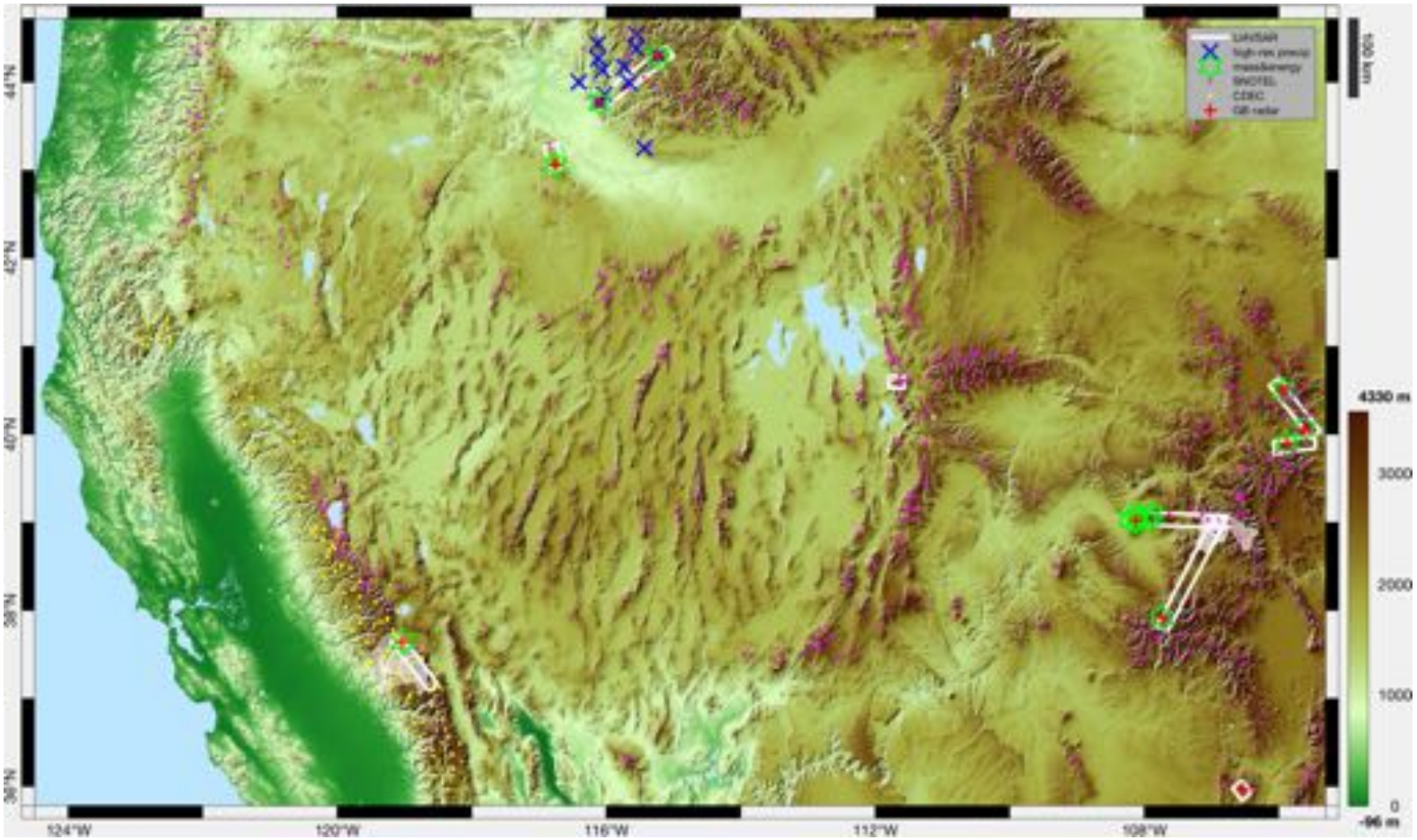
SnowEx 2019: Proposed Experimental Plan

A multi-sensor time-series experiment in multiple snow climates



THP16 Implementation Team:

H.P. Marshall, Jeff Deems, Eli Deeb, Glen Liston, Dorothy Hall, Charles Gatebe, Leung Tsang, Chris Derksen, Ed Kim, Tom Painter, Mel Sandells, Paul Houser, Noah Molotch

Outline

2019 Strategy

Science Traceability Matrix

Proposed Airborne Sensors

Science Plan Gaps / Priorities

Site Requirements & Priorities

Large Scale Focus Areas

Snow Climatology

Intensive Study Areas (ISAs)

UAVSAR flight plan

Core Western U.S. Field Activities

Trail Valley Creek Airborne and Field Experiment

SnowEx 2019: Timeline

Outline

- Strategy / Considerations for 2019
- Science Traceability Matrix
- Proposed Airborne Sensors
- Science Plan Gaps / Priorities
- Site Requirements & Priorities
- Large Scale Focus Areas
- Intensive Study Areas
- Core Western U.S. SnowEx19 Field Activities
- Trail Valley Creek Airborne and Field Experiment
- SnowEx 2019 Timeline

Outline
2019 Strategy
Science Traceability Matrix
Proposed Airborne Sensors
Science Plan Gaps / Priorities
Site Requirements & Priorities
Large Scale Focus Areas
Snow Climatology
Intensive Study Areas (ISAs)
UAVSAR flight plan
Core Western U.S. Field Activities
Trail Valley Creek Airborne and Field Experiment
SnowEx 2019: Timeline

Strategy / Considerations for 2019

SnowEx 2017:

- Larger available funding, comprehensive ground based effort
- Dedicated air and ground measurement effort, 100+ people involved
- Two nearby sites, 100+ people involved
- Wide range of aircraft and sensors, both high and low risk approaches
- Large continuous month-long campaign, but very small change in SWE
- 1 primary gap focus - impact of forest

SnowEx 2019:

- More limited funding for airborne/field experiments
- Leverage currently planned airborne acquisitions
- Twelve potential sites, small teams distributed across many snow climates
- Focus on low-risk sensor and aircraft combos
- Capture large change in SWE: ***time series approach***
- Focus on temporal change for multiple gaps

Outline
2019 Strategy
Science Traceability Matrix
Proposed Airborne Sensors
Science Plan Gaps / Priorities
Site Requirements & Priorities
Large Scale Focus Areas
Snow Climatology
Intensive Study Areas (ISAs)
UAVSAR flight plan
Core Western U.S. Field Activities
Trail Valley Creek Airborne and Field Experiment
SnowEx 2019: Timeline

NASA SnowEx 2019-2021 Science Traceability Matrix

SnowEx 2019 Airborne Campaign:

SnowEx Fundamental Question #1
What are the physical controls and dynamics of accumulation and melt of seasonal snow (SWE) across topographic gradients?

SnowEx 2020 Airborne Campaign:

SnowEx Fundamental Question #2
What are the patterns of snow accumulation and melt in boreal vs. temperate forests, and what is the resulting hydrologic partitioning of snowmelt in these areas?

Outline
2019 Strategy
Science Traceability Matrix
Proposed Airborne Sensors
Science Plan Gaps / Priorities
Site Requirements & Priorities
Large Scale Focus Areas
Snow Climatology
Intensive Study Areas (ISAs)
UAVSAR flight plan
Core Western U.S. Field Activities
Trail Valley Creek Airborne and Field Experiment
SnowEx 2019: Timeline

NASA SnowEx 2019 Airborne Campaign

Mission Objective #1:
Quantify snow mass and physical properties across topographic and vegetation gradients in different snow environments and across the snow accumulation and ablation seasons.

Mission Objective #3:
What is the sensitivity & accuracy of different sensors in measuring snow mass and physical properties?

Mission Objective #4:
What are the optimal spatial and temporal observation scales to capture variation in snow mass and physical properties?

(Mission Objective and Fundamental Question #'s refer to those in the STM.)

Outline
2019 Strategy
Science Traceability Matrix
Proposed Airborne Sensors
Science Plan Gaps / Priorities
Site Requirements & Priorities
Large Scale Focus Areas
Snow Climatology
Intensive Study Areas (ISAs)
UAVSAR flight plan
Core Western U.S. Field Activities
Trail Valley Creek Airborne and Field Experiment
SnowEx 2019: Timeline

Proposed SnowEx19 Airborne Sensors

Rationale for Proposed Sensors:

- Low-risk sensor and airborne combos with proven track record
- Time-series deployments to capture accumulation and melt
- Low and medium cost airborne deployments
- Sensor strategies with clear path to space

Proposed Core Airborne Sensors / Platforms:

- Airborne Snow Observatory: LiDAR and Hyperspectral imager
- UAVSAR: L-Band Interferometric SAR
- NASA IceBridge: LiDAR, radar, Hyperspectral imager
- UMass Ku-band SAR

Additional Community-Proposed Airborne Sensors

- UW Applied Physics: Thermal IR
- CRREL/NCALM HeliPod: LiDAR and Thermal IR
- GLISTIN-A: Ka-band Interferometric SAR
- Goddard SWESARR: multi-band SAR, radiometer
- NRL SnowRadar: 2-18 GHz FMCW
- AVIRISng

Outline
2019 Strategy
Science Traceability Matrix
Proposed Airborne Sensors
Science Plan Gaps / Priorities
Site Requirements & Priorities
Large Scale Focus Areas
Snow Climatology
Intensive Study Areas (ISAs)
UAVSAR flight plan
Core Western U.S. Field Activities
Trail Valley Creek Airborne and Field Experiment
SnowEx 2019: Timeline

THP16 Science Plan Gaps

Identified Gaps Addressed by SnowEx 2019

- Forest snow
- mountain snow
- tundra / alpine snow
- wet snow

Identified Gaps Partially Addressed by SnowEx 2019

- snow surface energetics (proposed thermal IR campaign)
- Prairie snow (but not with volume scattering microwave approaches) - SnowEx 2021?
- maritime snow (California site, but not technically maritime) - add additional more maritime CA site? Or 2021?

Outline
2019 Strategy
Science Traceability Matrix
Proposed Airborne Sensors
Science Plan Gaps / Priorities
Site Requirements & Priorities
Large Scale Focus Areas
Snow Climatology
Intensive Study Areas (ISAs)
UAVSAR flight plan
Core Western U.S. Field Activities
Trail Valley Creek Airborne and Field Experiment
SnowEx 2019: Timeline

THP16 Science Plan Recommended Priorities

Priorites Addressed by SnowEx 2019

- L-Band InSAR - UAVSAR biweekly acquisitions to determine causes of decorrleation
- LiDAR - ASO in California and Colorado, proposed CRREL/NCALM HeliPod

Priorities Partially/Possibly Addressed by SnowEx 2019

- Ku-band radar (IceBridge contribution to TVC, proposed SWESARR)
- Ka-band InSAR (proposed GLISTIN-A)
- Snow model integration (Liston/Reinking model results, and availability of forcing data and stream gauges used guide study region selection)
- Hyperspectral imaging (ASO; BRDF still needed)
- Thermal IR (proposed UW-IR campaign)
- FMCW radar (IceBridge; proposed NRL SnowRadar)

Outline
2019 Strategy
Science Traceability Matrix
Proposed Airborne Sensors
Science Plan Gaps / Priorities
Site Requirements & Priorities
Large Scale Focus Areas
Snow Climatology
Intensive Study Areas (ISAs)
UAVSAR flight plan
Core Western U.S. Field Activities
Trail Valley Creek Airborne and Field Experiment
SnowEx 2019: Timeline

Site Requirements

- Variation in elevation, slope, aspect
- Variation in snow climatology (warm forest, mountain, alpine, wet, prairie)
- Ability to study time series of accumulation and melt
- Existing snow-free LiDAR data
- Well-instrumented, gauged watershed, publicly available data
- Historical record of meteorological and hydrological data
- Access to safe terrain for field operations in winter
- Within range of primary airborne platforms (e.g. UAVSAR - from Palmdale, CA)

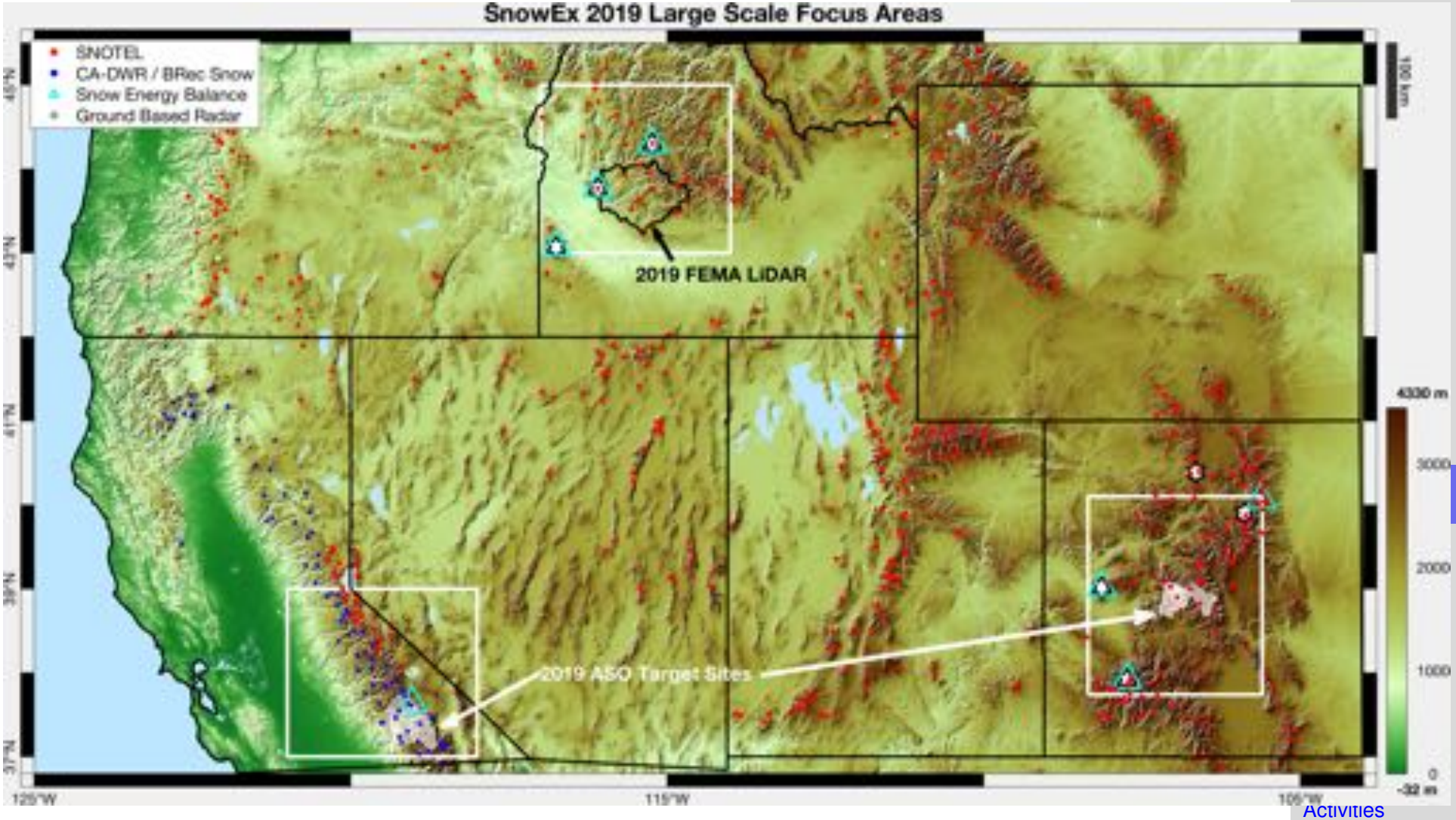
Outline
2019 Strategy
Science Traceability Matrix
Proposed Airborne Sensors
Science Plan Gaps / Priorities
Site Requirements & Priorities
Large Scale Focus Areas
Snow Climatology
Intensive Study Areas (ISAs)
UAVSAR flight plan
Core Western U.S. Field Activities
Trail Valley Creek Airborne and Field Experiment
SnowEx 2019: Timeline

Site Priorities

- Locations of planned, funded 2019 airborne flights (per Jared's directive)
- Existing airborne snow remote sensing datasets
- Coincidence with satellite acquisitions
- Comprehensive snow energy and mass balance observations
- Ongoing synergistic research activities
- Existing ground-based remote sensing
- Pool of experienced field personnel within one day's drive

Outline
2019 Strategy
Science Traceability Matrix
Proposed Airborne Sensors
Science Plan Gaps / Priorities
Site Requirements & Priorities
Large Scale Focus Areas
Snow Climatology
Intensive Study Areas (ISAs)
UAVSAR flight plan
Core Western U.S. Field Activities
Trail Valley Creek Airborne and Field Experiment
SnowEx 2019: Timeline

SnowEx 2019: Large Scale Focus Areas



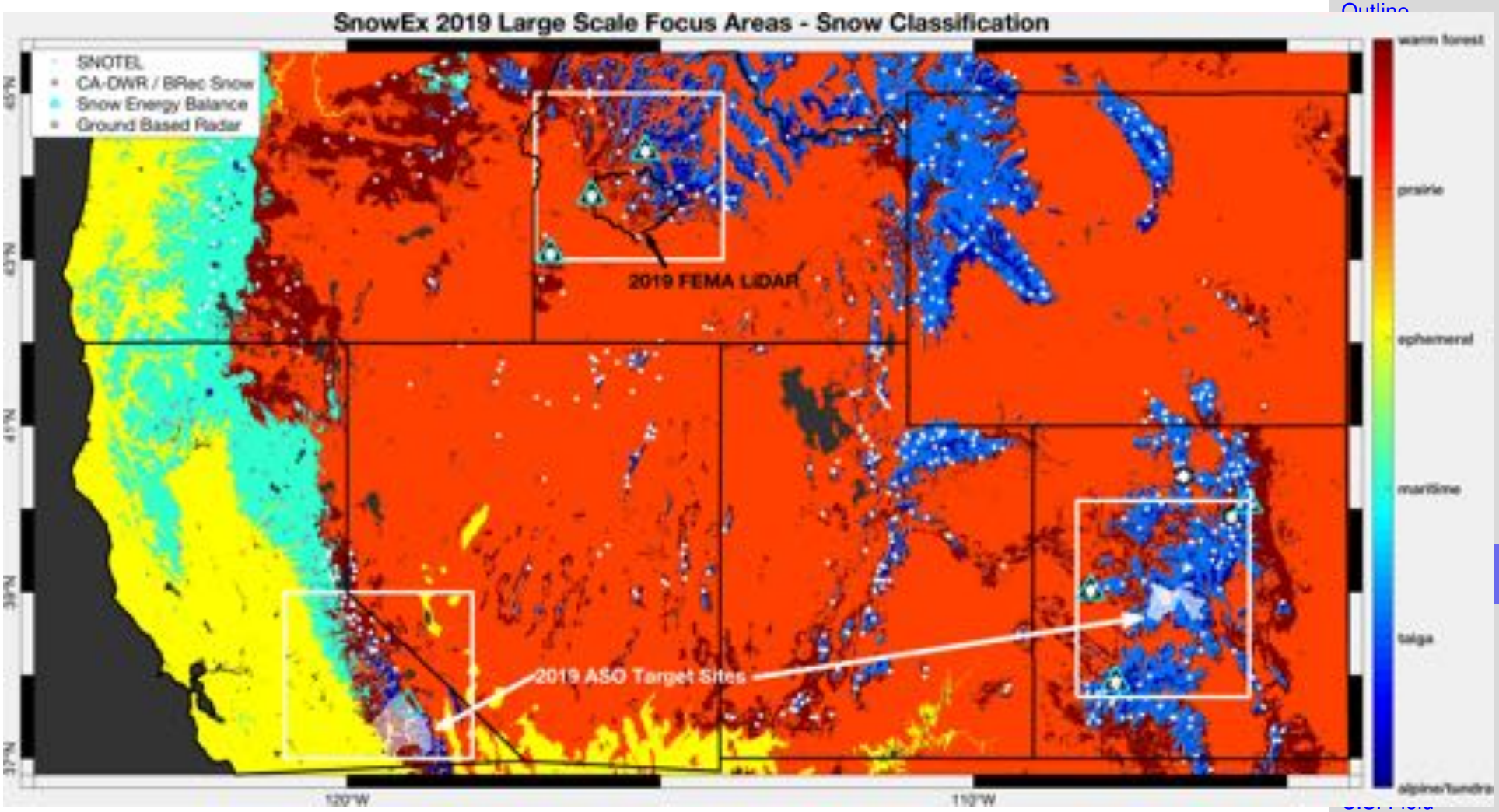
Focus areas include: ASO target sites in CA and CO, FEMA LiDAR site in ID, Western US snow energy balance sites (e.g. Bair et. al, 2018; Bales et. al, 2006) and SnowEx 2017 locations

Activities

Trail Valley Creek Airborne and Field Experiment

SnowEx 2019: Timeline

Snow Climatology



Focus areas include: Alpine/Tundra, Taiga, Prairie, Warm Forest snow climates (Sturm and Liston, 1995; Liston and Sturm, 2014). Each focus area contains at least 3 snow classes.

Intensive Study Areas

Site Requirements	Site Priorities
Range of topography	Planned, funded airborne flights
Range of snow climatology	Existing snow remote sensing datasets
Range of vegetation	Coincident with satellite overpasses (e.g. IceSAT2)
Existing snow-free LiDAR data	Ongoing synergistic research activities
Well-instrumented, gauged watershed	Existing ground-based remote sensing
Historical record of meteorological and hydrological data	Pool of experienced field personnel within one day drive
Access to safe terrain for field ops in winter	Comprehensive snow mass & energy balance observations
Within range of airborne platforms	Nearby infrastructure for field logistics

Outline

2019 Strategy

Science Traceability Matrix

Proposed Airborne Sensors

Science Plan Gaps / Priorities

Site Requirements & Priorities

Large Scale Focus Areas

Snow Climatology

Intensive Study Areas (ISAs)

UAVSAR flight plan

Core Western U.S. Field Activities

Trail Valley Creek Airborne and Field Experiment

SnowEx 2019: Timeline

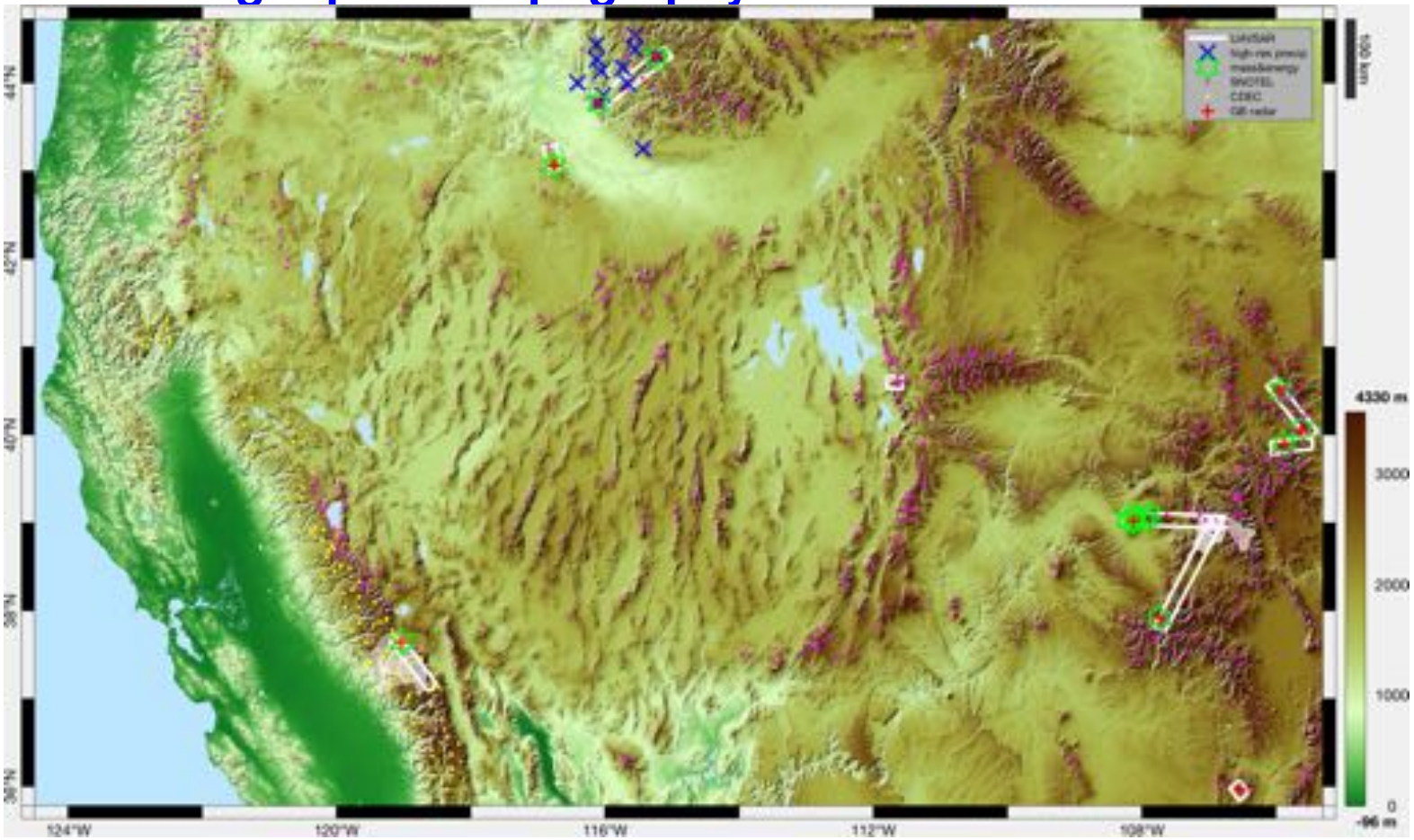
Intensive Study Areas (ISAs)

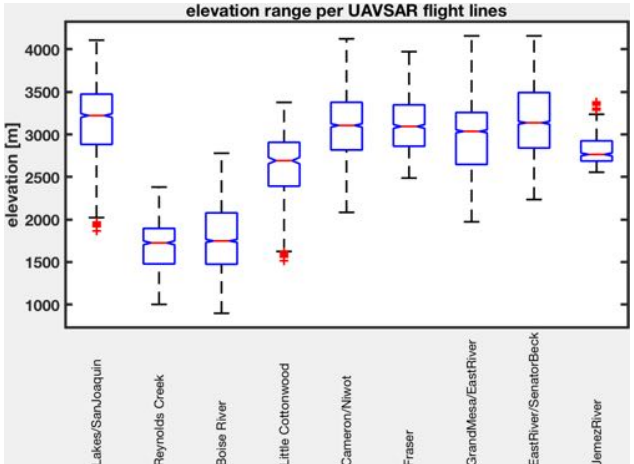
Sites that met all of the requirements and priorities (see table in Implementation Plan) and are being considered for ISAs are listed below with additional rationale unique to each:

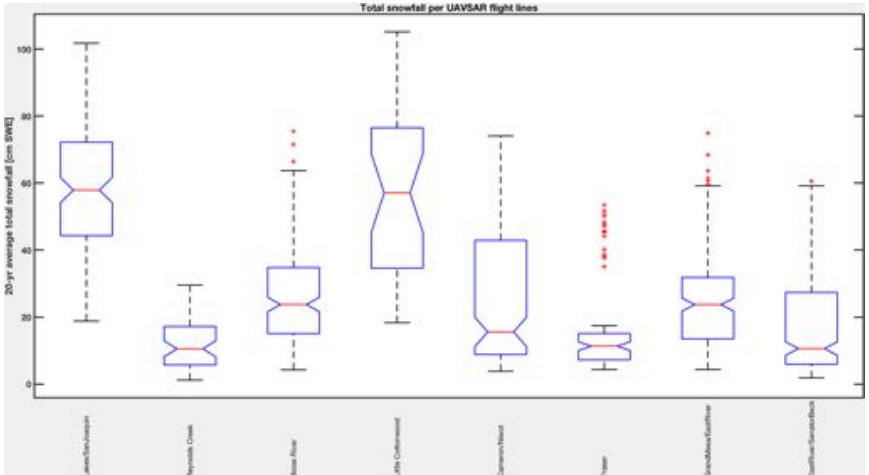
- San Joaquin and Lakes, CA (CUES site, winter-long ASO time series)
- East River, CO (spring ASO, large multi-institution DOE project)
- Senator Beck, CO (SnowEx17 site, ASO/UAVSAR target of opportunity on transit, L-band GPR)
- Grand Mesa, CO (SnowEx17 site, many full energy balance sites)
- Niwot Ridge, CO (CZO site, LTER site, L-band GPS experiments)
- Fraser Experimental Forest, CO (CLPX site, SoOp tower experiments)
- Cameron Pass, CO (L-band GPR experiments)
- Reynolds Creek Experimental Watershed, ID (CZO site, long term modeling and hydrologic monitoring)
- Boise River Basin, ID (L-/C-/X-/Ku-band GPR experiments, TLS, FEMA LiDAR, snow/WRF modeling, cloud seeding)
- Jemez River, NM (CZO site, L-band GPR experiments)
- Alta, UT (target of opportunity on transit, UAV SfM)

Outline
2019 Strategy
Science Traceability Matrix
Proposed Airborne Sensors
Science Plan Gaps / Priorities
Site Requirements & Priorities
Large Scale Focus Areas
Snow Climatology
Intensive Study Areas (ISAs)
UAVSAR flight plan
Core Western U.S. Field Activities
Trail Valley Creek Airborne and Field Experiment
SnowEx 2019: Timeline

UAVSAR flight plan - Topography / Total snowfall







Outline

2019 Strategy

Science Traceability Matrix

Proposed Airborne Sensors

Science Plan Gaps / Priorities

Site Requirements & Priorities

Large Scale Focus Areas

Snow Climatology

Intensive Study Areas (ISAs)

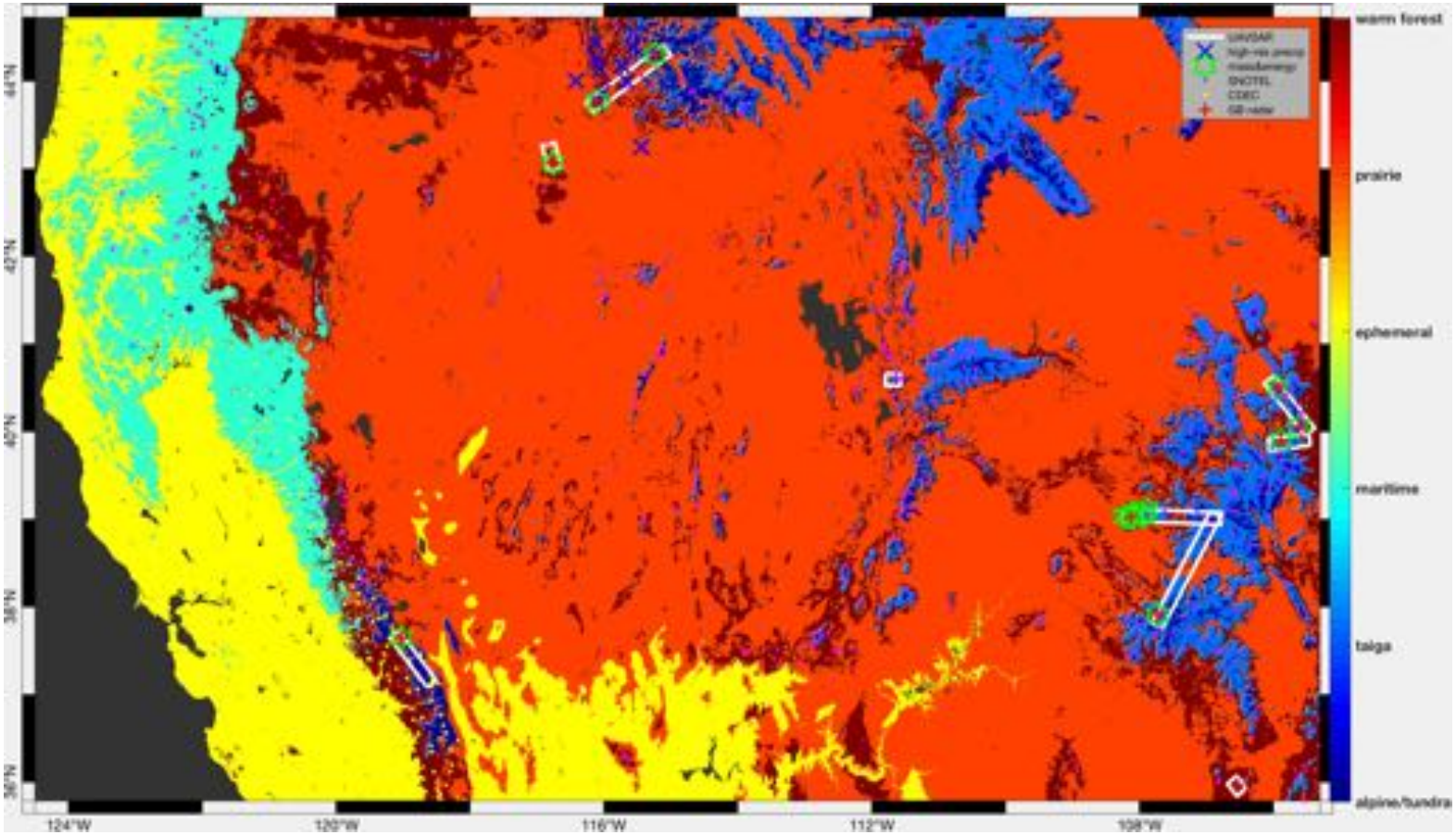
UAVSAR flight plan

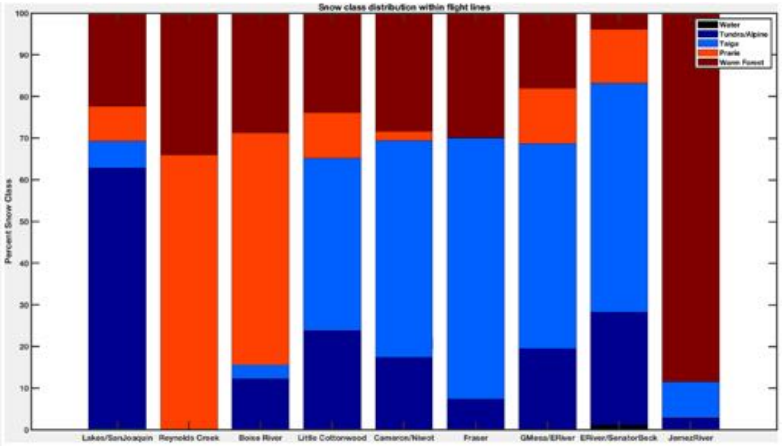
Core Western U.S. Field Activities

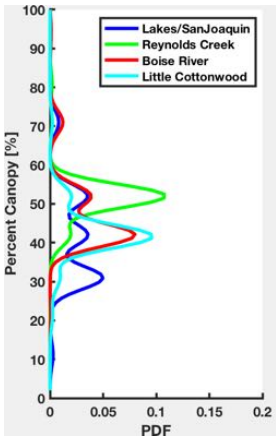
Trail Valley Creek Airborne and Field Experiment

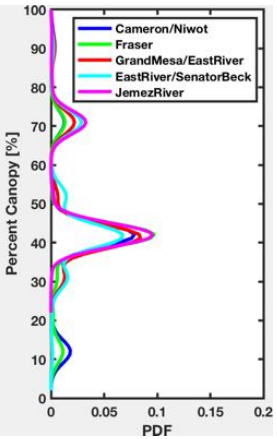
SnowEx 2019: Timeline

UAVSAR flight plan - Snow Climate / Canopy Cover









Outline

2019 Strategy

Science Traceability Matrix

Proposed Airborne Sensors

Science Plan Gaps / Priorities

Site Requirements & Priorities

Large Scale Focus Areas

Snow Climatology

Intensive Study Areas (ISAs)

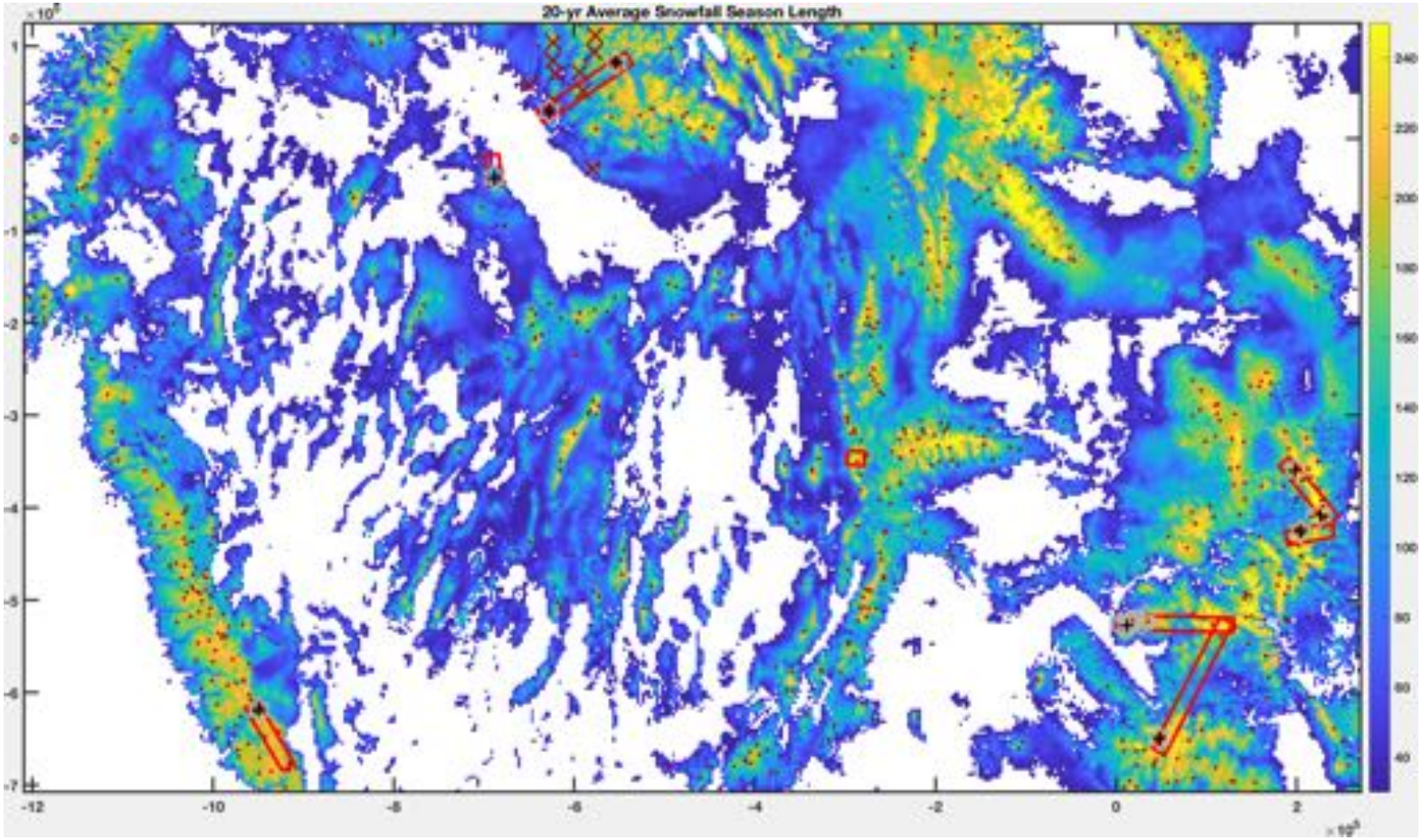
UAVSAR flight plan

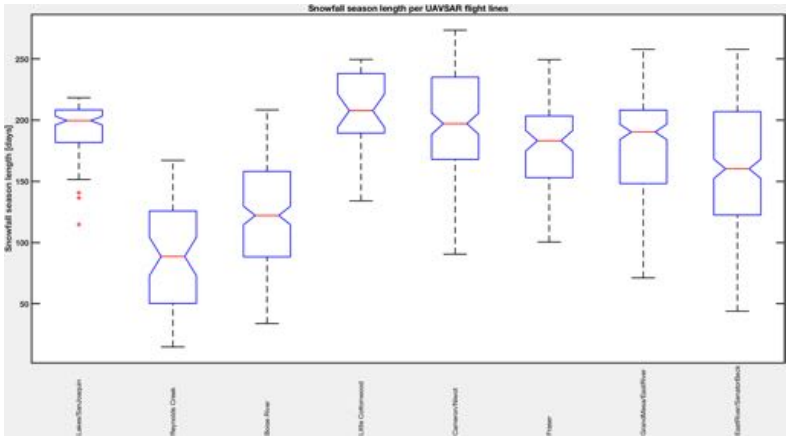
Core Western U.S. Field Activities

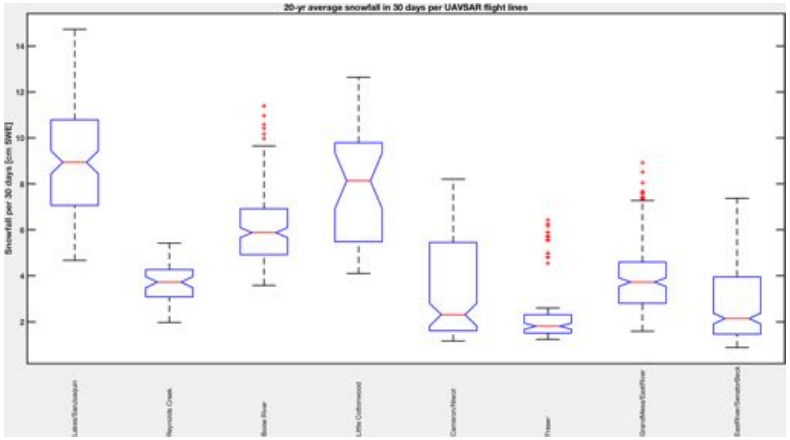
Trail Valley Creek Airborne and Field Experiment

SnowEx 2019: Timeline

UAVSAR flight plan - Season Length / Accumulation rate







Outline

2019 Strategy

Science Traceability Matrix

Proposed Airborne Sensors

Science Plan Gaps / Priorities

Site Requirements & Priorities

Large Scale Focus Areas

Snow Climatology

Intensive Study Areas (ISAs)

UAVSAR flight plan

Core Western U.S. Field Activities

Trail Valley Creek Airborne and Field Experiment

SnowEx 2019: Timeline

Core SnowEx19 Field Activities (preliminary)

- Focus on SWE, depth, snow density, liquid water content, snow temperature
- Short ($\sim$1 day) campaigns aligned with overflights (every 2 weeks), throughout winter
- 1-2 teams at each of up to 11 sites, deploy on same day
- Additional campaigns organized around winter ASO flights, other proposed airborne observations

Outline

2019 Strategy

Science Traceability Matrix

Proposed Airborne Sensors

Science Plan Gaps / Priorities

Site Requirements & Priorities

Large Scale Focus Areas

Snow Climatology

Intensive Study Areas (ISAs)

UAVSAR flight plan

Core Western U.S. Field Activities

Trail Valley Creek Airborne and Field Experiment

SnowEx 2019: Timeline

2018/19 Airborne Campaign – Trail Valley Creek

Led by Environment and Climate Change Canada in collaboration with Wilfrid Laurier University and UMass, funded by the Canadian Space Agency and NASA THP

Nominal UMass Ku-band radar schedule:

August 2018:	Engineering flight near Toronto
September 2018:	Science 1 - snow free/unfrozen soil
October 2018:	Science 2 - thin snow/frozen soil
December 2018:	Science 3 - defined slab/hoar layers
March 2019:	Science 4 - near peak SWE

Other potential airborne opportunities:

- GSFC SWESARR (engineering flights over Grand Mesa in November)
- NASA Operation IceBridge overfly TVC along an ICESat-2 track (late March/early April 2019)

Ground Activities

- in situ instrumentation (soil, snow, discharge)
- Distributed bulk and microstructure measurements of snow coincident to flights
- UAV structure-for-motion derived snow depth mapping

Environment Canada Environnement Canada

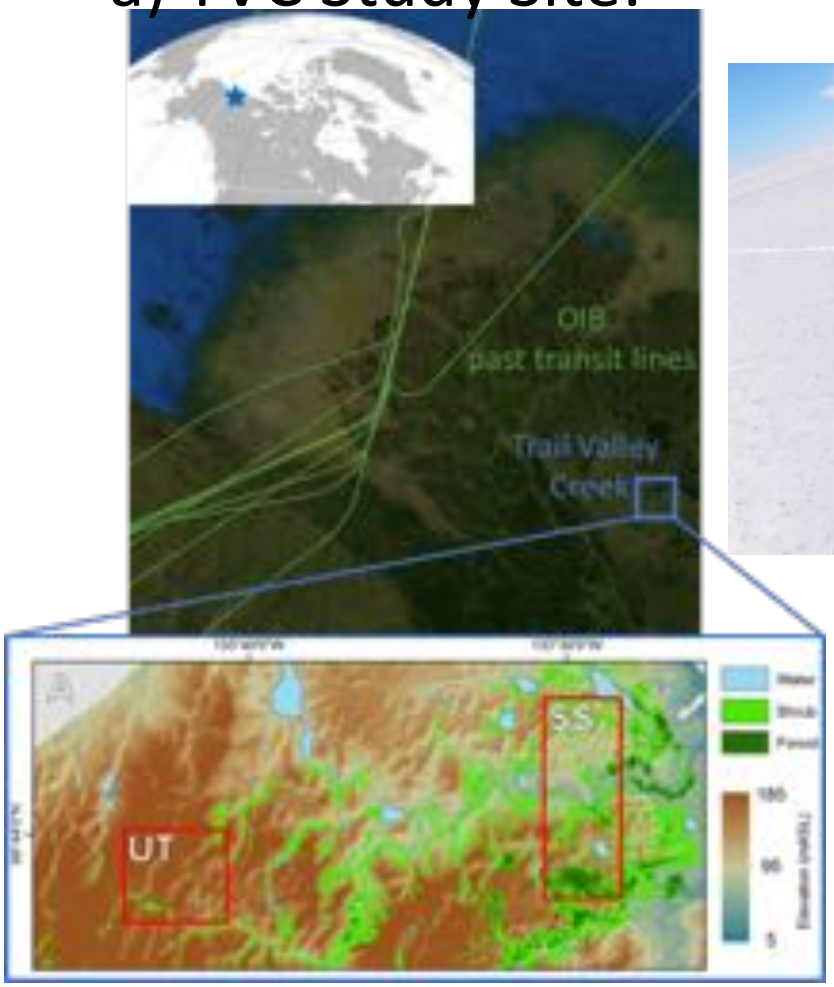
Joint SnowEx/OIB/ICESat2/ECCC March/April 2019

C.K. Gatebe, L. Brucker, B. Osmanoglu J. MacGregor, et al.

For more details: *https://docs.google.com/document/d/1h3cm-cuCTVkjNJdr2bLUf0ludhgt9RsKpRkp0Gs2sU8/edit#heading=h.57iqb0xvp0uw*

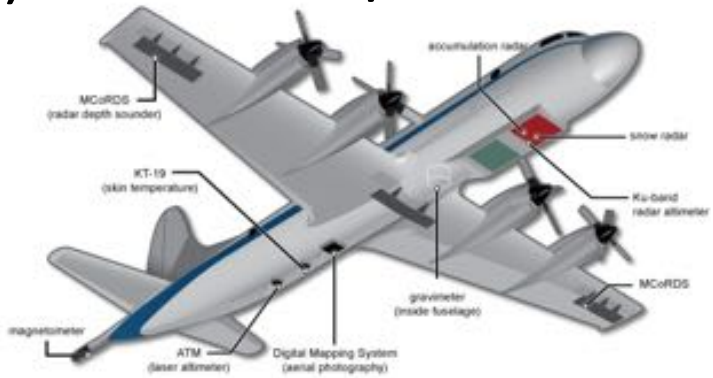
Leveraging OIB for SnowEx-19 & link to SnowEx 2020:

a) TVC Study Site:



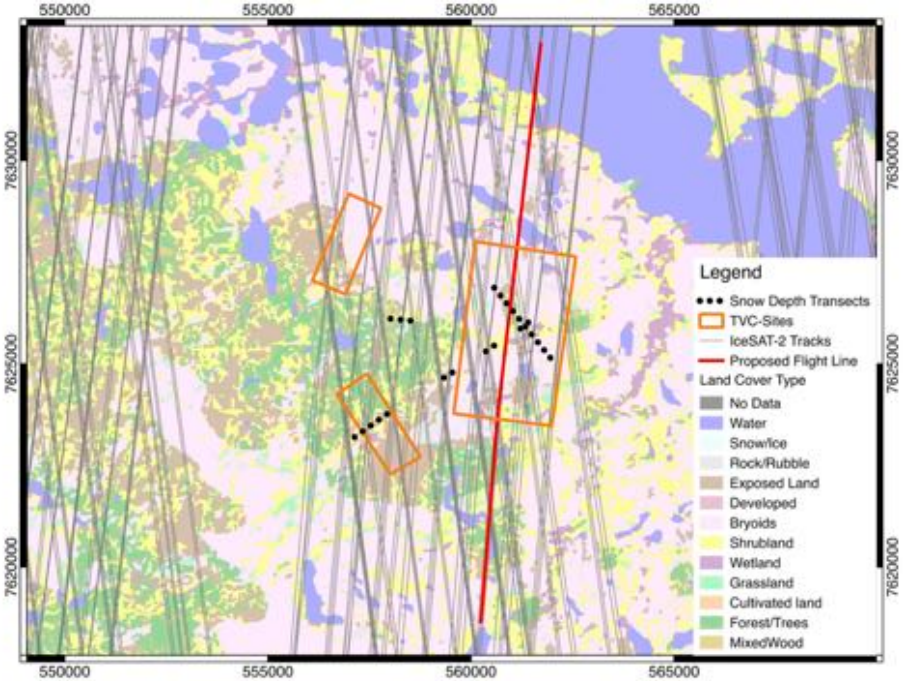
b) TVC in Winter:

c) NASA P-3B/OIB:

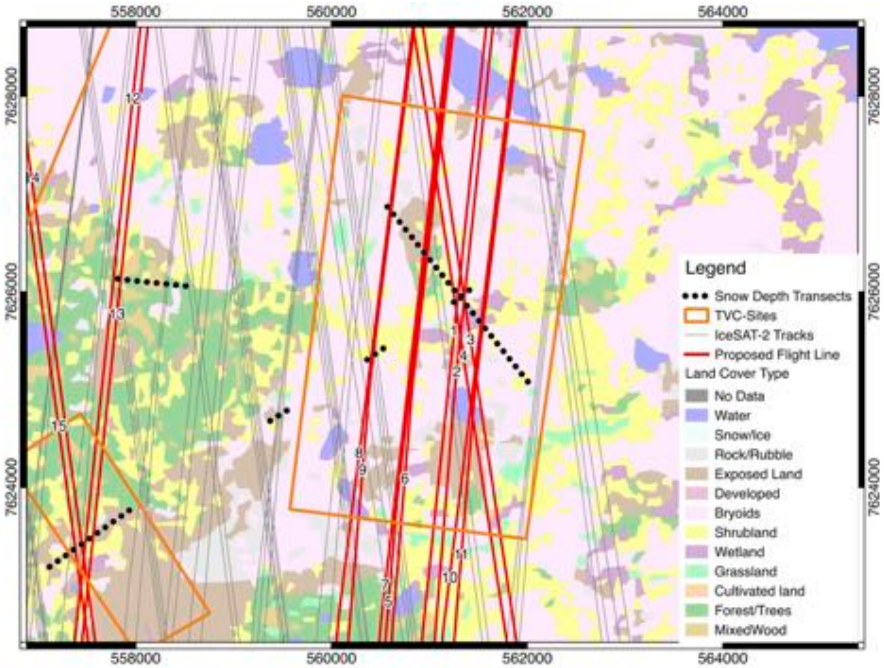


Flight Plans:

a) Single Pass:



b) Extended on-site survey:



SnowEx 2019: Timeline

- Science Traceability Matrix revision : Feb-May 2018
- Implementation Plan team forms : June 4
- Strategy guided by historical snow record (Liston/Reinking) : Aug, 2018
- OSSE results guide flight planning : Aug-Oct, 2018
- Final UAVSAR flight plans : Sept 15, 2018
- UAVSAR flights begin : Dec, 2018
- Field activities begin : Dec, 2018
- IceBridge overflight of Trail Valley Creek : March, 2019

Outline
2019 Strategy
Science Traceability Matrix
Proposed Airborne Sensors
Science Plan Gaps / Priorities
Site Requirements & Priorities
Large Scale Focus Areas
Snow Climatology
Intensive Study Areas (ISAs)
UAVSAR flight plan
Core Western U.S. Field Activities
Trail Valley Creek Airborne and Field Experiment
SnowEx 2019: Timeline

Want to volunteer / get involved with SnowEx2019 and beyond?

- Modeling activities in each ISA
- Remote sensing analysis in each ISA
- Near-realtime QC of both field and met data
- Get involved with SnowEx 2020 planning
- Participate in iSWGR SnowSchool and Snow Modeling School

Due to the time series approach requiring 1 field day every 2 weeks throughout winter, core field observations will be performed by experienced local observers, who will deploy on the same day. Larger more centralized field efforts may be organized around ASO flights and/or other proposed airborne sensor deployments.

If you have snow field experience and want to commit to participating in bi-weekly sampling at any of the sites, or are interested in participating in a possible larger week-long effort, please email SnowEx19@gmail.com. Time series experiments with snow and atmospheric sensors are of interest - if you have a non-standard instrument that you would like to deploy within an ISA this winter, please contact us (SnowEx19@gmail.com).

Outline
2019 Strategy
Science Traceability Matrix
Proposed Airborne Sensors
Science Plan Gaps / Priorities
Site Requirements & Priorities
Large Scale Focus Areas
Snow Climatology
Intensive Study Areas (ISAs)
UAVSAR flight plan
Core Western U.S. Field Activities
Trail Valley Creek Airborne and Field Experiment
SnowEx 2019: Timeline