Planned Field Campaigns

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Presenting Several Team Efforts

Summary

- Needs: Gaps in knowledge / Model validation
- MOSAiC
- SIDEX
- Remote Sensing / Airborne Campaigns
- What's Missing?

The following summarizes my knowledge of field plans.
We need your insight to design field campaigns that support you.

- Models generally poor at reproducing sea ice deformation.
- Hence may misrepresent ice thickness redistribution, wind stress transfer to the ocean, distribution of leads and ridges.
- Lead and ridge spatial patterns not parameterized.

Gaps in knowledge

- Interaction with coastal boundaries.
- Scaling properties of sea ice deformation below ~10km.
- How transitions in scaling properties relate to changes in mechanical properties of ice.
- Mechanisms of floe cracking.
- Stress propagation through mixtures of ice type.

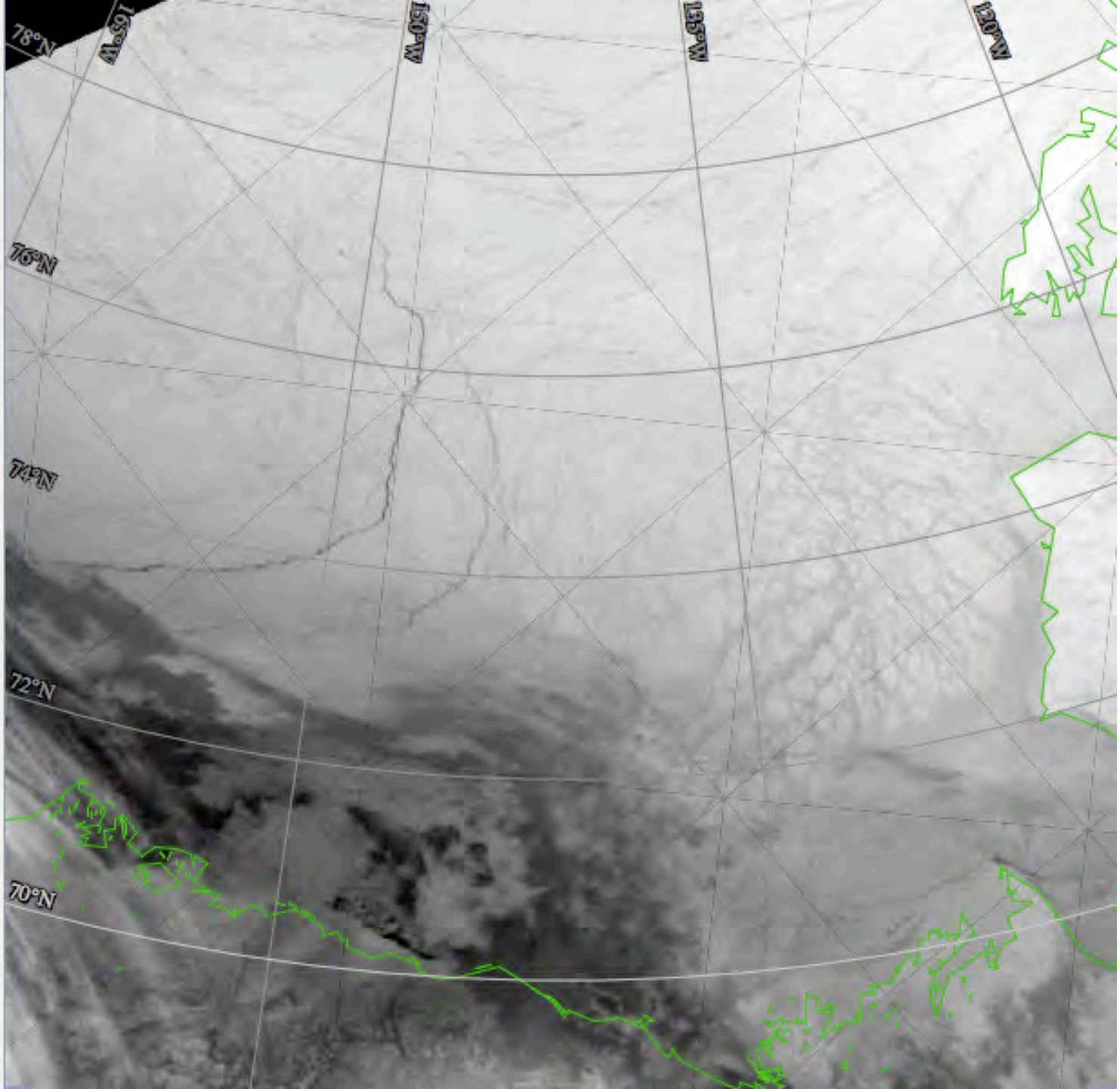
Gaps in knowledge

- Interaction with coastal boundaries. NSF/NASA
- Scaling properties of sea ice deformation below ~10km. MOSAiC
- How transitions in scaling properties relate to changes in mechanical properties of ice. Ongoing
- Mechanisms of floe cracking. MOSAiC/SIDEx
- Stress propagation through mixtures of ice type. SIDEx + Modeling (proposed, unfunded)
- There are more gaps e.g. anisotropy in ice structure, stress weakening by ridging, time scales of healing, stress propagation in mixed ice.

Model Validation

Thoughts on validating Robert's model.

- Survey ice thickness, snow and area incorporated into ridges.
- Requires (1) high fidelity deformation and thickness measurements, (2) coordinated mapping and surveying.
- Ridge height statistics and shapes.
- How to estimate density on large scales? Snow is a large uncertainty.



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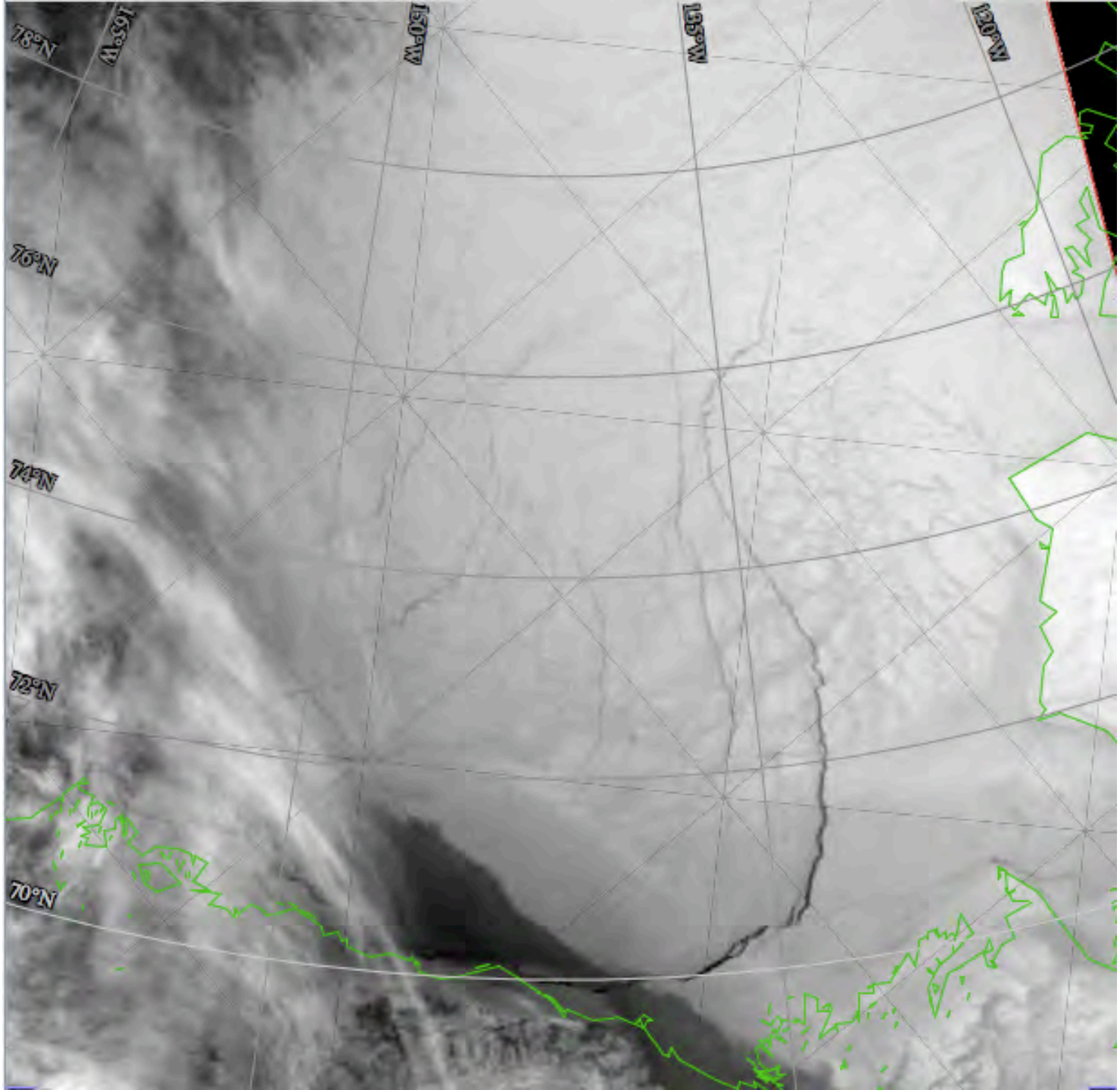

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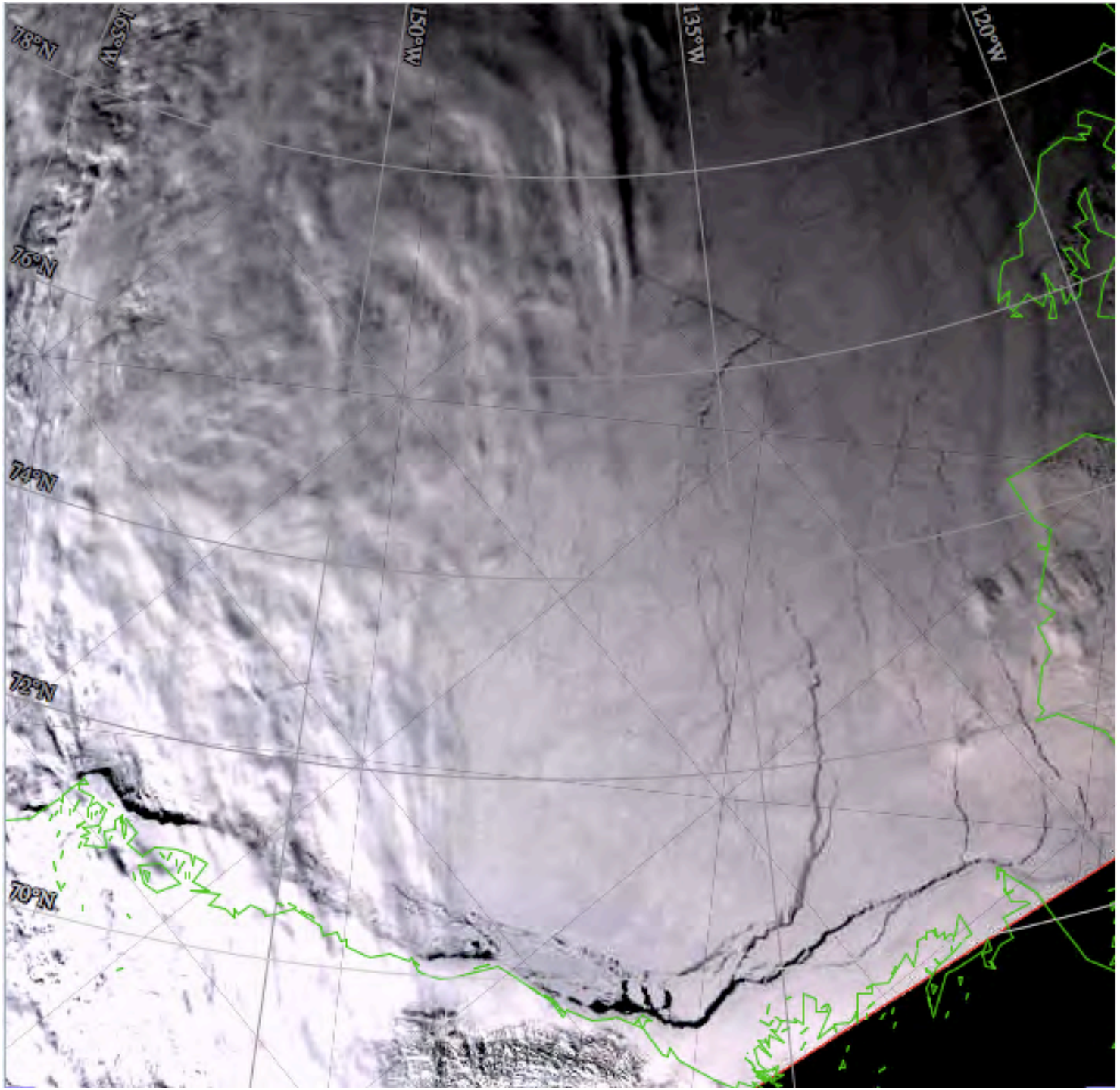

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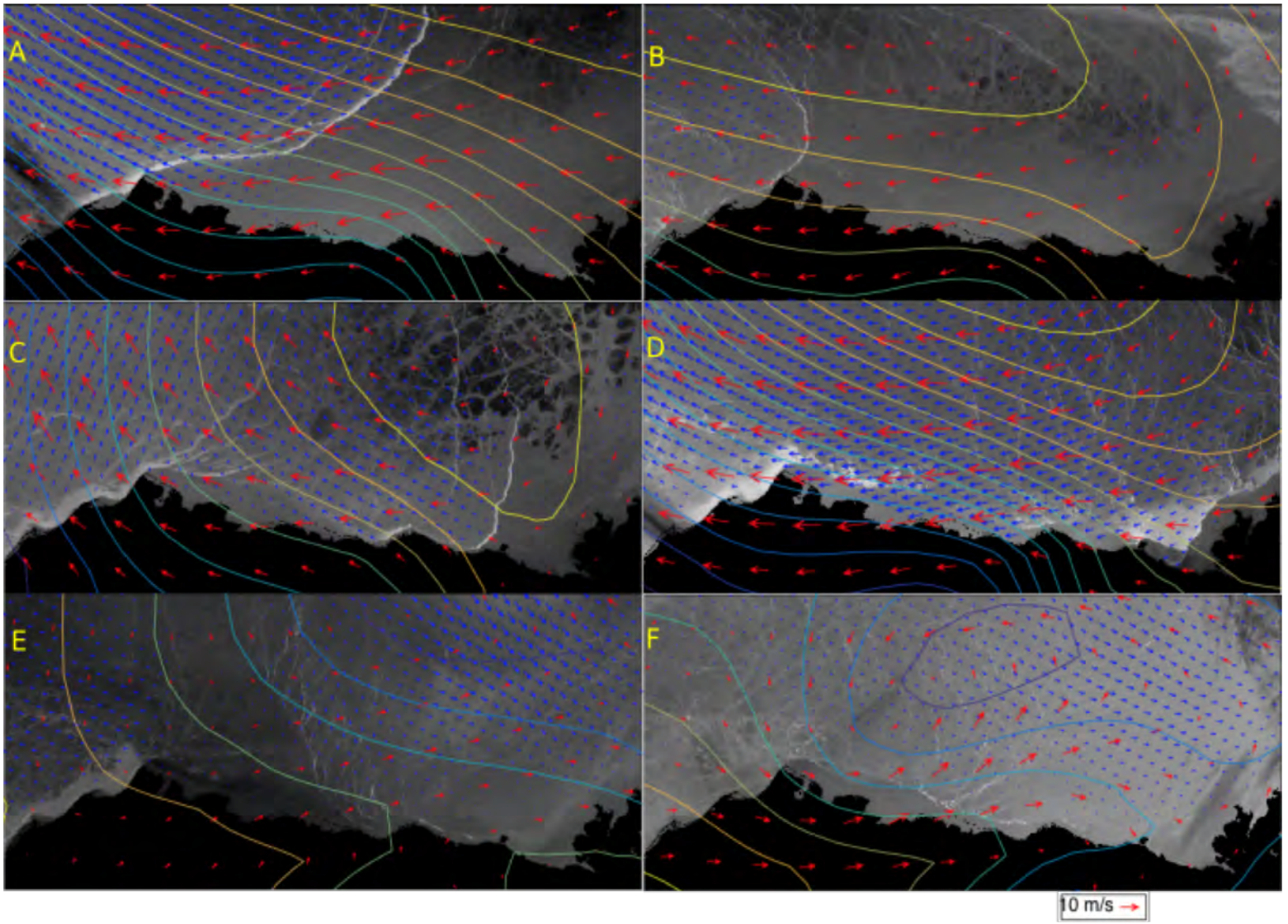
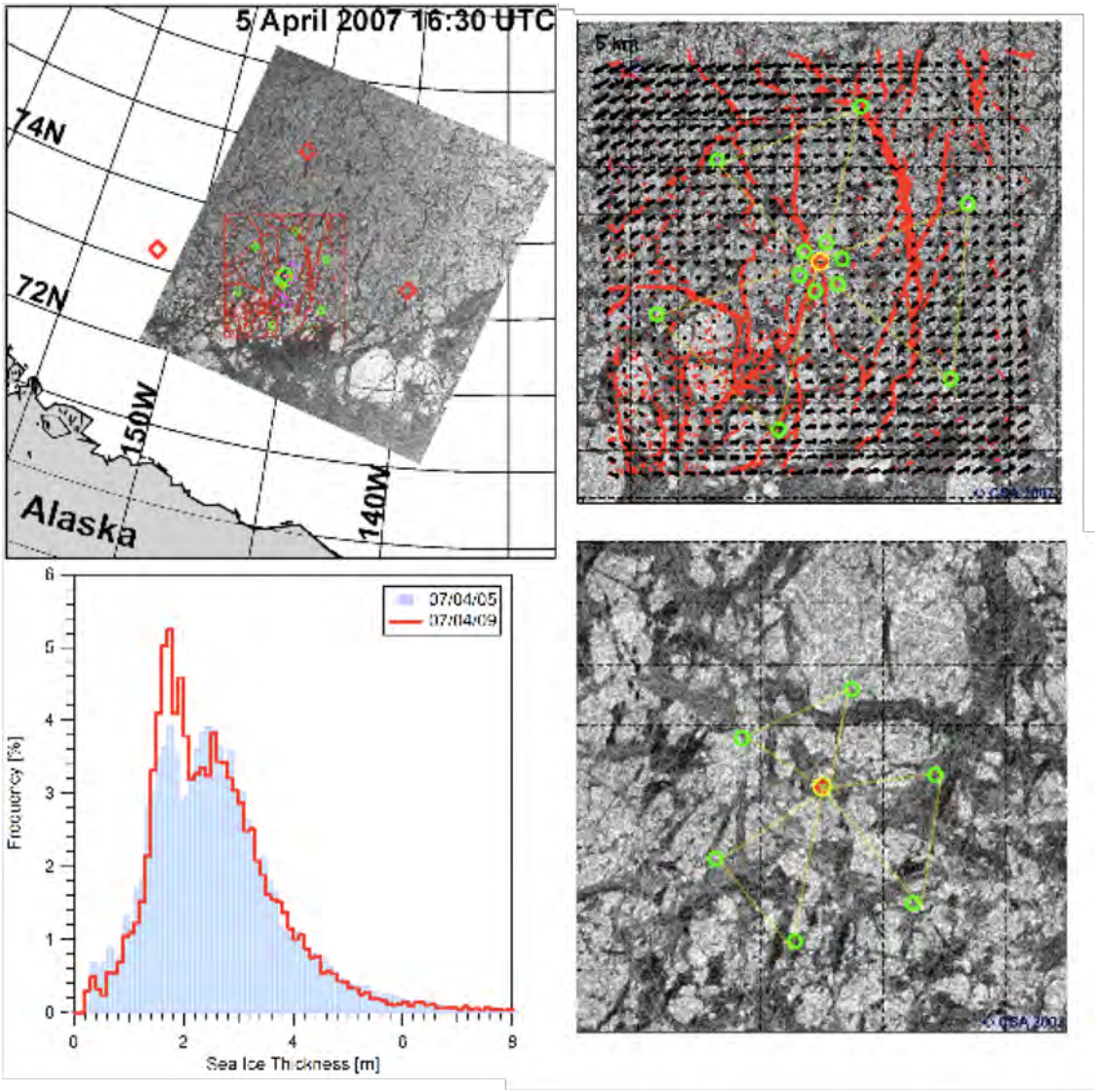
Ice – Coast Interaction



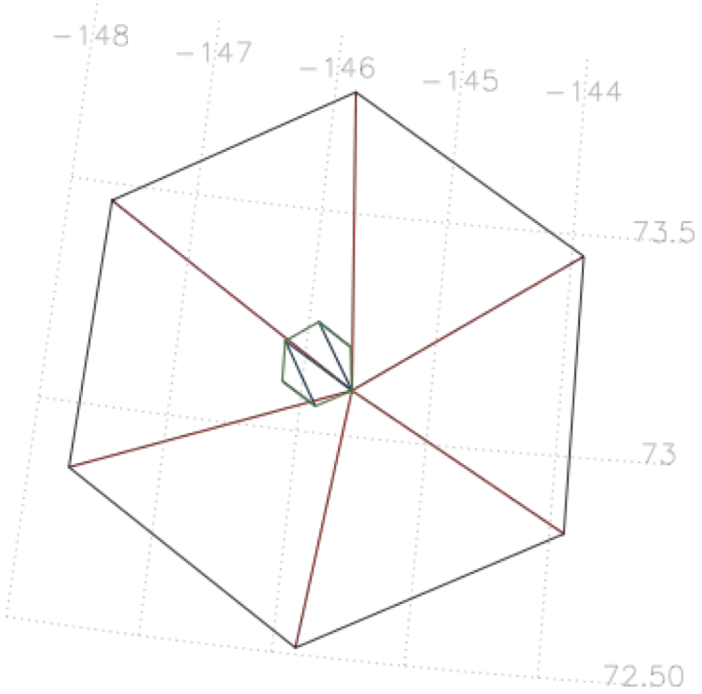
SEDNA

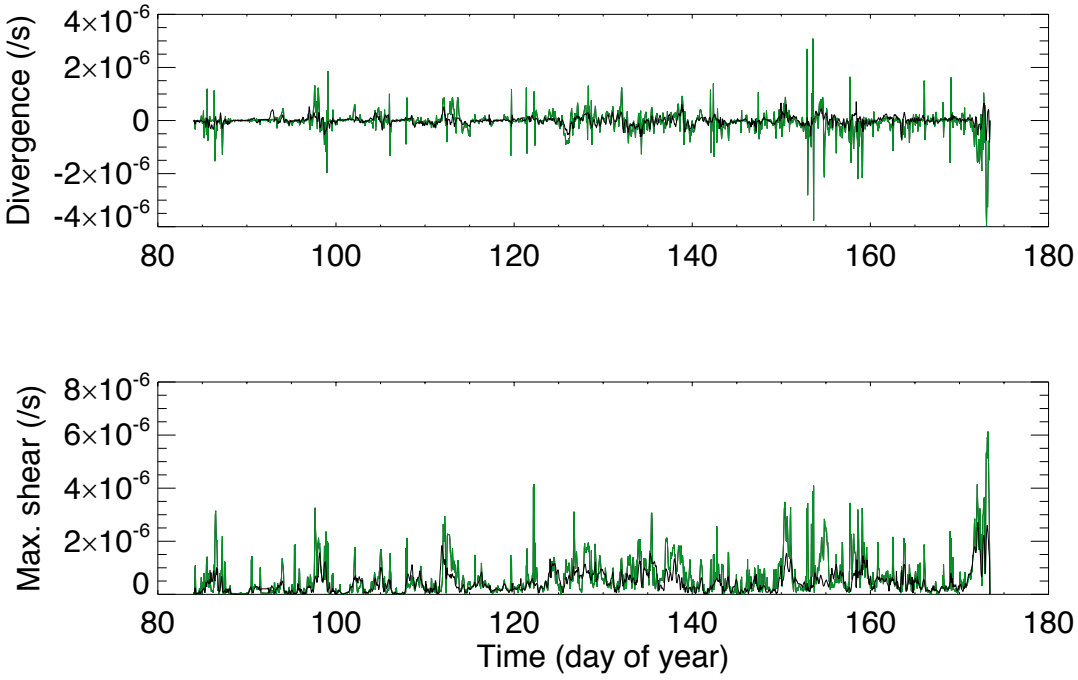


- late March - end May 2007
- Coordinated strain-rate, thickness and stress measurement
- Campaign focus on stress / strain-rate relationship.

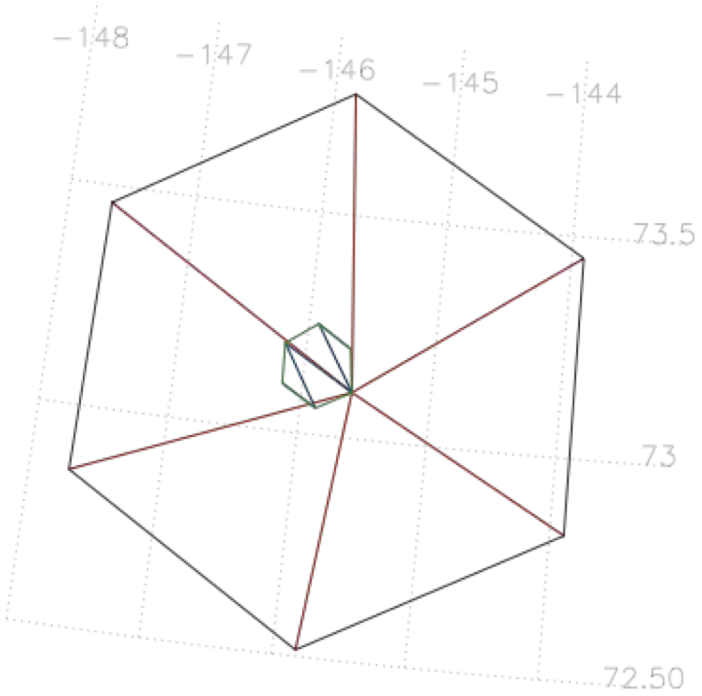
Hutchings et al. 2007, EOS

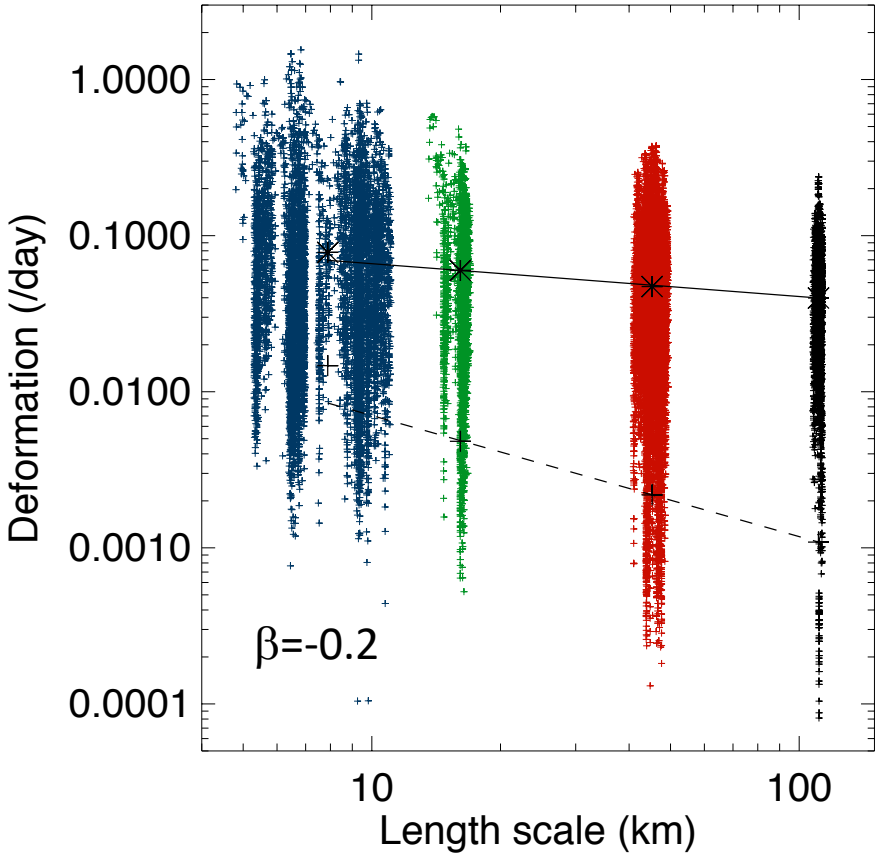
GPS buoy array



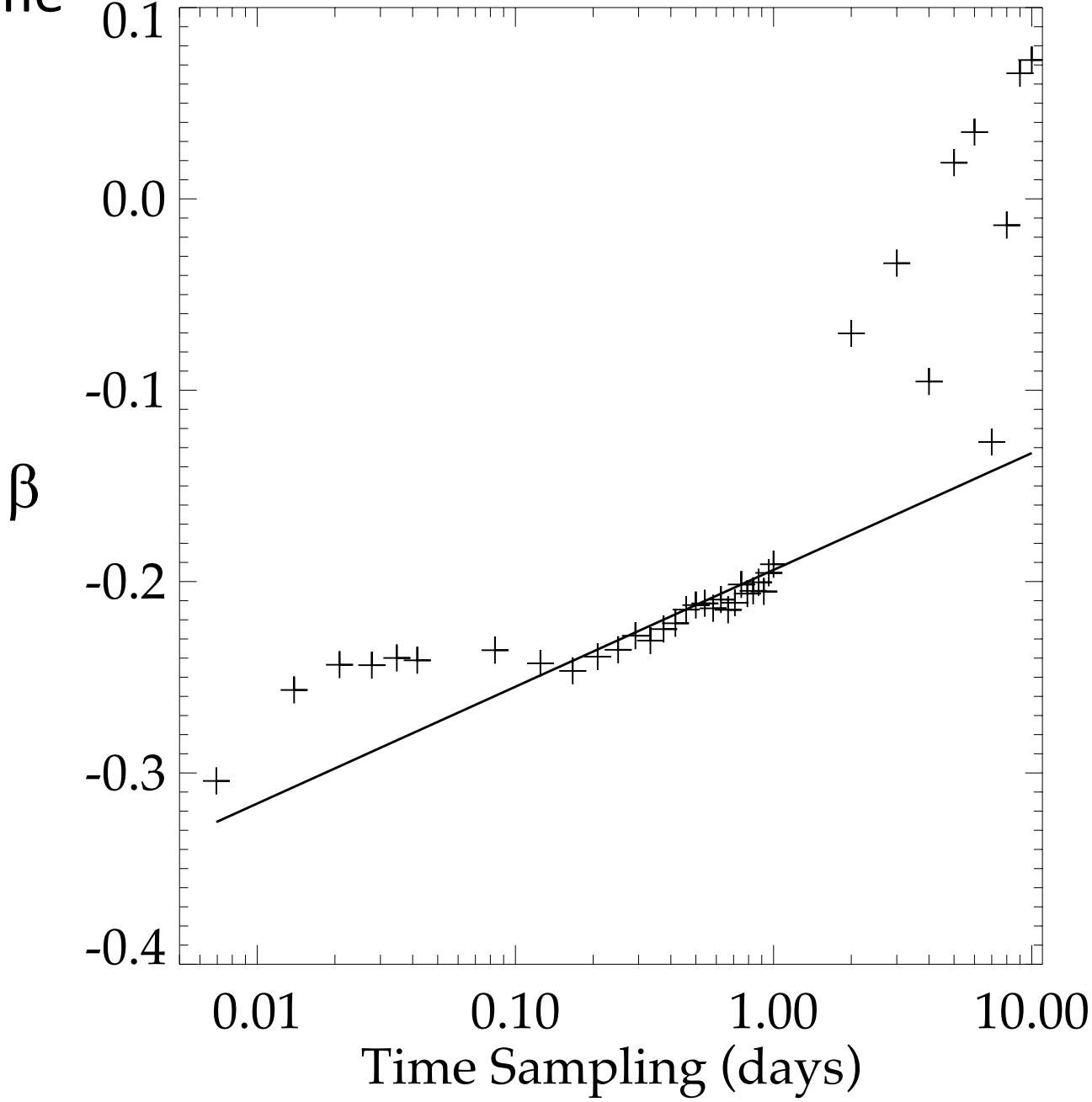


Spatial Scaling





Space-Time Coupling



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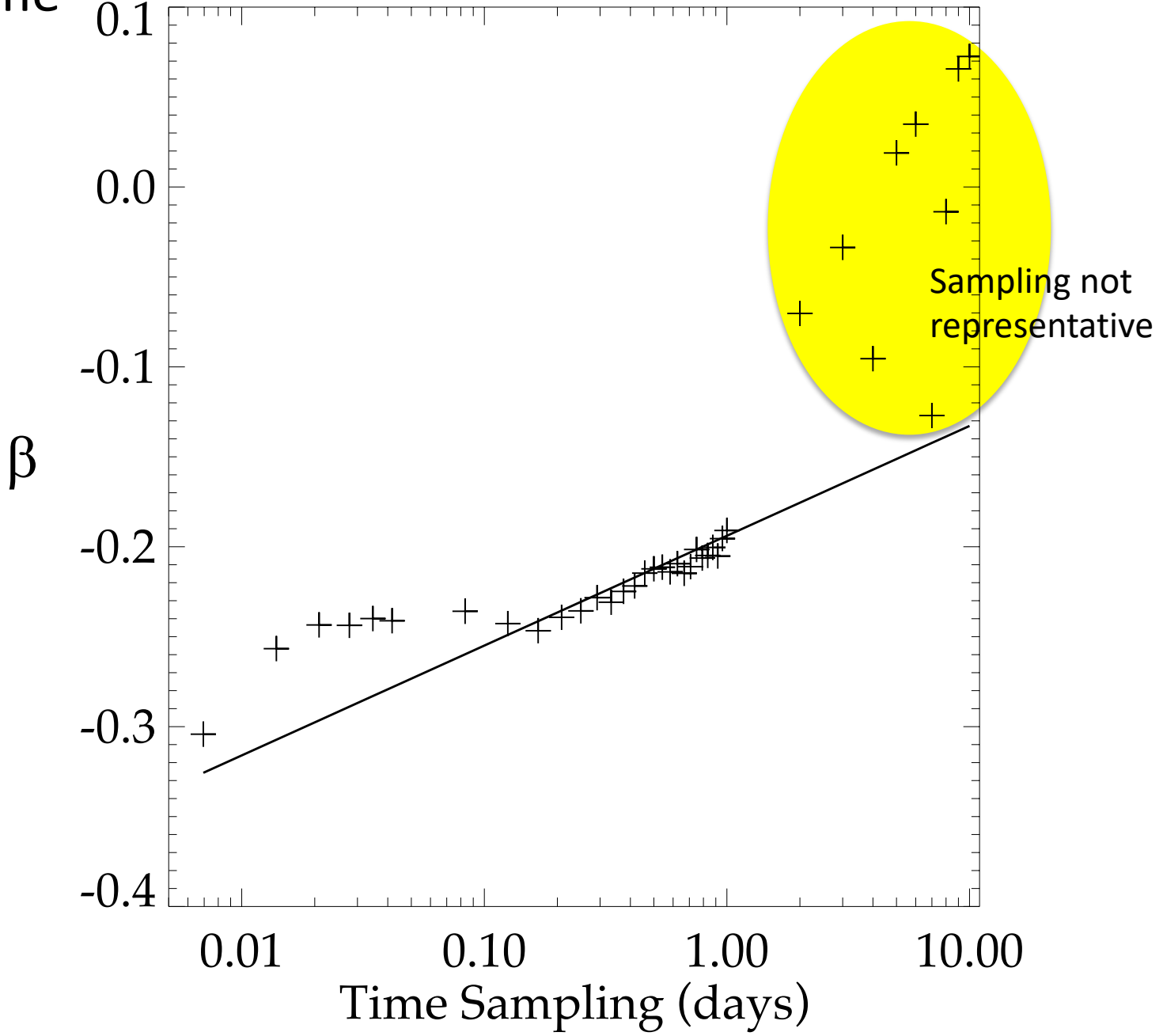

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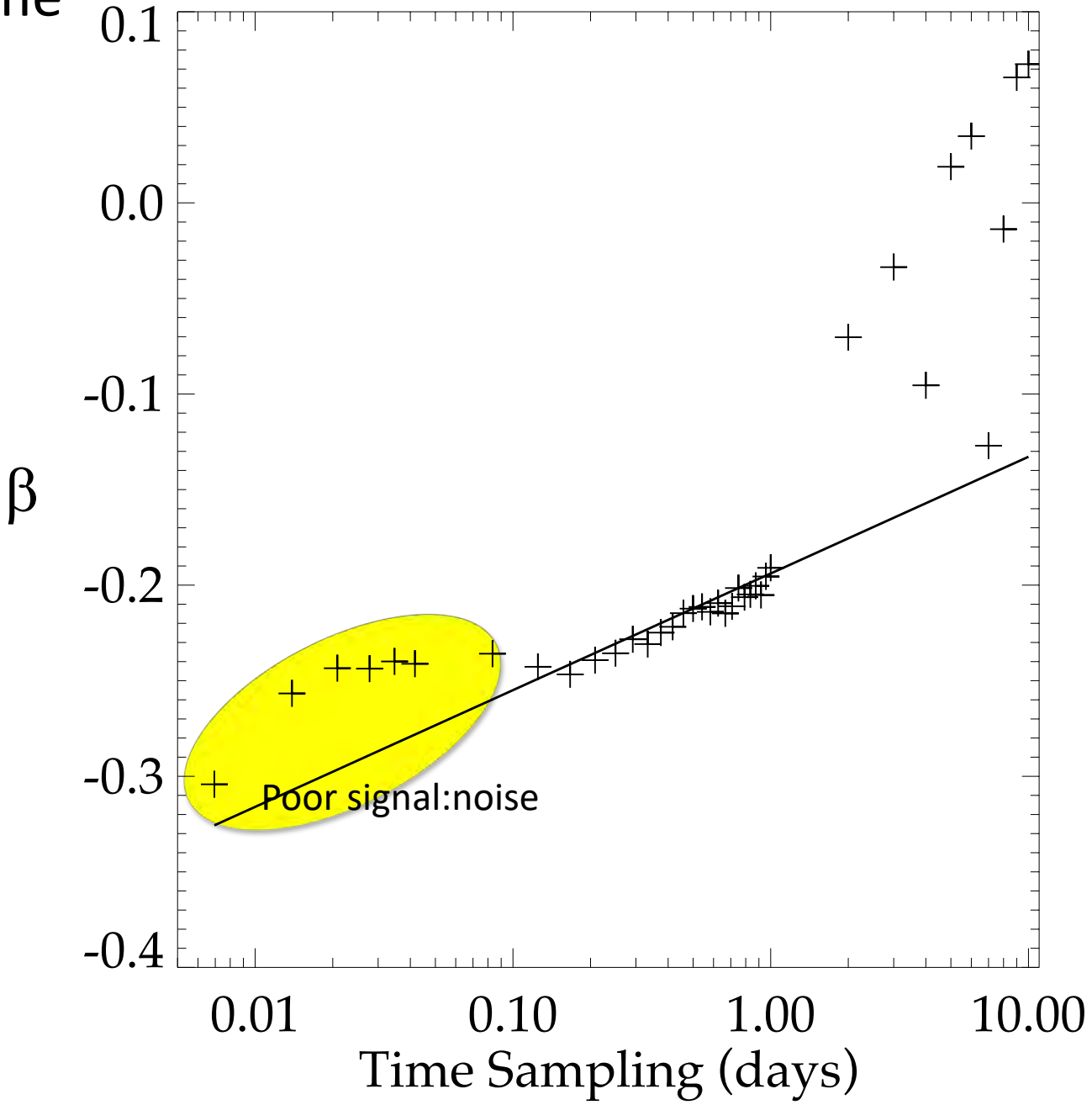

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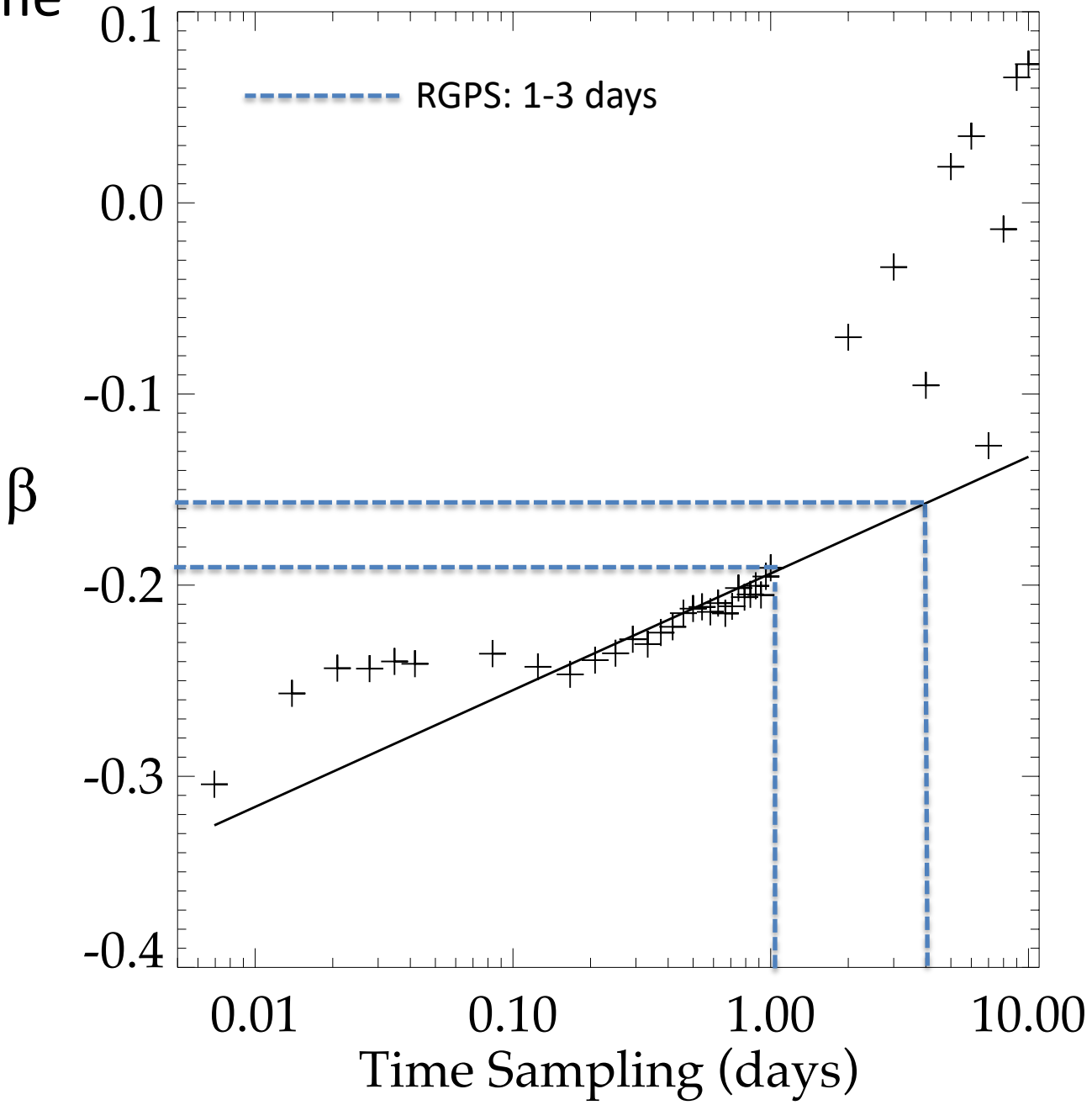

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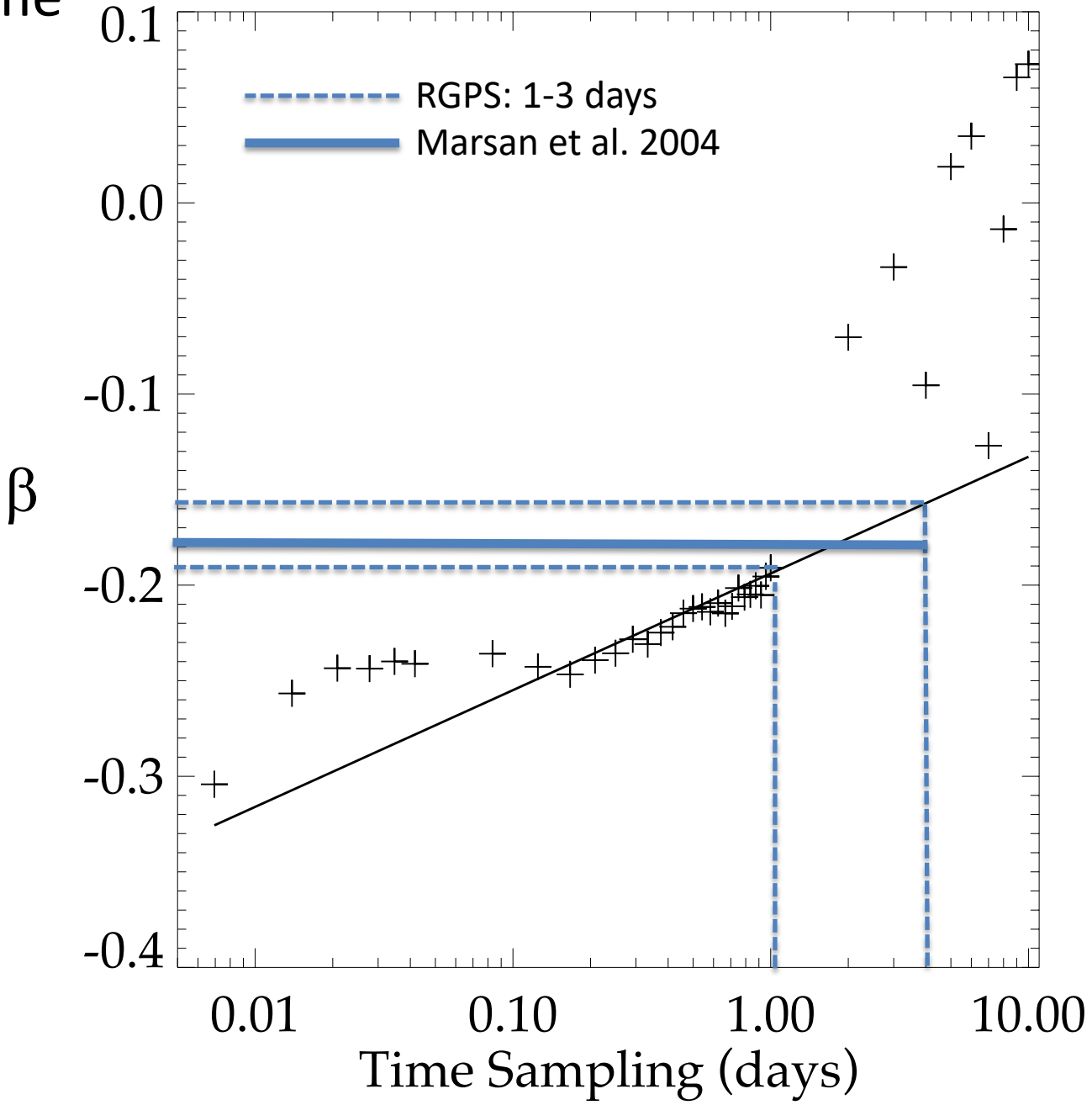

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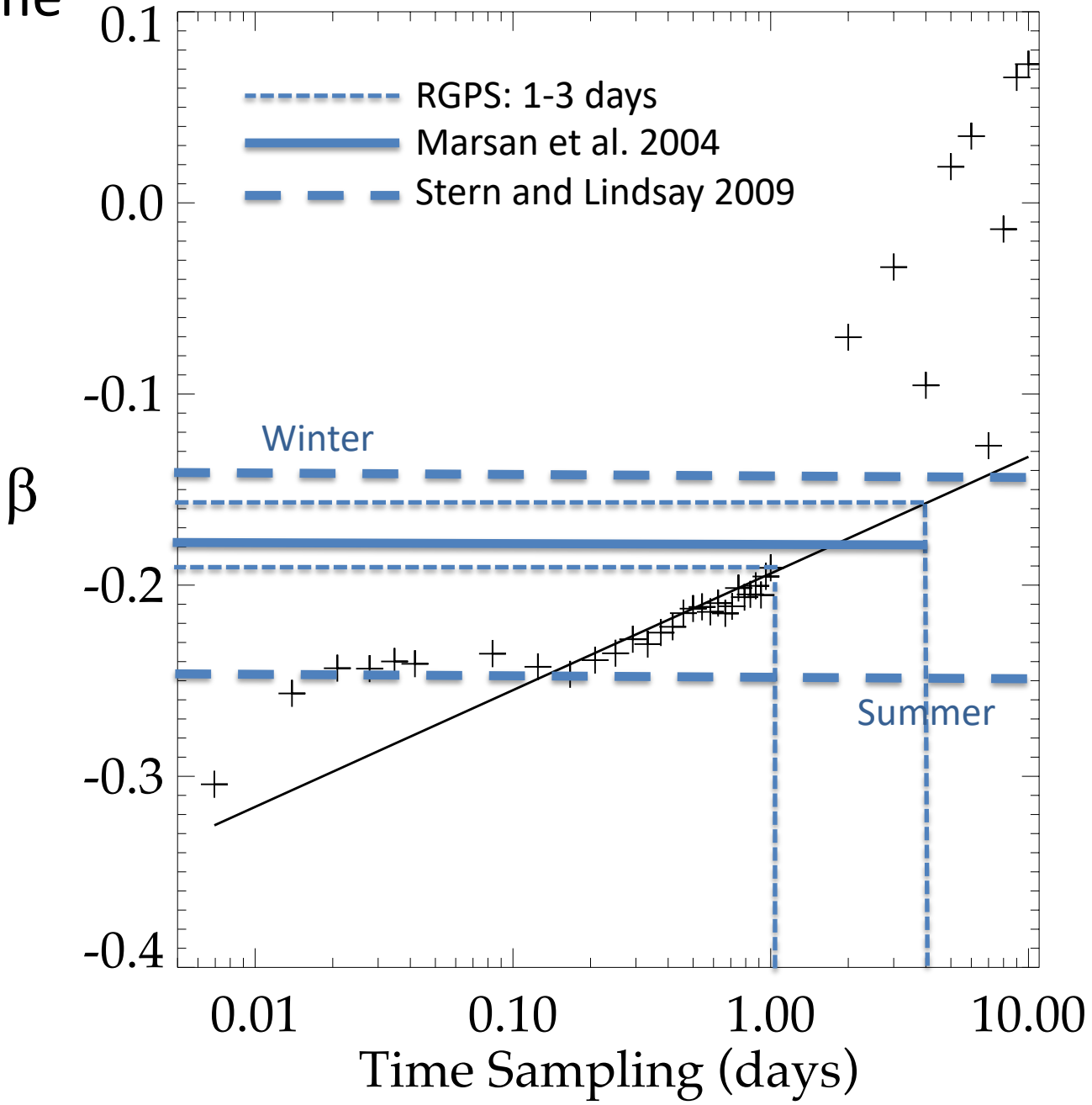
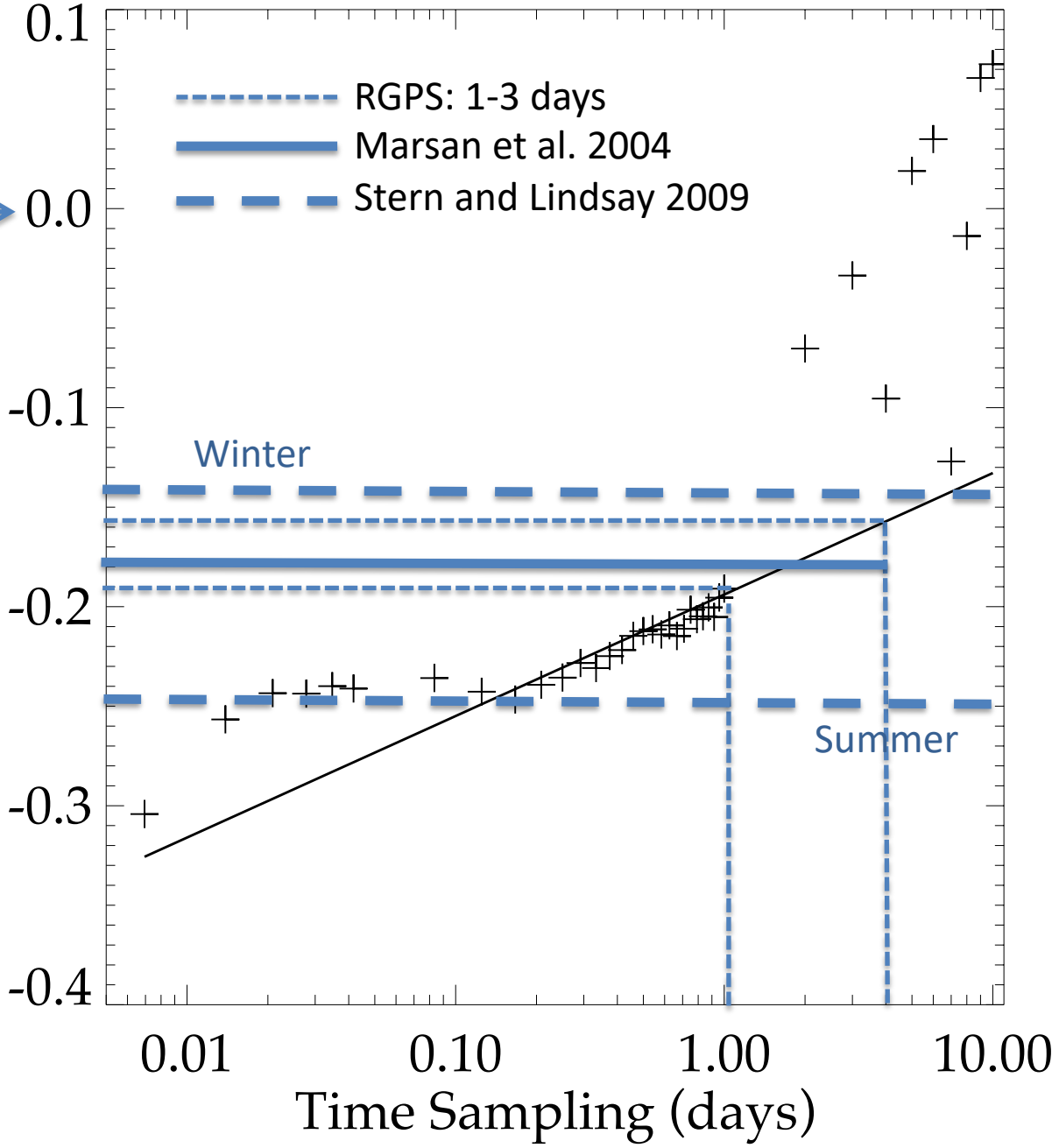


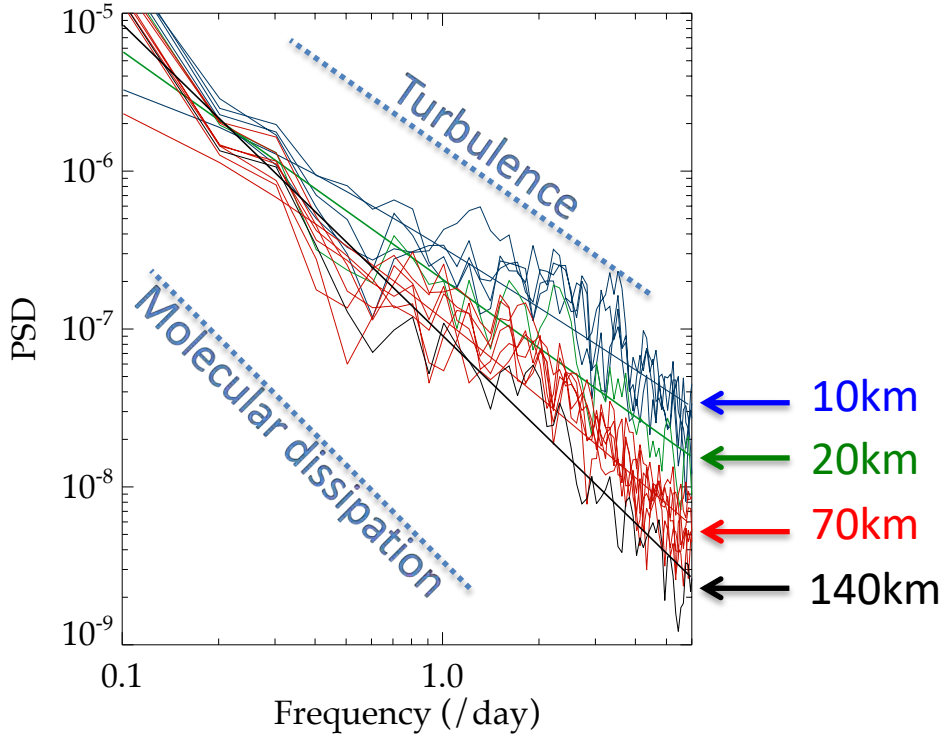
Space-Time Coupling

Homogeneous Deformation →

Increasing Localisation ↓

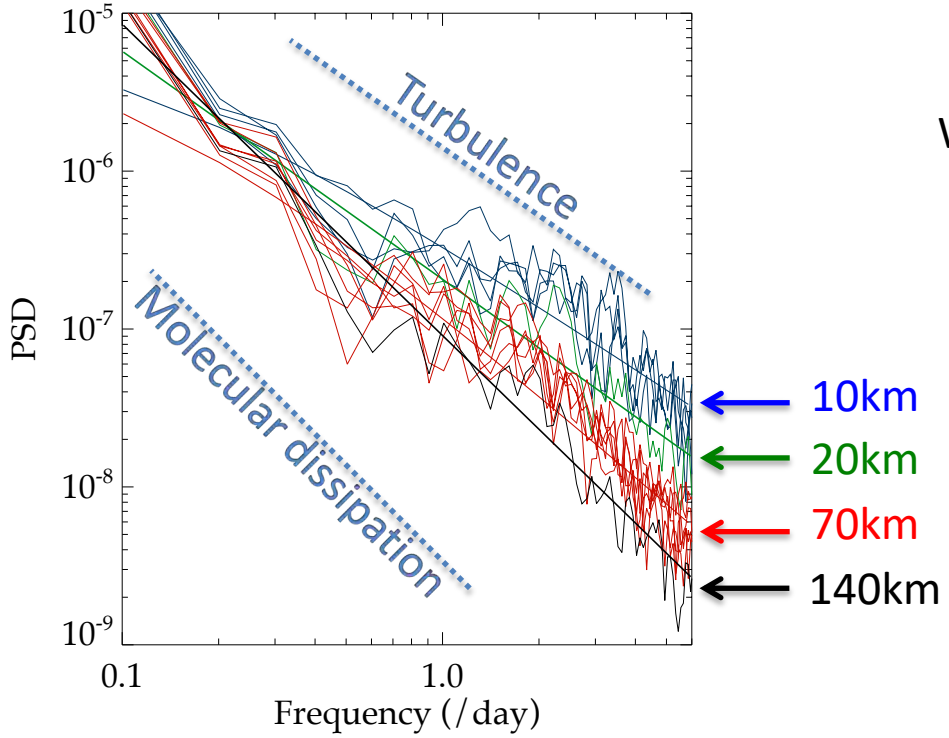


Spectral Analysis to Estimate Fractal Dimension (Frequency Scaling)



- At largest scale (140km): Deformation is a red noise ($1/f^2$) process.
- At smaller scales: becoming increasingly pink.

Spectral Analysis to Estimate Fractal Dimension (Frequency Scaling)



Whitening rate is enhanced as L reduces

- At largest scale (140km): Deformation is a red noise ($1/f^2$) process.
- At smaller scales: becoming increasingly pink.

Current Models

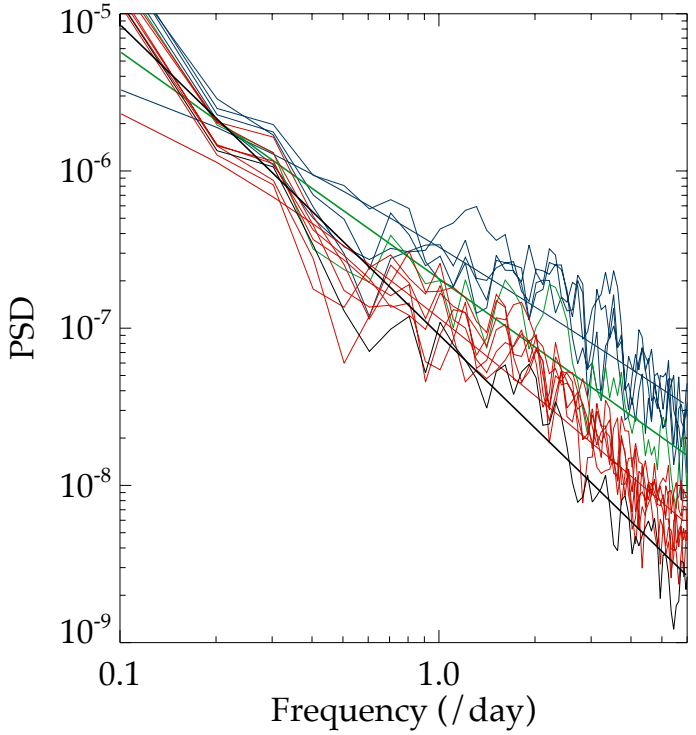
- Hurst exponent reflects the balance between external forcing (winds/currents) and internal energy dissipation by the ice pack.

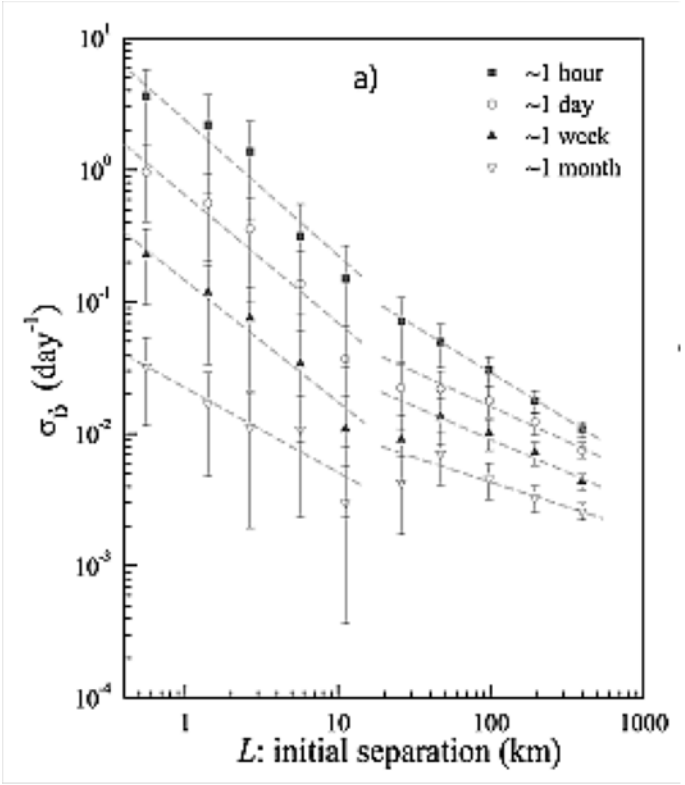
$$\frac{\partial m\mathbf{U}}{\partial t} + \nabla \cdot (m\mathbf{U}\mathbf{U}) = \boldsymbol{\tau}_a + \boldsymbol{\tau}_w - mf\hat{\mathbf{k}} \times \mathbf{U} - mg\nabla H + \nabla \cdot \boldsymbol{\sigma},$$

Surface forcing
Body forcing
Dissipative term

Analogy to turbulence: In current models Div(σ) assumes homogenous deformation.

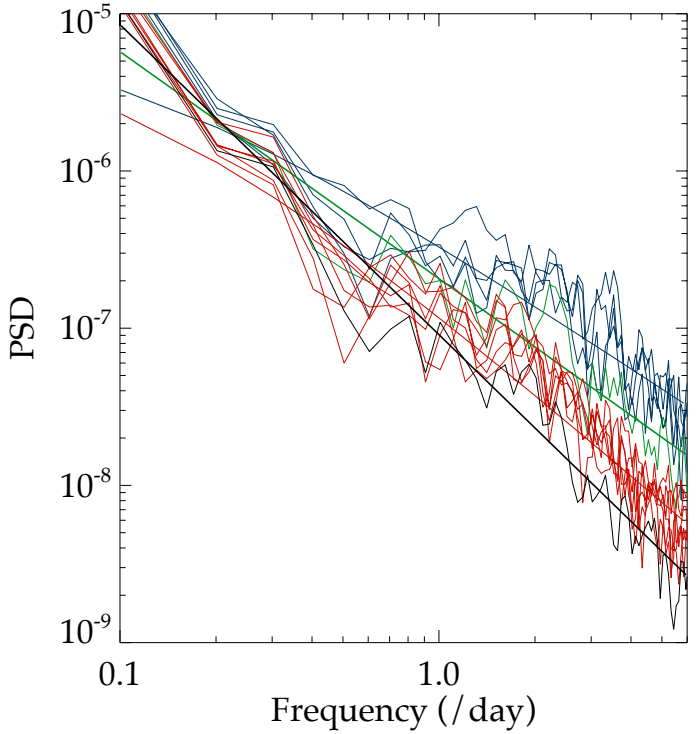
Spectral Analysis to Estimate Fractal Dimension (Frequency Scaling)

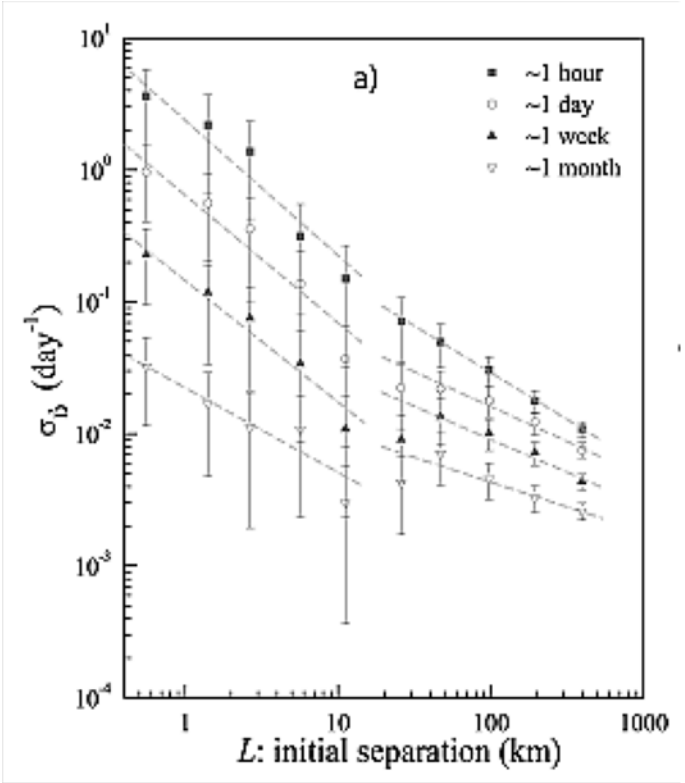




- Rampal found a similar result.
- IABP buoy position error > SEDNA buoy position error
- **Pierre: is your transition due to signal:noise?**
- See Hutchings et al. (2012), erratum (2018), for error propagation.

Spectral Analysis to Estimate Fractal Dimension (Frequency Scaling)





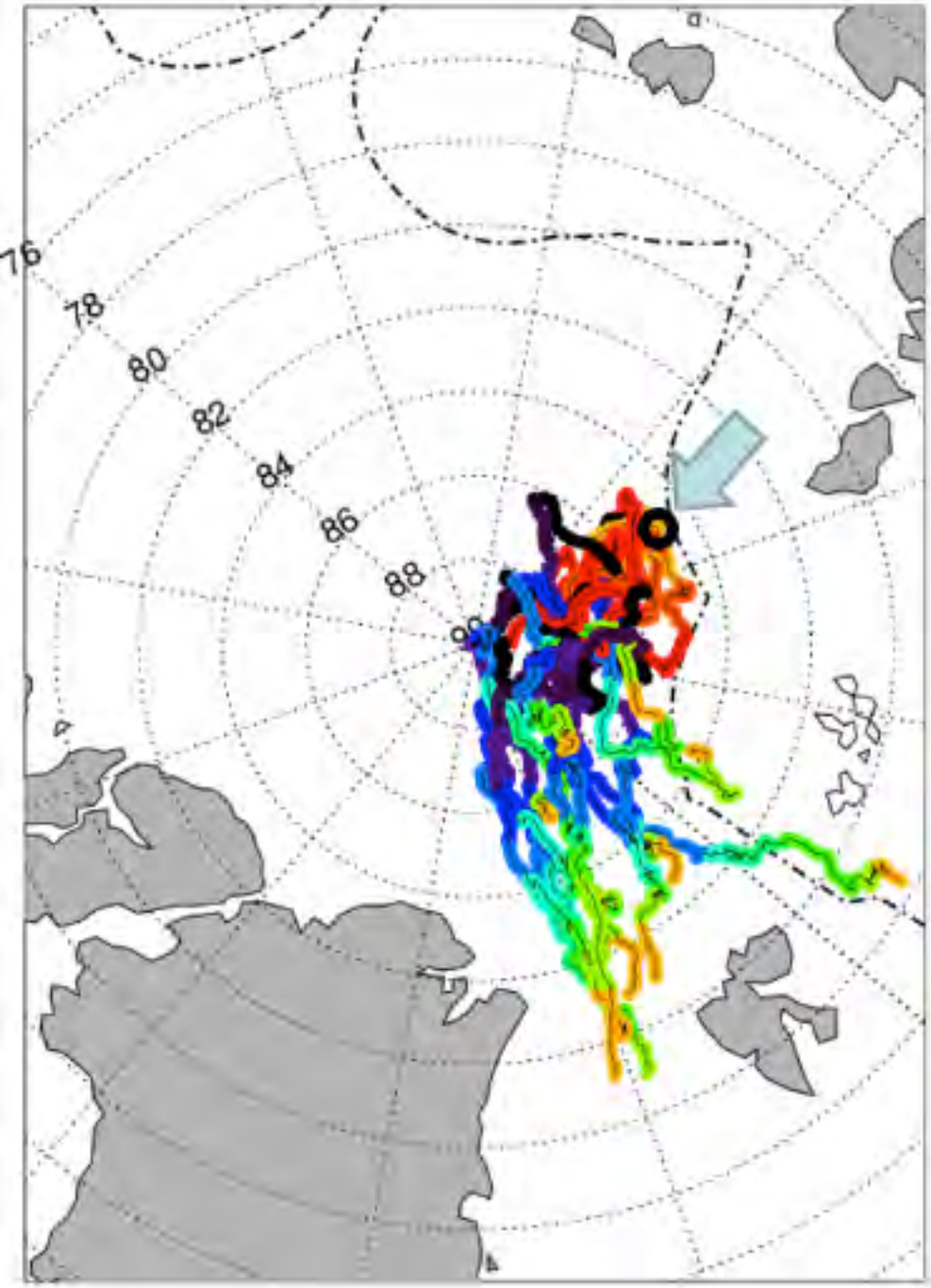
- No data resolving deformation at the scale of individual lead spacing.
- Higher precision GPS deployment in the field could resolve this question

MOSAiC

- Distributed Network
- Scaling up concepts. Experiment built around up-scaling ocean-air fluxes.
- Sea ice team is highly collaborative. 8 onboard running many experiments.
- Hence limited opportunity to run labor intensive experiments
- Good opportunity: (i) second year / first year ice (new Arctic); (ii) full annual cycle

Conditions expected during MOSAiC deployment

Projected drift tracks



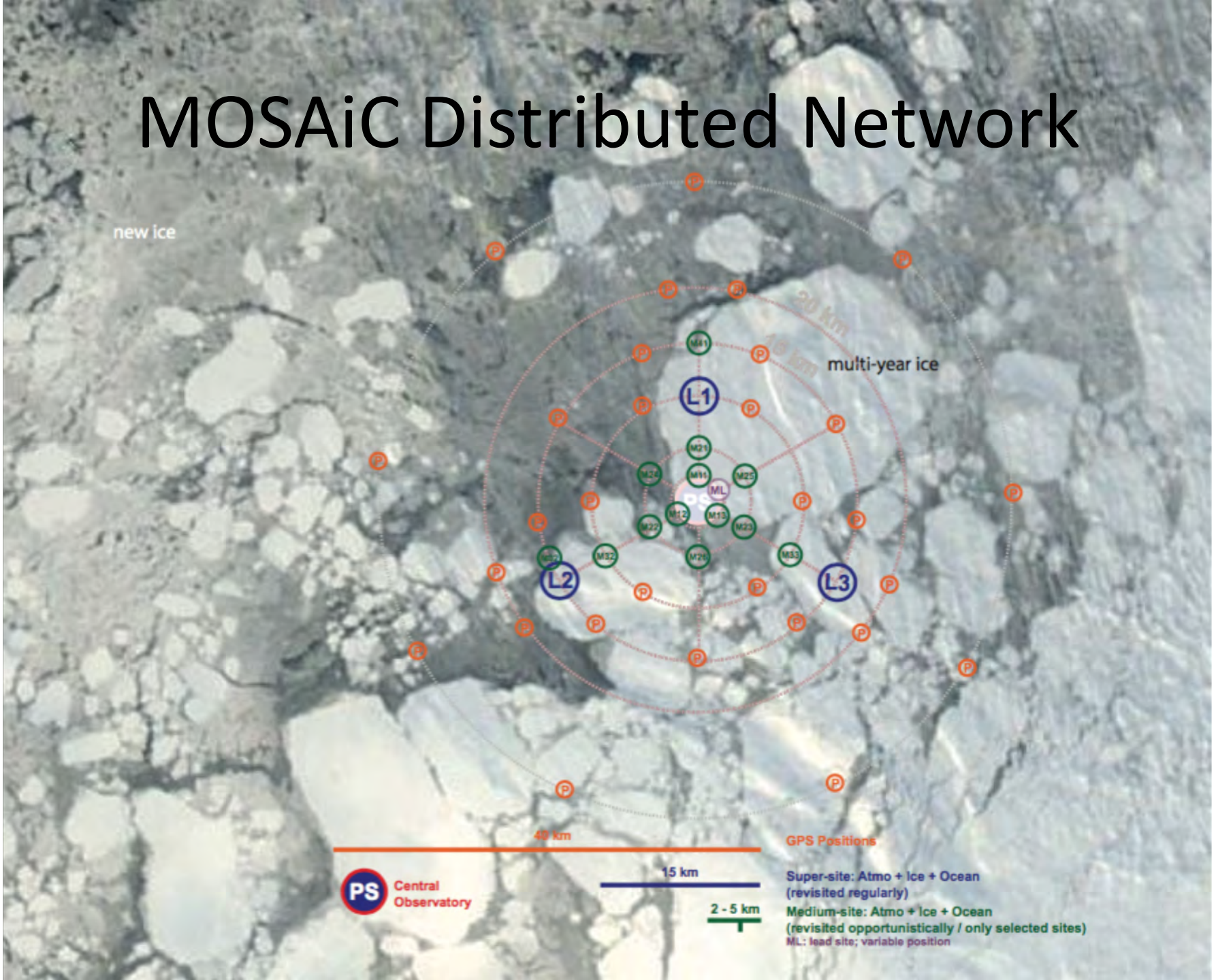
Drift Statistics

Start point: 85°N/105°E

Thomas Krumpen


Where would you place the Central MOSAiC Camp?
The remote sites?
MODIS
Sep 29, 2017
~79° N, 140° E
15 km
open water
new ice
multi-year ice
L1
L2
L3
PS
Central Observatory
40 km
15 km
2 - 5 km
GPS Positions
Super-site: Atmo + Ice + Ocean (revisited regularly)
Medium-site: Atmo + Ice + Ocean (revisited opportunistically / only selected sites)
ML: lead site; variable position

MOSAiC Distributed Network

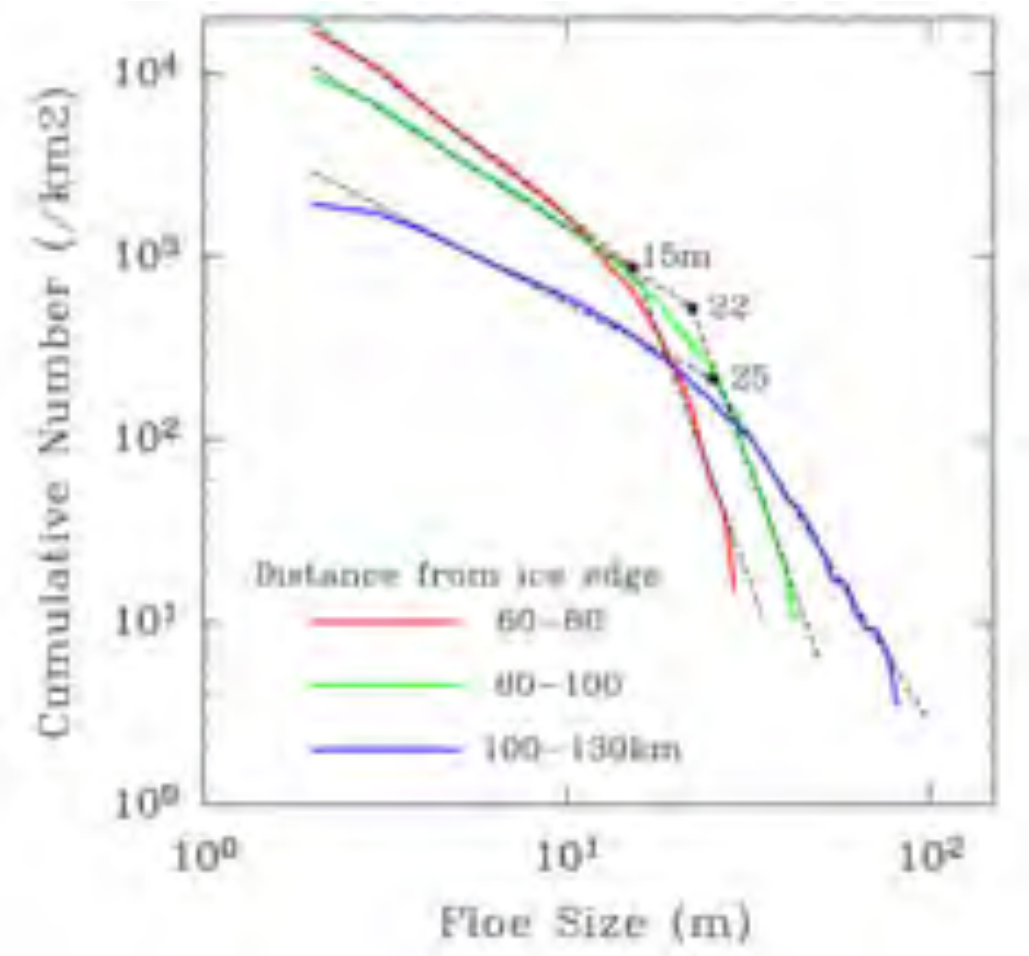


High Fidelity Deformation Monitoring

- RADAR
- GNSS (partially covered by collaboration)
- Seismic
- SAR drift + deformation
- Laser Strain Array
- Attempting repeat worldview imagery
- Repeat aerial surveys.
- AUV not funded (no long-range underwater surveying)

Haapala, Krumpen, Kolabutin, Hwang, Itkin, Polashensky, Webster + others

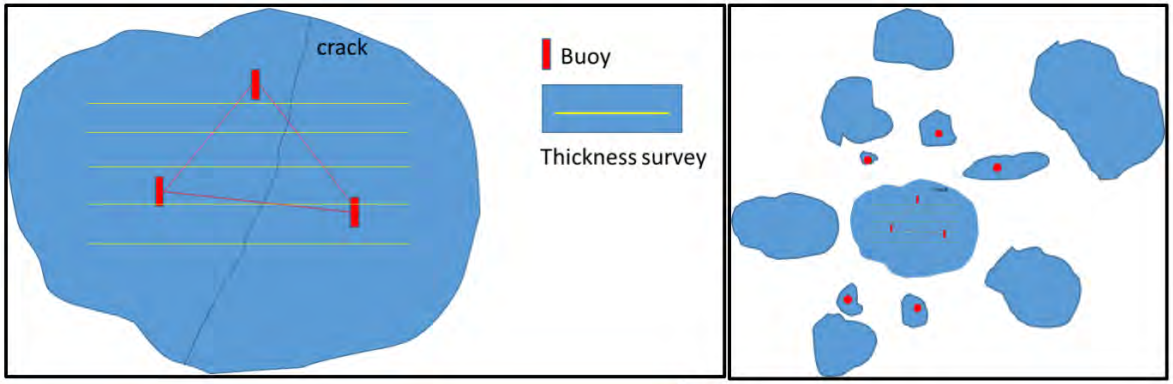
Tracking Seasonal Transitions

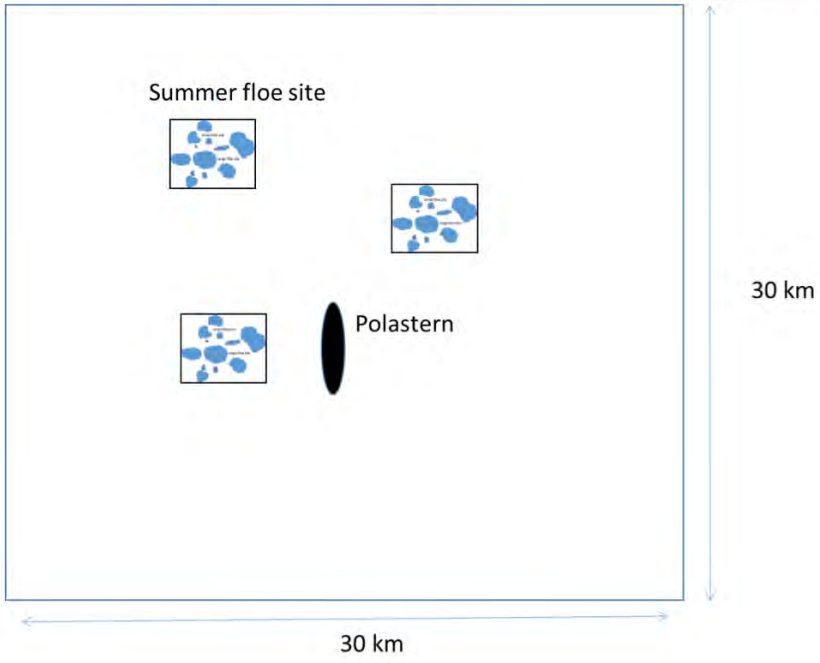


[Toyota et, al 2006] Two regimes, with differing fractal scaling (gradient on graph) for floe size exist within the MIZ, and vary with distance from the ice edge. These may be attributed to different processes controlling floe size. Note that the observed data can also be fit to a function that emerges from competition between three stochastic processes controlling floe size (Herman 2010).

Takenobu Toyota

MOSAiC Summer Deformation





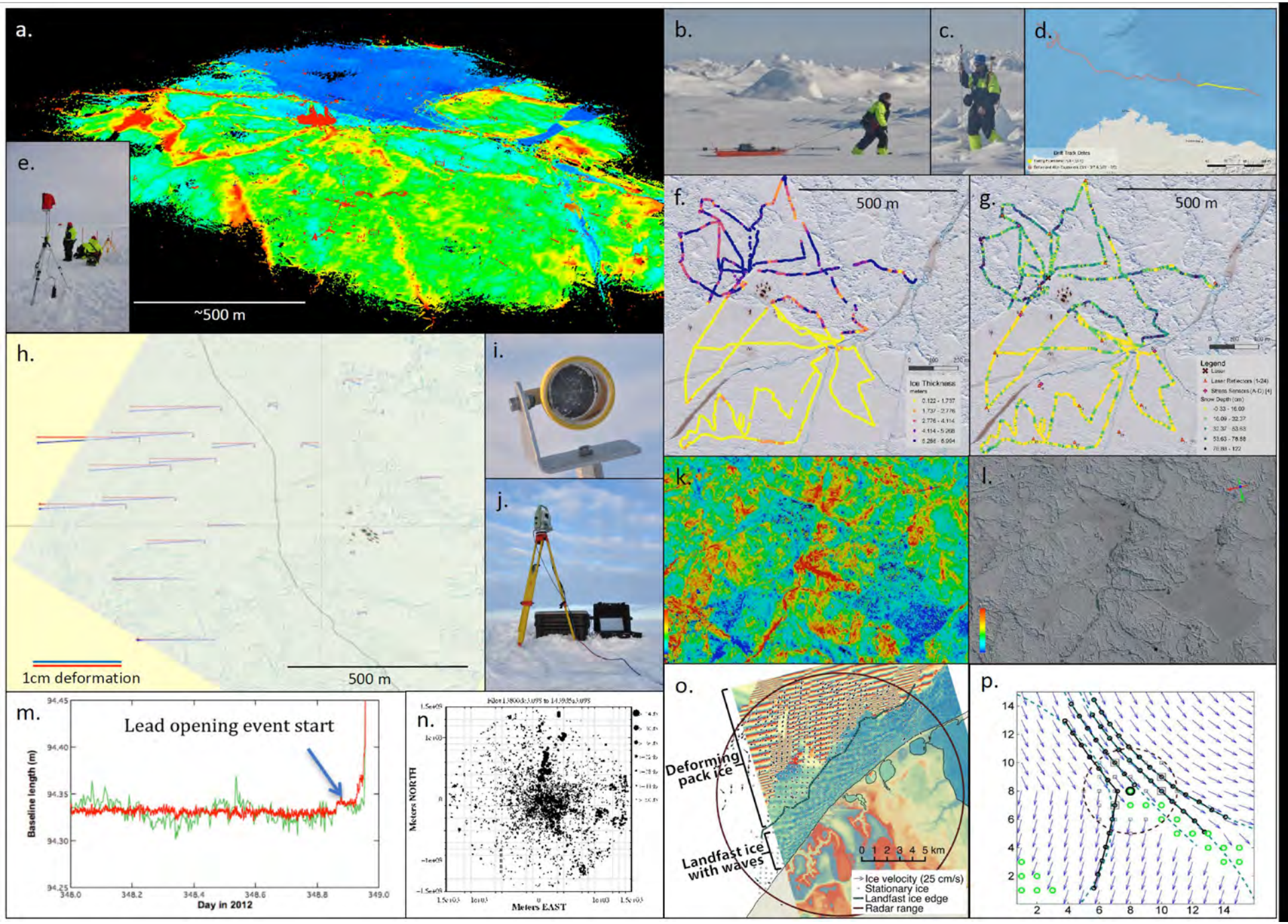
GNSS, accelerometers:

- high resolution horizontal and vertical motion
- Investigate modes of mechanical failure

Phil Hwang and collaborators

SIDEx

- Chris Polashenski, Andy Mahoney, Jenny Hutchings + others.
- Small scale: floe cracking to floe-floe interaction.
- Mapping stress and strain fields.
- Identifying stress concentrators.
- Dissociating thermal and mechanical stresses.
- Identifying mechanisms and modes of failure
- 3 campaigns.



Compiled by Chris Polashenski

2019

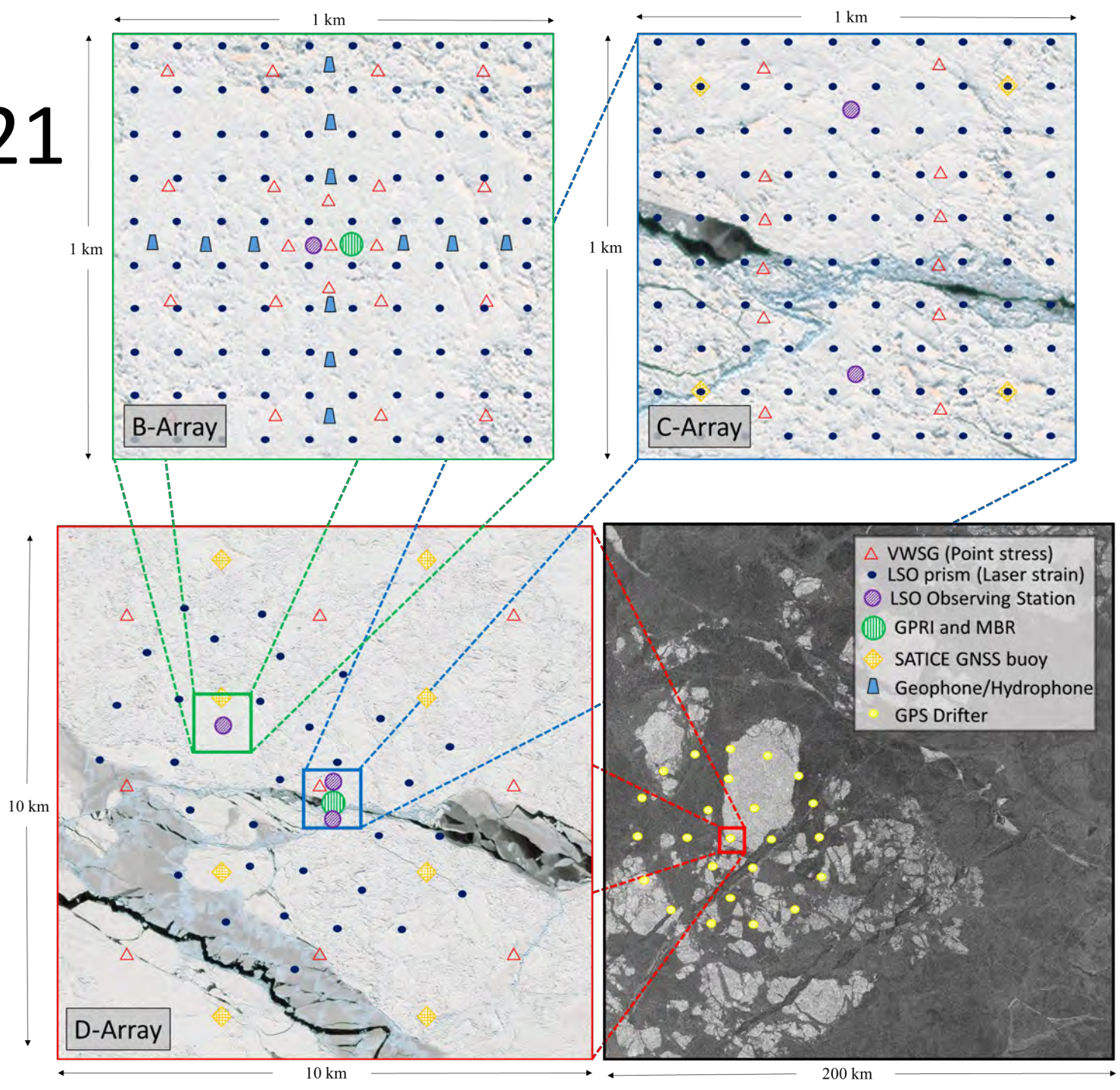
- Landfast ice experiment in a lagoon
- Thermal cracking
- Related deformation
- and Stress field

Seismic, acoustic, high-resolution strain monitoring, point stress measurements, stress from linear elastic model.

2020

- Test equipment and methods at MOSAiC.

2021


1 km
1 km
B-Array
1 km
1 km
C-Array
10 km
10 km
D-Array
200 km
VWSG (Point stress)
LSO prism (Laser strain)
LSO Observing Station
GPRI and MBR
SATICE GNSS buoy
Geophone/Hydrophone
GPS Drifter

Remote Sensing

- OIB. ATM inappropriate for measuring ridges.
- Steriophotography and shadow methods
- Worldview (~50cm resolution satellite imagery, single band)
- SAR cover greatly improved
- New missions: Tandem-X, SWOT

What's Missing?

- A few details in field campaigns still unfunded.
- A coordinated modeling project that utilizes field observations to build process understanding across ice aggregates. (Will recent MURI call fill this gap?)
- Coordinated effort to validate new redistribution and rheological models.
- Workshops/Collaborations to collate observational knowledge.
- Models that accurately simulate deformation and associated episodic ice motion.
- Models that can be applied to any scale and adjust to transitions in physical processes controlling deformation.

Thoughts for developing rheological models …… Div(σ)

- Differing mechanisms for sea ice deformation for different spatial scales, seasons and ice types.
- This could explain transitions in scaling behavior across different ice zones and seasons.
- Is a homogenous (elliptical) rheological model ever valid? Perhaps for large regions of the MIZ? Perhaps for scale between cracks (floe scale)? Within damage zones?

Thoughts

- Observation evidence points to several physical mechanisms of sea ice deformation on various spatial and time scales.
- Perhaps variability in scaling behavior can be used to identify dynamically distinct sea ice zones.
- i.e. while one process may be scale invariant, it does not universally apply to the entire pack at all times.

Thoughts

- To date we know that scaling laws vary with ice properties (strength), but do not have a clear understanding of how the dissipative processes in deformation change as the behaviour transitions seasonally and spatially.

Summary

- Needs: Gaps in knowledge / Model validation
- MOSAiC
- SIDEX
- Remote Sensing / Airborne Campaigns
- What's Missing?

Let's continue this conversation over coffee/dinner/email.
We need your insight to design field campaigns that support models.

Thanks: NSF, ONR, CMI (MMS), NASA, MOSAiC collaborators