Introduction
Surface water inundation strongly regulates land-atmosphere energy and carbon exchange in northern environments. However, the dynamic nature of inundation in Arctic-boreal landscapes, and the potential impact of changing surface water extent on wetland methane (CH₄) emissions, is not well understood.

Here we examine recent changes in surface inundation across Alaska and northern Canada, including the proposed NASA Arctic-Boreal Vulnerability Experiment (ABOVE) domain, using daily passive microwave remote sensing retrievals of fractional open water extent (Fw) derived from calibrated AMSR-E and AMSR-2 sensors over an 11-year (2003-2014) observation period [1, 3].

We also investigate the impact of high-temporal Fw variability on regional wetland carbon dynamics using a joint UK Land Environment Simulator (JULES) model approach, that accounts for primary environmental factors regulating northern CH₄ emissions (i.e. soil temperature, soil moisture, and carbon substrate). We use the combined monitoring of surface hydrology and carbon cycles through satellite remote sensing and ecosystem modeling to identify Arctic-boreal regions vulnerable to longer-term wetting or drying trends and associated changes in annual CH₄ emission budgets [6].

Study Area
This investigation extends over Alaska, Canadian Yukon and Northwest Territories, including the ABoVE domain (bottom-left). These Arctic tundra and boreal ecosystems are characterized by continuous permafrost in the north, transitioning to discontinuous and sporadic/isolated permafrost in interior and southern portions of the domain.

Over 24% of the region is covered by open water lakes, stream networks (top-right), and inundated vegetation (bottom-right) in addition to wet surface soil environments [5]. Wet anoxic surface conditions, and abundant soil organic carbon reservoirs, result in environments that are vulnerable to heightened CH₄ emissions with climate warming [4, 6].

Dynamic Wetland CH₄ Sensitivity Analysis
We use the JULES model to estimate daily CH₄ emissions for wetland ecosystems across the ABoVE domain. Input surface (≤ 10 cm) labile carbon substrates, soil temperature (Tsoil and freeze/thaw (FTW) indices constrain optimum Kₐ emission (3.7 × 10⁻¹ d⁻¹) and metabolic response (Tₑ = 273.15 K), Qₑ = 3.4 ± 3.7 rates calculated using flux chamber and tower eddy covariance records [6].

Dynamic 15-day mean surface soil moisture (% saturation) and Fw inundation are then applied to regulate CH₄ emission totals (Tonene) for each 25-km grid cell.

Step 1: \( F_{CH_4} = \text{Carbon} \times k_{CH_4} \times Q_{10}^{(T_{soil}-T_{e})/10} \times FTW \)

Step 2: \( F_{CH_4} = f(Fw, \text{Soil Moisture}) \)

Data Records:
- \( T_{soil} \) and surface soil moisture (% saturation) at ≤ 0.5° spatial resolution are provided using the Goddard Earth Observing System Model (GEOS-5) MERRA archive.
- Surface soil organic carbon (kg m⁻²) at 25-km resolution is supplied using Terrestrial Carbon Flux (TCF) model simulations for pan-Arctic environments [6].
- 25-km grid surface cell FTW (0 = frozen, 1 = thaw) and Fw inundation constraints are obtained using the UMT AMSR Global Land Parameter Record [1, 3].

Model Simulations for the ABoVE Domain
JULES summer (May – August) CH₄ lattitudinal averages (top-left) for the 2003-2011 simulation period indicate low (< 250 tonne CH₄) 25-km grid cell emissions along the Arctic Rim (~ 67°N) relative to wetlands in the Northwest Territories and Interior to coastal Alaska that are characterized by warmer summer climate and longer non-frozen season (top-right).

Annual variability (1.6 – 0.56 tonne CH₄) in regional CH₄ emission totals relative to the 2003-2011 mean primarily reflects periods of warmer (e.g. 2004, 2010) or cooler (e.g. 2006, 2008) summer soil temperatures (top-right), which are enhanced or moderated by dynamic Fw inundation and soil moisture conditions (bottom).

Study Conclusions
The AMSR Fw record reveals large seasonal and interannual variability in surface inundation over the ABoVE domain. Longer-term (2003-2011) wetting and drying patterns correspond with regional disturbances, including fires and thermokarst activity. A CH₄ model sensitivity study indicates respective summer emissions of 3.4 and 8.9 ± 0.6 tonne CH₄ yr⁻¹ for Alaska and the extended ABoVE domain. High peak CH₄ emissions occur in years with warm and wet summers (e.g. 2004, 2007) or an extended non-frozen season (e.g. 2009). Regional declines in CH₄ emissions reflect surface drying and soil cooling patterns. In contrast, landscapes with heightened CH₄ emissions reflect warming soils and inundation increases. Continued satellite monitoring of Fw inundation, including ongoing ABoVE-2 operations, is needed to identify Arctic-boreal regions vulnerable to changing surface hydrology and CH₄ emissions in a warming climate.

References