Remote sensing of martian aeolian dynamics

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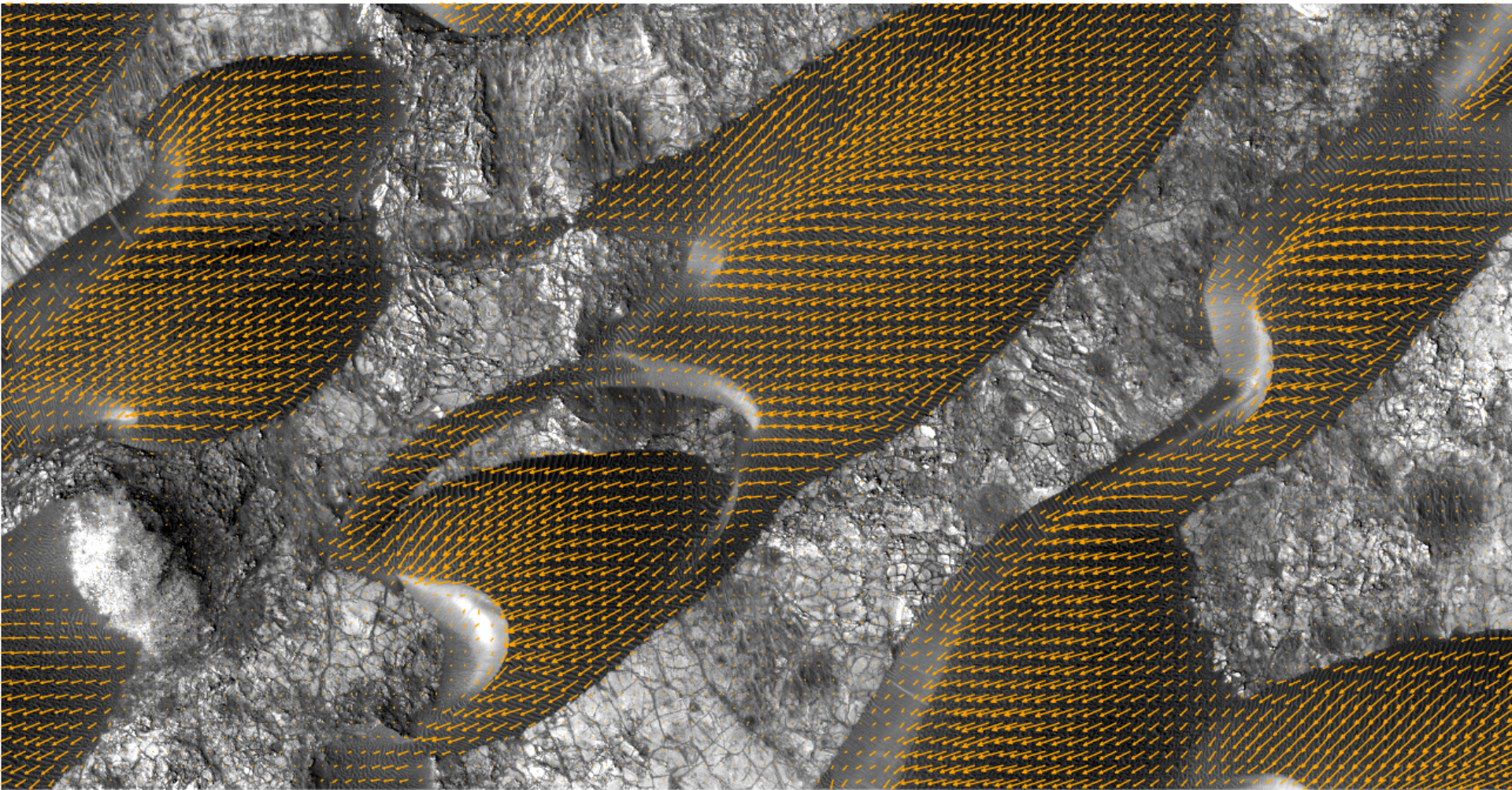
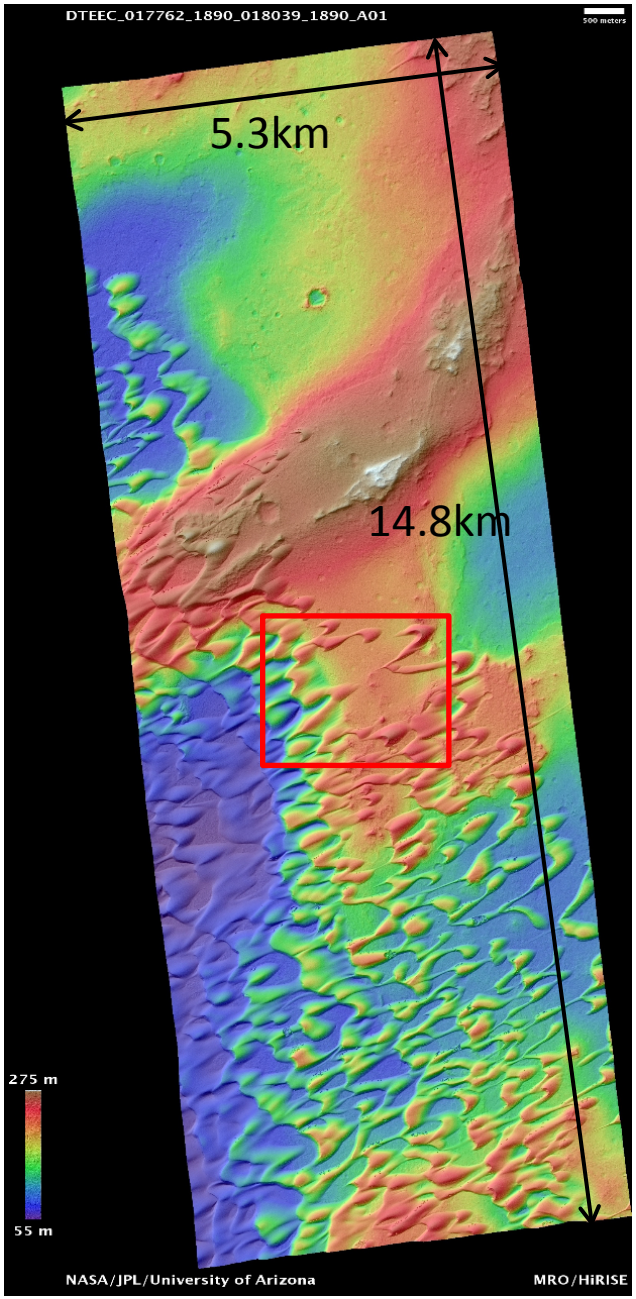
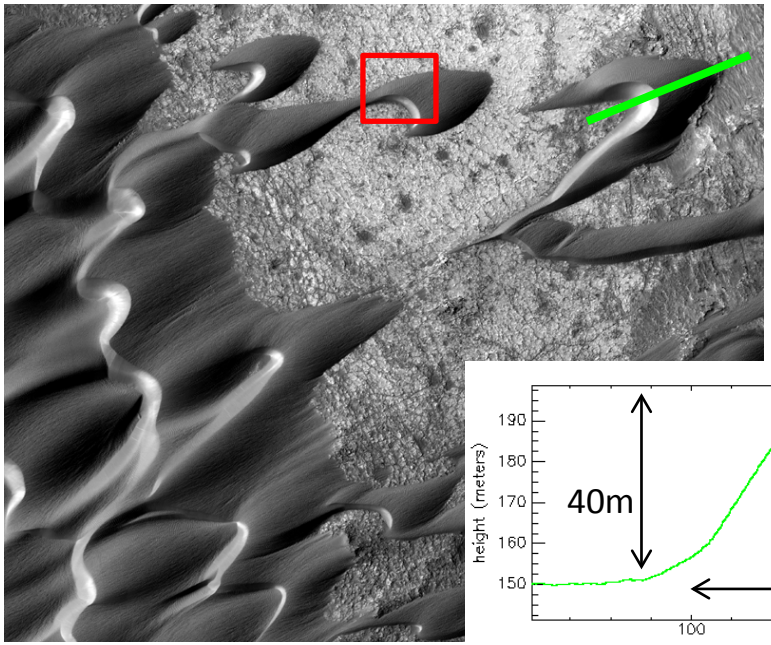
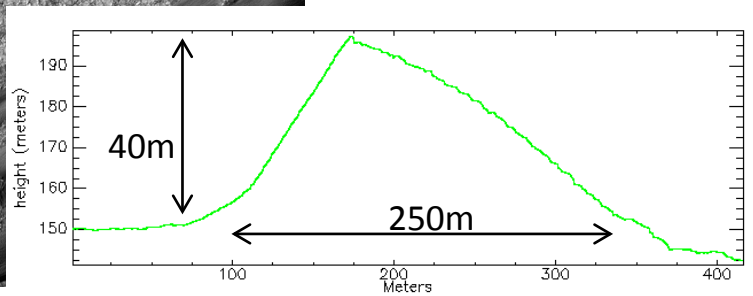
KISS workshop, June 16-19, 2014 - fayoub@gps.caltech.edu

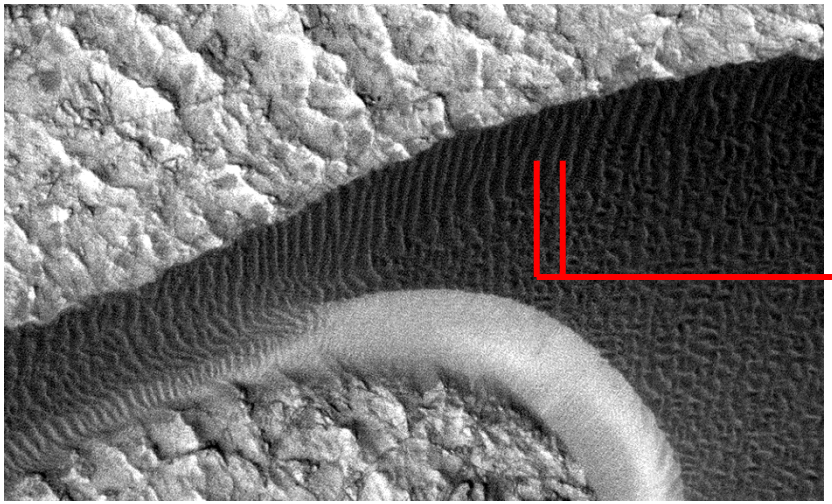


Nili Patera dune field & HiRISE data









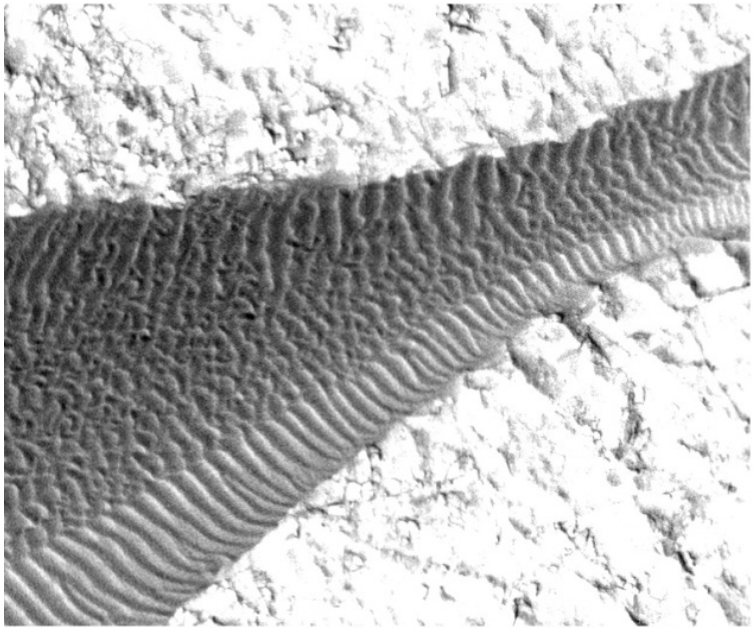
Questions to address

- How active is the dune field? Can we quantify the sand flux and its seasonality?
- What would the sand flux dynamic implies for atmospheric and landscape simulations?
- How the observed morphologic changes of the ripples and dunes compares to our a priori knowledge on dune field dynamics?

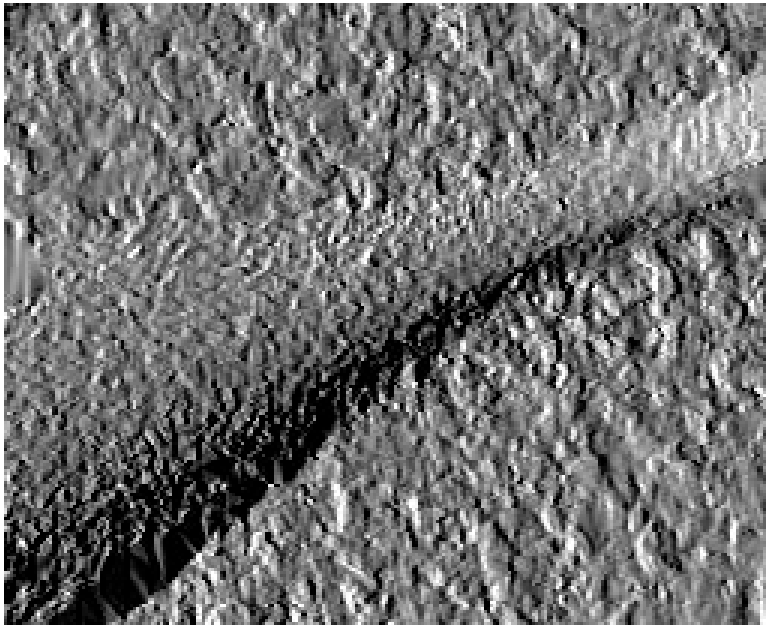
What can we measure from the HiRISE dataset ?

	Static		Dynamic	
	Planimetric shape (2D)	3D shape	Planimetric change (2D)	3D change
Ripples				
Dunes				

Ripple topography not resolved in the DEM

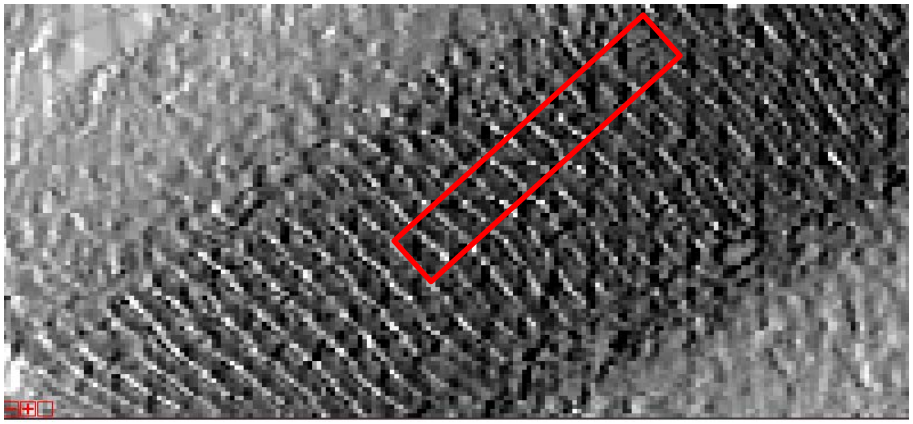


HiRISE image

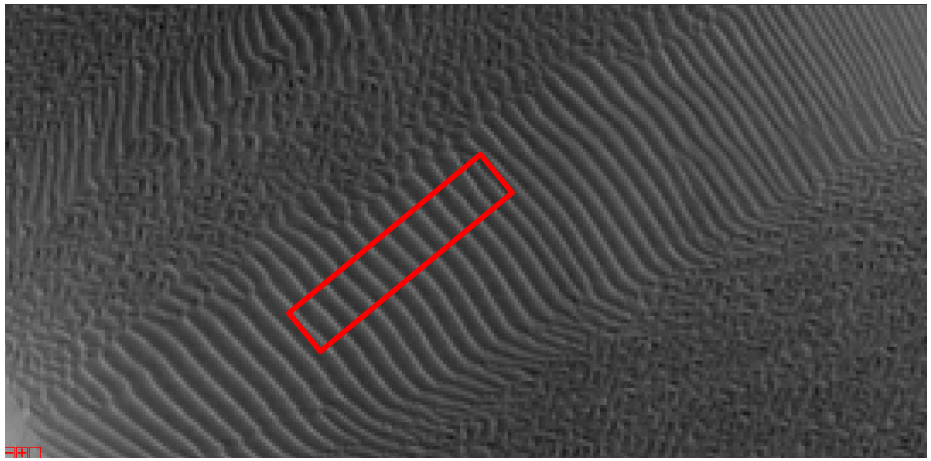


Shaded DEM

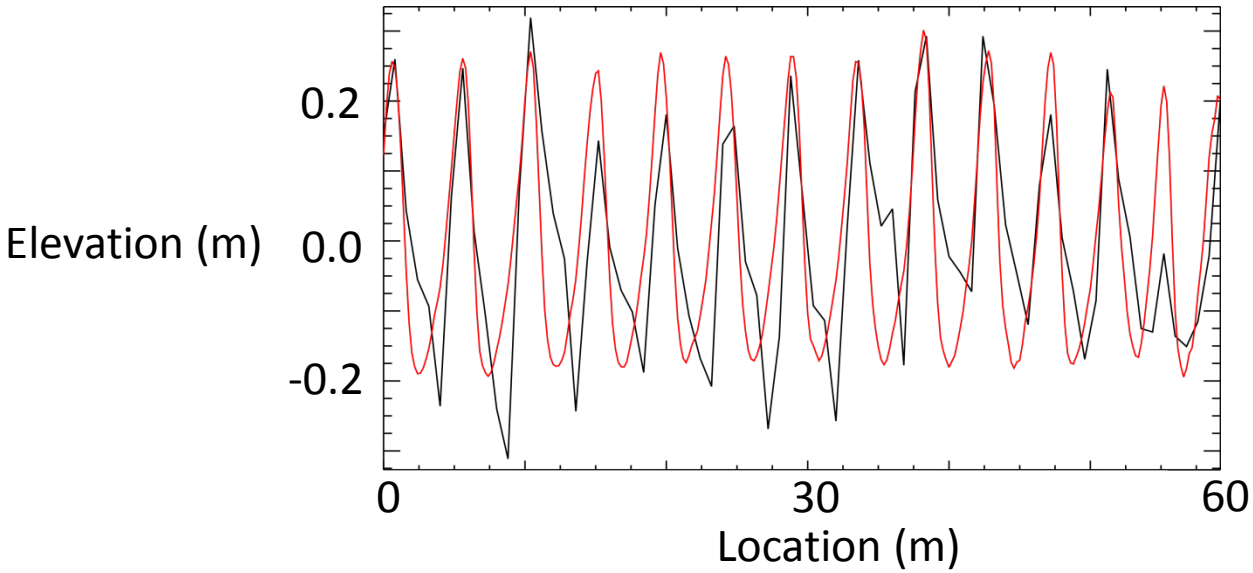
Ripple height estimation from DEM + photoclinometry



Shaded DEM



HiRISE image

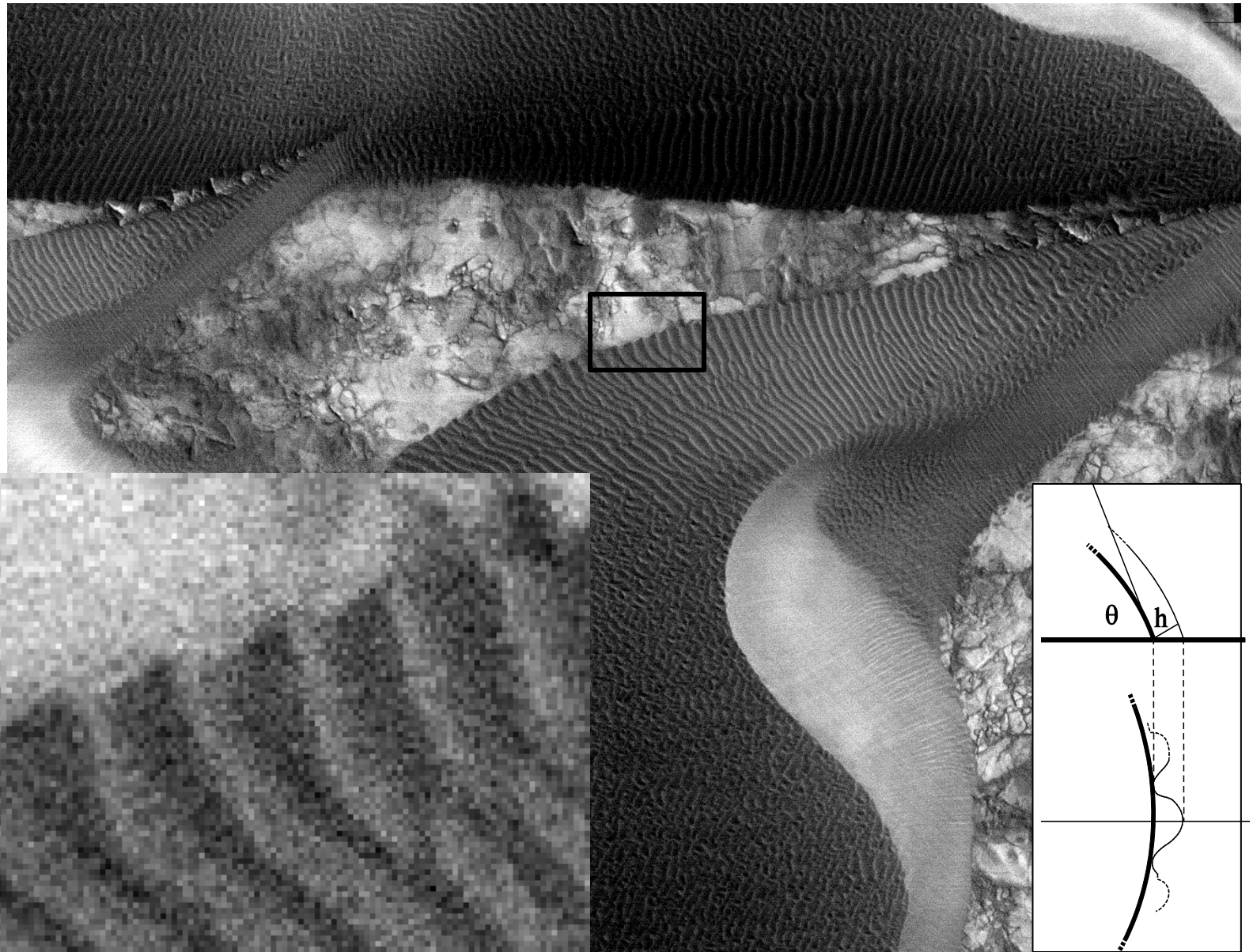


DEM

Pseudo-clinometry

Approximate ripple height: 42 cm

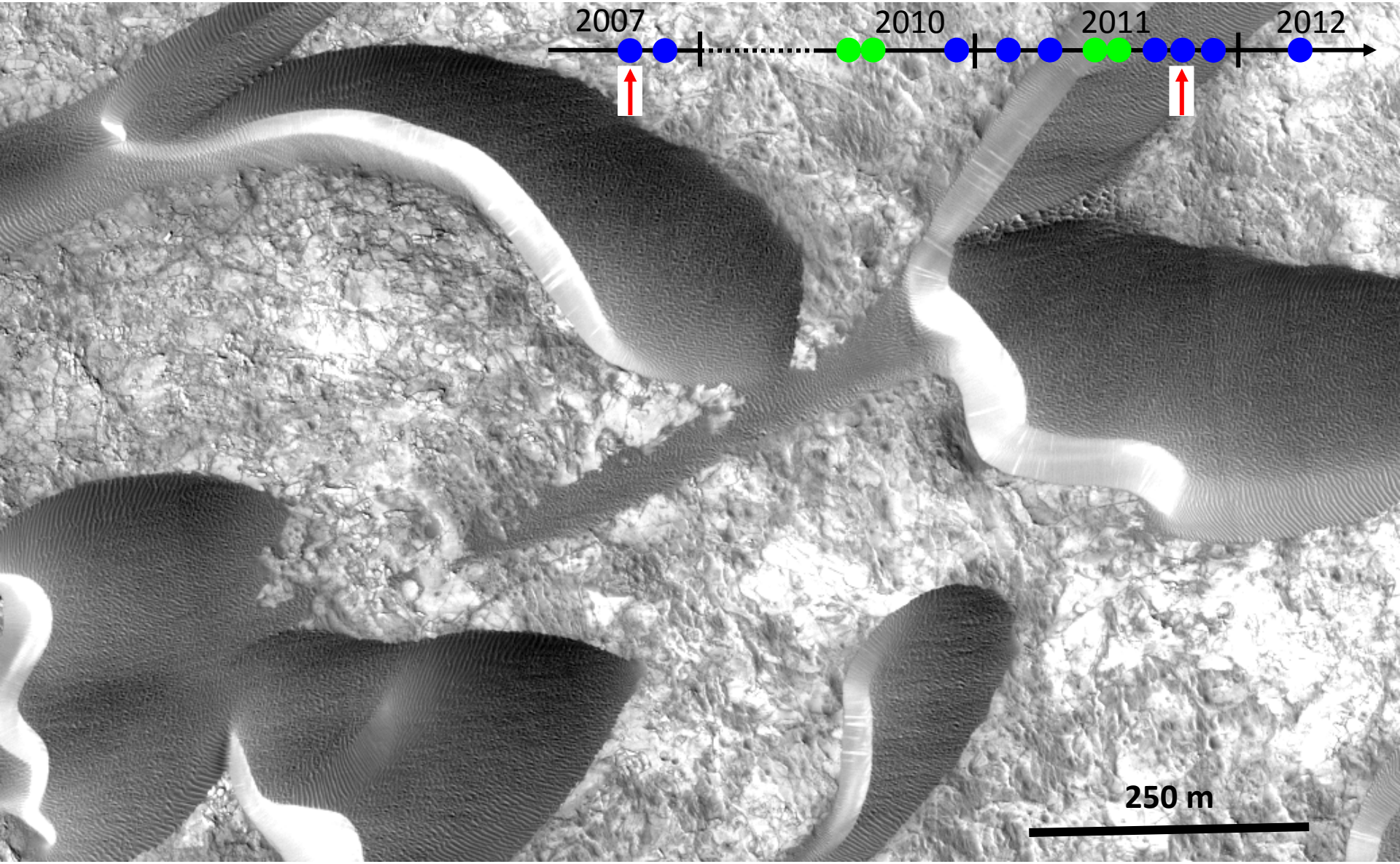
Ripple height estimation from ripple projection on the bedrock



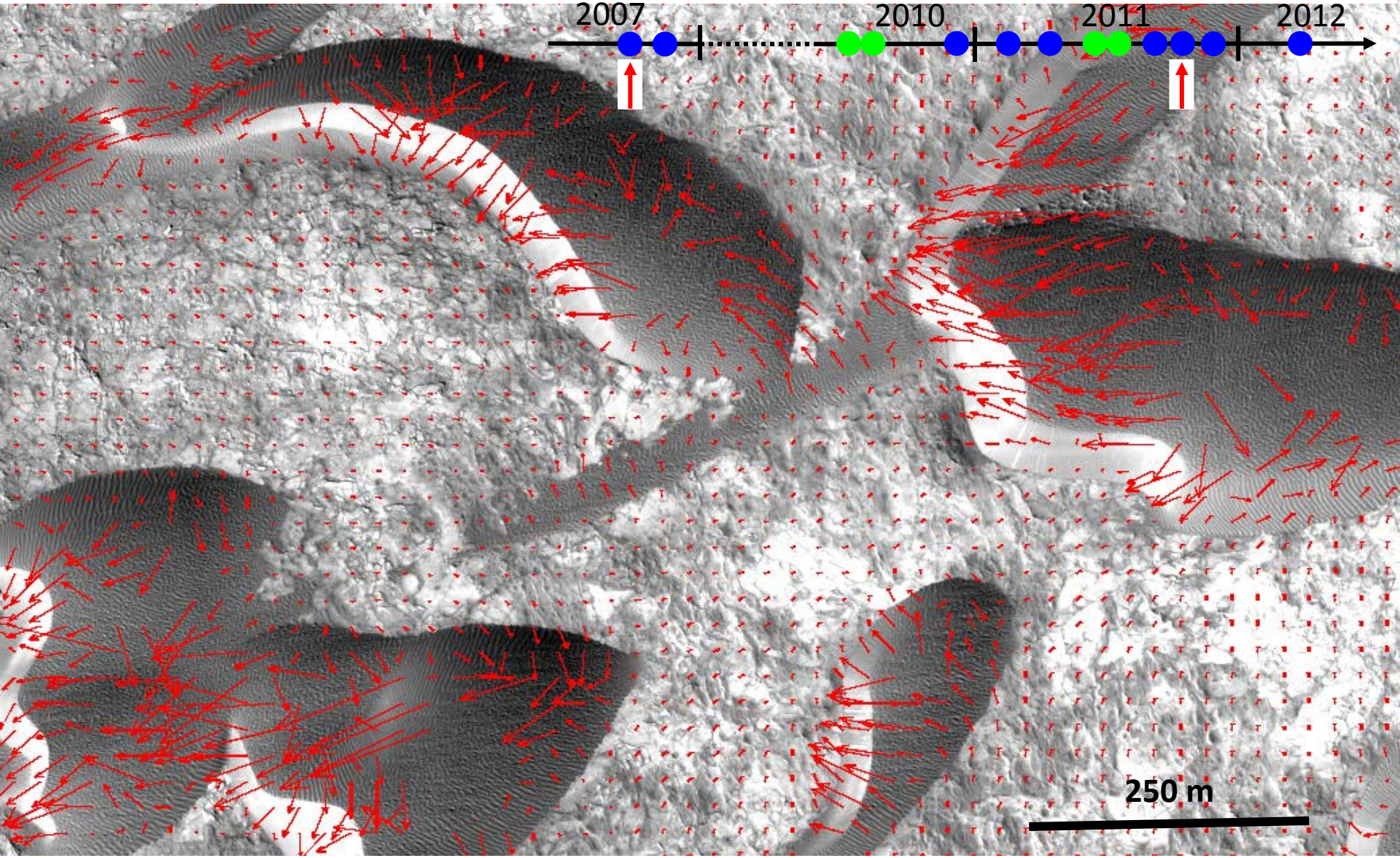
What can we measure from the HiRISE dataset ?

	Static		Dynamic	
	Planimetric shape (2D)	3D shape	Planimetric change (2D)	3D change
Ripples				
Dunes				

In 3 years, dunes (not ripples) have migrated



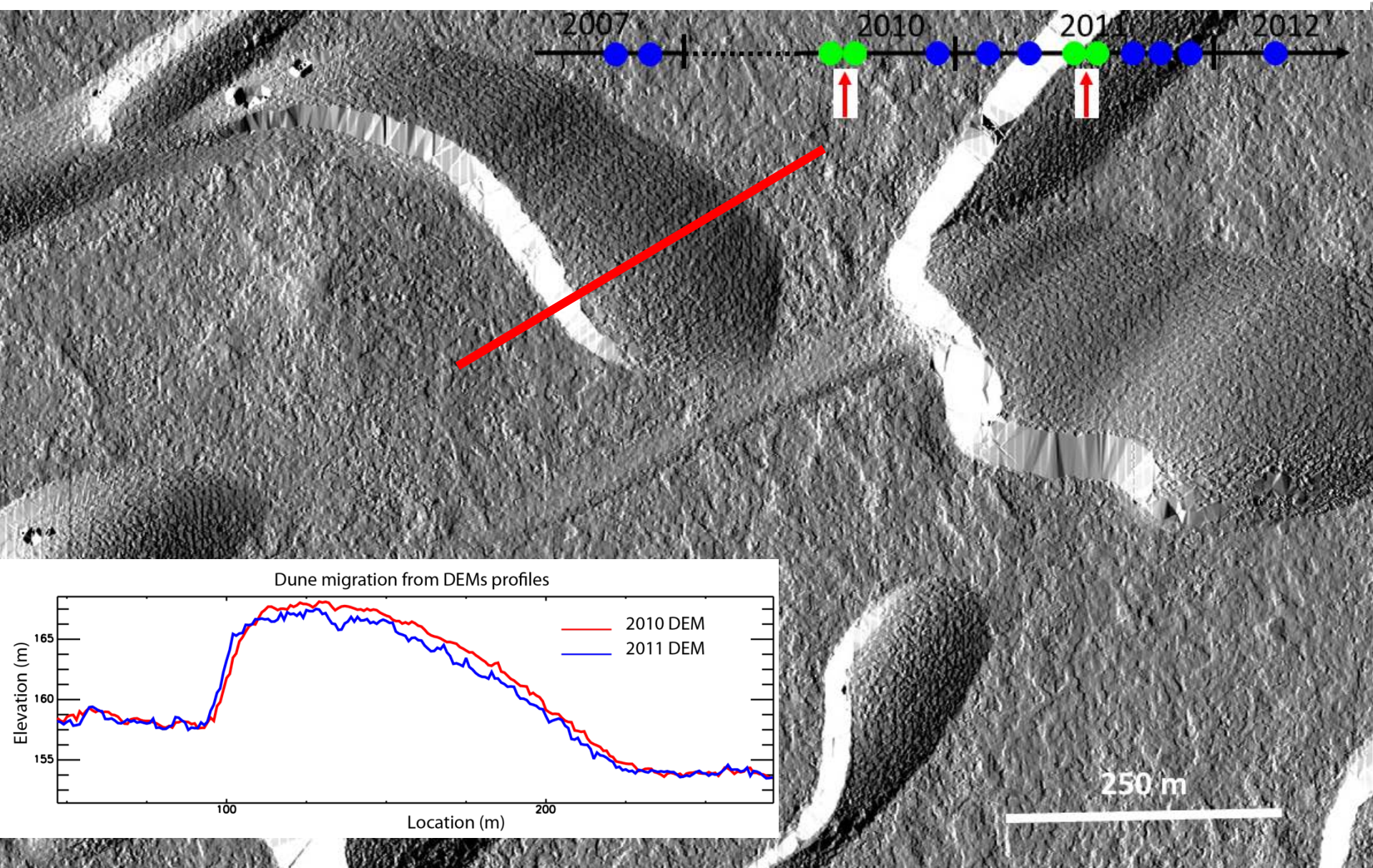
But local 2D matching for dune migration does not work well



What can we measure from the HiRISE dataset ?

	Static		Dynamic	
	Planimetric shape (2D)	3D shape	Planimetric change (2D)	3D change
Ripples				
Dunes				

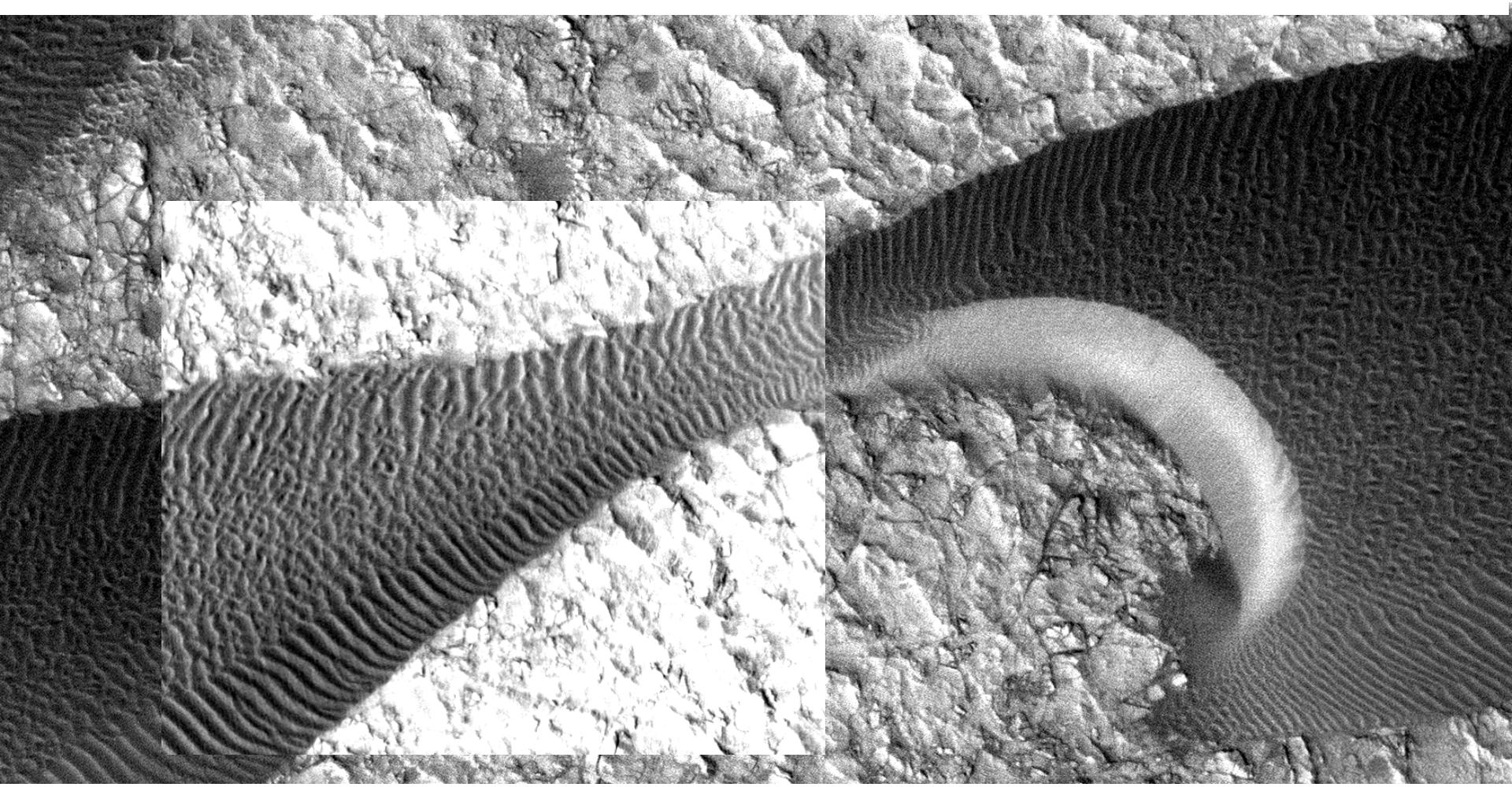
Comparison of multi-temporal DEMs for 3D change monitoring



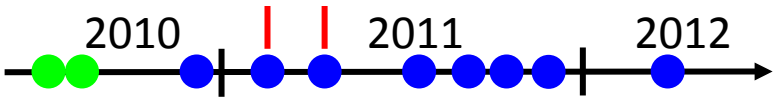
What can we measure from the HiRISE dataset ?

	Static		Dynamic	
	Planimetric shape (2D)	3D shape	Planimetric change (2D)	3D change
Ripples				
Dunes				

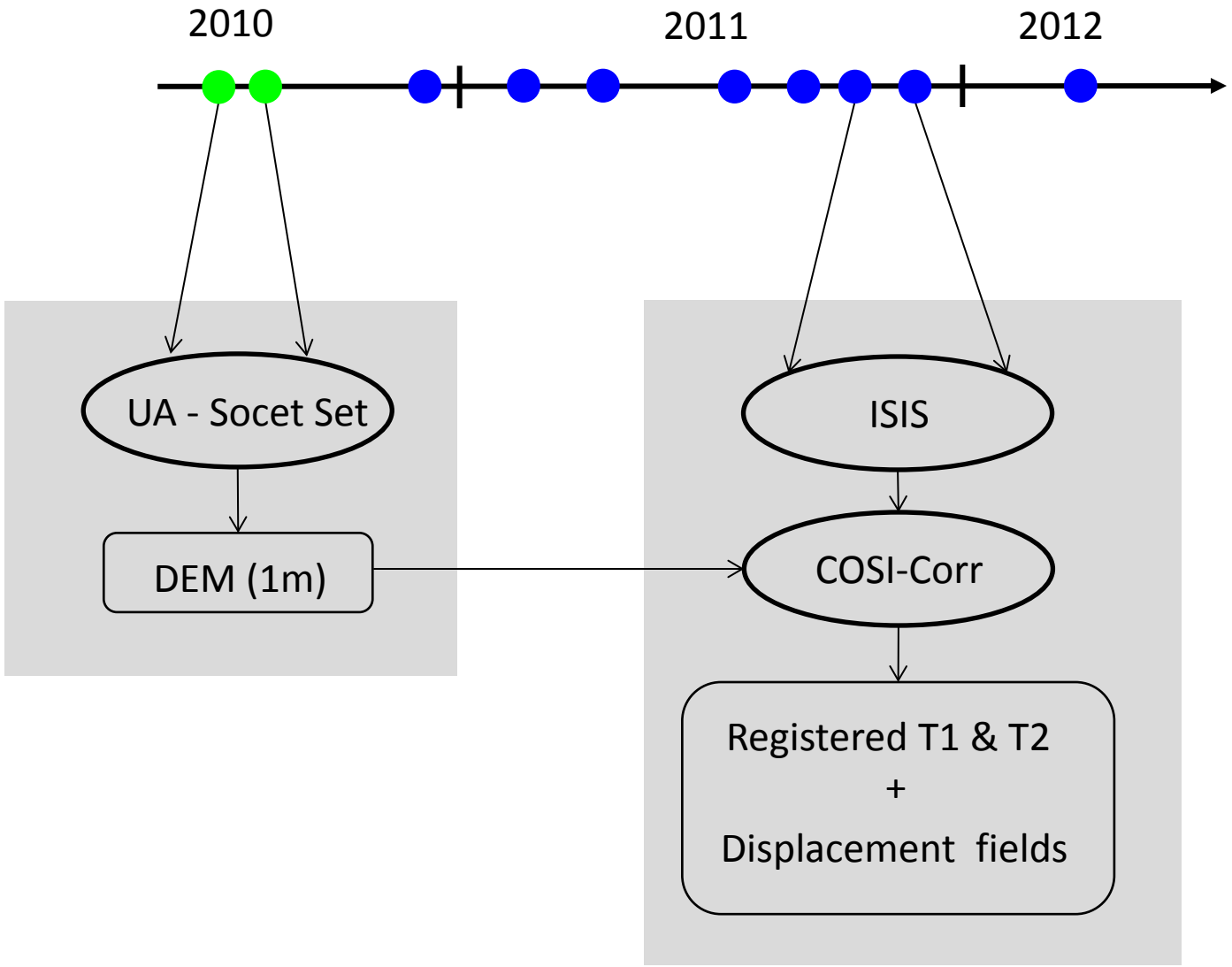
Tracking ripple migration



85m

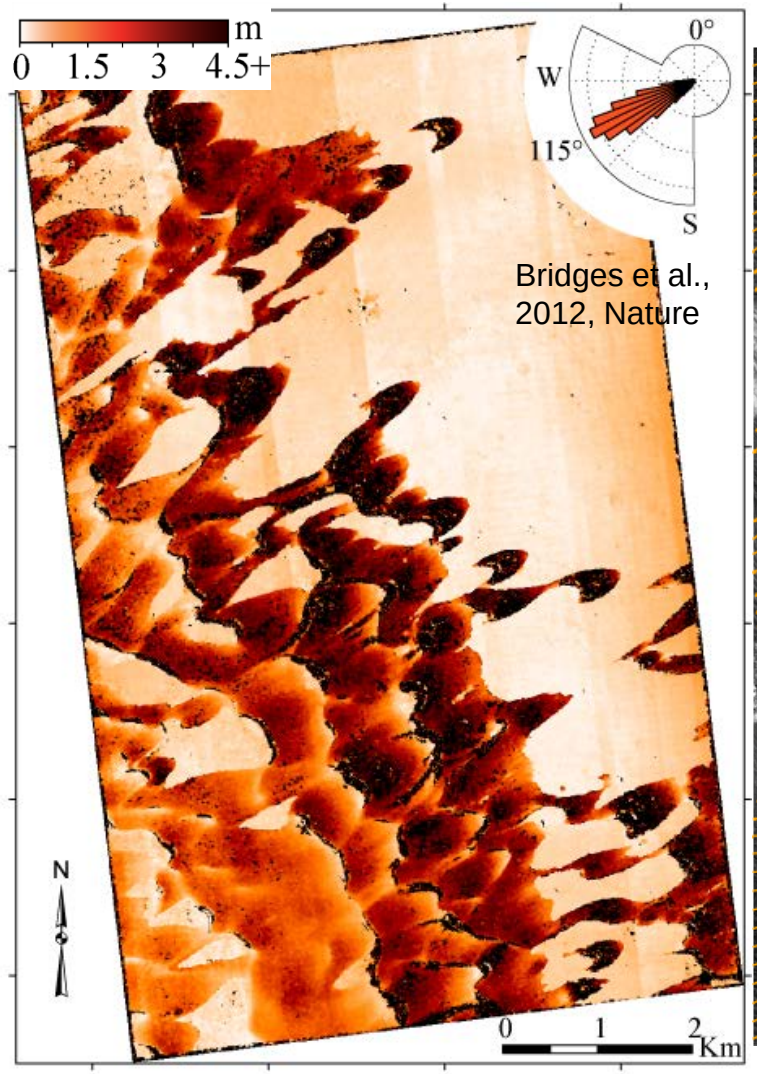


Data & processes

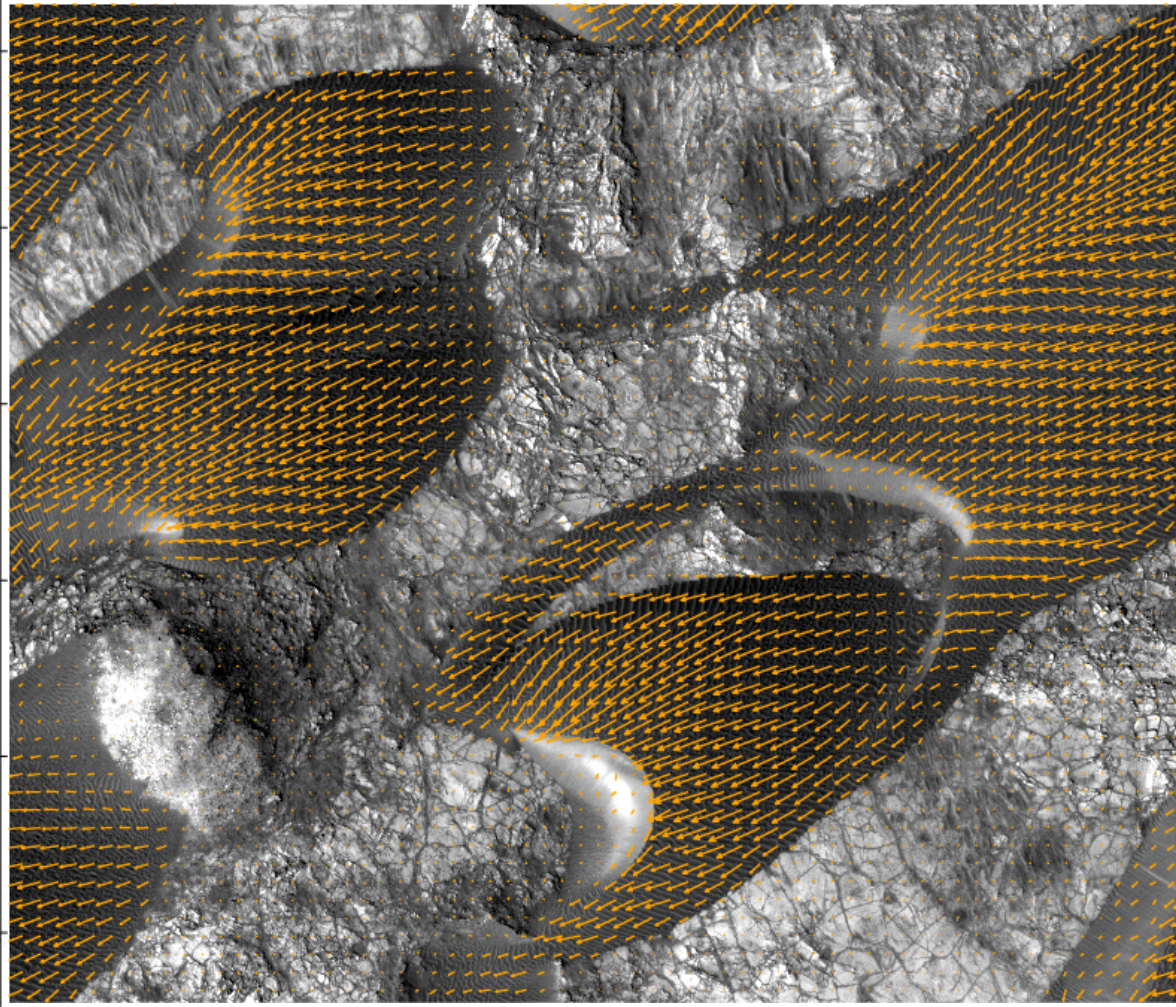


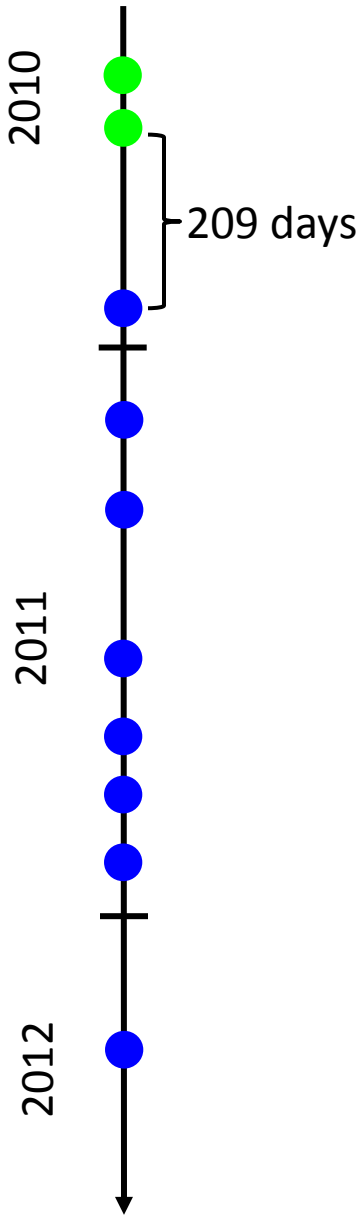
Measurement of ripple migration (amplitude and orientation)

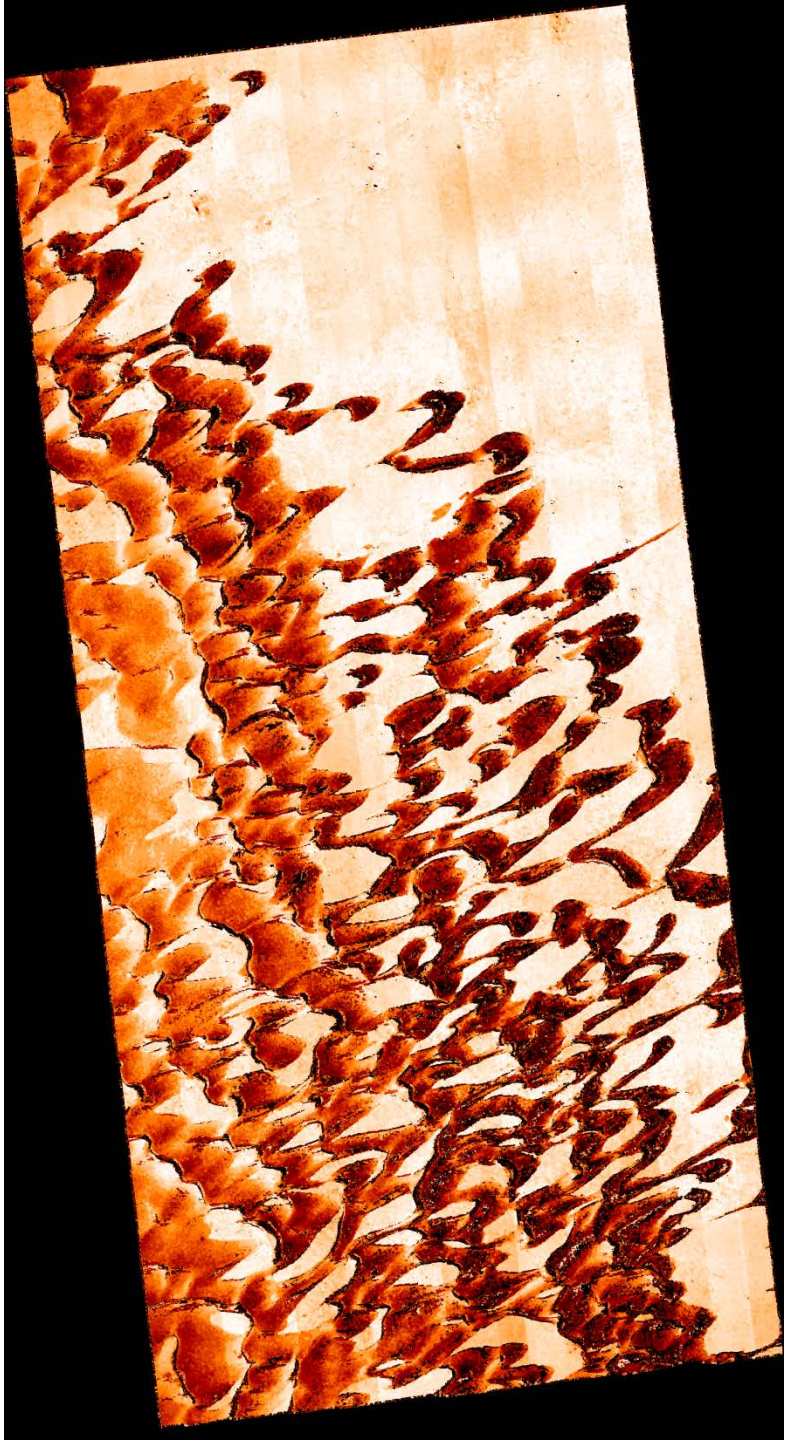
Ripples displacement amplitude

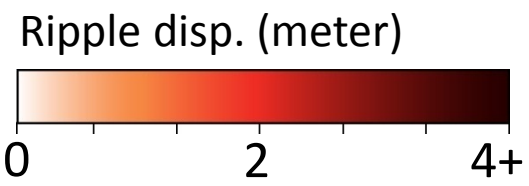


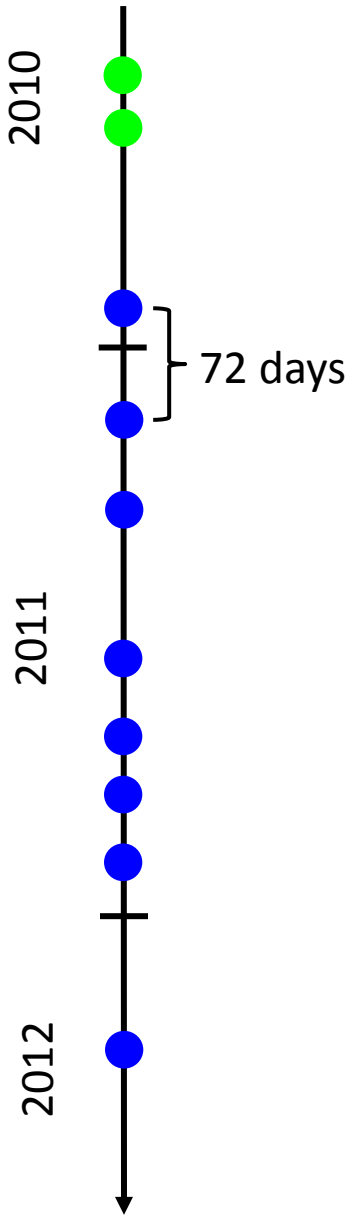
Bridges et al., 2012, Nature

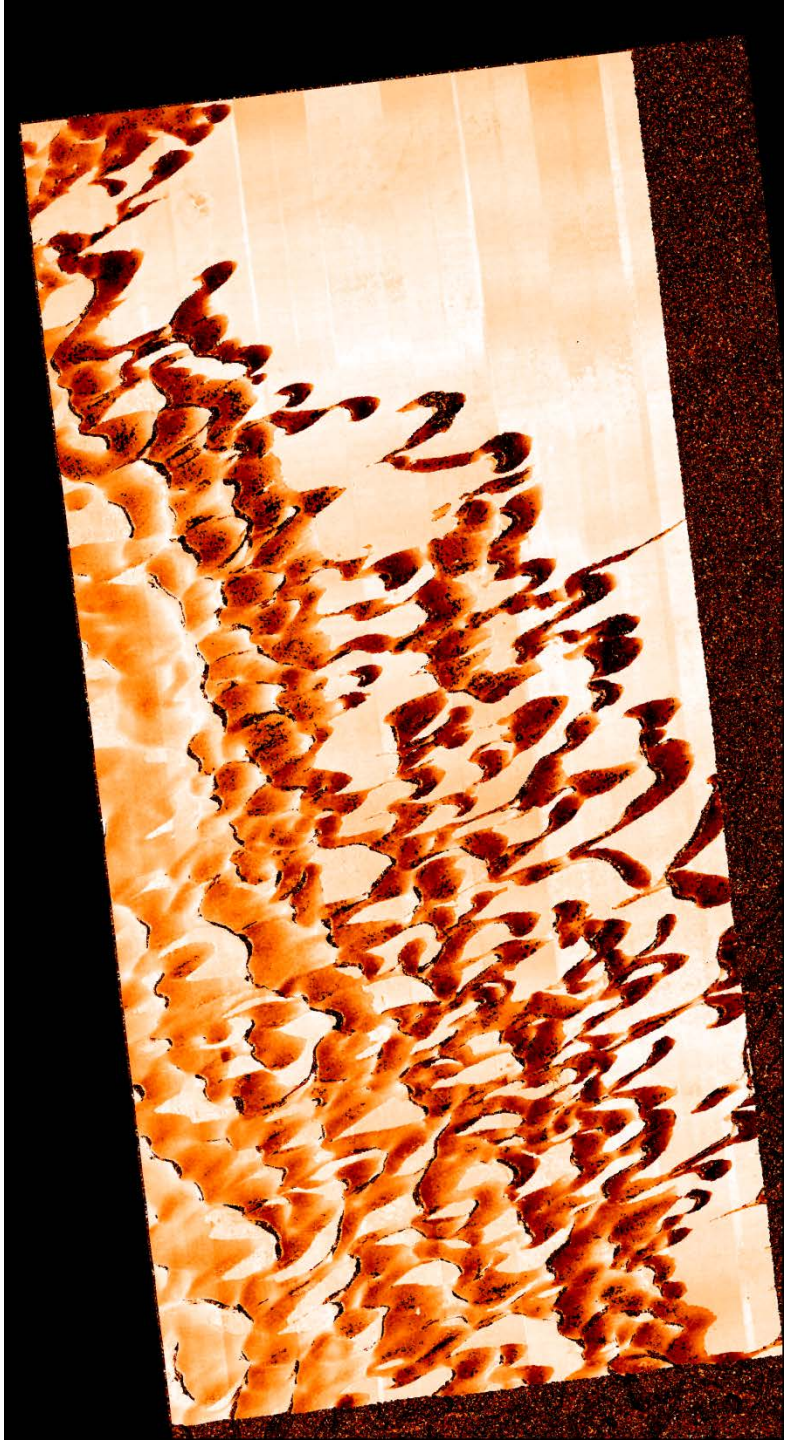


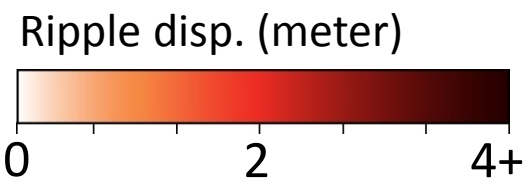

2010
209 days
2011
2012

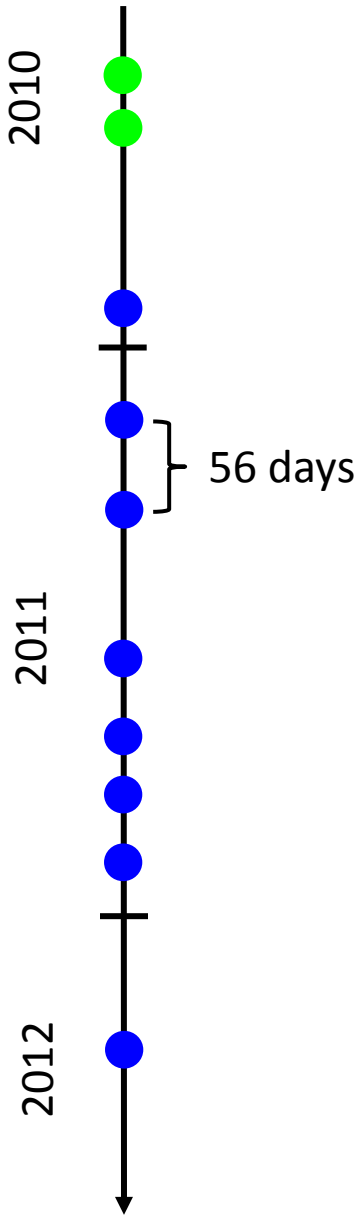


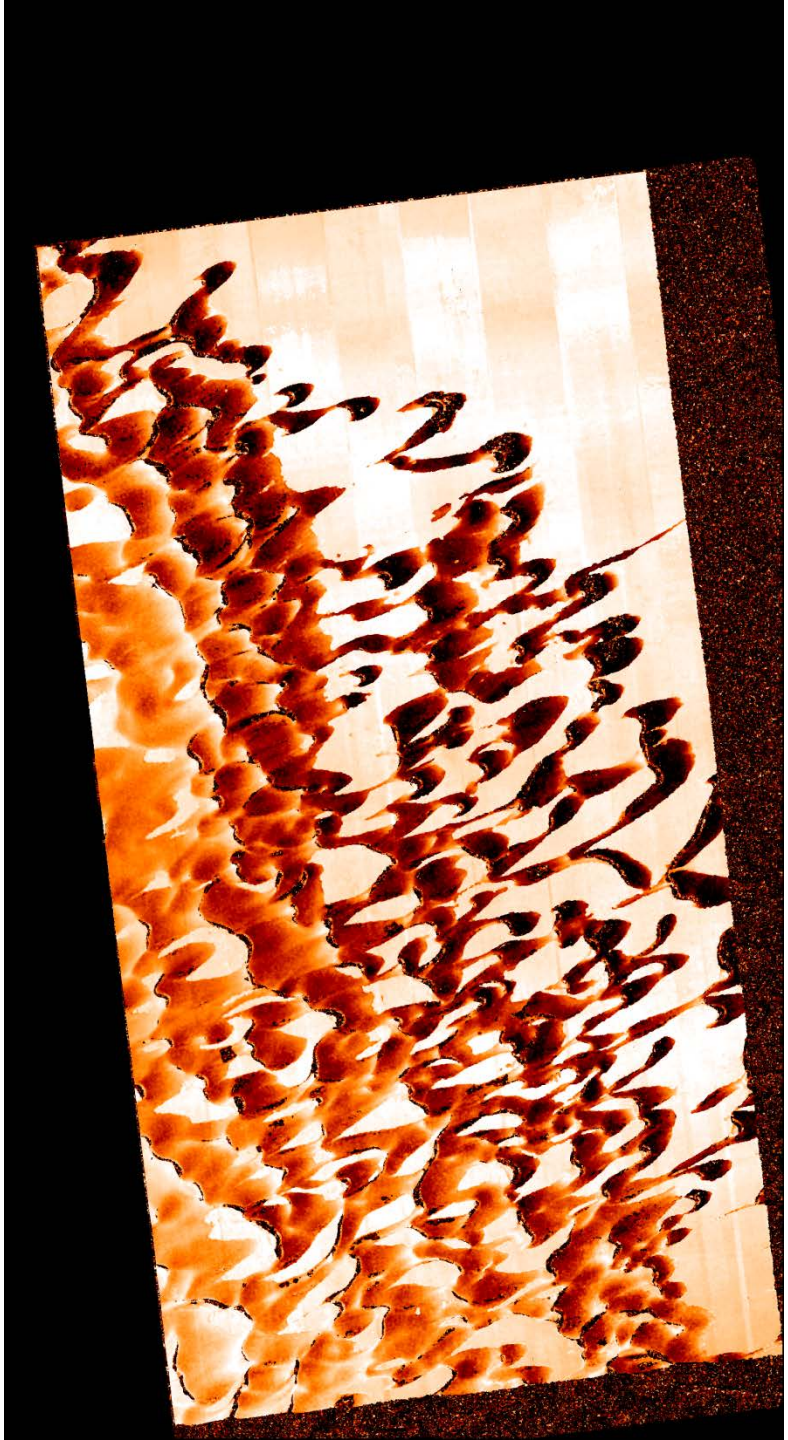

Ripple disp. (meter)
0
2
4+

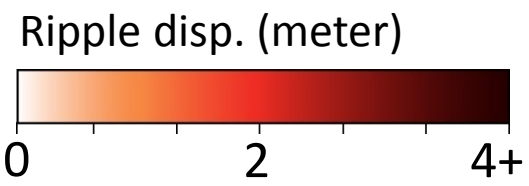

2010
2011
2012
72 days

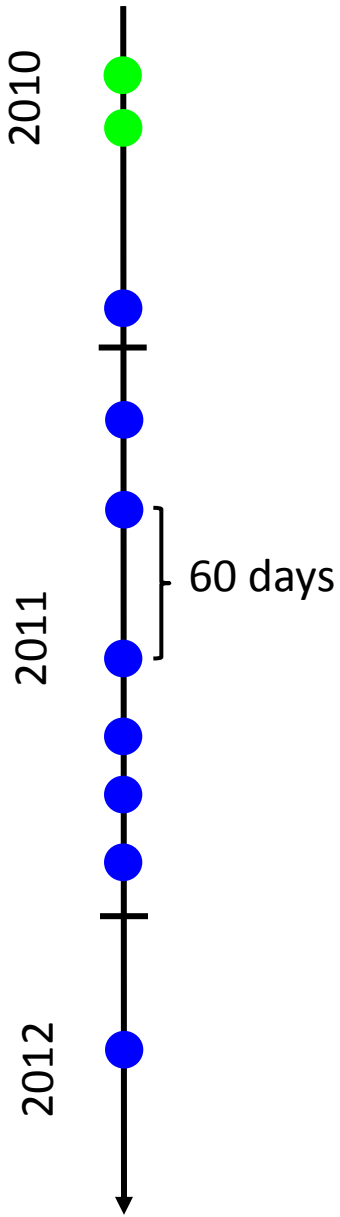


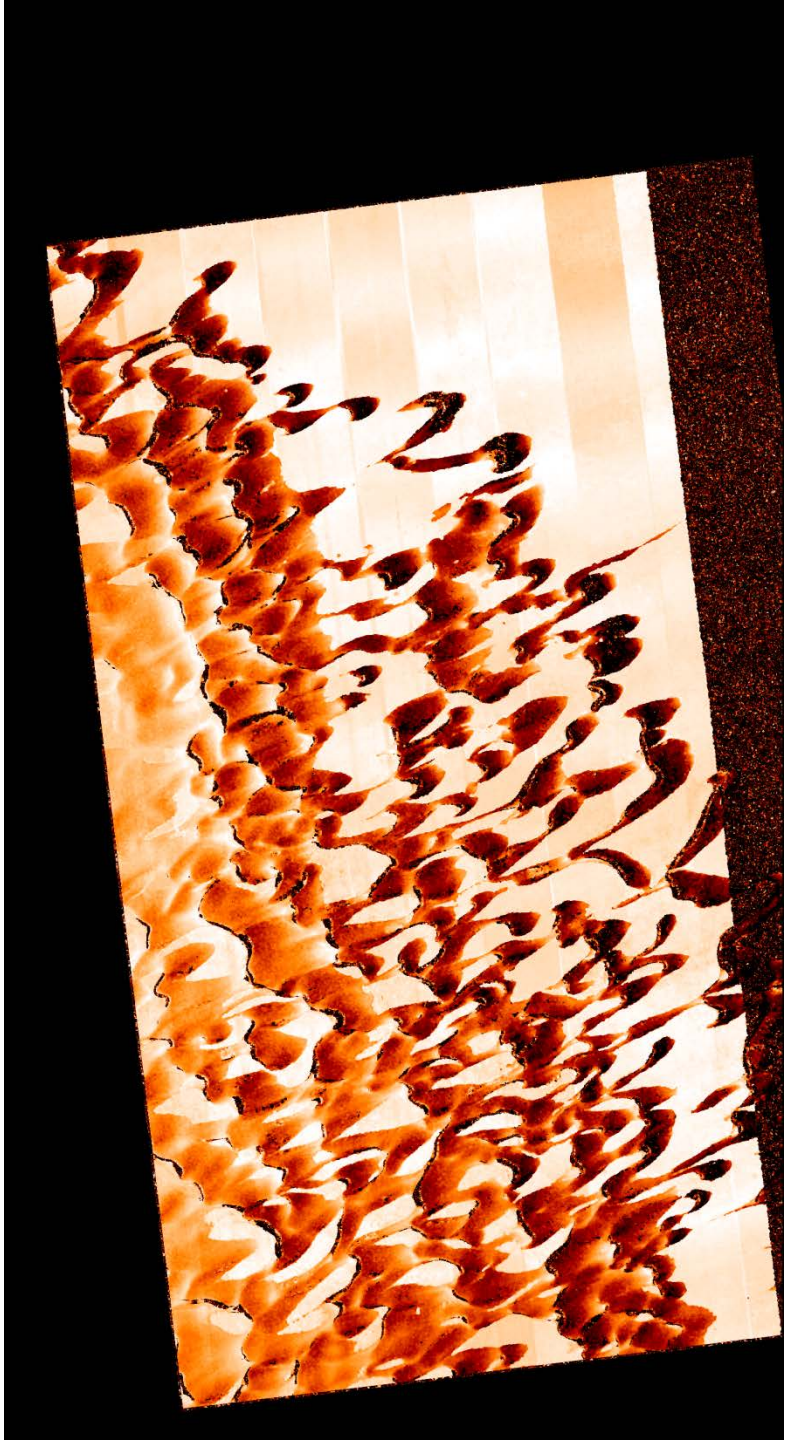

Ripple disp. (meter)
0
2
4+

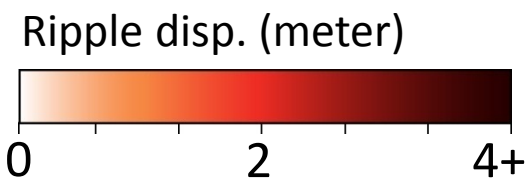

2010
56 days
2011
2012

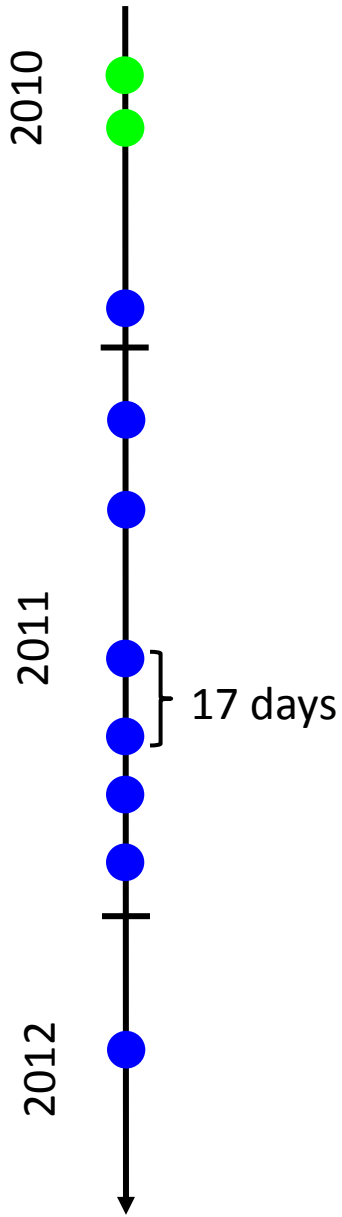


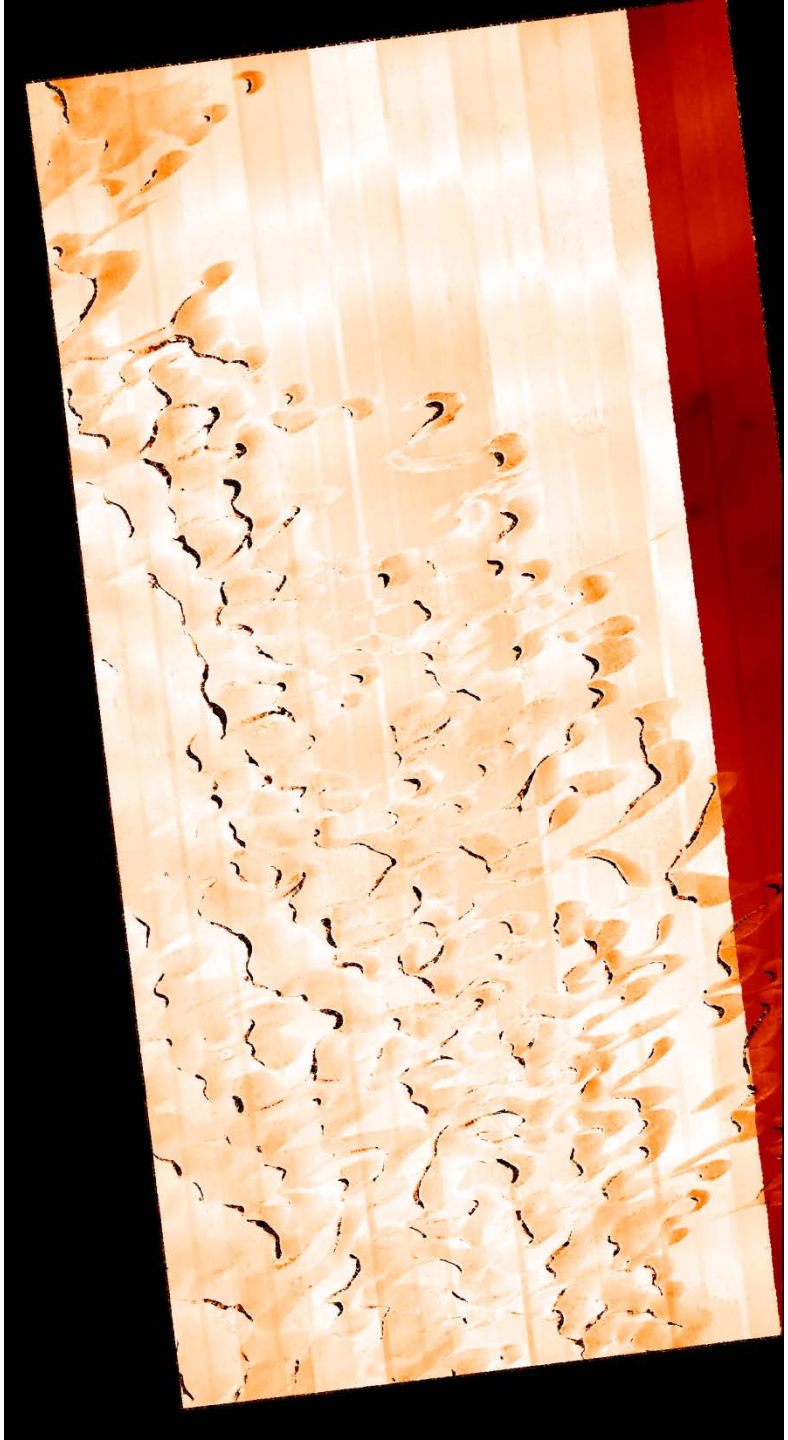

Ripple disp. (meter)
0
2
4+

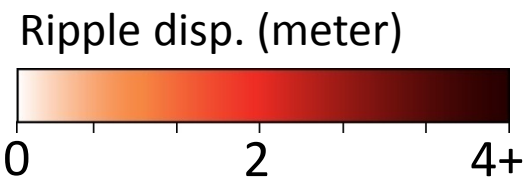

2010
2011
2012
60 days

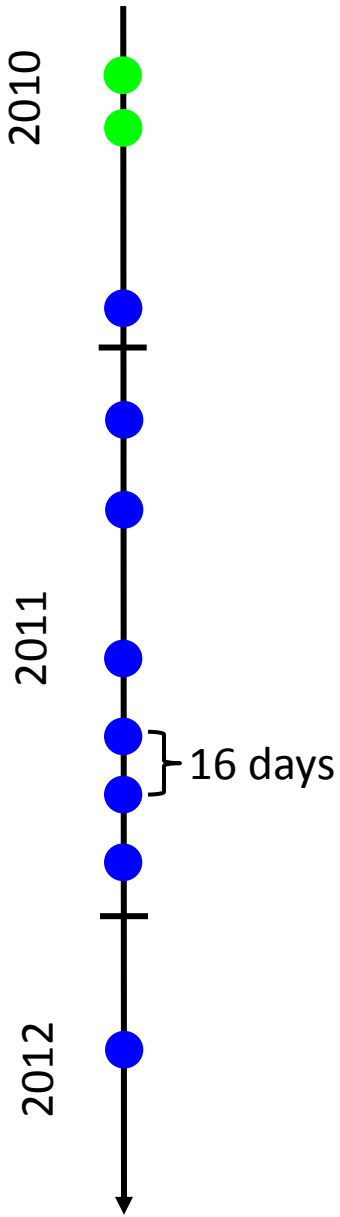


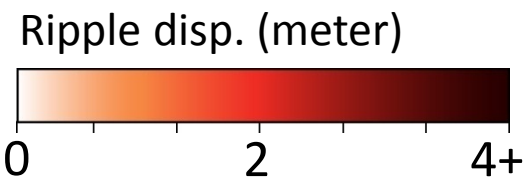

Ripple disp. (meter)
0
2
4+

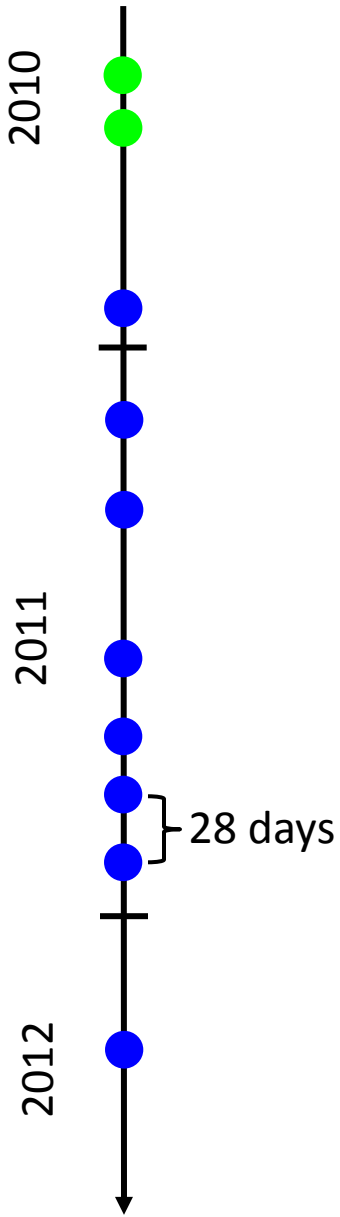

2010
2011
17 days
2012

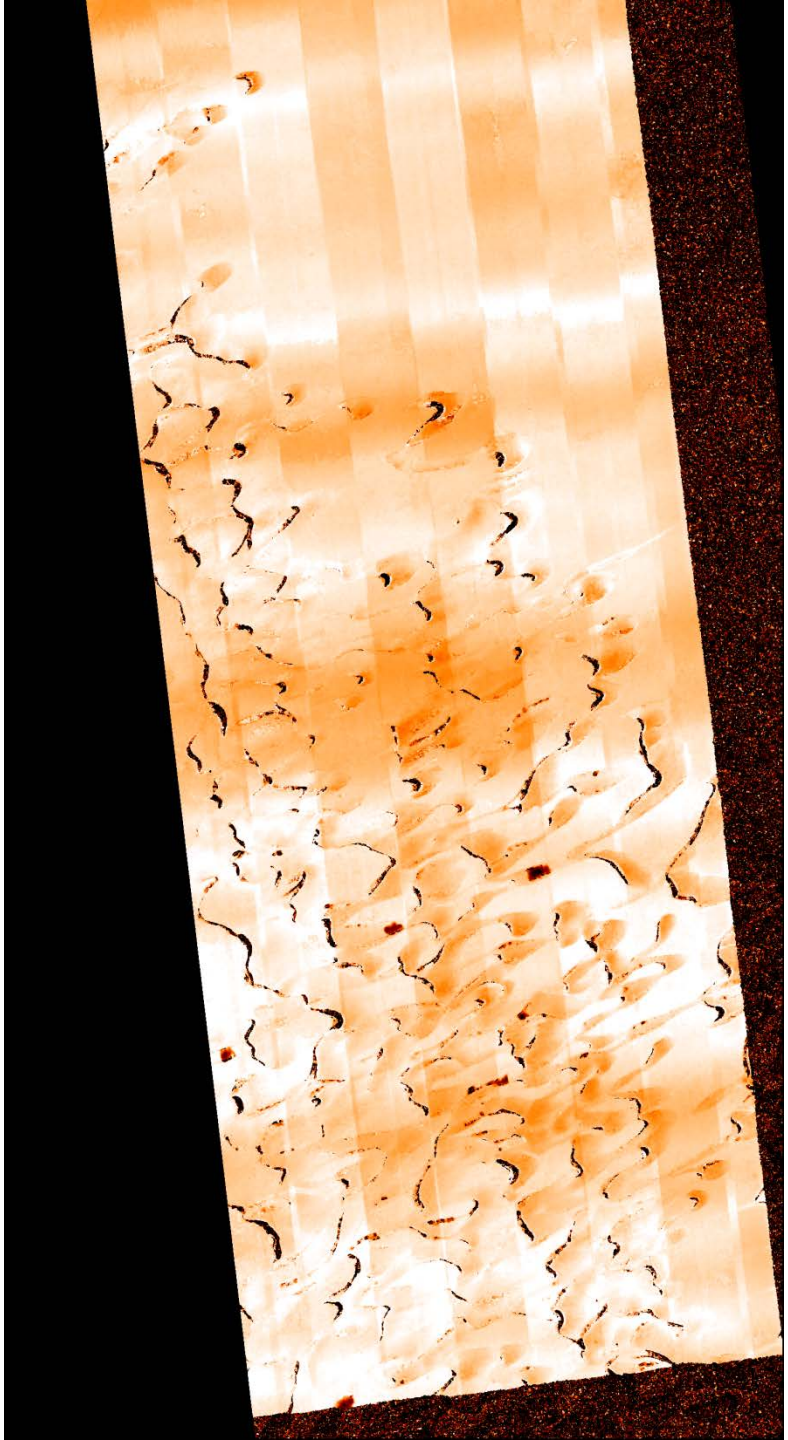


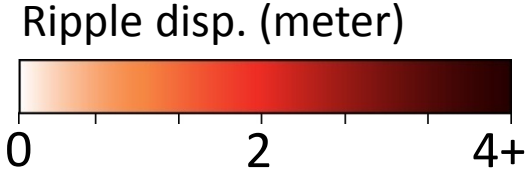

Ripple disp. (meter)
0
2
4+

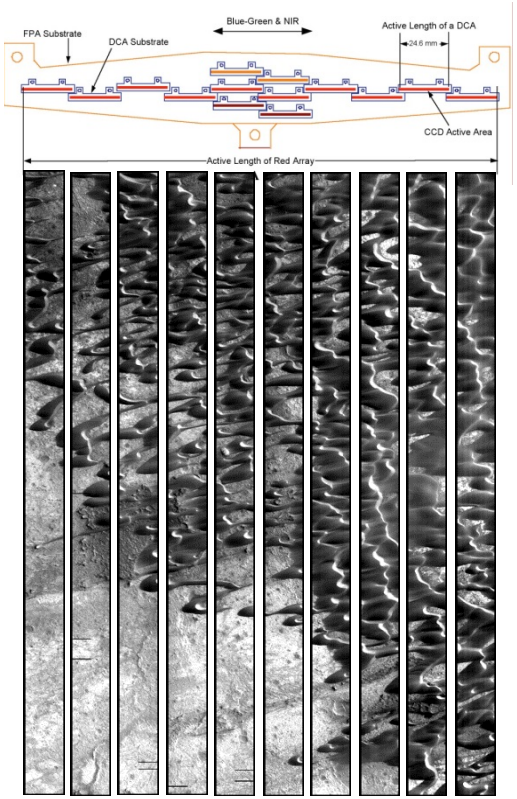

2010
2011
2012
16 days

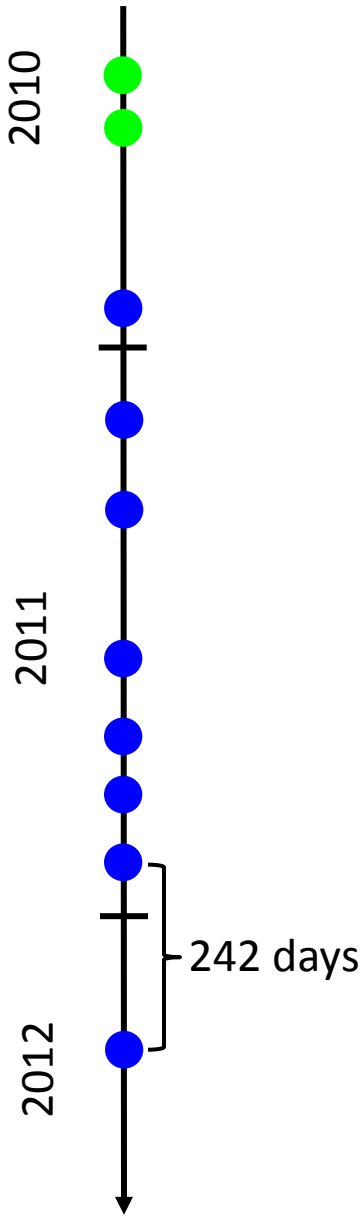

Ripple disp. (meter)
0
2
4+

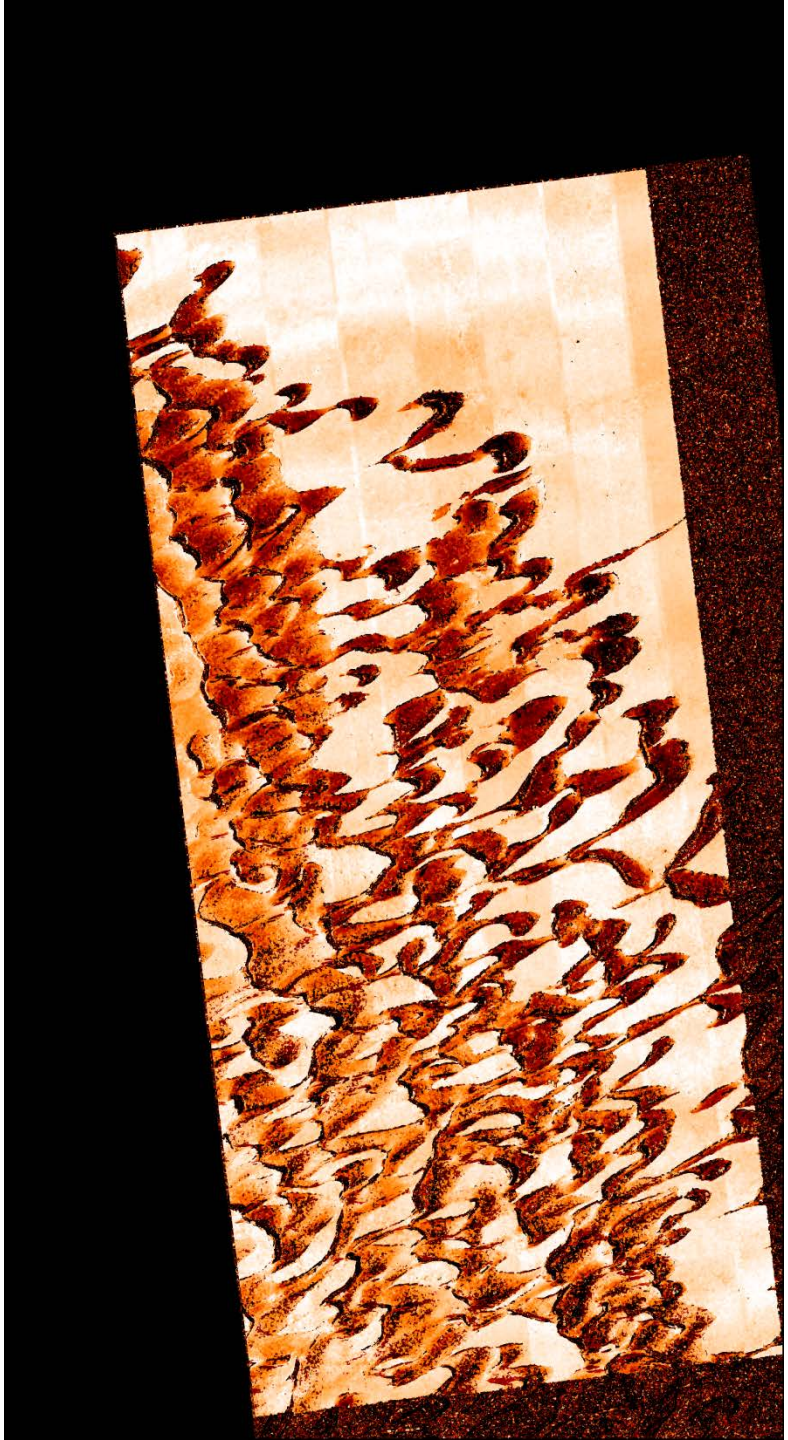

2010
2011
2012
28 days

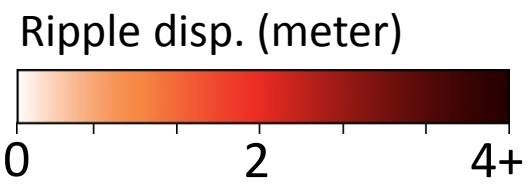



Ripple disp. (meter)
0
2
4+

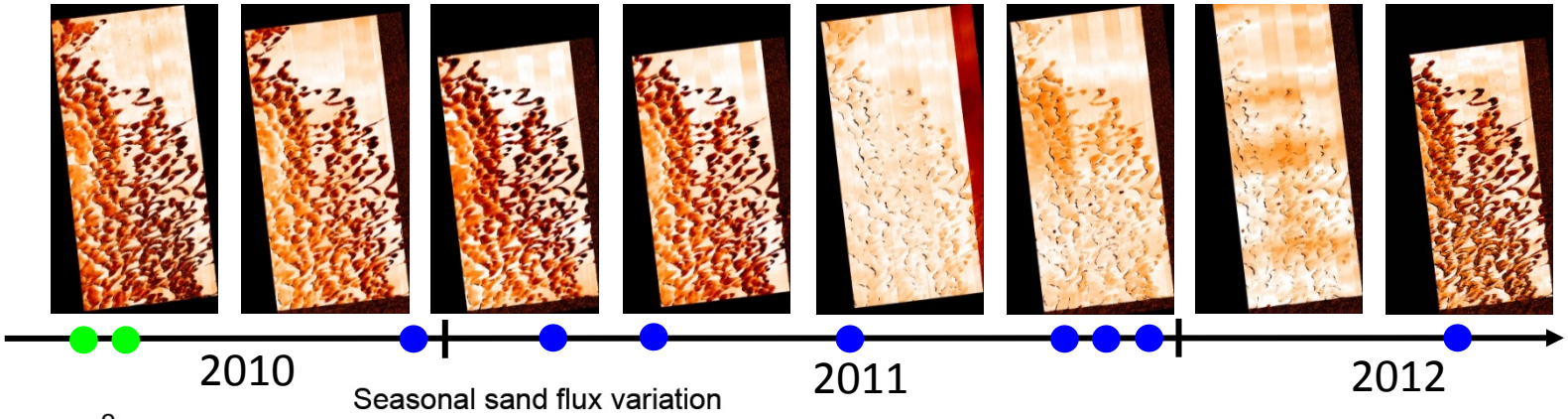

FPA Substrate
DCA Substrate
Blue-Green & NIR
Active Length of a DCA
24.6 mm
CCD Active Area
Active Length of Red Array

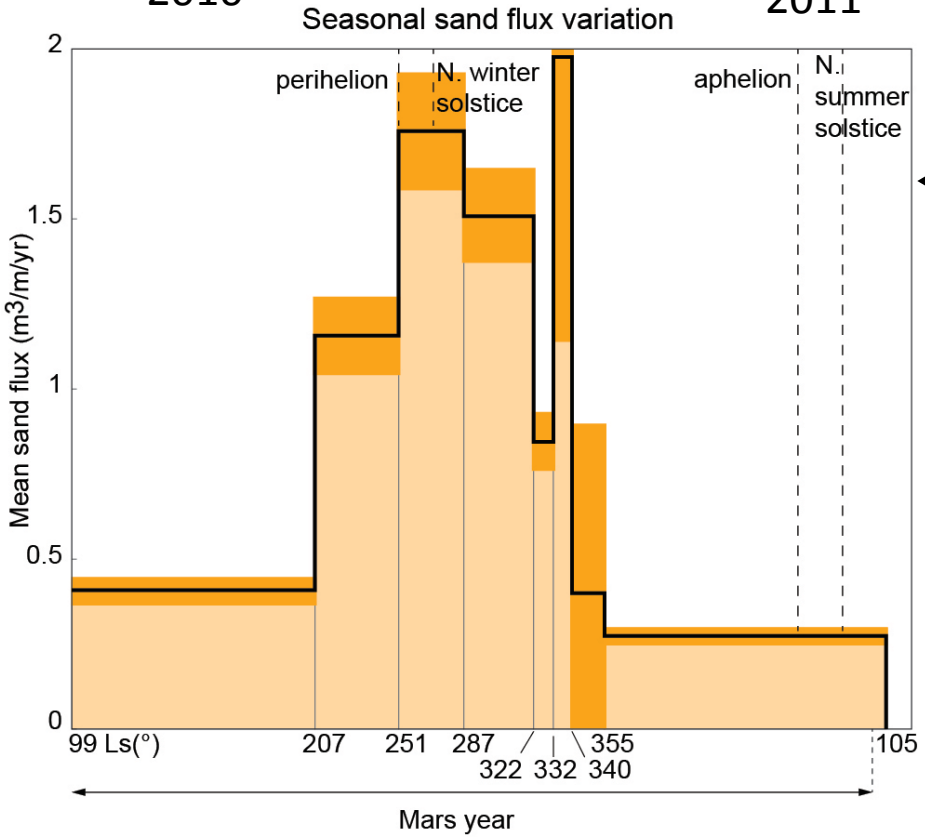

2010
2011
2012
242 days




Ripple disp. (meter)
0
2
4+

Estimating sand flux variability from ripple migration





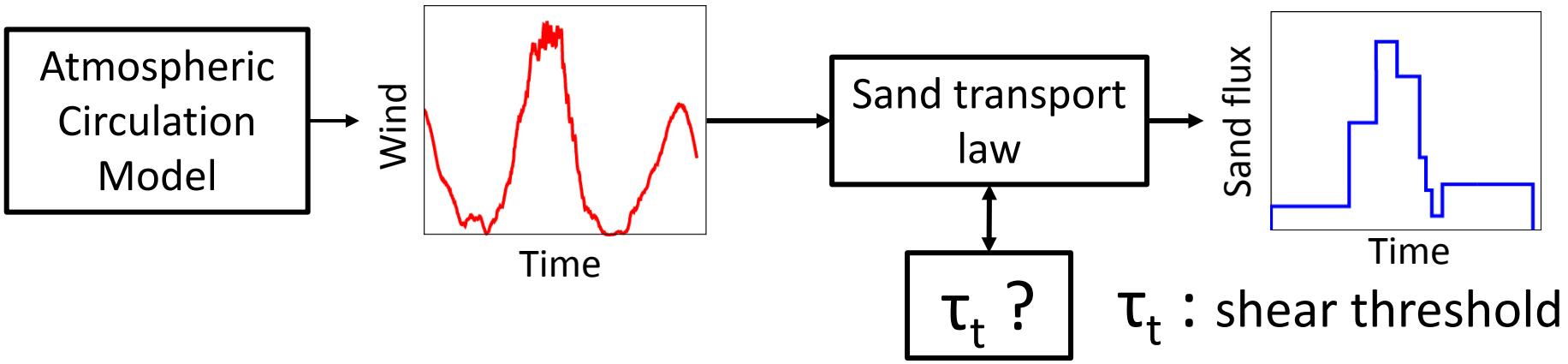
Using the measured ripple migration, we estimate a sand flux

We observe a strong seasonal variation of the flux

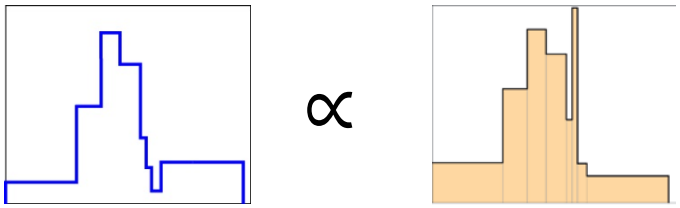
What could this sand flux measurement tell us about the sand shear stress threshold?

Which sediment shear threshold would allow climatic simulations to reproduce the sand flux observed?

What could this sand flux measurement tell us about the sand shear stress threshold?

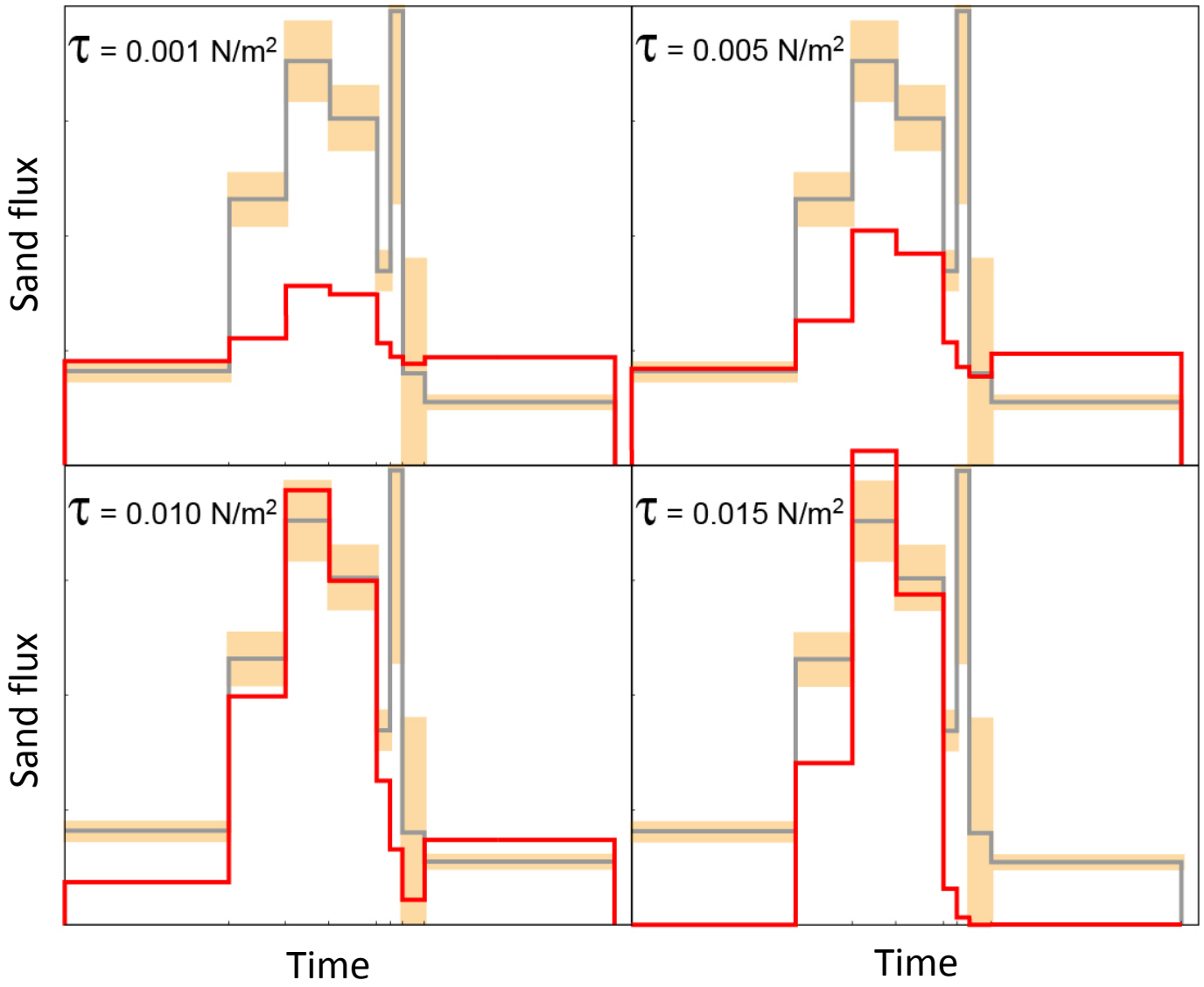


$Q_{predicted} \propto Q_{measured}$



Linear regression between predicted and measured fluxes for a range of τ_t

Only a small range of τ_t allows to reproduce the seasonal flux variation observed



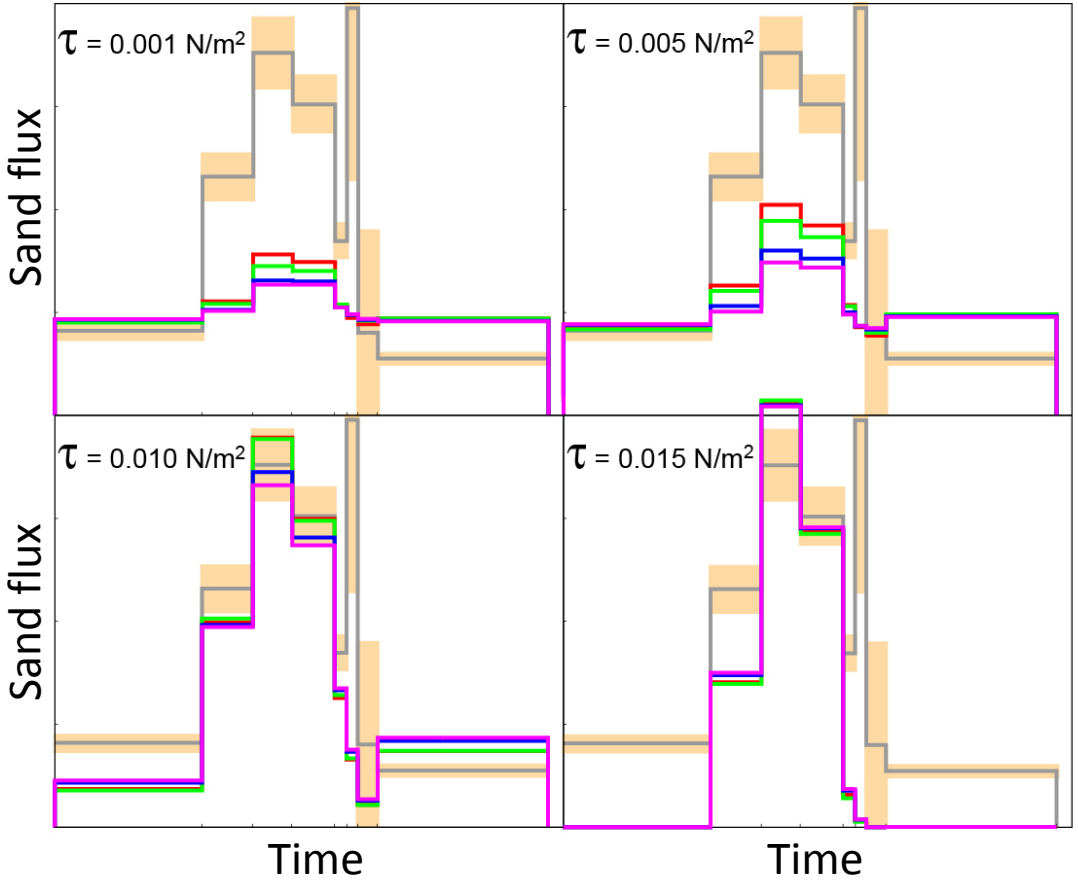
$Q_{measured}$

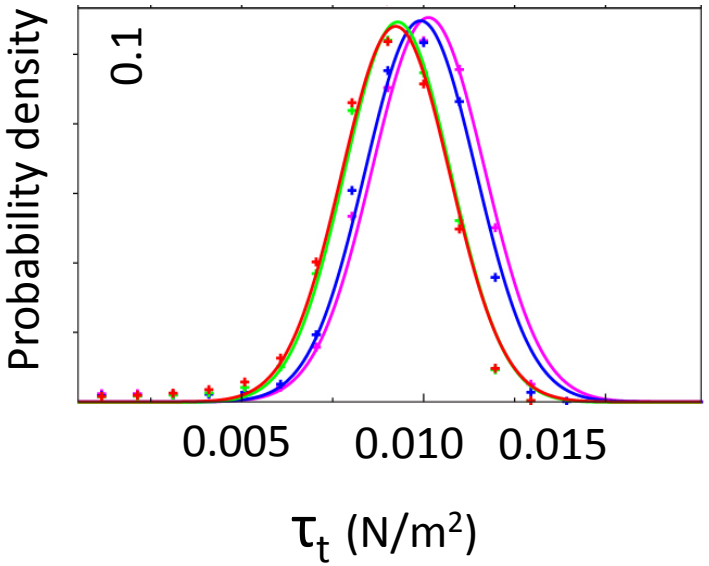
$Q_{predicted}$ (Lettau & Lettau)

Different transport laws give approximately the same optimal threshold

$$Q \propto \rho u^{*2}(u^* - u_t^*)$$
$$Q \propto \rho(u^{*2} - u_t^{*2})^{1.2}$$
$$Q \propto \rho u_t^*(u^{*2} - u_t^{*2})$$
$$Q \propto \rho(u^{*3} - u_t^{*2}/u^*)(\alpha + \gamma\, u_t^*/u^* + \beta\, u_t^{*2}/u^{*2})$$

Lettau & Lettau
Werner
Durán et al.
Sørensen





τ_t = 0.009-0.01 ± 0.0015 N/m²

Conclusion

1) HiRISE imager is an adequate sensor to detect and measure small scale surface processes. Potential geometric limitations due to CCD and jitter artifacts.

2) Measurement of the sand flux, and its seasonal variation. Estimation of an '*effective*' shear stress threshold relevant for simulation at scale from few km to few degrees.

However: Methodological limitations (dunes migration tracking,…)
Imagery limitations (stereo-pair acquistion, ripple resolution)