# Aquarius Pointing Assessment

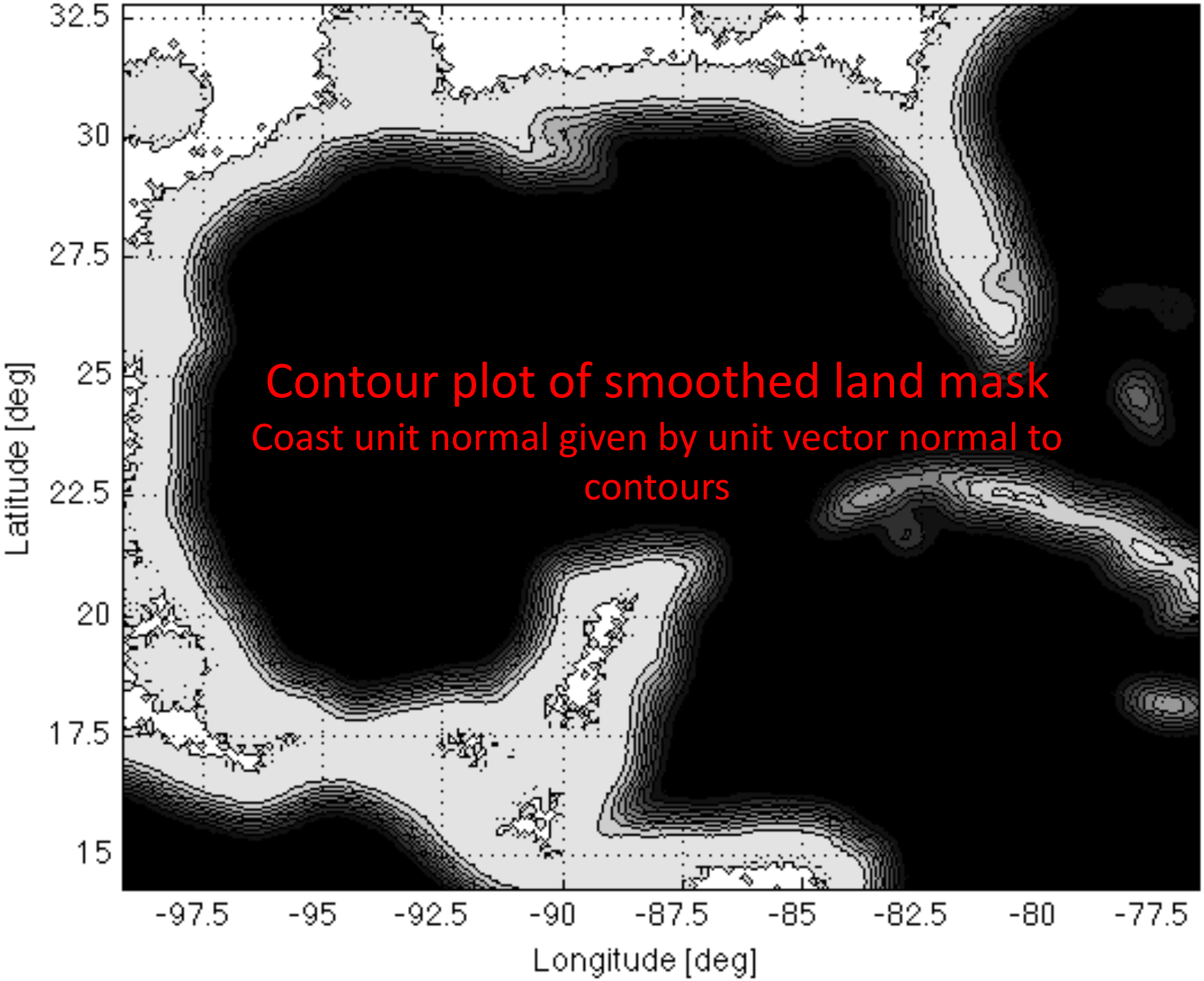
Alex Fore

# Overview

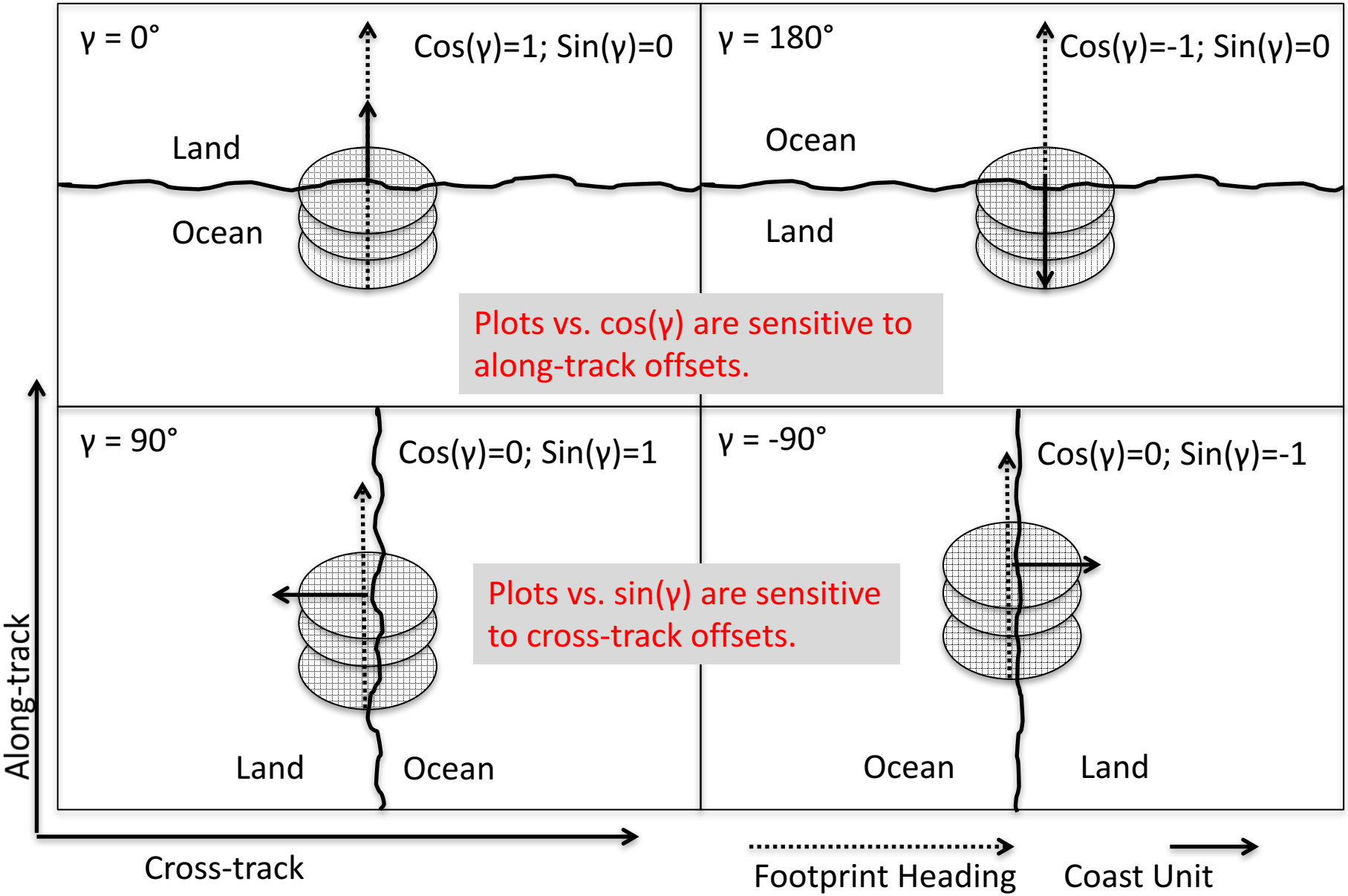
- We show the pointing error is stable over time to ~ 0.1 degrees.
- We show that the pointing errors can be represented well by the following biases:
  - B1: +0.45 Nadir; +0.5 Azimuth
  - B2: +0.25 Nadir; +0.2 Azimuth
  - B3: +0.40 Nadir; +0.2 Azimuth
- We show consistent results using both radar and radiometer data.

# Coastal Crossing Analysis Method

- For every mixed ocean/land observation we:
  - Compute footprint heading relative (call this $\gamma$) to coast unit normal.
  - Bin data by *predicted* land fraction and $\sin(\gamma)$ or $\cos(\gamma)$.
- Only include data from [-55,55] degrees latitude.
- Do this for radiometer $T_H+T_V$ and scatterometer $\sigma_{HH}$.
  - Use $T_I:=T_H+T_V$ since it is independent of Faraday rotation.
  - We use the antenna $T_f$, which has had RFI filtering applied.


Contour plot of smoothed land mask
Coast unit normal given by unit vector normal to contours
32.5
30
27.5
25
22.5
20
17.5
15
Latitude [deg]
-97.5
-95
-92.5
-90
-87.5
-85
-82.5
-80
-77.5
Longitude [deg]

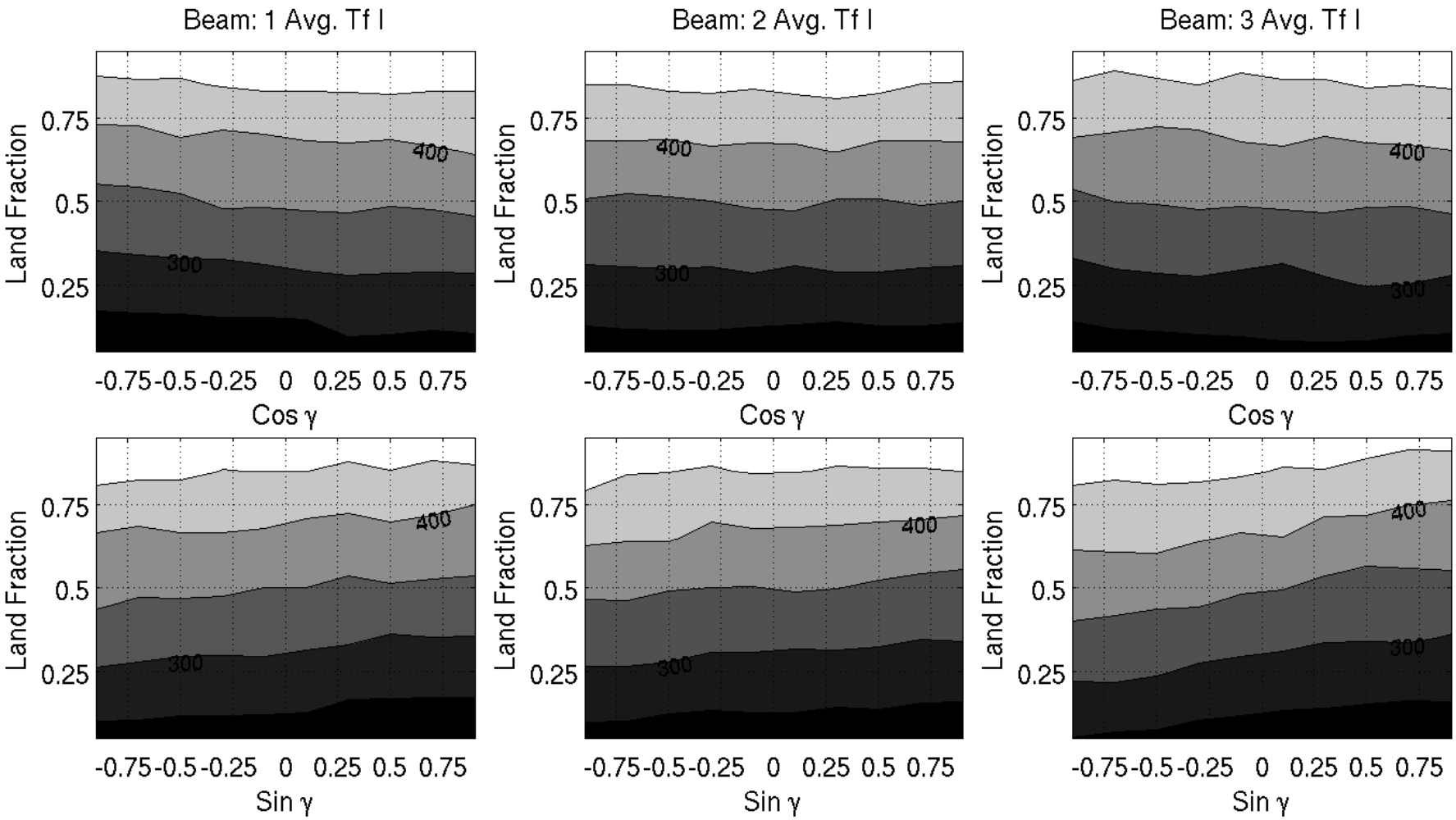
# Relative Heading Angle (γ)



# POINTING ANGLE STABILITY

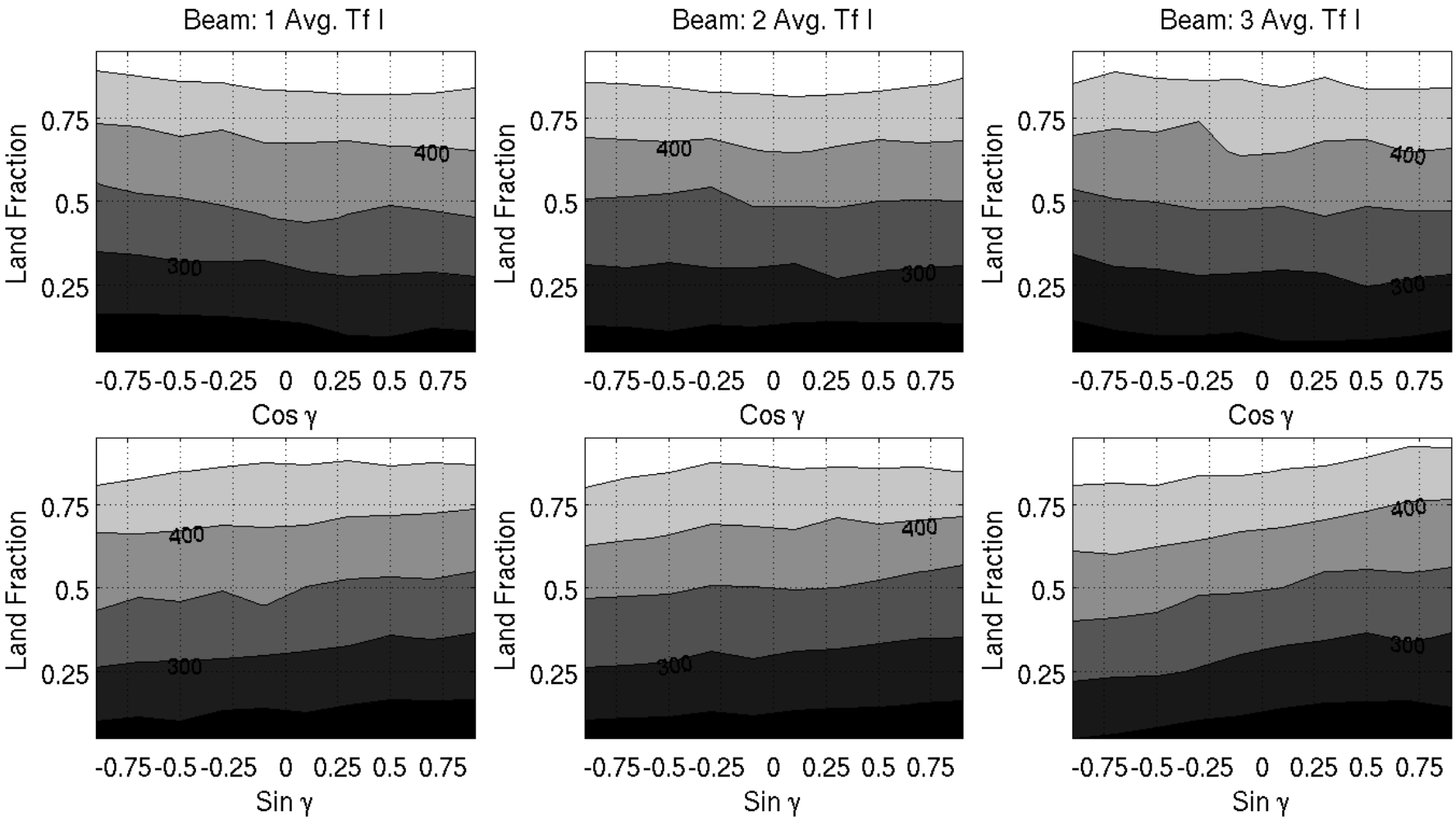
# Radiometer $T_l$
# Processed with Pre-Launch Pointing Angles
# 2011-238 to 2011-244

Y-axis is Scatterometer Land Fraction



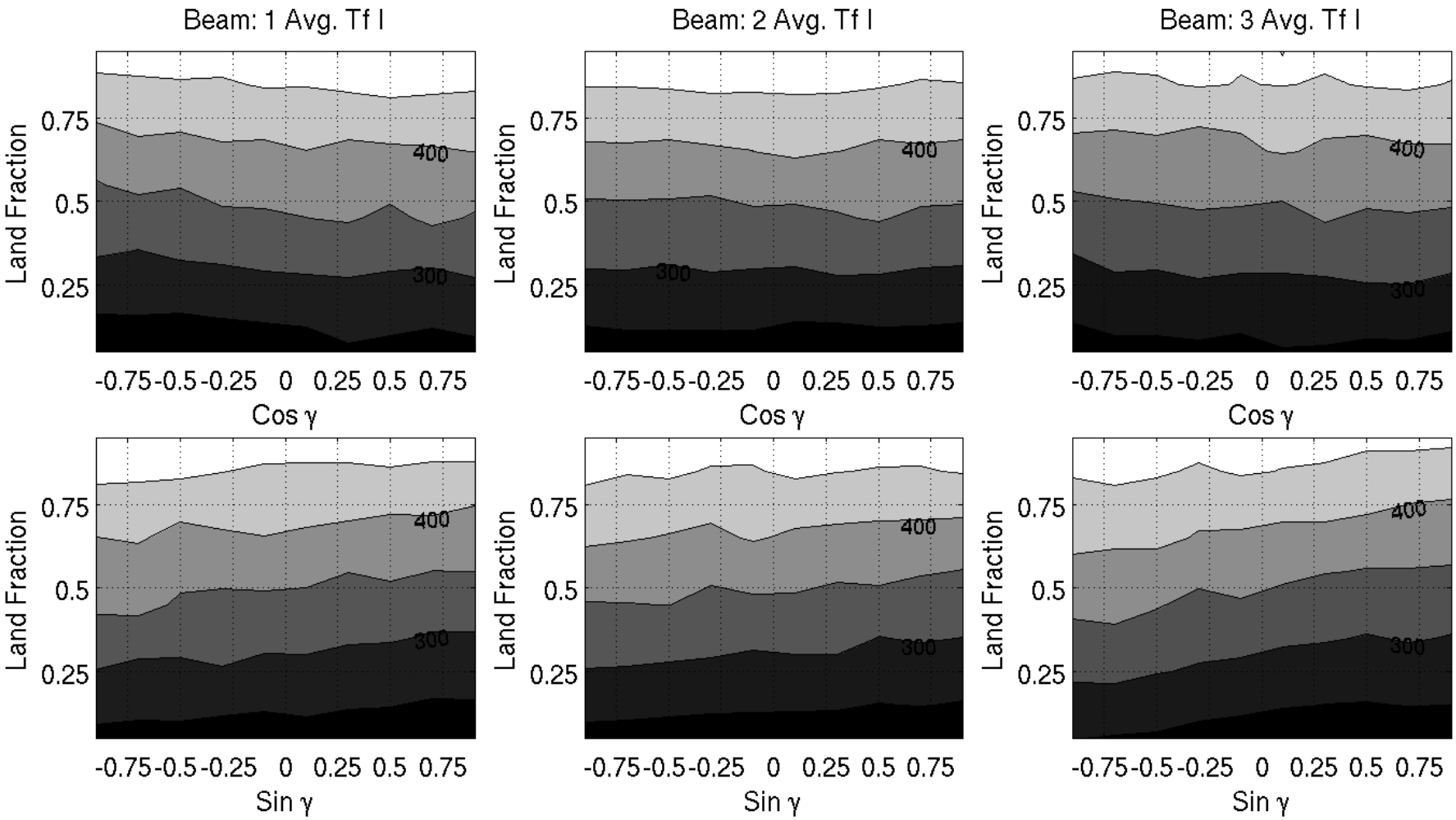
# Radiometer $T_l$
# Processed with Pre-Launch Pointing Angles
# 2011-245 to 2011-251

Y-axis is Scatterometer Land Fraction



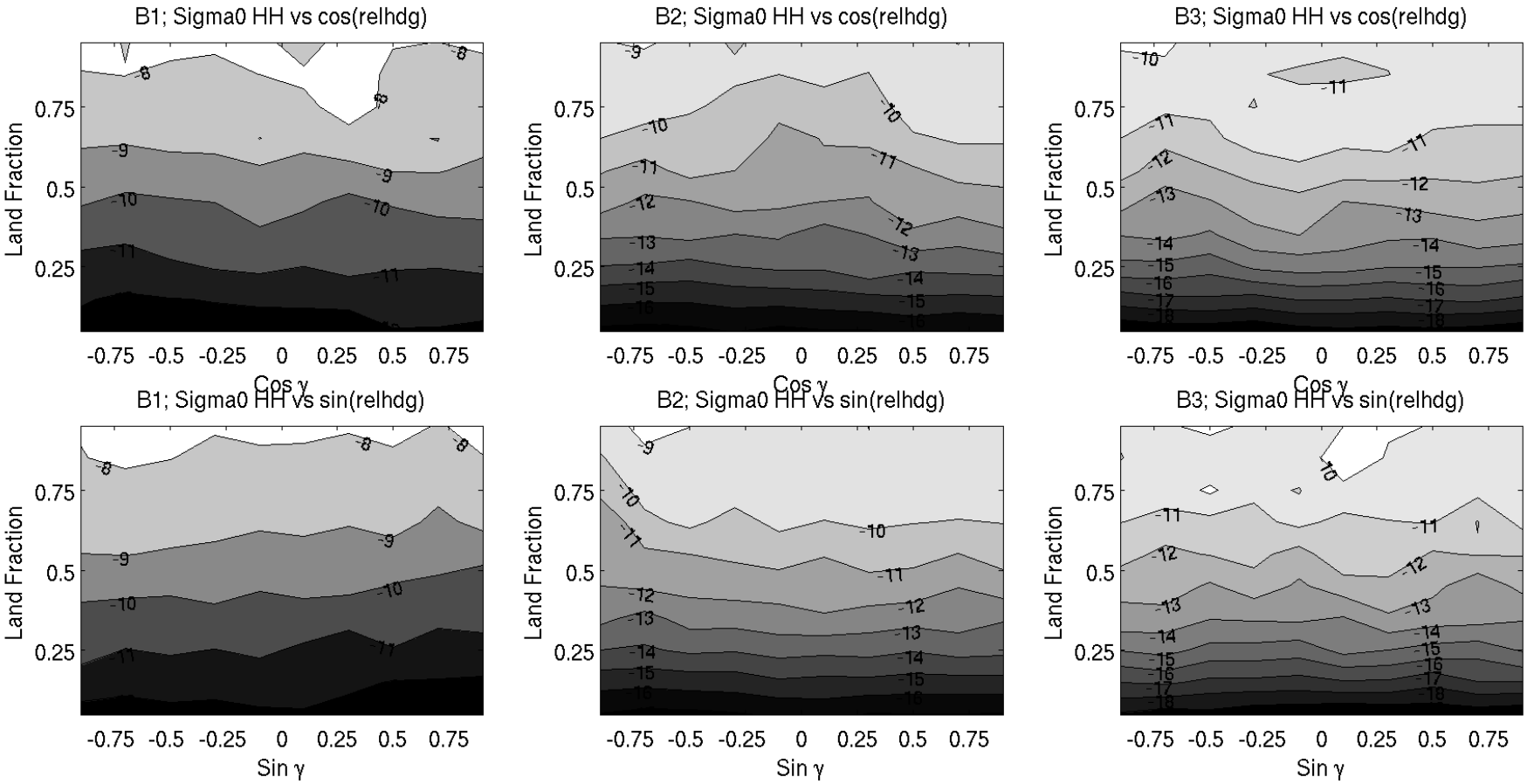
# Radiometer $T_l$
# Processed with Pre-Launch Pointing Angles
# 2011-252 to 2011-258

Y-axis is Scatterometer Land Fraction



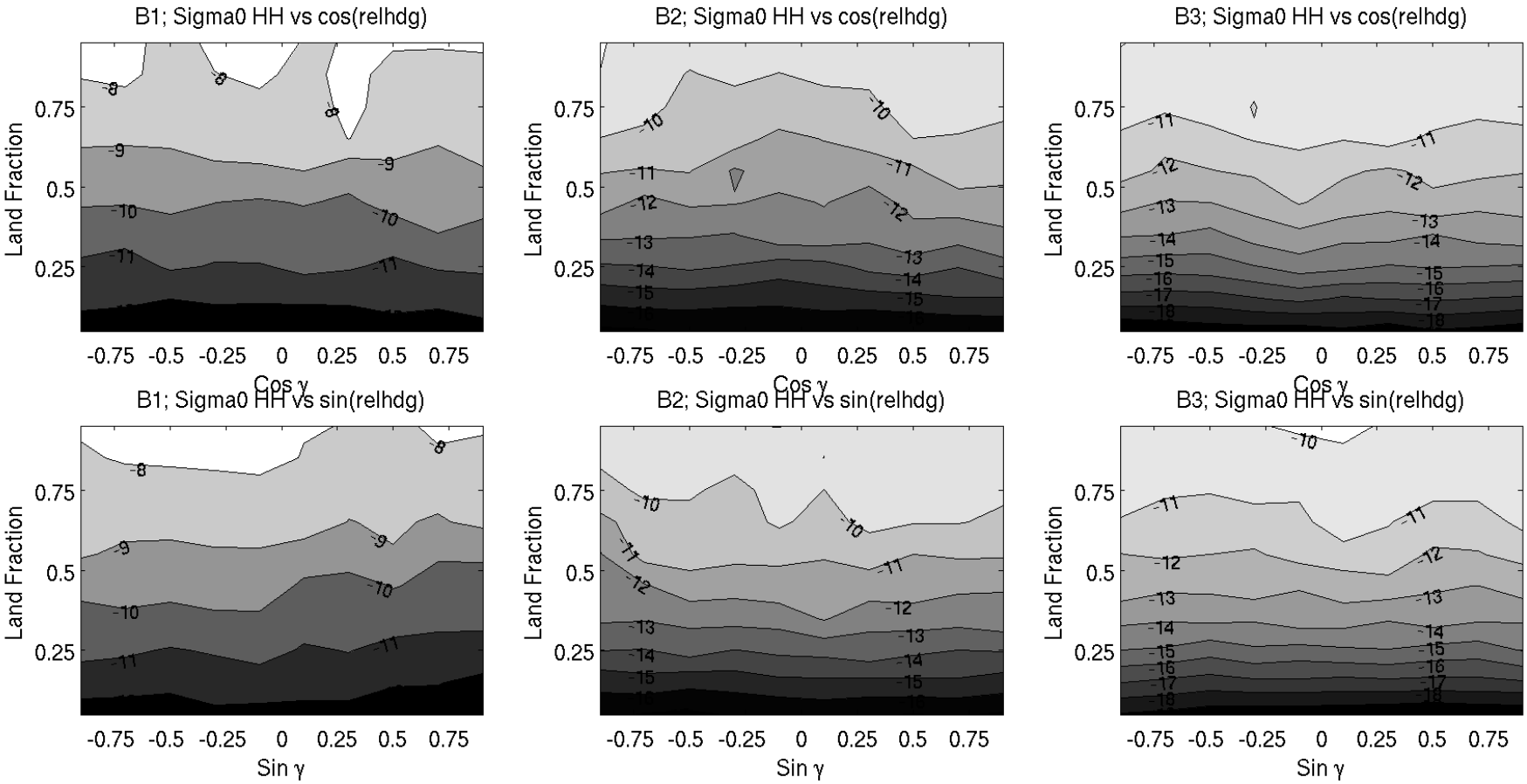
# Scatterometer $\sigma_0^{HH}$ Processed with Pre-Launch Pointing Angles 2011-238 to 2011-244

Y-axis is Scatterometer Land Fraction



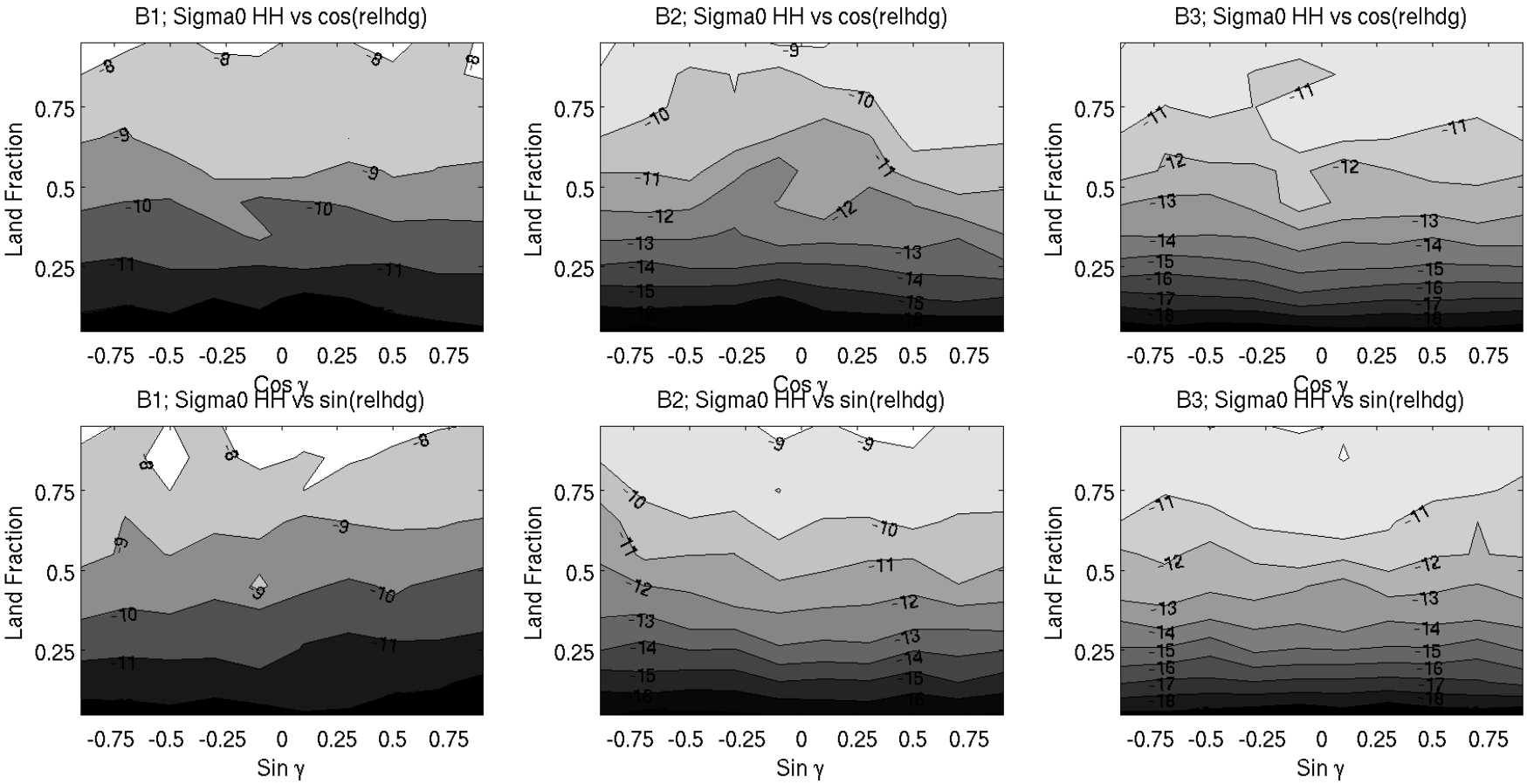
# Scatterometer $\sigma_0^{HH}$ Processed with Pre-Launch Pointing Angles 2011-245 to 2011-251

Y-axis is Scatterometer Land Fraction



# Scatterometer $\sigma_0^{HH}$ Processed with Pre-Launch Pointing Angles 2011-252 to 2011-258

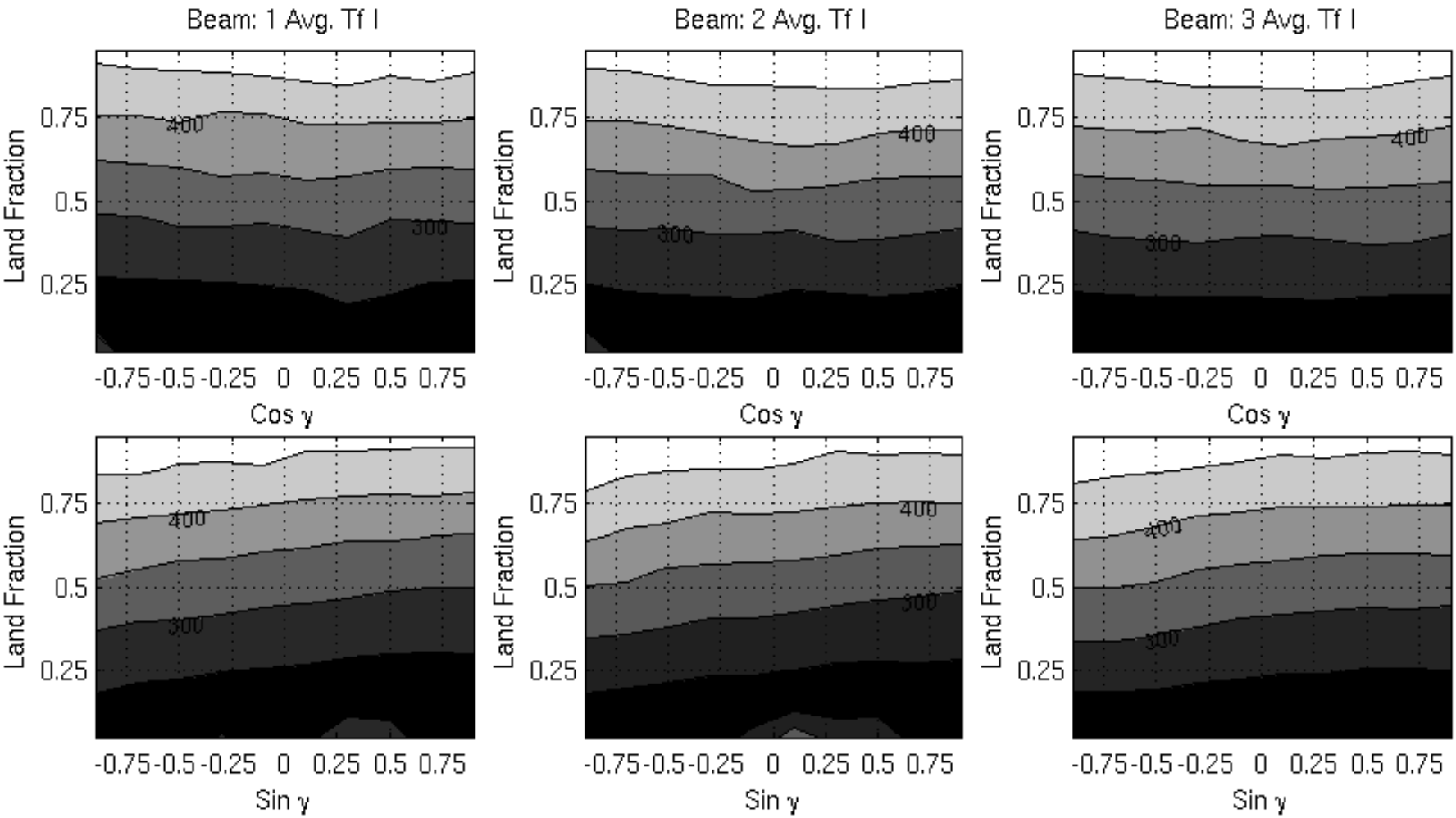
Y-axis is Scatterometer Land Fraction



# POINTING ANGLE OFFSET

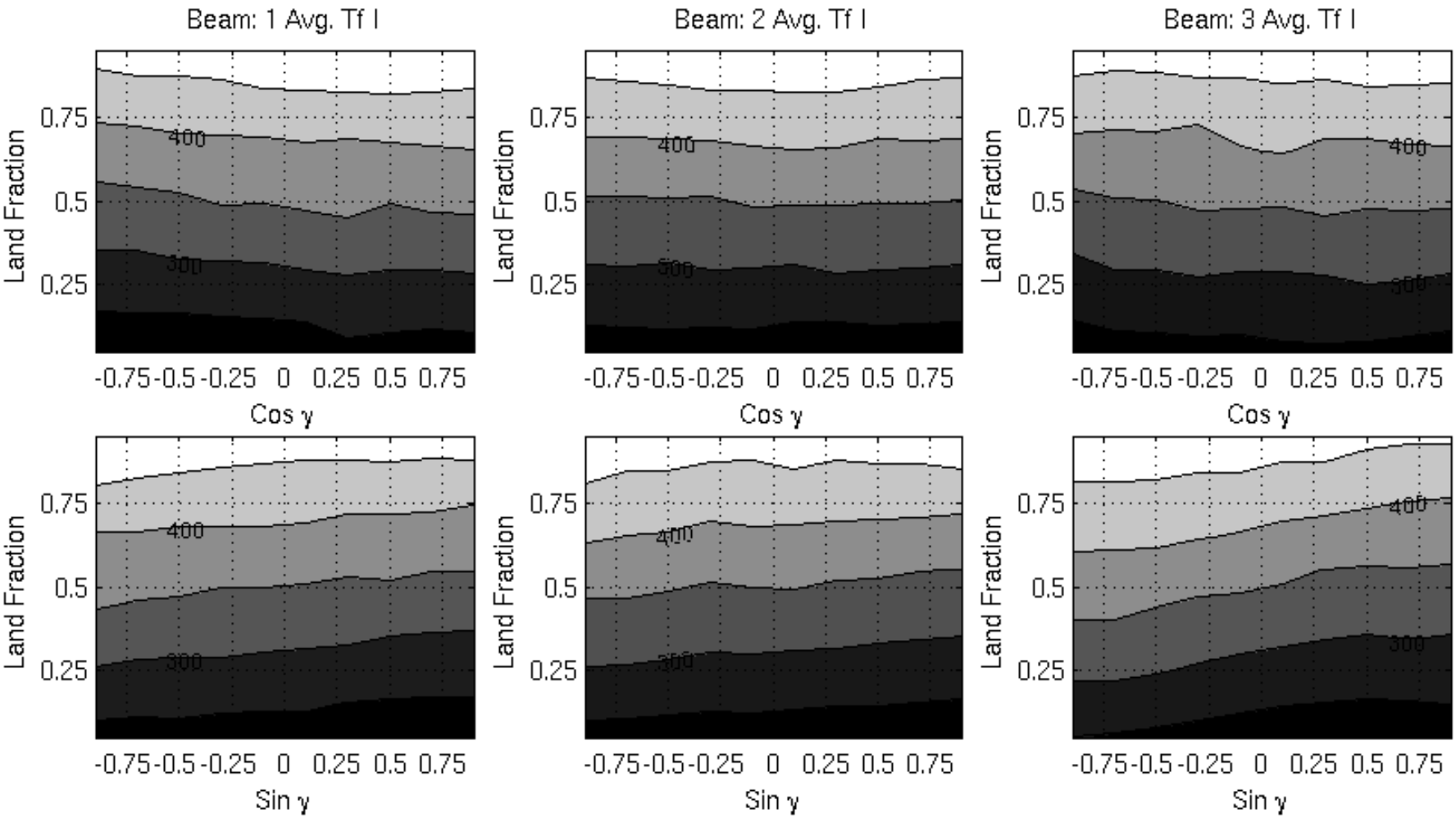
# Radiometer $T_l$
# Processed with Pre-Launch Pointing Angles

Y-axis is Radiometer Land Fraction



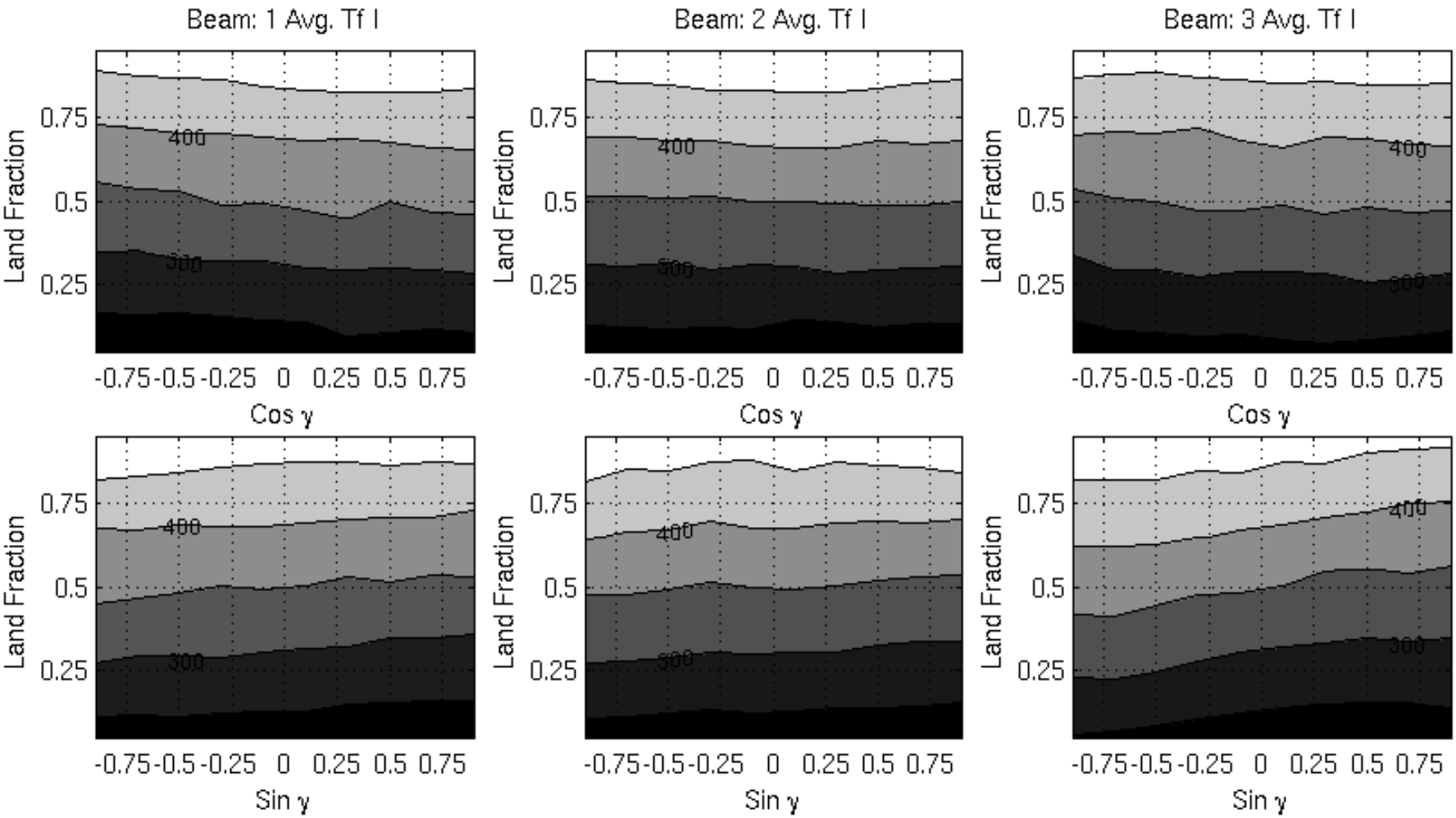
# Radiometer $T_l$
# Processed with Pre-Launch Pointing Angles

Y-axis is Scatterometer Land Fraction



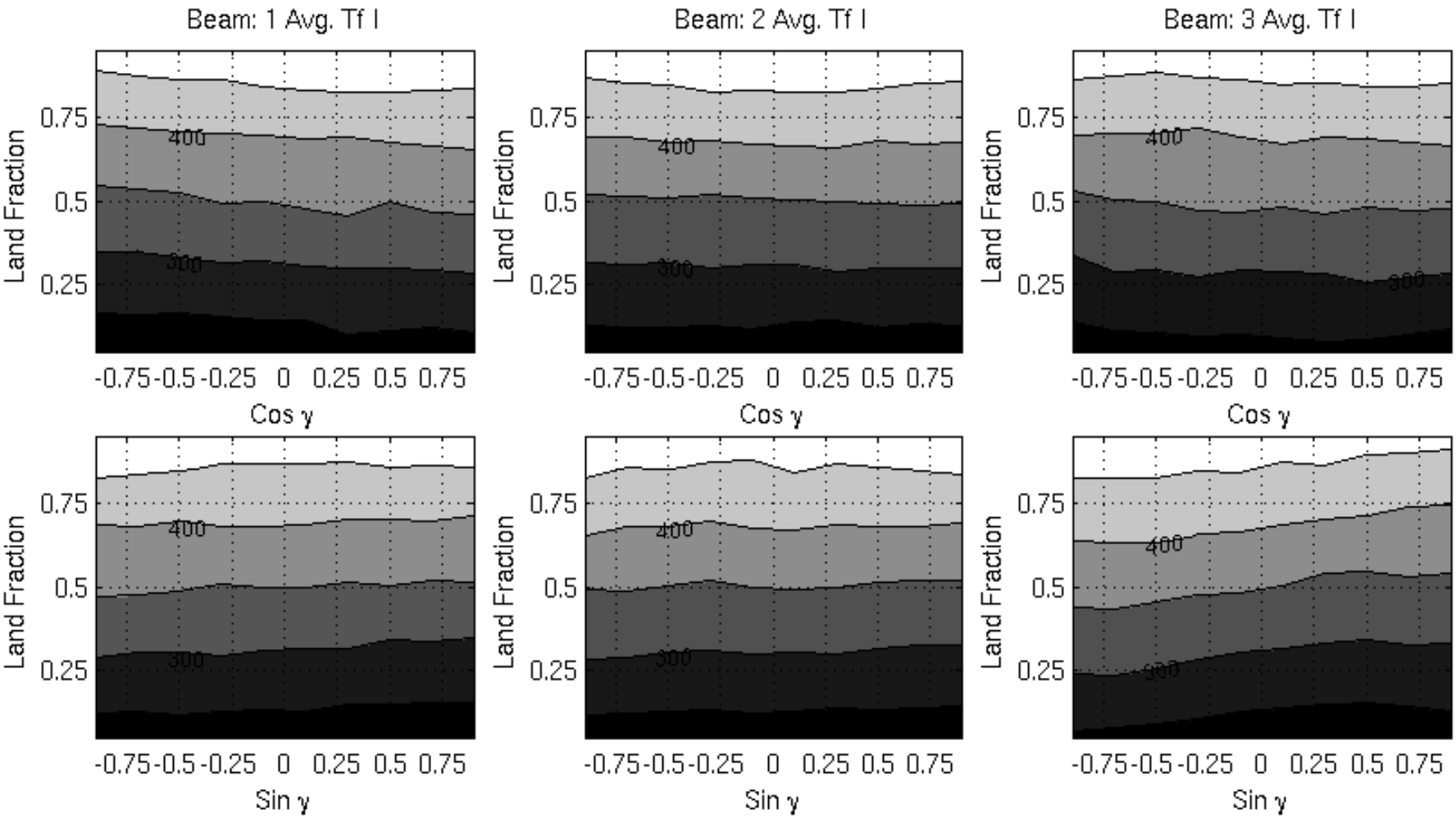
# Radiometer $T_l$
# Processed with +0.1 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



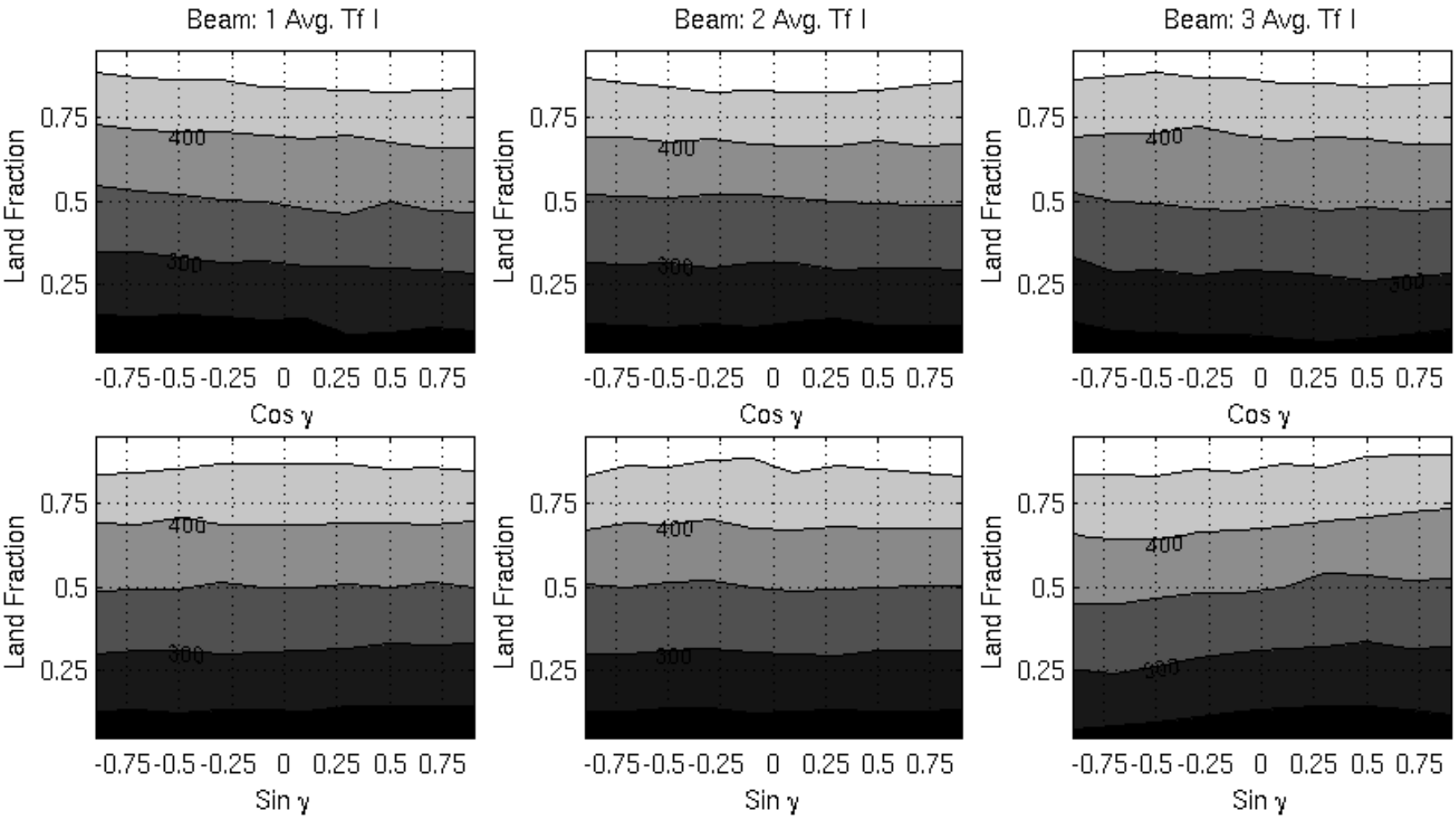
# Radiometer $T_I$
# Processed with +0.2 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



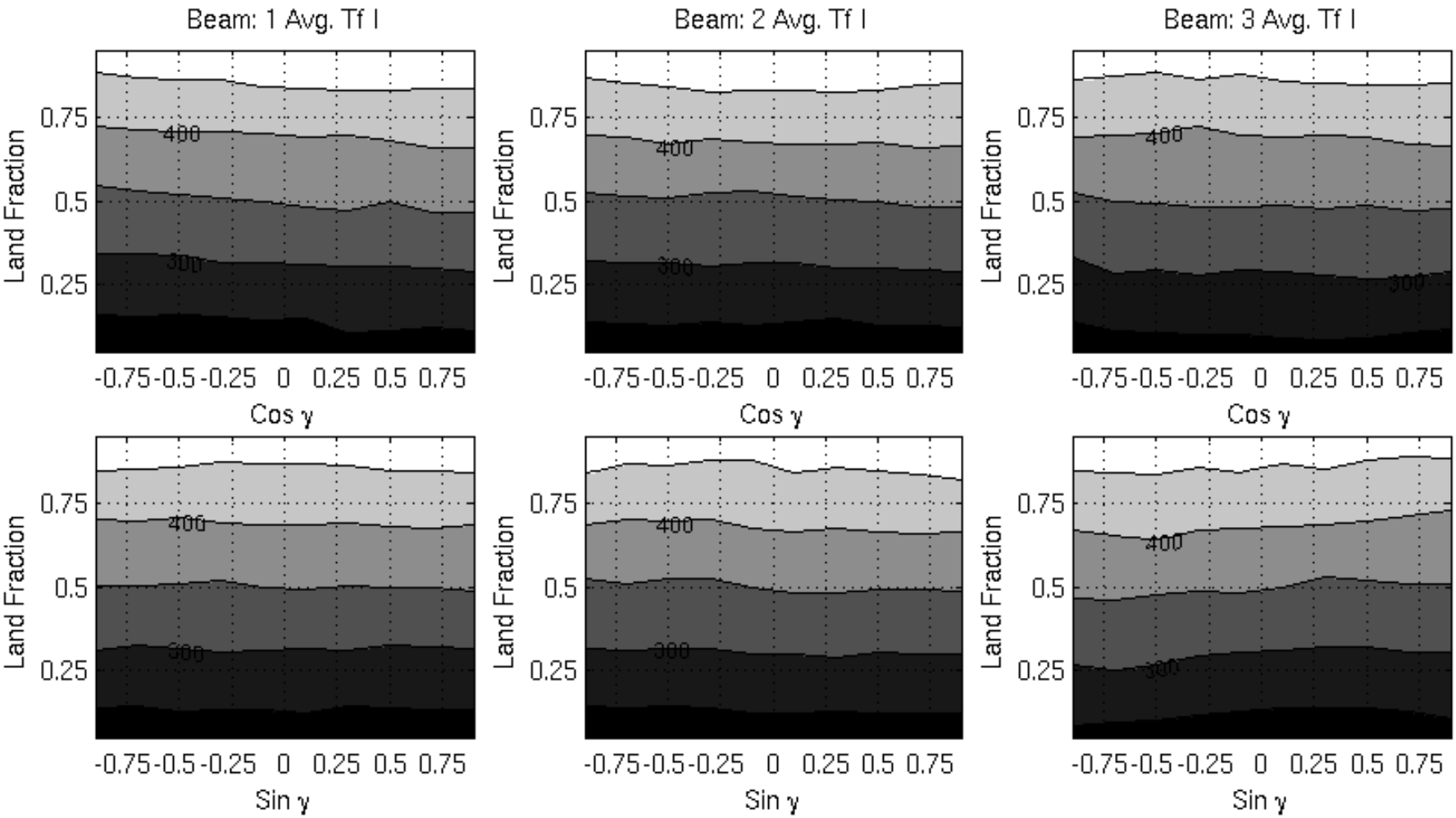
# Radiometer $T_l$
# Processed with +0.3 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



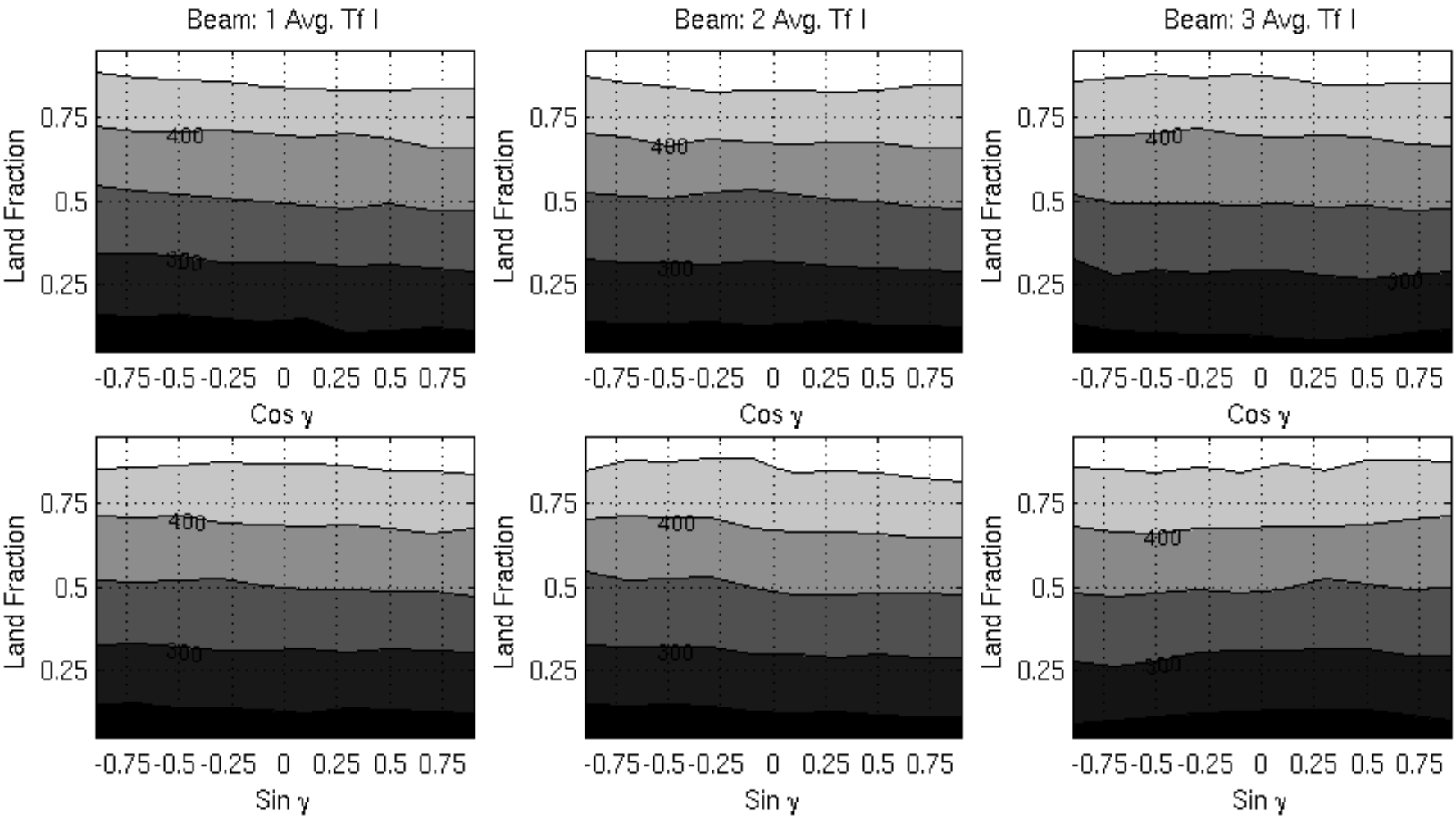
# Radiometer $T_I$
# Processed with +0.4 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



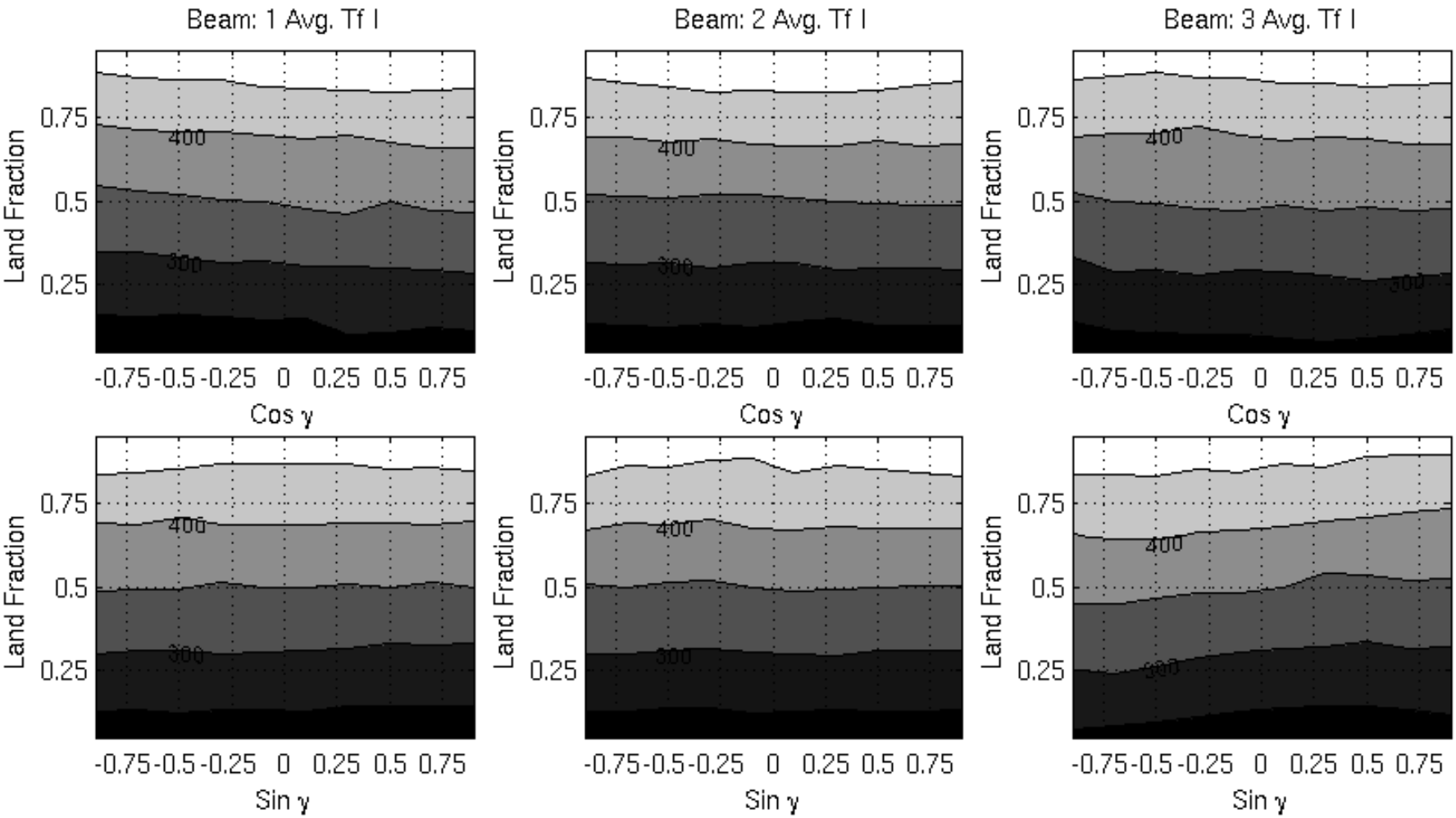
# Radiometer $T_l$
# Processed with +0.5 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



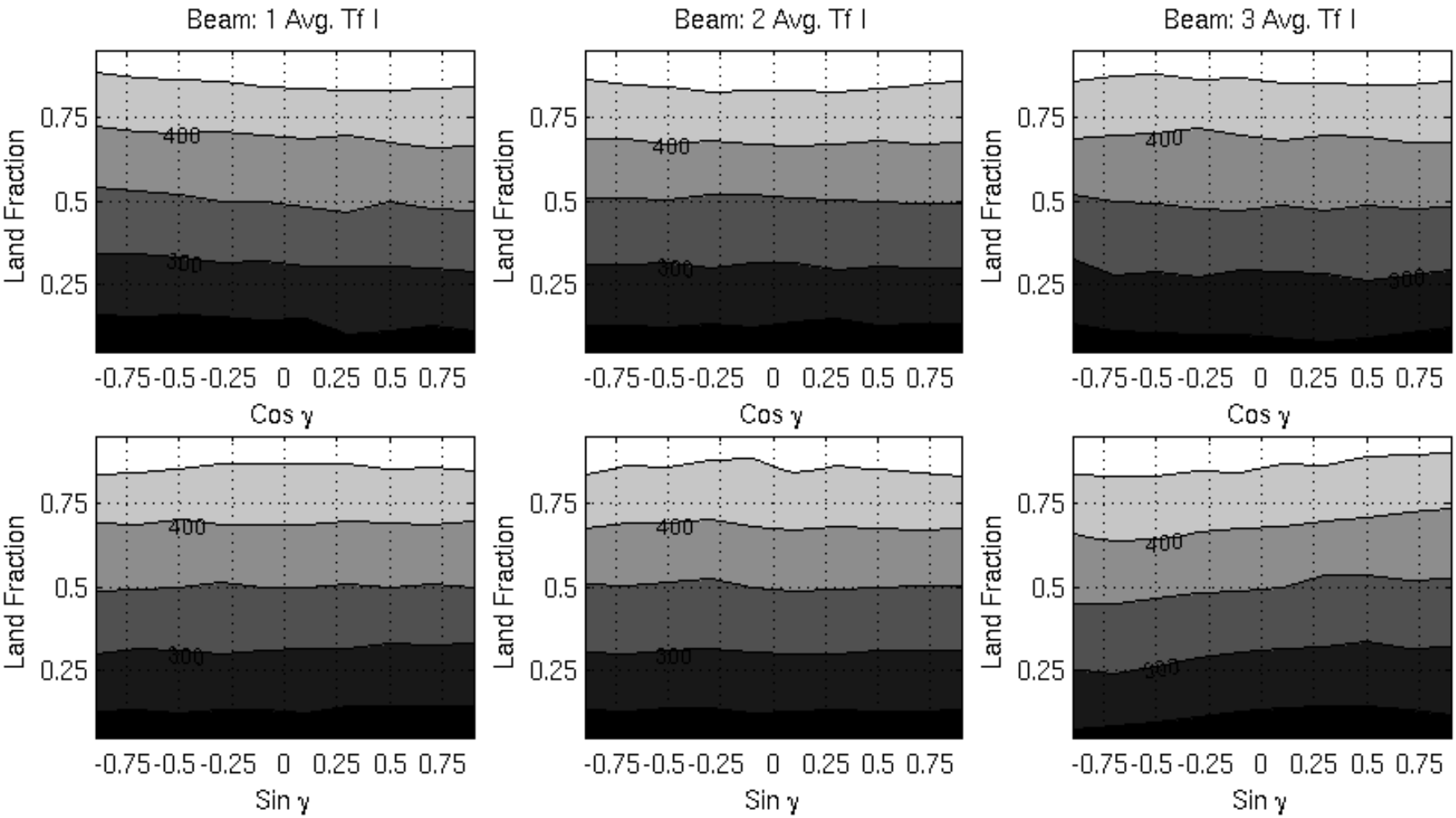
# Radiometer $T_l$
# Processed with +0.3 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



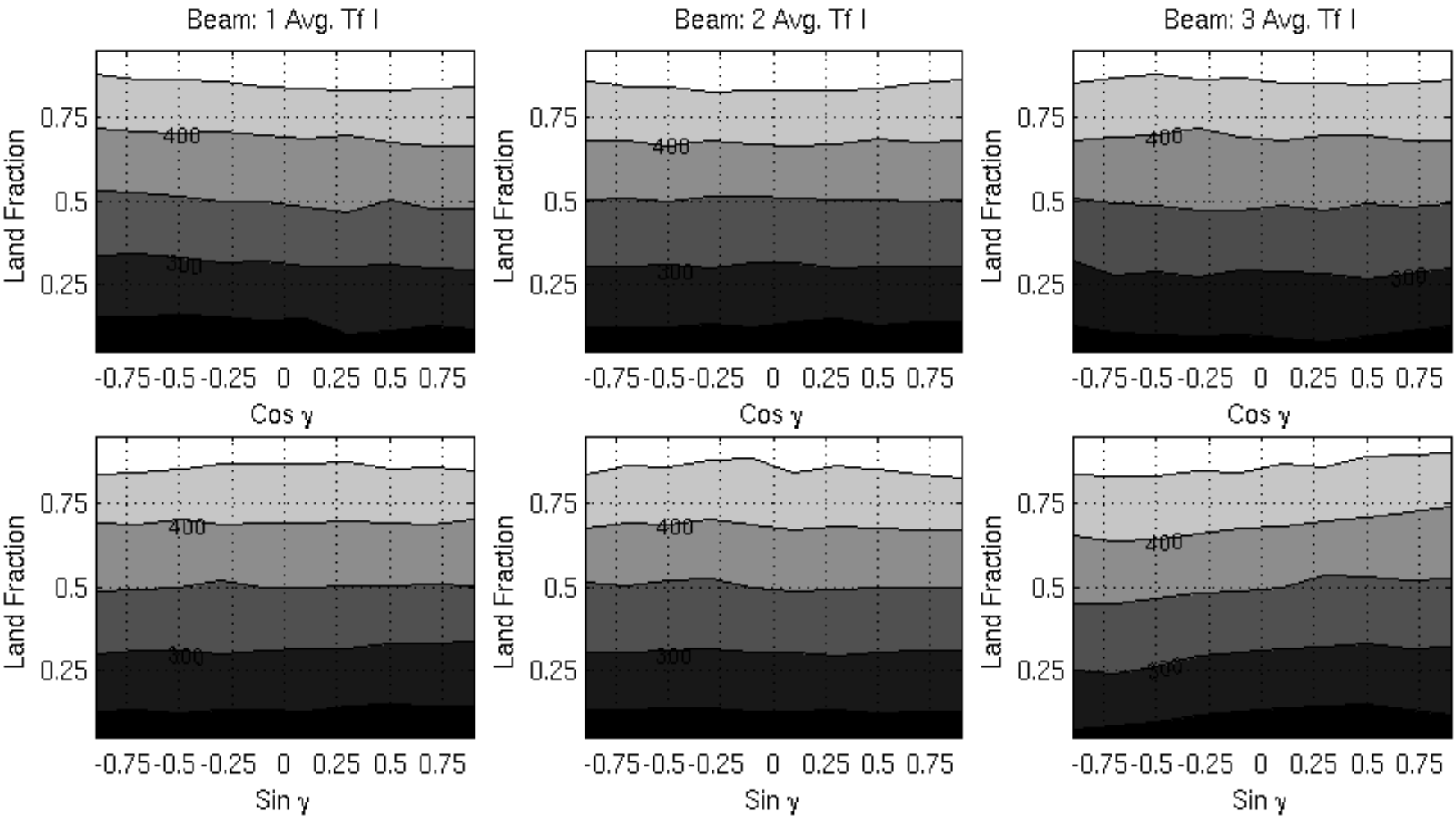
# Radiometer $T_l$
# Processed with +0.3 deg Nadir Angle Offset, +0.1 deg Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



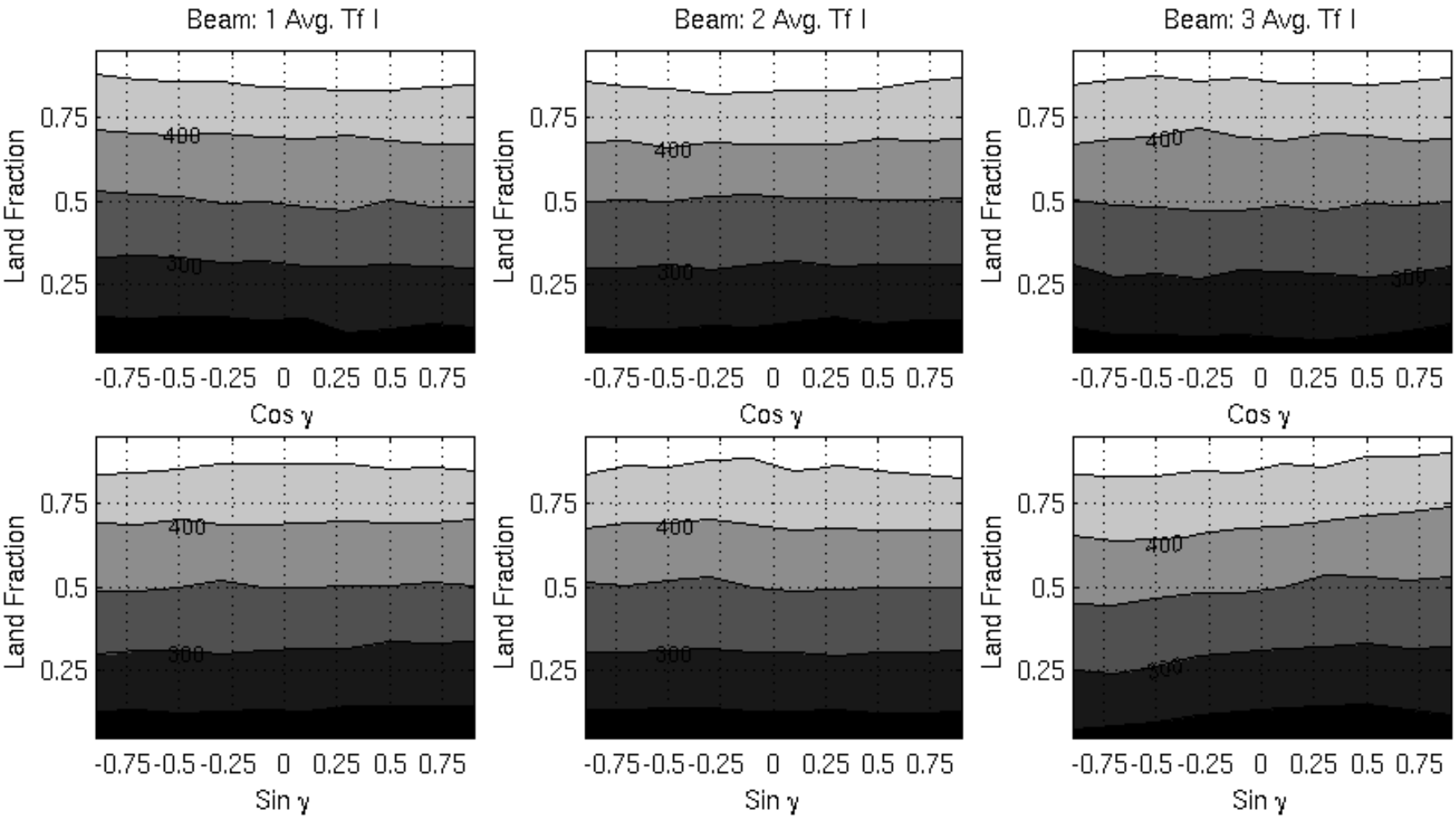
# Radiometer $T_l$
# Processed with +0.3 deg Nadir Angle Offset, +0.2 deg Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



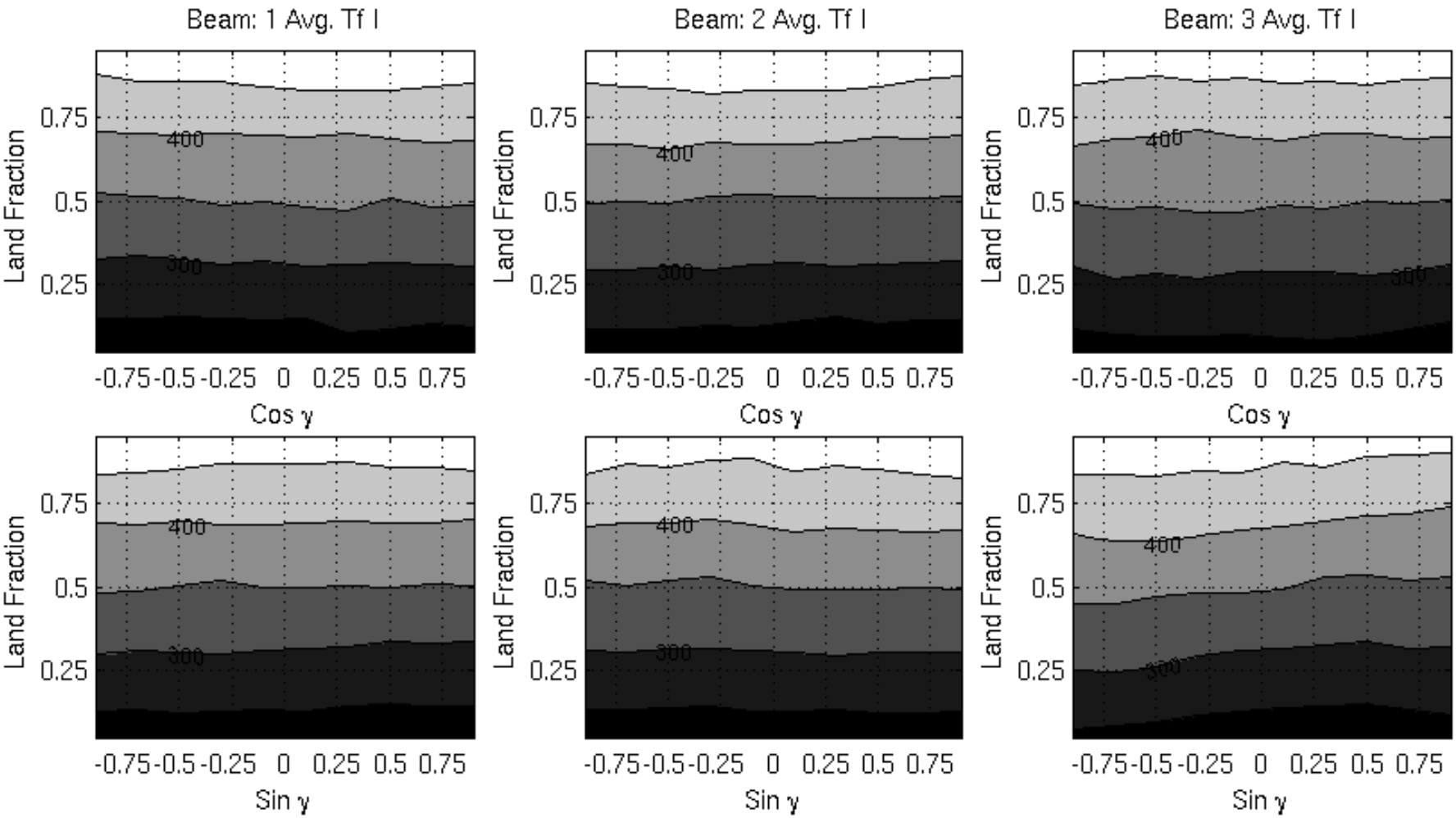
# Radiometer $T_l$
# Processed with +0.3 deg Nadir Angle Offset, +0.3 deg Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



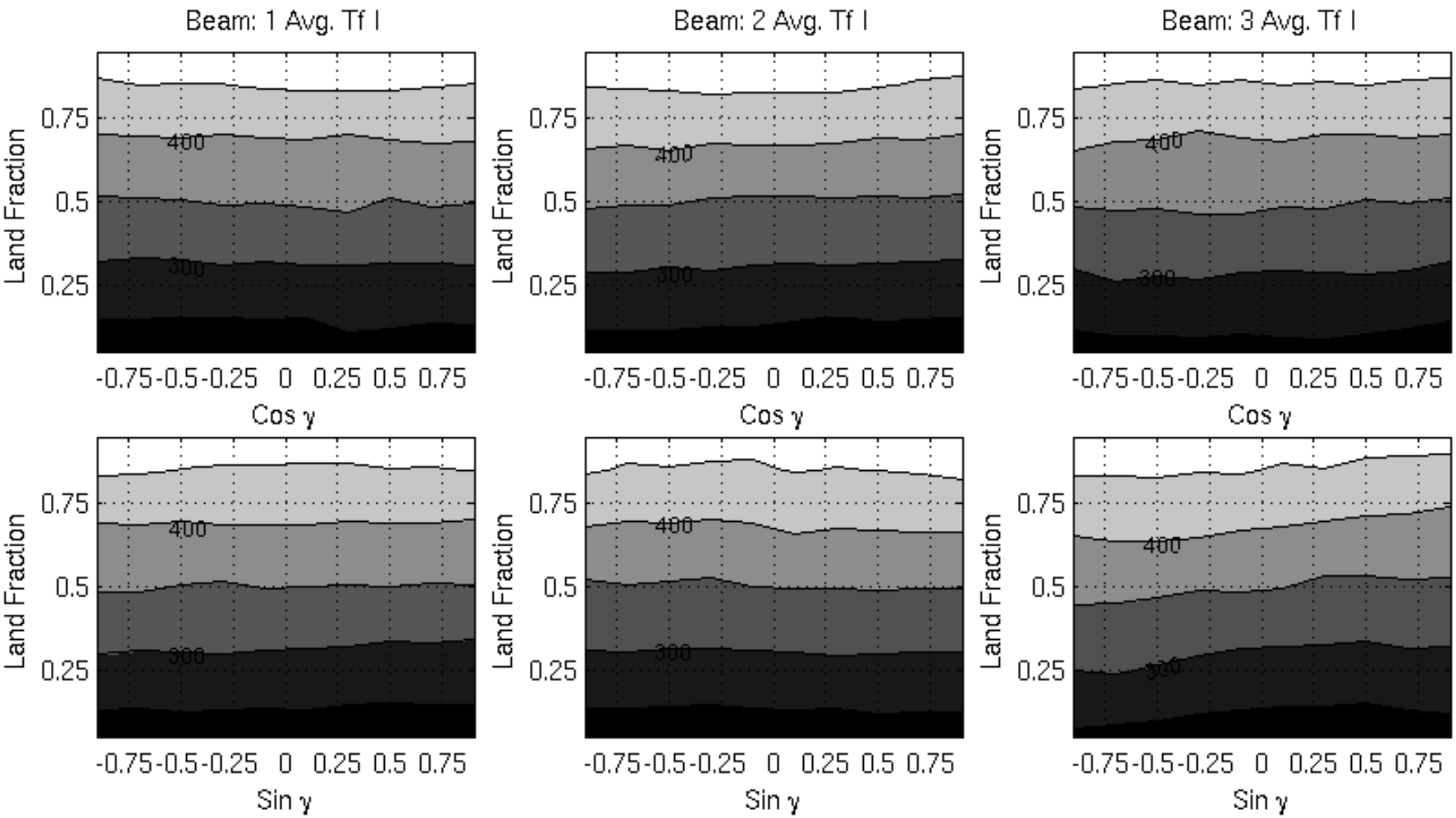
# Radiometer $T_l$
# Processed with +0.3 deg Nadir Angle Offset, +0.4 deg Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



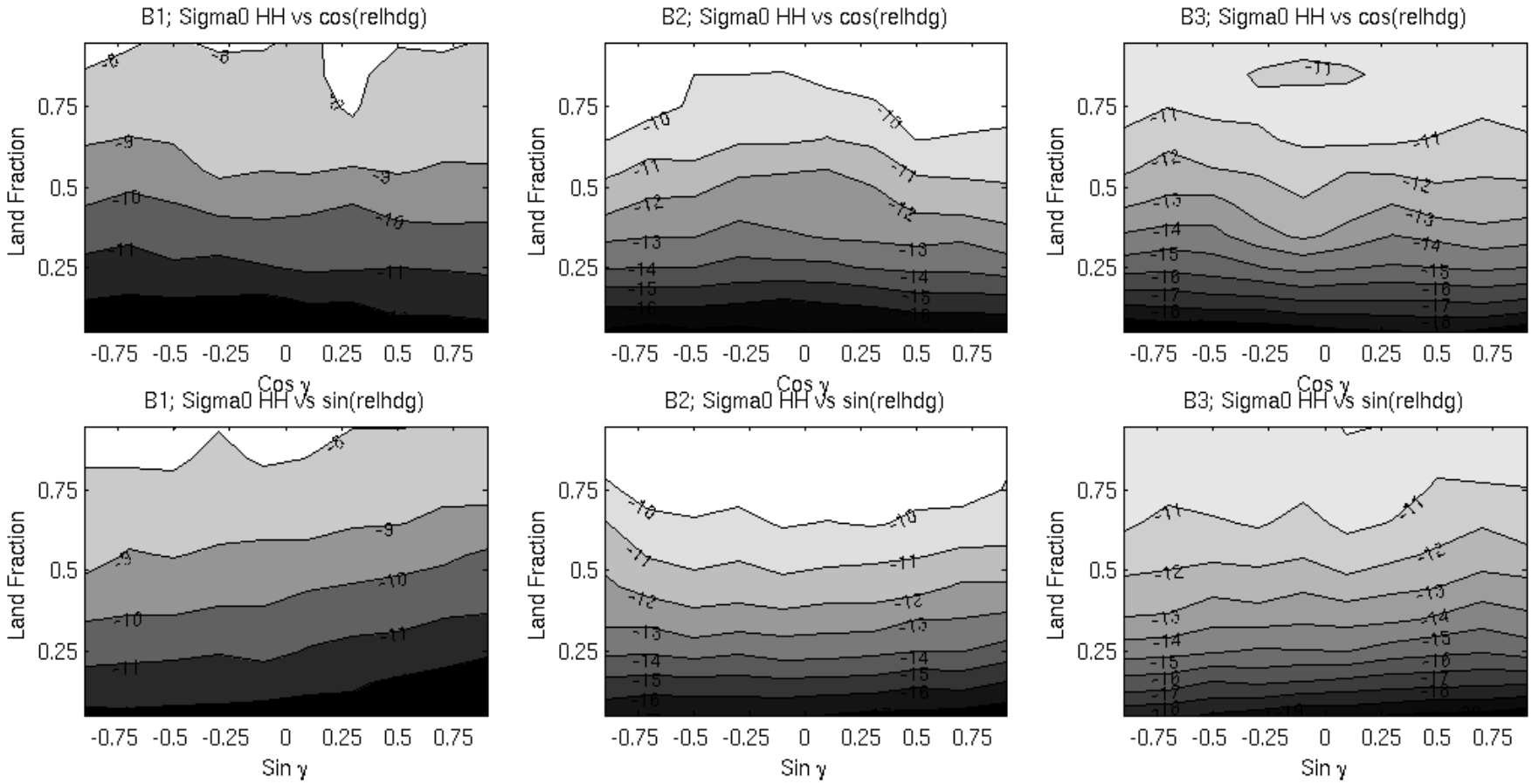
# Radiometer $T_l$
# Processed with +0.3 deg Nadir Angle Offset, +0.5 deg Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



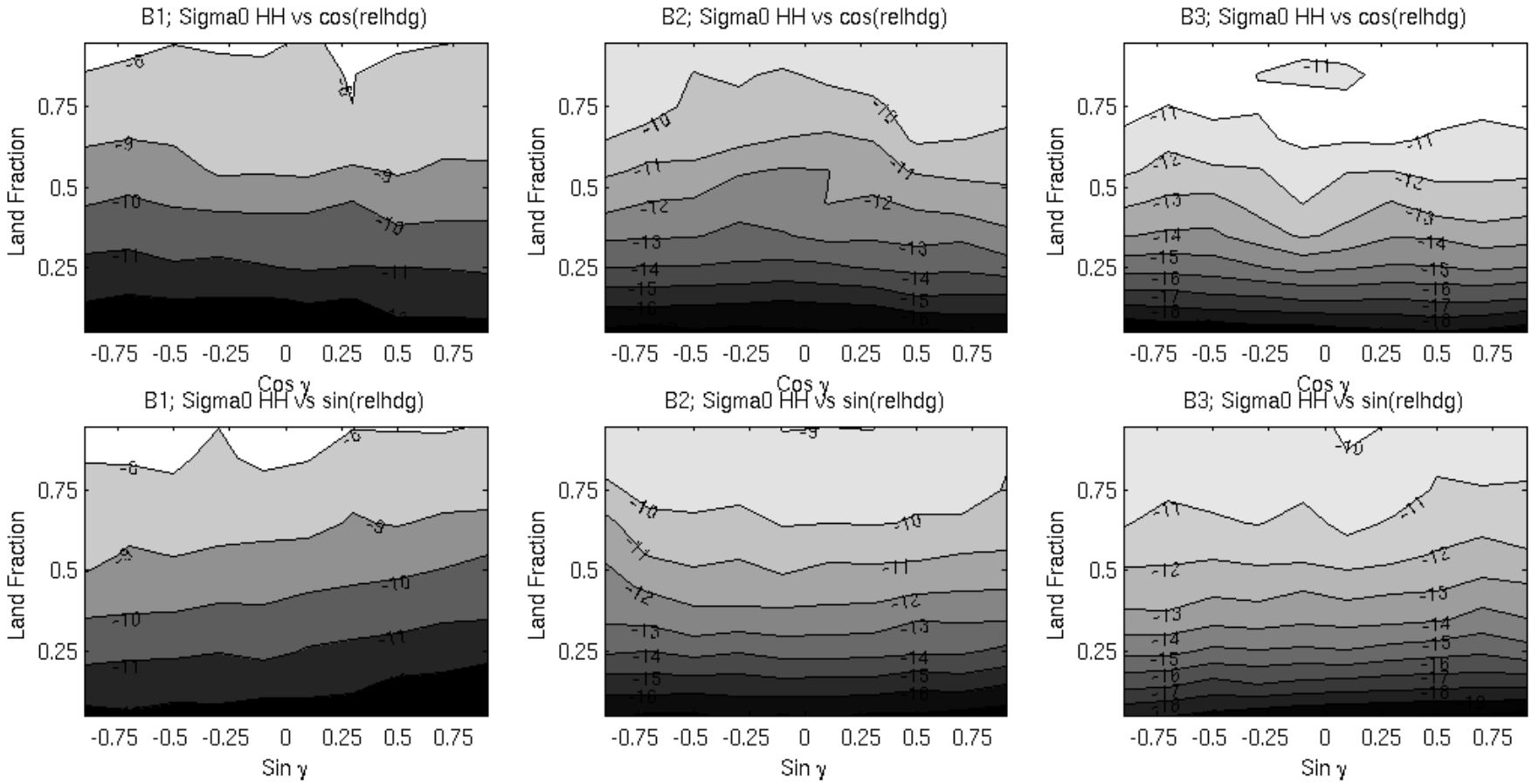
# Scatterometer $\sigma_0^{HH}$
# Processed with Pre-Launch Pointing Angles

Y-axis is Scatterometer Land Fraction



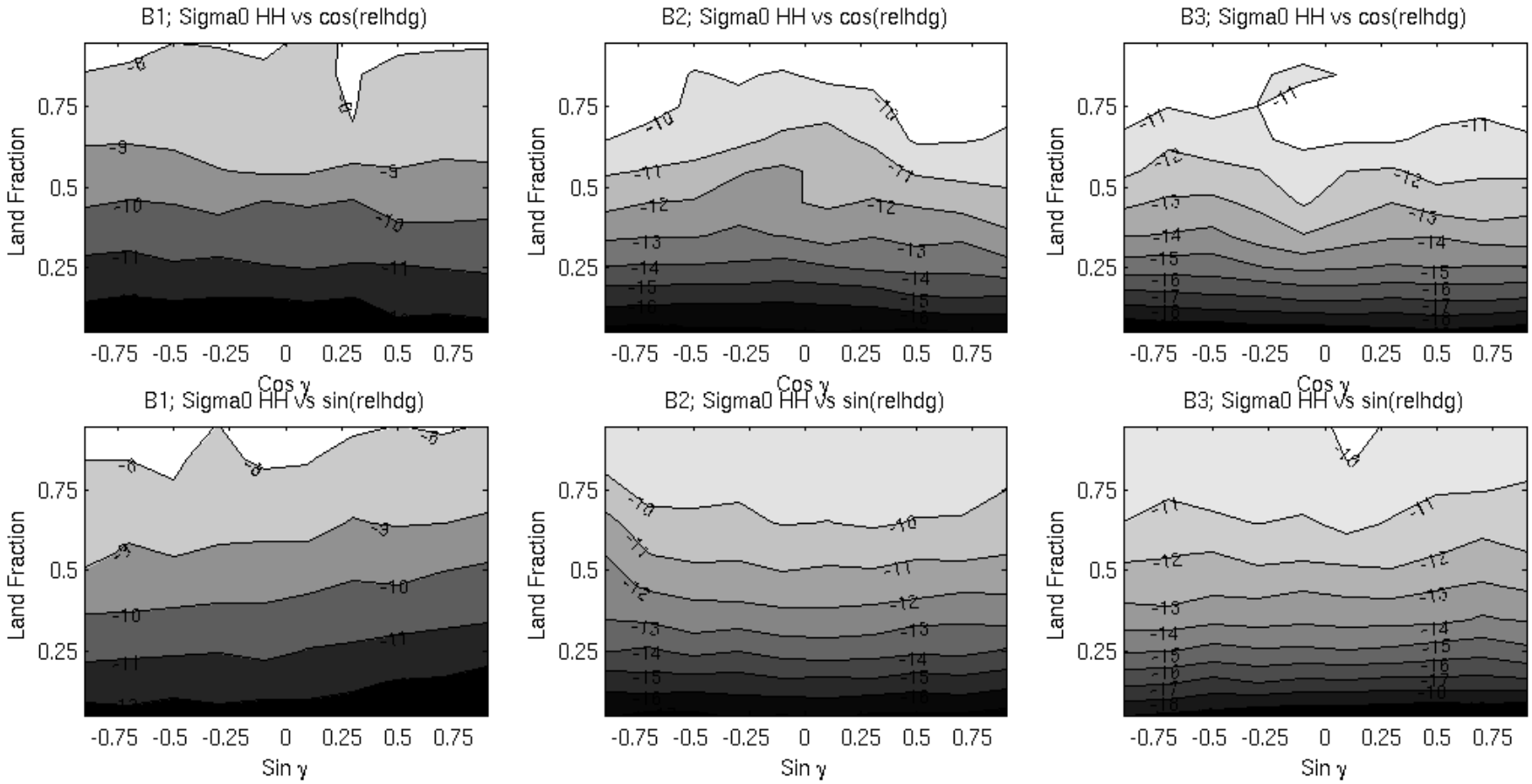
# Scatterometer $\sigma_0^{HH}$ Processed with +0.1 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



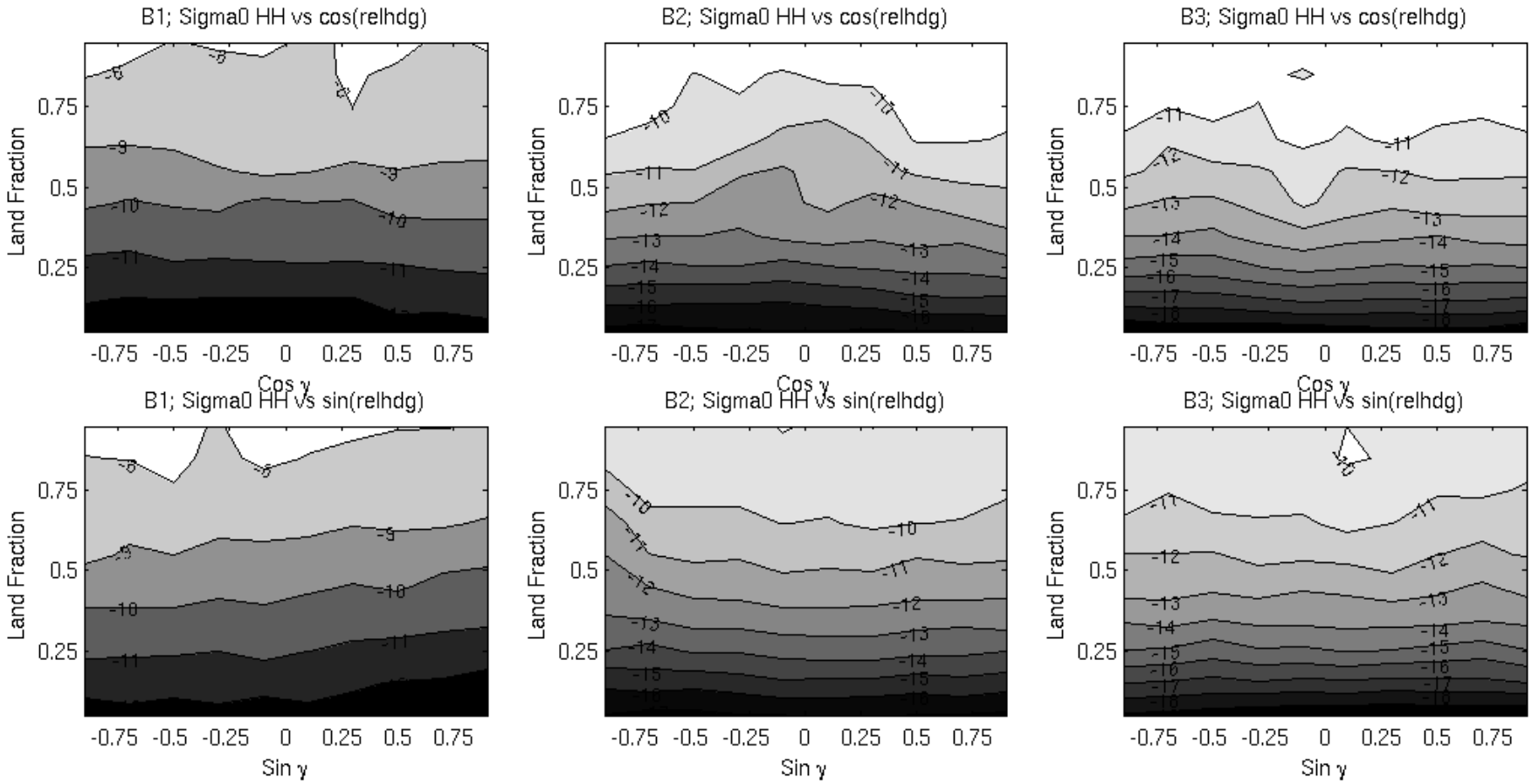
# Scatterometer $\sigma_0^{HH}$ Processed with +0.2 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



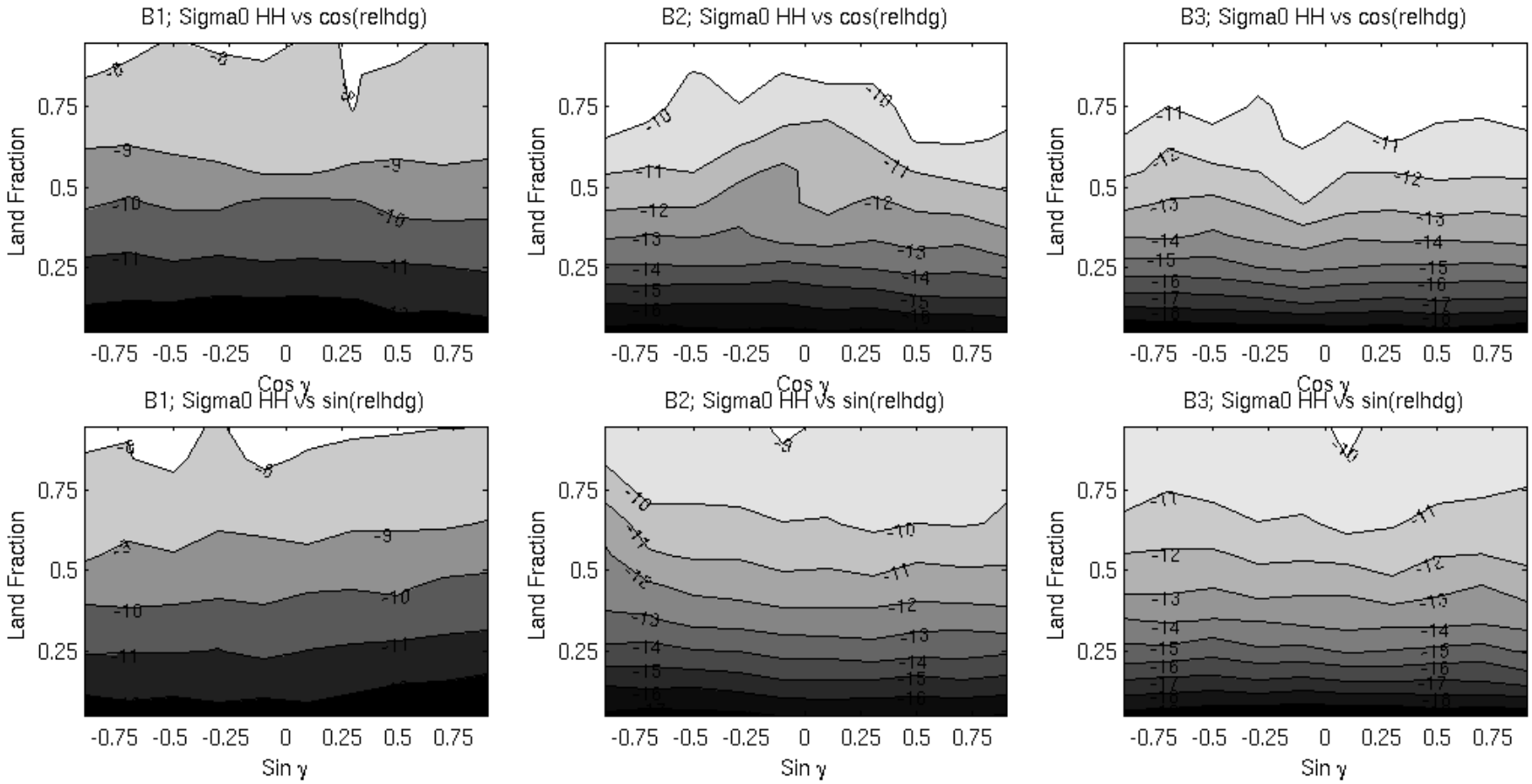
# Scatterometer $\sigma_0^{HH}$ Processed with +0.3 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



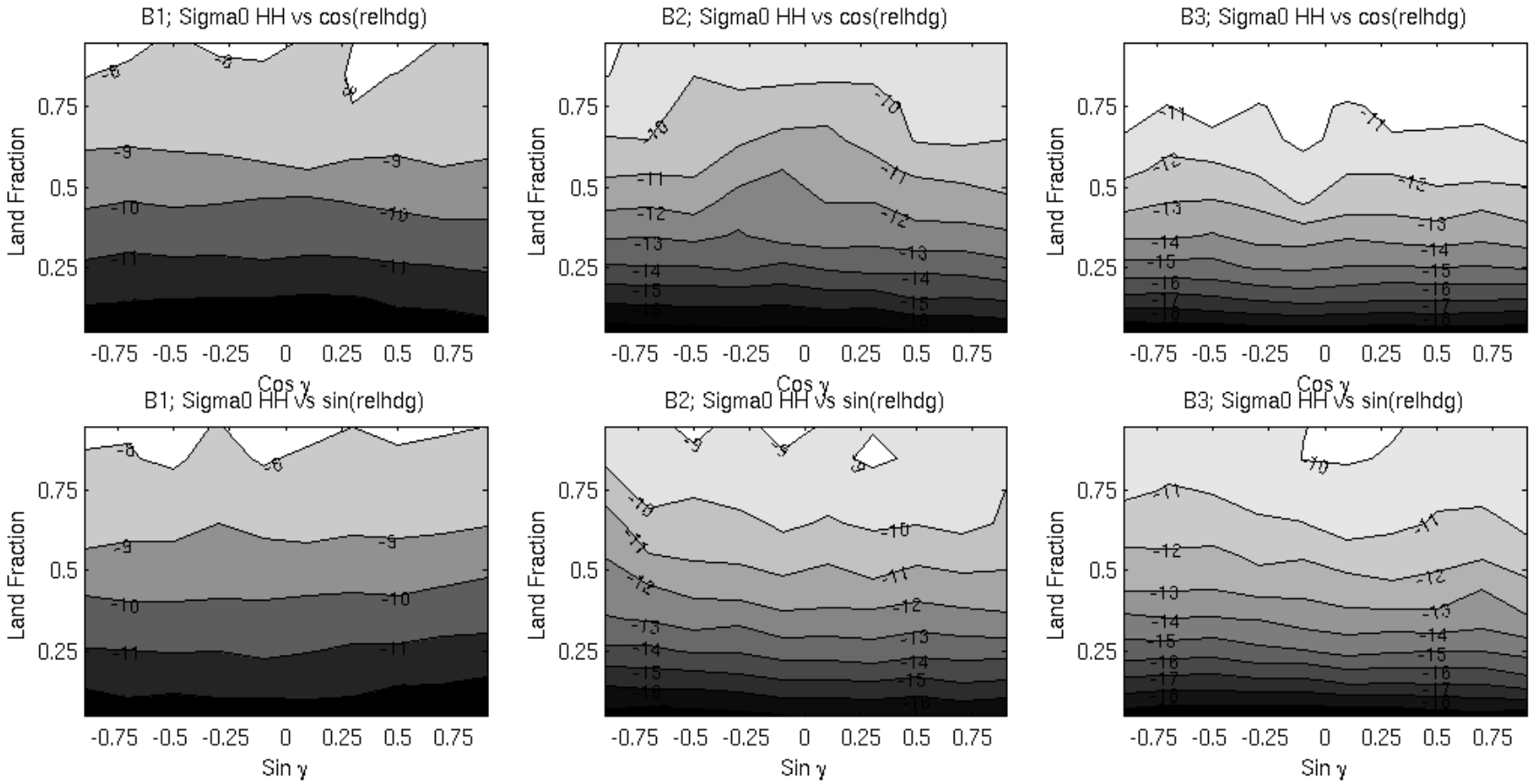
# Scatterometer $\sigma_0^{HH}$ Processed with +0.4 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



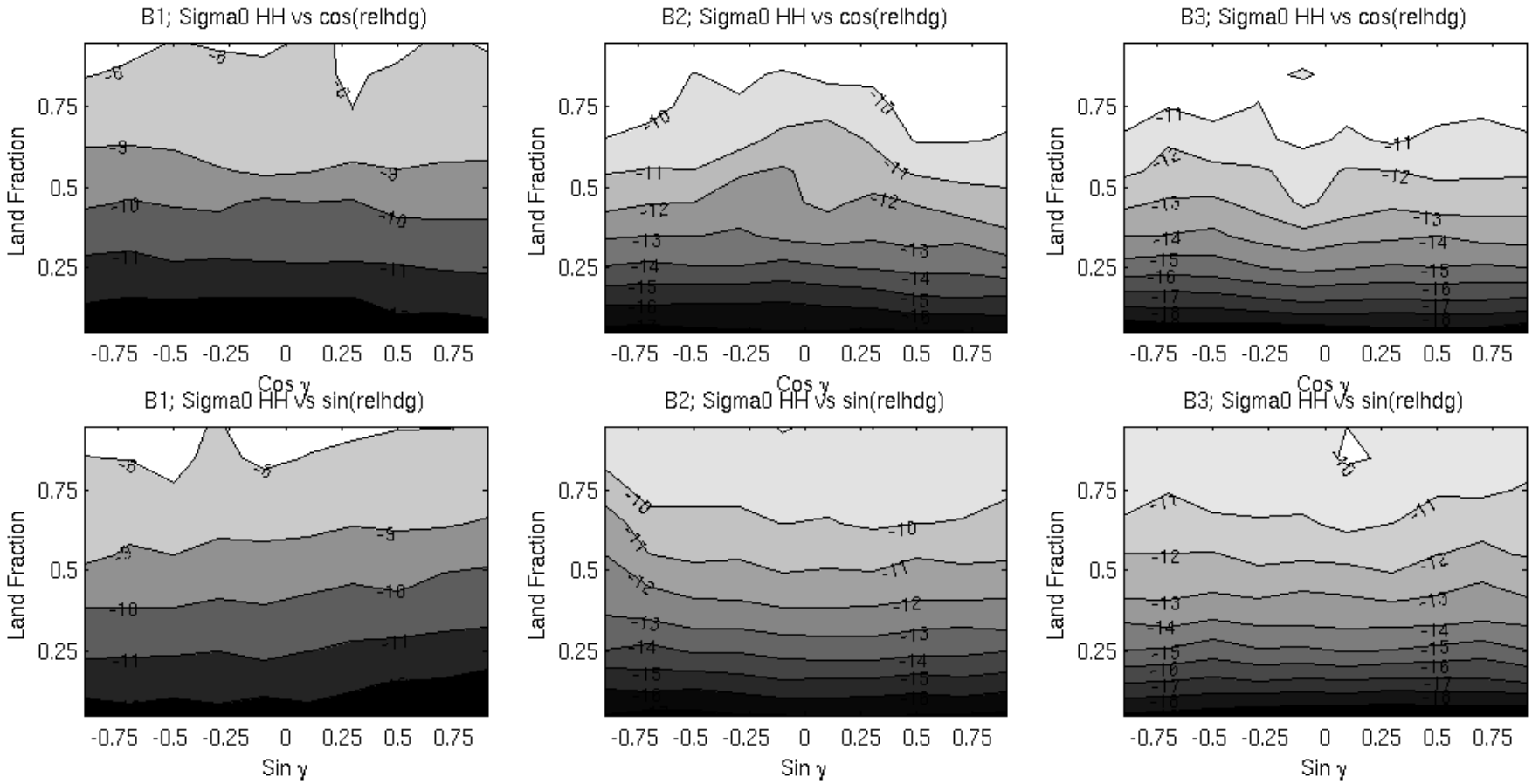
# Scatterometer $\sigma_0^{HH}$ Processed with +0.5 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



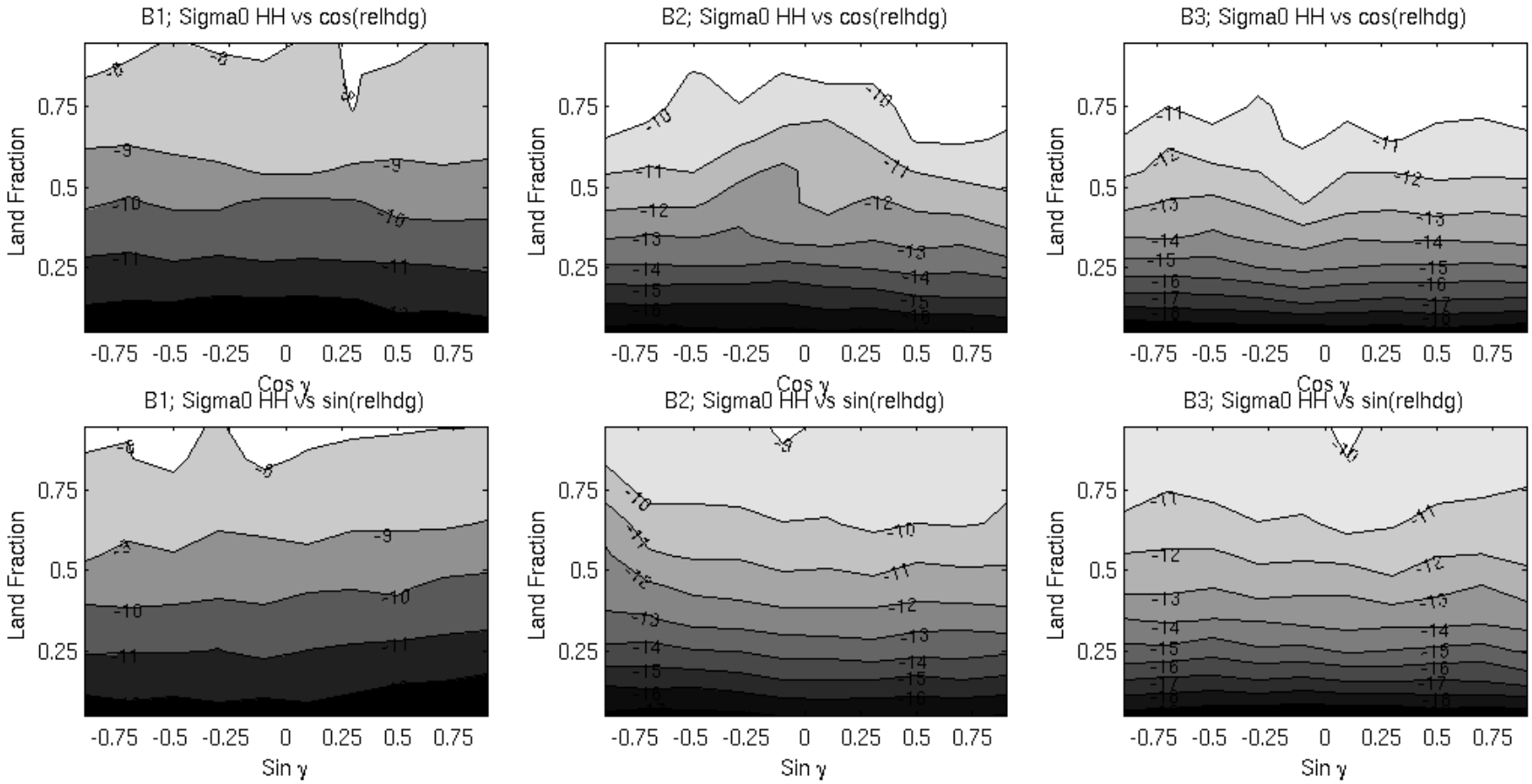
# Scatterometer $\sigma_0^{HH}$ Processed with +0.3 deg Nadir Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



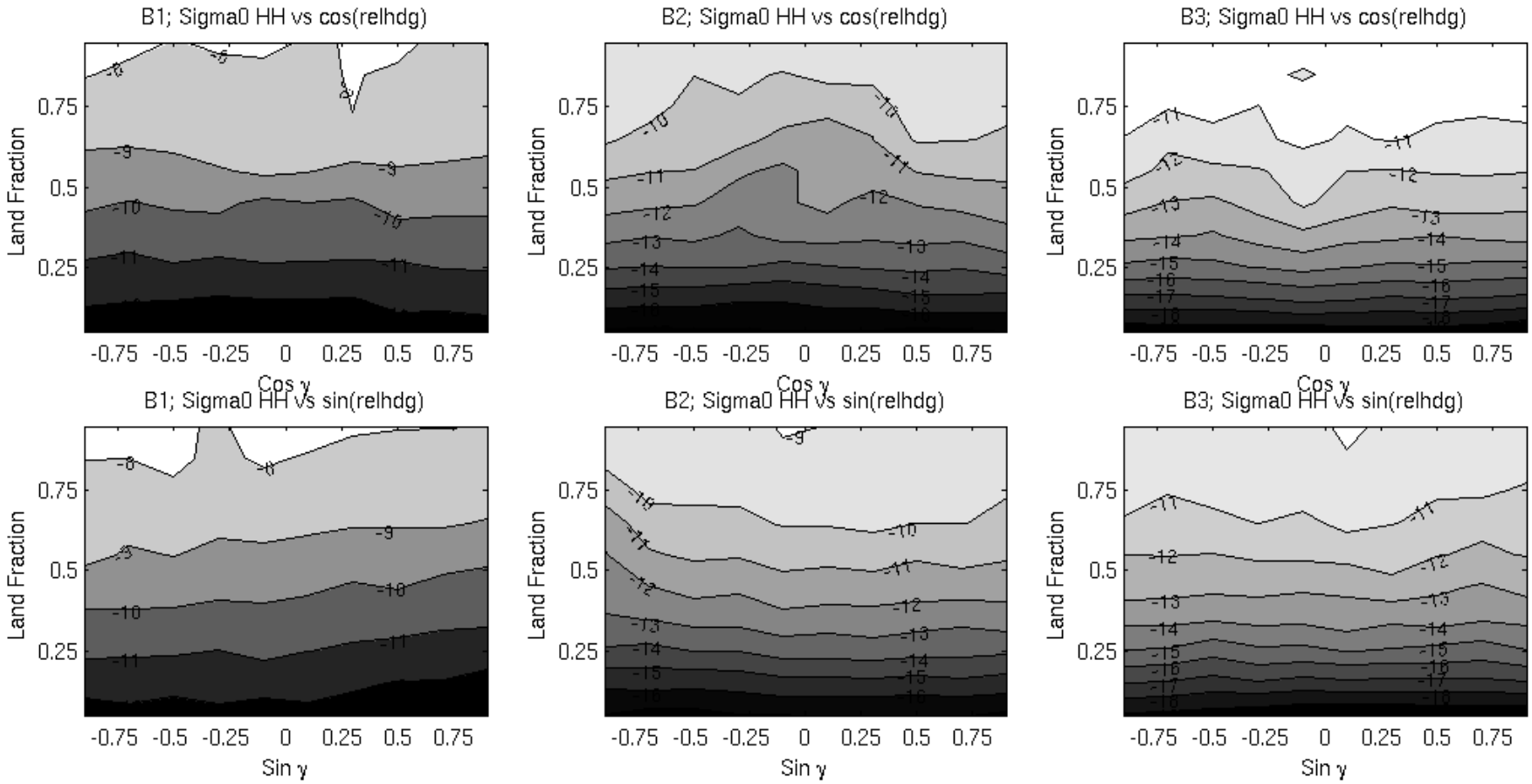
# Scatterometer $\sigma_0^{HH}$ Processed with +0.3 deg Nadir Angle Offset, +0.1 Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



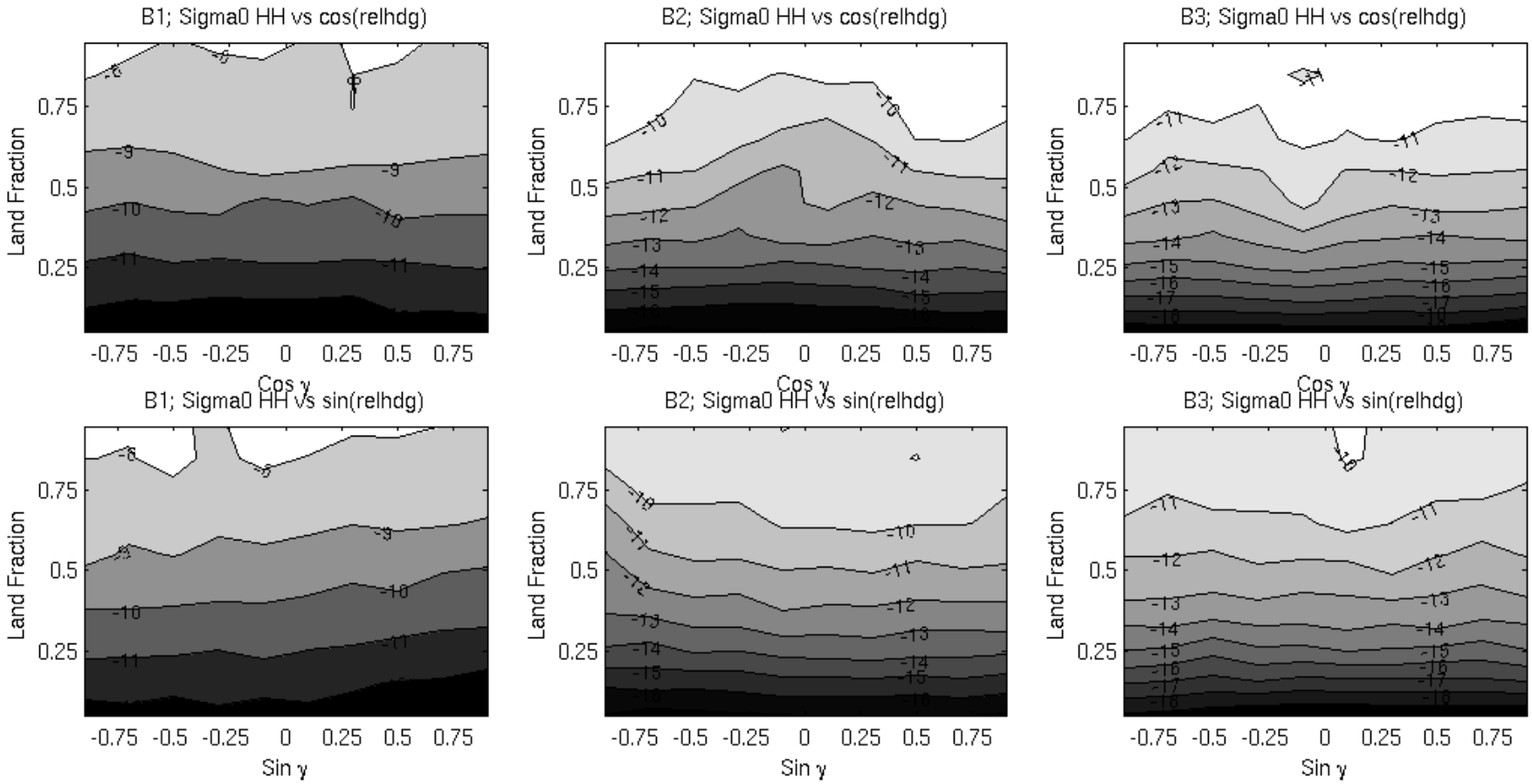
# Scatterometer $\sigma_0^{HH}$ Processed with +0.3 deg Nadir Angle Offset, +0.2 Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



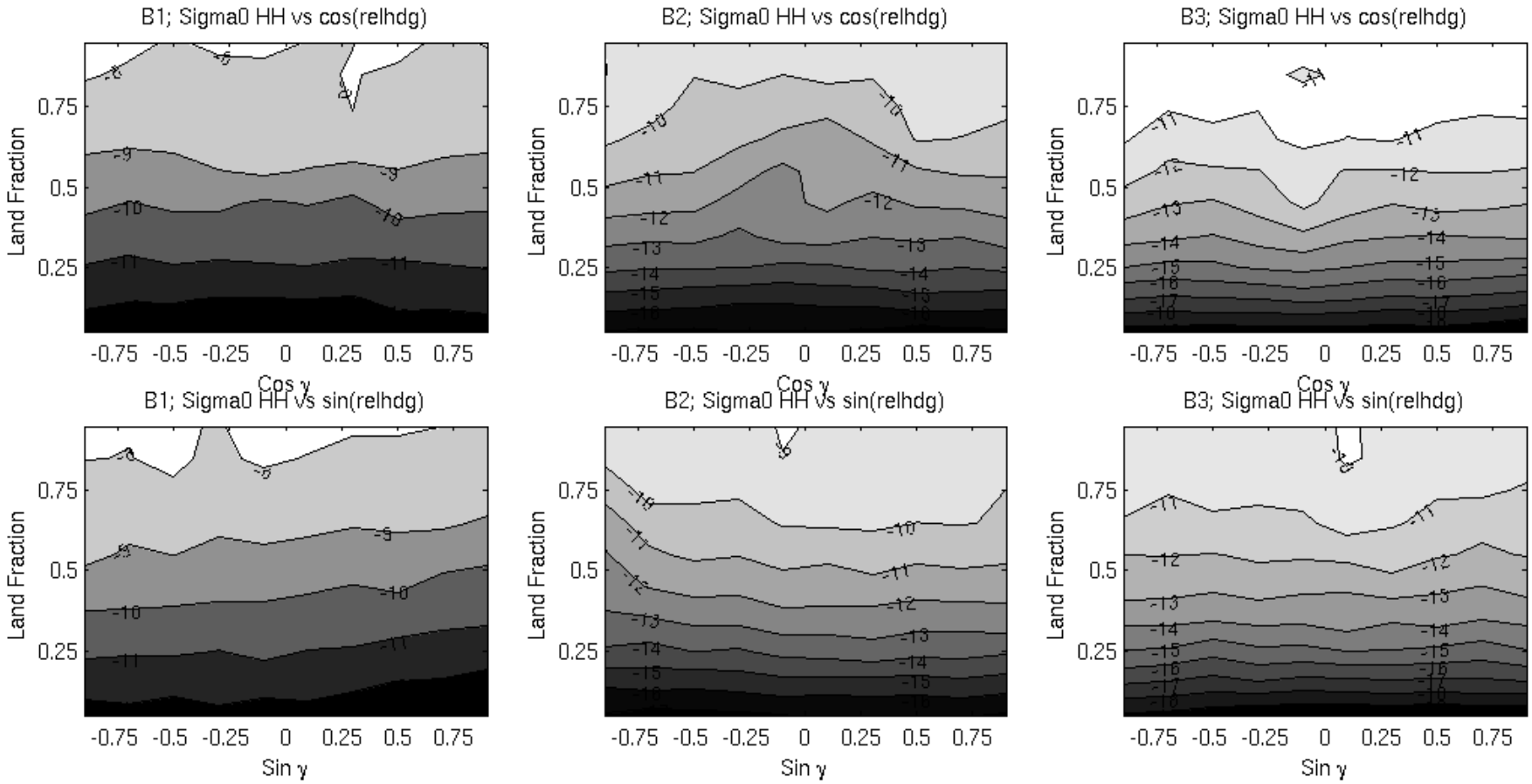
# Scatterometer $\sigma_0^{HH}$ Processed with +0.3 deg Nadir Angle Offset, +0.3 Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



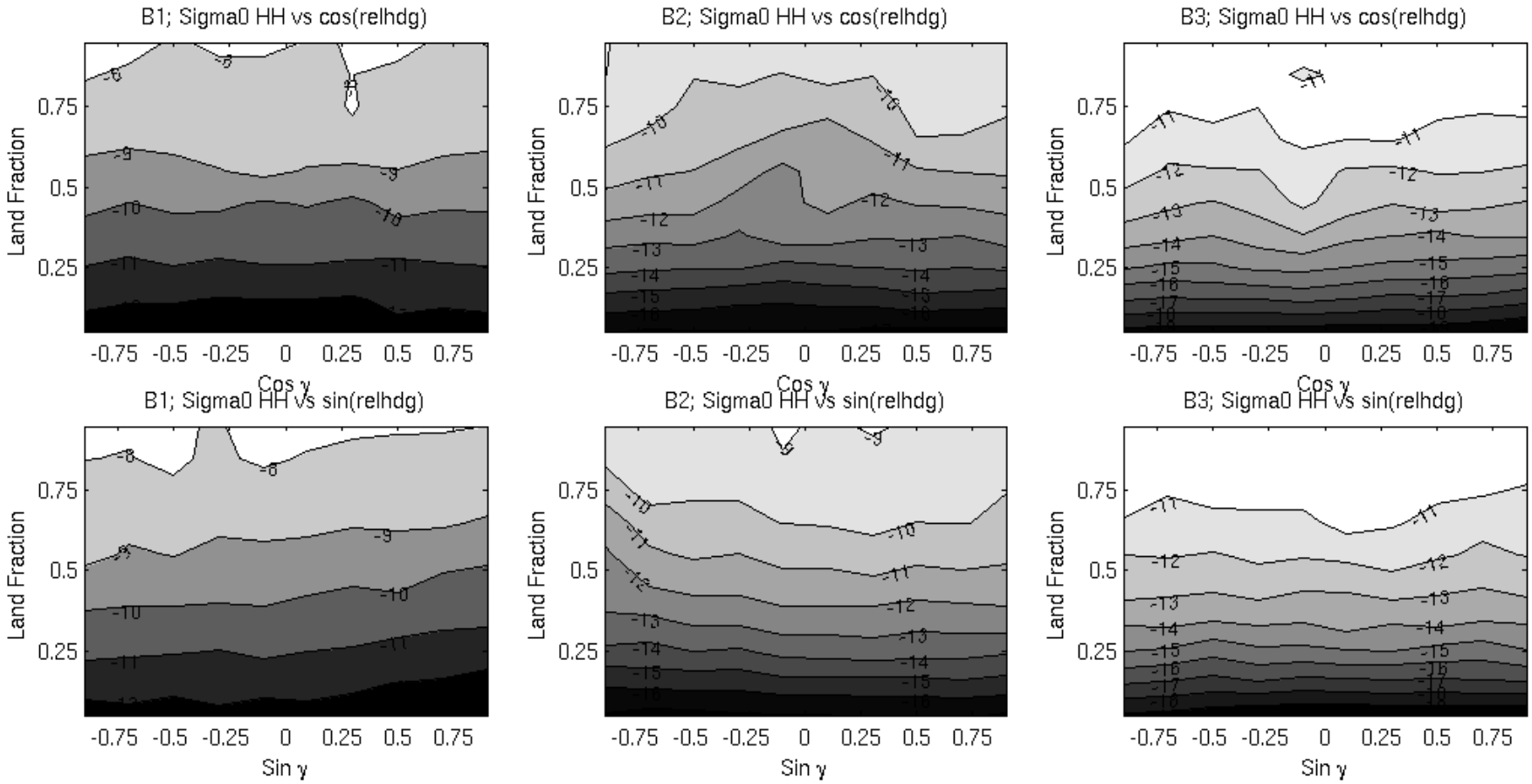
# Scatterometer $\sigma_0^{HH}$ Processed with +0.3 deg Nadir Angle Offset, +0.4 Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



# Scatterometer $\sigma_0^{HH}$ Processed with +0.3 deg Nadir Angle Offset, +0.5 Azimuth Angle Offset for all Beams

Y-axis is Scatterometer Land Fraction



# Summary

- We show the pointing angle is stable to within 0.1 degrees over time.
  - We used both the radar and radiometer data.
  - Weekly analyses yield very similar results.
- We show that a radiometer and scatterometer give a consistent assessment of the best pointing offsets:

| | Beam 1 | Beam 2 | Beam 3 |
|---|---|---|---|
| Rad Delta Nadir | +0.4 | +0.3 | +0.5 |
| Rad Delta Azi | +0.5 | +0.2 | +0.2 |
| Scat Delta Nadir | +0.5 | +0.2 | +0.3 |
| Scat Delta Azi | +0.5 | +0.2 to +0.3 * | +0.2 to +0.3 * |
| Compromise Between Radiometer and Radar Best Fit Angles | | | |
| Delta Nadir | +0.45 | +0.25 | +0.4 |
| Delta Azi | +0.5 | +0.2 | +0.2 |

*Hard to tell the difference

# Possible Actions

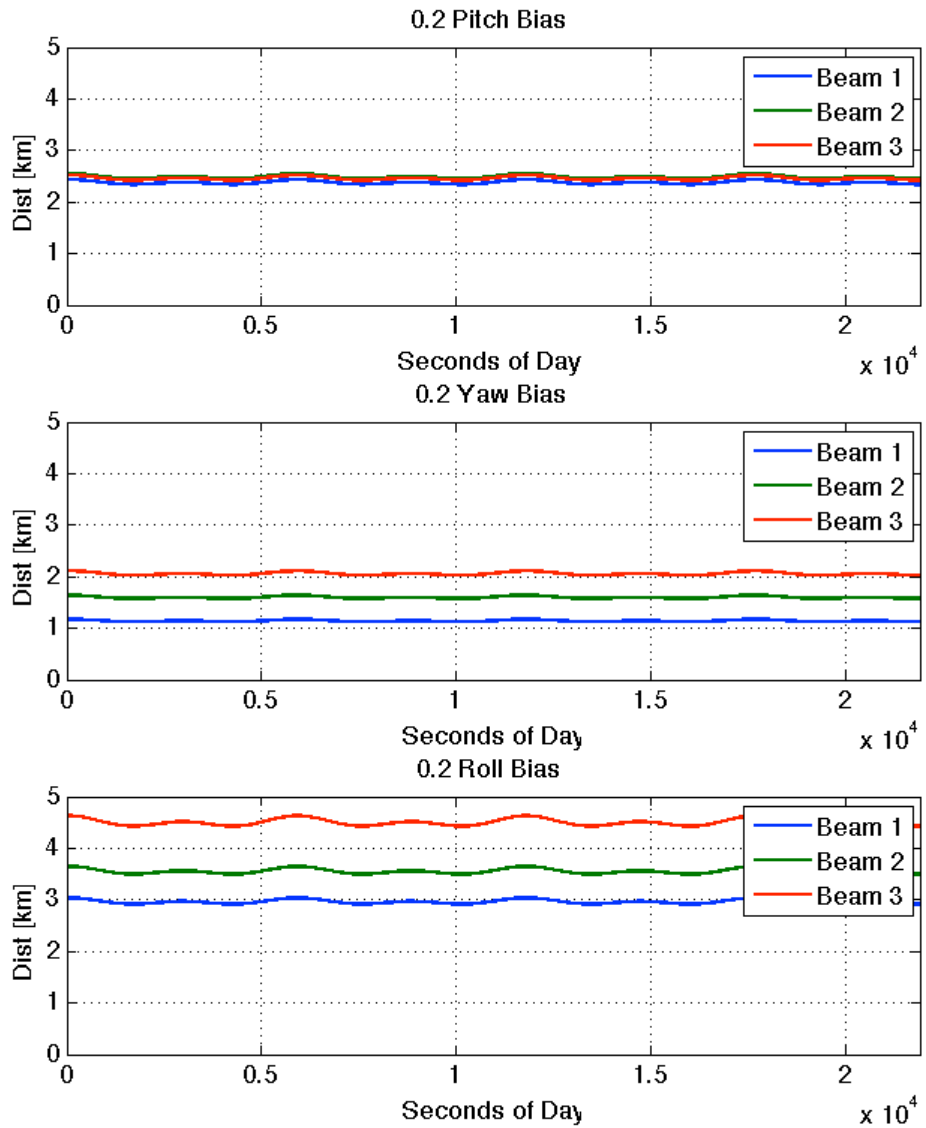
- Adjust beams individually
  - B1: +0.45 Nadir; +0.5 Azimuth
  - B2: +0.25 Nadir; +0.2 Azimuth
  - B3: +0.40 Nadir; +0.2 Azimuth
  - Pros:
    - Improved land fraction computations will give better ability to correct for land contamination in both the radiometer and radar retrievals.
    - Reduced biases/errors when using incidence angle dependent model functions. (i.e. attributing an incidence angle error to a calibration error)
  - Cons:
- Leave the pointing angles as they are
  - Cons:
    - Reduced utility of the predicted land fraction.
    - Changing it in the future will require much more work than changing it now.

- Azimuth angle offset and time-tag errors are indistinguishable.
  - Both are along-track type of offsets.

# BACKUP SLIDES

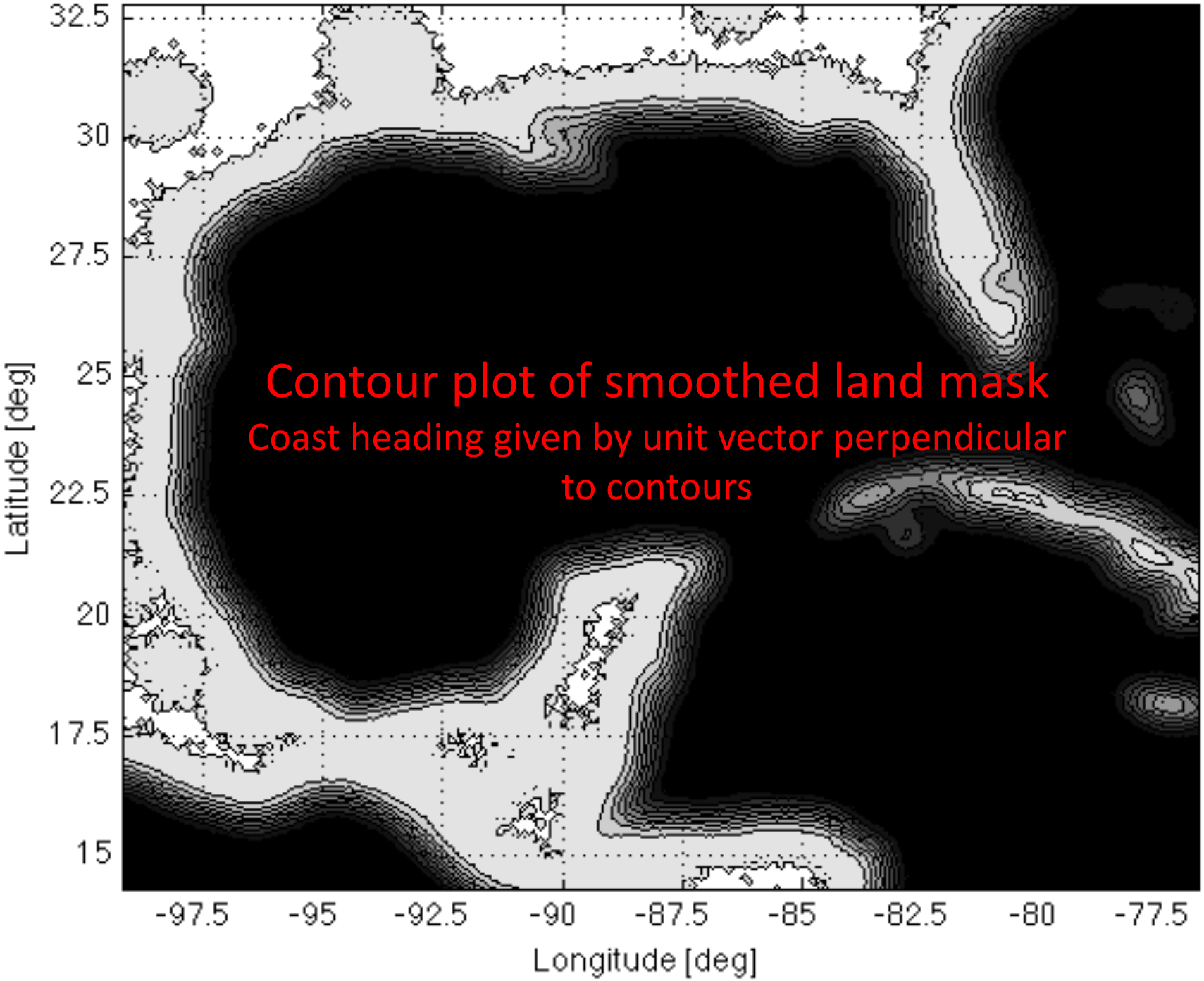
# Pointing Angle Bias (Sensitivity Analysis)

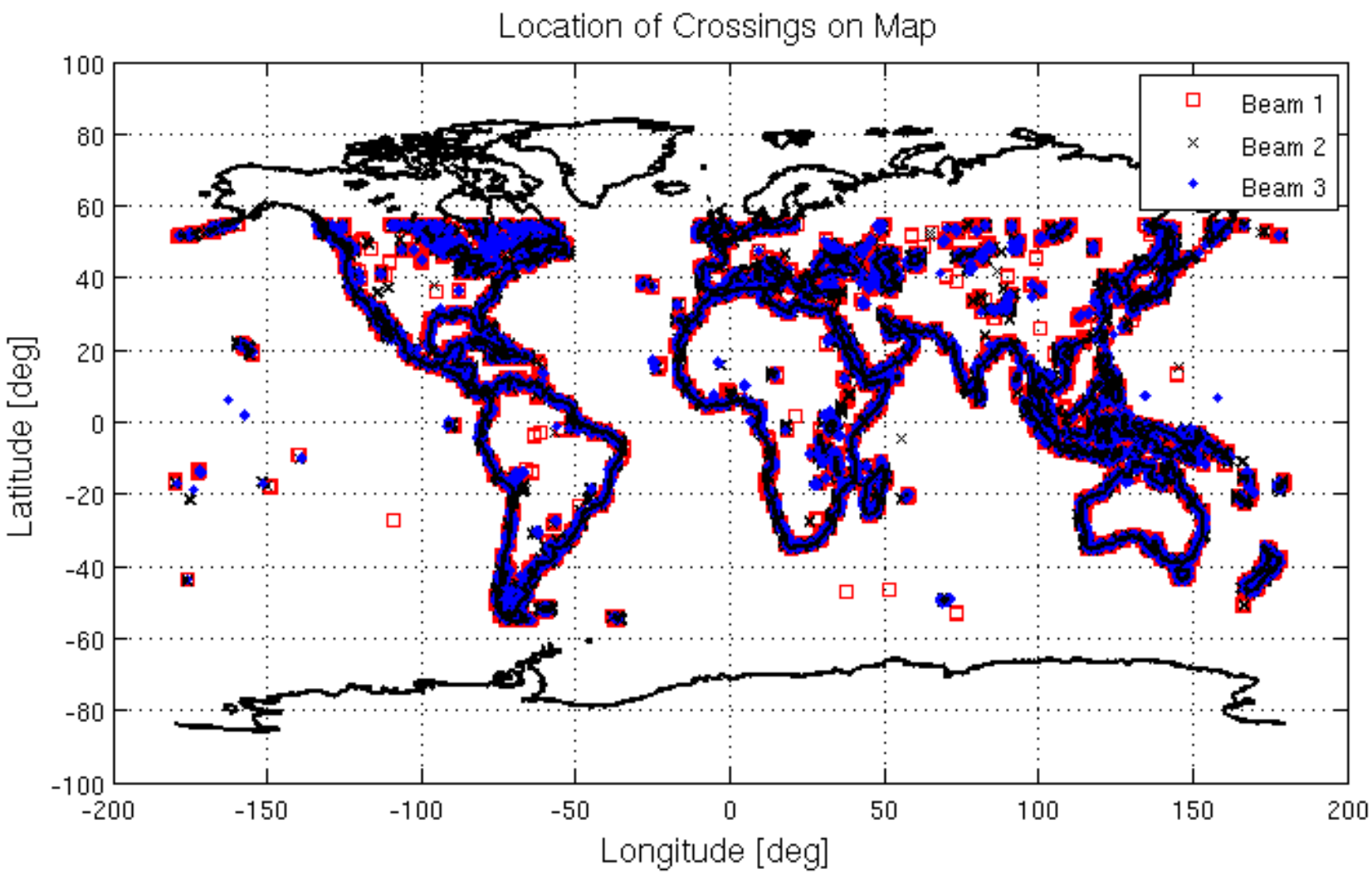
- Simulated data with a constant 0.2 deg bias in yaw, pitch, and roll.
- We see beam center geo-location errors on the order of 2 km for a pitch and yaw bias.
  - Pitch bias results in a slightly varying offset which is almost the same for all beams.
  - Yaw bias results in a bias which is more different per beam.
- Roll bias results in the largest offset. (~ 4km)
- Beam footprint ~ 100km; these biases are a few *percent* of that.



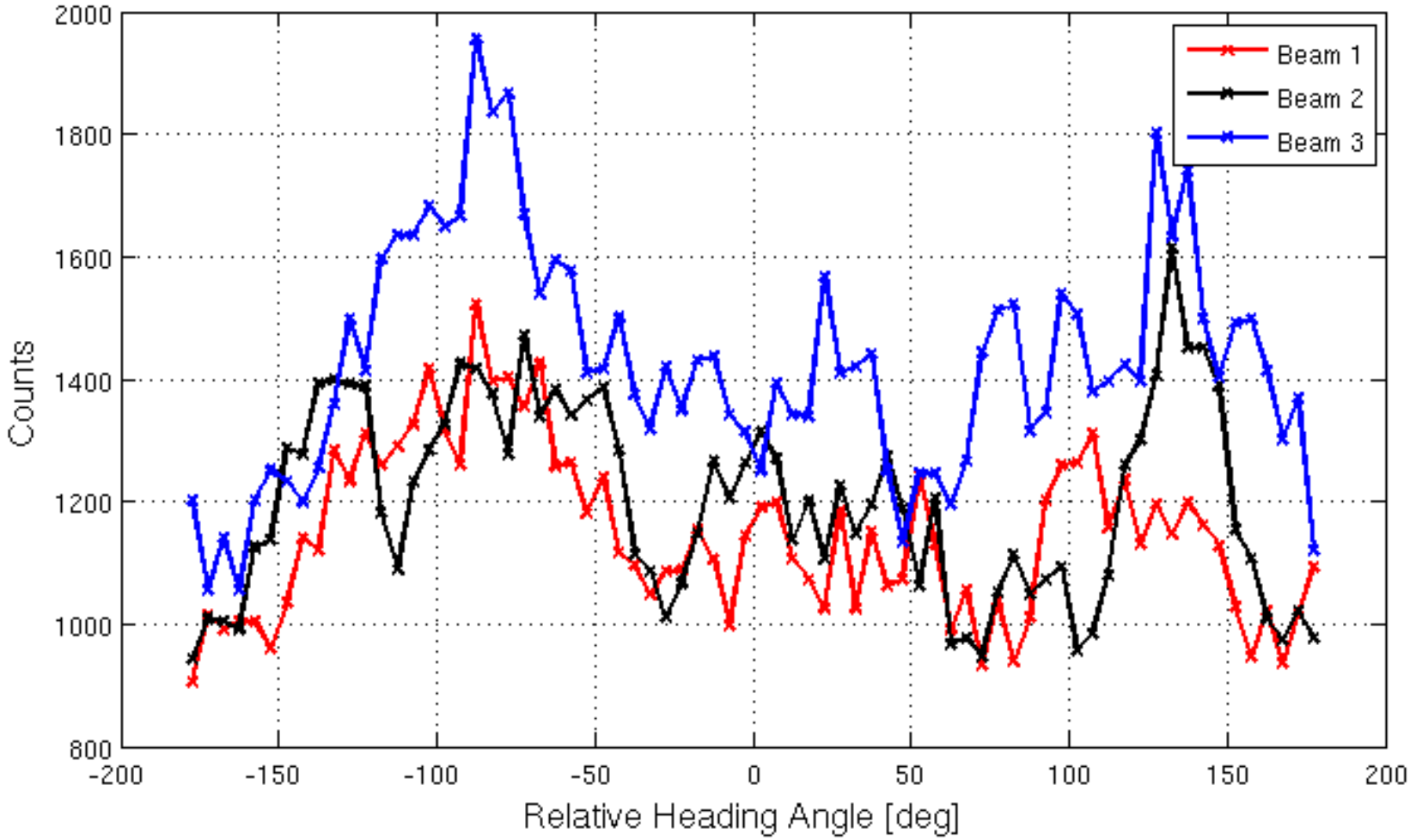
# Coast Heading

- We create a land fraction map using the simulator land mask which is posted at 1/128 degree.
- Create 1/12 degree grid; for each grid point:
  - Take random samples and average resulting land mask over 2000 (lon_mask, lat_mask) samples given by:
    - Lon_mask = lon_grid_point + 0.3 * n_0 / cos( lat_grid_point )
    - Lat_mask = lat_grid_point + 0.3 * n_1
    - Where n_0, n_1 are from Gaussian distribution with zero mean and unit variance.
    - 0.3 deg * FWHM( n(0,1) ) * 110 (km/deg) = 76 km FWHM on ground.
  - Yields a very smooth land fraction
  - Take the gradient of this and arctangent of resulting gradient vector components to get a coast heading map. (coast heading points towards max increase in land fraction).
  - *Note: we don't use this land fraction map in analysis, only use the gradient for computing the beam heading relative to the coast normal direction.*


Contour plot of smoothed land mask
Coast heading given by unit vector perpendicular to contours
32.5
30
27.5
25
22.5
20
17.5
15
Latitude [deg]
-97.5
-95
-92.5
-90
-87.5
-85
-82.5
-80
-77.5
Longitude [deg]

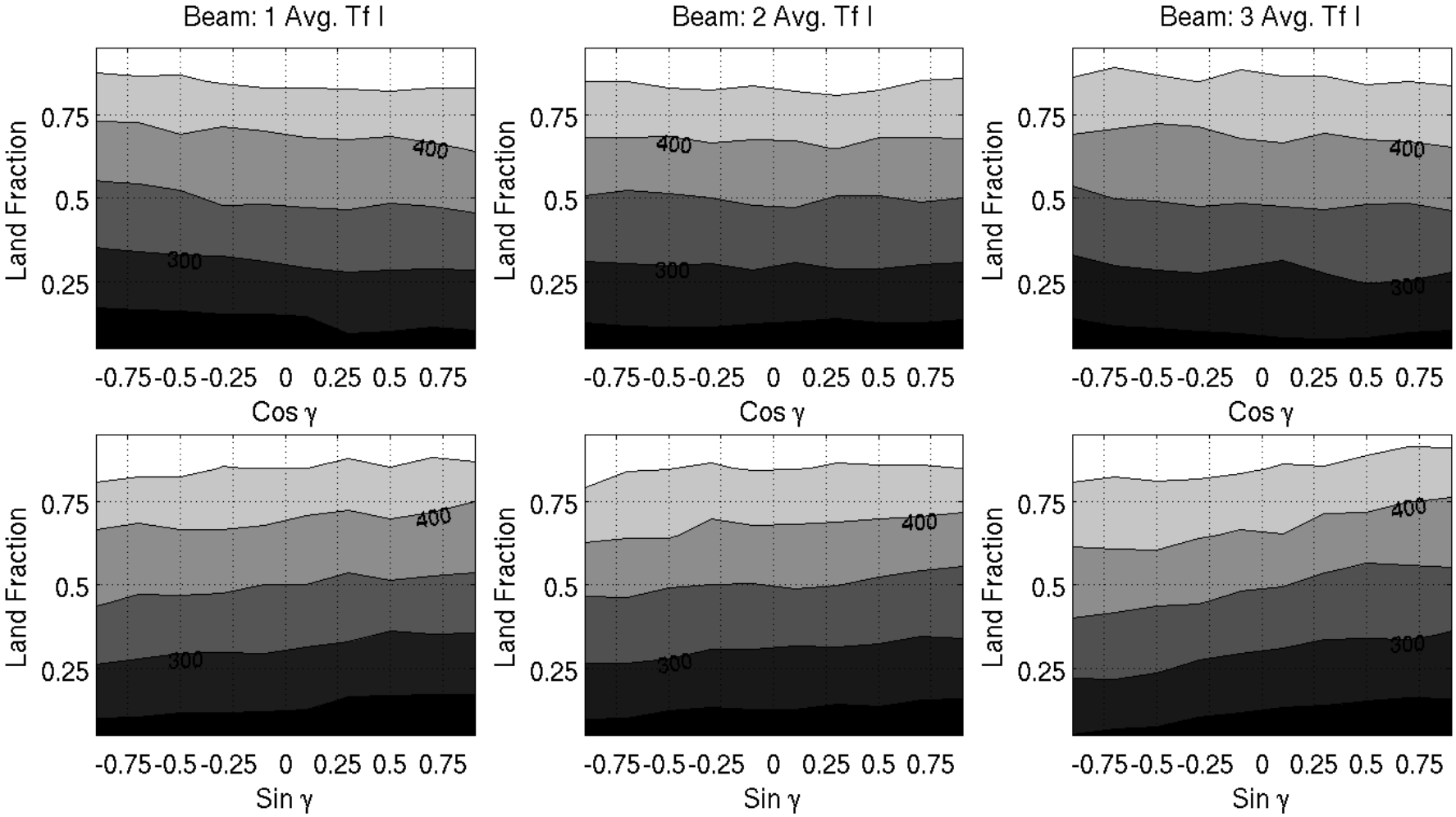

Location of Crossings on Map
Beam 1
Beam 2
Beam 3
Latitude [deg]
Longitude [deg]
100
80
60
40
20
0
-20
-40
-60
-80
-100
-200
-150
-100
-50
0
50
100
150
200

# Histogram of Relative Heading Angles

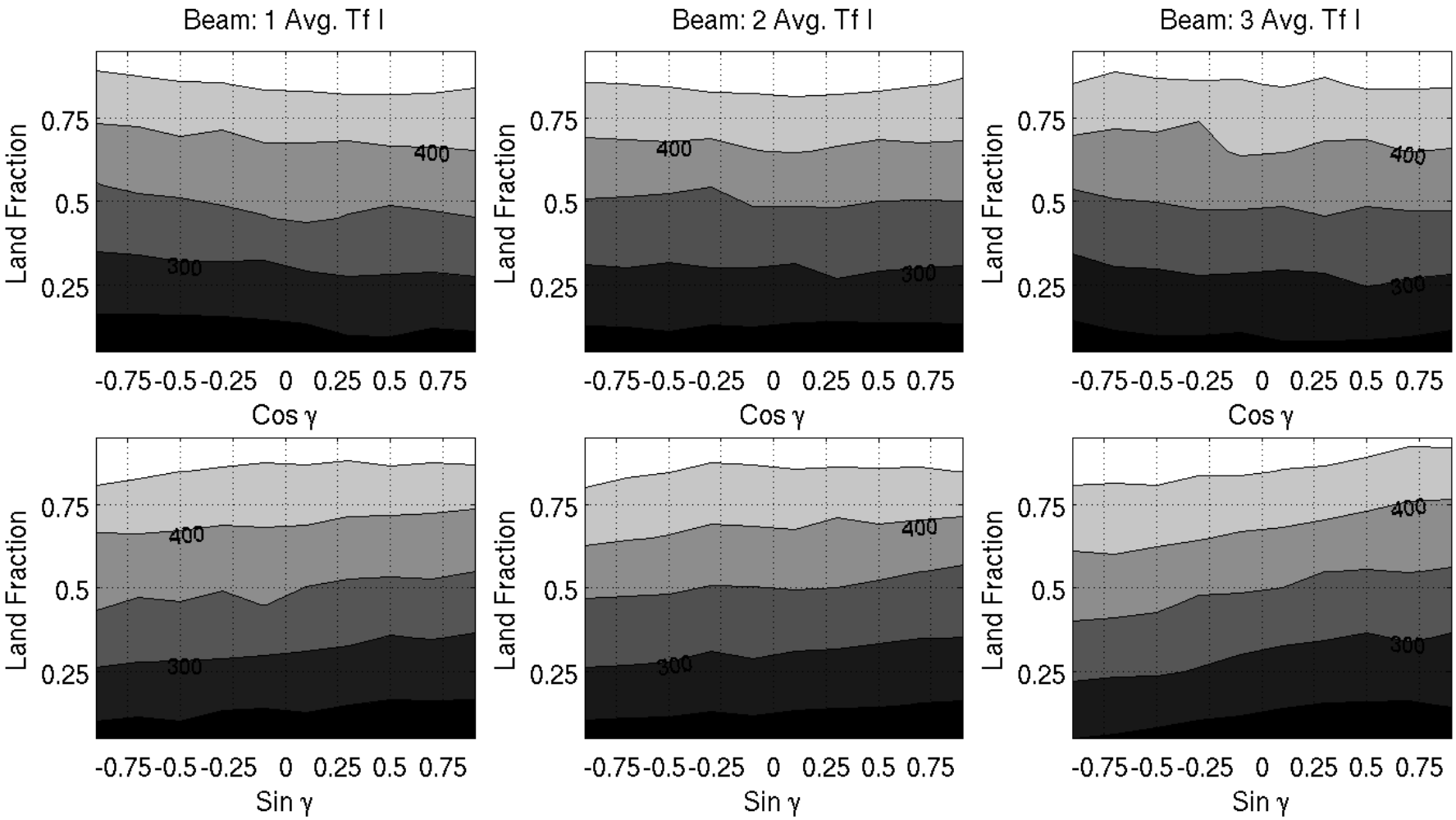


# SEPARATE ANALYSIS PER WEEK
# RADIOMETER
# NOMINAL POINTING

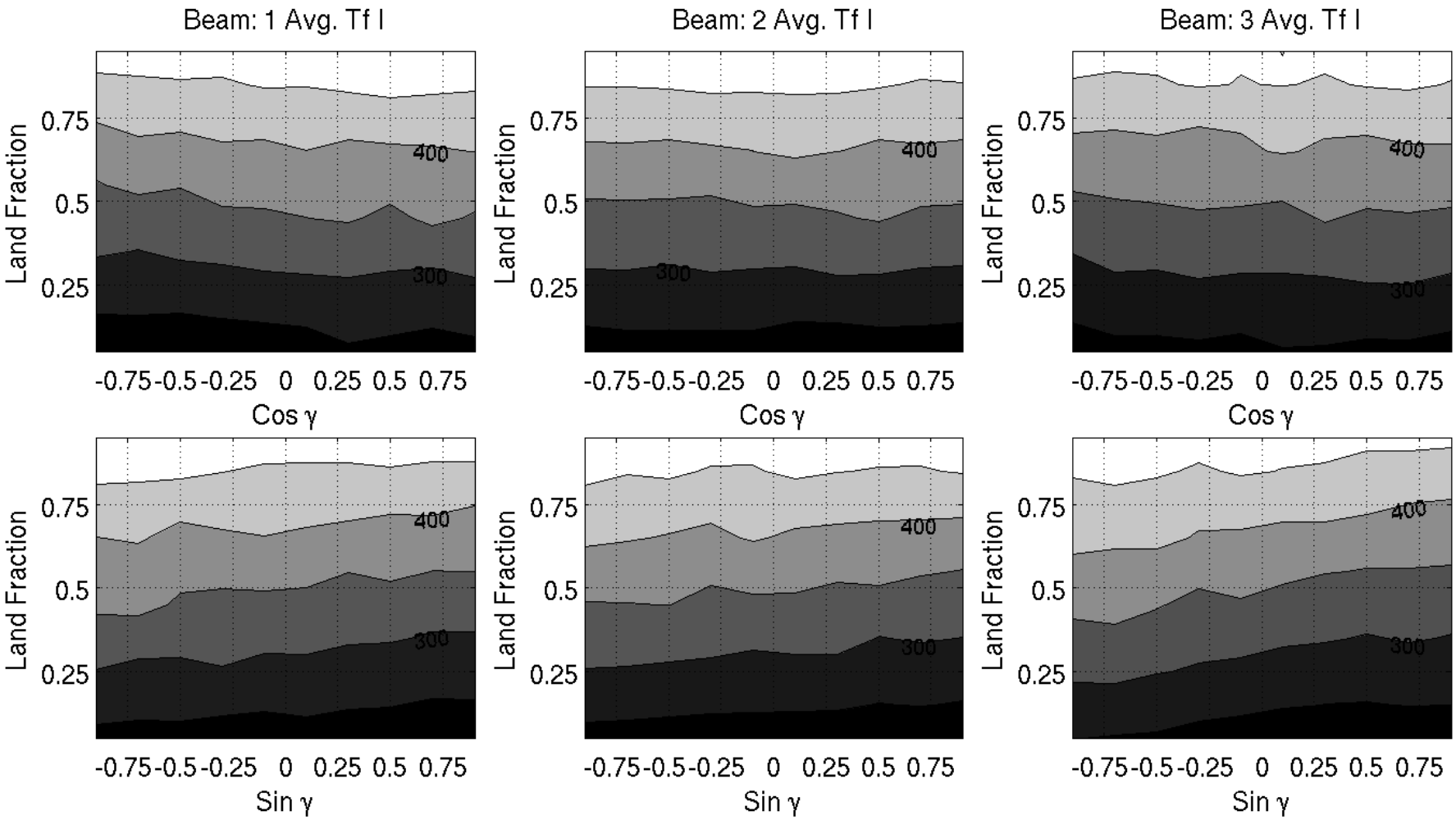
# Radiometer; 1 week starting 2011-238 Nominal Pointing



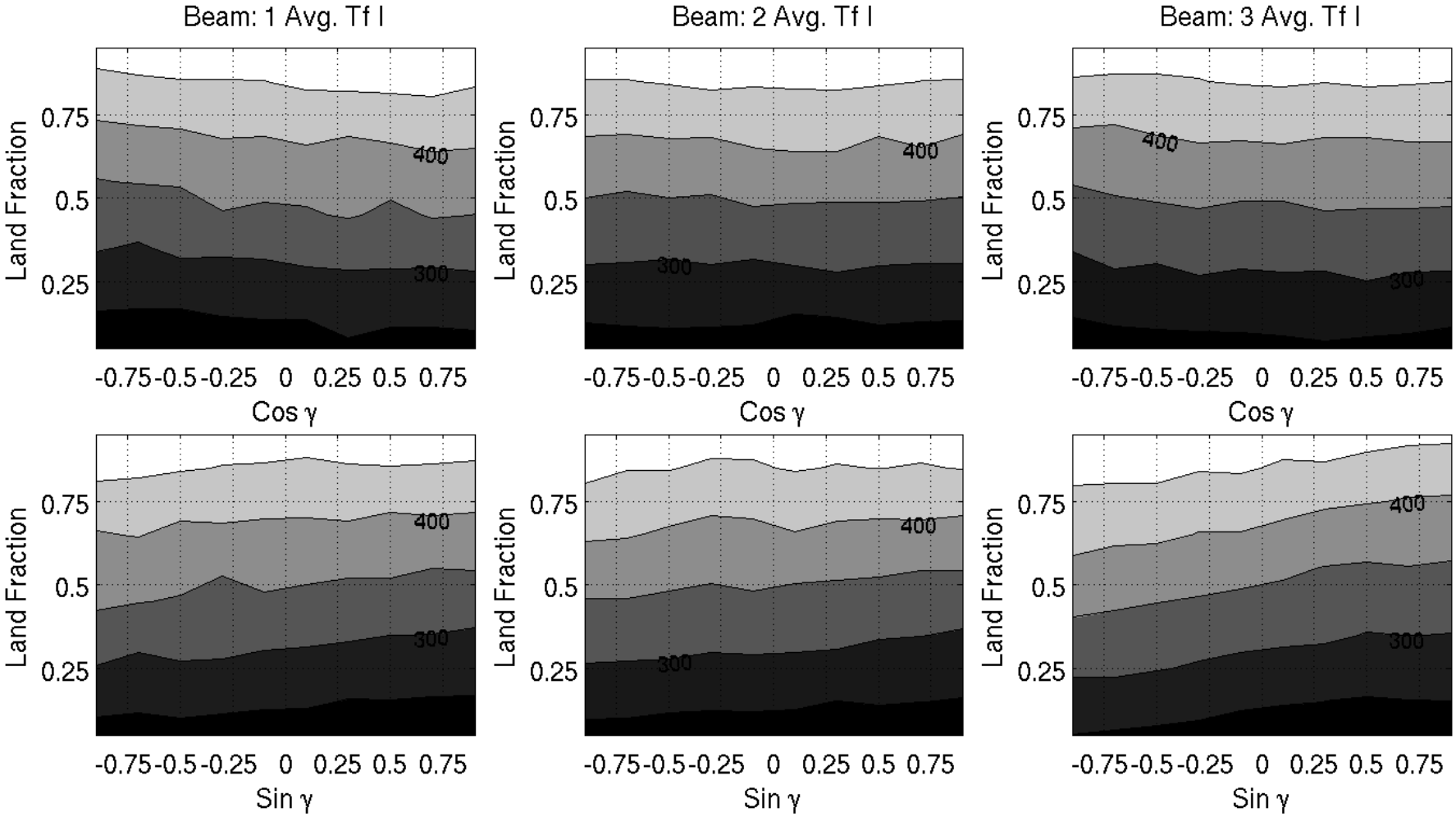
# Radiometer; 1 week starting 2011-245 Nominal Pointing



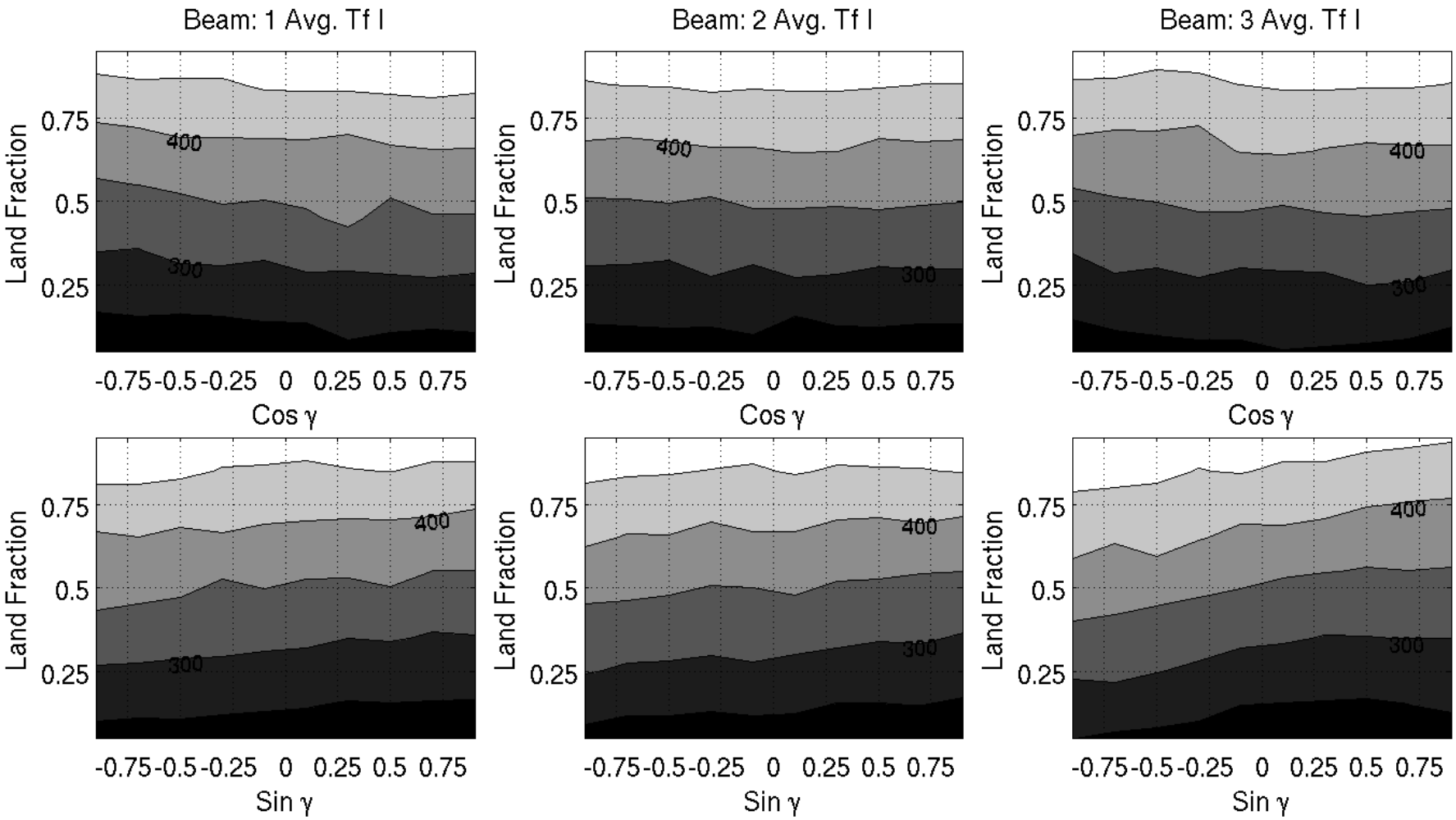
# Radiometer; 1 week starting 2011-252 Nominal Pointing



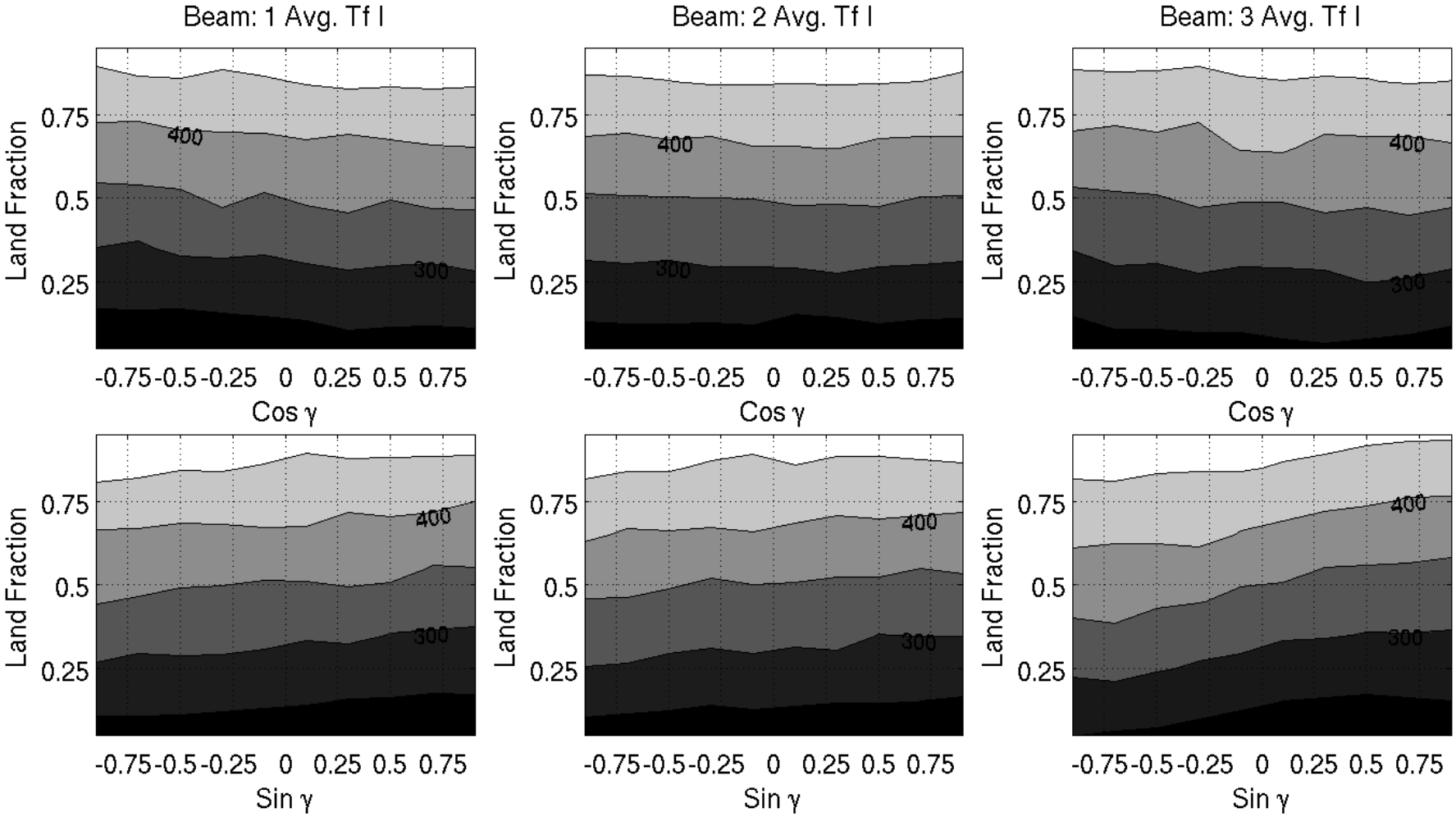
# Radiometer; 1 week starting 2011-259 Nominal Pointing



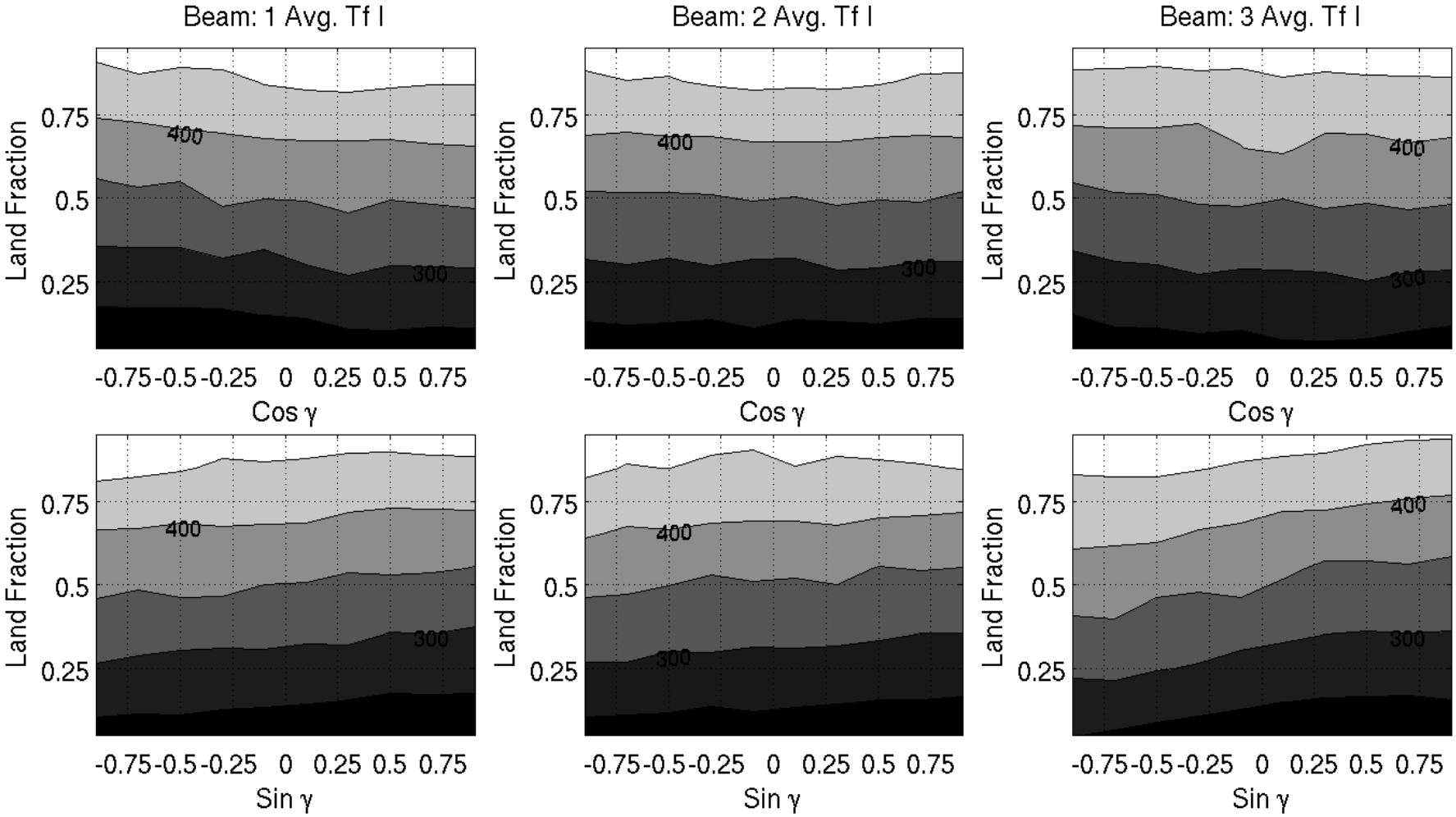
# Radiometer; 1 week starting 2011-266 Nominal Pointing



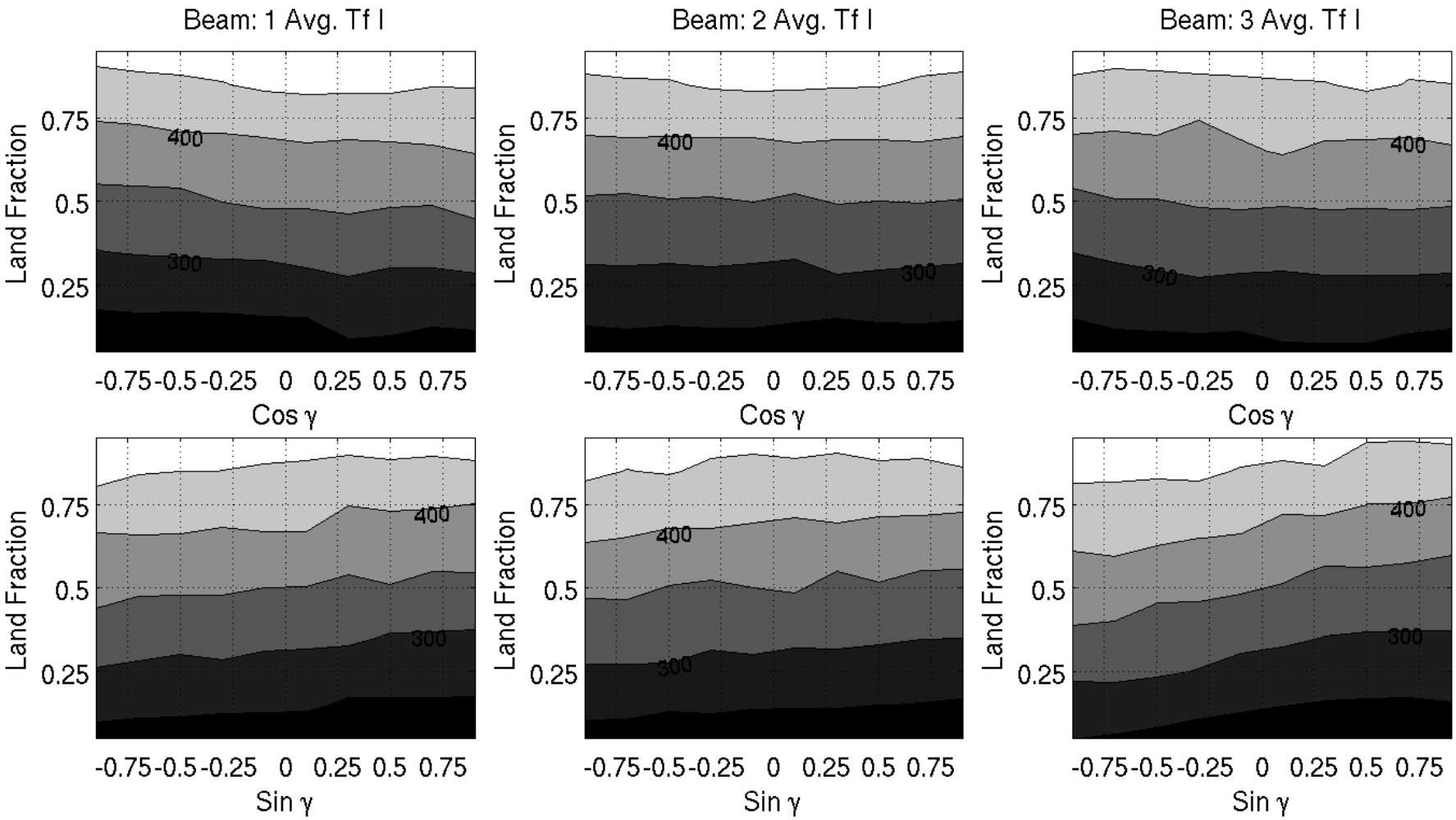
# Radiometer; 1 week starting 2011-273 Nominal Pointing



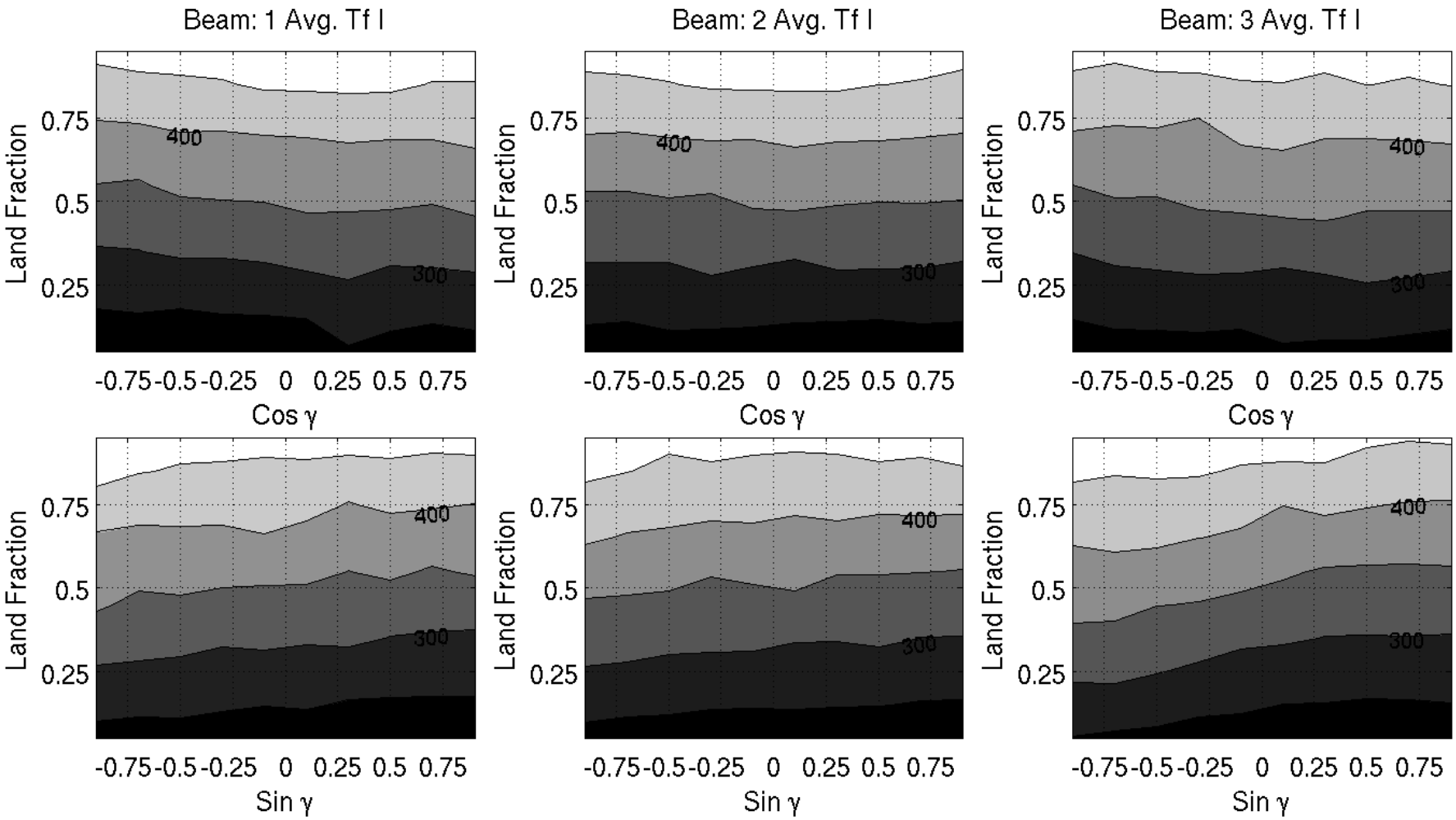
# Radiometer; 1 week starting 2011-280 Nominal Pointing



# Radiometer; 1 week starting 2011-287 Nominal Pointing

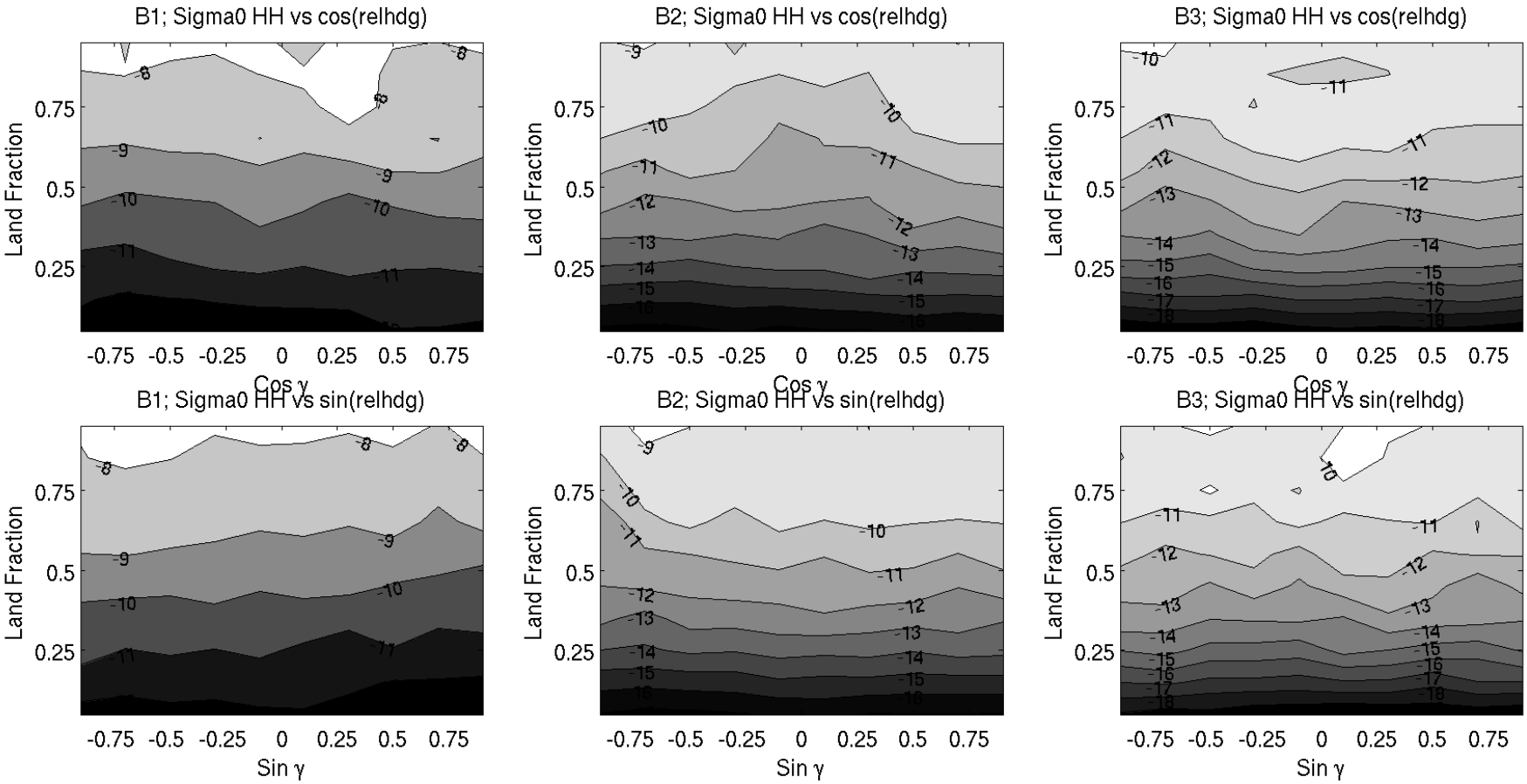


# Radiometer; 1 week starting 2011-294 Nominal Pointing

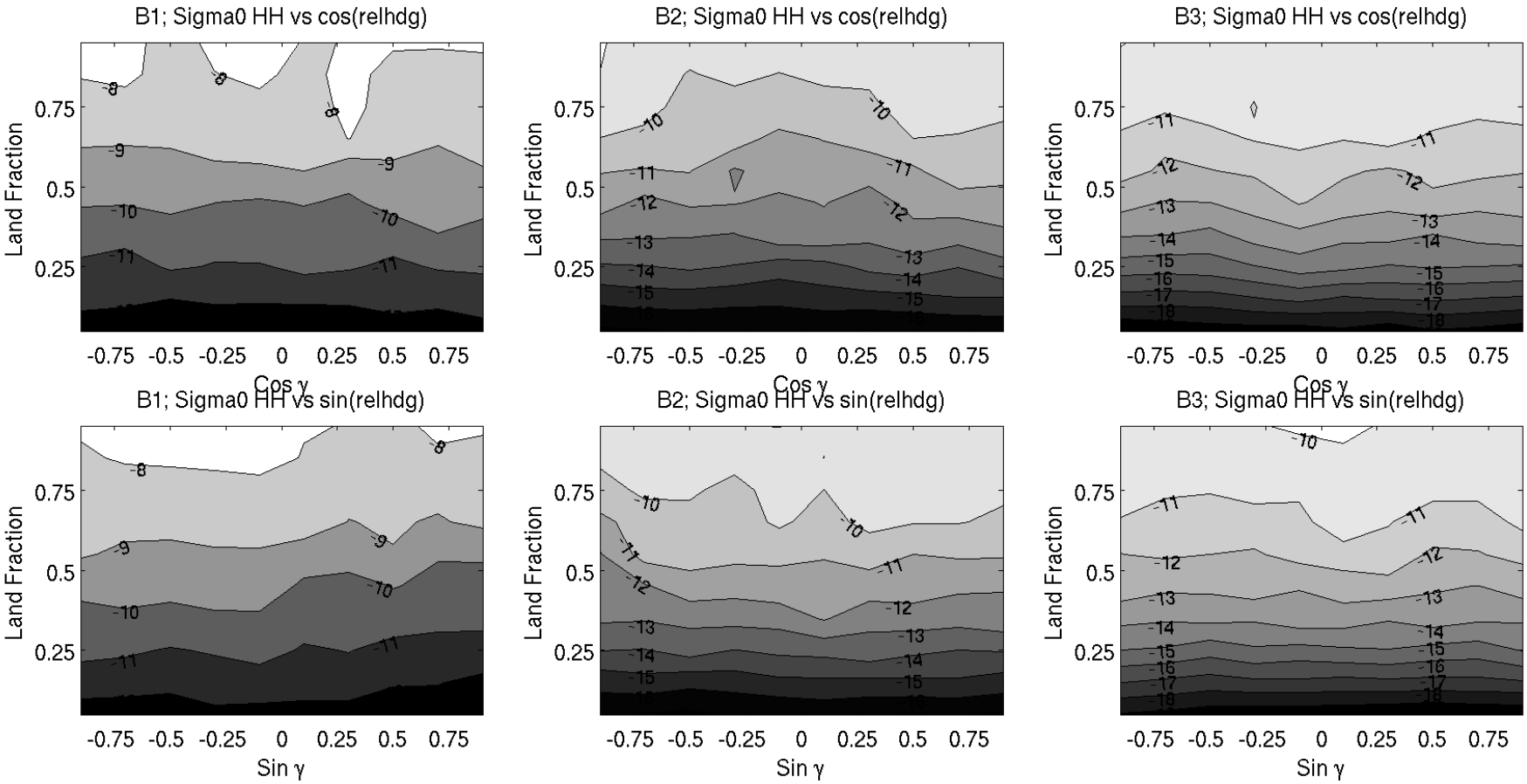


# SEPARATE ANALYSIS PER WEEK
# SCATTEROMETER
# NOMINAL POINTING

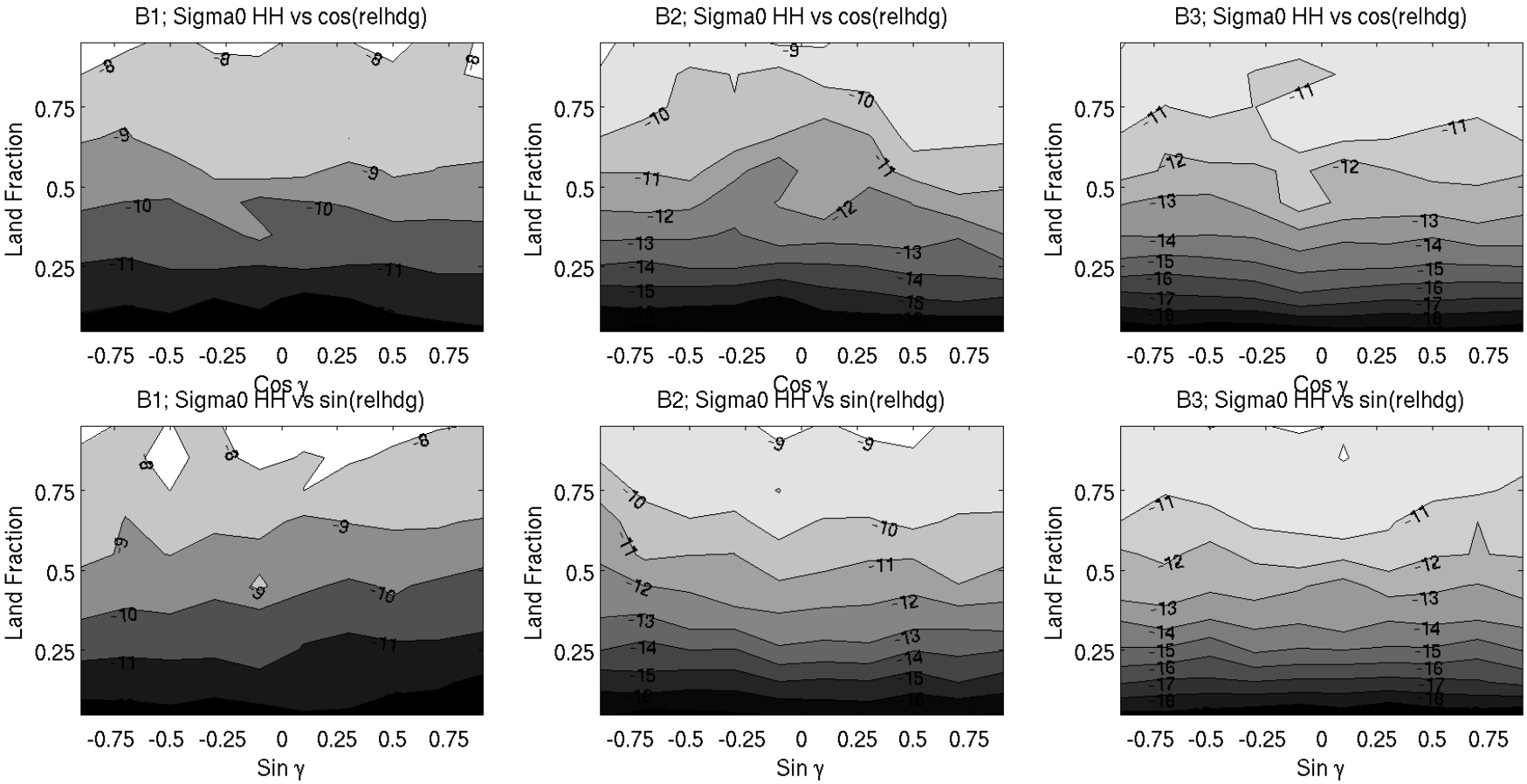
# Scatterometer; 1 week starting 2011-238 Nominal Pointing



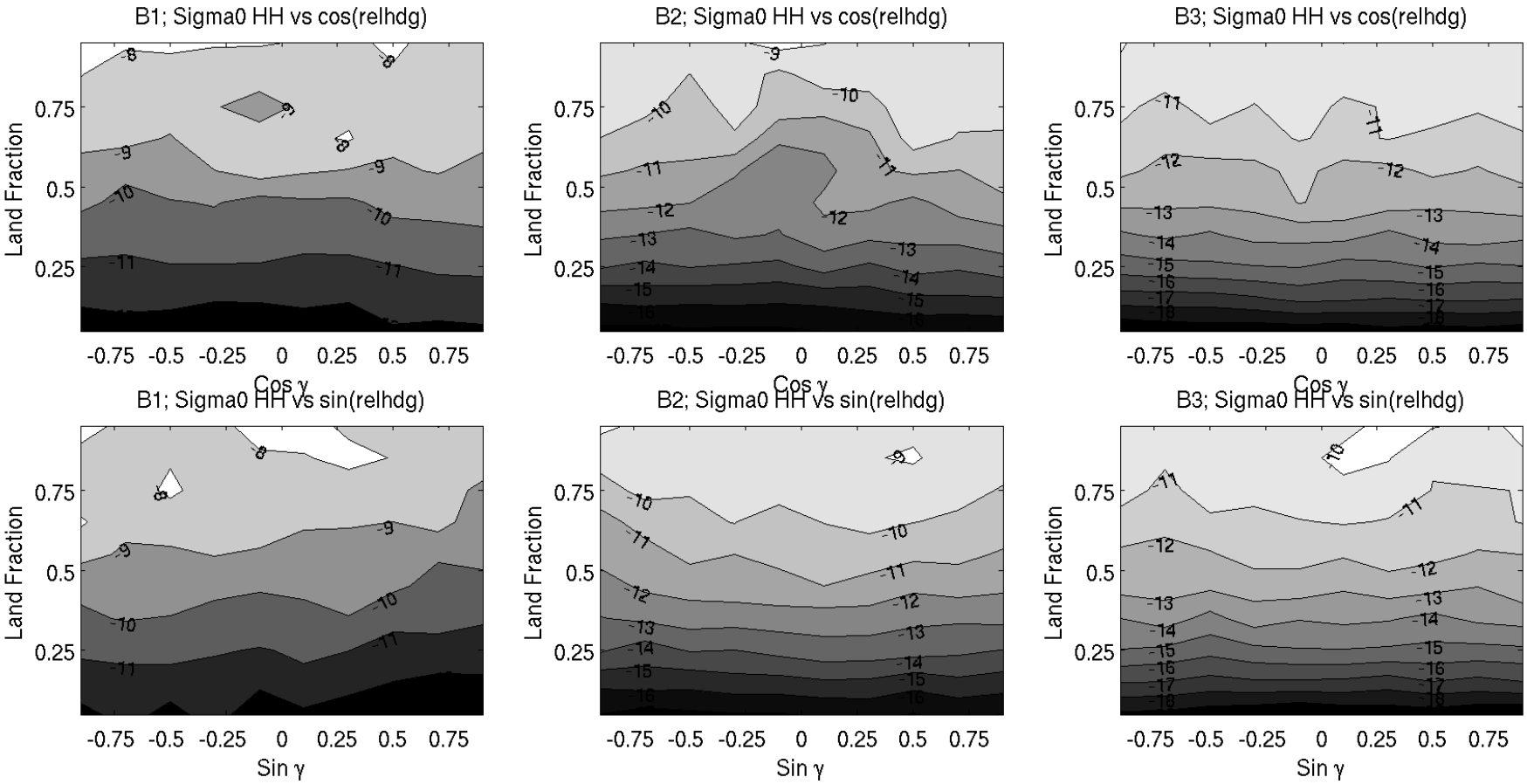
# Scatterometer; 1 week starting 2011-245 Nominal Pointing



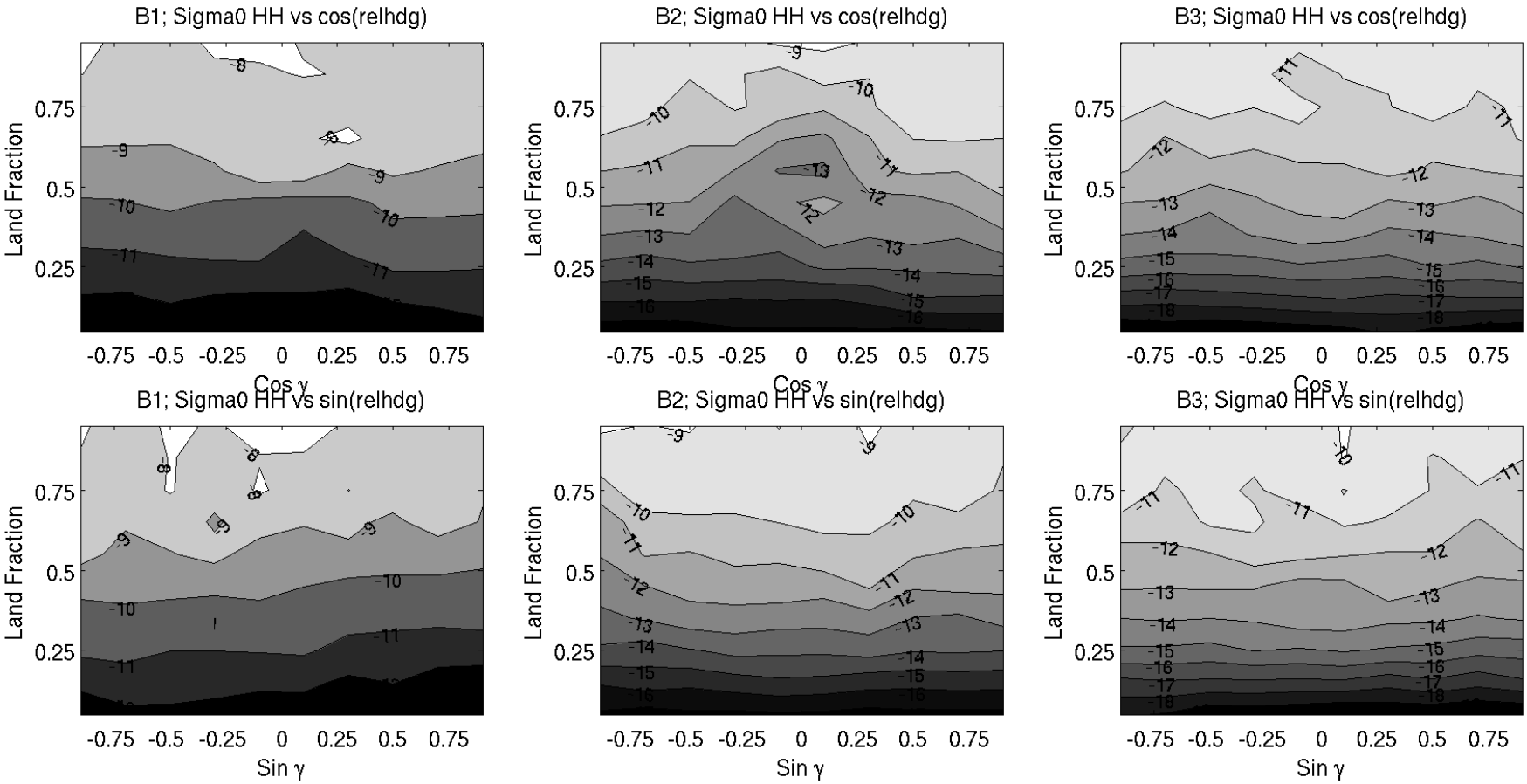
# Scatterometer; 1 week starting 2011-252 Nominal Pointing



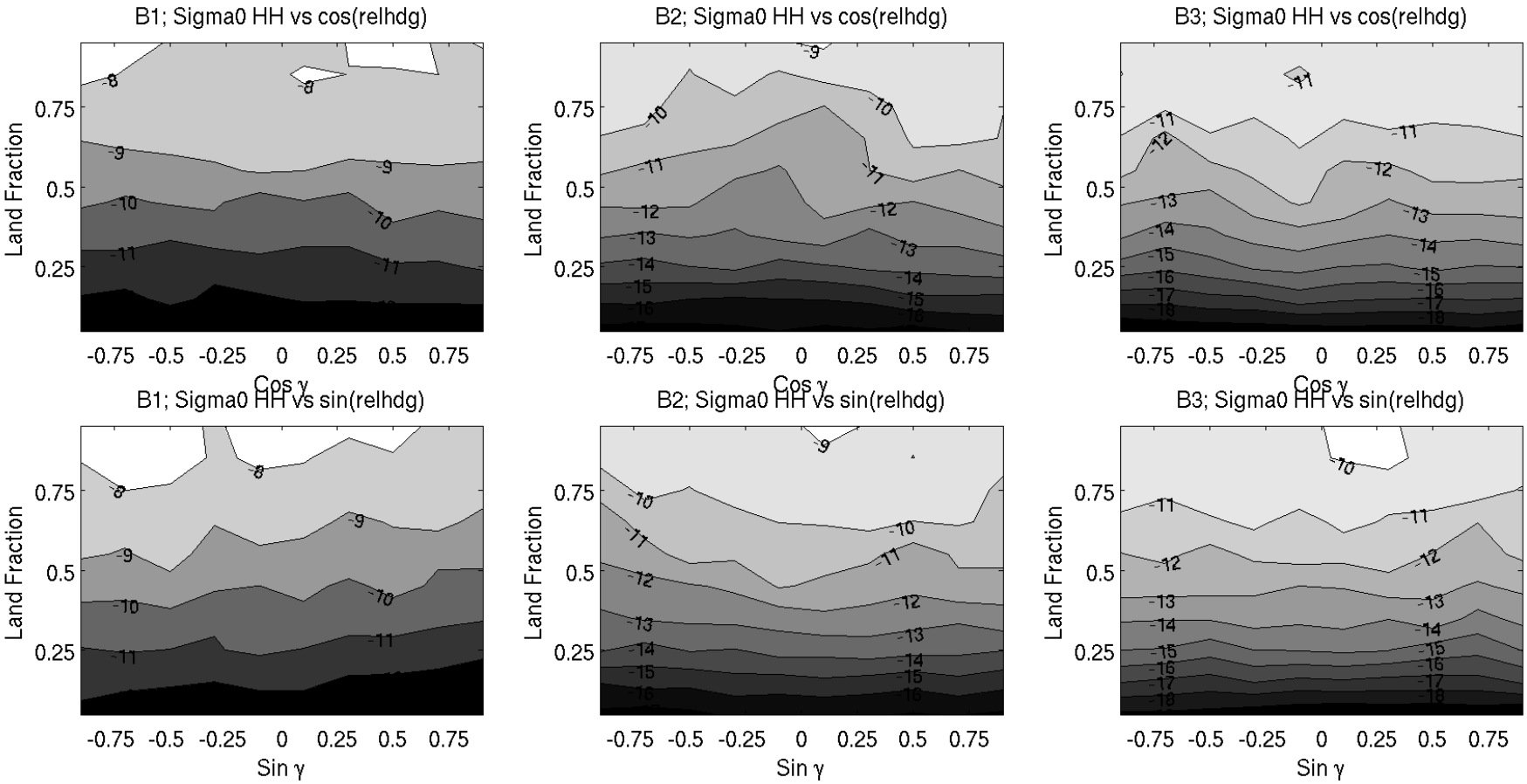
# Scatterometer; 1 week starting 2011-259 Nominal Pointing



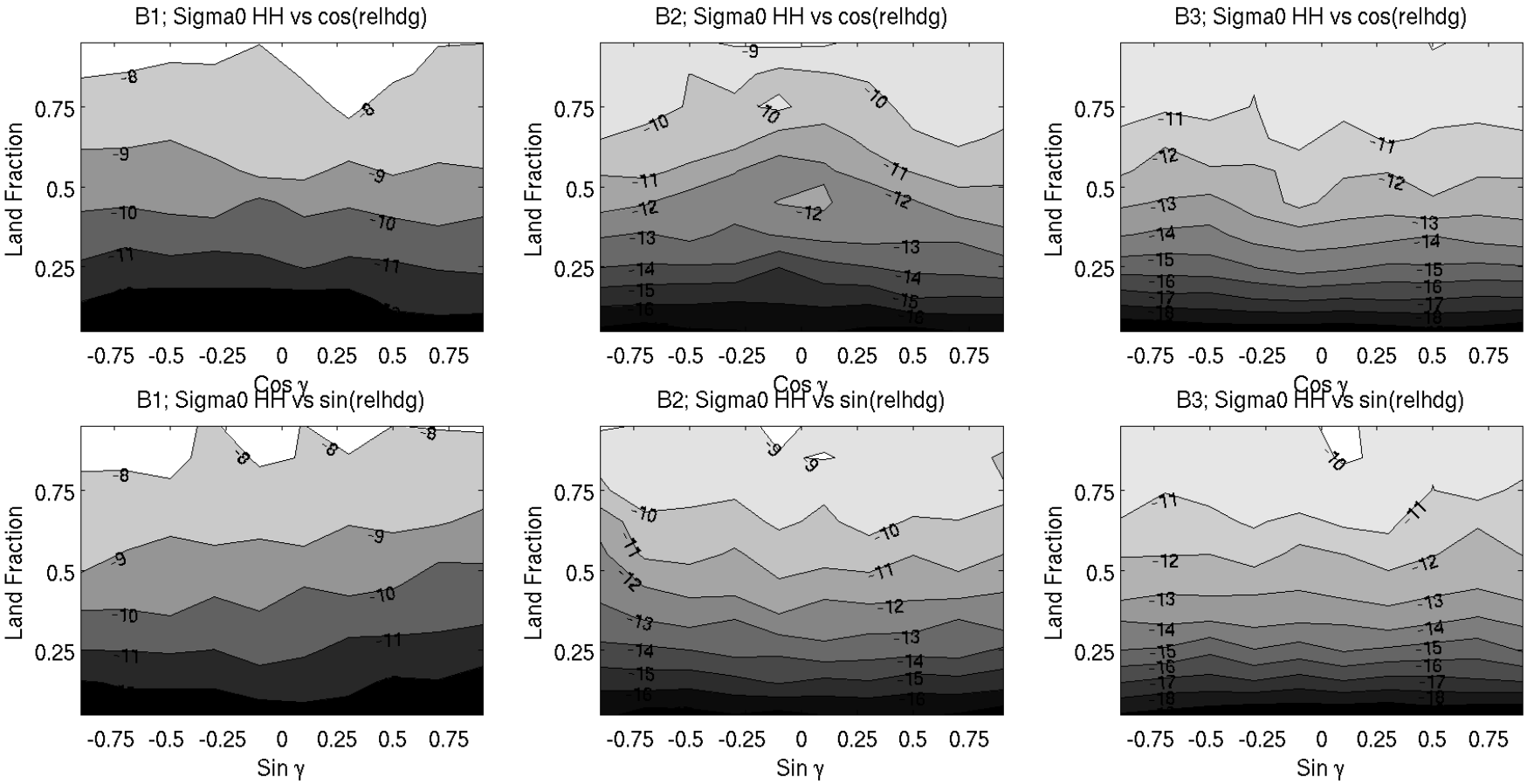
# Scatterometer; 1 week starting 2011-266 Nominal Pointing



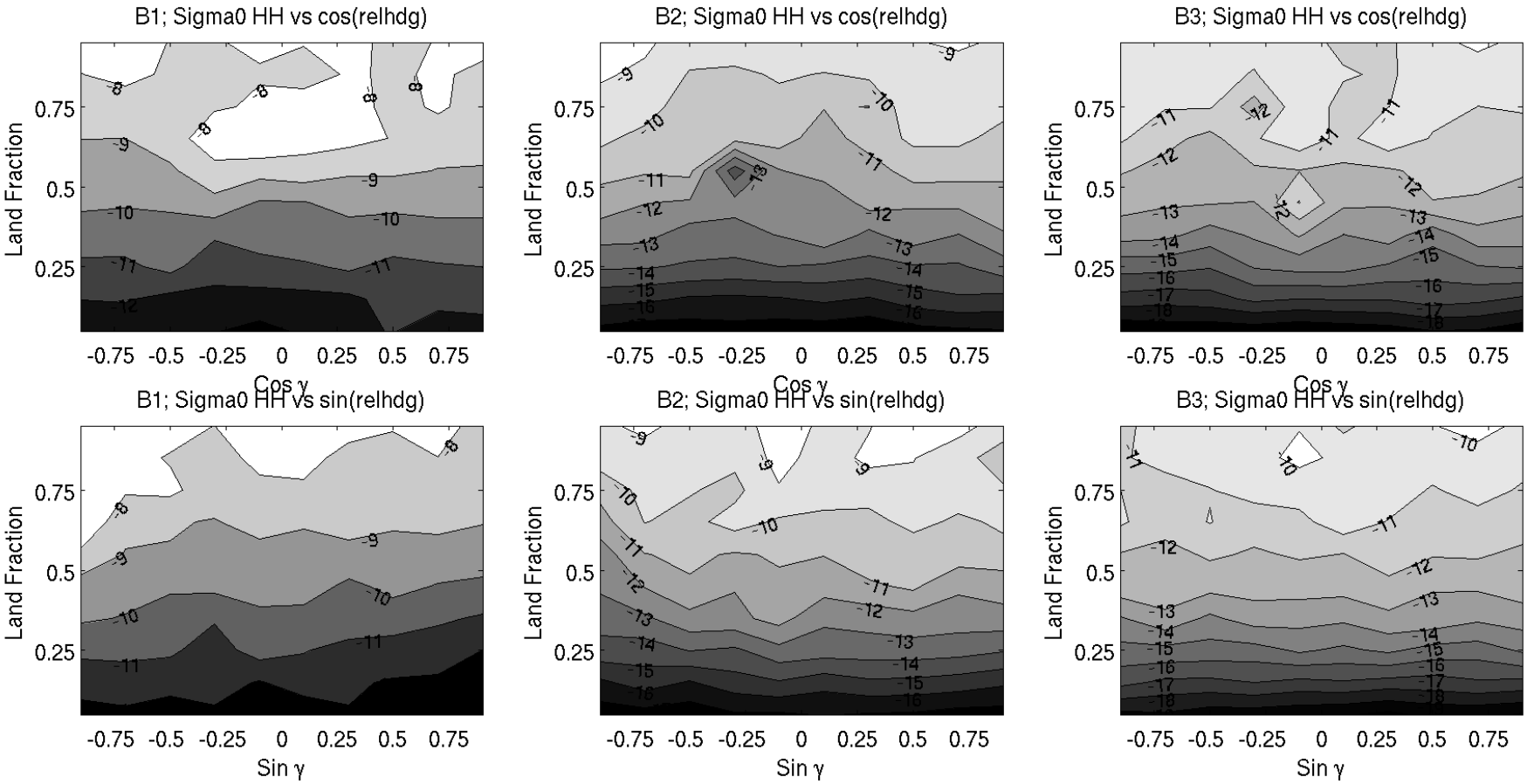
# Scatterometer; 1 week starting 2011-273 Nominal Pointing



# Scatterometer; 1 week starting 2011-280 Nominal Pointing

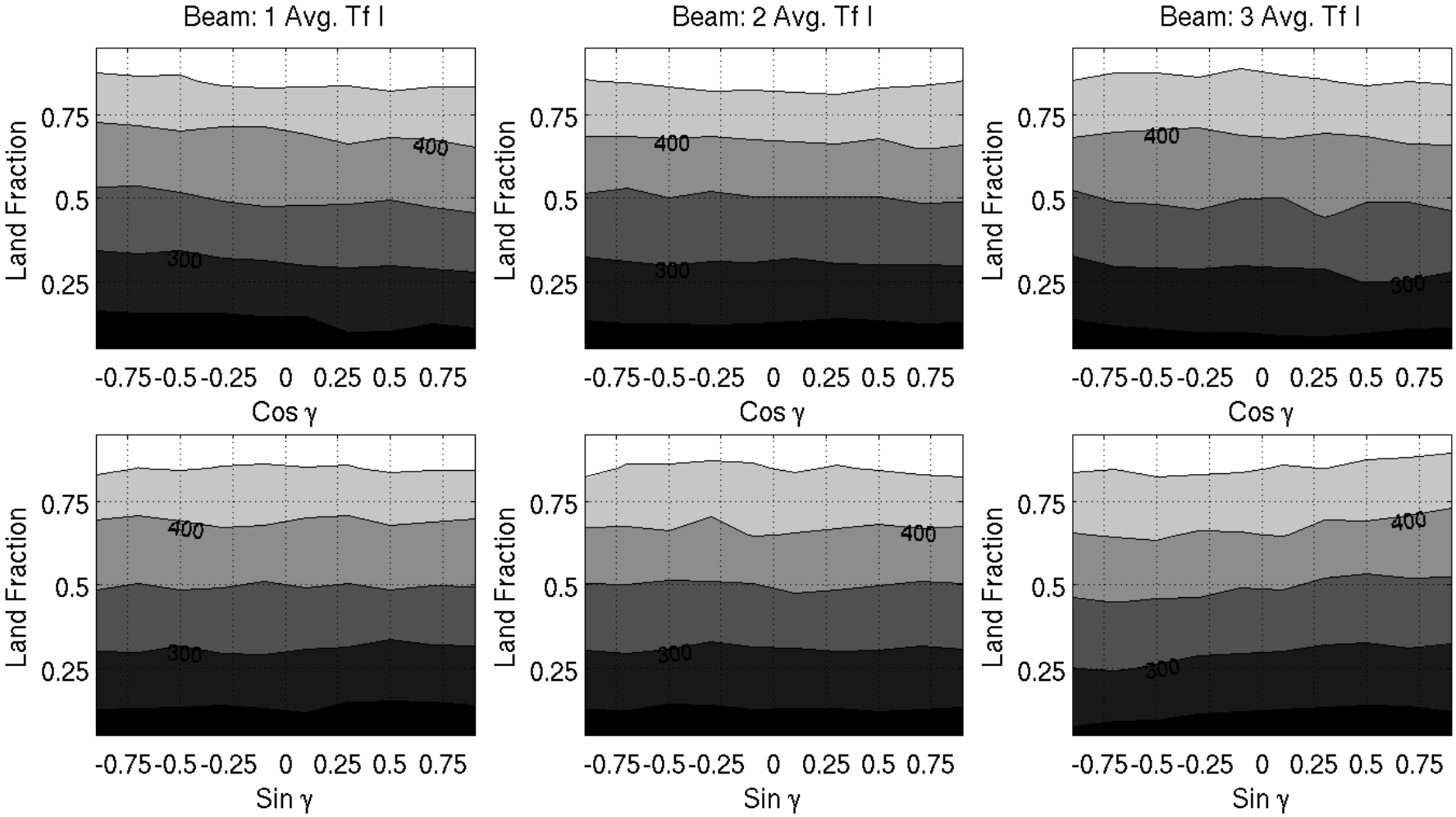


# Scatterometer; 1 week starting 2011-287 Nominal Pointing

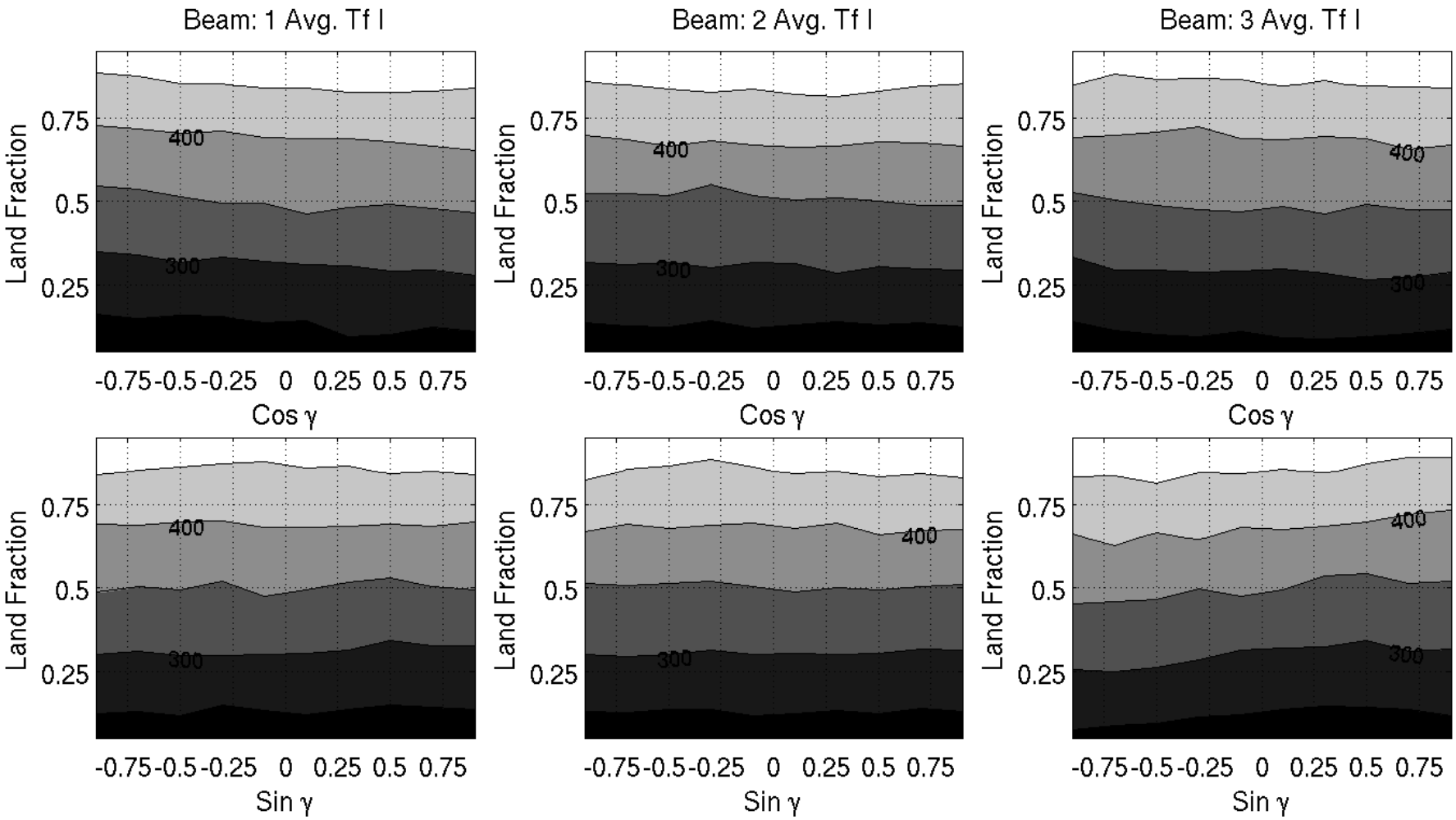


# SEPARATE ANALYSIS PER WEEK
# RADIOMETER
# NADIR ANGLE +0.3

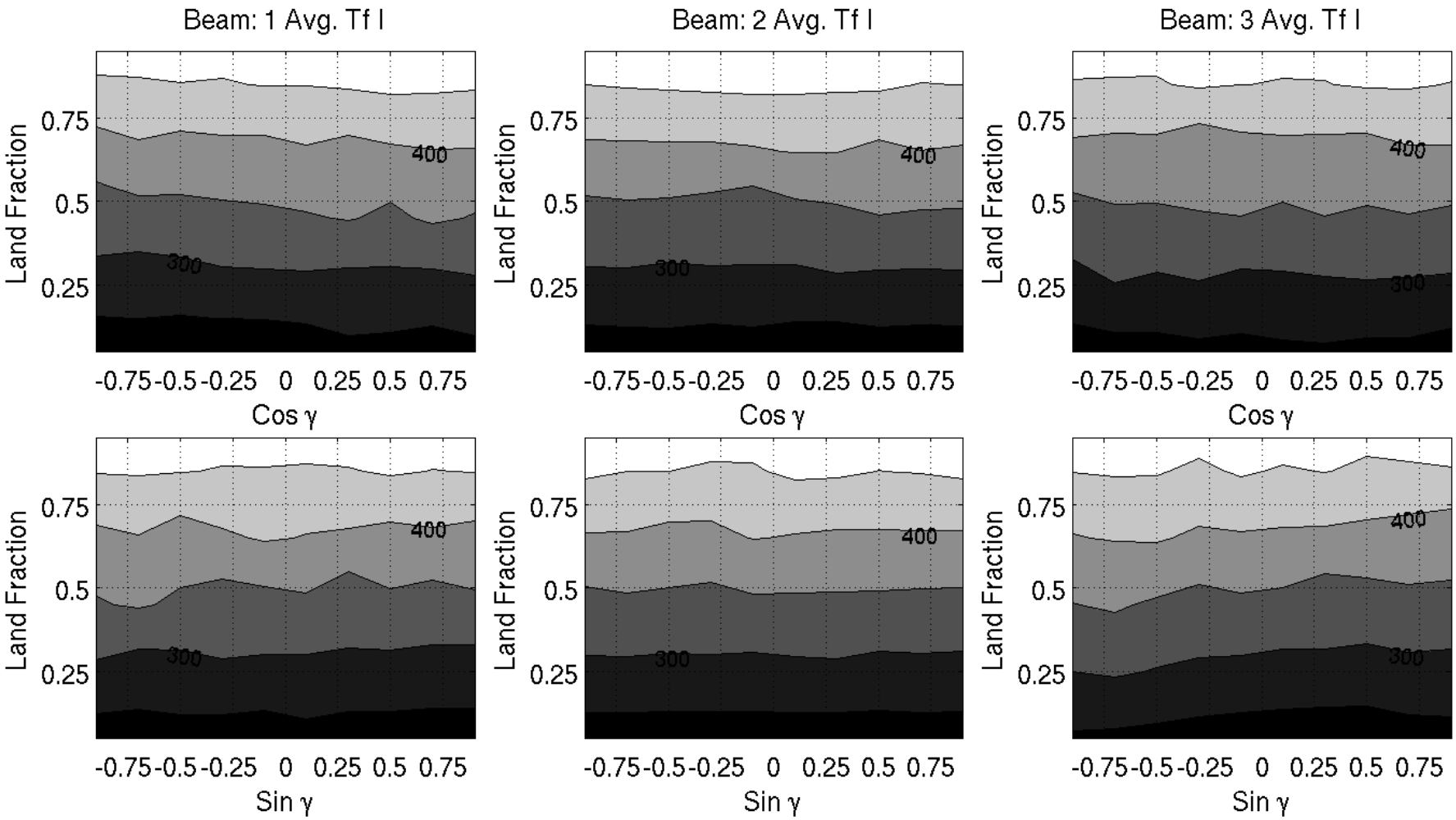
# Radiometer; 1 week starting 2011-238
# Nadir Angle +0.3, all beams



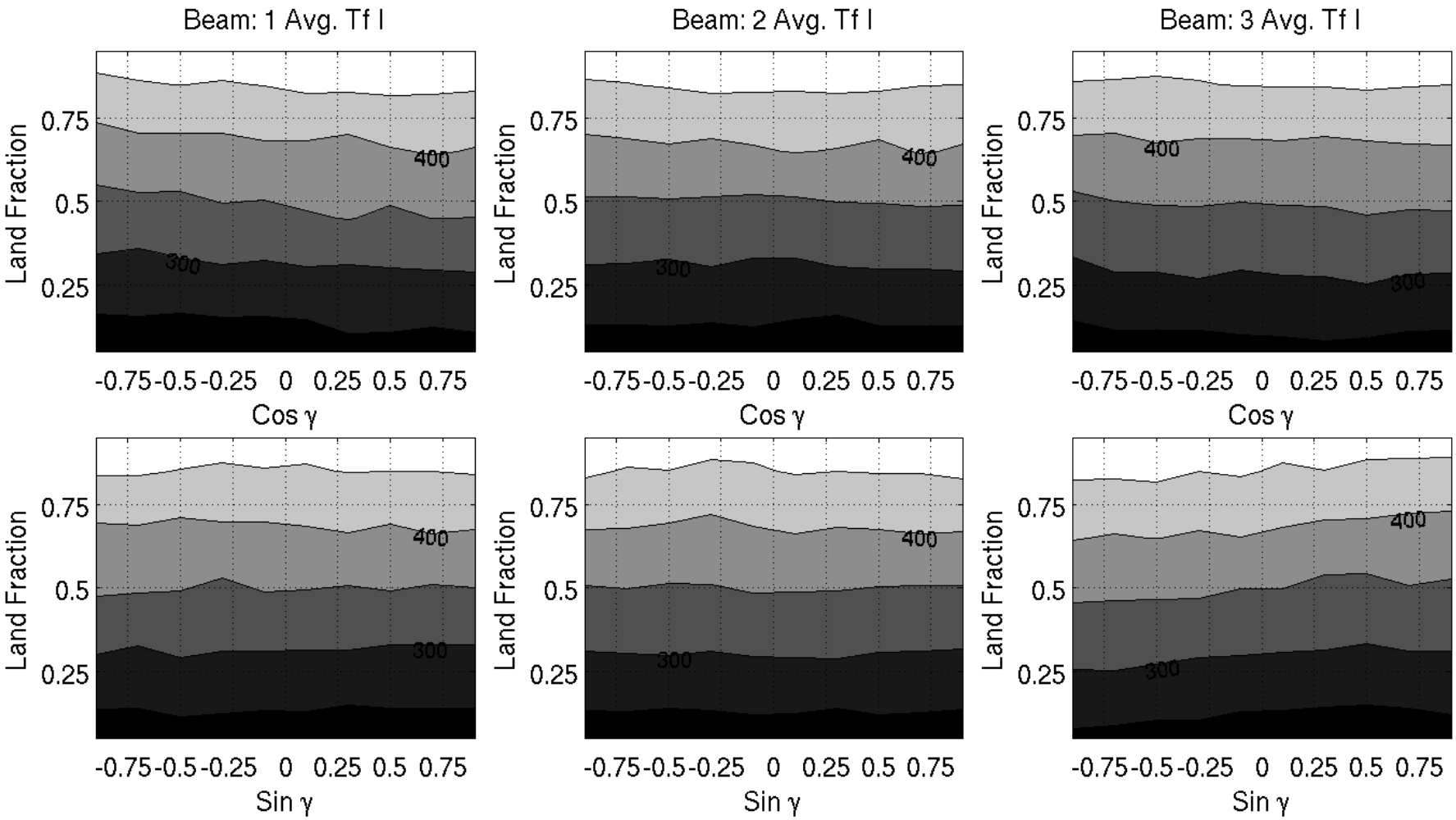
# Radiometer; 1 week starting 2011-245
# Nadir Angle +0.3, all beams



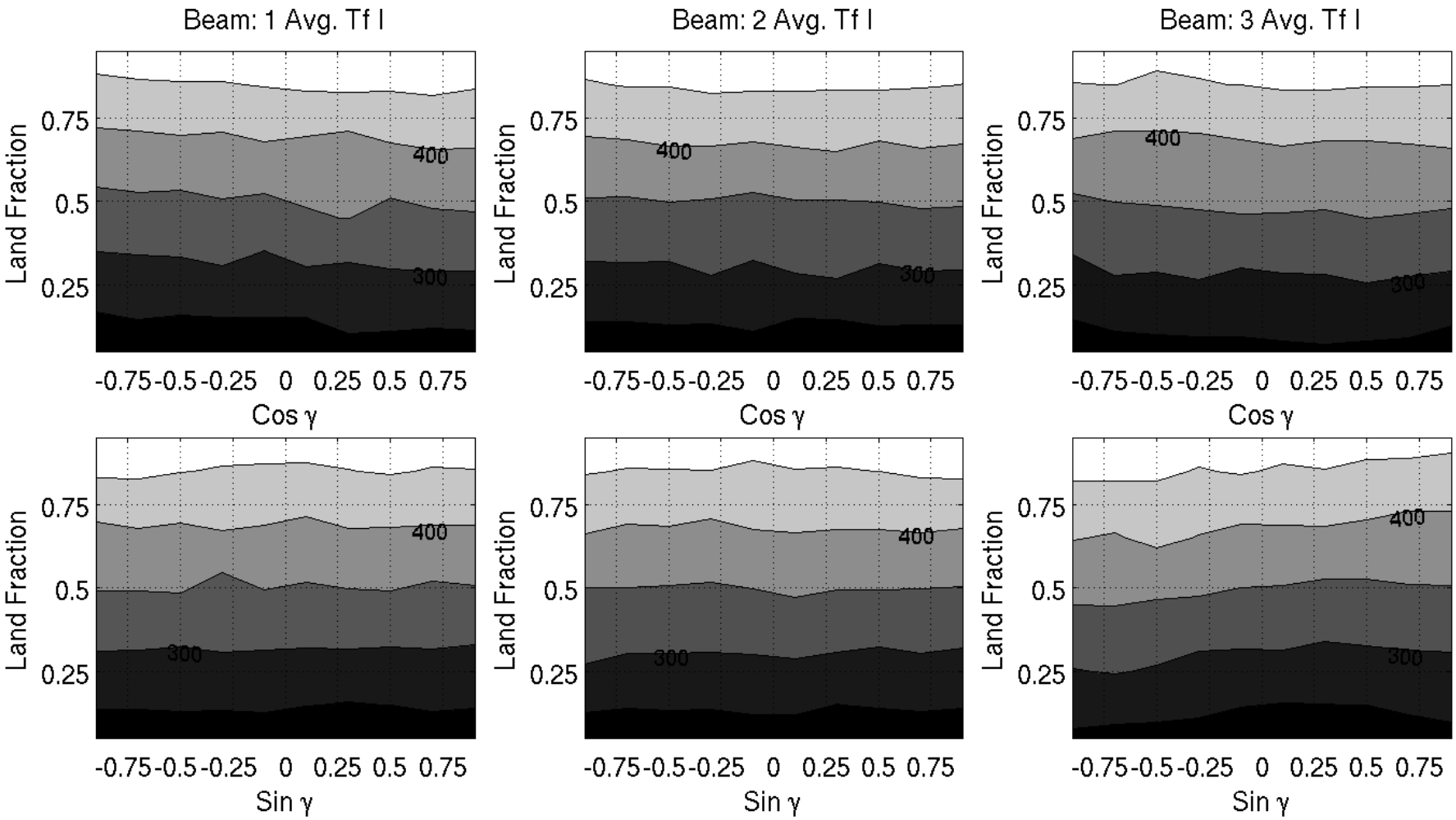
# Radiometer; 1 week starting 2011-252
# Nadir Angle +0.3, all beams



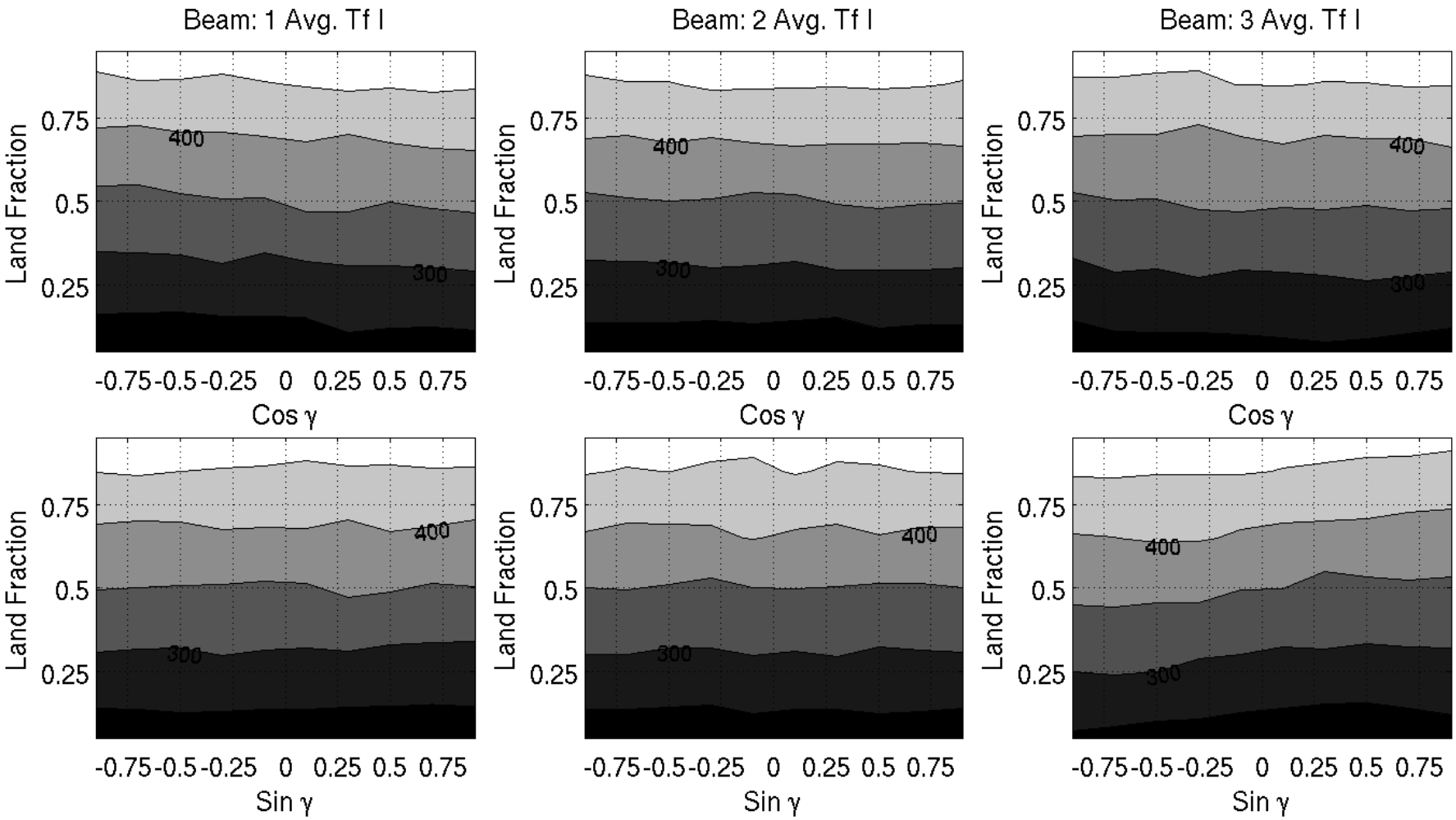
# Radiometer; 1 week starting 2011-259
# Nadir Angle +0.3, all beams



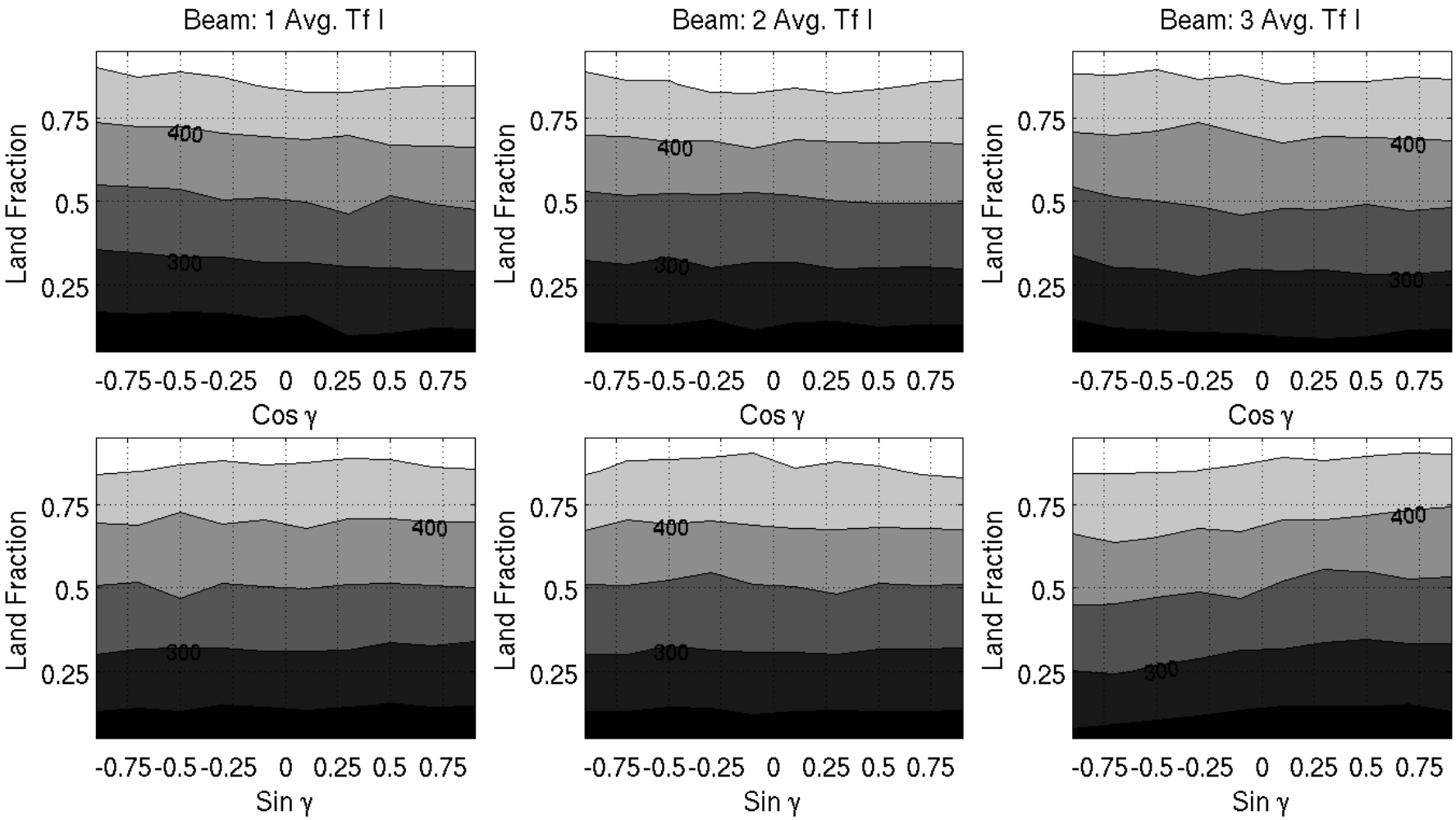
# Radiometer; 1 week starting 2011-266
# Nadir Angle +0.3, all beams



# Radiometer; 1 week starting 2011-273
# Nadir Angle +0.3, all beams



# Radiometer; 1 week starting 2011-280
# Nadir Angle +0.3, all beams



# Radiometer; 1 week starting 2011-287
# Nadir Angle +0.3, all beams