



U.S. Sites for CTA NORTH

**CTA-US and SCT Meeting
SLAC, 24 February 2012**

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(*CTA-US SITE Working Group*)**

Outline



- **Major** Update from previous meetings (New York 2/11, Toulouse 5/11 and Madrid 11/11) – a huge amount of work has been done.
- Introduce:
 - General features of N. Arizona
 - Site selection process
 - Two sites in the proposal - Meteor Crater and Yavapai Ranch
- Review (quickly) the extensive material gathered on sites
- Key Issues:
 - Cloud cover and night sky background
 - Monsoons and lightning
 - Why more than one site?
- Where do we go from here ?
US Site Visit (Feb 27-28), CTA SITE WP Mtg (Mar 1-3)

Next talks: **Jeff Hall – Lowell Observatory as partner and host**
 Gagik Tovmassian – SPM, US-Mexico partnership

State of Arizona

Large state
~300,000 km²

Major International
Airports:
Las Vegas
Phoenix



**Lowell
Observatory**

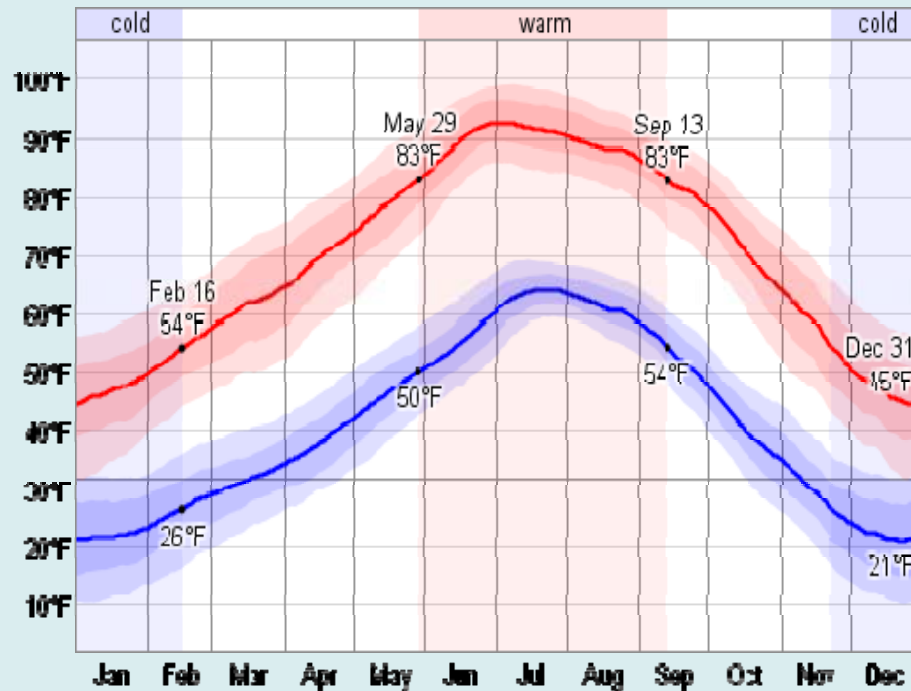


**City of Flagstaff
(pop: 65,000)**



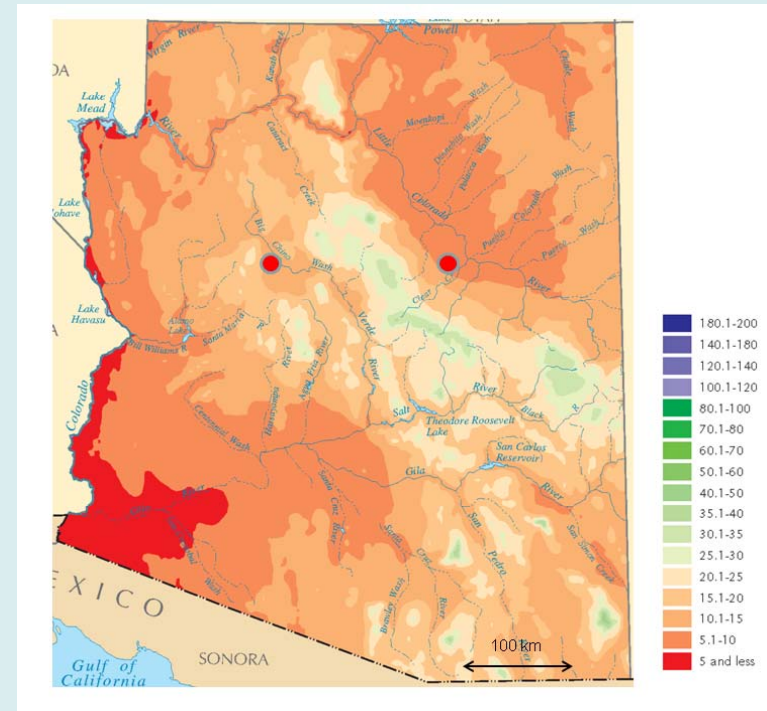
VERITAS

Arizona Weather



Temperature range for northern Arizona sites [7]. The average high temperatures (red) and low temperatures (blue) are shown for Winslow, AZ. 25-75% (inner band) and 10-90% (outer band) ranges are also shown.

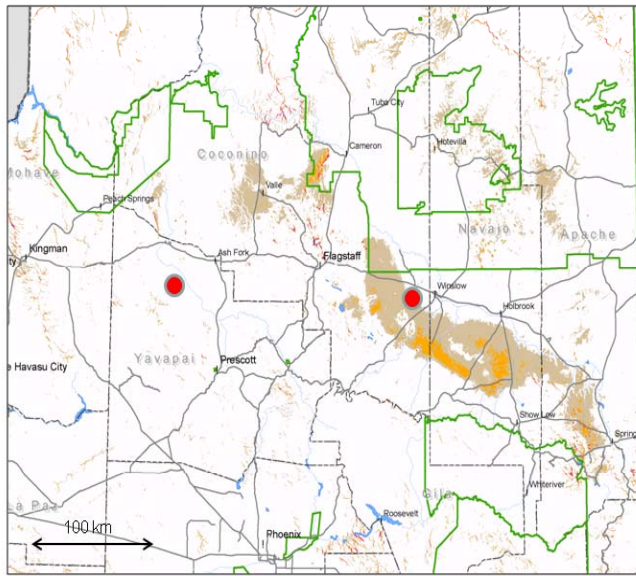
Reasonable temperature range



Map of total annual precipitation for the state of Arizona [8]. The legend at right indicates totals in inches. The proposed sites for CTA are indicated by the red circles.

Low precipitation
(lower than VERITAS site)

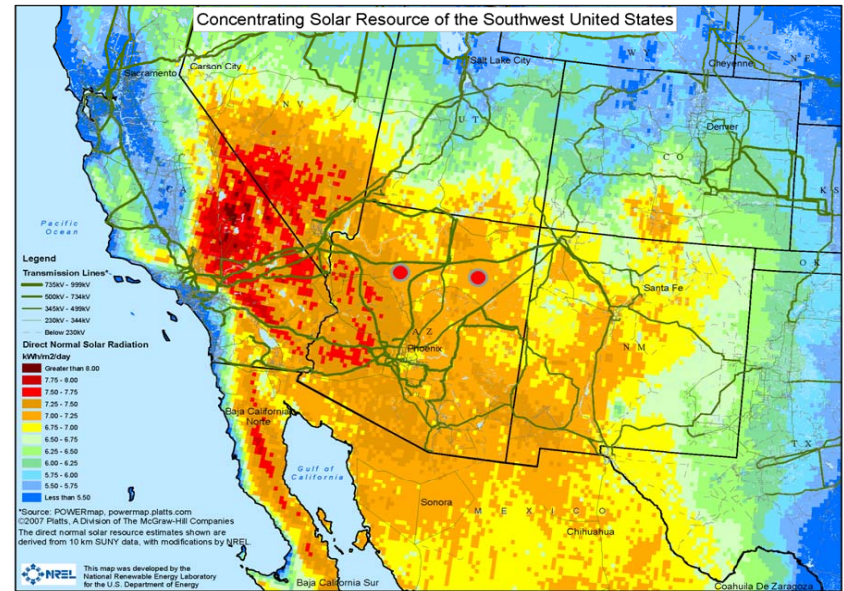
Wind, Solar



Wind Power Class	Wind Power Density (W/m ²)	Wind Speed (mph)
1 Poor	0 - 200	0.0 - 12.3
2 Marginal	200 - 300	12.3 - 14.1
3 Fair	300 - 400	14.1 - 15.7
4 Good	400 - 500	15.7 - 16.8
5 Excellent	500 - 600	16.8 - 17.9
6 Outstanding	600 - 800	17.9 - 19.7
7 Superb	> 800	> 19.7

Map of average wind speeds for northern Arizona [5]. The legend on the right indicates the color classification of different areas for viability for wind power generation. Both proposed CTA sites (red circles) are in the Poor or Marginal wind power classifications. These measurements were made at a height of 30m above ground level. Wind speeds at 10m above ground level are expected to be lower [10].

Moderate winds

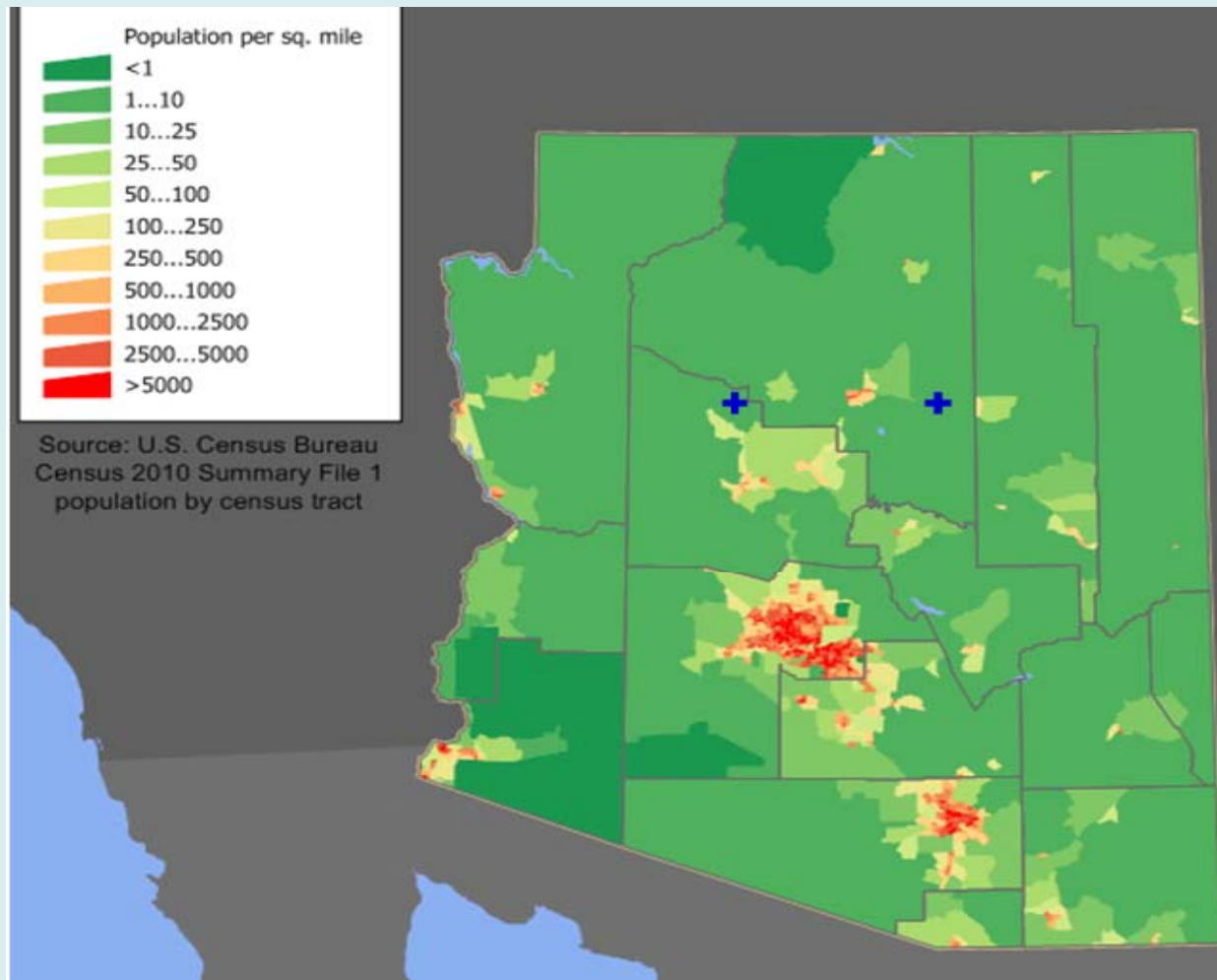


Map of direct normal solar radiation for the U.S. Southwest [11]. The proposed sites are indicated by the red circles.

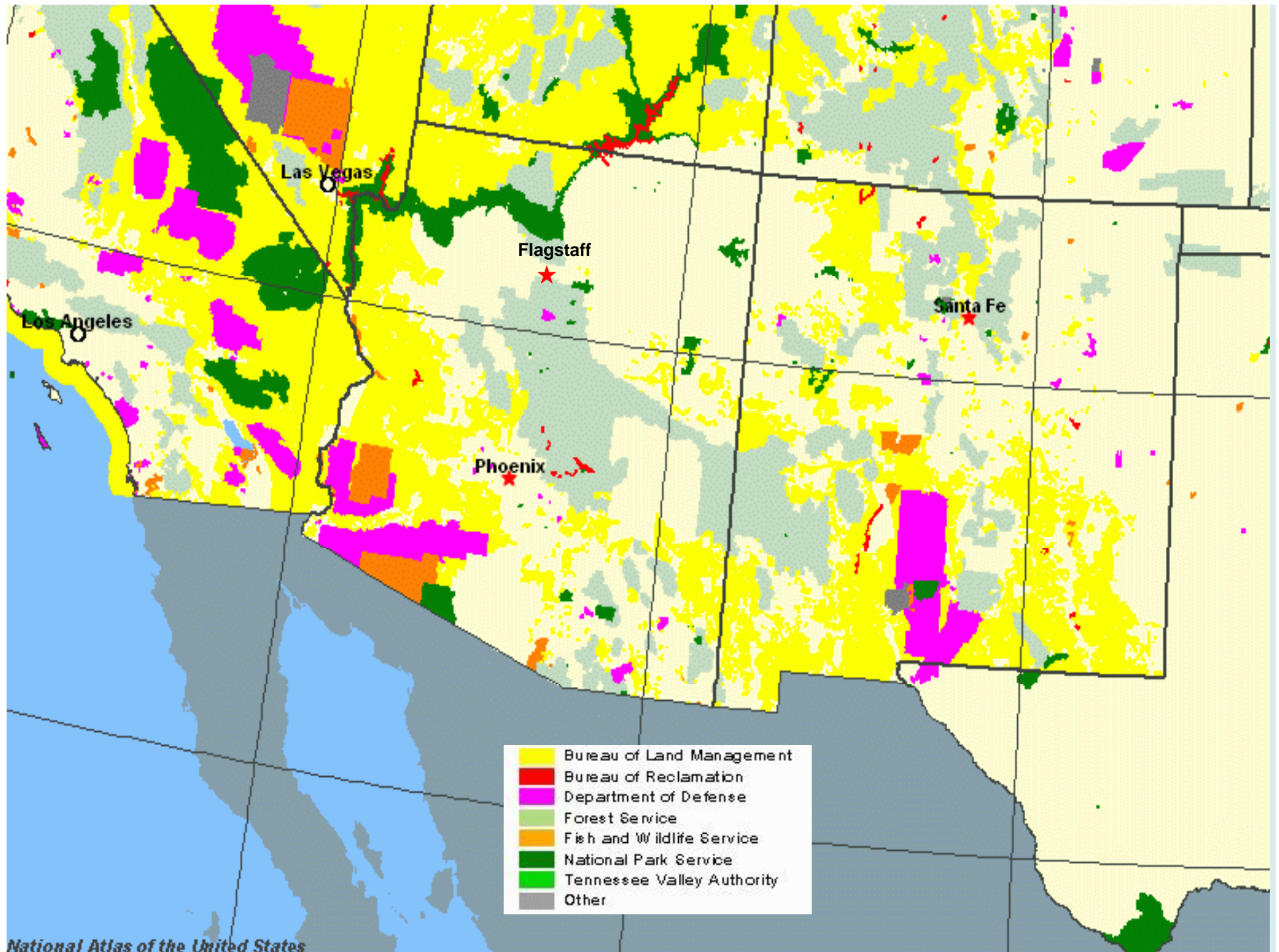
Good sky conditions

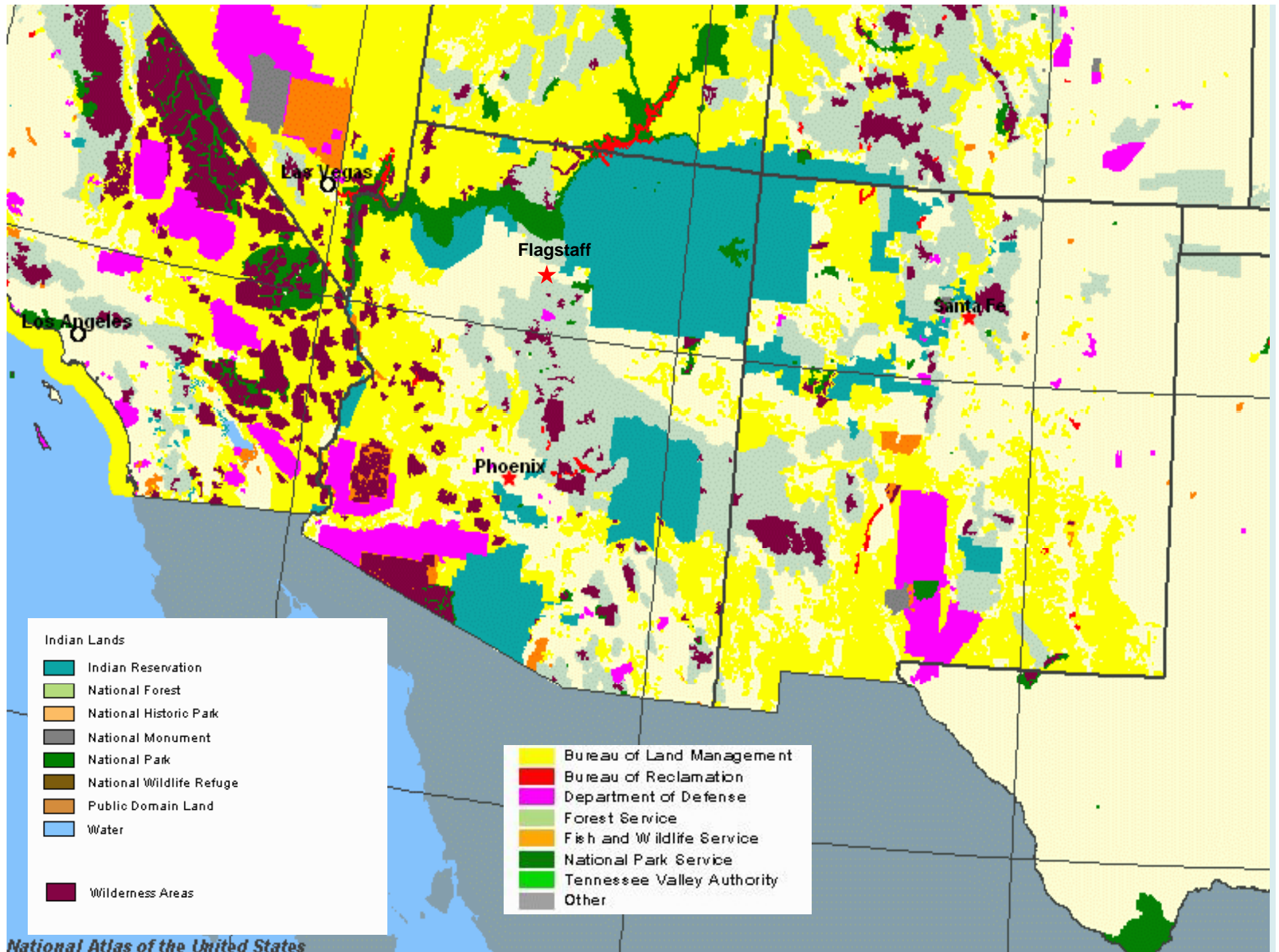
Note: alternative energy possibilities are very good for these sites and need to be fully explored

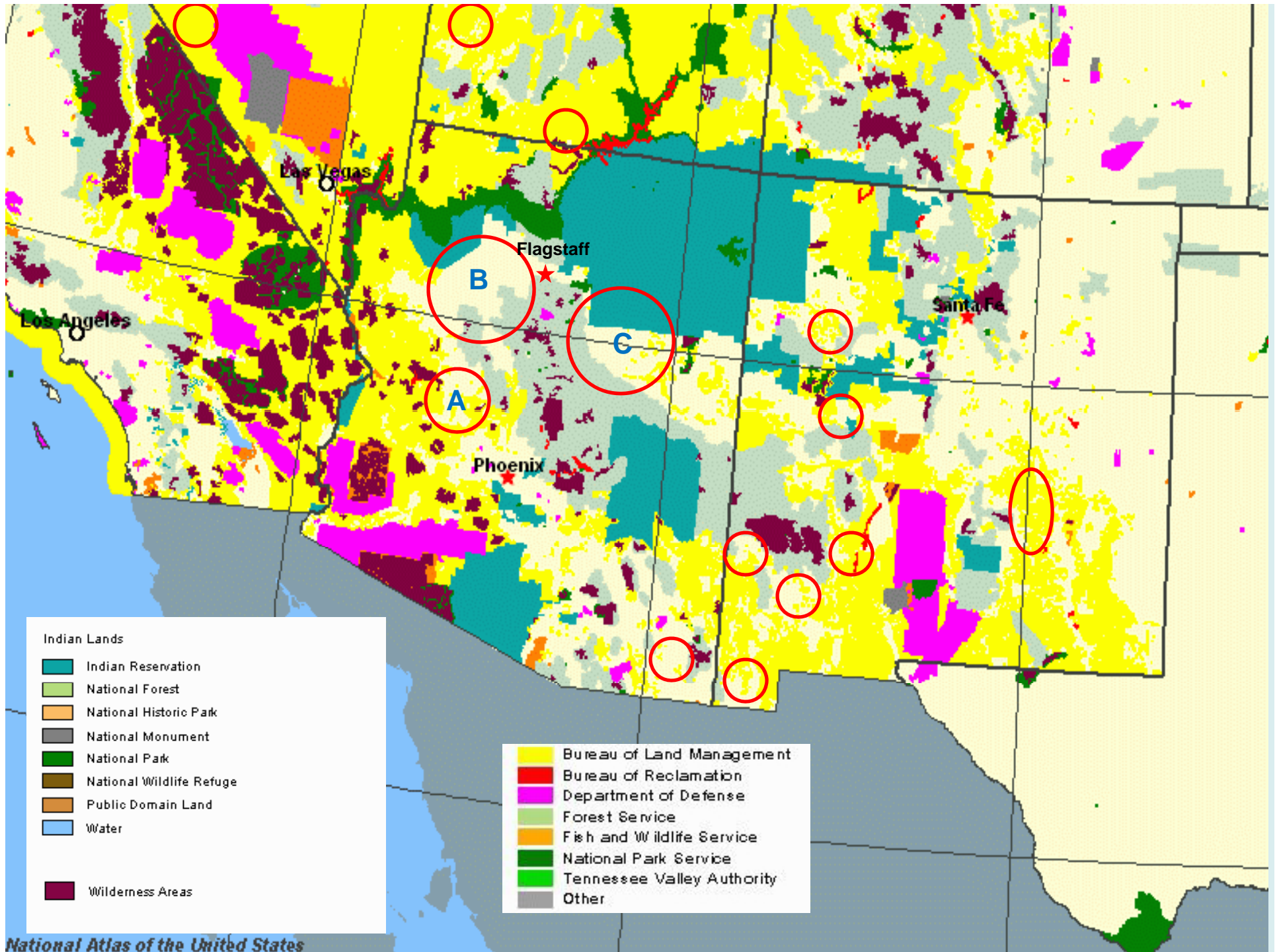
Population Density

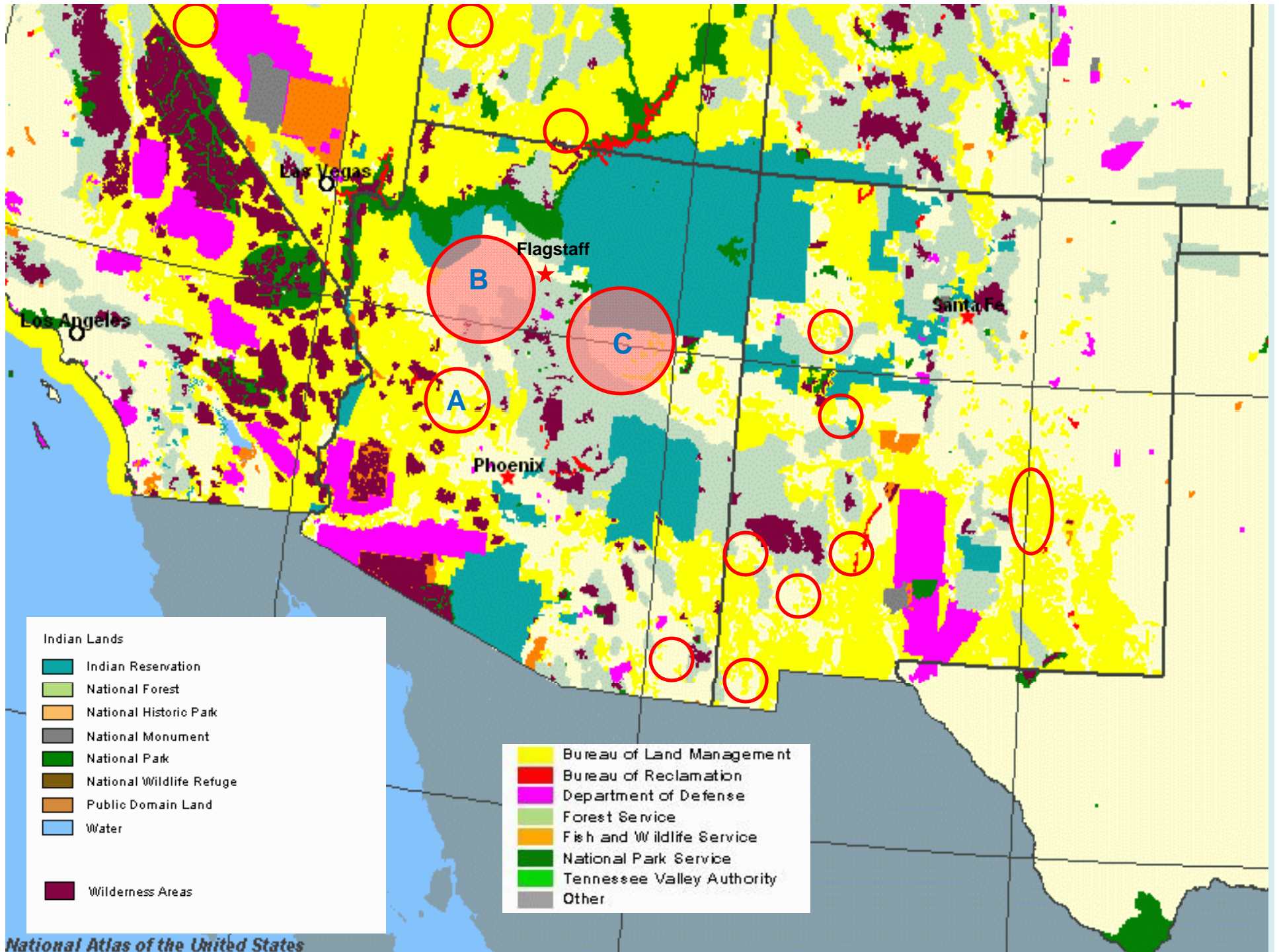


Map of population density of Arizona from the Census of 2010 [19]. The blue plus symbols indicate the locations of the two sites proposed for CTA. (The distance between the sites is approximately 180 km).









Arizona Land Pattern

Arizona has a unique land ownership pattern that dates back to original settlement and the building of the railroad across state.

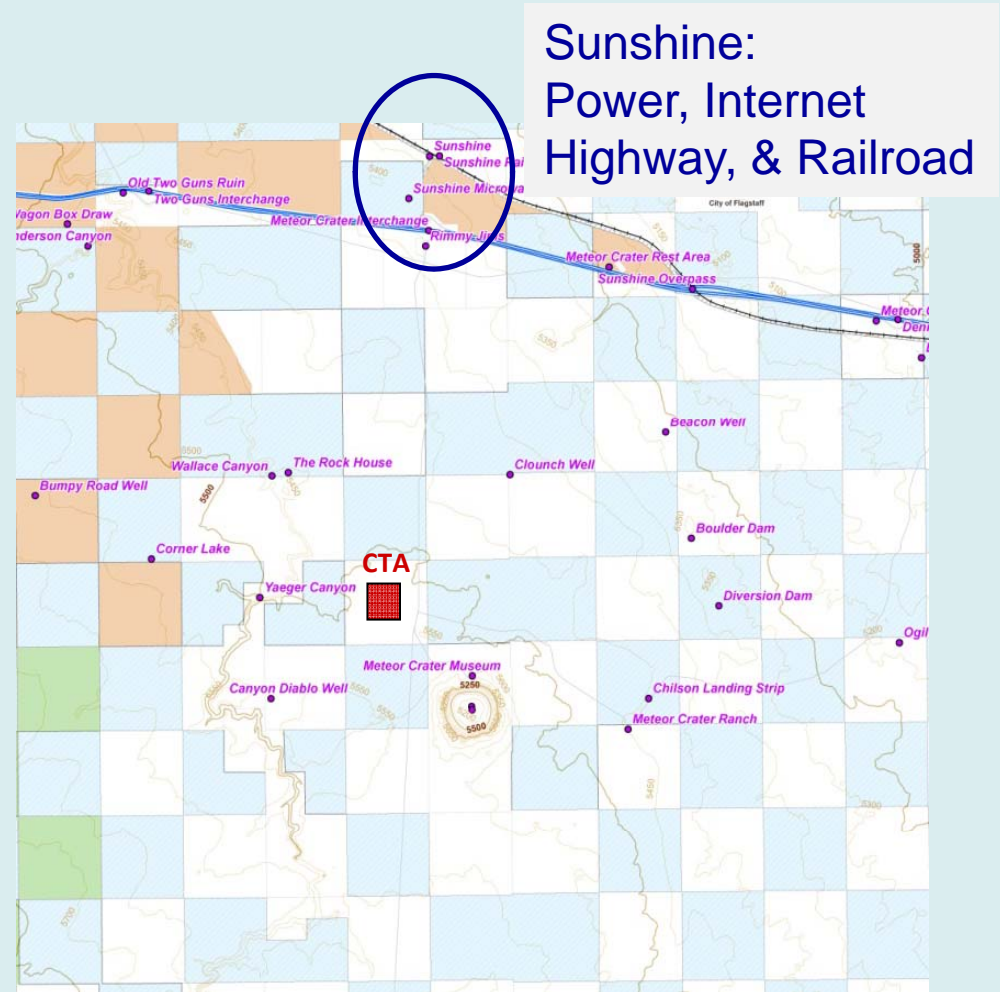
“Checkerboard” pattern of Private land and State Trust land.

Squares of 1mi x 1mi (1.6 km x 1.6 km).

Private land was consolidated into large ranches.

Perfect match for size of CTA North !

**Private land =
much less difficulty for permitting**



Meteor Crater site

Coconino and Yavapai Counties

Coconino County:

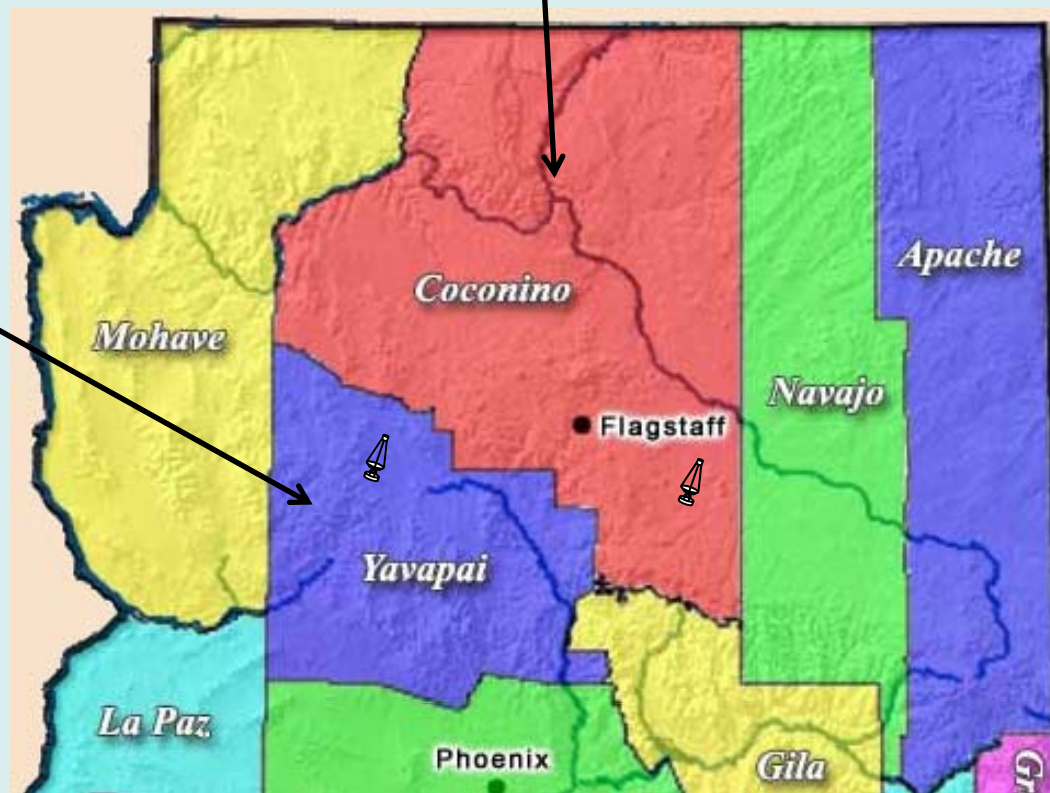
Large and sparsely populated

- ~50,000 km², second largest county in US-48 states
- Population ~ 135,000 (~half in Flagstaff)

i.e. larger than Switzerland and 1/6 population of Tenerife

Yavapai County

- ~21,000 km²
- Population ~ 210,000

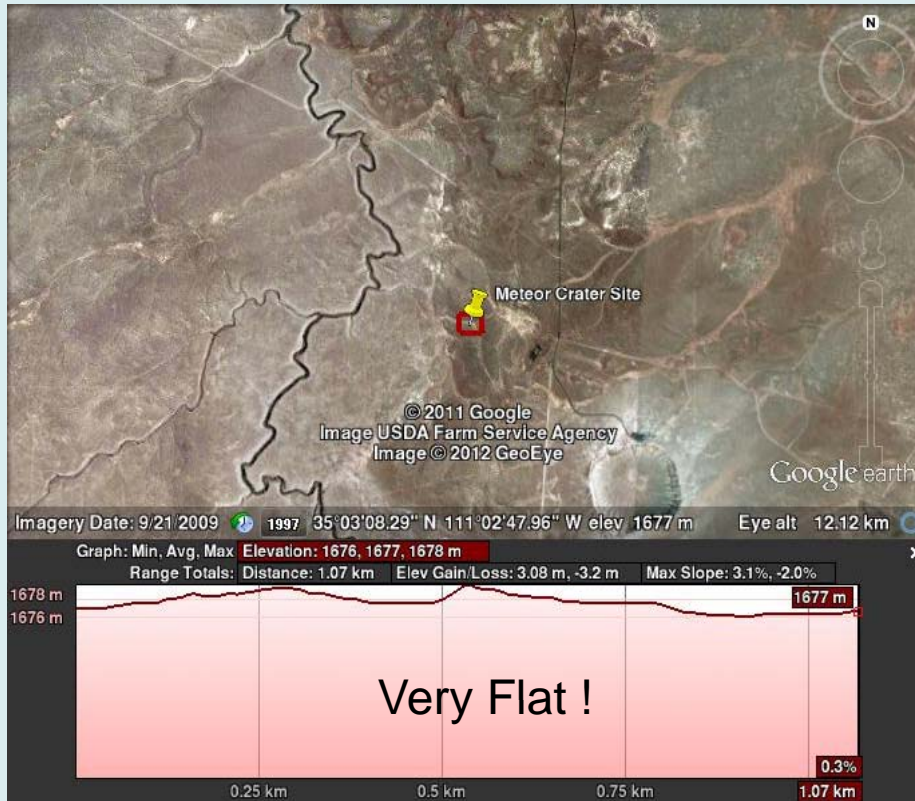


Proposed Sites



Map of a portion of Arizona near Flagstaff, AZ. The access routes from the East Site (A) and the West Site (B) to Flagstaff (C) are shown in blue. The Grand Canyon starts at the top of the figure.

Meteor Crater Site



Satellite views of the East Site, showing the proposed CTA location and the elevation profile.

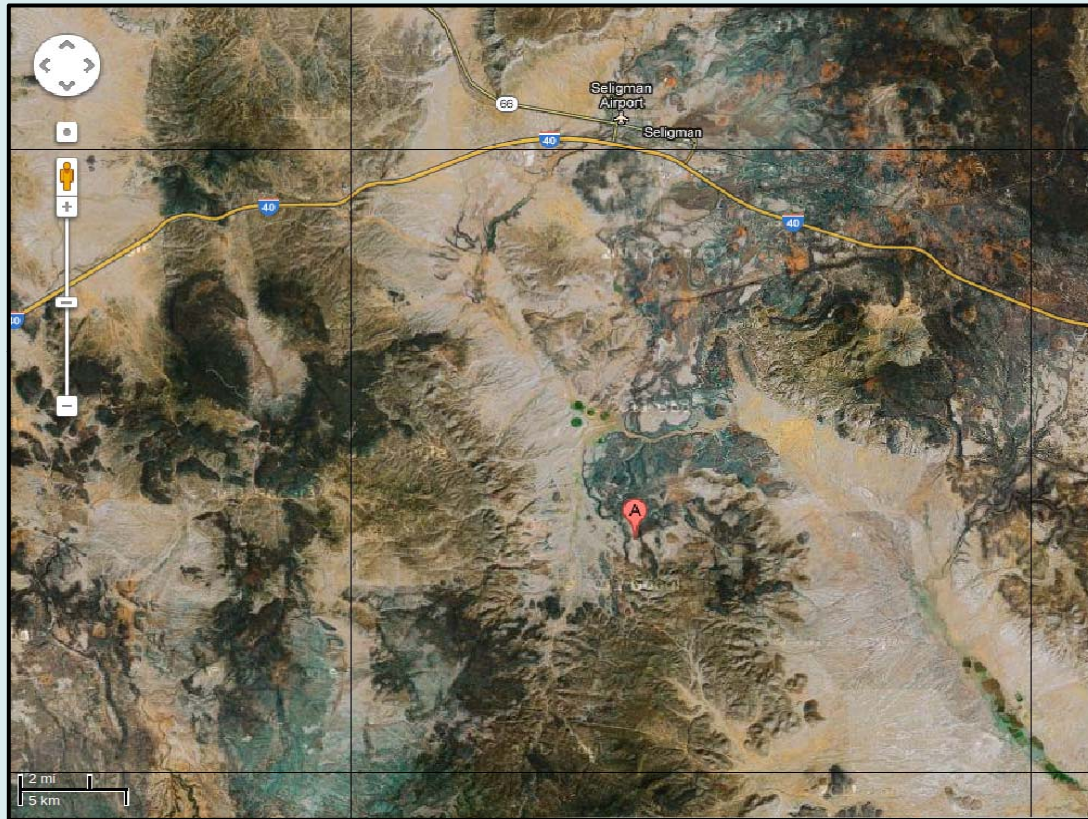
Meteor Crater Site



- Very flat, no vegetation
- 1677m elevation
- Excellent access – short distance and high-quality road to Interstate-40.
- Railroad very close by
- Power nearby, but needs upgrade
- Excellent synergy with Meteor Crater (technical, outreach)



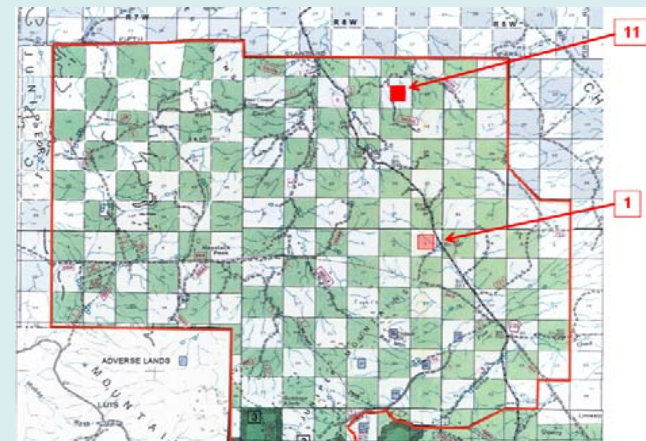
Yavapai Ranch Site



Satellite view of West Site (red circle), shown relative to Interstate 40 (yellow) and Seligman. The distance from I-40 to the site is 25 km.

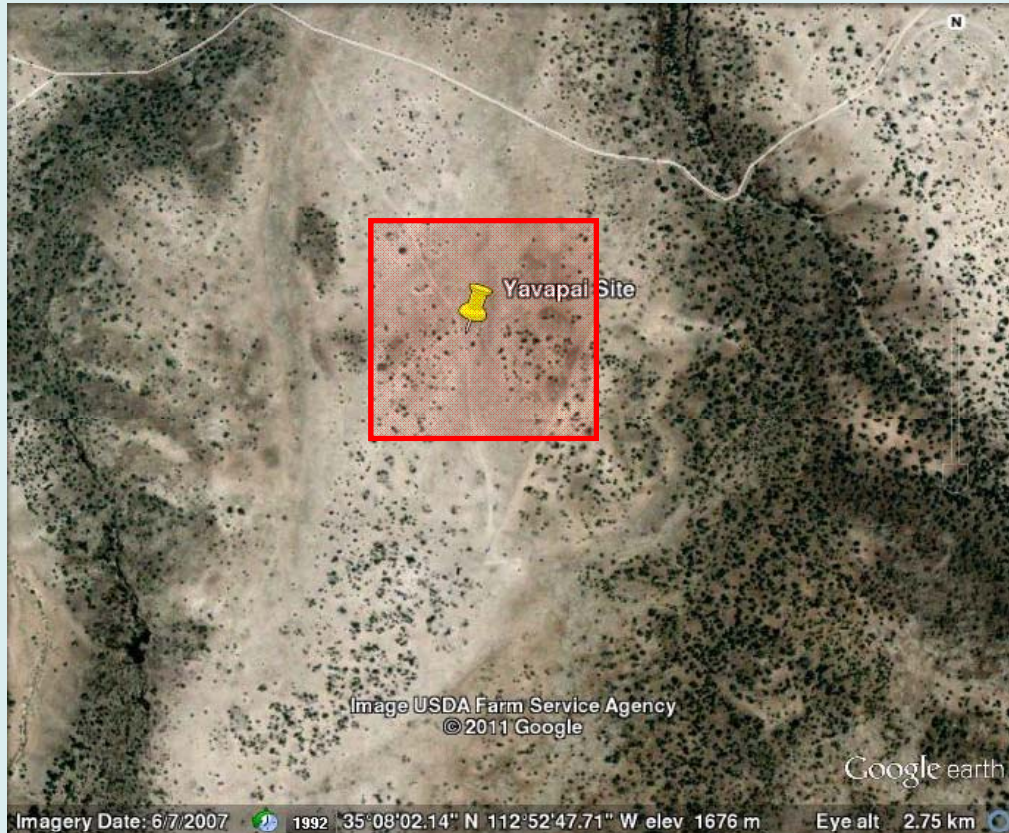


Williamson Valley Rd.



Map of Yavapai Ranch LC holdings. Parcels 1 and 11 are the top site candidates. Parcel 11 was selected as the proposed site for CTA, with Parcel 1 as a second option. The Williamson Valley Rd traverses the Ranch passing 2 km W of Parcel 11 and adjacent to Parcel 1.

Yavapai Ranch Site



- Very flat, little vegetation
- 1670m elevation
- More remote than Meteor Crater
- 25 km to I-40, railroad
- Power nearby, but needs upgrade
- Borders Forest Service land



Extensive Info for Each Site



Detailed, complete technical data for the sites:

- Geophysical: terrain, soil, magnetic field, rigidity cutoff
- Atmospheric: climatic conditions, cloud cover
- Infrastructure: roads, railroad, nearby towns/facilities
- Services: power, Internet, water, waste management, medical services
- Construction/operation: concrete, cranes, housing, office space
- Hazards: thunderstorms, seismic activity, hurricanes, tornadoes, volcanic, animals, crime and security
- Permitting, customs

Intellectual, economic, and political aspects:

- Lowell observatory – major research facility
- Regional university partners – NAU, ASU, UNLV
- Political and economic support – county, state, industry
- Excellent outreach potential

Complete Matrix for Each Site



EAST SITE - METEOR CRATER

Site Specifications I

For each item, the value for the site is given, along with the relevant proposal page number.

GEOGRAPHICAL CONDITIONS	METEOR CRATER SITE	PAGE
Total available flat area [km ²]	2.5 km ²	22
Latitude	35°N 2' 45.64"	21
Longitude	111°W 2' 47.44"	21
Altitude [masl]	1677 m	21
Soil composition - Ground type	Firm aggregate of limestone, Moenkopi sandstone	24
Clear horizons	Yes	22
Terrestrial magnetic field	Fully calculated, see text	24
NATURAL HAZARDS:		
Seismic activity	Very low, max accel. of 1.5 m/s ² with 2% prob. in 50 years	41
Rigidity cutoff	4.5 GV	24
Volcanic activity	No risk	42
Hail	Very small risk, ave number of days/year with hail = 0.0	41
Tomadoes-Hurricanes	Hurricanes: no risk, Tornadoes: none in last 60 years	42
Thunderstorms	July, August: ~10/month, no risk from winds, moderate to low risk for lightning during summer	41
ATMOSPHERIC/METEOROLOGICAL	METEOR CRATER SITE	PAGE
Light pollution	Low, county-wide lighting restrictions	11
Average summer max/min temperature	July: 32°C / 15°C	26
Average winter max/min temperature	December: 7.2°C / -6.5°C	26
Average wind velocity	5 m/s	26
Number of days with wind velocity > 15 m/s	< 3%	26
Wind gusts	No significant risk	26
Average summer humidity	25% (June), minimum	8
Average winter humidity	55% (December), maximum	8
Cloud coverage (Clear Sky Fraction)	>70% from ground-based measurements in region	34
Fog	uncomon. < 4 days/year	8
Precipitation	~19 cm/year	25
Snow accumulation	~28 cm/year	25
Nearby mining activity	None	
Risk of nearby population growth	Low risk: very low population density, land mostly owned by a few families; lighting restrictions in place	12

EAST SITE - METEOR CRATER

Site Specifications II

For each item, the value for the site is given, along with the relevant proposal page number.

SITE ACCESSIBILITY	METEOR CRATER SITE	PAGE
Distance to nearest town / city	Winslow: 40 km (25 mins), Flagstaff: 70 km (50 mins)	45
Size of nearest town / city	Winslow: 9,600, Flagstaff: 65,000	46
Type of road to nearest town /city	31 km Interstate Highway, 9 km wide paved road	46
Access by rail	Yes, 11 km to major freight line, 40 km to passenger line	45
Distance to nearest local airport	70 km (50 mins) to Flagstaff Pulliam Airport	46
Air landing path on site	No	
Distance to nearest international airport	300 km (3.5 hrs) to Phoenix Sky Harbor	46
Travel time to EU	10 hrs (eastward) by air to UK	
Travel time to North America	< 5 hrs to 100 cities	
Travel time to Asia	12 hrs (westward) by air	
Maximum allowed width on access road	No restrictions	45
Maximum allowed height on access road	No restrictions	45
Maximum allowed weight on access road	No restrictions	45
Distance to nearest gasoline station	9 km	45
Distance to medical emergency service/hospital	40 km (25 mins) to Emergency Room 70 km (50 mins) to major hospital with Level 1 trauma center	48
Distance to nearest fire station	40 km (winslow)	45
Accessibility by public transportation	No	
Distance to car rental	40 km (Winslow), 70 km (Flagstaff)	45
Distance to hotel	40 km (Winslow), 70 km (Flagstaff)	45
Distance to restaurants and food provision	Restaurants/food along Interstate 40, or 40 km to Winslow	45
Distance to workshops, supply stores	70 km (Flagstaff)	46
Distance to high bandwidth connection	9 km at present time	47
Nearby convention facilities	Flagstaff: many hotels, Lowell Observatory, N. Ariz Univ.	46
Local manpower availability	Yes, 3 major scientific institutions in Flagstaff	46
INFRASTRUCTURE	METEOR CRATER SITE	PAGE
Provision of electrical energy	Available, improvements needed to substation and lines	46
Distance of required power line	9 km	46
Alternative power supply	Not yet known, some Green Energy projects in region	
Power costs	In discussion	
Internet access / bandwidth	9 km needed to high-speed connection	47
Cost of bandwidth	In discussion	
Gas	Delivery to site can be arranged	
Water supply	Water only needed for personnel and fire safety (concrete delivered pre-mixed)	49
Drinking water supply	Well (240m depth) for ~\$80K, or trucked in at \$30-40K/yr	48

Multiple Sites = Multiple Options



	Meteor Crater	Yavapai Ranch	X-One Ranch
Geophysical	Very Good	Excellent	Excellent
Hazards/Risk	V. Low	V. Low	V. Low
Cloud cover and NSB	V. Good	V. Good	Excellent
Access, Services	Excellent	Good	Good
Construction/Operation	Excellent	Good	Good
Land Acquisition	No Issues	FS SUP	No Issues
Outreach/Visitors Center	At Site	Flagstaff ?	Flagstaff ?

The sites are not identical
Still early in site selection process – makes sense to keep good alternate possibilities, *since they exist*
Review committee(s)/Consortium will refine criteria

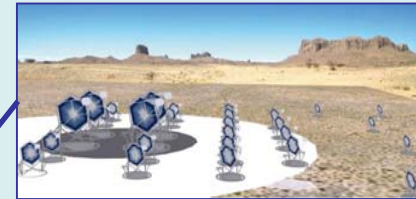
Local University Partners



Map of Arizona showing the major transportation hubs (green squares), the locations of VERITAS and the Lowell observatory (blue stars) and the locations of the two proposed sites for CTA (red circles). The locations of three nearby universities (ASU, NAU, UNLV) are shown. The major highways are indicated by red lines. The primary rail line goes east-west through Flagstaff.

Tremendous Outreach Potential

A major destination ...
but sparsely populated.



CTA !



Las Vegas



Route 66



Meteor Crater
(200K visitors)



Sedona

Tremendous Outreach Potential

A major destination ...
but sparsely populated.



Las Vegas



Route 66



Crater



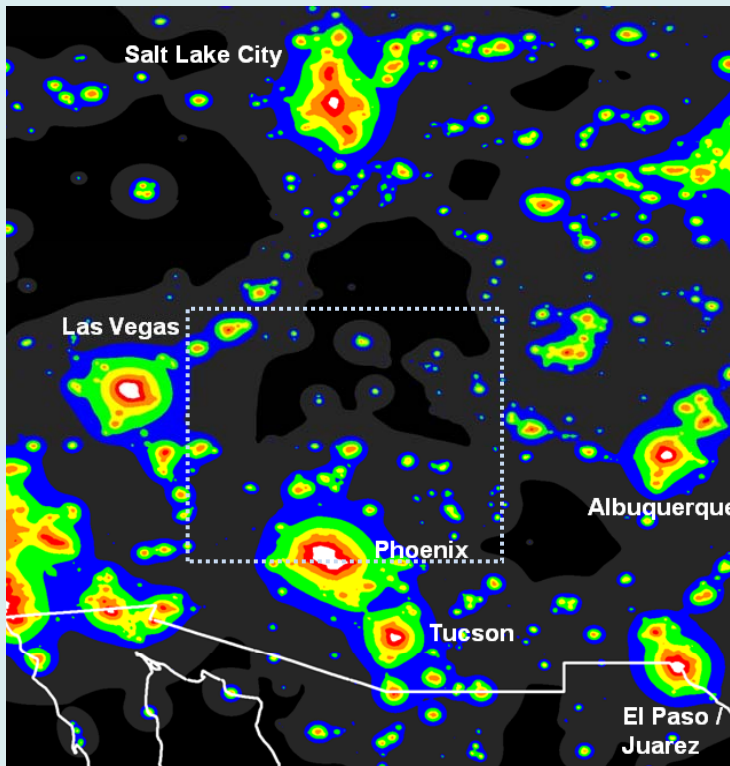
Yona

Some key remaining issues:

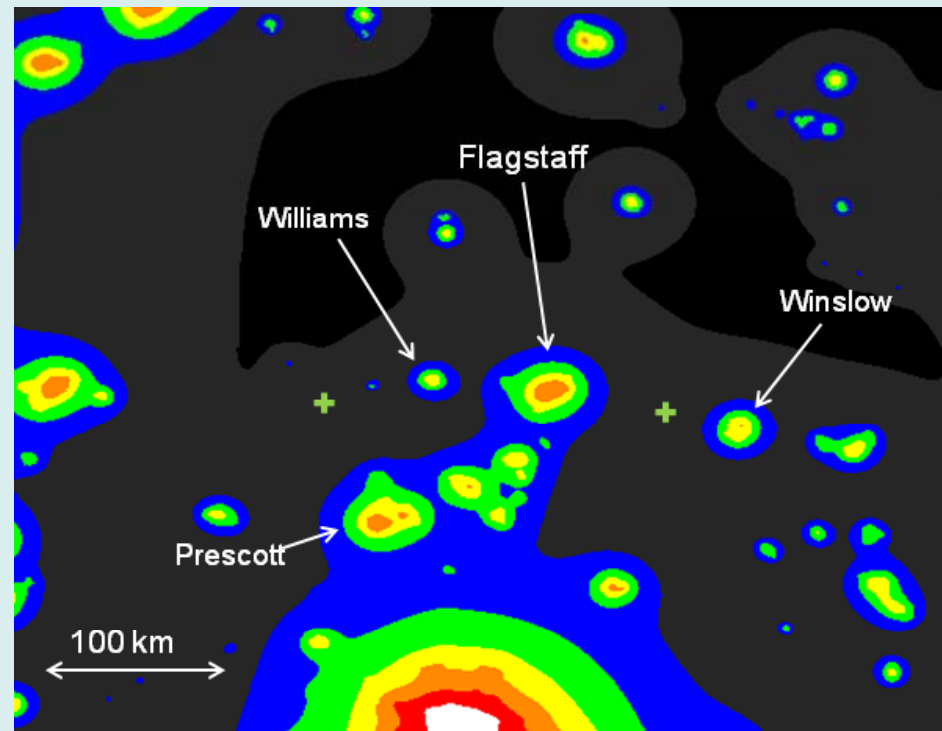
- Night sky background
- Cloud cover
- Summer operations

Night Sky Background

DMSP Satellite Atlas of night sky light (2010 data)



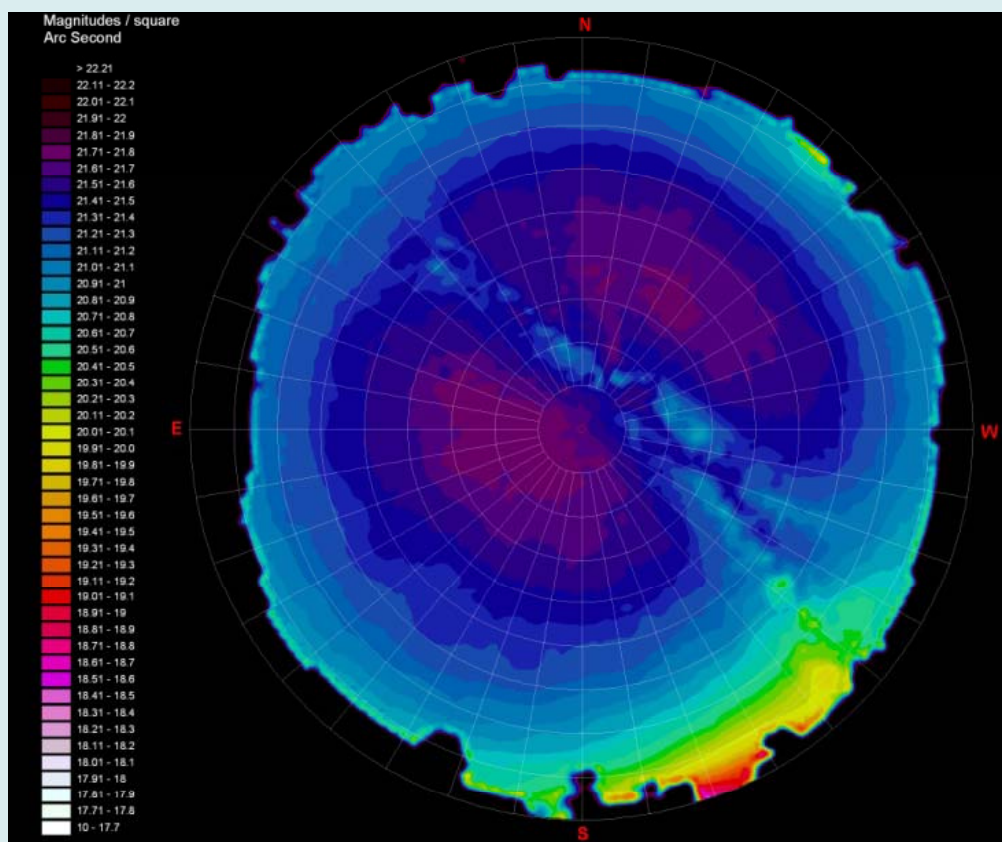
Artificial light intensity for the U.S. southwest from the DMSP atlas [20]. The dotted box indicates the blown-up region in Figure 9.



Blow-up of the DMSP atlas for northern Arizona. The proposed site locations are indicated by the green crosses.

Night Sky Background

Relatively recent measurements have been made of the NSB light at several locations in northern Arizona as part of a study on light pollution levels in the U.S. National Parks [21]. Measurements were made at three National Monuments close to Flagstaff, Walnut Canyon, Sunset Crater, and Wupatki, using a wide-field CCD camera and a V band filter. Table gives the NSB levels for each of these locations; also listed is the distance of each location to the center of Flagstaff.



NSB map for Sunset Crater



Location	Altitude	Distance to Flagstaff	NSB Sample Point (mag /arcsec ²)
Walnut Canyon	2045 m	12 km	21.87
Sunset Crater	2133 m	<u>21 km</u>	22.16
Wupatki	1411 m	43 km	22.25

Meteor Crater: ~65 km
 Yavapai Ranch: ~125 km
 X-One Ranch: ~170 km

Cloud Cover



Cloud cover, general points:

- N. Arizona is mostly desert-like and cloud cover is low.
- Monsoon weather in summer (July & August).

Data Mining:

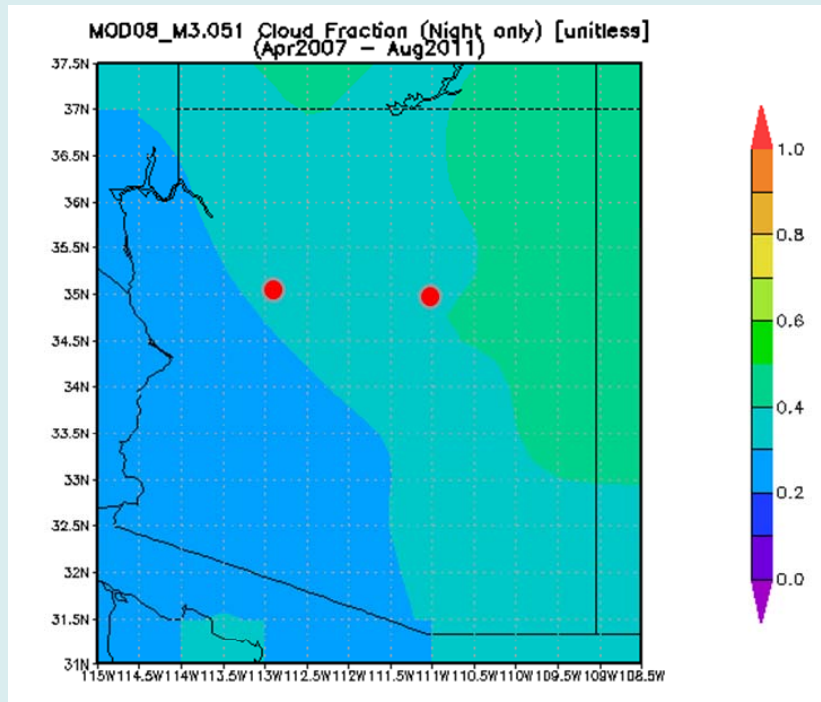
1. Historical records exist in a number of locations:
Mars Hill (Flagstaff), Winslow, Kingman, etc.
Also VERITAS
2. Satellite data from MODIS and other instruments (e.g. GOES).
Analysis being carried out by
Marek Cieslar (Warsaw) and Paulus Kruger (NWU)
CTA-US group

Validation:

- Validation studies with ground-based data sets and MODIS
New analysis of VERITAS and Mars Hill data now done

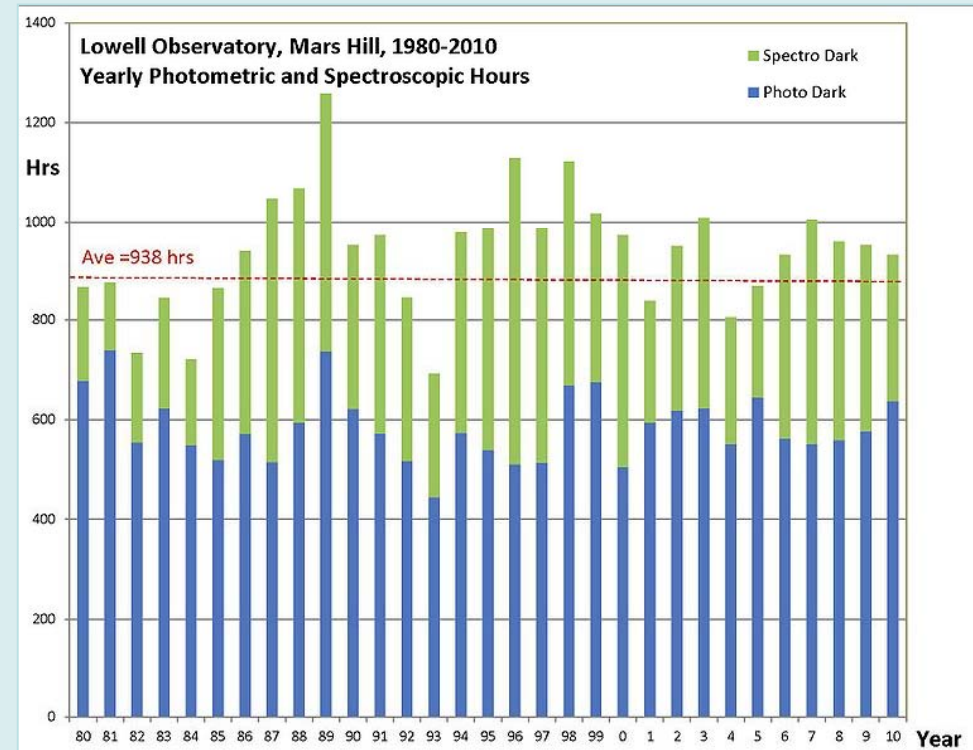
Cloud Cover

Coarse MODIS study (5km resolution)



Nighttime cloud cover fraction for Arizona for the most recent four years of data from the MODIS instrument [12]. The proposed CTA locations are indicated by the red circles.

Observing data from Mars Hill (Lowell Obs.)



Number of clear hours (photometric plus spectroscopic) per year for the thirty year data set of the Lowell Observatory at Mars Hill, AZ [45].

VERITAS – MODIS Comparison

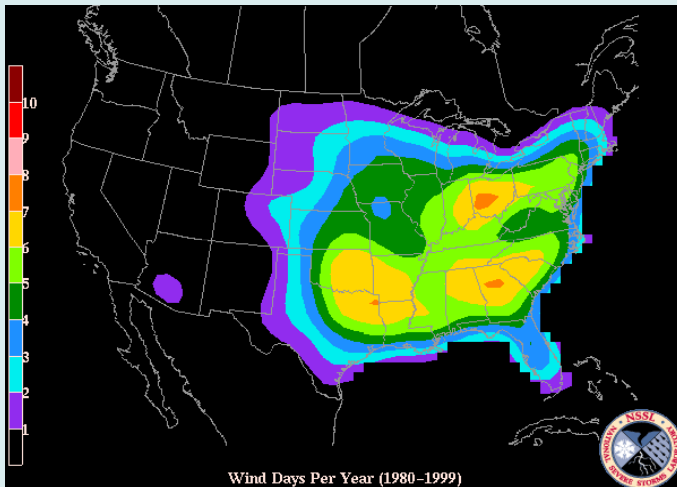


		VERITAS CODE		
MODIS Code	# of Nights	CLEAR	PARTIAL	CLOUDY
CLEAR (<20%)	265	242 (91%)	10 (4%)	13 (5%)
PARTIAL (20-60%)	22	5 (23%)	17 (77%)	0 (0%)
CLOUDY (>60%)	51	5 (10%)	8 (16%)	38 (75%)

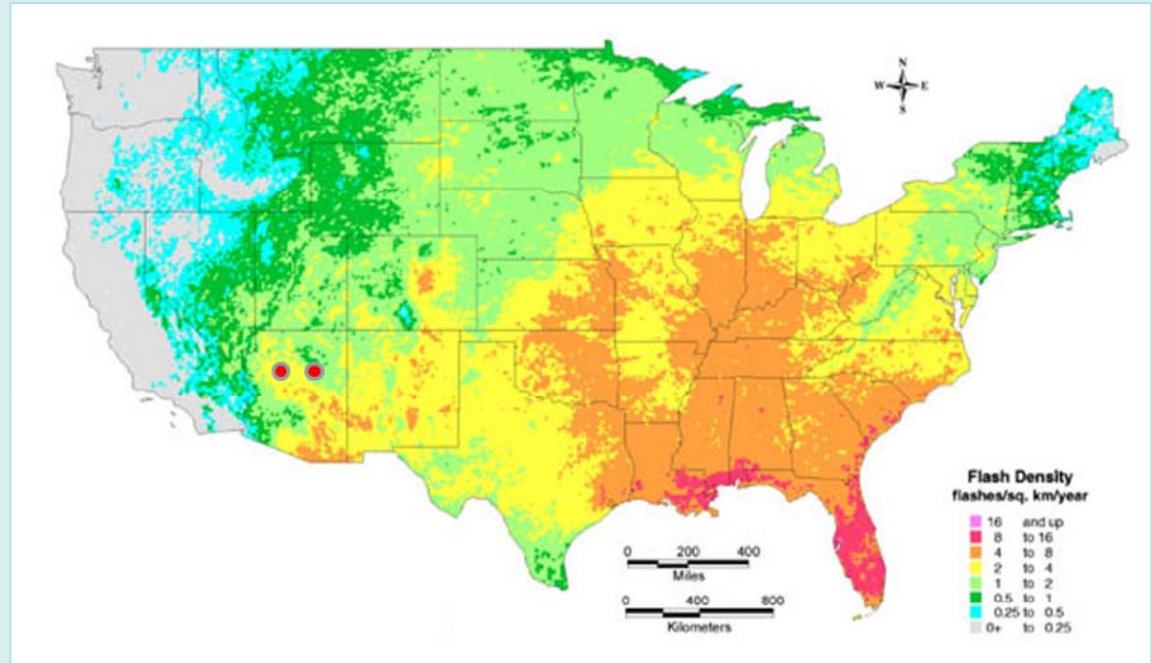
Table shows the comparison between the VERITAS weather code and the MODIS code for 338 nights of data. There are several conclusions that can be drawn from these data. First, the overall correlation between the MODIS and the VERITAS data is reasonably good, within the limited statistics. However, this correlation is best for data which MODIS classifies as CLEAR where 91% of the time the VERITAS code is also CLEAR. For MODIS classifications of PARTIAL or CLOUDY, the correlation is worse (~75%) and the VERITAS code indicates a better condition. Given that VERITAS takes data during CLEAR conditions and usually during PARTIAL conditions, a simple MODIS cut (of <20%) will underestimate the number of usable hours.

- Simple MODIS cut underestimates the number of usable hours
- Mars Hill data are more striking:
 - correlation with MODIS much weaker
 - significant underestimation of number of usable hours

Thunderstorms, monsoon



Average number of days per year with strong thunderstorm winds over the period 1980-1999 [46].



Map of lightning flash density (number/km²/year) for 1995-2000. Red circles indicate the locations of the proposed sites for CTA. [47].

Thunderstorms:

- Not severe to cause wind damage
- Less prevalent in N. Arizona than in the south
(occur once every 3 days in July, August)
- Lightning less prevalent by factor of 2 (Yavapai) to 4 (Meteor Crater)

Can CTA run in July/August ?



Comparing N. Arizona Sites to VERITAS/Whipple Site:

Thunderstorms generally occur during the daytime as the atmosphere is rapidly heated up. In the evening as the temperature decreases, the sky often clears up (see Section 2.4), permitting observations.

The Whipple 10m and VERITAS telescopes use electronics located in a trailer and connected to the telescope via hundreds of long (~50-75m) coaxial cables. The cables act as antennae that significantly increase the risk of damage by lightning. In CTA, the electronics will almost certainly be contained in the camera itself and that camera will be powered off during the day (when it is hottest).

The monsoon is weaker in northern Arizona than in the southern end of the state where the Whipple 10m and VERITAS telescopes are located. In the region where the proposed sites for CTA are located, the lightning strike density is at a relatively moderate level, in comparison with southern Arizona and other parts of the U.S.

CTA may be able to operate in summer months – provided steps taken for lightning protection (needed anyway) and safe operation of array.

Summary: Advantages for US Sites

- **Excellent physical and climatic characteristics:**

The sites are flat, dry, dark, and have a low cloud cover fraction. Snowfall and winds are moderate. No significant hazards exist.
- **Suitable private land available for CTA:**

Northern Arizona checkerboard arrangement of land ownership means that a single parcel of private land can be leased for CTA North.
- **Excellent access and infrastructure:**

The sites are close to major roads, the railroad, and relatively close to major international airports. All services are readily available. Flagstaff has good technical infrastructure (construction, medical, airport, etc.) and is a suitable base for personnel.
- **Excellent local intellectual and political support:**

There is strong support from local government and land-owners. The counties have dark-sky ordinances and there is a heritage of first-rate astronomical facilities in the area. A good partnership exists with the Lowell Observatory that can serve as the host for CTA North. The proximity of three major universities in the area will enhance the local intellectual environment for CTA.
- **Strong national groups in field of VHE gamma-ray astronomy:**

The U.S. has a long and very successful history in HE/VHE gamma-ray astronomy. There is currently major involvement in Fermi, VERITAS, HAWC, and CTA.
- **Excellent synergies with public:**

The combination of good access to the sites and the large number of visitors offers a very unique opportunity for CTA in the area of outreach and education.

US Site Visit I (Feb, 2012)



US Site Visit for the Cherenkov Telescope Array February 27-28, 2012

Visit Participants

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(* Visit coordinators)

- Excellent participation – **thank you** to all that are coming.
- Visit Meteor Crater (Mon), Yavapai and X-One (Tuesday)
- Visit to Lowell Obs., Meetings with County officials, reception in Flagstaff
- Weather looks good (sunny and cool)