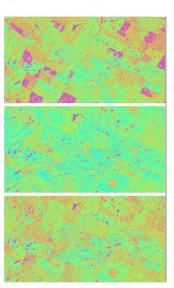# EFFECT OF SOIL MOISTURE ON POLARIMETRIC-INTERFEROMETRIC REPEAT PASS OBSERVATIONS BY UAVSAR DURING 2010 CANADIAN SOIL MOISTURE CAMPAIGN

DOY 153

DOY 160

by

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Red=Jet Propulsion Laboratory, California Institute of Technology
Green=United States Department of Agriculture

UAVSAR

Parameter	Value
Frequency	L-Band 1217.5 to 1297.5 MHz
Bandwidth	80 MHz
Resolution	1.67 m Range, 0.8 m Azimuth
Polarization	Full Quad-Polarization
ADC Bits	2,4,6,8,10 & 12 bit selectable BFPQ, 180Mhz
Waveform	Nominal Chirp/Arbitrary Waveform
Antenna Aperture	0.5 m range/1.5 azimuth (electrical)
Azimuth Steering	Greater than ±20° (±45° goal)
Transmit Power	> 3.1 kW
Polarization Isolation	<-25 dB (<-30 dB goal)
Swath Width	> 23 km

- UAVSAR is an L-band fully polarimetric SAR employing an electronically scanned antenna that has been designed to support a wide range of science investigations.

  - The UAVSAR design incorporates:

- A precision autopilot developed by NASA Dryden that allows the platform to fly repeat trajectories that are mostly within a 5 m tube.

- Compensates for attitude angle changes during and between repeat tracks by electronically pointing the antenna based on attitude angle changes measured by the INU.
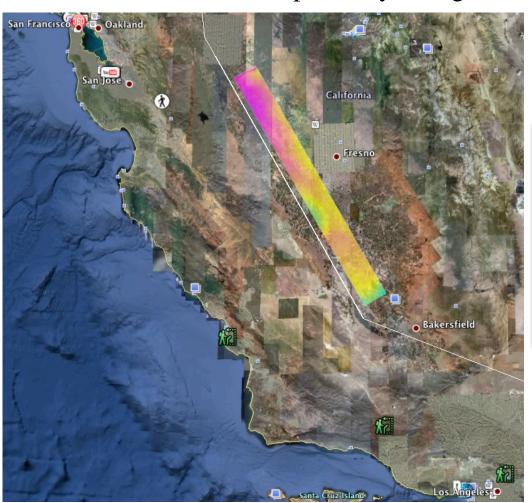
California San Joaquin Valley

- Repeat-pass tracks about 220 km in length were collected and processed over the San Joaquin Valley with a temporal baseline of 6.823 days.
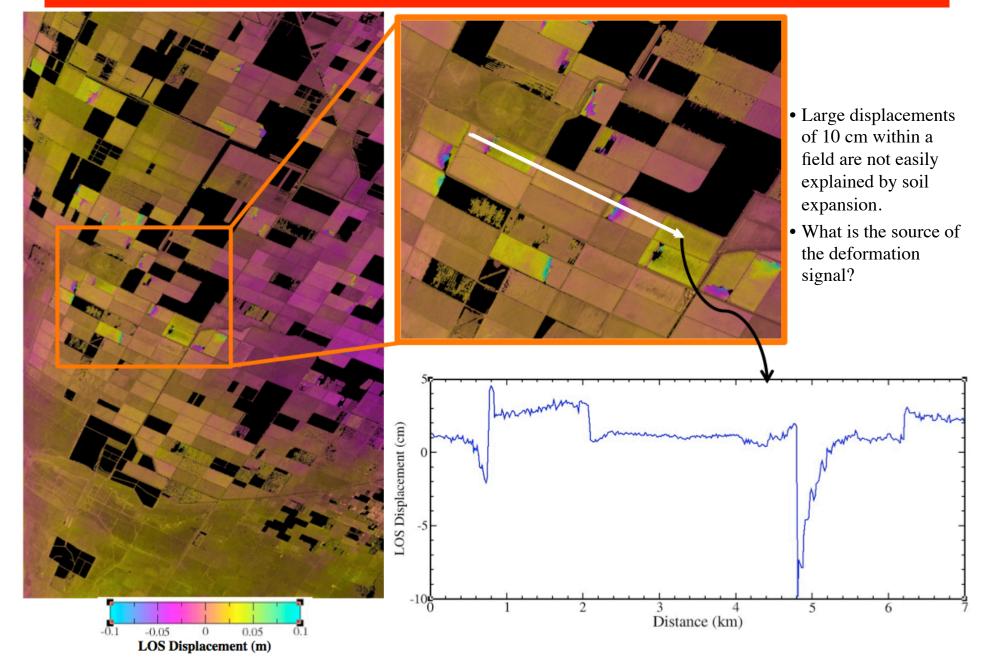- The scene consists of primarily flat agricultural areas.

Parameter	Track 1	Track 2
Date Collected	3/31/2008	3/25/2008
Yaw (deg)	10.6°	10°
Pitch (deg)	0.7°	0.3°
Steering Angle	-8.8°	-8.0°
Altitude	12.5 km	12.5 km

Large Rodents?

- Large displacements of 10 cm within a field are not easily explained by soil expansion.
- What is the source of the deformation signal?

LOS Displacement (m)
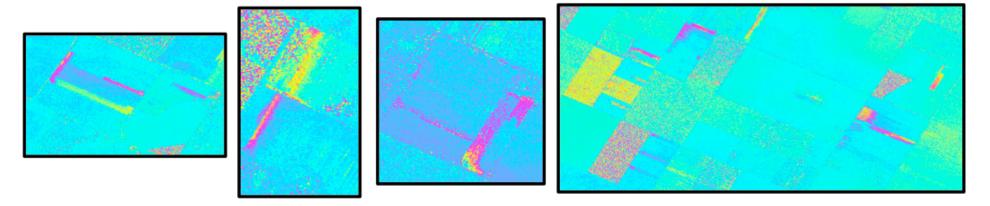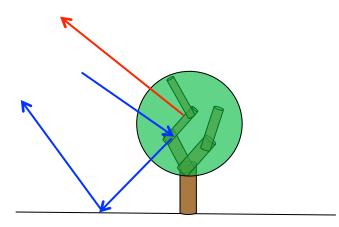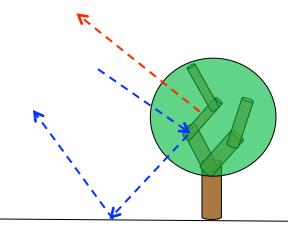
- In order for vegetation growth to explain the observed deformation phase the plants would have to grow in such a way as to:

  – Preserve the HH and VV correlations while growing as much as 12 cm in 7 days

  – Explain line-of-sight deformations that are both positive and negative (shrinking plants?)
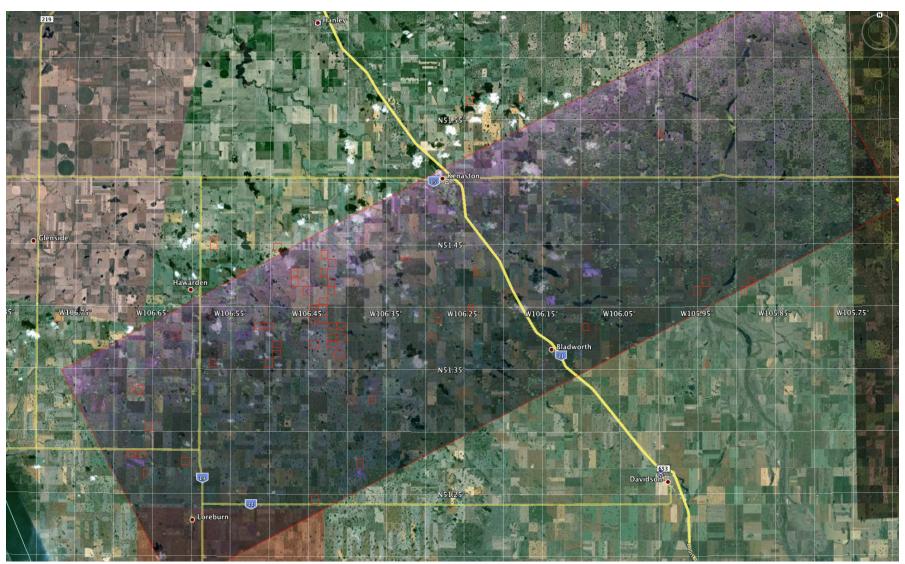
- Repeat-pass UAVSAR interferometric data was collected collected for seven days (DOYs: 153, 156, 157, 160, 164, 165, 166) at a heading of 242° that covered many of the in situ measurement sites.
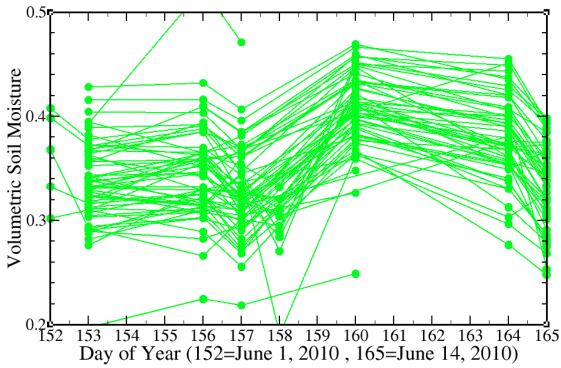
- *In situ* soil moisture measurements were collected for 59 fields mapped by the Kenaston lines.

  - Multiple measurements (approximately 12-15) per field were made and the average and standard deviation of measurements were reported.

  - Measurements were made over a two week period from June 1, 2010 to June 14, 2010 on DOY=152, 153, 156, 157, 158, 160, 164, 165.

  - Soil measurements were not made at all sites on all measurement days.
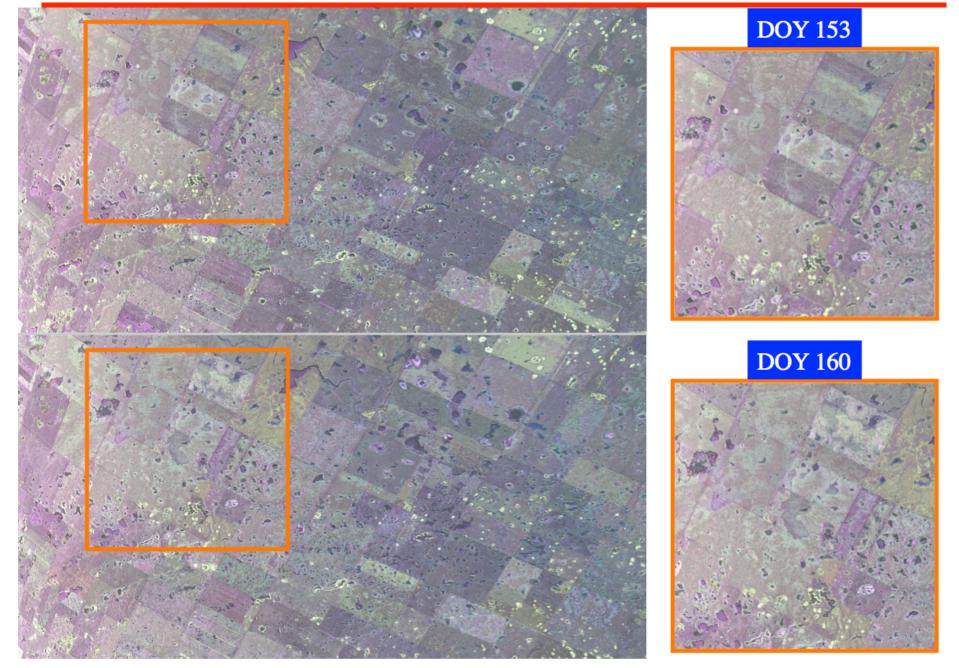

- Measured soil moisture for the 59 sites plotted versus DOY.

- Overall variation of the soil moisture measurements is about 15%, however for an individual field the temporal variation was typically much less, around 5-6%.
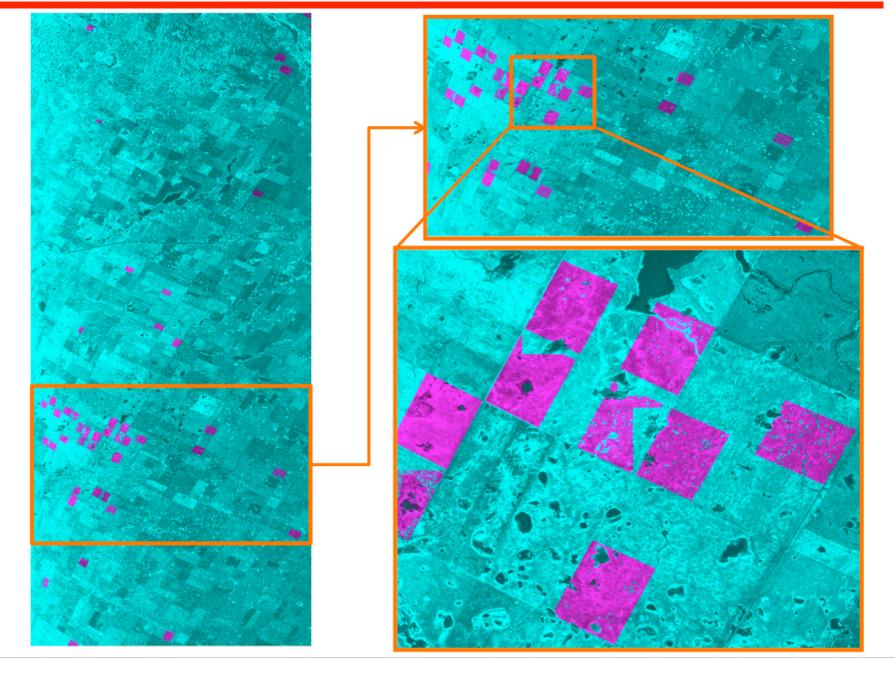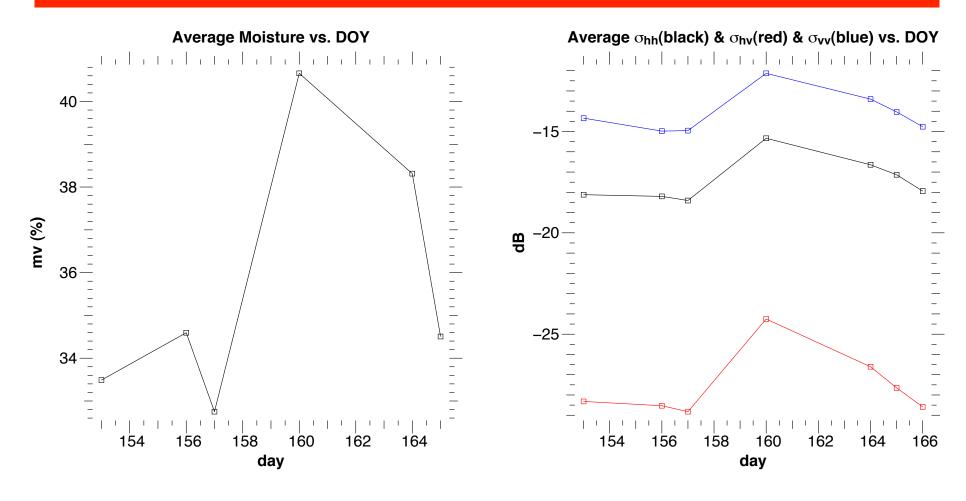
Polarimetric Imagery

DOY 153

DOY 160

Data Masks

Average Moisture vs. DOY

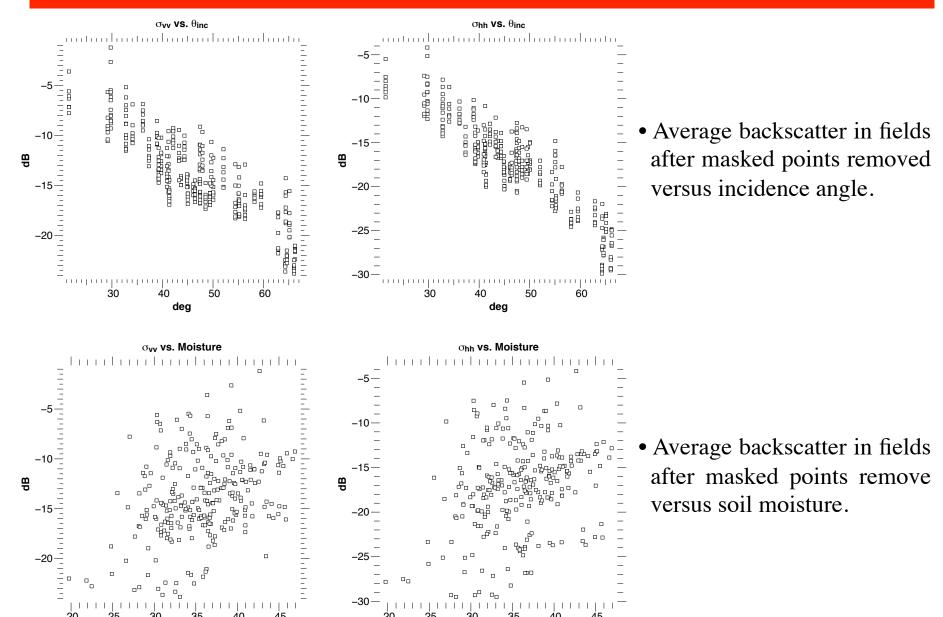**Average σ_{hh}(black) & σ_{hv}(red) & σ_{vv}(blue) vs. DOY**

- Average soil moisture for all fields contained within the SAR image versus day-of-year and SAR average backscatter in all fields (sans masked points) versus day-of-year.
- In a mean sense backscatter follows soil moisture as expected.
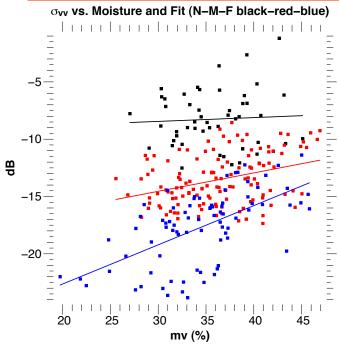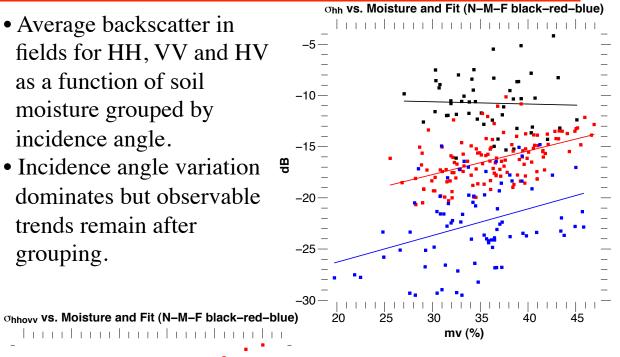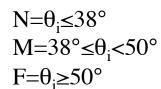
Backscatter Sensitivity

- Average backscatter in fields after masked points removed versus incidence angle.

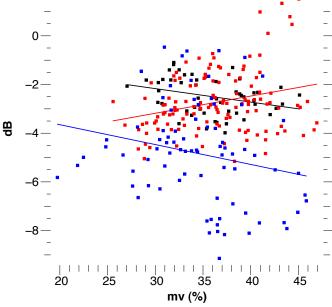- Average backscatter in fields after masked points remove versus soil moisture.

- Average backscatter in fields for HH, VV and HV as a function of soil moisture grouped by incidence angle.
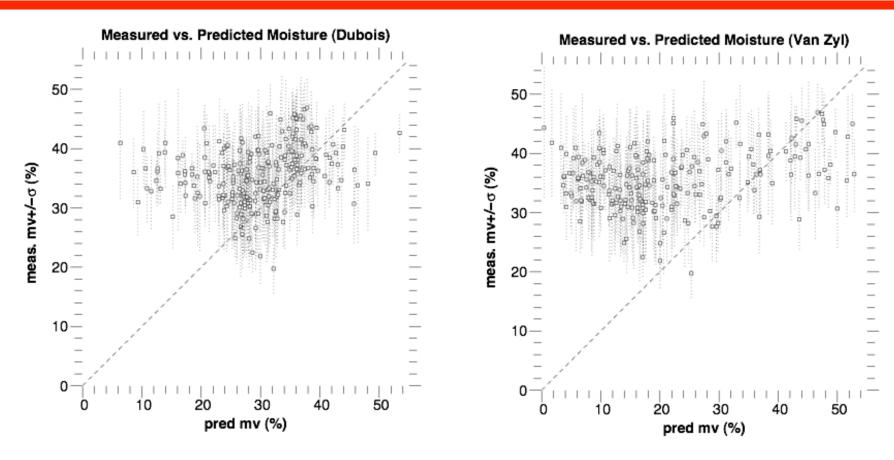- Incidence angle variation dominates but observable trends remain after grouping.

$N = \theta_i \leq 38°$
$M = 38° \leq \theta_i < 50°$
$F = \theta_i \geq 50°$

Measured vs. Predicted Moisture (Dubois)

Measured vs. Predicted Moisture (Van Zyl)

- Sample inversions of soil moisture from polarimetric backscatter measurements using the Dubois and Van Zyl algorithms.
- Both algorithms are extracting the mean level correctly, however both have trouble for low soil moisture values.
- Dubois algorithm follows trend somewhat better.

Interferometric Measurements

- Kenaston data was processed for 7 days (153,156,157,160,164 165 & 166).
- DOY 165 was used as the reference pass for interferometric imagery shown in presentation.
- Data for all possible pairs (see matrix) was analyzed over the *in situ* field measurement sites.

Reference Pass
Wettest Day

Pass Number	DOY
1	153
2	156
3	157
4	160
5	164
6	165
7	166

Wettest Day Pre/Post Rain Event Spans Rain Event
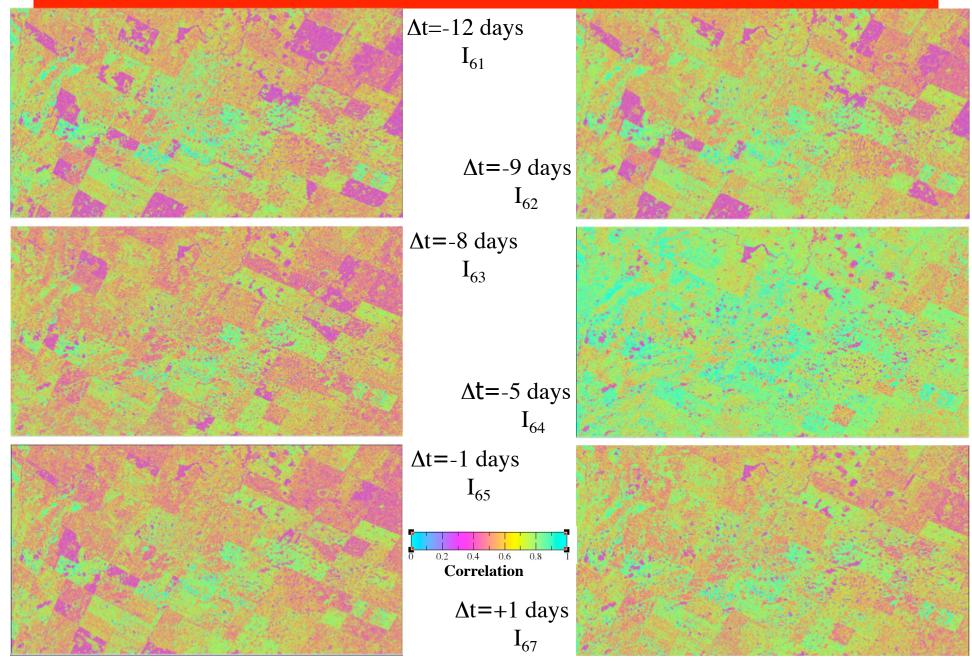
	153	156	157	160	164	165	166
153						I_{61}	
156						I_{62}	
157						I_{63}	
160						I_{64}	
164							I_{65}
165							I_{67}
166							

I_{jk} = Interferograms Generated Entire Image

HH Correlation Images
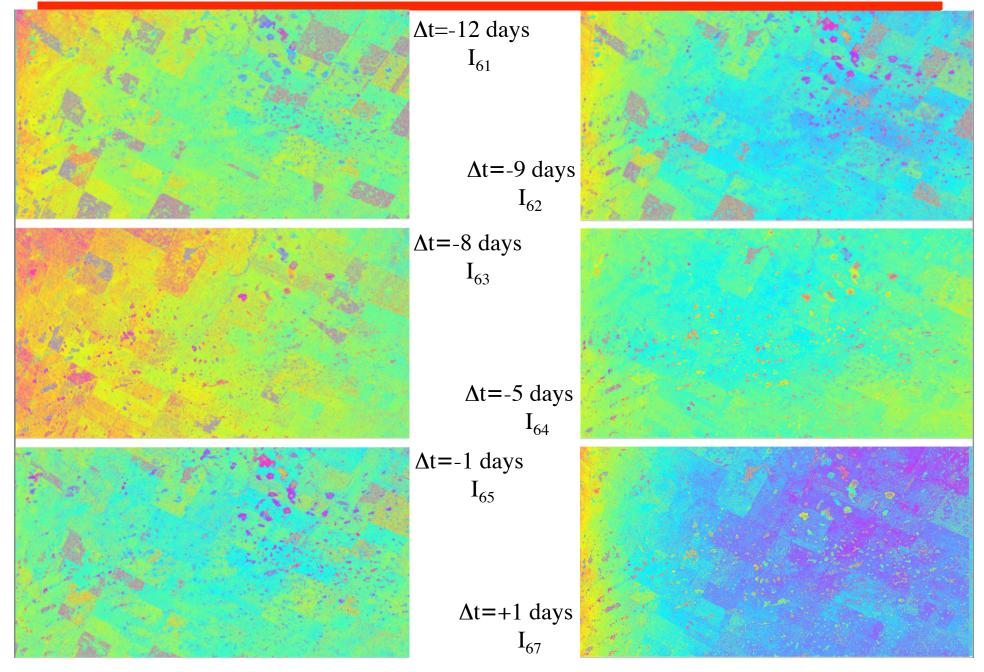
$\Delta t=-12$ days
I_{61}

$\Delta t=-9$ days
I_{62}

$\Delta t=-8$ days
I_{63}

$\Delta t=-5$ days
I_{64}

$\Delta t=-1$ days
I_{65}

Correlation

$\Delta t=+1$ days
I_{67}

VV Correlation

$\Delta t=-12$ days
I_{61}

$\Delta t=-9$ days
I_{62}

$\Delta t=-8$ days
I_{63}

$\Delta t=-5$ days
I_{64}

$\Delta t=-1$ days
I_{65}

$\Delta t=+1$ days
I_{67}

Correlation

HH Interferograms
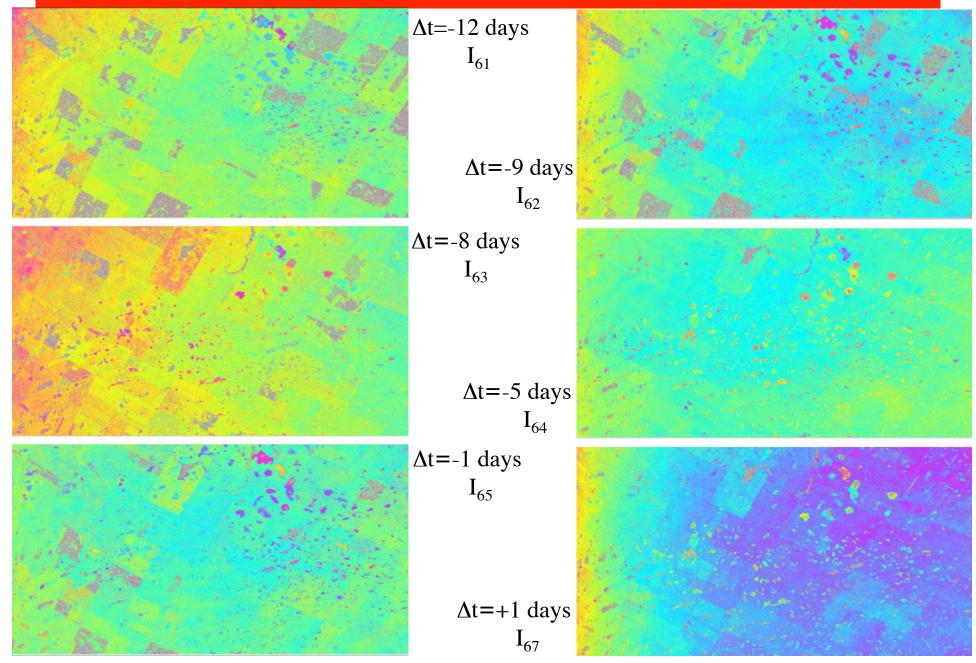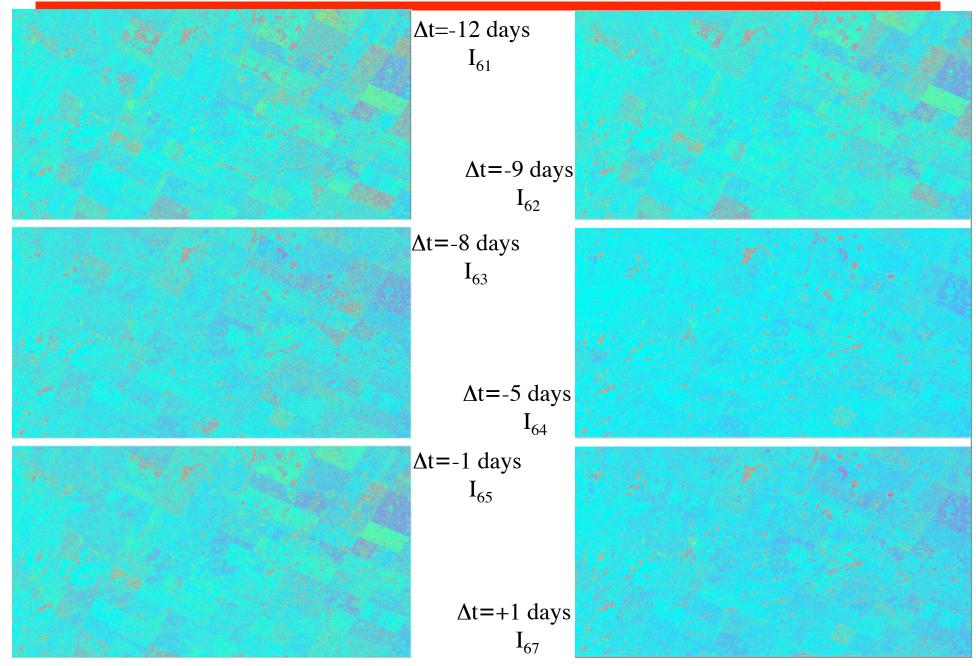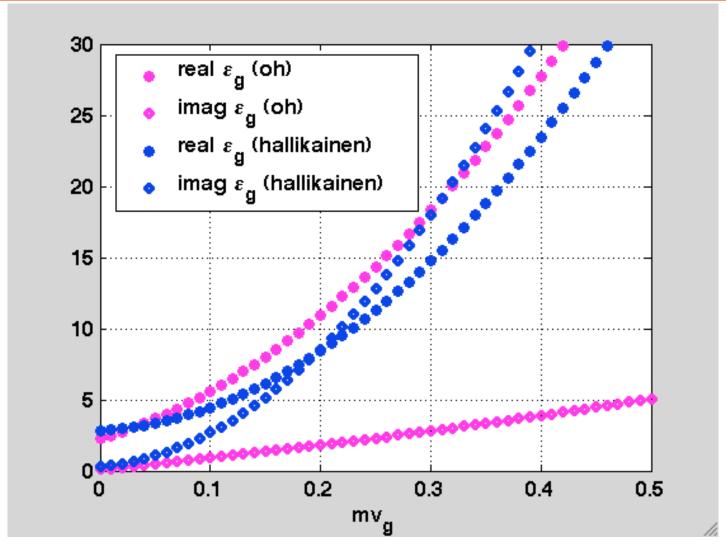
$\Delta t = -12$ days
I_{61}

$\Delta t = -9$ days
I_{62}

$\Delta t = -8$ days
I_{63}

$\Delta t = -5$ days
I_{64}

$\Delta t = -1$ days
I_{65}

$\Delta t = +1$ days
I_{67}

Δt=-12 days
I_{61}

Δt=-9 days
I_{62}

Δt=-8 days
I_{63}

Δt=-5 days
I_{64}

Δt=-1 days
I_{65}

Δt=+1 days
I_{67}

$\Delta t = -12$ days
I_{61}

$\Delta t = -9$ days
I_{62}

$\Delta t = -8$ days
I_{63}

$\Delta t = -5$ days
I_{64}

$\Delta t = -1$ days
I_{65}

$\Delta t = +1$ days
I_{67}
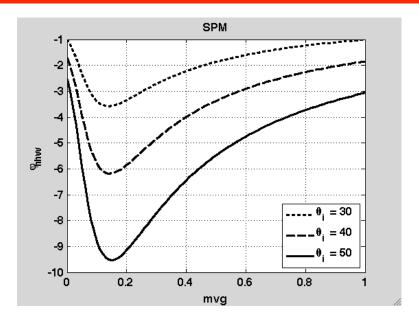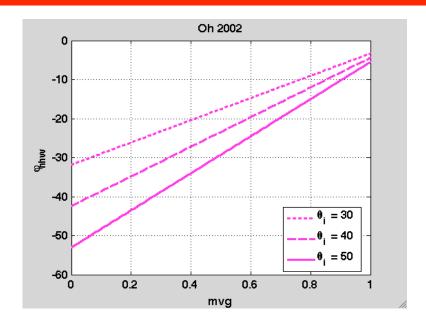
- Large difference in imaginary part of dielectric constants predicted by two models.
- Oh model seems to match phase measurements better and was used in generating comparisons of polarimetric/interferometric Kenaston data to models.
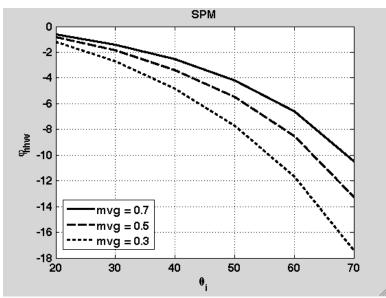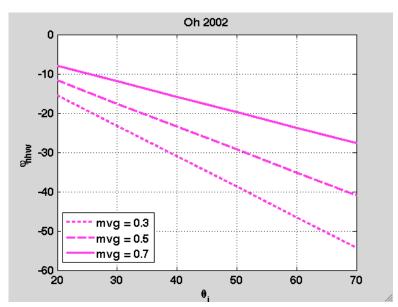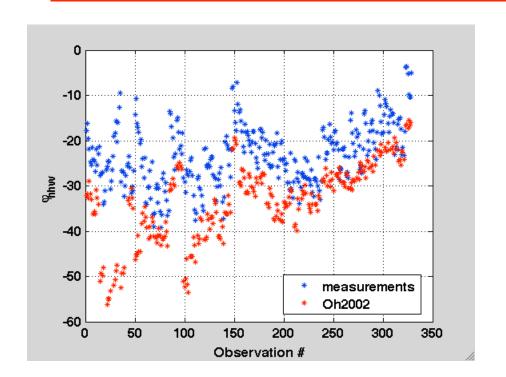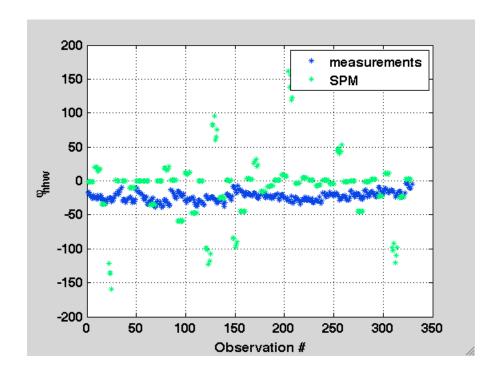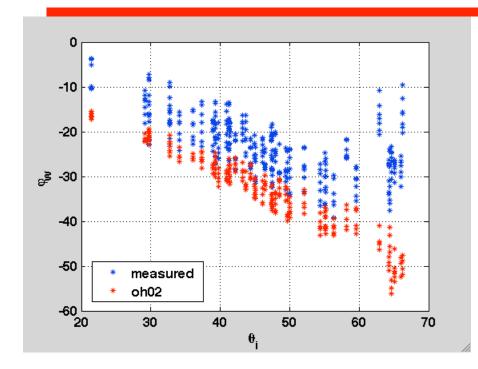
VV Polarimetric Phase Model Comparisons

- Comparison of Oh and SPM models of VV polarimetric phase with field measurements after data making for all dates and fields within our repeat-line Kenaston pass.

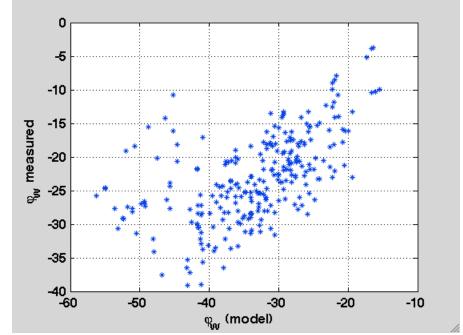- Much better agreement with Oh model and measurements than SPM model.

- Oh model VV polarimetric phase versus and measured VV polarimetric phase plotted versus incidence angle.

- There is good agreement with the trend except at high incidence angles and there is a slight bias of about 5°.

- Predicted spread from soil moisture is much less in predicted phase than in observed phase (about a factor of 2).
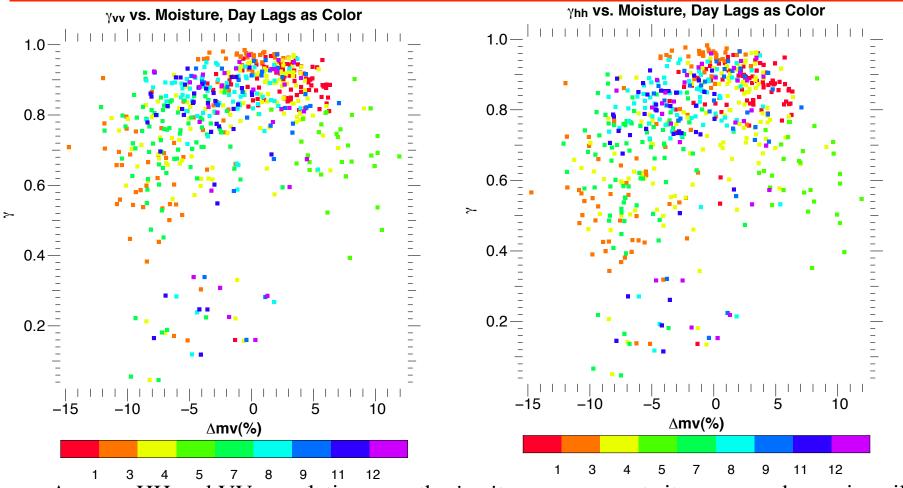
- Scatter plot of measured VV polarimetric phase versus Oh model polarimetric phase.

- Models agree reasonably well expect at high incidence angles (greater than 60°).

Interferometric Correlation Versus Δm_v

γ_{vv} vs. Moisture, Day Lags as Color

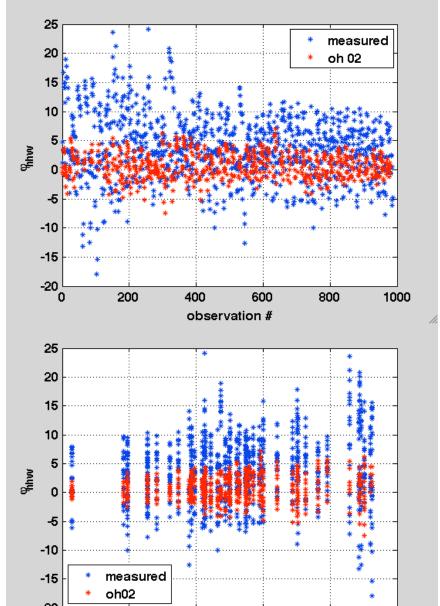γ_{hh} vs. Moisture, Day Lags as Color

- Average HH and VV correlation over the *in situ* measurement sites versus change in soil moisture.

- Note, the correlation tends to decrease more for larger changes in soil moisture indicating soil moisture is effecting the interferometric measurement.
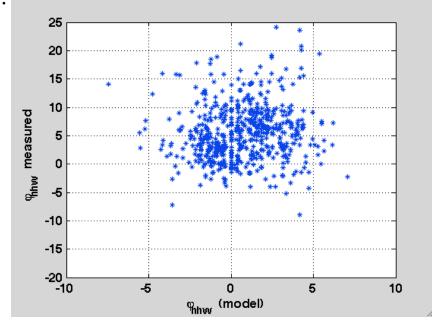
- Differential HH and VV interferometric phase plotted versus Oh model predictions for all the ground truth sites and interferometric combinations.

- Measured interferometric phase versus model predictions as a function of incidence angle and as a scatter plot.

- Although the order of magnitude is similar actual phase measurements are larger than model predicts.

- Soil moisture changes are clearly observed in both the polarimetric and interferometric data.

- General trends in backscatter variation with soil moisture variation trends follow existing models reasonably well.

- Oh models predicts the general behavior of the VV polarimetric phase, however the variation with soil moisture appears to be a factor of two larger than that predicted by the model.

- Interferometric decorrelation increases with increasing deltas in soil moisture.

- Still trying to develop a quantitative link between soil moisture change and interferometric phase observables. Order of magnitude agreement but not a strong correlation with data at this point.

γvv vs. Moisture, Day Lags as Color