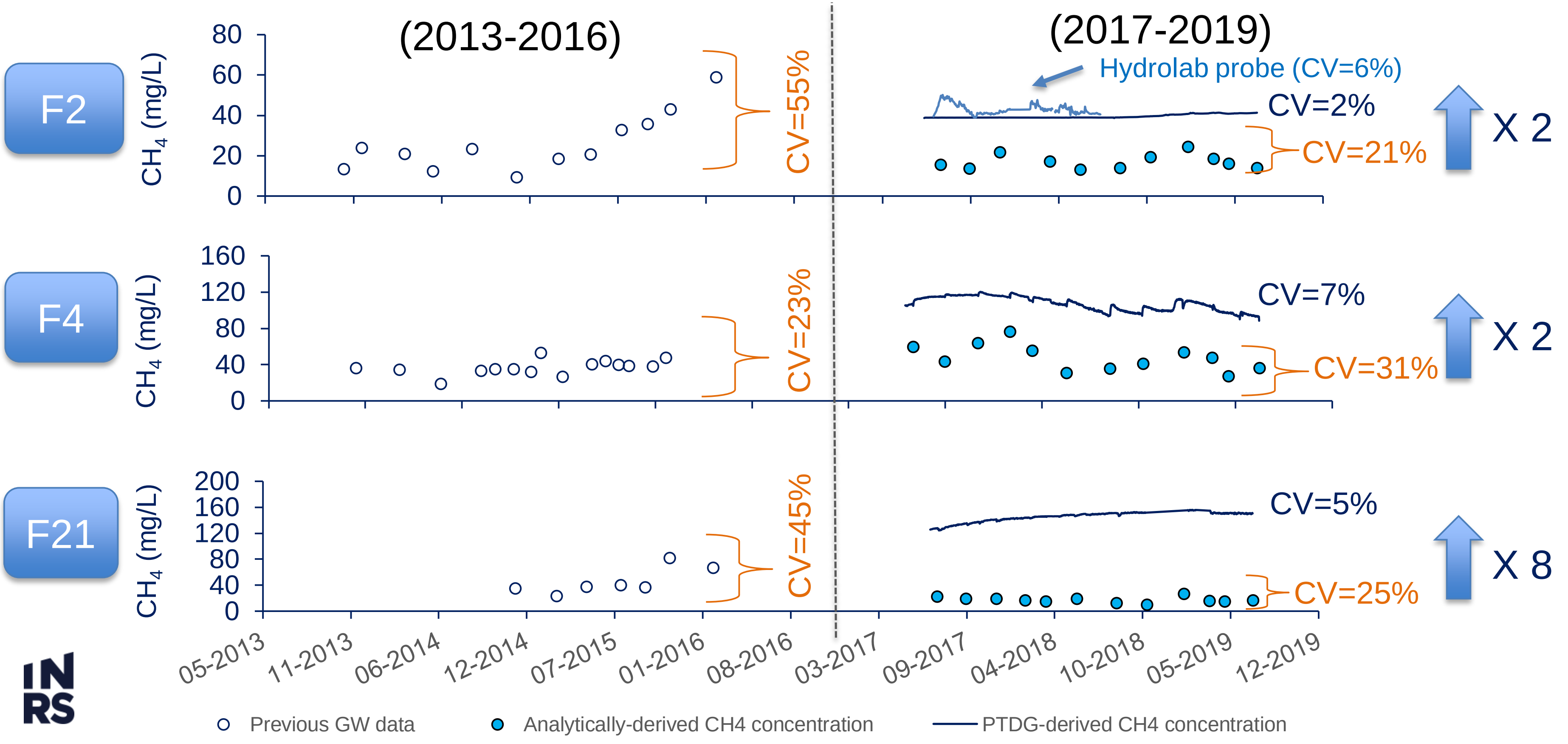
- Analysis by GC-TCD-HID: X_{gas} for each gas
- Partial pressure of a gas= $X_{gas} \times P_{atm} = P_{gas}$ (atm)
- Knowing **Henry's** constants for each gas (H_{gas}) at 22ºC
- $H_{gas} \times P_{gas} \times molar\ weight_{gas} = C_{gas}\ in\ water\ (\frac{mg}{L})$

P_{TDG}-derived CH_4 concentration

- **Dalton's** Law: $P_{TDG} = P_{N2} + P_{CO2} + P_{O2} + P_{Ar} + P_{CH4} + P_{C2H6} + P_{H2O}$
- Ideal gas law: $PV = nRT$
- $P_{CH4} = \left(\frac{n_{CH4}}{\sum n_{gas}}\right) \times P_{TDG} = X_{CH4}(equilibrated\ gas\ phase) \times P_{TDG}$
- Use **Henry's** Law (H @ T in the wells, 7ºC) → $C_{gas}\ in\ water\ (\frac{mg}{L})$



Results – methane concentrations



Conclusion

- Continual in-situ measurements (possible to detect sudden or short-term changes)
- Faster/better timing for sampling (if remote access systems are employed)
- Reduced field trips

- Packers must be installed (not suitable for domestic wells)
- Proportions of methane relative to other gases should remain stable over time. If not, different ratios can be used on different portions of the pressure curves, but interpolation between sampling events may be questionable

- Areas where oil and gas activities occur (monitoring wells)
- Remote areas (difficult road access, seasonal access only)
- Scientific tool to better understand methane dynamics under background conditions (e.g. for estimating greenhouse gas emissions)

INRS

- Comparison with Isoflasks (more representative CH_4 concentrations in gas-charged water)
- Sensors that measure methane directly (currently unavailable for such concentrations)

Questions?

climate change – groundwater – surface-water – modelling – sustainable communities

Regional Climate Modeling in Support of Canada 1 Water

Andre R. Erler, Aquanty Inc.

National Dialogue on Groundwater
January 19th 2022

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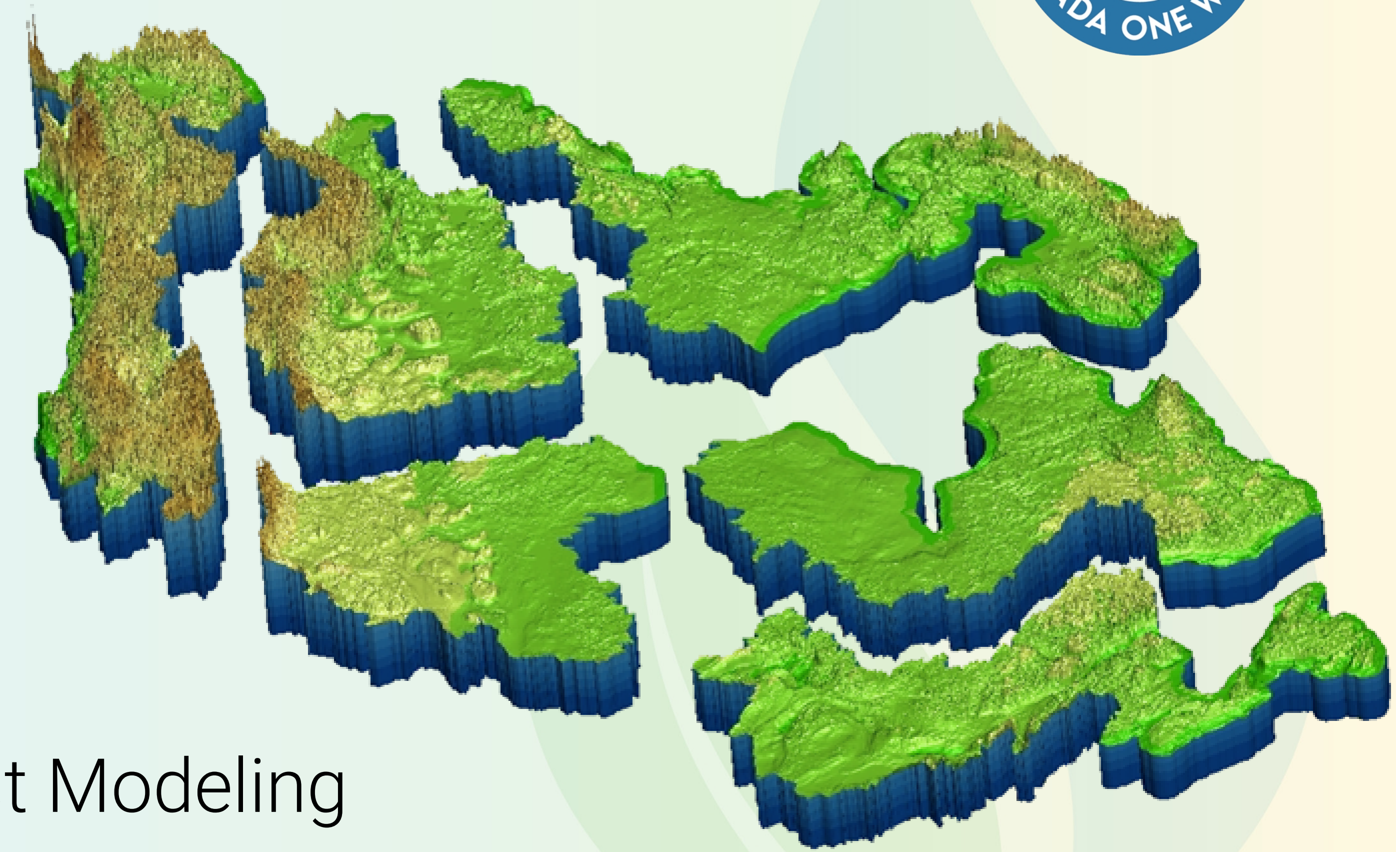

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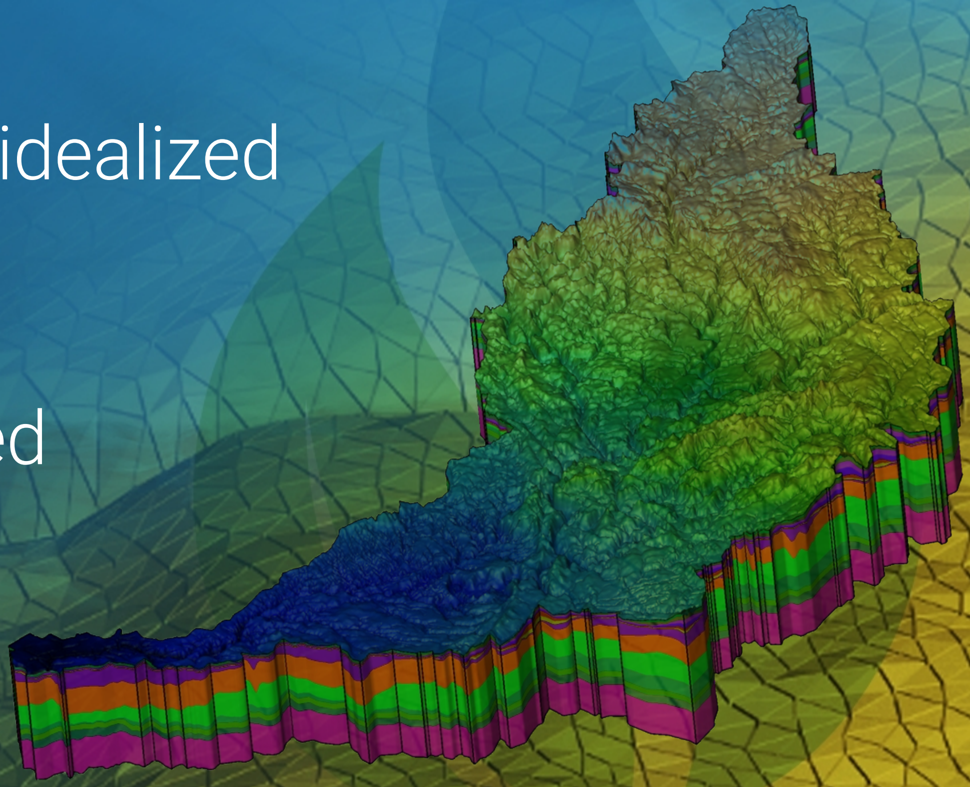
Modelling Climate Change Impacts on Groundwater - Previous Attempts:

- Small or regional scale (watershed) or idealized

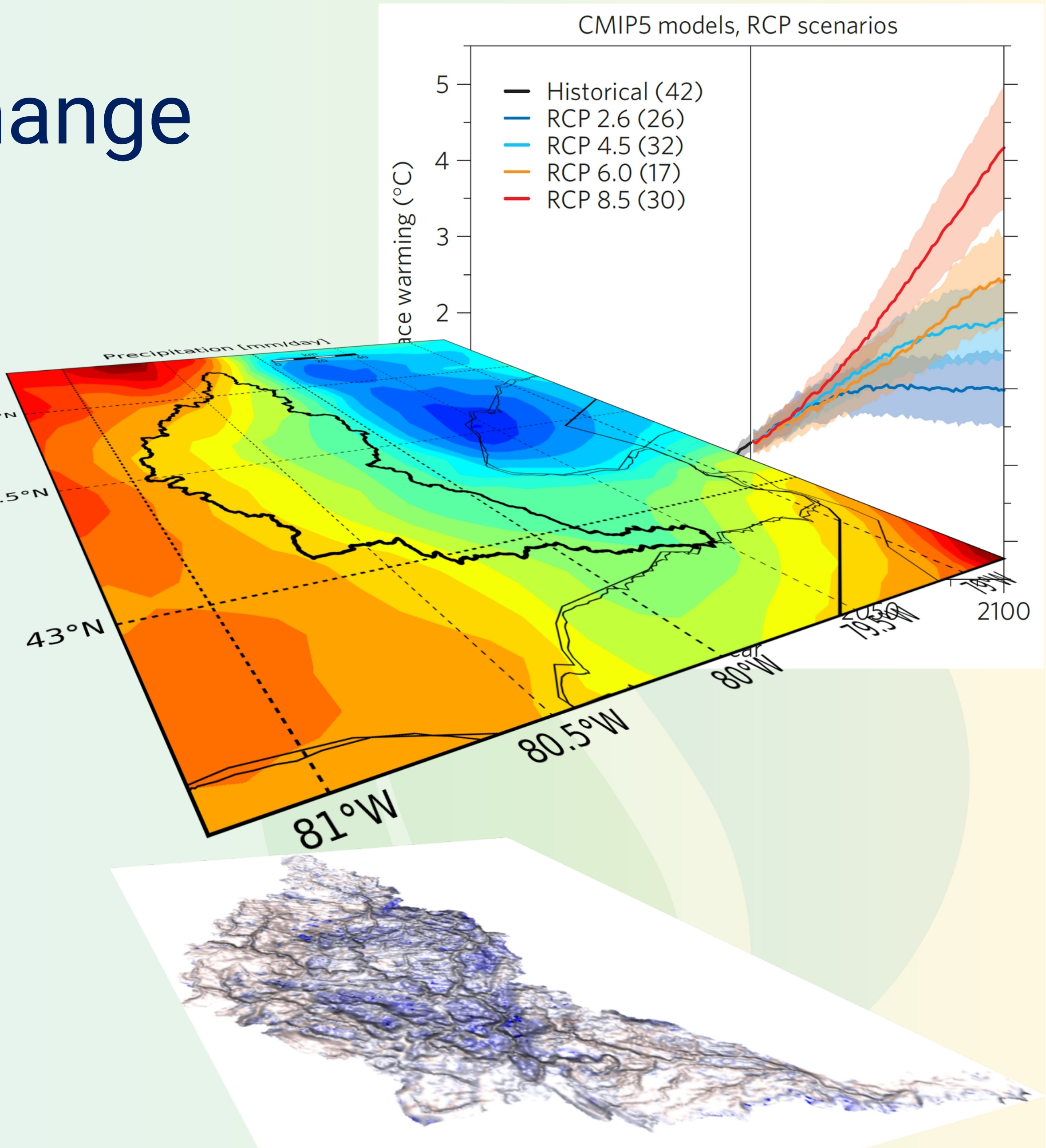
… and …

- often relying on statistically downscaled Global Climate Models



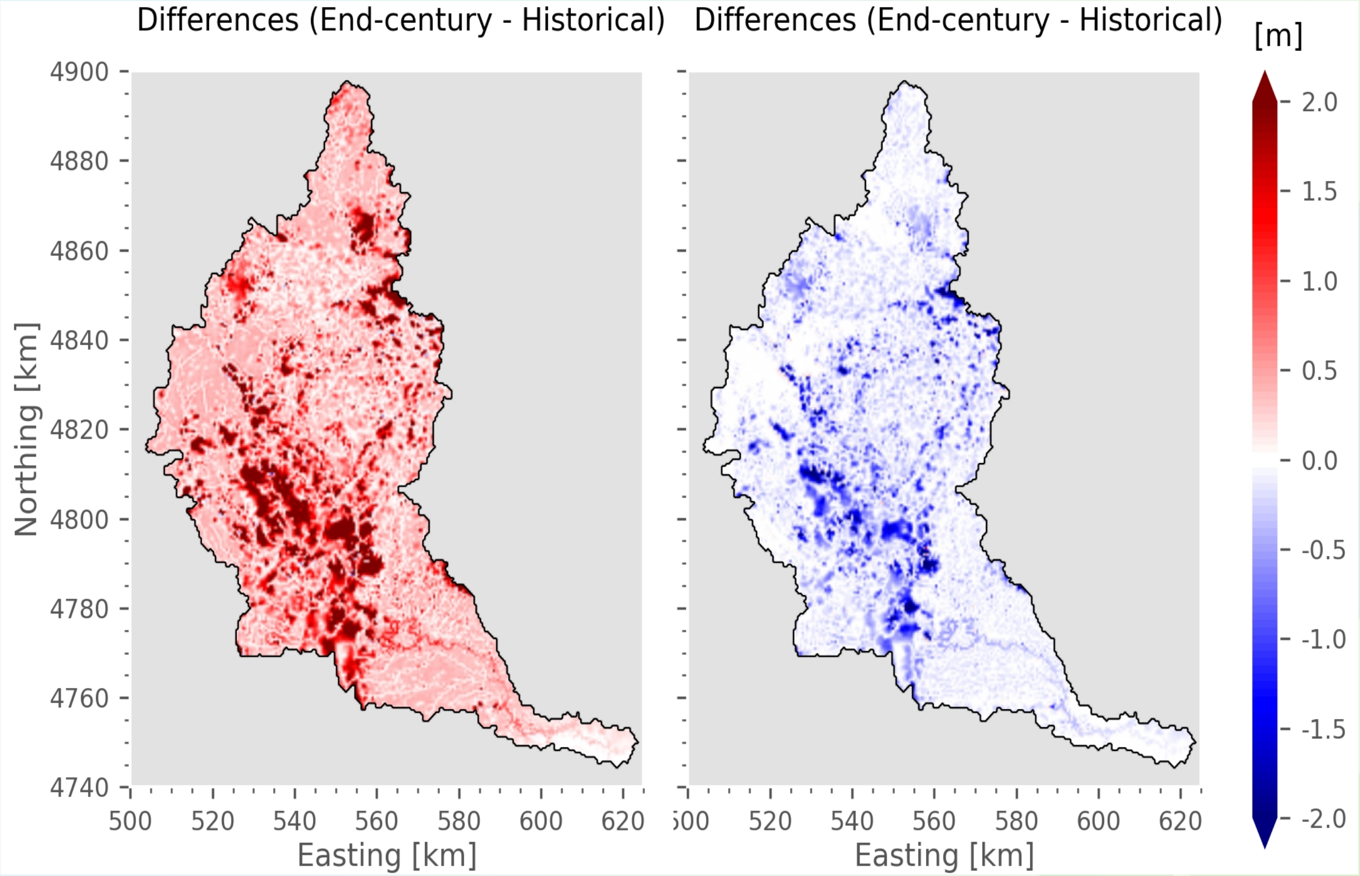
Previous Work on Climate Change and Groundwater

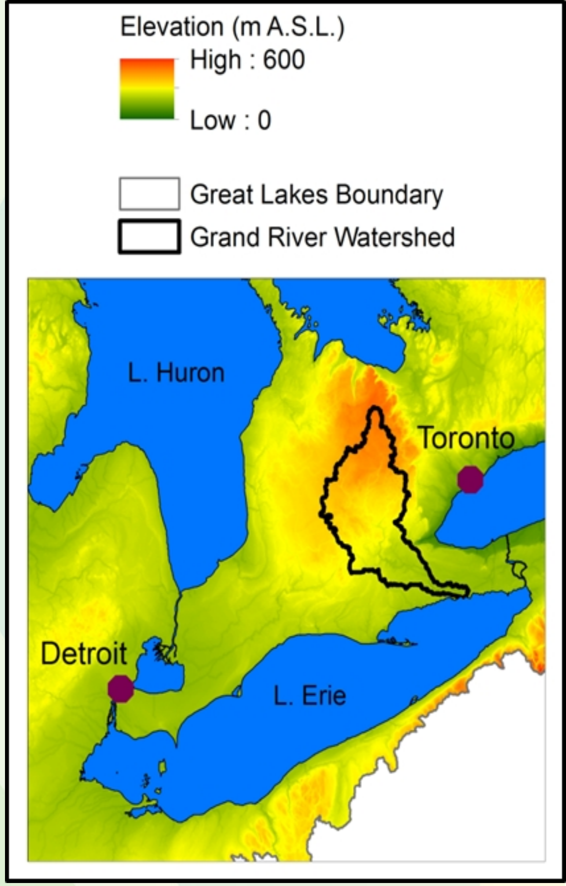
- Goderniaux et al. (2009, 2015), Karlsson et al. (2016) and Sulis et al. (2011) used downscaled climate model ensembles over small catchments (~500km²)
- Erler et al. (2019) used a small climate model ensemble over the 6800 km² Grand River Watershed
- All found dominant uncertainty in climate projections



The Grand River Study

Figure: changes in groundwater table depth at the end of the century, using two different climate model projections





aquanty
HGS Simulation™

- Sign and magnitude follow climate change signal…
- … but regional modulation by topography is significant
- Deep groundwater tables tend to be more sensitive

Current Limitations and Goals for Canada 1 Water

Current Limitations

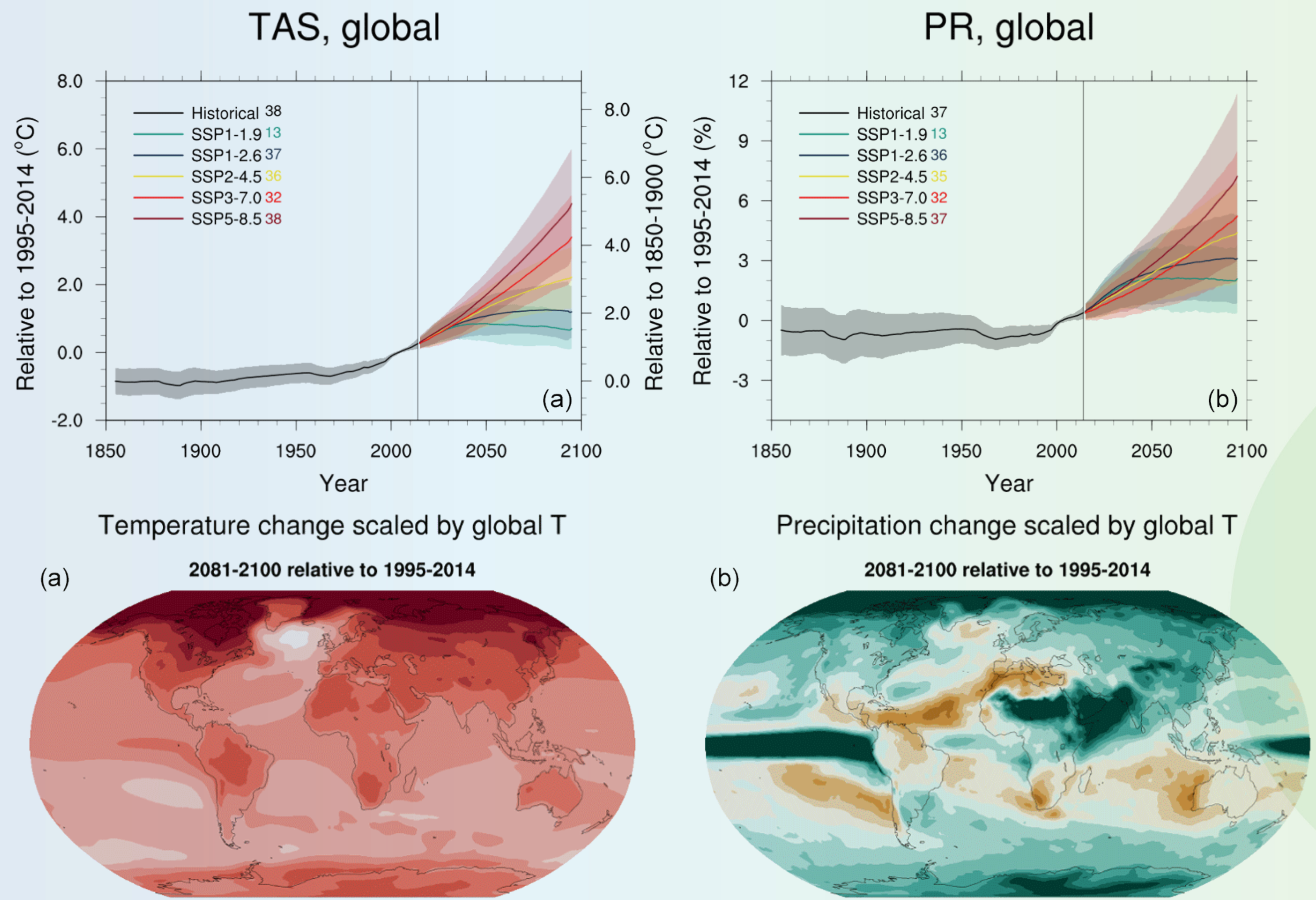
- Uncertainty in Climate Data
  - Large biases in GCMs
  - Uncertainty in projection
- Small scale of studies
  - Limited to existing watershed models
  - Interactions across scales

C1W Goals

- Employ best possible, high-resolution regional climate projections
- Build dedicated, large-scale integrated models
- Consider cold-region processes

The IPCC 6th Assessment Report

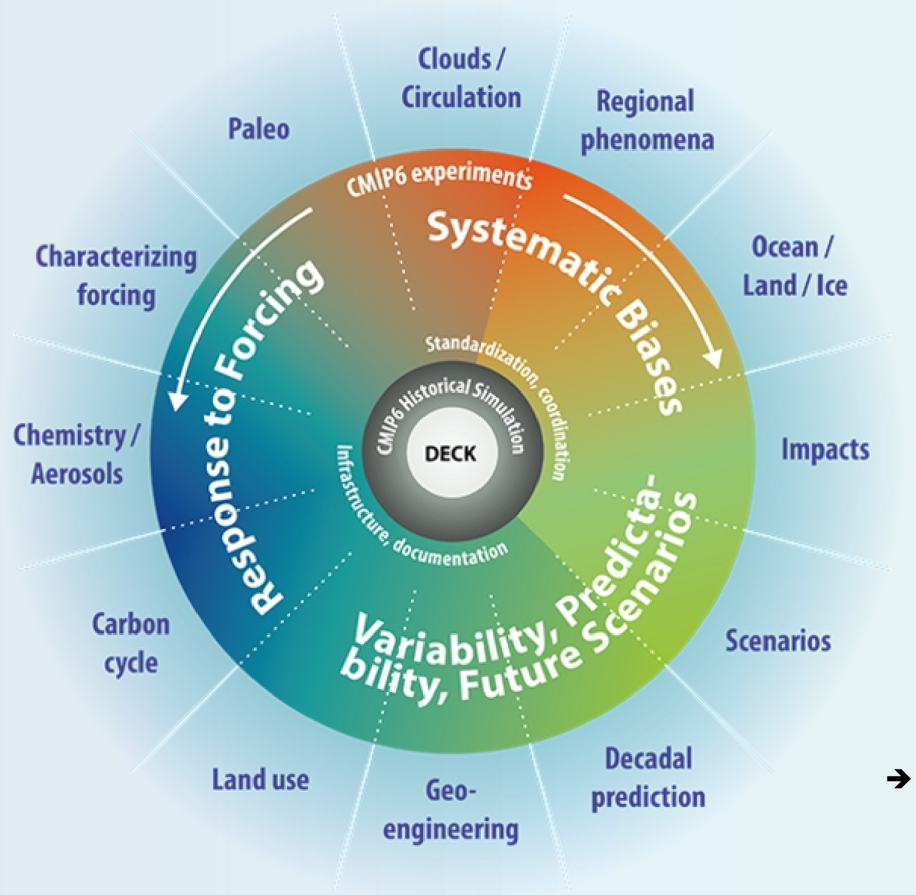
- Physical science assessment released last year (2021), impact and mitigation assessment to be released this year (2022), along with Summary of Policy Makers
- New GHG concentration scenarios



6th Assessment Report & CMIP6

- Very New! - Only populated last year!
- Successor to CMIP5, with new GHG concentration scenarios
- Similar warming as before, but larger range between models

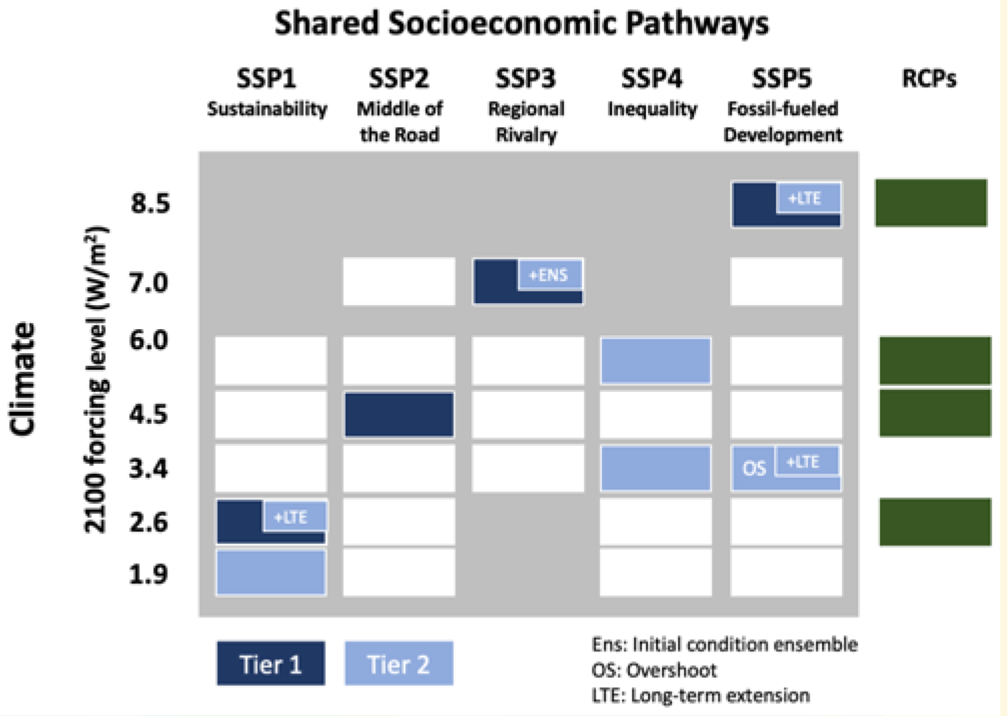
WCRP CMIP6
World Climate Research Programme



AR6 & CMIP6

<u>New Scenarios</u>

- Now called **SSP*N***, but most have equivalent RCP's (right figure)



- A new repository of global climate projections from different national modeling centers
- **SSP3-7.0 is the preferred one** (somewhat below RCP 8.5)
- Besides the new scenario simulations (**ScenarioMIP**) also many science experiments, e.g. Geoengineering, Paleo-climate and Decadal Prediction (left figure)

Simple Conversion:

SSP*N*-*RF* = RCP-*RF*

WCRP World Climate Research Programme CMIP6

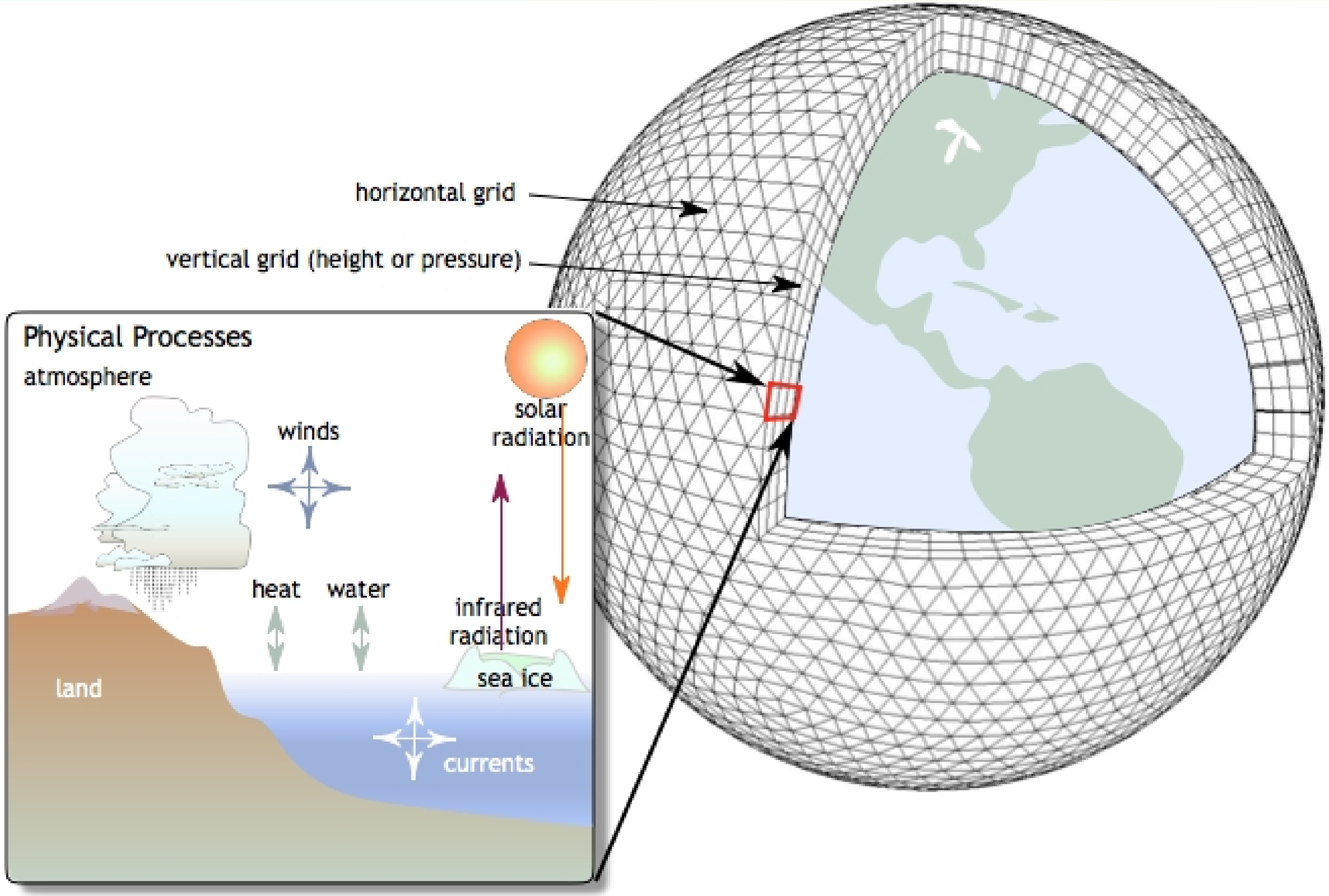
Weather and Climate Models

At the core, these are fluid- and thermodynamical numerical solvers – *essentially CFD*

<u>However:</u>

- Several **component models** (ocean, atmosphere, sea ice, land etc.)
- **Sub-grid scale processes** like clouds and convection are **parameterized**
- **Land-surface/vegetation processes** are important, but very hard to model

Weather and climate models are essentially the same, with different process emphasize and resolution



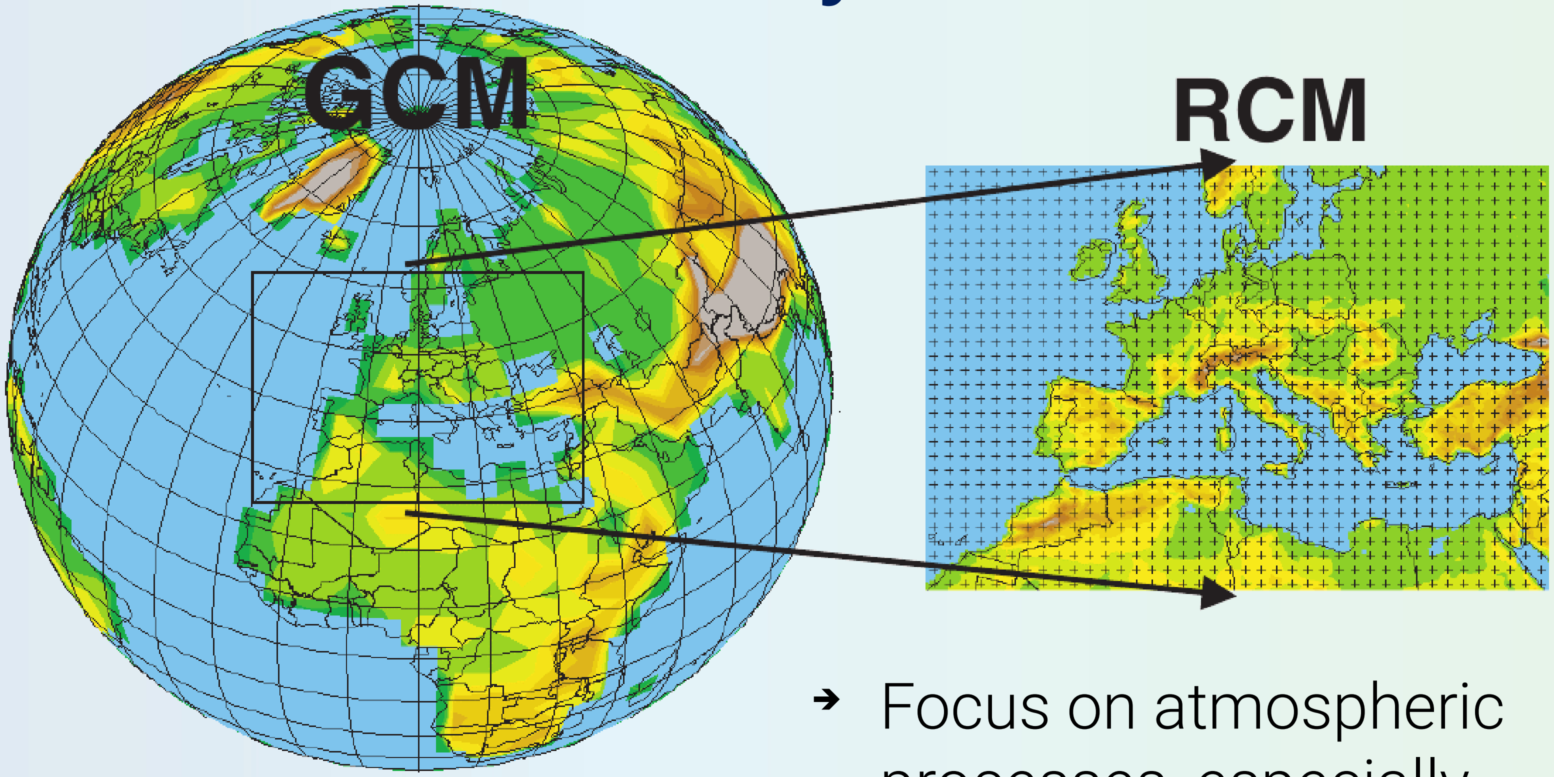
At the core, climate models are similar to groundwater models (nonlinear PDE solvers), but parameterizations are like conceptual rainfall-runoff models (empirical)

Regional Climate Modeling
a.k.a. *Dynamical Downscaling*

- Using a high-resolution climate model for regional modeling over a limited area
- CORDEX is the Coordinated Regional Downscaling Experiment with chapters in all major regions

WCRP CORDEX
Coordinated Regional Climate Downscaling Experiment

Dynamical Downscaling



- Focus on atmospheric processes, especially precipitation
- Land surface processes are often simplified

- Regional Climate Models (RCMs) essentially work like GCMs, but at higher resolution
- RCMs require boundary conditions from GCMs

Statistical Downscaling

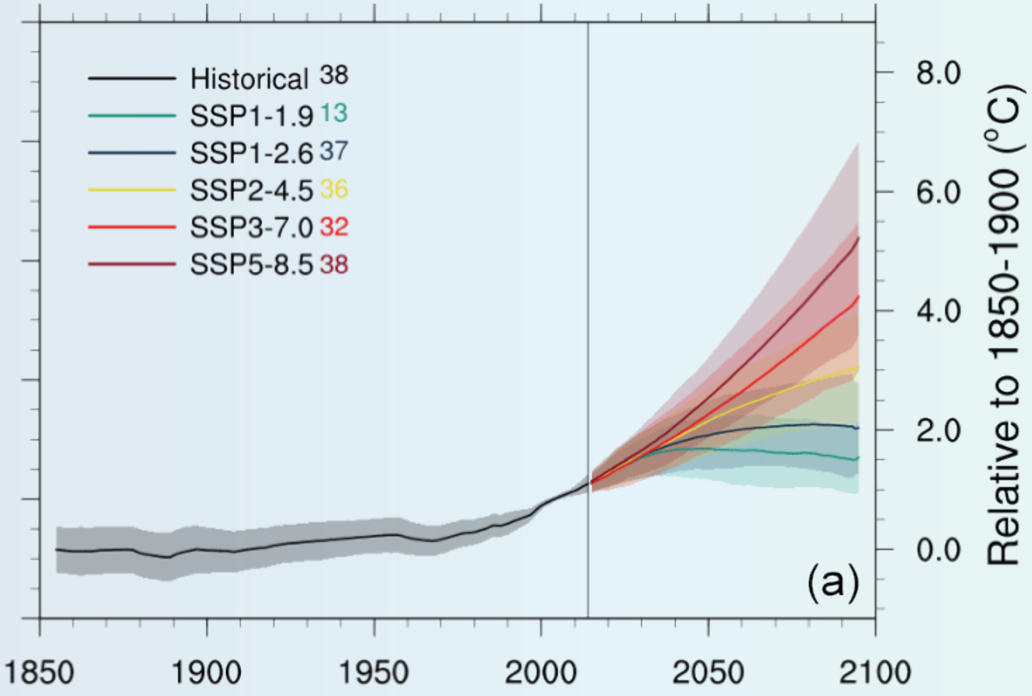
Uses statistical relationships to estimate small-scale variability and unresolved processes from GCMs directly

WCRP CORDEX
Coordinated Regional Climate Downscaling Experiment

Dynamical Downscaling for C1W

Experimental design will follow CORDEX2 protocol:

- NA-CORDEX domain (right) at 12.5 km resolution
- Run transient and continuous from 1950 - 2100



Planned simulations:

- Historical run with ERA5 forcing
- Downscale 4-6 CMIP6 GCMs using SSP3-7.0
- Sensitivity experiments as needed

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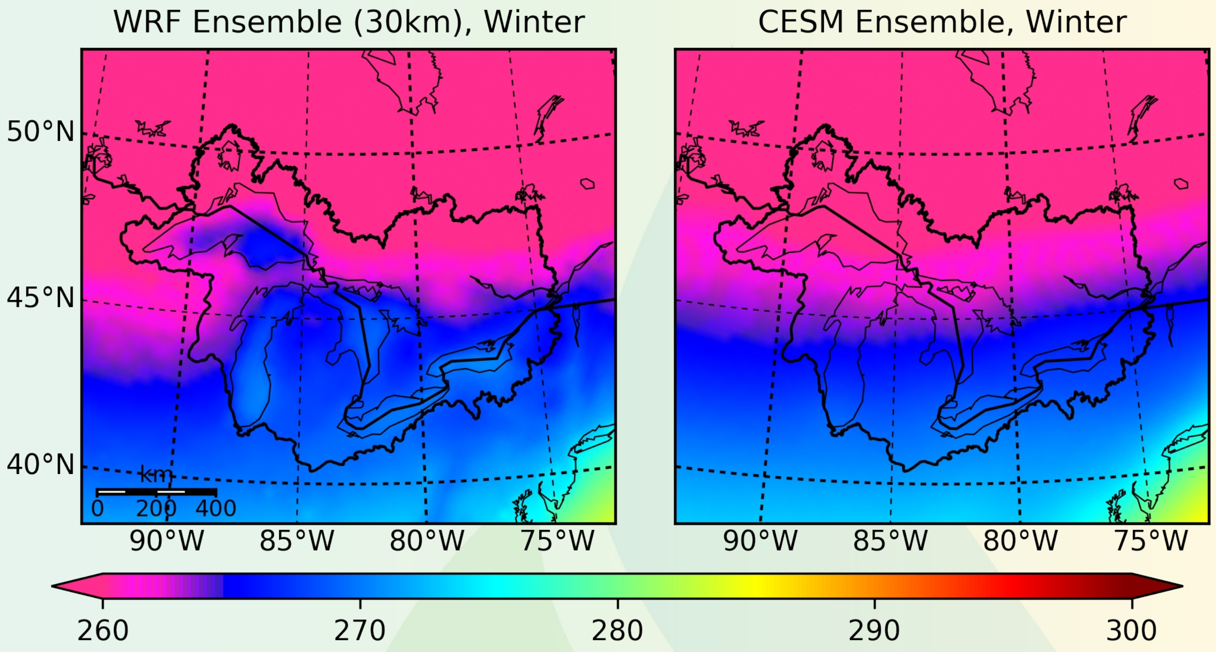
WRF: the Weather Research and Forecasting model

- A state-of-the-art regional weather prediction model
- Also widely used as an RCM
- Supports wide range of sub-grid scale parameterizations
- Developed by NCAR (US)



Also used for climate projection at UofT, e.g. in Great Lakes region (figure above):

➔ WRF (left) captures effect of lakes on winter temperatures much better than than the driving GCM (right)

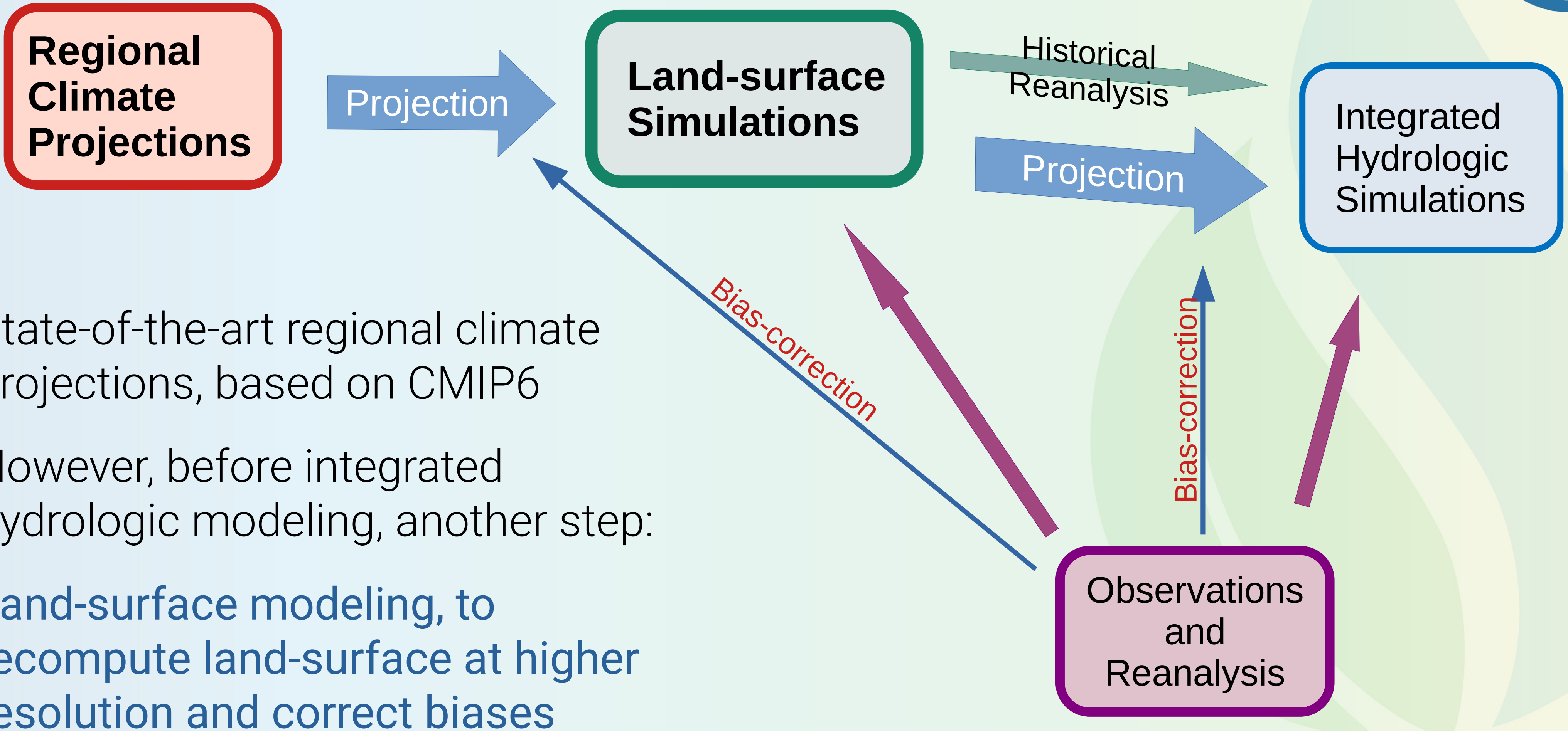
NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

WRF
Weather Research & Forecasting

Land-surface & Permafrost Modeling

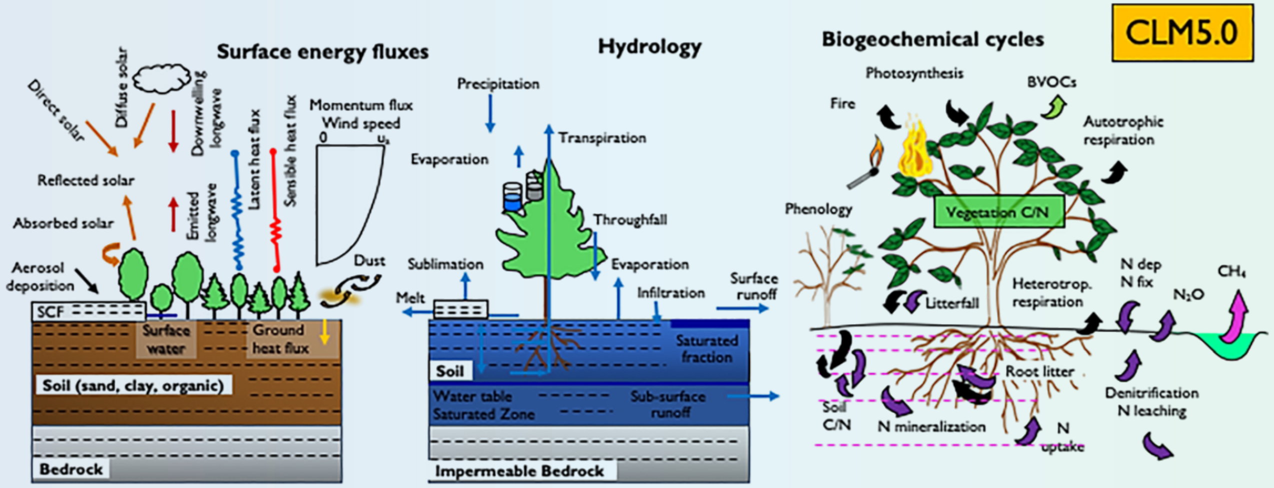
- Land-surface processes are critical, yet poorly resolved and subject to climate model biases
- Bias-correction of snow is difficult, due to non-linear dependence on temperature

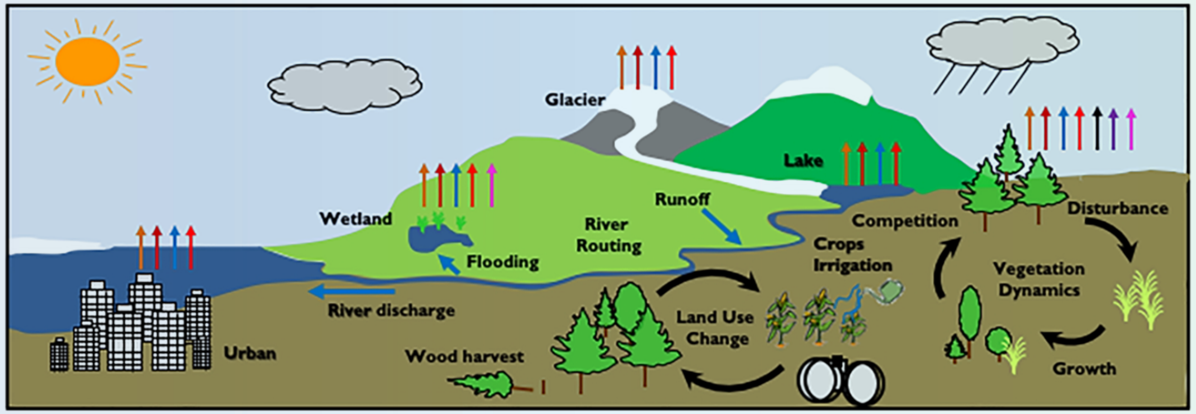
The C1W Modeling Pipeline



- State-of-the-art regional climate projections, based on CMIP6
- However, before integrated hydrologic modeling, another step:

  Land-surface modeling, to recompute land-surface at higher resolution and correct biases





CLM5 is CTSM

CLM5 (the Community Land Model v5) is also the land surface component of the Community Earth System Model

The Community Terrestrial Systems Model (CTSM)

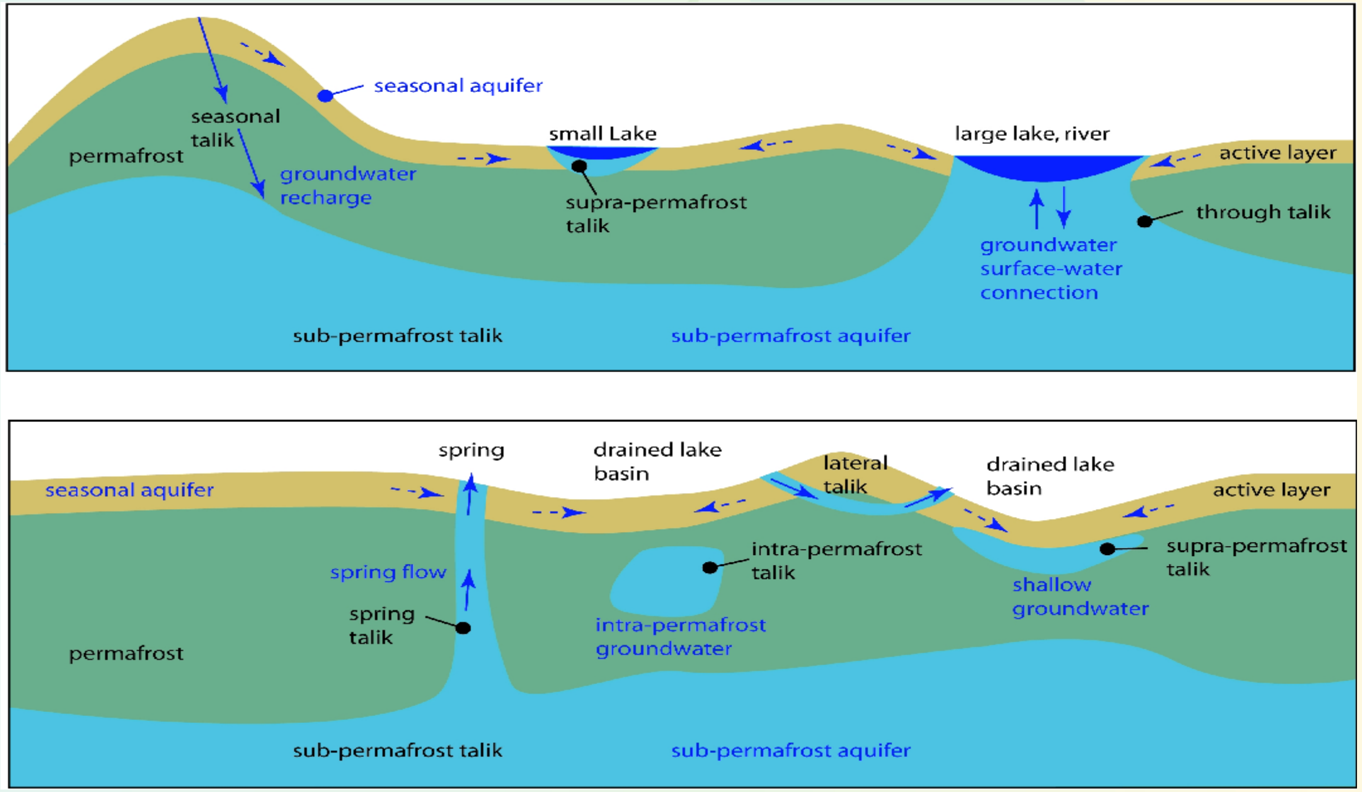
- CTSM is a **1D column** land surface model, i.e. only vertical fluxes, no interflow
- Physics-based, energy and mass balance:
  - **Multi-layer snow model**
  - Richards Equation for soil water movement/infiltration
  - Full heat flux and **soil freezing**
- Carbon and Nitrogen Cycle

Permafrost Representation in CTSM

Permafrost is a critical component of Arctic landscapes; it has a strong impact on regional hydrology and is likely to degrade significantly in the future

- CTSM can model permafrost dynamically
- In addition, small-scale process studies will be conducted (collaboration with UW)

→ Prescribe dynamic permafrost for HydroGeoSphere models

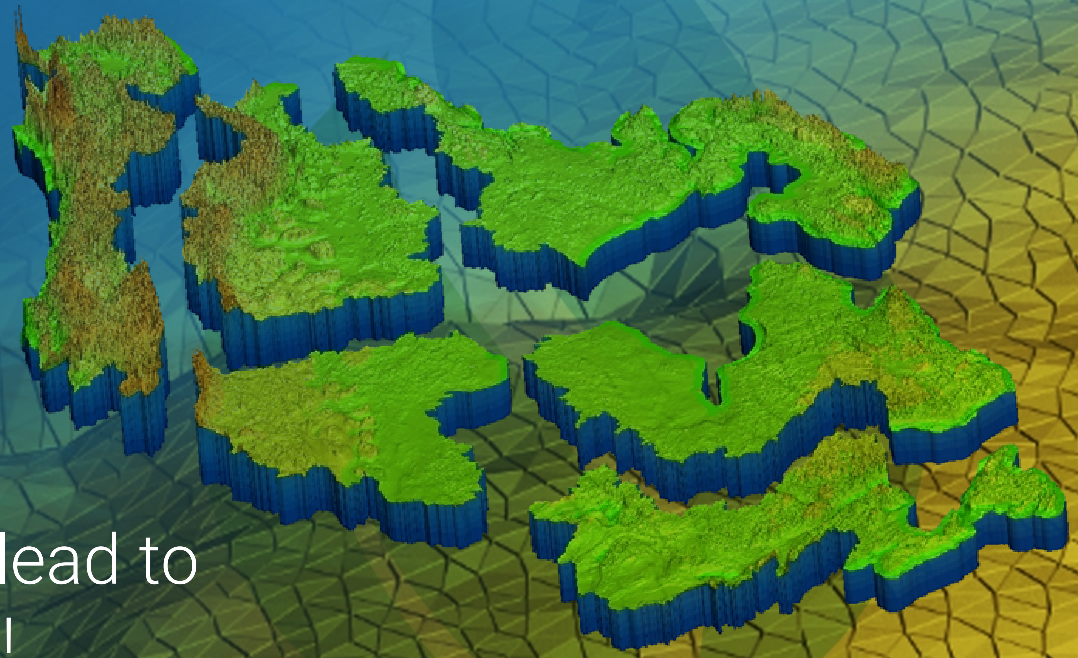


Summary

- State-of-the-art Regional Climate Modeling, based on the just-released CMIP6 ensemble

- Land-surface representation will be enhanced by using CTSM (CLM5) to pre-process climate projections

- Combination of WRF, CTSM and HGS will lead to interesting science on the changing Arctic!



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Thank you and see you all at the next meeting:
April 6, 2022 from 1 to 2 p.m. (ET)