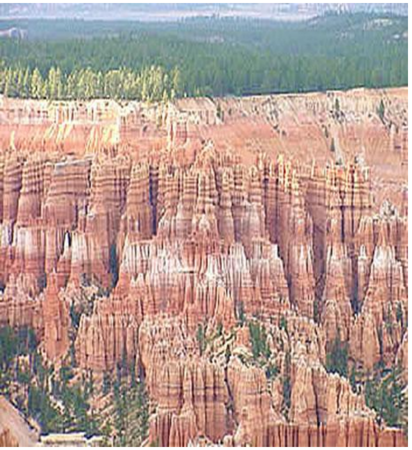
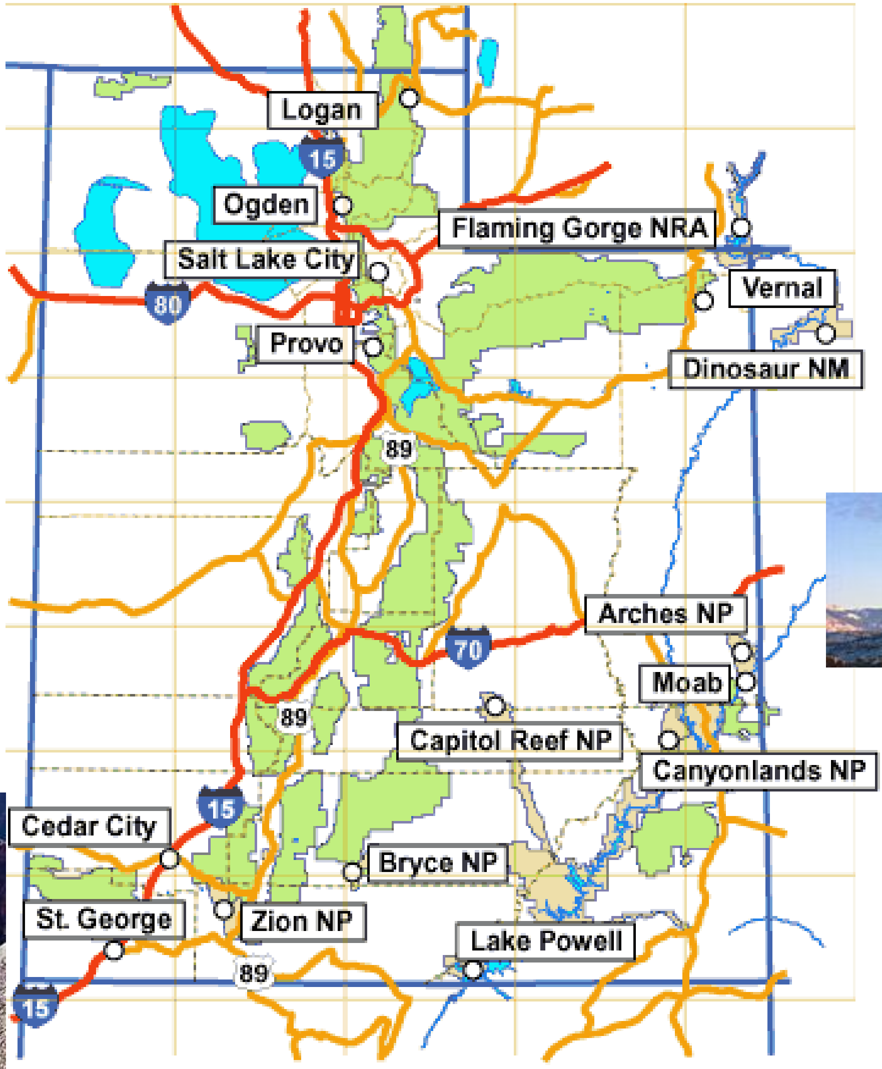
Welcome to Utah!





U.S. Army Dugway Proving Ground

The Granite Mountain Atmospheric Sciences Testbed (GMAST): A Facility for Complex Terrain Airflow Studies

John Pace
Chief, Meteorology Division
West Desert Test Center
U.S. Army Dugway Proving Ground, Utah

Topics

- Dugway Proving Ground Information
- Safety Briefing
- Granite Mountain Atmospheric Sciences Testbed
- Site Visit

Dugway Proving Ground Mission/Vision Statement

Protecting American interests with the nation's premier chemical and biological proving ground by:

- Adhering to Army Values
- Conducting testing, training, and evaluation of in-use equipment to the highest scientific and technical standards
- Fostering environmental stewardship
- Providing non-testing support to the mission, and
- Exceeding customer expectations

Science Serving Warfighters and Civilians

Remote Location

- 1,300 sq. miles of remote desert
- 85 miles SW of Salt Lake City
- Free of urban encroachment
- Bordered on three sides by mountains and desert terrain
- Salt flats for 90 miles north
- Quiet -- audibly and electronically
- Dark -- free of light pollution

Remote Location (Cont.)

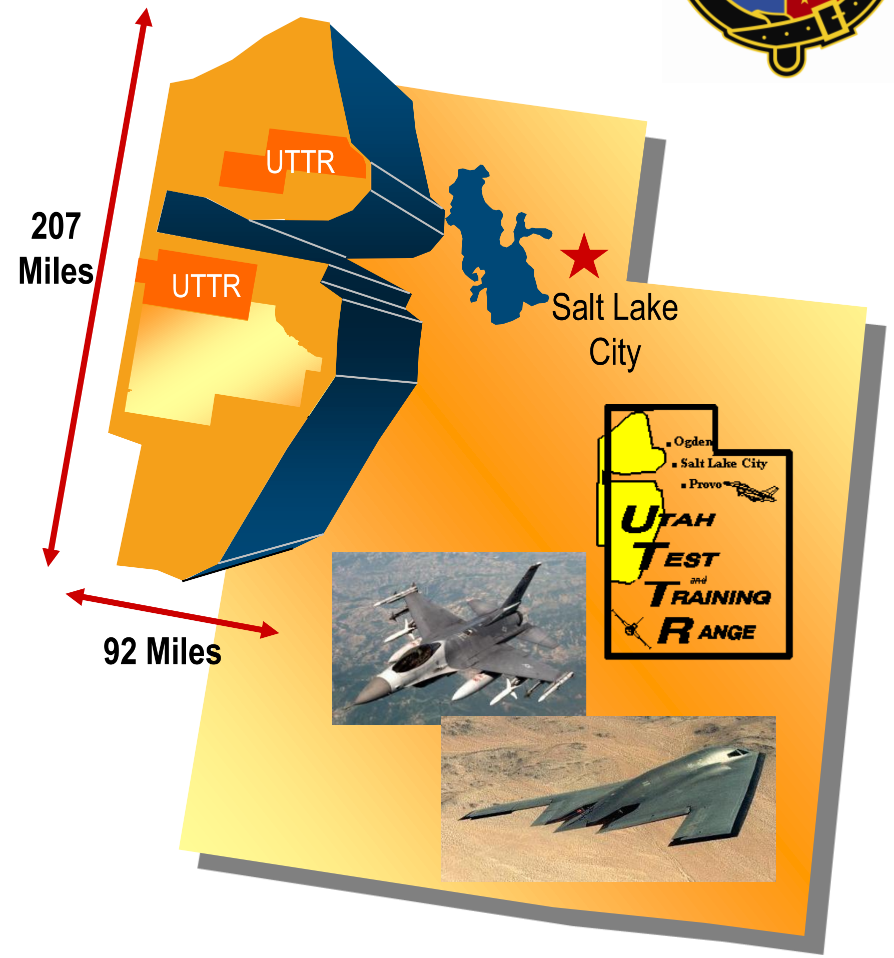
- Dugway borders the Utah Test and Training Range

Airspace - 19,161 square miles

Restricted airspace - 9,158 square miles

Military operation area - 10,004 sq. miles

DoD exclusive use land - 3,078 sq. miles



Dugway Environment

- 798,214 total acres
- Environmental permits in place
- Pristine air quality
- Less than 8 inches rainfall a year
- No endangered species

Granite Mountain 7,080 eleva

59,078 acres mountain terrain

279,768 acres of desert terrain (sage and sand dune)

462,180 acres playa (mud and salt flats)

Salt Flats 4,230 ft elev.

Dugway Partners

Chem-Bio Center of Excellence

- Acknowledged experts in Chem-Bio testing
  1,300 square miles of controlled, remote, encroachment-free terrain


Warfighter support


Vast remote areas for testing and training


On-site airfield

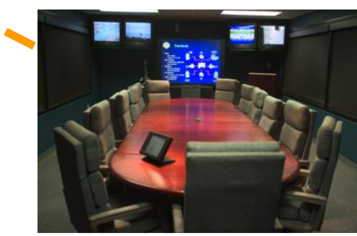

Positioned for future growth


Expert work force


Infrastructure in place with state-of-the-art equipment


Environmental permits granted


Established working relationships


Capability to support DoD transformation

Unexploded Ordnance Safety Briefing

UXO

Explosive Safety

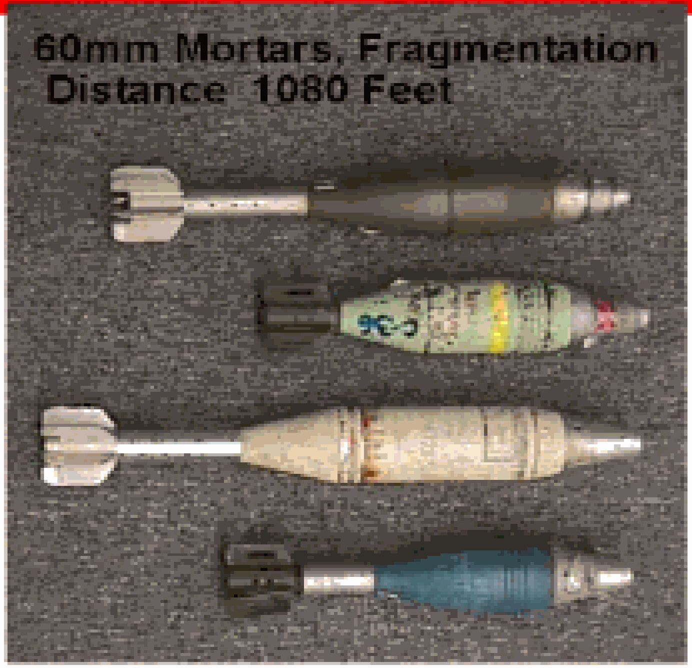
Definition

- Unexploded Ordnance (UXO): military munitions that have been primed, fused, armed, or otherwise prepared for action, and have been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installation, personnel, or material and remain unexploded either by malfunction, design or any other cause. **DoD 4715.11 & DoD 6055.9**

UXO Management

- UXO Remediation
  - Range clearing
- Risk Management (this class)
  - Range briefings
  - Installation policy
  - Educational campaign for schools

Photos of UXO



Lengths (approx.)
- 16 inches
- 11 inches
- 1.5 ft
- 1 ft

UXO stands for UneXploded Ordnance

Most Important Safety Rule

"If you did not drop it, do not pick it up!"

Requirements DPG-R 385-1

- Personnel sponsoring visitors must brief them on UXO hazards
- Permanent government and contractor employees whose duties involve range areas must have the UXO Hazard Familiarization Training

More References

- DoD Directive 4715.11 Environmental and Explosive Safety management on DoD Active and Inactive Ranges within the US
- FM 21-16, UXO Procedures
- AR 385-63, Policies and Procedures for Firing Ammunition for Training, Target Practice and Combat

Discarded Rounds

EOD sorting rounds

Documentation

- Visitor: DP-CMSA Form 3

- Permanent Employee:
  - DP-CMSA Form 1 (card)
  - Certificate
  - Attendance Roster

Mishaps

- More than 150 UXO mishaps in last 5 years
- Soldier in Iraq – death
- Foreign munitions abandoned – death
- Corps of Engineers – beach reclamation
- War souvenirs
- Junk on range

Remember the 3 Rs

Recognize

Retreat

Report

UXO stands for UneXploded Ordnance

Examples of what you might see…

Examples of what you might see…

Examples of what you might see…

UXO MISHAP

What about radios?

- Don’t touch it!!
- Don’t let anyone else touch it!!
- If safe to do so, mark it’s location.
- Notify Range Control.
- Don’t touch it!!

Granite Mountain Atmospheric Sciences Testbed

- Accurate weather predictions are key to DPG mission accomplishment

- Airflow patterns across most of DPG are well-understood

- Areas near the mountains pose challenges
  - Thermally driven flows known to disrupt pattern
  - Mechanical interaction between large-scale winds and terrain may induce effects aloft

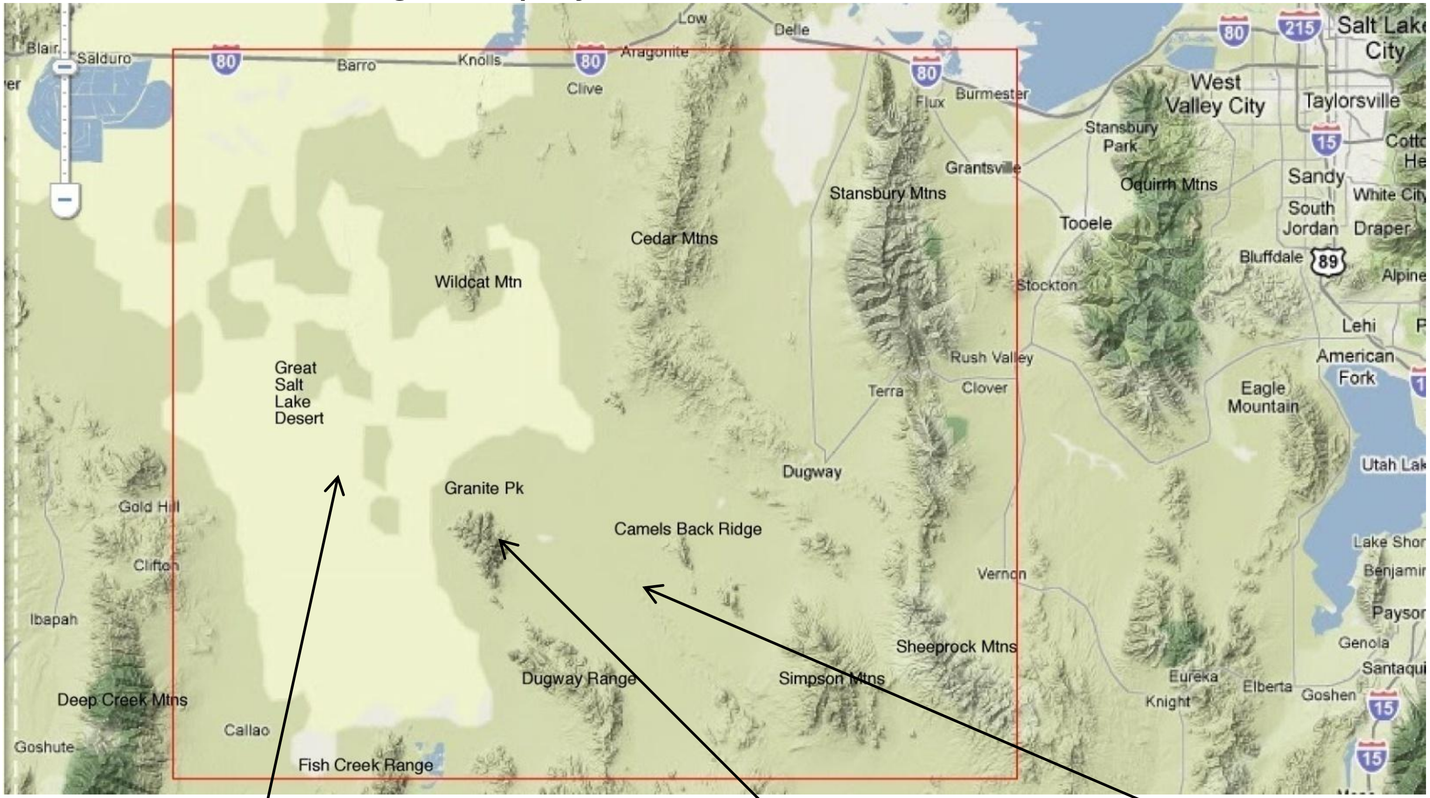
- GMAST will lead to improved forecasting capabilities near DPG mountains

GMAST Motivation

- Sep 07 – I observed the RTVS field trial at V Grid near northern extent of Granite Mountain
  - Winds were not well predicted
  - Lost a night's testing
- It's been my goal since I became Met Division Chief to improve our ability to forecast weather and dispersion near DPG's mountains
- Available funds not sufficient for long-term R&D project – GMAST will bring scientists and $ from other sources

Low-Level Weather Drivers

During summertime, nighttime conditions, low-level winds are driven primarily by interaction with topography
-- Land cools rapidly, cools the air – dense air flows downhill
-- Differential cooling over playa vs dirt



Desert Conditions

Generally fairly flat terrain

Isolated mountains

Thermally driven wind patterns during stable summertime nights

Very smooth upwind fetch west of Granite Mountain

Extremely smooth playa

Granite Mountain

Primary DPG test ranges – terrain slopes down from SSE to NNW

Army Proven Battle Ready

Multiple Flow Patterns

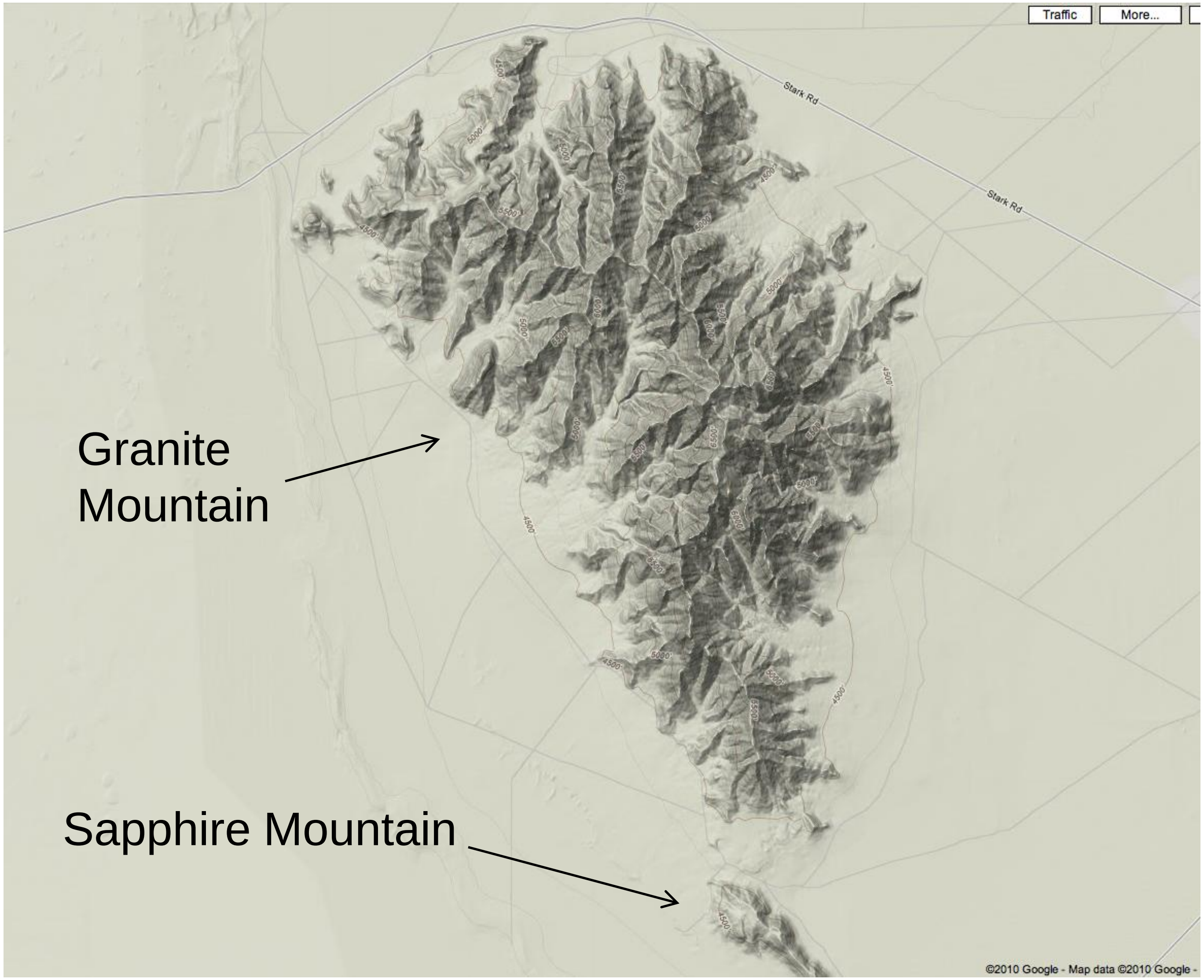
- Consistent flow patterns over primary test ranges
  - Prevailing nighttime flow from southeast toward northwest (downhill)
  - Weaker, less consistent daytime flow in reverse direction (warm air at surface flows upslope)
- Sebastian Hoch (Univ of Utah) performed an analysis of DPG SAMS data from fair-weather days
  - ..\..\GMAST\Streamlines\MM_70movie.mov
  - Note clockwise shift of wind direction throughout day
  - Generally a consistent pattern, but there are significant variations in wind direction and speed

Multiple Flow Patterns

- Wind vector movie
  - ..\..\GMAST\SAMS animation\DugwaySAMS.mov
- Different flow patterns near Granite Mountain, Cedar Mountains, Camelback Mountain
  - Strong downslope, upslope winds in different direction
- Interactions between flow regimes near base of mountains

ATEC

Granite Mountain



2156 m
(7074 ft) elevation

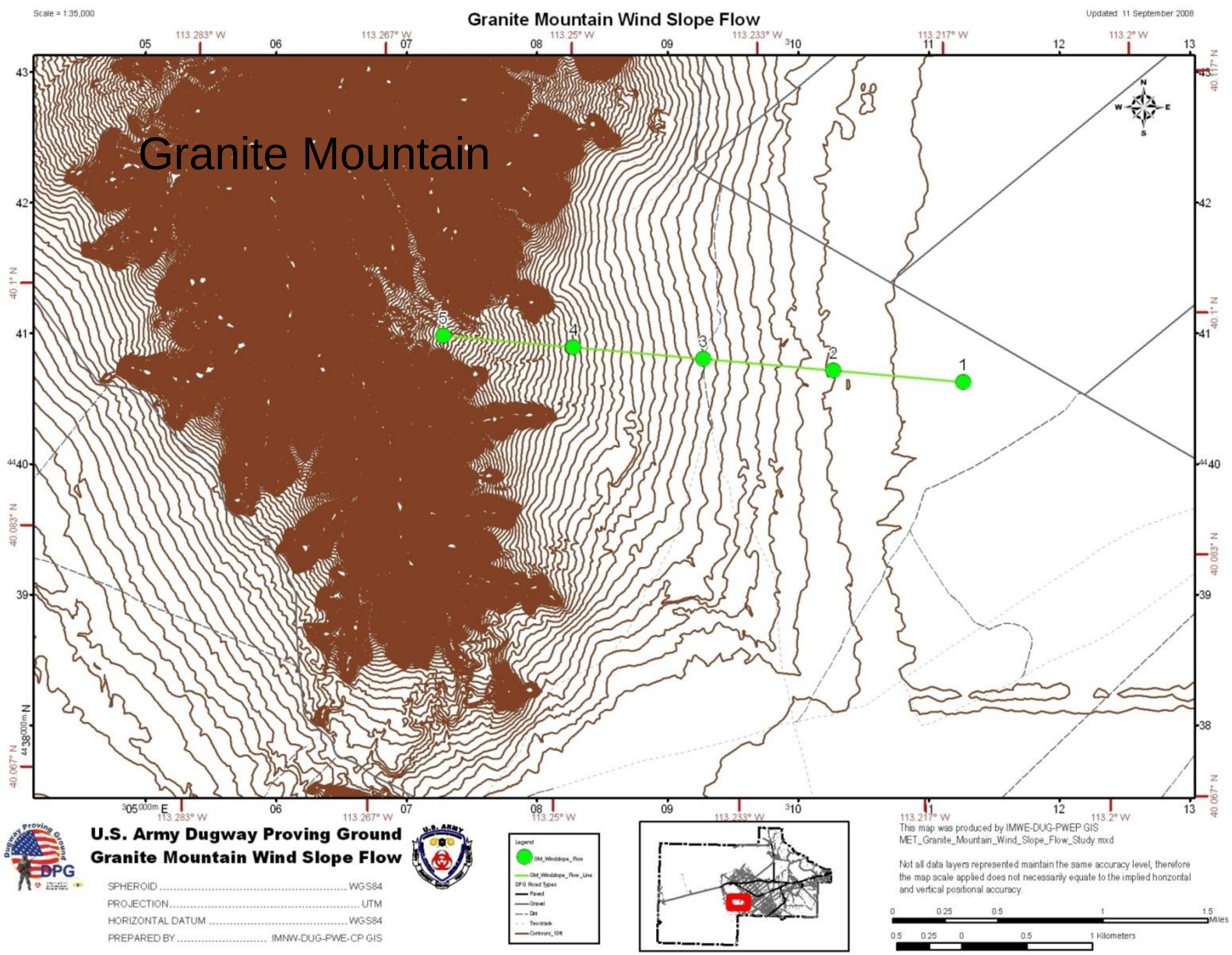
853 m
(2800 ft) above valley floor

Surface is primarily granite

Note gap between Granite Mountain and Sapphire Mountain

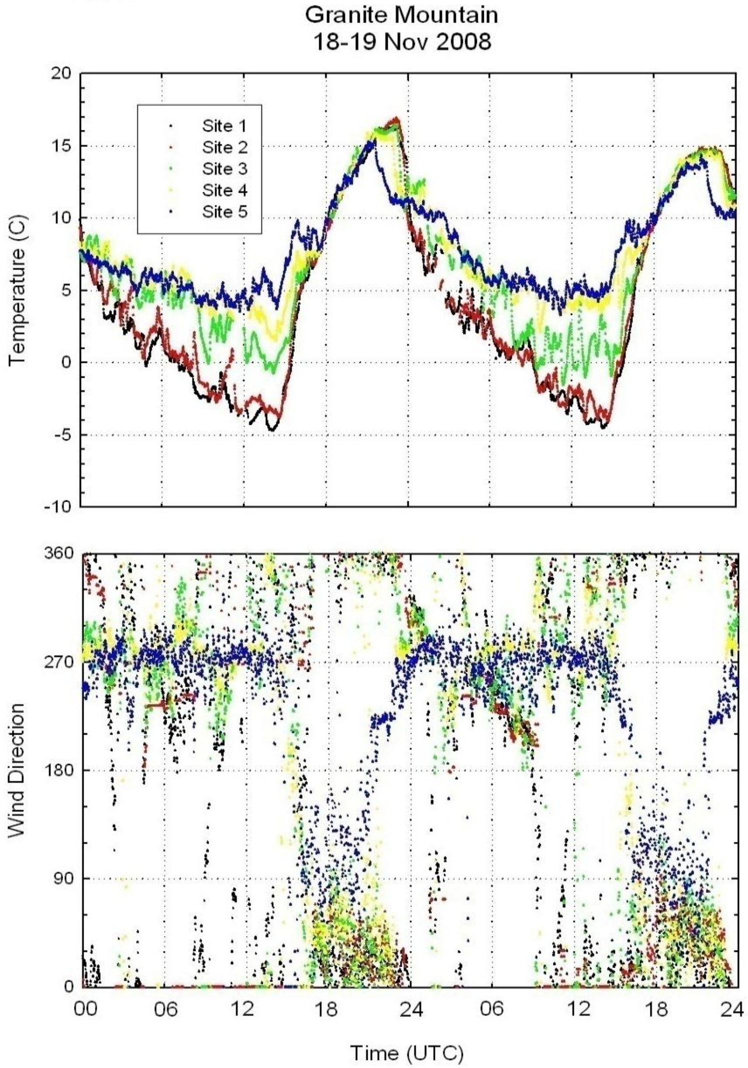
Another gap to south of Sapphire Mountain

Initial GMAST Deployment



- Five 2-m towers deployed down a major channel on east face of Granite Mountain
- Studying thermally driven flows

Sample of Data Analysis



PWIDS 5 elev 1447 m, PWIDS 1 elev 1312 m

10 K inversion develops during night -- height difference 135 m along the slope. Half of this temperature difference between the center and lowest PWIDS (within lowest 25 m)

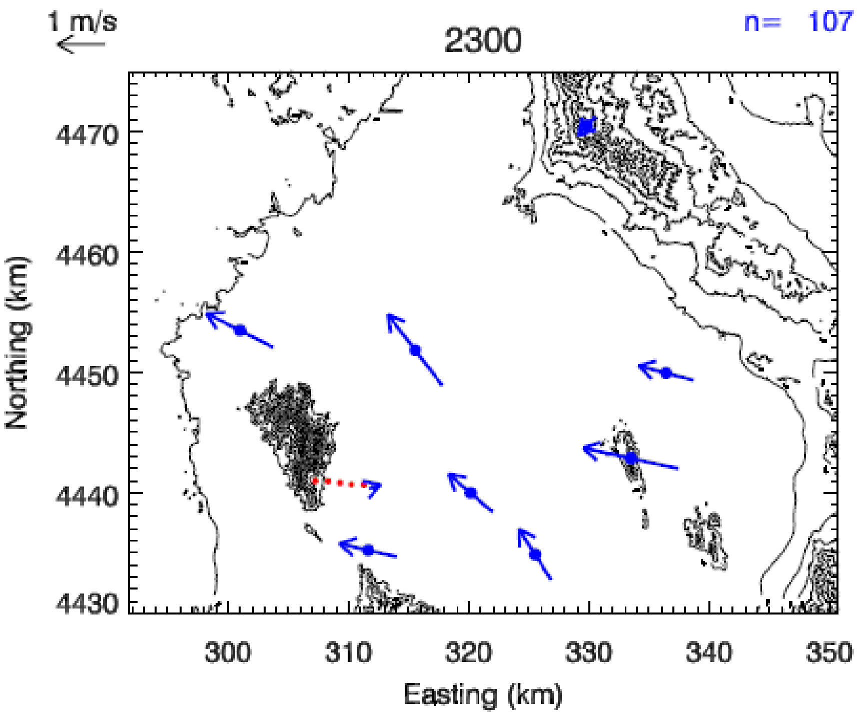
Note change in temperature as inversion depth reached each PWIDS

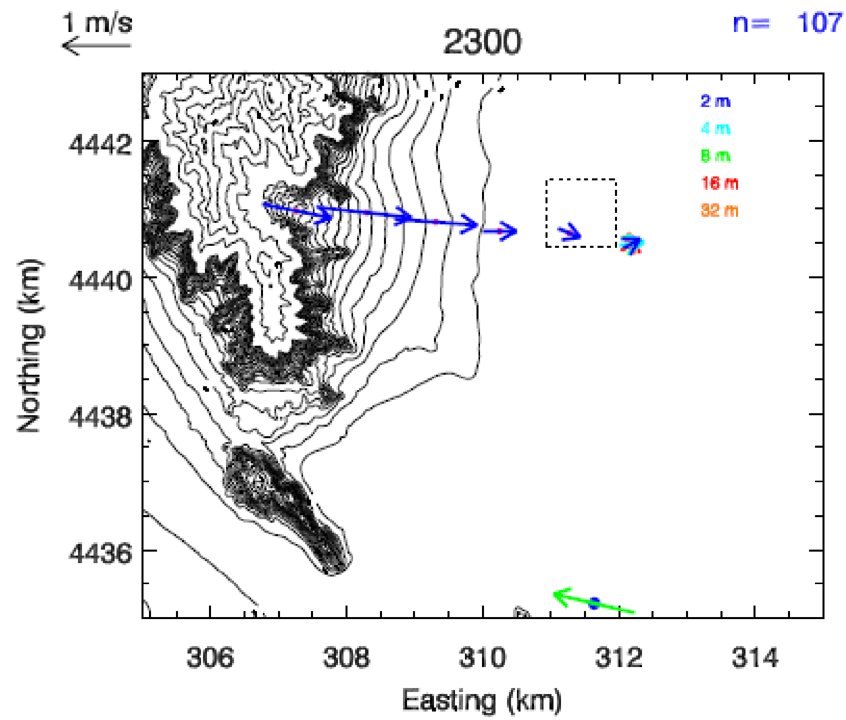
Blue – Site 5 (highest elevation) – coolest during afternoon – warmest during inversion (after 00Z) – less diurnal variation than lower elevation sites
Black – Site 1 (lowest elevation) – warmest during afternoon – coolest during inversion – rapid cooling from 00Z to 15Z (> 20C), then rapid warming

Shallow, very stable surface inversion on plain: 32-m tower data (not shown) reports 7-8 K inversion in lowest 32 m

Wind direction shows westerly nighttime drainage flows and north-easterly upslope afternoon winds on the east side of Granite Mountain

Example of Flow Interaction





Large scale drainage flow from southeast at 2300 MST (0600 UTC)

Granite Mountain drainage flow from west at 2300 MST (0600 UTC)

JJA, SAMS wind speed < 3 m s^{-1}

Cedar Mountain Flow

- Data collected along slope of Cedar Mountains in 2008
  - Study led by Dr Al Astling, formerly of Met Division
  - Analysis collaboration between Al and Larry Mahrt of Oregon State University
  - ..\..\GMAST\Mahrt\Feb14_Profile.mov
  - Shows example of interaction between synoptic scale winds and complex terrain

GMAST Concept of Operations

- Combine long-term data collection with intensive observation periods

- Visiting scientists will augment the DPG data baseline
  - Bring additional equipment, personnel
  - Use DPG data collection system when possible
  - Limited funding needs for DPG labor

- Opportunity to conduct repeated studies, comparing results with other scientists working in the same domain
  - Standard topography reference feature

GMAST Planning

- Coordinating with University of Utah Meteorology Department
- Leading authorities on mountain meteorology (C. David Whiteman) and postdoc (Sebastian Hoch)
- Univ of Utah conducted analyses of available data and suggested a long list of useful research projects

Potential Areas for Studies

- Effect of background winds on mountain drainage flows
  - How do winds west of Granite Mountain compare to drainage flows on eastern slope?
- Effect of large-scale drainage flows on Granite Mountain downslope winds
  - How do depths and strengths of inversions affect this interaction?
  - Use network of taller towers
- Effect on drainage flows of inversion structure
  - Relate strength of drainage flow to inversion structure
  - How does gap north of Sapphire Mountain affect flows?
  - Use towers, microwave radiometers, and tethered balloons to evaluate temperature structure
  - Use sodars and towers to measure flow across gap

Potential Areas for Studies

- Effect of local topography on drainage flow homogeneity
  - Canyon walls may channel flow
  - Intensive field study could support numerical modeling research
- Energy budget effects on drainage flows
  - Study sensible and radiative flux divergences
  - Attempt to identify energy balance
- Studies of mechanical interaction between airflow and mountain
  - Downwind waves, rotors, etc
  - Use lidars, tethered balloons

Potential Areas for Studies

- Link field studies and Numerical Weather Prediction model development
  - Place sensors to correspond to critical sites in model structure
  - Collect data elements most relevant to model forcing
  - Could support LES, RANS model development
- Conduct weather model data assimilation technique development and verification
  - Isolate critical processes
  - Evaluate 3DVAR, 4DVAR, ensemble Kalman filtering

DPG Support

- Little or no internal funding required
- DPG requires external funding only for direct costs to support GMAST visiting scientists (e.g., labor to deploy instrumentation as needed) and for normal test support (environmental, safety, range control)
  - Do not expect these costs to be great
  - DPG's interest is the data collected, and the improved understanding of airflow near Granite Mountain
- Visiting scientists concentrate on field study design
  - Avoid need for expensive network of sensors, and data collection/archival
  - Avoid need to secure permissions, do site surveys, etc for new research sites

GMAST Benefit for Dugway

- Improved understanding of mountain airflow patterns
  - Gap flows, drainage flows, mechanical interaction
- Improved modeling
  - Requires NCAR access to observational data
  - MATERHORN use of ensemble modeling data
  - Development of LES modeling
- Concepts for additional instrumentation
  - IR camera?
  - More extensive instrumentation – need to determine locations

GMAST Summary

- Looking for win-win relationships
- DPG provides access to our assets
  - Unique topography
  - Instrumentation
  - Numerical modeling
  - Data archival
- Visitors collect unique datasets
  - Concentrate on specialized instrumentation, field study

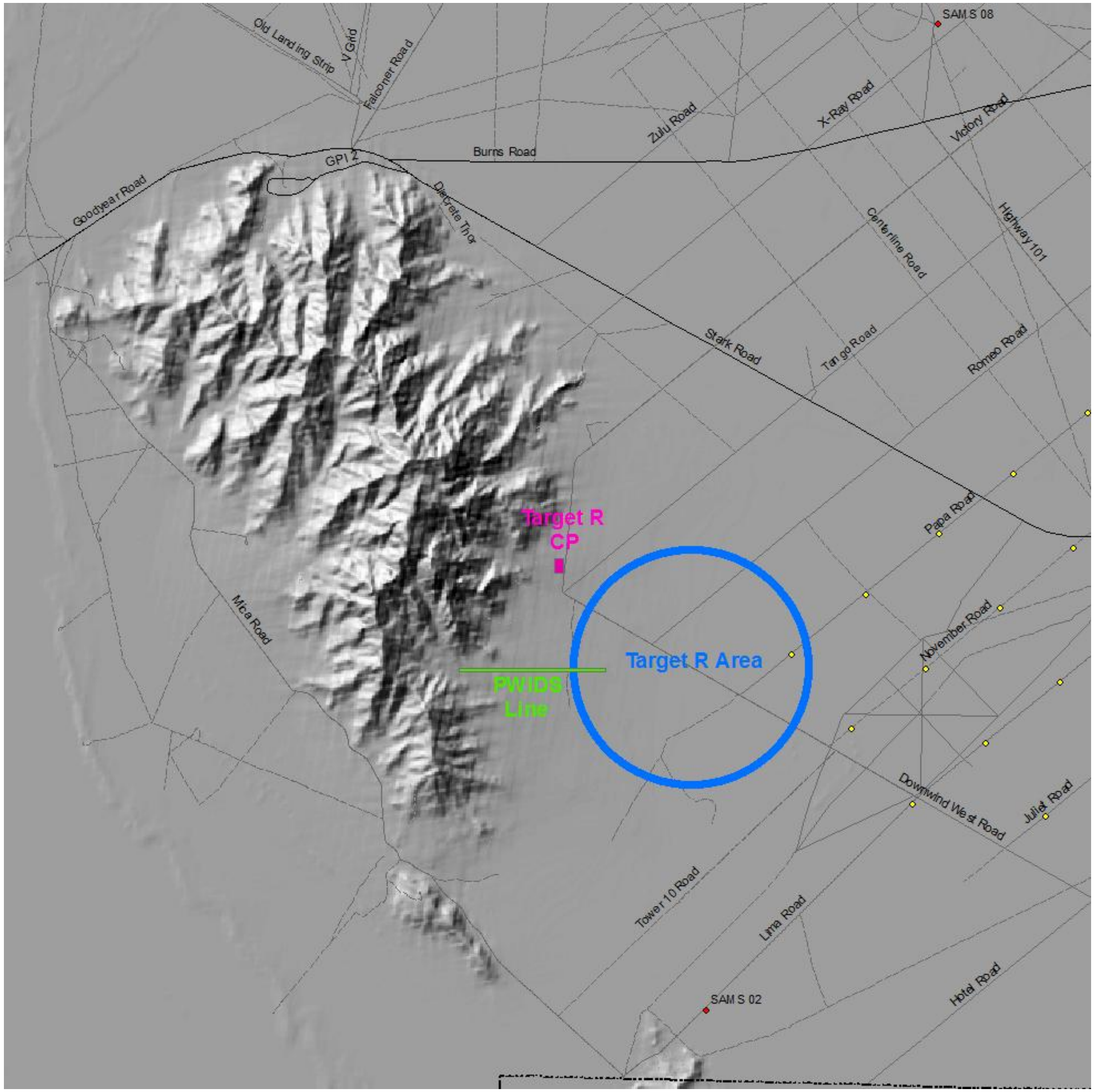
MATERHORN MURI

- Mountain Terrain Atmospheric Modeling and Observations
- Multi-University Research Initiative to Office of Naval Research and Army Research Office – goal is improved weather forecasting capability for UAS systems in complex terrain in Afghanistan
- Led by University of Notre Dame
- Team members include University of Utah, University of California (Berkeley), Naval Postgraduate School, University of Virginia
- Data collection from many locations around Granite Mountain in 2012

MATERHORN MURI

- Scientific objectives:
  - Understand predictability of mesoscale phenomena in complex terrain – evaluate error growth rate
  - Identify sensitivities to boundary conditions
  - Evaluate skill of various data assimilation approaches
  - Evaluate benefit of new sensor platforms (e.g. UAS)
  - Reformulate Monin-Obukhov Similarity Theory for complex terrain
  - Improve understanding of Stable Boundary Layer over complex terrain, including transition periods during morning and evening
  - Improve understanding of Unstable Boundary Layer over complex terrain, including transition periods during morning and evening
  - Observe slope flow interactions and compare to numerical modeling
  - Study interaction between synoptic scale flows and thermal flows

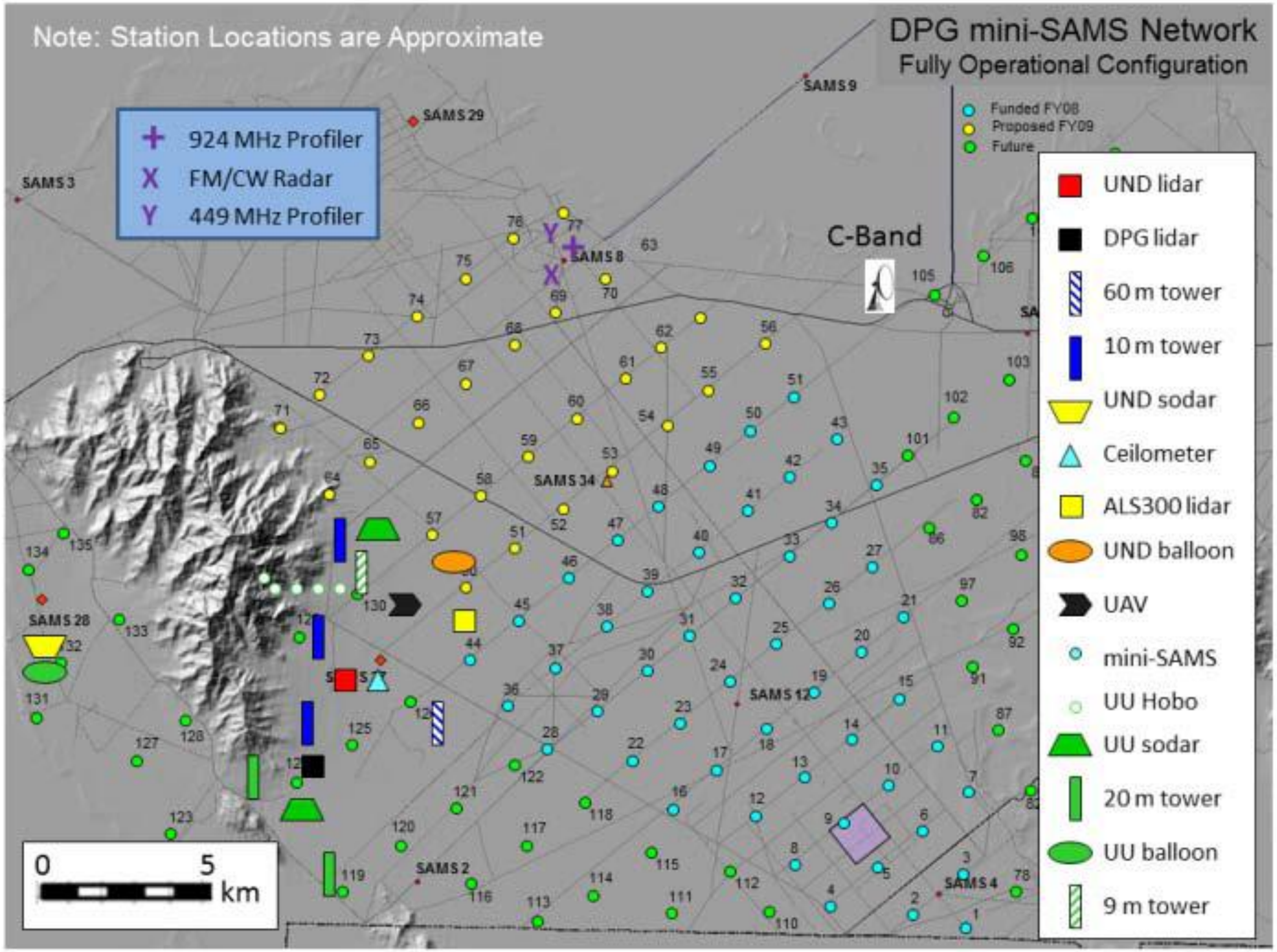
Granite Mountain Vicinity



Ditto
Area

Entry
(English
Village)

MATERHORN Instrumentation



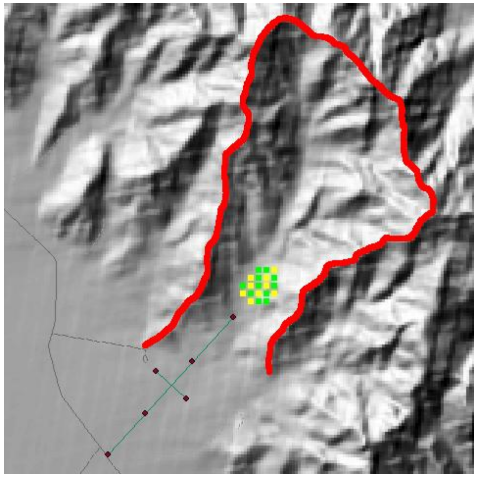
Army Proven
Battle Ready

Other Field Test Proposals

- Encouraging use of complex terrain sites for field tests when possible
- Met Division submitting proposals for projects involving complex terrain

Jack Rabbit Follow-On

- Jack Rabbit was conducted on flat terrain in 2010
- Department of Homeland Security / Transportation Security Administration agrees with our proposal to conduct next set of tests on southwestern slope of Granite Mountain
  - Understand interaction between gravity-driven downhill flow of dense gas, vs uphill wind flow



- Anticipate next test series to be conducted in 2013 or 2014

TIC-MUST Proposal to DTRA

- Follow-on to Mock Urban Setting Test (MUST) conducted at DPG for DTRA in 2001
- Study dense gas and neutrally buoyant gas dispersion in a scaled urban setting, in complex terrain – proposed field study in 2013
- DTRA's goal is urban dispersion source term estimation but also recognizes need to consider urban areas in complex terrain
- JEM report states need for better handling of TICs

Summary

- Improved understanding of wind patterns near Granite Mountain and other mountains needed for test support
- GMAST will address this need without funding expensive R&D project
    - GMAST will be paid for by sponsors of visiting science programs, and DPG is paid for labor and other costs
- We have clear scientific objectives
- We have several promising projects in line
- Supports DPG, WDTC, Met Division vision and strategic goals

DPG Weather Assets

- Very dense network of meteorological sensors
  - 82 fixed 10-m towers, 9 32-m towers, 113 portable 2-m towers
  - 3 radars
  - Sodars, lidar, profilers, lightning arrays, and much more
- Excellent numerical weather modeling
  - Four-Dimensional Weather (4DWX)
  - 1.1 km resolution WRF runs 8 times per day
  - 3.3 km resolution 30 member ensemble runs 4 times per day
- Robust, automated data retrieval and archival
- Highly skilled forecaster staff

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Questions and Discussion