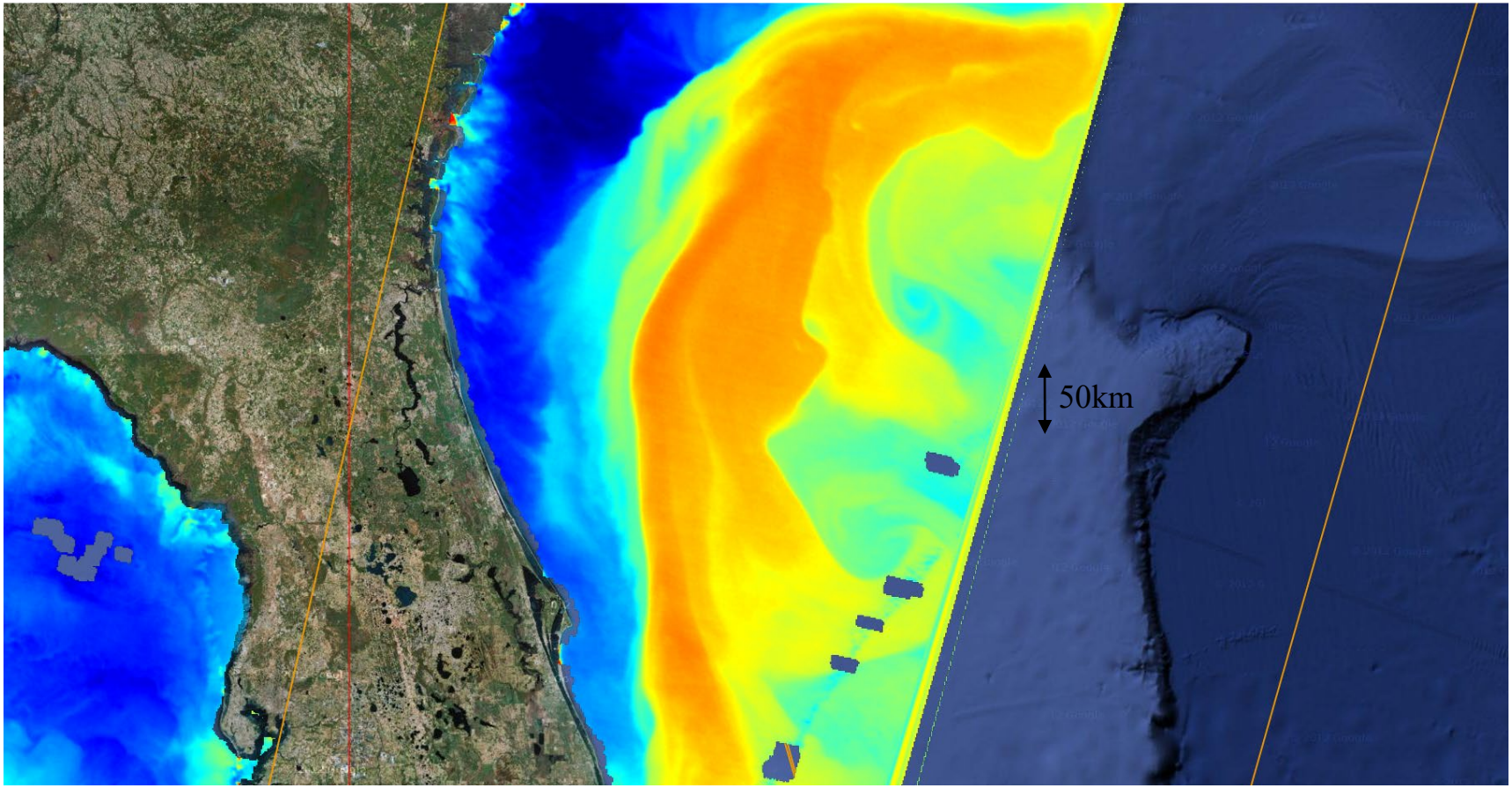
Nicolas Rascle et al.

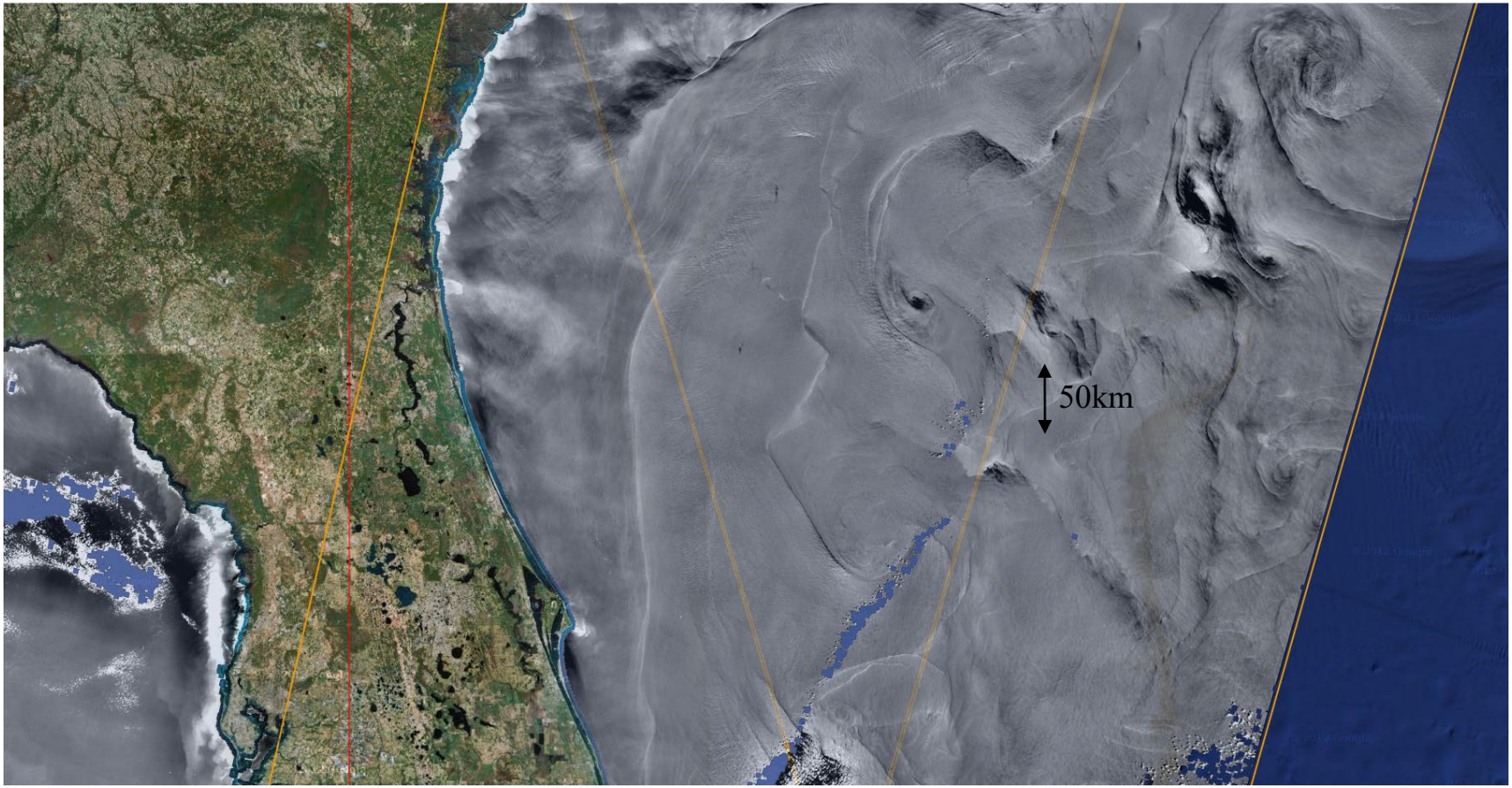
Intense deformation field at oceanic front inferred from directional sea surface roughness observations

Scientific goal:
Provide satellite observations to support high resolution (1km) understanding of the ocean (and ocean/waves/atmosphere) system



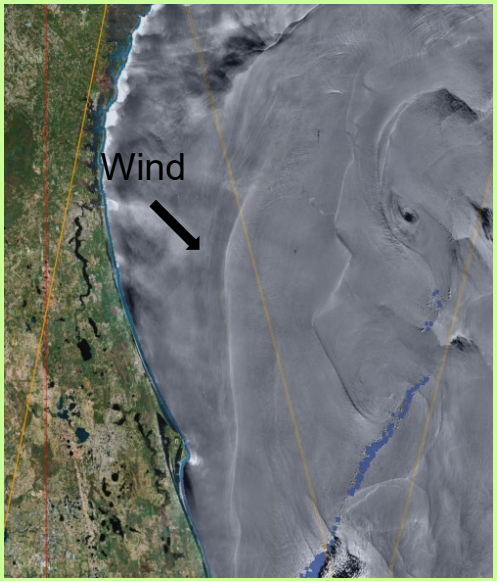
SST, Modis (250m)

Scientific goal:
Provide satellite observations to support high resolution (1km) understanding of the ocean (and ocean/waves/atmosphere) system



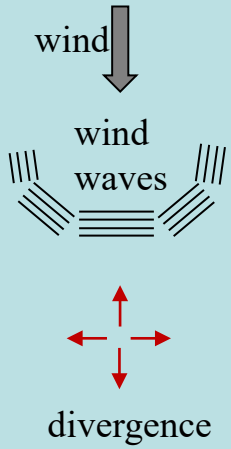
Roughness, sun glitter, Meris (250m)

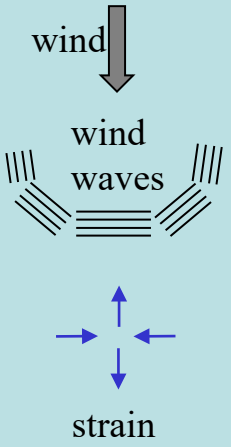
"Current gradient"
Which deformation property of the surface currents?



Meris glitter

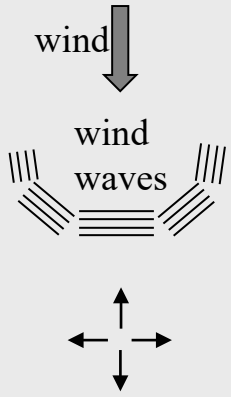
Roughness images show the interactions of wind waves with current divergence and strain in the wind direction.



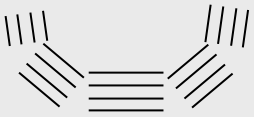


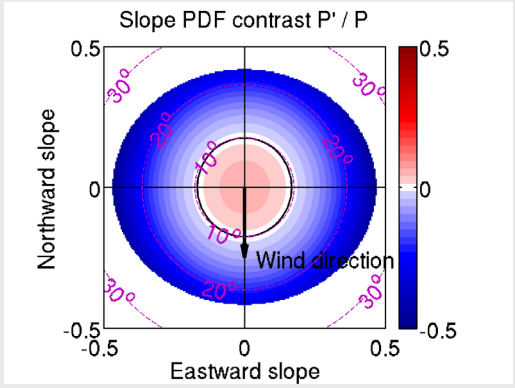
"Surface roughness imaging of currents shows divergence and strain in the wind direction"

N. Rascle, B. Chapron, A. Ponte, F. Ardhuin, P. Klein
Journal of Physical Oceanography, 2014

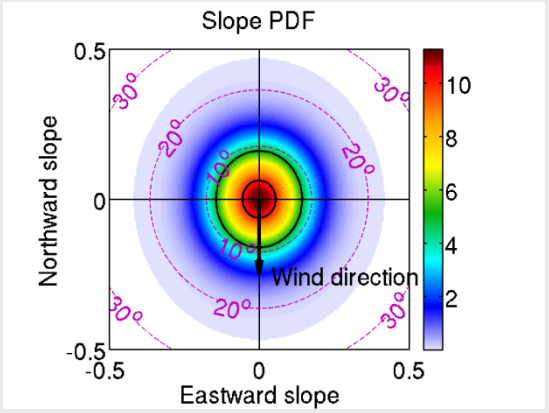


All waves are elongated.

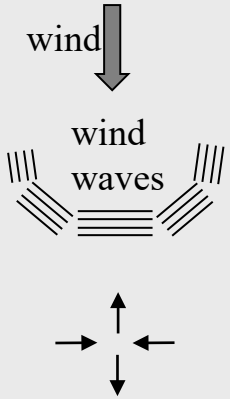




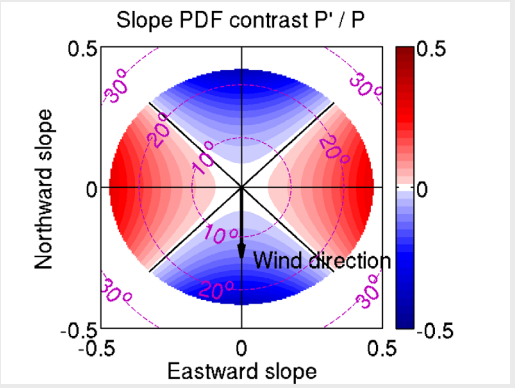
Slope PDF contrast:
Less roughness



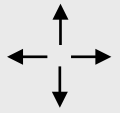
Background slope PDF



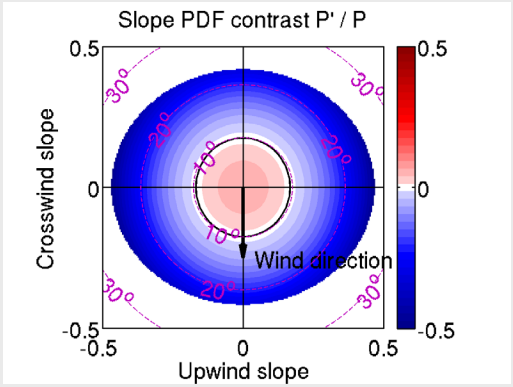
Alongwind waves are elongated.
Crosswind waves are compressed.



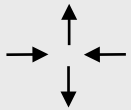
Slope PDF contrast:
More crosswind roughness
Less upwind roughness



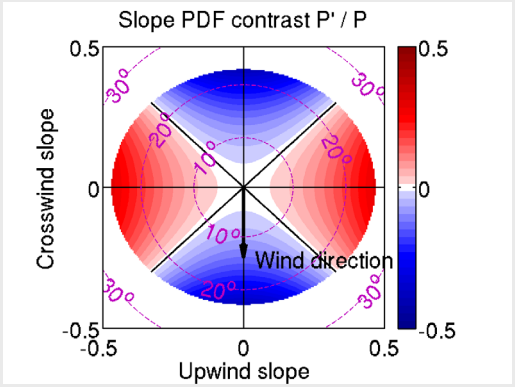
divergence



Slope PDF contrast:
Less roughness



strain

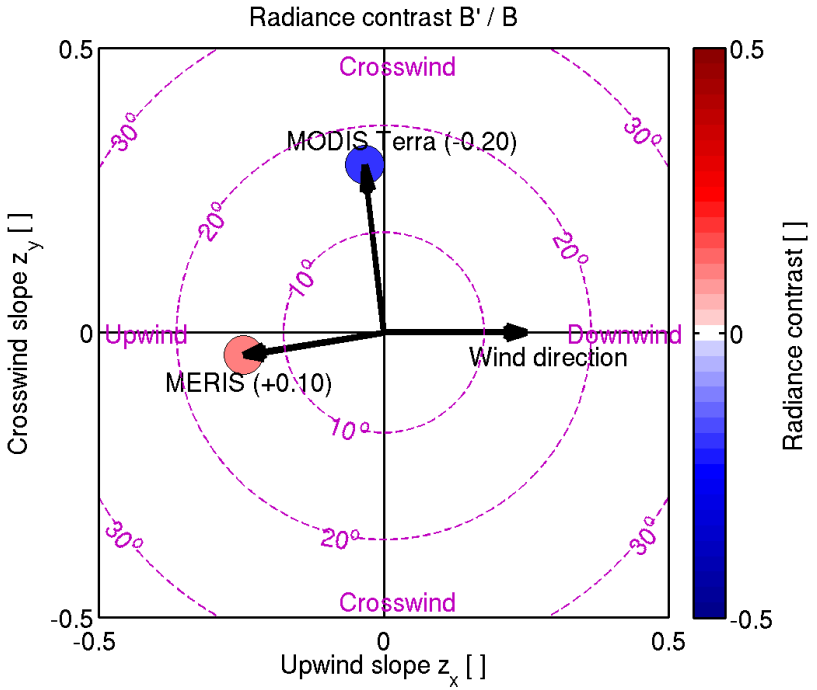


Slope PDF contrast:
More crosswind roughness
Less upwind roughness

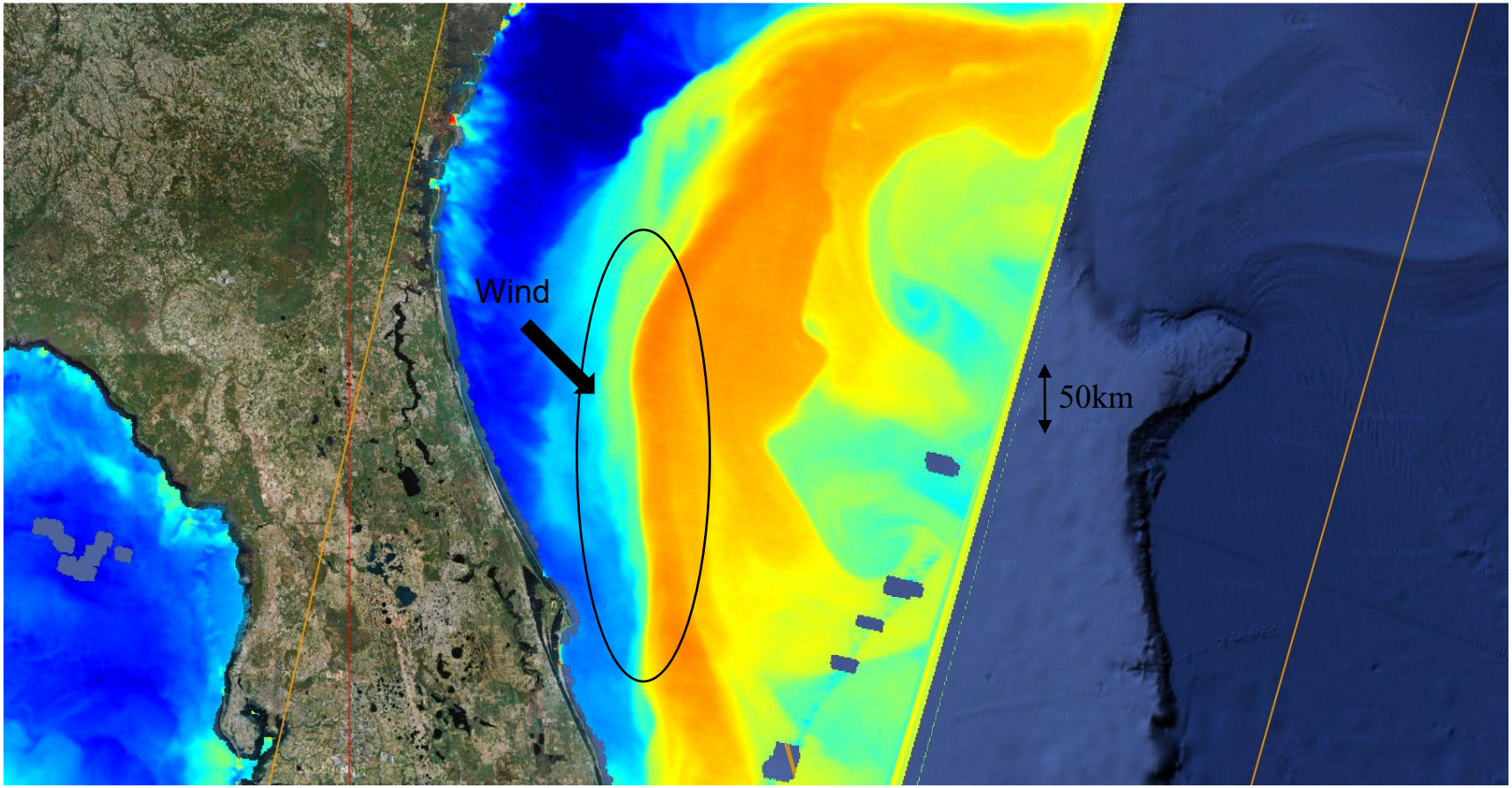
We can separate the different components of the current gradient (divergence, strain,…) using roughness observations at multiple view angles
(same as wind retrieval in scatterometry)

Exemples of sunglitter at multiple azimuth view angles

Using 2 different satellites
(Terra and Envisat):

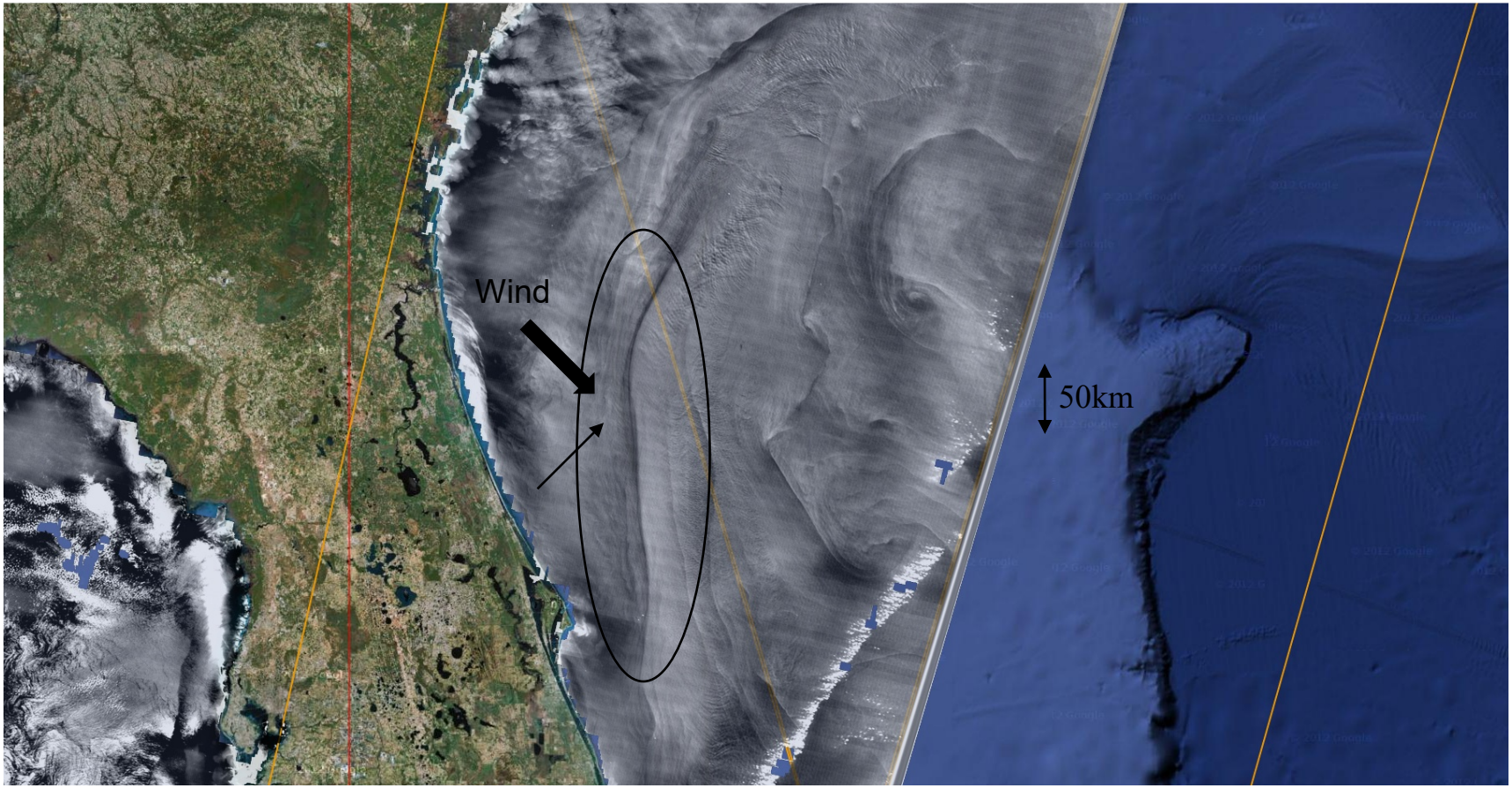


3) Multiple view angles



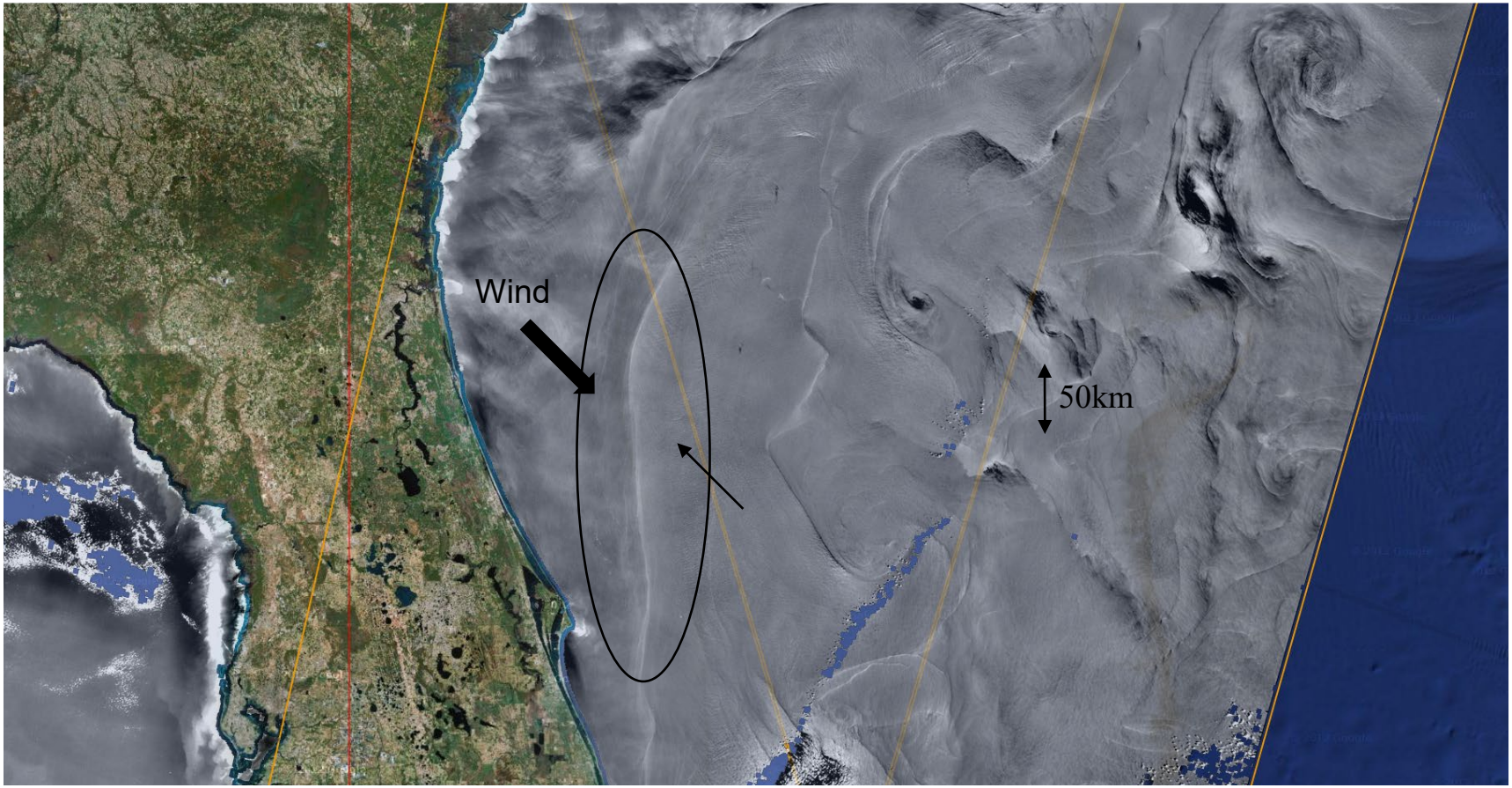
Modis SST

3) Multiple view angles



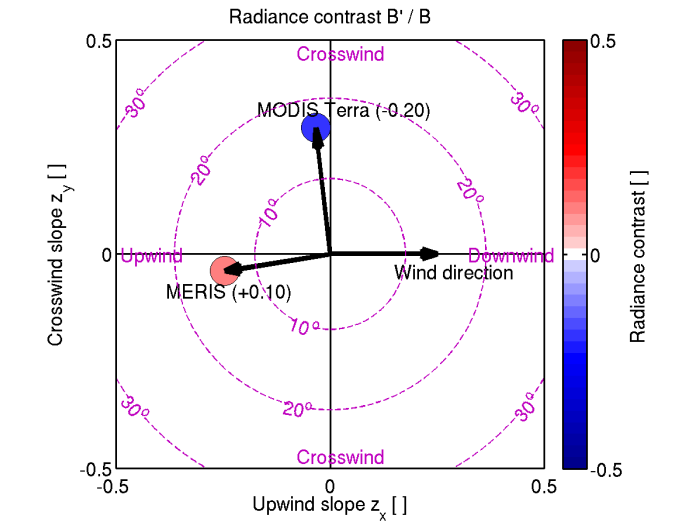
Modis Terra glitter

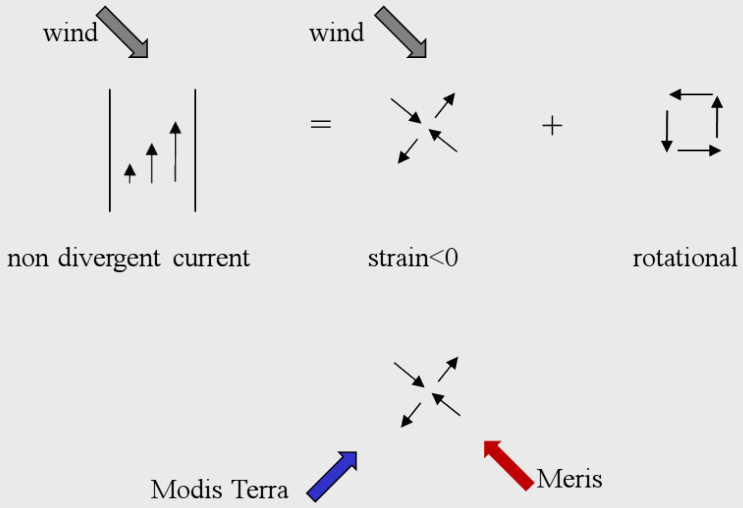
3) Multiple view angles



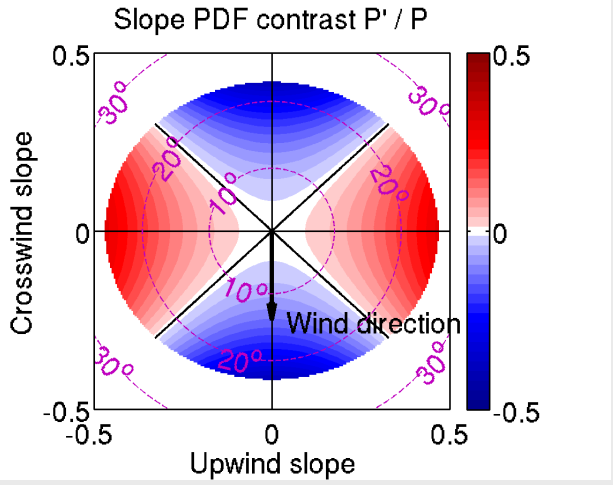
Meris glitter

3) Multiple view angles





Evidence of strain in surface roughness at multiple view angles

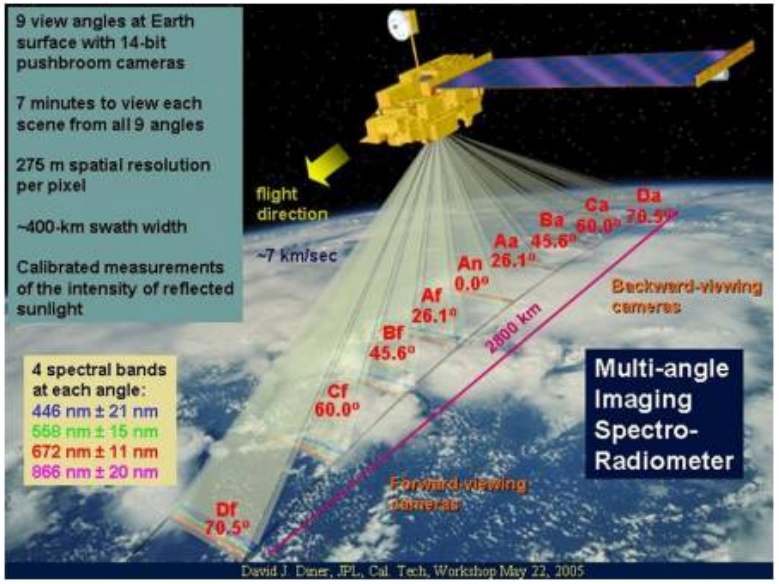


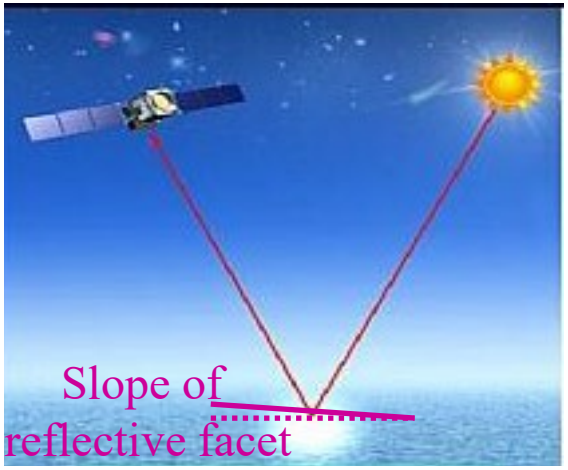
"Surface roughness changes by fine scale current gradients: Properties at multiple azimuth view angles"

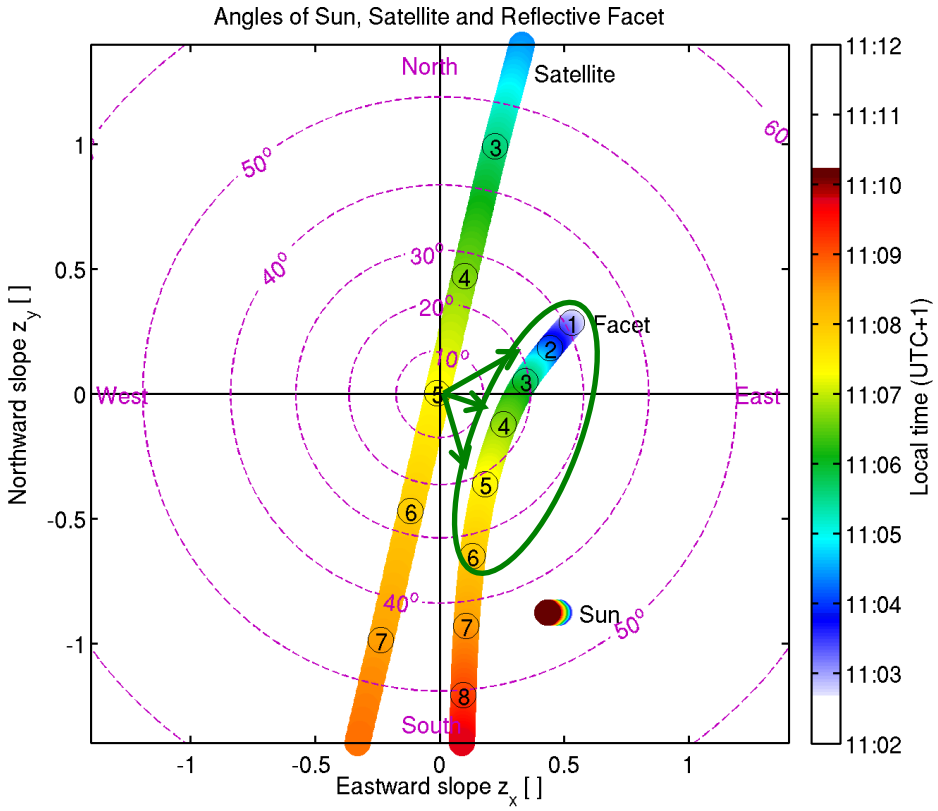
N. Rascle, F. Nouguier, B. Chapron, A. Mouche, A. Ponte
Journal of Physical Oceanography, 2016

Exemples of sunglitter at multiple azimuth view angles

Using 1 satellite with multi-look sensor: MISR (onboard Terra)

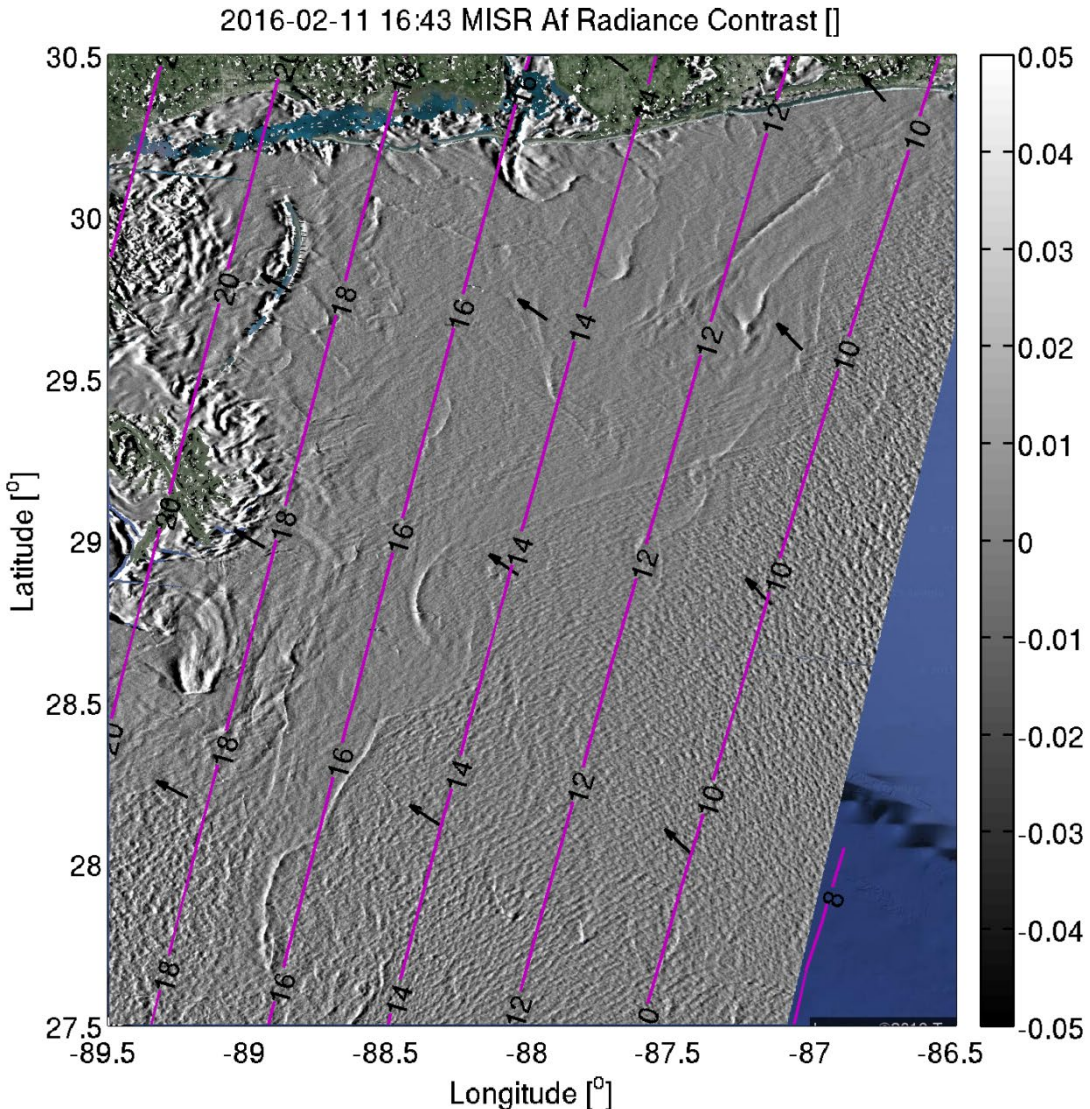




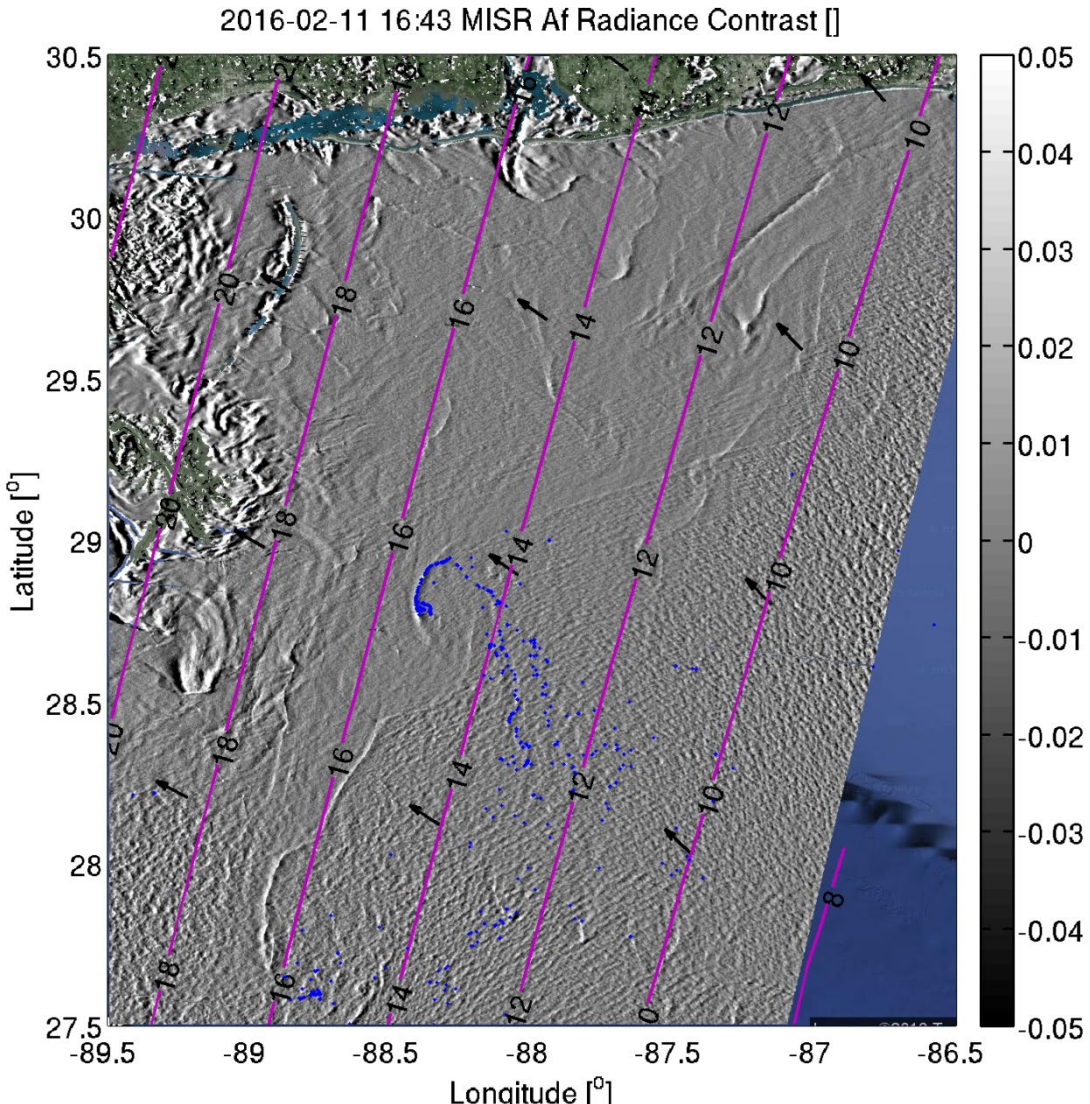


Azimuth diversity of facets from zenith diversity of sensor

Surface roughness from sun glint at multiple view angles: example during GoM experiment (LASER 2016, (CARTHE, Ozgokmen et al.)



Surface roughness from sun glint at multiple view angles: example during GoM experiment (LASER 2016, (CARTHE, Ozgokmen et al.)



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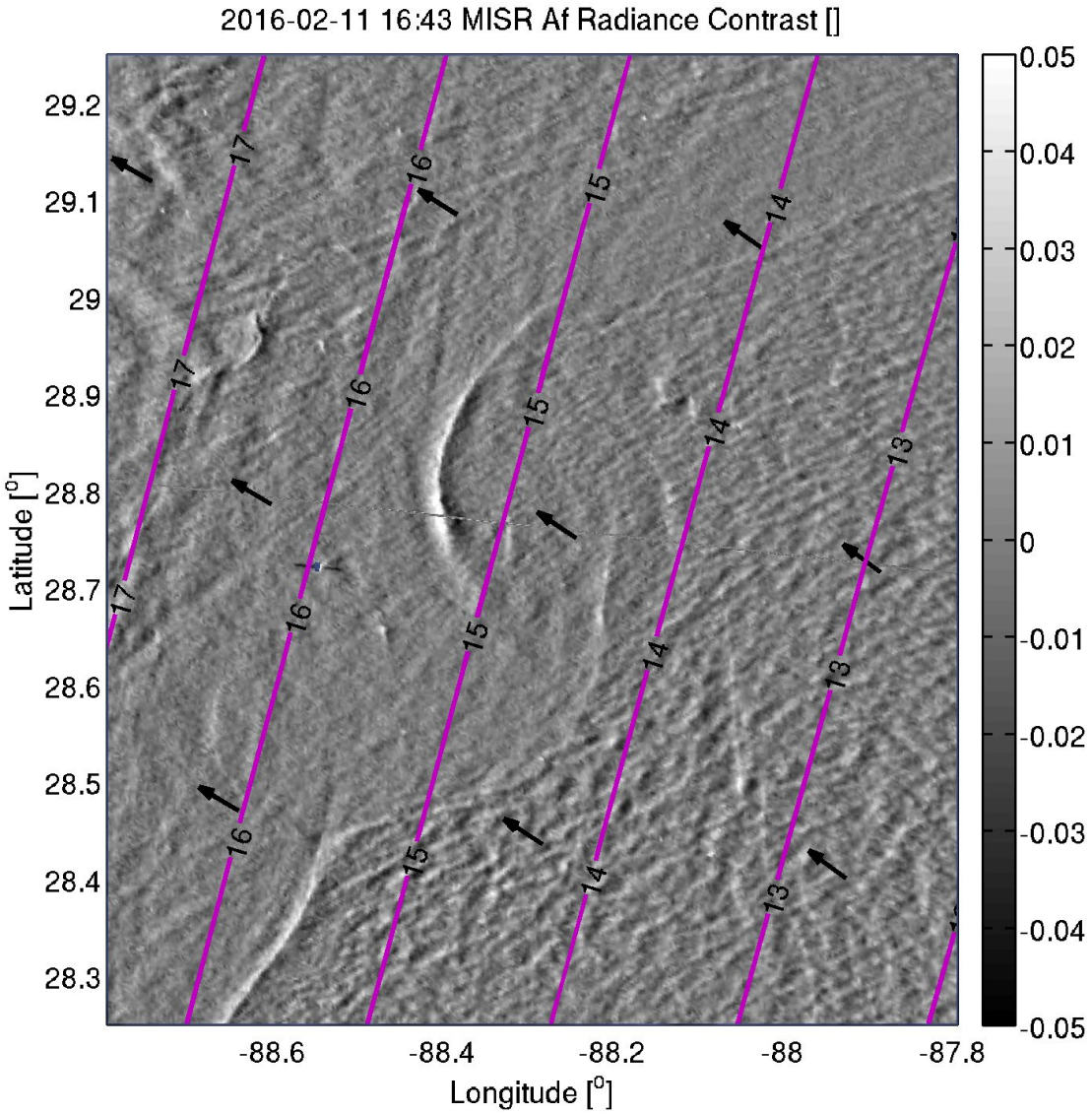

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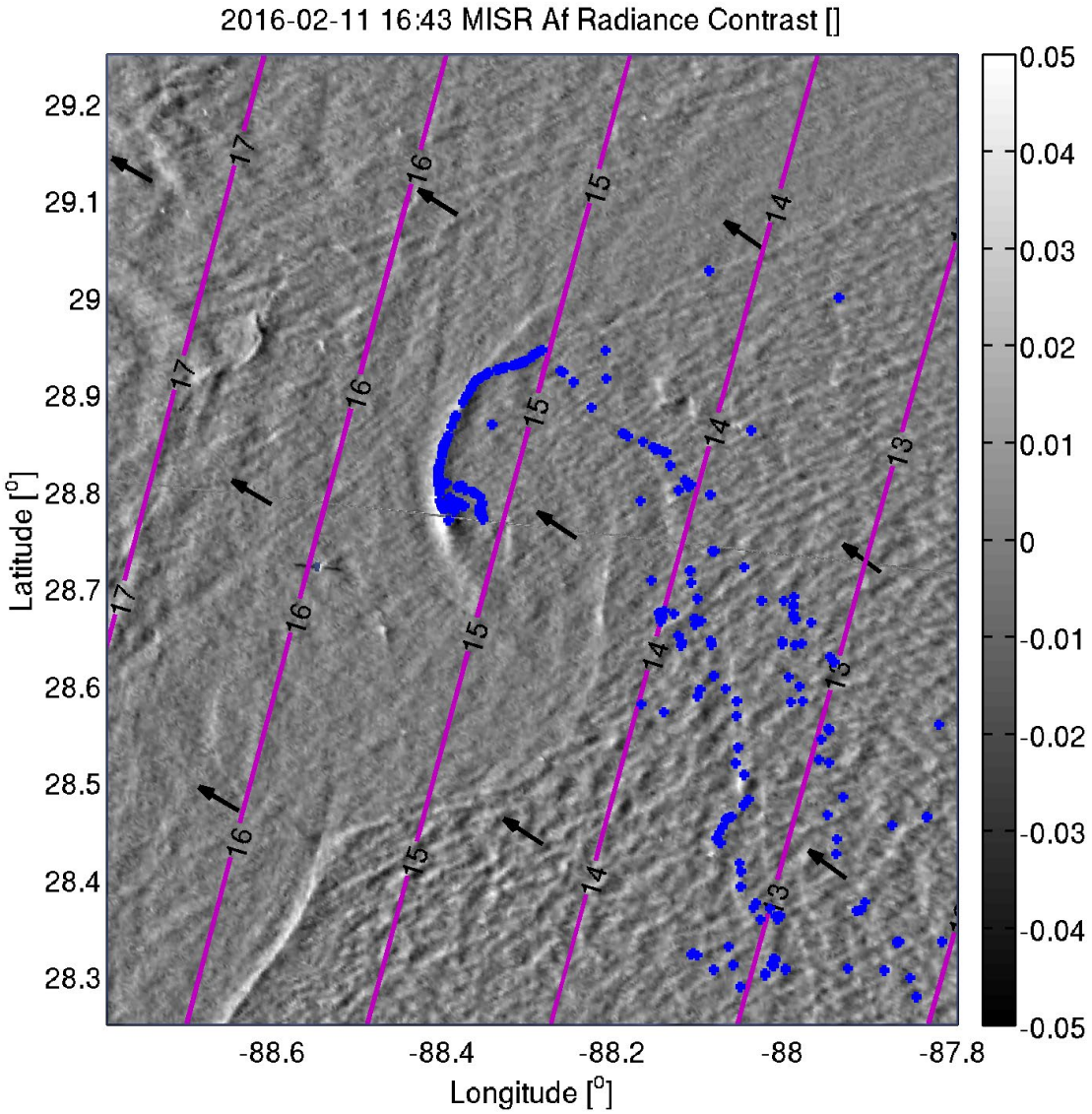

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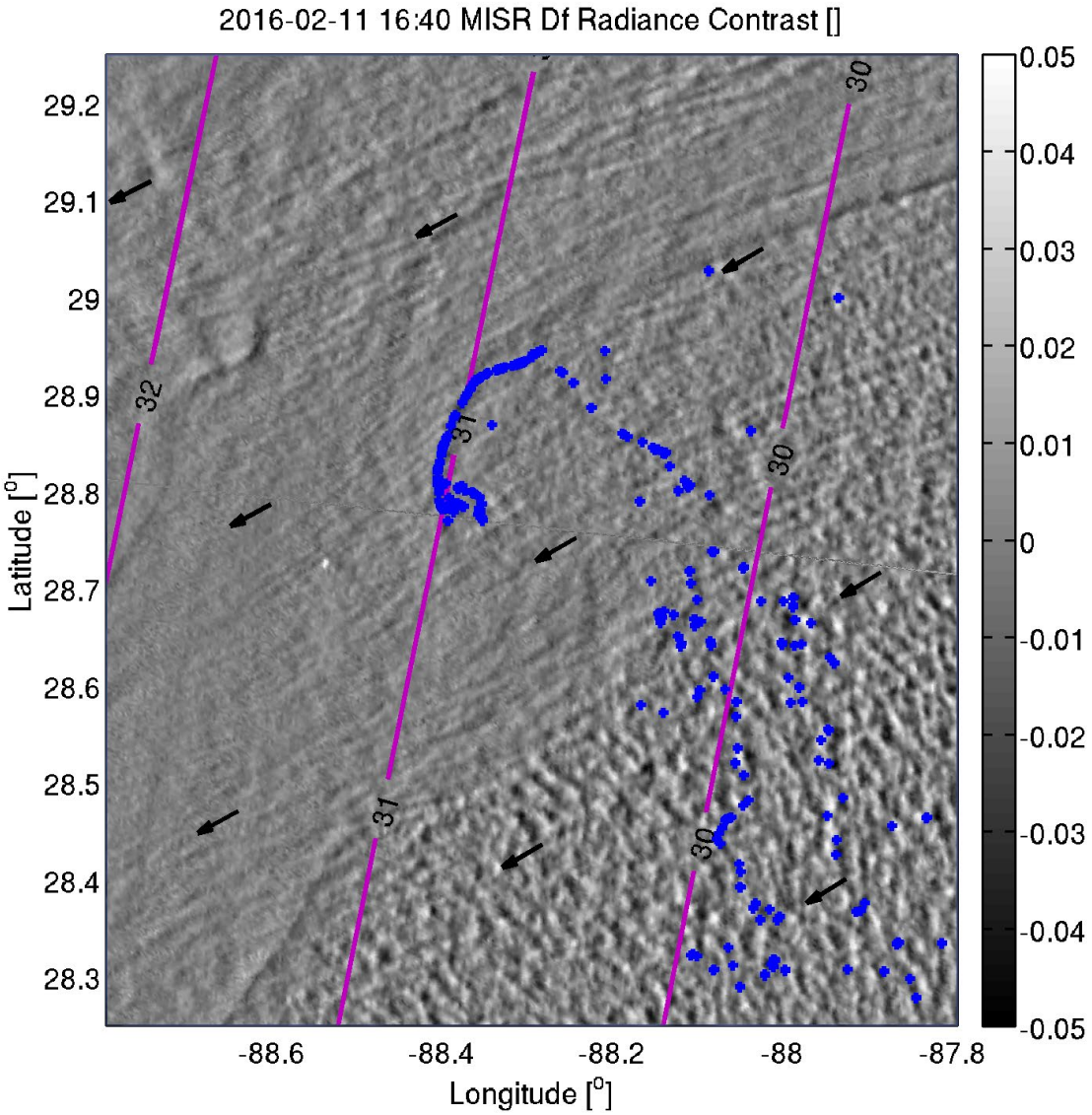

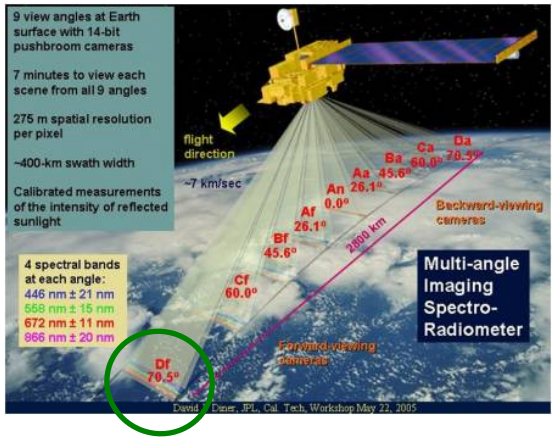

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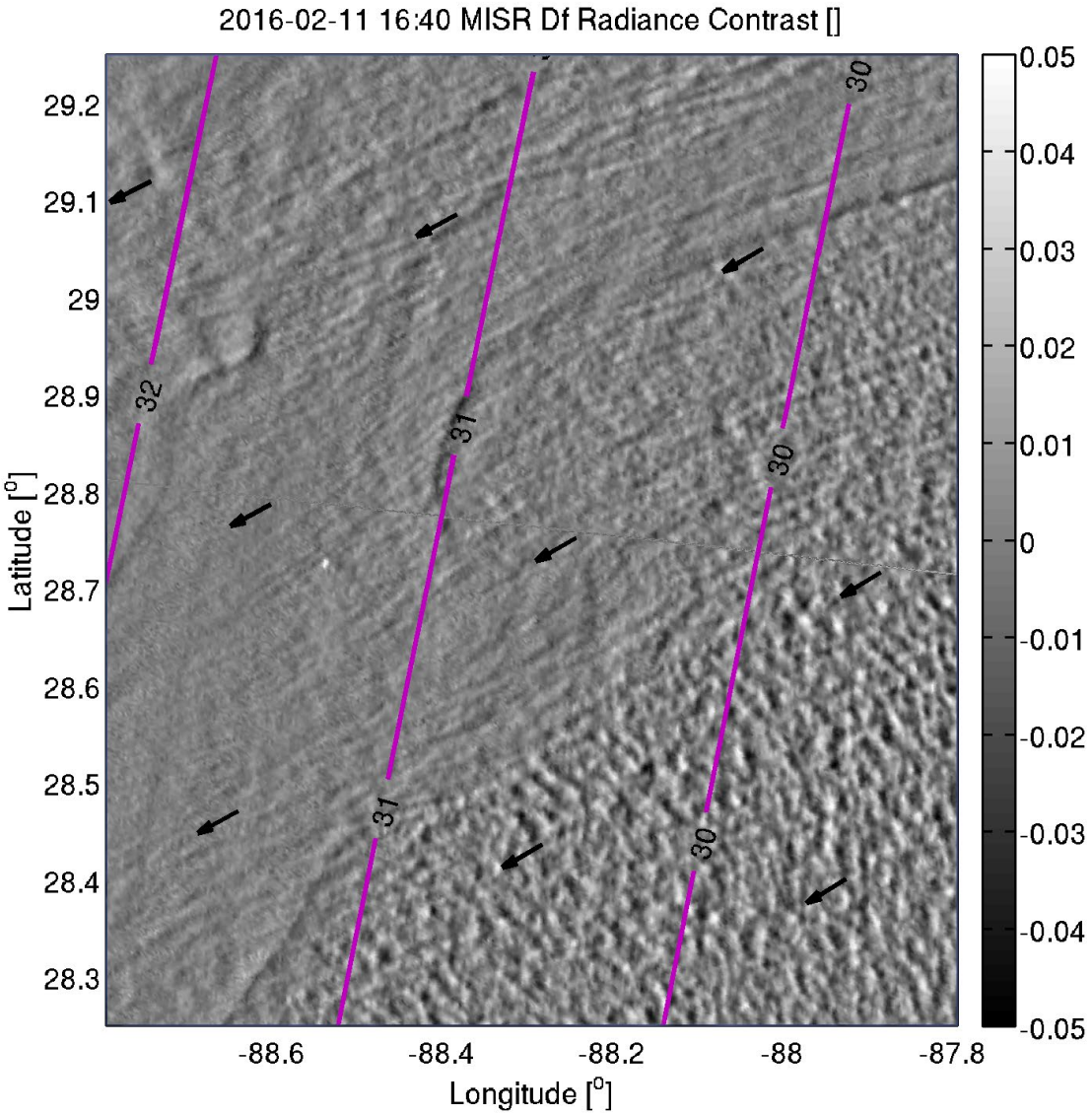
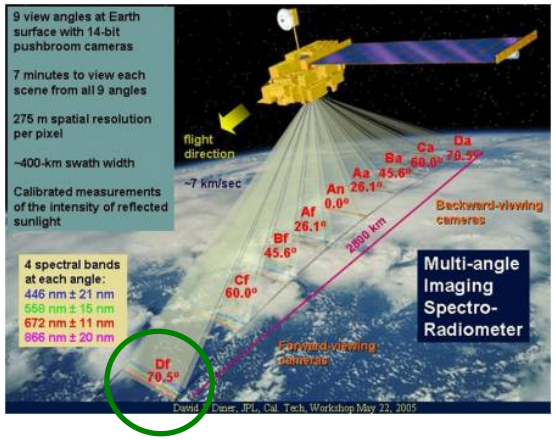
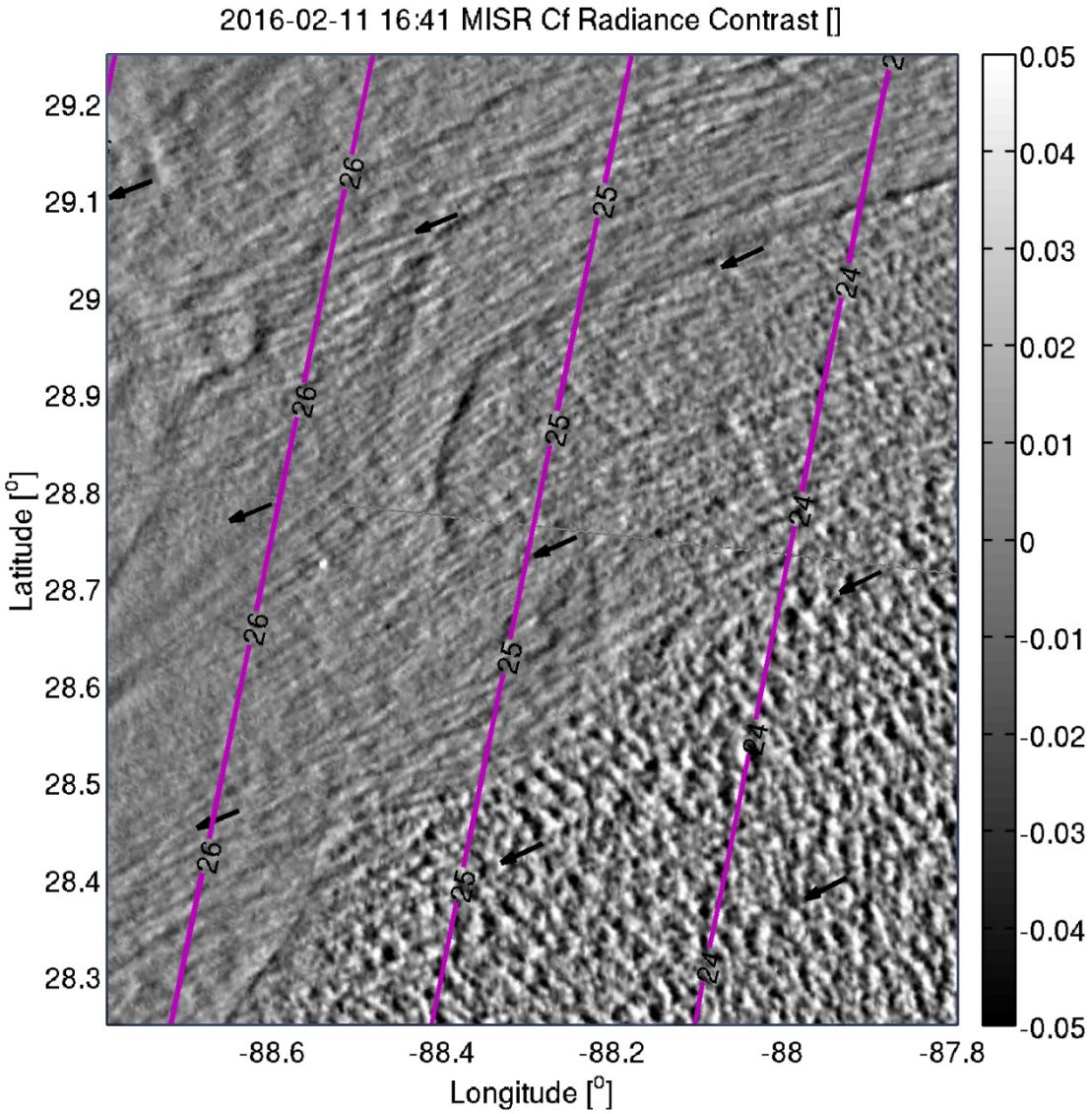
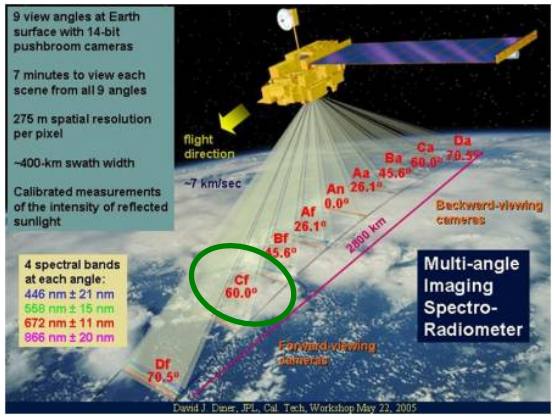


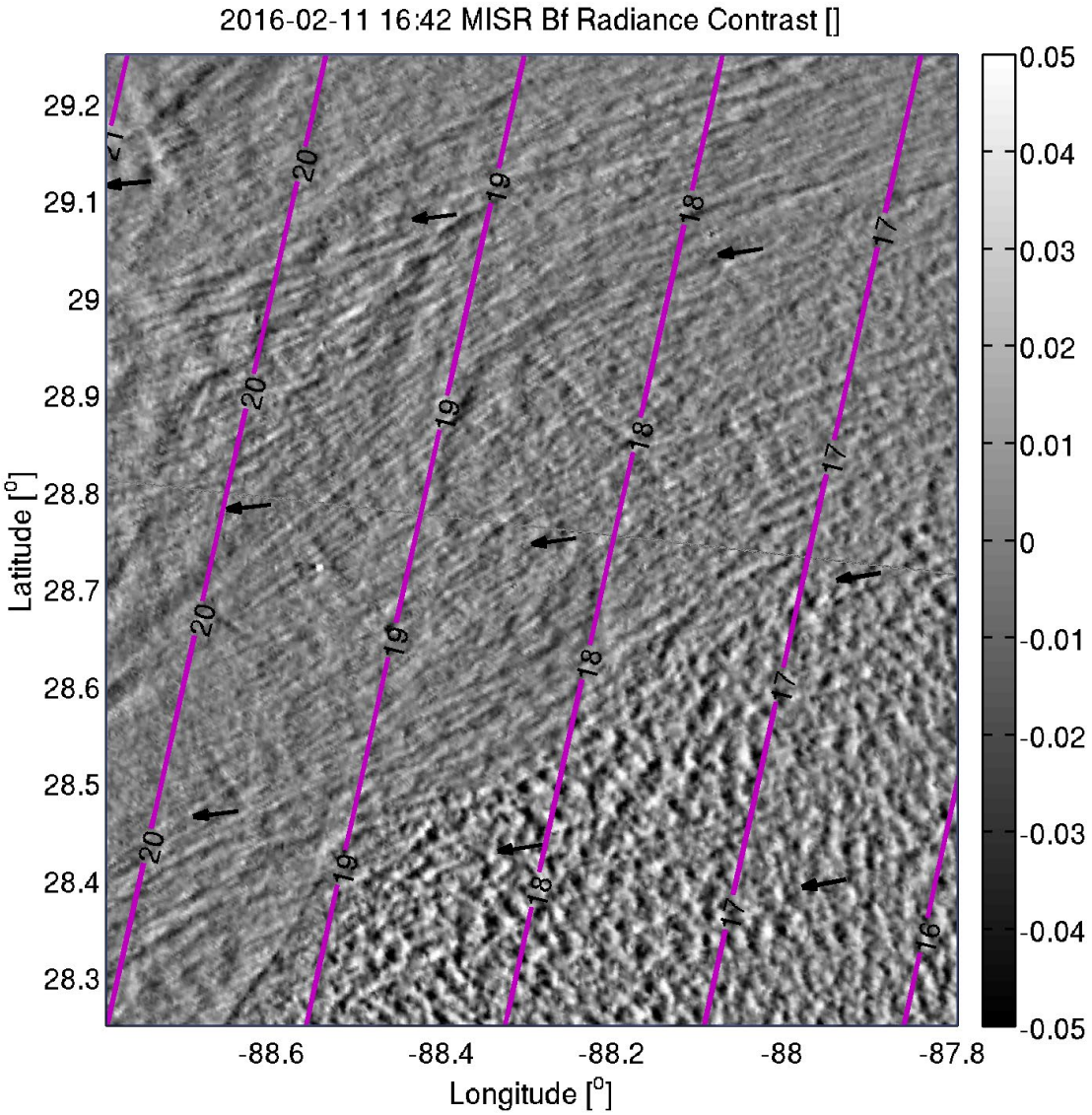


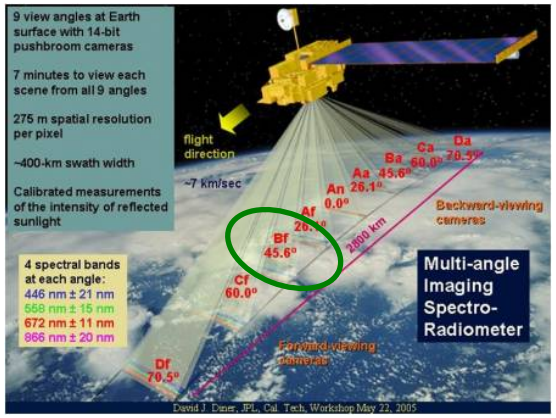
Surface roughness from sun glint at multiple view angles: example during GoM experiment (LASER 2016)



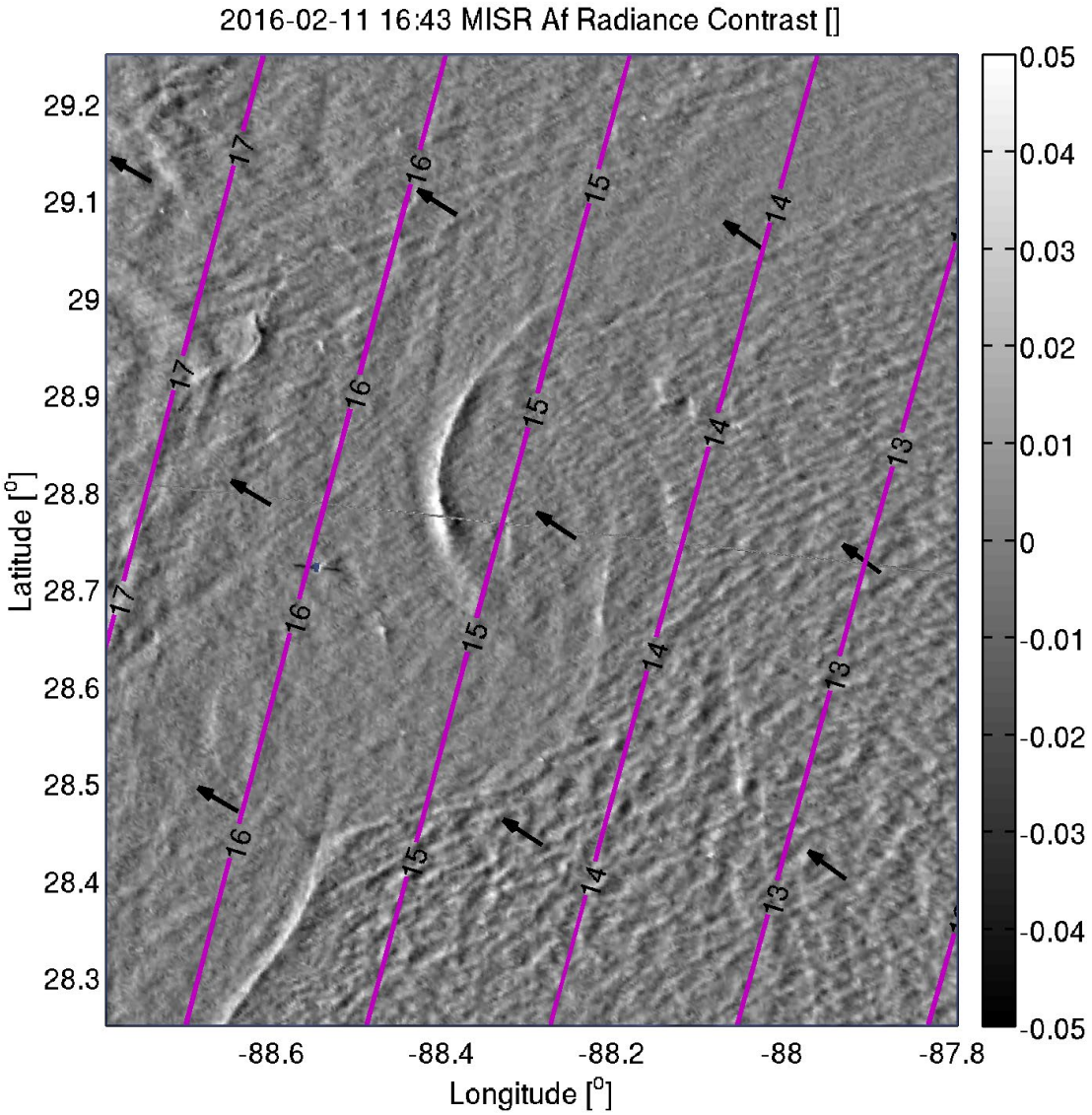


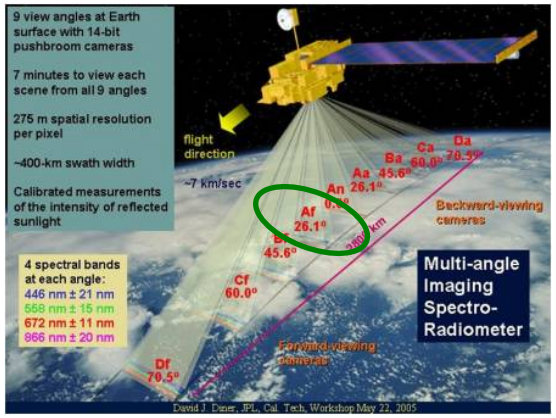
Surface roughness from sun glint at multiple view angles: example during GoM experiment (LASER 2016)



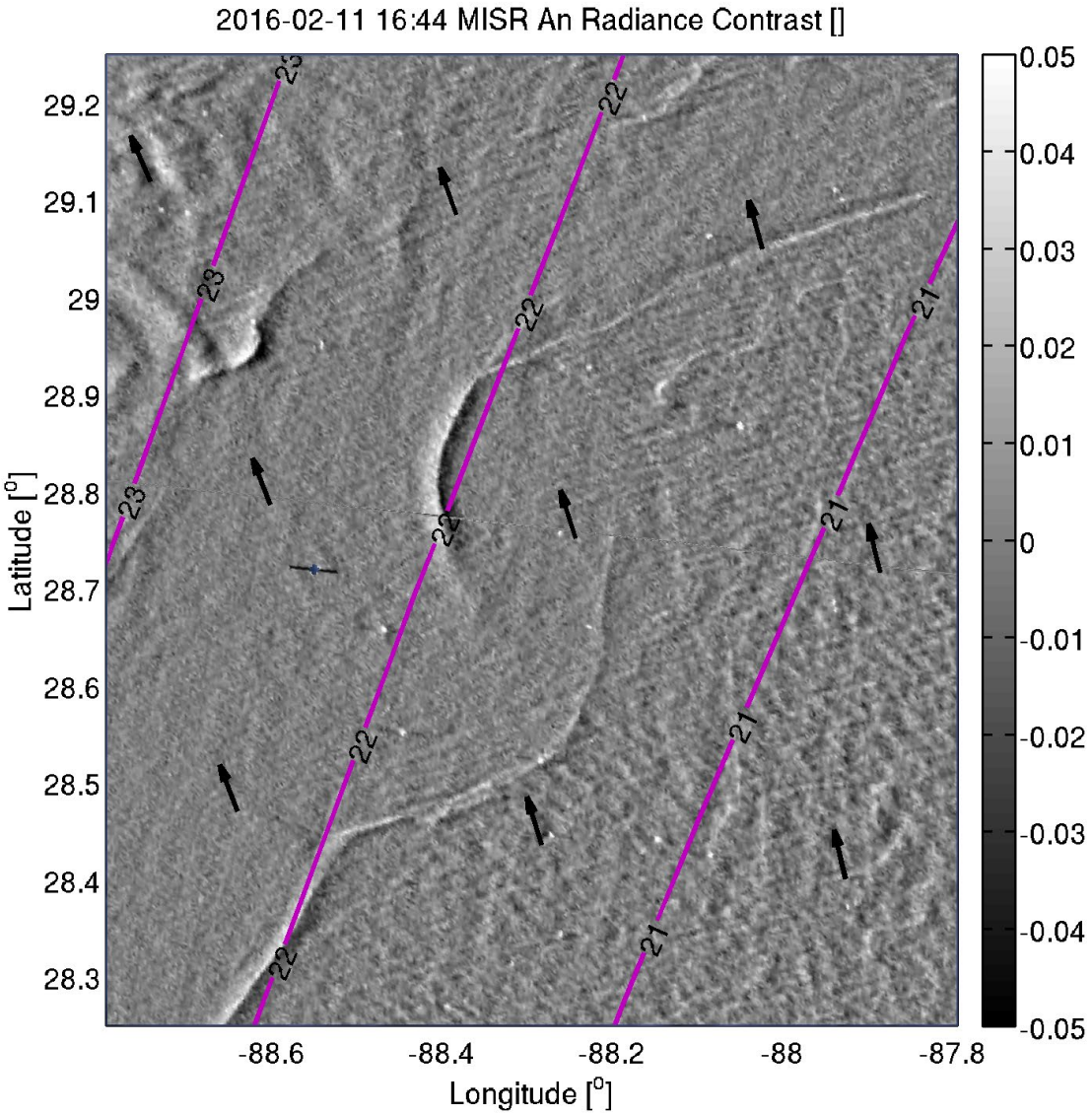


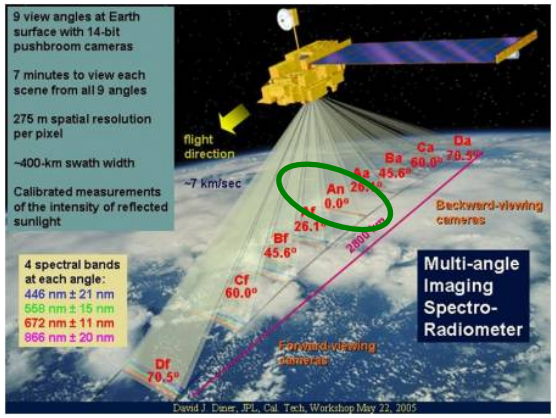
Surface roughness from sun glint at multiple view angles: example during GoM experiment (LASER 2016)



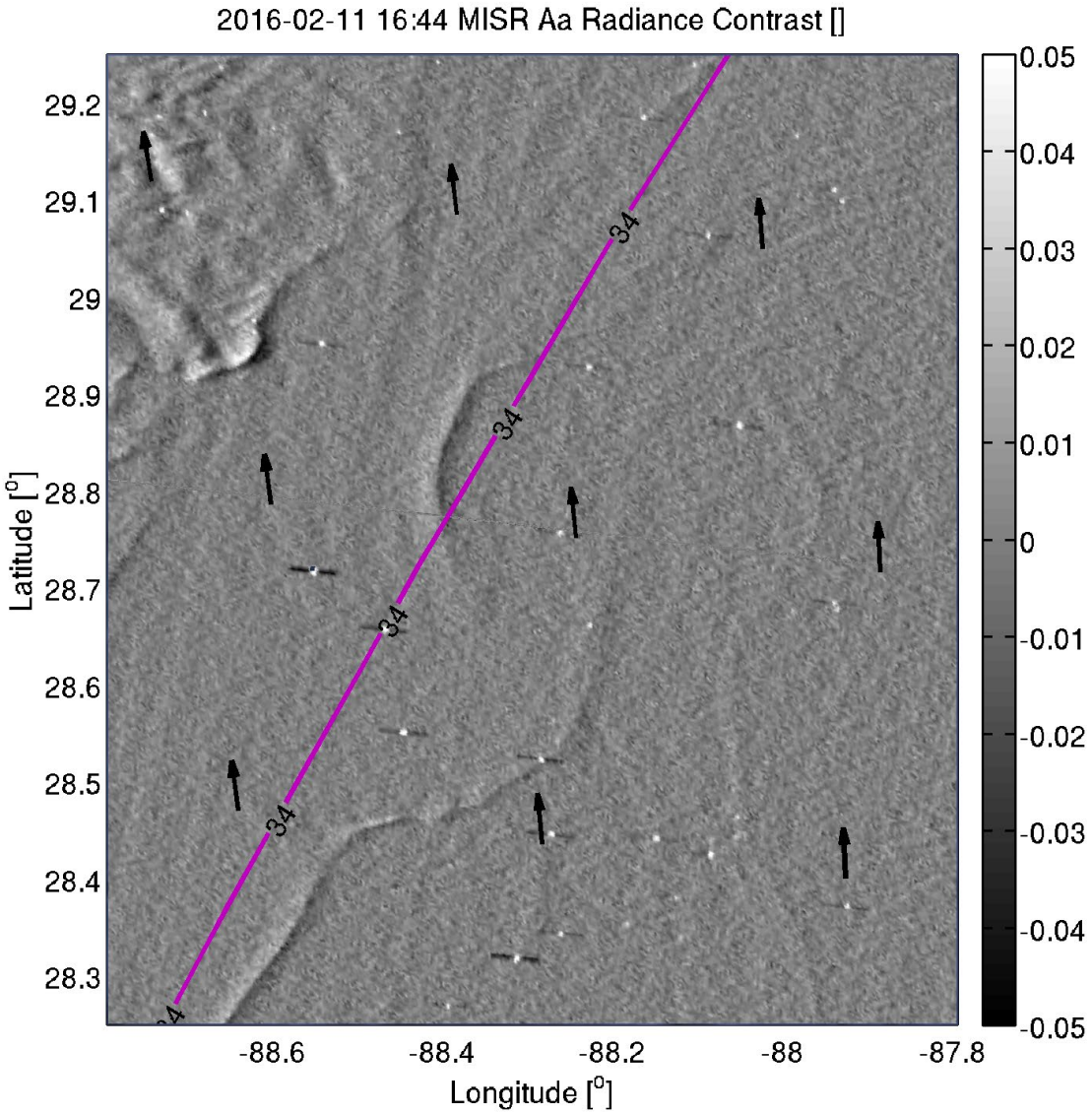


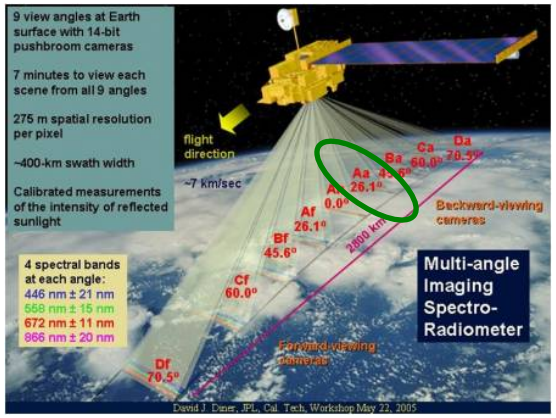
Surface roughness from sun glint at multiple view angles: example during GoM experiment (LASER 2016)



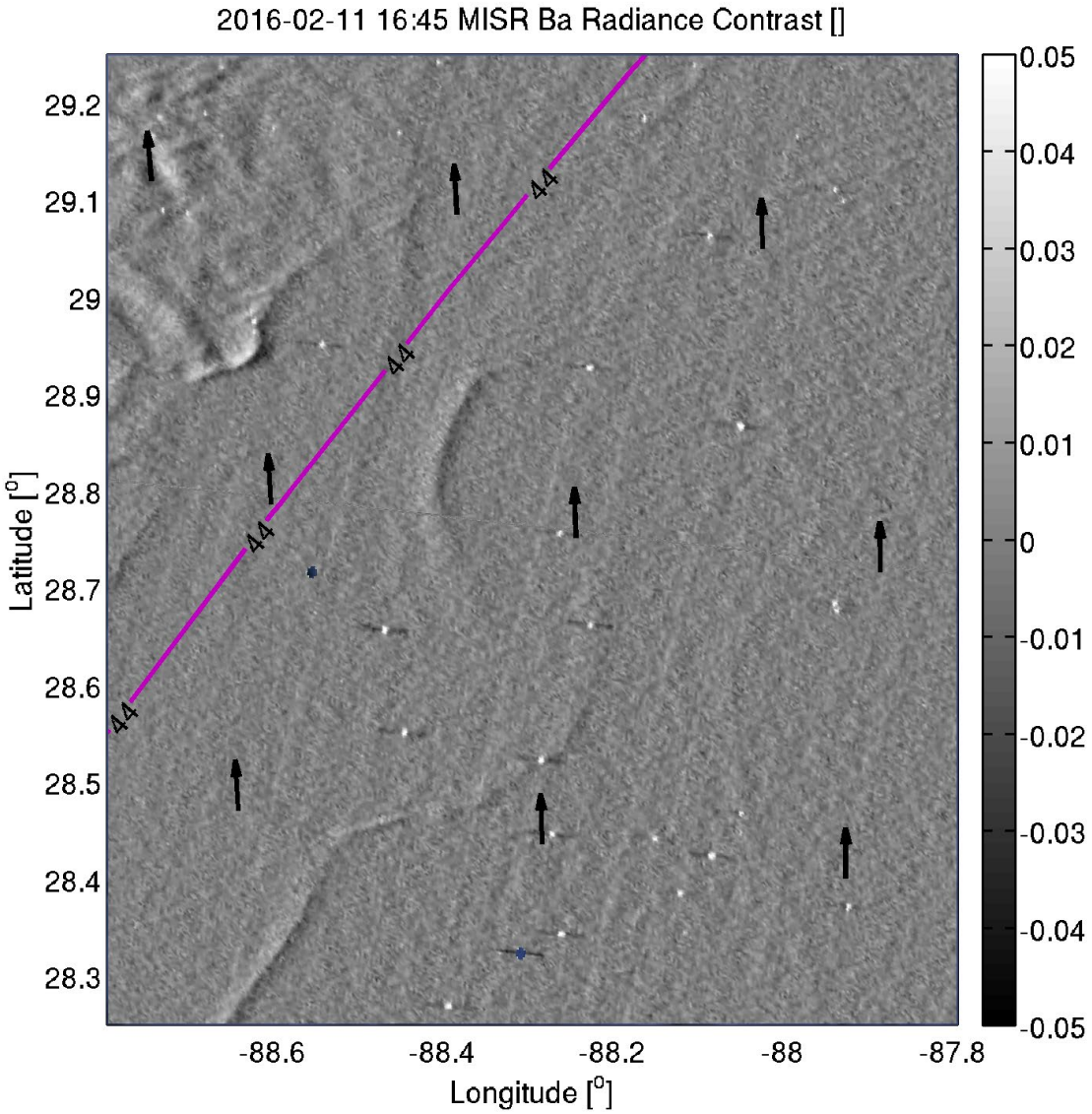


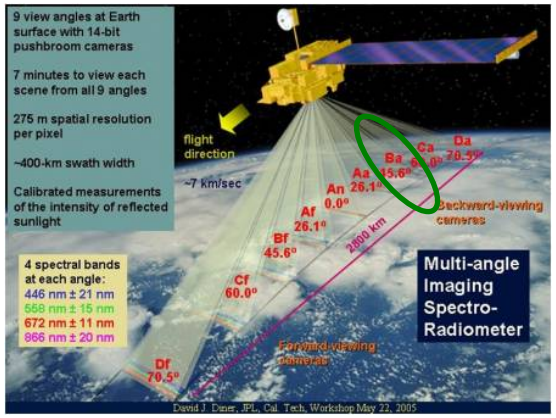
Surface roughness from sun glint at multiple view angles: example during GoM experiment (LASER 2016)



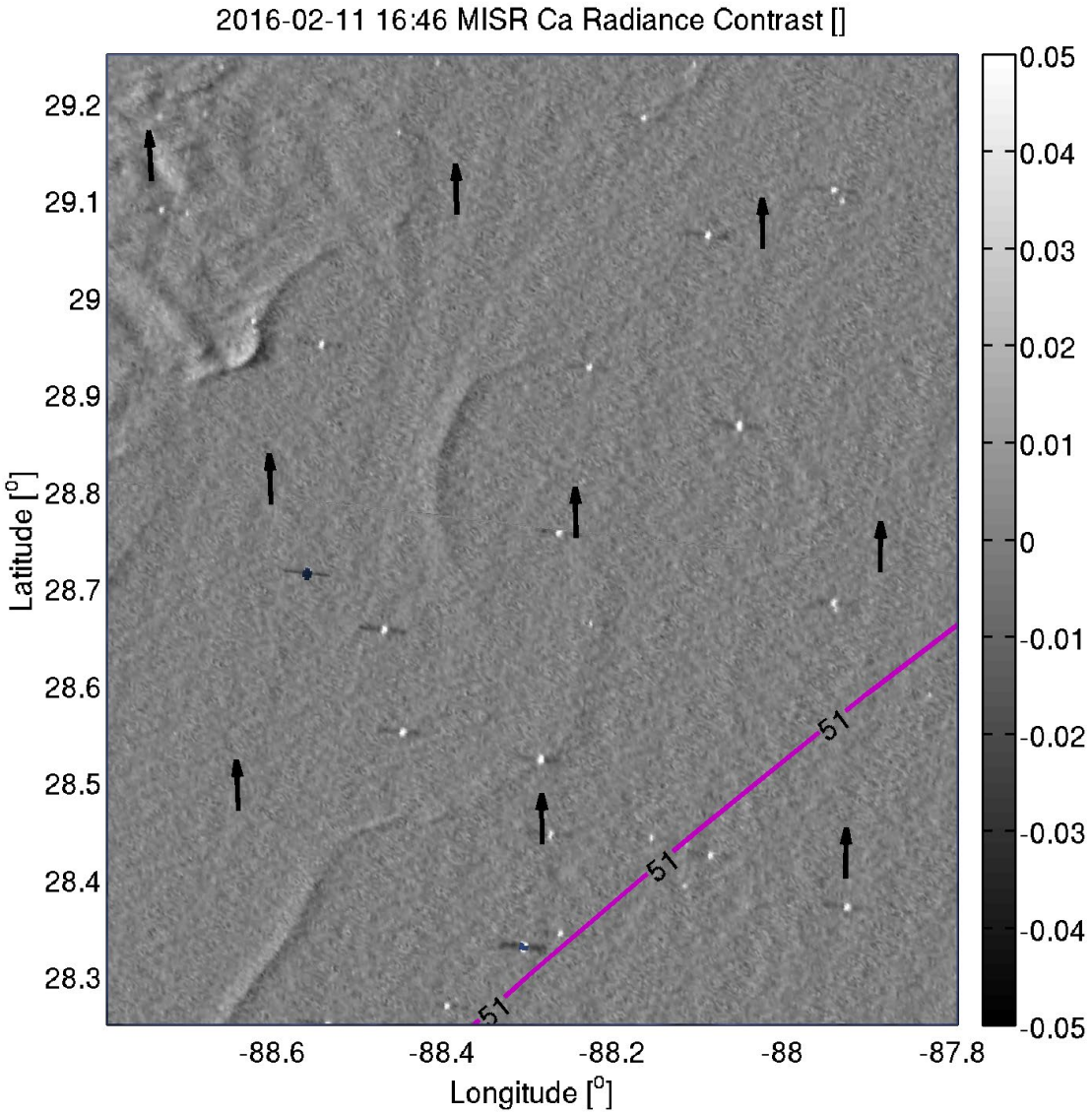


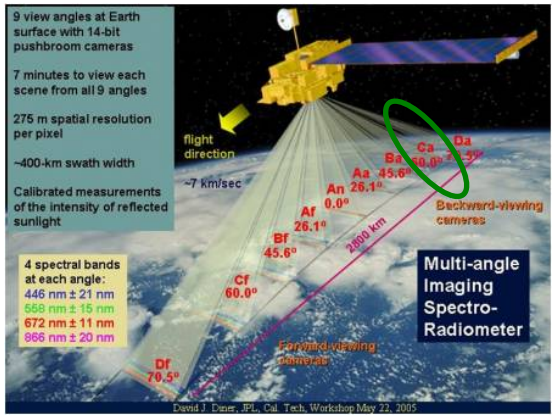
Surface roughness from sun glint at multiple view angles: example during GoM experiment (LASER 2016)



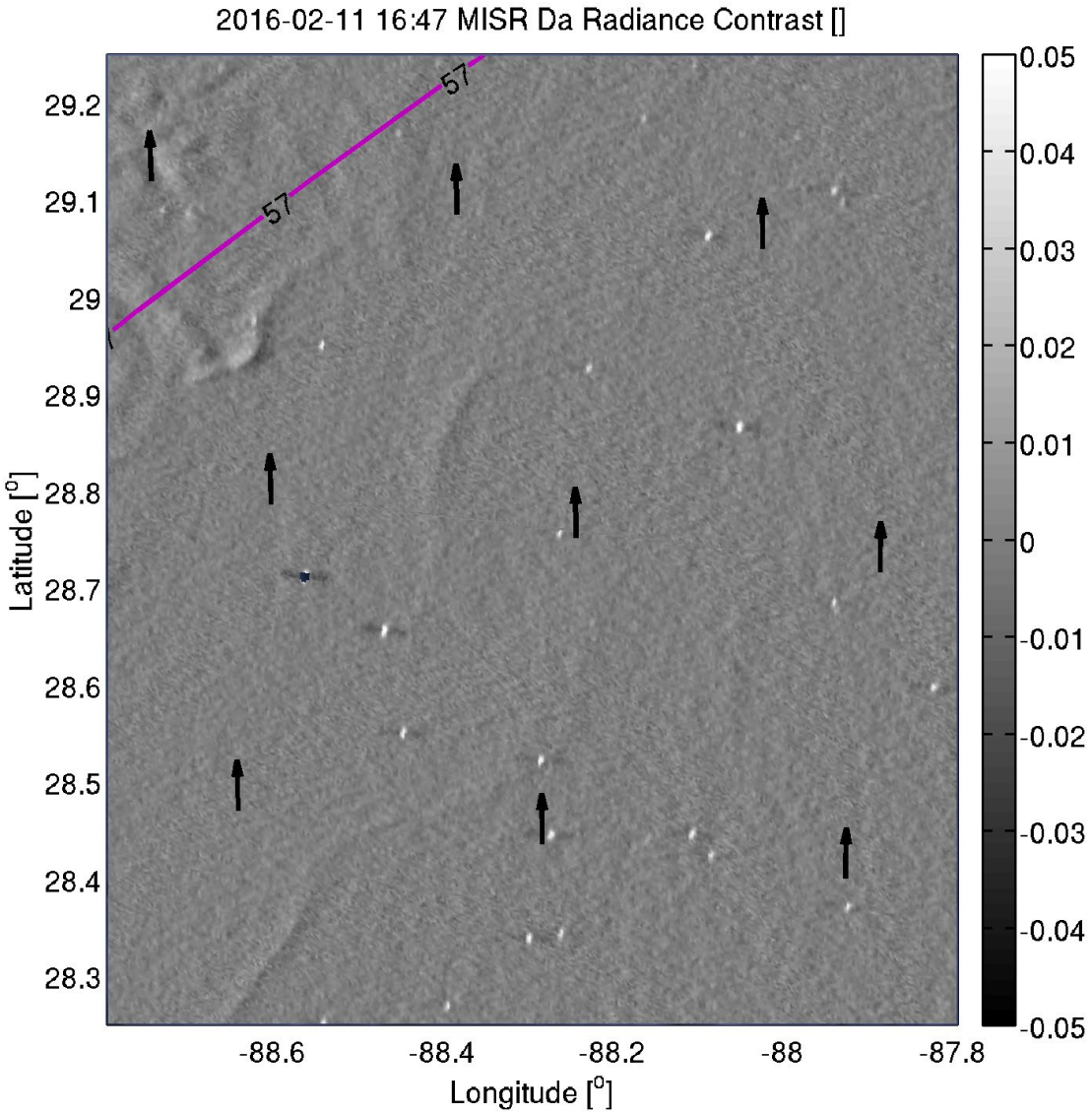


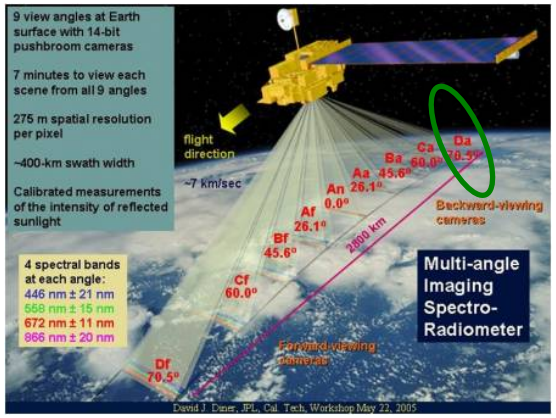
Surface roughness from sun glint at multiple view angles: example during GoM experiment (LASER 2016)



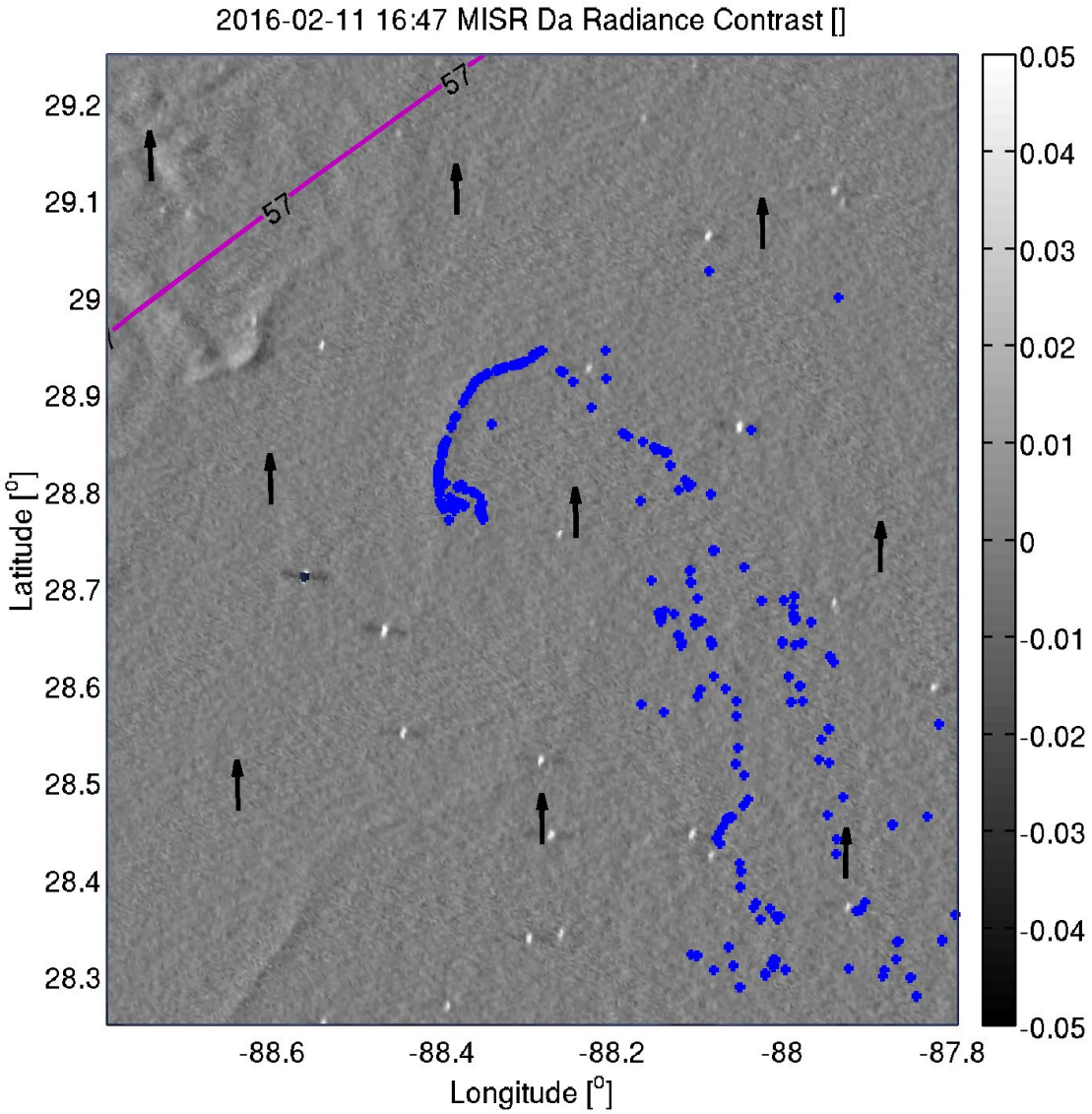


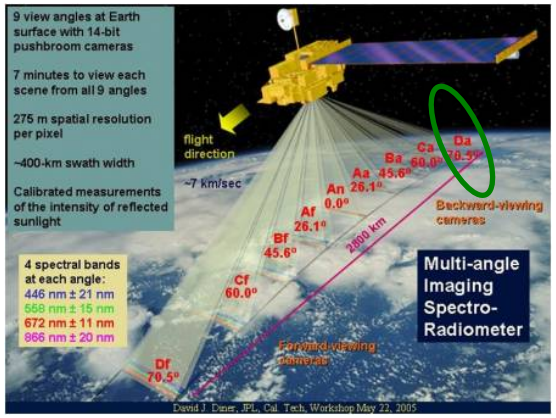
Surface roughness from sun glint at multiple view angles: example during GoM experiment (LASER 2016)



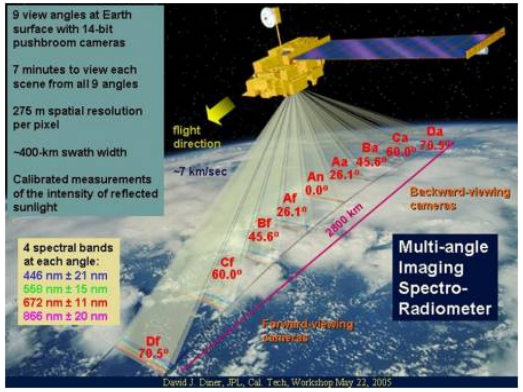


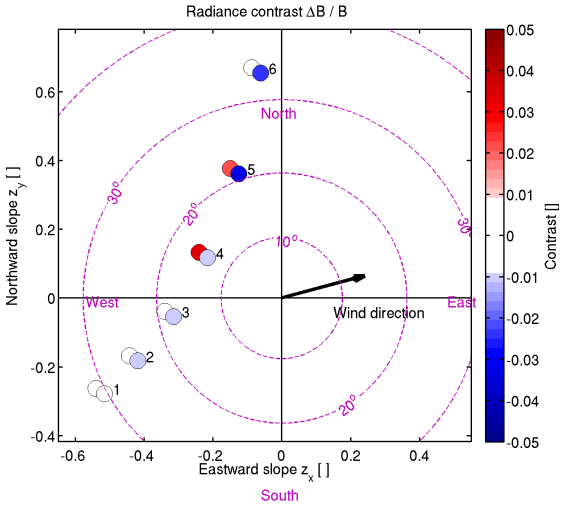
Surface roughness from sun glint at multiple view angles: example during GoM experiment (LASER 2016)



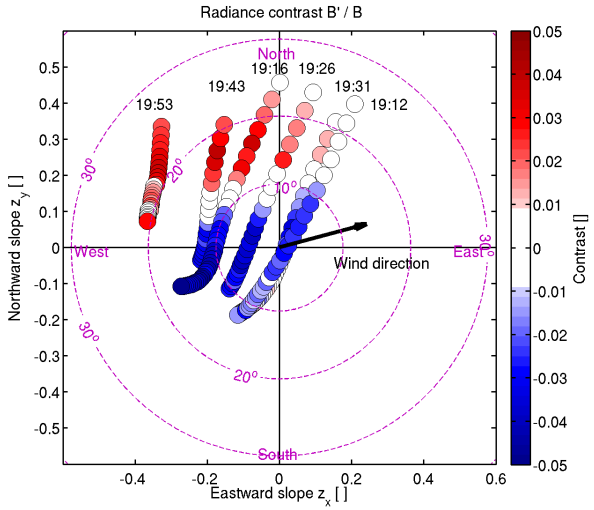


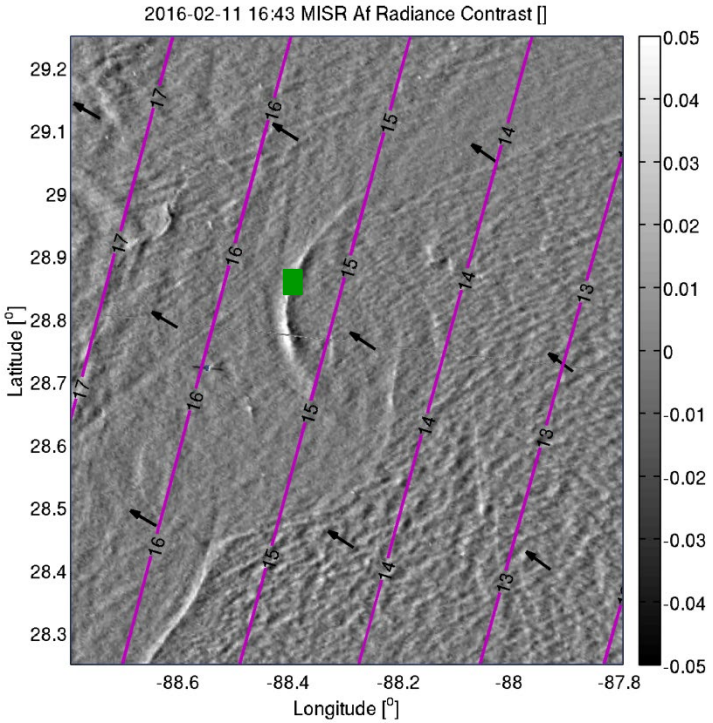
2) Airborne sunglitter at multiple azimuth view angles

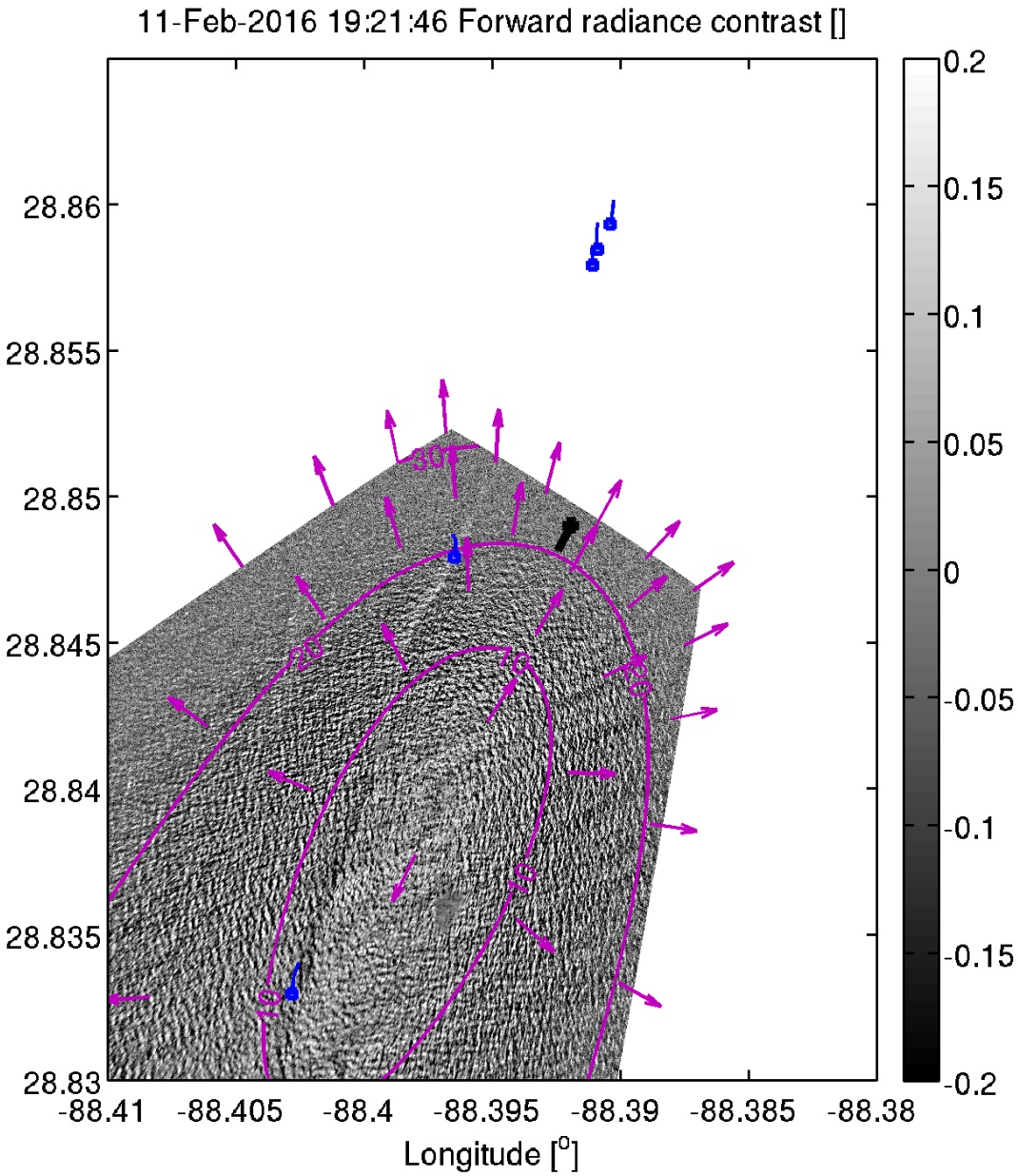




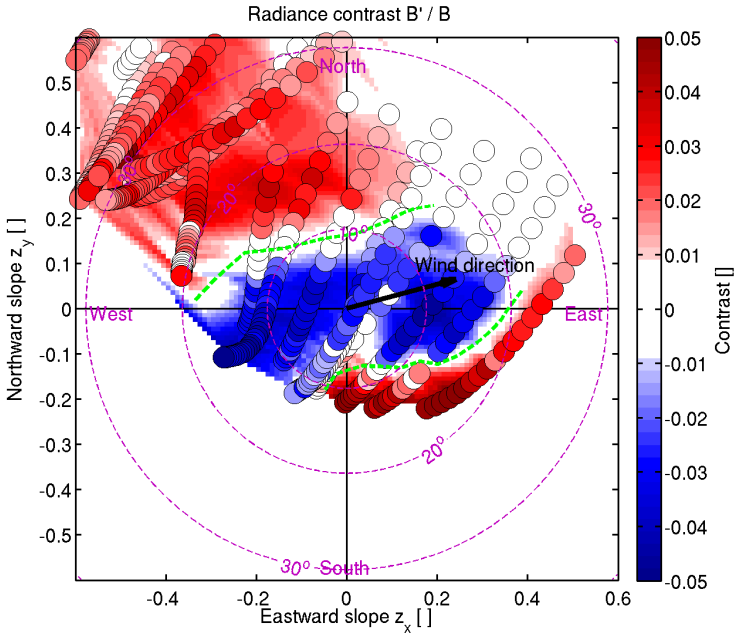
Using visible cameras from airplane with J. Molemaker et al.



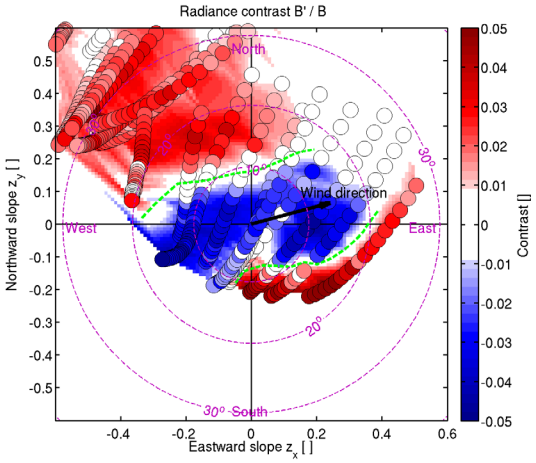

2016-02-11 16:43 MISR Af Radiance Contrast []
Latitude [°]
Longitude [°]
29.2
29.1
29
28.9
28.8
28.7
28.6
28.5
28.4
28.3
-88.6
-88.4
-88.2
-88
-87.8
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05


11-Feb-2016 19:21:46 Forward radiance contrast []
Longitude [°]
28.86
28.855
28.85
28.845
28.84
28.835
28.83
-88.41
-88.405
-88.4
-88.395
-88.39
-88.385
-88.38
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2

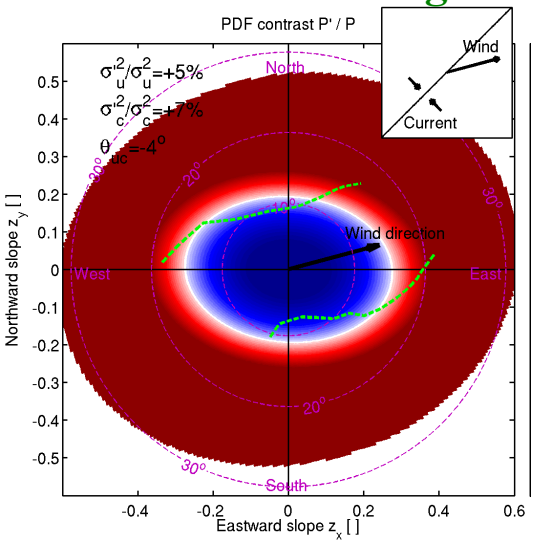
2) Airborne sunglitter at multiple azimuth view angles



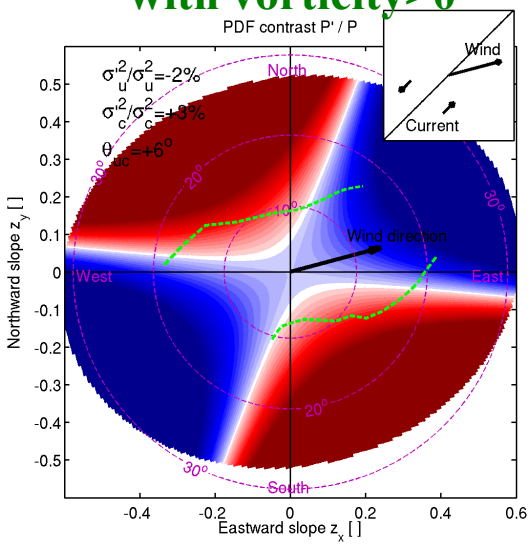
2) Airborne sunglitter at multiple azimuth view angles



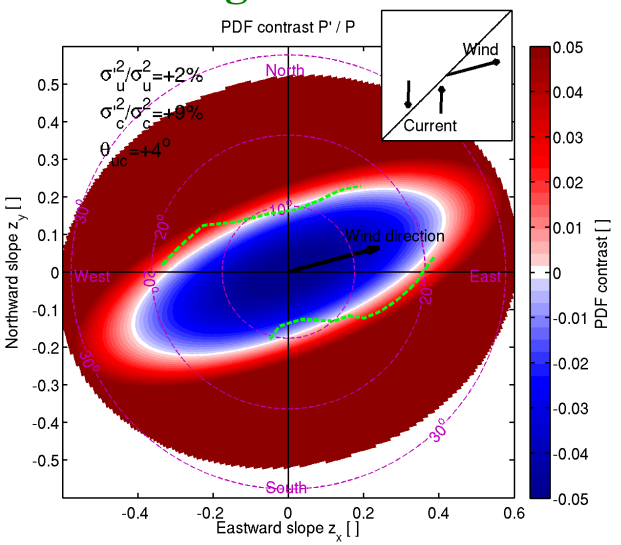
Across front convergence



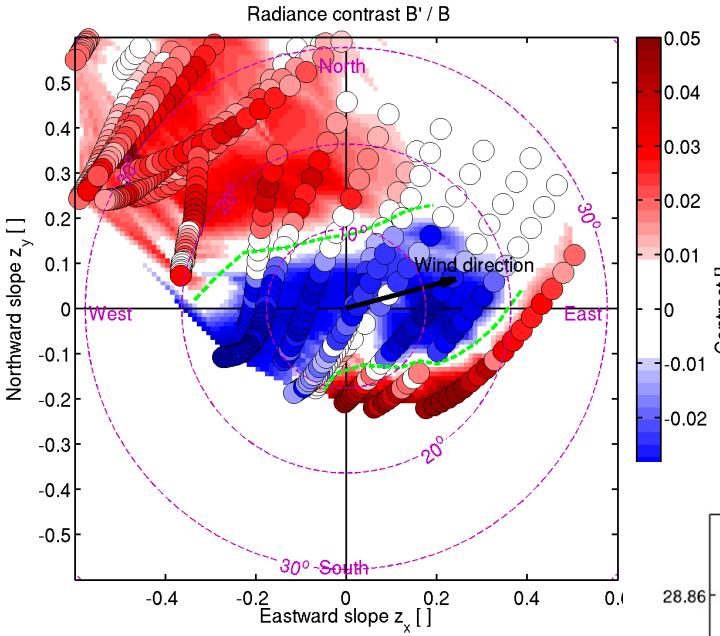
Along front shear with vorticity>0



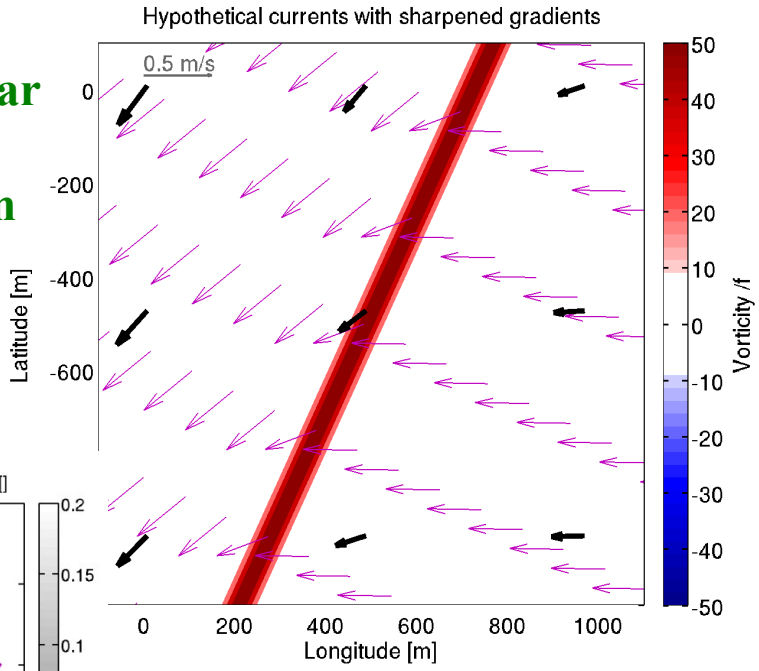
Best fit: convergence + shear

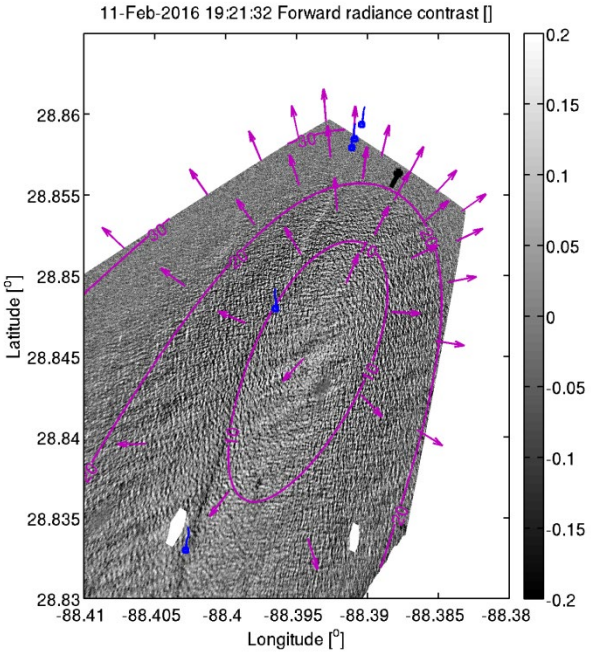


2) Airborne sunglitter at multiple azimuth view angles

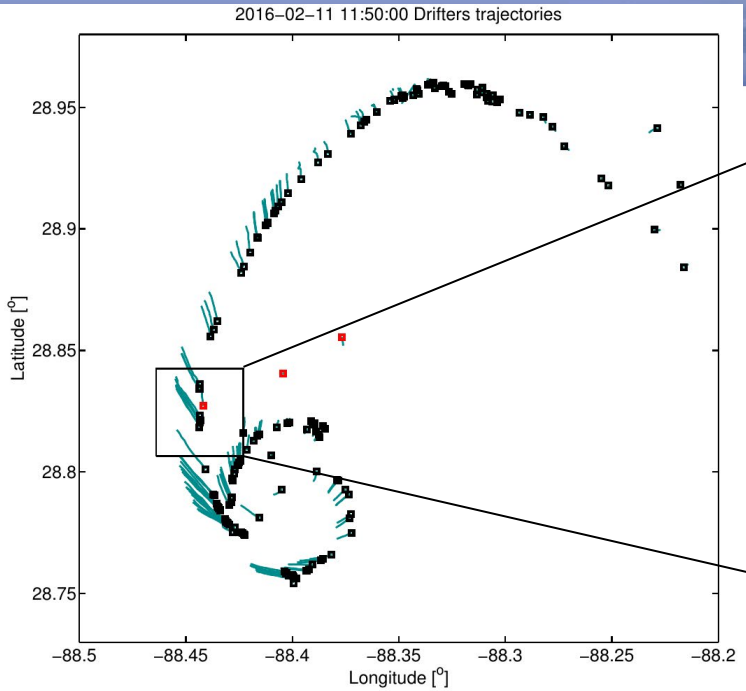


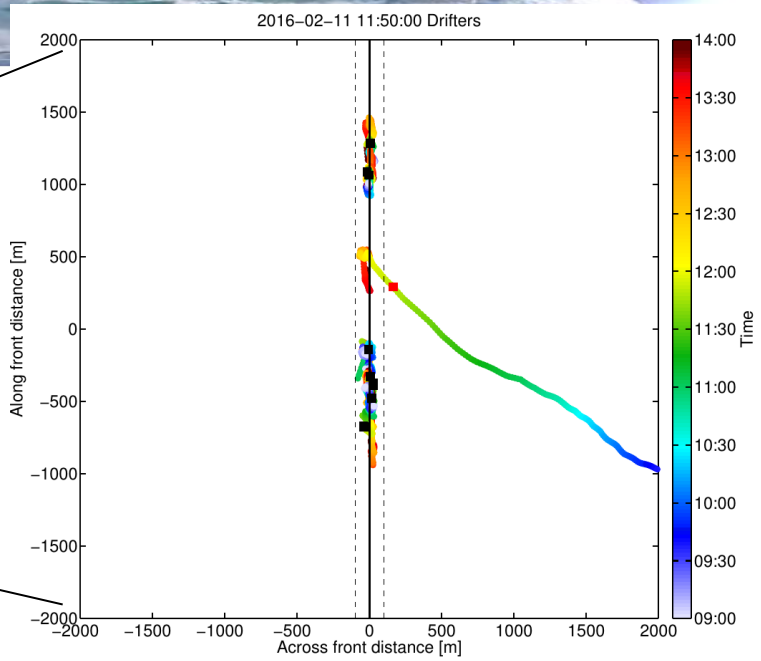
Best fit:
convergence + shear
Magnitude:
30 cm/s over 50 m
(~ 50 f)

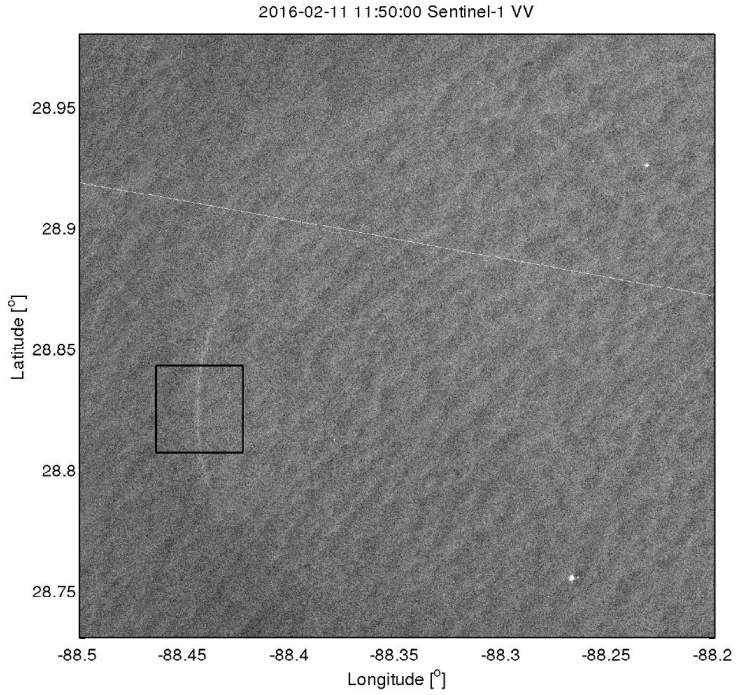


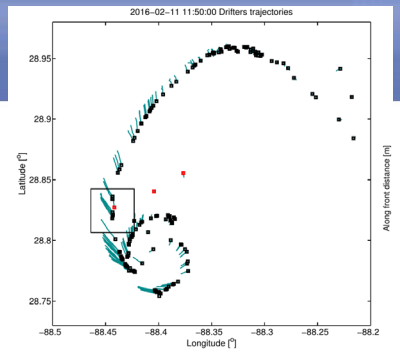


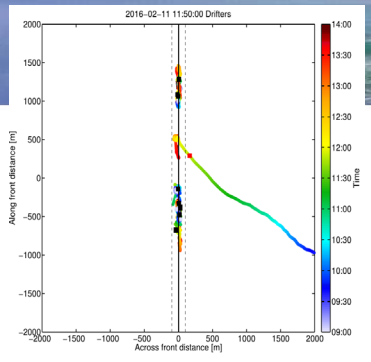
Consistent with
X-band radar obs:
convergence + shear
Magnitude:
30 cm/s over 500 m
(~ 5 f)

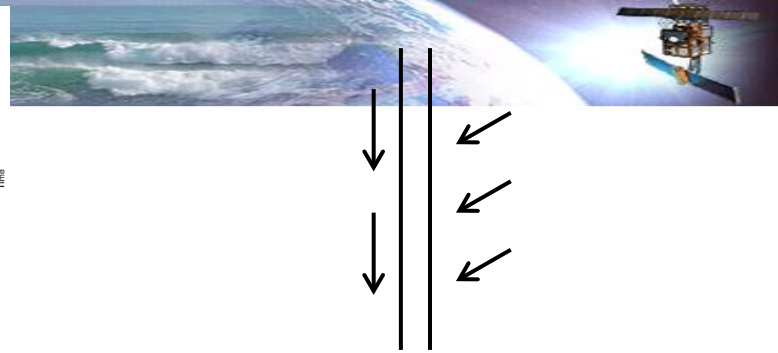

2016−02−11 11:50:00 Drifters trajectories
Latitude [°]
Longitude [°]
28.95
28.9
28.85
28.8
28.75
−88.5
−88.45
−88.4
−88.35
−88.3
−88.25
−88.2

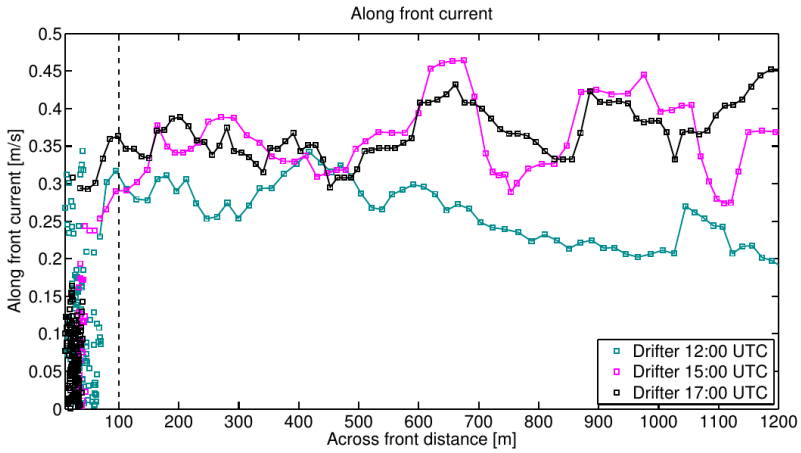

2016−02−11 11:50:00 Drifters
Along front distance [m]
Across front distance [m]
Time
2000
1500
1000
500
0
−500
−1000
−1500
−2000
14:00
13:30
13:00
12:30
12:00
11:30
11:00
10:30
10:00
09:30
09:00

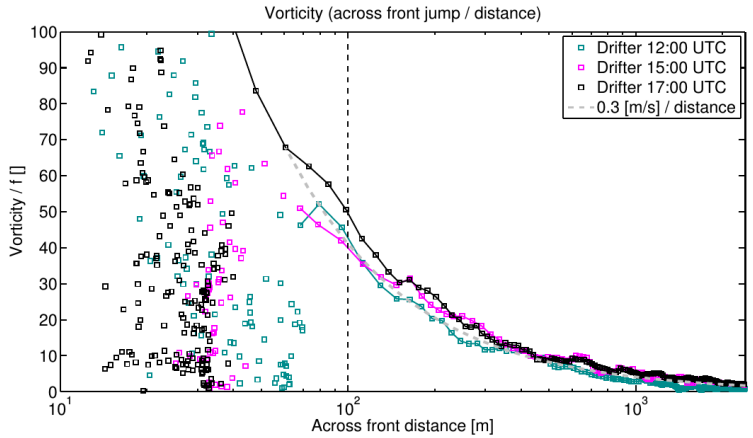

2016-02-11 11:50:00 Sentinel-1 VV
Latitude [°]
Longitude [°]
28.95
28.9
28.85
28.8
28.75
-88.5
-88.45
-88.4
-88.35
-88.3
-88.25
-88.2

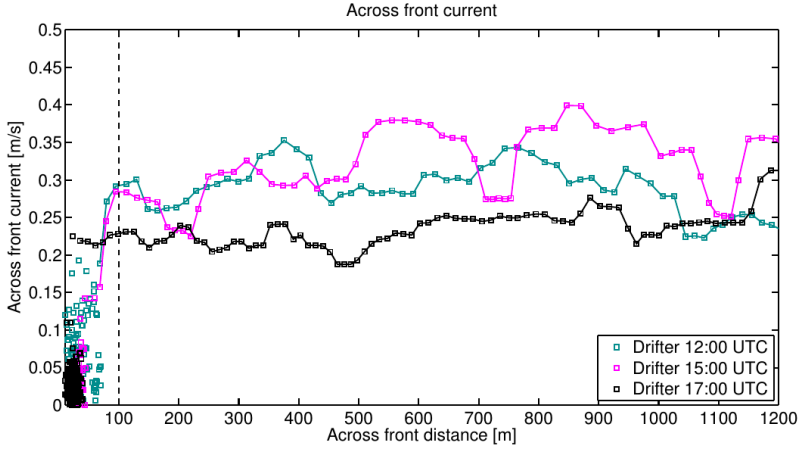

2016-02-11 11:50:00 Drifters trajectories
Latitude [°]
Longitude [°]
Along front distance [m]

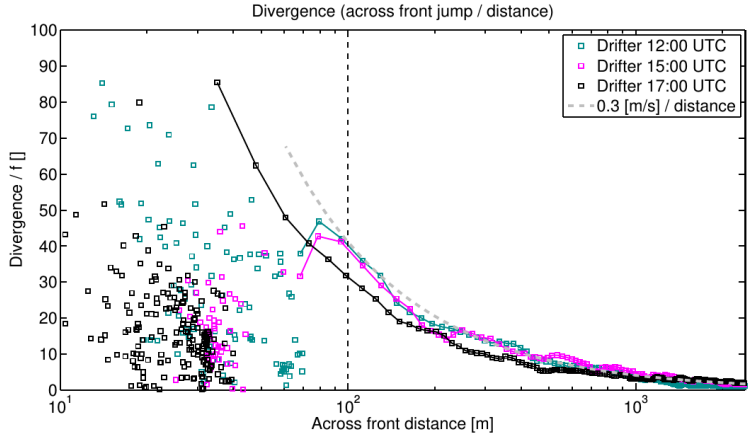

2016-02-11 11:50:00 Drifters
Along front distance [m]
Across front distance [m]
Time




Along front current
Along front current [m/s]
Across front distance [m]
Drifter 12:00 UTC
Drifter 15:00 UTC
Drifter 17:00 UTC


Vorticity (across front jump / distance)
Vorticity / f []
Across front distance [m]
Drifter 12:00 UTC
Drifter 15:00 UTC
Drifter 17:00 UTC
0.3 [m/s] / distance


Across front current
Across front current [m/s]
Across front distance [m]
Drifter 12:00 UTC
Drifter 15:00 UTC
Drifter 17:00 UTC


Divergence (across front jump / distance)
Divergence / f []
Across front distance [m]
Drifter 12:00 UTC
Drifter 15:00 UTC
Drifter 17:00 UTC
0.3 [m/s] / distance

Conclusion

- Observing small scales from space: SST, color and surface roughness.
- At scales < 5km, surface roughness is related to current gradients.
- Multiple view angles to separate the current gradient components (divergence, strain,…).
- Field experiments to provide opportunities to validate the short wave models.
- Satellites already provide a huge amount of fine scale observations (global coverage, seasonal variations,…)