Linking precipitation and temperature with forest inventory data

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Forest Inventory and Analysis Program

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Forest Inventory and Analysis

Questions

Why link climate and forests?

Where can we get forest inventory data?

Where can we get climate data?

How do we link forest and climate data? (Case studies)

Why link climate and forests?

Forest dynamics = *f*(moisture, temperature, site factors, …)

Dynamics at the stand scale:

- Disturbance (e.g., fire, insects, disease)
- Succession

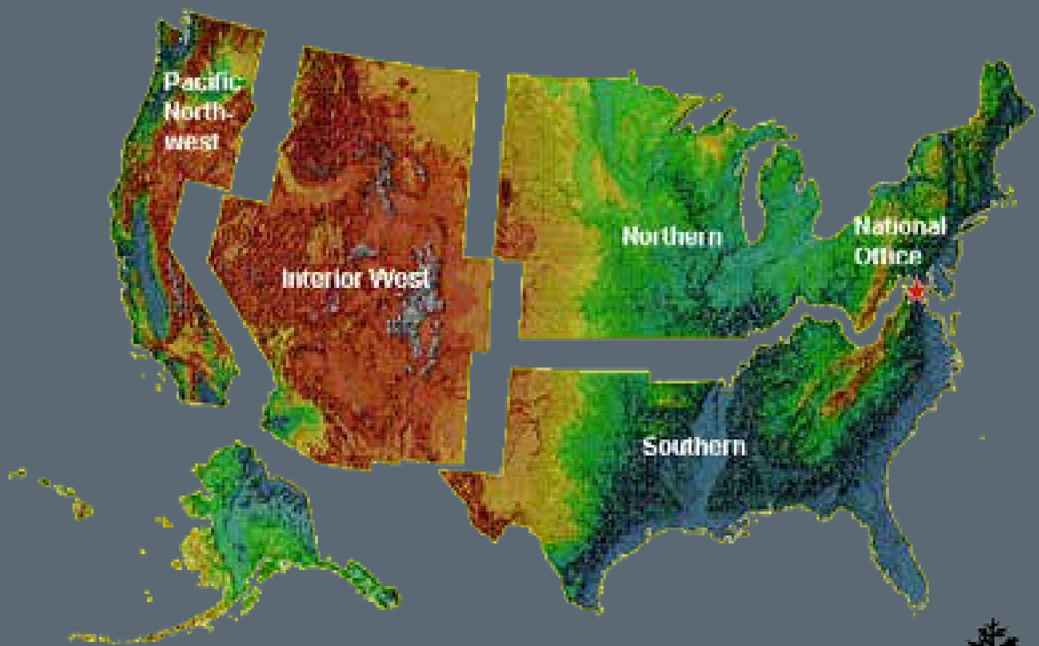
Dynamics at the tree scale:

- Mortality
- Regeneration
- Growth

Photo: Jeremy Marshall, US Forest Service, Valles Caldera fire

Where can we get forest inventory data?

The Forest Service's Forest Inventory and Analysis Program (FIA), a.k.a. the nation's forest census



Trees count; we count trees.

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Forest data: FIA sample design

Spatial resolution:

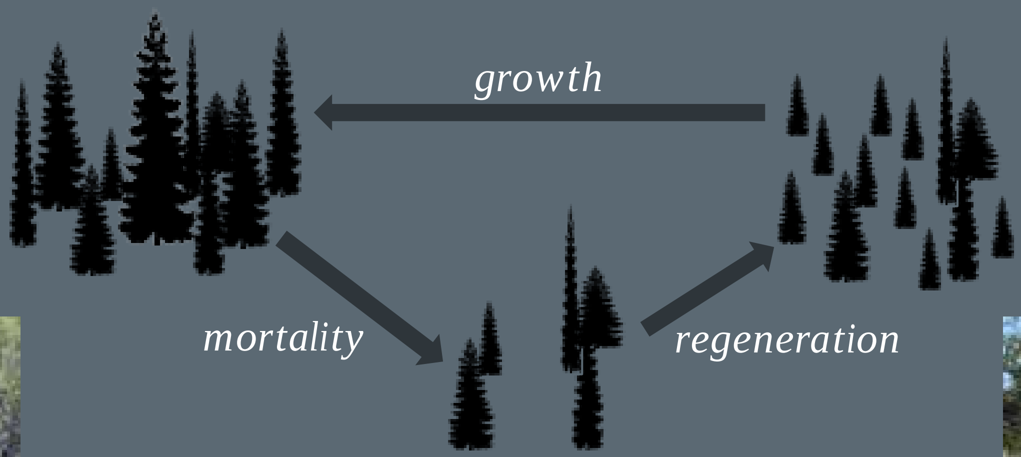
One plot per hex (~6,000 acres);
Plots ~3 km apart

Temporal resolution:

Each plot is visited every 10 years;
All plots done on 10-yr cycle

Forest data:
Response variables

Tree-level and seedling variables summarized to the plot scale…



Forest data:
GIS workflow

FIA data are available online at http://apps.fs.fed.us/fiadb-downloads/datamart.html

& spatial analysis

Summarize variables of interest

Link

PLOT.CSV
(with “fuzzed” lat and long)

Climate data:
Where can we get climate data?

PRISM CLIMATE GROUP

Berkeley EARTH

DAYMET

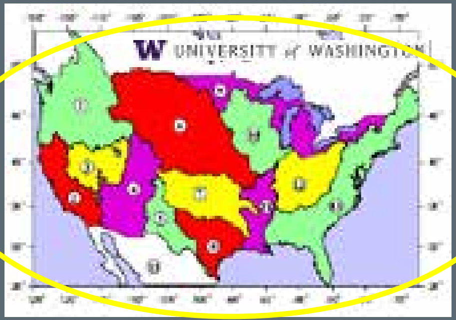
CMAP

NATIONAL INTERAGENCY FIRE CENTER

NCDC

NCEP

NOAA



NCAR UCAR | ClimateDataGuide

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Climate data:
Data types

Point observations (station data)

Gridded data

- Radar/satellite observations
- Mechanistic meteorological models
  - Long-term predictions
  - Forecasts
- Phenomenological/statistical models
  - Interpolation
  - Downscaling
- Reanalysis data – combine info from many sources

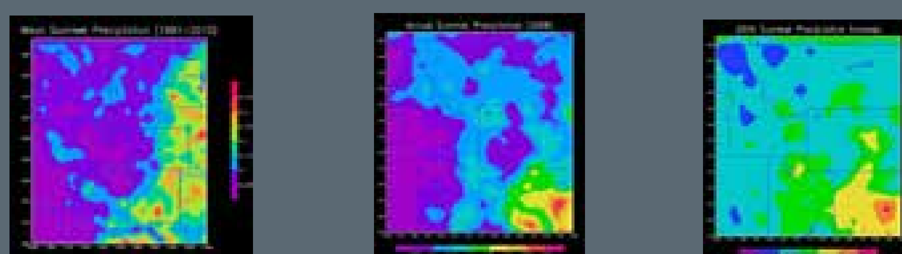
Climate data: Typical variables

Off-the-shelf metrics:

- **Summaries** – mean (temp) or sum (precip) → *weather*
- **Normals** – typically 30-yr means → *climate*

Calculated metrics that may be important for forest dynamics:

- **Variability** – standard deviation, range, quartiles, etc.
- **Anomalies** – deviations from 30-yr normals

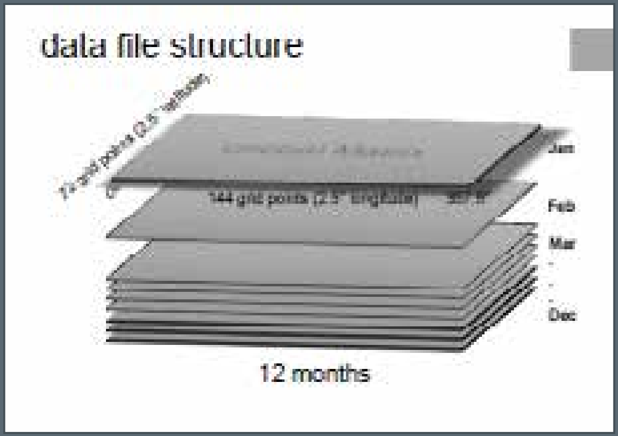


Summer normal – 2006 summer = 2006 summer anomaly

Climate data: Temporal and spatial resolutions

Temporal resolution:

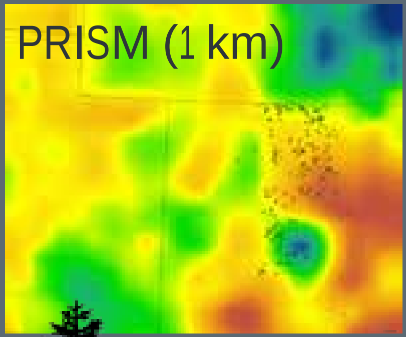
15-minute, hourly, daily, monthly, seasonal, annual, multi-annual, multi-decadal

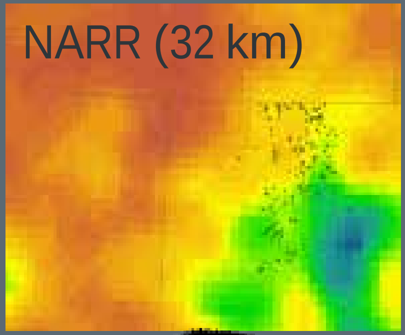


Spatial resolution (gridded data):

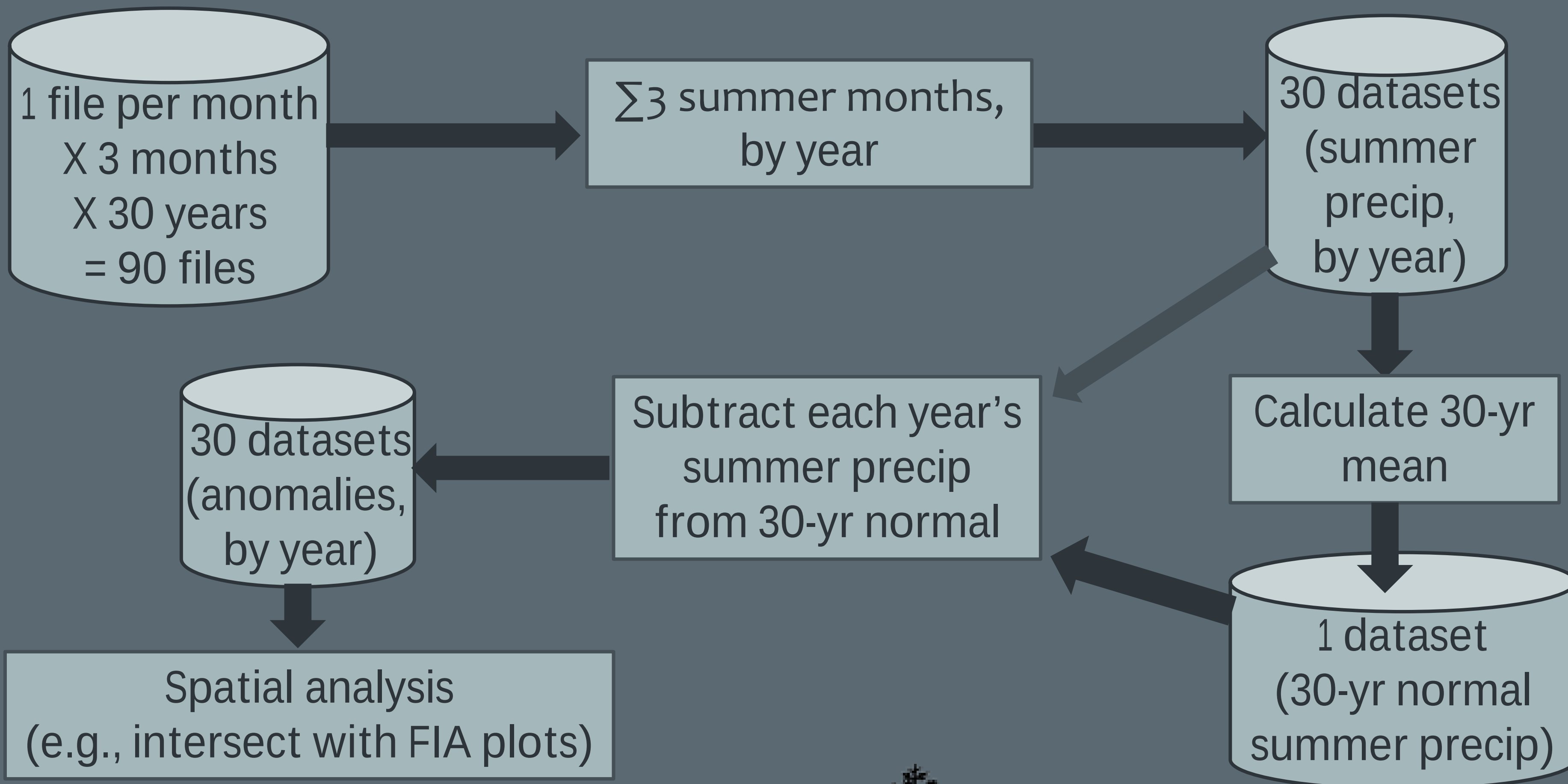
<1 km to 5°

2006 summer precip





Sample workflow: Calculating summer precipitation anomalies



Climate data formats

GIS-ready:
- ASCII
- GeoTIFF
- BIL
- NetCDF

Import to ArcGIS here…

Non-GIS-ready:
- GRIB2
- HDFx
- HDFx-EOSx

Or ….?

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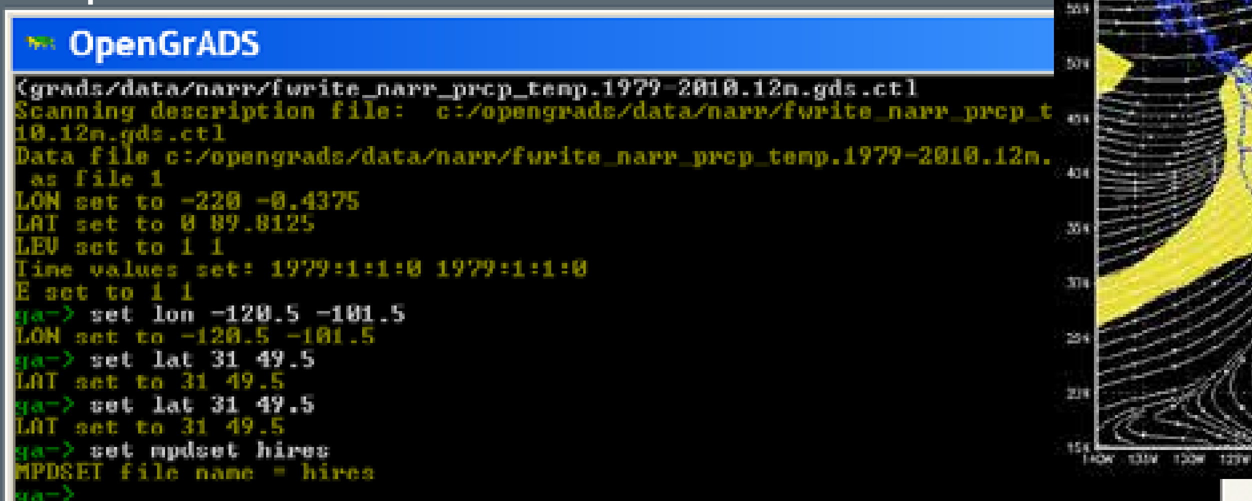
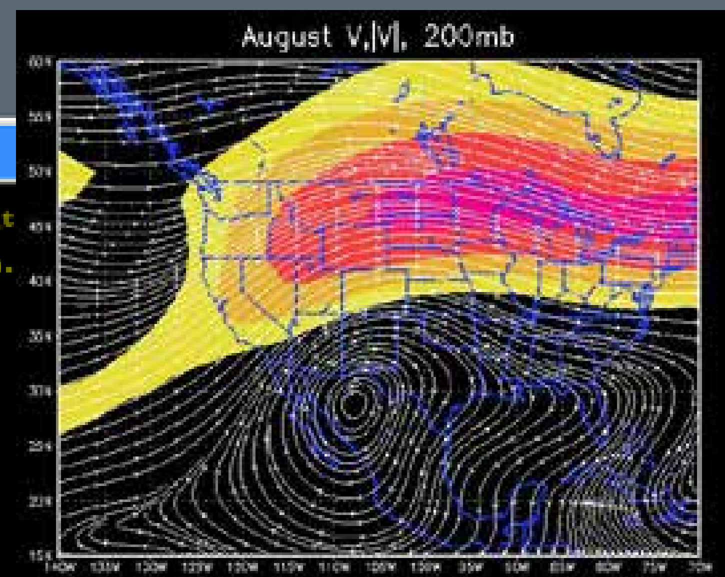
Analysis of non-GIS-ready climate data

OpenGrADS
"Opening GrADS to a World of Extensions"

- Open source
- Command line
- Designed to efficiently handle climate data with multiple dimensions
- Works with OpenDAP
- Produces graphics
- Exports GeoTIFFs

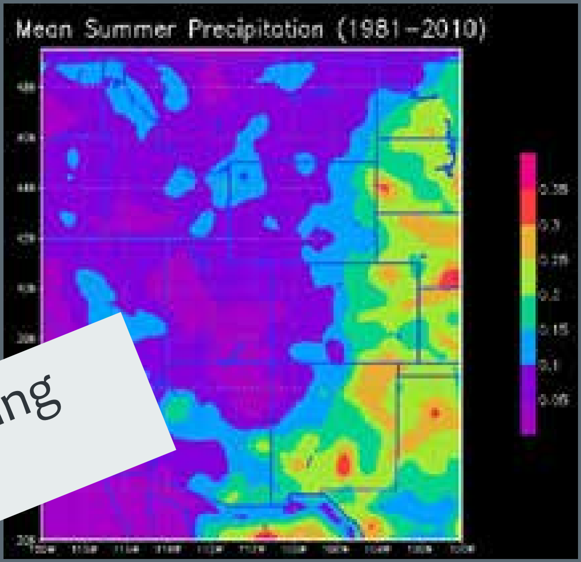




Analysis of non-GIS-ready climate data

Draw/export monthly means

'set geotiff c:/opengrads/narr/temp_m_means/t'yyyy'-'mm' '
'set gxout geotiff'
'set time jan'yyyy' '
'set z 'mm' '
'd tmp2m'



Calculate 30-yr monthly normals

'set geotiff c:/opengrads/narr/temp_normals/t_ave'mm' '
'set gxout geotiff'
'set z 'mm' '
'd ave(tmp2m,time=jan1981,time=dec2010,1)'

Calculate anomalies:

'set geotiff c:/opengrads/data ... alies/t_ano'yyyy'-'mm' '
'set gxout geotiff'
'set time jan'yyyy' '
'set z 'mm' '
'd ave(tmp2m,time=jan'yyyy',time=dec'yyyy',1)-ave(tmp2m,time=jan1981,time=dec2010,1)'

OpenGrADS is very efficient at cycling through multi-dimensional data!

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Or here?


1 file per month
X 3 months
X 30 years
= 90 files
∑3 summer months, by year
30 datasets (summer precip, by year)
Calculate 30-yr mean
1 dataset (30-yr normal summer precip)
Subtract each year's summer precip from 30 yr normal
30 datasets (anomalies, by year)
Spatial analysis (e.g., intersect with FIA plots)

Case studies:
Linking climate & forest data

1) Tree growth and mortality
2) Lodgepole pine mortality
3) Spruce beetle distribution
4) Whitebark pine regeneration

Case study #1:
Tree growth and mortality

FIA
forest data

>20,000 plots

PRISM
climate data

NARR
climate data

ArcGIS
compile time series

OpenGrADS
compile time series

ArcGIS
Intersect climate rasters and FIA plots

Statistical software (r or SAS)

Multivariate analysis or modeling

Case study #1:
Tree growth and mortality

Potential models:

Best

1) Include stand variables, climate means, and climate variability (SD)
2) Include stand variables, climate means
3) Include stand variables, climate variability
4) Include stand variables only

Worst

Greg C. Liknes and
Sara A. Goeking (2013)

Case study #2: Lodgepole pine mortality due to mountain pine beetle in Colorado

Percent mortality

- 0 - 10
- 10 - 25
- 25 - 50
- 50 - 75
- 75 - 100

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Case study #2: Lodgepole pine mortality due to mountain pine beetle in Colorado

Climate metrics (NARR):

- Means & Anomalies, with time lags
  - 1-yr
  - 3-yr
  - 5-yr
- Time periods:
  - Seasonal
  - Annual

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Lodgepole pine mortality due to mountain pine beetle in Colorado

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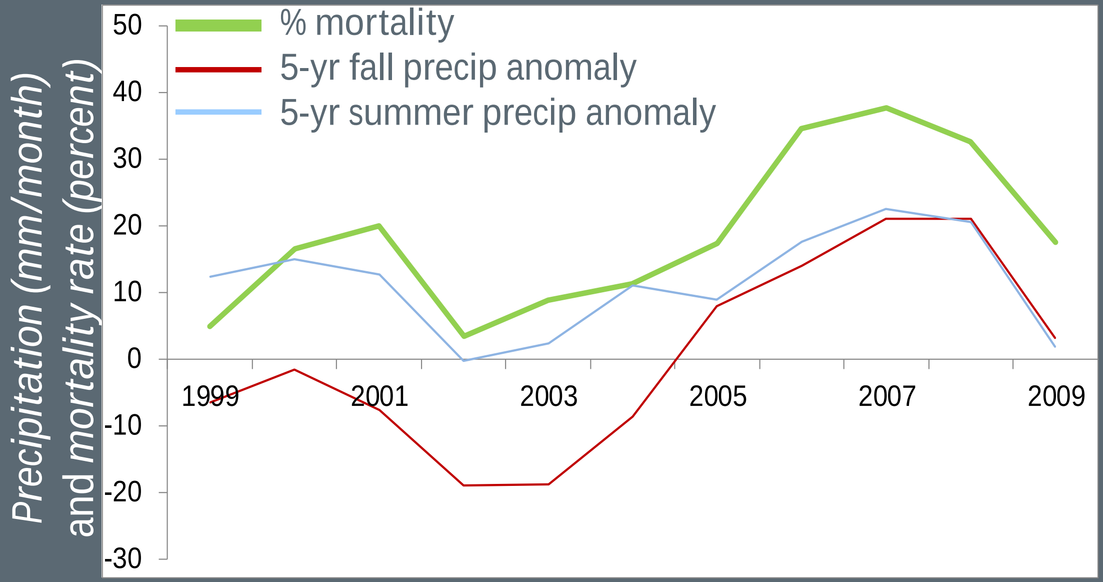

Sara A. Goeking and Greg C. Liknes 2013

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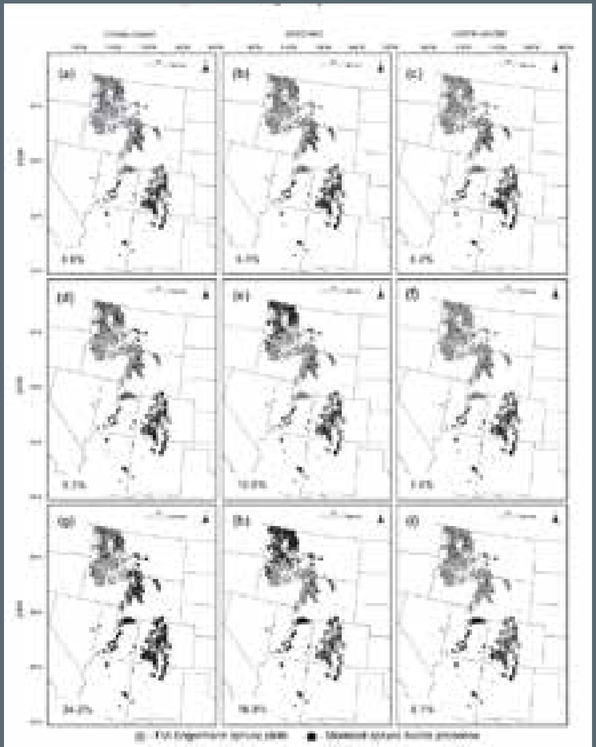
Case study #3: Spruce beetle distribution

Most important predictors of spruce beetle distribution:

- Stand characteristics (from FIA data)
- Maximum summer temperature
- Minimum winter temperature

These results allow predictions of future spruce beetle distributions.



DeRose et al. 2013

Case study #4:
Whitebark pine seedling density

Most important predictors of whitebark pine seedling density:

- Stand characteristics (from FIA data)
- **Maximum** and **minimum** summer temperature

Conclusions

1. Mean conditions are not always the most important metrics.

   Ø*Also consider anomalies and variability.*

2. Linkage effects are not always immediate.

   Ø*Consider time lags and identify the appropriate lag.*

3. Data formats and analytical tools aren't always compatible.

   Ø *Use the most appropriate dataset, not just the one that is easiest or most familiar…*

Future considerations

1) More climate datasets may eventually be made available in more user-friendly, GIS-ready formats.

2) GIS software may adapt to accommodate the large number of spatially explicit climate datasets in non-GIS-ready formats (Big Data).

Import to ArcGIS here?

Questions?

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