Biomass and NDVI circumpolar relationship

Martha Raynolds
D.A. (Skip) Walker
Howard Epstein*
Marcel Buchhorn

Alaska Geobotany Center
Institute of Arctic Biology
University of Alaska Fairbanks

*University of Virginia

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Outline of presentation

Circumpolar relationship between arctic biomass and NDVI

Where did these numbers come from?

- NDVI data – two AVHRR data sets

- Biomass data

  - Two arctic transects
    Site selection and scale – Skip Walker, Howie Esptein

  - Biomass methods
    Harvesting biomass
    Sorting biomass

  - Issues with sampling biomas
    Defining live vs. dead
    Contamination with dust, soil

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A new estimate of tundra-biome phytomass from trans-Arctic field data and AVHRR NDVI

MARTHA K. RAYNOLDS*†, DONALD A. WALKER†, HOWARD E. EPSTEIN‡, JORGE E. PINZON§ and COMPTON J. TUCKER§
†Institute of Arctic Biology, University of Alaska, Fairbanks, AK 99775, USA
‡Department of Environmental Sciences, University of Virginia, Charlottesville, VA 22904, USA
§Biospheric Science Branch, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

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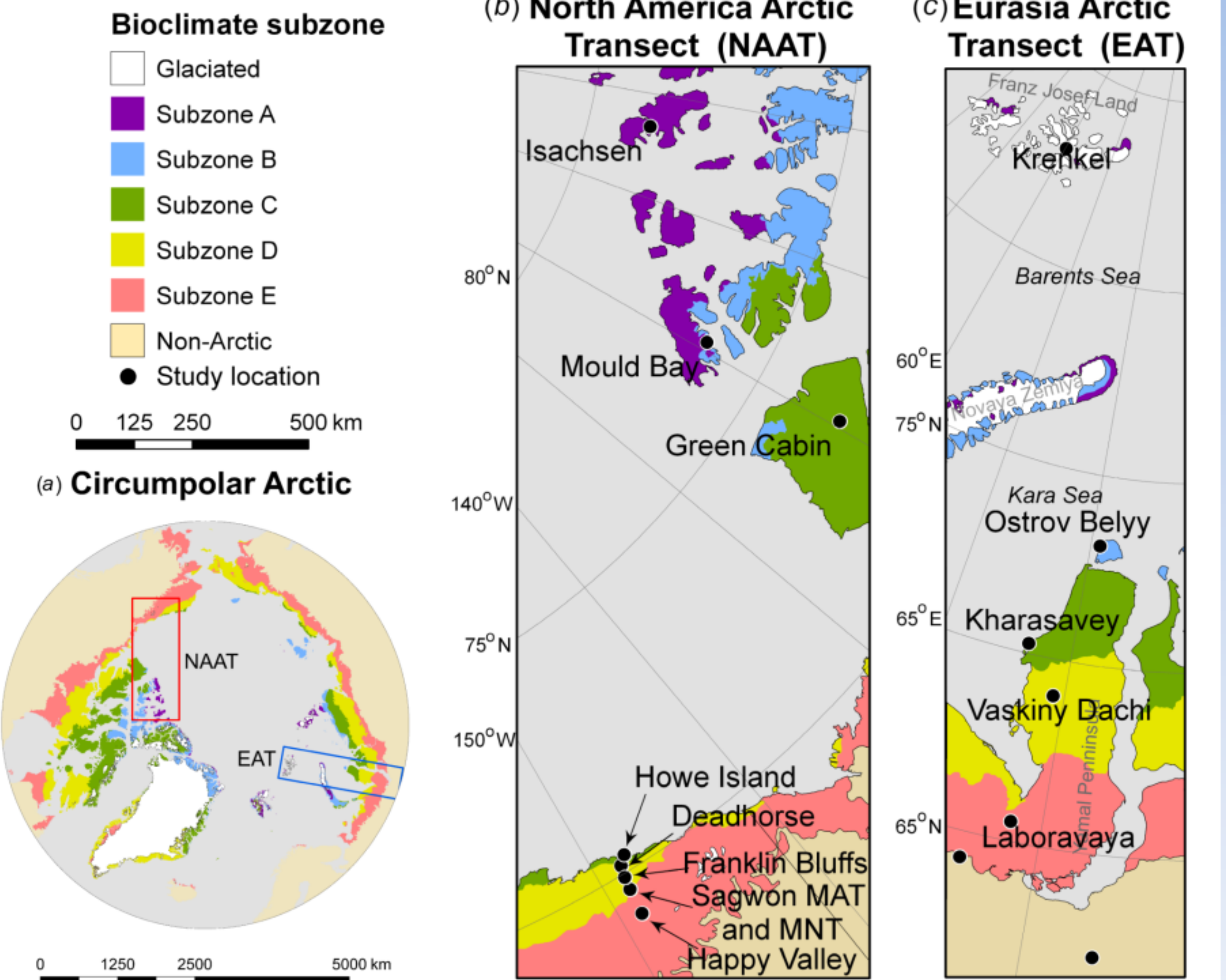
It is often assumed that the Normalized Difference Vegetation Index (NDVI) can be equated to aboveground plant biomass, but such a relationship has never been quantified at a global biome scale. We sampled aboveground plant biomass (phytomass) at representative zonal sites along two trans-Arctic transects, one in North America and one in Eurasia, and compared these data to satellite-derived NDVI. The results showed a remarkably strong correlation between total aboveground phytomass sampled at the peak of summer and the maximum annual NDVI ($R^2 = 0.94$, $p < 0.001$). The relationship was almost identical for the North America and Eurasia transects. The NDVI–phytomass relationship was used to make an aboveground phytomass map of the tundra biome. The approach uses a new and more accurate NDVI data set for the Arctic (GIMMS3g) and a sampling protocol that employs consistent methods for site selection, clip harvest and sorting and weighing of plant material. Extrapolation of the results to zonal landscape-level phytomass estimates provides valuable data for monitoring and modelling tundra vegetation.

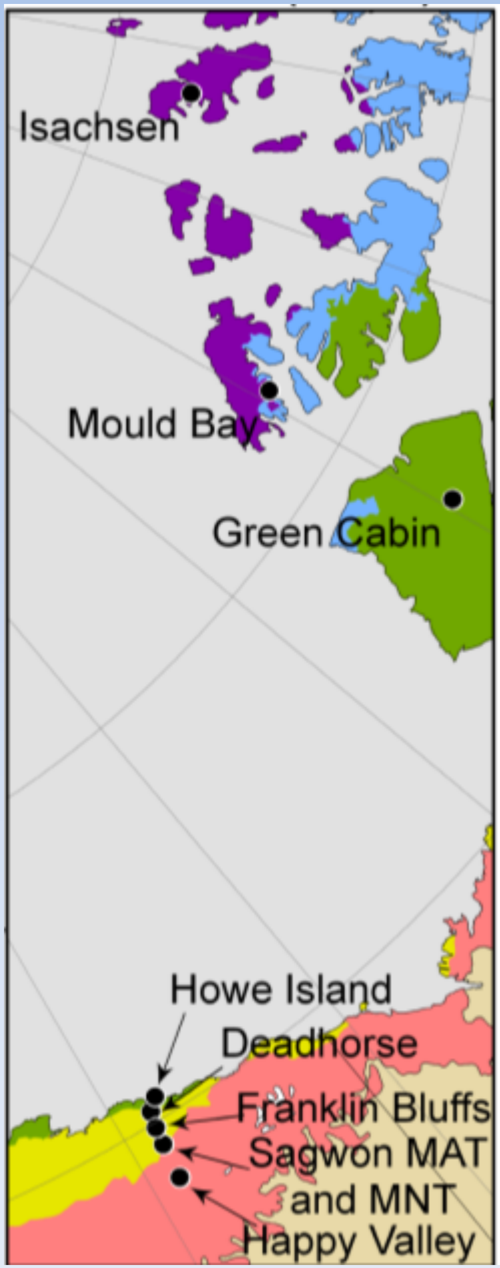
Two arctic transects

North America

Russia



Bioclimate subzone
Glaciated
Subzone A
Subzone B
Subzone C
Subzone D
Subzone E
Non-Arctic
Study location
0 125 250 500 km
(a) Circumpolar Arctic
NAAT
EAT
0 1250 2500 5000 km
(b) North America Arctic Transect (NAAT)
Isachsen
Mould Bay
Green Cabin
Howe Island
Deadhorse
Franklin Bluffs
Sagwon MAT and MNT
Happy Valley
80° N
140° W
75° N
150° W
(c) Eurasia Arctic Transect (EAT)
Franz Josef Land
Krenkel
Barents Sea
Novaya Zemlya
60° E
75° N
Kara Sea
Ostrov Belyy
Kharasavey
65° E
Vaskiny Dachi
Laborovaya
65° N



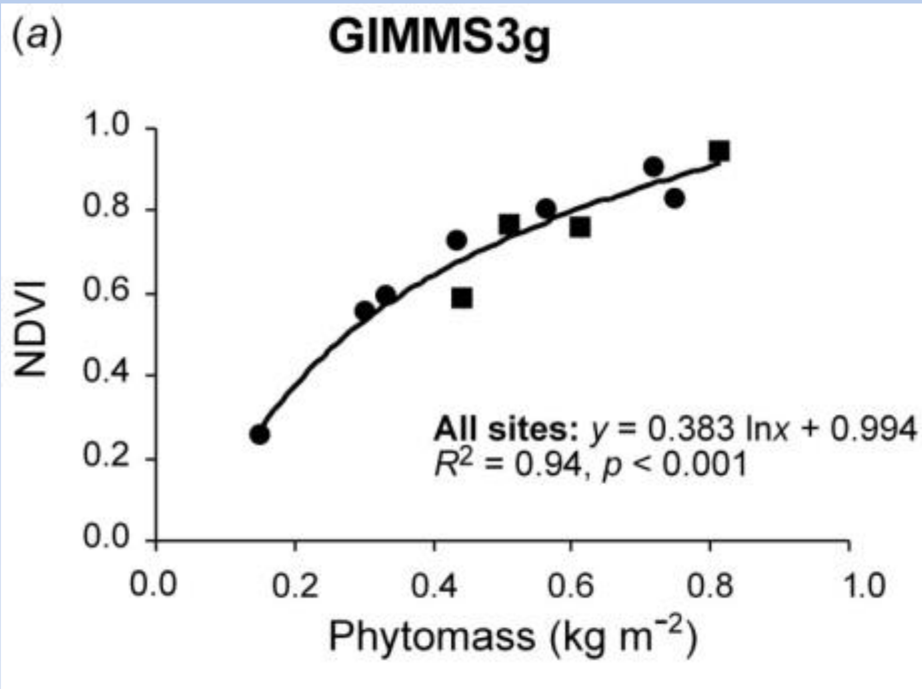
North American Arctic Transect (NAAT)

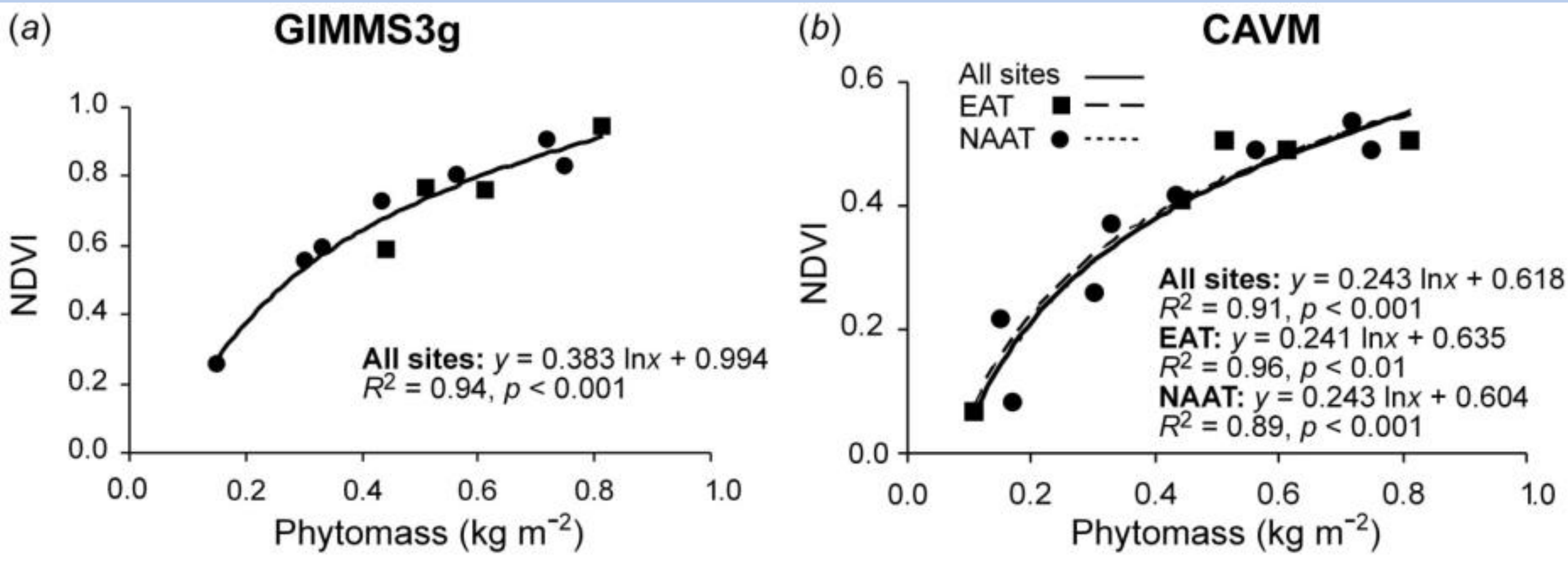
- 1750 km long
- 8 locations
- sampled 2003–2006

Eurasian Arctic Transect (EAT)

- 1500 km long
- 5 locations
- sampled 2007–2010

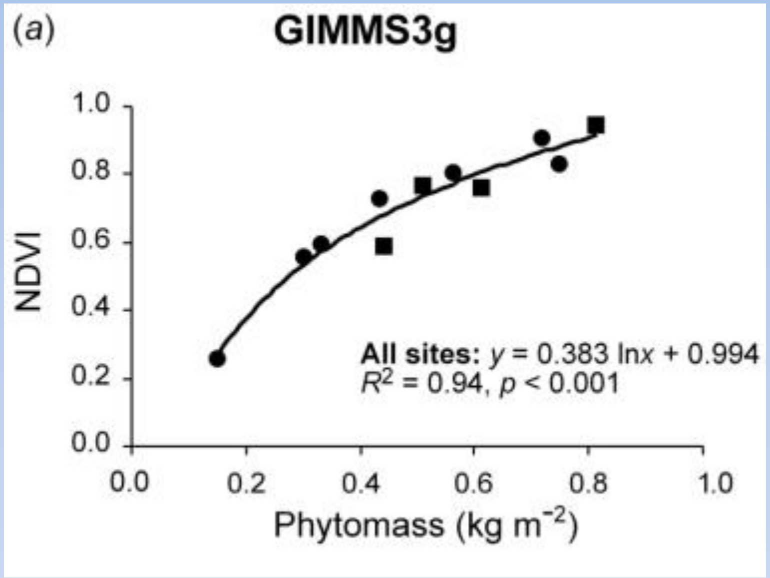
Figure 2(a) Displays two regression lines that are so similar they cannot be distinguished on the graph





Data for figure 2(b) includes northern most sites (Subzone A) on small islands

Sources of AVHRR NDVI data

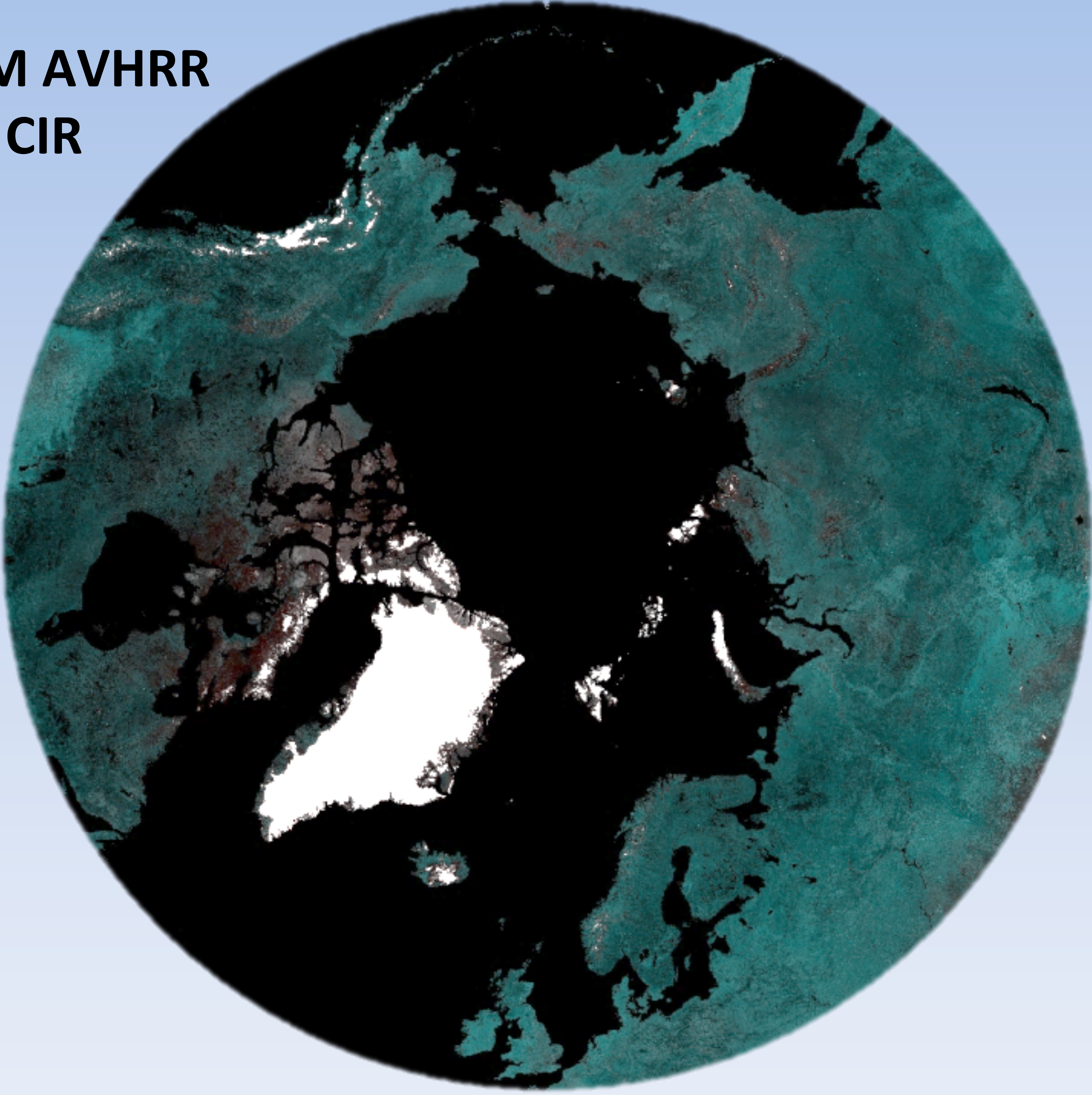


GIMMS3g NDVI data

- Global data set
- 8-km pixel resolution
- NDVI data only (no band data)
- Maximum annual NDVI selected from bi-monthly max NDVI composites
- Data used from AVHRR/3 instruments on NOAA 17 and 18 (2003-2010)

Pinzon J.E. & Tucker C.J. (2014) A non-stationary 1981–2012 AVHRR NDVI3g time series. *Remote Sensing, 6, 6, 6929-6960*

CAVM AVHRR false CIR



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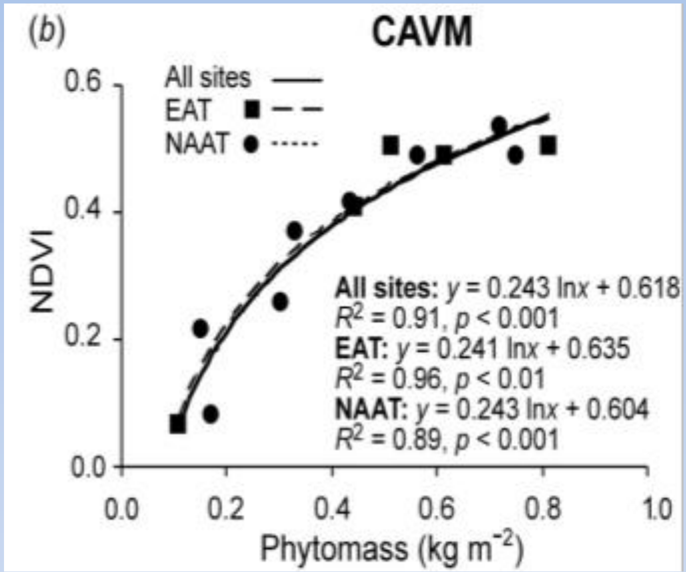

CAVM NDVI data

- Data north of 50° N latitude
- 1.1-km pixel resolution
- Band 1 & Band 2 data used to calculate NDVI
- Maximum NDVI from biweekly images from 11 July - 31 August in 1993 and 1995
- Data from AVHRR/2 on NOAA 9 and NOAA 11

Raynolds M.K., Walker D.A. & Maier H.A. (2006) NDVI patterns and phytomass distribution in the circumpolar Arctic. *Remote Sensing of Environment, 102, 271-281*

Biomass harvest methods

1. Photo of site before sampling
2. Secure 20 x 50 cm (0.1 m^2) aluminum frame
3. Clip all overhanging vegetation
4. Cut with serrated knife along edges of frame, cutting down through the litter, moss and organic soil
5. Remove sample and place in labelled plastic bags
6. Keep cool or frozen until sorting.

Sampling for areas with shrubs > 40 cm in height

1 x 1 m frame for sampling shrubs
Same 20 x 50 cm (0.1 m2) for understory.

photo from Seward data report

Biomass sorting methods

1. Cut off everything below the live moss or soil layer.

2. If organic layer can be consistently harvested, this can be dried and weighed separately.

3. Sort remaining plant material by plant growth form:
   a) deciduous shrub
   b) evergreen shrub
   c) graminoid
   d) forb
   e) horsetail
   f) lichen
   g) moss
   f) algae

4. Then sort by:
   a) woody
   b) leaf
   c) reproductive
   d) dead

5. Dry and weigh all samples

Example of results from sorting biomass samples

Sample	deciduous stem	deciduous foliar live	deciduous foliar dead	deciduous shrub reproductive	evergreen stem	evergreen foliar live	evergreen foliar dead	evergreen shrub reproductive
301	0	0	0	0	0.485	0.098	0.454	0
302	0	0	0	0	8.533	3.404	8.406	0.073
303	0	0	0.009	0	13.213	3.985	16.685	0.005
304	0	0	0	0	0	0	0	0
305	0	0.008	0	0	0.012	0.022	0	0
306	1.962	3.579	0.325	0.564	4.049	1.519	24.787	0.359
307	0	0.043	0.022	0	0	0.003	0	0
308	0	0	0	0	0	0	0	0

Sample	graminoid live	graminoid dead	forbs	horsetail	lichen	moss	algae	TOTAL
301	0	0	0.064	0	0	0	0	1.101
302	0.027	0.044	1.909	0	0	0.247	0	22.643
303	0.335	0.542	0.405	0	0	0.147	0	35.326
304	0	0.006	0.213	0	0	0	0	0.219
305	0.1	0.408	2.831	0	0.095	0.354	0	3.83
306	0	0.027	0	0	0.107	4.775	0	42.053
307	0.194	0.497	0.003	0	0	0	0	0.762
308	0.093	0.451	0.131	0	0.014	0	0	0.689

Seems straightforward, but there are always issues

1. **Choosing the location of sample sites**
2. **Sampling design at sites, including number of repetitions (5 from each site in our study)**
3. Determining live vs. dead vs. peat for graminoids – by partial leaf, or whole leaves. Especially difficult with tussocks.
4. Determining live vs. dead vs. peat for mosses. Especially difficult for brown mosses, and at times of year when mosses are dry.
5. Removing soil from mosses and lichens in windy areas with nearby dust sources. Possible to wash in some situations, burning required in others.
6. Sampling thin moss or lichen crusts, which are common in the Arctic. Cryptogamic soils, where much of biomass is actually within the top layer of the mineral soil require burning.

Picture of looking for sites (Mould Bay?)

Yamal sampling design

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photo by Skip Walker

Howie Epstein, Vaskiny Dachi, Russia

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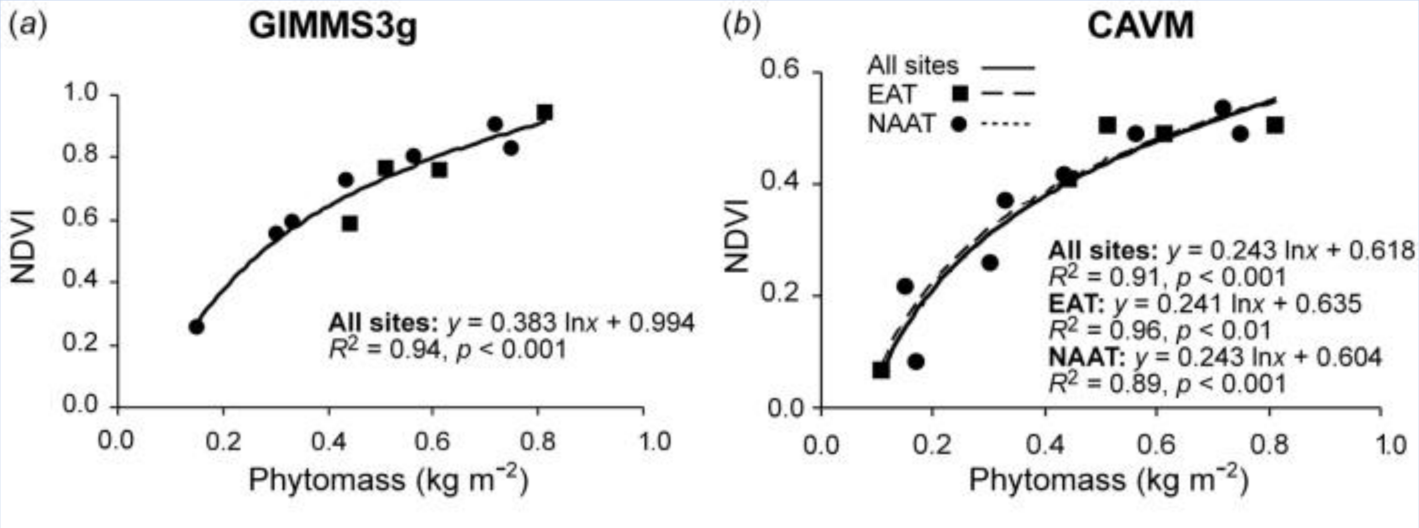
Isachsen, Canadian Arctic Islands



Given all these issues, the relationship we found between biomass and NDVI is amazingly strong.

Recognized issues with the numbers in these graphs

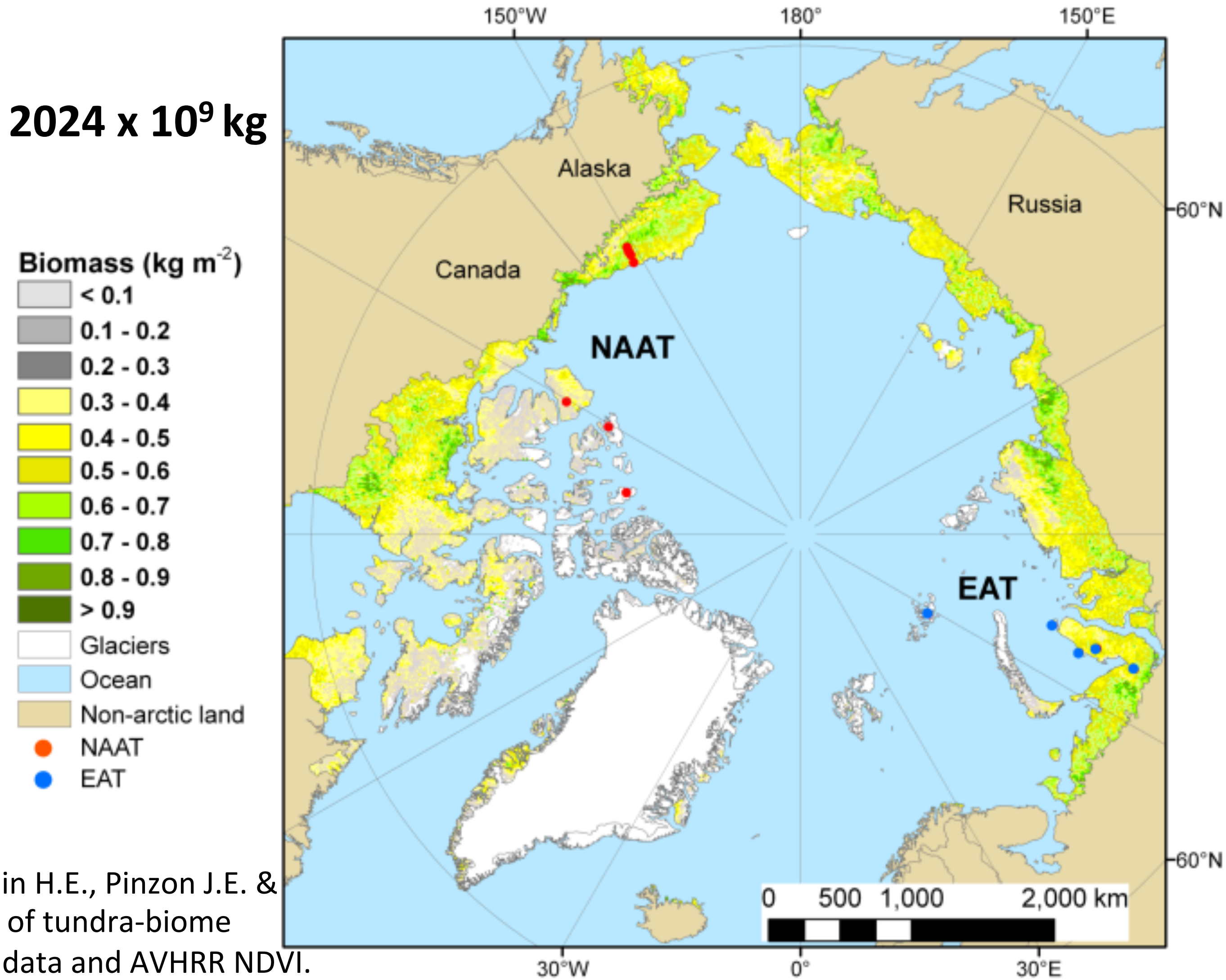
- Possible inconsistencies with AVHRR NDVI data
- Scaling issues (more from Howie Epstein)
- Site selection and sampling design (more from Skip Walker)
- Issues with cryptogam biomass – dead vs. live and soil contamination

Howie Epstein sampling NDVI at Howe Island, Alaska, 2006

Scaling issues

Despite all these issues, the relationship between biomass and NDVI from this study was very strong, and allowed us to estimate above ground circumpolar phytomass

Total = 2024 x 10^9 kg



Raynolds M.K., Walker D.A., Epstein H.E., Pinzon J.E. & Tucker C.J. (2012) A new estimate of tundra-biome phytomass from trans-Arctic field data and AVHRR NDVI. *Remote Sensing Letters, 3, 403-411*

Questions?