Identifying new sources of dust emissions from high latitudes

WMO Barcelona Dust Regional Center Webinar
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James King, Associate Professor

Université de Montréal
Laboratoire d'Érosion Éolienne

NSERC CRSNG
INNOVATION.CA
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Global Dust Circulation

NASA MODIS Aqua image: Juin 24, 2014

Global Dust Circulation

Image STS049-92-071 - Algeria / Niger border, space shuttle Endeavour May 13,

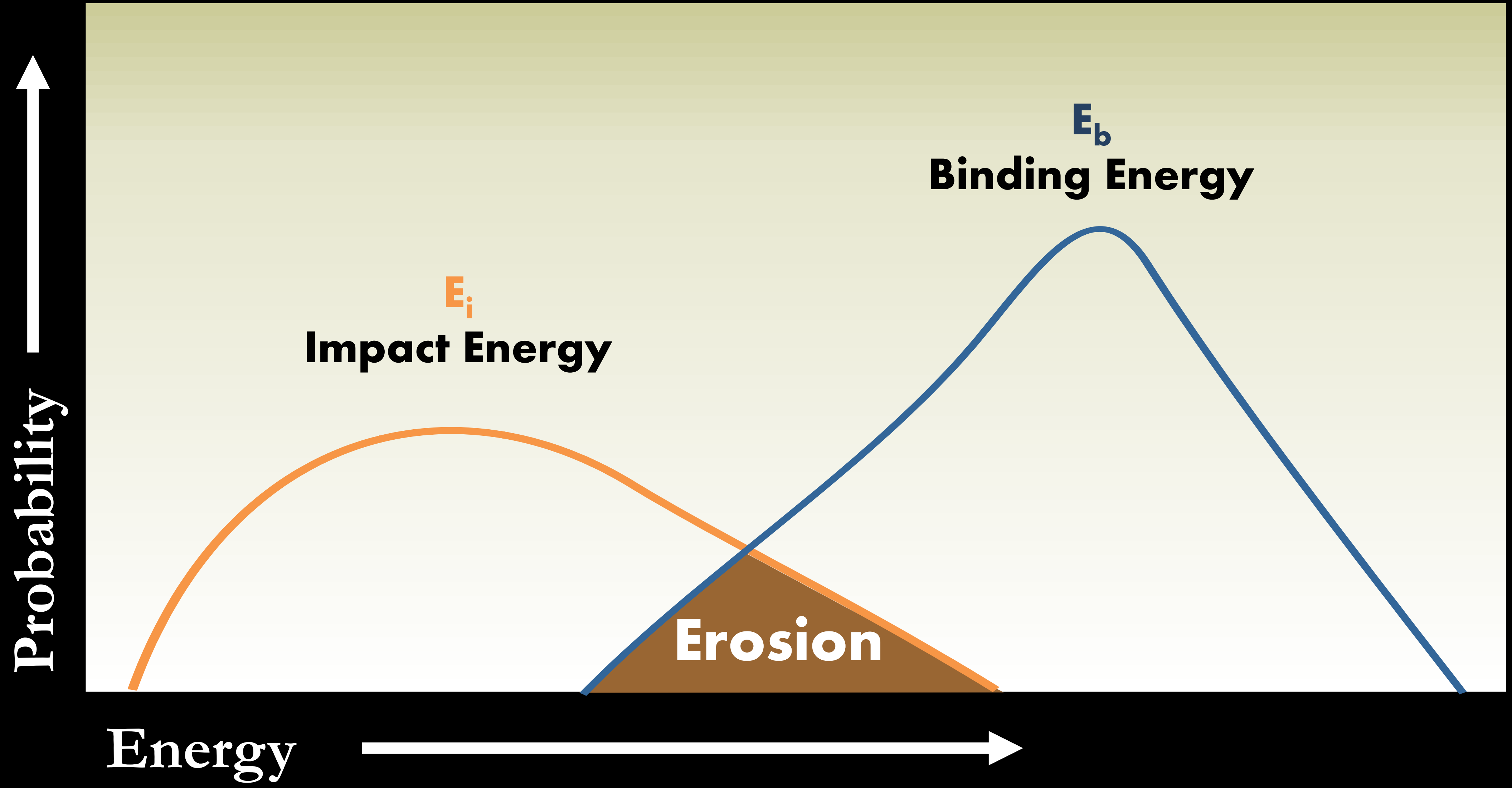
Global Dust Circulation

NASA MODIS Aqua image: July 18, 2023

How does a dust storm begin?

© Jerry Ferguson 2018

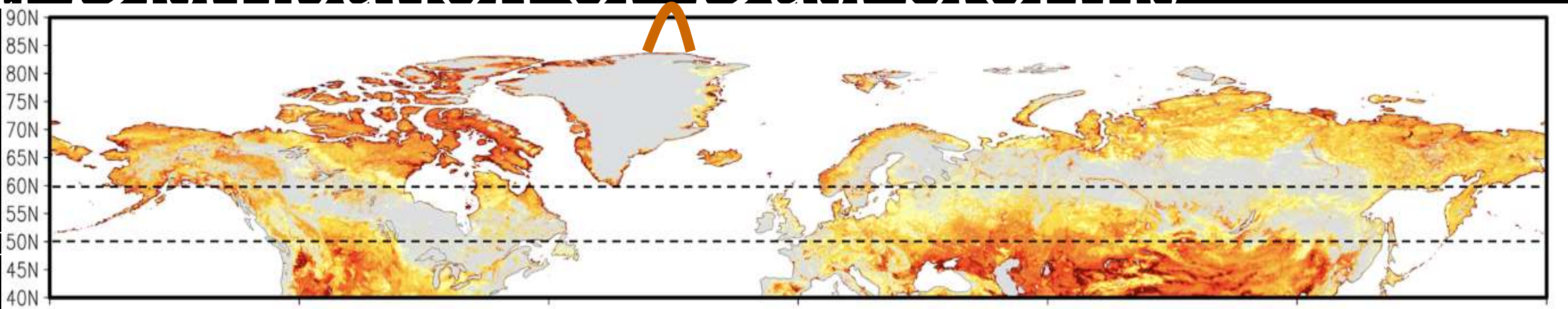
How does a dust storm begin?

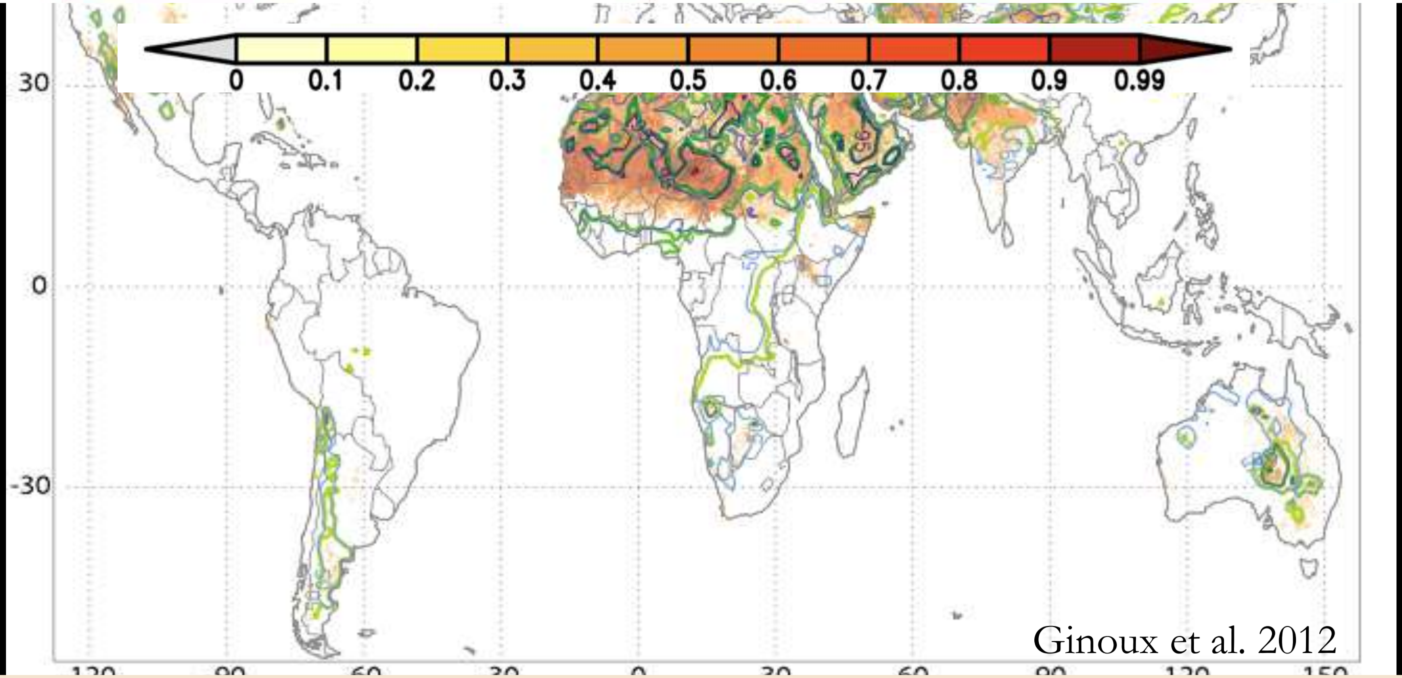


Adapted from Rice et al., 1999

~~Global~~ Distribution of High Latitude Dust Storms

- Are based on global sensing approach us surface reflectance
- Ground-truthing via high-resolution field campaigns
- Used directly in regional and global climate models



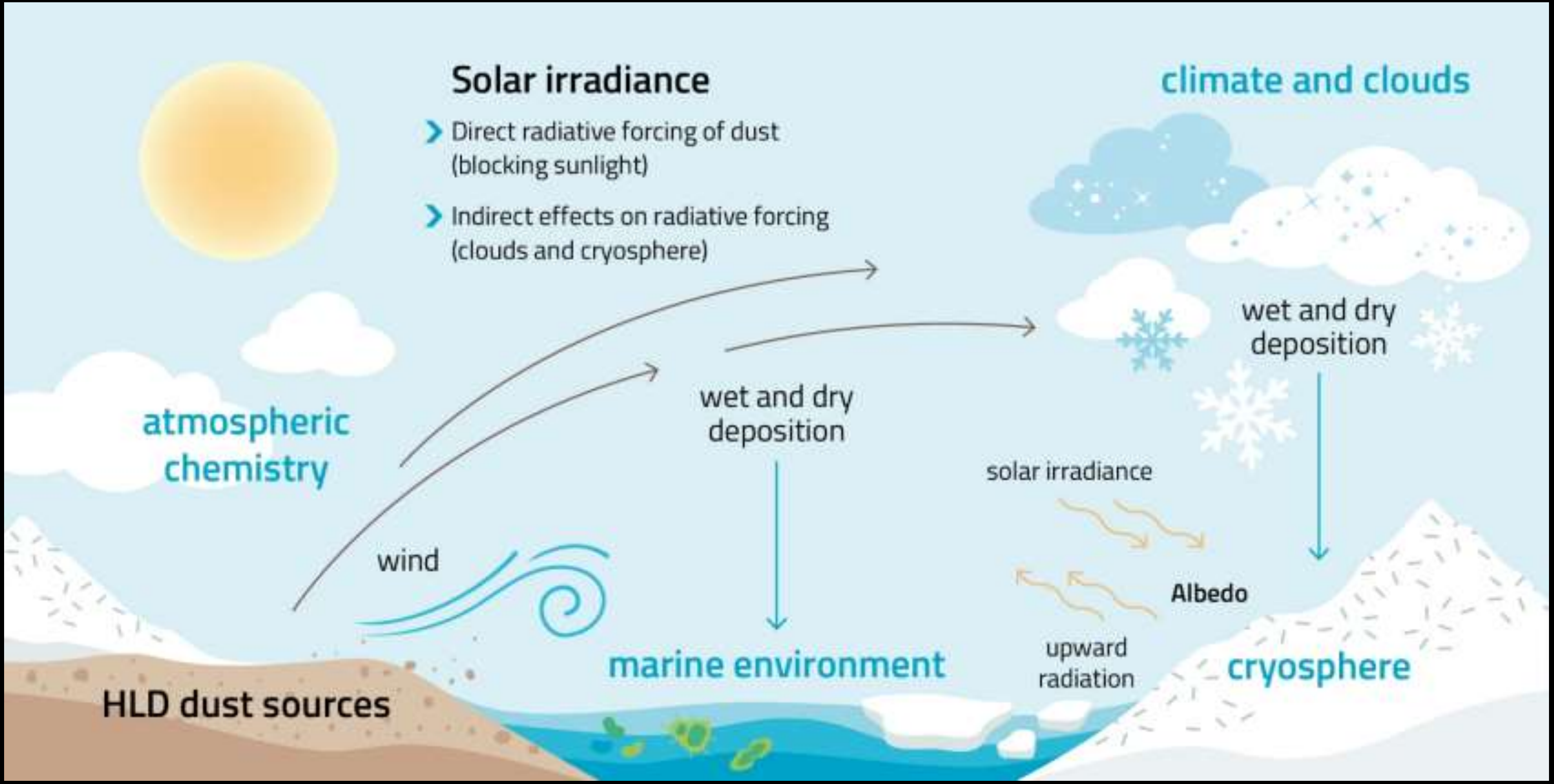


Ginoux et al. 2012

~~Global~~ Distribution of High Latitude Dust Storms

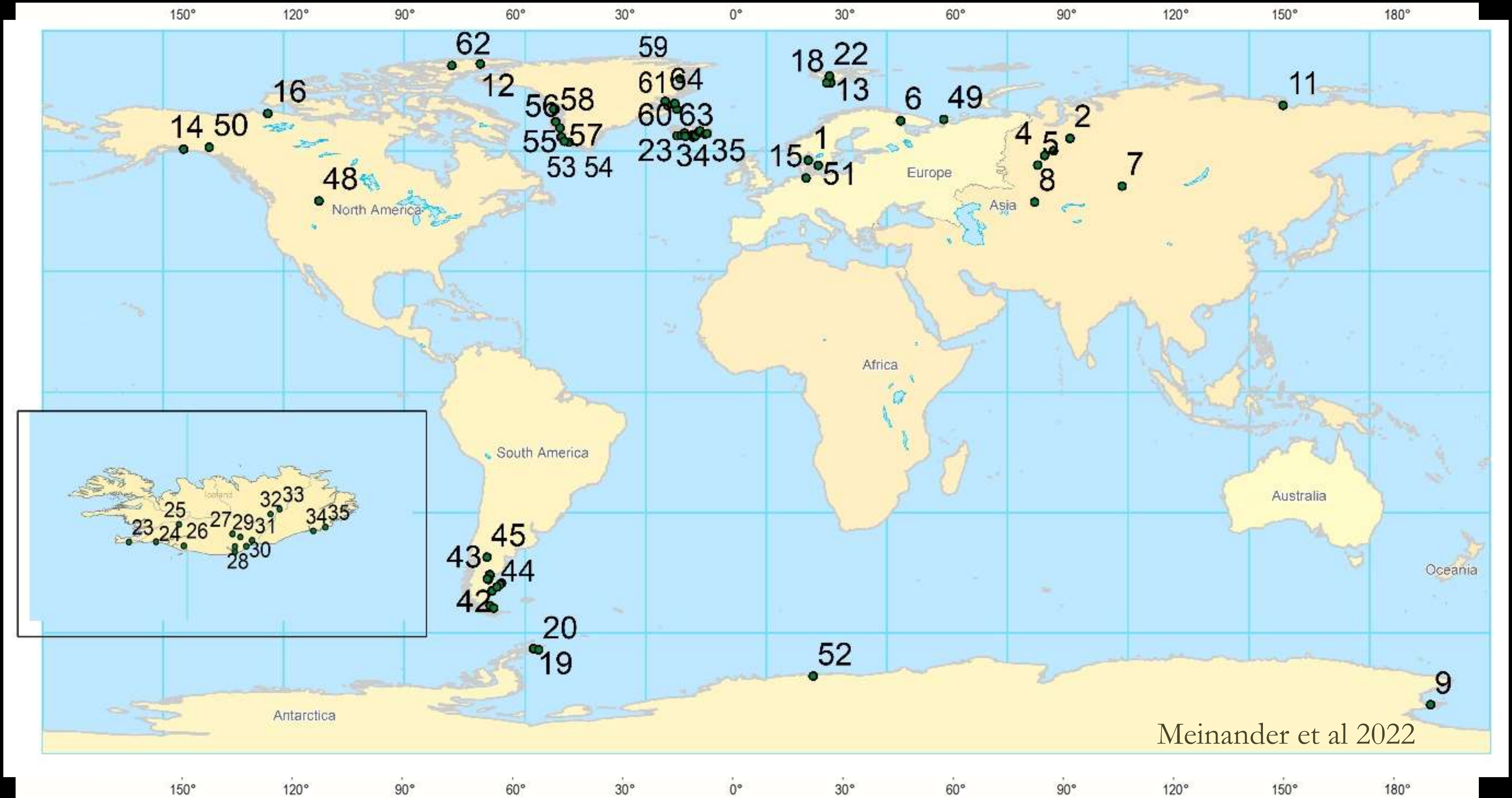
Differences/Importance

- Seasonal production of wind erodible material
- Shallow boundary layer concentrates emissions
- Local and synoptic meteorological mechanisms important
- Hydrologically isolated landscapes limit nutrient distribution

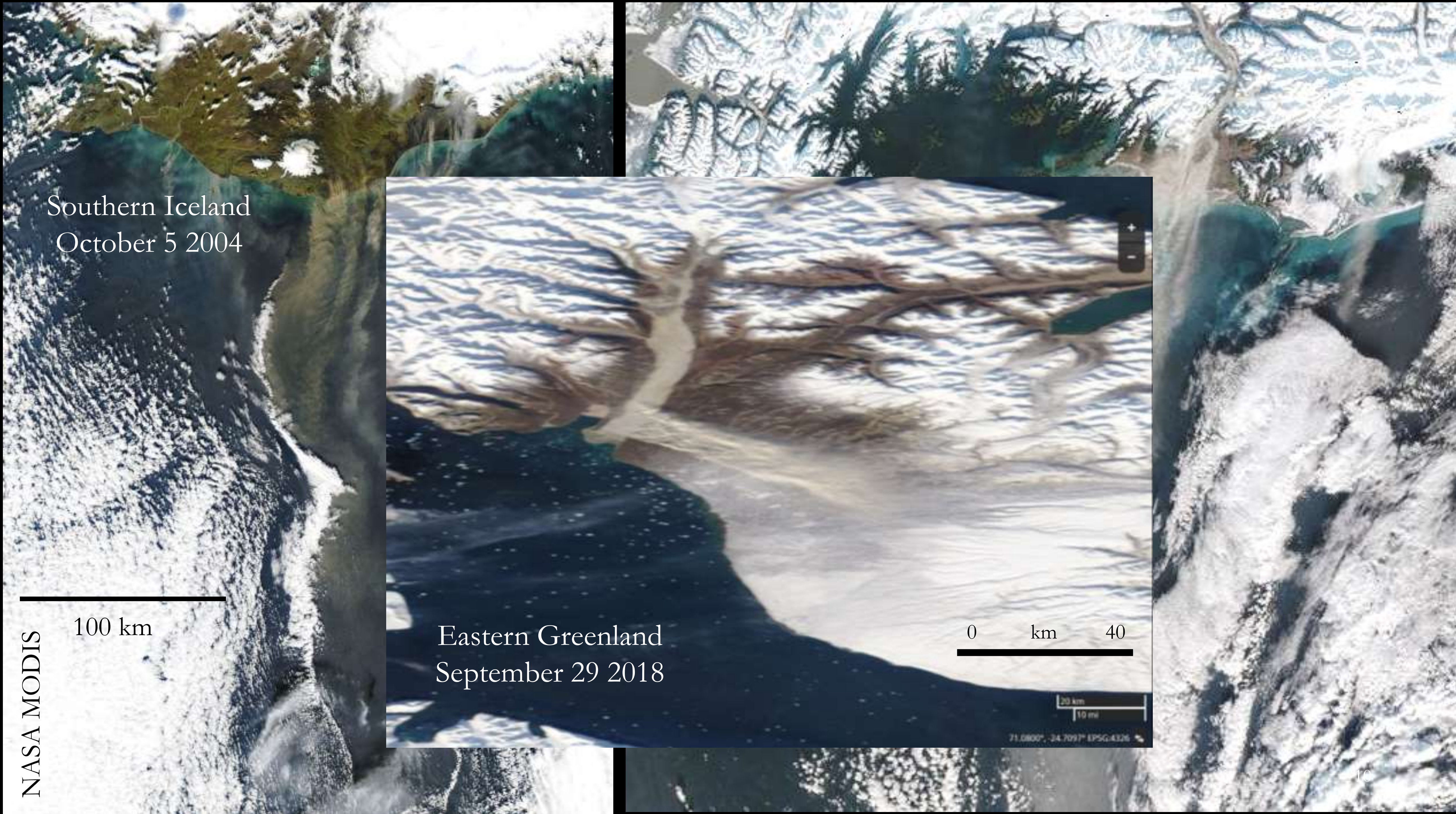


Meinander et al 2022

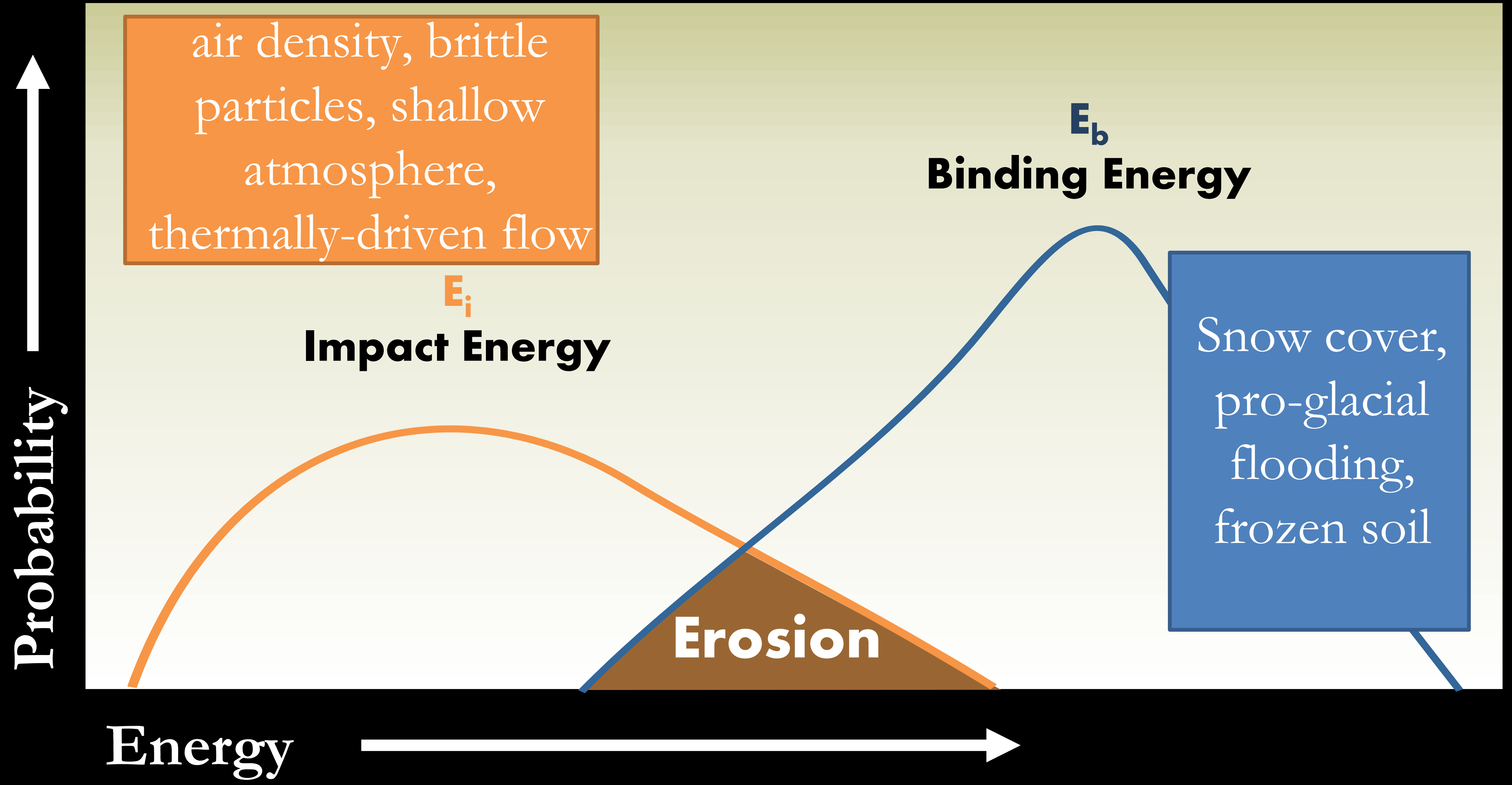
Where are the known HLD sources?



Meinander et al 2022

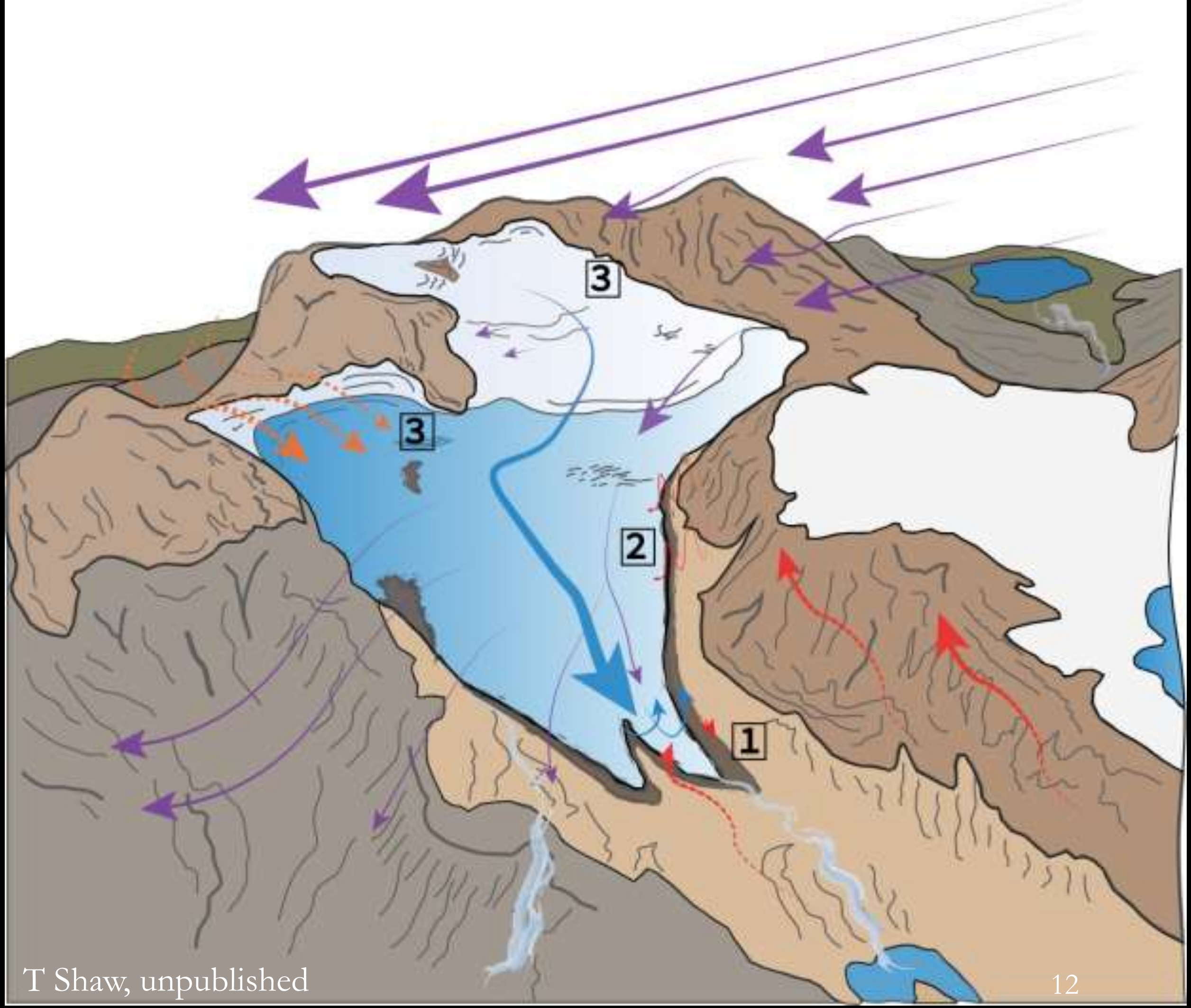

Southern Iceland
October 5 2004
100 km
NASA MODIS
Eastern Greenland
September 29 2018
0 km 40

How does a ^High Latitude dust storm begin?



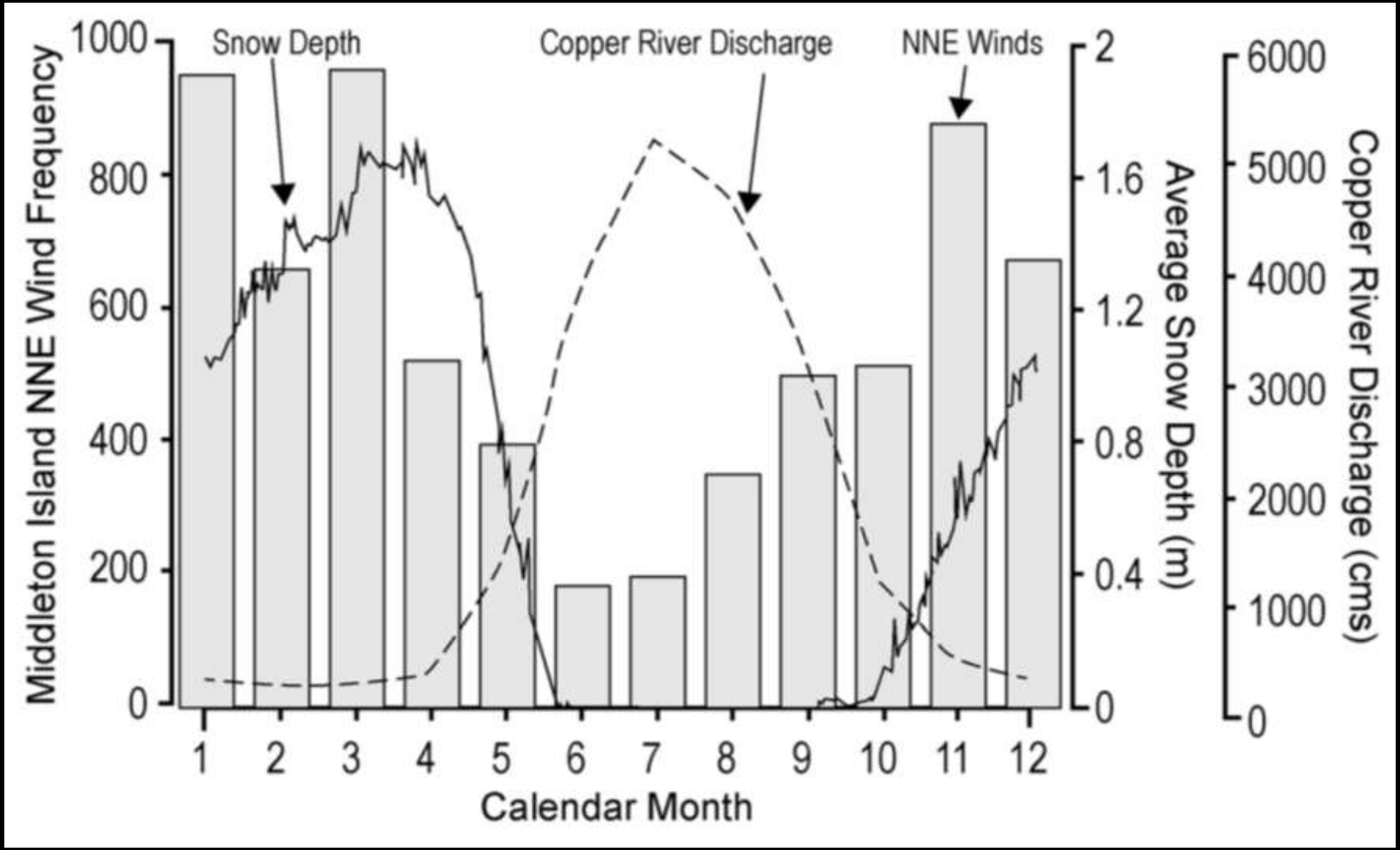
Impact Energy / Erosivity (thermal winds)

- Develop on surfaces of snow and ice as they cool the surface air below 0°C
- This cold and dense air flows downslope by gravitational forces (blue arrows)
- Synoptic or regional winds (purple arrows) can help increase this effect, especially in coastal environments.



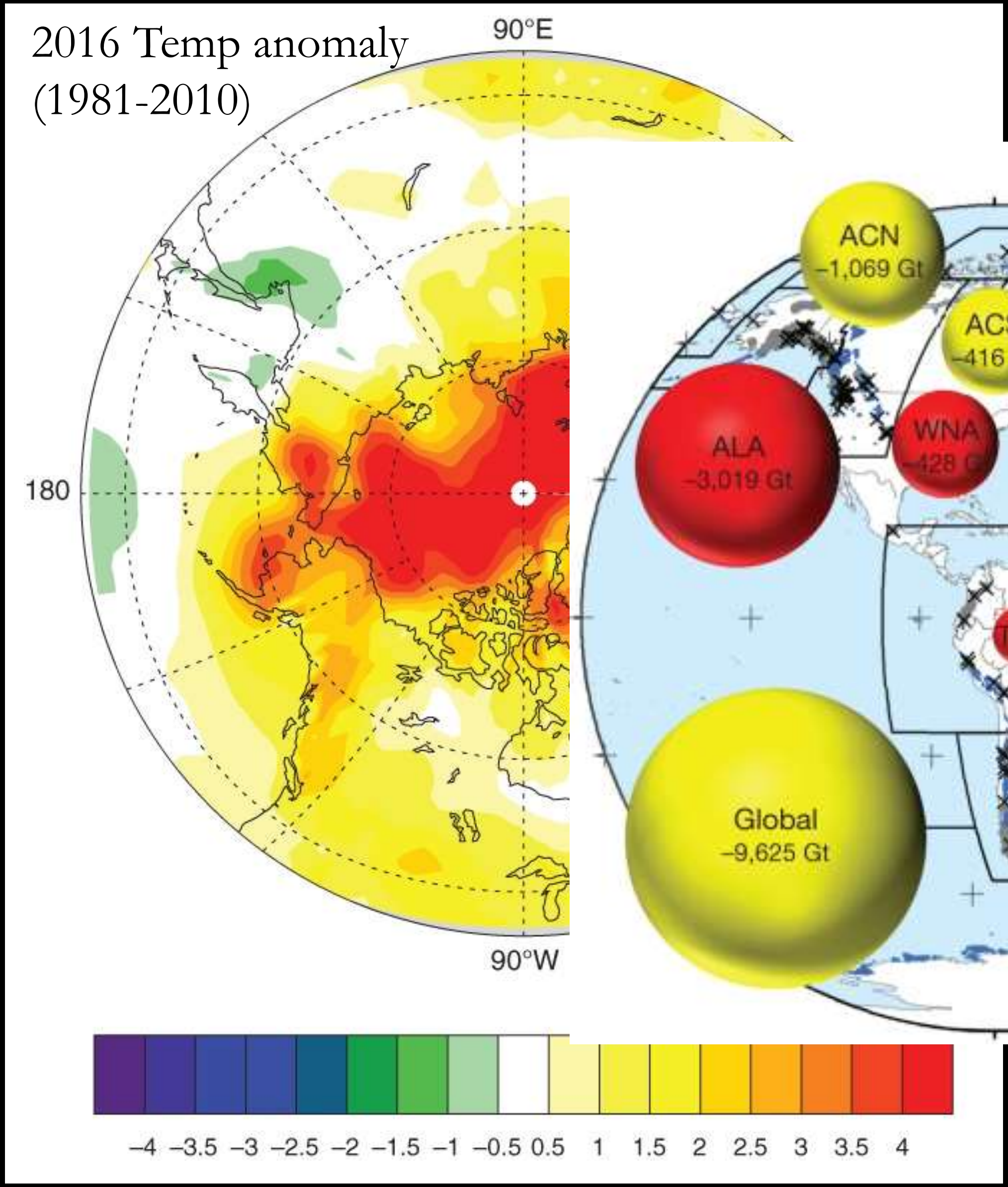
T Shaw, unpublished

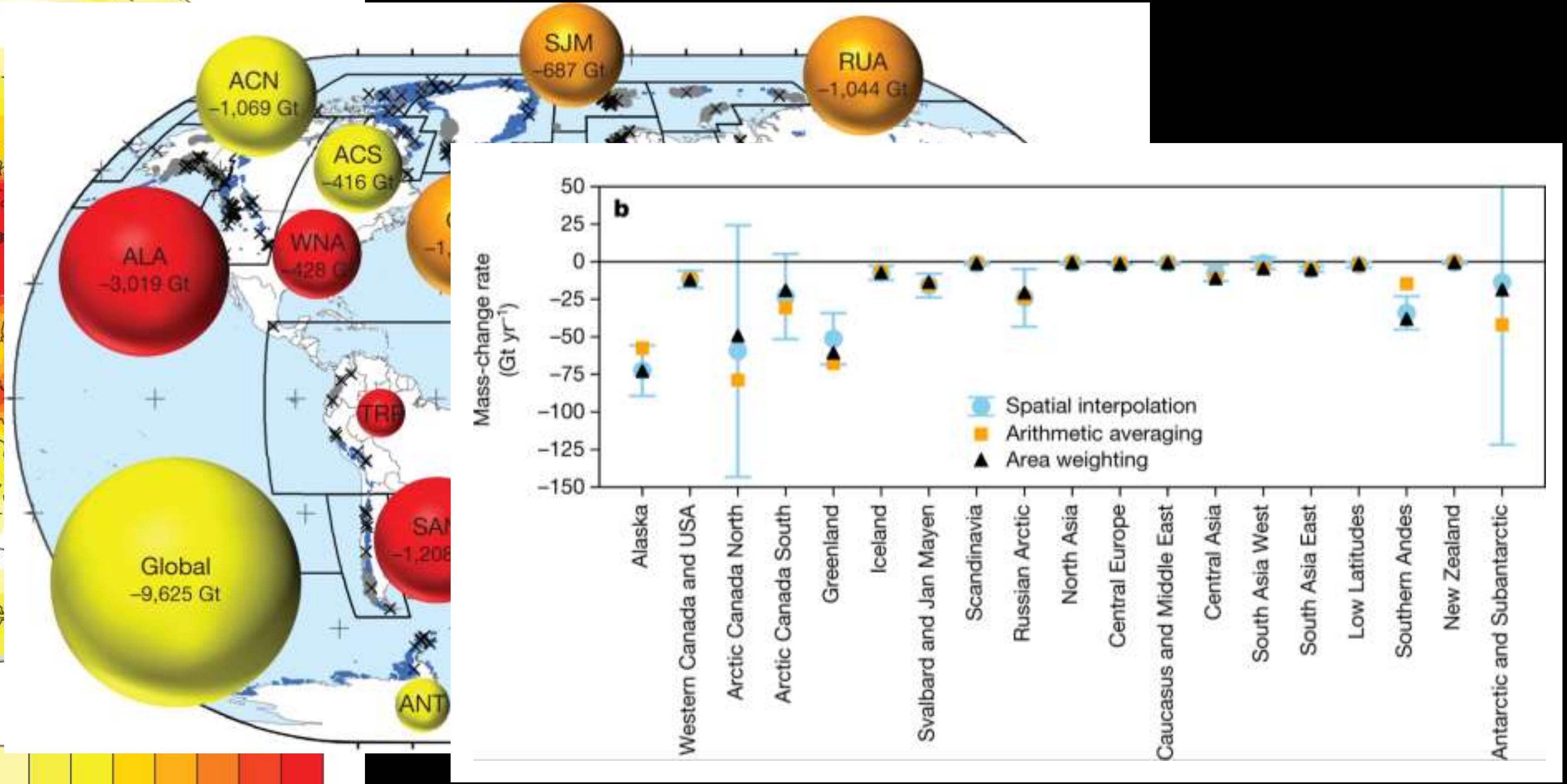
Binding Energy / Erodibility



Crusius et al., 2011

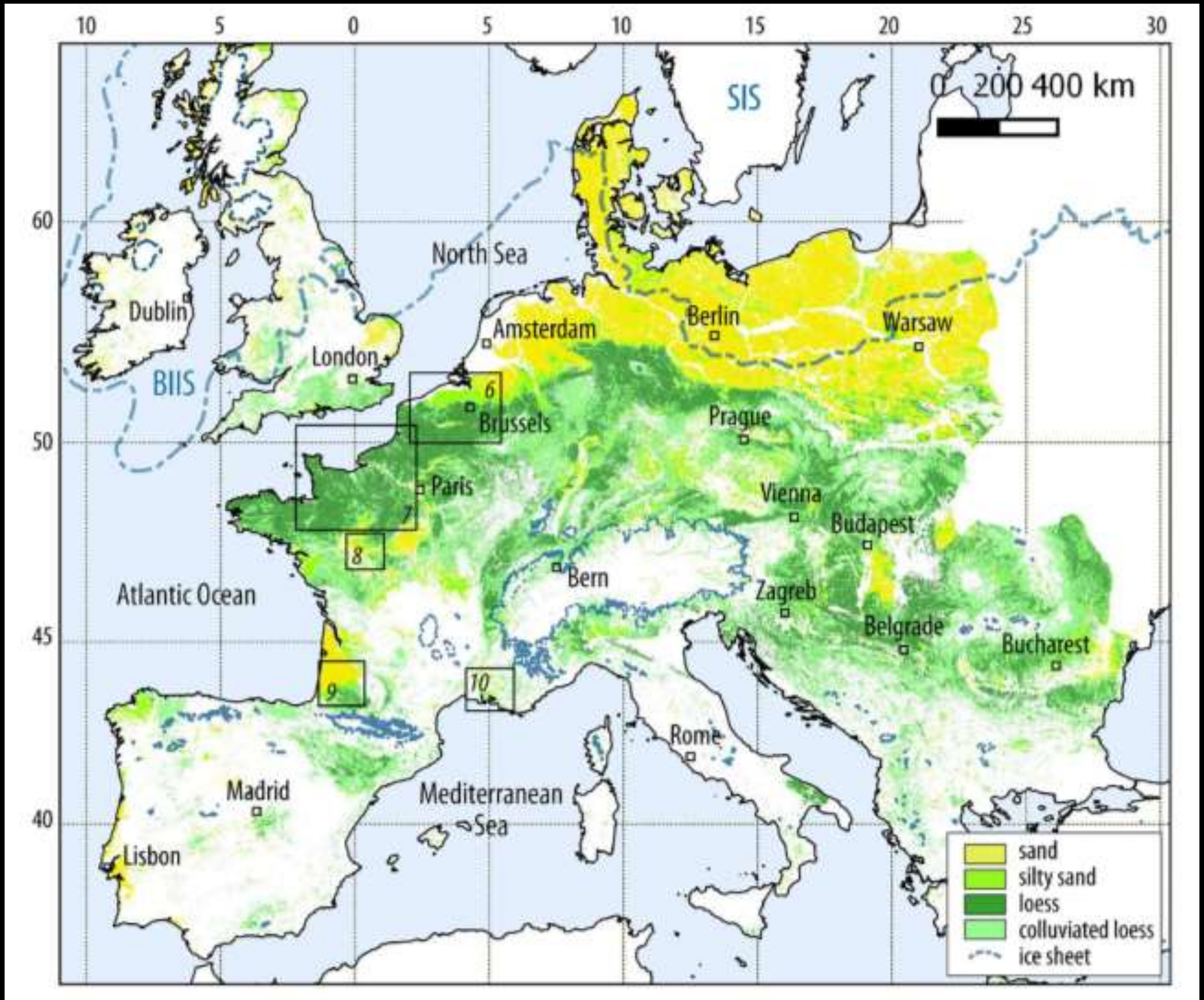
Climate Change Context

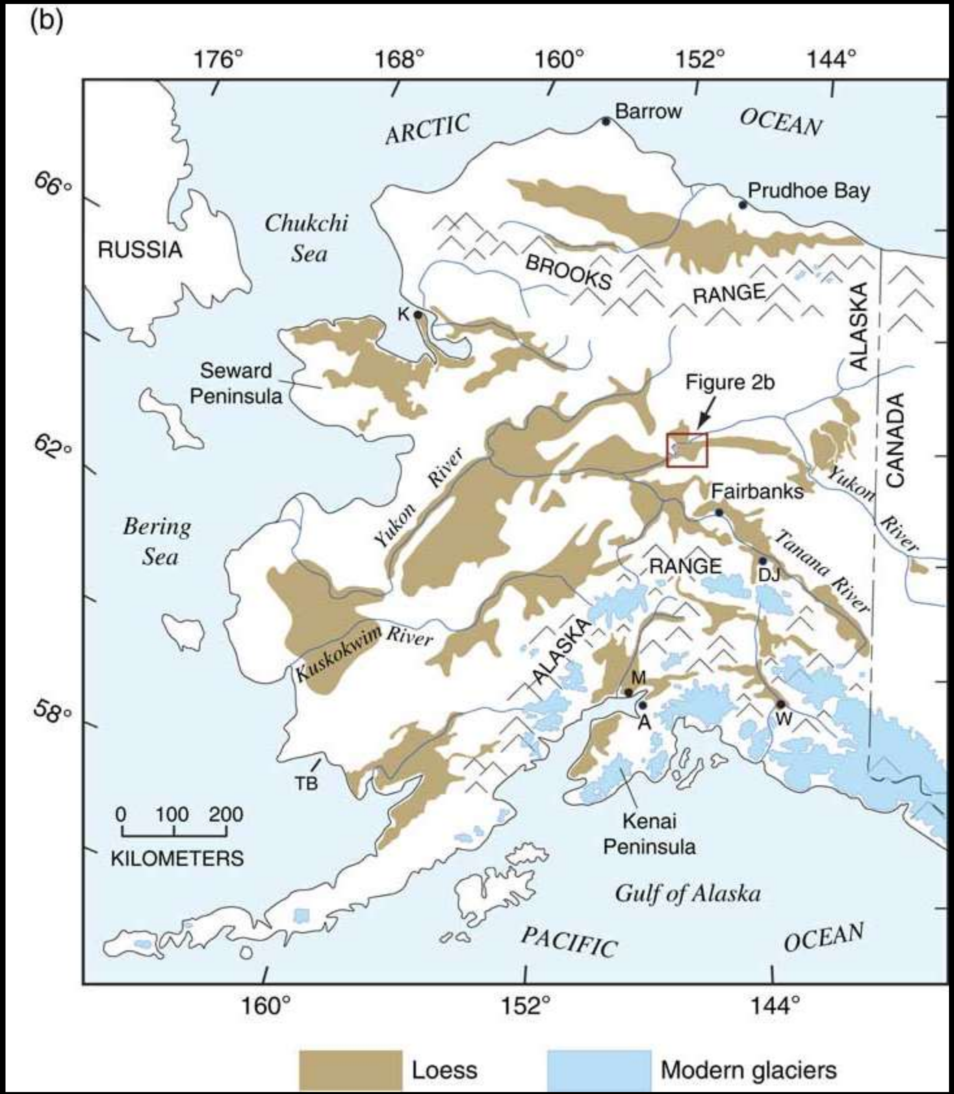




Francis et al., 2017; Zemp et al., 2019

Historical Context





Bertran et al., 2016

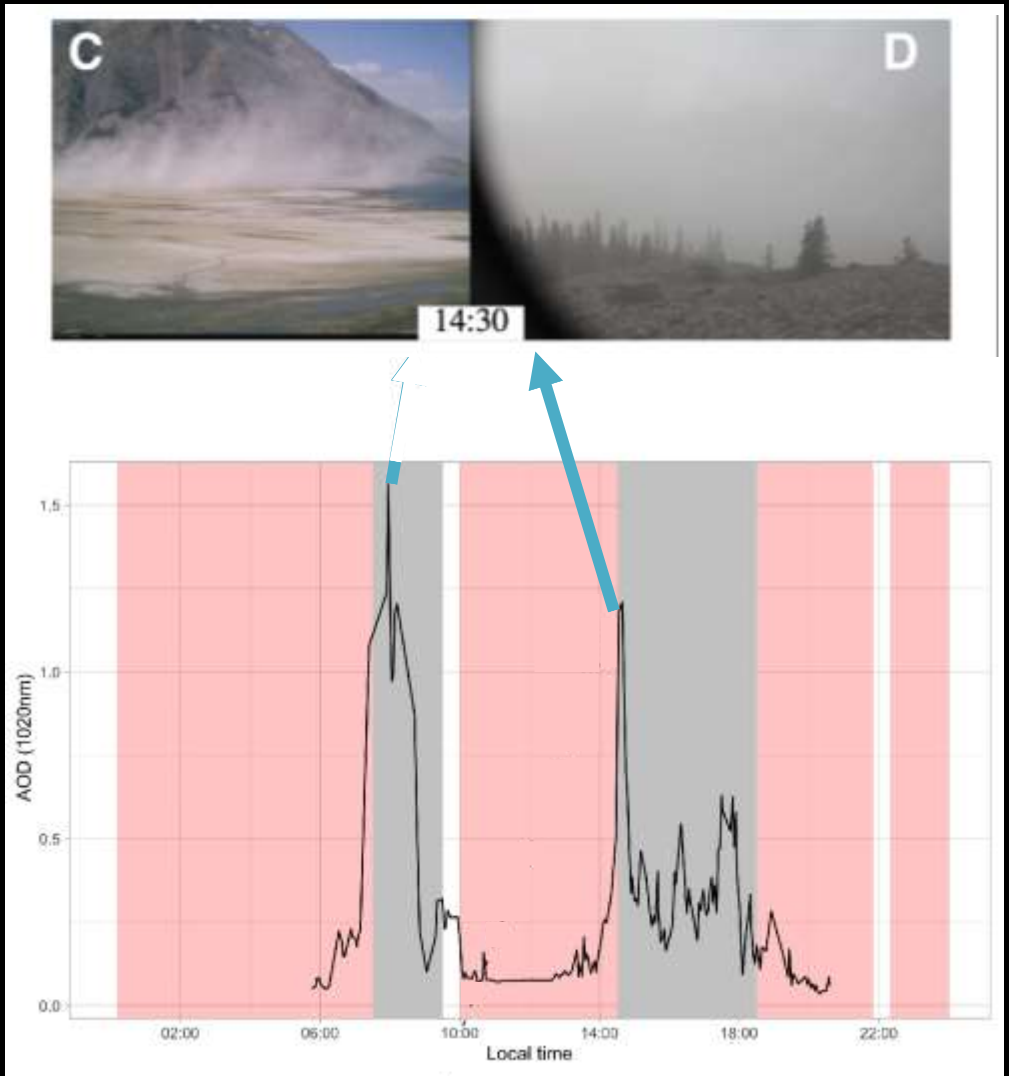
Muhs et al., 2018

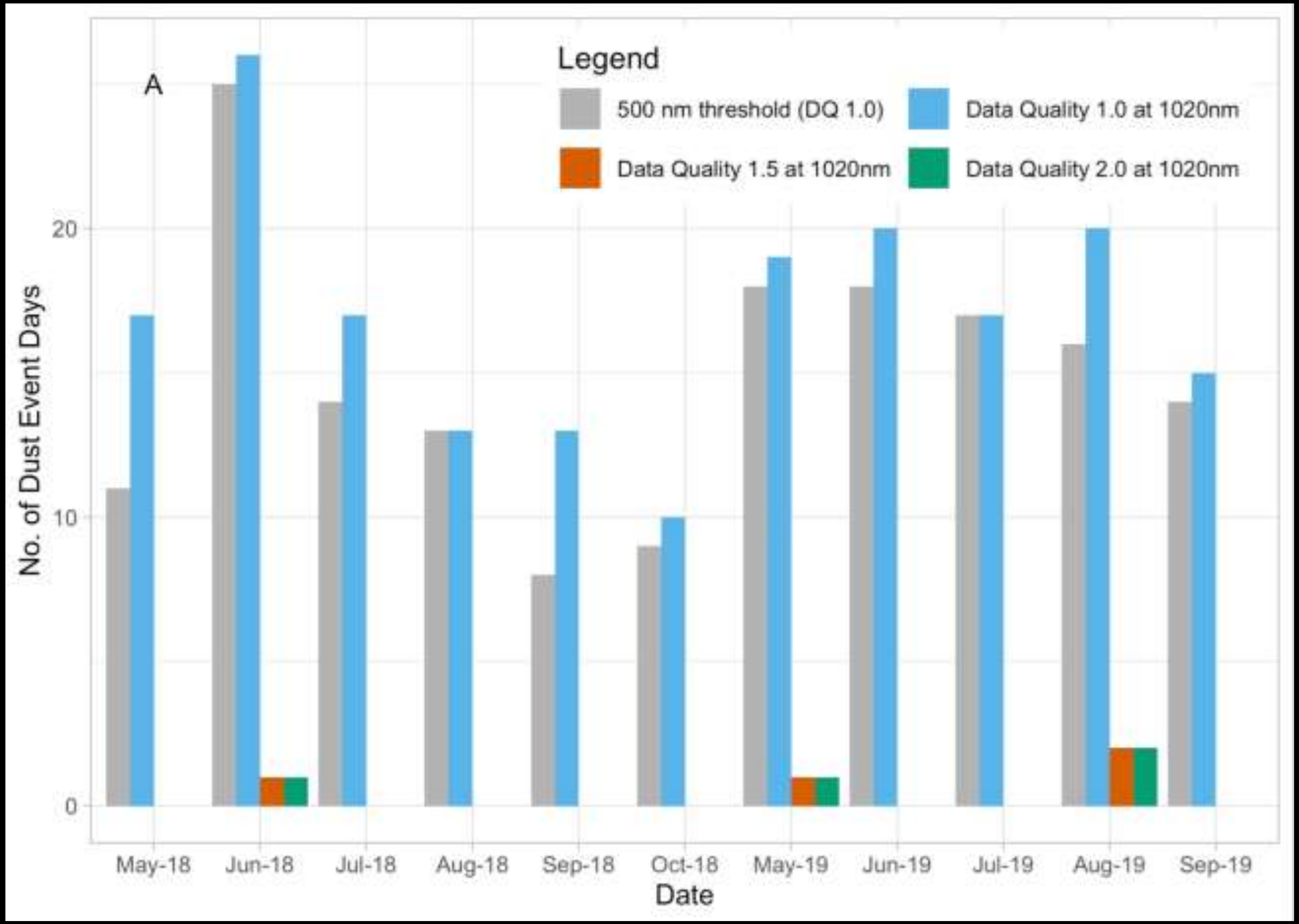
Ongoing Projects

1. HLD Detection
2. HLD Emission Dynamics
    a) Erodibility
    b) Erosivity
3. Modelling HLD

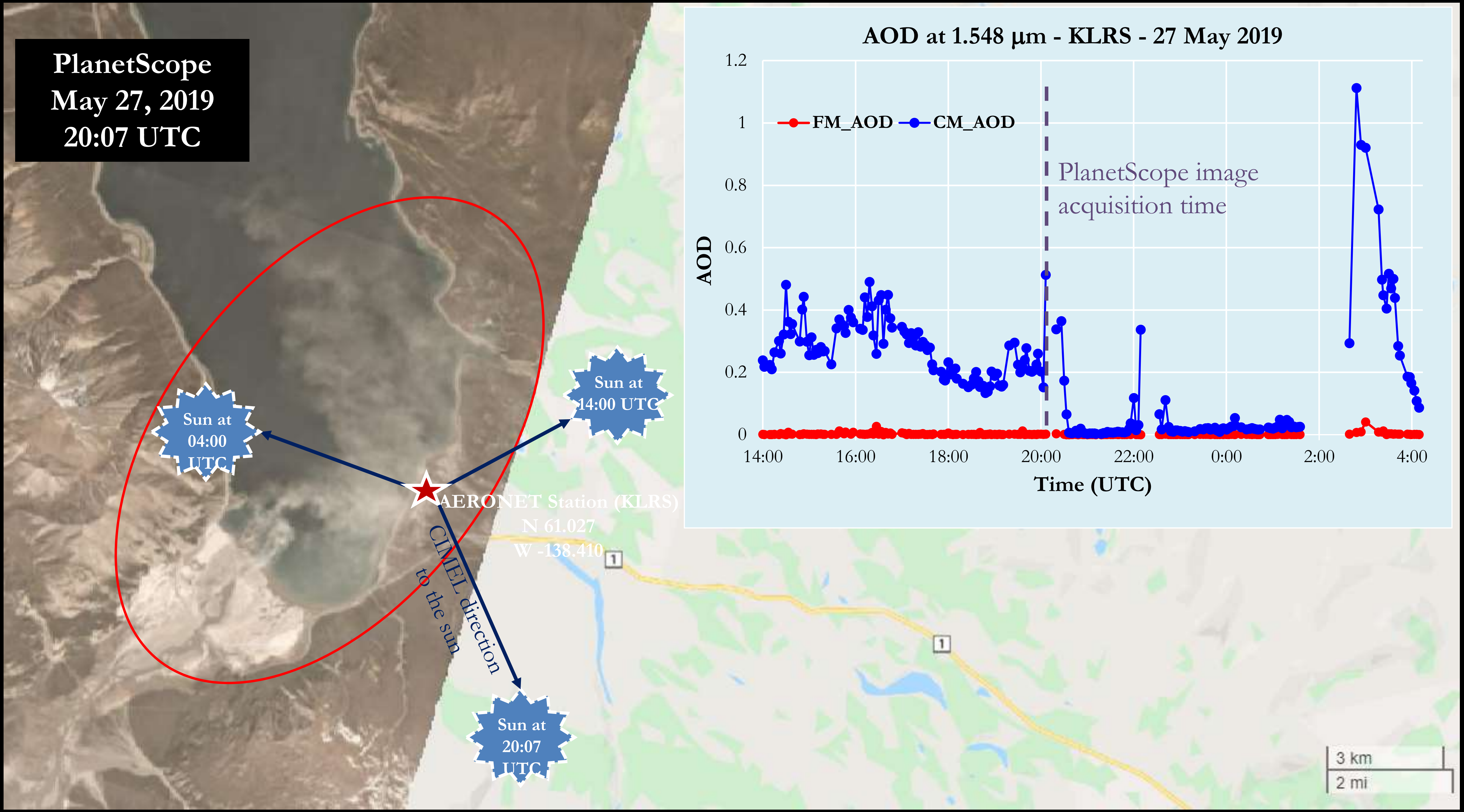
1. HLD Detection

HLD Detection: Method limitations

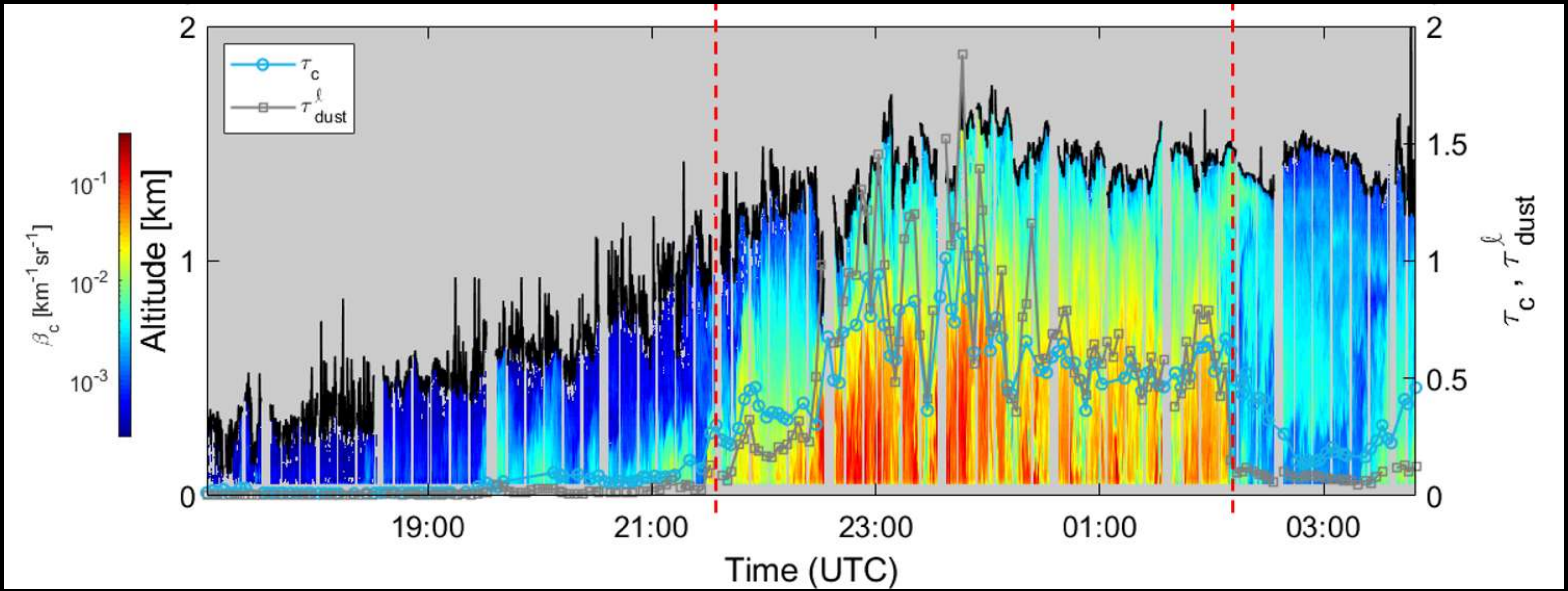




Huck et al. 2023

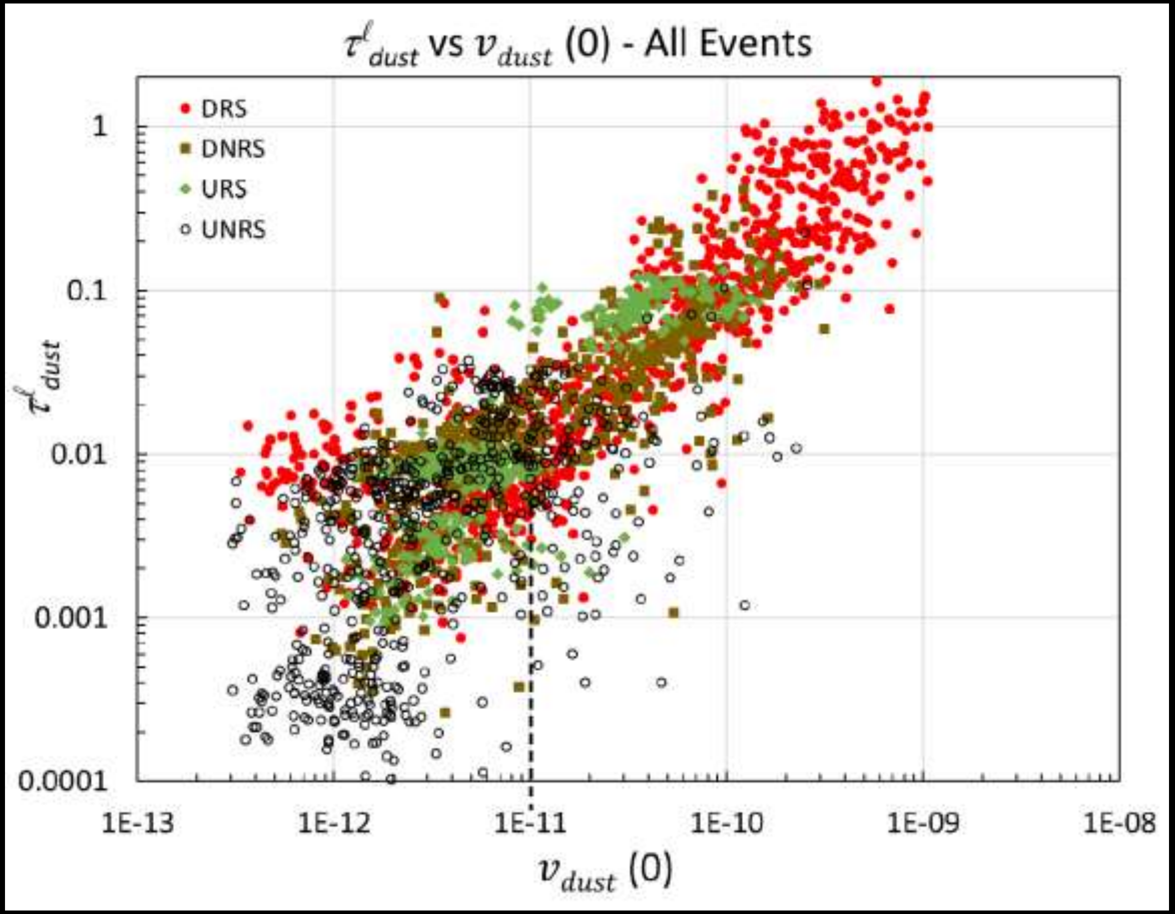

PlanetScope
May 27, 2019
20:07 UTC
Sun at 04:00 UTC
Sun at 14:00 UTC
Sun at 20:07 UTC
AERONET Station (KLRS)
N 61.027
W -138.410
CIMEL direction to the sun
AOD at 1.548 μm - KLRS - 27 May 2019
FM_AOD
CM_AOD
PlanetScope image acquisition time
AOD
Time (UTC)
1.2
1
0.8
0.6
0.4
0.2
0
14:00
16:00
18:00
20:00
22:00
0:00
2:00
4:00
3 km
2 mi

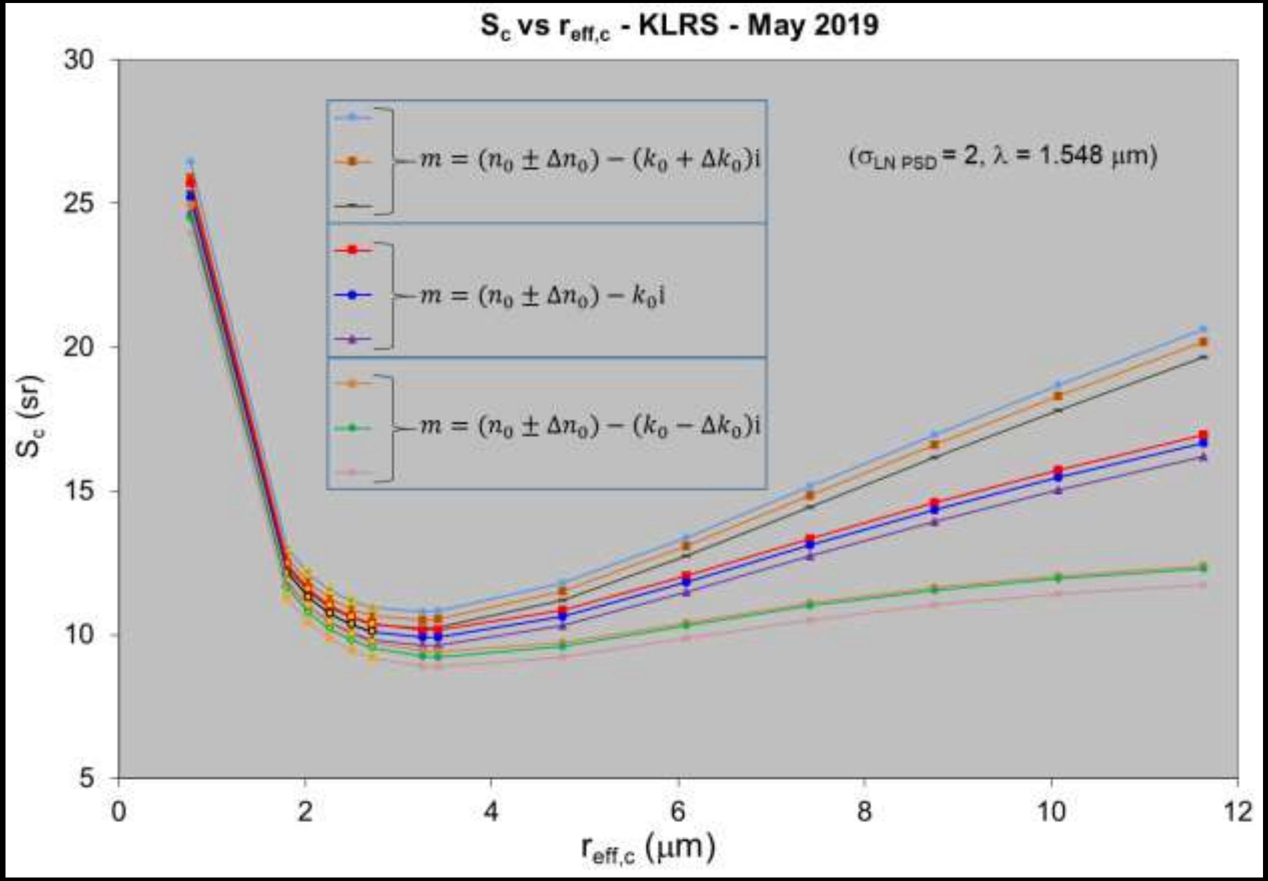
HLD Detection: Instrument limitations



Sayedain et al. 2023

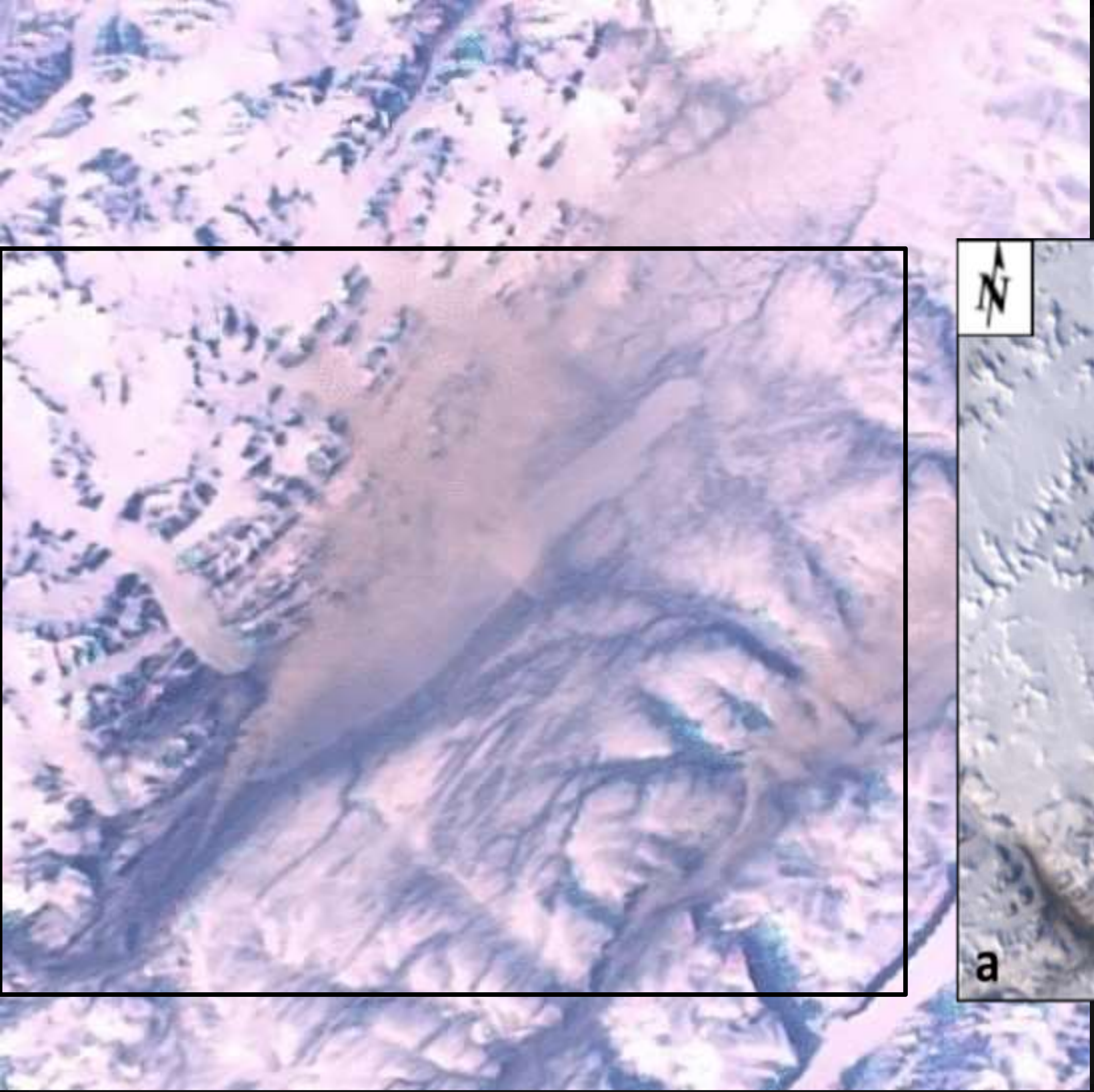
HLD Detection: Instrument limitations



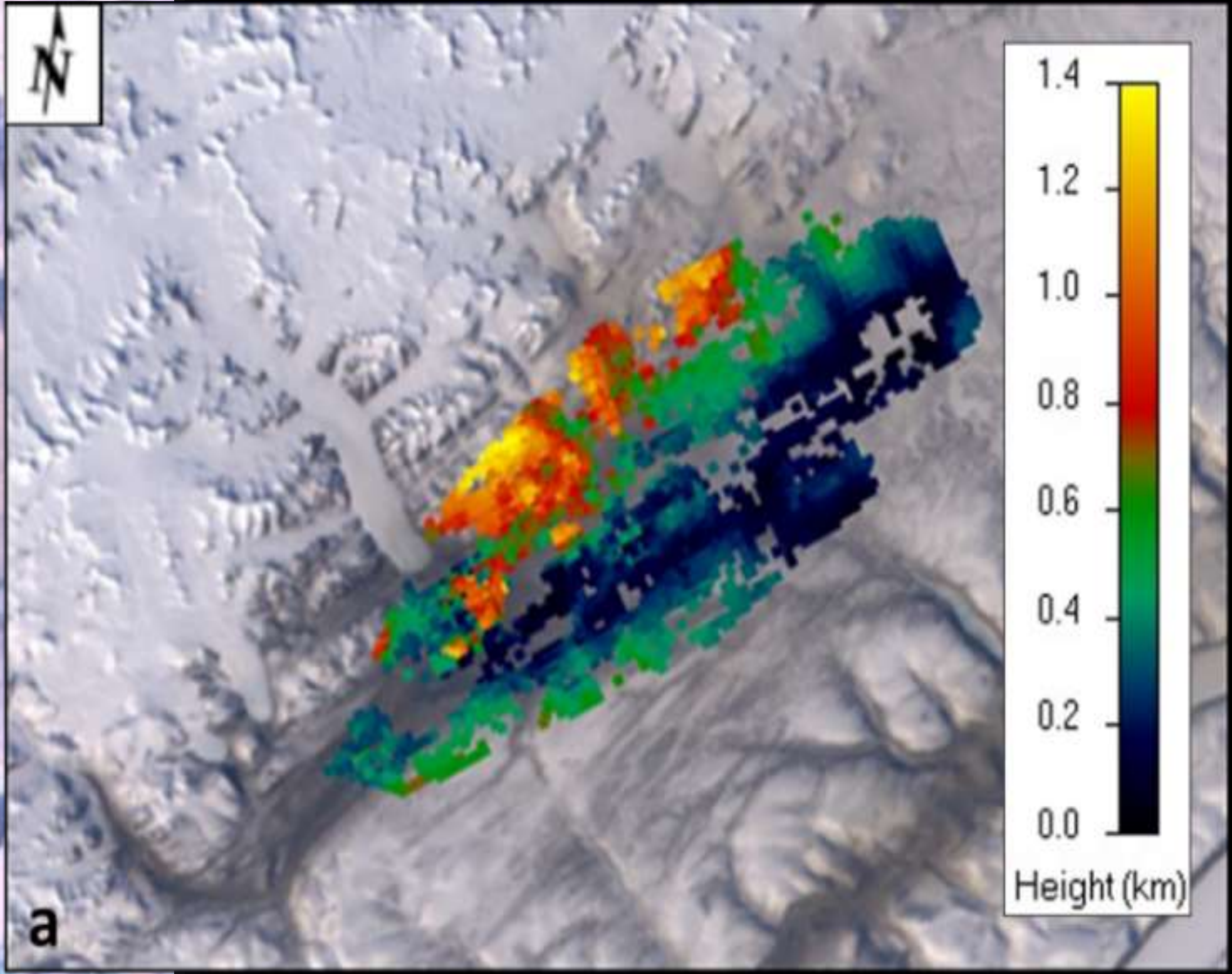


Sayedain et al. 2023

HLD Detection (successful)



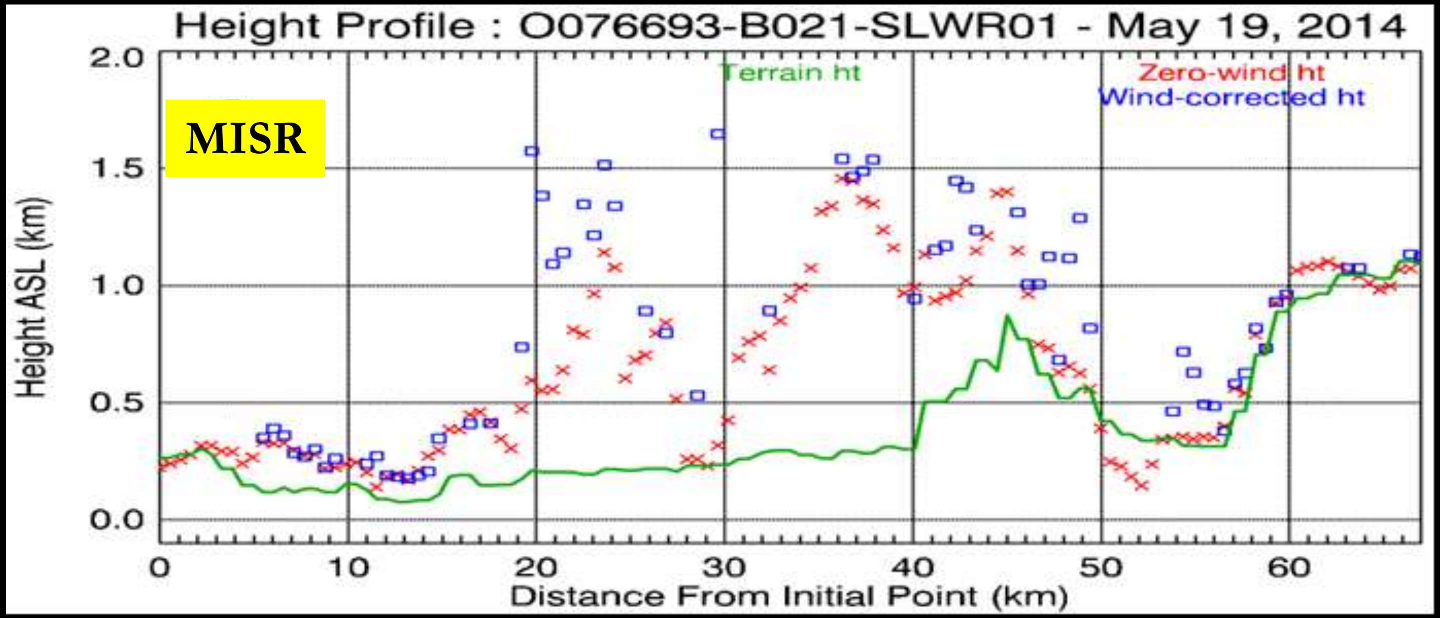
Lake Hazen

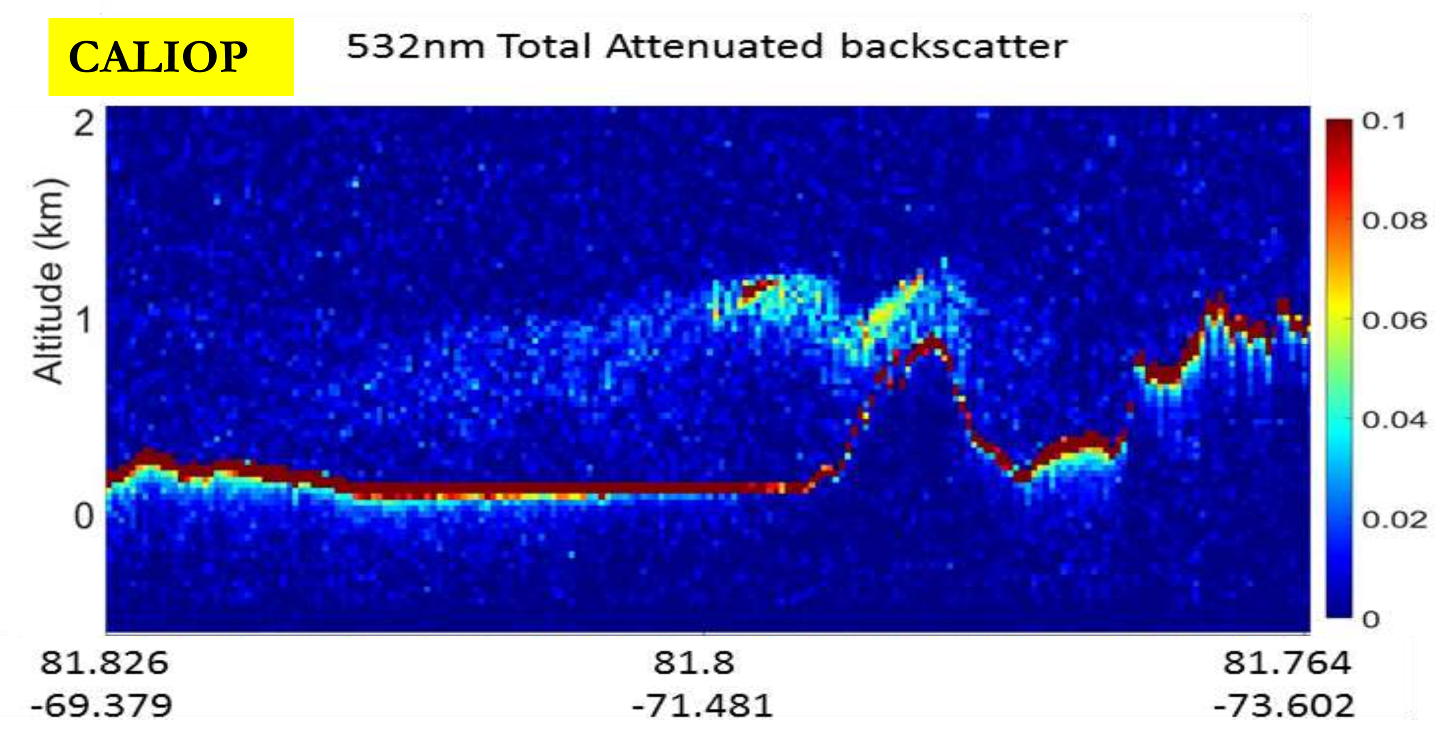


(Ranjbar et al. 2021)

Dust plume height retrieval

- Zero-velocity wind heights (red x)
- Wind-corrected heights (blue rectangles)
- Terrain height (green line)
- Total attenuated backscatter and depolarization ratio confirm the existence of the dust plume
- Median plume effective radius 8.82 (±1.43) μm

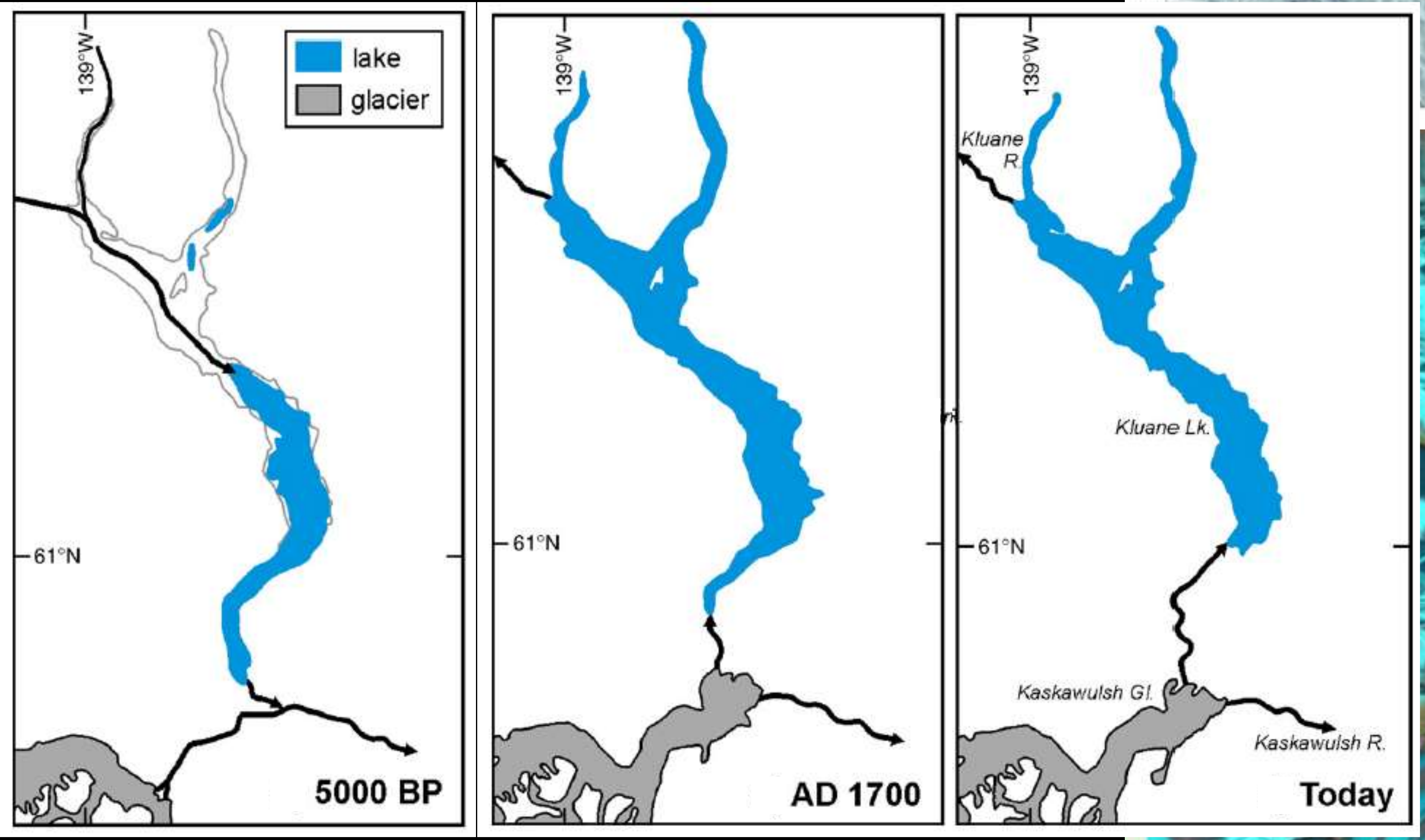




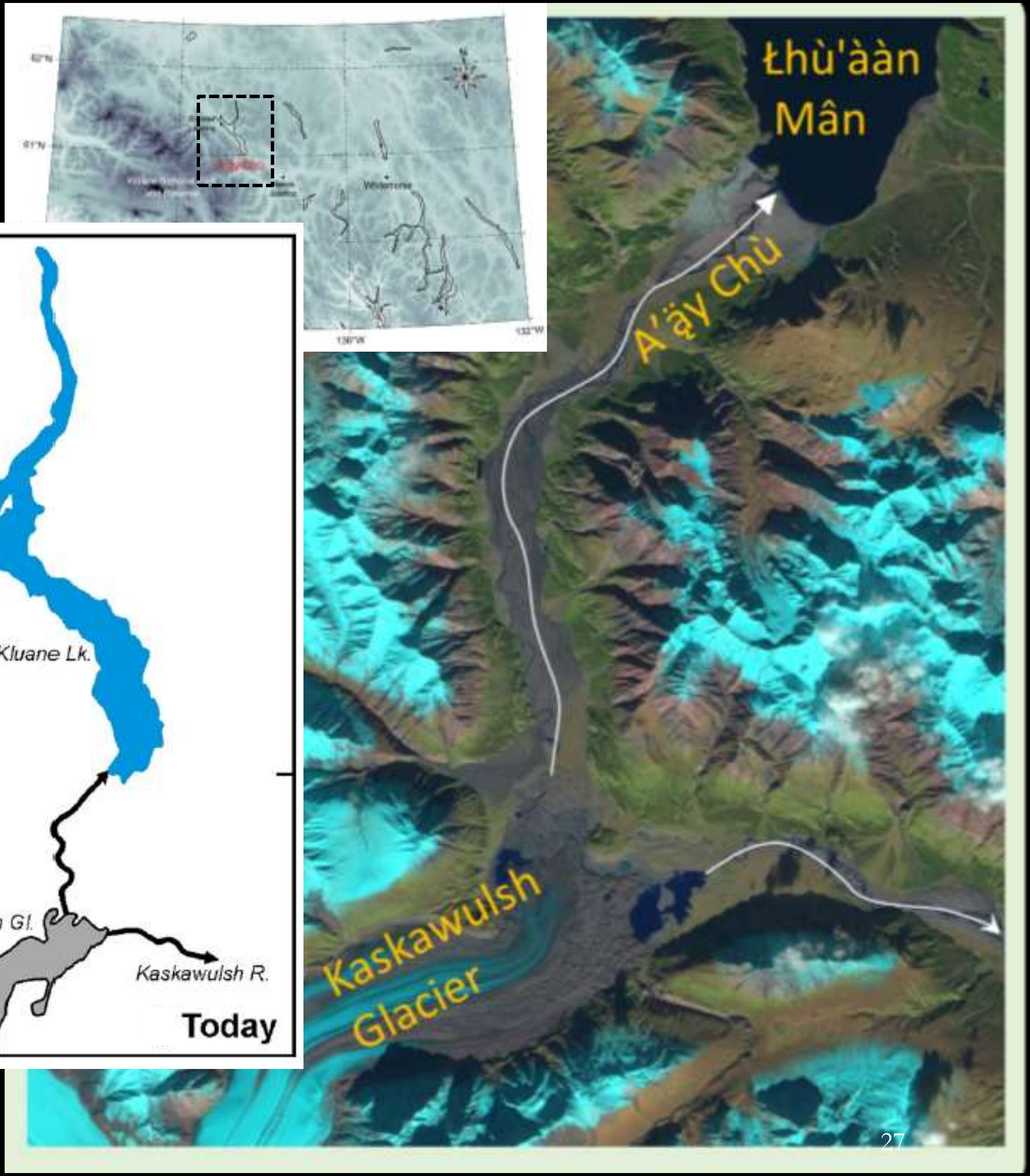
(Ranjbar et al. 2021)

2. HLD Emission Dynamics

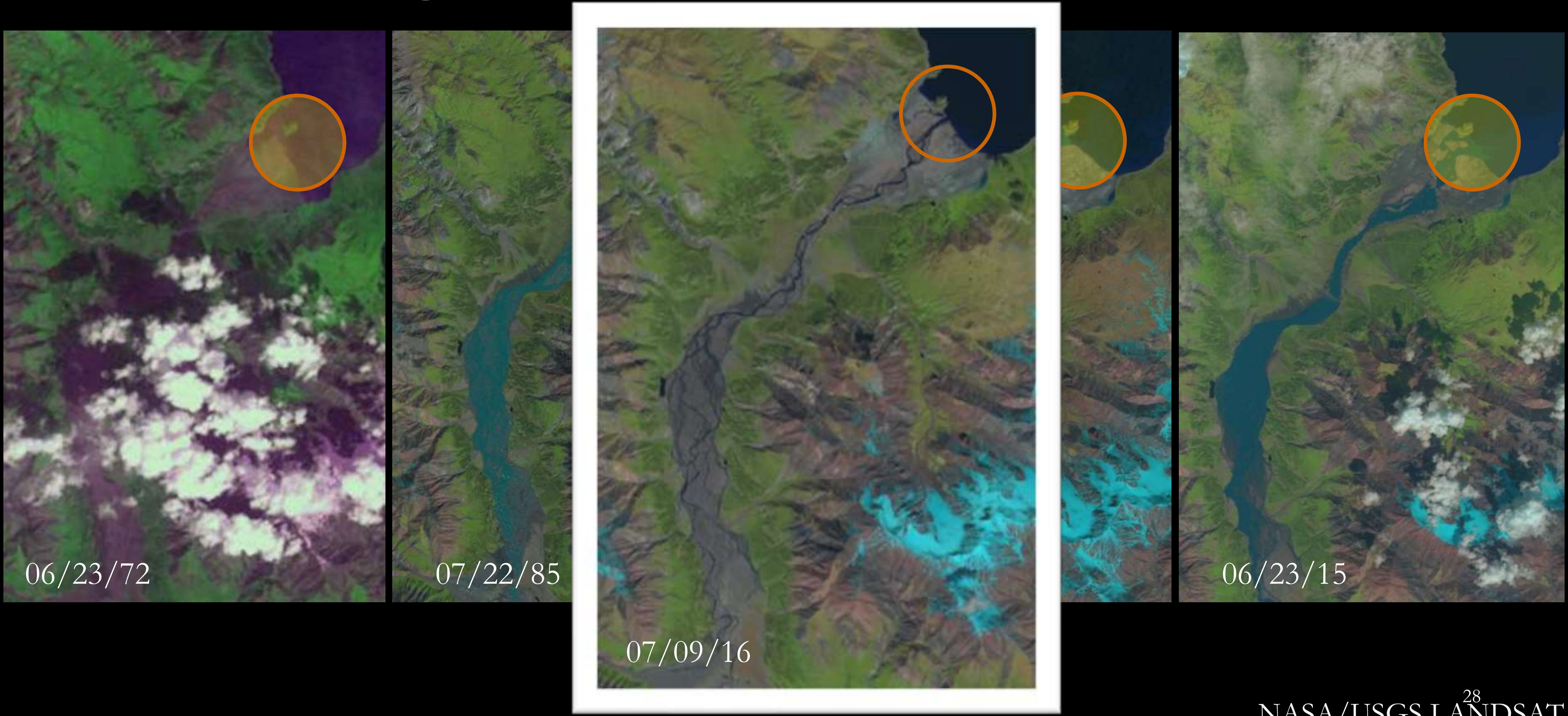
Ä'äy Chù (Slims River)



Clague et al., 2006



Changes over the last several decades



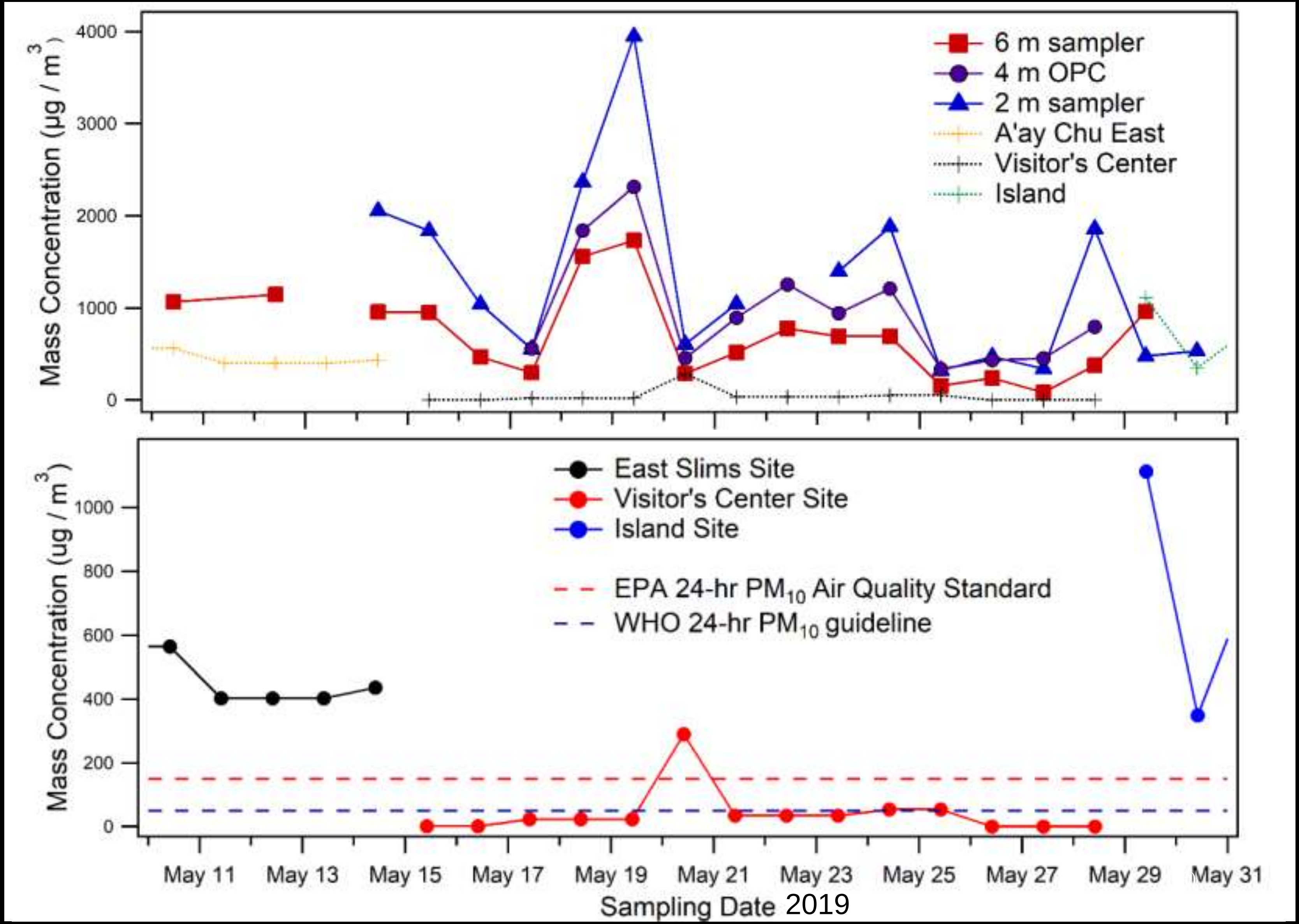
NASA/USGS LANDSAT

HLD Emission Dynamics : A’äy Chù Instrumentation

- FAI OPCs (4 Hz; 0.28 – 10μm)
- ARA Minivols (filter; 17 LPM)
- CSAT 3B Sonic anemometers
- Cimel AERONET photometer
- Halo Photonics Lidar (1.548 μm)
- Supporting meteorology

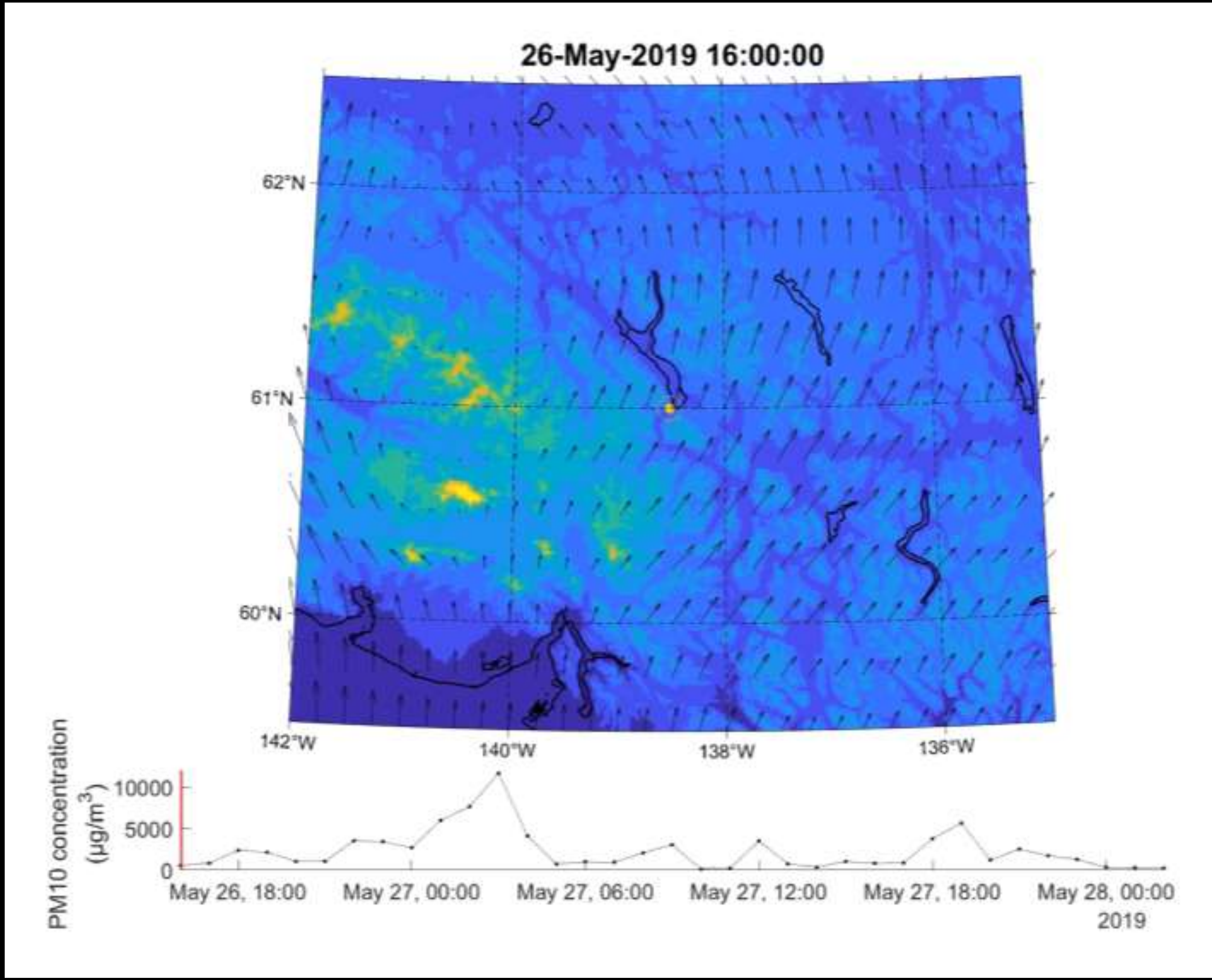
HLD Emission Dynamics: Erodibility

- Surface conditions remain most important factor
- Spalling/auto-abrasion of saltators important for dust production
- Soil moisture & roughness limiting factors

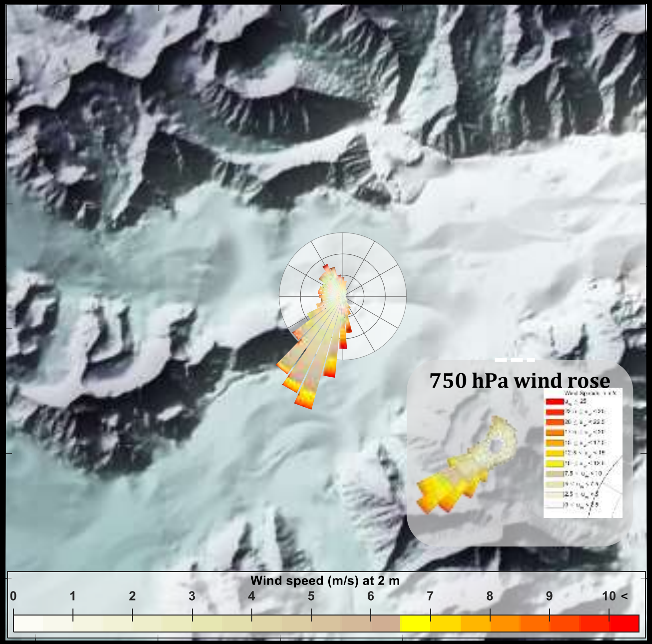


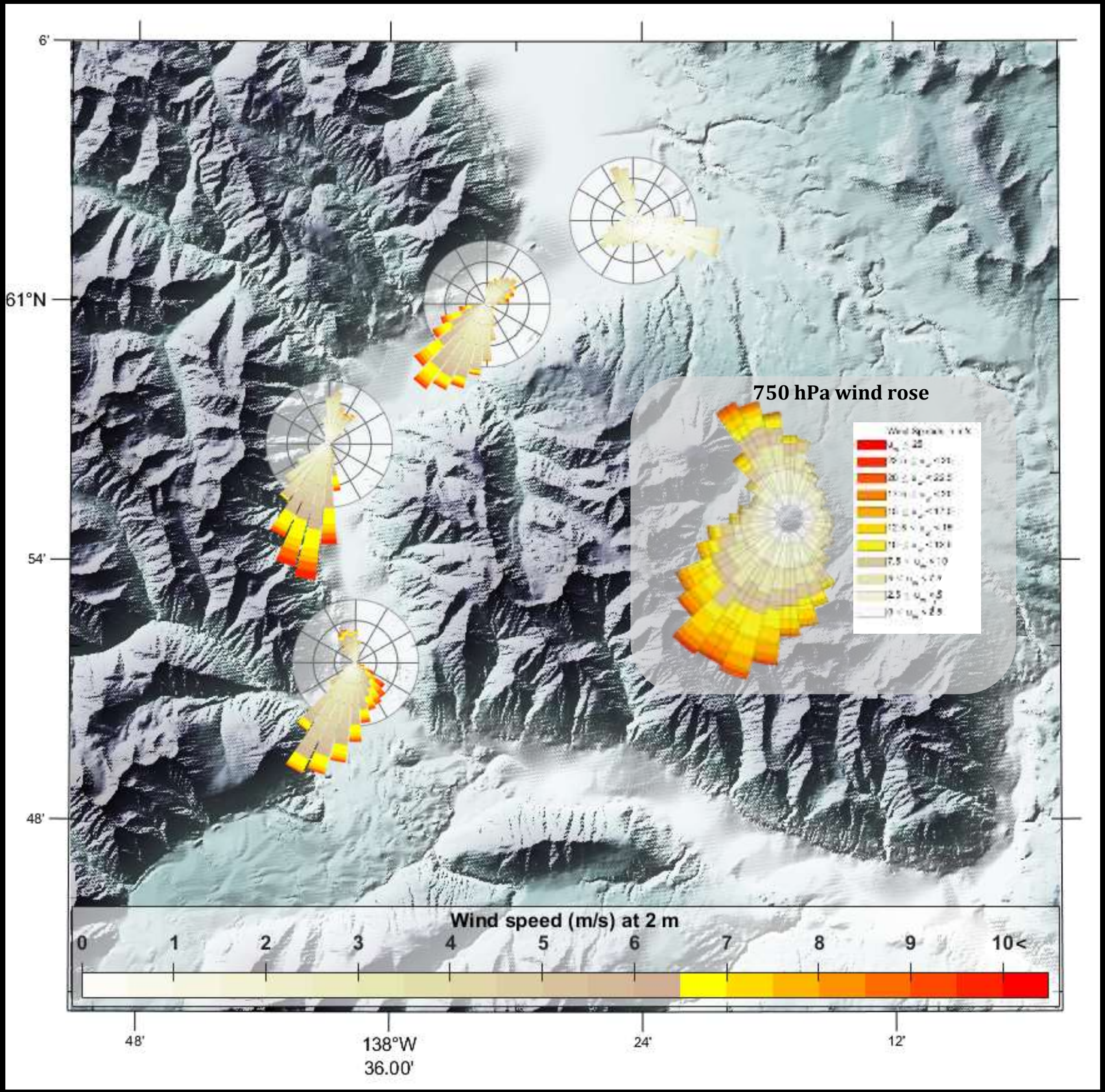
(Bachelder et al. 2020)

HLD Emission Dynamics: Erosivity



HLD Emission Dynamics: Erosivity





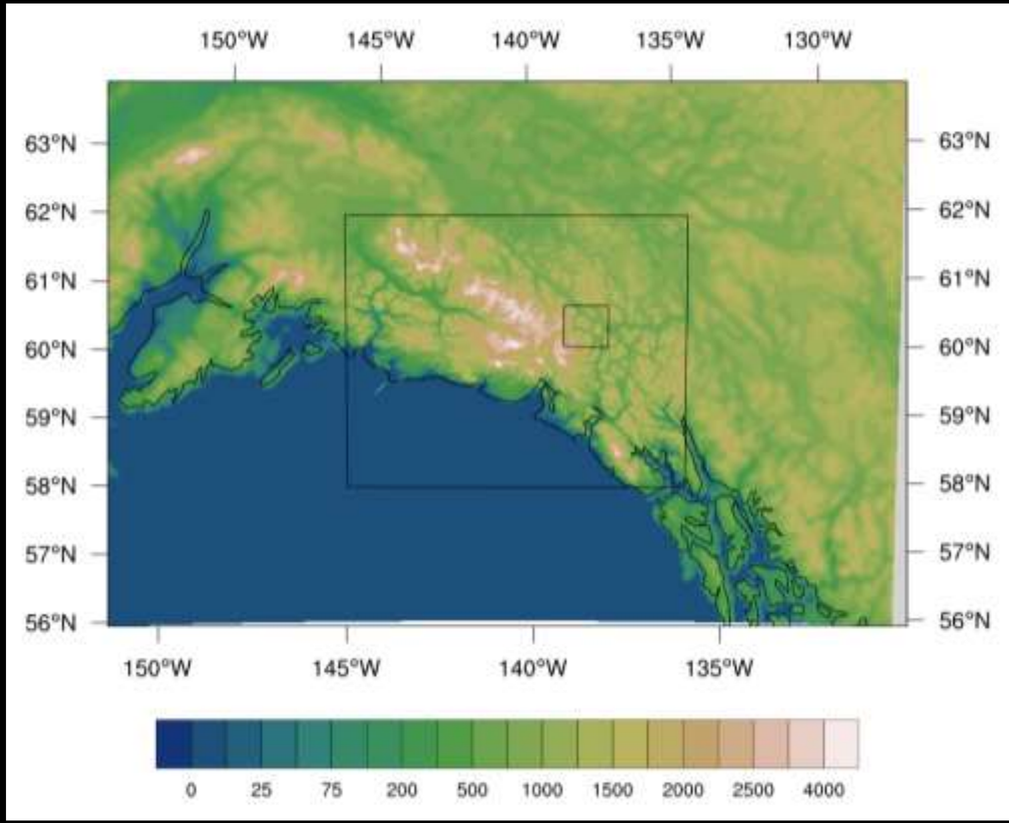
3. Modelling HLD

WRF-CHEM v.4.4.2

Weather Research and Forecasting (WRF) coupled with Chemistry

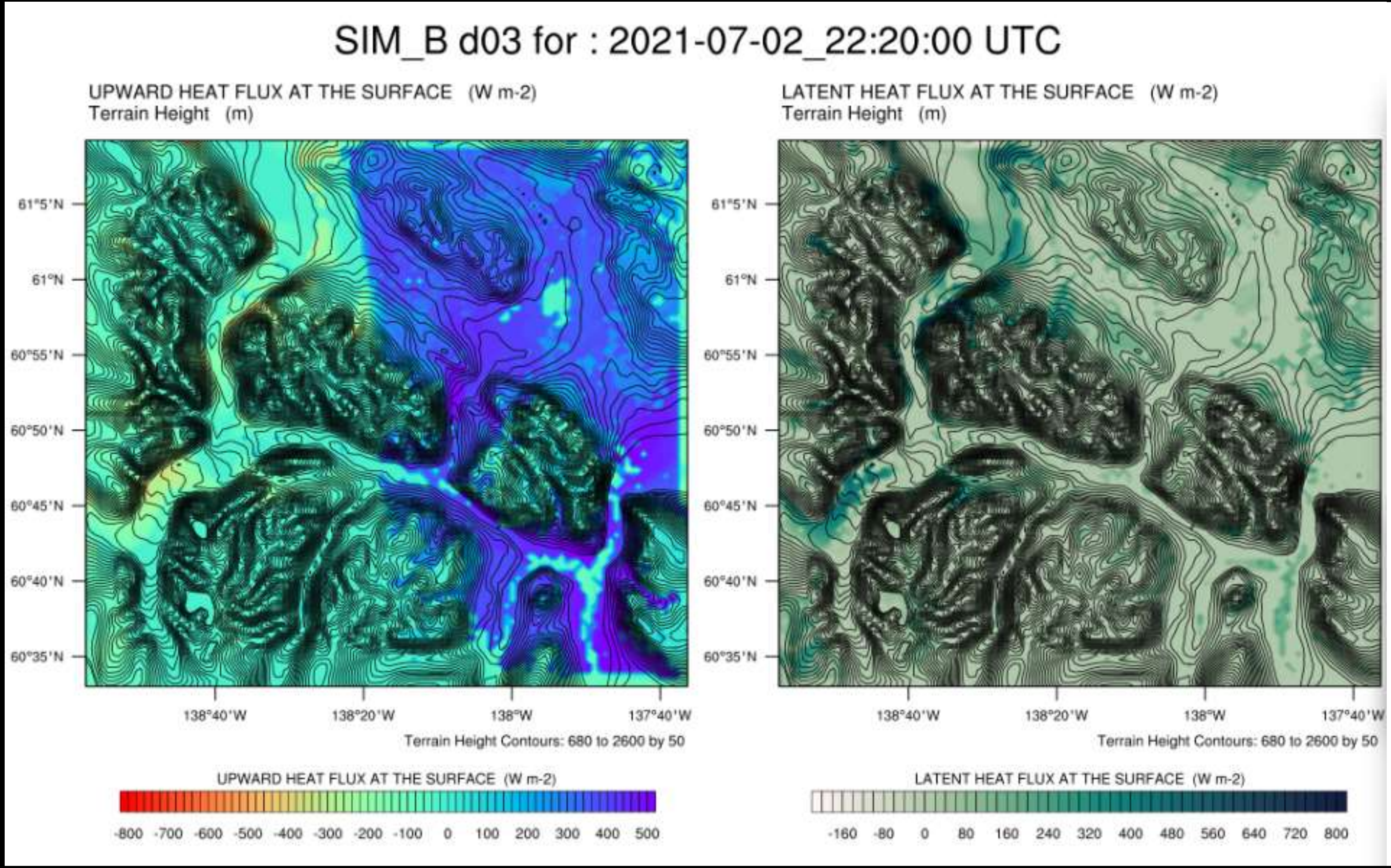
Mesoscale numerical weather prediction system used for atmospheric research and forecasting.

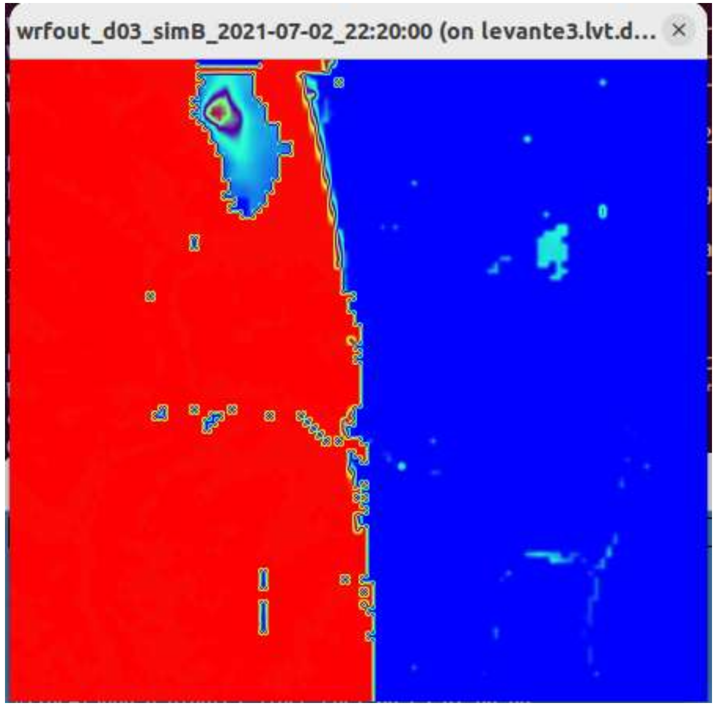
WRF-CHEM (v4.4.2)	
Input	ERA5 reanalysis, 1hr, 0.25°x0.25°x38
Domain	Dx/dy (m): 6000/2000/666. Dims: [222, 152, 52], [283, 226, 52], [112, 103,52].
Land use	NALCMS 2015 (NALCMS, 2022) 30 m product adapted to MODIS classifications already integrated into WRF. Present day water cover identification following Feyisa et al. (2014) used to correct land use in the A'ą̈y Chu and Kaskawulsh valleys, and the glacier moraine region.
Microphysics	Thompson: Thompson et al. (2008)
Radiation schemes	RRTMG: Iacono et al. (2008). Slope radiation and topographic shading active.
Land surface scheme	Noah LSM
Surface layer	Revised MM5 (Jiminez et al. 2012)
PBL	SH: Shin-Hong (2015)



Extensive static data preparation required:
- Topography
- Land use
- Soil texture

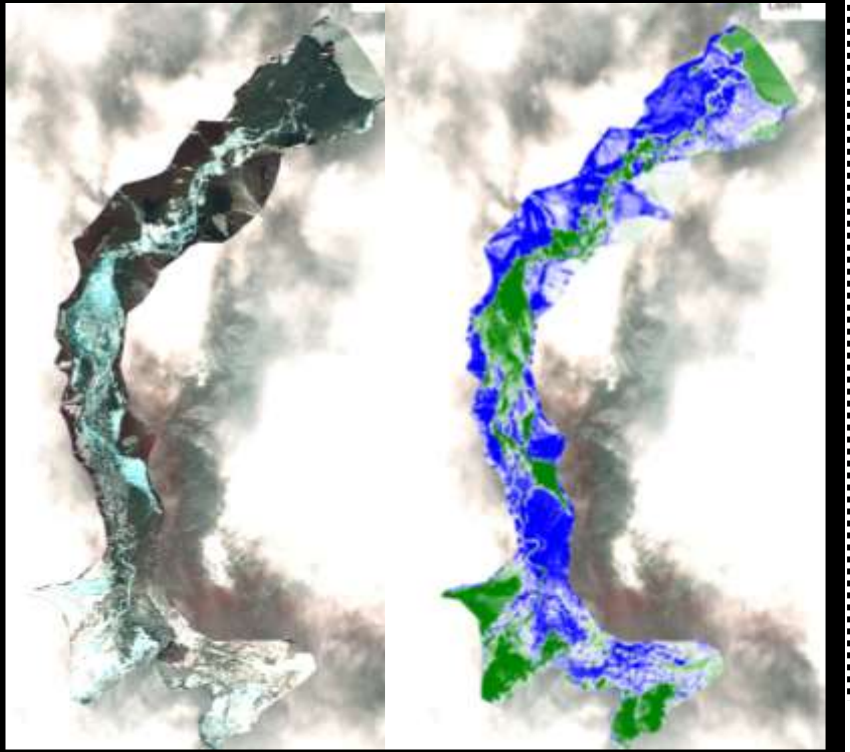
Modelling HLD: Inputs

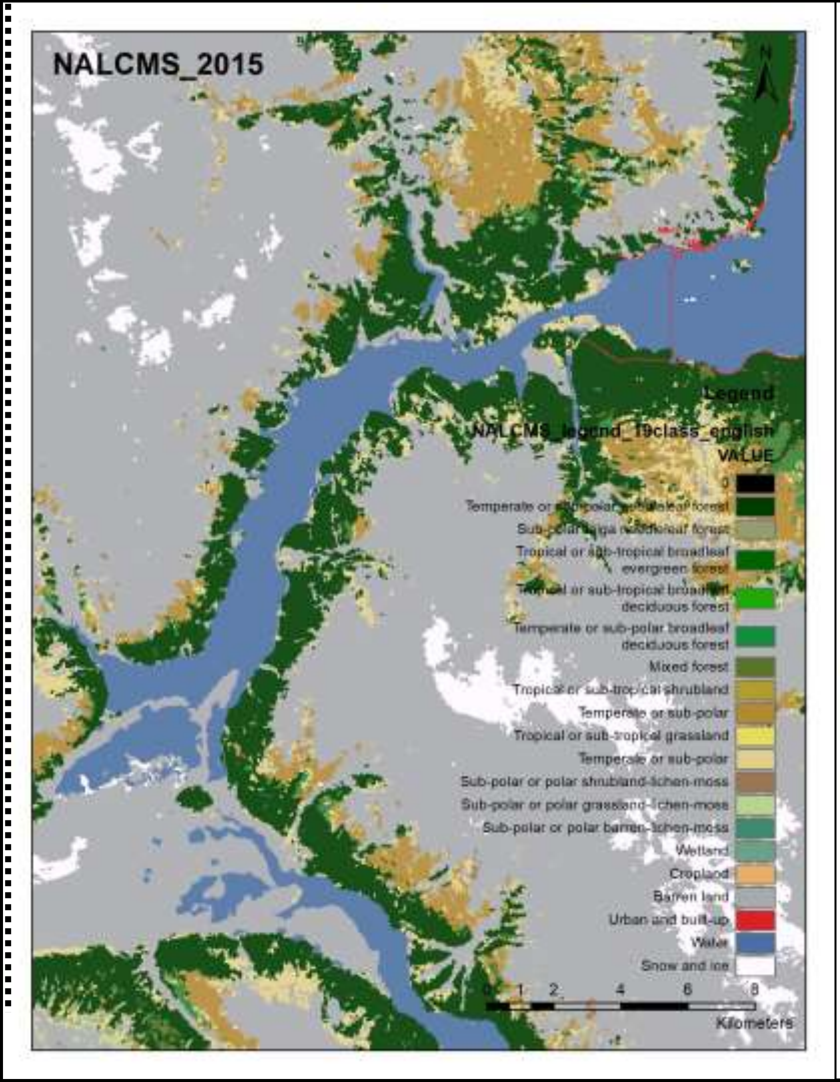


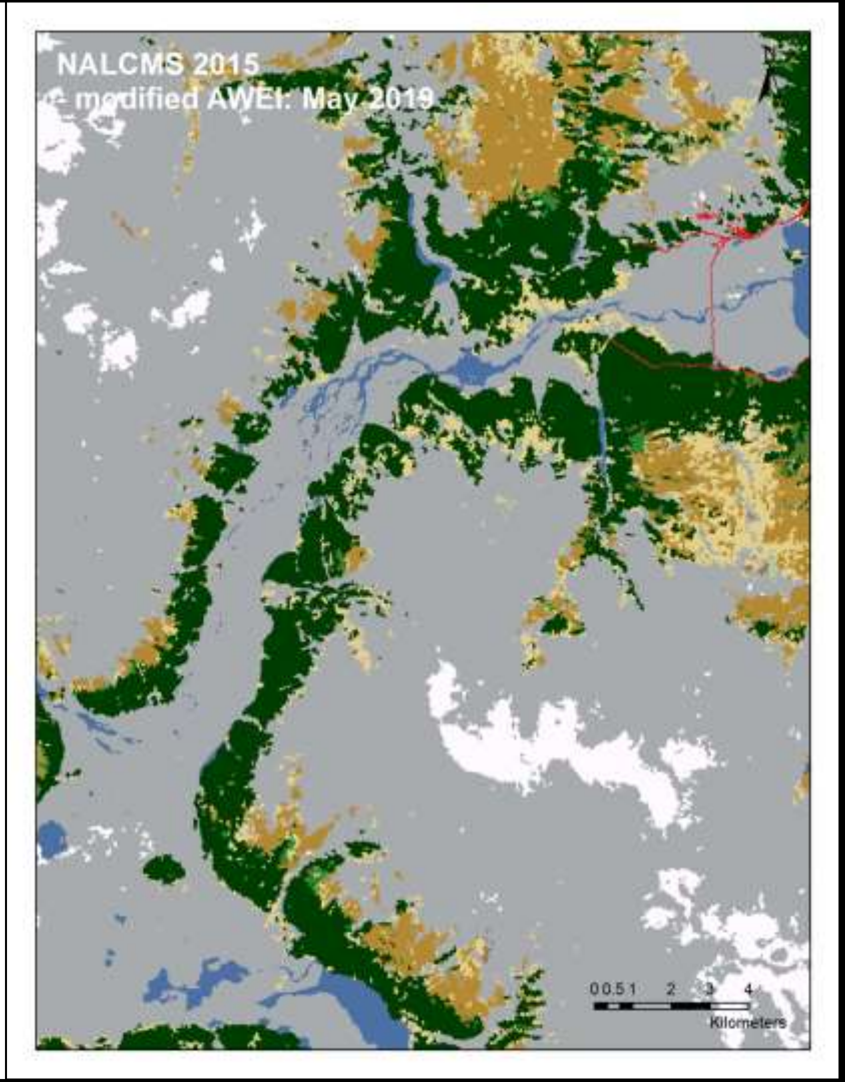


HLD Modelling: Inputs

Land use correction

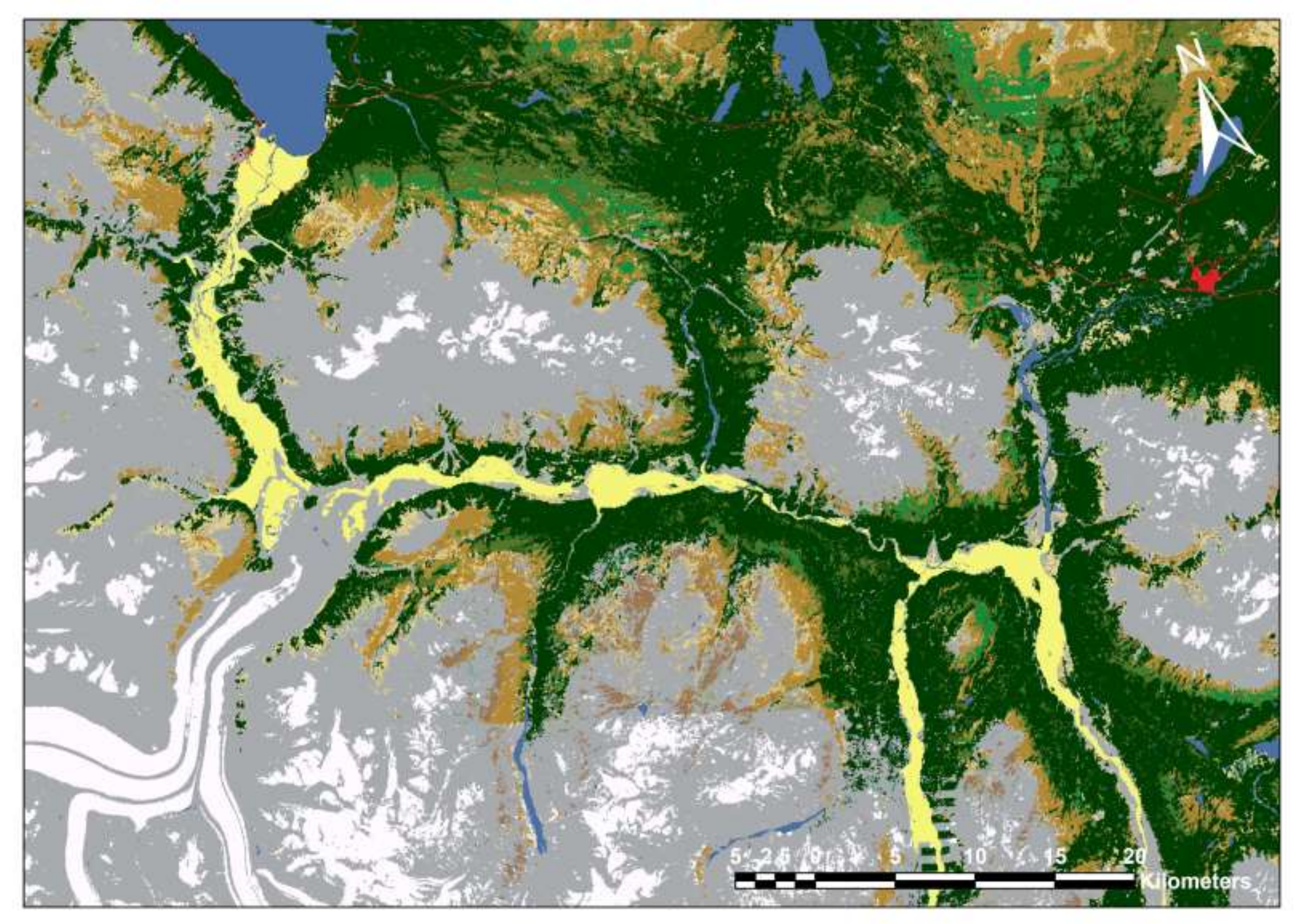




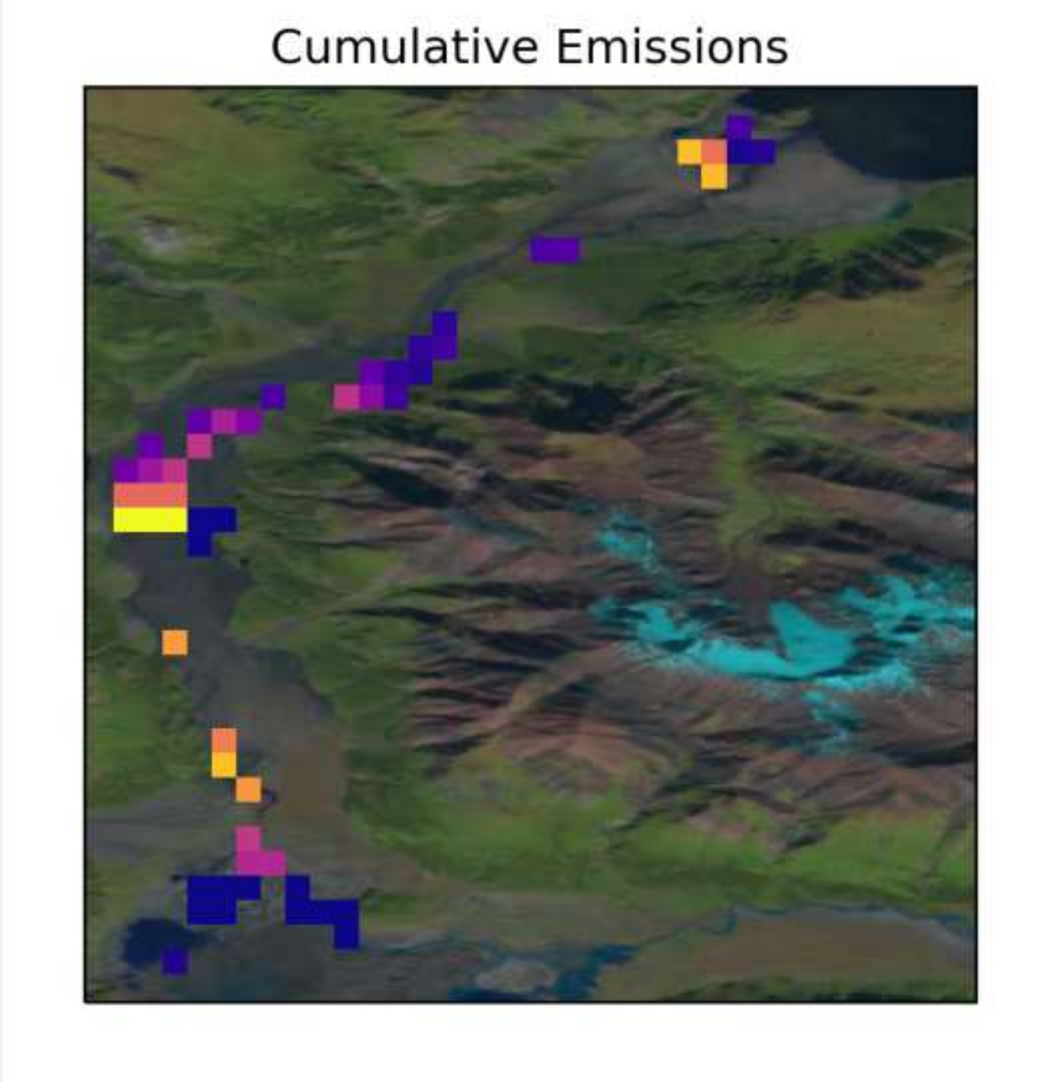


Example for A'ą̈y Chù valley May 2019. Applied to all valleys in domain 3.

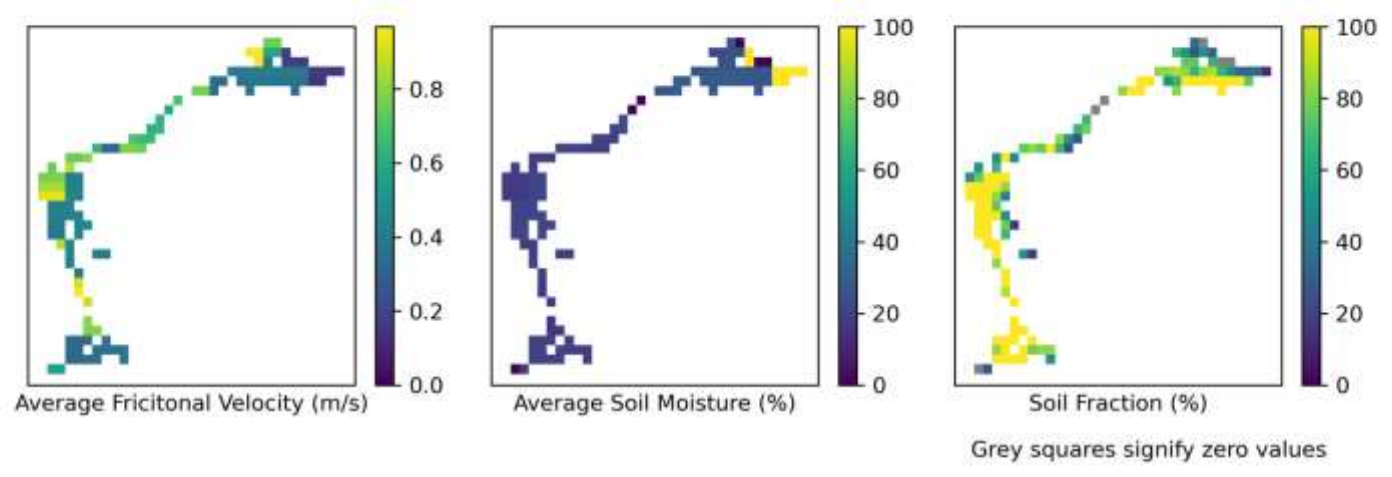
HLD Modelling: Inputs



HLD Modelling: Outputs



- FLEXDUST with FLEXPART-WRF
- Temporally correlated results
- Magnitudes and source areas need further improvement



Thanks for your attention !

Photo: Lance Goodwin

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Fonds de recherche – Santé
Fonds de recherche – Société et culture
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