Satellite-based Evapotranspiration Mapping in Idaho

Bill Kramber, Idaho Dept. of Water Resources
in partnership with
Dr. Rick Allen, University of Idaho

Partners and Collaborators: Dr. M. Tasumi, Univ. Miyazaki, Japan; Dr. R. Trezza, Univ. Idaho; Anthony Morse, Spatial Analysis Group; Dr. Jeppe Kjaersgaard, Univ. Idaho; Clarence Robison, Univ. Idaho; Dr. Magali Garcia, Univ. LaPaz, Bolivia; Dr. Wim Bastiaanssen, WaterWatch, Netherlands; Dr. J. Wright, USDA-ARS.

Upper Colorado River Commission Meeting, June 10, 2010

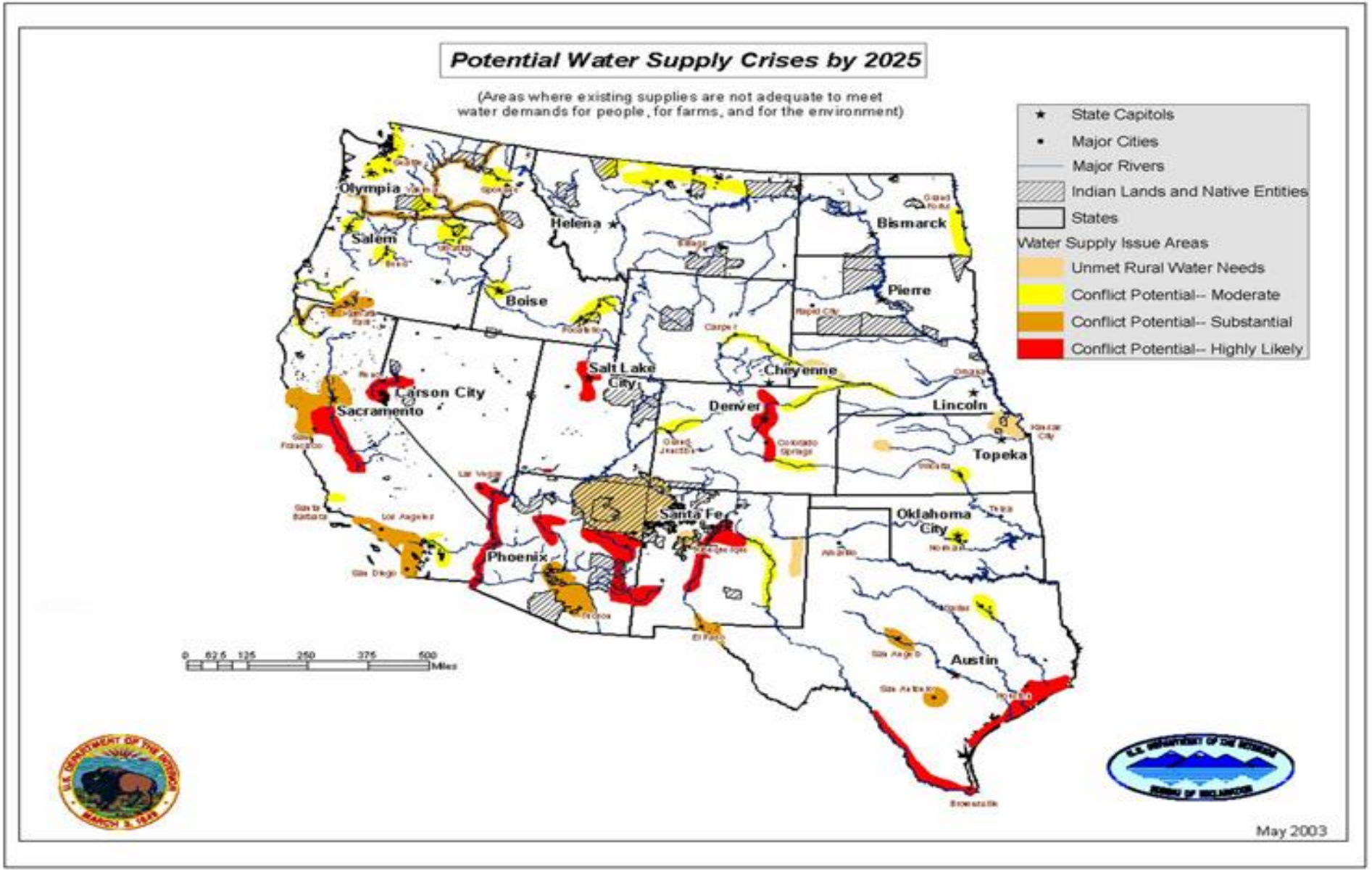
University of Idaho

INNOVATIONS IN AMERICAN GOVERNMENT AWARD WINNER

Why is Evapotranspiration (ET) important

- ET is the amount of water consumed by irrigated agriculture
- 3.4 million acres of irrigated agriculture in Idaho
- Over 90% of the water consumed is for irrigation
- Important for: water administration, water planning, and hydrologic models

Potential Water Conflicts

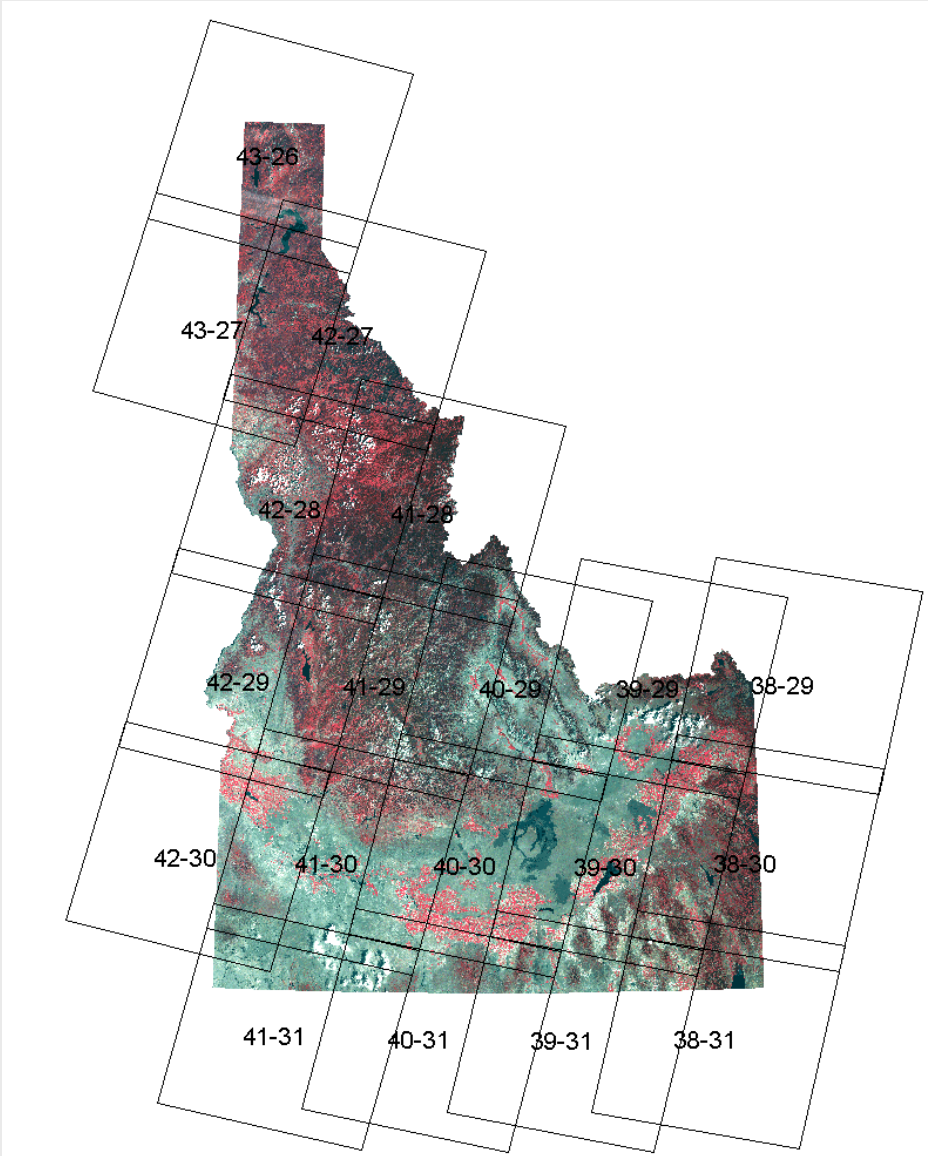


Landsat

- USGS/NASA mission
- L5 launched 1984
- L7 launched 1999
  (damaged May, 2003)

- 16 day cycle
- 100 by 100 miles
- Landsat data is free

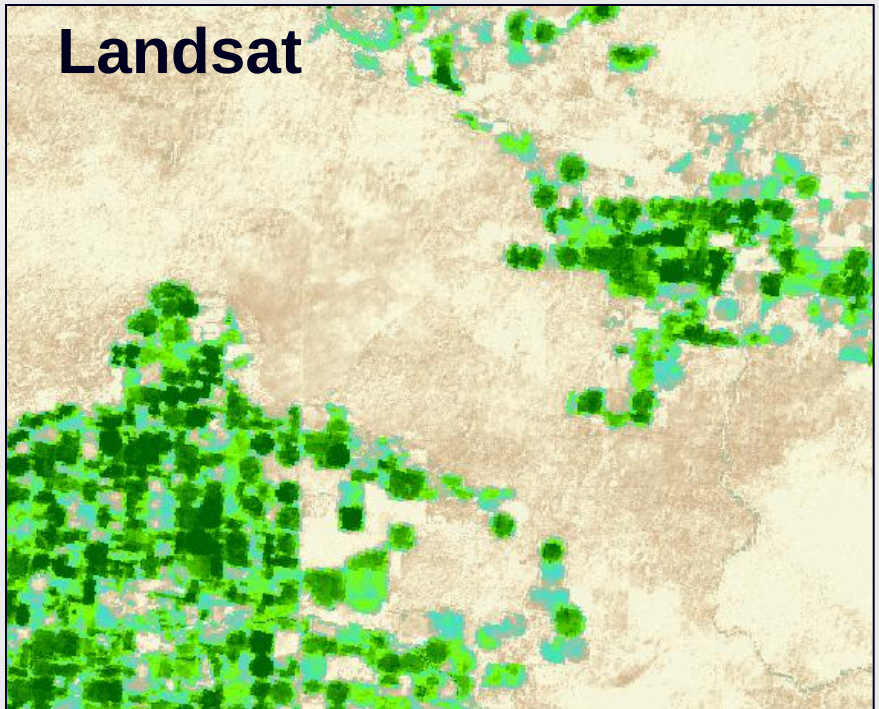
- Landsat 8 will launch in December 2012

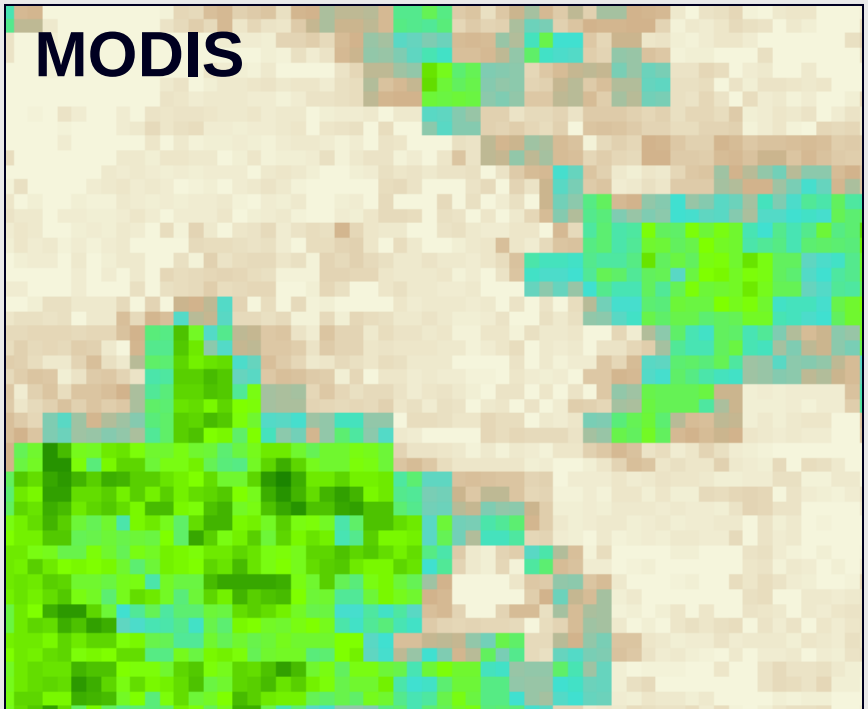


Landsat 7

Why not use other satellites

- MODIS: 500 meter pixels
- AVHRR: 1000 meter pixels
- SPOT: no thermal band
- IRS AWiFS: no thermal band
- Aster: for research





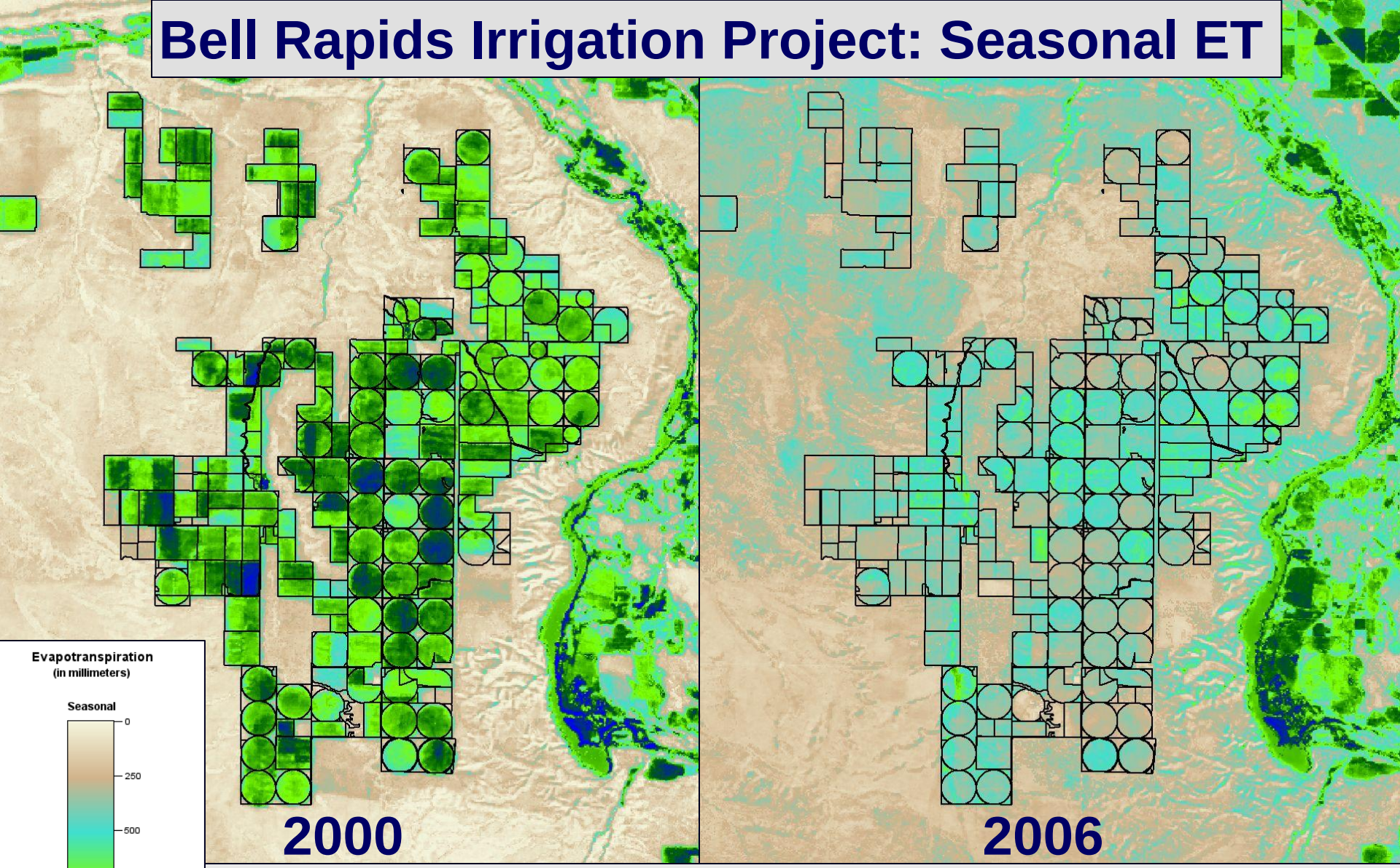
In the past

- Potential ET using crop coefficients
  - Needs crop type acres and stage of growth
  - Produces one ET value per county

In the present

- Actual ET from Landsat using METRIC
  - No crop information required
  - ET per pixel can be summed by field

Bell Rapids Irrigation Project: Seasonal ET



- High lift pumps irrigated 25,000 acres
- State purchased water rights in 2005
- Supports endangered salmon

Landsat Thermal Band

- Required for surface temperature
- Landsat is the only operational satellite with a “thermal band” that has a pixel size small enough to compute and map ET for individual fields!

LDCM

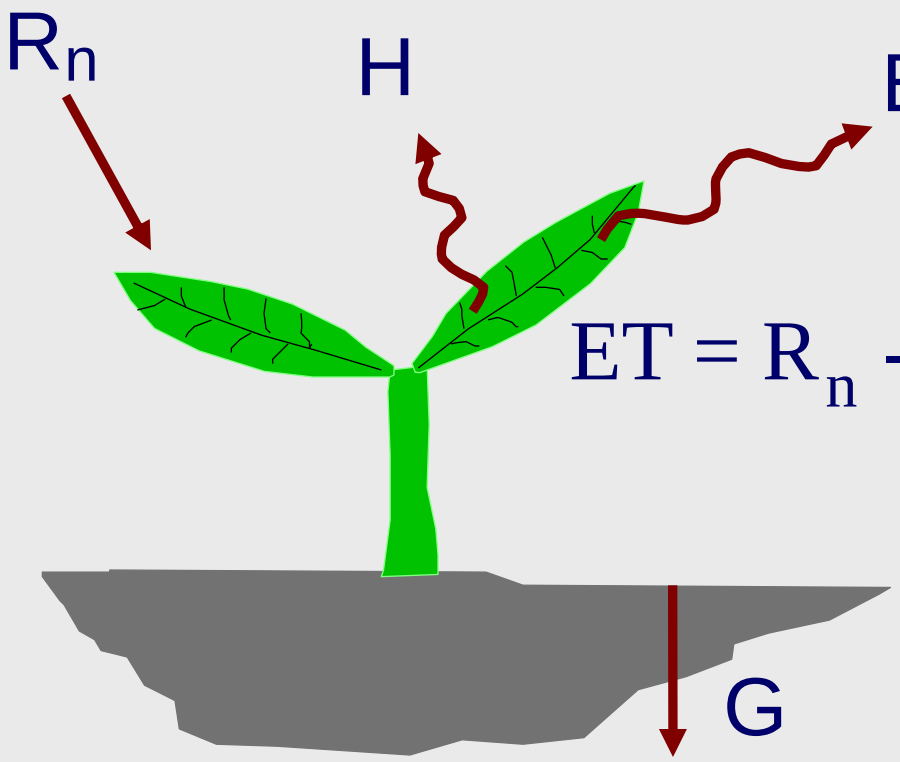
METRIC

Mapping EvapoTranspiration at high Resolution with Internalized Calibration

- Satellite based energy balance model that computes and maps actual ET
- Internalized Calibration ties down the ET data to local weather data

Energy Balance for ET

- ET is calculated as a “residual” of the energy balance



$$ET = R_n - G - H$$

The energy balance includes all major sources (R_n) and consumers (ET, G, H) of energy

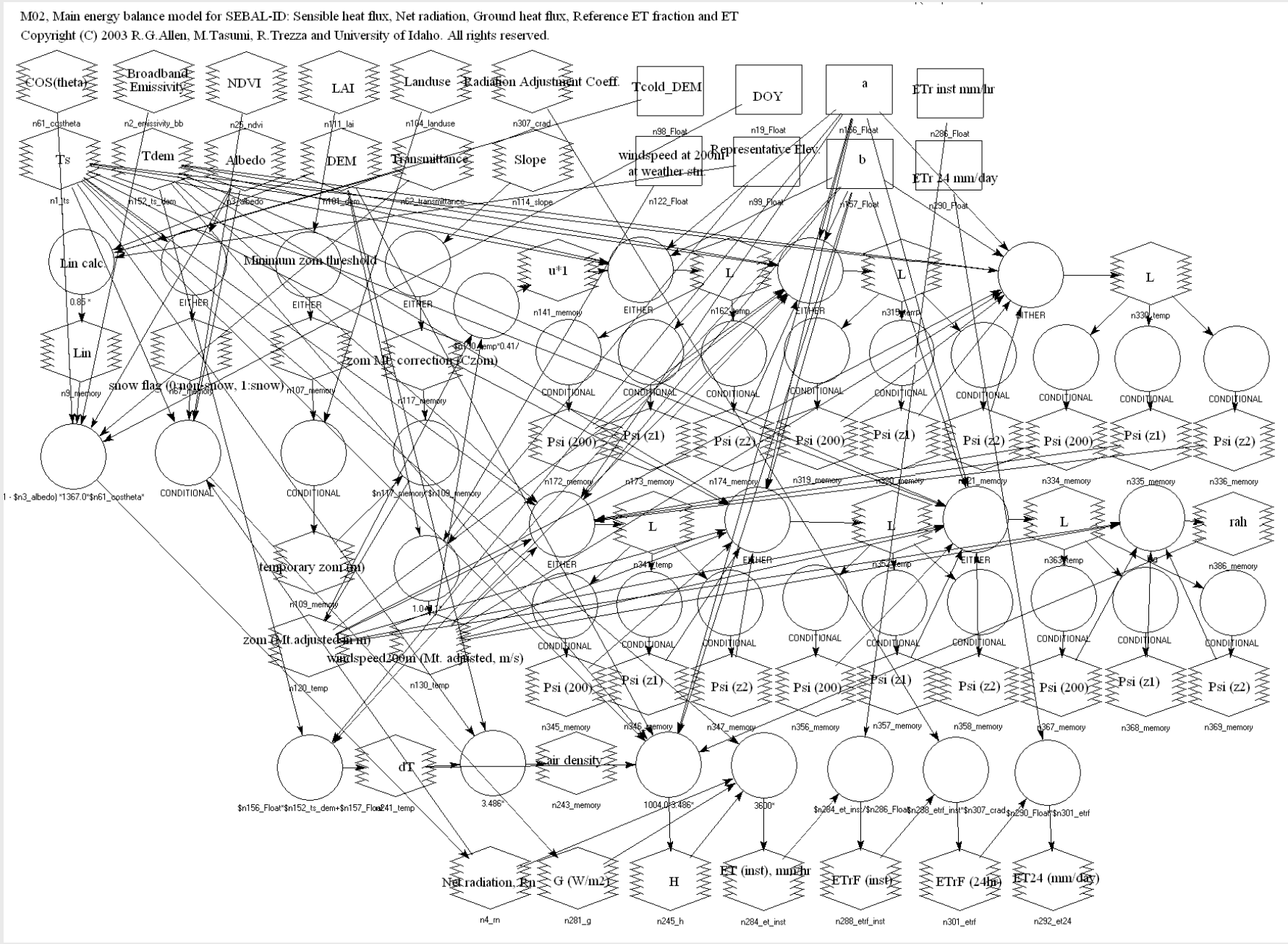
Energy balance computes “actual” ET

Can ‘see’ impacts on ET caused by:

- water shortage
- disease
- crop variety
- planting density
- cropping dates
- salinity
- management

- *(these effects can cause the ratio ET / amount of vegetation to vary widely, thus the need to compute ET as a residual of the energy balance)*

METRIC^{tm}-ERDAS submodel for sensible heat and ETrF



Weather Data

In METRIC, Weather Data are used for:

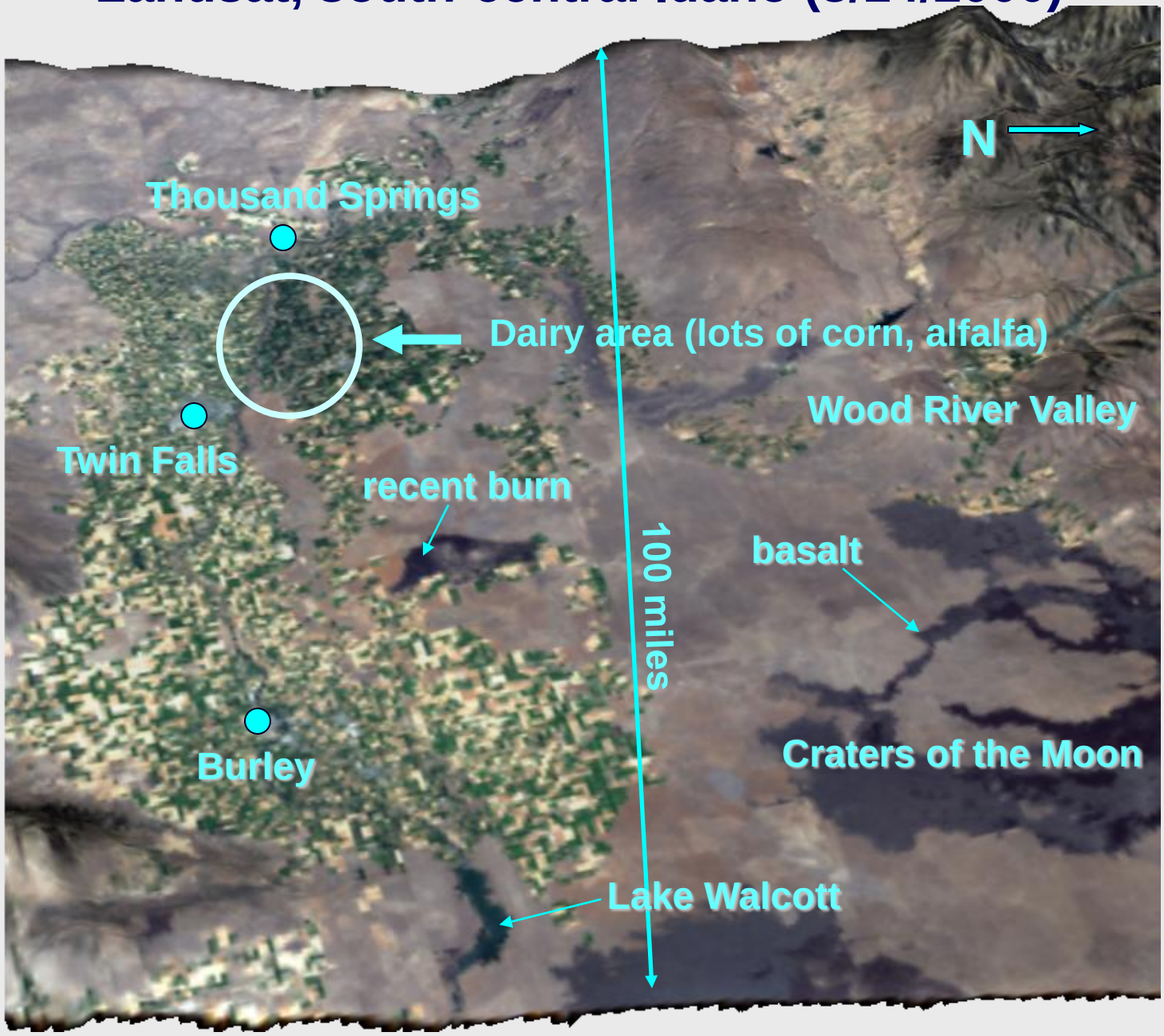
Wind speed for **sensible heat flux** calculation

Reference ET for **calibrating the Energy Balance**

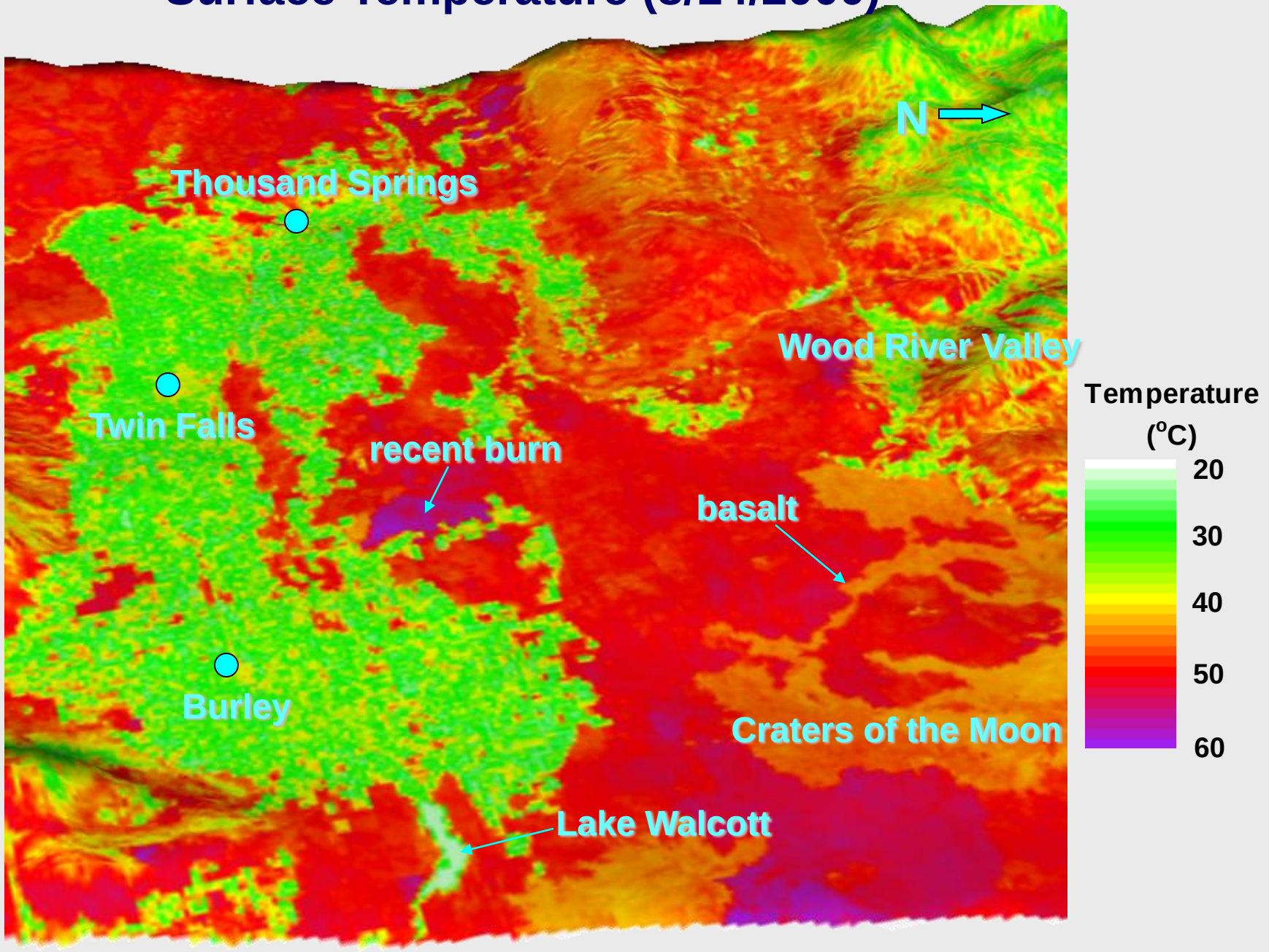
Reference ET to **extrapolate ET** over:

- **24-hour period**
- **Days between images**

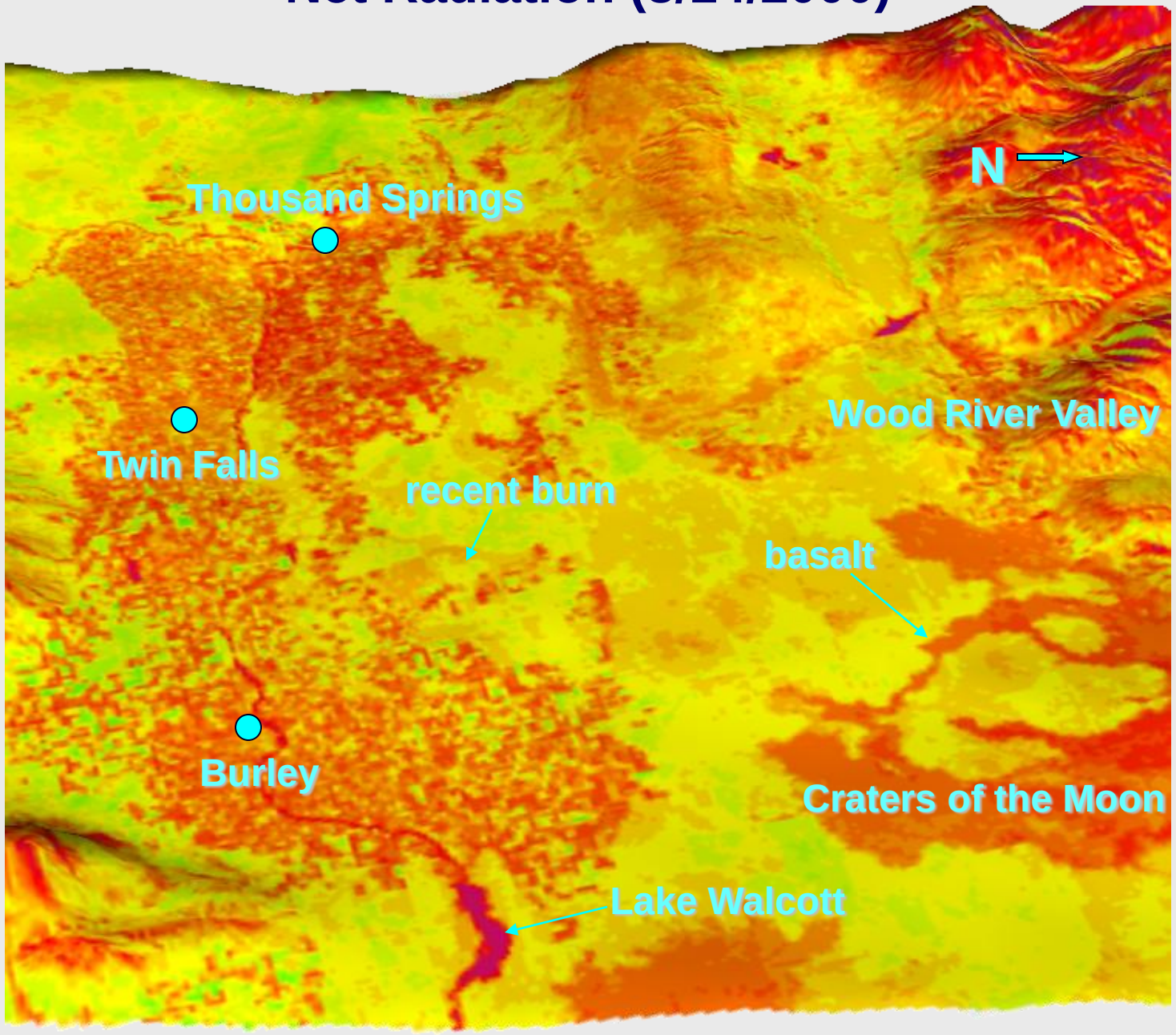
Landsat, south-central Idaho (8/14/2000)

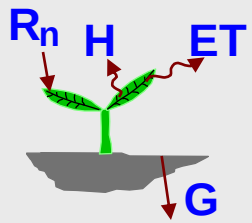


Surface Temperature (8/14/2000)

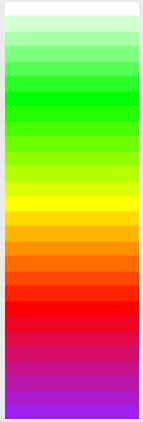


Net Radiation (8/14/2000)

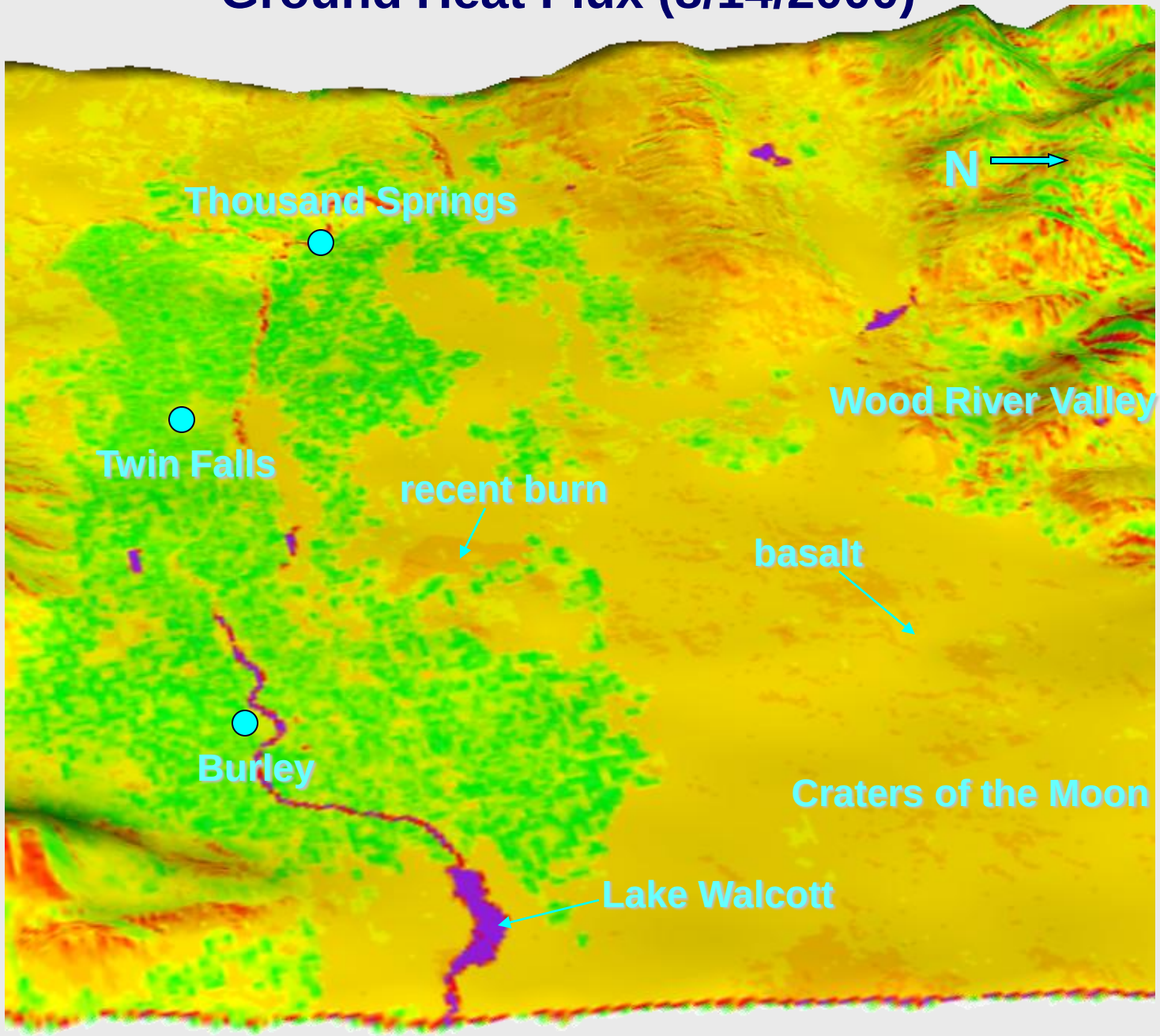


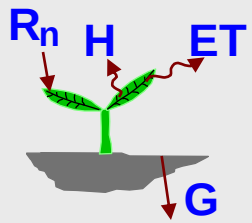


Net Radiation (W/m^2)

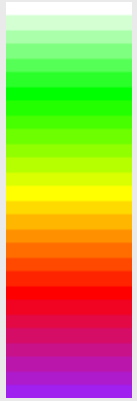


Ground Heat Flux (8/14/2000)

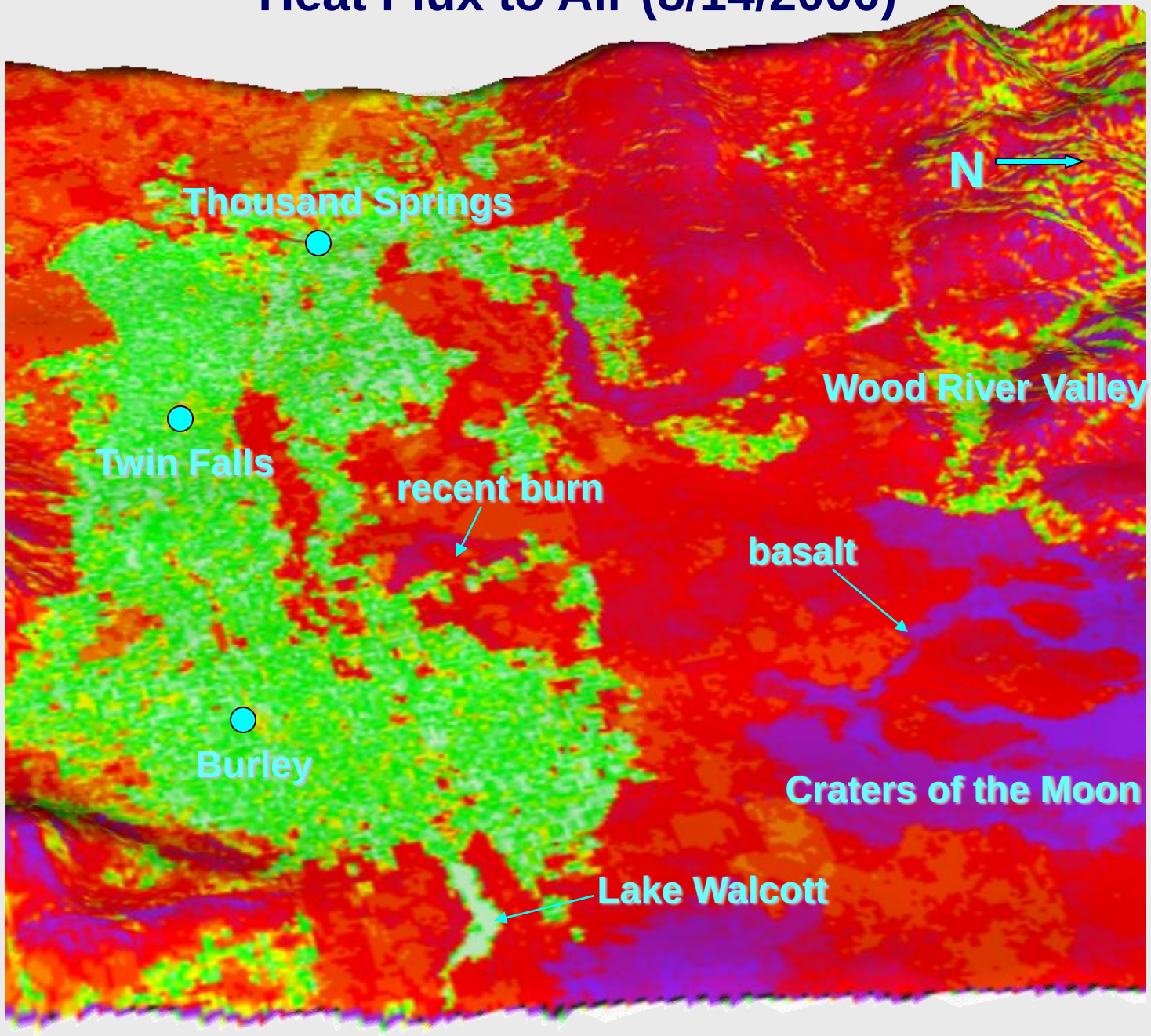


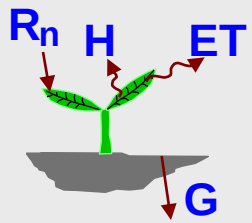


Soil Heat Flux (W/m^2)

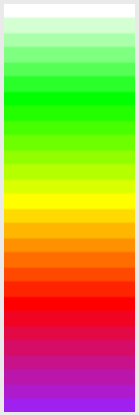


Heat Flux to Air (8/14/2000)

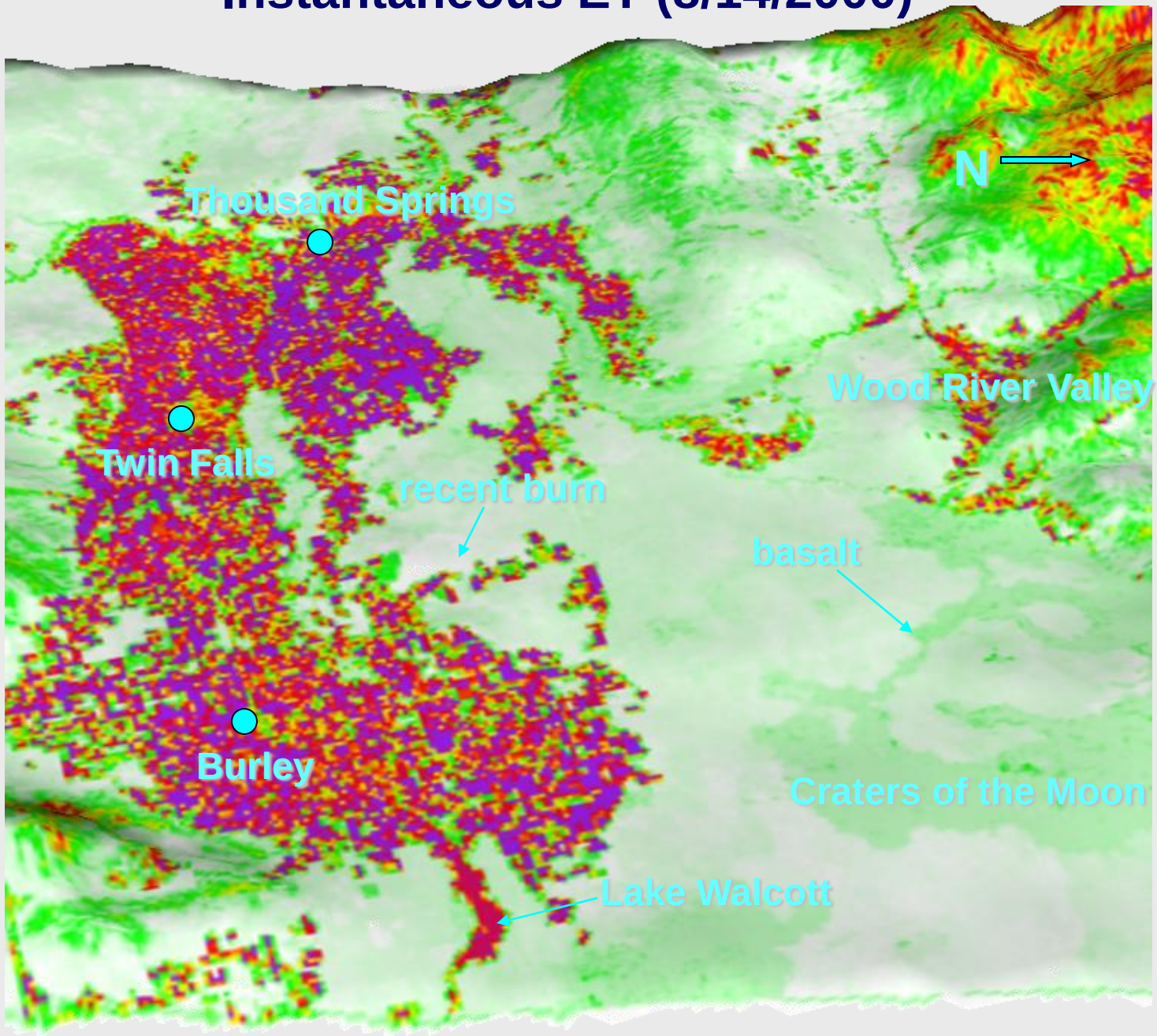


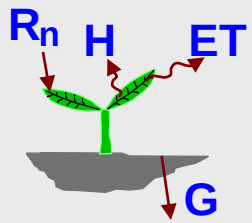


Sensible Heat (W/m^2)

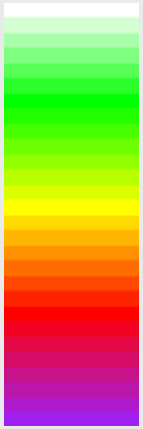


Instantaneous ET (8/14/2000)

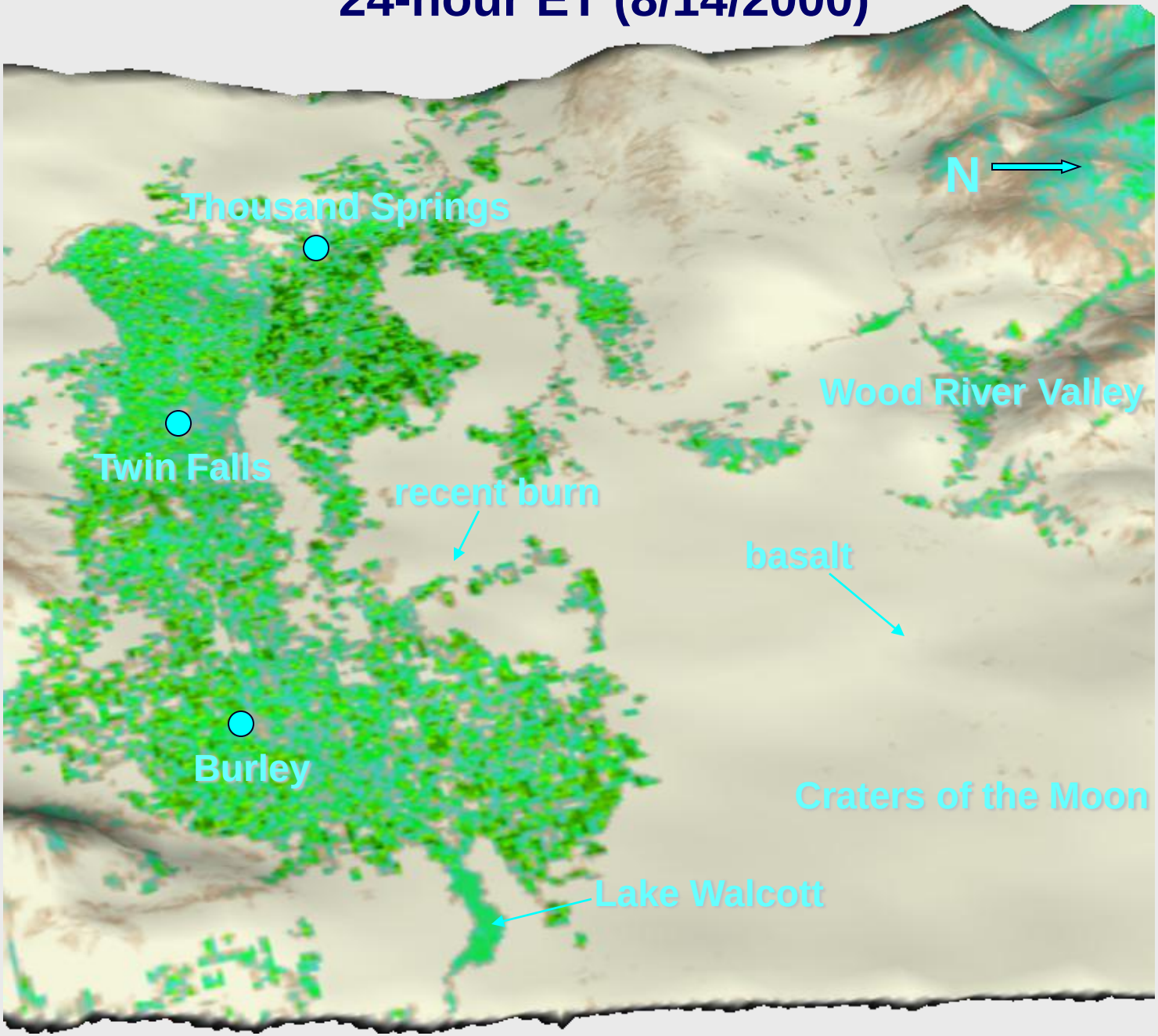




Latent Heat (W/m^2)

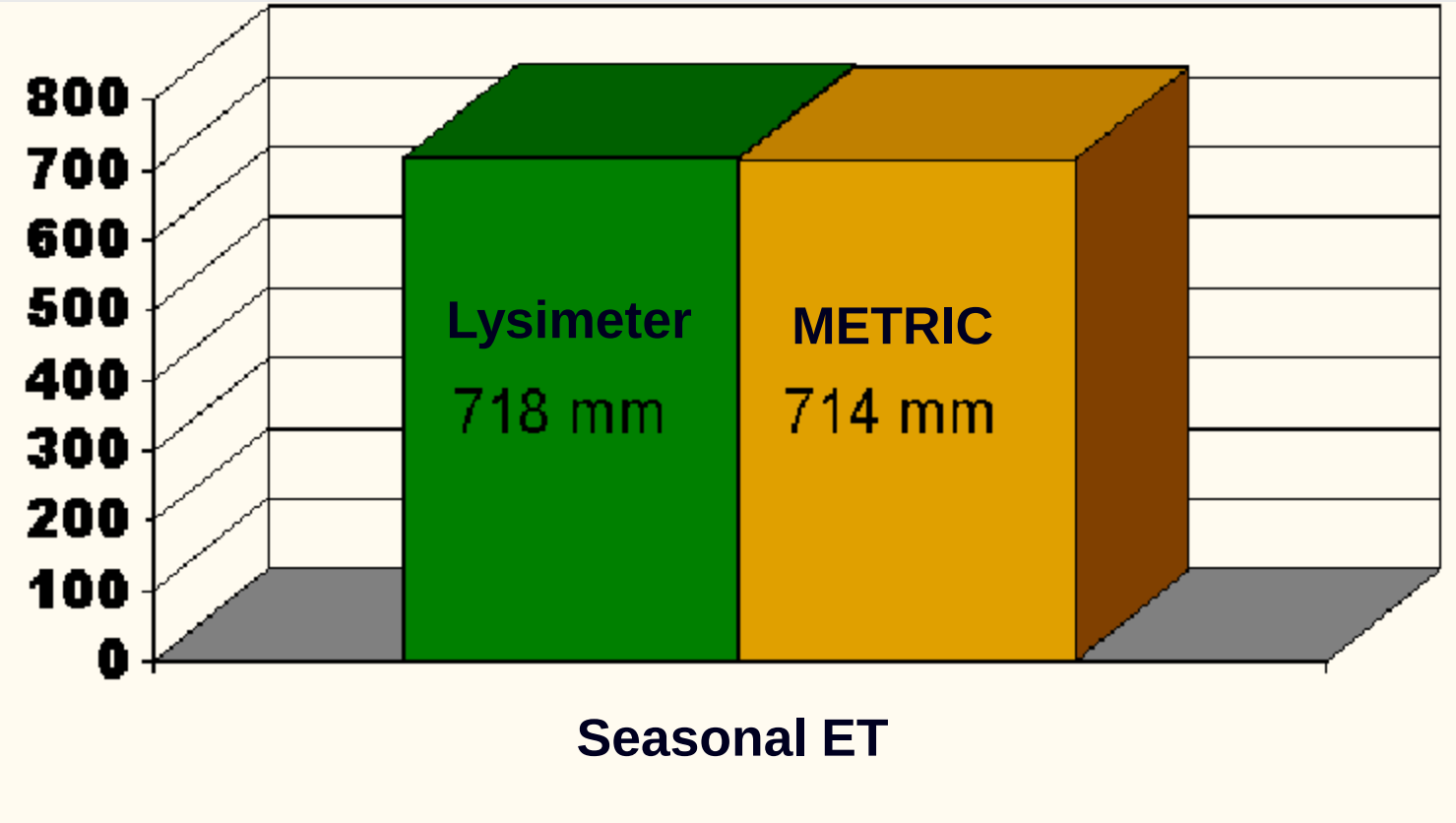


24-hour ET (8/14/2000)



Comparison with Lysimeter Measurements

1968-1991



Comparison of seasonal ET as measured by lysimeter and computed by METRIC for sugar beets at the Kimberly Research Station, for April to September, 1989.

Other states using or gearing up to use METRIC

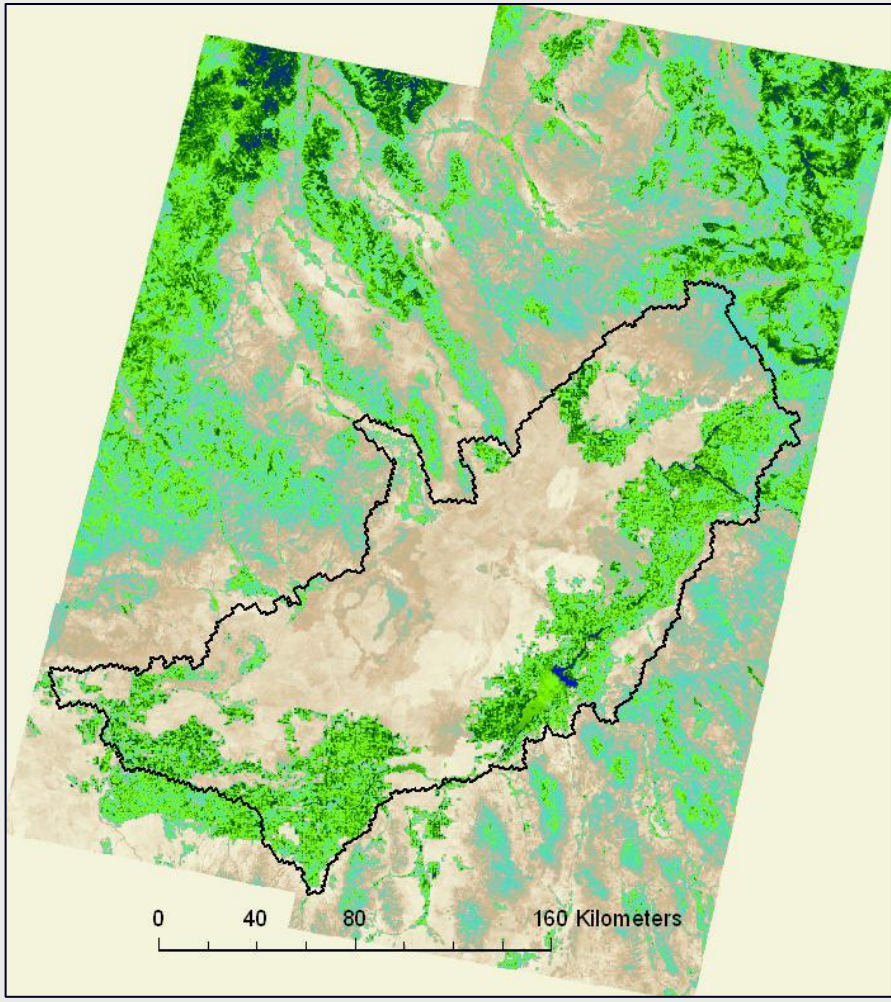
- Nevada
  - Ag. water is being transferred to Reno and Las Vegas – what is impact on environment?
- Nebraska
  - Over pumping of the Ogallala Aquifer (high plains aquifer)
- Colorado
  - Kansas vs. Colorado over Arkansas River
  - Nebraska vs. Colorado over S. Platte River
- Wyoming
  - Nebraska vs. Wyoming over N. Platte River
- Oregon
  - Klamath Basin water shortages

More states using or gearing up to use METRIC

- California
  - Imperial Irrigation District: for total water consumption by irrigated agriculture
- New Mexico
  - Middle Rio Grande: for water consumption by agriculture and riparian systems
- Montana
  - Flathead Indian Reservation and ground water areas east of Helena: for improved irrigation water management and management of total depletion

Cost of METRIC

- About one year to develop monthly ET for 100,000 square kilometers
- Area covered by 4 Landsat images, need one image per month, at least 28 total images
- Cloudy areas require extra effort
- Other costs if you do it yourself
  - training
  - image processing and GIS software
  - disks for processing and storage



An alternative approach
Satellite NDVI

- NDVI (Normalized Difference Vegetation Index)
  - (IR – Red) / (IR + Red)
- Based on relationship between METRIC ET and NDVI
- Advantage
  - Quicker and lower cost (about 25% of the cost)
  - Can use other satellite data like SPOT or AWiFS
- Disadvantage
  - May not see ET reductions caused by stress (water shortage)
  - Not as accurate

Innovations in American Government Award

- Idaho's Mapping ET program was one of 6 winners out of nearly 1,000 applicants in 2009
- $40,000 grant to support replication
  - Short presentations
  - ½-day presentations with more details
  - 4-day hands-on training workshops
    - The 1st will be in Boise the week of August 16th
    - Send me an email if you are interested in the workshop

      Bill.Kramber@idwr.idaho.gov

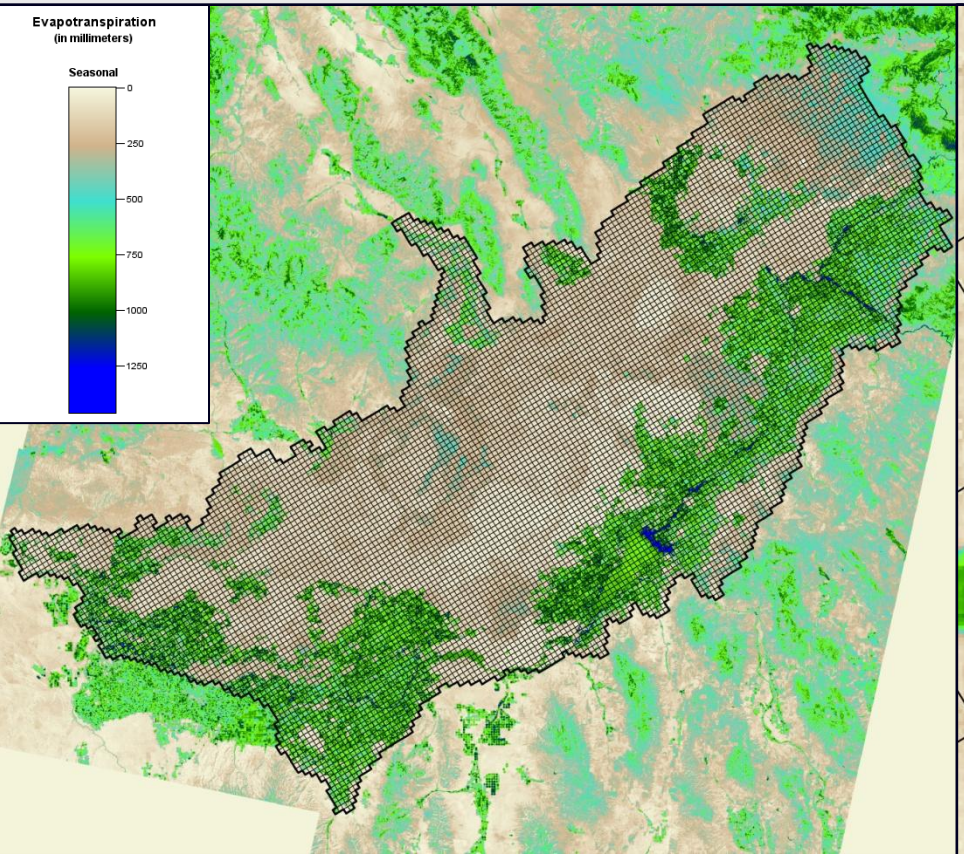
Applications in Idaho

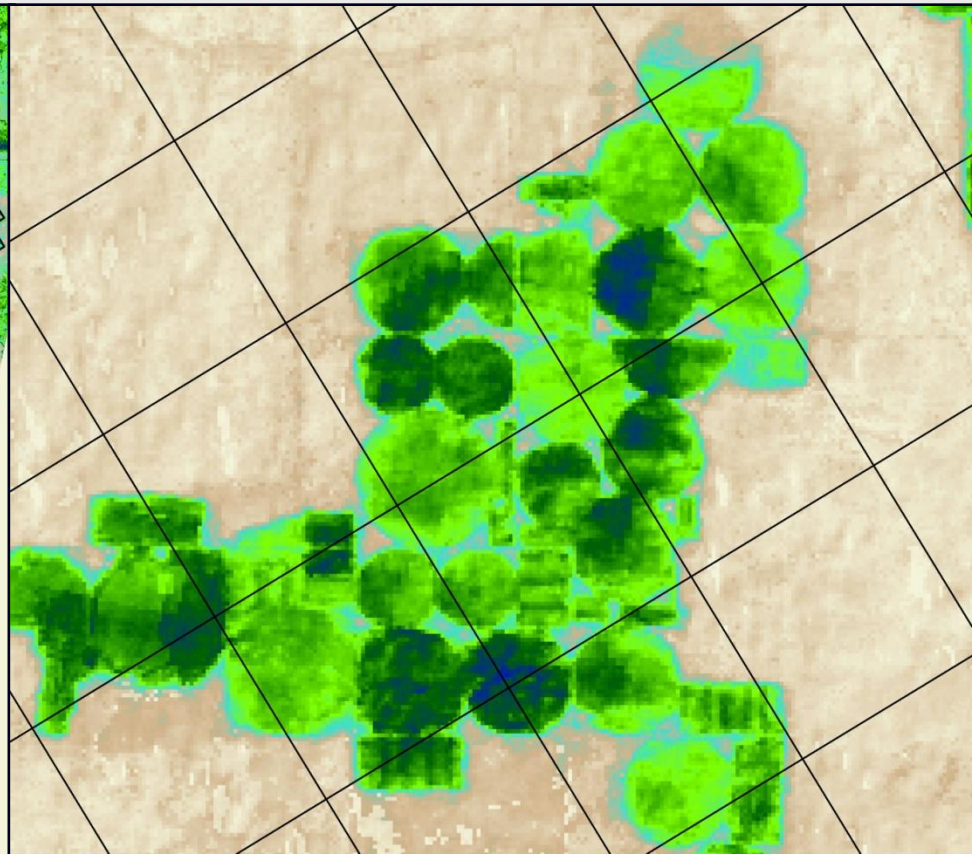
- Hydrologic modeling
- Water planning
- Water administration

Hydrologic Modeling

Eastern Snake Plain Aquifer Model

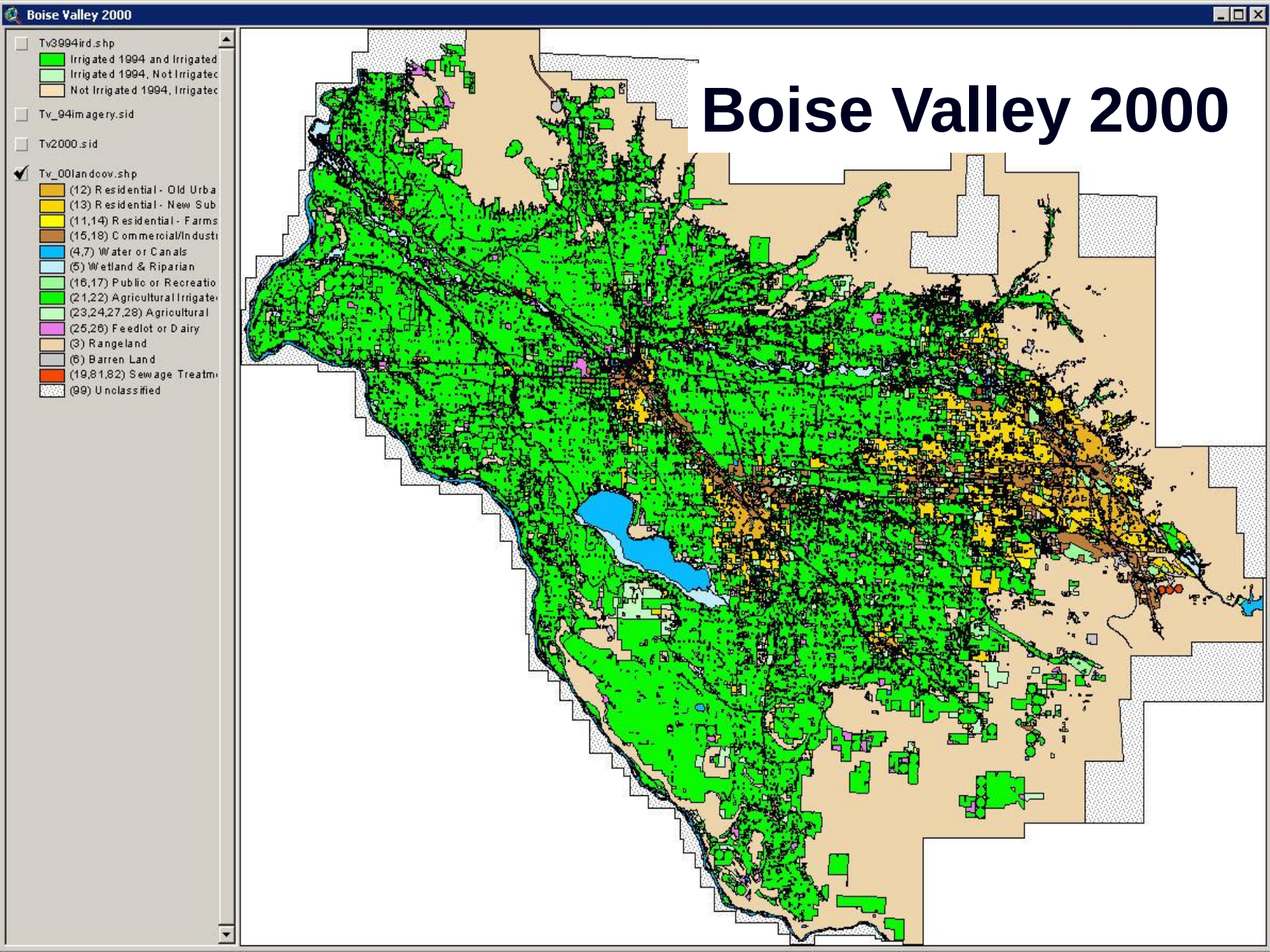
- Year 2000, 2002, and 2006 data completed
- Developing ET data from 1986 to present



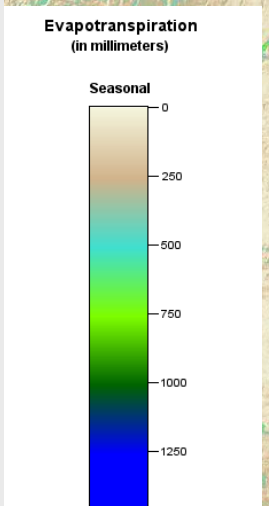


Water Planning
ET by Land Use

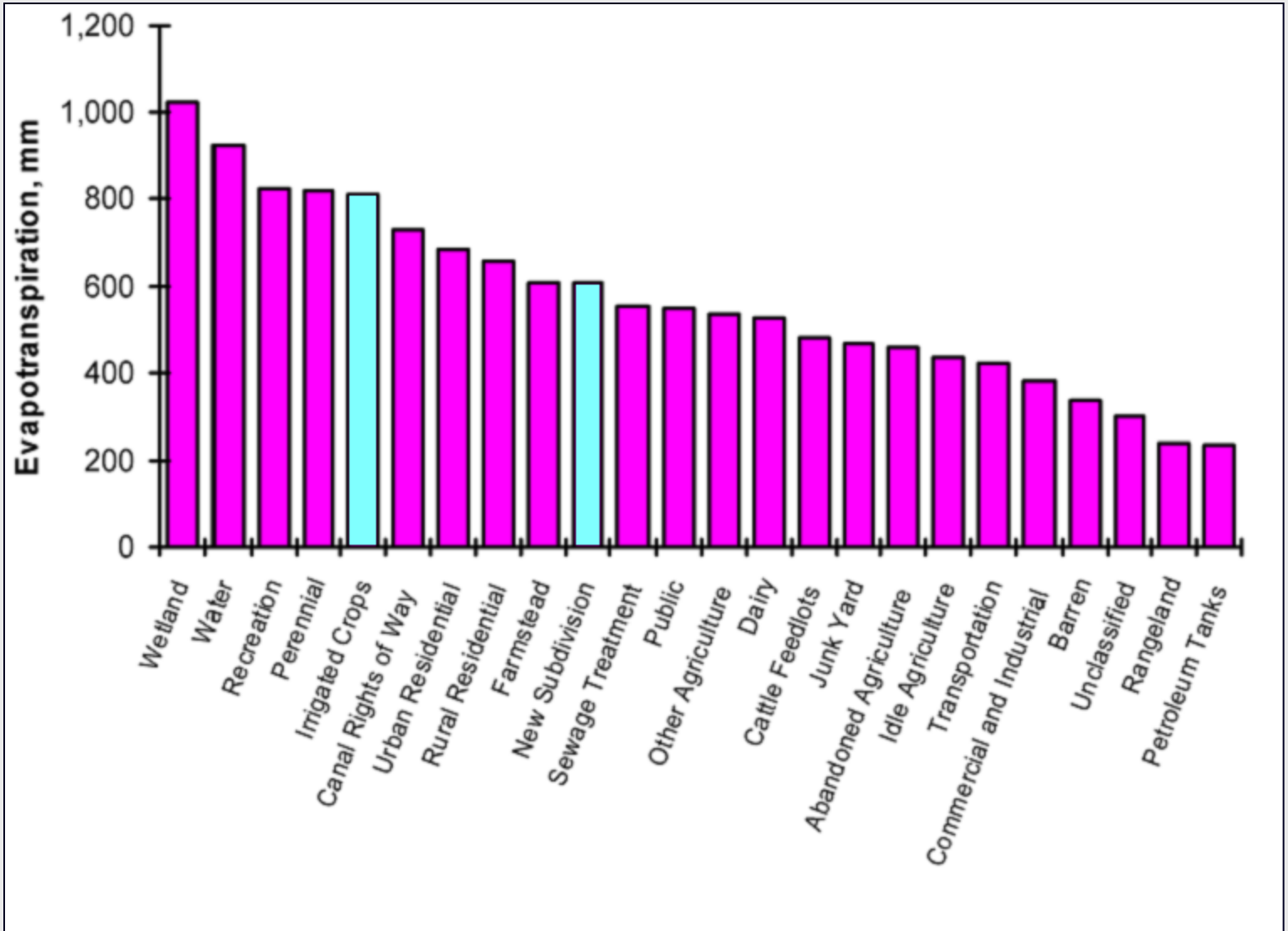
- Used for estimates of future water demand
- Year 2000 land use data overlayed on year 2000 seasonal ET data


Boise Valley 2000
Tv3994ird.shp
Irrigated 1994 and Irrigated
Irrigated 1994, Not Irrigatec
Not Irrigated 1994, Irrigatec
Tv_94imagery.sid
Tv2000.sid
Tv_00landcov.shp
(12) Residential - Old Urba
(13) Residential - New Sub
(11,14) Residential - Farms
(15,18) Commercial/Industr
(4,7) Water or Canals
(5) Wetland & Riparian
(16,17) Public or Recreatio
(21,22) Agricultural Irrigate
(23,24,27,28) Agricultural
(25,26) Feedlot or Dairy
(3) Rangeland
(6) Barren Land
(19,81,82) Sewage Treatm
(99) Unclassified
Boise Valley 2000

Boise Valley 2000

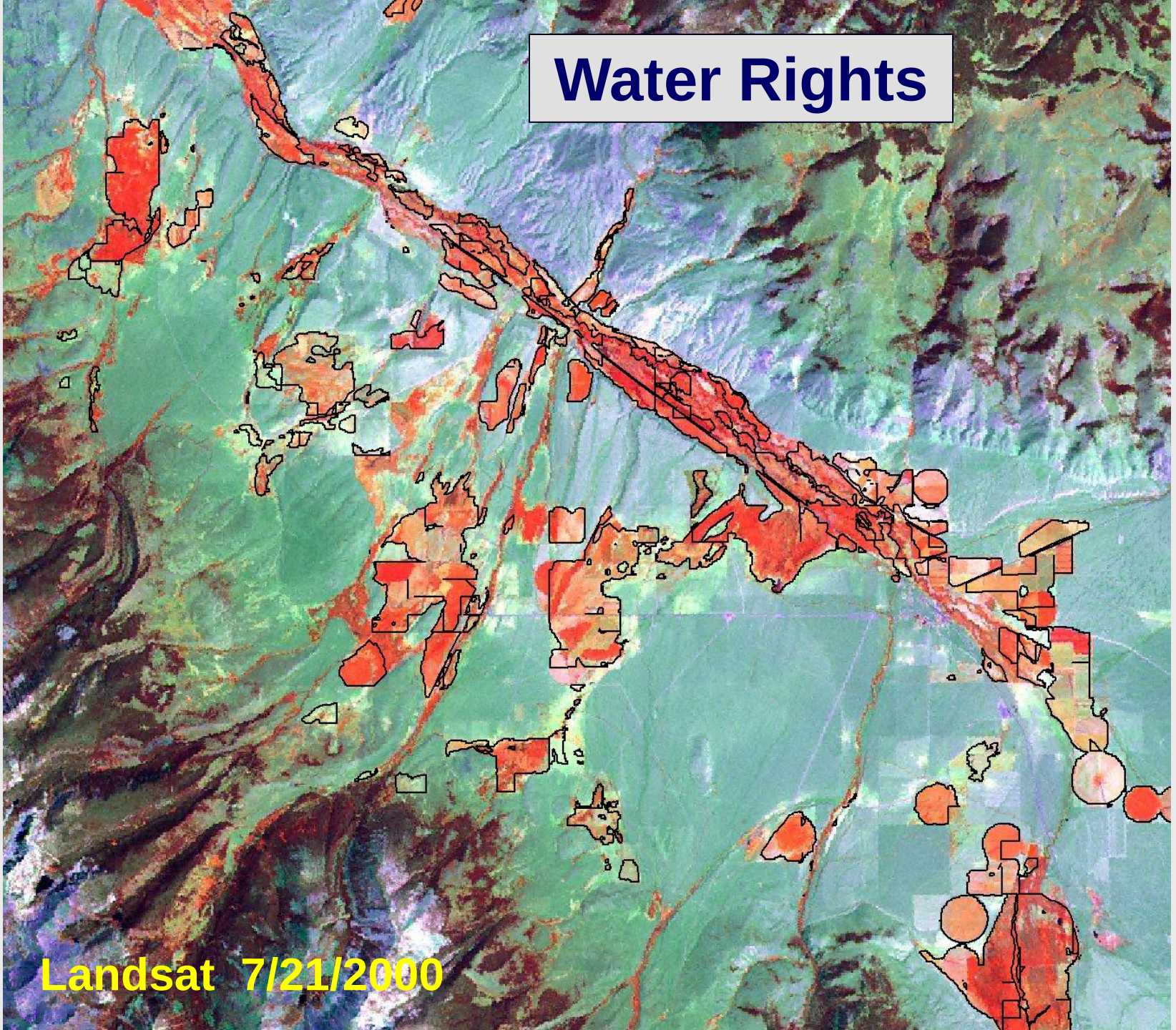


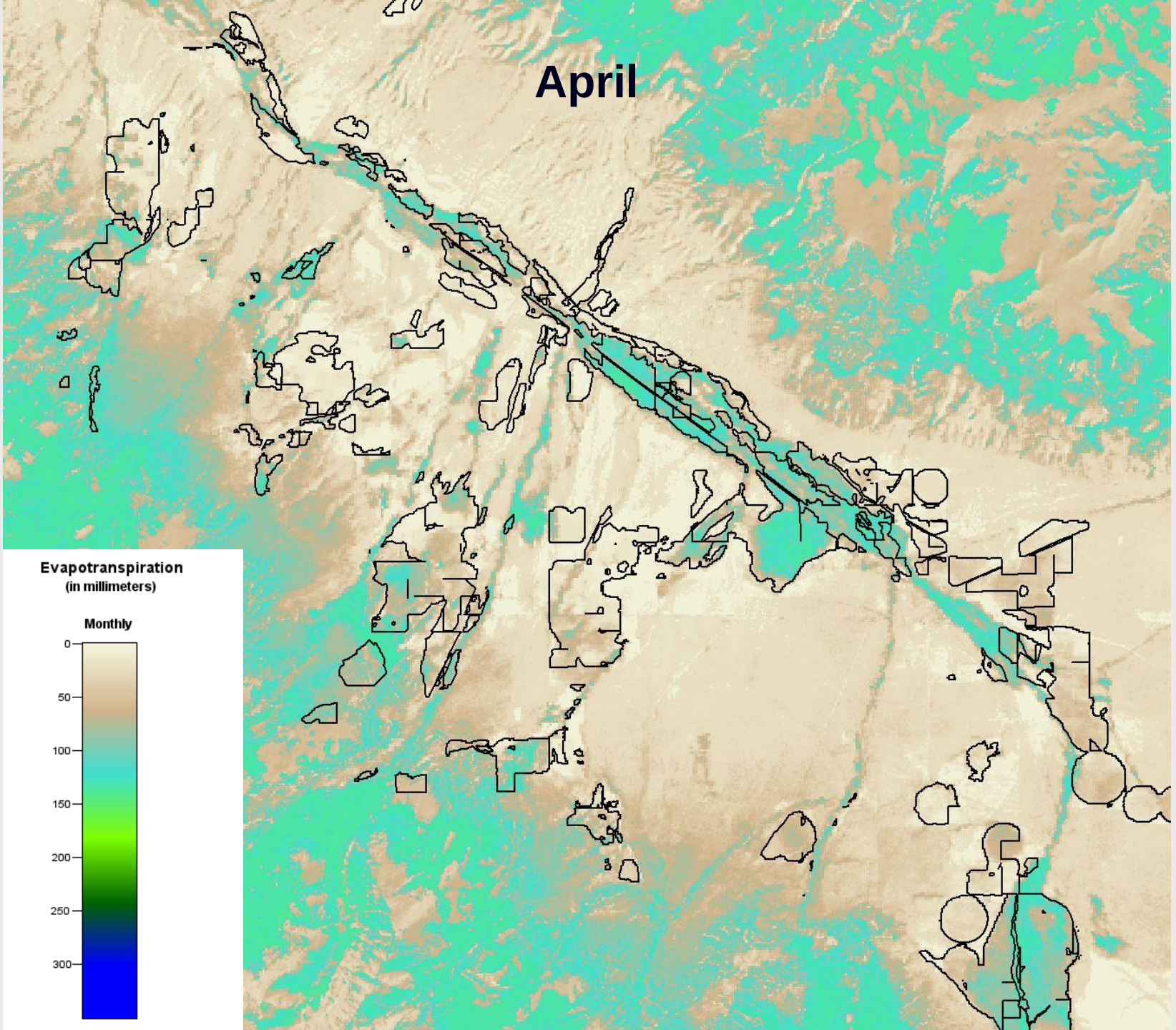
ET by land use

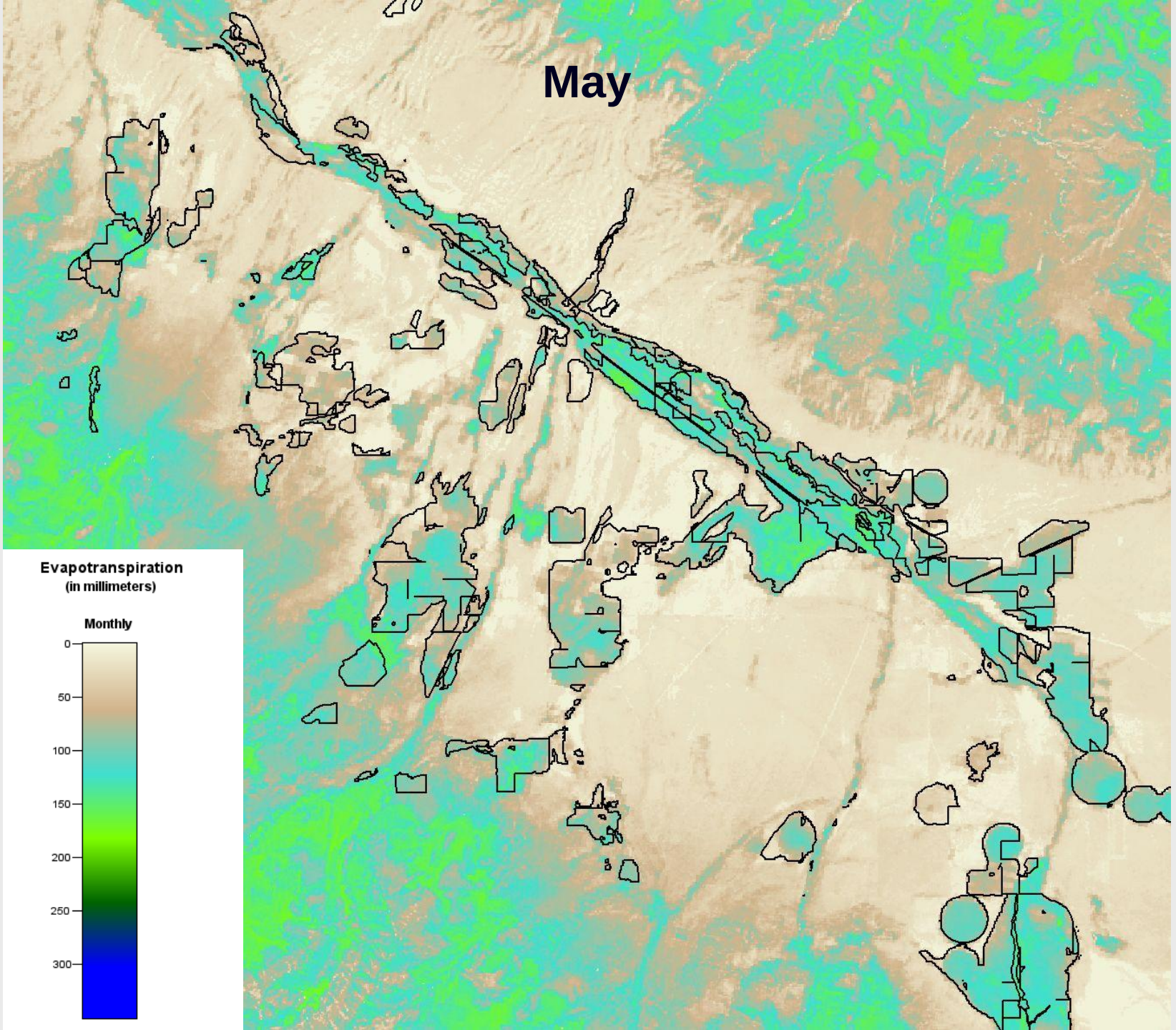


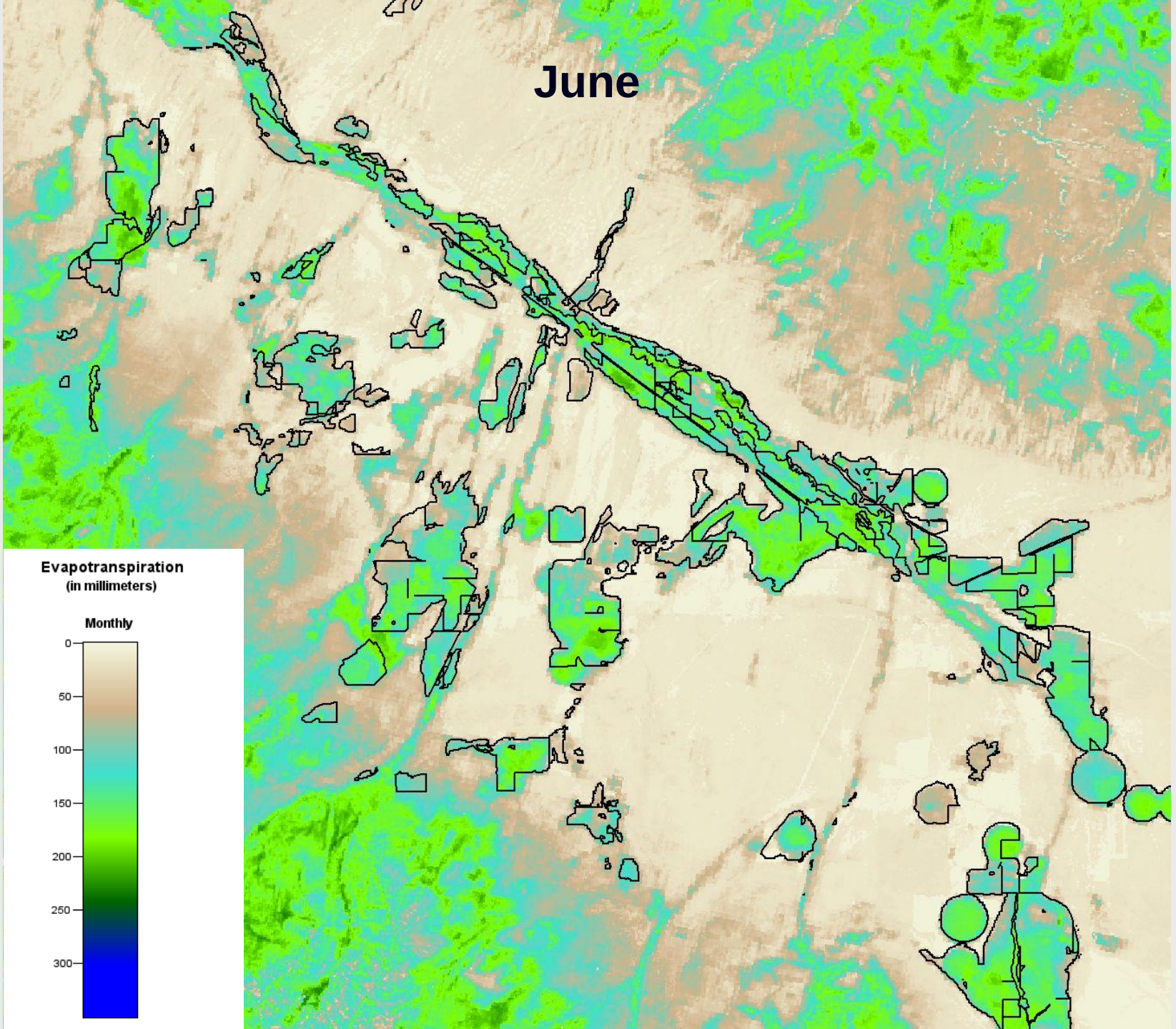
Water Planning
Endangered Species

- Landsat-based ET estimates volume of water used for irrigation of specific water rights

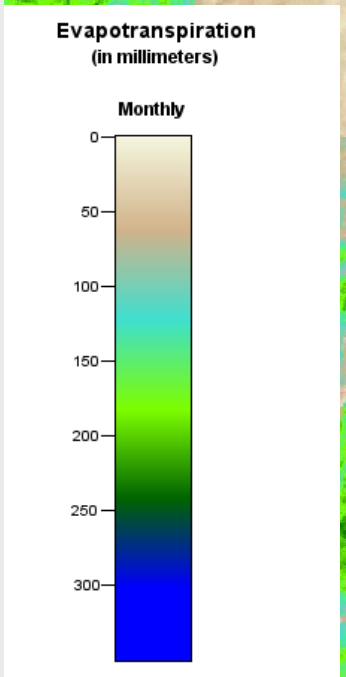

Water Rights
Landsat 7/21/2000


April
Evapotranspiration
(in millimeters)
Monthly
0
50
100
150
200
250
300

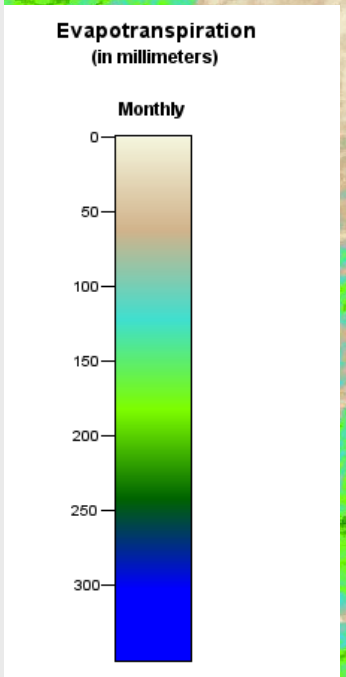

May
Evapotranspiration
(in millimeters)
Monthly
0
50
100
150
200
250
300


June
Evapotranspiration
(in millimeters)
Monthly
0
50
100
150
200
250
300

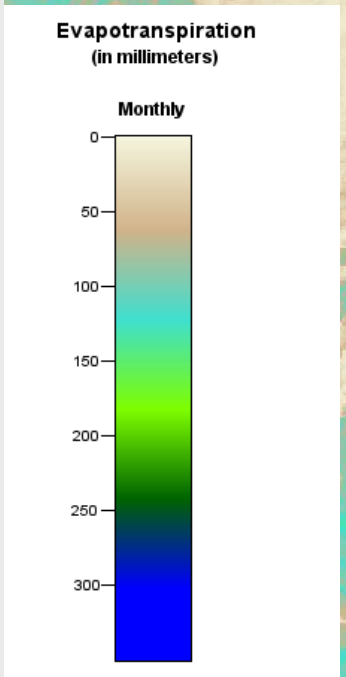
July


Evapotranspiration
(in millimeters)
Monthly
0
50
100
150
200
250
300

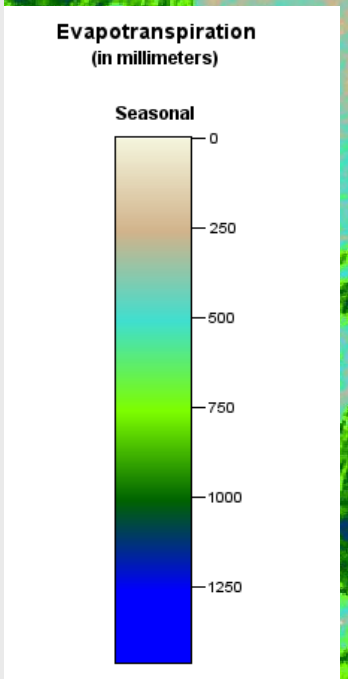
August


Evapotranspiration
(in millimeters)
Monthly
0
50
100
150
200
250
300

September


Evapotranspiration
(in millimeters)
Monthly
0
50
100
150
200
250
300

Seasonal



19,997 acres of irrigated land

33,520 acre-feet of ET for the year 2000 season

- (11 Billion gallons)
- (41 Billion liters)

Water Administration
Litigation

- Clear Springs Foods water call
- A&B Irrigation District water call

Water Law Terms

- Water Right
  - Authorization to use water
  - Includes priority date
- Call
  - When a senior water right holder experiences a water shortage they may place a call
- Curtailment Order
  - Defines how the state directs junior water right holders to stop diverting water in response to a call

Clear Springs Foods Water Call

Idaho Business *News*

Water curtailment ordered in Magic Valley

POSTED: 11:13 MDT Thursday, July 23, 2009
by IBR Staff

Idaho Department of Water Resources Interim Director Gary Spackman on July 22 issued a **curtailment order** to about 250 holders of 315 junior water rights in south central Idaho's Magic Valley. The curtailment order is part of a continuing response to a water delivery call made in 2005 by senior water right holder Clear Springs Foods.

State goes ahead with first large-scale well closure of more than 300 water rights in M.V.

7/31/2009

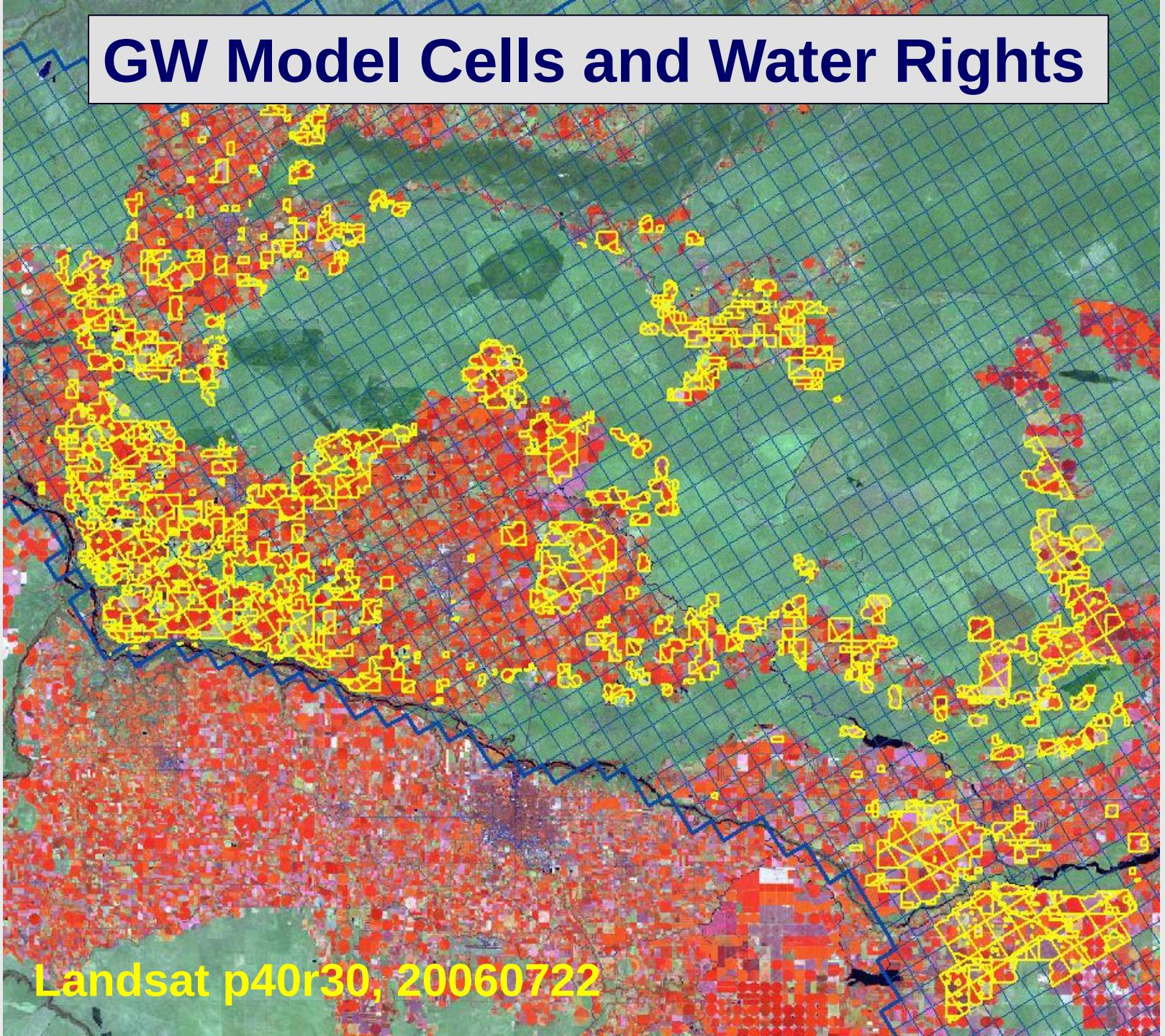
Water districts have limited options, could file a stay

By Nate Poppino
Times-News writer

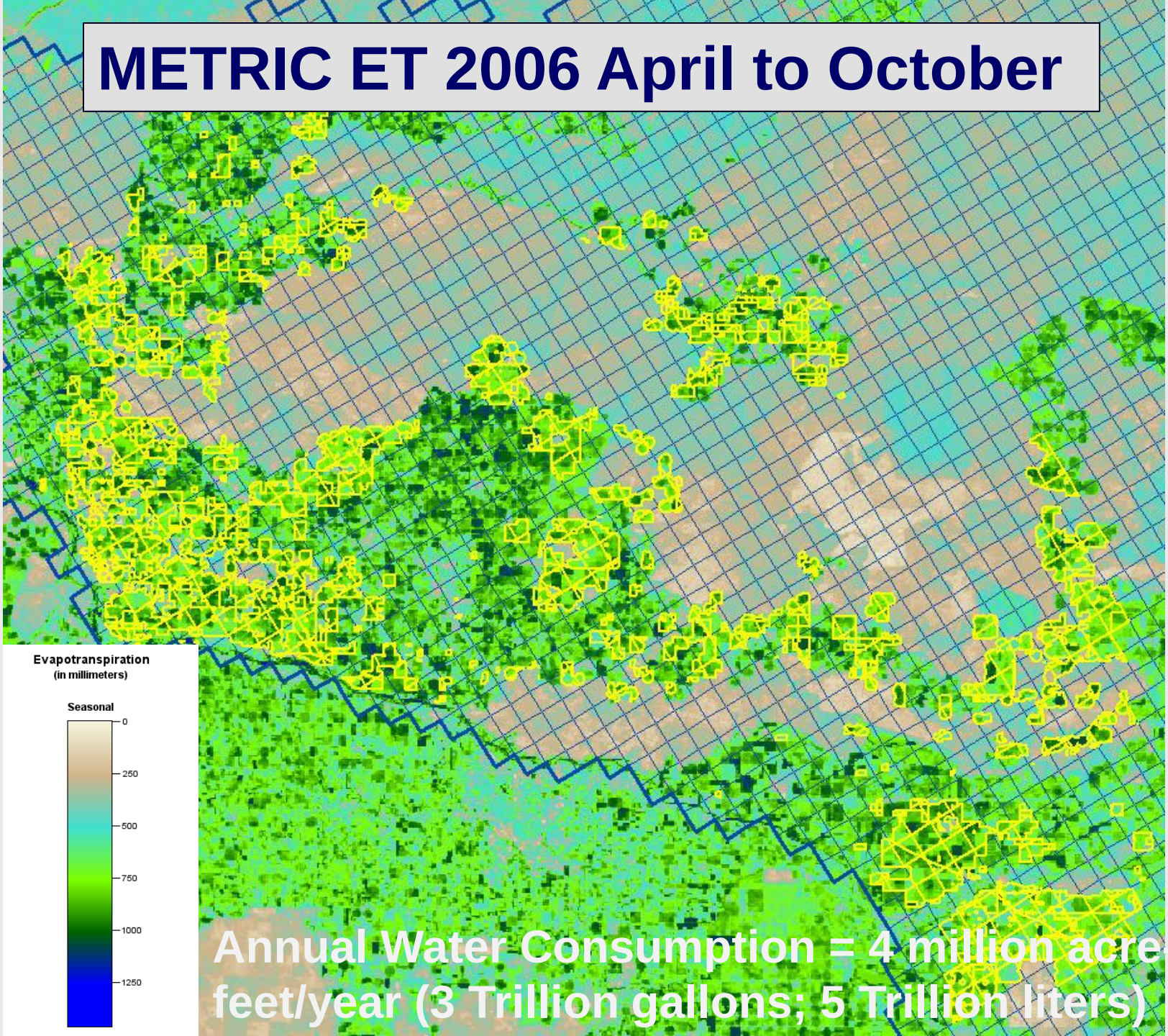
The Idaho Department of Water Resources will go forward this morning with a plan to shut off more than 300 water rights irrigating just less than 9,000 acres of Magic Valley farmland, the first wide-scale well curtailment to actually be carried out by the state.

Clear Springs Foods, Inc.

GW Model Cells and Water Rights



METRIC ET 2006 April to October



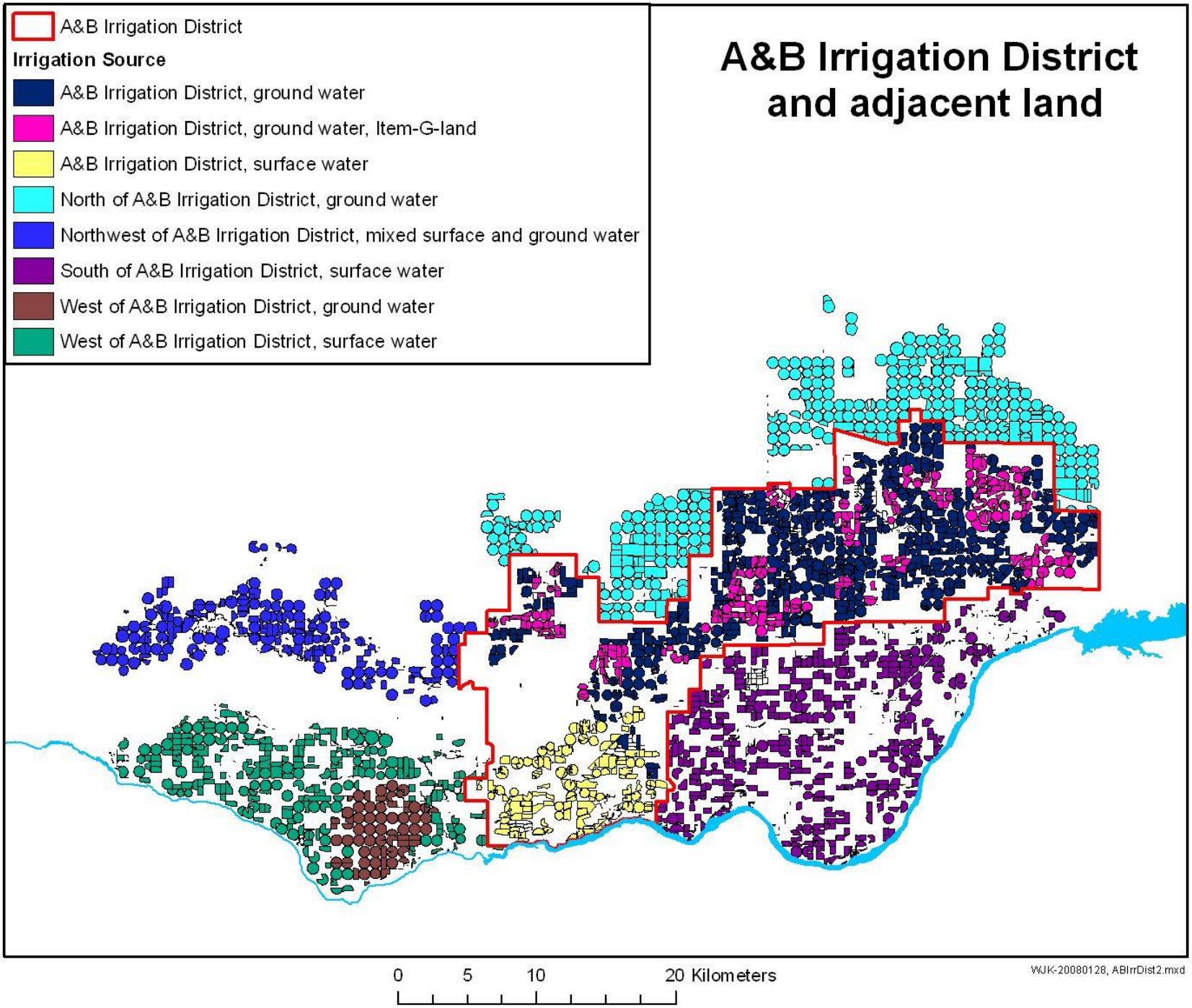
Annual Water Consumption = 4 million acre-feet/year (3 Trillion gallons; 5 Trillion liters)

Clear Springs Foods Water Call

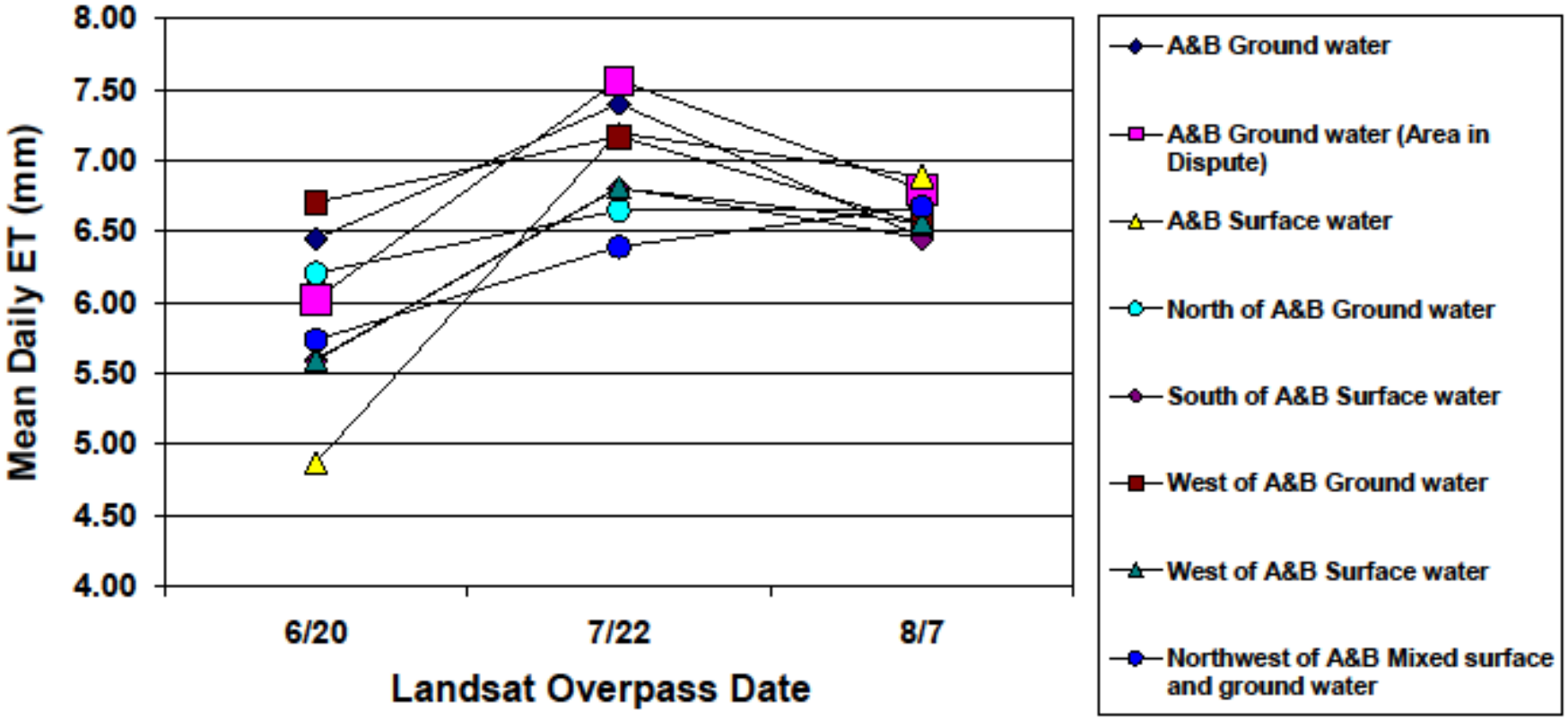
Summary

- ESPA GW model used METRIC ET data
  - For model calibration
  - To select water rights to curtail
- No complaints from junior users about GW model or METRIC ET data

A&B Irrigation District and adjacent land



Year 2006: Mean Daily Evapotranspiration (ET)



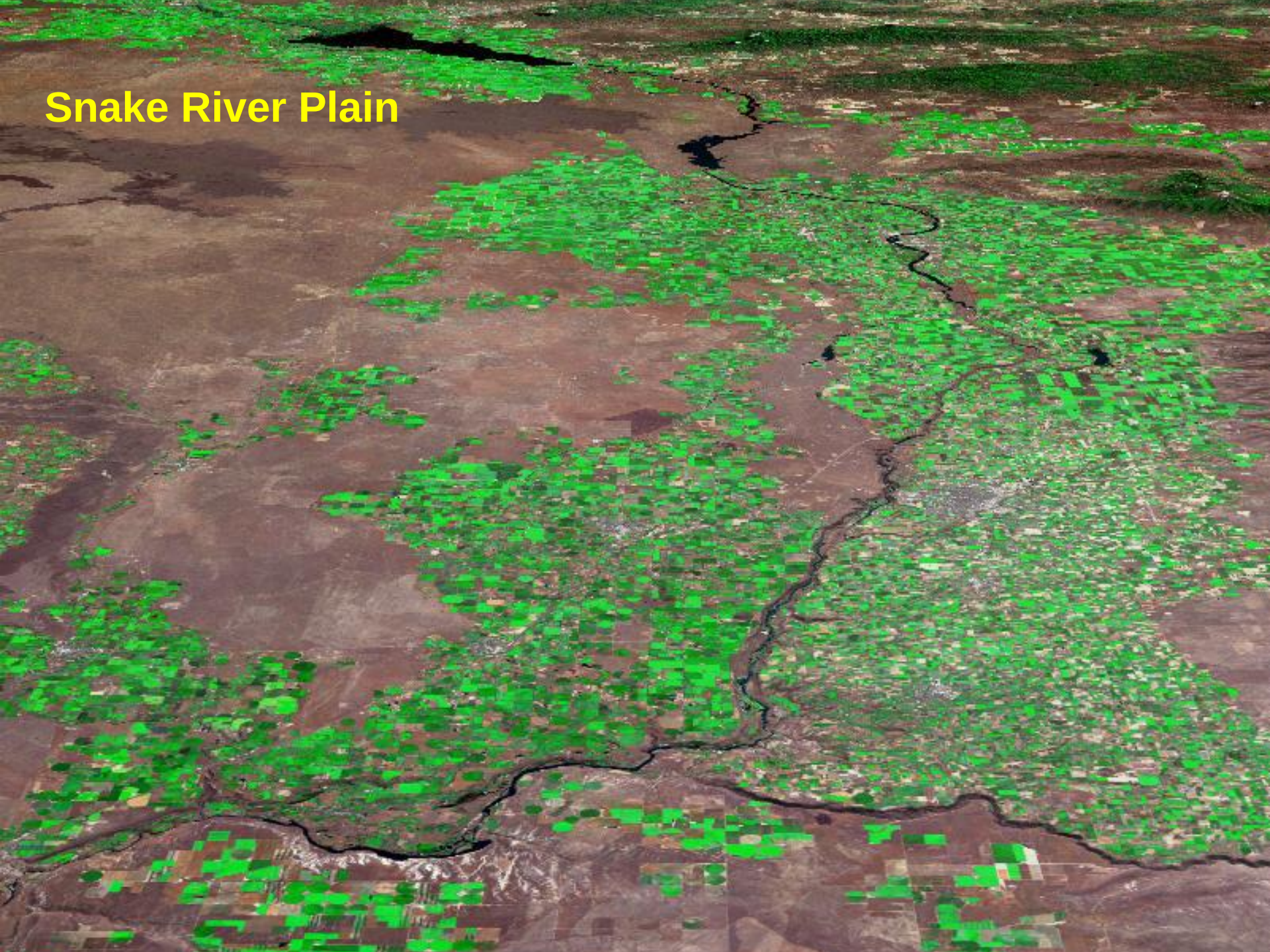
Acknowledgements

Dr. Allan Wylie, IDWR
NASA
USGS

More Information

www.idwr.idaho.gov/GeographicInfo/METRIC/et.htm

www.kimberly.uidaho.edu/water/metric


Snake River Plain