

Enhancing Water Management DSS with High Spatio-temporal Resolution Mapping of Actual Evapotranspiration

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METRIC™

**NIDIS Workshop:
Contributions of Satellite Remote Sensing to Drought
Monitoring**



Agricultural Water Consumptive Use

- Quantifying water consumption over large areas and within irrigated projects is important for:
 - water demand forecasting
 - water rights management
 - water resources planning, and
 - water regulation
- Difficult to capture
 - often most poorly understood & weakly represented components of water DSS for management activities
 - $P = Q + ET + \Delta S$

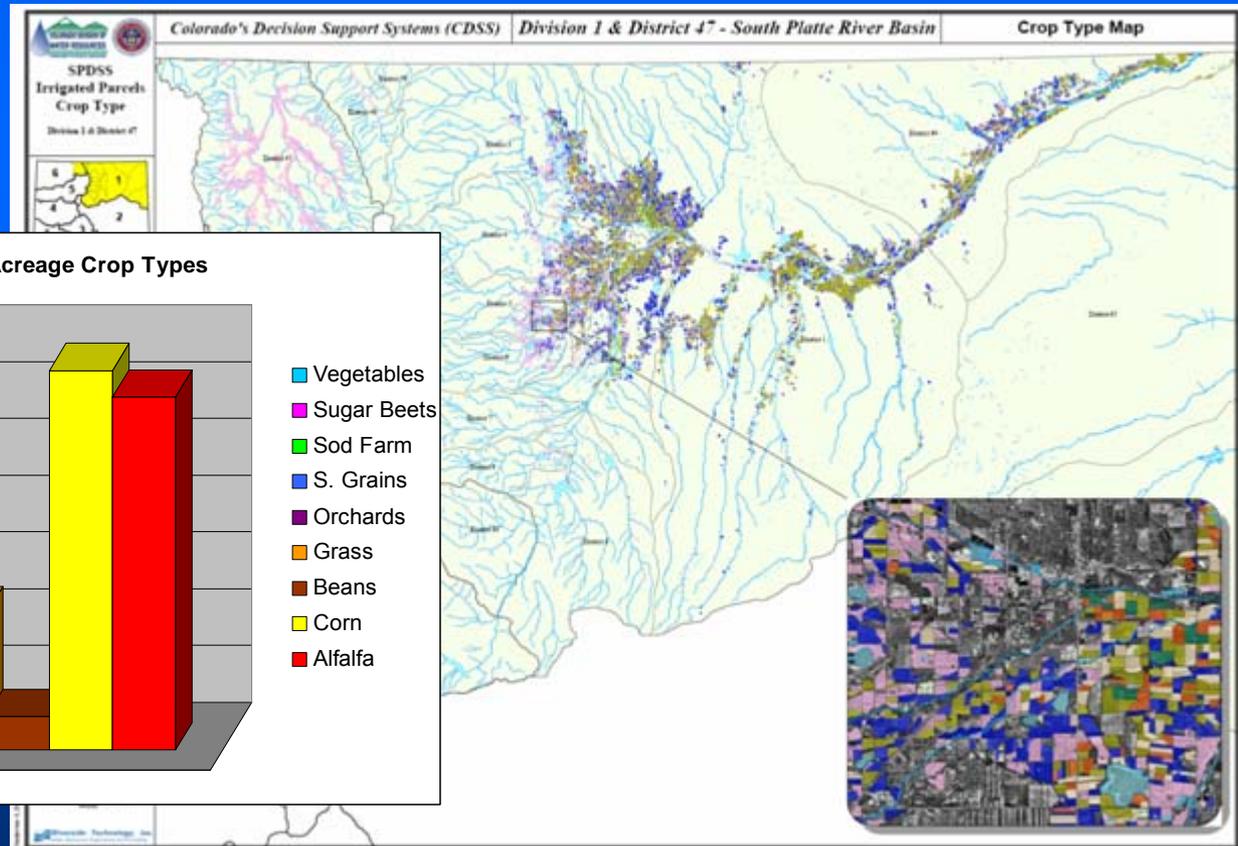


Agricultural Water Consumptive Use

- Typical method for ET:
 - CU computed based on estimates of ET for crops
 - Crop ET estimated as a fraction (i.e., crop coefficient, K_c) of computed ET for reference crop
 - Reference ET is a standardized estimate of potential ET calculated at a weather station and for a specific vegetation condition
 - crop ET estimated by selecting derived K_c corresponding to the crop growth stage, and multiplying by the reference ET value

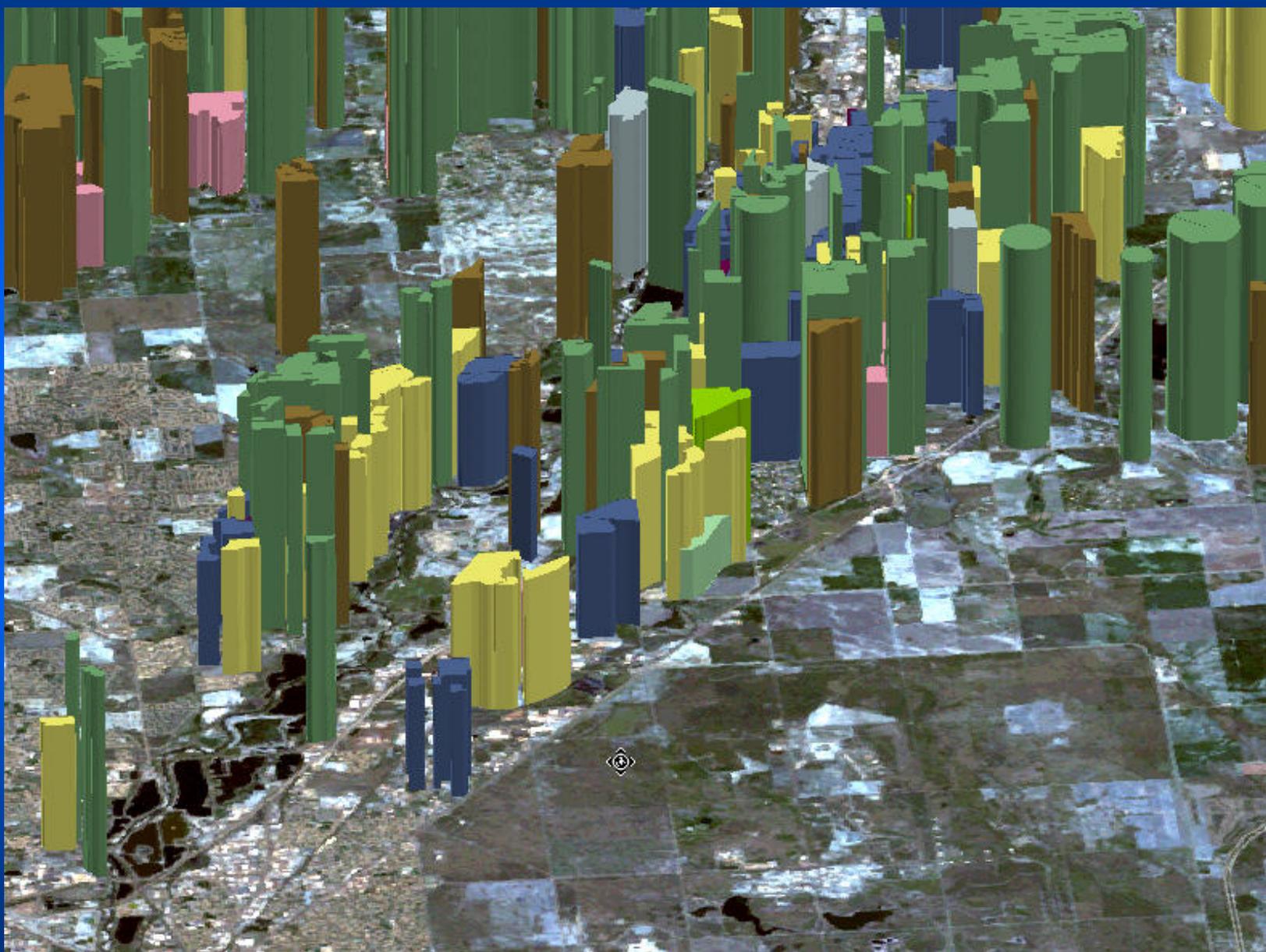
Agricultural Water Consumptive Use

- Typical method for ET:
 - Aggregated ET over a large area calculated by summing across all fields (if specific field-crop information is available)





Agricultural Water Consumptive Use

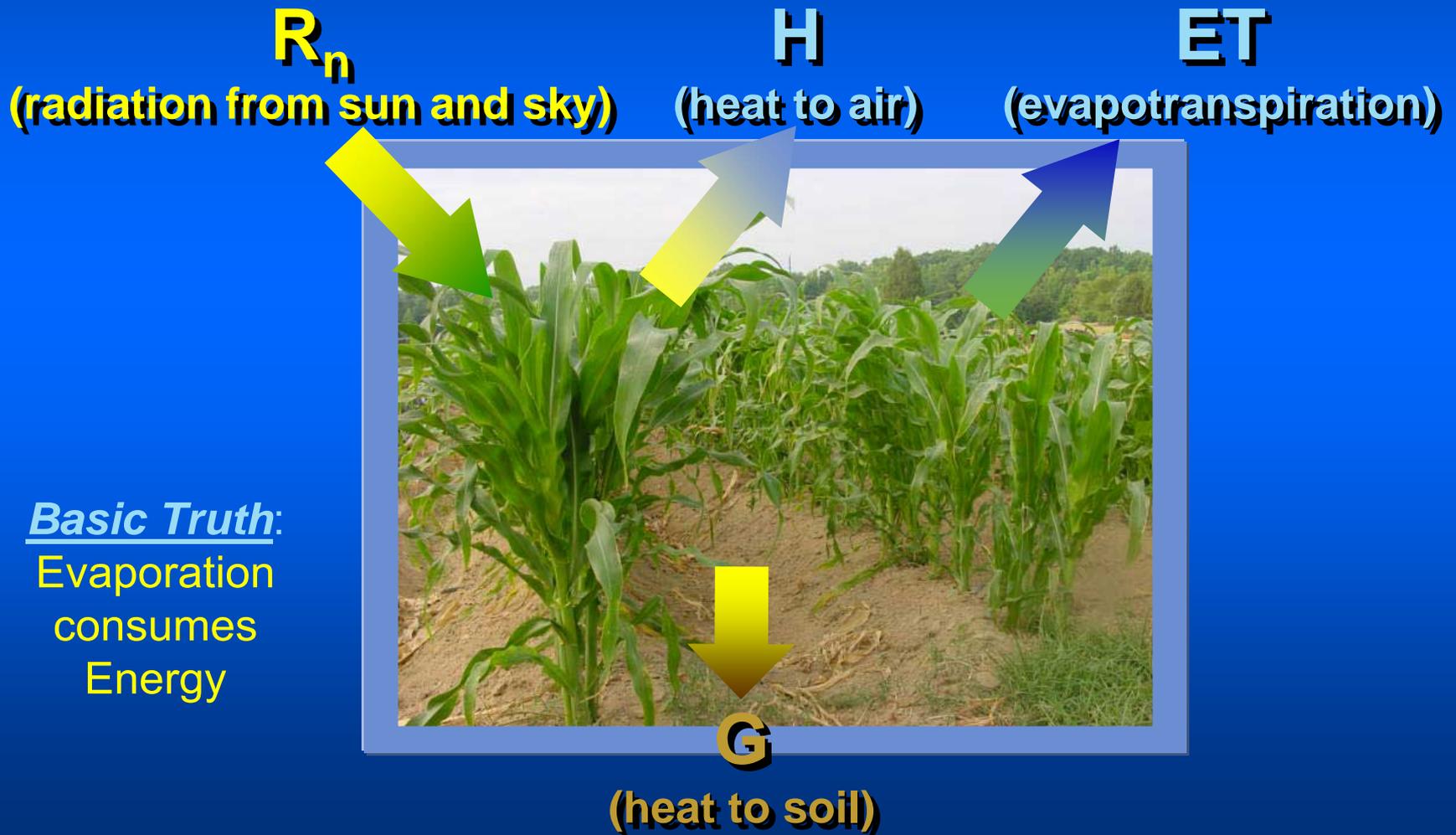


Why Satellite Remote Sensing?

- Limitations of Typical method for ET:
 - **Weather data** are gathered from fixed points -- assumed to extrapolate over large areas
 - **Crop coefficients** assume “*well-watered*” situation (impacts of drought stress are difficult to quantify)
 - **Crop maps** are required
- Satellite imagery:
 - Areas where **Water shortage reduces ET** are identified
 - **Little or no ground data** are required
 - Valid for **natural vegetation**
 - **Energy balance** applied at each “*pixel*” to map spatial variation

Energy Balance

ET is calculated as a “residual” of the energy balance: **(LE)** $ET = R_n - G - H$



• **Net Radiation (R_n)** = function of:

- Date and time
- Reflectance (brightness of surface)
- Surface temperature
- Humidity (minor effect)

– **Heat to Air (H)** = function of:

- Surface temperature
- Wind speed
- Vegetation type and 'roughness'
- Surface to air temperature difference:

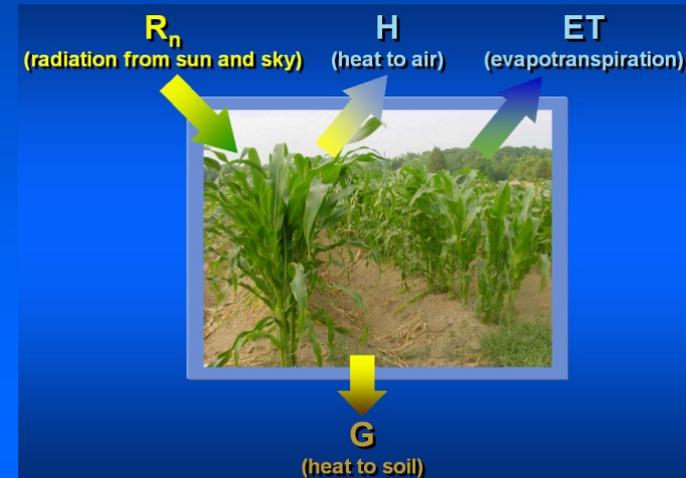
– H at the 'cold' pixel = $R_n - G - ET_{\text{reference}}$

– H at the 'hot' pixel = $R_n - G - 0$

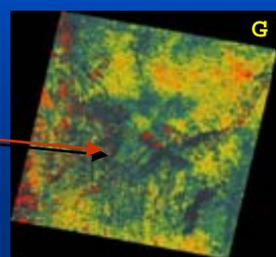
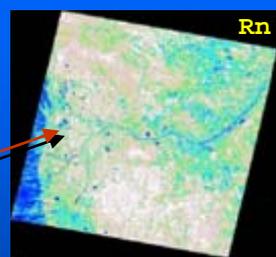
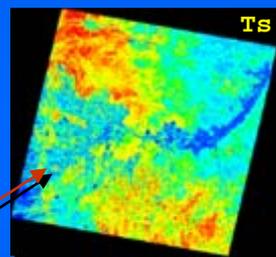
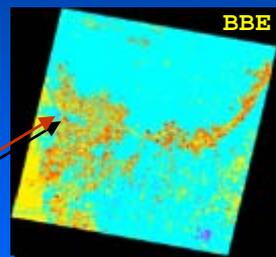
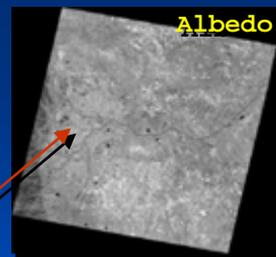
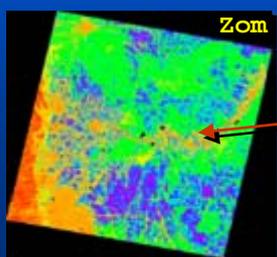
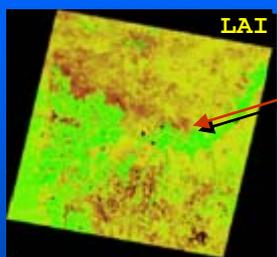
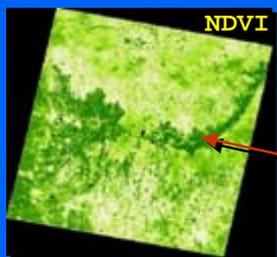
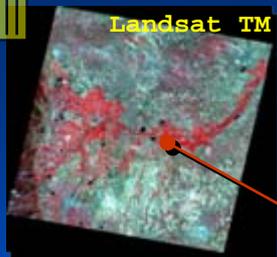
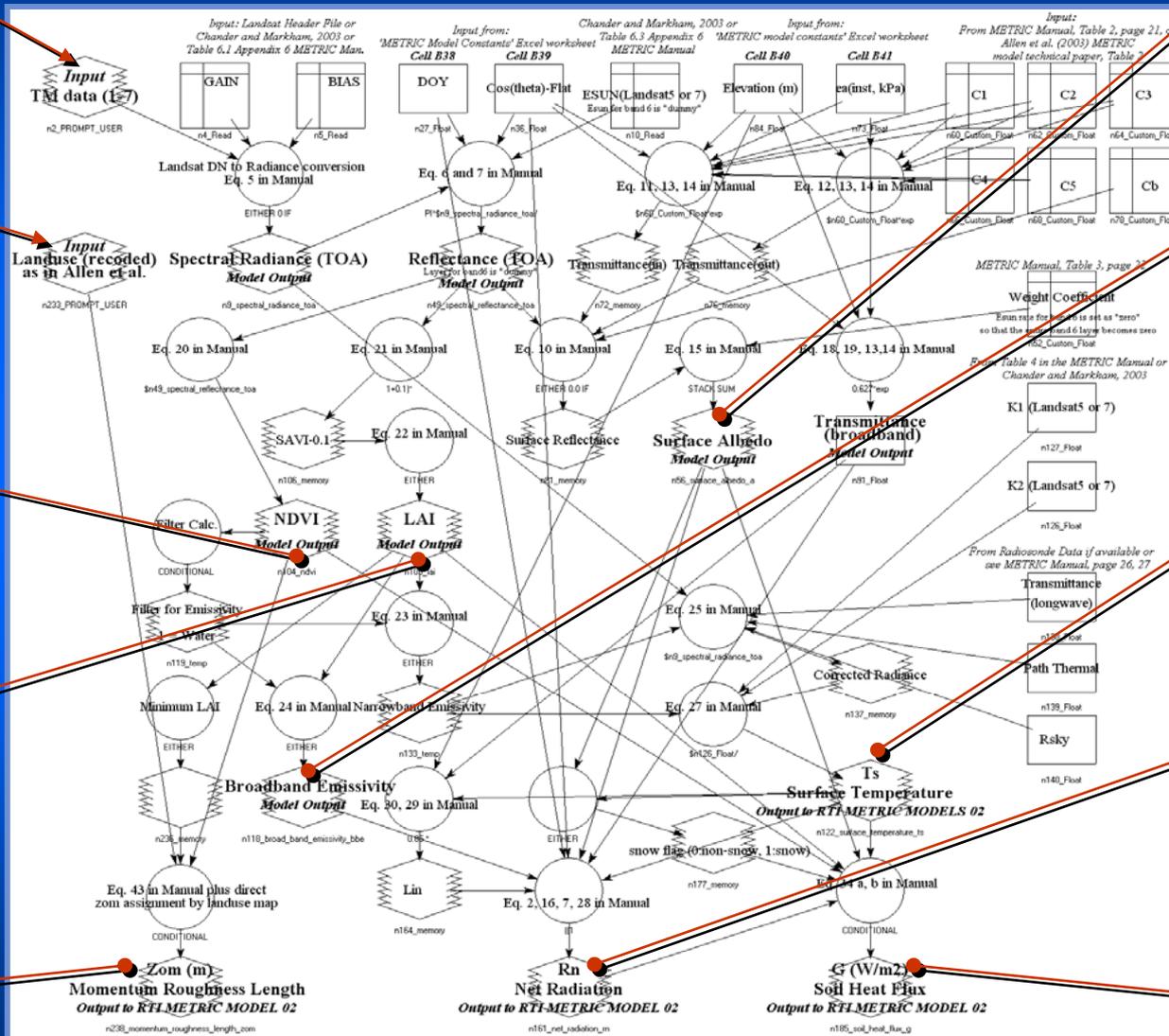
– **Heat to Ground (G)** = function of:

- Amount of vegetation
- Net radiation
- Surface temperature, reflectance

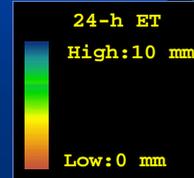
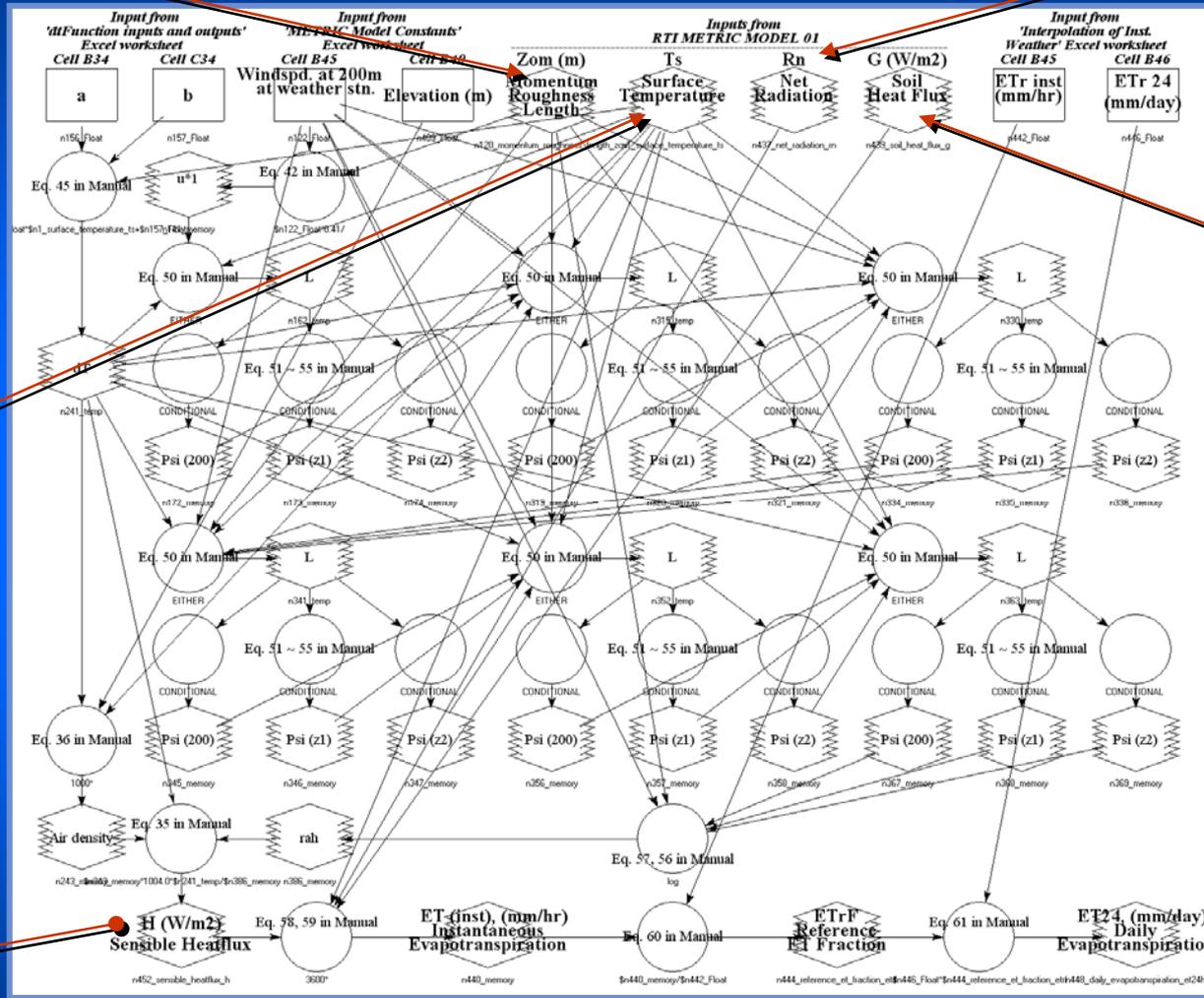
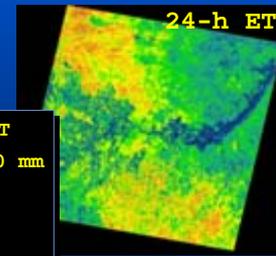
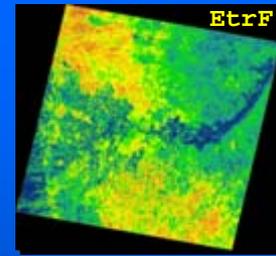
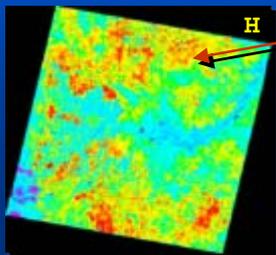
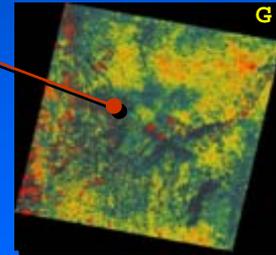
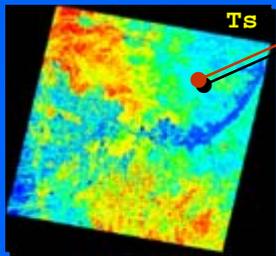
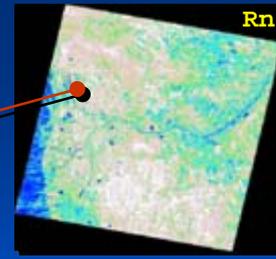
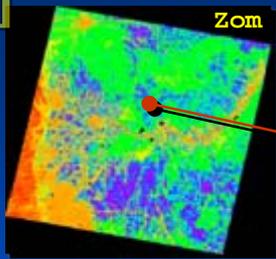
underlined terms are measurable by satellite



METRIC Model Inputs and Outputs

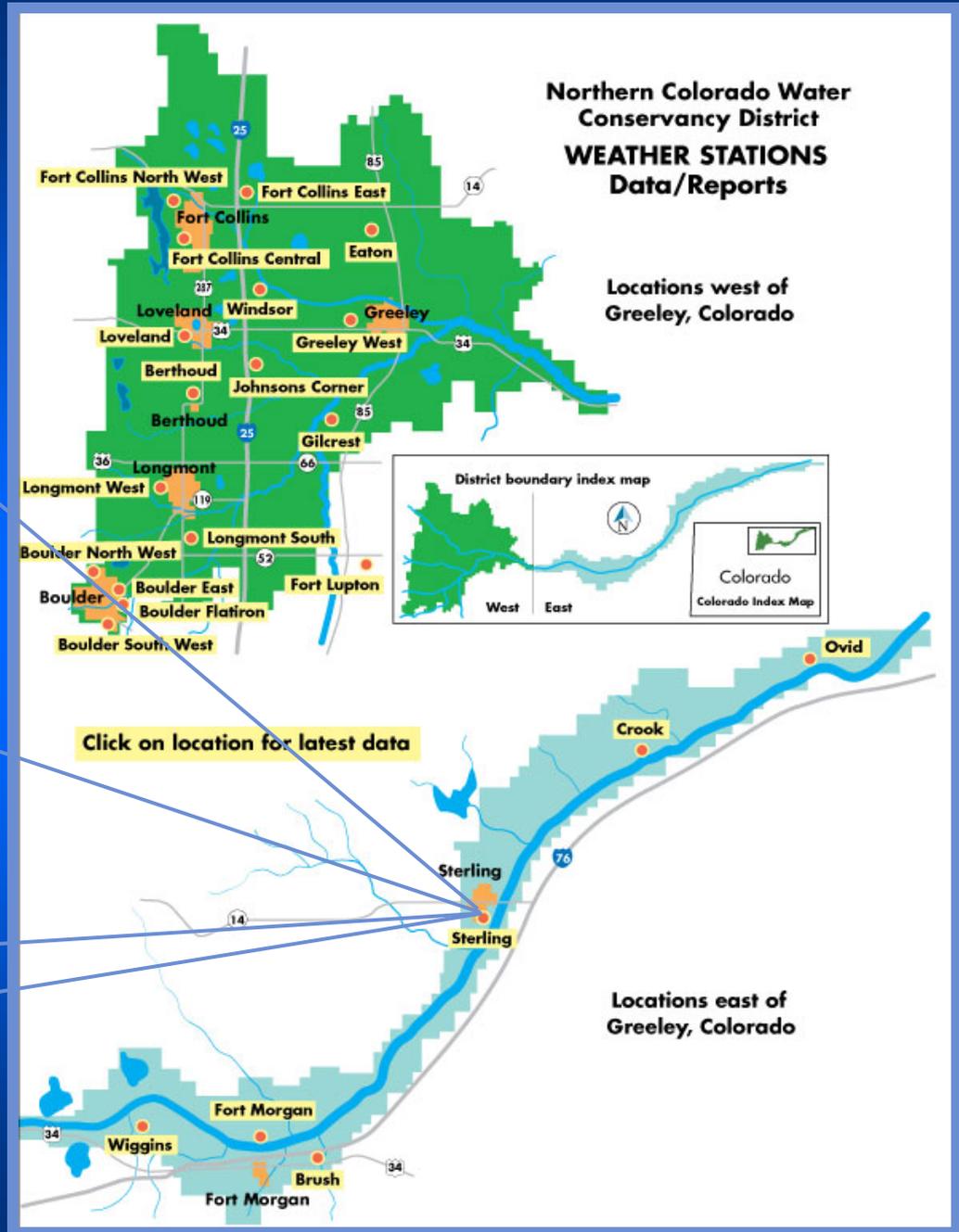


METRIC Model Inputs and Outputs

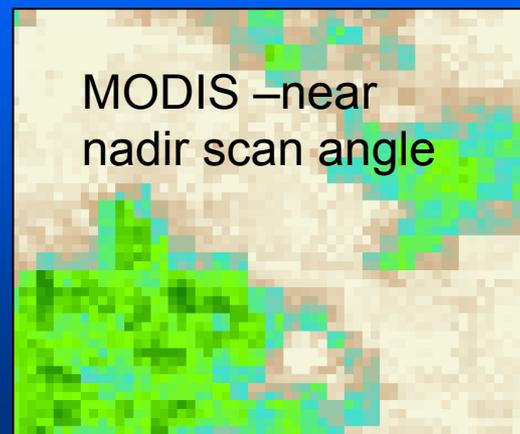
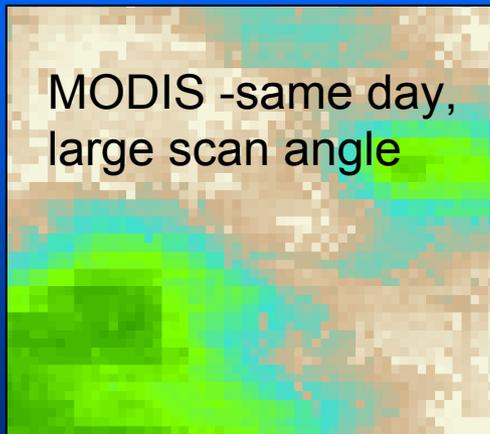
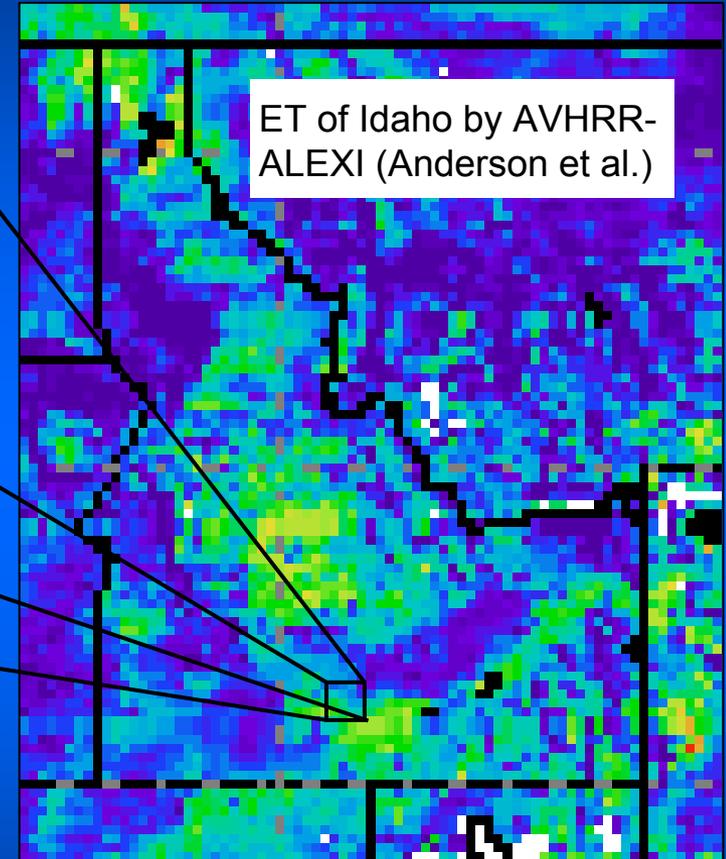
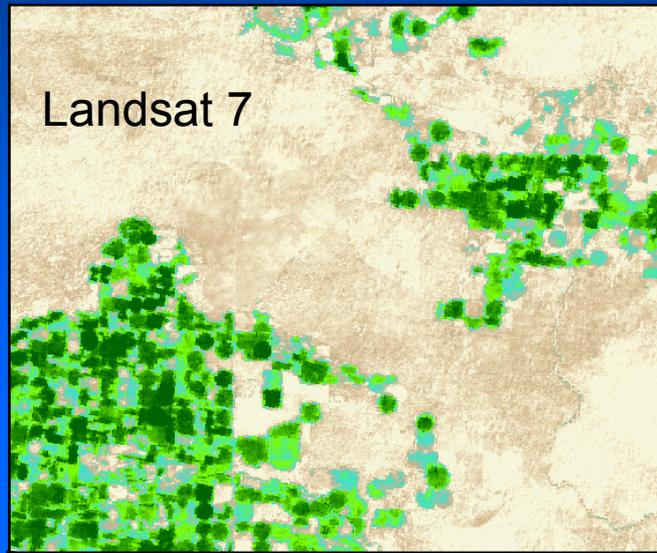
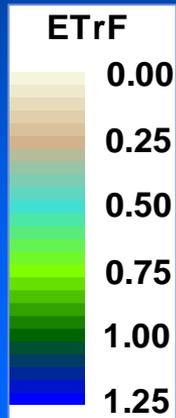


NCWCD Weather Stations Network

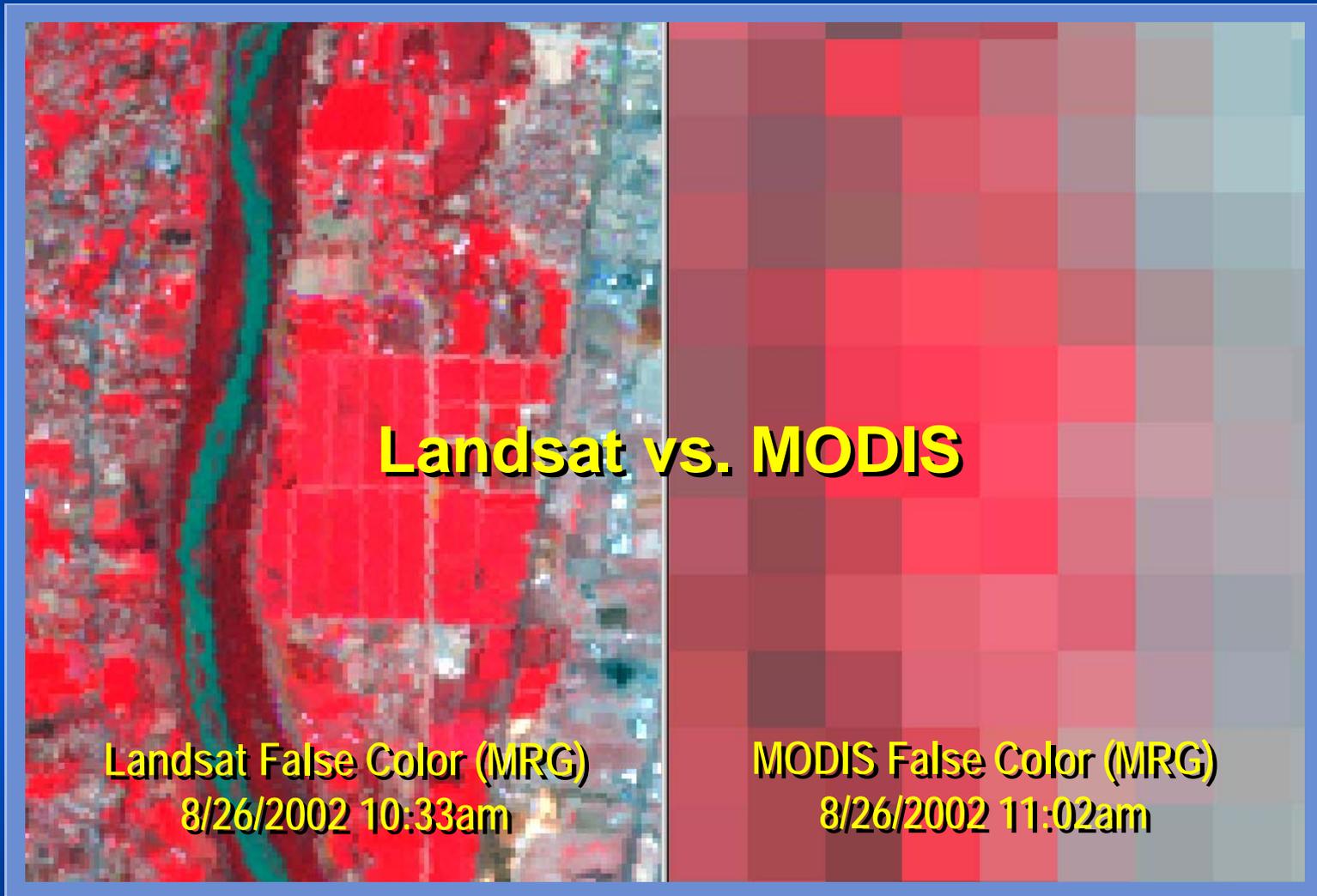
DOY	HrMn	Year	Tmax	Tmin	RS	wind	DewP
235	0	2000	12.8	12.8	0	1.4	3.9
235	100	2000	10.3	10.3	0	0.9	4.9
235	200	2000	13.4	13.4	0	2.1	3.3
235	300	2000	8.7	8.7	0	1	4.5
235	400	2000	7	7	0	1.3	3.5
235	500	2000	5.8	5.8	0	1.4	3.2
235	600	2000	4.6	4.6	0	1	2
235	700	2000	4.7	4.7	2	0.9	1.3
235	800	2000	5.8	5.8	97	1.3	2.1
235	900	2000	10.1	10.1	290	1.6	3.5
235	1000	2000	14.3	14.3	450	1.7	4.6
235	1100	2000	17.5	17.5	629	1.1	4.2
235	1200	2000	20.4	20.4	747	1.4	4.6
235	1300	2000	23.3	23.3	836	1.9	5.3
235	1400	2000	25.8	25.8	874	1.5	4.9
235	1500	2000	27.9	27.9	858	1.1	3.8
235	1600	2000	29.9	29.9	784	2.8	4.3
235	1700	2000	31.1	31.1	662	2.8	-0.3
235	1800	2000	31.3	31.3	484	2.5	-1.6
235	1900	2000	30.9	30.9	261	1.2	-0.6
235	2000	2000	29.1	29.1	80	0.8	2
235	2100	2000	23.3	23.3	4	0.4	6.4
235	2200	2000	18.9	18.9	0	1.2	9.3
235	2300	2000	14.3	14.3	0	1	9.6



Why use High Resolution Imagery?



Why use High Resolution Imagery?



Energy balance gives us “actual” ET

We can ‘see’ impacts on ET caused by:

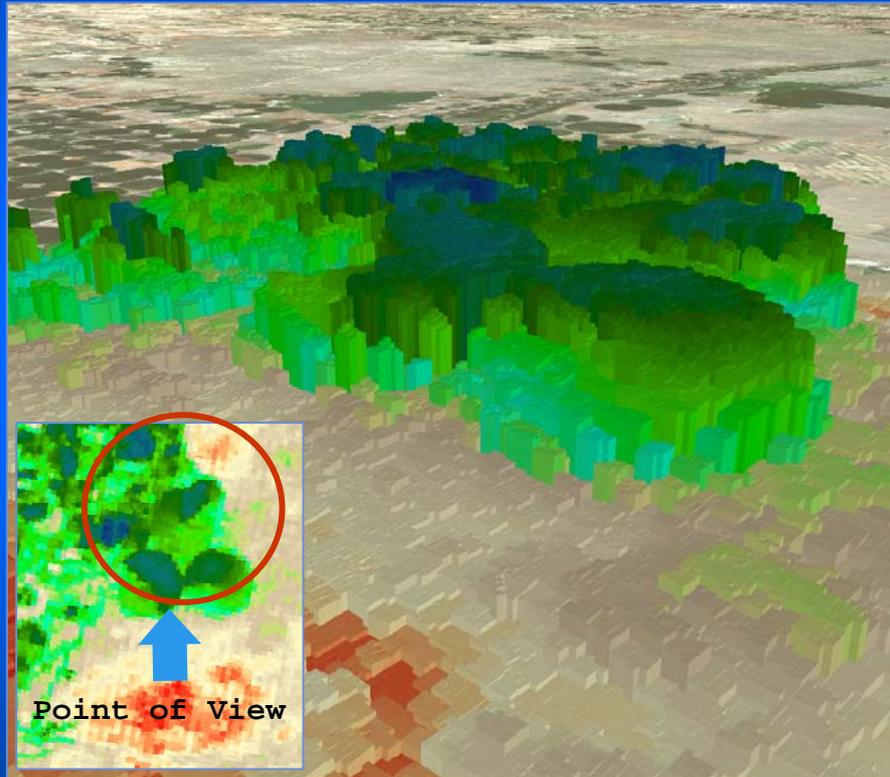
- Water shortage
- Disease
- Crop variety
- Planting density
- Cropping dates
- Salinity
- Management



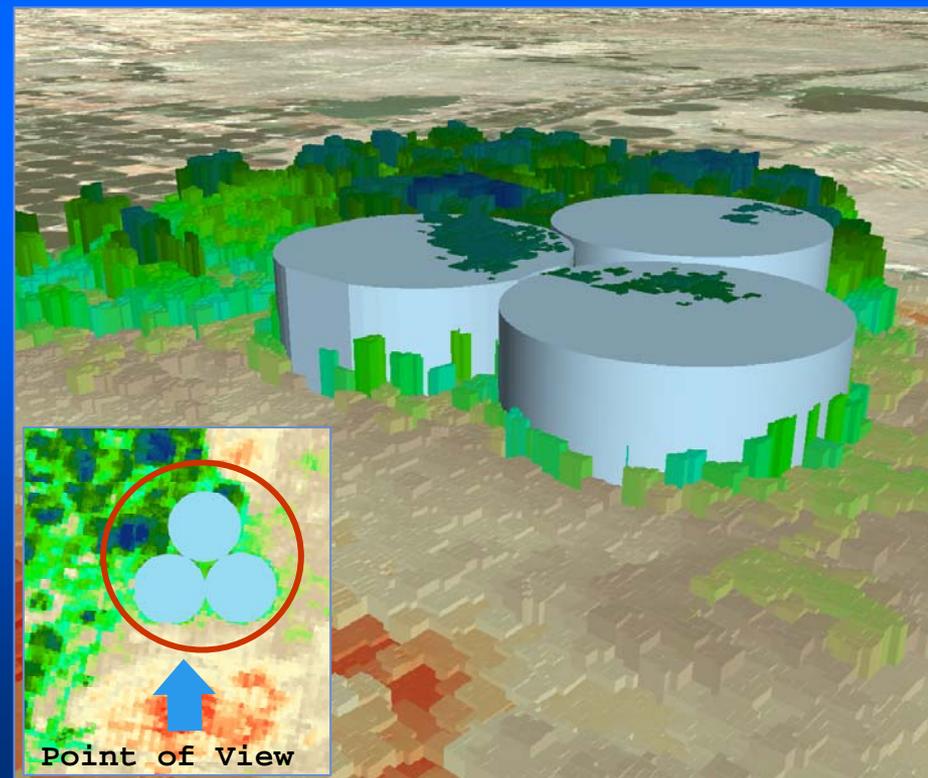
- *Many of these effects can be ‘missed’ by vegetation index based methods*
- *ET reduction effects can be converted directly into an evapotranspiration coefficient*

Differences between METRIC and Traditional Consumptive Use Estimates

3-D Visualization of METRIC ET Consumptive Use Estimates

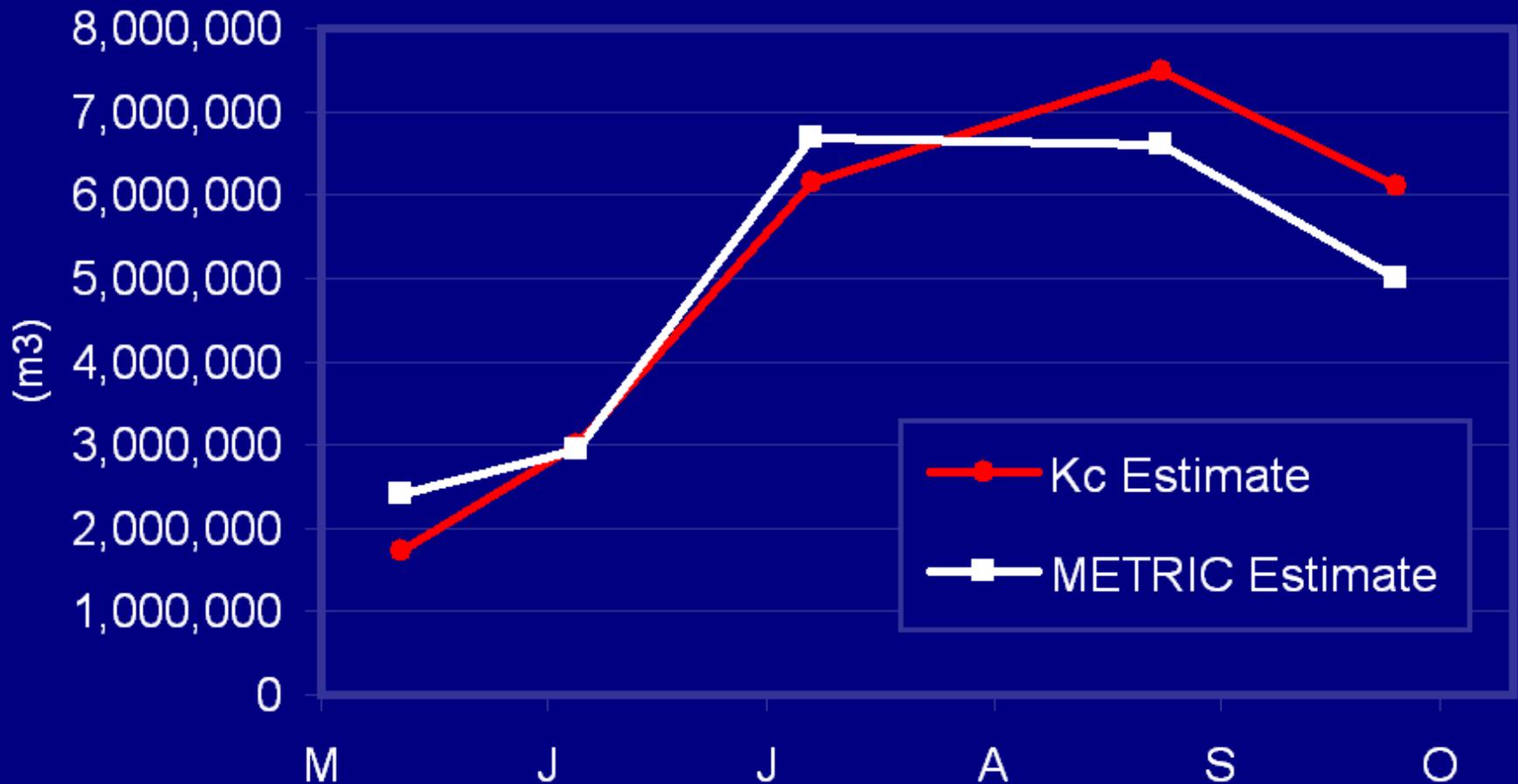


3-D Visualization of Kc Consumptive Use Estimates Superimposed on METRIC Estimates



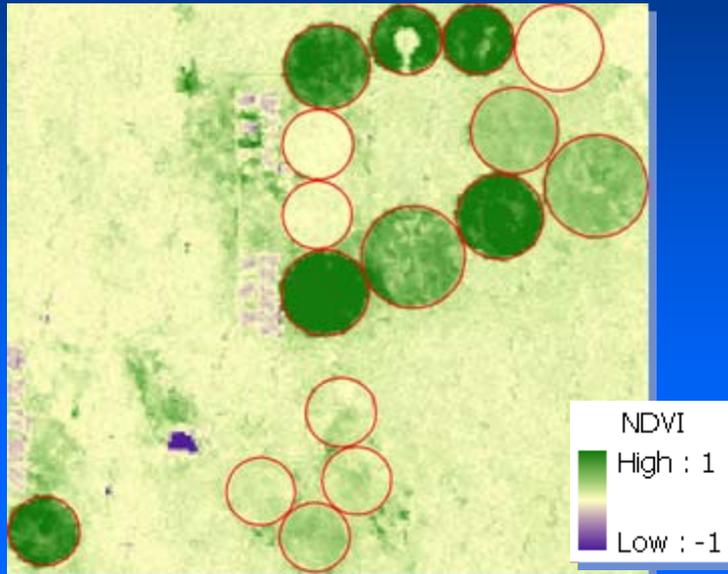
Differences between METRIC and Traditional Consumptive Use Estimates

Comparative 24-h Consumptive Use Estimates for 6821 Corn Fields in the South Platte River Basin in 2001 (m³)

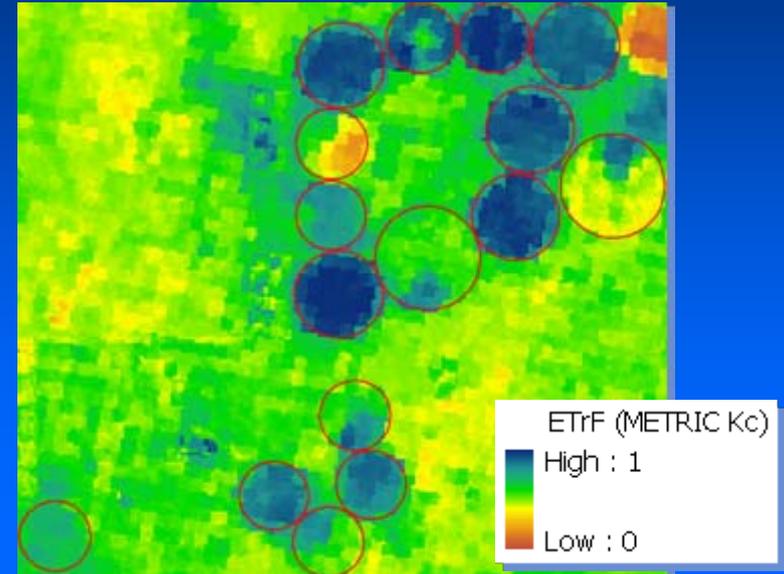


Drought Index

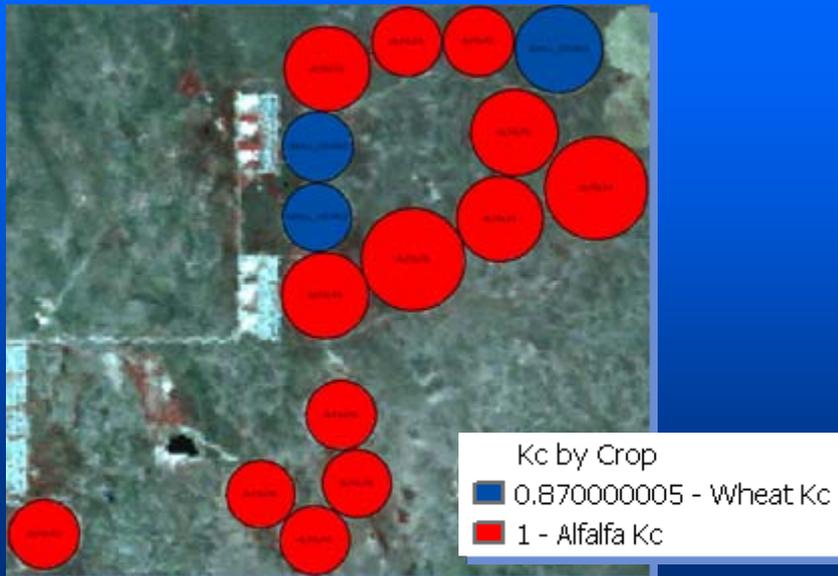
NDVI September 25, 2001



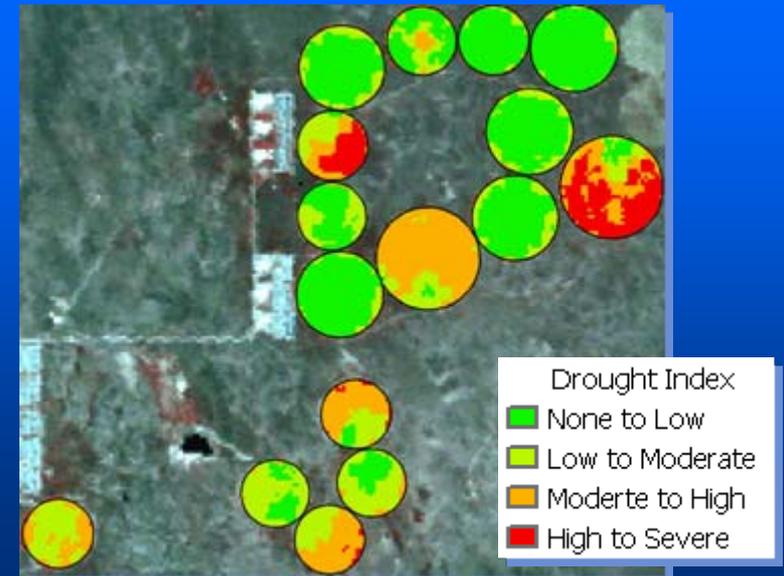
ETrF September 25, 2001



Crop Type September 25, 2001

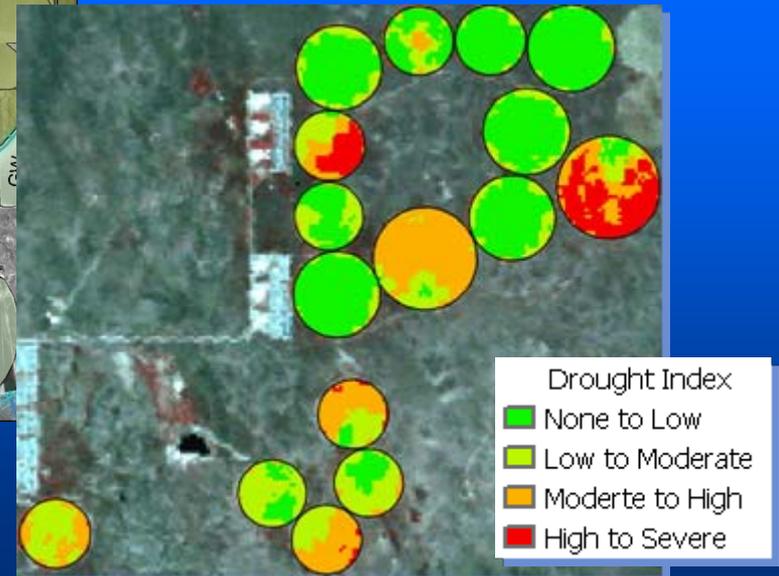
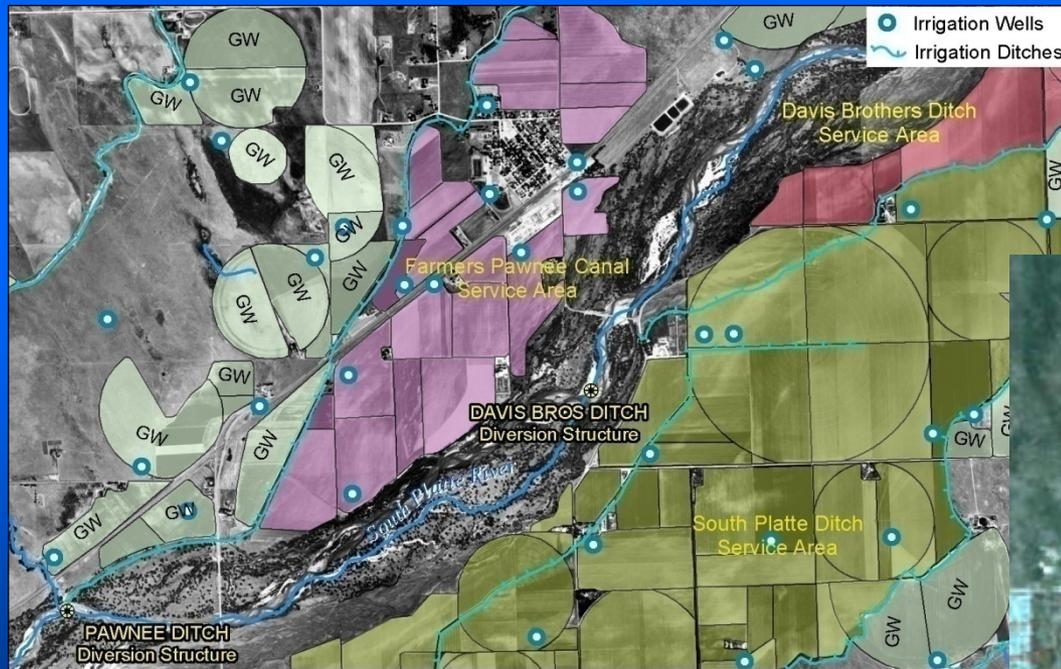


Drought Index September 25, 2001



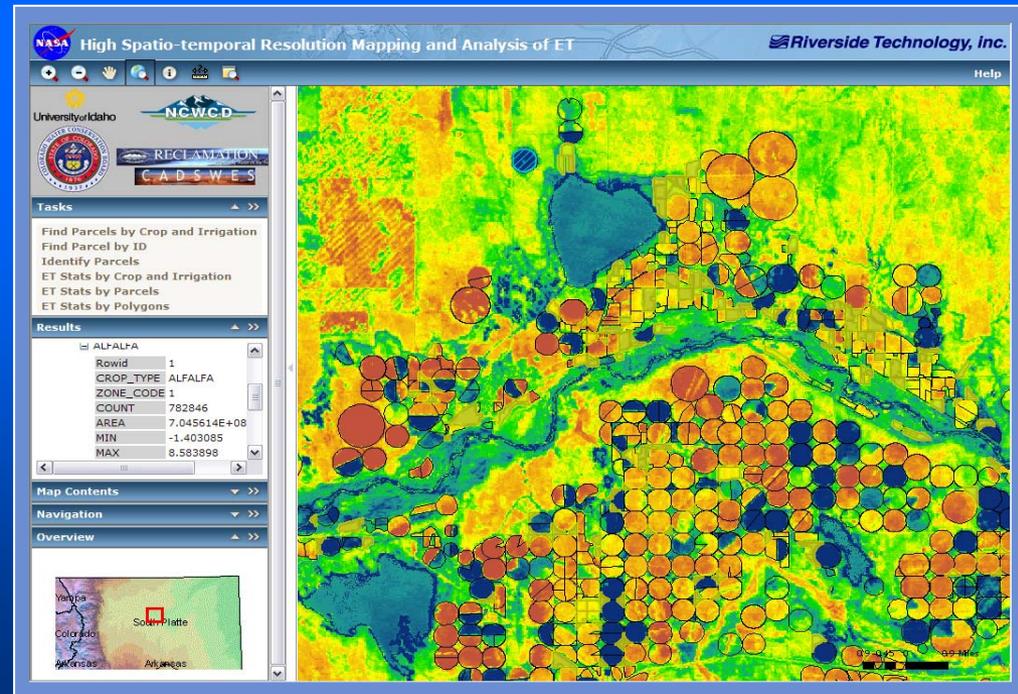
Parcels and Service Areas

- Potential irrigation service areas combined with irrigated parcels
- Parcels attributed with the ID of the diversion structure for each service area

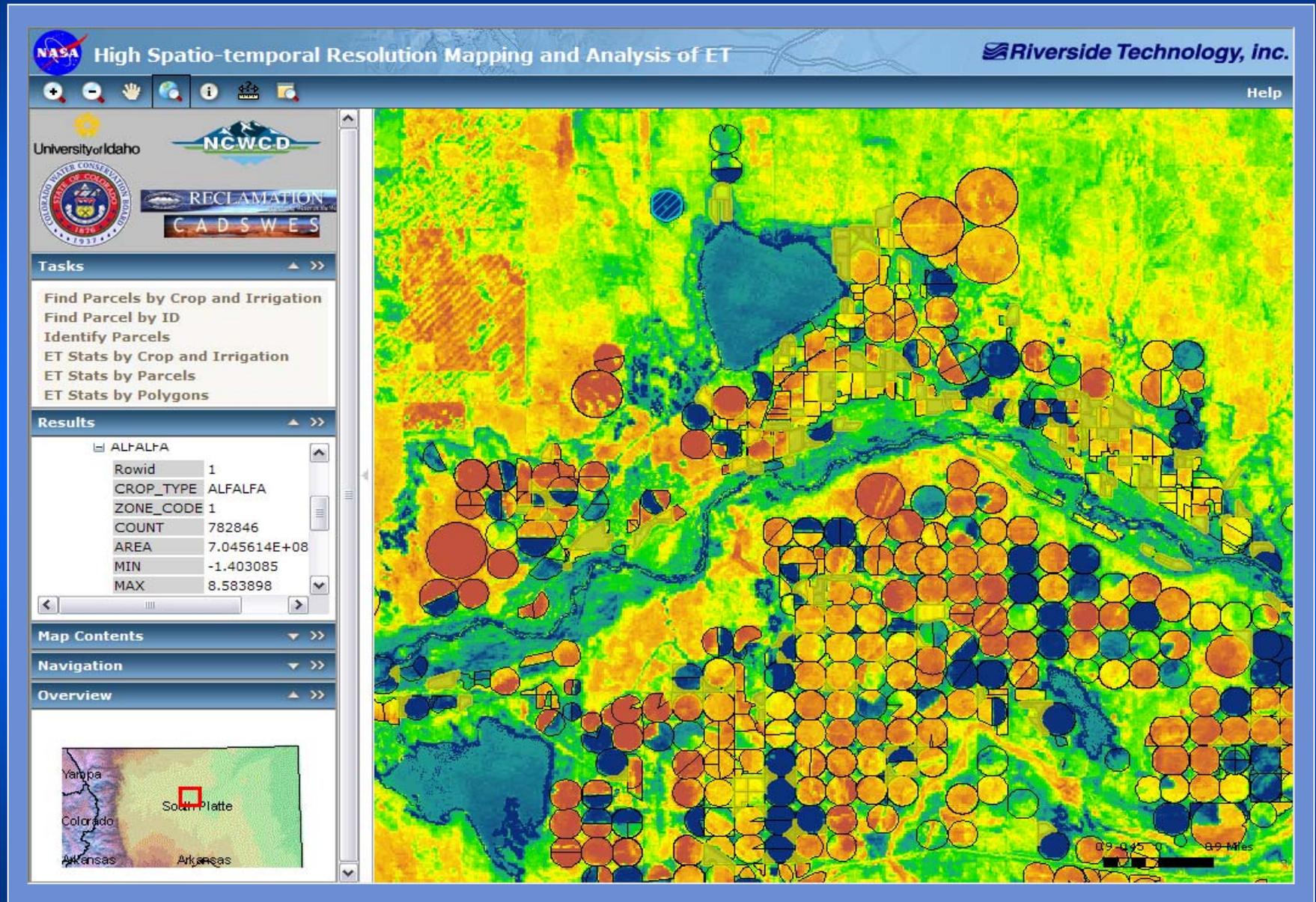


Data Dissemination

- Internet map server, powered by ESRI ArcServer technology
- Web mapping tool has analytical geospatial capabilities
- Modeler can select an AOI (e.g. return flow contributing area) by digitizing on-screen, and compute ET for that area
- Streamlines flow of data into the Decision Support Systems



Data Dissemination



Limitations

- Should not expect perfect accuracy in estimating ET by energy balance driven by satellites that orbit 700 km above the earth's surface
- ET and energy balance processes are energy driven, but are impacted by aerodynamics at the surface that are largely invisible to the satellite

METRIC ET Products

	Landsat TM	Landsat ETM	Aster	MODIS
Source instrument	Landsat TM	Landsat ETM	Aster	MODIS
Spatial resolution (Determined by the thermal band)	120 m	60 m	90 m	1 km
Frequency of product availability	16 days	16 days	Inconsistent	4 days
Delay between observation and product availability	Approx. 1 week after image acquisition			
Geographic projection and file format	UTM or other common geographic projections and data formats			
Compatibility with GIS software	Most common GIS and image processing software			

Conclusions

ET maps are valuable for:

- Determining **Actual** ET
 - Water Transfers
 - Water Rights Conflicts
 - Diversion Management for Endangered Species
 - Ground-water Management
 - Consumption by Riparian Vegetation
 - Drought monitoring and management
 - Excellent means for determining and mapping the **spatial** and **temporal structure of ET**
-
- Maps by METRICtm have good accuracy and consistency
 - A single, high resolution **thermal band** is **adequate** and **essential**

Contacts and Thanks

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