Climate Change Projections for Western Forests

Dr. Dominique Bachelet, Dept of Biological and Ecological Engineering, OSU

Forest Health in Oregon – State of the State 2020
Corvallis, OR – February 26, 2020
The next IPCC Report (AR6) is coming!

AR = assessment report
CMIP = climate model intercomparison project

49 different modelling groups (CMIP5 had ~15)
21 CMIP6-Endorsed MIPs

The Community Land Model Version 5: Description of New Features, Benchmarking, and Impact of Forcing Uncertainty


Implementation of UK Earth system models for CMIP6


First published: 07 February 2020 | https://doi.org/10.1029/2019MS001946

Evaluation of CNRM Earth System Model, CNRM-ESM2-1: Role of Earth System Processes in Present-Day and Future Climate

Roland Séférian, Pierre Nabat, Martine Michou, David Saint-Martin, Aurore Voldoire, Jeanne Colin, Bertrand Decharme, Christine Delfre, Sarah Berthet ... See all authors

First published: 06 November 2019 | https://doi.org/10.1029/2019MS001791 | Citations: 2

The Canadian Earth System Model version 5 (CanESM5.0.3)


Canadian Centre for Climate Modeling and Analysis, Environment and Climate Change Canada, Victoria, BC, Canada

University of Victoria, 3885 Penelick Rd, Victoria, BC, V8P 5C2, Canada

Climate Processes Section, Environment and Climate Change Canada, Victoria, BC, Canada

Credit: aerosol movement -NASA/Goddard Space Flight Center
Increased Complexity - Earth System Models
AR5 in 2014 – AR6 in 2021  (AR=assessment report)

GCMs to ESMs

NEEDS MORE WORK!

Radiation
Wind patterns
Storms
Rainfall events

Land area
Salt Intrusion
Storm surges
CMIP6 vs CMIP5 – greater warming

Comparing CMIP5 and CMIP6 scenarios
For currently available runs, from 1880-1900 to 2090-2100.

Global mean surface air temperature
Degrees C

RCP2.6  RCP4.5  RCP6.0  RCP8.5
SSP-2.6  SSP-4.5  SSP-4.0  SSP-8.5

RCP = Representative Concentration Pathways
SSP = Shared Socioeconomic Pathways

https://www.carbonbrief.org/cmip6-the-next-generation-of-climate-models-explained
Warming trend
1895-2019: +0.10°C
1950-2019: +0.17°C
1980-2019: +0.23°C

Data Source: NCEI

Seasonal Temperature change: Warmer Winters

- Earlier budburst
- Chilling requirements not met
  - e.g. Harrington and Gould 2015
- Damaging late frost
- Longer fire season
- Longer growing season

Heat Waves

Antarctica logs hottest temperature on record with a reading of 18.3°C. A new record set so soon after the previous record of 12.5°C in March 2013 is a sign warming in Antarctica is happening much faster than global average.

Anchorage was 90 degrees on July 4. That’s not a typo.

By Monica Garrett and Susan Scott, CNN
© Updated 3:40 AM ET, Sat July 6, 2019

Northwest Extremes in Maximum Temperature (Step 1)
Warm Season (April–September)

More hot weather
Less cold weather
More record hot weather

https://www.ncdc.noaa.gov/extremes/cei/graph/nw/04-09-1
Physiological mechanisms of drought-induced tree die-off in relation to carbon, hydraulic and respiratory stress in a drought-tolerant woody plant

Shin-Taro Sakai, Atsushi Ishida, Kenichi Yoshimura & Kenichi Yasaki

Sc. Reports 2017

The increasing importance of atmospheric demand for ecosystem water and carbon fluxes

Kimberly A. Novick1,2, Darren L. Field1, Paul C. Stoy1, Christopher A. Williams1, Gil Bolhar9, A. Christopher Oishi1, Shirley A. Papuga1, Peter D. Blanken1, Asko Noormets1, Benjamin N. Sulman10, Russell L. Scott11, Linxi Wang12 and Richard P. Phillips13
Natural Variability in Precipitation

The relative amount of annual rainfall that comes from large, single-day precipitation events has increased over the past century.

Source: NCA4 2017
Floods and Droughts

The Flood of 2020

By JADE MCDOWELL and JESSICA POLLARD Staff Writers

Feb 11, 2020

Image of flood water covering a road with text: Trucks sit in flood water covering Interstate 84 just west of milepost 188 at the Pilot truck stop at Stanfield.
GRAND CHALLENGES for VEGETATION MODELLERS

- Inputs
  - Extreme events
  - Disturbance
- Processes
- Thresholds
  - Trait plasticity
  - Emerging new traits
- Feedbacks
  - Mortality events
Little is known about the interactions among climate, vegetation, and disturbance. Interactions among different disturbance regimes could create novel landscape behaviors. (Behrens et al. 2018).

Credit: Monte Dolack
Published Direct, Indirect and Interaction Effects of CC on Forest Disturbance Agents

EXOTIC INVASIVES
NUH-UH, SOME GUY ON TWITTER JUST SAID YOU'RE WRONG.
Model: CLM (Community Land Model)
Spatial Resolution: 4km x 4km
Future Climate: IPSL-CM5A-MR and MIROC5
Period: 1979–2049
Scenario: RCP 8.5

- high short-term drought vulnerability = 2+years with NPP = 0
- high vulnerability to prolonged drought = 4+years with low allocation to growth
Model: MC2
Spatial Resolution: 4km x 4km

Future Climate: 20 inc. IPSL-CM5A-MR and MIROC5
Period: 2010-2100
Scenario: RCP 8.5
Simulating Vegetation Shifts by Mid-Century

Pure evergreen forests

MIROC5 (Japan) RCP8.5

Mixed type forests - Decline of Grasslands

1971-2000

2036-2065

2071-2100

Loss of subalpine forests
Loss of temperate grasslands
Loss of temperate shrublands

Warmer mixed type forests
Expansion of shrublands and woodlands
Some changes mediated by fire
Simulation results - carbon implications
Some changes just happen
Transition to new climatic conditions

“Vegetation is projected to change from predominantly conifer to predominantly mixed conifer and hardwood forests, regardless of CO$_2$ fertilization and fire effects. With climate, not fire, driving vegetation change, much of the current vegetation can be expected to experience mortality. It is reasonable to anticipate that climate stress will make forests more susceptible disease and pests”
The purpose of models is not to fit the data but to sharpen the questions.

*Samuel Karlin (1924-2007)*
Fig. 2. In the negative carbon-climate feedback (left), increasing CO₂ concentrations stimulate plants to take up carbon from the atmosphere, which lowers the atmospheric concentration and causes a stabilizing effect. Conversely, in the positive feedback (right), higher temperatures from increasing atmospheric CO₂ concentrations cause drying of vegetation, leading to increased fire frequency and severity, which releases more carbon to the atmosphere, resulting in an amplifying effect. Credit: The authors and David Hinkle, NASA/JPL-Caltech

Source: Kaushik et al. EOS 2020
Local conditions are changing

Urbanization causes increased cloud base height and decreased fog in coastal Southern California

Meddens et al. 2018

The Missing Mountain Water: Slower Westerlies Decrease Orographic Enhancement in the Pacific Northwest USA

C. H. Luce, J. T. Abatzoglou, Z. A. Holden

2013
# Vegetation Demography Models in Earth System Models

<table>
<thead>
<tr>
<th>Model acronym</th>
<th>Name</th>
<th>Vegetation representation</th>
<th>Coupled to ESM?</th>
<th>Stochastic?</th>
<th>Canopy structure</th>
<th>Disturbance history patches?</th>
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<tbody>
<tr>
<td>SEIB</td>
<td>Spatially Explicit Individual-Based model</td>
<td>Individual</td>
<td>MIROC-ESM</td>
<td>Yes</td>
<td>Individuals</td>
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<tr>
<td>LPJ-GUESS</td>
<td>Lund-Potsdam-Jena General Ecosystem Simulator</td>
<td>Individual or Cohort</td>
<td>EC-Earth, RCA-GUESS</td>
<td>Yes (optional for some processes)</td>
<td>Flat-top</td>
<td>Yes</td>
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<td>Perfect Plasticity Approximation</td>
<td>Cohort</td>
<td>GFDL-ESM</td>
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<td>RAMS</td>
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<td>Cohort</td>
<td>CESM</td>
<td>No</td>
<td>PPA</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Fisher et al. 2017 Global Change Biology

- **Mortality**
- **Disturbance recovery**
- **Seedling establishment**
- **Competition water**
- **New traits**
- **Land use transitions**
- **Nutrients**
IN SUMMARY

• Model projections have been conservative – rate of warming is increasing; weather records are broken; physiological thresholds exceeded.

• Validation of climate and vegetation models is still based on 20\textsuperscript{th} century observations but “the future ain’t what it used to be” so monitoring is critical.

• Disturbances (pest outbreaks, diseases, wildfire) are hastening shifts in vegetation cover – understanding interactions with climate is critical.

• Human actions are causing meddling changes (introduction of invasives/plants & diseases, fuel build up, fire ignition timing and location, landuse).

• Teams of modelers around the world are synthesizing current knowledge and building tools to simulate interactions and help inform management decisions.

• Ecological patience is required to record and understand the changes, protect climate/fire refugia, distinguish between climate refugees and exotic invasives.
Thank you for your attention

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