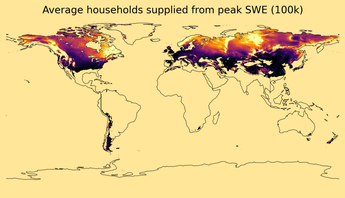
Quantifying changes in global snow at high spatial resolutions under future warming scenarios via deep-learning models

Andrew Bennett, University of Arizona (andrbenn@arizona.edu)
Oriana Chegwidden, CarbonPlan (oriana@carbonplan.org)

Background

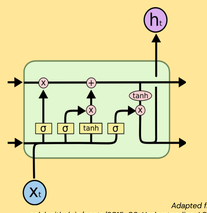
- Snow is a major water resource globally
- Climate change will reduce the overall amount of snow globally due to warming
- The coarse spatial scale of climate model projections makes it difficult to quantify the overall trends



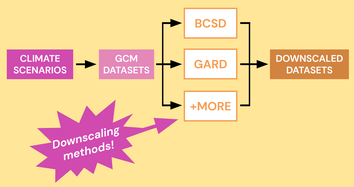
In this project we are working to use ERA5 reanalysis data and high-resolution downscaled climate projections to estimate future snowpack

Methods

- We trained a Long Short Term Memory network to predict snow using daily data from ERA5
- We also processed elevation, slope, and aspect from SRTM to match the ERA5 grid for use as input features
- The model is trained region-by-region so that we can make spatially separated test, validation, and training datasets



Adapted from colah.github.io/posts/2015-08-Understanding-LSTMs

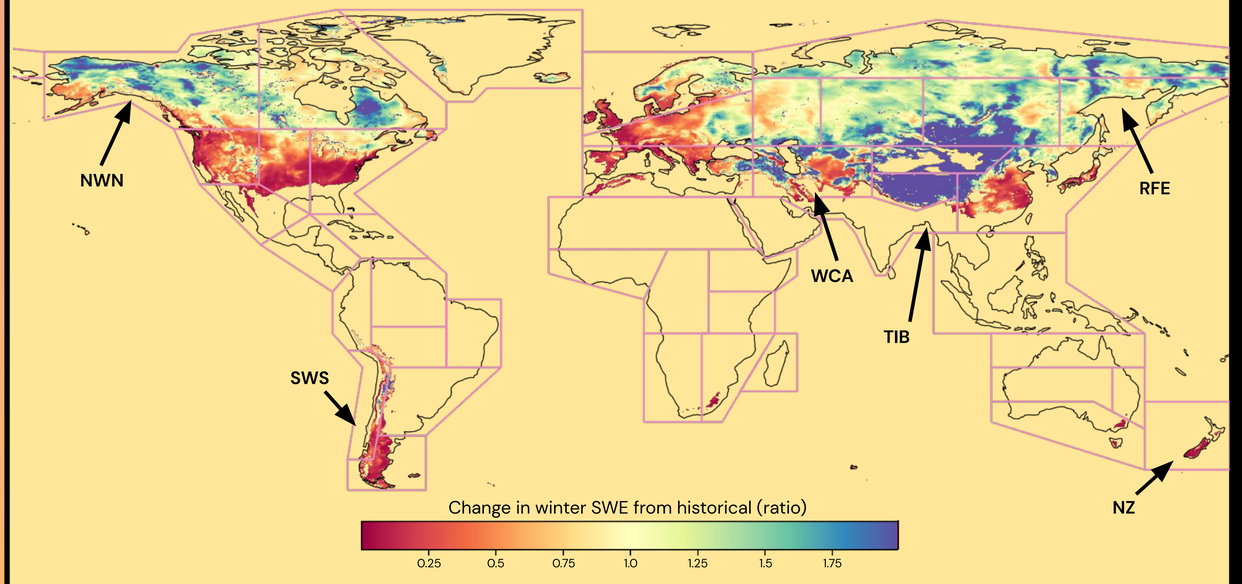


Adapted from carbonplan.org/research/cmip6-downscaling-explainer

- CarbonPlan has produced an ensemble of downscaled CMIP6 climate projections that match the ERA5 25km grid resolution and made it available in an Analysis Ready, Cloud Optimized (ARCO) data format
- We use this data as input to our trained model to make predictions about snow

We train LSTM based models with ERA5 data to predict the snow water equivalent given a 180 day past timeseries of daily air temperature, precipitation, elevation, and aspect for points across the globe

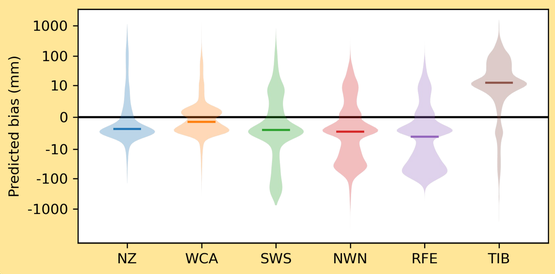
We are able to project changes of global snow at a 25km spatial scale with deep learning and downscaled CMIP6 data



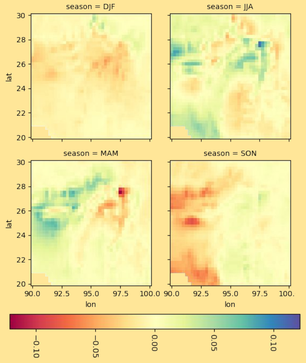
- Showing results from CanESM5, GARD-SV, SSP245 for the 2060s
- Redder colors show loss of peak SWE, blue shows gains

Predictive performance in test regions is good!

- Here we show performance compared to ERA5 SWE for regions in the test dataset, for the historic period (1985-2015)
- Majority of predictions have errors <10mm, but there are very long tails in the distributions which need investigation



What's going on, on the Tibetan plateau?

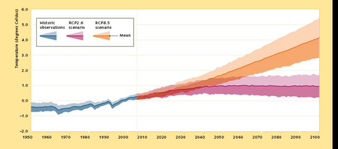


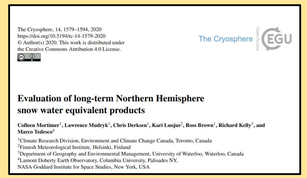
- The clear outlier in the testing results shows overprediction in the Tibetan plateau (TIB)
- We also see projected increases in SWE for our example projection
- We posit model errors which are related to high elevation, not found in training data
- Precipitation changes do not drive this shift

This work was funded by the ESIP ML Tutorial Grant and is supported by the GeoSMART framework
https://geo-smart.github.io/
https://www.esipfed.org/

Discussion/Future Work

- This work was only an initial proof-of-concept! We have only run a single scenario, GCM downscaling method combination
- Before moving to working with the full ensemble we have to implement more rigorous training/testing procedures
- We definitely need to investigate performance in the Tibetan plateau




The Cryosphere, 14, 1579–1594, 2020
https://doi.org/10.5194/tc-14-1579-2020
© Author(s) 2020. This work is distributed under the Creative Commons Attribution 4.0 License.
The Cryosphere
EGU
Evaluation of long-term Northern Hemisphere snow water equivalent products
Colleen Mortimer[1], Lawrence Mudryk[1], Chris Derksen[1], Karl Luojus[2], Ross Brown[1], Richard Kelly[3], and Marco Tedesco[4]
[1]Climate Research Division, Environment and Climate Change Canada, Toronto, Canada
[2]Finnish Meteorological Institute, Helsinki, Finland
[3]Department of Geography and Environmental Management, University of Waterloo, Waterloo, Canada
[4]Lamont Doherty Earth Observatory, Columbia University, Palisades NY, NASA Goddard Institute for Space Studies, New York, USA

- There are also open questions as to how good ERA5 snow data is for this purpose
- We could also target other products such as GlobSnow
- Mortimer et al. (2020) found almost all reanalysis products still could be improved significantly, especially for higher amounts of snowpack

This work is very preliminary! Aside from improving the model for snow predictions we also would like to explore if this approach could work for other ERA5-land based variables like soil moisture.

Open science

- This work would not be possible without the growing python geoscience community & tools
- All of our data, code, and environments are publicly accessible, and reproducible using the Microsoft Planetary Computer and Azure Cloud Storage

xarray
DASK
Zarr

Want to learn about how we built our model? Stay tuned at: https://github.com/geo-smart

We are writing a set of interactive tutorials that reproduce the key ideas all while running in the cloud using publicly available datasets!