



Decision Support Tools for Mobility Analysis over Snow, Ice, Frozen/Thawing Ground

Cold Regions Research & Engineering Laboratory (CRREL)

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Force Projection & Sustainment Branch

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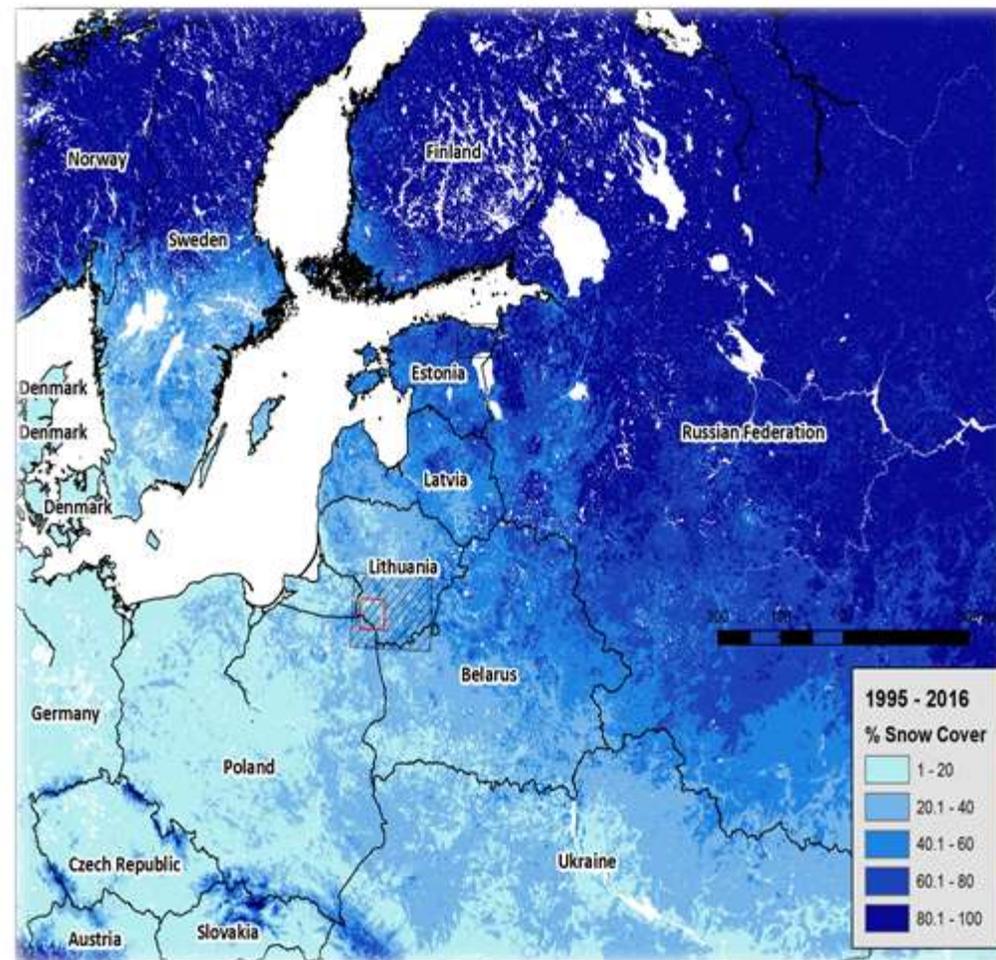


Issue

- The US Military has been fighting in the desert for the last 20 years.
- We have adversaries with well known capabilities in northern climates.
- New technologies need to be adapted to terrains unique to the far north for mobility superiority



Probability of snow cover





Snow, Ice, Frozen/Thawing Ground, Peat, Vegetation

Snow

Traction decreases

Additional resistance and plowing forces

Need to decrease weight and pressure

Deep snow can obscure obstacles

- Cannot “see” them
- Could float over them



Ice

Decreased traction

- Climbing, braking, cornering
- Very slippery when wet
- Very slippery with light snow cover

Lake & river ice

- Strength varies with thickness and temperature
- Moving loads cause waves under ice
- Predicting safe ice crossings
- Removing river ice to place a bridge



Freezing & Thawing Soil

- Very strong when frozen
- Very slippery and weak when thawed (water doesn't drain)





Seasonal Mobility Assessments in Northern Regions

Characterize
terrain/vehicle interactions



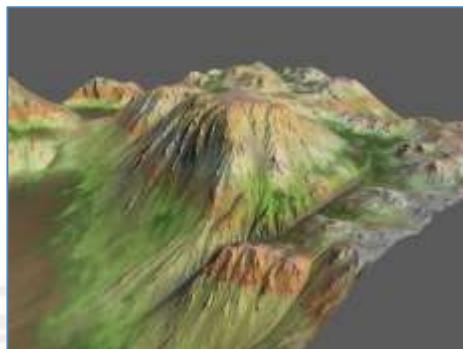
Develop vehicle
models



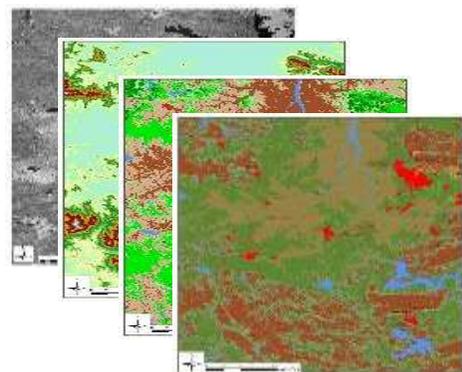
Validate mobility models



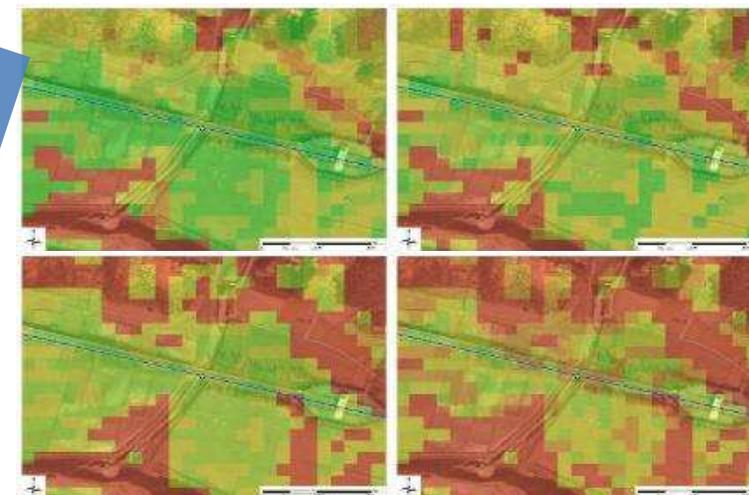
Analyze physical terrain
conditions



Construct terrain database



Predict speed maps



Vehicle Models

Terrain Models

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Dynamic Cold Regions Terrain Variables

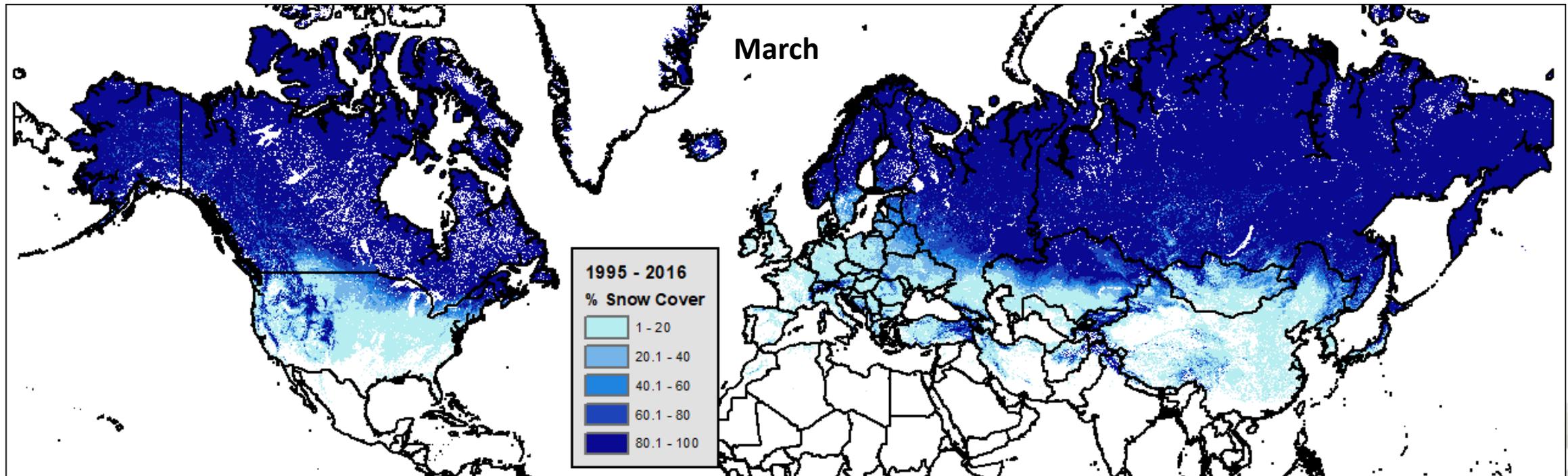
- Snow cover characteristics (covered area, depth, density)
- Temperature
- Precipitation
- Frost Depth
- Freeze/thaw cycles
- Wind speed
- Wind direction
- Humidity
- Soil moisture
- Soil temperature





Example: Global Snow Cover Area (SCA)

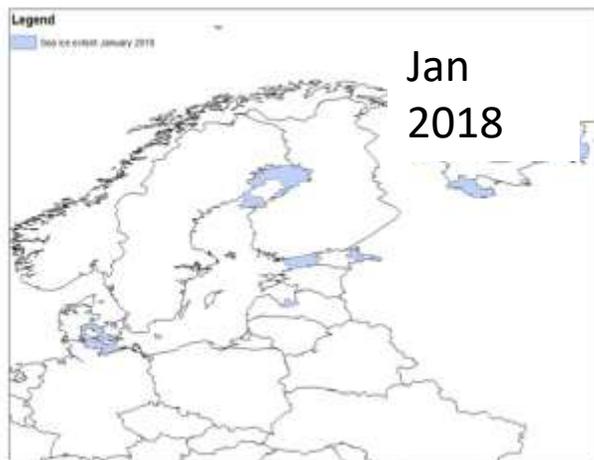
Snow cover likelihood in MARCH
Based on GlobSnow 1 km Snow Extent product
From optical remote sensing (AVHRR, MODIS, VIIRS)



Statistical estimates of Snow Water Equivalent (SWE) used to estimate snow depth and density



Example: Sea ice extent January to April 2018

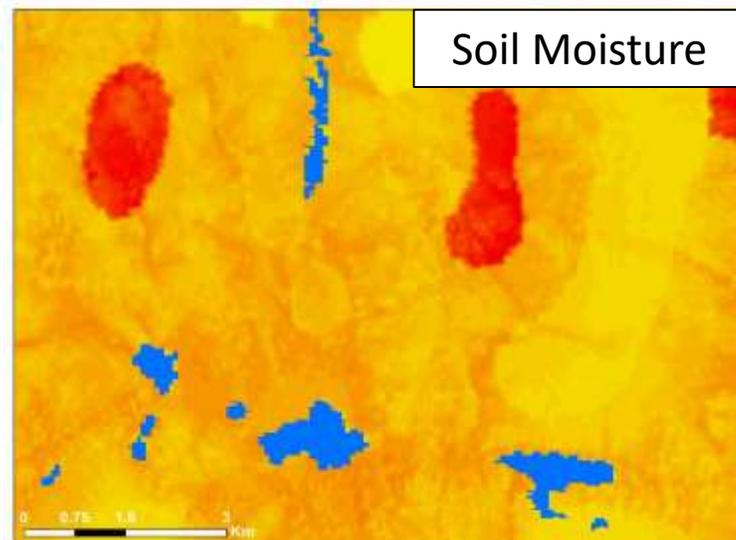
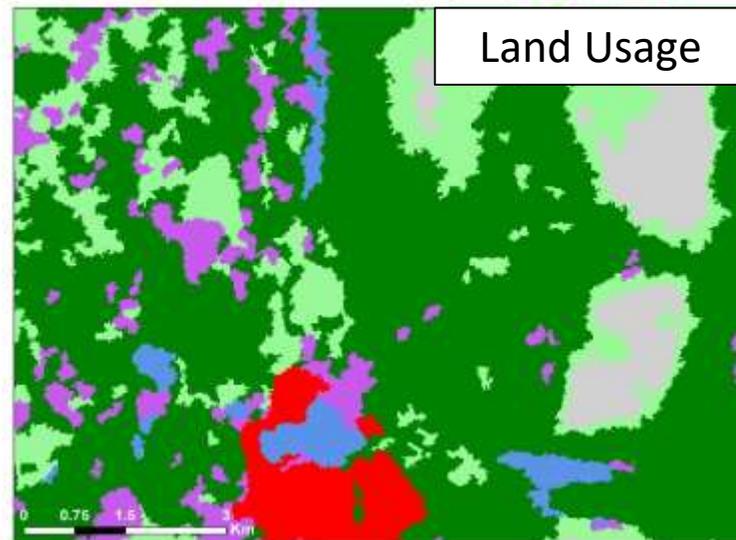
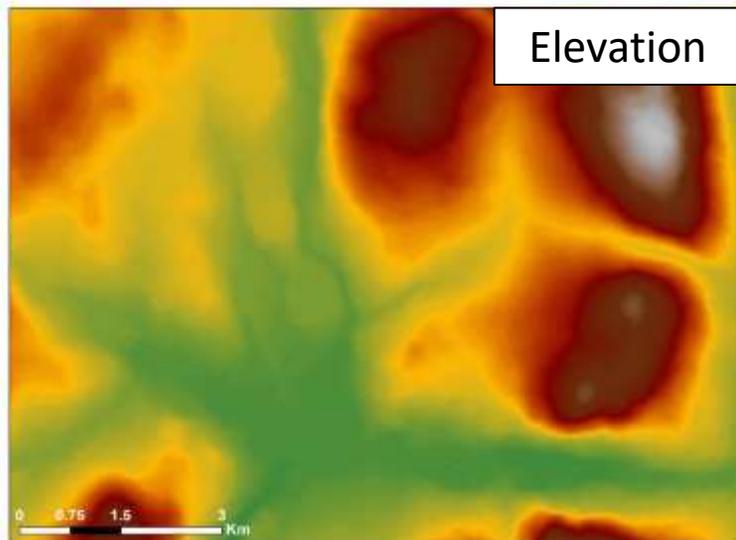
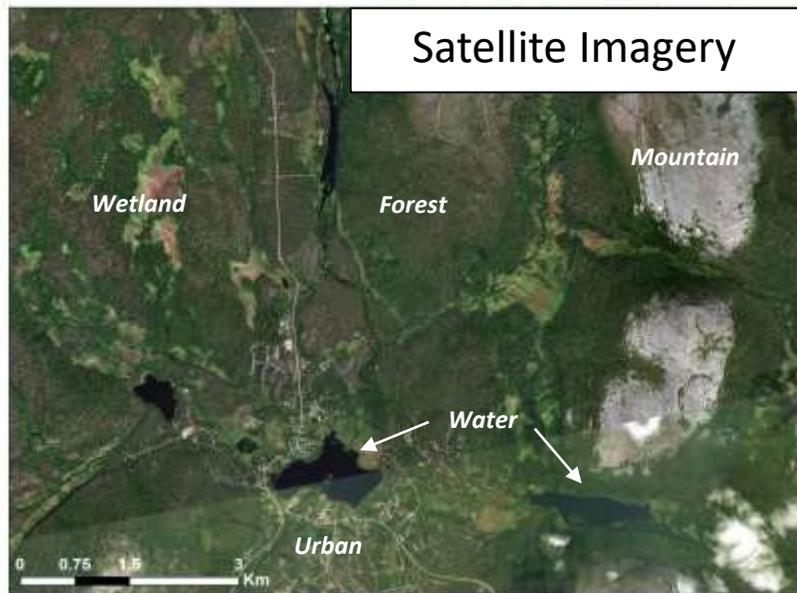


Source: http://nsidc.org/data/seaiice_index/archives

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Generate Summer Terrain Parameters:

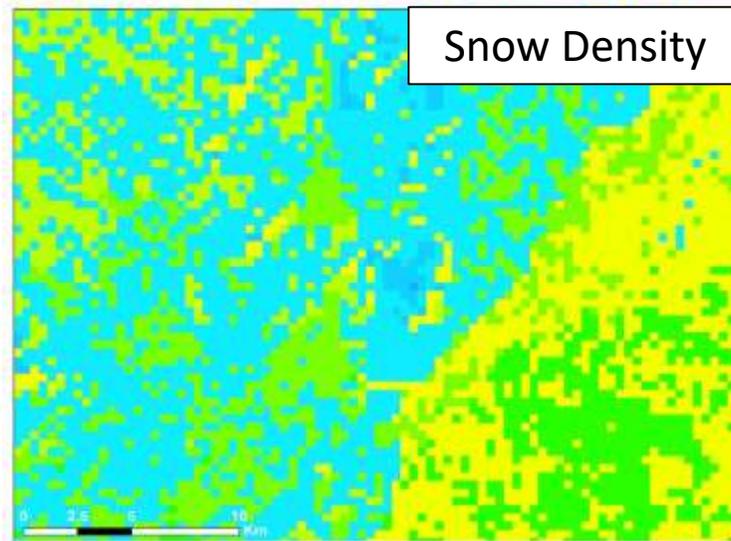
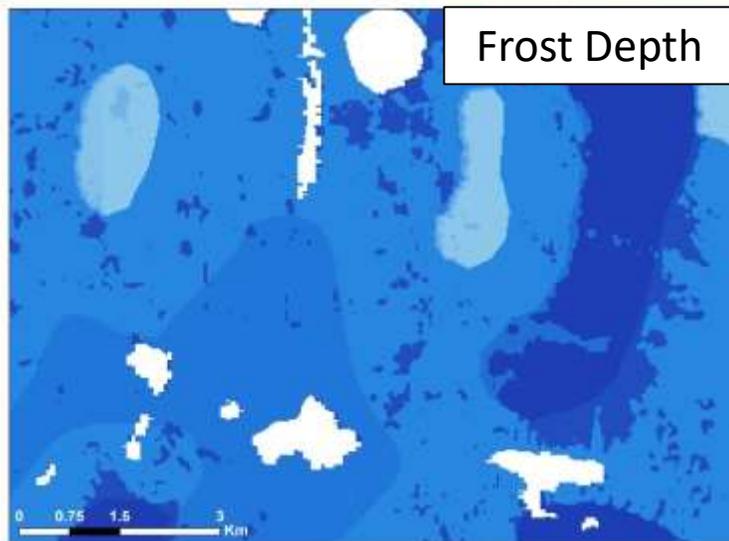
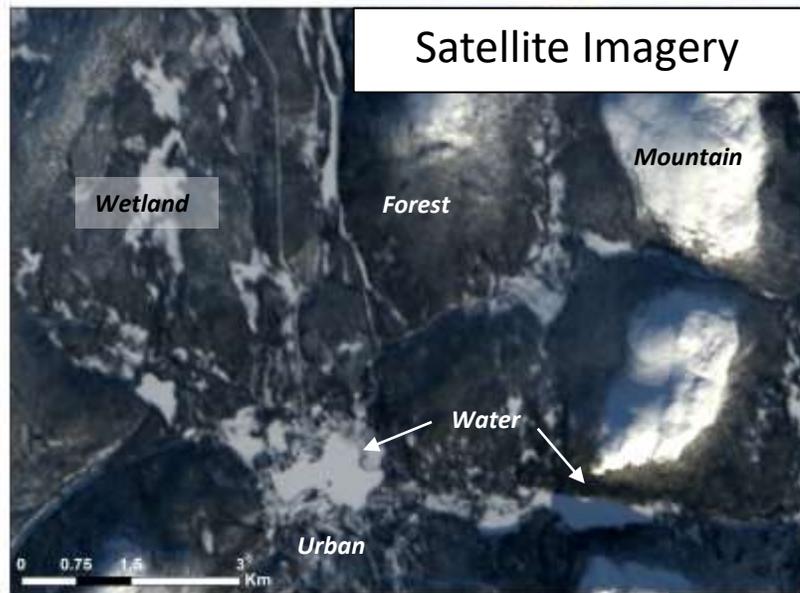


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Generate Winter Terrain Parameters:

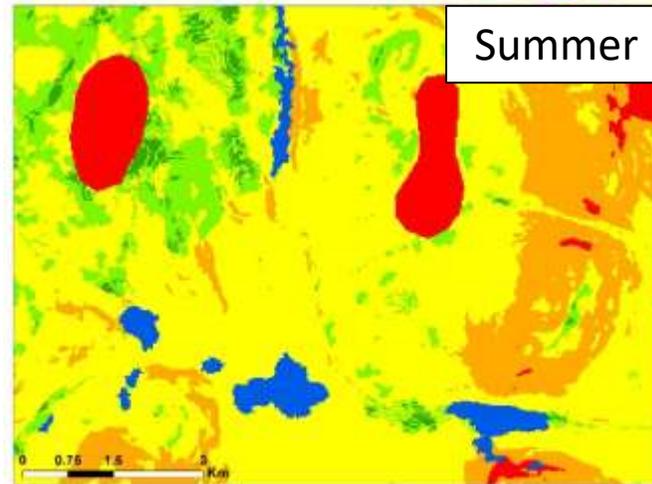
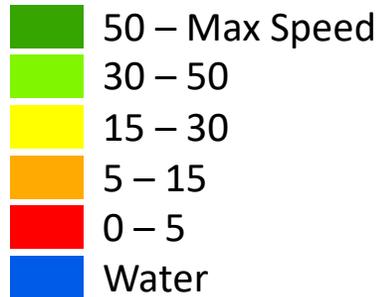




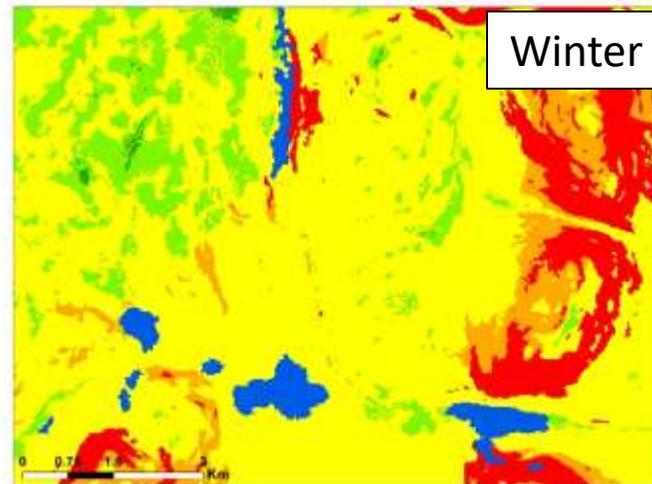
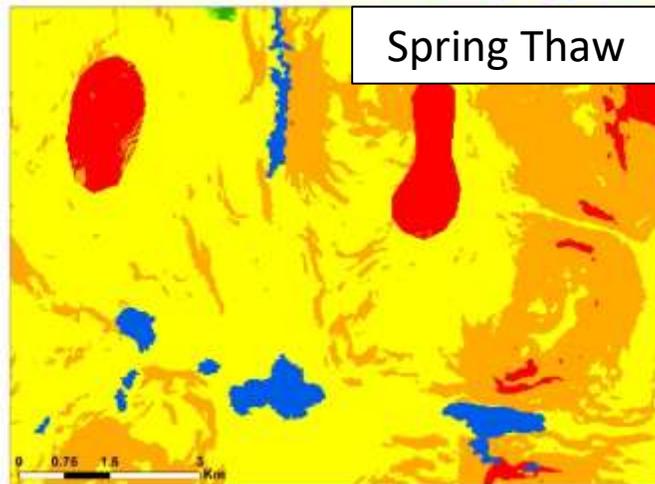
Example Results: Seasonal Impacts for Tracked Vehicle

Speed Maps

Speed Range (kph)



- In winter frozen ground improves vehicle mobility
- Not able to traverse peat soils unless frozen
- Greatest speed limiter is snow-covered slopes

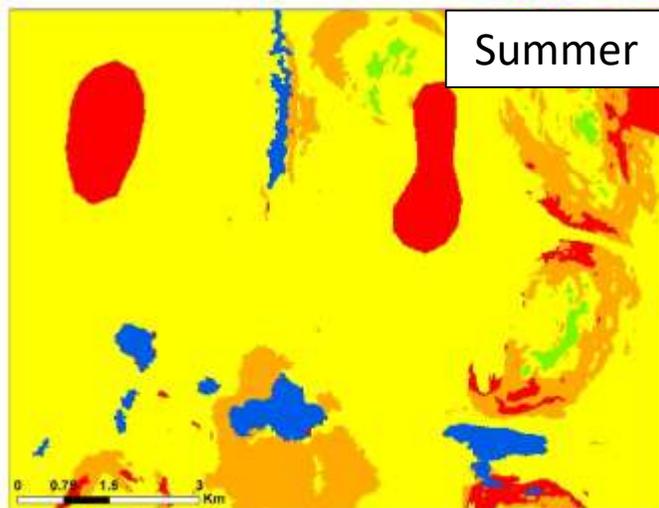
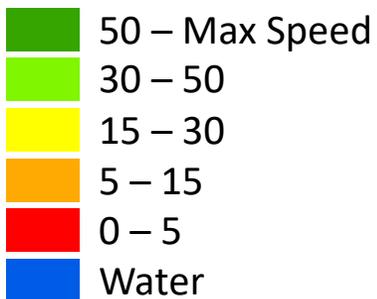


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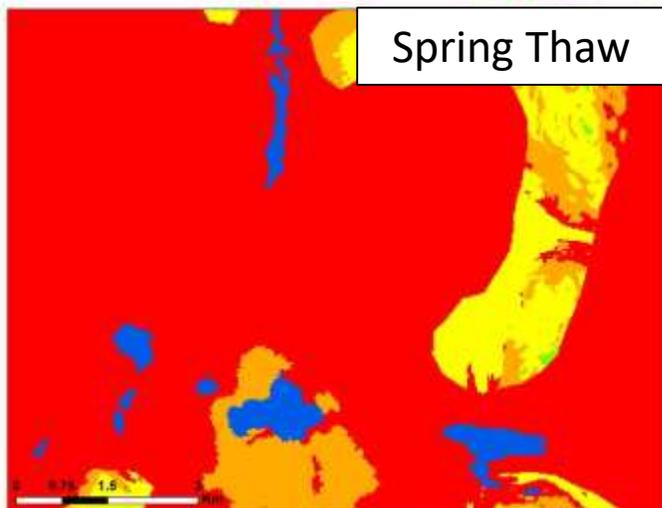
Example Results: Seasonal Impacts for Light Wheeled Vehicle

Speed Range (kph)

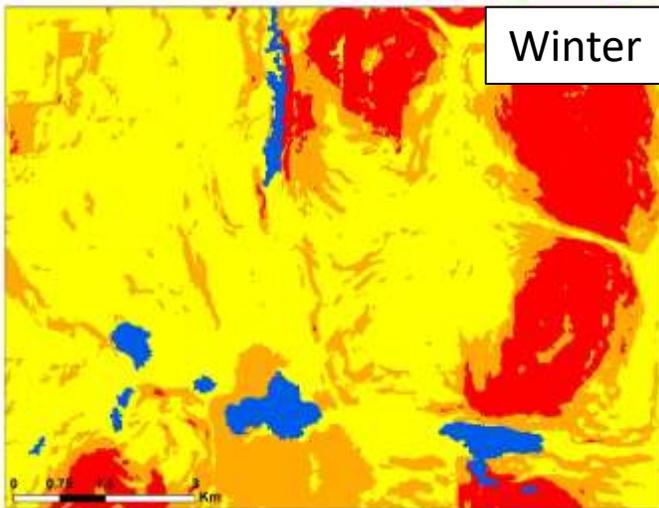


Summer

- Sufficient mobility during summer and winter, but not spring thaw
- Vehicles cannot traverse peat unless frozen
- Greatest speed limiter is wet soil and snow-covered slopes



Spring Thaw



Winter



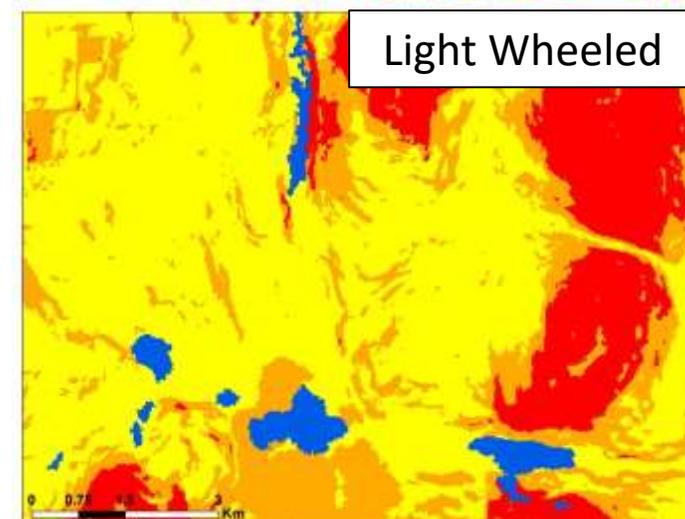
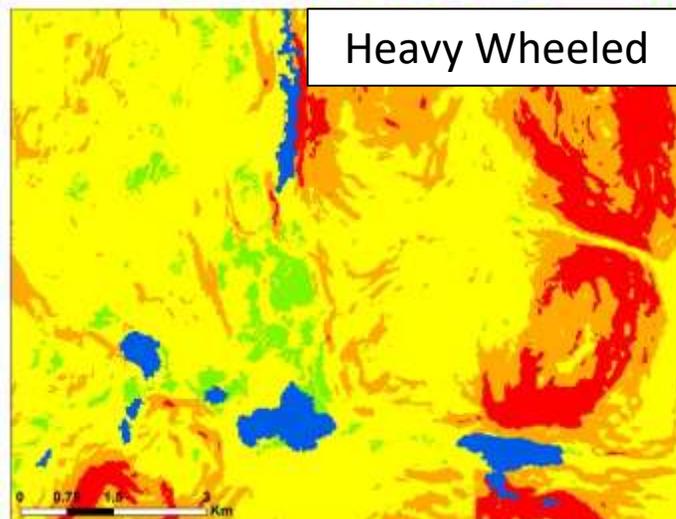
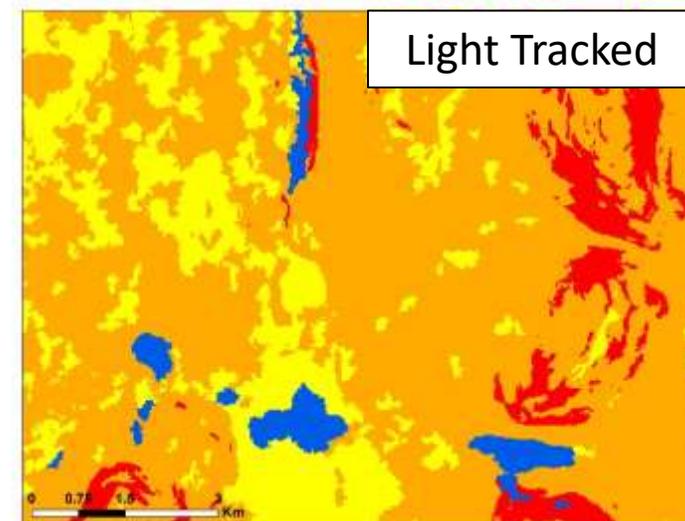
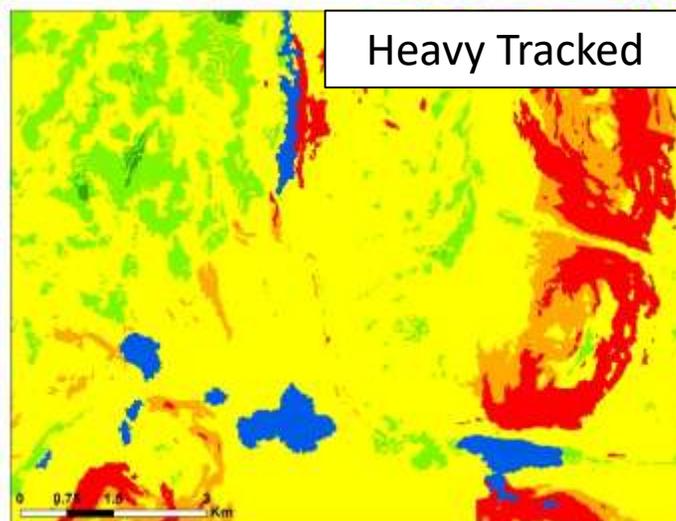


Example Results: Different Vehicles in Winter

- High slopes have greater impact on speed in winter
- Peat soils are now frozen so vehicles can traverse safely



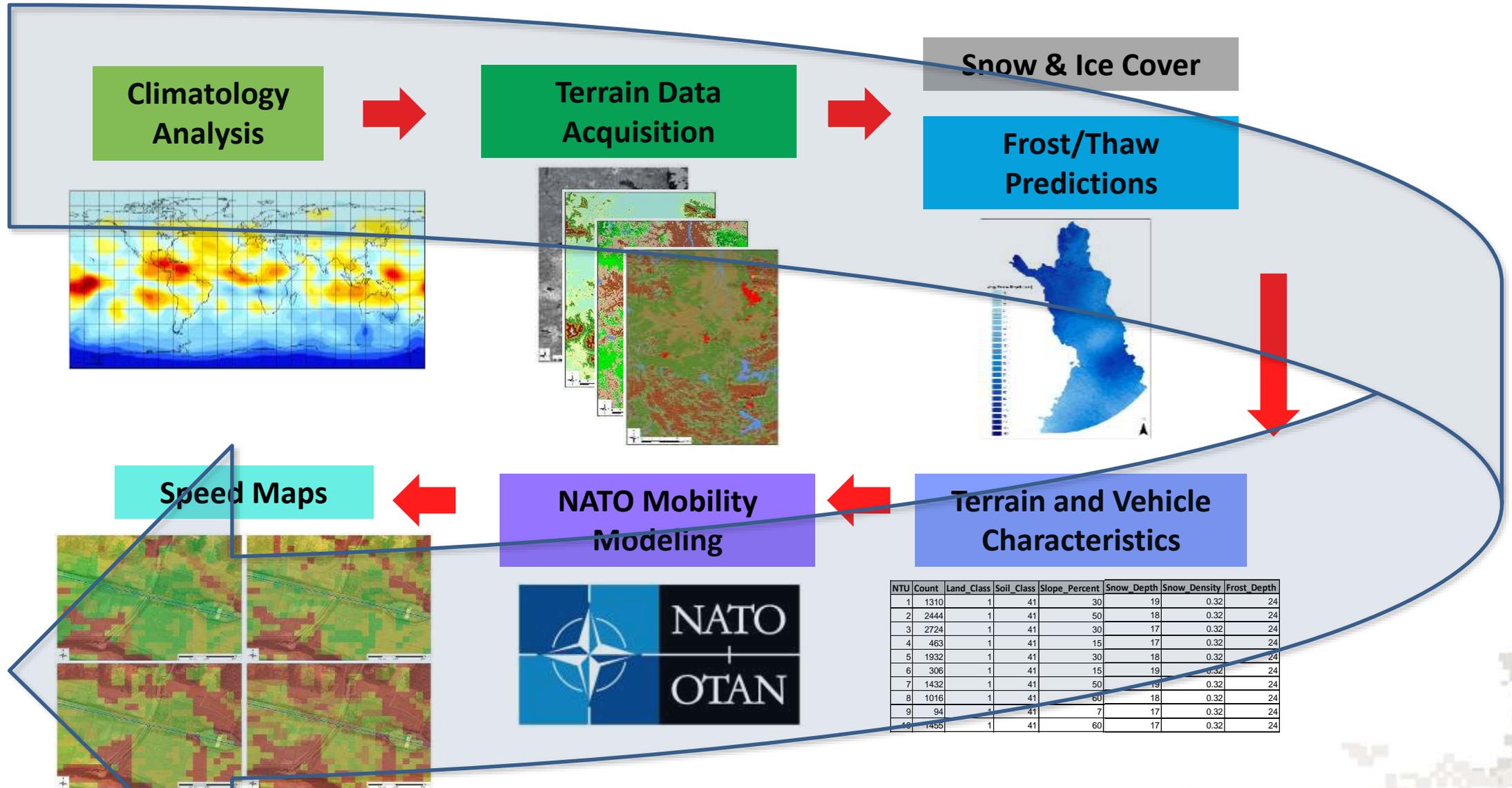
Speed Range (kph)



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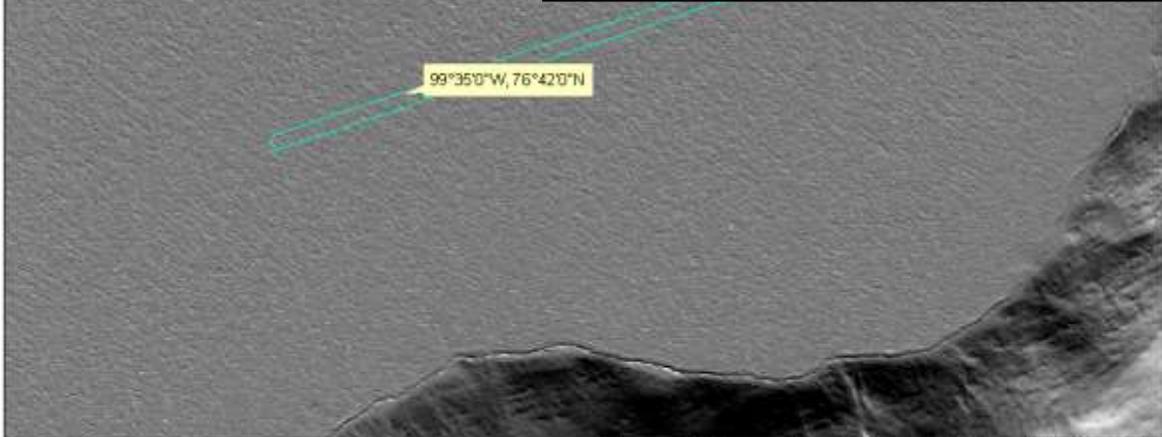
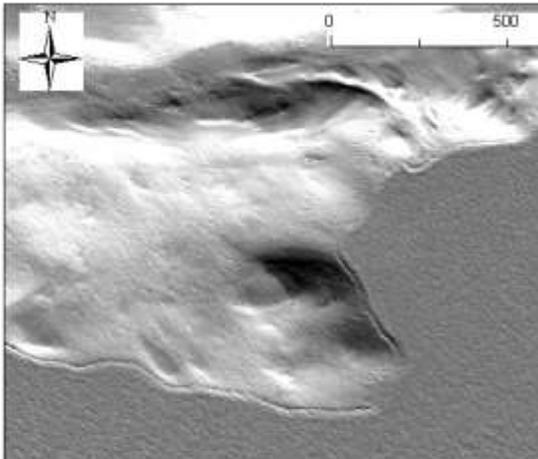
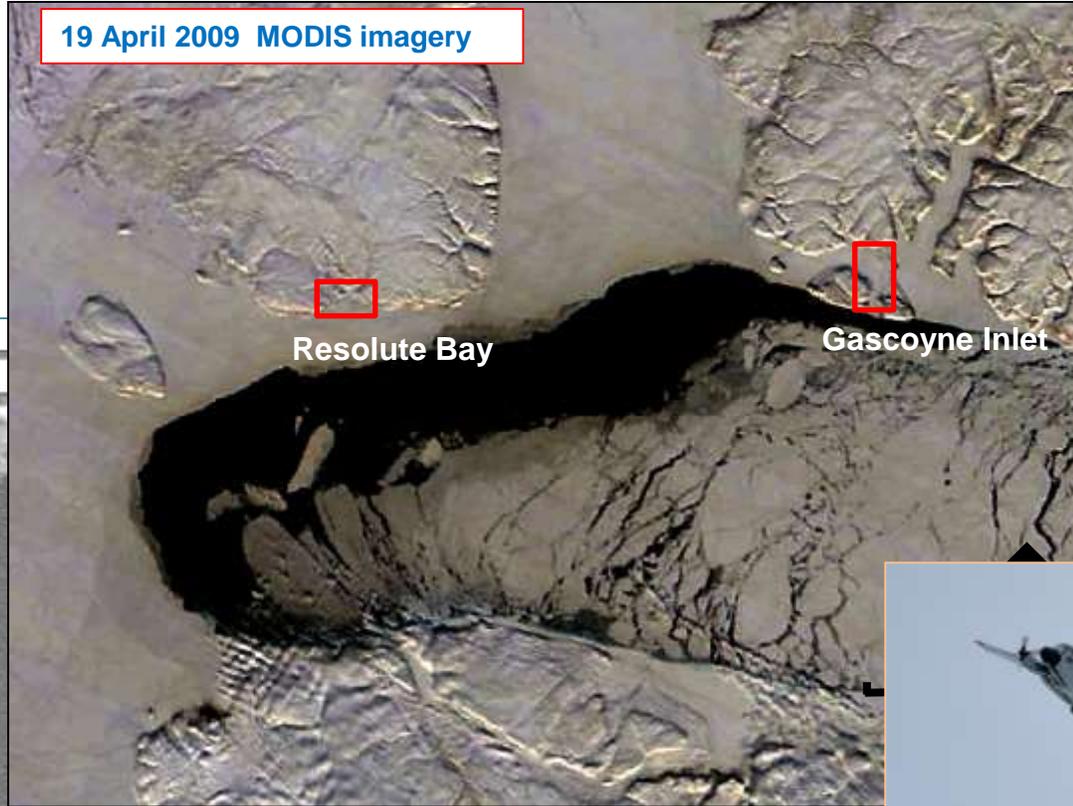


Summary: Seasonal Mobility Assessments Process





Similarities in The Search for an Arctic Landing Zone (LZ)





Phoenix Compacted Snow Airfield Engineering Design

First Landing,
Nov 2016



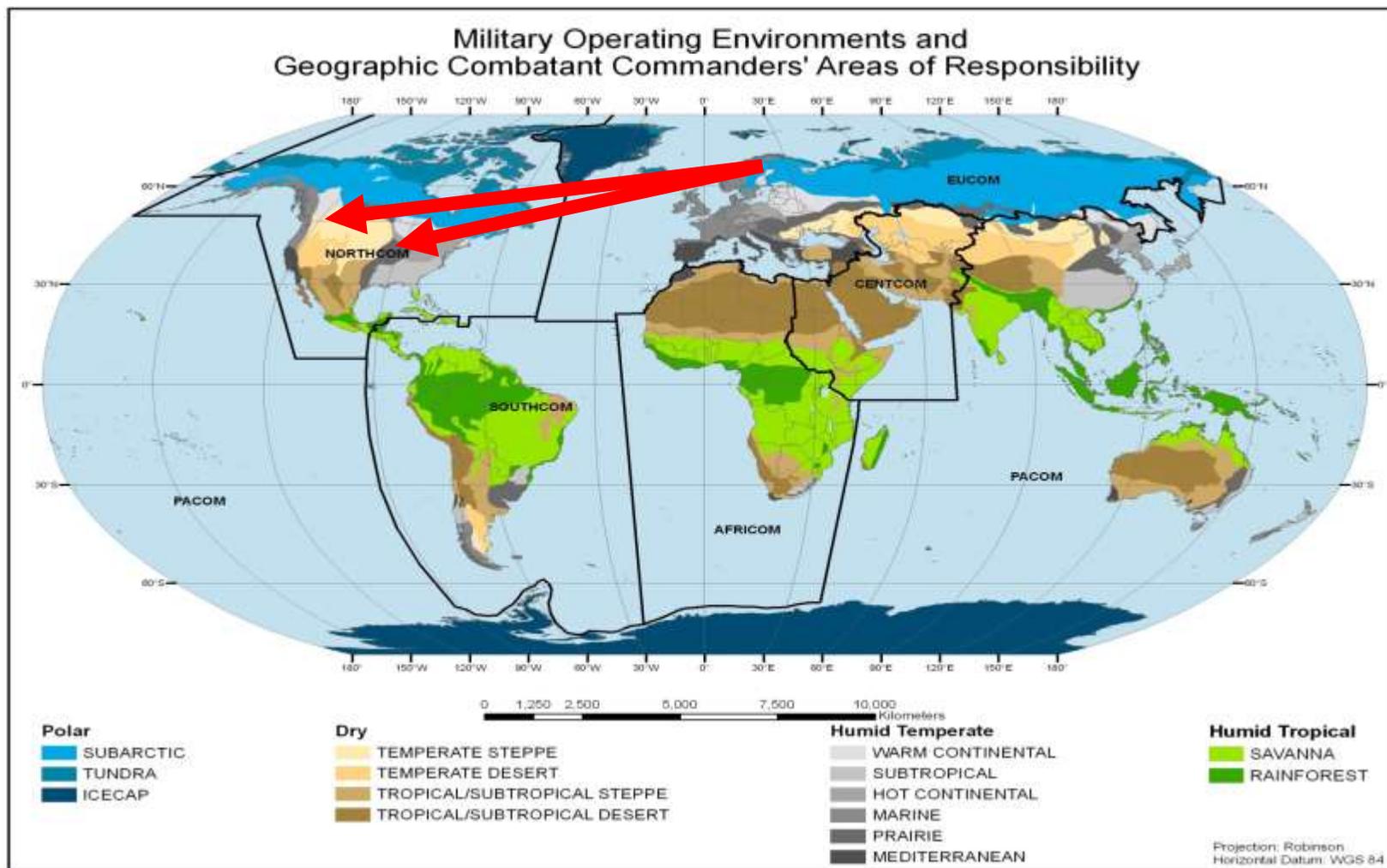
Compacted Snow Airfield:

- First wheeled snow runway since Russians in 1950s
- Heaviest wheeled aircraft on snow, ever!
- >500, 000lbs, 160 psi tires





Matching Similar Ecotypes: Atmospheric, Terrain & Biological Conditions





Next Steps:

Entry and Sustainment in Complex, Contested Environments

1. Develop new ways to generate terrain data using remote assessment
2. Quantify/Incorporate uncertainty in results
3. Automated tools for terrain file generation
4. Evaluate/validate results for current vehicle fleet
5. Incorporate deep snow, over-snow and other winter surfaces
6. Add capabilities for peat and highly organic soils
7. Add vegetation effects on terrain strength and mobility



Multinational terrain data sharing agreements!



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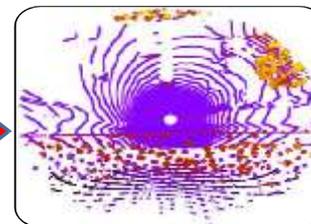
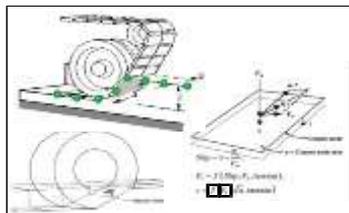


NG-NRMM and High-fidelity Modeling:

1. Cold regions terrain mechanics (snow, ice, frozen/thawing ground, peat and organic soils, heavily vegetated ground)
2. Implement results into high-resolution mobility models
3. Sensor performance models for cold terrains
4. VANE, ANVEL, plus OpenSource software

NATO: AVT 248: Next-Generation NRMM (Standards)

NATO: AVT-ET-194: Assessment and Tools for Mobility of Autonomous Military Ground Systems



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From: J. Durst, Dissertation Defense, March 4, 2019



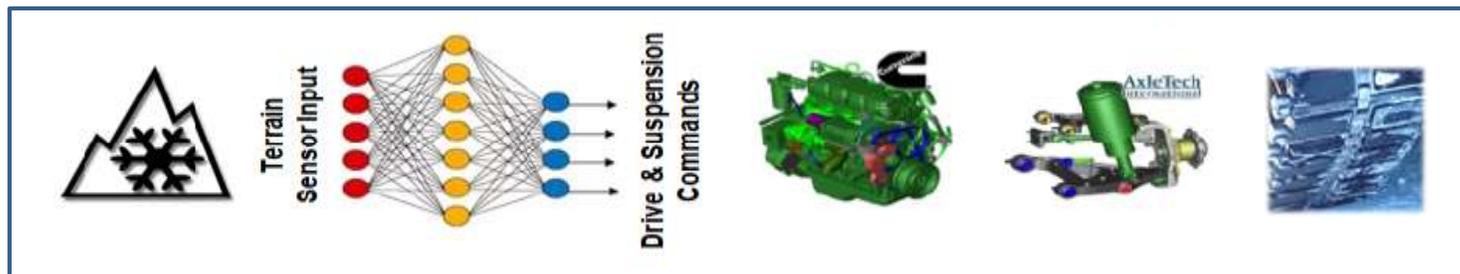


Next Generation Combat Vehicle: Autonomy in Cold and Challenging Terrain



If the autonomous vehicle can't sense it, it can not effectively maneuver

1. Artificial Intelligence/Machine Learning (AI/ML) using stand-off sensing data for terrain assessment
2. AI/ML for vehicle performance prediction in cold terrain
3. Autonomy and control in extreme environments





Seasonal Impacts on Mobility: Conclusions

- Seasonality has significant impacts on mobility, especially in austere, off-road environments
- Accurate representation of terrain conditions is essential for robust mobility predictions

Next Steps

- Future vehicle technology needs to be adapted for terrain unique to northern regions
 - Revive deep and over-snow vehicle capability
 - Address S&T gaps
 - Apply new M&S techniques
 - Develop autonomous capabilities

