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Vulnerability of boreal inland waters & the aquatic carbon cycle to changing permafrost & climate

(Striegl-01)

USGS science for a changing world

ARCTIC BOREAL VULNERABILITY EXPERIMENT

NASA

Co-Investigators

- **Torre Jorgenson –** Geomorphology
- **Jennifer Rover** –Surface water distribution
- **Bruce Wylie** - Soil carbon / permafrost distribution
- **Burke Minsley** - Geophysics / permafrost distribution
- **Brian Ebel** – Unsaturated zone hydrology
- **Michelle Walvoord** - Groundwater hydrology / hydrologic modeling
- **Josh Koch** - Surface water hydrology / biogeochemistry
- **Rob Spencer** - Dissolved organic carbon chemistry
- **David Butman** - Dissolved & particulate carbon age
- **Kim Wickland** - Organic carbon biodegradation
- **Rob Striegl** – Lateral C export; CO_2 & CH_4 dynamics

Institutional Collaborations

- US Fish and Wildlife Service
- Northwest Boreal LCC
- Geological Survey of Canada
- University of Washington – Seattle
- Florida State University
- University of Alberta (S. Tank - Mackenzie basin)
- Alaska Ecoscience

And… and… therefore

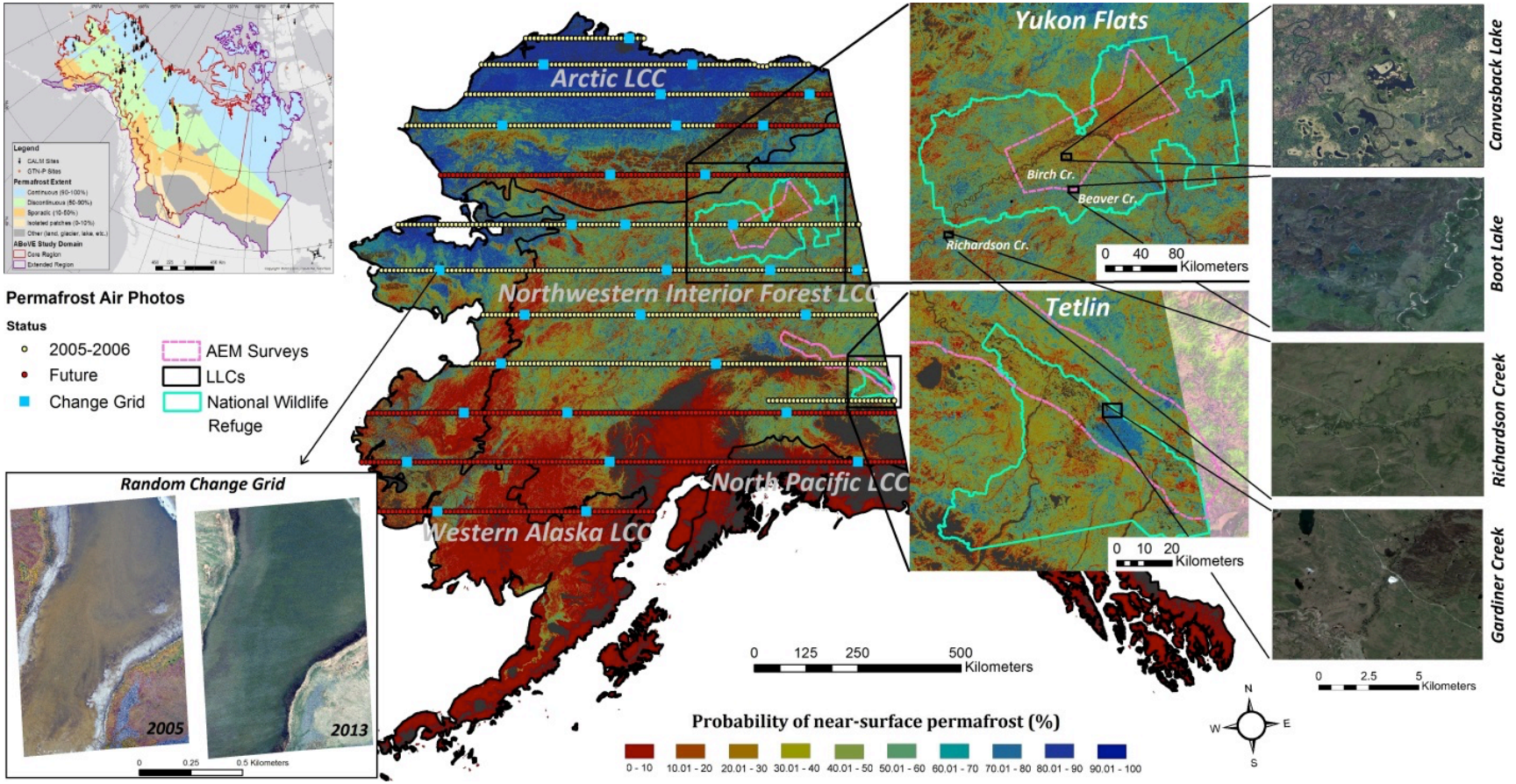
- Permafrost thaw is changing the distribution of surface & subsurface inland waters, particularly in regions of discontinuous permafrost.
- Water distribution & availability directly affect organic carbon decomposition, mineral weathering, C-gas emissions, & riverine exports of C to coasts.
- There is a need to quantify & generalize the vulnerabilities of hydrology & aquatic C biogeochemistry to changes in permafrost and climate across the northern boreal.

Science Questions & Objectives

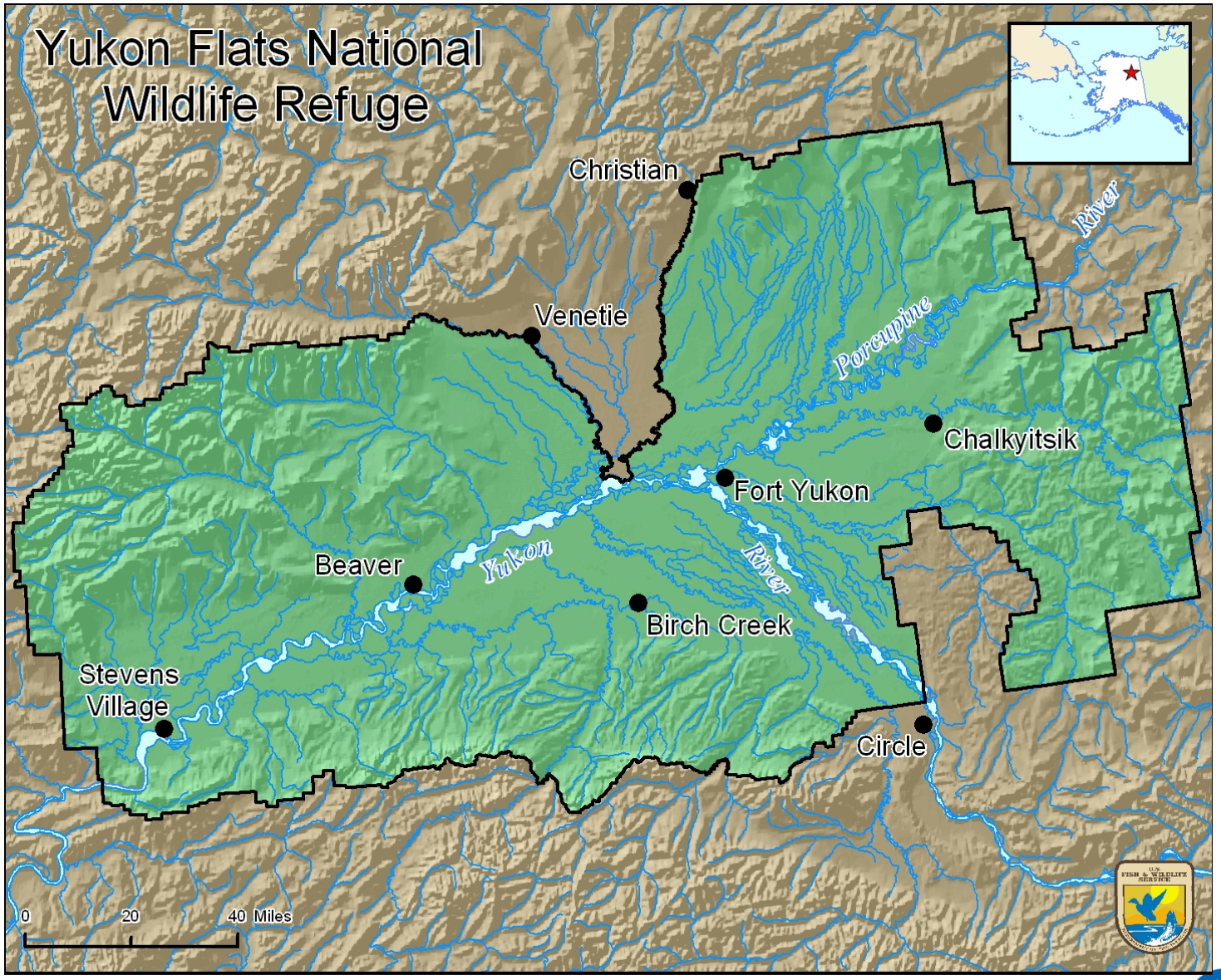
- **Tier 2 Science Questions addressed: 3.2, 3.3, 3.4, 3.6**
- How is the hydrologic system "replumbed" by permafrost thaw?
- What is the chemical character and fate of aged organic carbon released to inland waters?

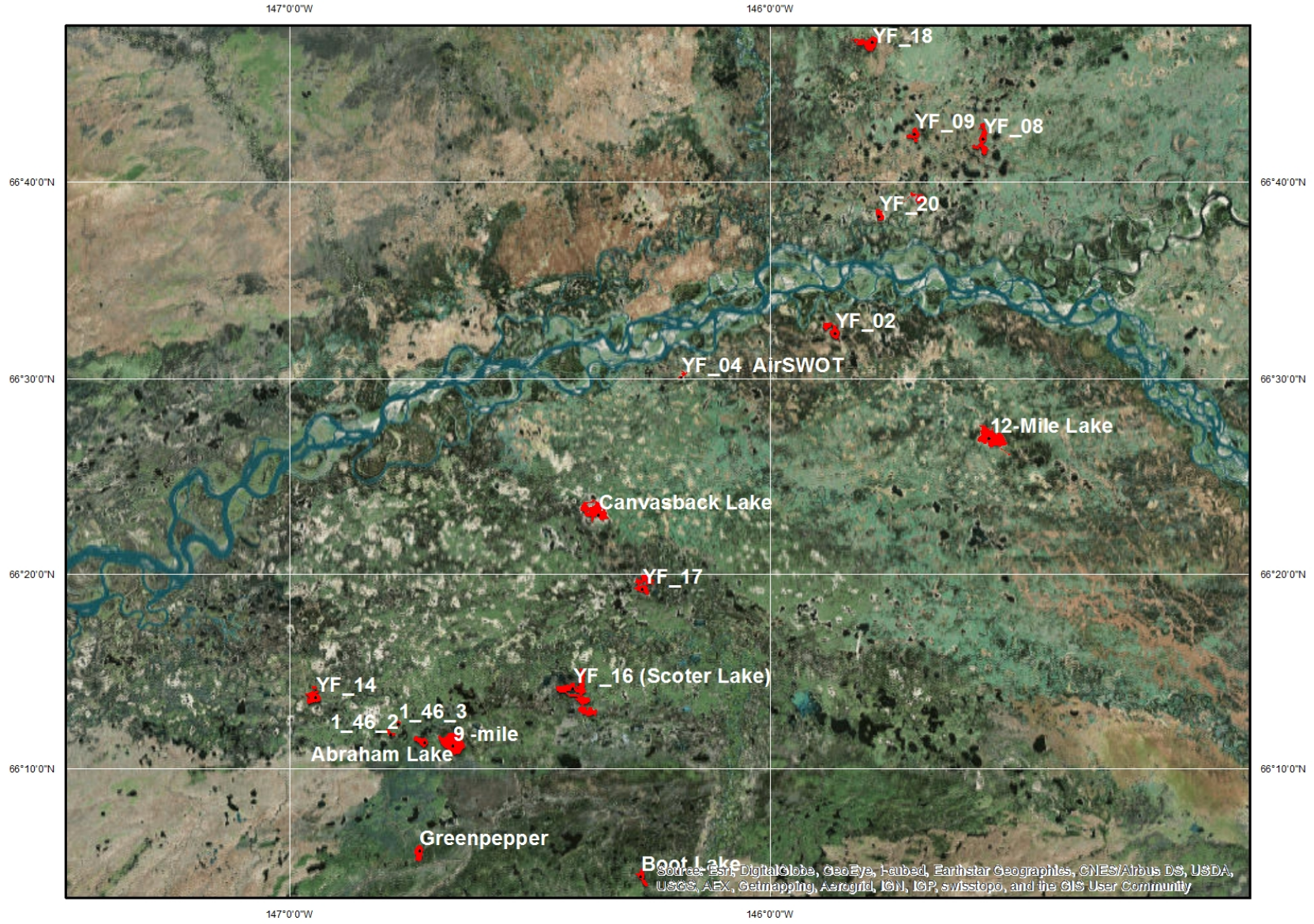
- **Tier 2 Science Objectives:**
- Measure & model the dynamics of the water & aquatic-carbon cycles of northern boreal ecosystems.
- Identify & quantify coupled hydrological & carbon biogeochemical vulnerabilities to climate & permafrost change.
- Improve process understanding of the transport, biogeochemical processing, & emissions of aquatic carbon in discontinuous permafrost landscapes.

Field Studies



2016 Field Studies: Yukon Flats National Wildlife Refuge





AirSWOT Lakes Sampled in 2015

Spaceborne Remote Sensing

Satellite sensing assets to be used for:

Permafrost and Land Surface Property Mapping:

- Sensors: Worldview 2, 3, Landsat ETM + & OL18
- Dates: 2010 to present
- May also use: IceSat-2, Sentinel C-band imagery
- Data sets: land cover, LAI, time-series DEM

Lake Area Historical Analysis:

- Sensors: TM4, TM5, ETM+7, OL18
- Data sets: binary water/not water data sets
- Dates: 1984 - present

Airborne Remote Sensing

- **Existing airborne remote assets to be used:**
- NAIP, LiDAR, & AEM: Leverage existing airborne electromagnetic (AEM) surveys in Yukon Flats [*Minsley et al.,* 2012] & DGGS along the Alaska Highway corridor [*Burns et al.*, 2006].
- *These are the only existing regional-scale datasets that inform on belowground physical properties influencing key hydrological and permafrost processes.*

- **Potential uses for new airborne data:**

- LiDAR, SAR, AEM, & multi- and hyper-spectral remote sensing datasets. New AEM surveys would complement other airborne and remote sensing products (e.g. AirSWOT, GLiHT, Landsat, aerial imagery) by linking land-surface observations with subsurface properties.

Modeling Approaches

- **Models to be used include**:
  - Predictive models for mapping (random forests, decision trees, support vector machines)
  - SUTRA 4.0 for coupled permafrost/hydrology
  - Inverse modeling for geophysical data interpretation
- **Driver data**:
  - Climate, topography, land surface properties
- **Data formats**:
  - .img, geotiffs, ascii
- **Metadata** will adhere to the FGDC standards.

Geospatial Data Products

- **Products**

  Maps: soil organic layer thickness, permafrost, ALT, thermokarst

  : lake area, lake area change (past 30 yrs), lake pCO_2, pCH_4, DOM

- **Geographic coverage**

  Varies

- **Data formats, grids, and projections**

  Thematic and continuous raster grids (e.g. img) with a WGS84-Albers projection

- **Temporal range**

  2010 to present for current map products

  1984 to present for lake area changes

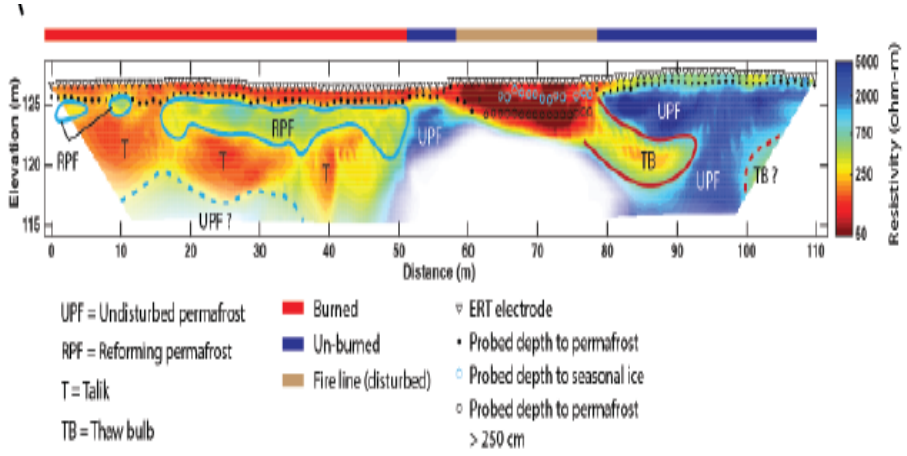
- **Stakeholder / user base**:

  Project team members, other ABoVE projects

  Land managers (federal, state, tribal), LCC

Geospatial *Subsurface* Data Products

- **Products** – Geophysical surveys and field hydrologic investigations will:
  - Characterize subsurface permafrost and lithology
  - Identify subsurface flowpaths and hydrologic connectivity
- **Geographic coverage**
  - Regional AEM data 100s of km^2
  - Select lake watersheds
- **Data formats, grids, and projections**
  - ascii format
- **Temporal range**
  - Primarily single snapshots in time. Some seasonal monitoring.
- **Stakeholder / user base**: Other project members, potentially other ABoVE projects



Aquatic C Biogeochemistry Products:

Chemical composition & Age:

- Inorganic & organic C in permafrost, terrestrial source waters, streams, & lakes

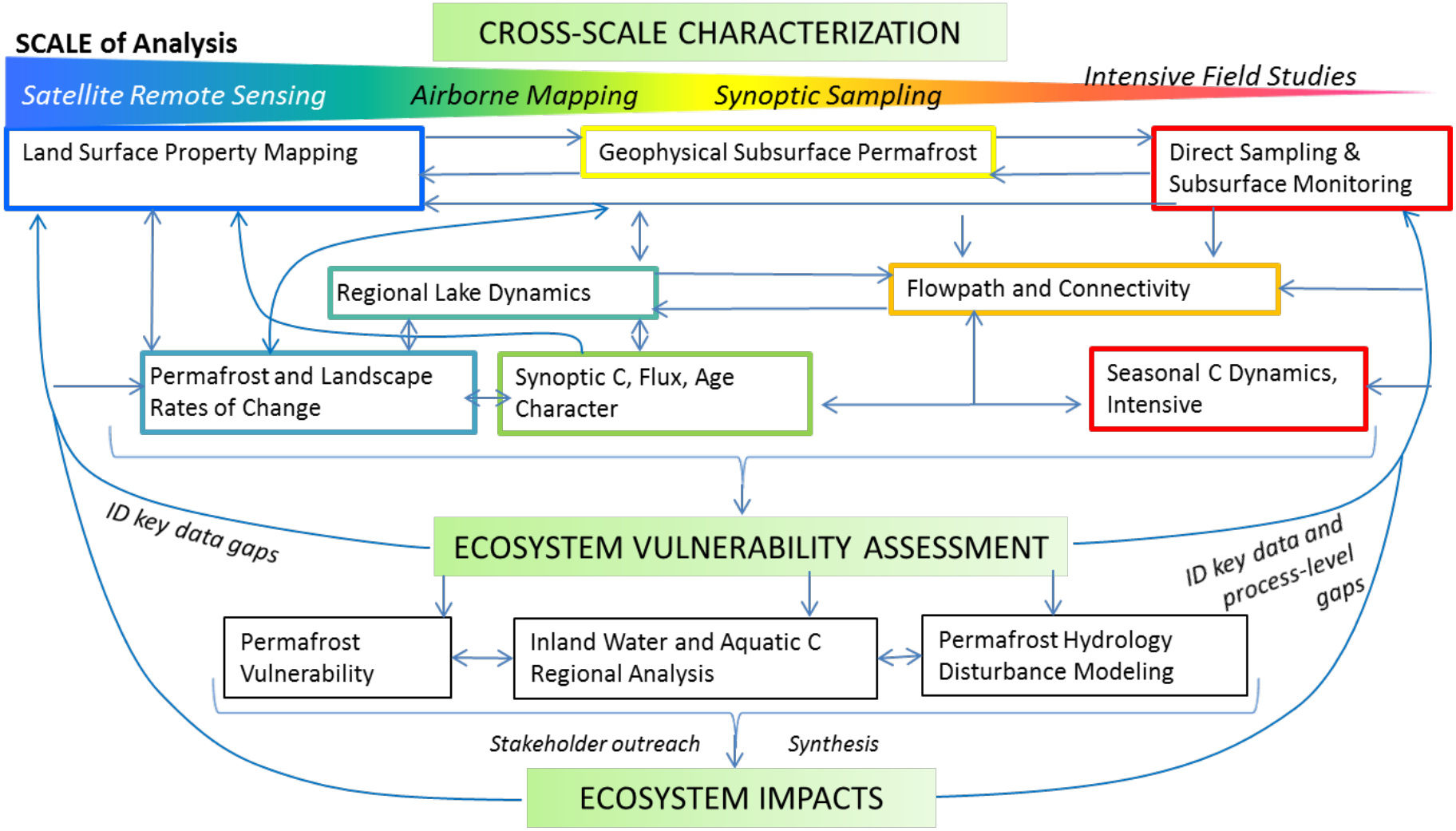
Biogeochemical Transformation:

- Rates of biological & photochemical degradation of DOM & terrestrial biomarkers in soil water, streams & lakes

Carbon dioxide and Methane Dynamics:

- Seasonal dynamics of CO_2 and CH_4 emissions from streams & lakes in study watersheds

Thanks


SCALE of Analysis
CROSS-SCALE CHARACTERIZATION
Satellite Remote Sensing
Airborne Mapping
Synoptic Sampling
Intensive Field Studies
Land Surface Property Mapping
Geophysical Subsurface Permafrost
Direct Sampling & Subsurface Monitoring
Regional Lake Dynamics
Flowpath and Connectivity
Permafrost and Landscape Rates of Change
Synoptic C, Flux, Age Character
Seasonal C Dynamics, Intensive
ID key data gaps
ECOSYSTEM VULNERABILITY ASSESSMENT
ID key data and process-level gaps
Permafrost Vulnerability
Inland Water and Aquatic C Regional Analysis
Permafrost Hydrology Disturbance Modeling
Stakeholder outreach
Synthesis
ECOSYSTEM IMPACTS