TOPOFIRE: A system for mapping terrain and insect-induced variation in fire danger in the wildland fire environment

- **Project Team:**
- Zack Holden, Allen Warren, Alan Swanson, Matt Jolly, Jared Oyler, Marco Maneta, Russ Parsons, Erin Landguth, John Abatzoglou, Charlie Luce
- Project Partners: WFAS, WFDSS, USFS Region1, WA DNR

- **Project Goals:**

- develop topographically resolved gridded fire danger products for the USA to support the Wildland Fire Assessment System (WFAS) and Wildland Fire Decision Support System (WFDSS)

- Integrate eco-hydrologic indices into wildfire danger assessment

- **Earth Observations applied**
- MODIS Vegetation Indices, MODIS snow extent, MODIS VCF, MODIS LAI, NLDAS-2, MODIS LST

Applied Sciences Program

TOPOFIRE: A system for mapping spatial variability in fire danger in complex terrain

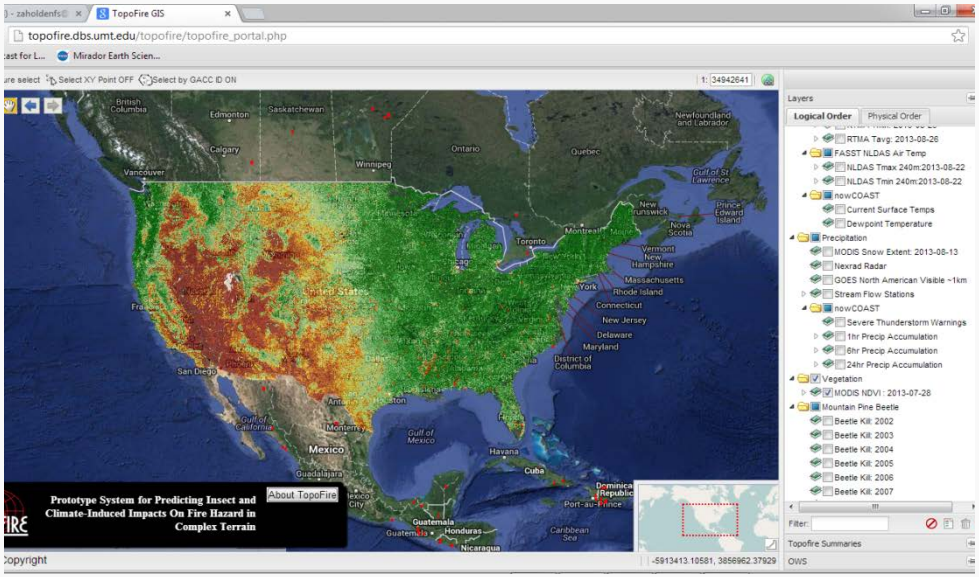
PI: Zack Holden, USFS Region 1 email: zaholden@fs.fed.us phone: (406) 329-3119

Wildland Fire Program
ACTIVE PROJECT
Date (02/10/2015

Purpose and Objective

TOPOFIRE is designed as the next generation of the Wildland Fire Assessment System (WFAS), a nationally mandated tool for monitoring fire danger in the US. It will integrate a suite of NASA data and imagery to deliver high resolution fire danger assessments that account for topographic variation in live and deal fuel moisture and potential insect-induced changes in canopy fuels.

Societal Benefit Area(s): Climate, Disasters, Ecosystems
Geographic Focus: Nationwide/North America/USA
Targeted End-Users: Federal Agencies/multiple/state agencies



MODIS Relative greenness on the TOPOFIRE web mapping server

Approach

1. ***Develop high spatial resolution weather and hydrologic models and integrate these to fire danger assessments***
2. ***Model/map recent insect outbreaks with MODIS time series imagery***
3. ***Deliver data via web mapping service with phone client for field use***

Key Milestones

Milestone Statement	Date
1. Incorporate MODIS snow cover into fire danger assessments	04/2015
2. Develop high resolution (250m) CONUS climate forcing data	03/2016
3. Develop iOS and android phone apps for data delivery	12/2016
4. Develop High resolution hydrologic model forecasts	08/2016
5. Incorporate hydrologic model outputs into fire danger	12/2016
6. Produce terrain/snow corrected fire danger maps for WFAS	07/2017

ARL_{Start} = 4/5 **$ARL_{Most\ Recent}$ = 5** **ARL_{Goal} = 9**

TOPOFIRE technical progress

Computational
Ecology
Laboratory

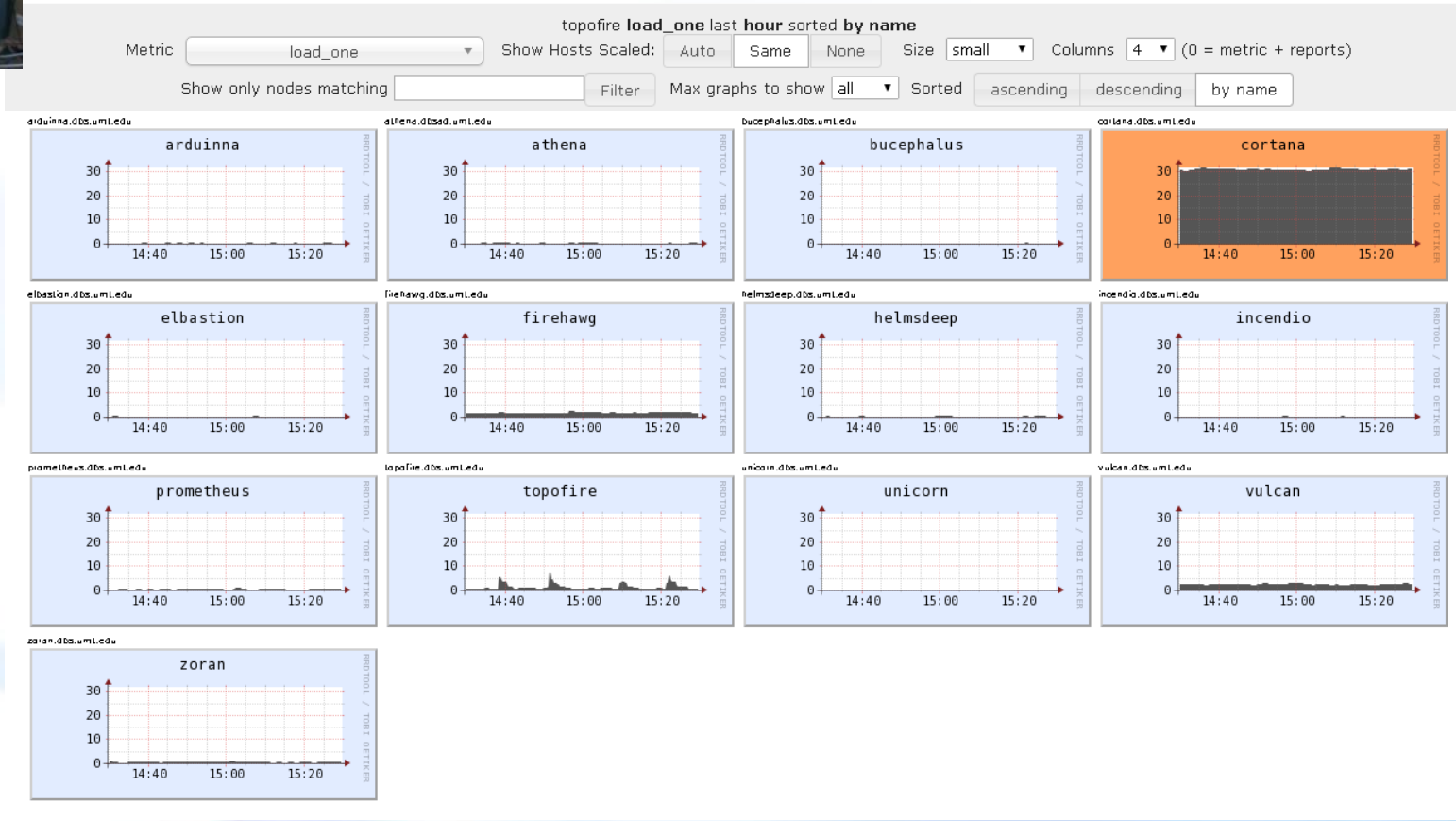
http://hs.umt.edu/dbs/labs/cel/

Allen Warren
Hardware/
software
engineer

416
cores

1.6 TB
RAM

290 TB
storage



TOPOFIRE technical progress

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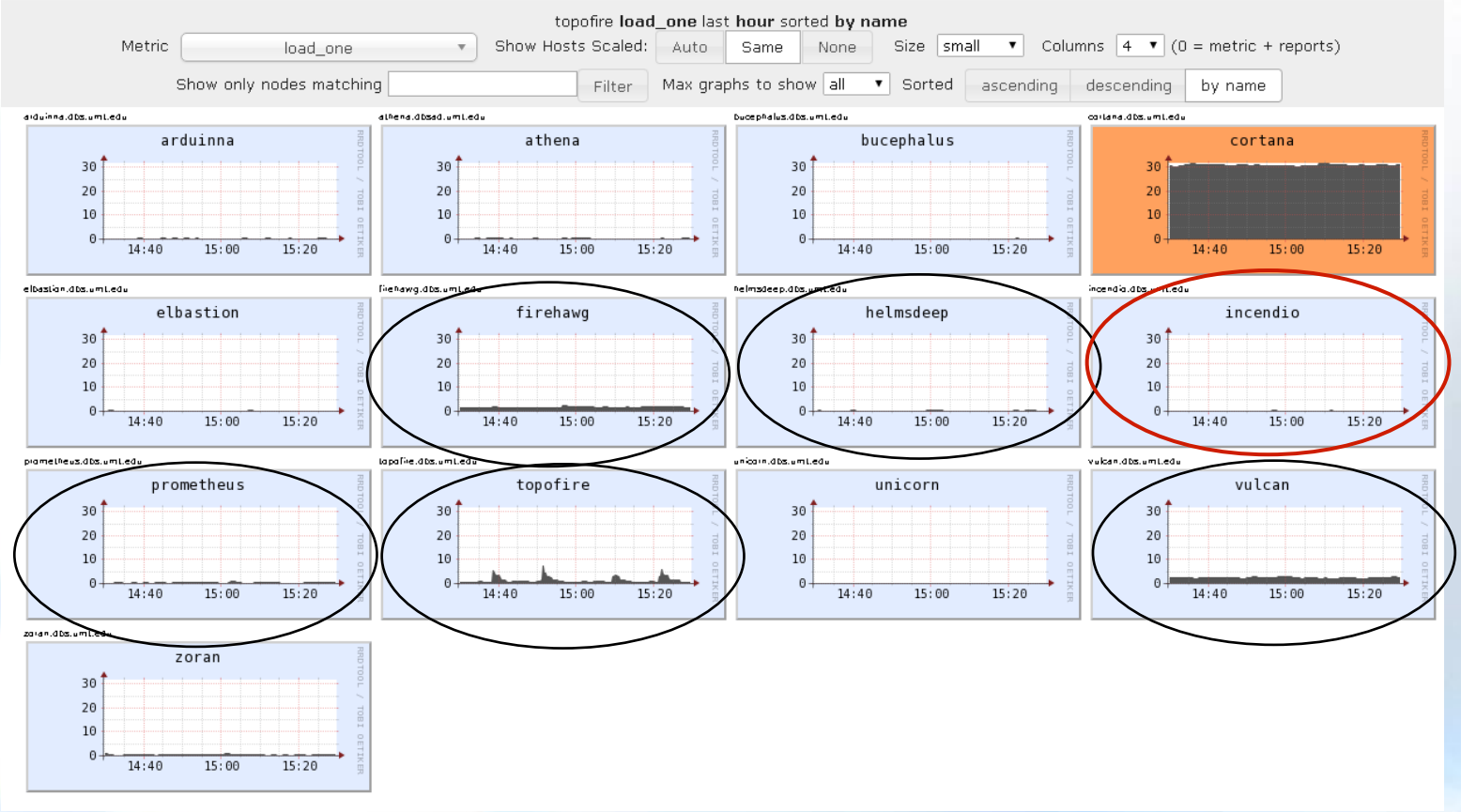
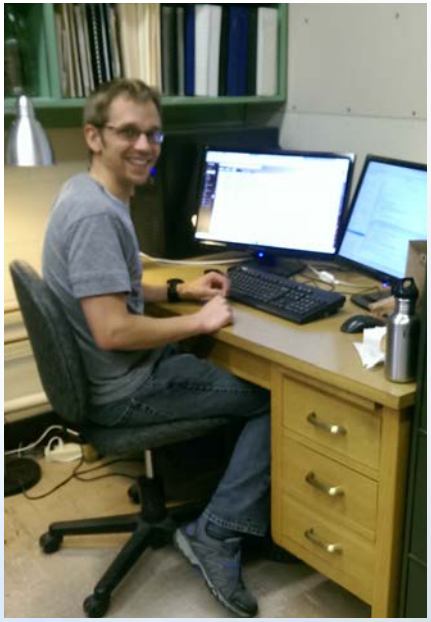


TOPOFIRE weather observation database

52 data providers

- SNOTEL
- RAWS
- GHCN
- National Solar Radiation Database (NSRDB)
- Climate Reference Network (CRN)
- Dept. of Transportation
- Many state Mesonets

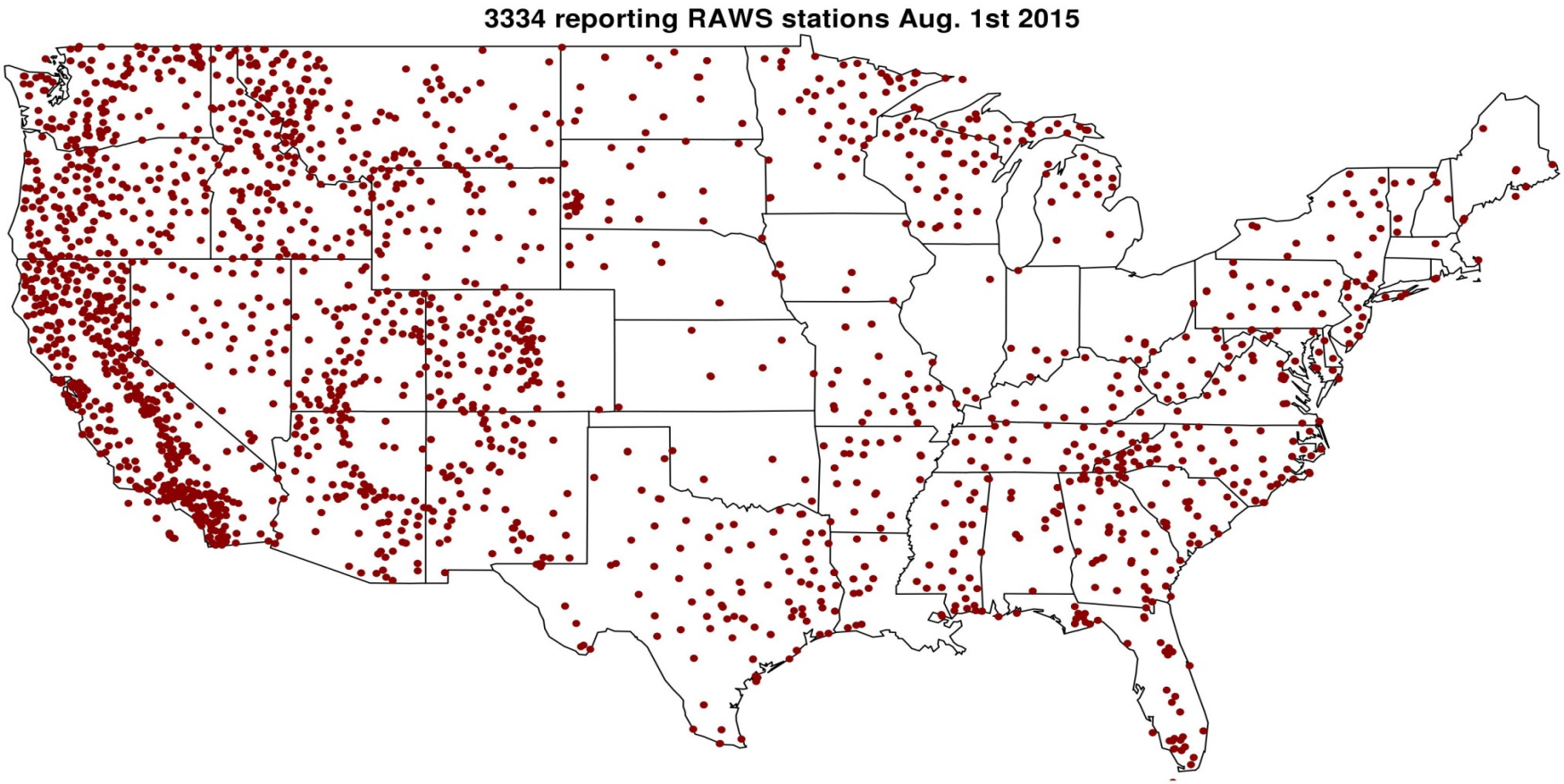
- Python package for data assimilation



Jared Oyler
Software engineer / Post doc

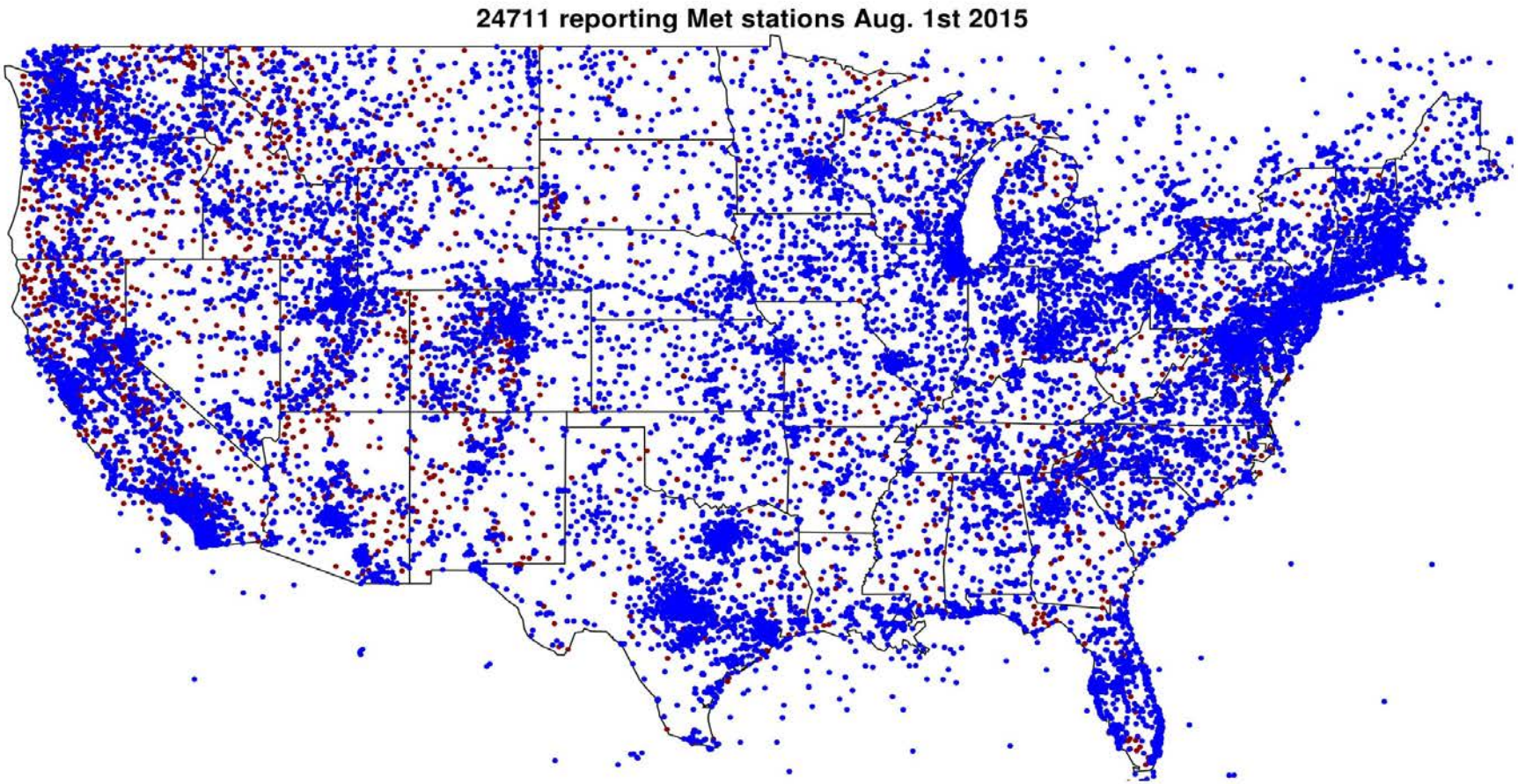
TOPOFIRE technical progress: weather obs. database

TOPOFIRE weather obs database



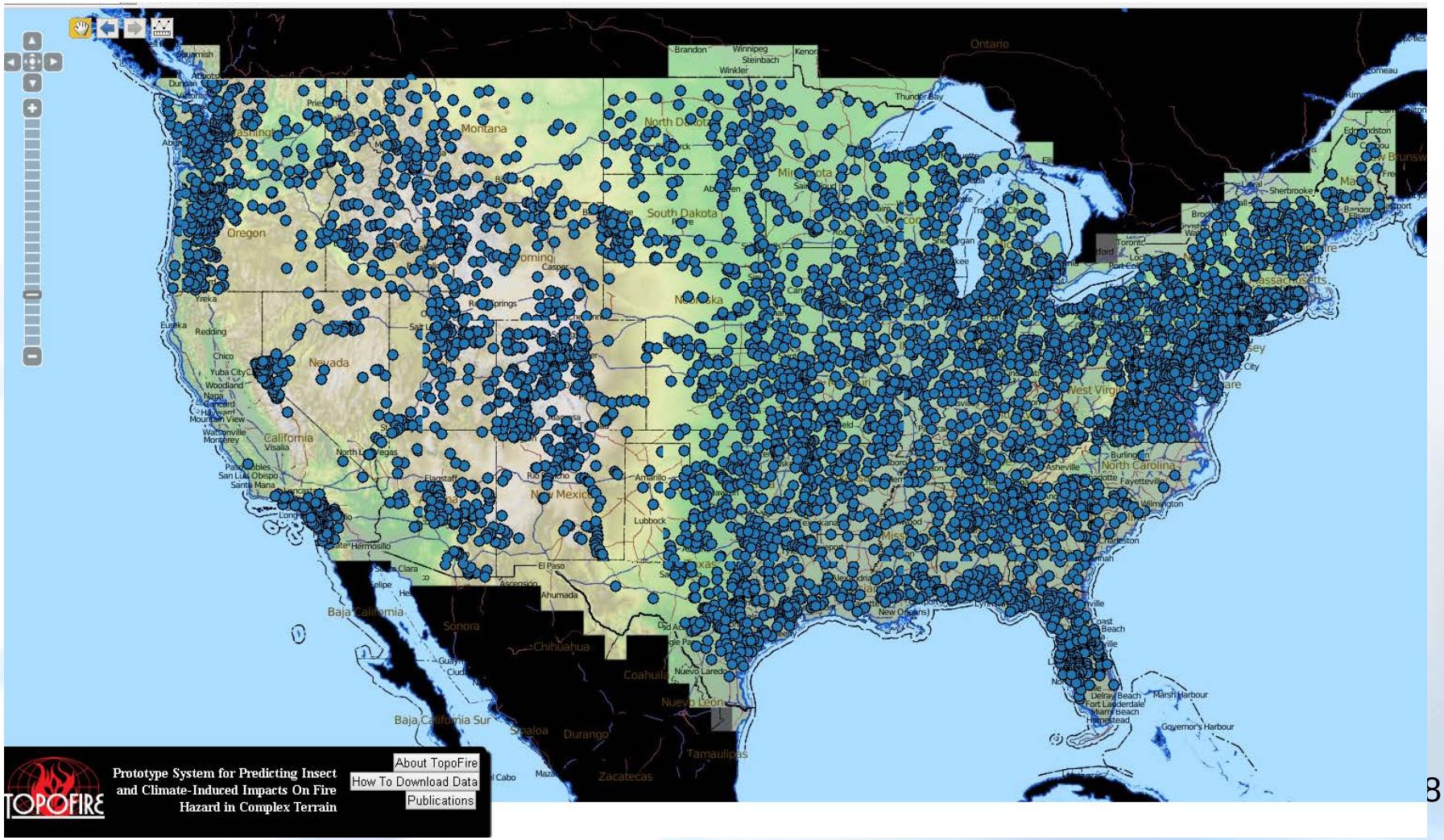
TOPOFIRE technical progress: weather obs. database

TOPOFIRE weather obs database



TOPOFIRE technical progress: weather obs. database

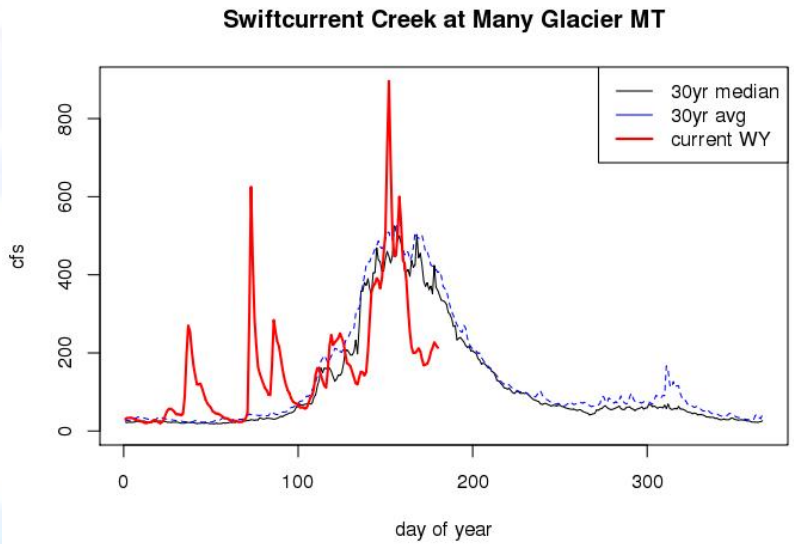
Snowpack and streamflow visualizations



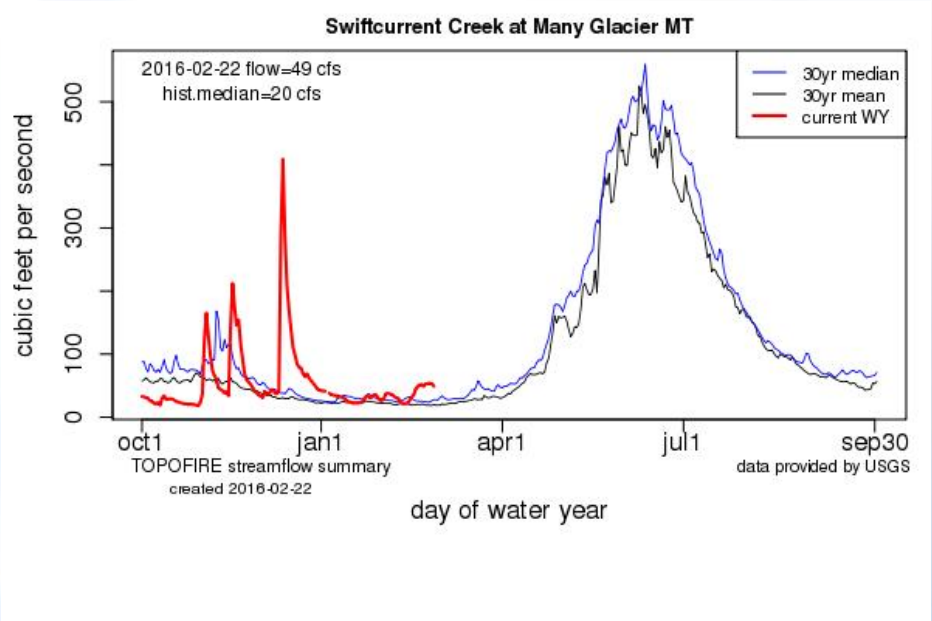
TOPOFIRE technical progress: weather obs. database

Early hydrologic indicators of fire season moisture availability

July 5th 2015 streamflow hydrographs



February 22th 2016 hydrographs



Daily PDF summary by GACC

Prototype System for Predicting Insect and Climate-Induced Impacts On Fire Hazard in Complex Terrain

National Code:NR06
PSA Name:N. Central Idaho & Bitterroot/Sapphire Mountains
GACC:Northern Rockies

Snow Extent for:2016-02-10
Snow Extent Avg for:2016-02-10

```
MODIS Snow Extent:
------------------
GACC ID:258
Current Snow Extent:0.81
12 Year Mean:0.84
Percent of Normal:0.97
```

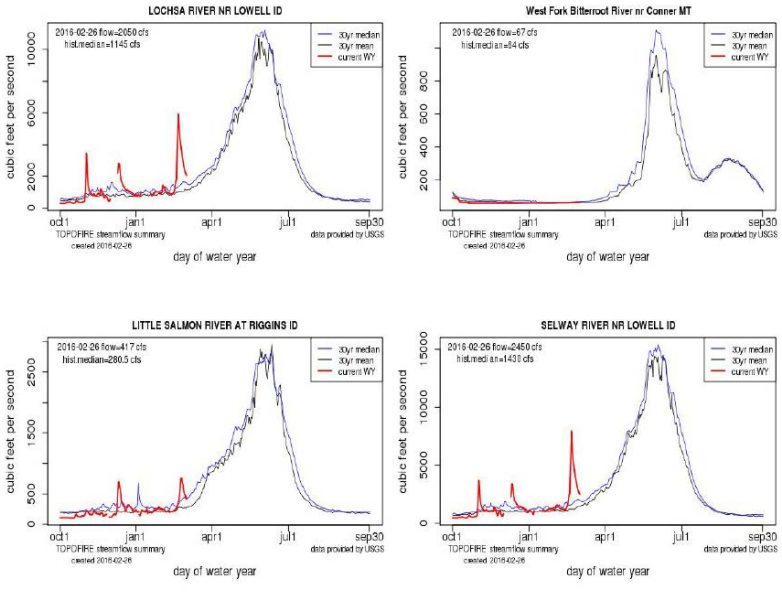
NDVI for:2016-02-02
NDVI Avg for:2012-02-02

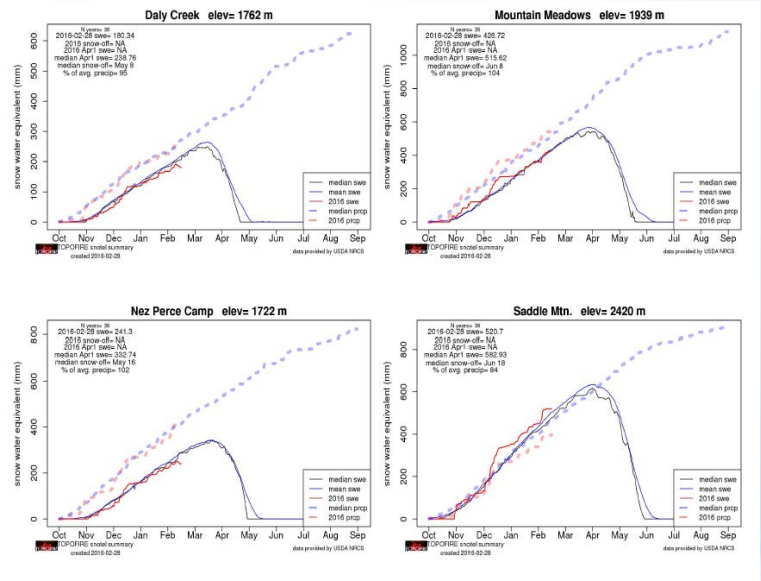
```
Relative Greenness:
------------------
GACC ID:258
Current Greenness Avg:2844.84
Historical Greenness Average:2728.46
Relative Greenness:1.04
```

Area Beetle Kill:2016-02-02

```
Beetle Kill:
------------------
GACC ID:258

Last Import Date:2011
Area Beetle Kill Hectares:1163.52
Area Beetle Kill Acres:2875.06
```

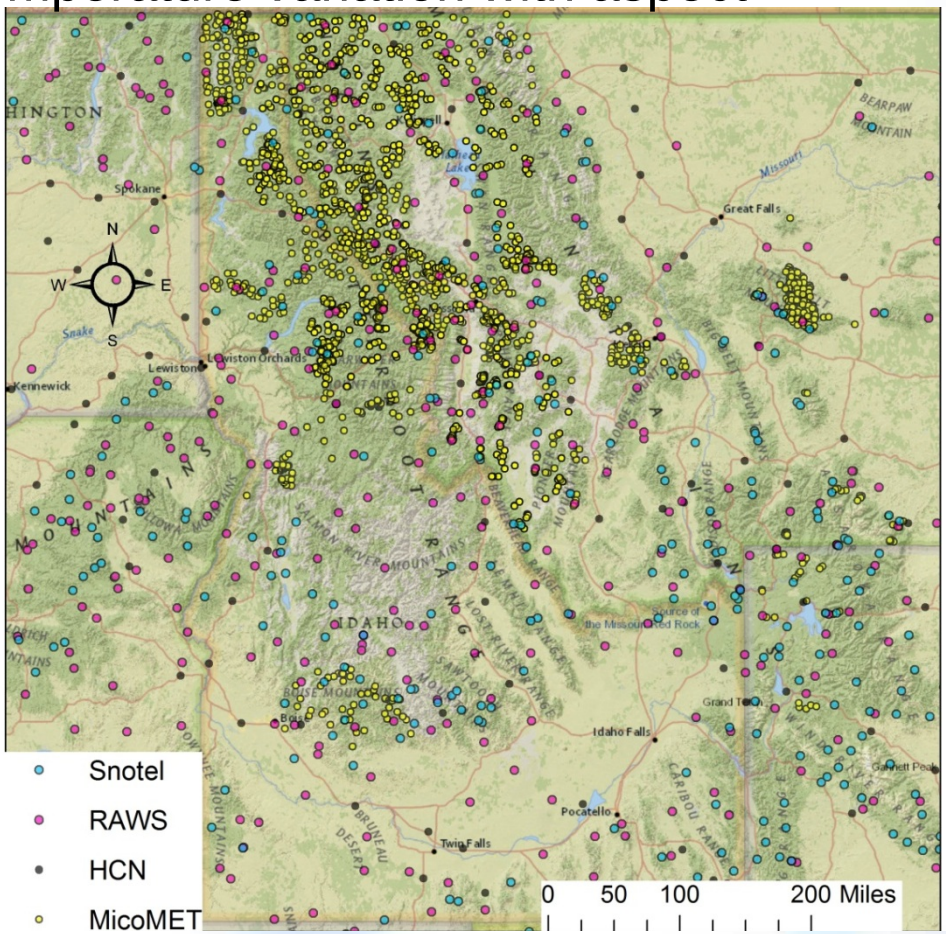




TOPOFIRE technical progress: weather obs. database

Massive microclimate sampling with low-cost sensors

Critical obs. For estimating temperature variation with aspect



Contents lists available at SciVerse ScienceDirect

Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet

Short communication

Design and evaluation of an inexpensive radiation shield for monitoring surface air temperatures

Zachary A. Holden[a,*], Anna E. Klene[b], Robert F. Keefe[c], Gretchen G. Moisen[d]

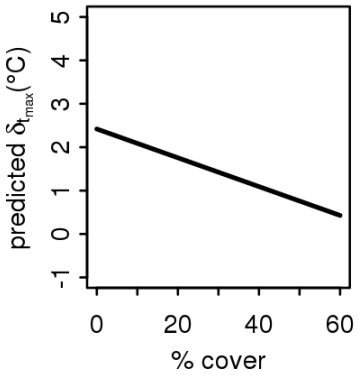
[a] USDA Forest Service, Missoula, MT 59807, United States
[b] University of Montana, Department of Geography, Missoula, MT 59812, United States
[c] University of Idaho, College of Natural Resources, Moscow, ID 83843, United States
[d] USDA Forest Service Rocky Mountain Research Station, Ogden, UT 84401, United States

INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. (2015)
Published online in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/joc.4580

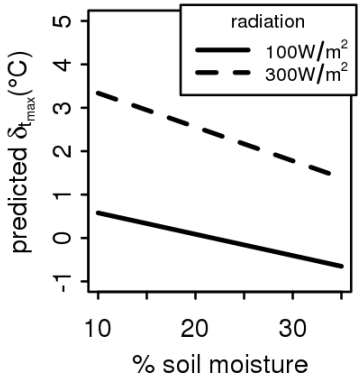
Development of high-resolution (250 m) historical daily gridded air temperature data using reanalysis and distributed sensor networks for the US Northern Rocky Mountains

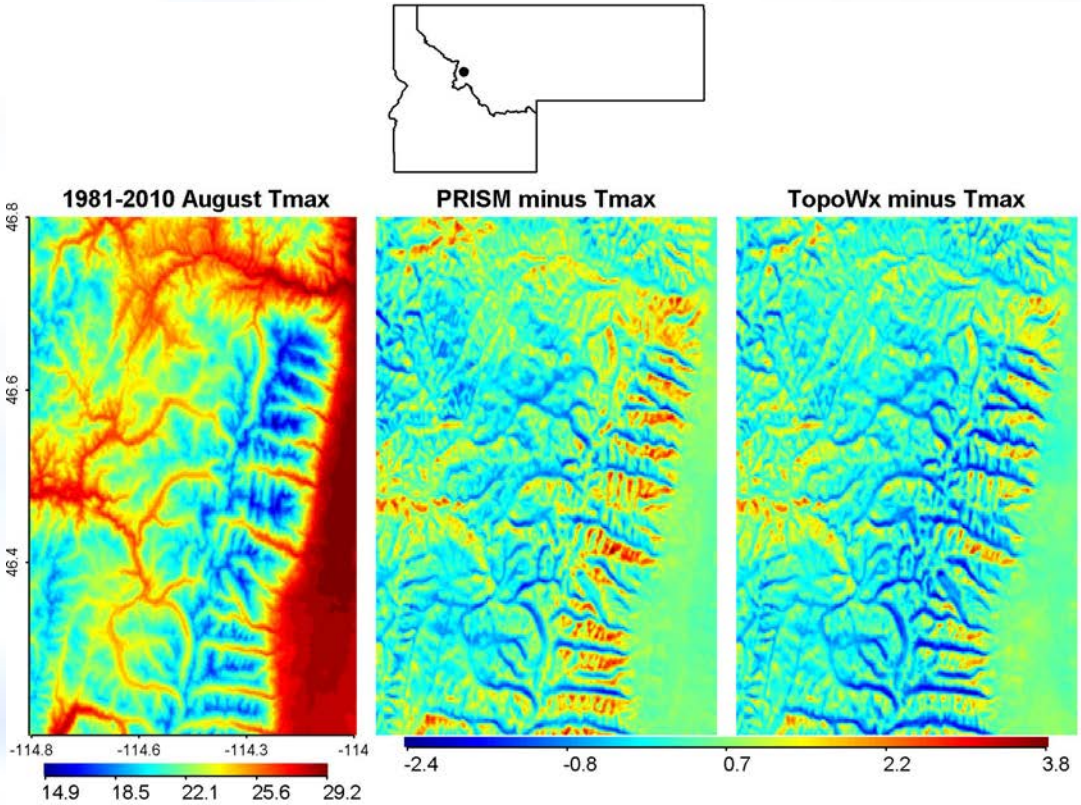
Zachary A. Holden,[a,b]* Alan Swanson,[b] Anna E. Klene,[b] John T. Abatzoglou,[c] Solomon Z. Dobrowski,[d] Samuel A. Cushman,[e] John Squires,[f] Gretchen G. Moisen[g] and Jared W. Oyler[h]

MODIS VCF



Solar x soil

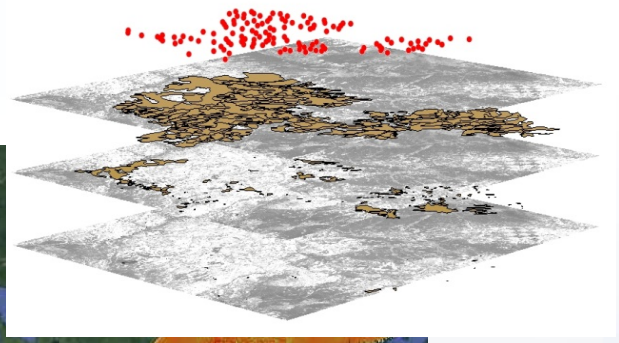


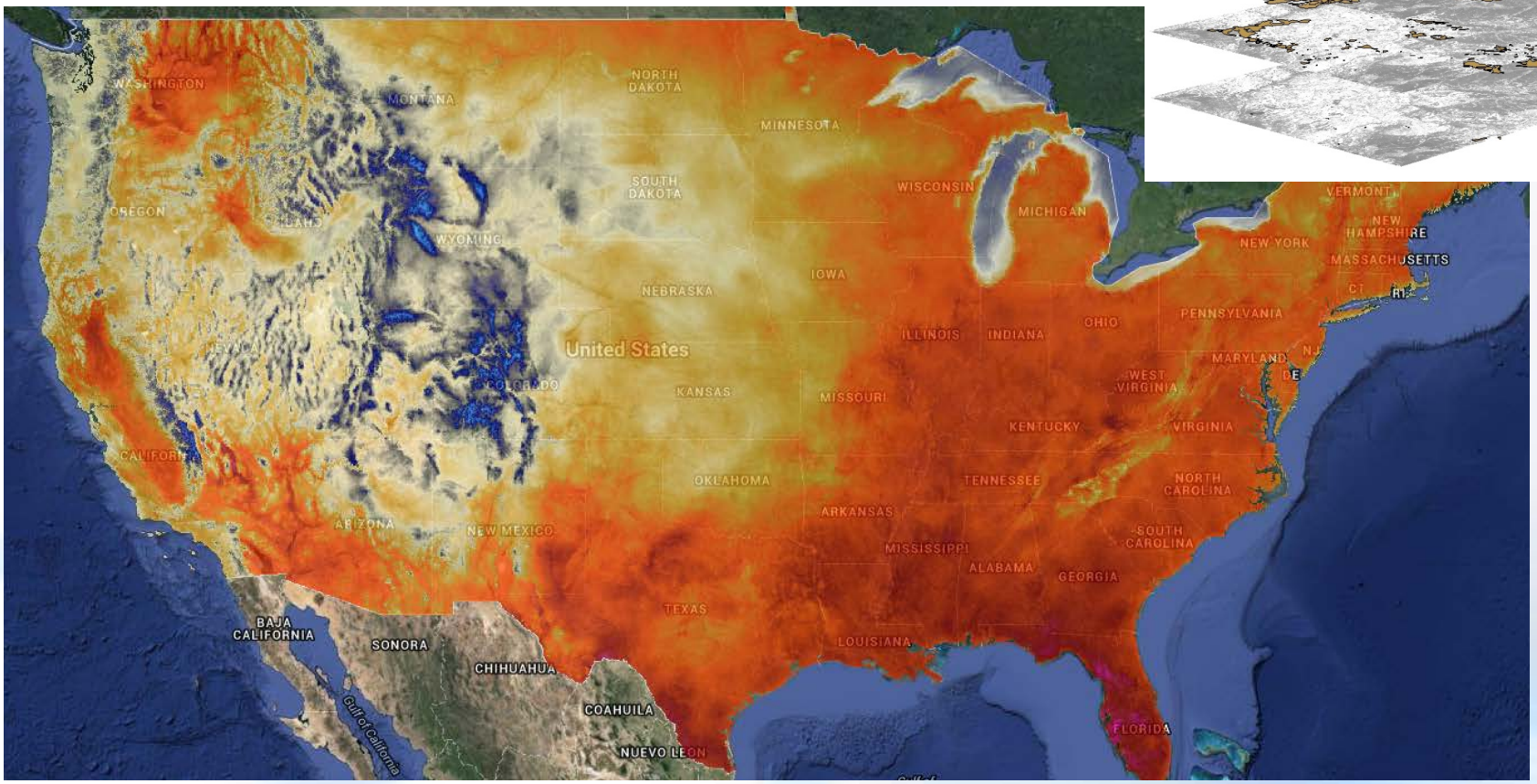


Temperature/humidity models for CONUS

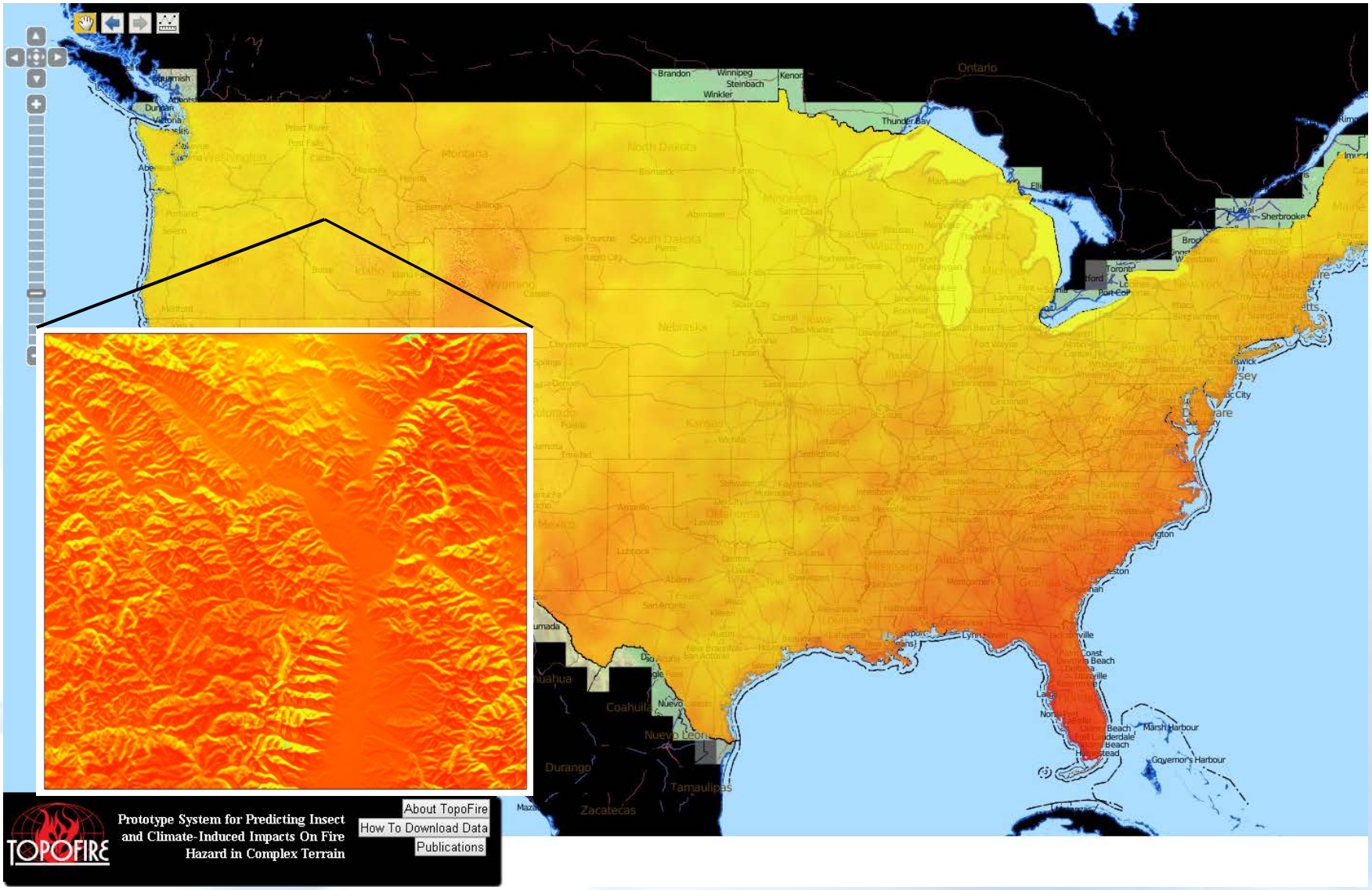
NOAA Climate Forecast System Reanalysis (CFS)

global hourly data from 1979-present + forecasts
42 Pressure levels (geopotential heights)
0.5 degree resolution



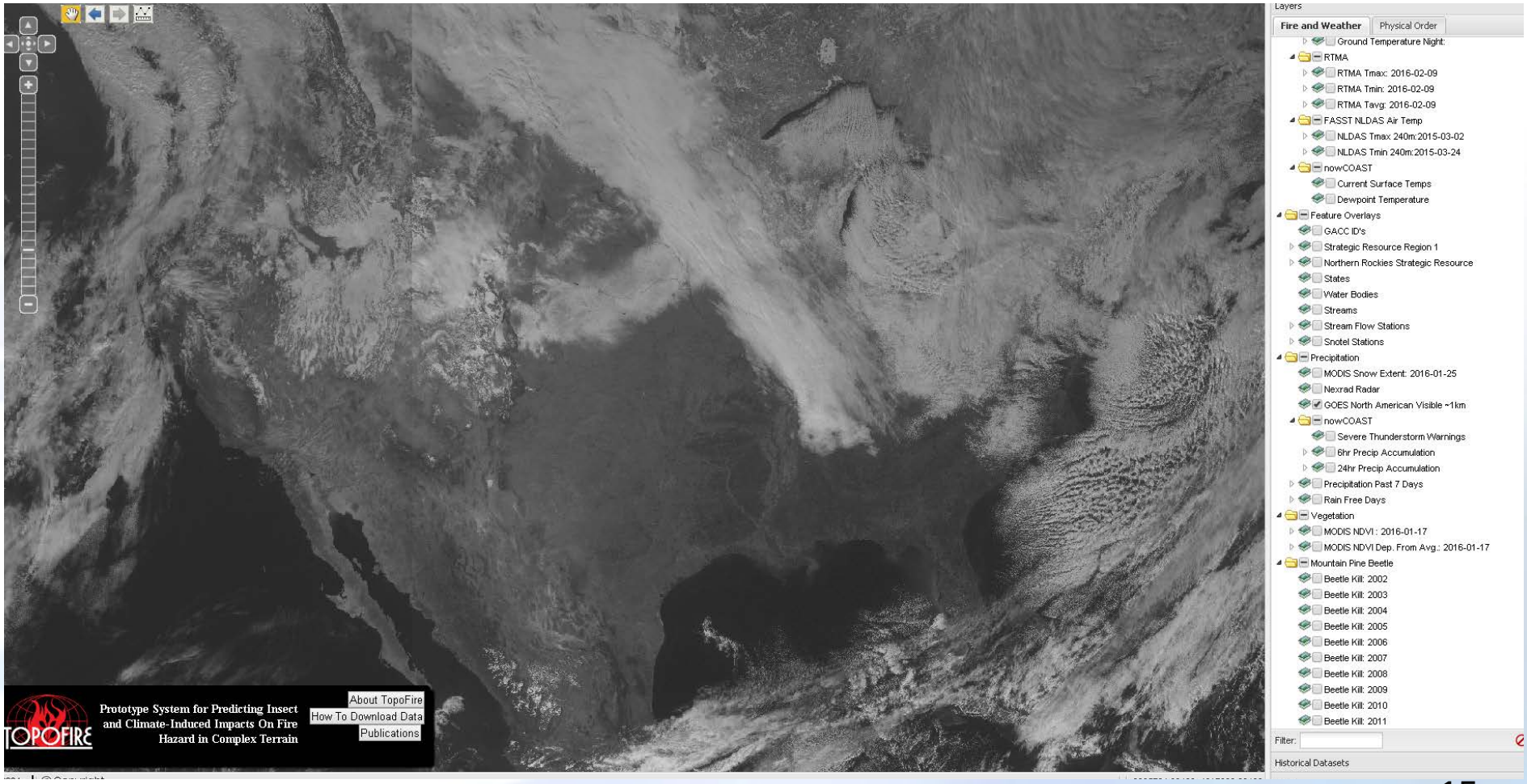


Daily cloud/shade corrected solar radiation climatology (1979-present)



Daily cloud and shade corrected solar radiation (1979-present)

Historical data: NLDAS-2 used to partition radiation into direct/diffuse radiation
Real time data: GOES cloud cover



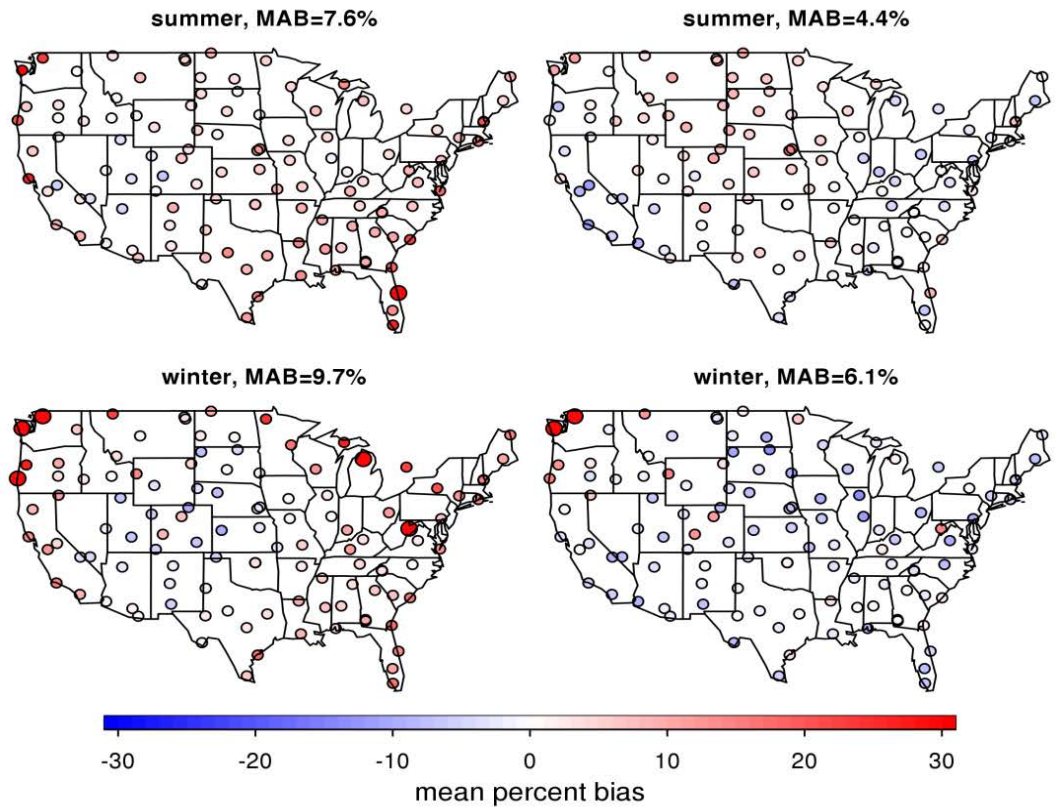
Bias correction of NLDAS-2 data

Reduce mean bias from ~ 8% to ~ 4%

Overal MAE < 20 w/m^2

Alan Swanson
Data scientist / statistician

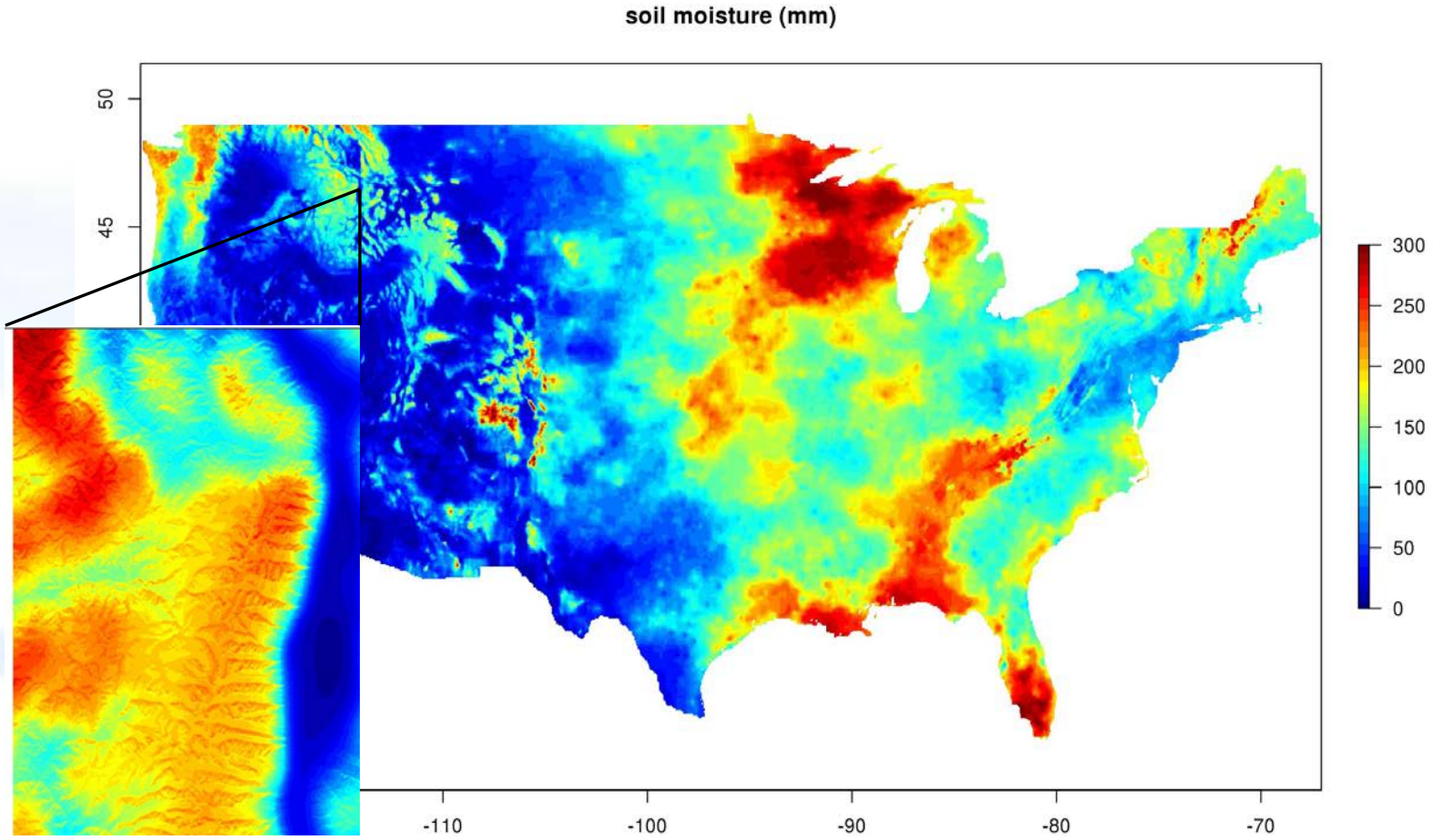
Raw NLDAS-2 data | TOPOFIRE 250 m data



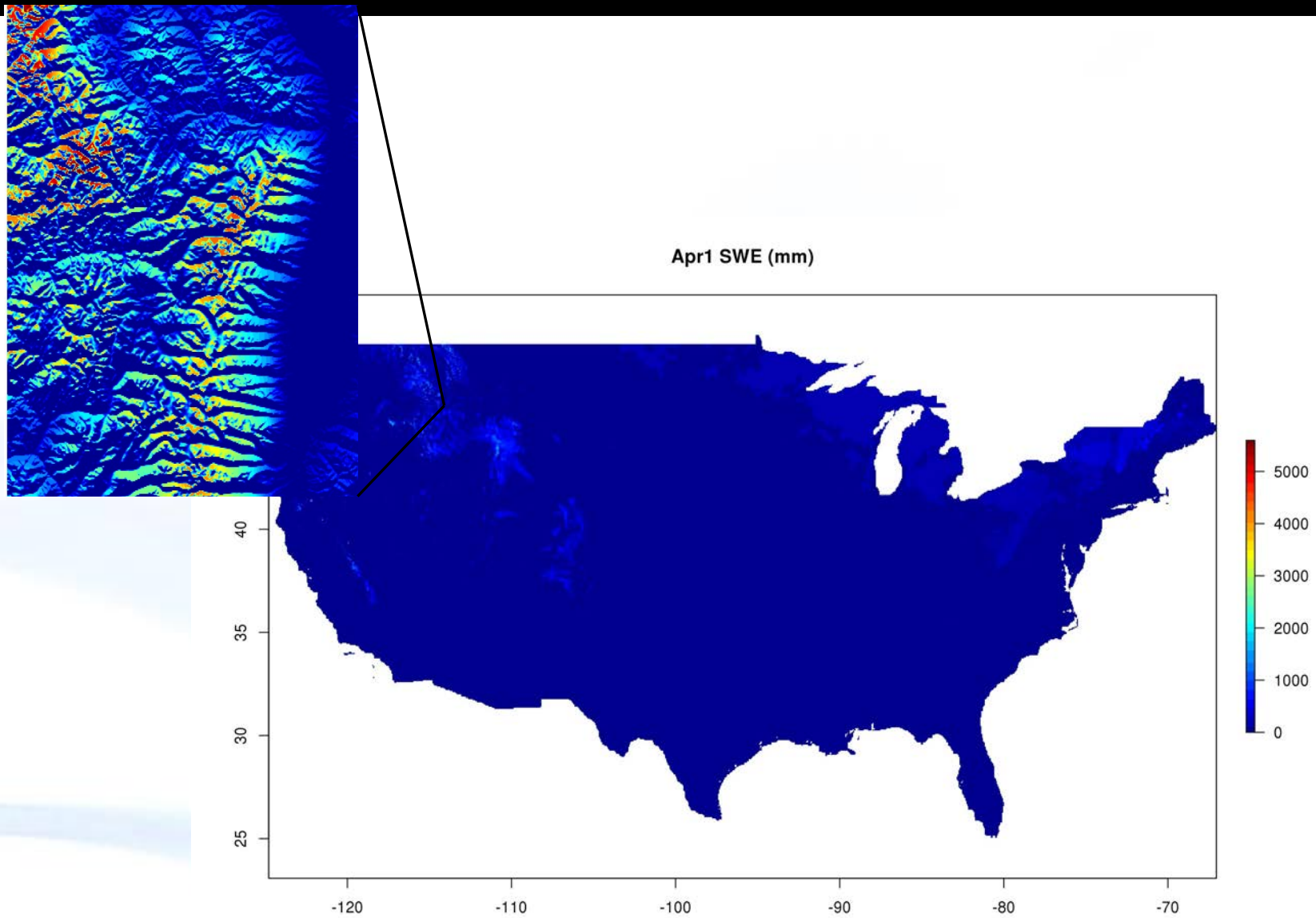
Daily evapotranspiration and soil moisture (1979-present)

Daily Penman-Monteith evapotranspiration

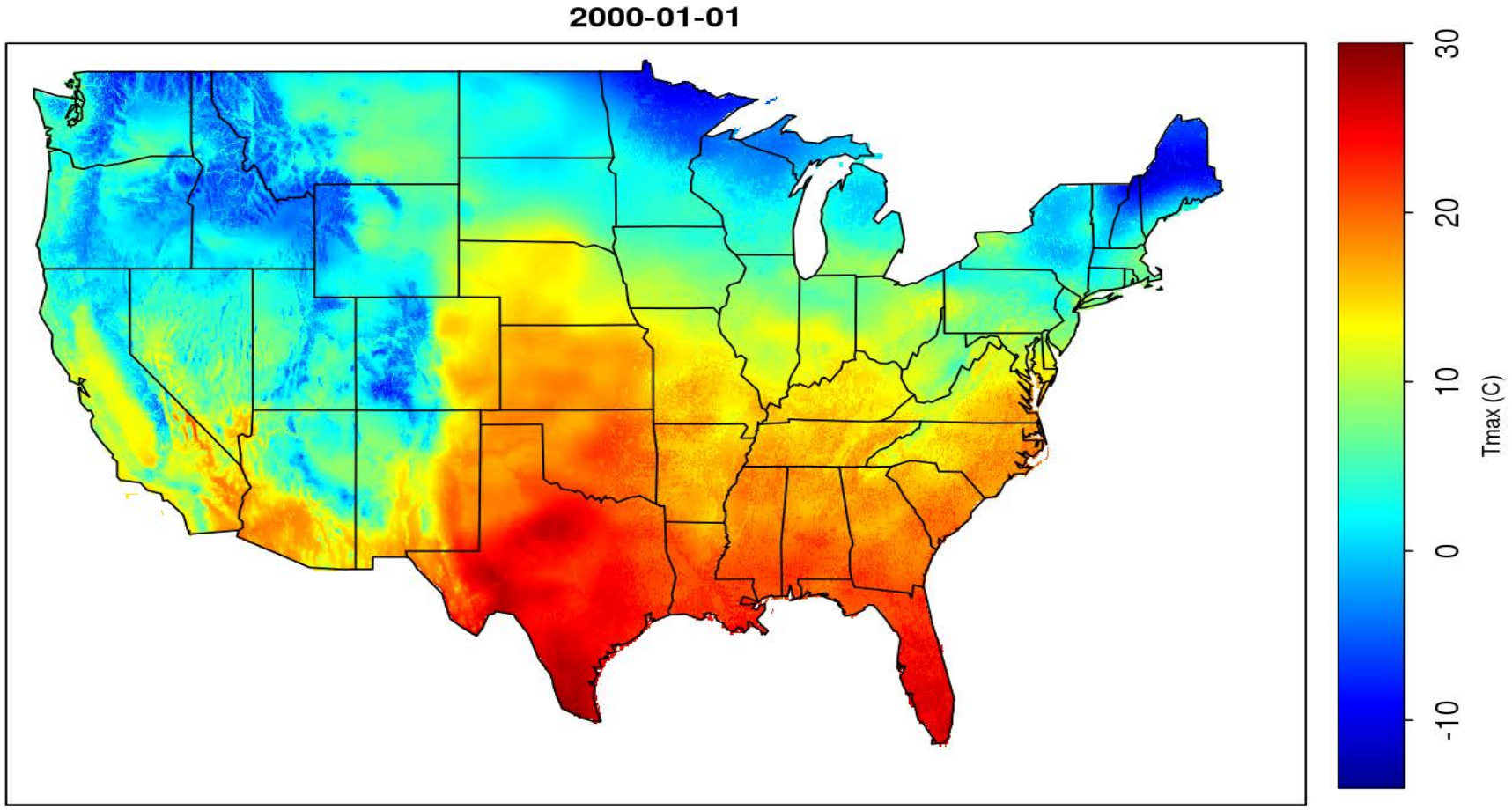
-250 m resolution, including solar radiation
-Strong aspect differences/drier south facing slopes



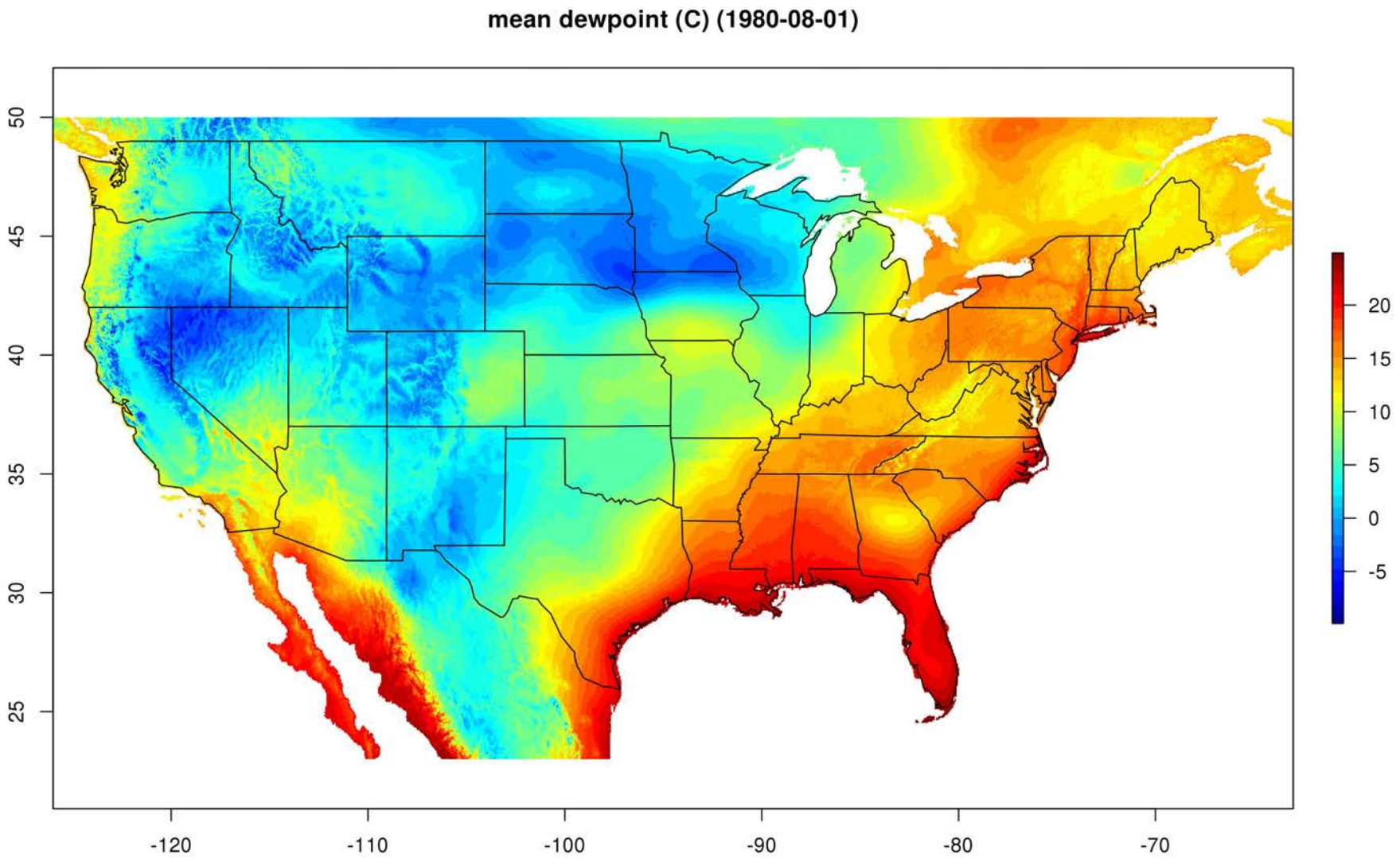
Daily snow accumulation and melt model (1979-present)



Daily Minimum/Maximum air temperature (2000-present)



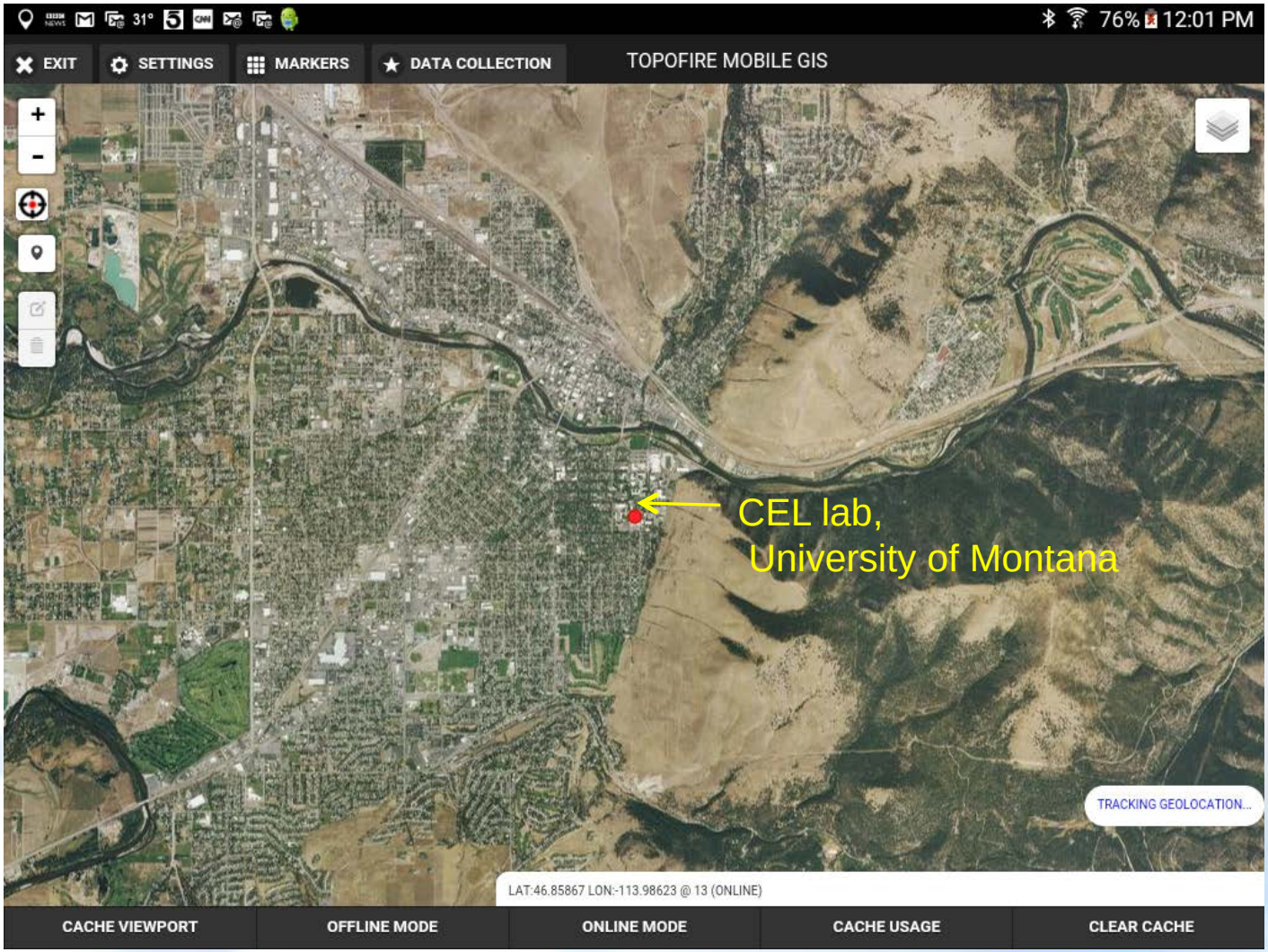
Daily average dewpoint temperature (2000-present)



TOPOFIRE technical progress: mobile GIS

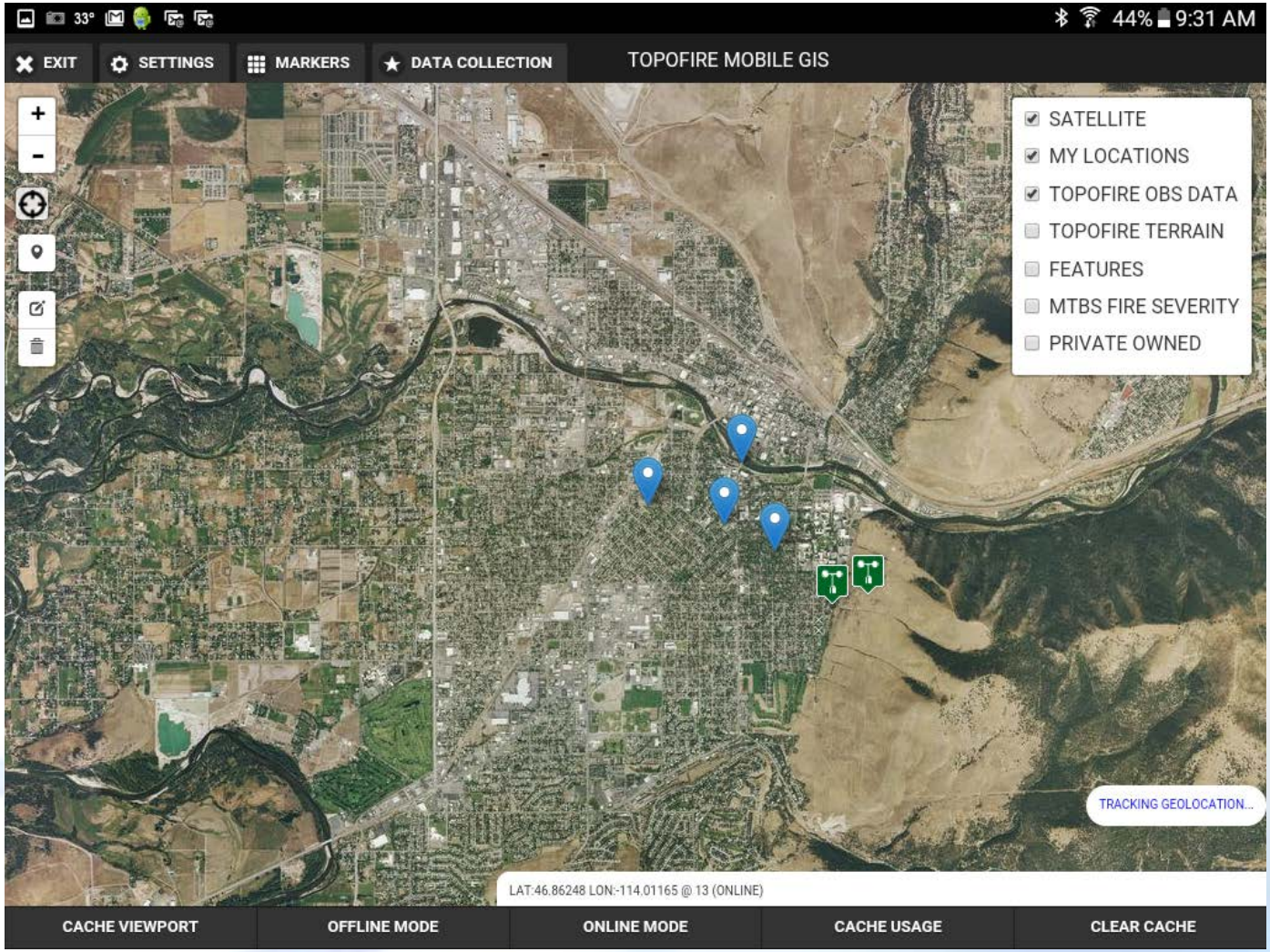
Tracks user location on or offline

Cache data layers – use without cell or network connection



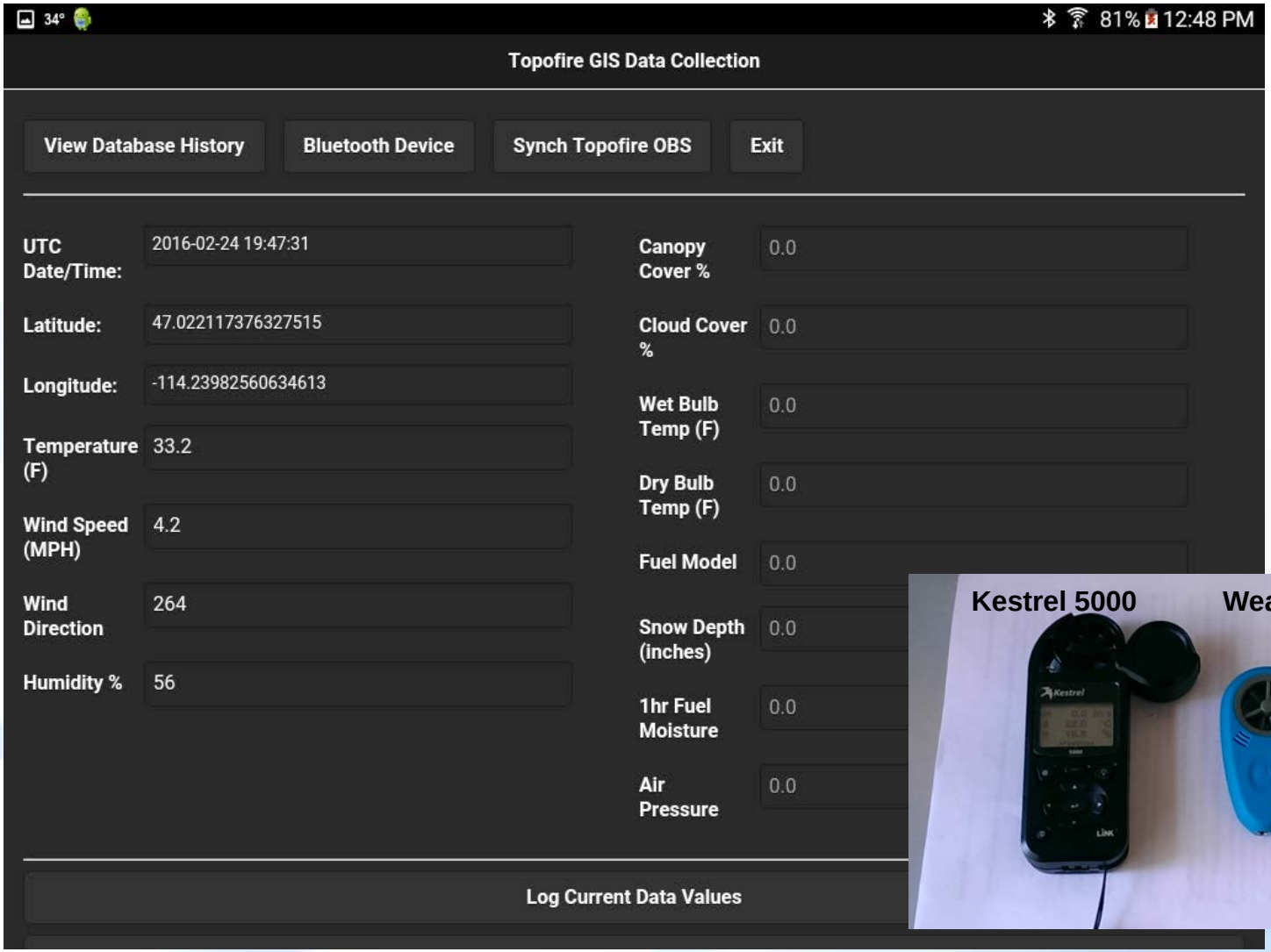
TOPOFIRE technical progress: mobile GIS

Place waypoints with labels and attach pictures



TOPOFIRE mobile GIS

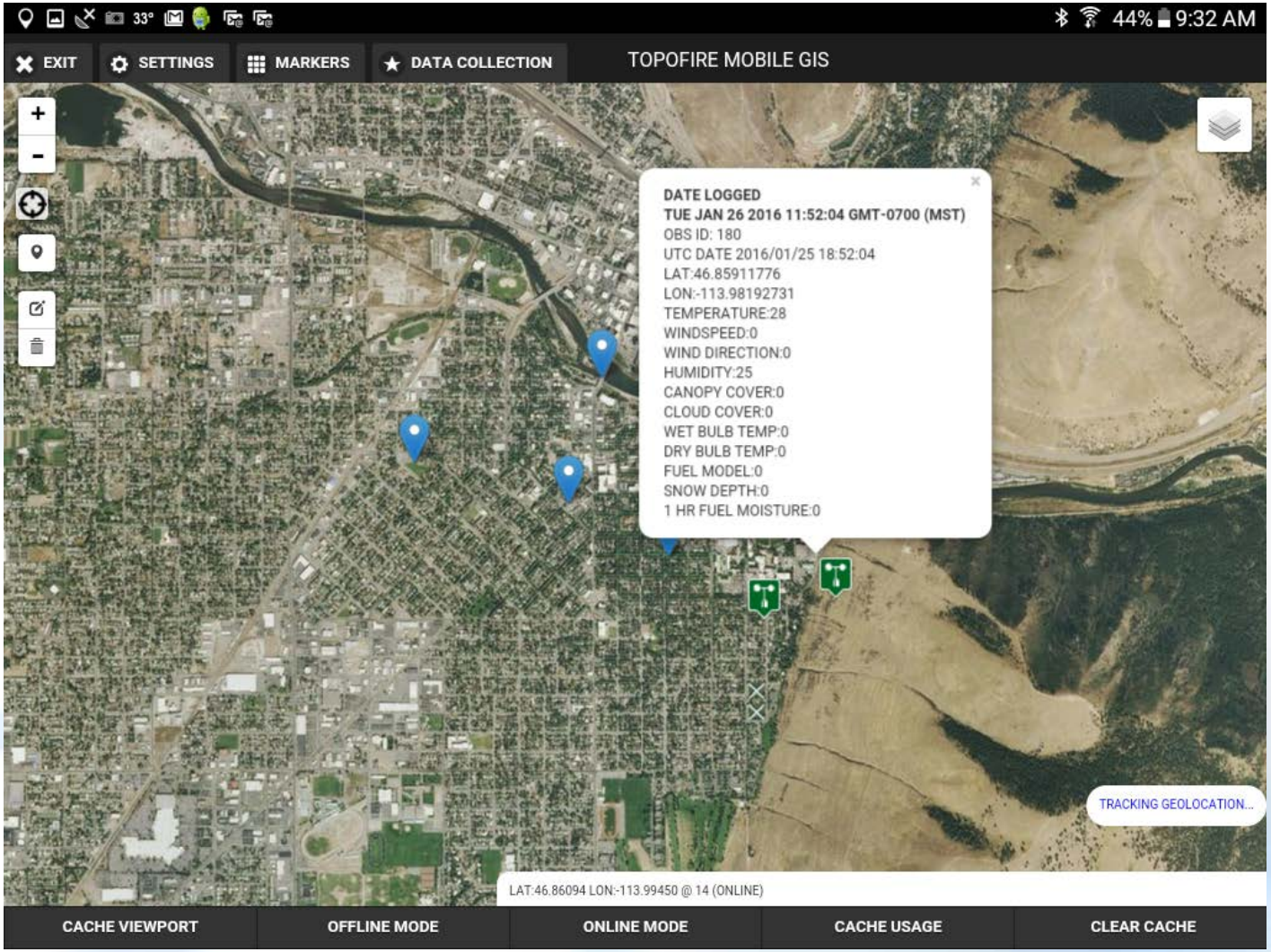
Collect fire weather observations manually or with Kestrel / bluetooth
Observations are synced and stored in TOPOFIRE database.



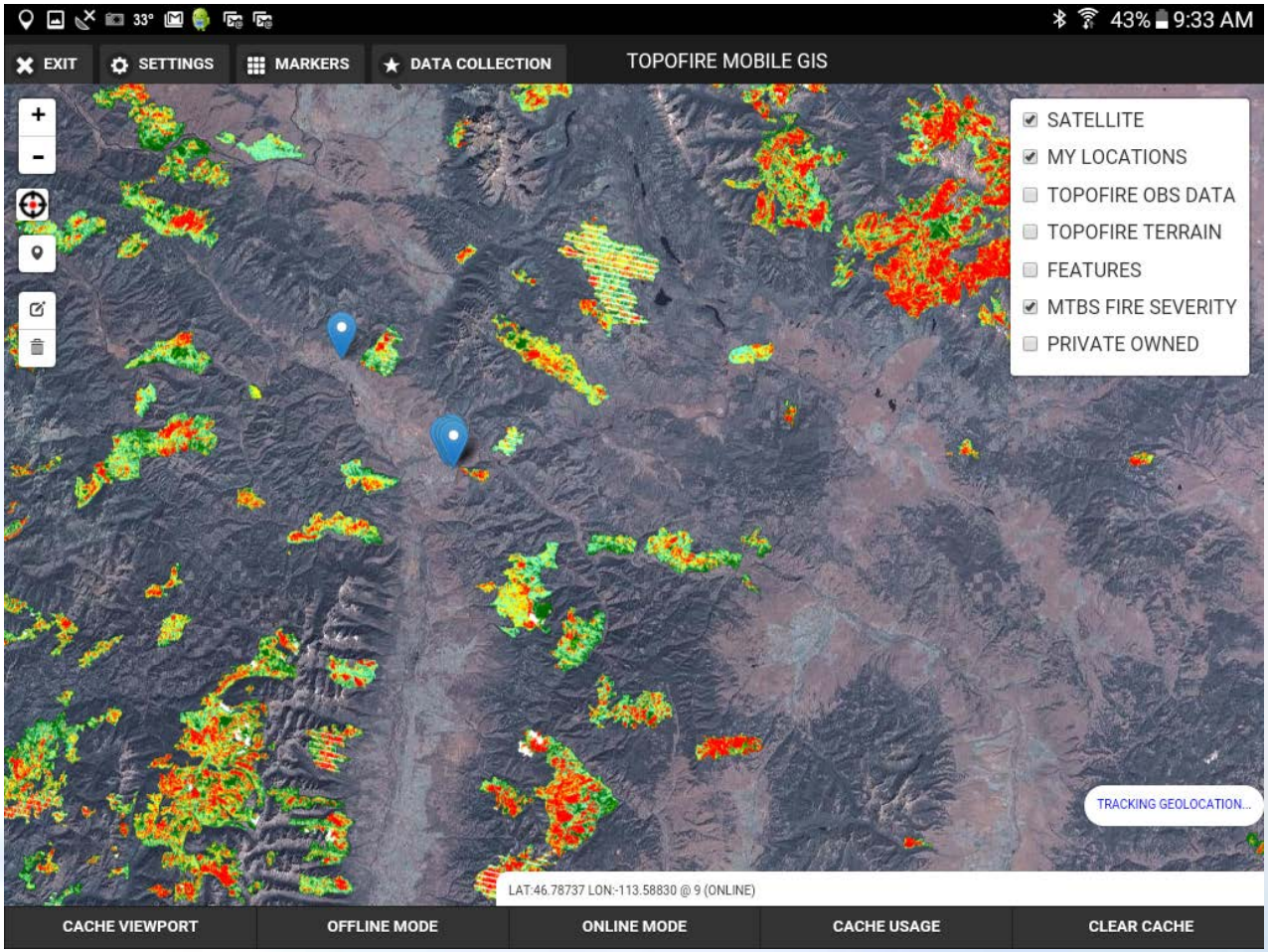
TOPOFIRE mobile GIS

Other users can sync to database, making observations available in real time.

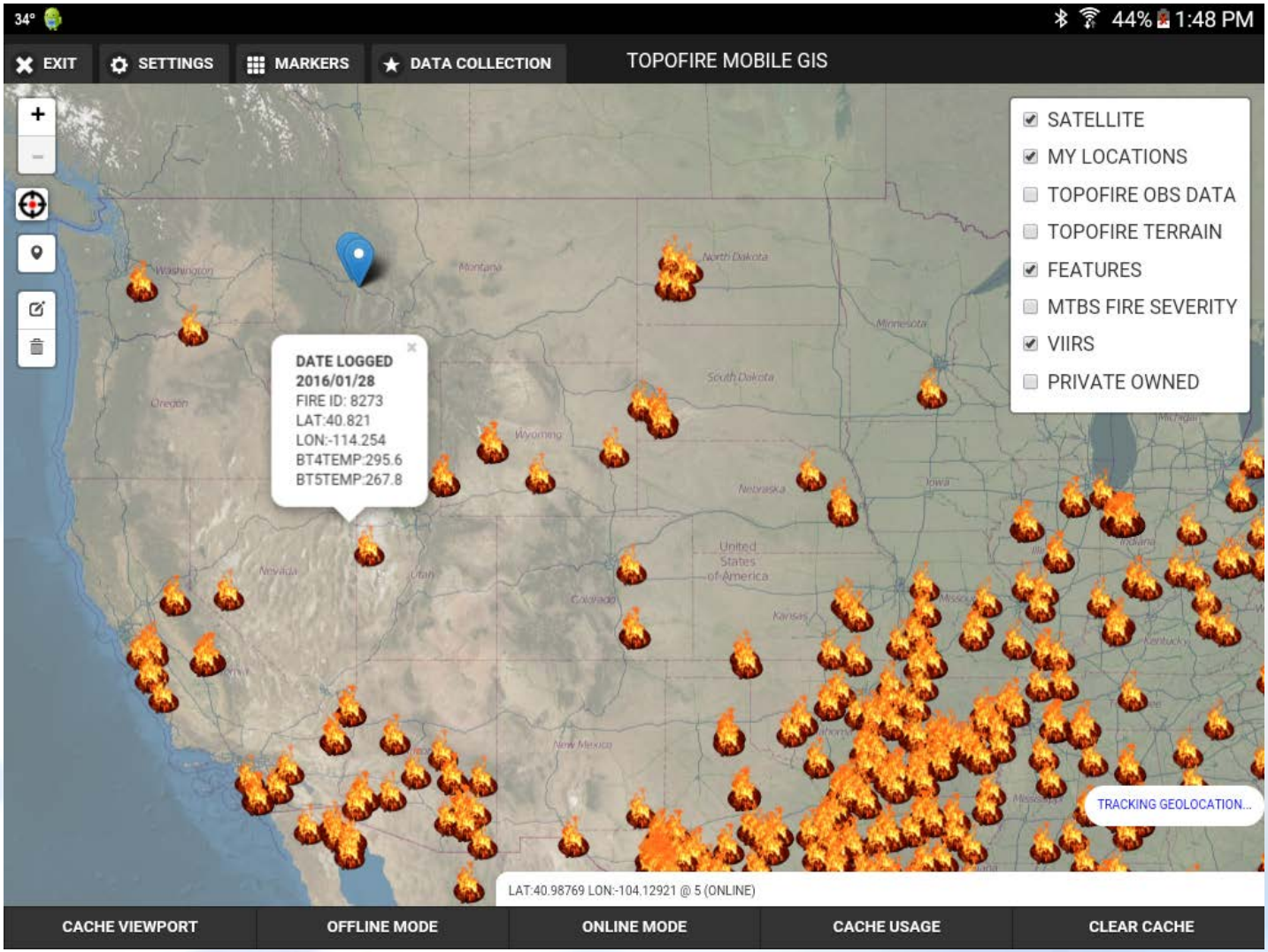
Mobile platform for rapid sharing of data, location and pictures.



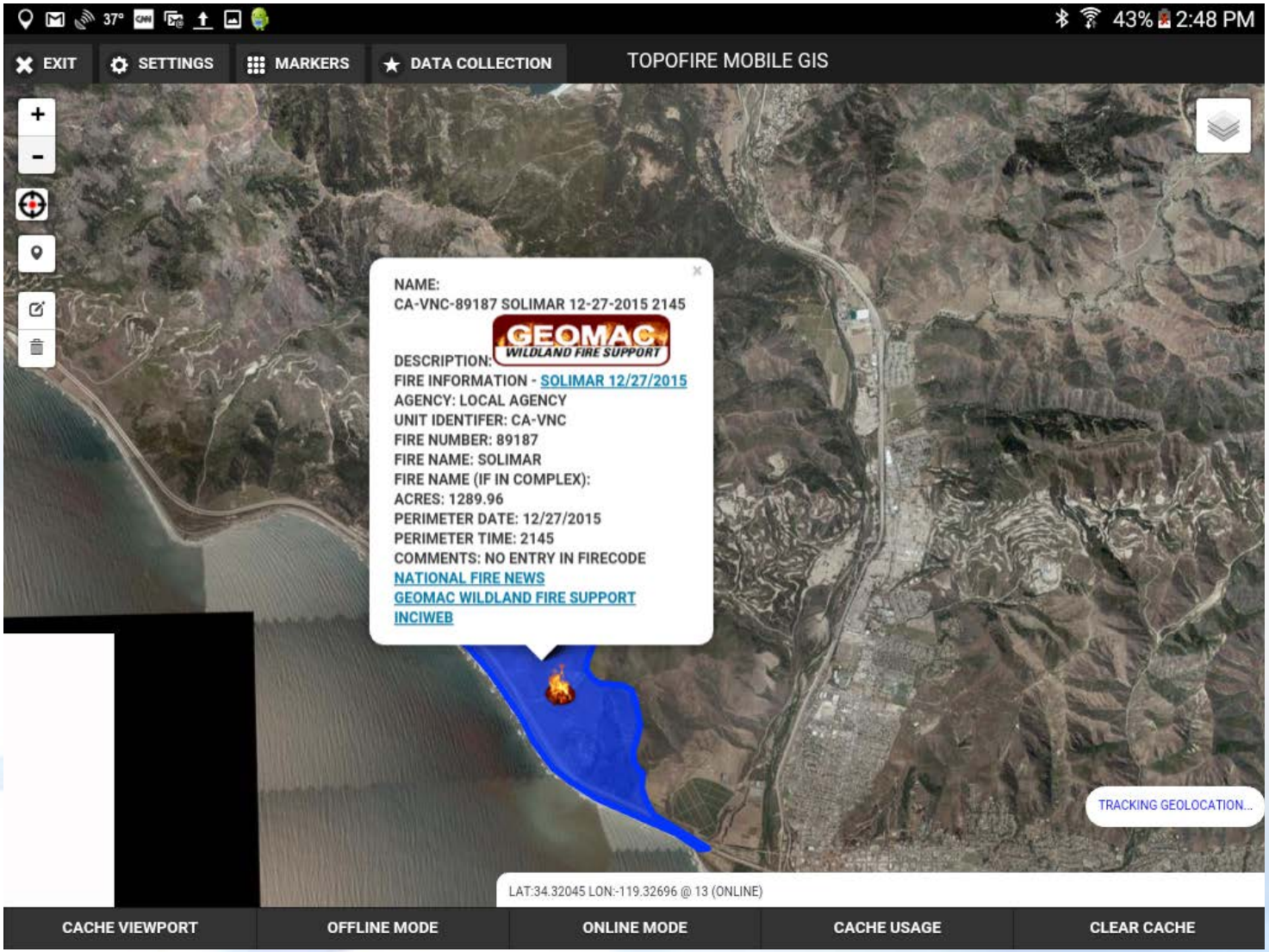
All historical MTBS fires



VIIRS active fires



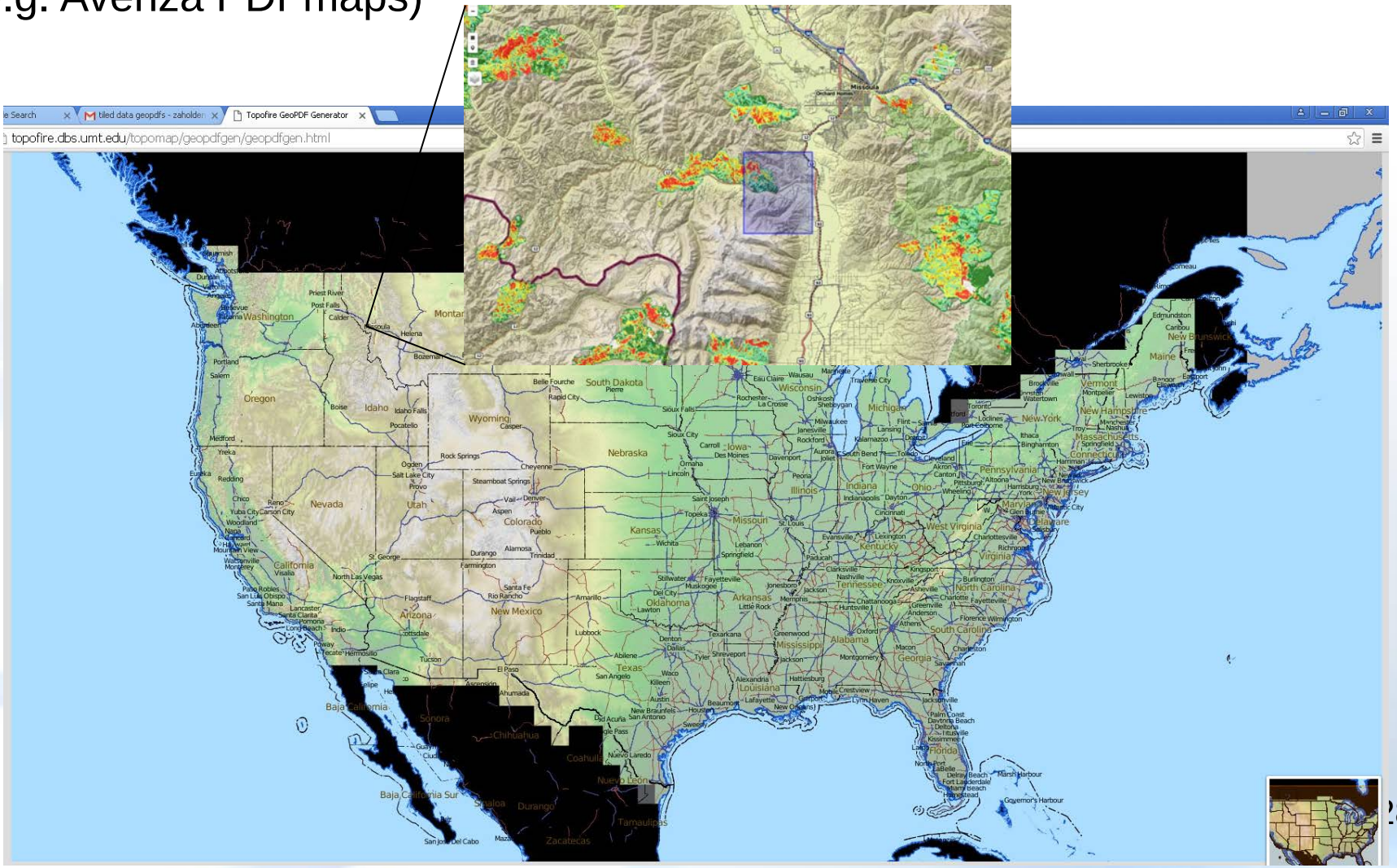
Geospatial multiagency coordination fire polygons



TOPOFIRE geoPDF generator

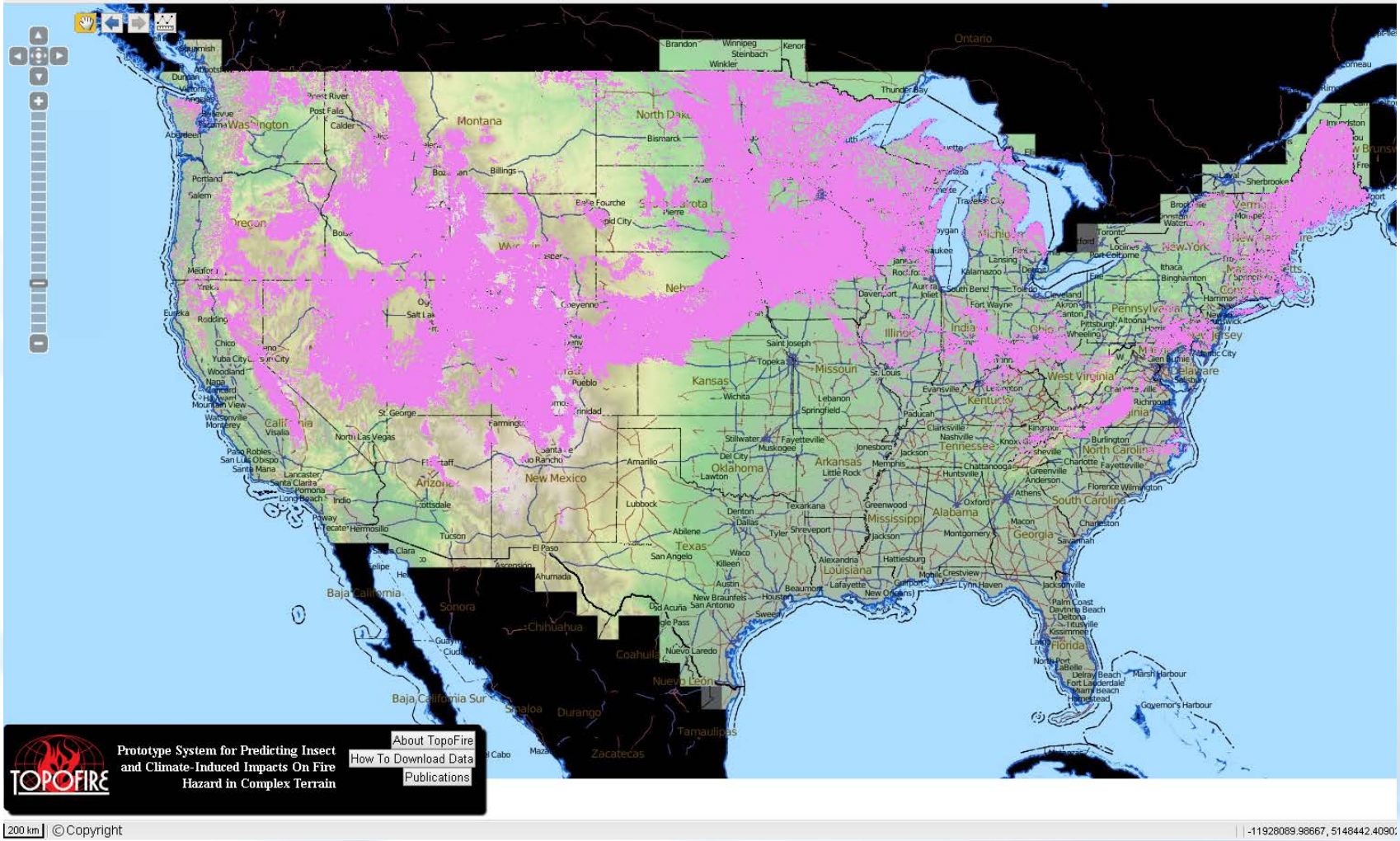
http://topofire.dbs.umt.edu/topomap/geopdfgen/geopdfgen.html

Generate custom georeferenced PDF maps for use in other applications (e.g. Avenza PDFmaps)



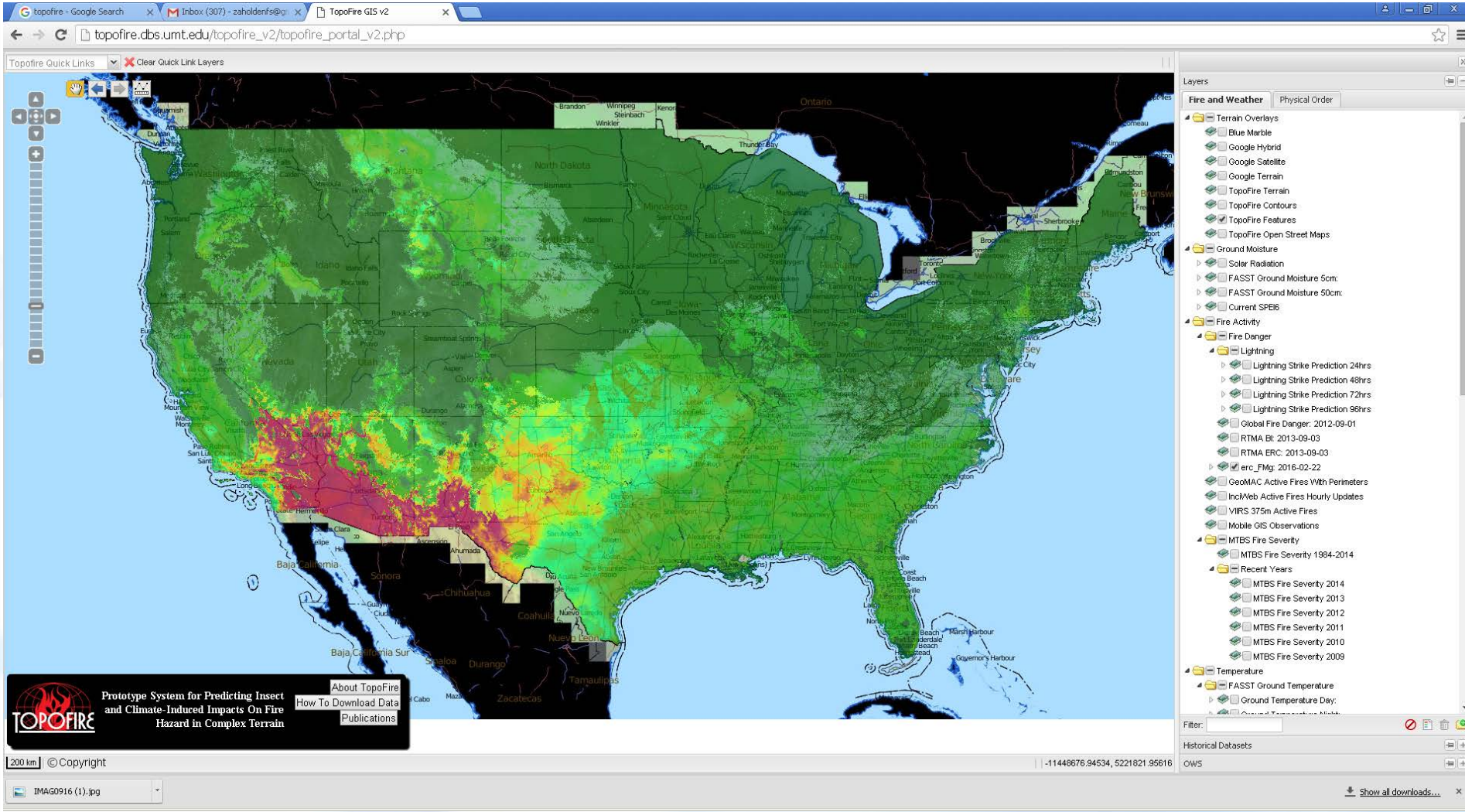
Fire danger accounting for presence of snow (MODIS)

MODIS snow extent (500 meter resolution) as of February 24th 2016



Fire danger accounting for presence of snow (MODIS)

Fire danger calculations by Matt Jolly (Real Time Mesoscale Analysis)



TOPOFIRE project challenges

Operational use of NASA datasets

NLDAS, MODIS **snow extent**, MODIS Vegetation Indices have delays in availability

NASA MERRA reanalysis not operational

Makes developing operational products using NASA data difficult

TOPOFIRE project challenges: Managing big data

Expected datasets (CONUS daily, 1979-present 250 meter)
6.5 Terrabytes each
Solar Radiation
Tmin
Tmax
VPD
Dewpoint
Min. Relative Humidity
Max. Relative Humidity
ET
Soil Moisture (0-10 cm; 10-30 cm)
Fuel moisture (1,10,100,1000 hr)
Energy Release Component
Burning Index
Land Skin Temperature
Snow

> 120 TB total; Grow by 3-4TB per year

PI Overall Assessment

Summary of Challenges; Problems; Objective Analysis

Many small technical challenges

More effort required to accurately model snow distribution in place of MODIS snow extent

Nothing that will prevent us from meeting project goals.

Summary of Positive Progress

Weather observation database complete

CONUS historical and real time radiation complete

CONUS historical ET/soil moisture grids complete

CONUS daily Tmin/Tmax and RH expected in < 2 weeks

MobileGIS beta version complete, ready for testing

Overall Assessment

Better than expected progress. Operational high resolution fire danger modeling expected by summer 2016.

ARL_{Start} = **4** $ARL_{Most\ Recent}$ = **5** ARL_{Goal} = 9

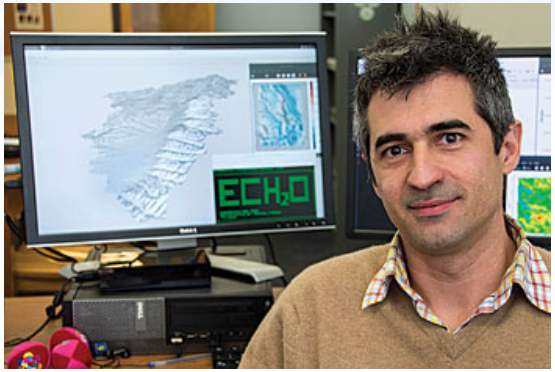
Next Steps and Future Project Progress

Final major project task:

Ecohydrology modeling

ECH20 model

- Soil moisture
- Skin temperature



Marco Maneta, Hydrologist
Geosciences, U. Montana

How can NASA help?

NASA computer support

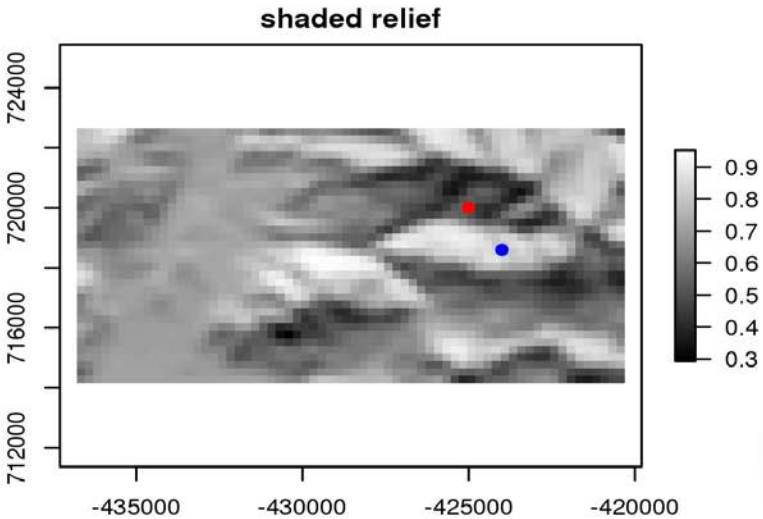
PLIEADES HPC

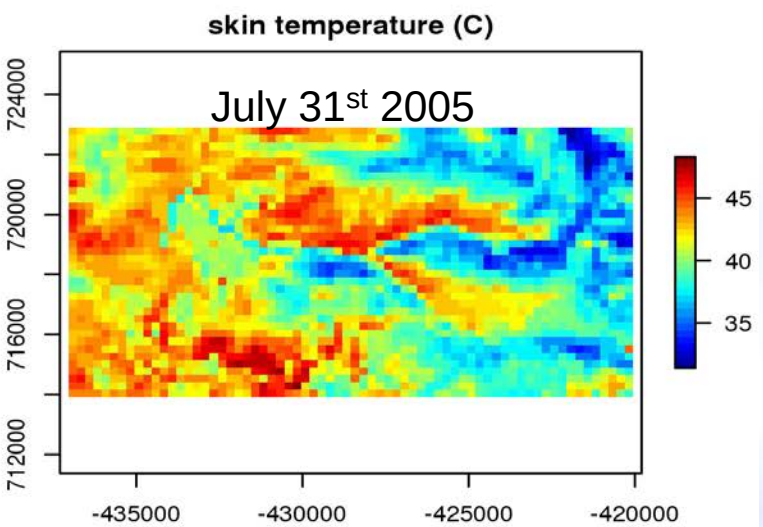
Speed and resource tests being done now.

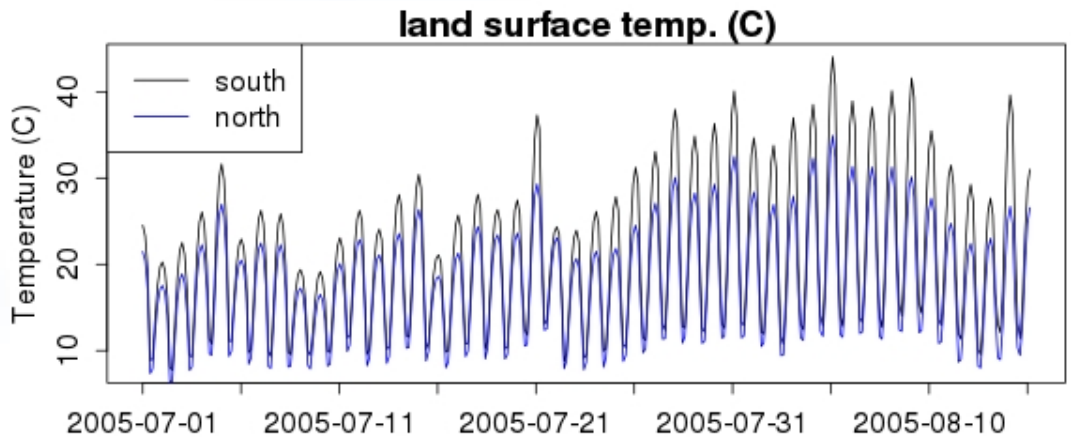
Summer 2016: move CONUS ecohydrology simulations to PLIEADES

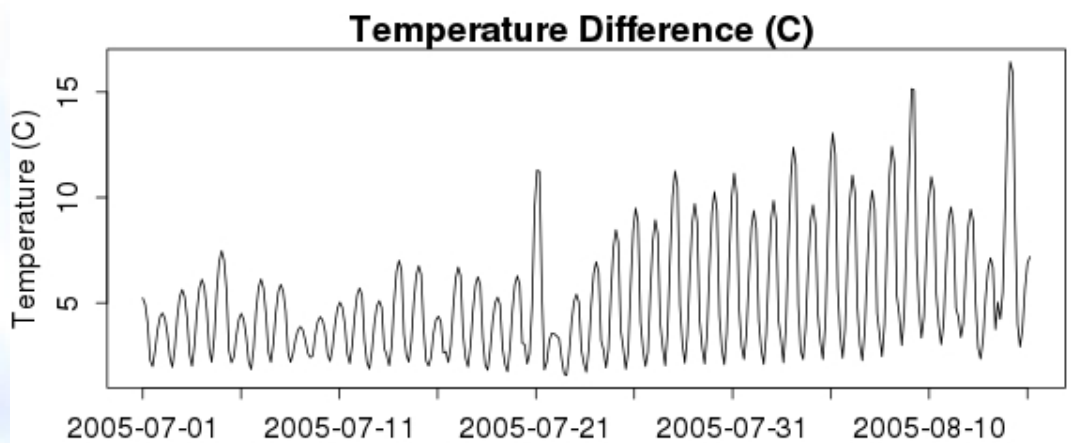
Next Steps and Future Project Progress

Modeling Temperature/RH where dead fuels actually experience climate









Relevant Publications

Holden et al. (2015). Development of high-resolution (250 m) historical daily gridded air temperature data using reanalysis and distributed sensor networks for the US Northern Rocky Mountains. Int. J. Climatol. doi: 10.1002/joc.4580

Holden, Z.A., J. Riddering, W. Jolly and A. Warren (2015). Smartphone applications for data collection, dynamic modeling and visualization in the wildland fire environment. Fire Management Today: 74(3) pp.10-14.

Jolly et al. (2015). Climate-induced variations in global wildfire danger from 1979 to 2013. Nature Communications. doi:10.1038/ncomms8537

Abatzoglou et al. (2014). Tracking interannual streamflow variability with drought indices in the Pacific Northwest, US. J. Hydrometeorology. doi: 10.1175/JHM-D-13-0167.1

Luce et al. (2014). Sensitivity of snowpack storage to precipitation and temperature using spatial and temporal analog models. Water Resources Research
DOI: 10.1002/2013WR014844

Luce et al. (2013). The missing mountain water: slower westerlies reduce orographic precipitation enhancement in the Pacific Northwest USA. (Science).

Holden, Z.A et al. (2013). Design and evaluation of an inexpensive solar radiation shield for monitoring surface air temperatures. Agric. For. Meteor.

Success stories?

Operational web mapping server with topographically resolved fire danger maps?

Research analyses and new indices are needed to characterize the relationship between topographic variation in fire danger and potential fire spread/fire effects

Real success may come in 5 years when a different decision is made about a particular wildfire incident .

Questions

A limerick!

Out of fear we put wildfires out
Despite the benefits to the land that we tout
One day with good data
We may respect fire not hate her
and use fire as tool with less doubt