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CLIMATE REFERENCE NETWORK STATIONS: LOCATION, LOCATION, LOCATION...

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ABSTRACT

The United States Climate Reference Network (USCRN) goal is to document long-term climate behavior in accordance with the 1999 Climate Monitoring Principles certified by the National Research Council. USCRN scientific success is based upon front-end careful and rigorous selection of appropriate instrument monitoring sites. The primary variables to be monitored are the air temperature and the precipitation. The secondary variables of solar radiation, wind velocity, and IR (skin) temperature are specifically designed to support the precision and understanding of the primary instrument measurements. The Phase 1 plan is for about 100 USCRN stations to be deployed across the United States by the end of 2006. A secondary grid of 75 stations has been envisioned for Alaska, Hawaii, and perhaps Puerto Rico and the Virgin Islands. 49 USCRN stations are now operating. Two experimental stations are also operating in severe environments in Alaska.

Criteria for USCRN sites targeted for operations during the next 50-100 years are very exacting. They exceed WMO standards for climate monitoring and station siting. This paper discusses primary climate station siting criteria: proper instrument and site exposures; land use and land tenure stability; avoidance of built-up areas and areas of future development; avoidance of agriculture, irrigated areas, and large artificial water bodies; regional climate representativiness with respect to temperature and precipitation; avoidance of localized microclimates, and consistent site maintenance and instrument re-calibrations. Examples are given of sites and locations sensitive to climate change and of sites representing special circumstances and environments.

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1. INTRODUCTION

The U.S. Climate Reference Network (USCRN) is a NOAA program designed to build and deploy a network comprised of baseline or benchmark ***CLIMATE MONITORING STATIONS*** across the United States. The purpose of this network is to monitor the long-term trend of the atmosphere, that is *CLIMATE trends*, through undisturbed and unmodified sites. The objective of such a climate monitoring mission by the USCRN is to observe and to document the stability or variance of climate over time. In this instance, the temporal goal of assessing the stability or variance of climate is that of the longer-term - on the scale of years, decades, 30-year normals, and even longer.

The base requirement of the USCRN to monitor and document long-term climate conditions requires that we identify candidate station sites representing "natural" or undisturbed environments. Therefore, a considerable research effort has benn directed at field surveys and site studies across the U.S. with a goal of identifying pristine and stable locations suitable for long-term USCRN stations. It is not scientifically valid to rigidly impose a network station grid and station siting density philosophy if the program requirement for climatic representativeness is not met during the site selection phase of the program.

2. GENERAL CONDITIONS OF ACCEPTANCE/ EXCLUSION OF STATION SITES BASED ON CLIMATE REPRESENTATIVENESS

Because individual USCRN stations are expected to be in place for the next 50 to 100 years, and because the composite signals are to be free of biases caused by station moves, land use changes, construction, etc., an initial condition for USCRN field surveyors is to find parcels of land within both a national and regional context that:

a. will most likely remain in a stable tenure or ownership for at least the next century. This requirement has resulted in close partnering of the USCRN with other Federal and State agencies who have large and undisturbed reservations set aside for use as National/State Parks, Federal-University research or reserved lands. Examples of such sites include many of the National Parks (e.g., Theodore Roosevelt, ND; Glacier, MT; Teton, WY, Mesa Verde, CO (pending), Death Valley, CA (pending); Agate, NE; Everglades, FL (pending)); National Wildlife Refuges (e.g. Ouachita NWR, LA; Muleshoe, TX; Necedah, WI); NASA facilities (Palestine, TX; Kennedy Spaceflight Center, FL); federal associated agency and university experimental and baseline lands such as Long-Term Ecological Research sites (e.g., Sevilleta/Jordana, NM; Konza Prairie, KS; Nunn, CO); University experimental lands such as Rogers Farm (University of Maine), Stillwater Farms (Oklahoma State University), Mauna Loa Observatory, HI (pending); a few selected Foundation lands such as the Sonoran Desert Museum near Tucson, AZ, the Audubon Society Reserve near Lincoln, NB, and the Nature Conservancy Reserve near Oyster, VA (pending); and even a Bureau of Land Management Superfund long-term site (Kesterston, CA (pending)) which has a tenure vision in the hundreds of years.

In the Western U.S. in particular, there is a rather amazing coalescence of National Parks that have active, complementary Air Quality Monitoring Programs (red stars) with desired CRN deployments (grid points)[1]. Additional National Parks are being surveyed (yellow stars) as potential CRN station sites (Figure 1).

b. are not envisioned as being areas of major development during at least the next century. Given the extent of development, local changes in airflow, thermal sources and sinks, and environmental modification around most large urban centers such as New York City (Figure 2), are arguably no longer representative of a natural climate. There is, indeed, sufficient doubt of the climatic representativeness of smaller urban agglomerations that suggests that these areas should also not be the focus of USCRN station deployments if we are to think a century ahead. As one example, the urban expansion of the montane valleys and ridges on the northern side of Honolulu (Figure 3) makes this region no longer suitable for long-term climate variance monitoring given the goal is to obtain sufficient confidence to separate the background (natural environment) signal from the induced signal due to urban development.

Therefore, we have to widen our search for stable CRN sites in many areas from the traditional monitoring sites located primarily in or near areas of human development and go further afield. In Figure 4 the focus for the CRN surveyor for this region (Dr. Kelly Redmond of the Western Regional Climate Center in Reno, NV) was turned away from the immediate Puget Sound area by the realization that the continuously growing conglomeration of Victoria-Vancouver-Bellingham-Seattle-Tacoma cannot be geographically confined or determined. Therefore, Dr. Redmond sought out the Darrington station at Marblemount in Skagit County, WA, as well as going even further afield to investigate other siting possibilities in and around the Olympic National Forest. Only by going further afield to find a "natural" climate do we feel that we can stay outside of the developing zone that will continue to spread over the coming 50-100 years.

c. that will not be subject to local microclimatic interferences such as might be induced by topography, katabatic flows or wind shadowing, poor solar exposure, the presence of large water bodies not representative of the region, agricultural practices such as irrigation, suspected long-term fire environments, human interferences, or nearby buildings or thermal sinks. The primary signals monitored in USCRN are temperature and precipitation. In order to assure that these primary signals at each site represent the general, natural background condition, candidate sites recommended by the Regional Climate Center (RCC) field surveyors for station deployments must be well-ventilated, and must meet the objective minimum criteria established for USCRN site exposures. These siting criteria have been codified into a series of documents which are based upon both the National Research Council (NRC)[2] principles and the World Meteorological Organization (WMO)[3] recommendations of the base principles required for acceptable climate station siting, instrumentation, exposures, and procedures.

3. THE SITE SURVEY PROCESS AND INITIAL NETWORK CONFIGURATION

In order to reduce the risk of siting a CRN station in an undesirable or non-representative environment, strict measures are undertaken by CRN site surveyors to ensure that their surveys conform to the U.S. NRC and the WMO principles of climate monitoring. All RCC surveyors have been trained in using an objective site fitness scoring system based upon the system first suggested by Michel Leroy in 1998[4].

CRN site surveyors are trained climatologists and physical geographers drawn largely from the NOAA RCCs. These surveyors conduct lengthy pre-field desk audits and communications with regional land-holding organizations to identify potential sites and to outline CRN siting guidelines and responsibilities prior to undertaking an actual site visit and survey. The RCC surveyors may be accompanied by the various State Climatologists or other NOAA personnel if they are available and interested in the front-end field surveys. CRN site surveyors use a standard set of NOAA documentation[5] prior to, during, and after their field surveys in order that CRN siting procedures are standardized nationwide.

Other considerations and guidance are taken into account in identifying candidate station sites by the CRN field surveyors. Surveyors are bound to a first priority of finding sites that not only are climatically representative, but also conform to an idealized 5-degree national grid of approximately 100 points in order to capture the U.S. climate signal at a national level (Figure 5). For Phase 1 of the USCRN network, from 2001 through 2005, the network will deploy 100 stations nationwide that should represent the 5-degree grid insofar as possible. The vast majority of these stations will be confined to the Lower 48 States.

Two USCRN stations have been deployed into severe winter environments near NOAA-staffed laboratories in Alaska. These stations are serving as engineering/operational testbeds to determine if any design changes will be required for later planned deployments into other severe mountain environments. A third station from the initial program phase may also be deployed to Mauna Loa (HI) to provide an initial pulse on verifying the possible existence of meaningful climate signals at a higher altitude of the deep pelagic Pacific Ocean atmospheric environment afforded by Hawaii's geography.

During the expected Phase 2 portion of the USCRN deployment, nearly 200 additional CRN stations are planned for deployments in all 50 States. This Phase 2 deployment cycle should enable NOAA to reduce climate uncertainty to about 95% at the levels of the nine U.S. climate regions, not just the national scale. A later phase of the USCRN is anticipated, that phase would include the outlying Commonwealths, Territories, and Islands of the U.S. to also be instrumented for completion of the USCRN domestically.

At this time, the Phase 1 deployments are about 45% complete. A map depicting the deployments through Fiscal Year 2003 is below (Figure 6):

4. THE SITE SELECTION PROCESS

The RCC field surveyor identifies a potential site, surveys it (usually more than once and in more than one micro-location), then analyzes its relative fitness, and forwards the entire site file to the USCRN technical team at the NOAA National Climatic Data Center (NCDC) in Asheville, N.C. The surveyor's file contains the history and identities of the potential site contacts and any ancillary personnel involved (e.g., State Climatologist, local National Weather Service personnel). Issues that will have been reviewed with the potential site host agency include data access and use, station power, station access for annual (re-)calibration and maintenance, routine maintenance and site care, record-keeping, and terms of the joint Site License Agreement (SLA).

The surveyors also provide to the NOAA CRN Site Selection Review Panel, usually in conjunction with the host agency, such high-resolution aerial photography, maps, and satellite imagery as may be available for the immediate site area. The surveys field notes, observations, digital photography, summary report and recommendations are also forwarded to NCDC. These data are supplemented with such cartographic, imagery, and climatological data as is available at the NCDC prior to a full review by the panel of NCDC science personnel involved in CRN. Of particular importance in recommending a site is not just its fit within the national grid, and its climatic representativeness, but also the presence of stations from other networks. Particularly desired are co-locations or near co-locations with stations from the existing NOAA COOP network, and especially COOP stations that are in the Historical Climatology Network subset. Other networks where co-locations have occurred or are occurring include NADP, Ozone, RAWS, SCAN, SNOTEL, NWLON, SURFRAD, State and regional mesonets, LTER stations. Co-locations are also entered into CRN metadata permanent files and a map of co-locations for each USCRN site is generated (Figure 7).

Plans are that the new Modernized COOP network to be deployed over the next several years will include that co-locations will occur between the two networks (MMTS of COOP/2 and USCRN). A chart of possible co-locations between these two NOAA networks is presented in Figure 8.

During the site review, a panel of 6-10 scientists reviews the site information packet to judge the fitness of the site. Two objective methods are used to score the site on a basis of 100 pts. The first method is a dual 100 point scale assessment of the climate of the site in terms of likely changes over time (temporally) and the representativeness of regional climate in terms of physical and biological parameters that may unduly influence climate (spatially). The temporal score is kept separately and includes likelihoods of development, encroachment, or other changes that might occur. The spatial score, also kept separately, evaluates the influence of nearby topography, vegetation, water, land use, buildings, etc., as influencing the likelihood of deriving an accurate measurement of the primary climate parameters (temperature & precipitation). The second method is an adjustment of the Leroy site classification scheme from the European system of landscape evaluation to the more homogeneous U.S. Eastern U.S. and the very mixed heterogeneity that typifies the multi-elevational, multi-ecotonal Western U.S.

All materials from the desk and field surveys by the RCC surveyors, the host agency materials provided, and the NCDC science panel deliberations and scoring are kept in the long-term permanent metadata files maintained for each site.

Assuming that a candidate site is approved at the NCDC CRN Site Review, the next step is approval of the Panel decision by the NCDC Director. The Director may modify the recommendations of the Panel, ask for more information, turn down, or approve the Panel's recommendation(s). For affirmative decisions the SLA process is begun between the two parties (NCDC CRN and the host agency). This SLA approval process may be swift, on the order of days or a few weeks. Usually it takes 2-3 months, but lengthy delays are possible, e.g., in one case the host agency agreement has been delayed for 27 months of archeological, historical, cultural, biological, hydrologic, and legal reviews. The average length of time between initial host agency contact to deployment of a CRN station to the site is 11 months.

5. REFERENCES

1. This map of NPS overlaid with CRN grid points was prepared by NPS during the early stages of negotiations between the USCRN Program Manager and the Superintendent of the Agate Fossil Beds National Monument in Western Nebraska on placement of a USCRN station at Agate. The Agate CRN station is particularly well-sited and climatically representative. Agate, NM is an area rich in both untapped historical and paleoclimatological evidences, as well as having a nearby long-term NOAA COOP station.

2. National Research Council (NRC), 1999. Adequacy of Climate Observing Systems, National Academy Press, Washington, D.C.

3. WMO, WMO Guide to Climatological Practices, "The Siting of Climatological Stations", Chap 4, para 2.5, pp. 45-50. Also see the 1996 WMO Document 8, Guide to Instruments and Methods of Observation, Geneva, Switzerland.

4. Leroy, Michel. 1998a. "Meteorological Measurements Representativity: Nearby Obstacles Influence", 10th Symp on Meteorological Observations & Instrumentation (pp. 233-236), AMS, Phoenix, AZ (Jan 11-16, 1998). Also see Leroy, 1998b. "Climatological Site Classification", at the same conference.

5. CRN site survey manuals, checklists, procedures, instructions on survey techniques and products are available for review at:

http://www.ncdc.noaa.gov/oa/climate/research/crn/crnsitesurvey.html. (United States Climate Reference Network: Site Survey Requirements, *National Climatic Data Center, 10 April 2000 (updated February 2002).*

NOAA Climate Reference Network Site Information Handbook, December 10, 2002; CRN Site Survey Checklist, April 26, 2002 (use Adobe Acrobat or MS Word); CRN FY02 Site Selection Task (use Adobe Acrobat or MS Word) (all are available at: http://www.ncdc.noaa.gov/oa/climate/uscrn/siteselectguide.html).

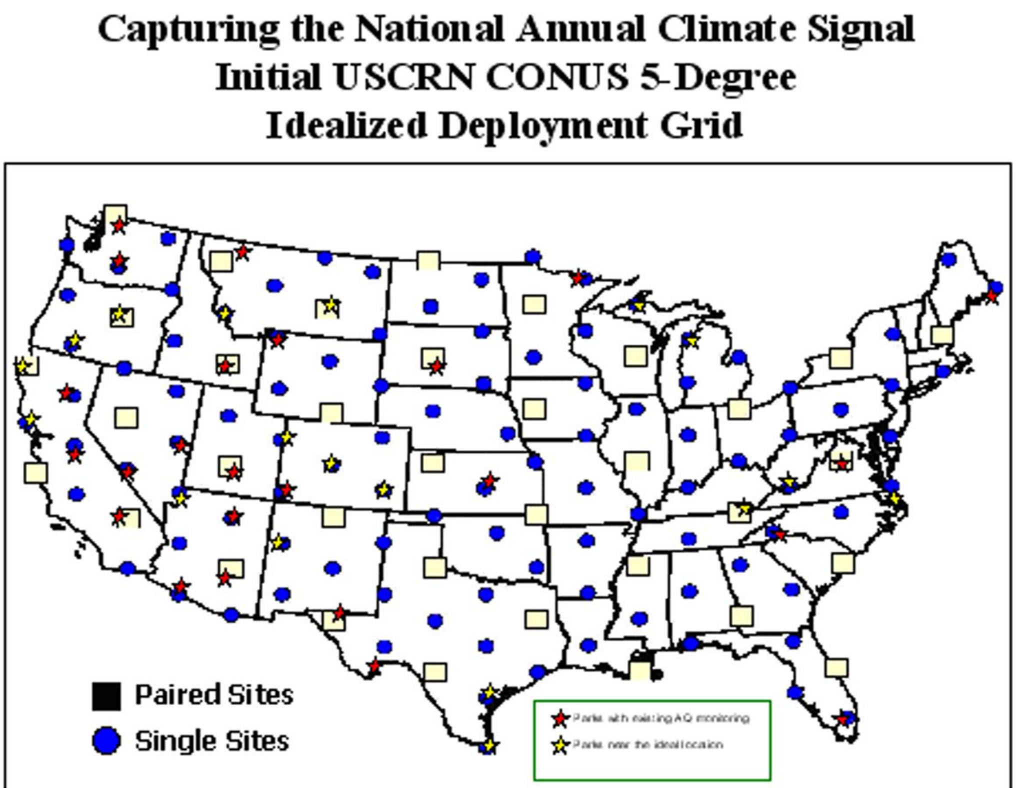

Figure 1. Coalescence of Western National Parks with CRN Deployment Grid

Figure 2. New York City area.

Figure 3. Northern Honolulu urban expansion fingers into the mountainous interior of Oahu.

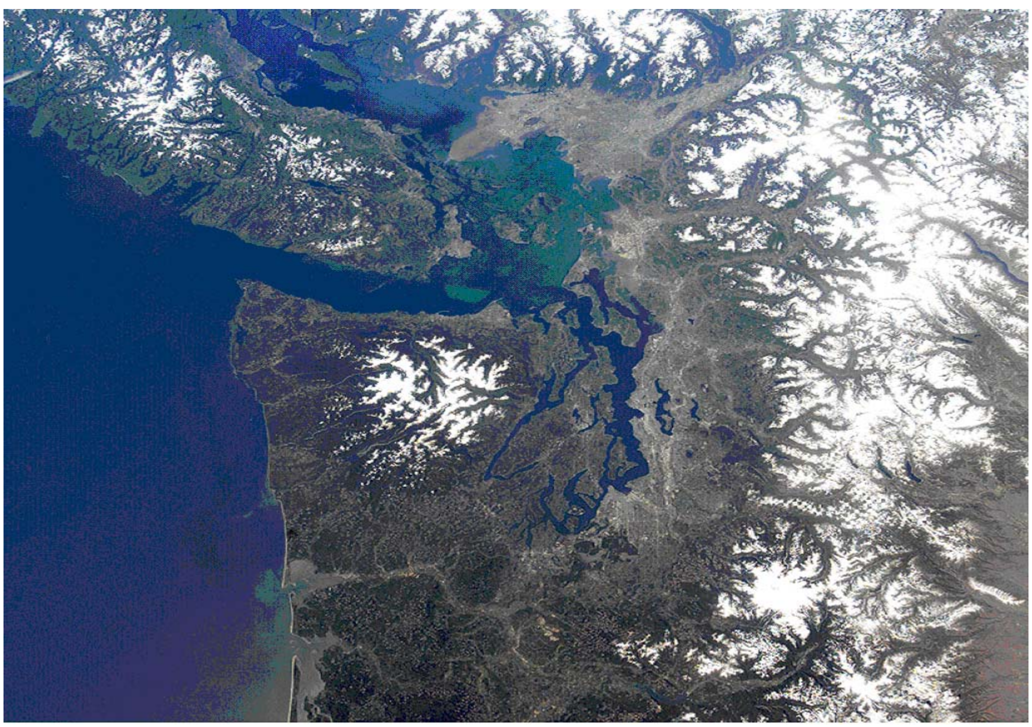

Figure 4. Pacific Northwest/Puget Sound region.

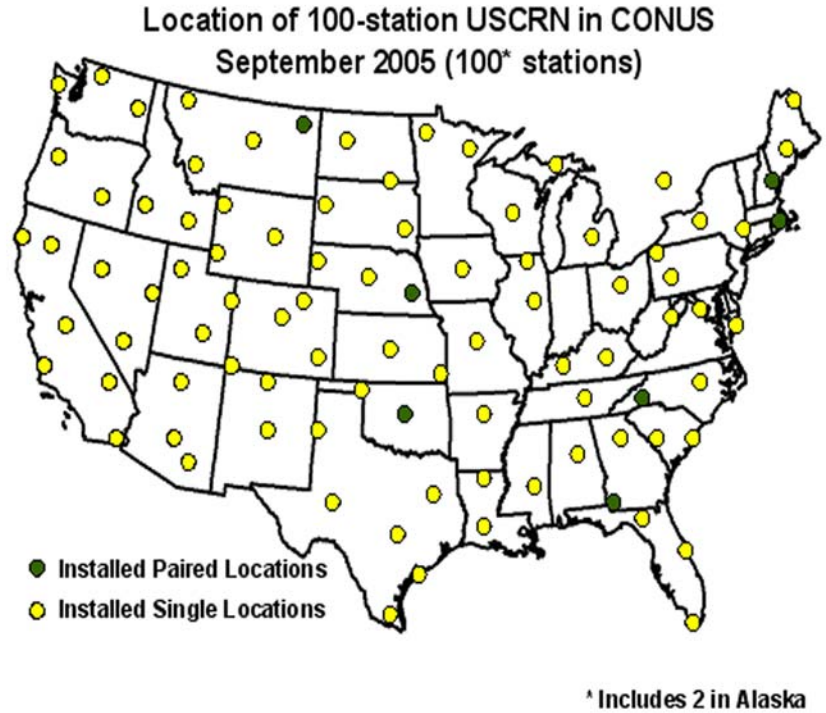

Figure 5. USCRN Phase 1 (2001-2006) Station Deployments.

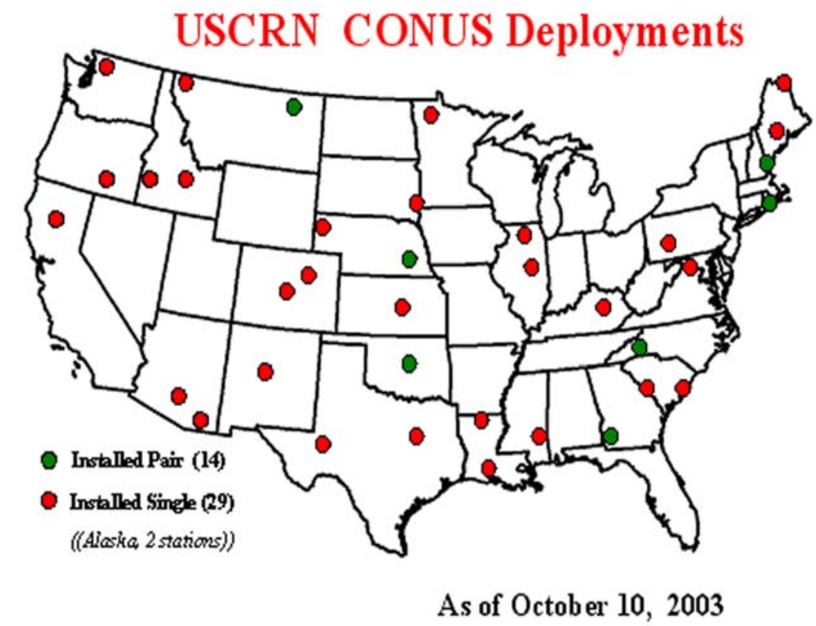

Figure 6. Current USCRN Station Deployments.

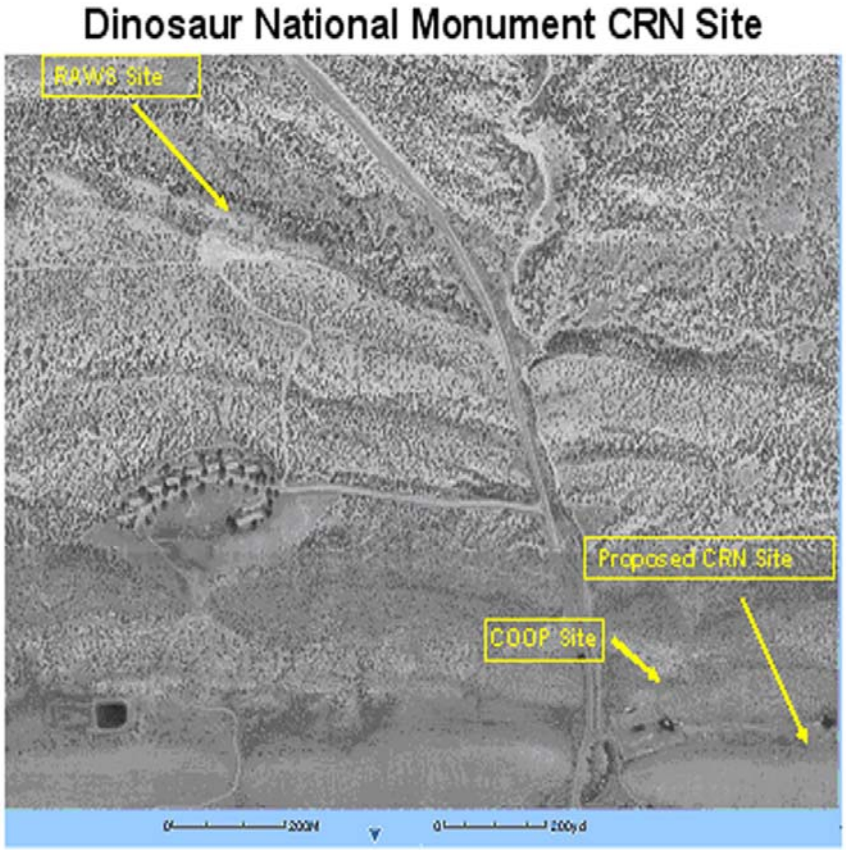

Figure 7. Dinosaur, NM Co-Locations (RAWS & COOP).

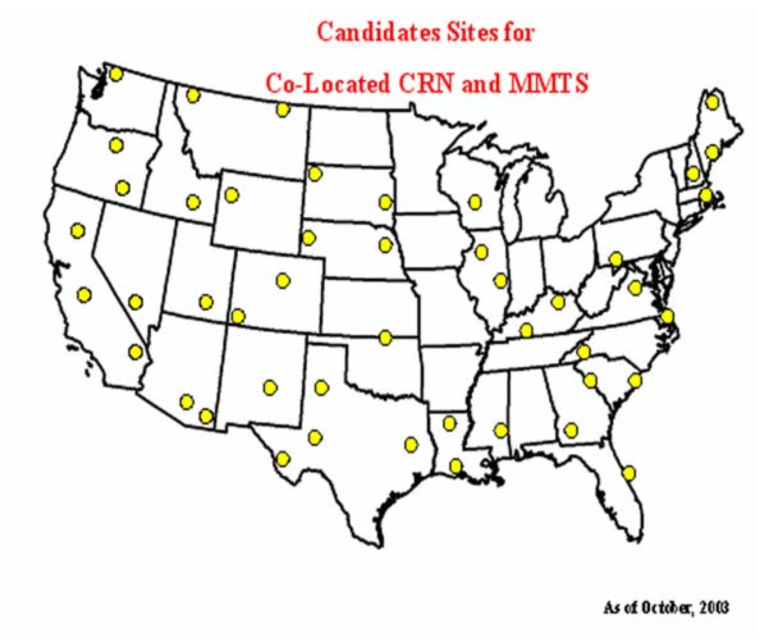

Figure 8. Possible Co-Locations of MMTS and USCRN.