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Long-term wildfire impacts on North American Tundra

Loboda-03 (+)

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Institutional Collaborations

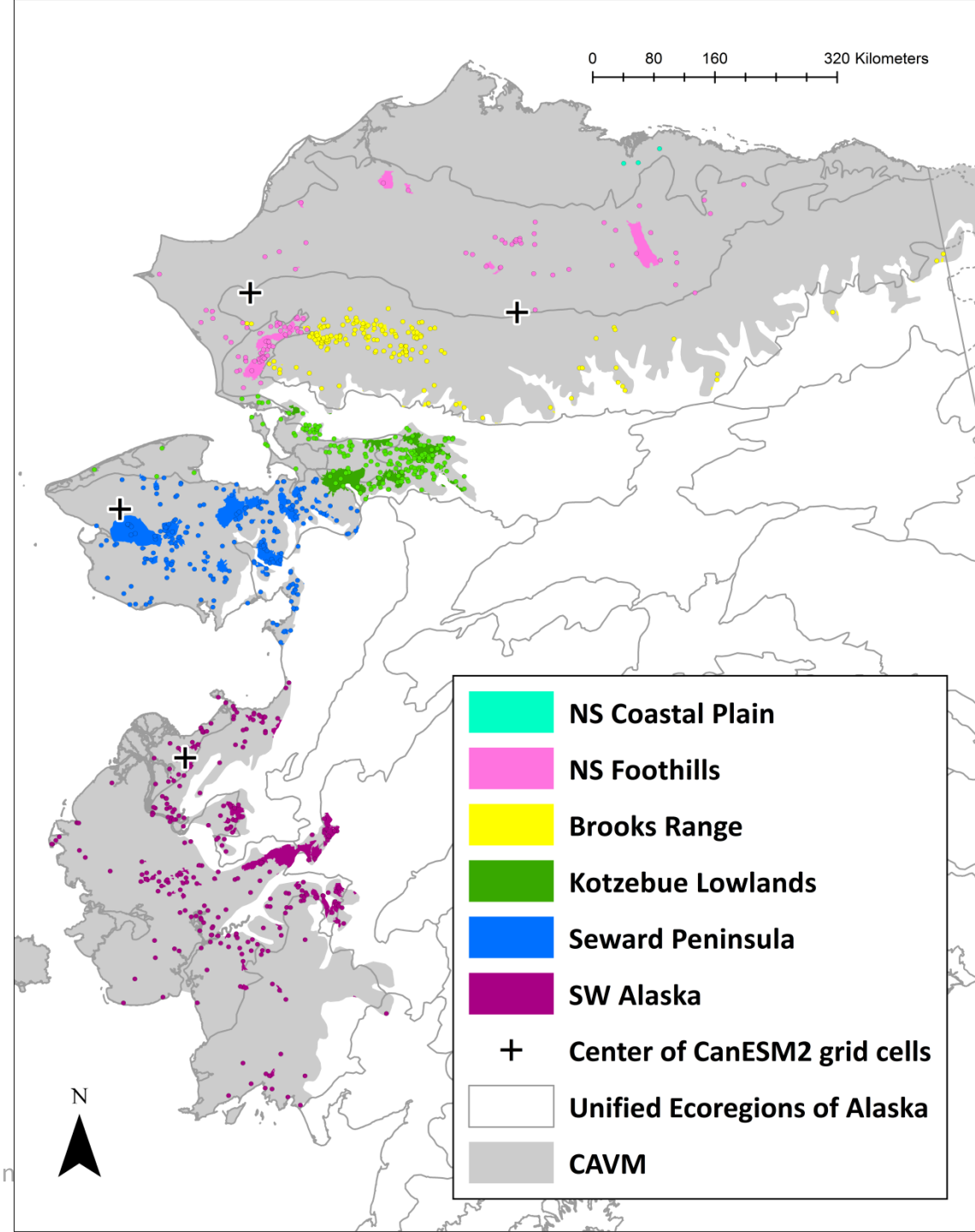
- Officially: only between institutions UMD/MTRI
- Implicitly:
  - NPS
  - BLM
  - Native Corporations
  - Other corporate land owners

The gist

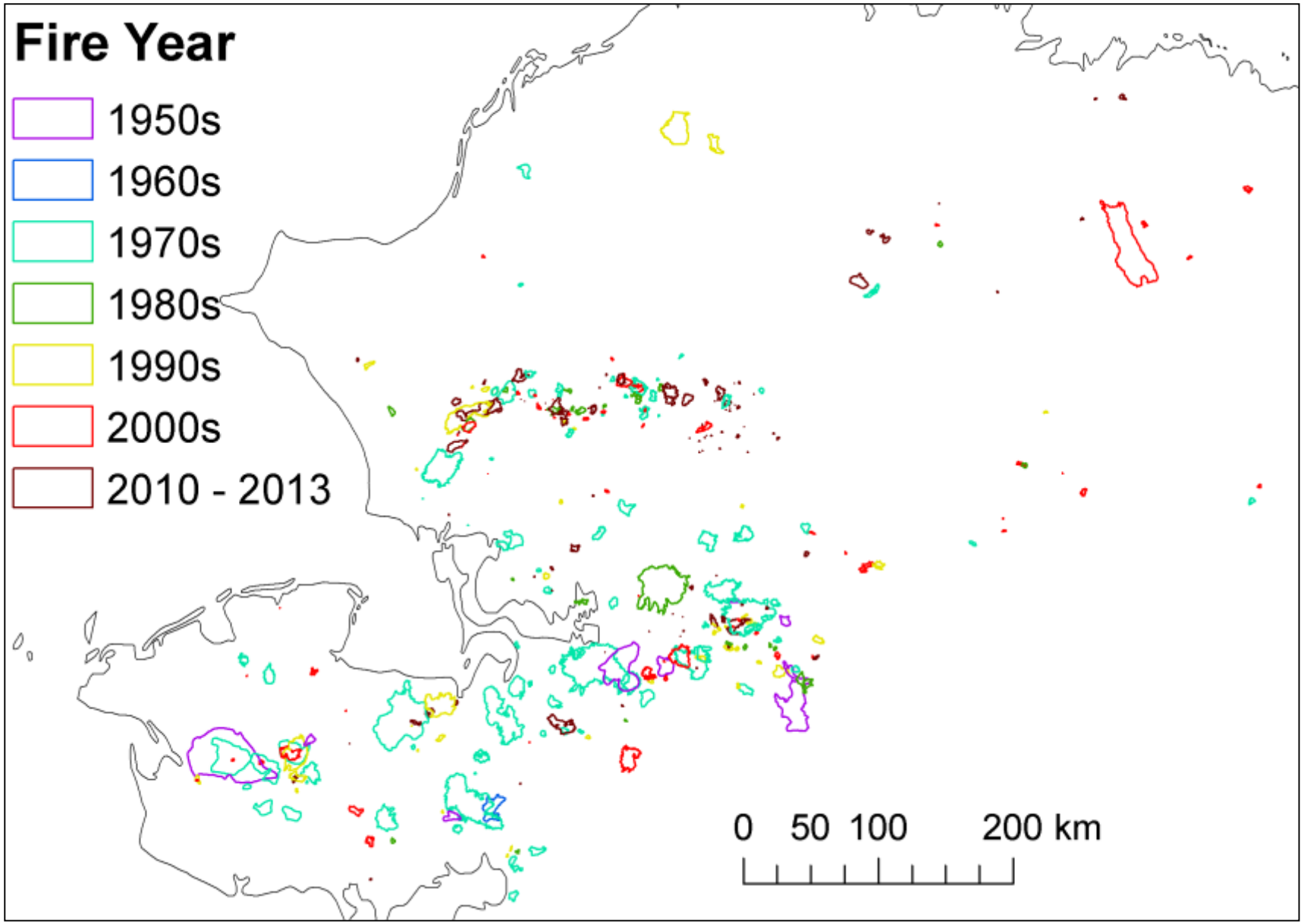
- Fire in the tundra is a common recurring widespread disturbance

Historical Alaskan fires within the tundra as defined by the Circumpolar Arctic Vegetation Map (CAVM; (Walker *et al.* 2005).

Figure from French et al. (2015).



ARCTIC BOREAL VULNERABILITY EXPERIMENT

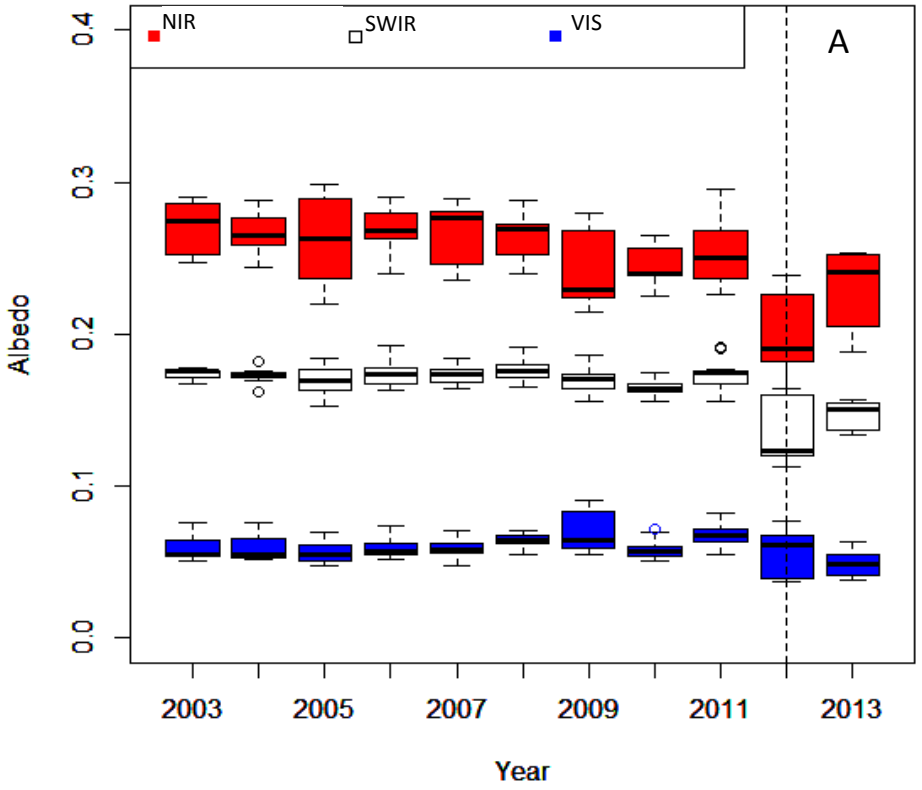

Fire Year
1950s
1960s
1970s
1980s
1990s
2000s
2010 - 2013
0 50 100 200 km

The gist

- Fire in the tundra is a common recurring widespread disturbance
- AND it has a major impact on a variety of ecosystem attributes with a potential for strong modification in ecosystem functioning

- Carbon cycling:
  - the extreme Anaktuvuk fire with the total are burned 1,039 km^2 released ~ 2.1 Tg C to the atmosphere or around 2 kg C m^{-2}. (Mack et al. 2011)
- Permafrost (destabilization during summer):
  - warmer soils within burned areas (Rocha and Shaver 2011)
  - our field data show a statistically significant ($p<0.001$) relationship between depth of active layer and burn severity
  - the difference between the depth of active layer between burned and unburned areas increased over time from 134% to 180% over 4 years (Jandt et al. 2012)

MODIS measurements of annual surface albedo of pixels at Kucher Creek fire site within the burned (A) and unburned (B) areas: red – NIR, grey – SWIR, and blue – visible range albedo. Fire years are marked with a dashed line.



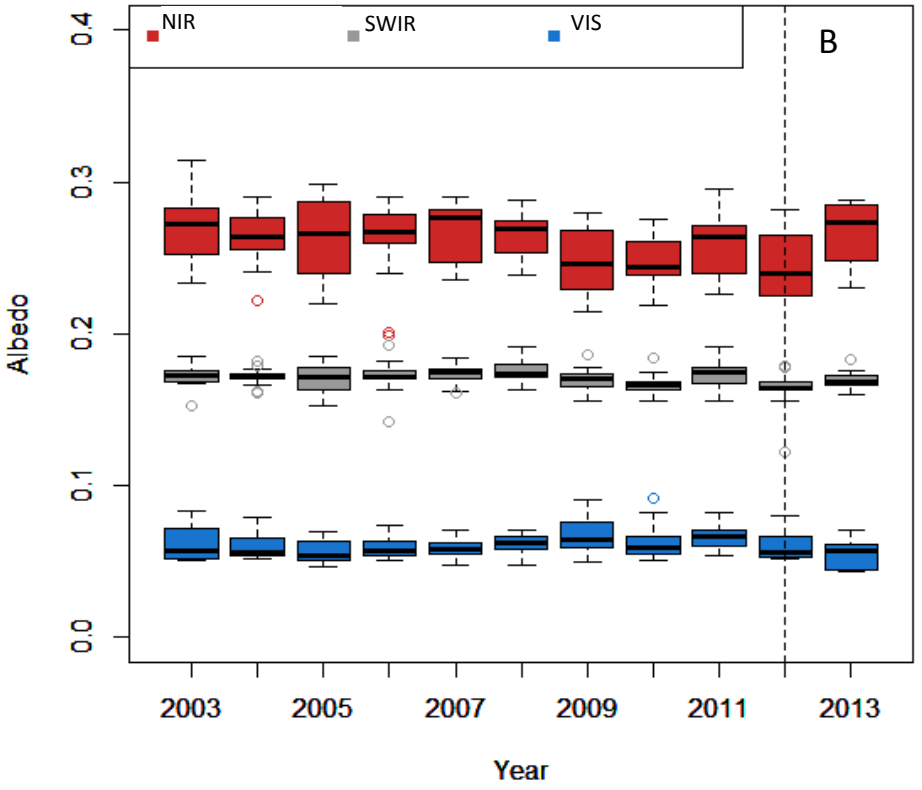
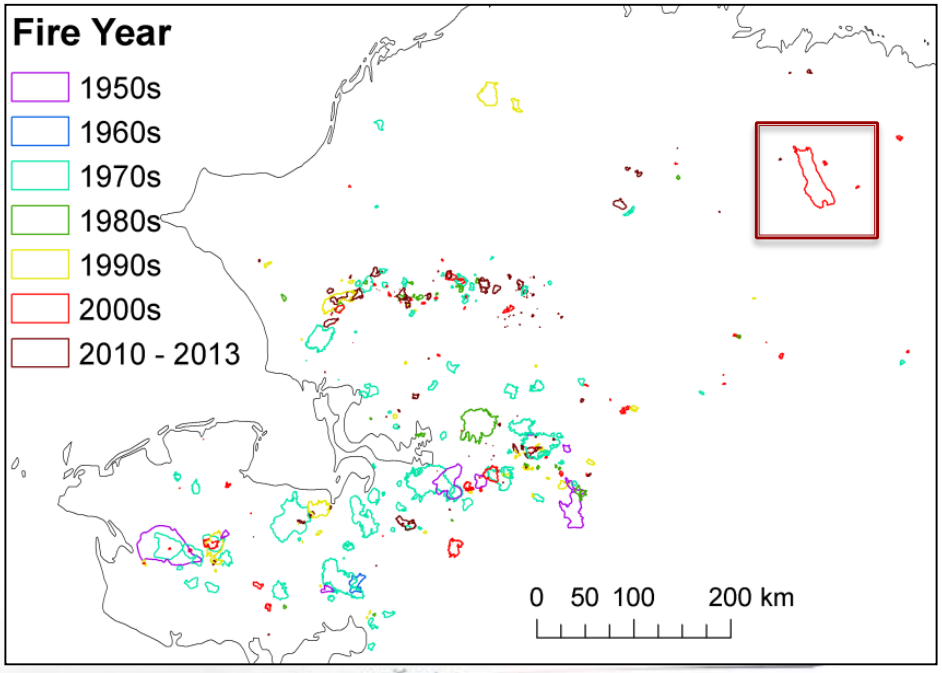


Image courtesy of N. French

The gist

- Fire in the tundra is a common recurring widespread disturbance
- AND it has a major impact on a variety of ecosystem attributes with a potential for strong modification in ecosystem functioning
- BUT most of existing data comes from a single extreme case - not representative of typical burns

http://news.lternet.edu/images/anaktuvuk-river-fire-burning-mid-september-2007-foothills-region-north-slope-alaska-about-30-0



- Total area burned 1,039 km^2
- Extreme longevity (July 16 – early October)
- Extreme severity

http://www.sciencedaily.com/releases/2013/08/130830104258.htm

The gist

- Fire in the tundra is a common recurring widespread disturbance
- AND it has a major impact on a variety of ecosystem attributes with a potential for strong modification in ecosystem functioning
- BUT most of existing data comes from a single extreme case - not representative of typical burns
- THEREFORE we propose to go and collect data in a variety of conditions with a particular interest in repeated burning

Science Questions & Objectives

- Tier 2 Science Questions addressed
  - *What processes are contributing to changes in disturbance regimes and what are the impacts of these changes?*
  - *What processes are controlling changes in the distribution and properties of permafrost and what are the impacts of these changes?*
  - *What are the causes and consequences of changes in the hydrologic system, specifically the amount, temporal distribution, and discharge of surface and subsurface water?*

Science Goal

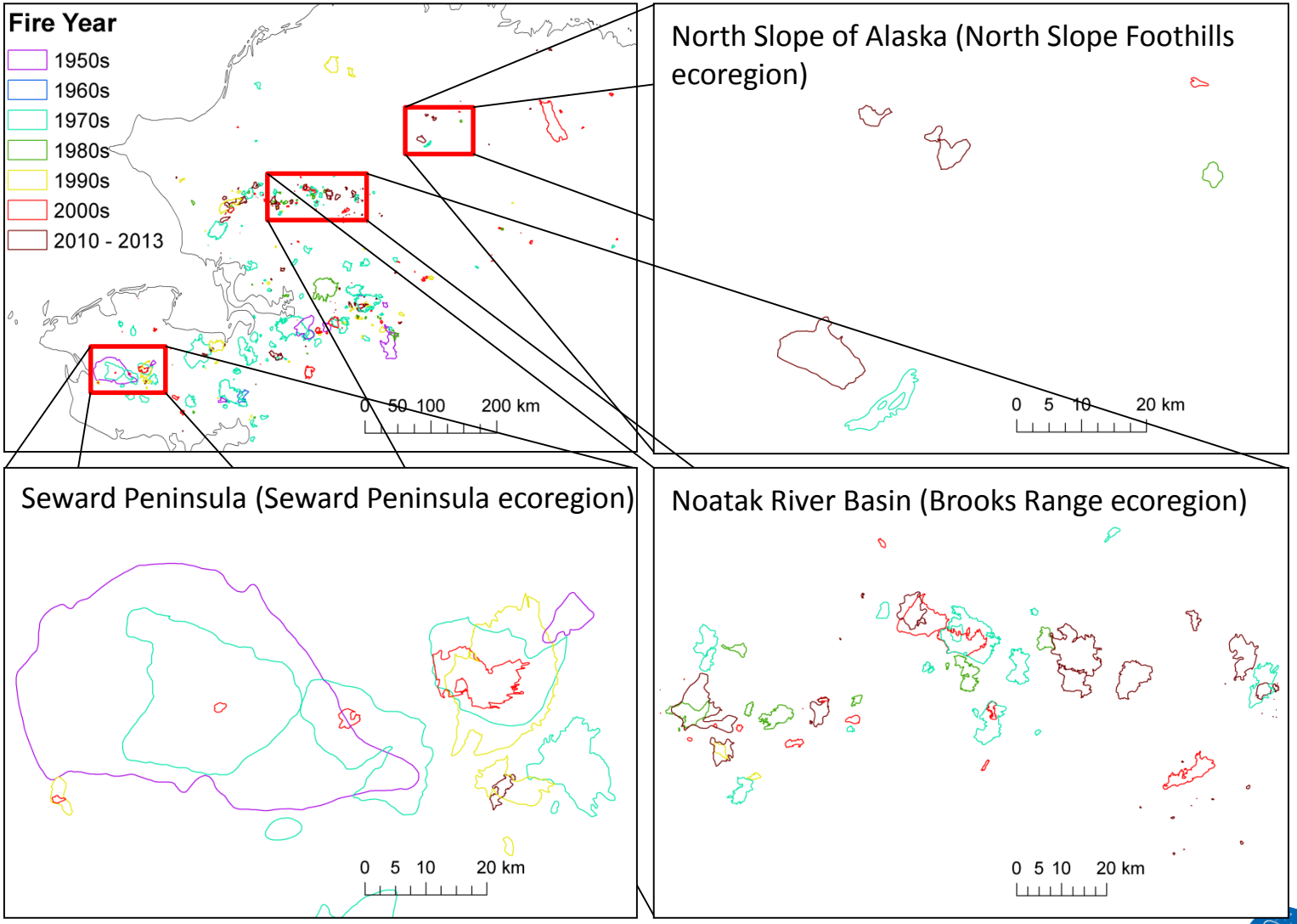
- Quantify the short- and long-term impacts of wildfire occurrence on Alaskan tussock and shrub-tundra and assess variations in:
  - 1) active layer depth,
  - 2) soil moisture content,
  - 3) soil temperature,
  - 4) composition and characteristics of above ground vegetation,
  - 5) thickness of upper horizons of organic layer unaffected by permafrost

  as a function of a) time since the occurrence of the most recent wildfire event, b) fire return interval, and c) burn severity in recent fire events.

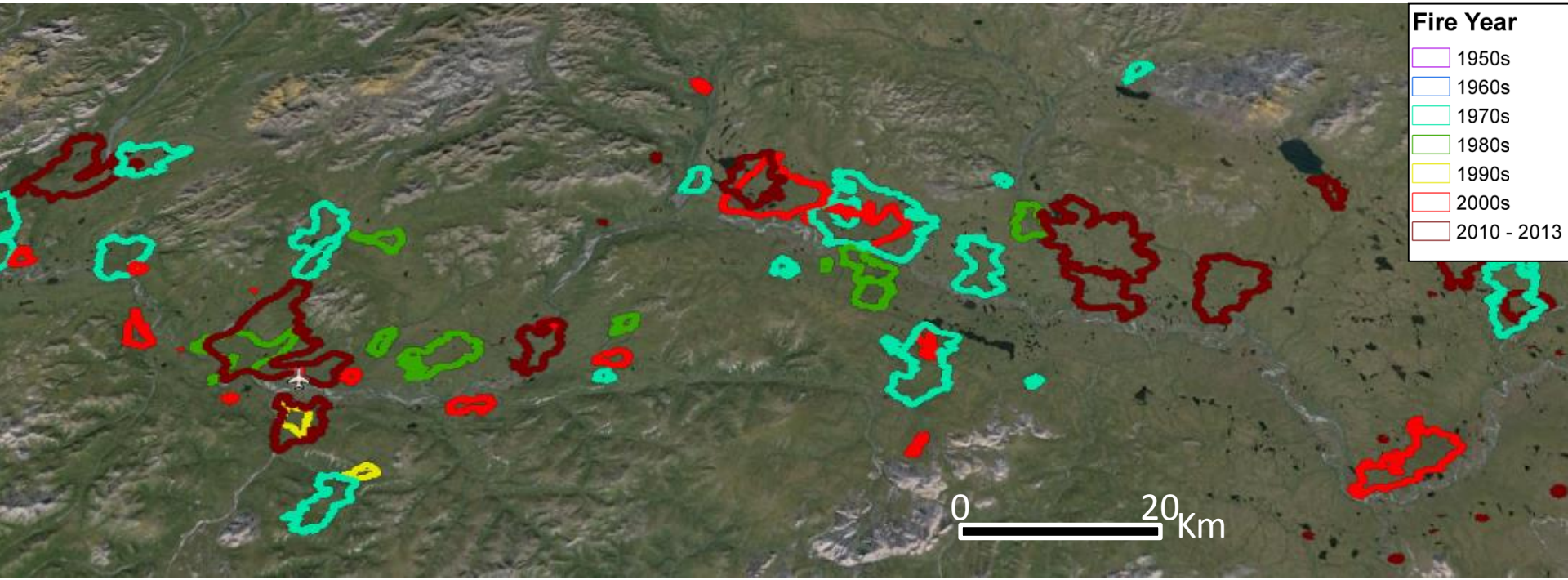
Field Measurements

- Depth of active layer
- Soil moisture
- Soil temperature
- Vegetation characteristics
  - fractional representation
  - tussock metrics
  - shrub stem count and
  - dimensions
- SOL thickness

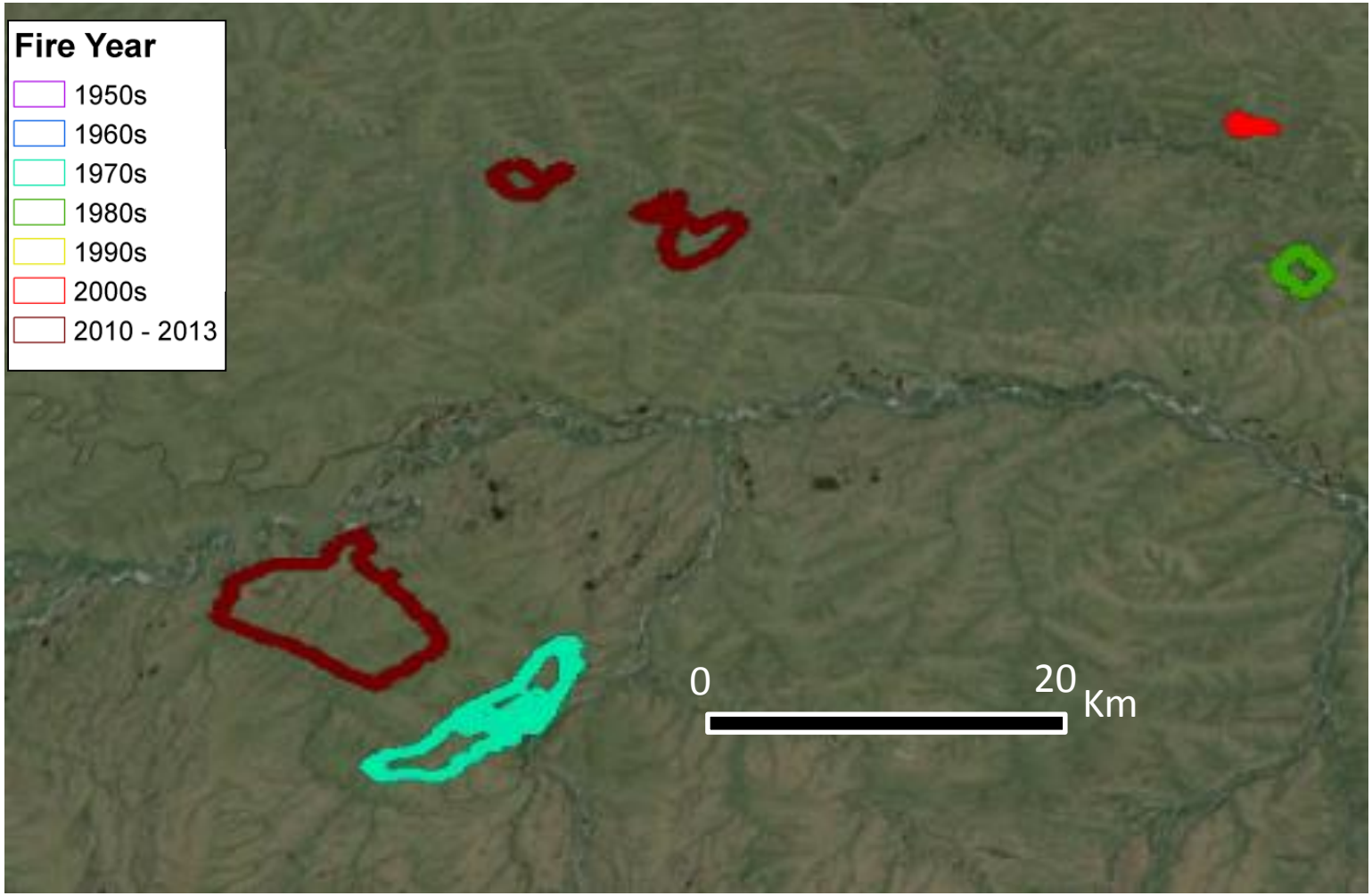
Field Sites


Fire Year
1950s
1960s
1970s
1980s
1990s
2000s
2010 - 2013
0 50 100 200 km
North Slope of Alaska (North Slope Foothills ecoregion)
0 5 10 20 km
Seward Peninsula (Seward Peninsula ecoregion)
0 5 10 20 km
Noatak River Basin (Brooks Range ecoregion)
0 5 10 20 km

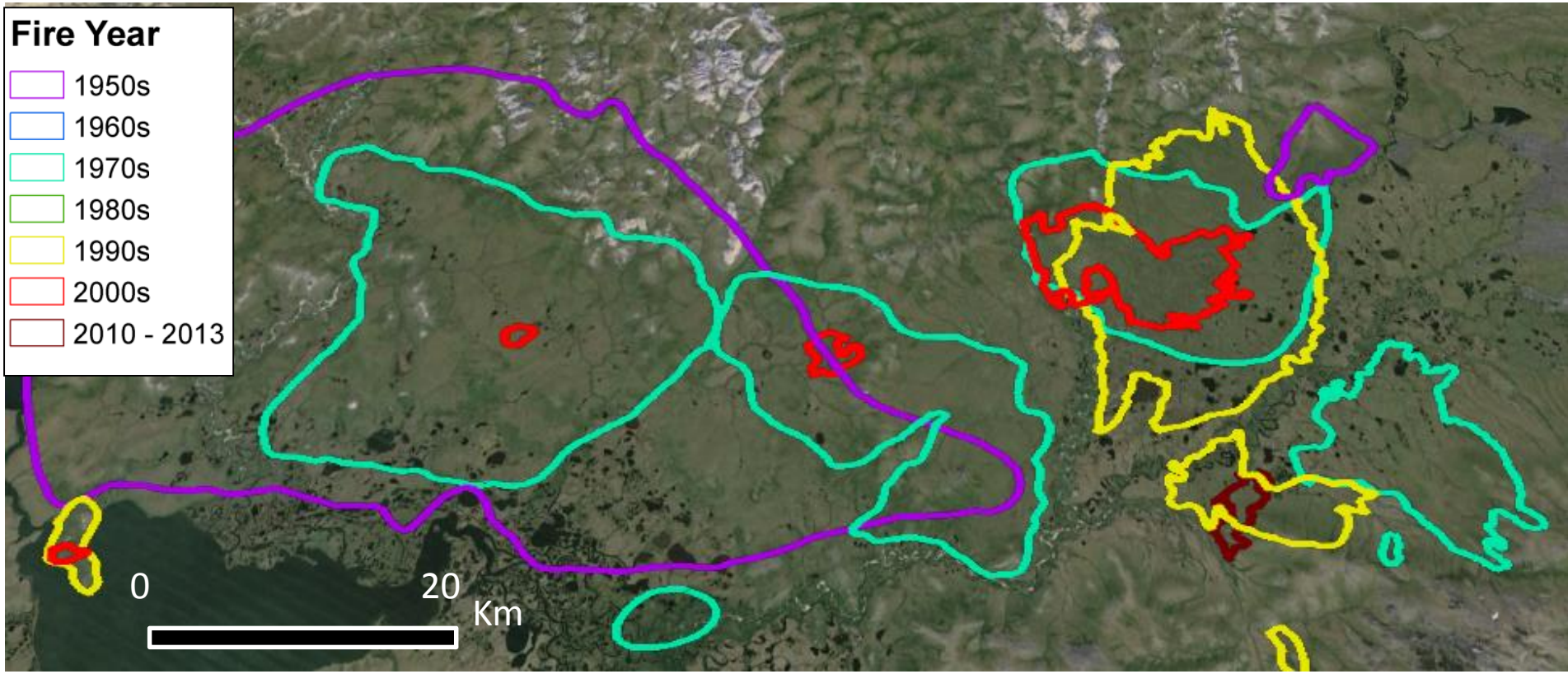
Noatak (Brooks Range)



North Slope


Fire Year
1950s
1960s
1970s
1980s
1990s
2000s
2010 - 2013
0
20
Km

Seward Peninsula



Spaceborne Remote Sensing

- Satellite sensing assets to be used
  - Landsat (TM, ETM+, OLI) 1985 -2017 as available
  - MODIS 2001 – 2017
  - Radar (ERS-1 and -2, Radarsat-1, ALOS PALSAR, Radarsat-2, Envisat) - varies

Airborne Remote Sensing

- Existing airborne remote assets to be used:
  - NONE
- Potential uses for new airborne data:
  - High resolution thermal (no data is available to elaborate on the resolution needs – highly speculative)
  - Potential interest in hyperspectral to track floristic composition of recovering vs unburned areas

Modeling Approaches

- Types of models used:
  - Statistical Random Forest
- Driver data needed:
  - All input variables described below
- Data formats and metadata standards:
  - None specific to this project

Project Implementation Flow

Stage 1. Preparatory geospatial information analysis and data collection planning

Assemble site history suite for each burn (including but not limited to)

Previous fire history (ALFD):
- Burned/unburned
- Years since last fire

Burn severity metrics (Landsat):
- summer rDNBR
- spring TCB

Landscape parameters:
- Topography
- Drainage

Develop a stratified sampling strategy for the site
- Stratified disproportional randomized sample to ensure coverage of most of the presented combinations of the metrics above

Stage 2. Intensive field data collection campaign

Collect field measurements
- Depth of active layer
- Soil moisture
- Soil temperature
- Vegetation characteristics
  - fractional representation
  - tussock metrics
  - shrub stem count and dimensions
- SOL thickness

Stage 3. Post-collection field and satellite data analysis

Build multi-temporal data cube for each fire event (including but not limited to):

Landsat metrics:
- Soil exposure (spring TCB)
- Surface thermal brightness (seasonal if possible)
- Surface albedo
- Vegetation greenness (NDVI)

InSar metrics:
- Soil moisture
- Surface roughness

MODIS/VIIRS metrics:
- Fire spread rate
- Fire Radiative Power

Develop statistical relationships between field observations and satellite-based metrics
- Univariate statistical analyses
- Multivariate statistical analyses

Develop a wall-to-wall predictive map of landscape conditions as a function of wildfire
- Add new significant landscape variables to the stratification scheme as needed

Geospatial Data Products

- Stage 1 - Preparatory satellite-image analyses:
  - 1) site vegetation map,
  - 2) year since fire,
  - 3) burn severity,
  - 4) slope, aspect, elevation,
  - 5) drainage

Geospatial Data Products

- Stage 2 – field data measurements:
  - Depth of active layer
  - Soil moisture
  - Soil temperature
  - Vegetation characteristics
    - fractional representation
    - tussock metrics
    - shrub stem count and
    - dimensions
  - SOL thickness

Geospatial Data Products

- Stage 3 – Post-collection satellite data metrics:

  Landsat metrics:

  - Soil exposure (spring TCB)
  - Surface thermal brightness (seasonal if possible)
  - Surface albedo
  - Vegetation greenness (NDVI)

  InSar metrics:

  - Soil moisture
  - Surface roughness

  MODIS/VIIRS metrics:

  - Fire spread rate
  - Fire Radiative Power

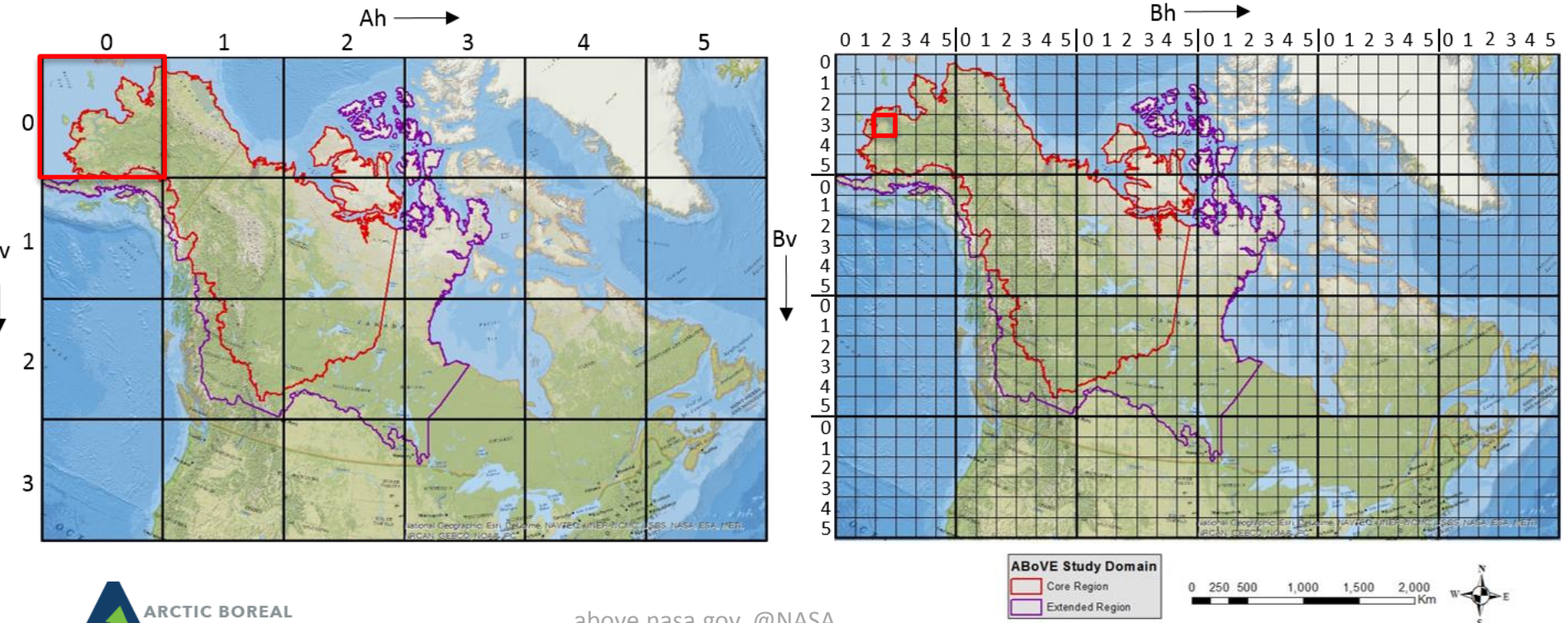
Geospatial Data Products

- Geographic coverage:
  - Satellite-based datasets: coverage for all fire events within tundra ecoregions including North Slope coastal range and foothills, Brooks Range tundra, and Seward Peninsula
  - Field data: sampled locations in Noatak National Preserve, Seward Peninsula, and North Slope

Geospatial Data Products

- Data formats, grids, and projections
  - Stage 1 - Preparatory satellite-image analyses:
    - available as GEOTIFF files at native resolution of the input data source with an accompanying dataset description document detailing the method of dataset production and associated uncertainty
  - Stage 3 – Post-collection and modeling:
    - available as GEOTIFF files at 30 m resolution possibly gridded to the proposed common ABoVE gridding system (if adopted by the ABoVE ST)

ABoVE.water.2001001.Ah0v0.Bh2v3.001.2014075120101.hdf
ABoVE – refers to the campaign
Water – refers to the product ID or type
2001001 – refers to the data reference date
Ah0v0 – refers to the upper left tile in the “A” or larger grid
Bh2v3 – refers to the central tile in the “B” or smaller grid
001 – refers to the version of the product
2014075120101 – is a production date for the product



Geospatial Data Products

- Varies but centered around 2015-2017

Geospatial Data Products

- Most likely modeling community (e.g. TEM – personal communication H. Genet)
- Potential uses:
  - Intercomparison of permafrost maps
  - Hydrological studies
  - Carbon cycle studies
  - Vegetation composition and biodiversity studies

Other expected products / outcomes

- Random Forest-based maps of landscape-scale characterization of fire impact on ecosystem properties:
  - a) active layer depth;
  - b) soil temperature;
  - c) soil moisture;
  - d) SOL thickness; and
  - e) above ground biomass