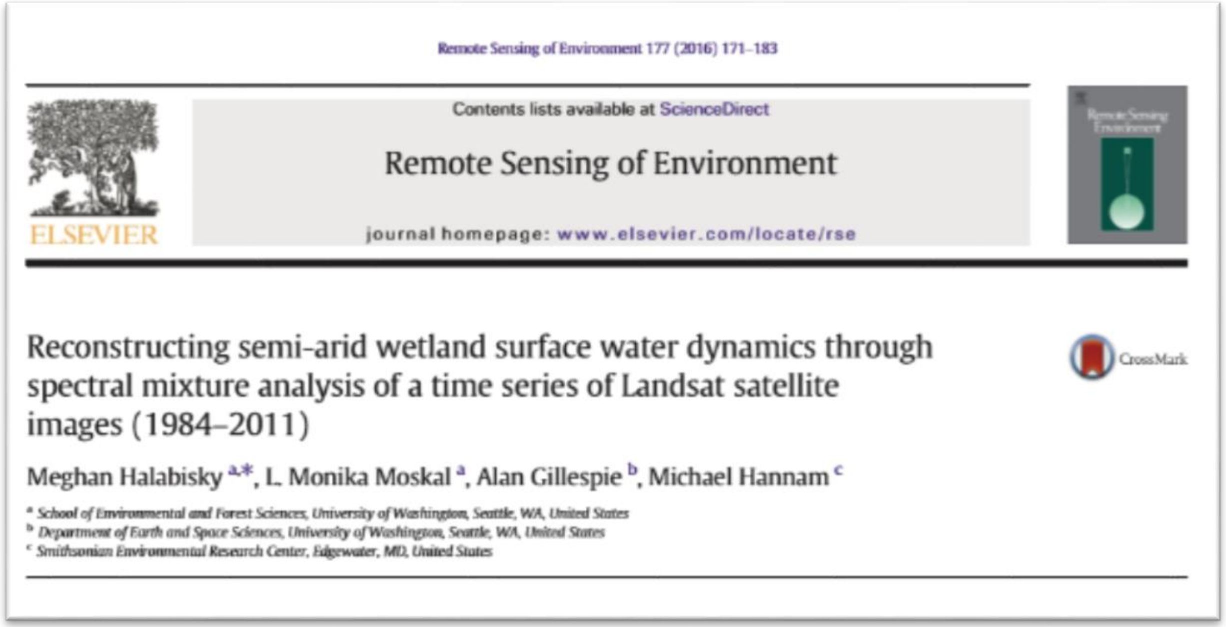
Mapping thirty years of wetland surface water dynamics using Landsat satellite imagery: implications for climate change and species management

Methods



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ELSEVIER

Reconstructing semi-arid wetland surface water dynamics through spectral mixture analysis of a time series of Landsat satellite images (1984–2011)

CrossMark

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[c] Smithsonian Environmental Research Center, Edgewater, MD, United States

Applications

1.) Projecting Climate Change Impacts to wetland dynamics

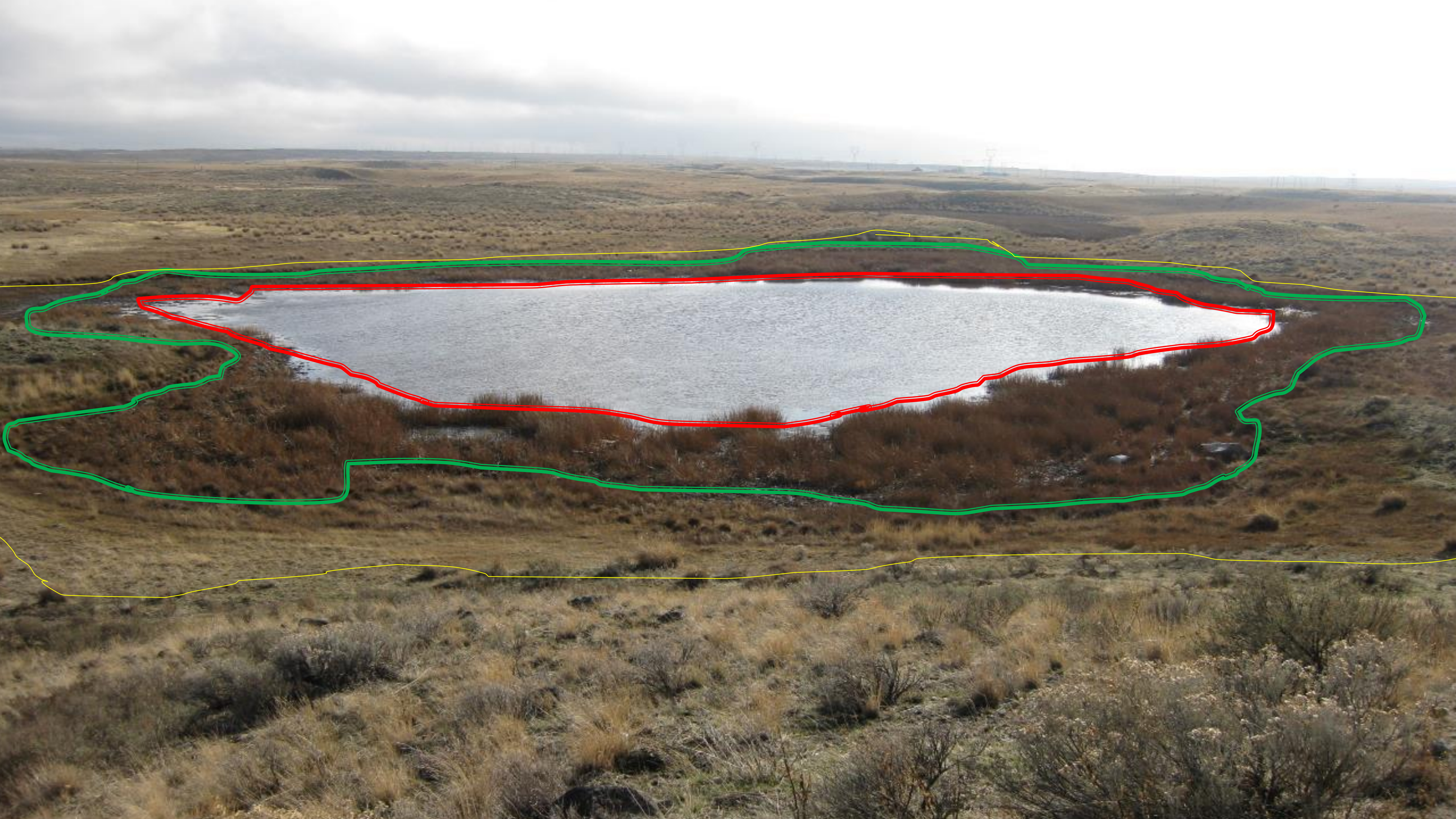
2.) Applications to species management

Reconstructing semi-arid wetland surface water dynamics through spectral mixture analysis of a time series of Landsat satellite images (1984 – 2011)

Meghan Halabisky (UW- RSGAL), **Se-Yeun Lee** (UW- CIG), **Alan Hamlet** (Notre Dame), **Sonia Hall** (SAH Ecologia LLC), **Mike Rule** (USFWS), **Monika Moskal** (UW), **Maureen Ryan** (Conservation Science Partners)

Great Northern LANDSCAPE CONSERVATION COOPERATIVE

NWCSC Northwest Climate Science Center







Challenges of modeling wetland ecosystems

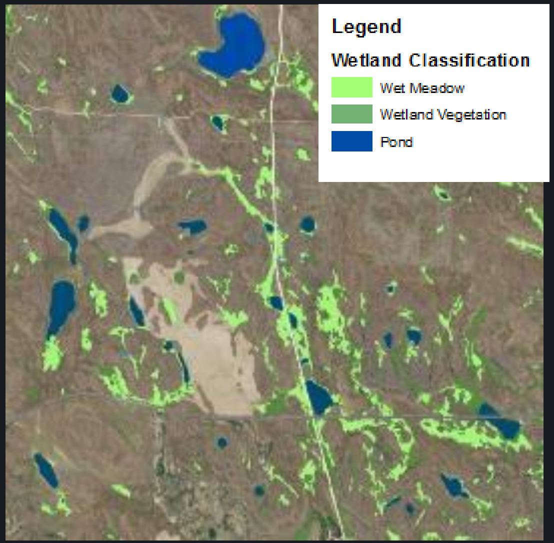
- Wetlands are dynamic.
- Wetlands are diverse.
- Wetlands vary in size.

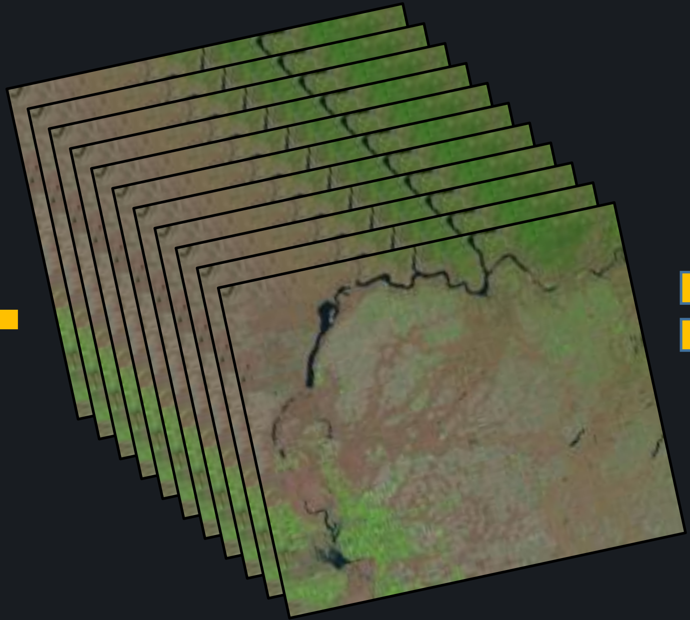
= Lack of adequate baseline data

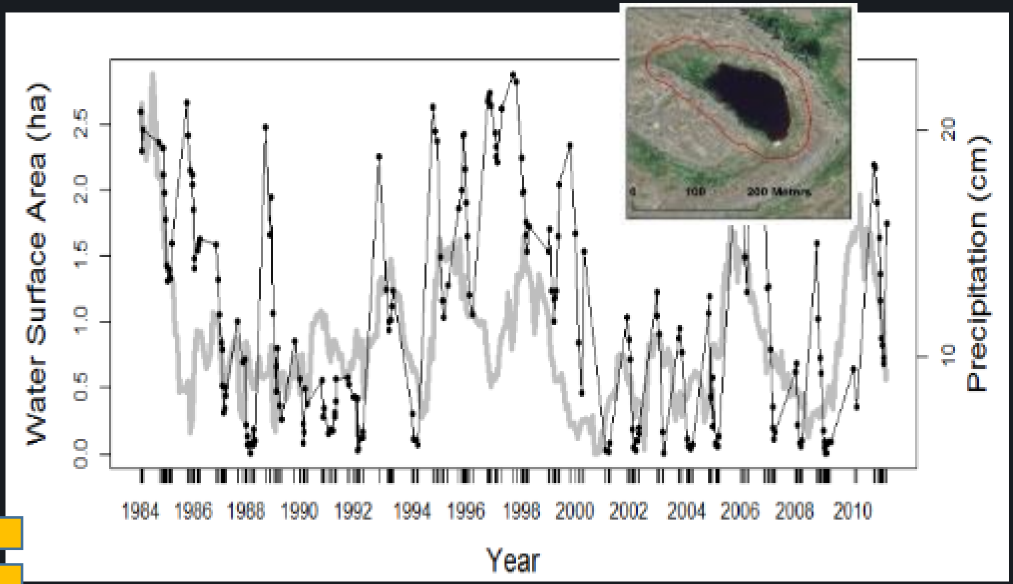
Wetland surface water dynamics

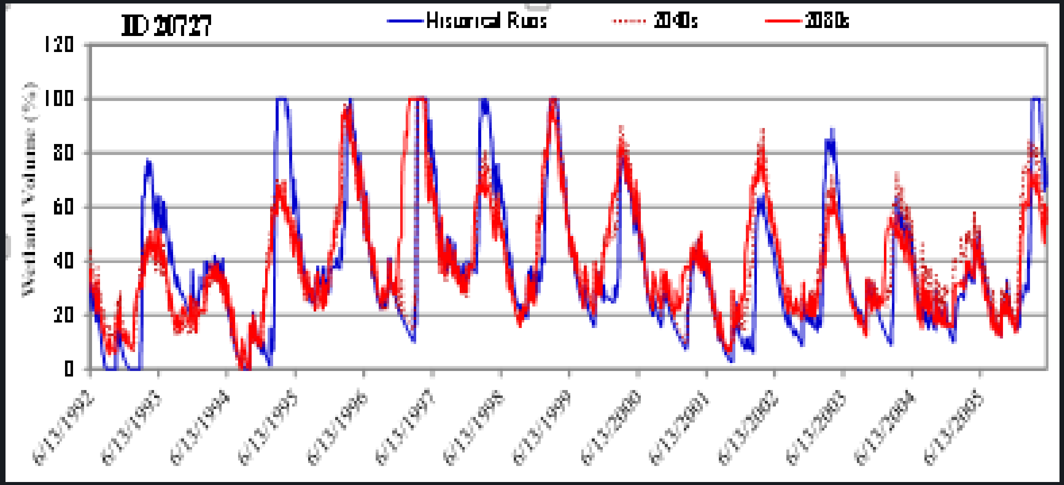
- Quantity
- Timing
- Duration of inundation

Wetlands and Climate Change


Legend
Wetland Classification
Wet Meadow
Wetland Vegetation
Pond

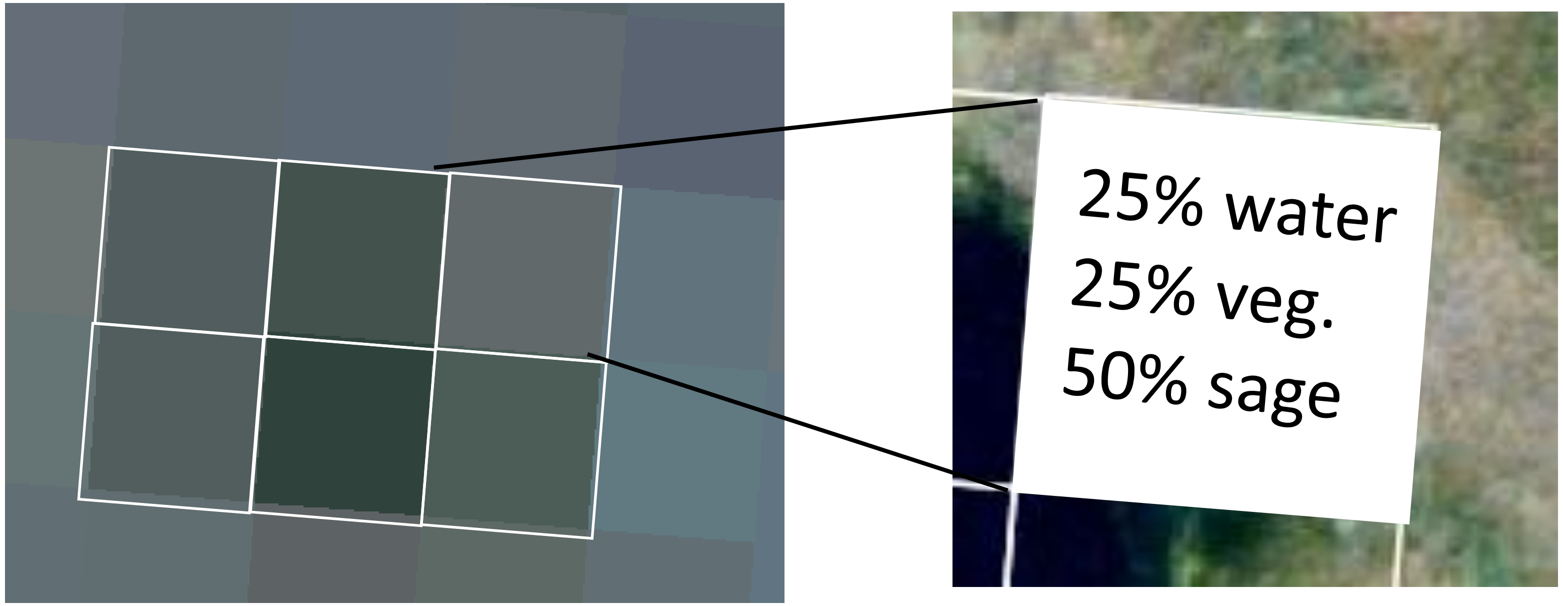



Water Surface Area (ha)
0.0
0.5
1.0
1.5
2.0
2.5
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
Year
Precipitation (cm)
10
20

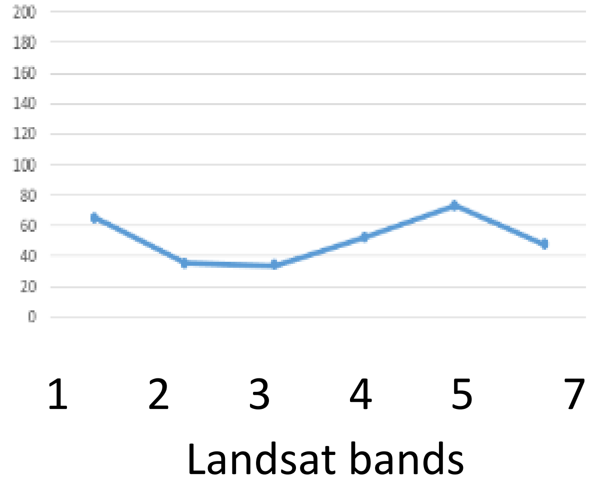

Historical Runs
2040s
2080s
0
20
40
60
80
100
120

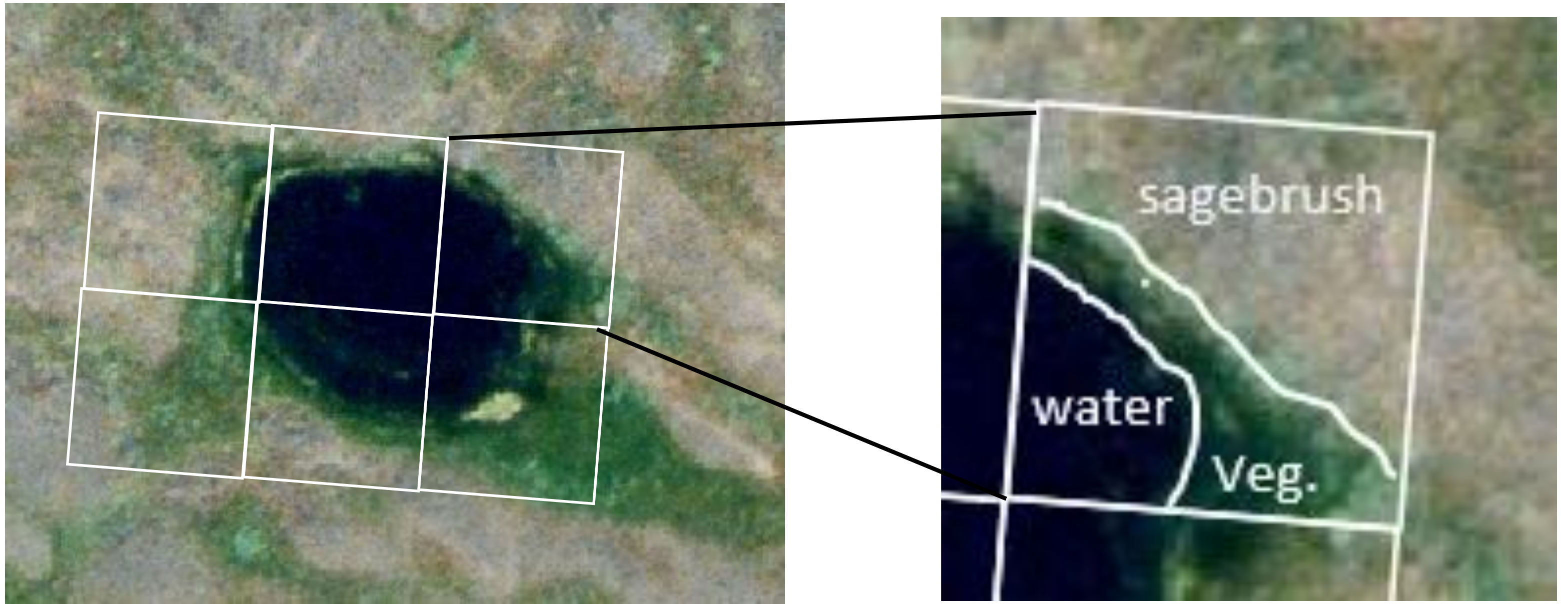
Methods – Reconstructing 30 years of wetland dynamics

Spectral Mixture Analysis

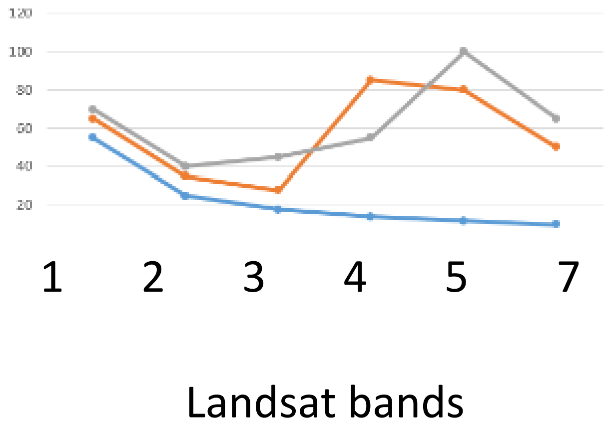


Spectral signature for 1 pixel

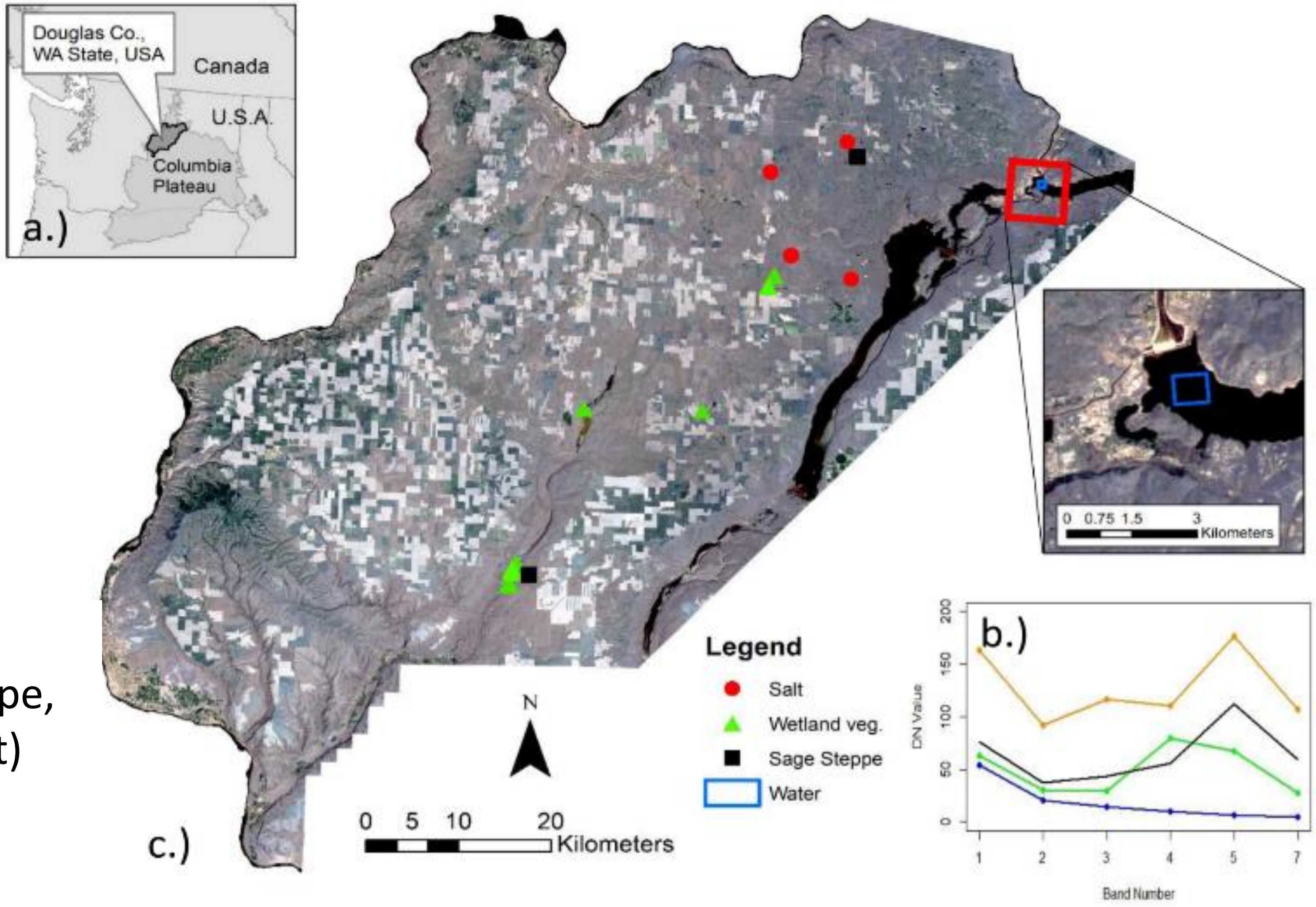




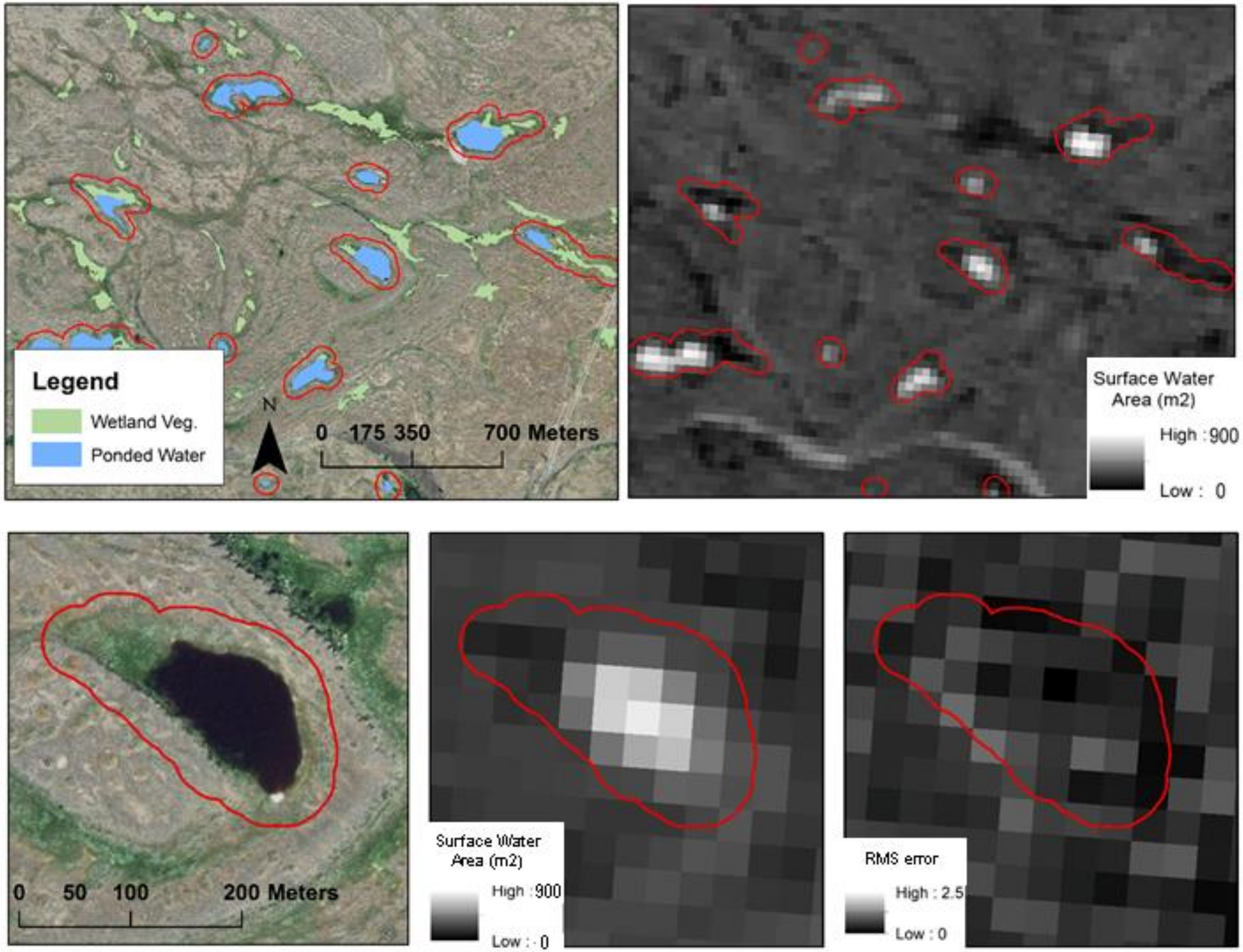
Spectral signature for 3 features (water, sage, veg.)



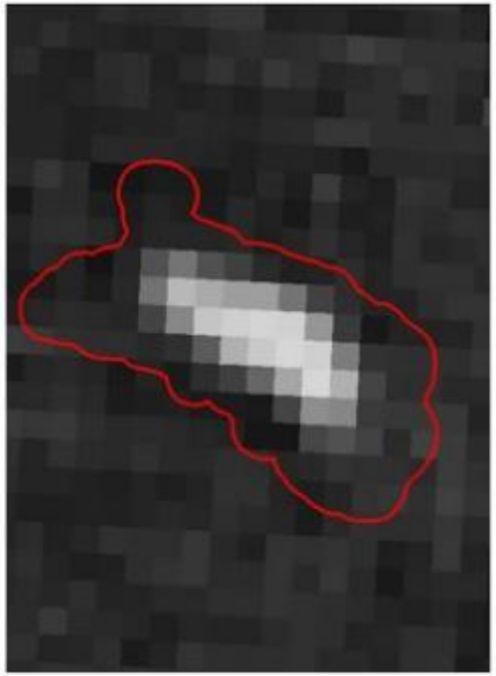
Spectral Mixture Analysis



4 endmembers:
(water, sage steppe, wetland veg., salt)
Target = “Water” from Banks Lake


Legend
Wetland Veg.
Ponded Water
N
0 175 350 700 Meters
Surface Water Area (m2)
High : 900
Low : 0
0 50 100 200 Meters
Surface Water Area (m2)
High : 900
Low : 0
RMS error
High : 2.5
Low : 0

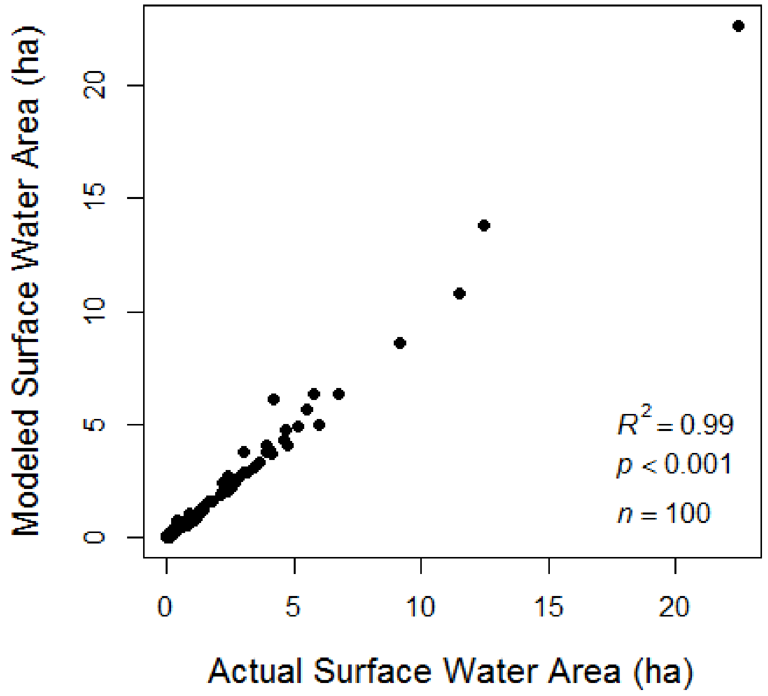
Validation – Surface Water

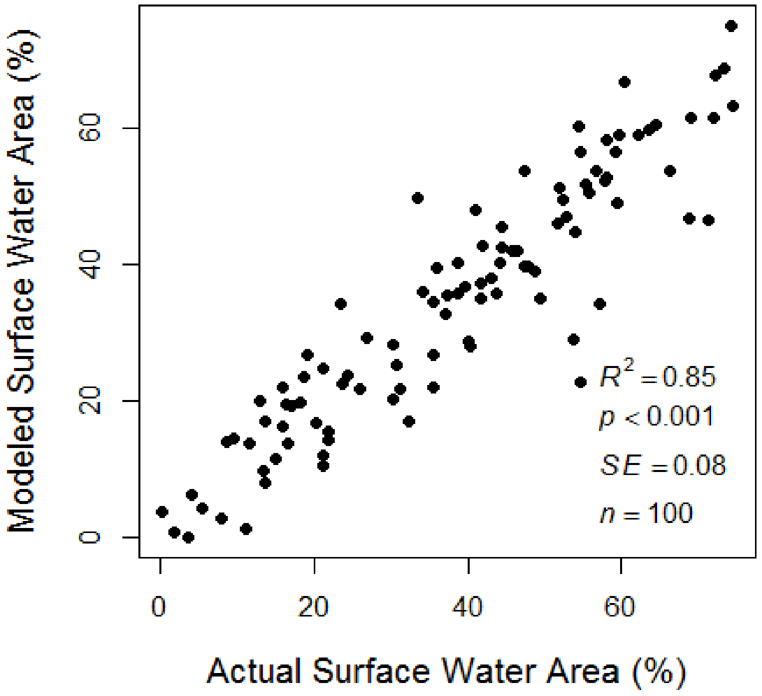


SMA = 1.457 hectares

Delineated = 1.295 hectares

Comparison of SMA to validation data

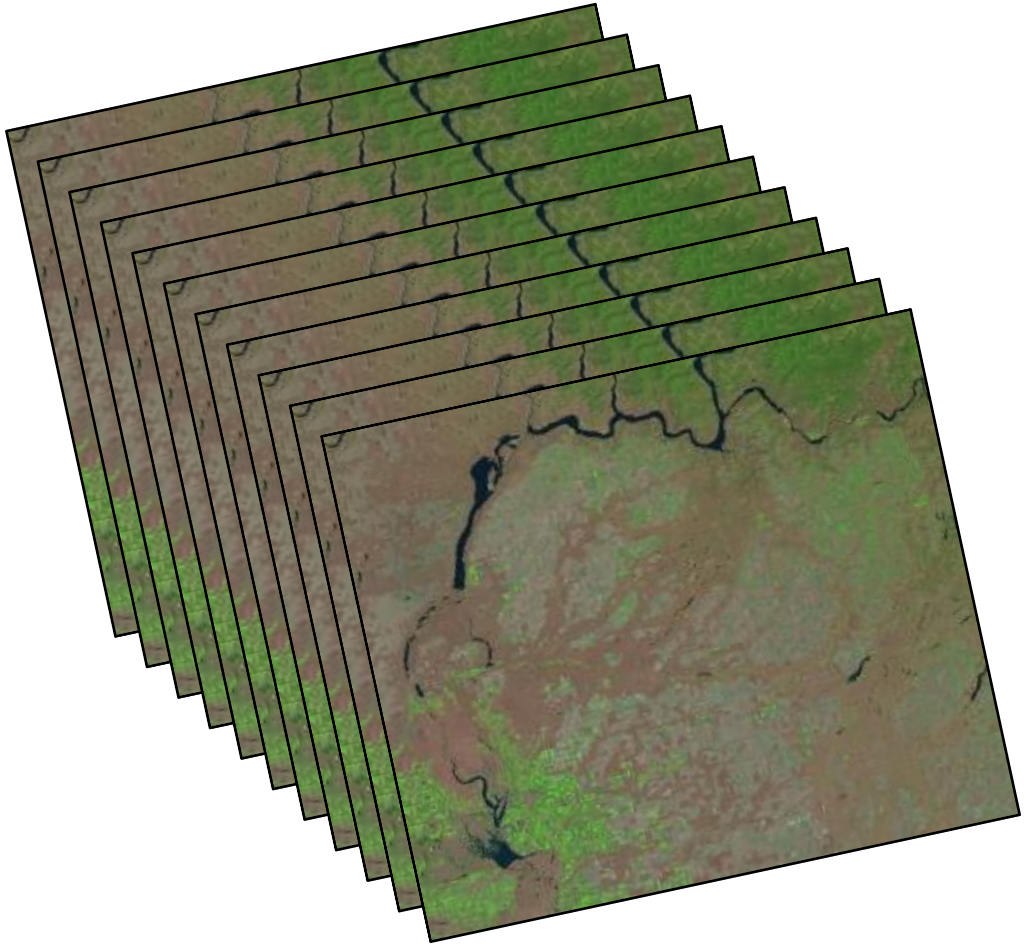




Reconstructing a wetland timeseries

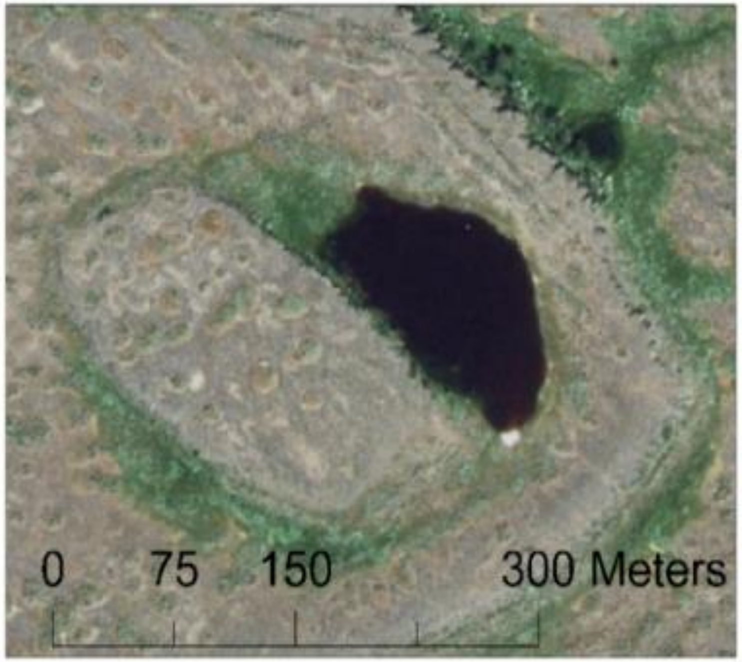
Object Based Image Analysis (OBIA)

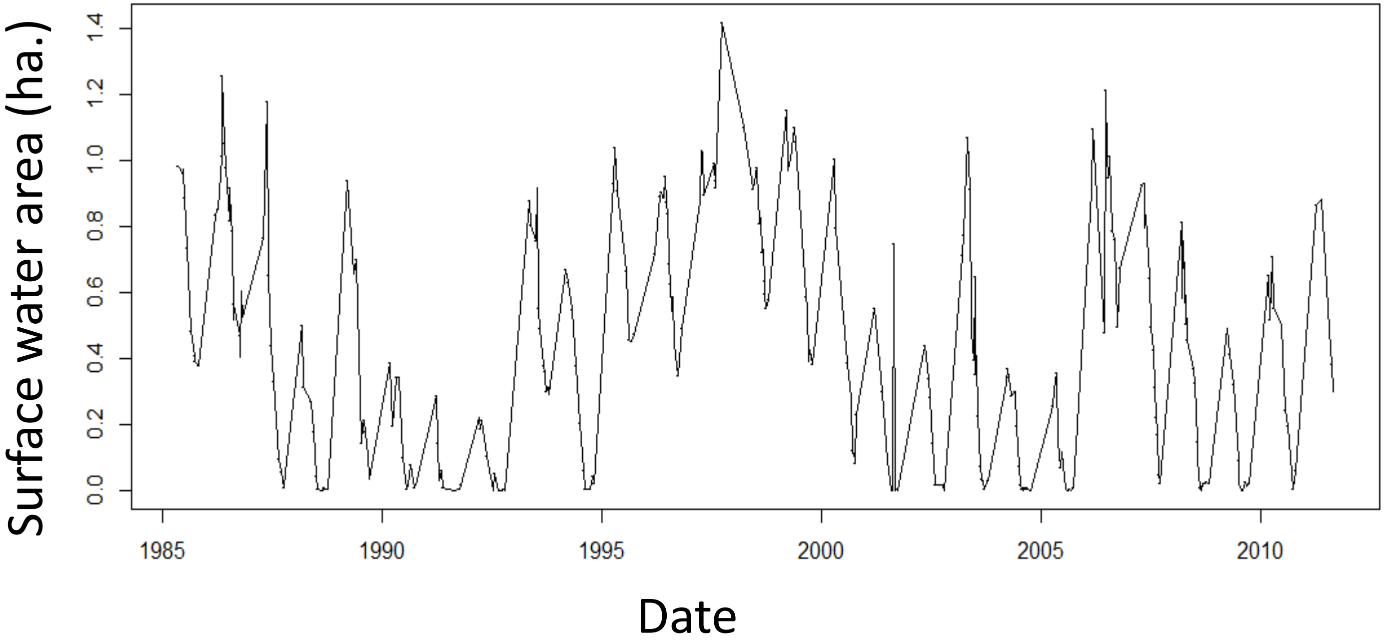
+

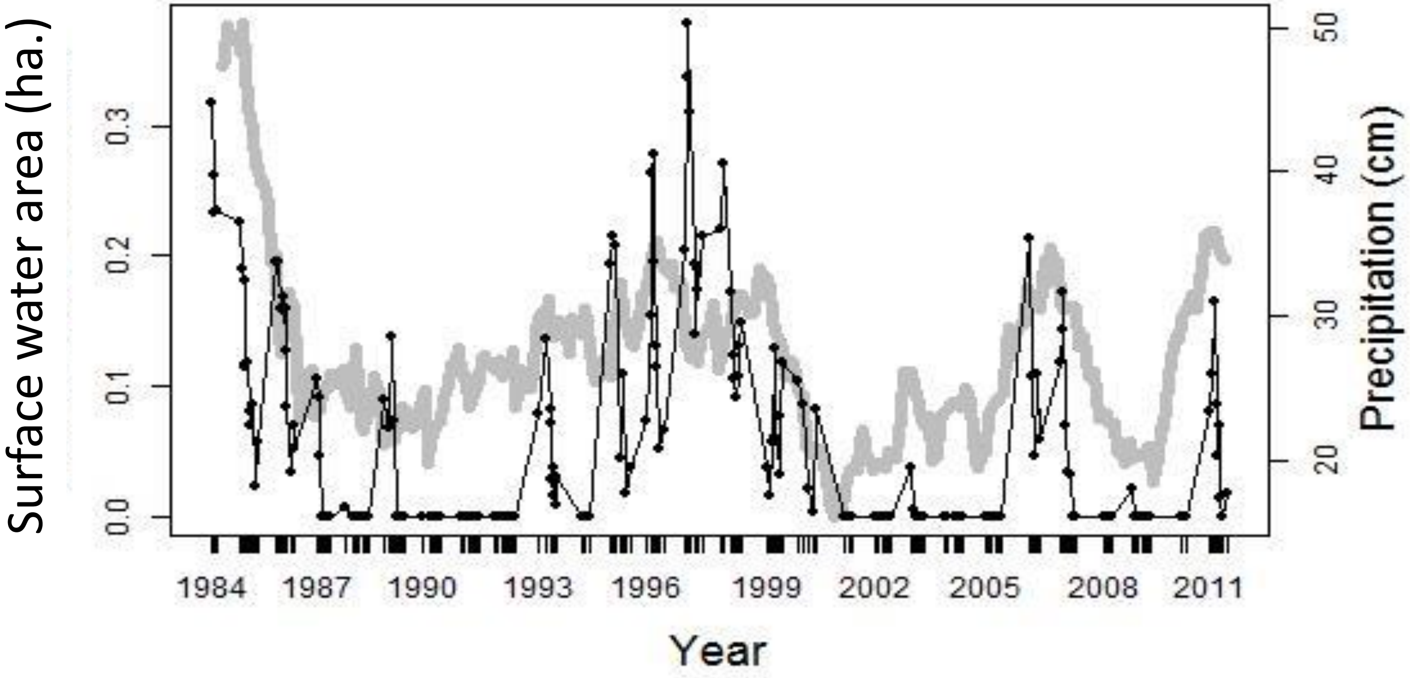


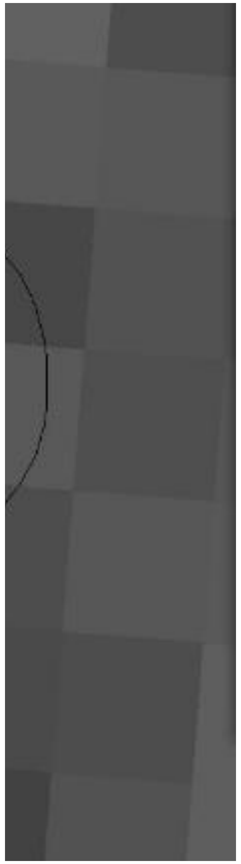
Landsat satellite archive (1984 – 2011) to measure changes in surface water for each wetland.

Example surface water area hydrograph of a wetland

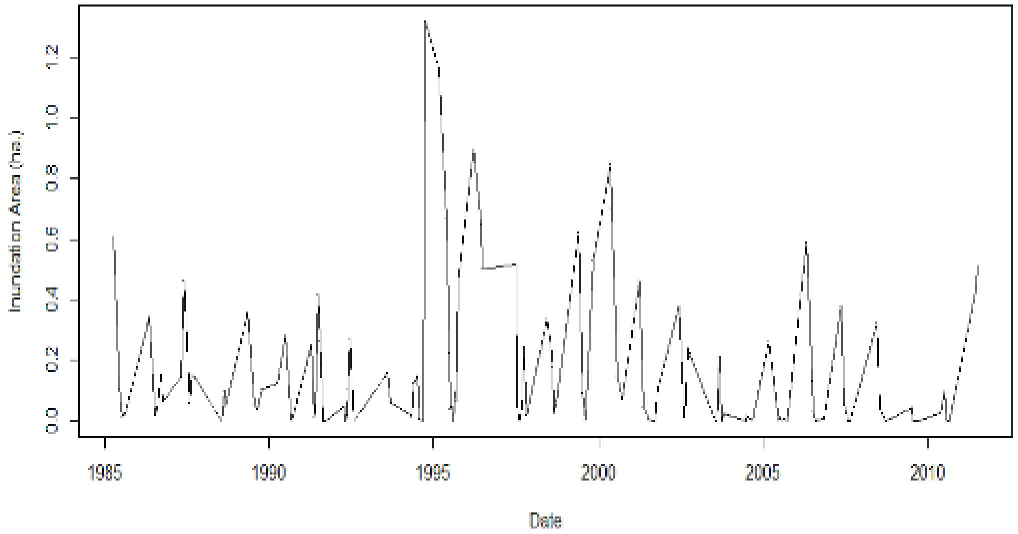


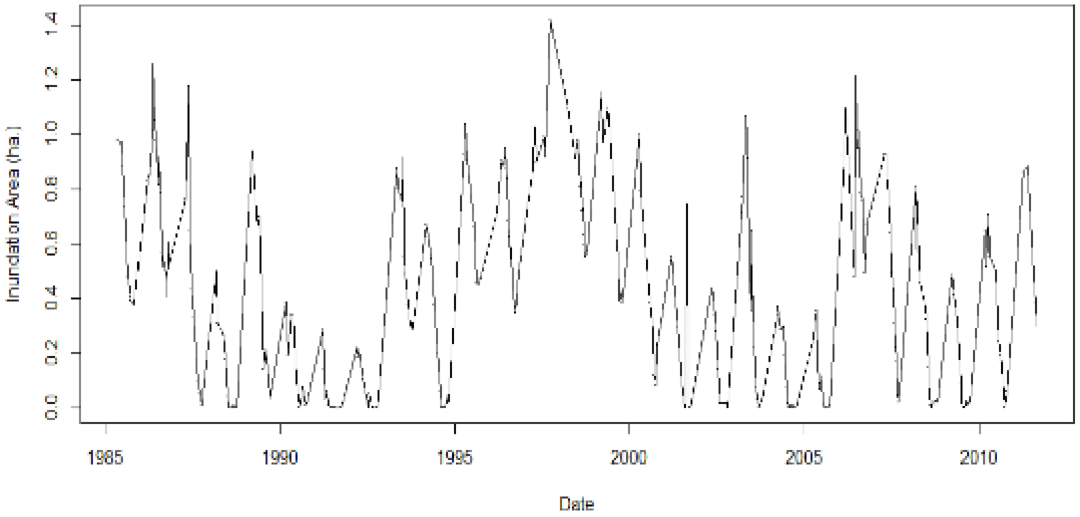


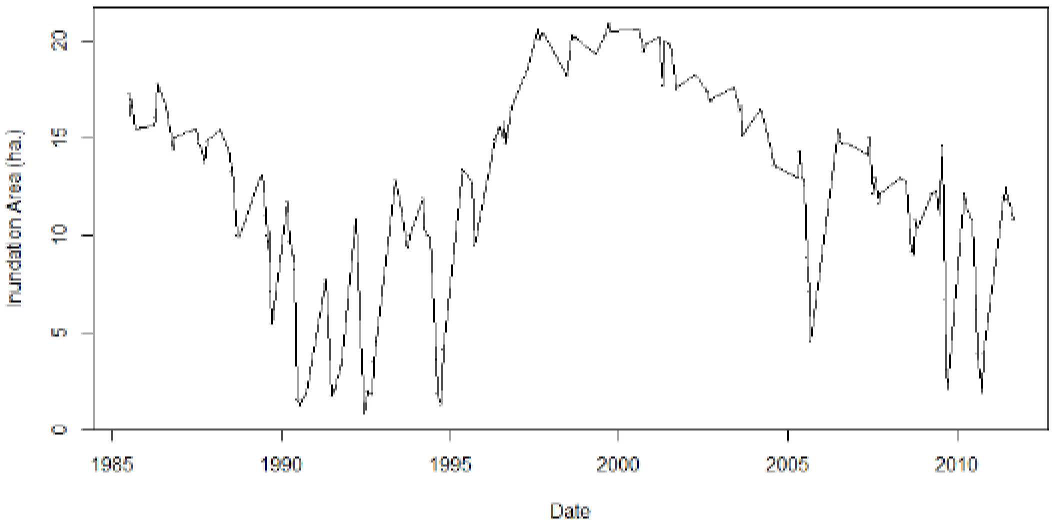

Surface water area (ha.)
0.0
0.1
0.2
0.3
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
Year
20
30
40
50
Precipitation (cm)

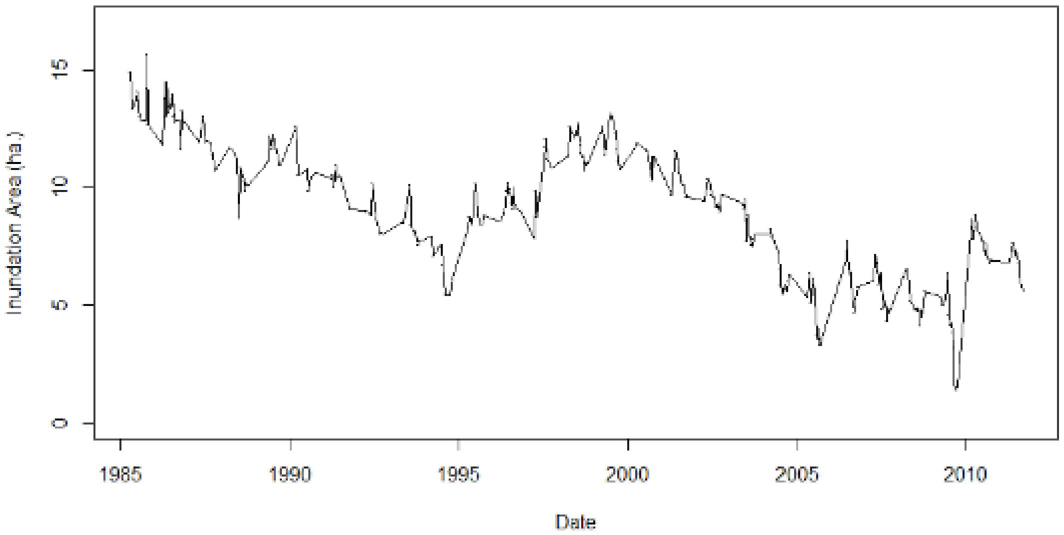


Variability of Wetland Hydrographs



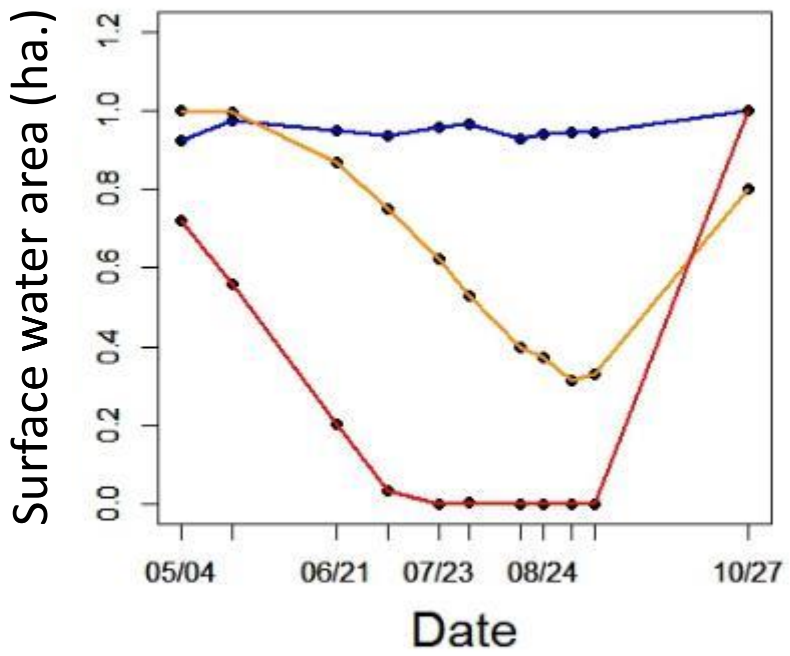




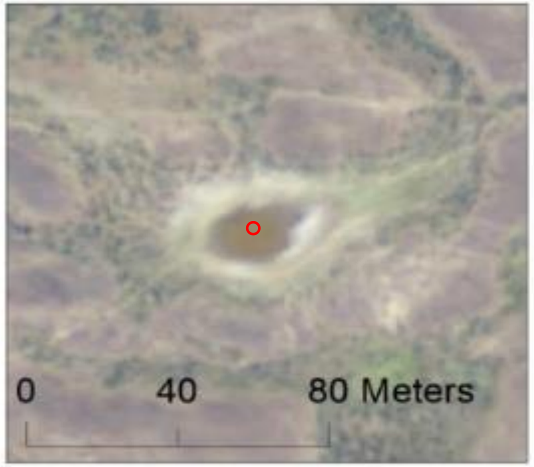


Seasonal Change

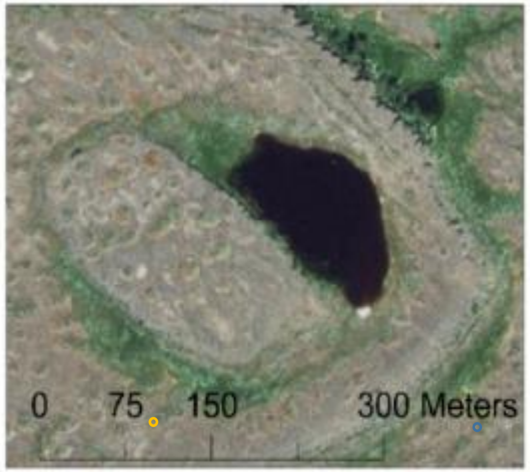
An example of drying rate for one year - 2011



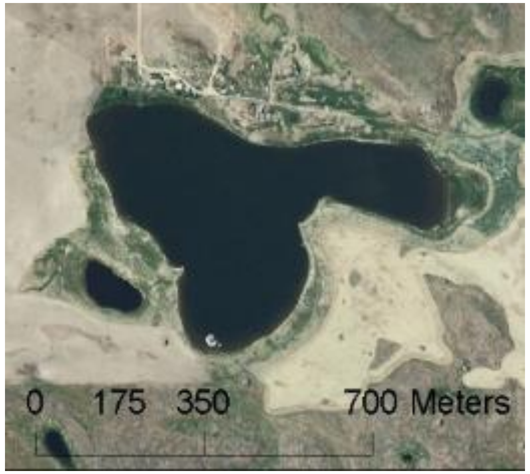
Seasonal



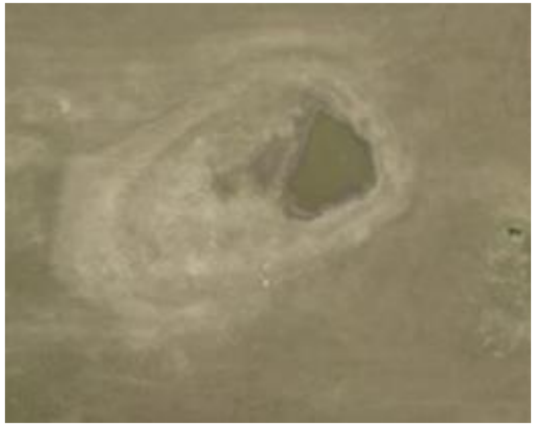
Semi-permanent

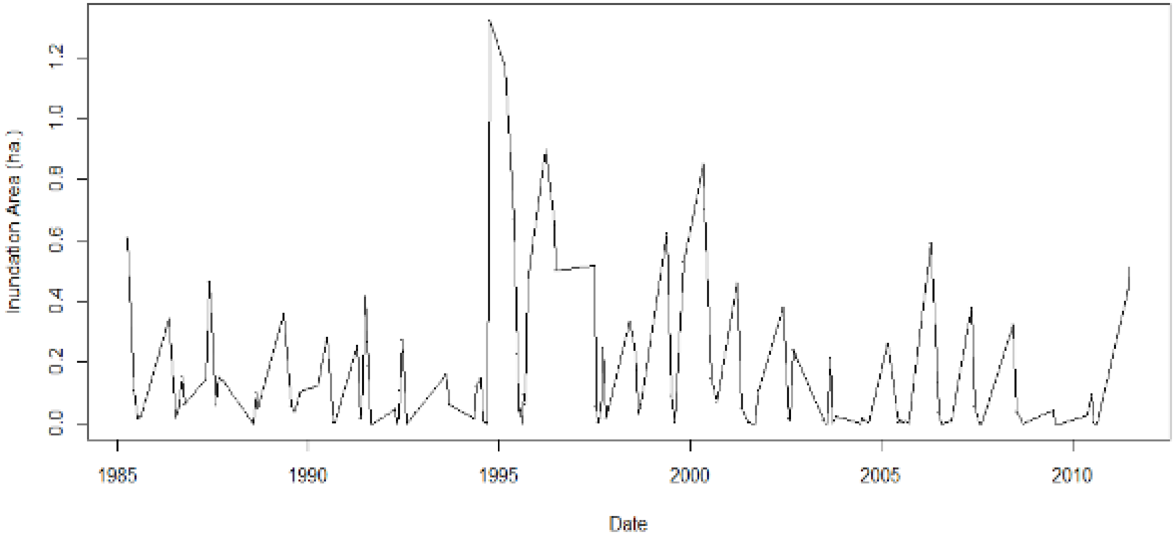


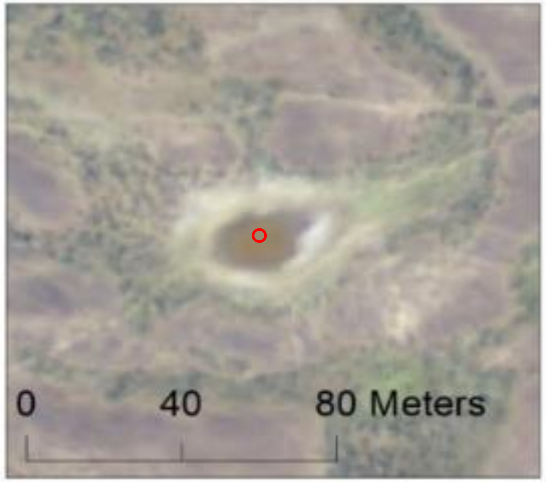
Permanent

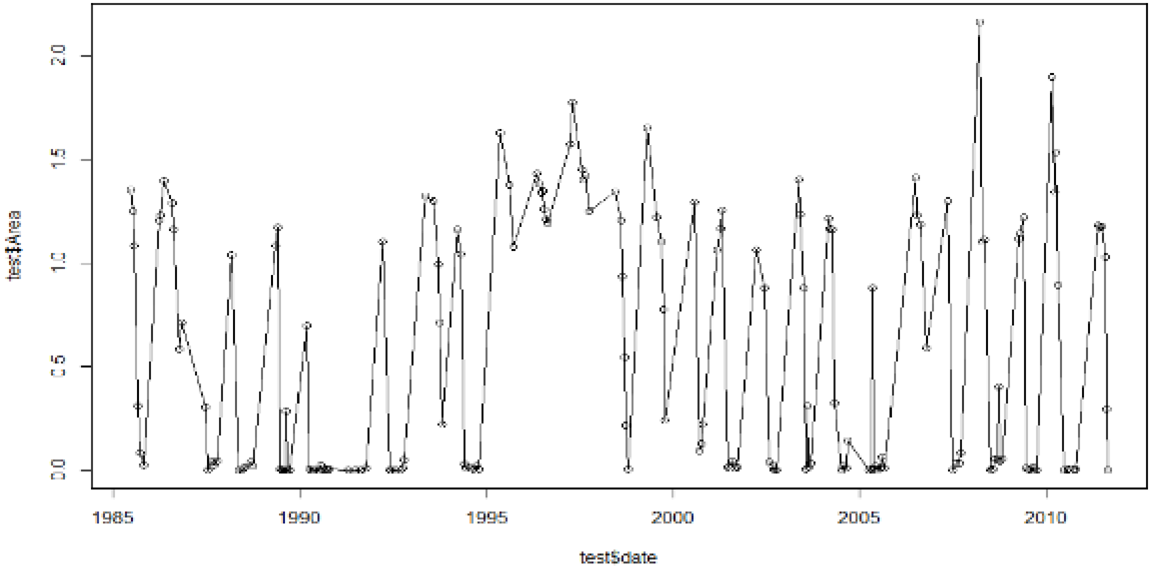


Seasonal Wetland

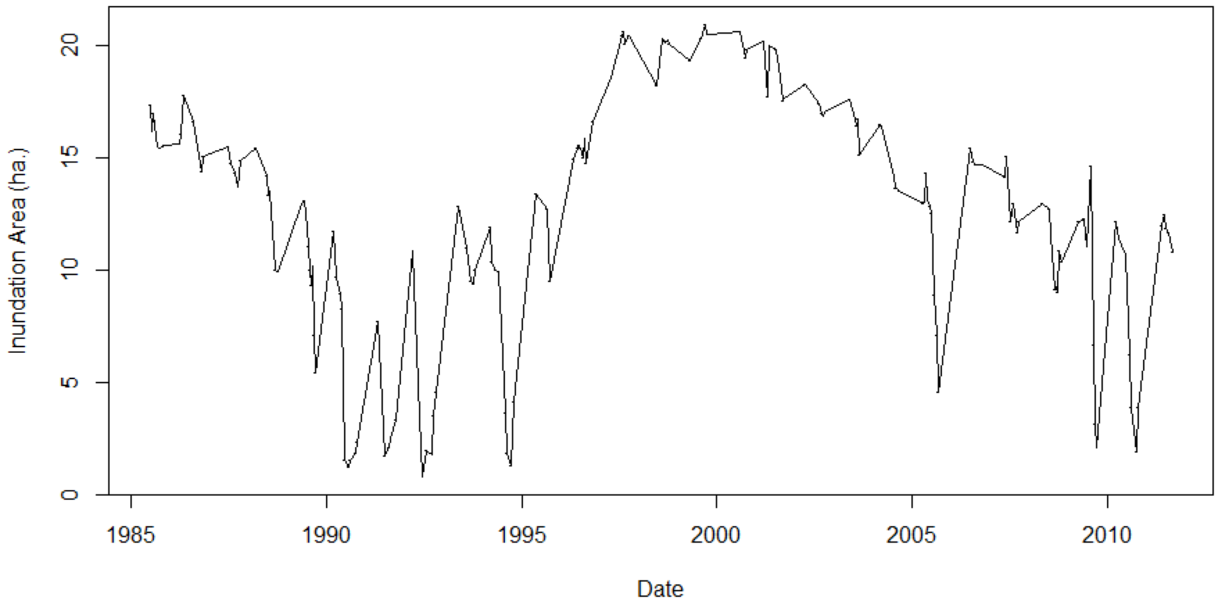


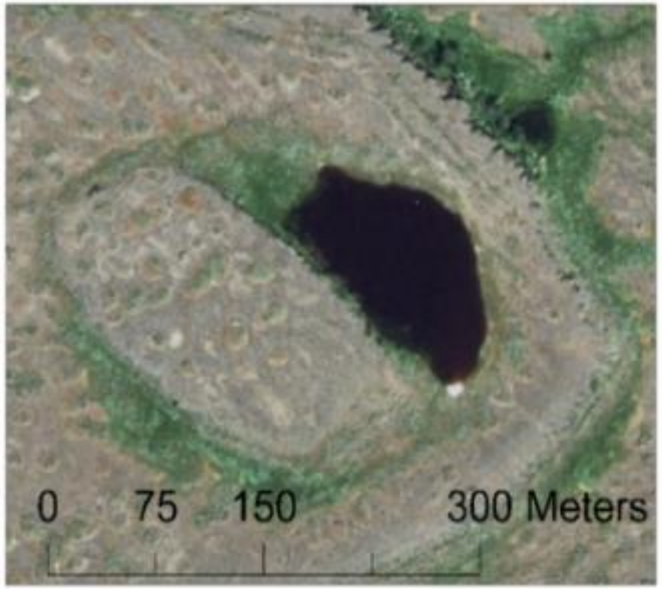


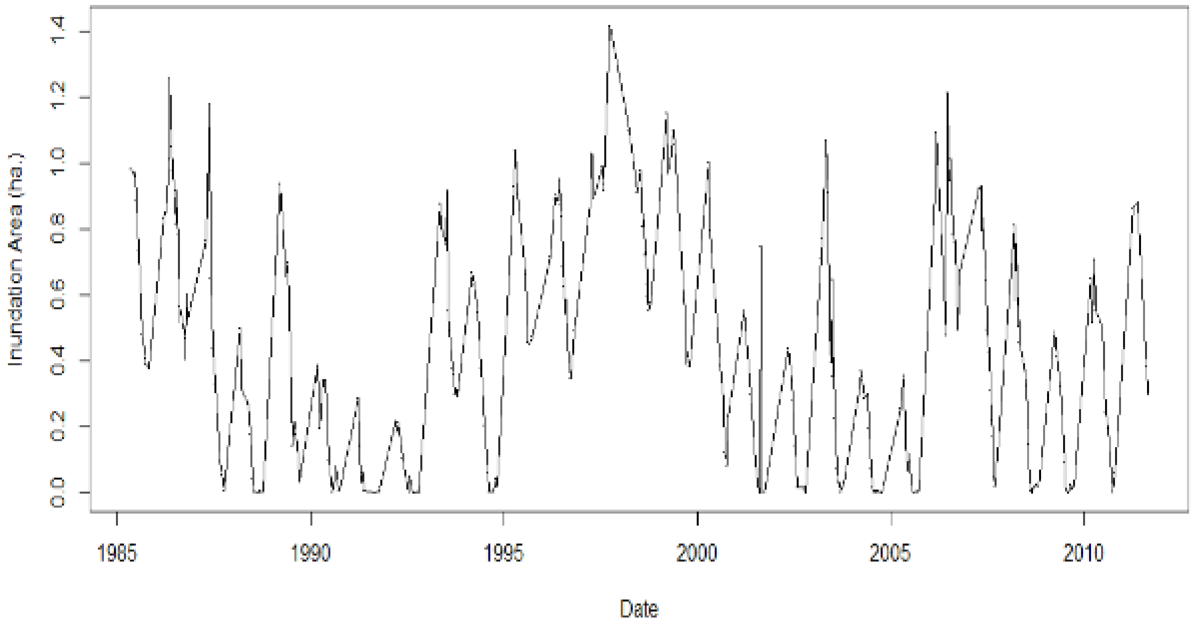




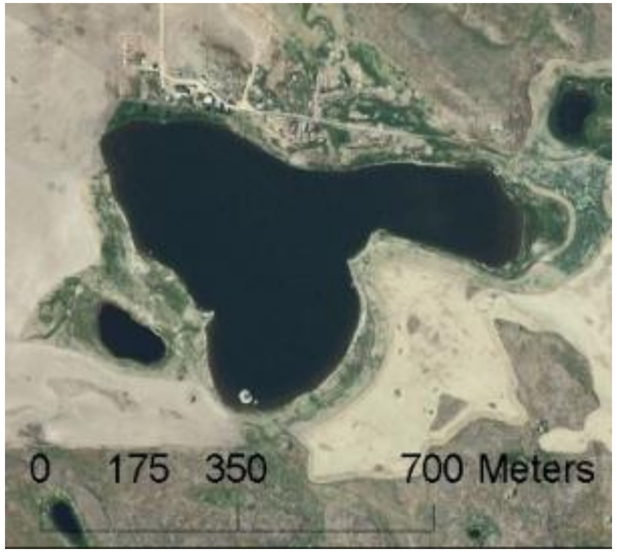
Semi-permanent Wetland

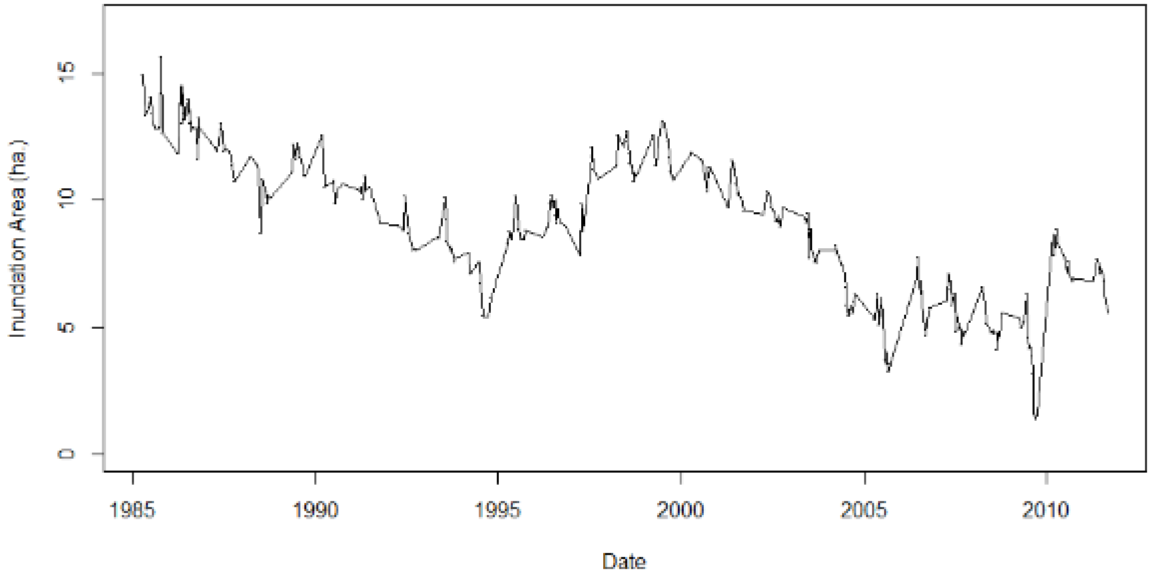


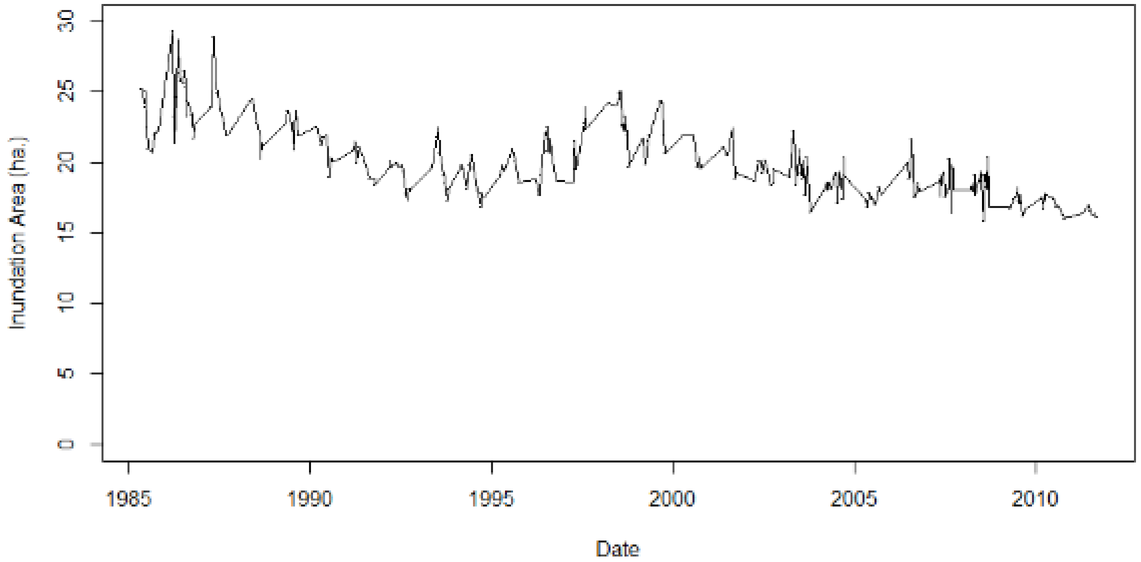




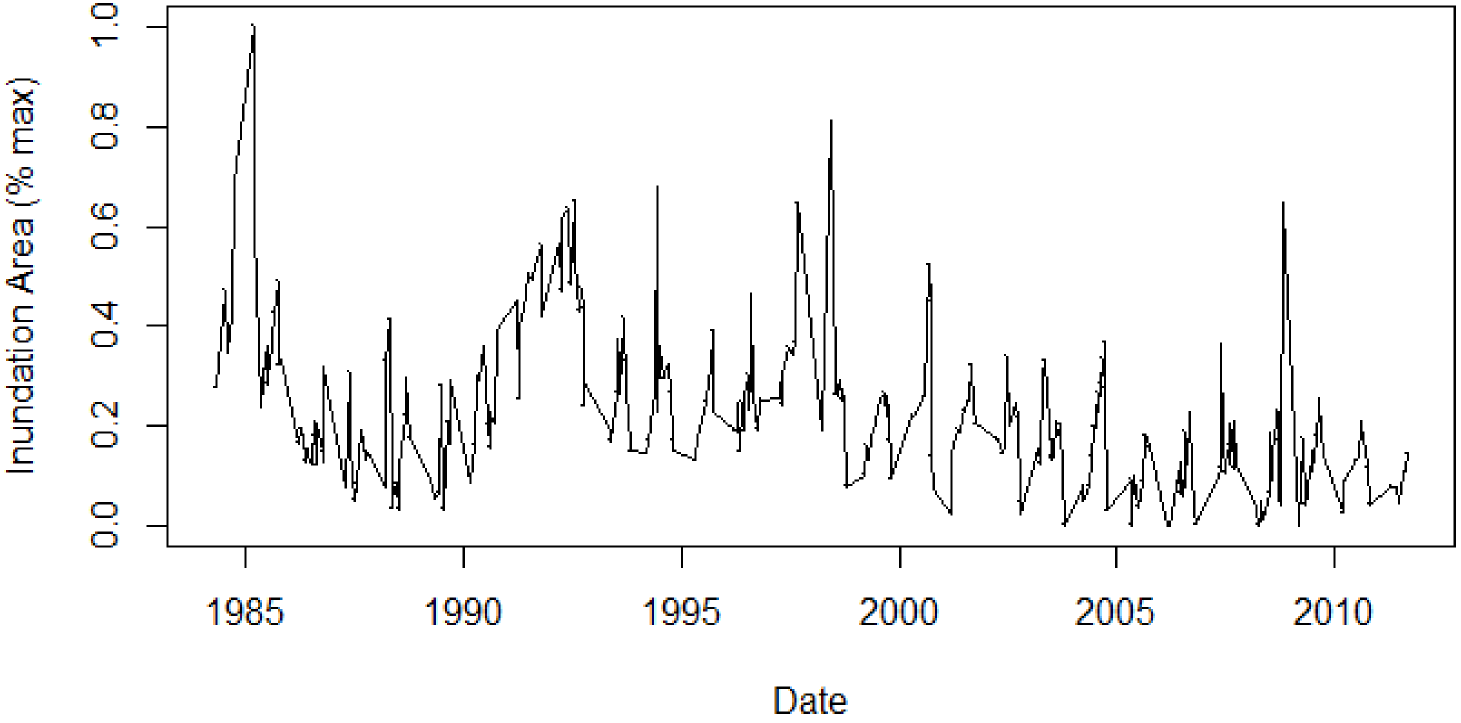
Permanent Wetland







Human Impacts



Strengths of remote sensing approach

- Can be used to reconstruct the past using archived Landsat data.
- Provides a tangible measurement of wetland dynamics (surface water area v. an index (eg. NDVI)
- Measure change at fine resolutions, sub-pixel (e.g. <30m for Landsat).
- Can be merged easily with other sensors without need for calibration (e.g. Landsat 4,5,7,8 etc..)
- Treats wetlands as objects not pixels.

Limitations of remote sensing approach

- Measures an approximation of surface water area.
- Cannot detect water under canopy.
- Impacted by snow, clouds, shadows.
- Need endmembers – pure pixels or a spectral library

Projecting Climate Change Impacts to wetland dynamics

How will wetland hydrology change in the future?

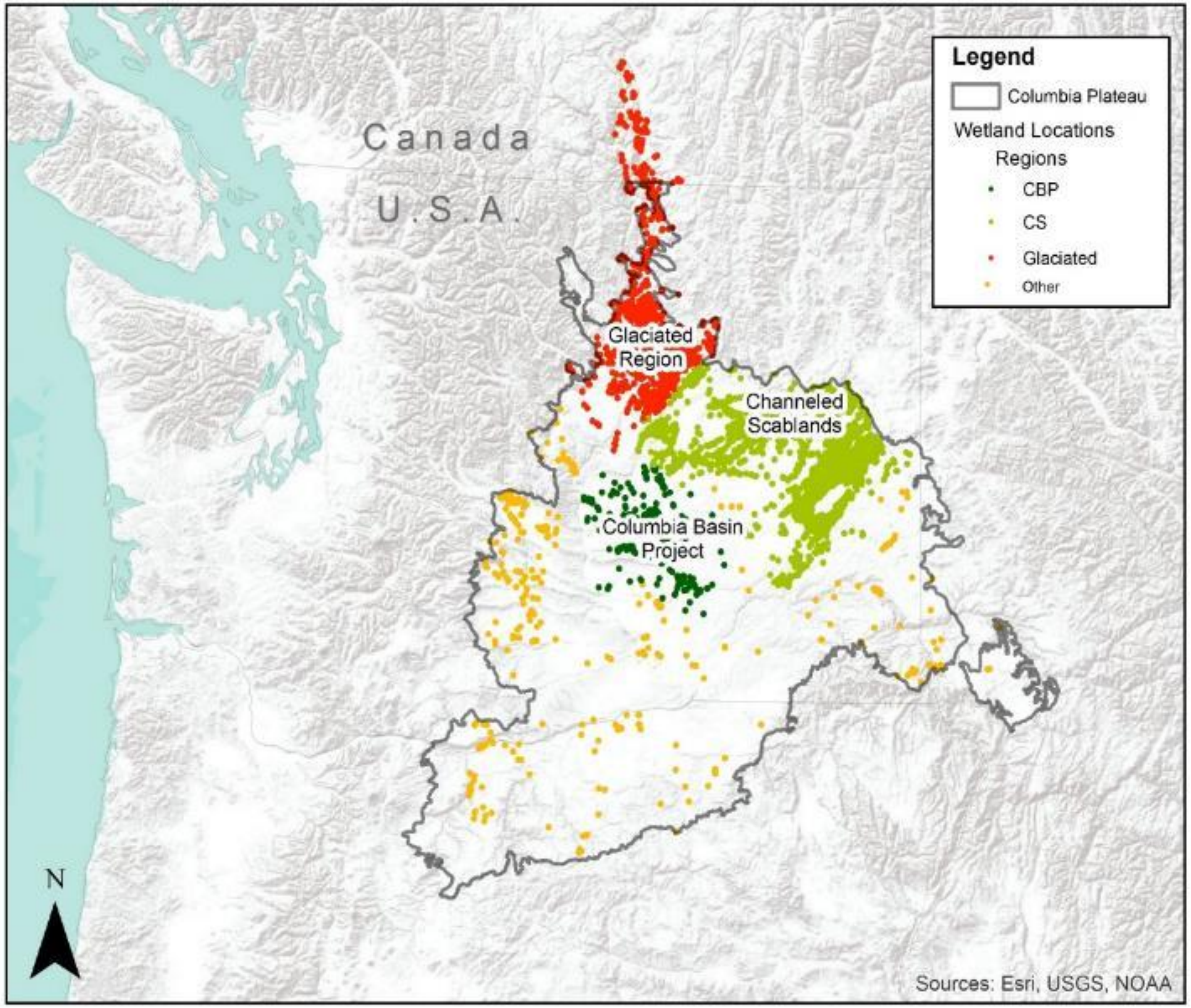
1.) Combine remote sensing tools to map and reconstruct the flooding and drying patterns for individual wetlands.

2.) Relate this dataset to historical climate and make future climate change projections.

3.) Co-develop data products with stakeholders to ensure data is useful and will get used.

Study Area: Columbia Plateau

- Depressional wetlands
- Mostly ephemeral
- Not forested
- 3 areas: Glaciated Region, Channeled Scablands, & Columbia Basin Irrigation Project



How will wetlands change in the future?

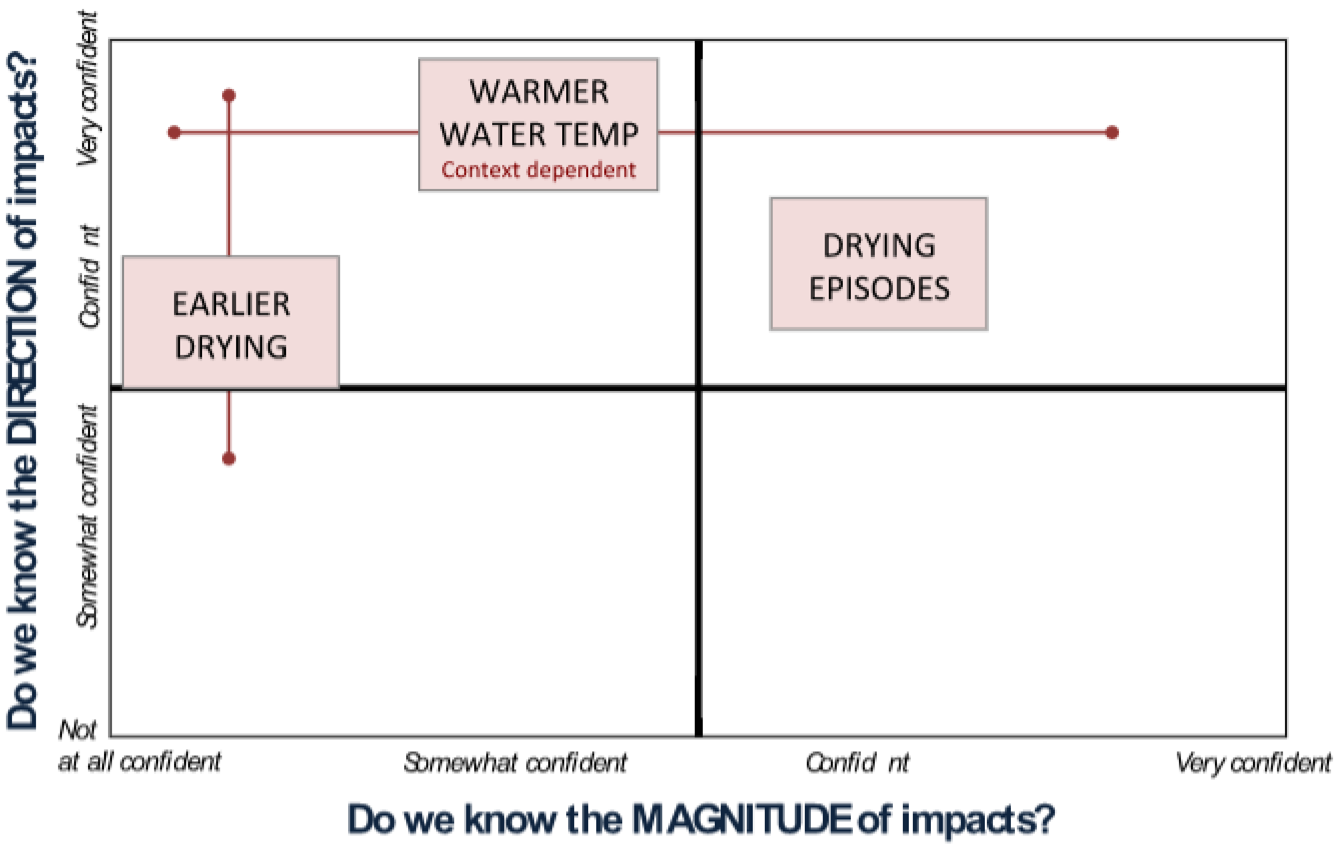
- Change in how frequently a wetland dries.

- Change in average max/min water levels.

- Change in when a wetland dries (drying date).

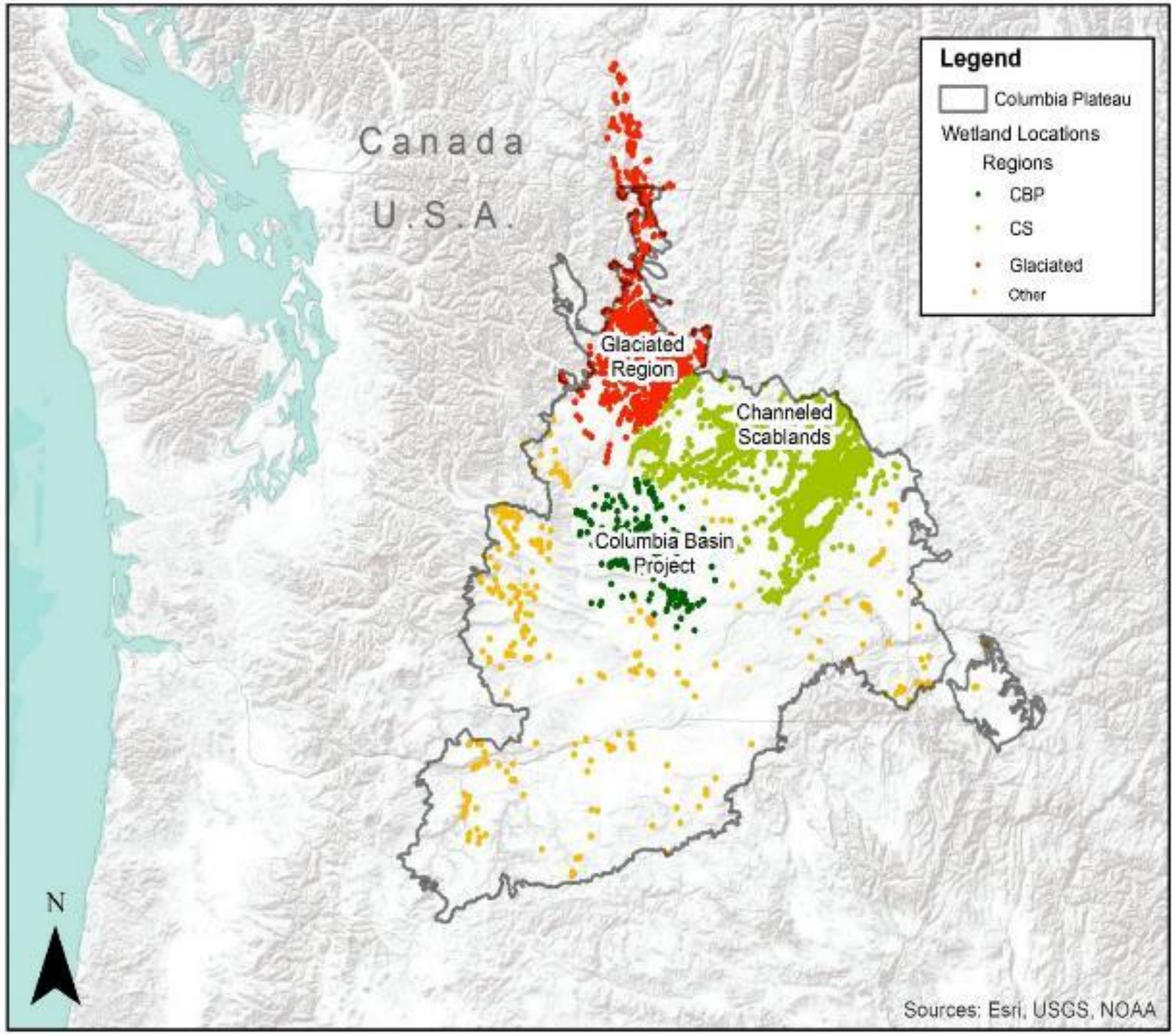
- Change in distribution of wetland types

Workshop to Identify Project Products

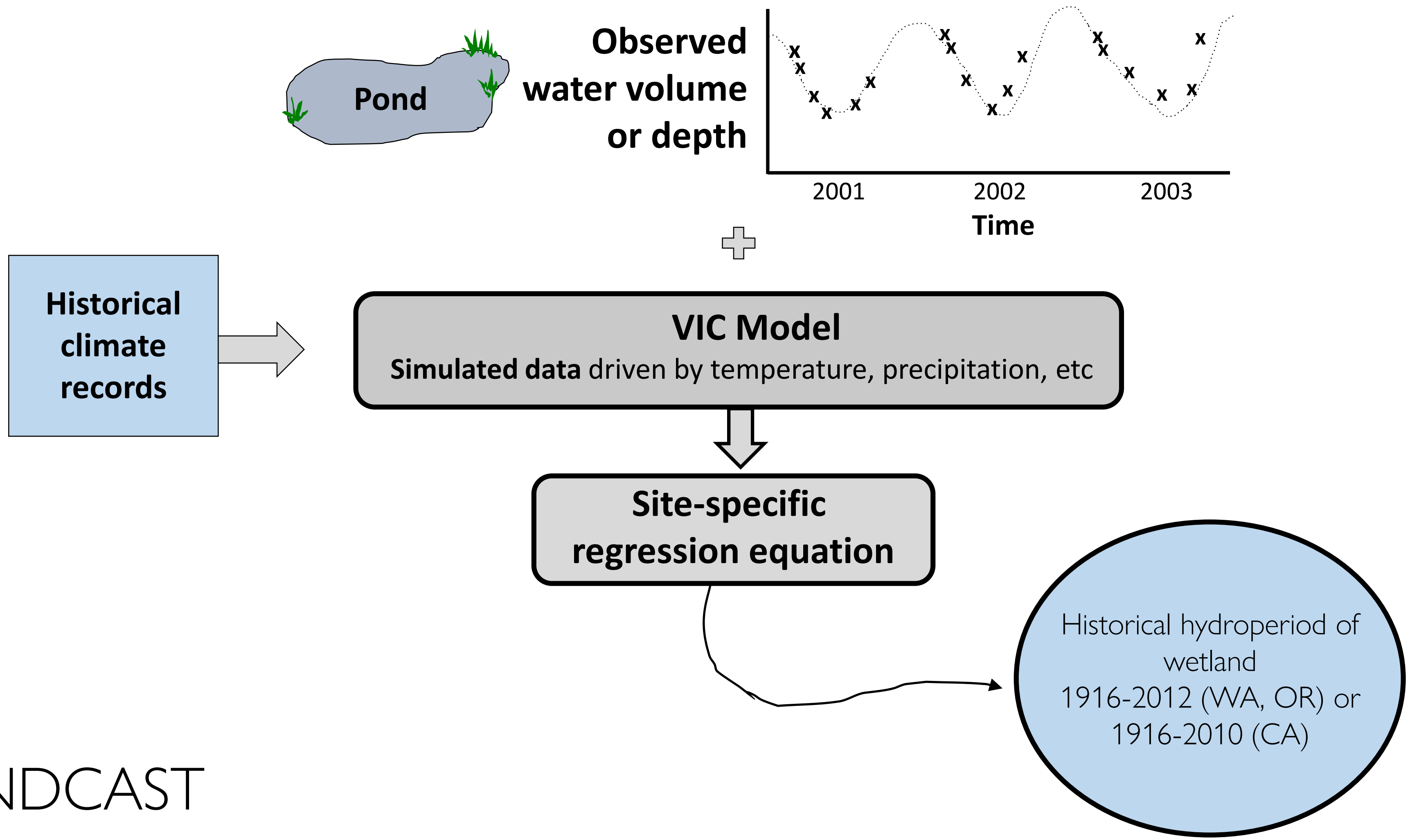


Wetland dataset

- sample size (> 5,000)
- temporal extent (27 years)
- frequency (~ 16 days)
- spatial scale (<30m)

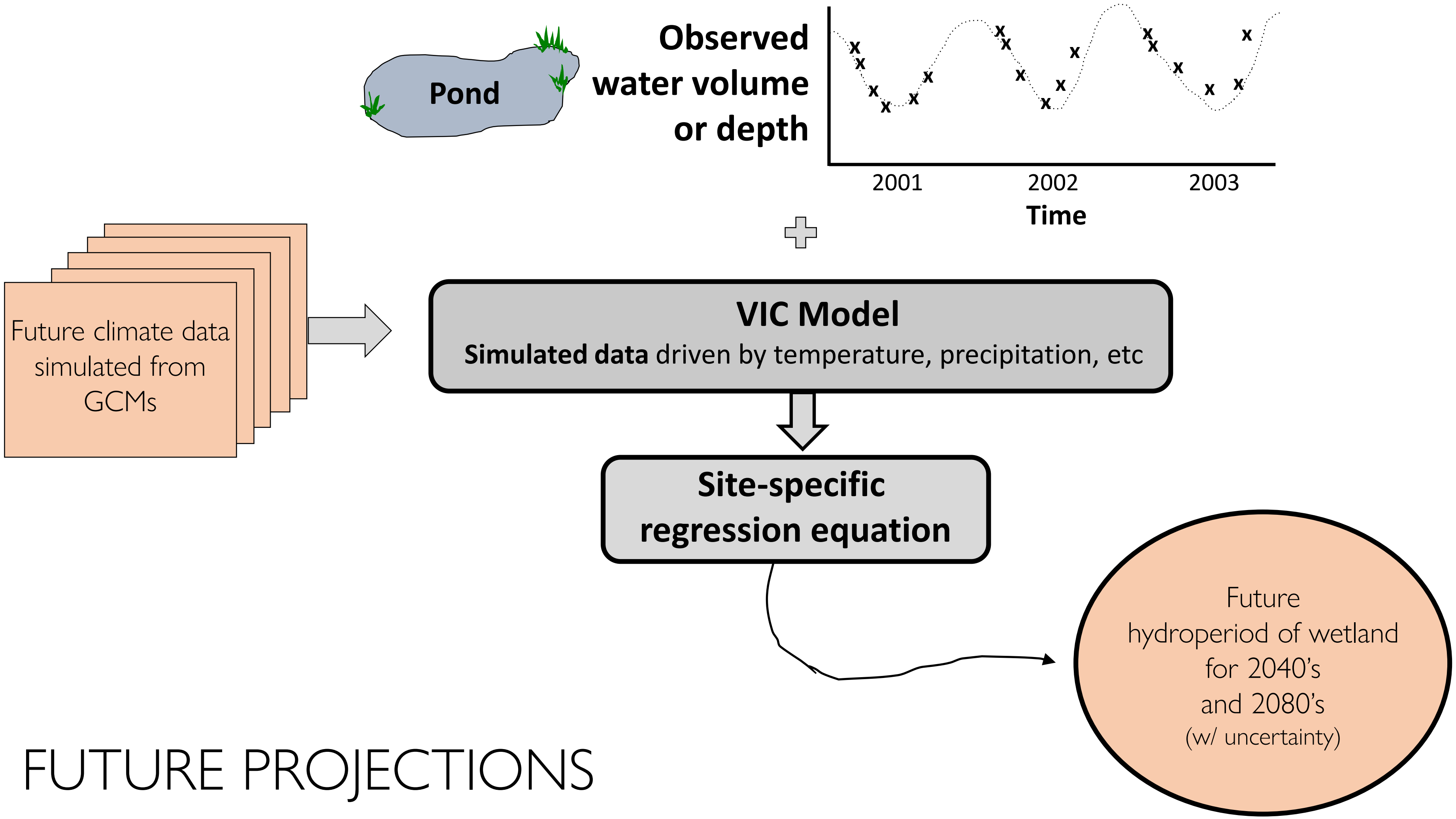


Regression-based wetlands models

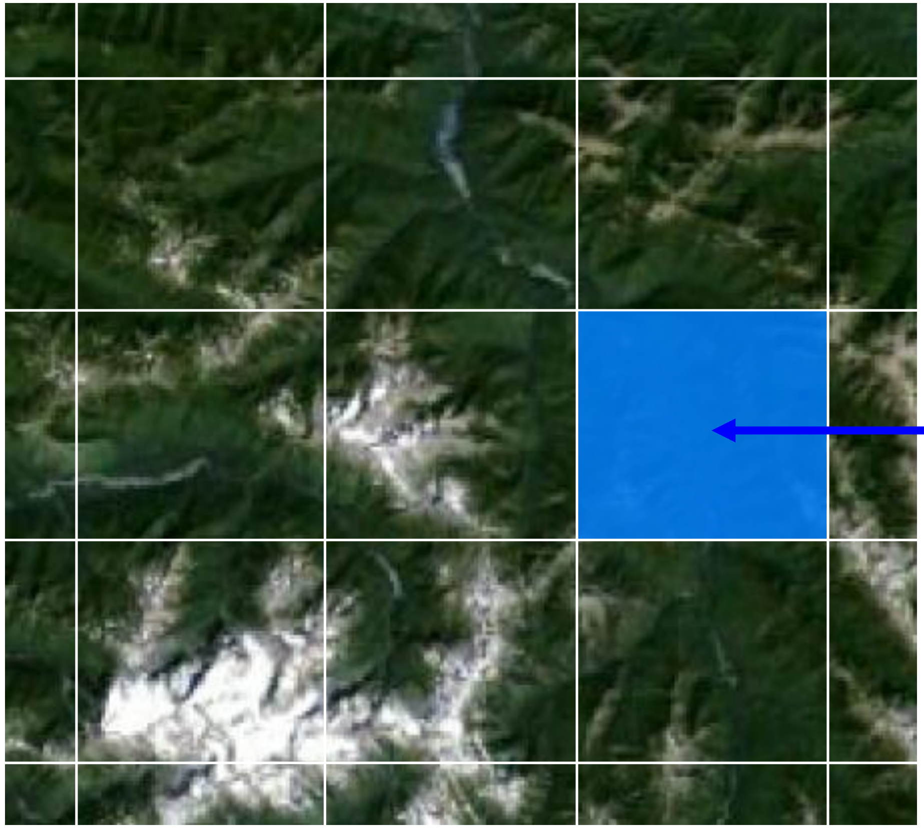


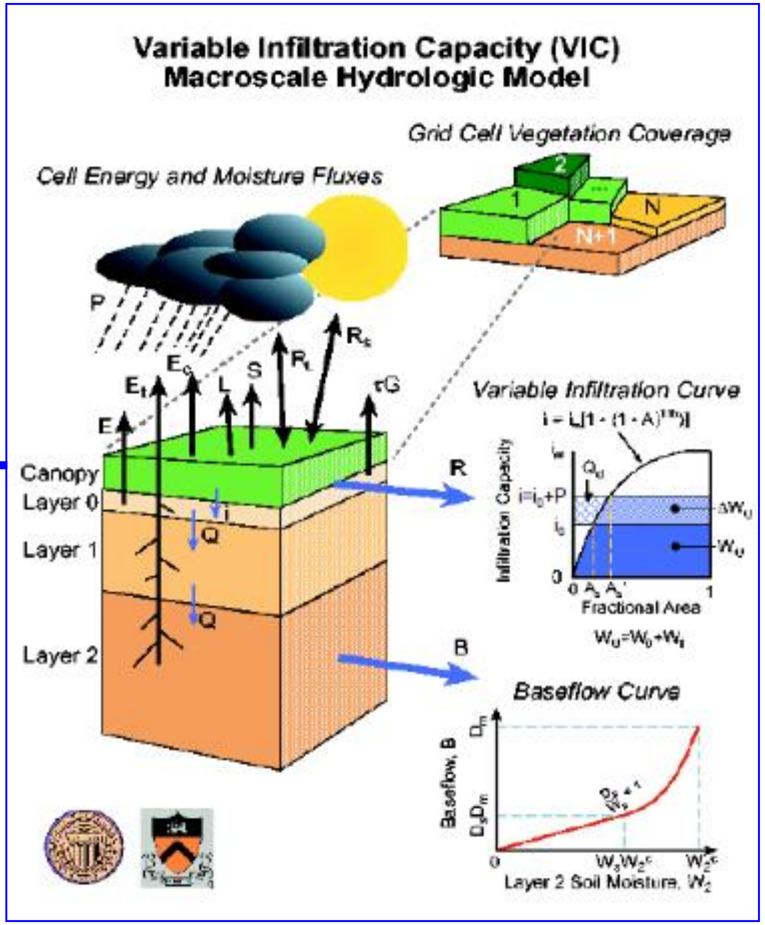
HINDCAST

Regression-based wetlands models

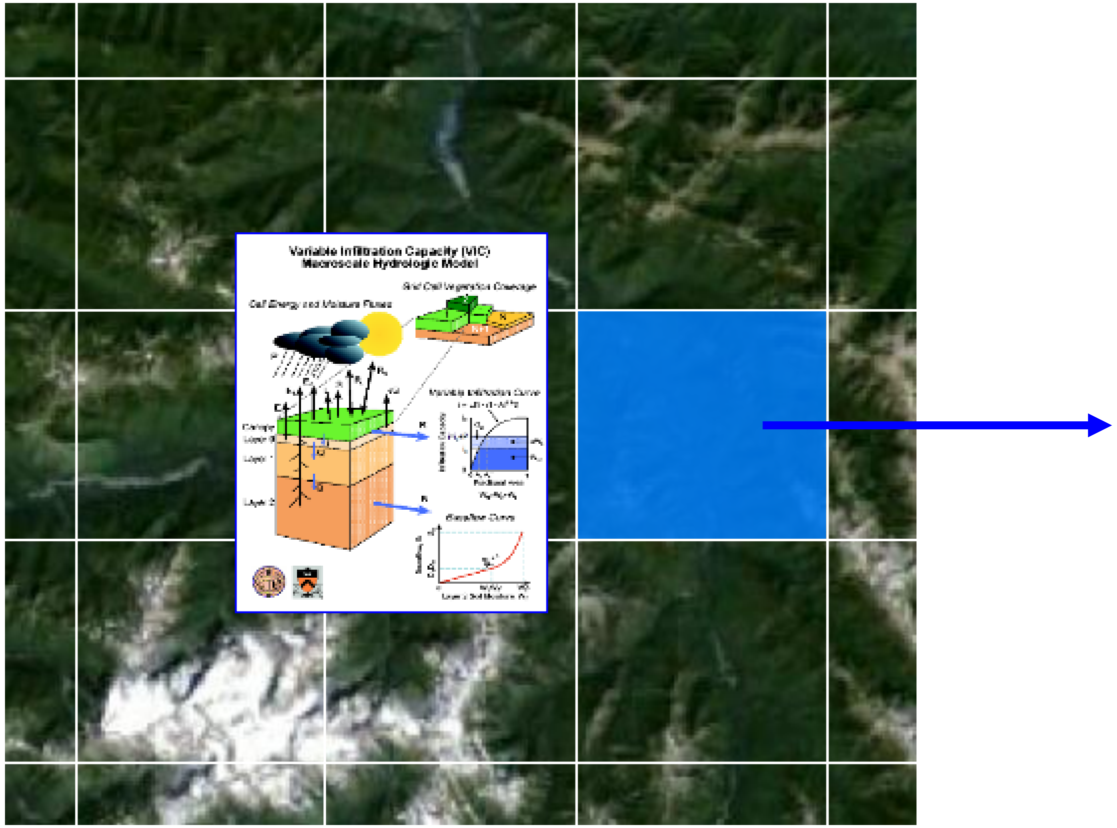


3. Variable Infiltration Capacity (VIC) macroscale model

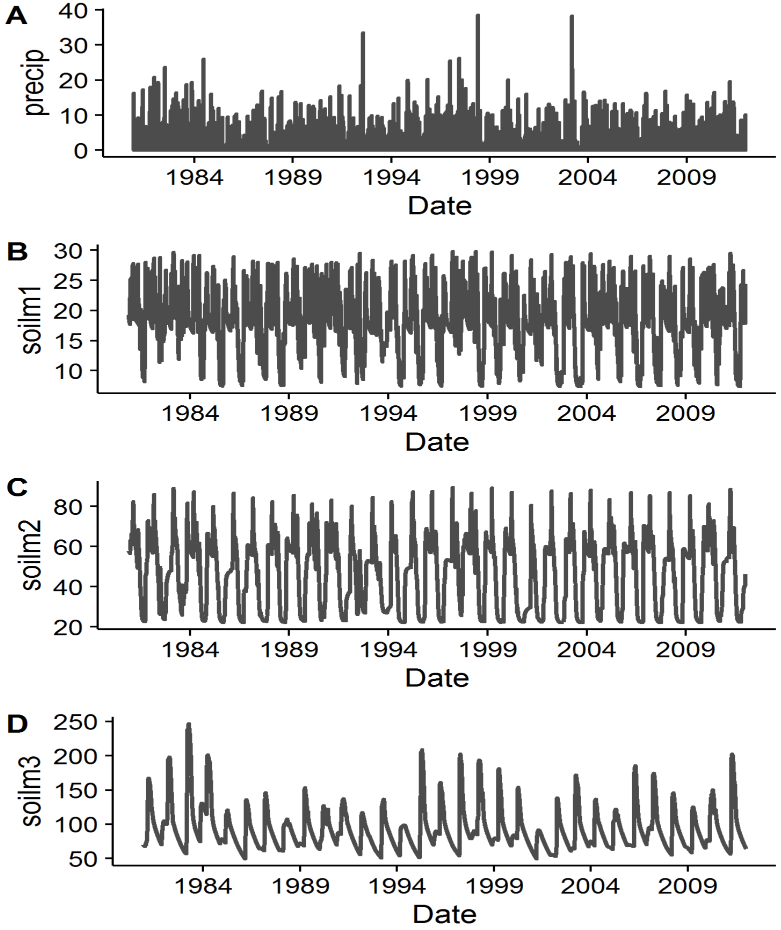




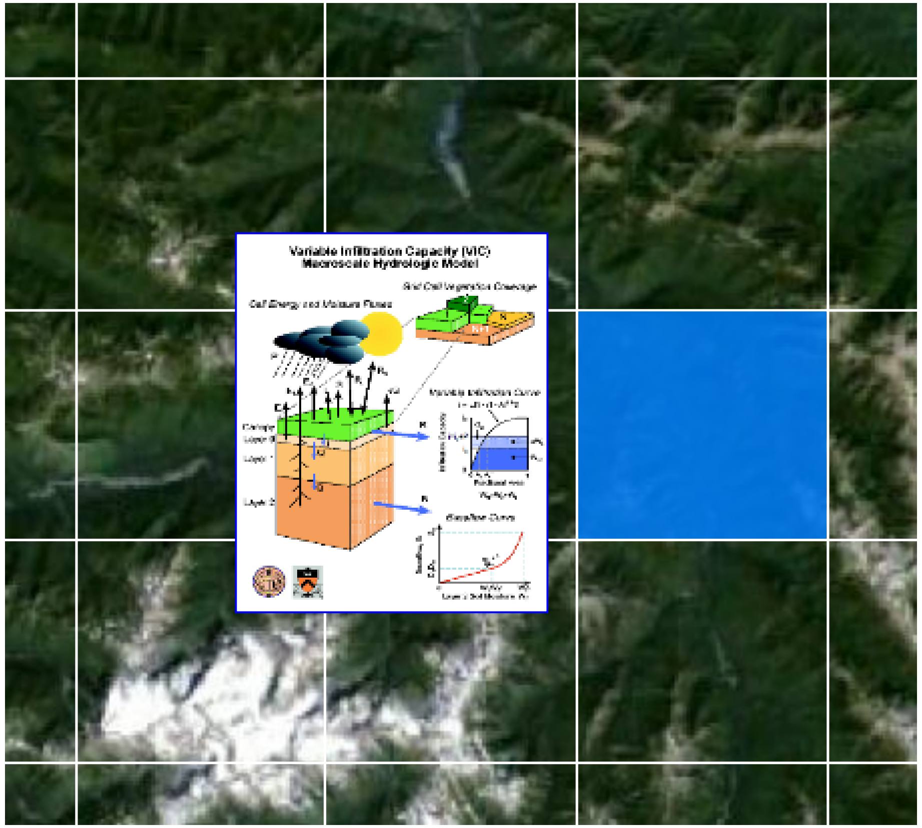
Variable Infiltration Capacity (VIC) macroscale model



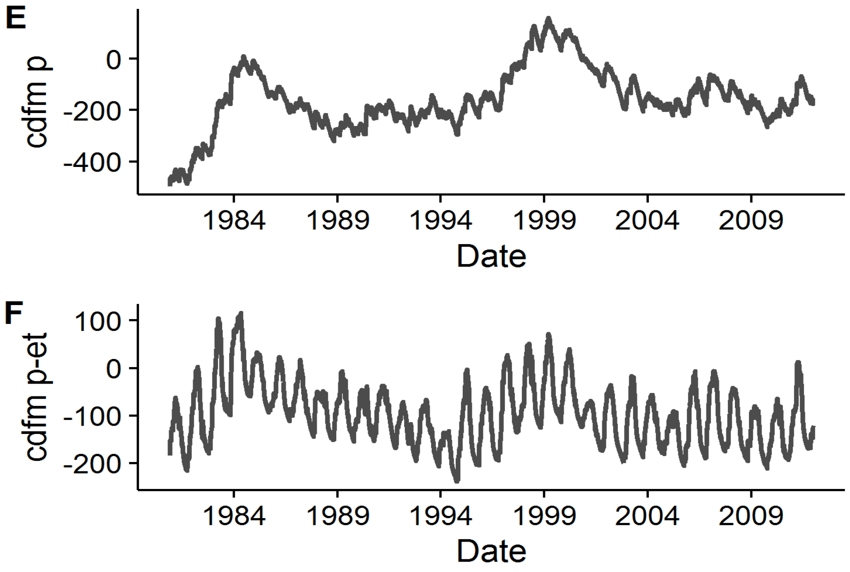
VIC Outputs



Variable Infiltration Capacity (VIC) macroscale model



Groundwater Proxy

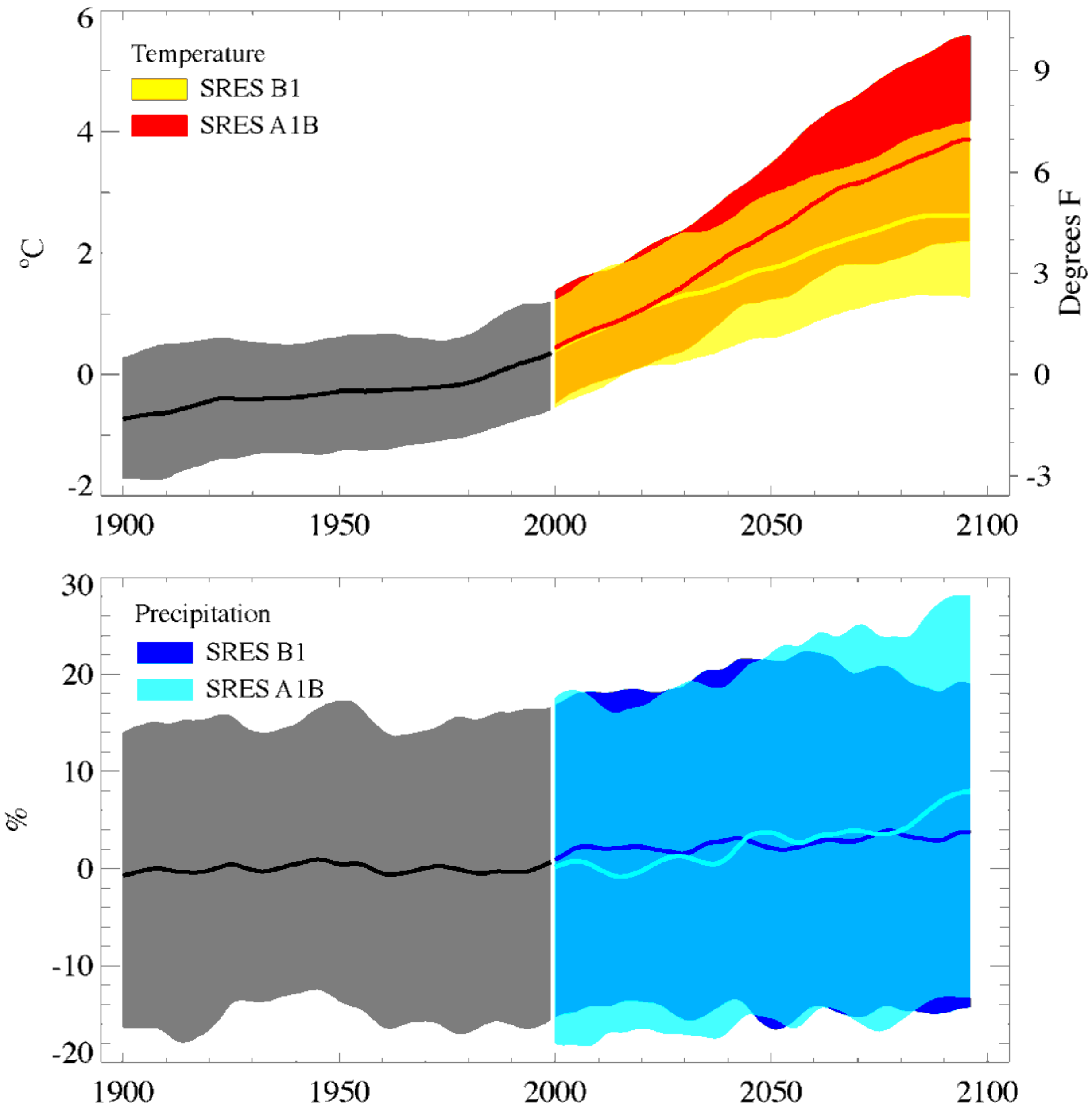


Climate modeling

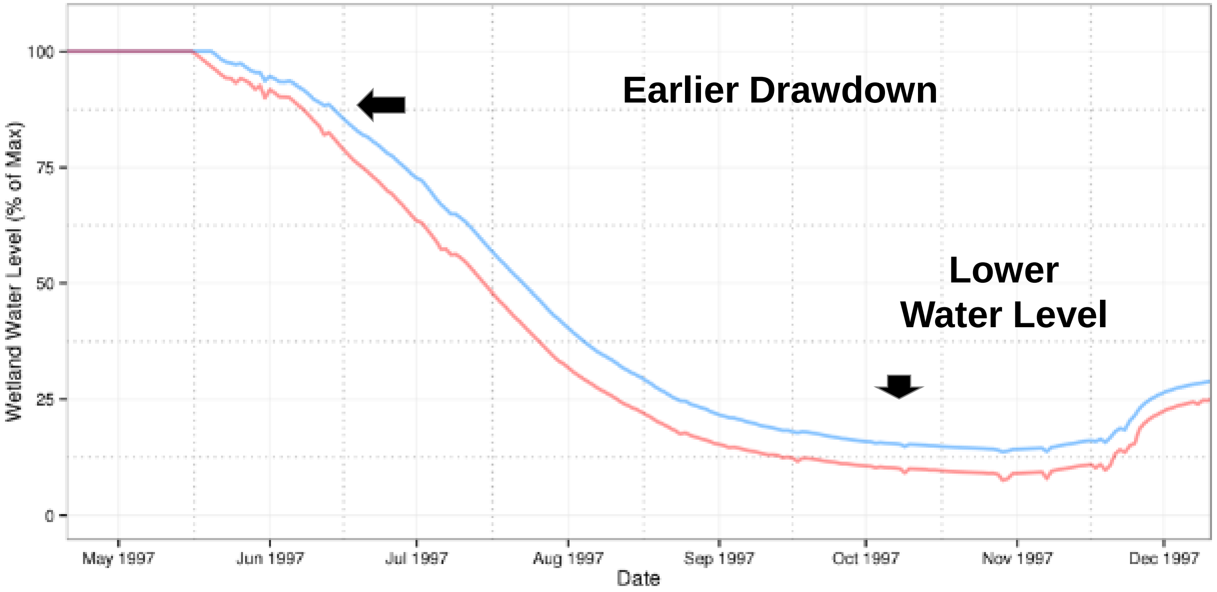
A1B scenario 2080s:

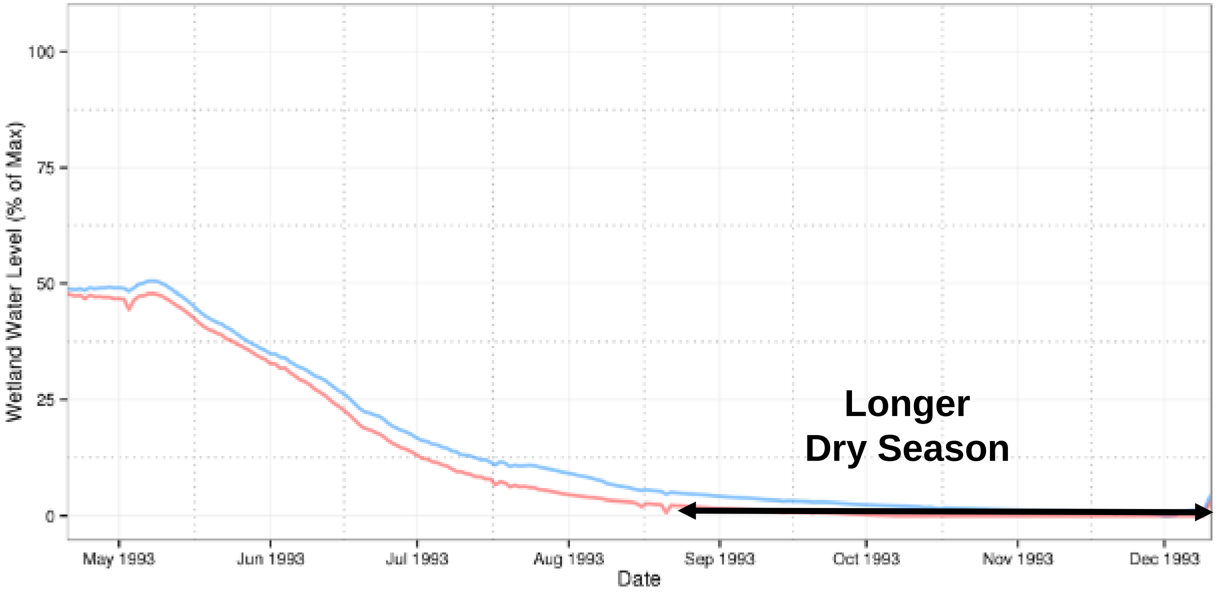
- Air temperature increase by 5.3°F (2.8-9.7°F)

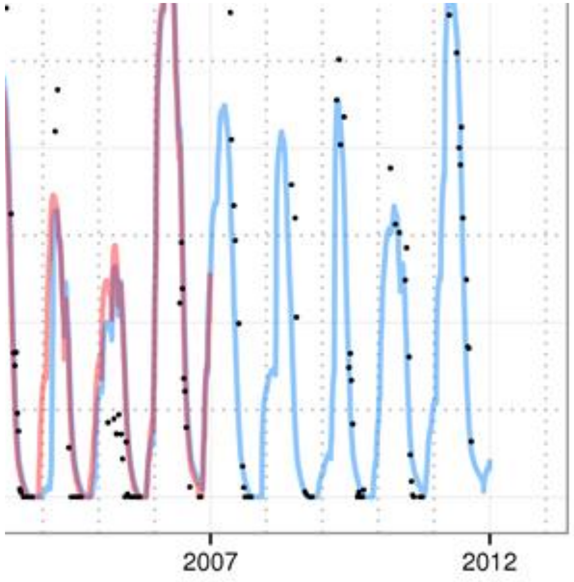
- Annual precipitation increase by 4%.



Seasonal Wetland



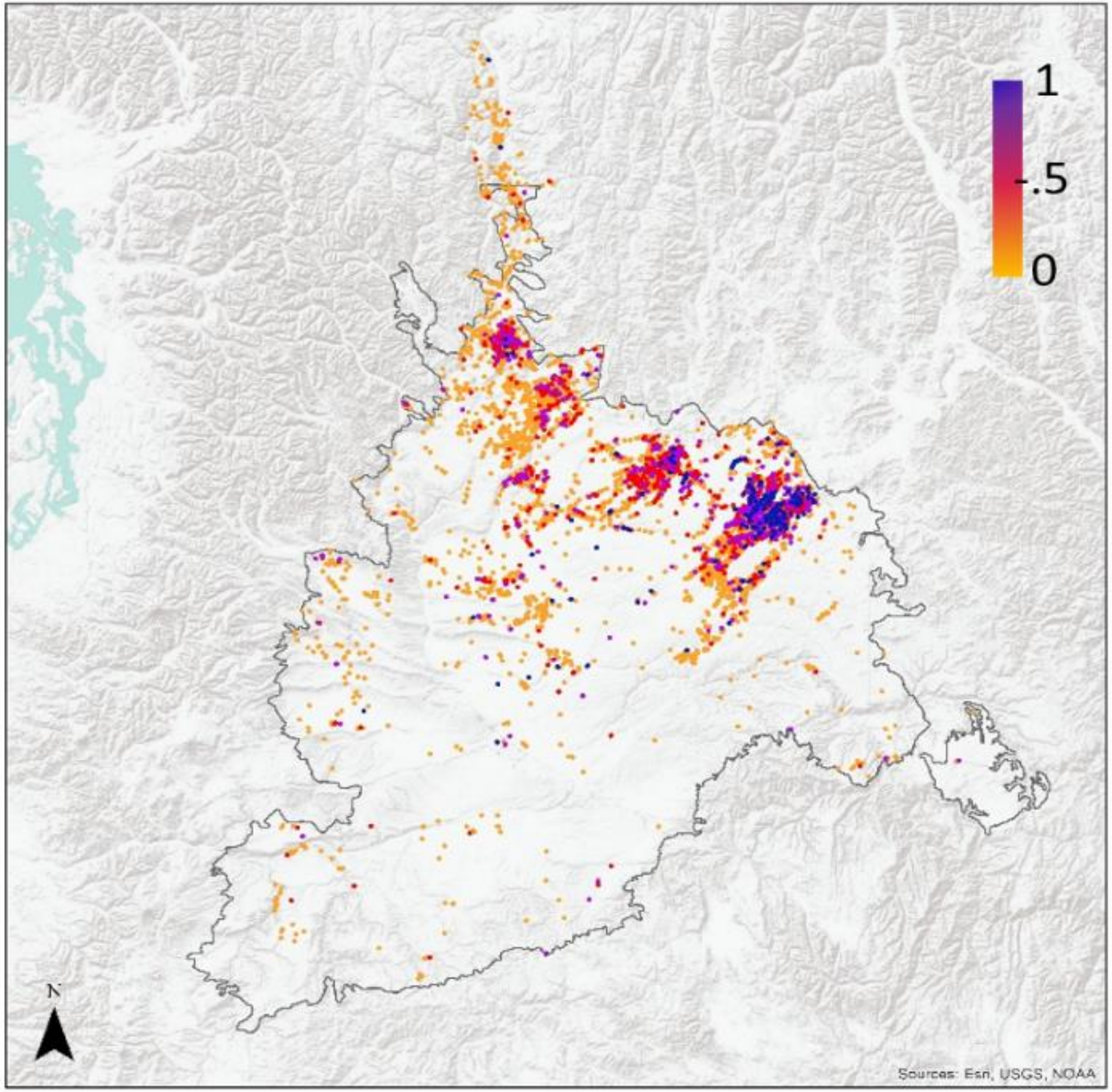




Results

How well does the model work?

Site-Specific Regression Model Fit (R^2)



VIC variables:

Soil Moisture Layer1

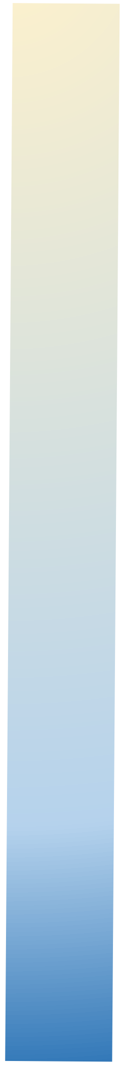
Soil Moisture Layer2

Soil Moisture Layer3

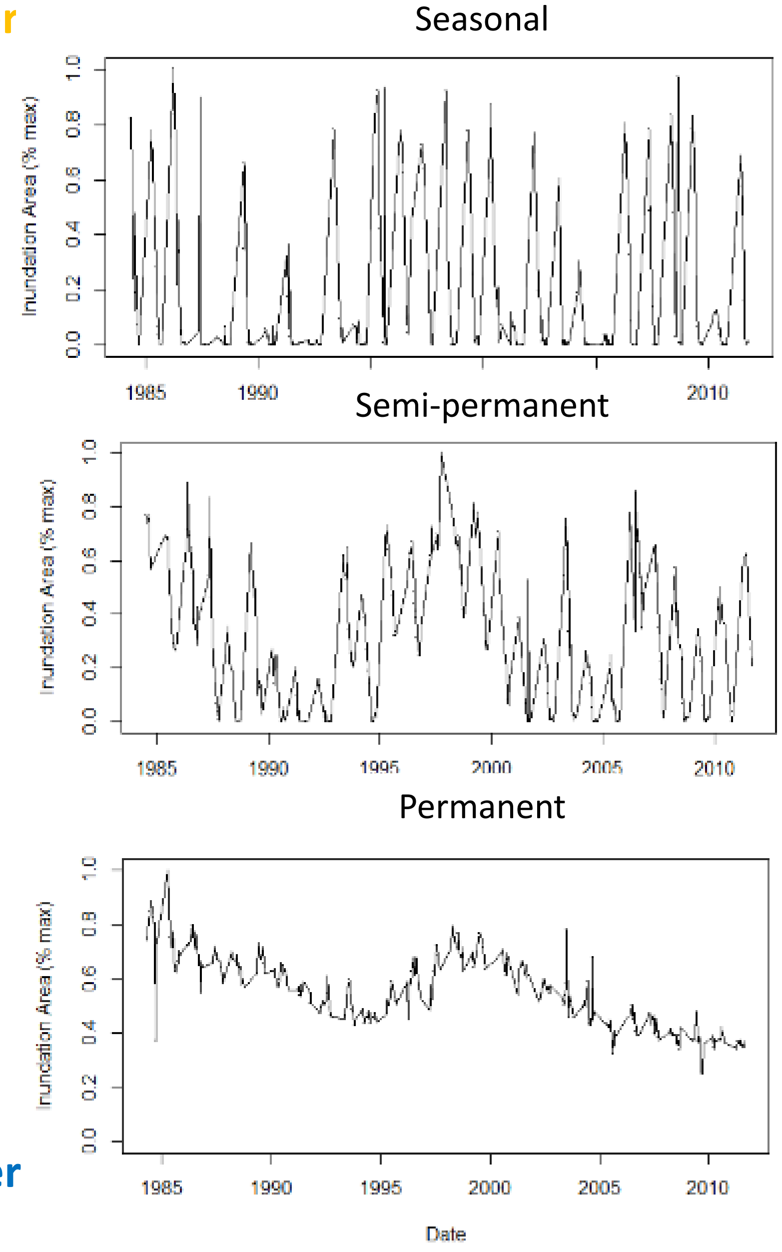
Proxy for groundwater CDFM : Precip – ET

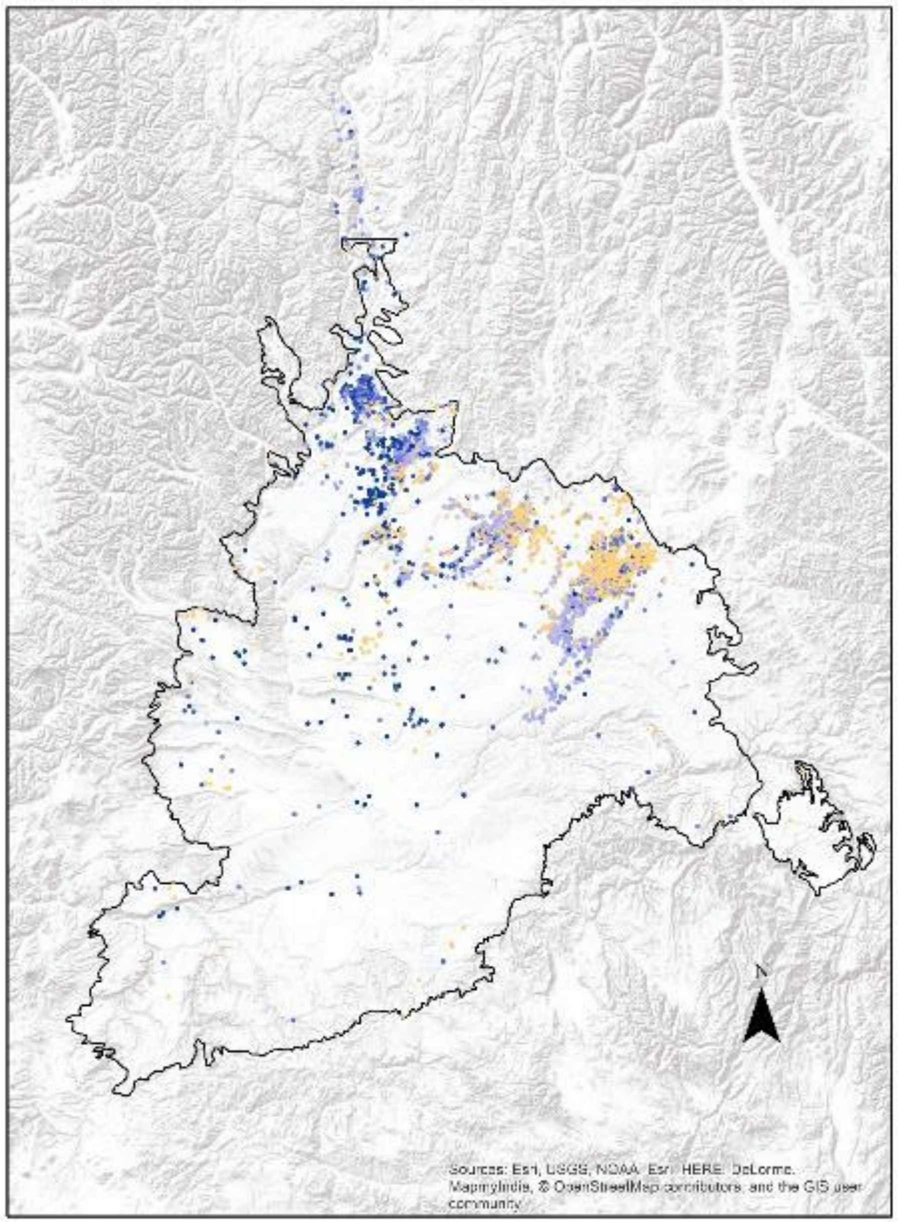
Proxy for groundwater CDFM : Precip

Surface Water



Ground Water

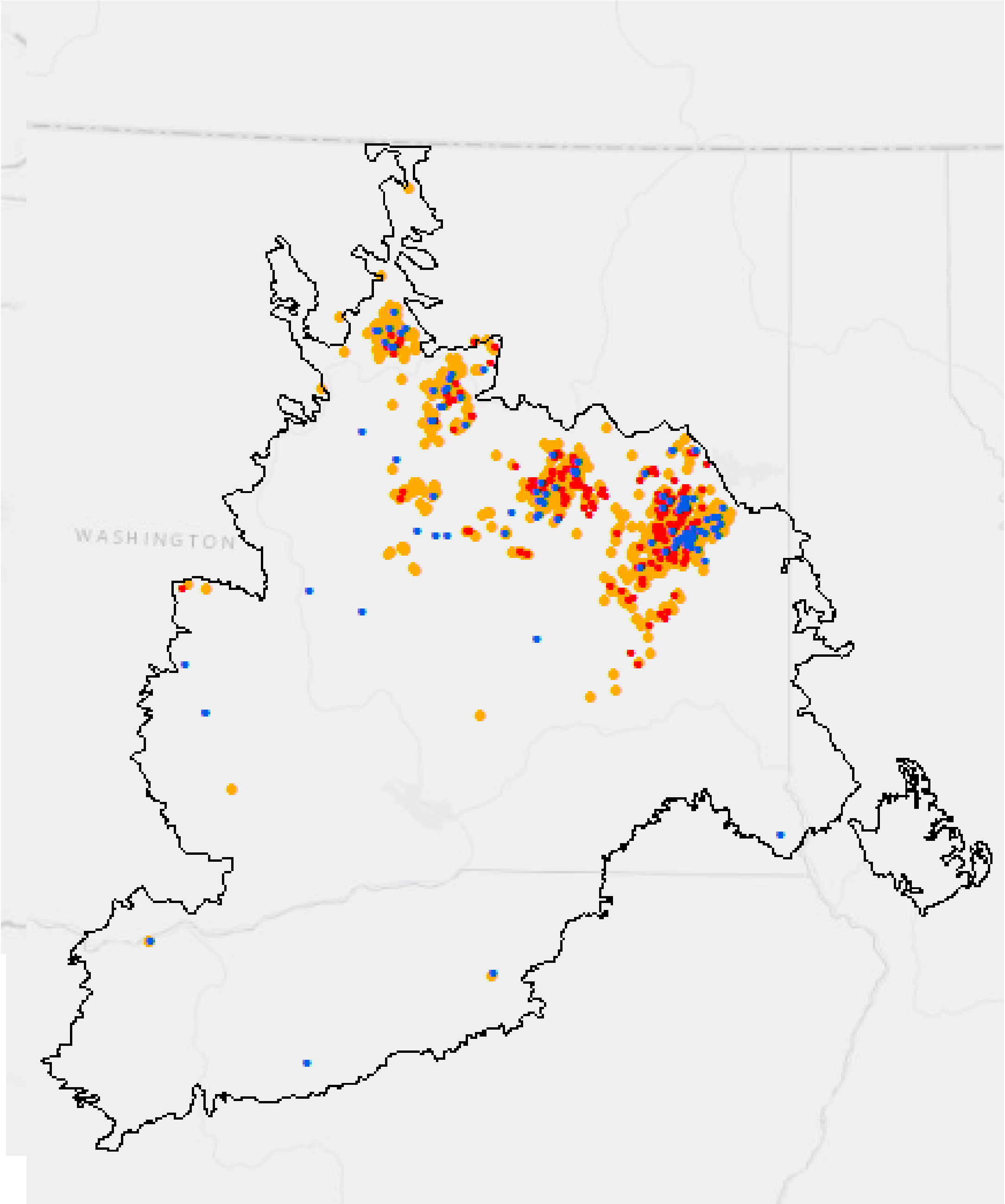




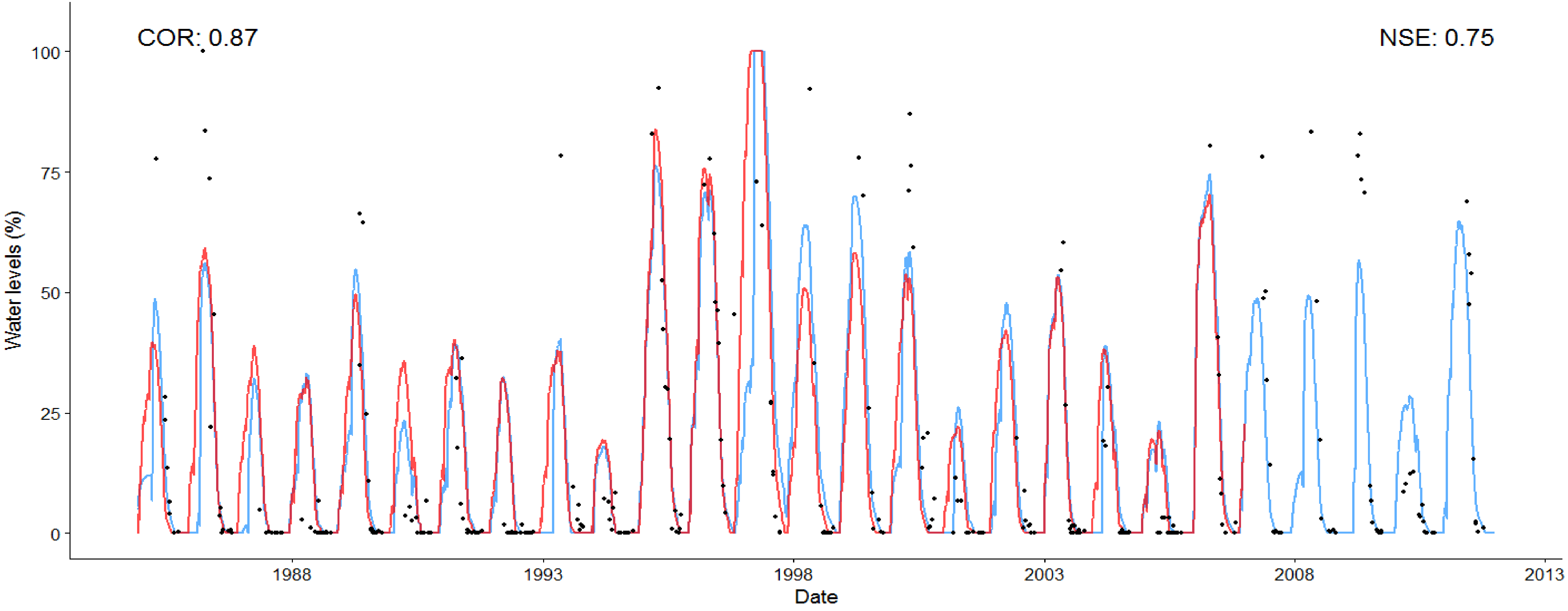
Climate modeling

Limitations:

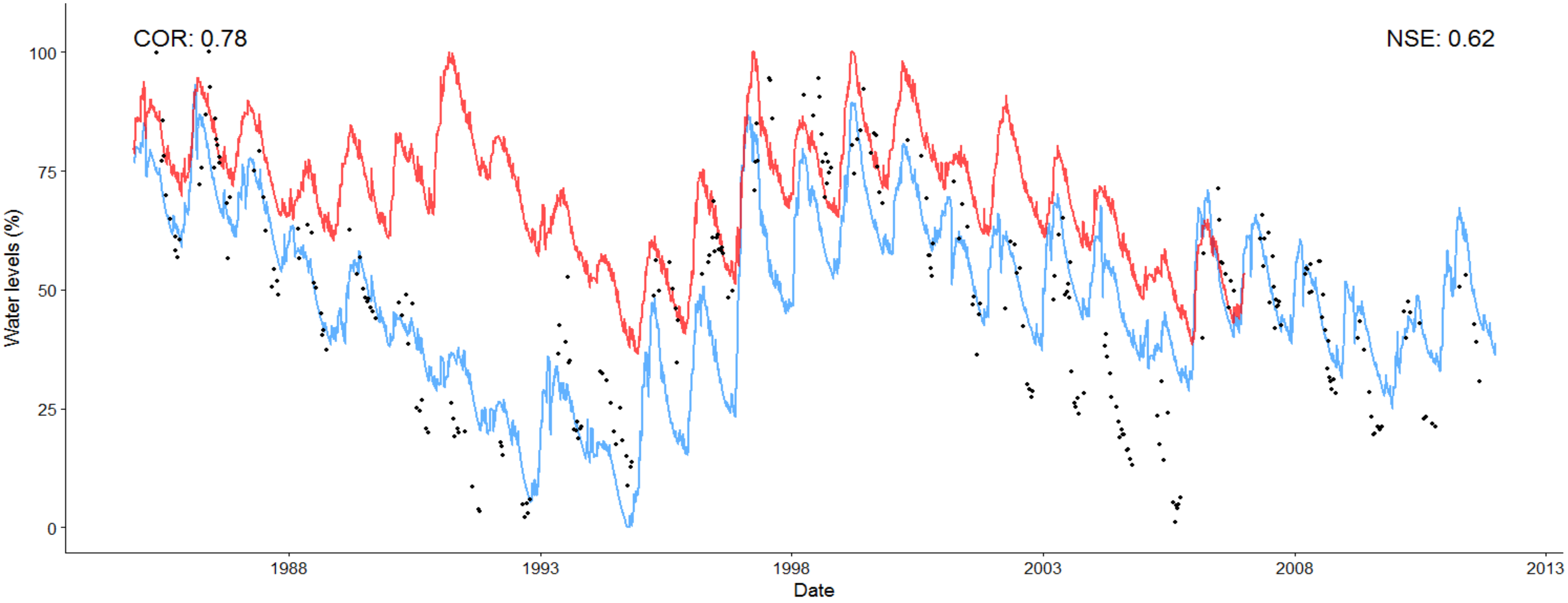
- Can’t model wetlands with large human impacts
- Simple proxy for groundwater
- Reduces dataset to ~ 1,700 wetlands (1/3 of all wetlands).



Example of a Surface Water Driven Wetland

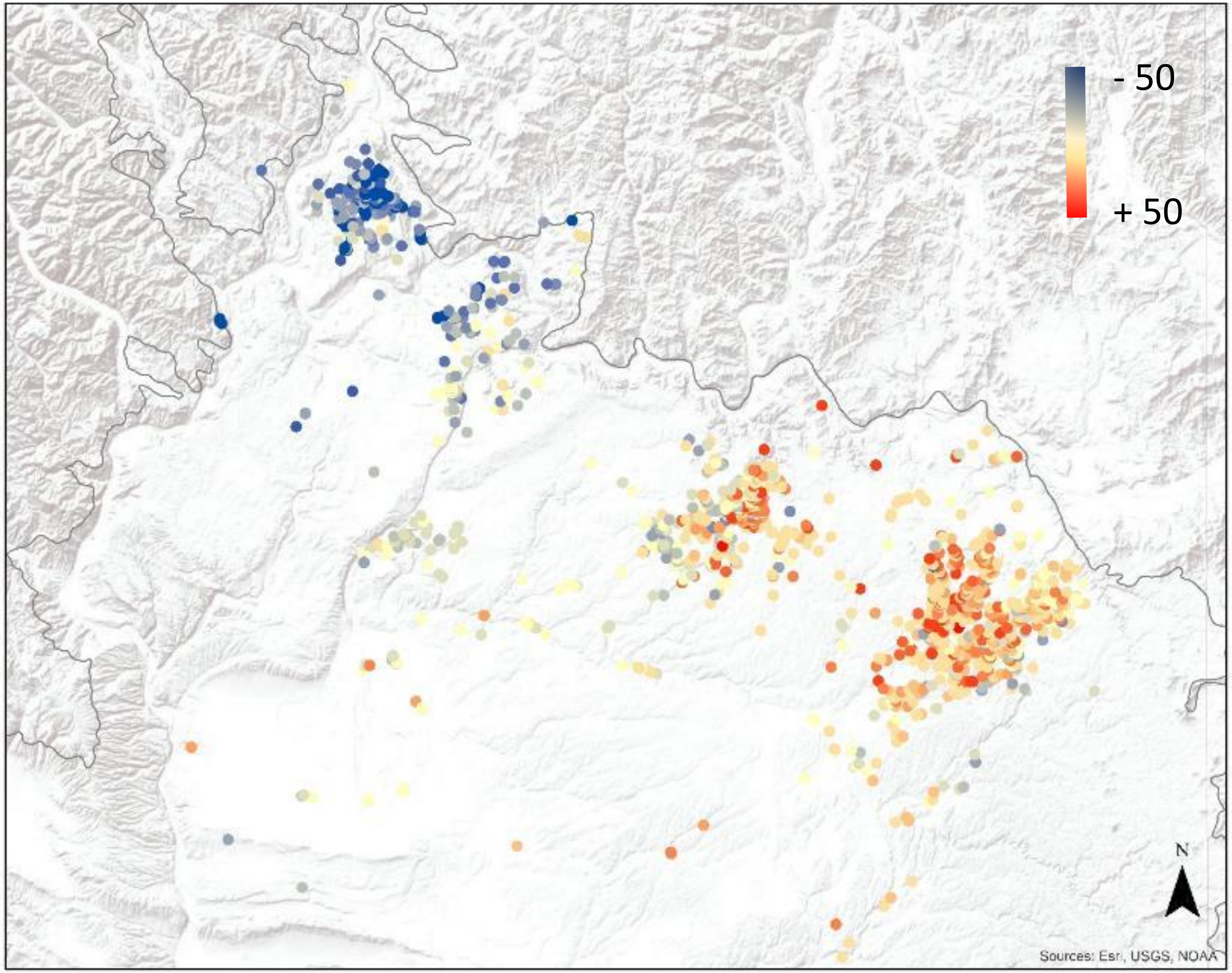


Example of a Groundwater Driven Wetland

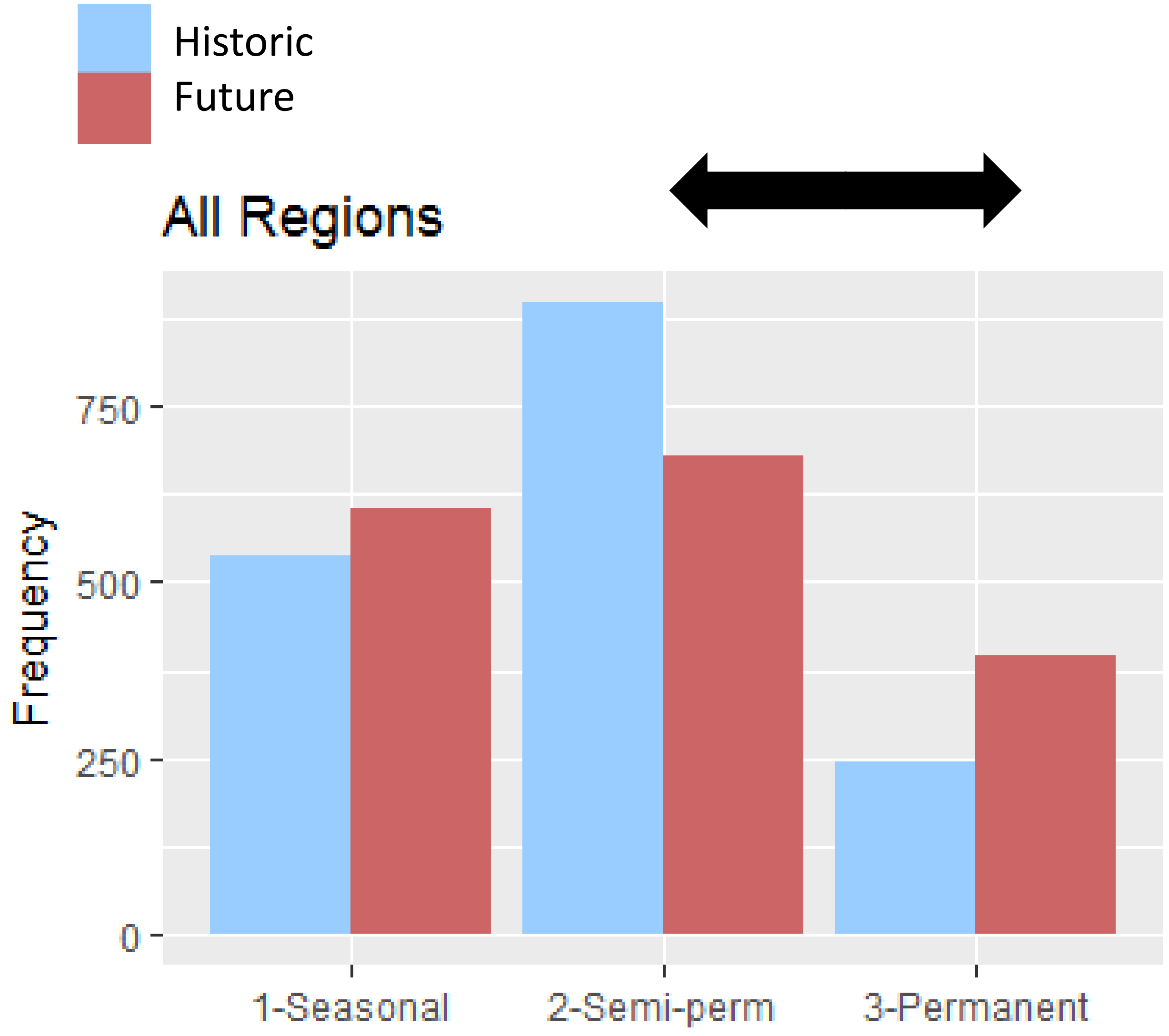


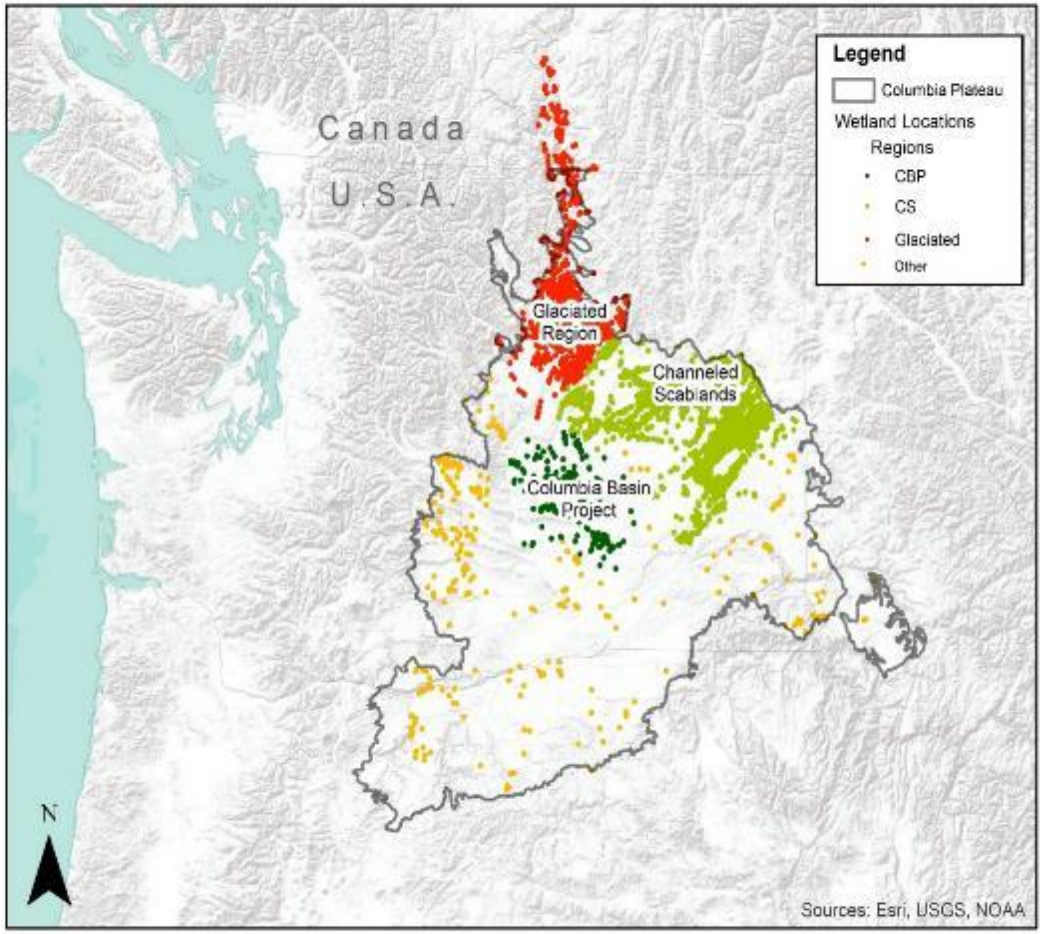
How will wetland hydrology change?

Change in drying frequency (years out of 100)



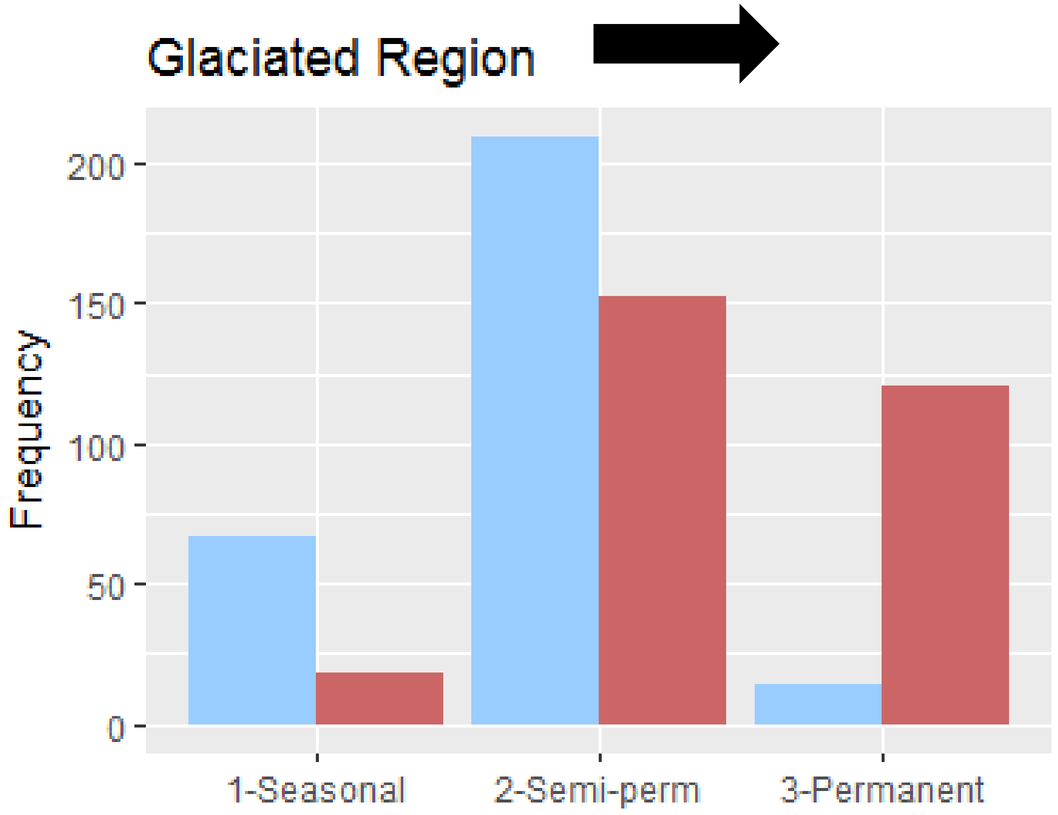
Change in Distribution of Wetland Types

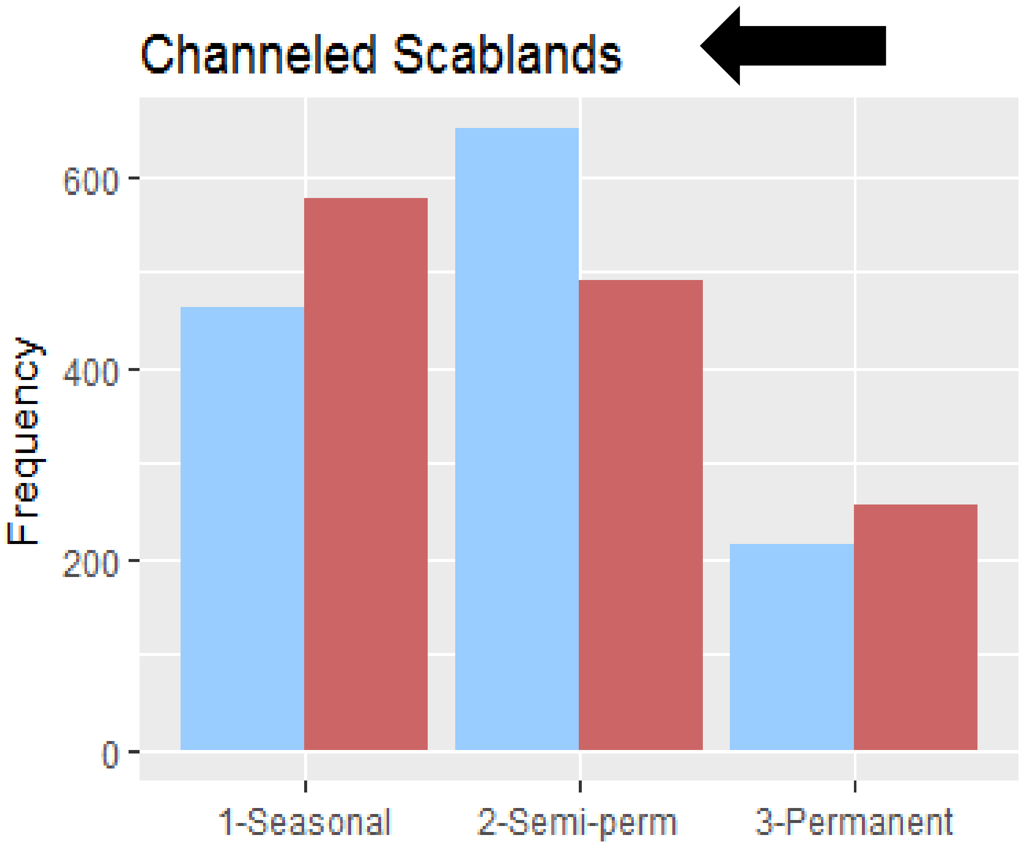




Change in Distribution of Wetland Types

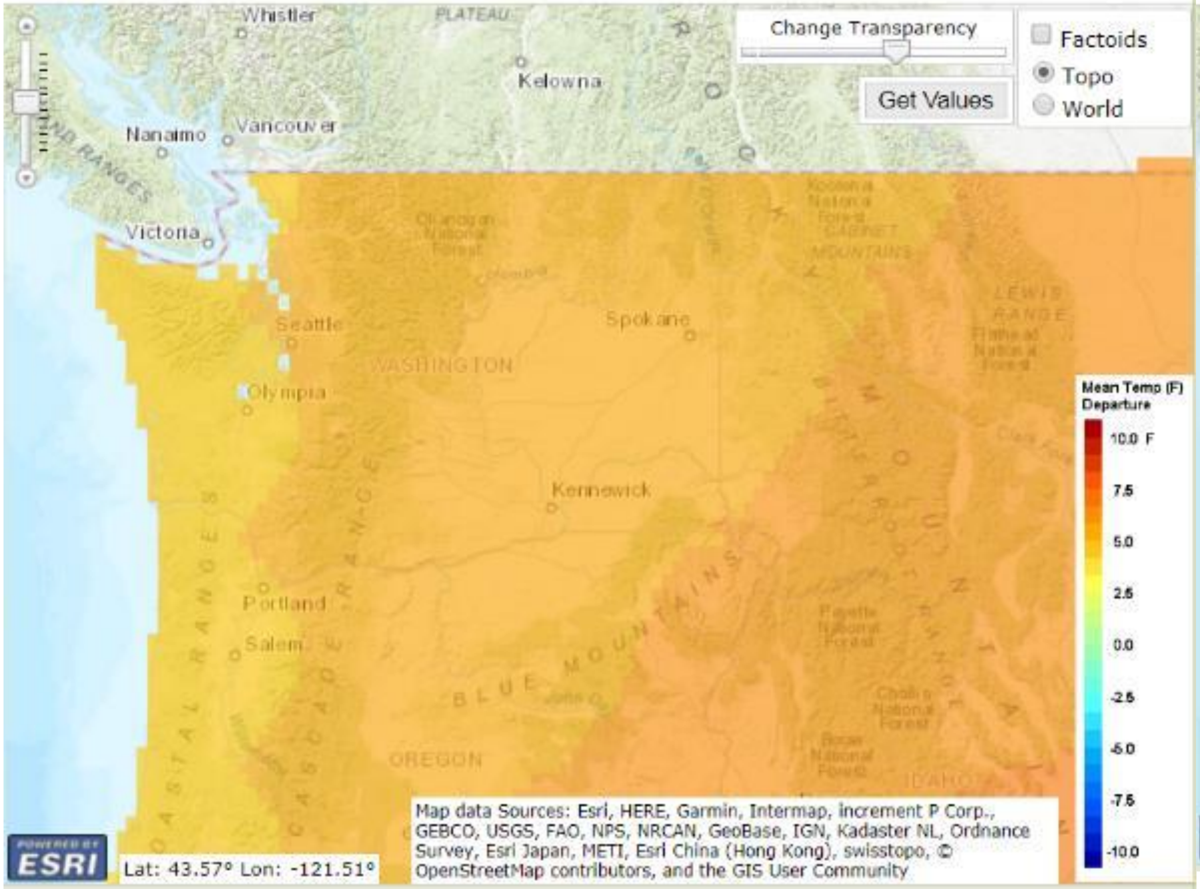
Historic
Future





Change in Annual Temperature by the 2080s

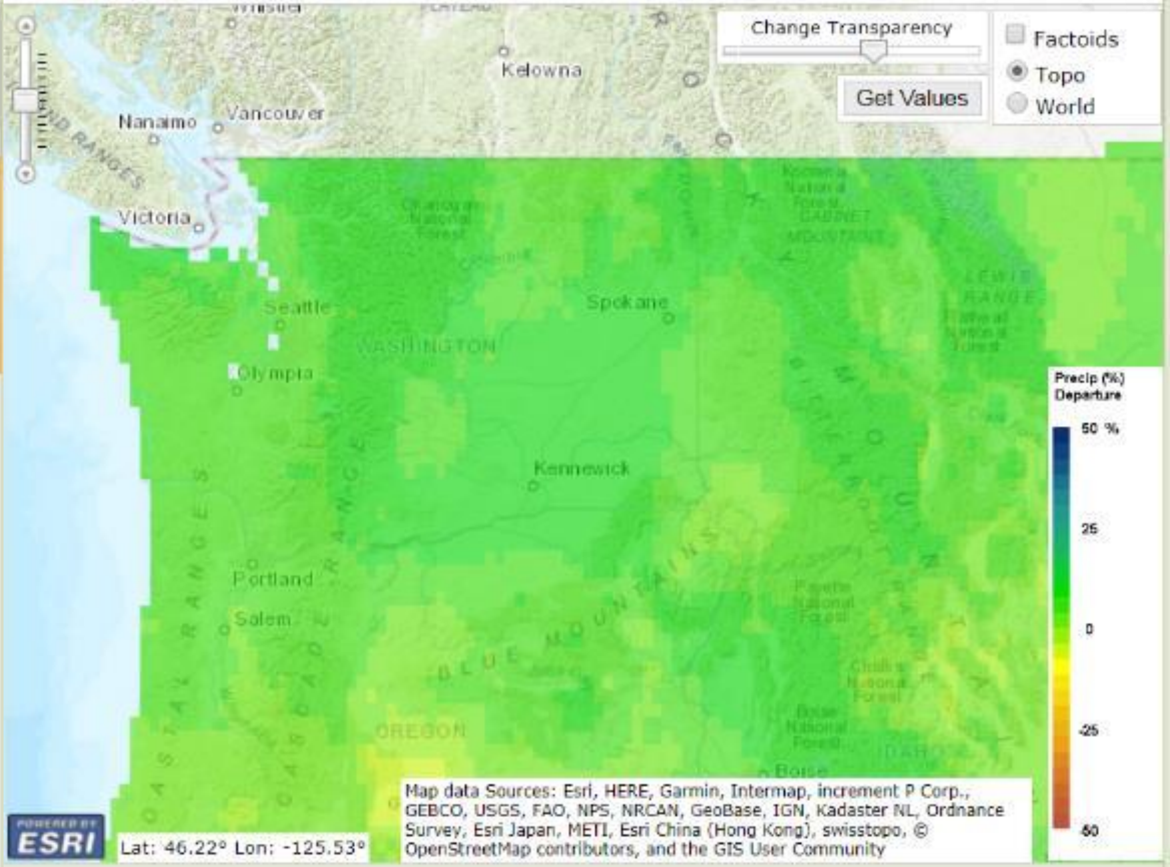
Model: Ensemble Average, SRES emission scenario: A1B



Data Source: Base climate projections downscaled by Maurer, et al. (2007) Santa Clara University. For more information see About Us.

Change in Annual Precipitation by the 2080s

Model: Ensemble Average, SRES emission scenario: A1B



Summary

- Downscaled climate models and high resolution remote sensing data provides better spatial and temporal detail for understanding wetland response to climate change.

- Wetlands will not have a linear response to climate. Some wetlands may get drier, but some may get wetter. – even for wetlands within close proximity to one another.

How is this data being used?

https://fws.maps.arcgis.com/apps/MapJournal/index.html?appid=f9dcd2bf5cc649a7b1d6681a8c811c01