Sentinel-1 synthetic aperture radar coherence for erosion mapping in arid and semi-arid environments

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Bodo Bookhagen

19th Wegener General Assembly
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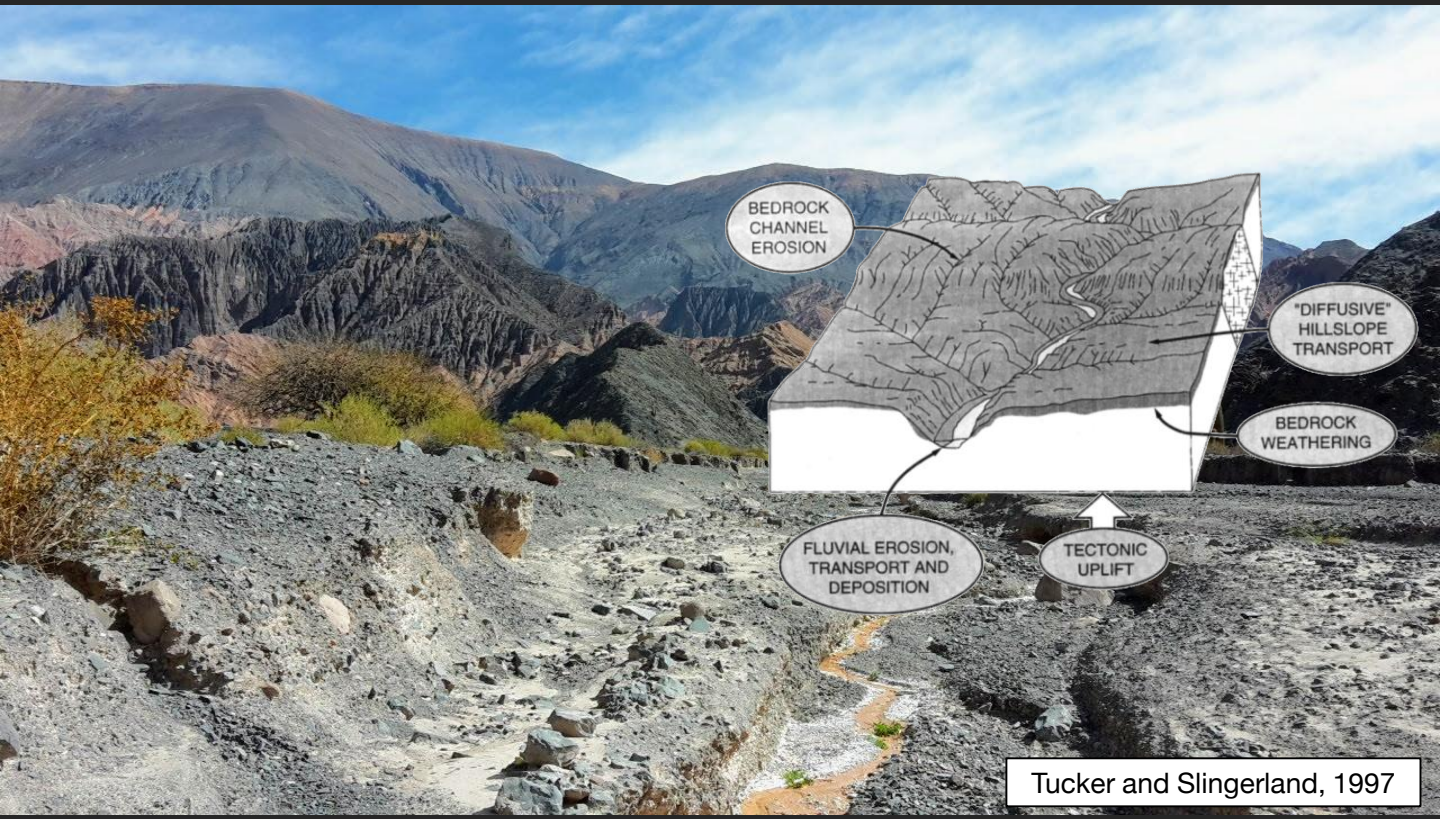
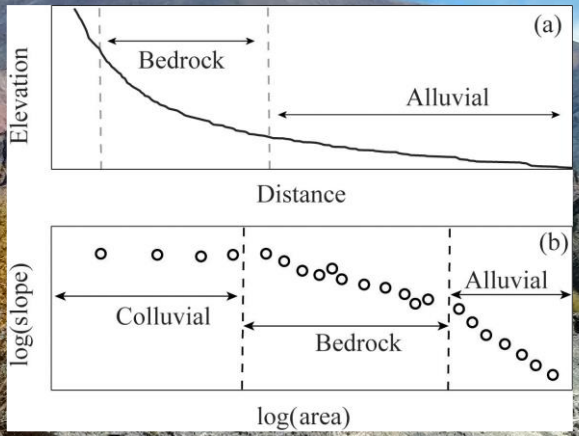
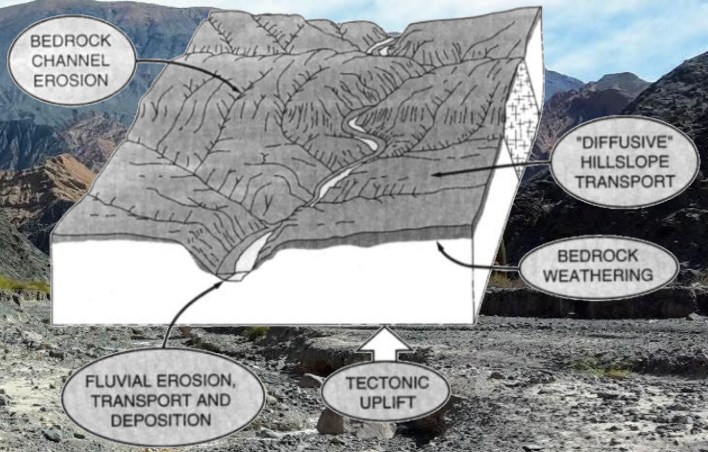


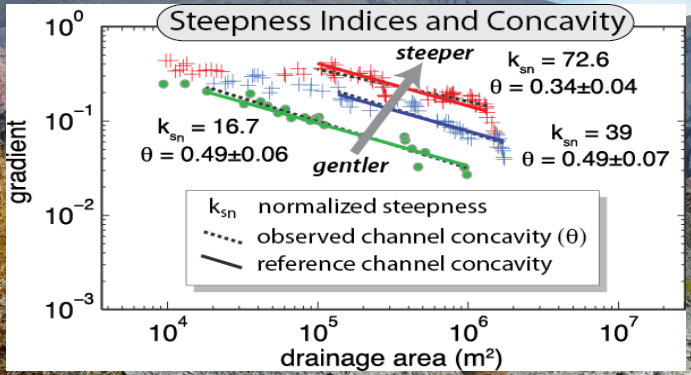
Tucker and Slingerland, 1997

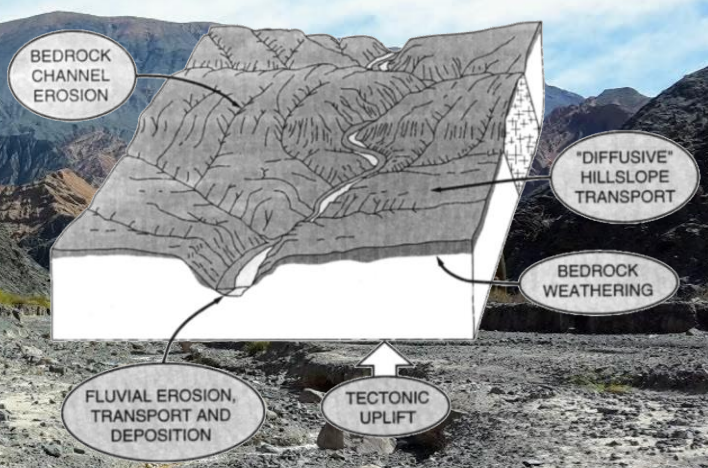




After Montgomery and Foufoula-Georgiou, 1993

Tucker and Slingerland, 1997





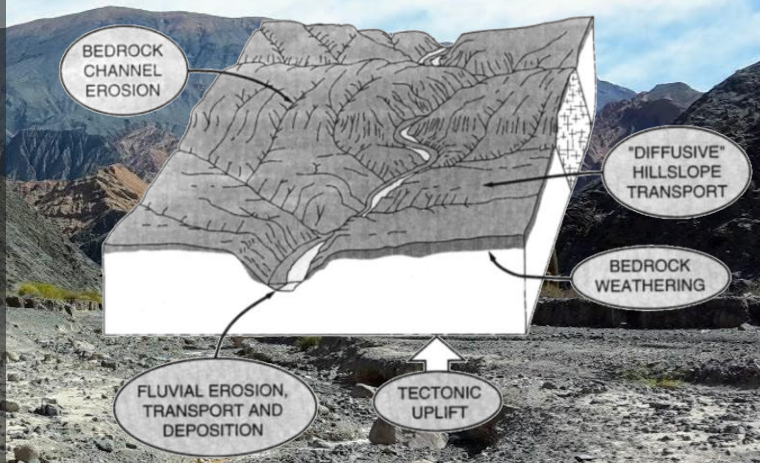
Burbank and Anderson, 2011

Tucker and Slingerland, 1997

1. *Can we track sediment movement through SAR imagery?*

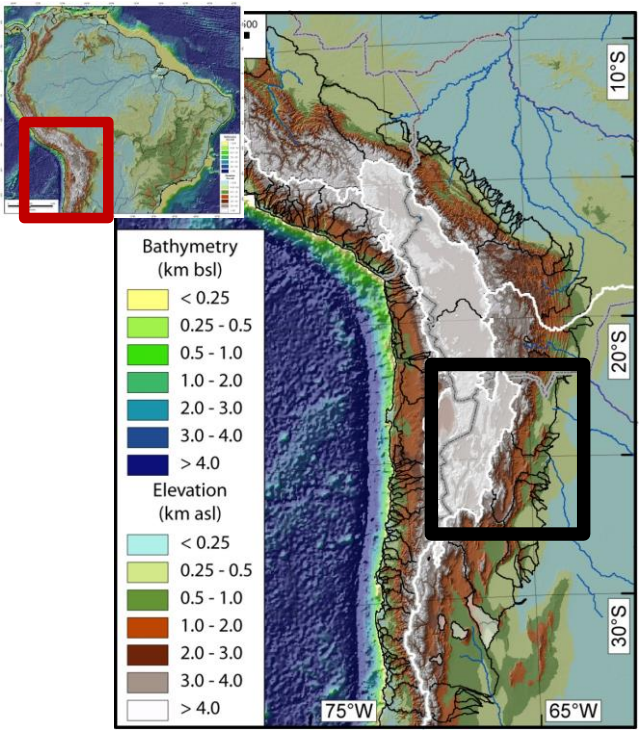
2. *What methods can we use to effectively map and quantify the transition between bedrock and alluvial regimes?*

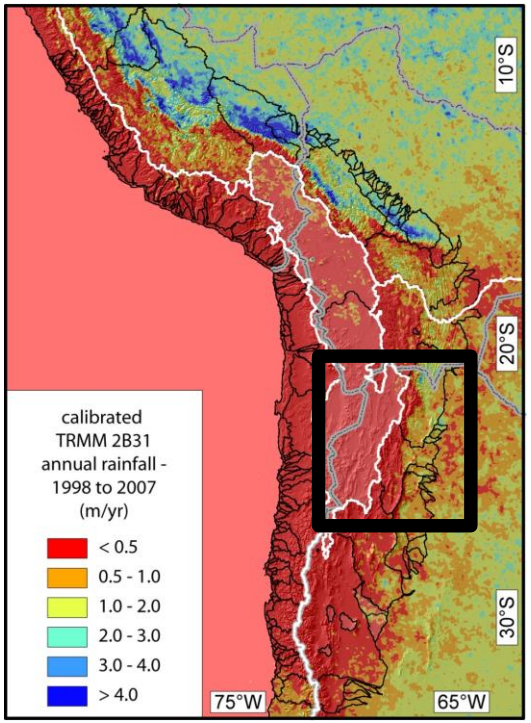
3. *How do these transitions change over different geologic, climatic, or biotic environments?*



Tucker and Slingerland, 1997

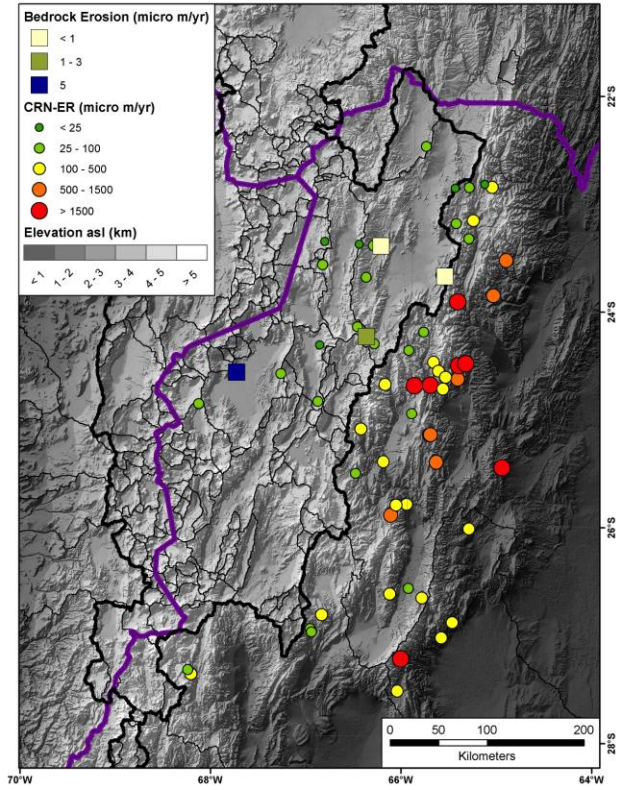
Climatic Gradients in the Central Andes



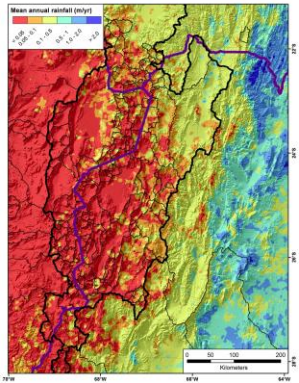


Bookhagen and Strecker, 2008 , 2012

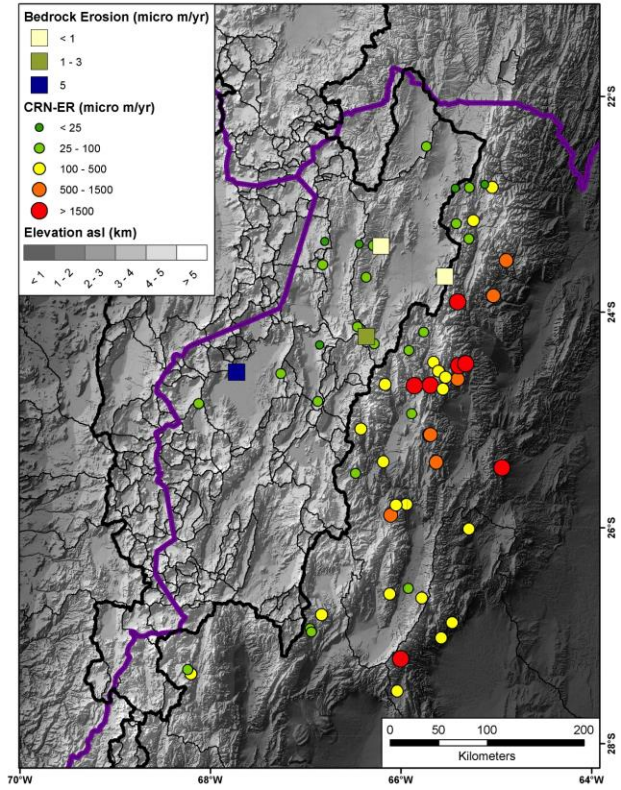
Southern Central Andes – CRN erosion rates



- 59 CRN-derived erosion rates
- East-to-West erosion gradient roughly follows climatic gradient



Bookhagen and Strecker, 2012 , 2015



Southern Central Andes – CRN erosion rates

- 6 bedrock erosion-rate samples (10Be/26Al) indicate westward increasing aeolian erosion

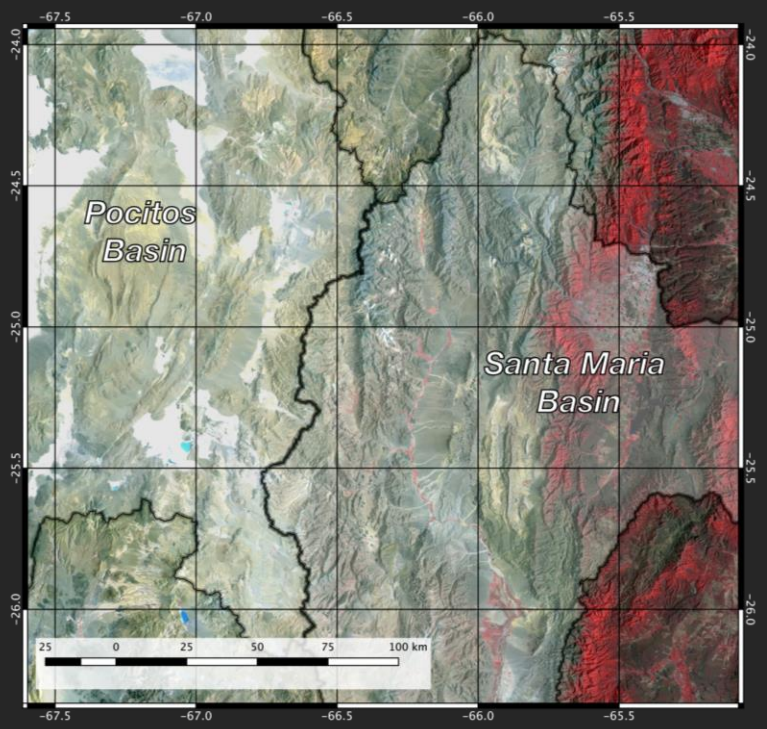
Bookhagen et al., in prep.

Mapping erosional transitions in the Central Andes

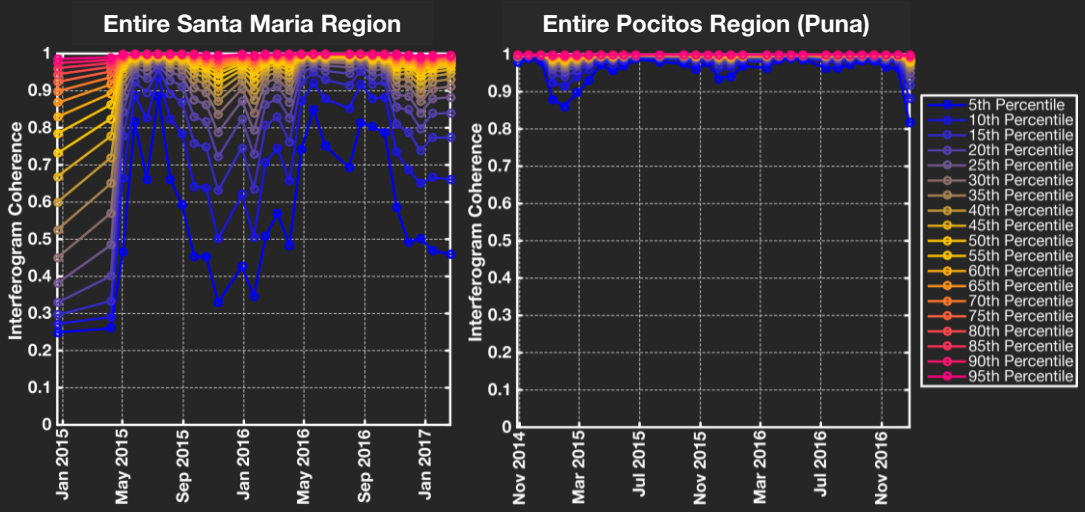
Santa Maria Basin:	Pocitos Basin (Puna):
2014-12-21 to 2017-03-04 Ascending Track 10 Average Temporal Baseline: 12/24 days	2014-10-27 to 2017-01-20 Ascending Track 76 Average Temporal Baseline: 12.24 days

Regions masked out:

1. ***Surface slope angle of less than 8 degrees*** (TanDEM-X 12-m Research DEM)
2. ***NDVI (Normalised Difference Vegetation Index) greater than 0.2*** (LANDSAT-8 30-m NDVI using three year greenest pixel average)
3. ***Shadowed regions and regions with uncharacteristically low amplitude*** (soil moisture proxy)



Coherence value between each adjoining date



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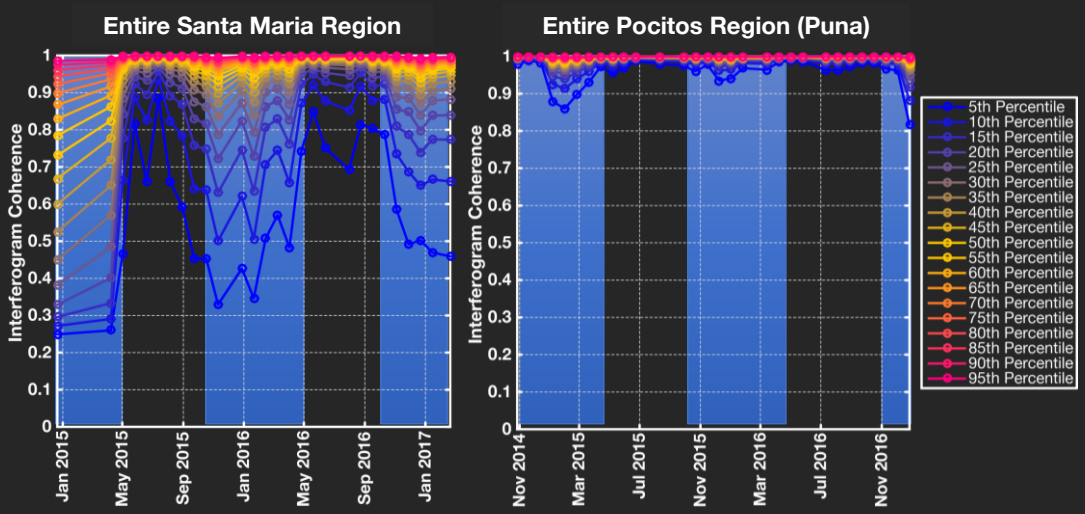
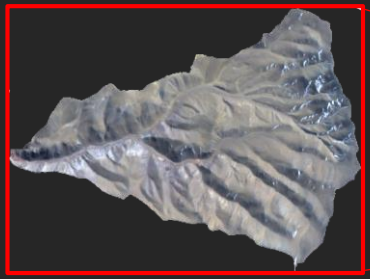
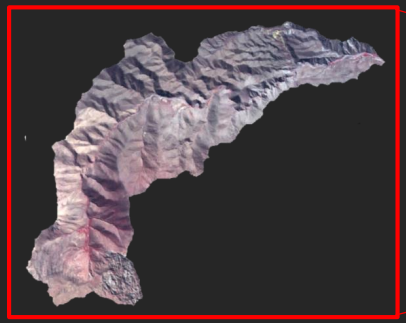


Seasonal coherence loss corresponding to wet-dry cycles

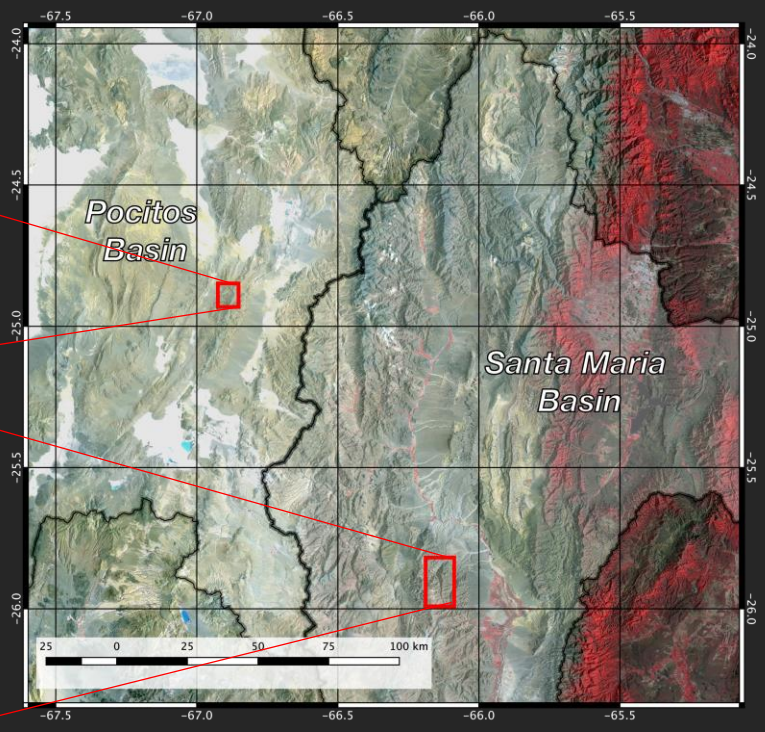
Mapping erosional transitions in the Central Andes

How does coherence behave at local watershed scales?

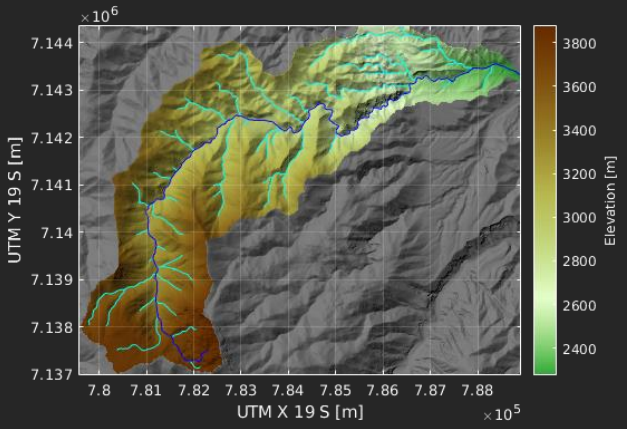


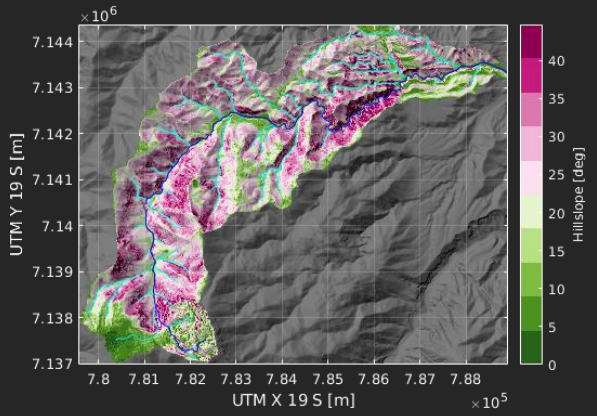


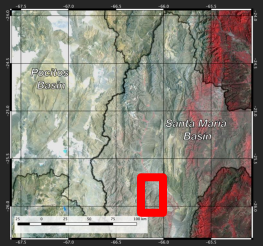
Sentinel-2 False Color
R = NIR
G = Red
B = Green



Mapping erosional transitions in the Central Andes



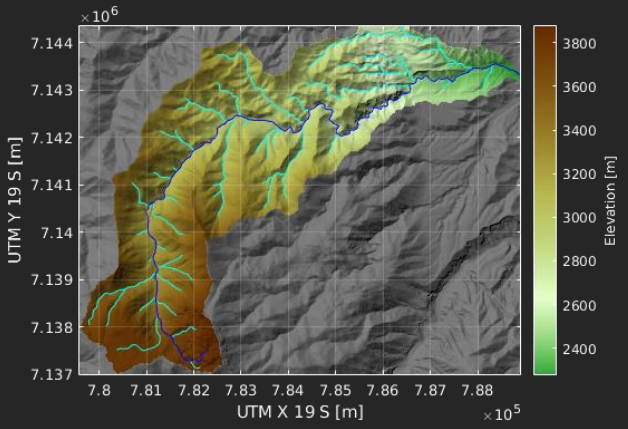


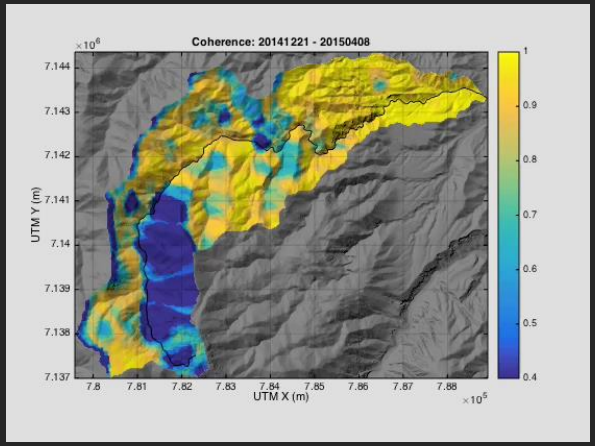


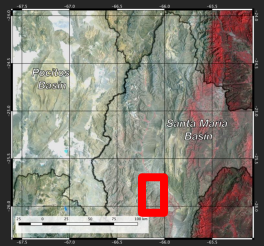
Santa Maria Tributary Characteristics:

Basin Area: 25.8 km^2
Median Elevation: 2932 m asl
Median Annual Rainfall: 370 mm/yr
Median Hillslope Angle: 20.13 degrees
Median 100-m Relief: 78.75 m

Mapping erosional transitions in the Central Andes







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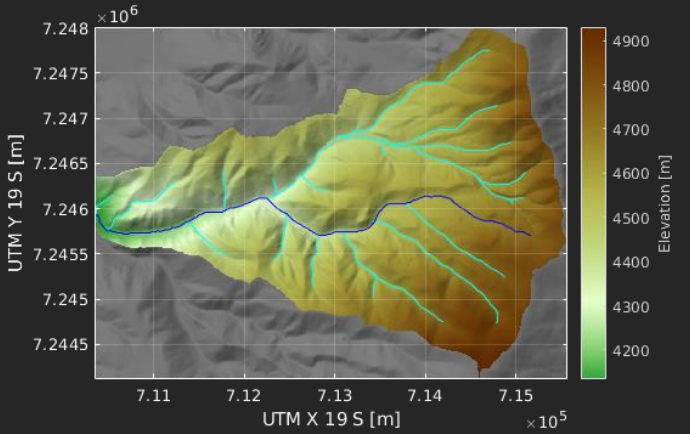
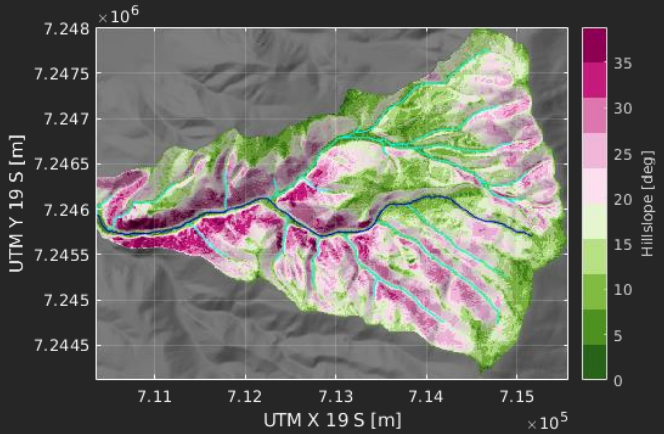
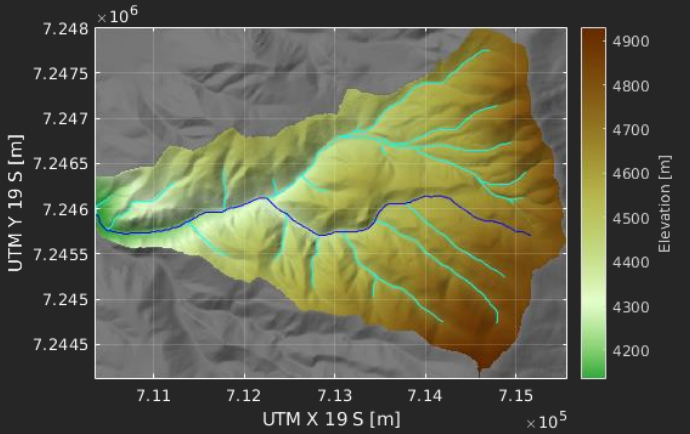


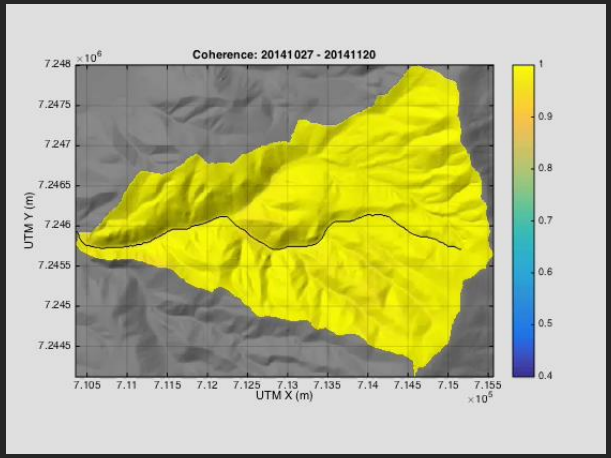


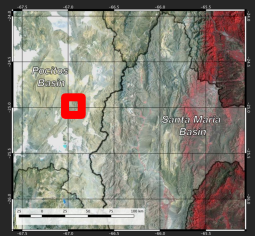
Pocitos Tributary Characteristics:

Basin Area: 18.11 km^2
Median Basin Elevation: 4604 m asl
Median Annual Rainfall: 168 mm/yr
Median Basin Slope: 18.4 degrees
Median 100-m Relief: 73.5 m

Mapping erosional transitions in the Central Andes







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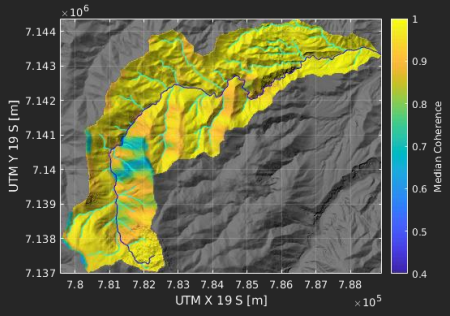

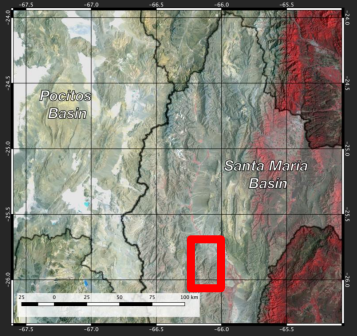

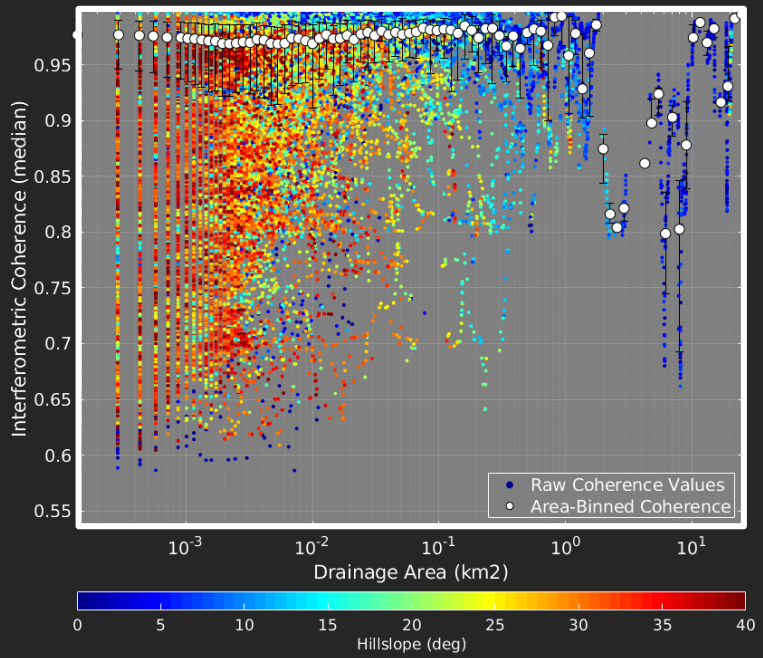

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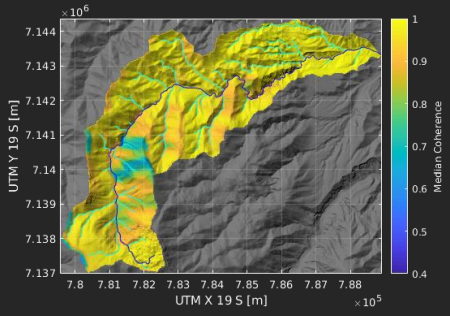
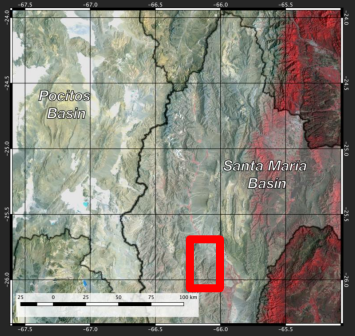
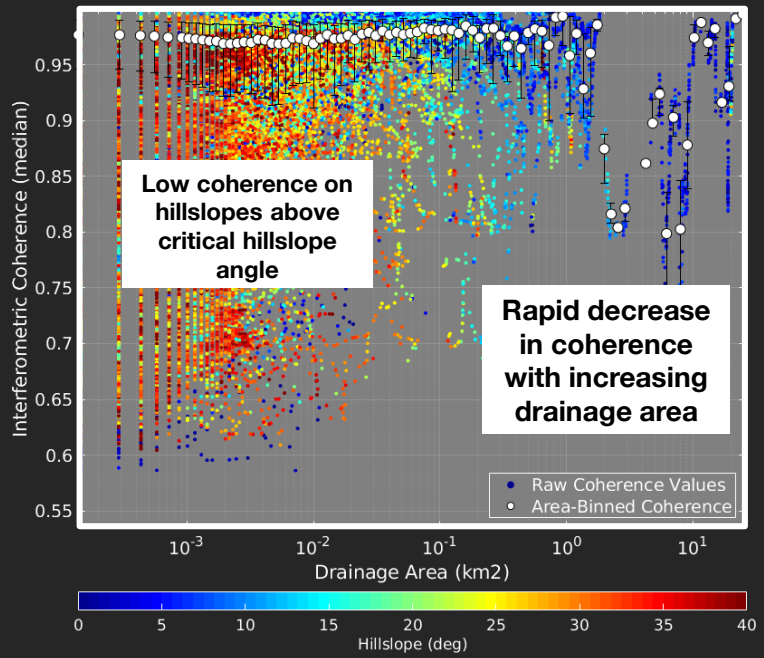


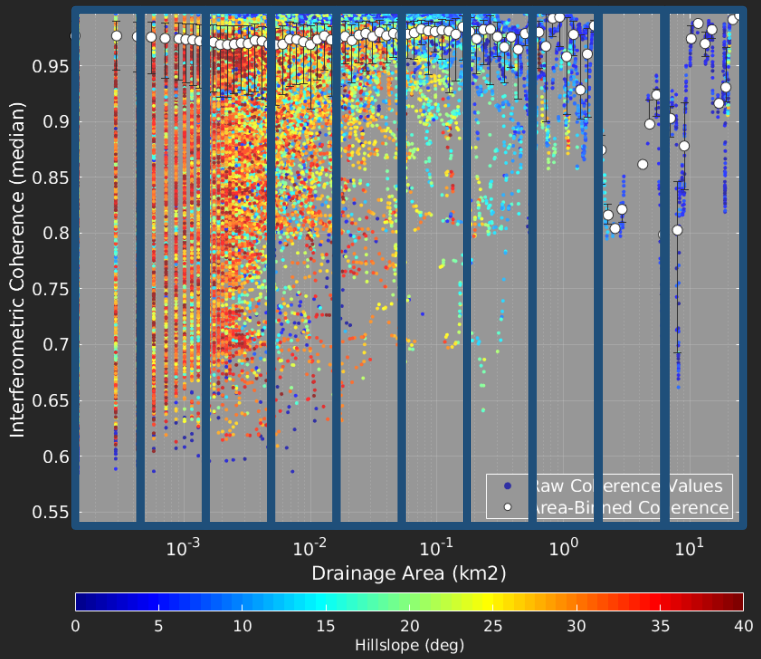




Mapping erosional transitions in the Central Andes

Change point detection in area-coherence relationship:

- Bin coherence values by drainage area (log-spaced bins)
- Calculate relevant statistics of each bin (percentile range [95th – 5th], skewness, standard deviation, median, mean)
- Perform change point analysis based on cumulative sums (Taylor, 2000)
    1. Repeat with multiple bin numbers (20-200 bins), including all samples in each bin
    2. Set single bin number (e.g., 100) and use bootstrapping to subsample the dataset



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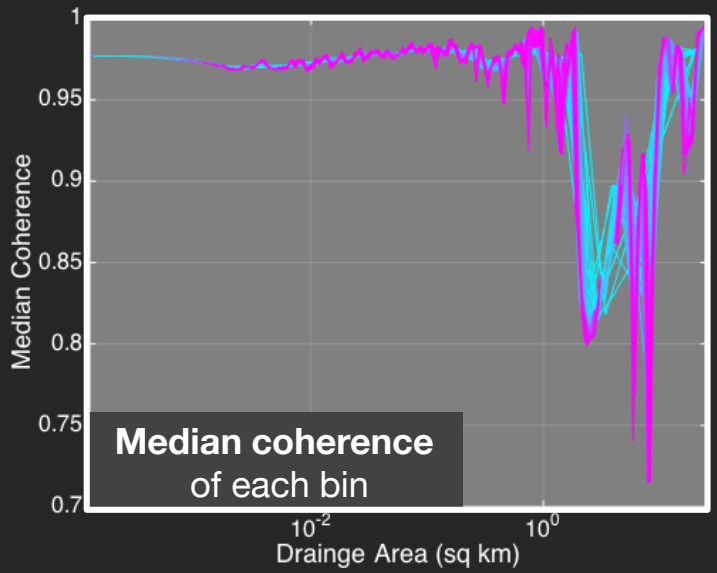

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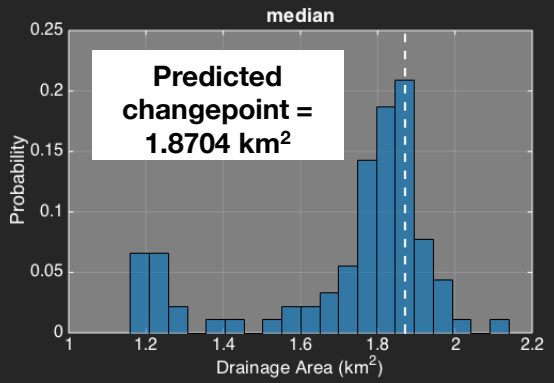
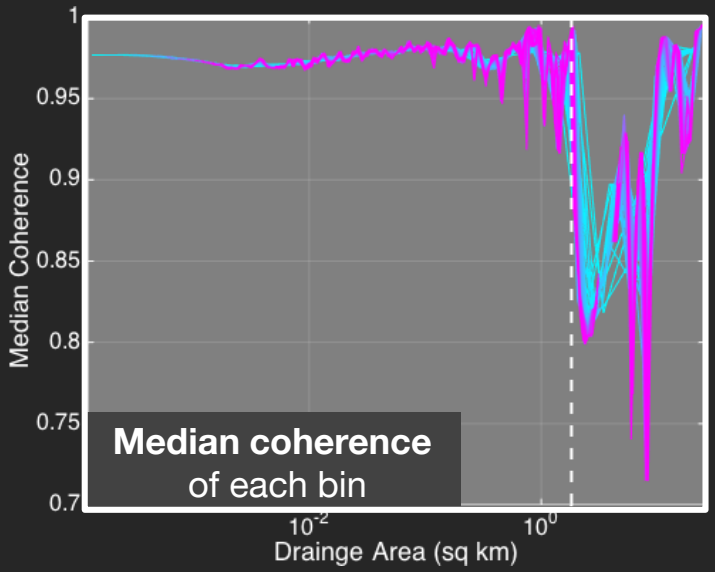
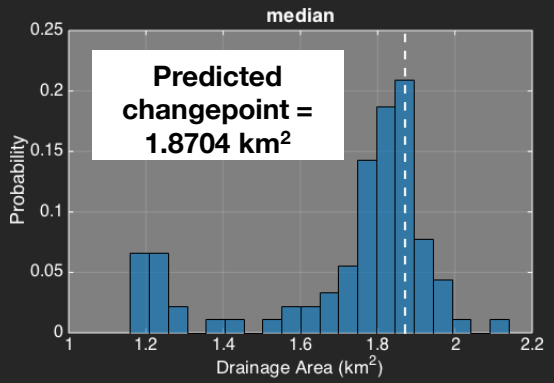
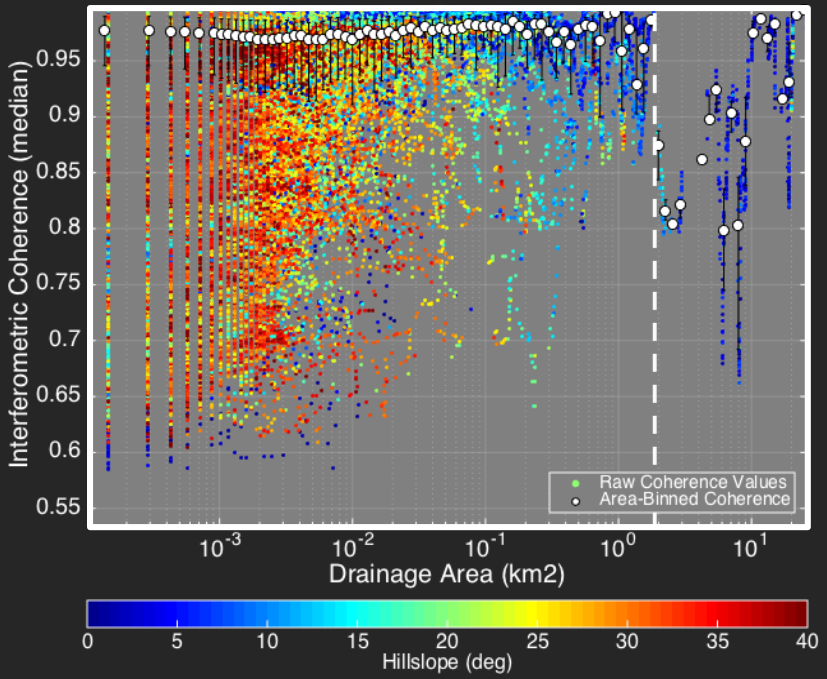




Mapping erosional transitions in the Central Andes

Decrease in coherence with increasing drainage area





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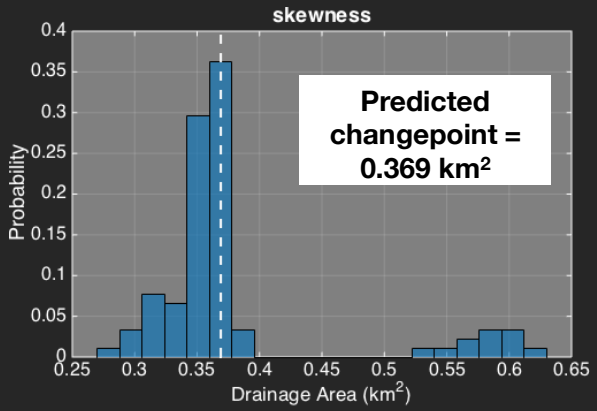
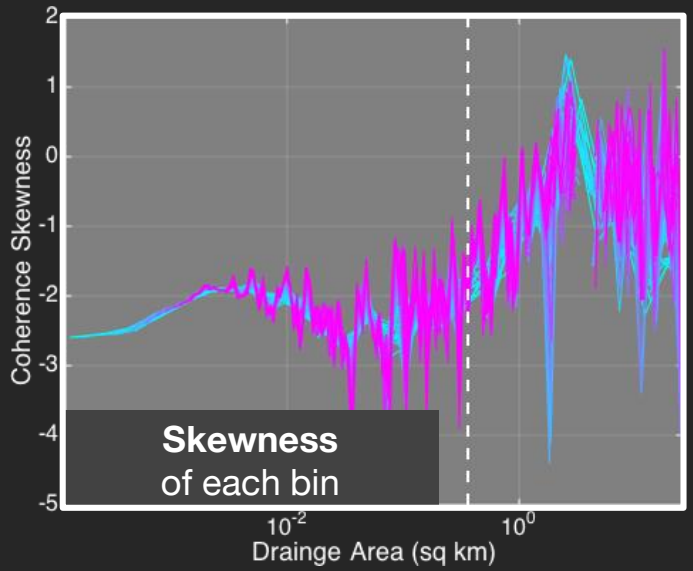
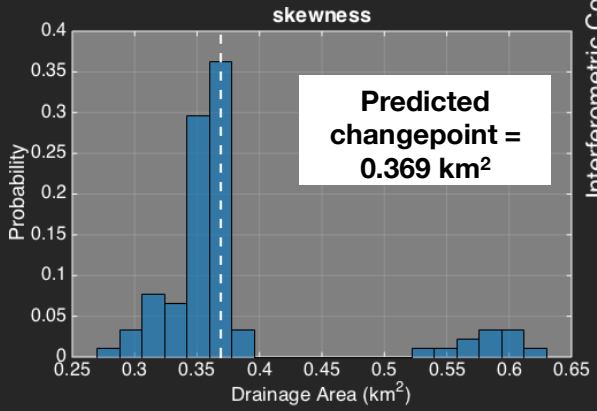
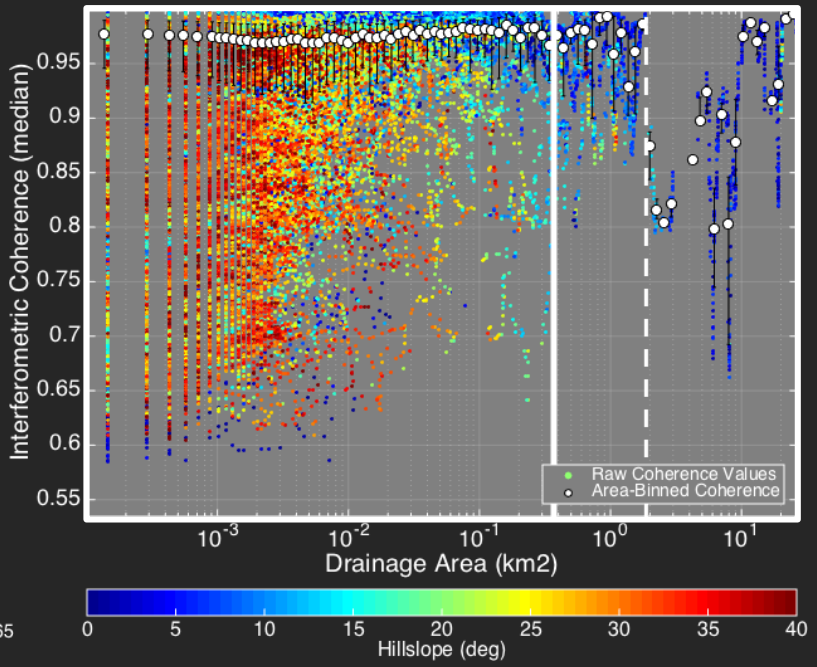




Mapping erosional transitions in the Central Andes

Low coherence on hillslopes above critical hillslope angle



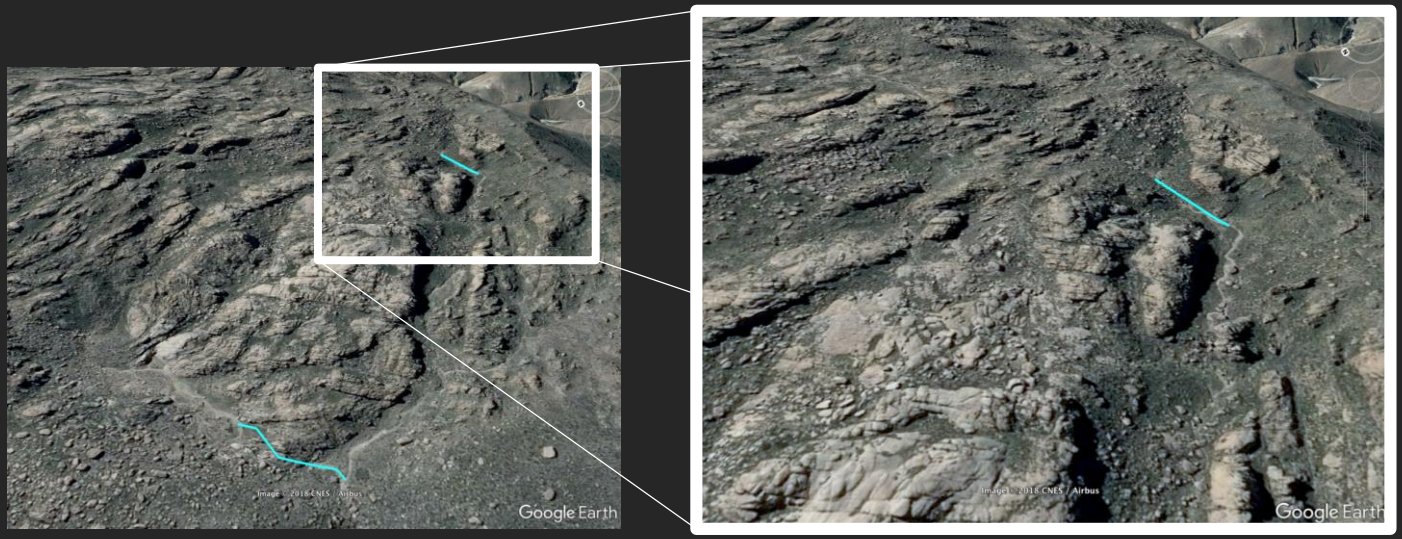


Mapping erosional transitions

Development of bedrock-fluvial channel

Mapping erosional transitions

Development of bedrock-fluvial channel



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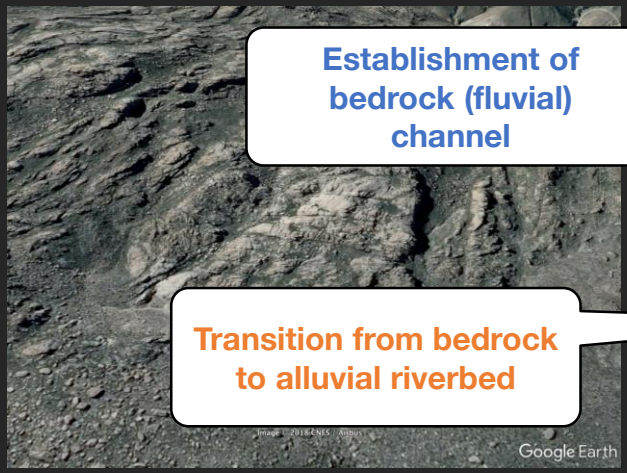
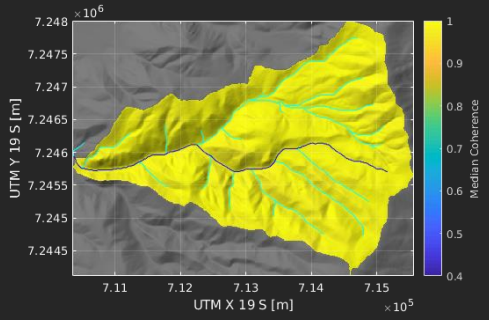
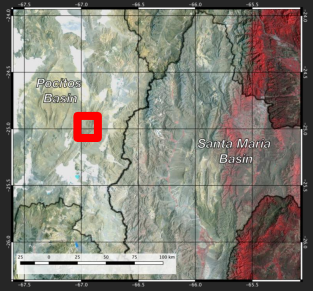
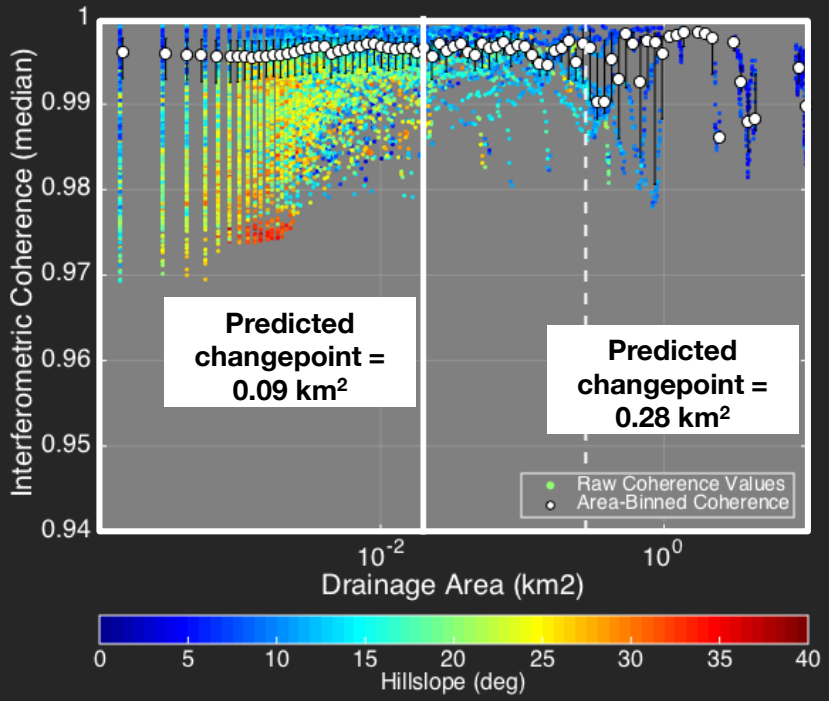


Mapping erosional transitions in the Central Andes

Pocitos Tributary







Pocitos Tributary

Establishment of bedrock (fluvial) channels

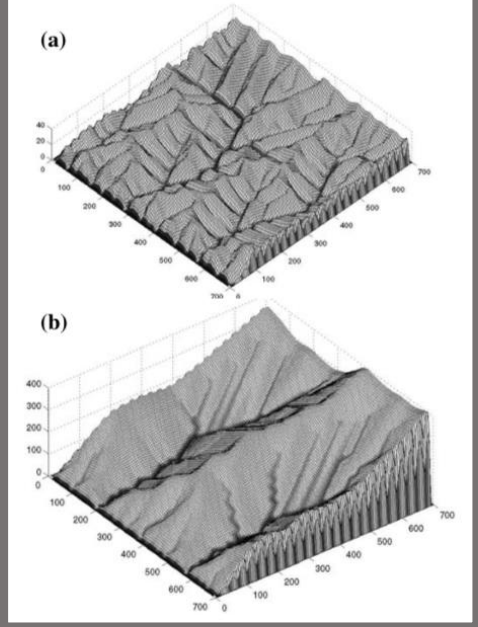
Transition from bedrock to alluvial riverbed

Preliminary Conclusions

1. Sediment movement on hillslopes and in alluvial channels detectable with InSAR coherence.

2. Sentinel-1 coherence can be used to map hillslope-bedrock (fluvial) and bedrock-alluvial transitions in landscapes in arid and semi-arid landscapes (with minimal vegetation).

3. Erosion transitions to bedrock regime at smaller drainage areas in the arid Pocitos Basin (Puna Plateau), while hillslopes make up a relatively larger part of the erosional regime in the semi-arid Santa Maria Basin (confirming modelling studies).



(Istanbuollogu and Bras, 2005; JGR)