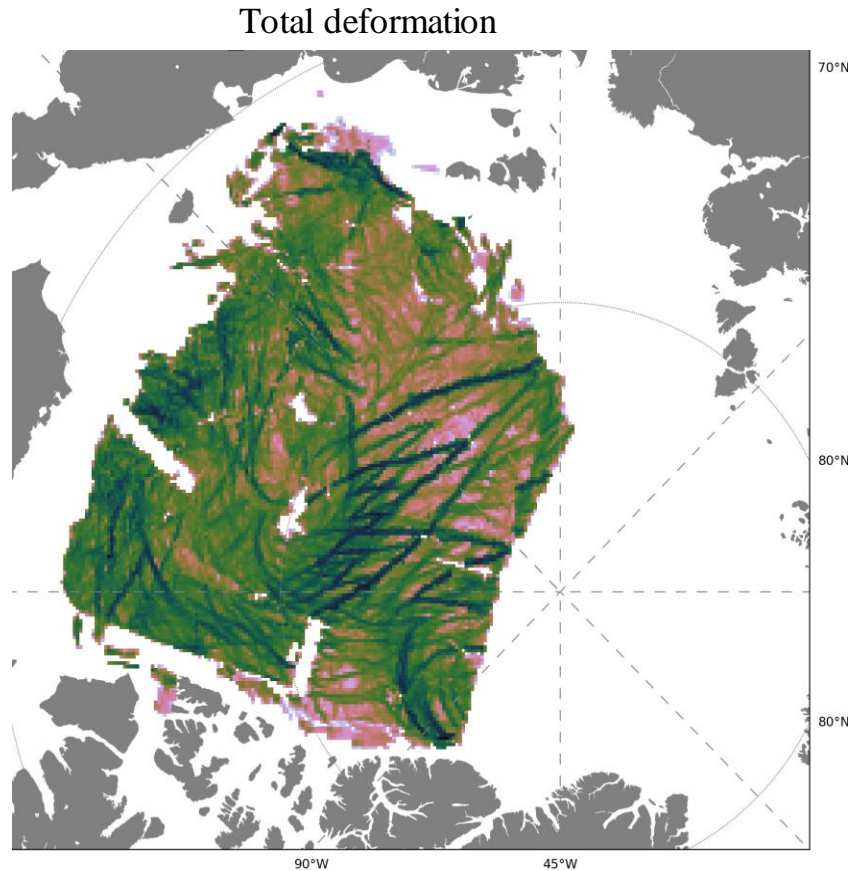# Comparing Arctic Sea Ice Model Simulations to Satellite observations by Multiscale Directional Analysis of Linear Kinematic Features

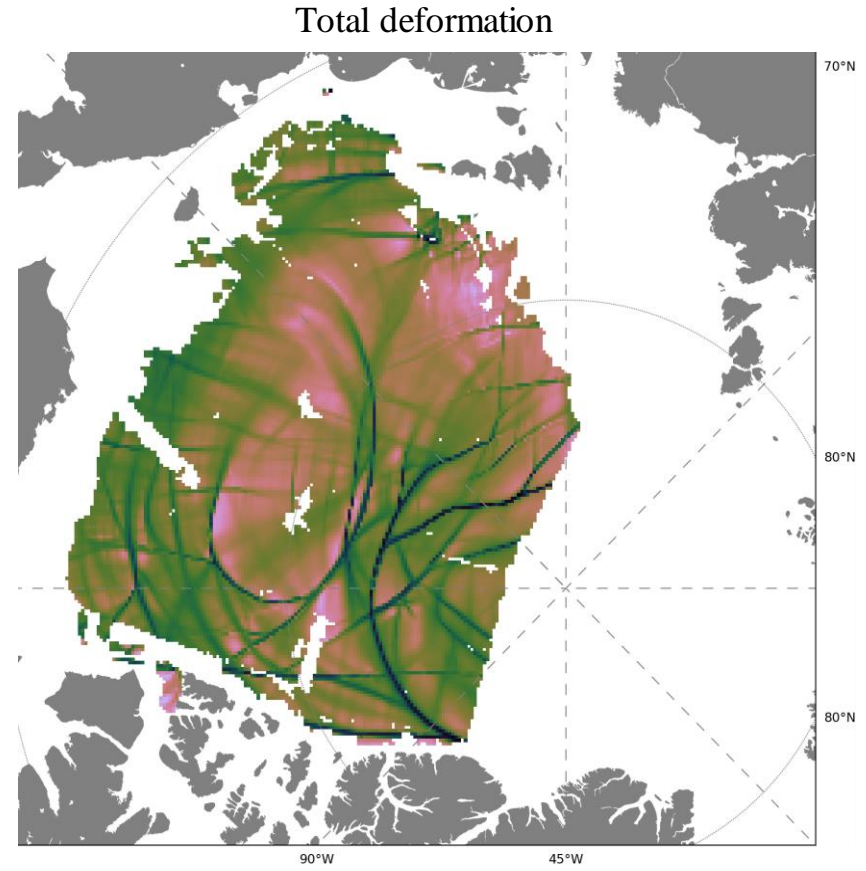Mahdi Mohammadi-Aragh, Martin Losch, Helge F. Goessling
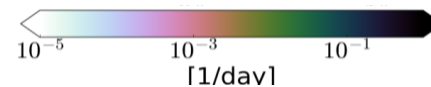
EGU 2020

# Objective

Meaningful comparison of satellite observations and high-resolution model simulations

Total deformation

Total deformation



RGPS (Radarsat Geophysical Processor System)

High resolution simulation (~ 4.5 km) MITgcm

$10^{-5}$     $10^{-3}$     $10^{-1}$
[1/day]

RGPS:
https://asf.alaska.edu/data-sets/derived-data-sets/seaice-measures/sea-ice-measures-data-products/

# 1- Linear Kinematic Features (LKF)

We define LKF as a one-dimensional curve in a two dimensional sea ice deformation field.

# 2- Multiscale Directional Analysis (MDA)

## 2.1. Methodology

a)  Detecting LKF -  Edge Detecting and Image Separation (EDIS)
b)  Estimation of main orientation
c)  Feature classification
d)  Estimation of intersection angles
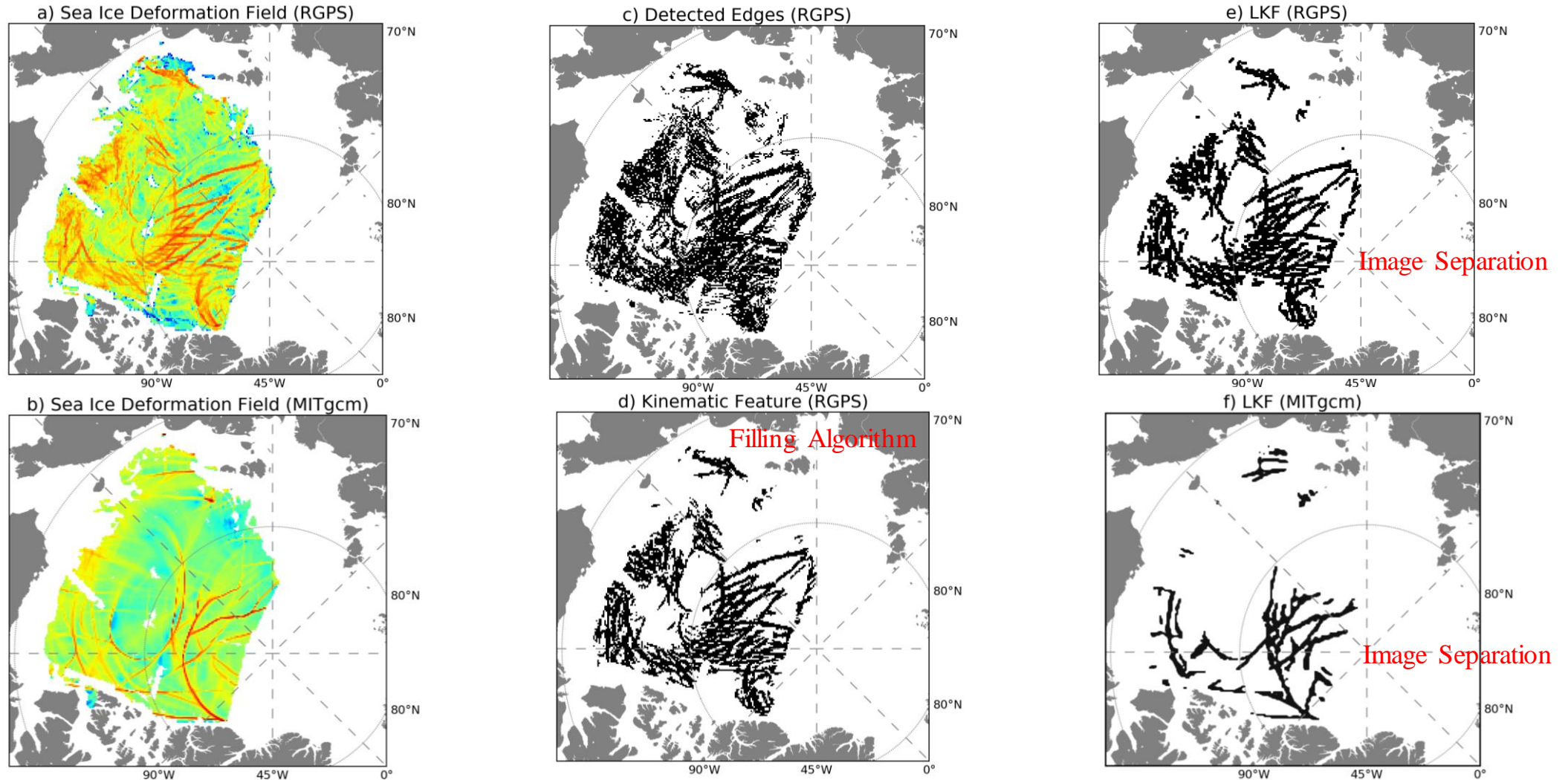e)  Distance and similarity measures

# 3- Application of the MDA

## 3.1. MDA of high-resolution sea ice deformation

# a) EDIS

- **E**dge **D**etection — using a two dimensional Marr-Hildreth Operator (MHO)
- Filling algorithm — using detected edges to find kinematic features
- **I**mage **S**eparation — curve-like features are separated from point-like features

2002-04-18



a) Sea Ice Deformation Field (RGPS)

b) Sea Ice Deformation Field (MITgcm)

c) Detected Edges (RGPS)

d) Kinematic Feature (RGPS)

Filling Algorithm

e) LKF (RGPS)
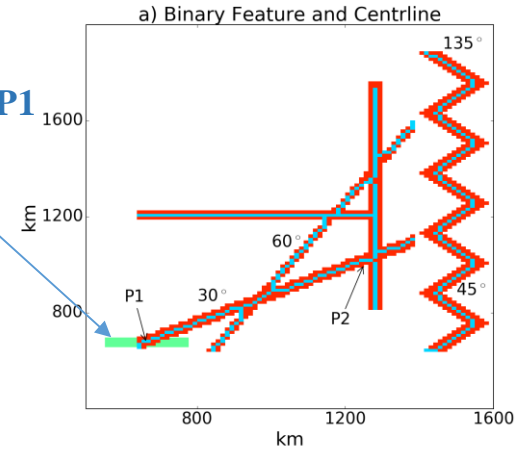
Image Separation

f) LKF (MITgcm)

Image Separation

4

# b) Estimation of main orientation

Measuring the angle of the centerlines with horizontal direction

- Thinning or centerline tracing of LKFs
- Estimating directional responses – using a set of multiscale directional filters
- Determining the main orientation

**Spatial filter at P1**



a) Binary Feature and Centrline

**Histograms of the directional response at P1 and P2**



b) Histogram
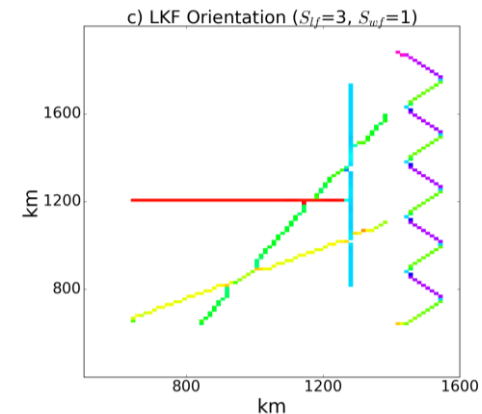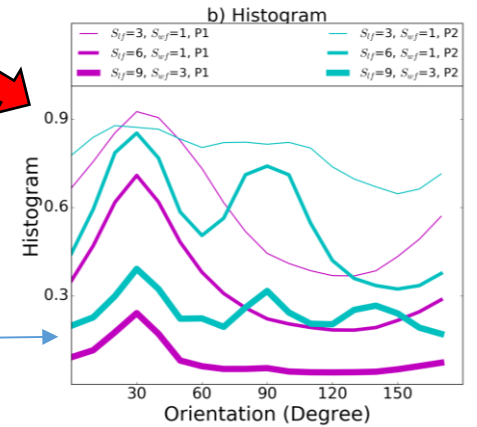
**Main local orientation**



c) LKF Orientation ($S_{lf}=3$, $S_{wf}=1$)

5

# c) Feature classification

I. All points on the centerline with more than one local maximum in the directional response

⟹ Class of intersection-points

Other points

⟹ Class of line-points

II. Contiguous patches of the extended set of Intersection-points

⟹ Intersection-point clusters & an arbitrary point in each cluster as initial centroid

III. Search for the points on the graph of centerline that are at most five grid points away from the centroid of each intersection-point cluster

⟹ Updated set of intersection-point clusters

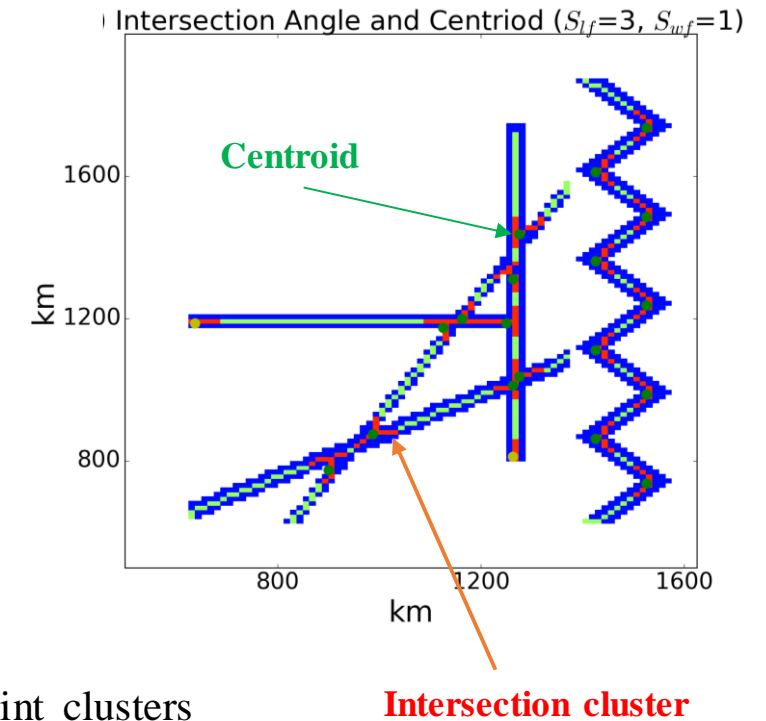IV. In each cluster, find the closest point to the actual centroid of the cluster

⟹ Updated centroid

V. Repeat III & IV steps

⟹ Until centroids do not change

Intersection Angle and Centriod ($S_{lf}$=3, $S_{wf}$=1)

**Centroid**

**Intersection cluster**

# d) Estimation of intersection angles

The difference between the main orientation of the points that are furthest away from each centroid but still within the same intersection-point cluster

# e) Distance and similarity measures

Comparison of frequency distributions of orientations and intersections angles of LKFs.

We use the Earth Mover's Distance (EMD).

Low EMD ⟹ High similarities

We compare EMD to a Benchmark EMD.

We compute EMD benchmark values for each date by averaging the EMD of the single RGPS scene relative to all individual MITgcm scenes.
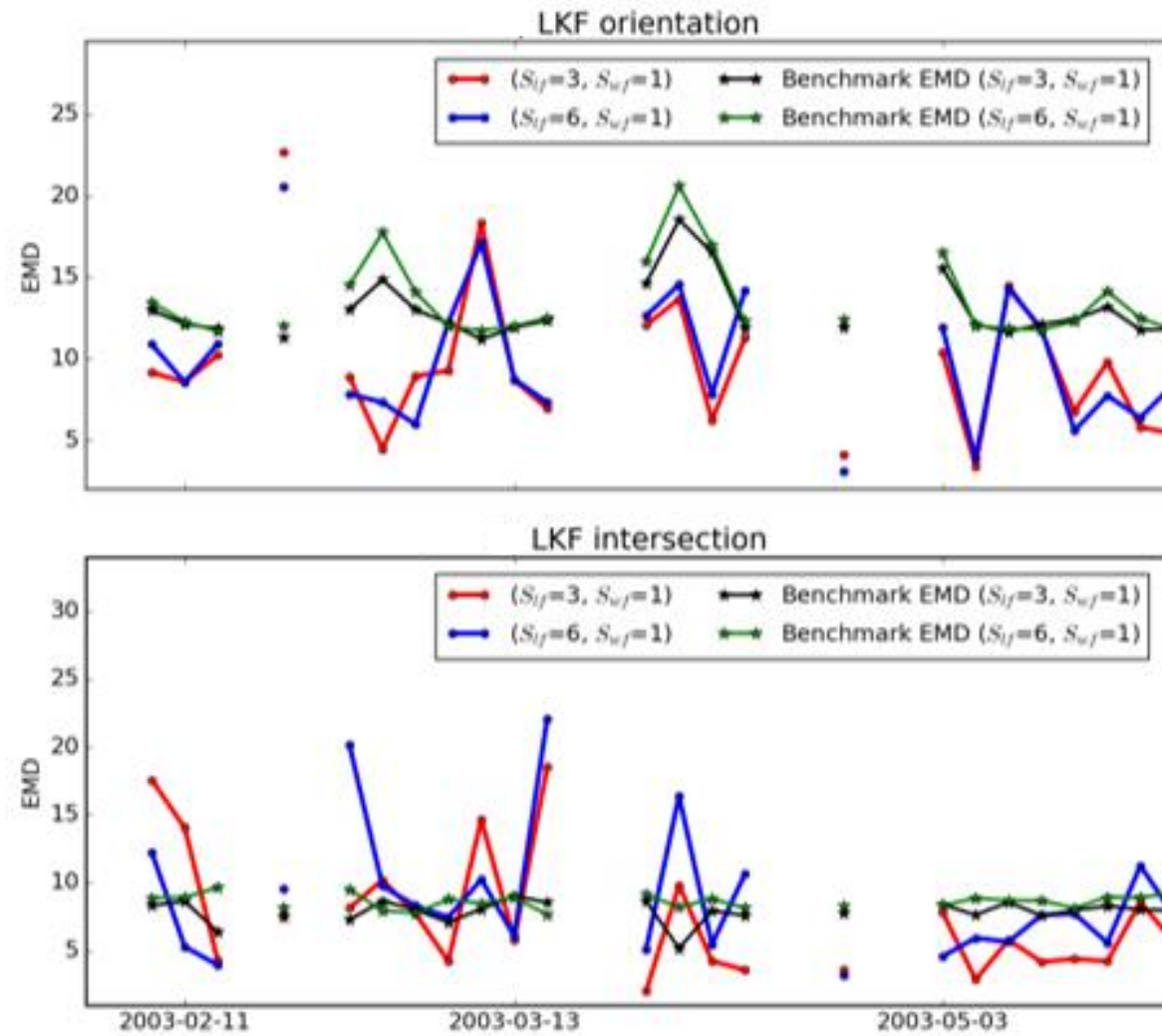
# MDA of high-resolution sea ice deformation
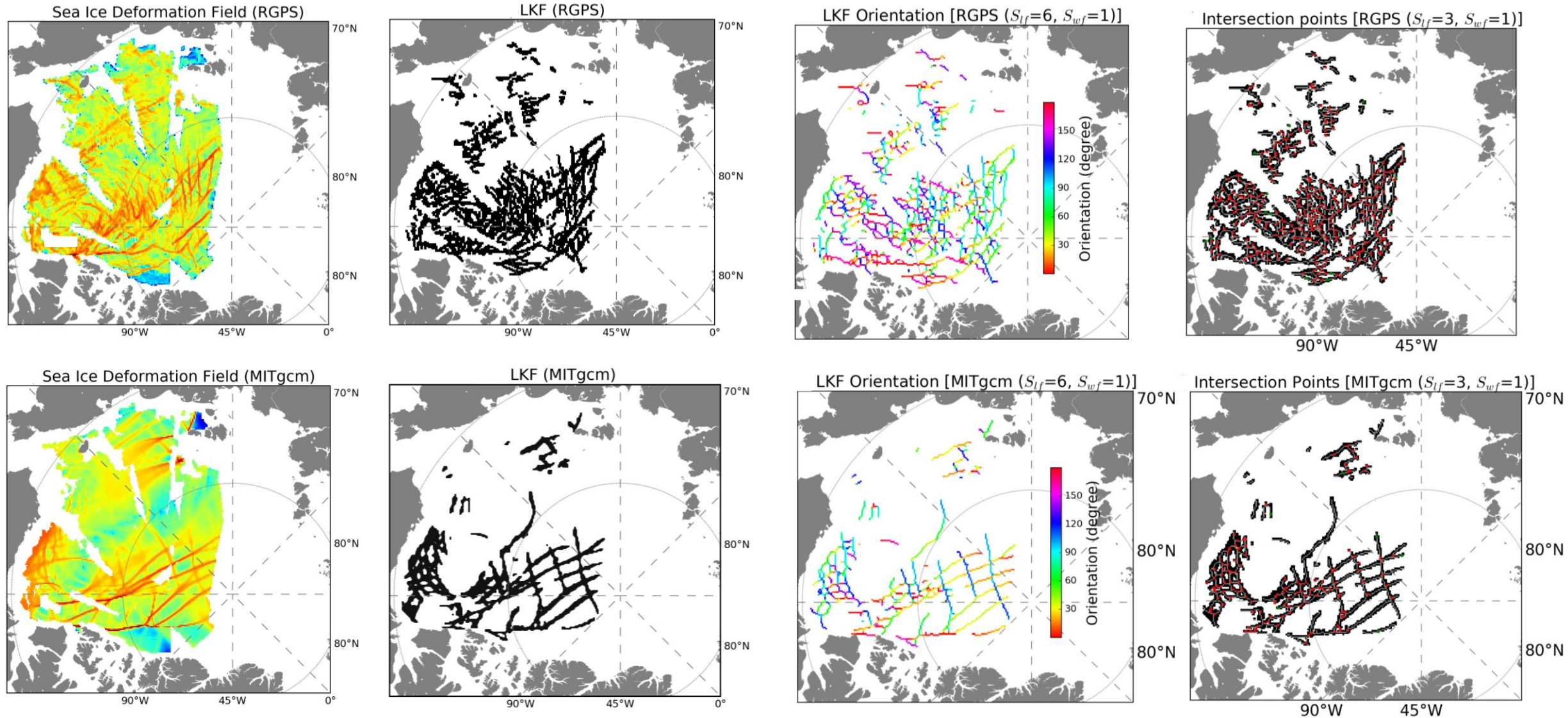


2003-03-13

# MDA of high-resolution sea ice deformation

# Summary and Conclusions

1 - We introduce a Multi-Directional Analysis (MDA) as a new method for evaluating the spatial patterns of linear kinematic features (LKF).

2- A MDA-based comparison will complement established sea-ice forecast verification methods by adding local and scale-dependent spatial information of geomorphological patterns of LKFs.

3- MDA quantifies properties such as orientation for each LKF-classified grid point individually instead of assigning one value for a segment of LKF.

4- The possibility to use different spatial filters enables us to assess sea-ice dynamics on different spatial scales while properly accounting for the finite width of LKFs.

5- MDA is designed to work reliably, even in places with complex patterns of LKFs, and avoids the cost of feature segmentation and semantic post-processing.

Submitted manuscript:
http://mitgcm.org/~mlosch/mohammadi-etal_mda.pdf