Erosion and Climate in South America – Examples from the Central Andes

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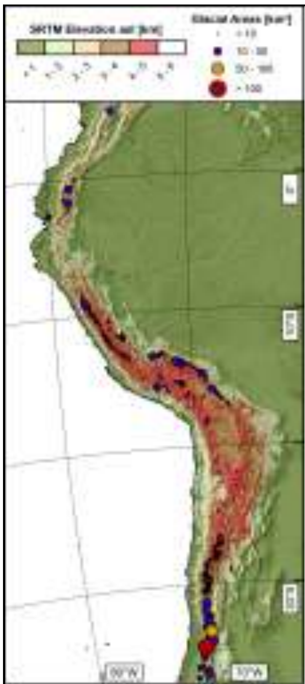
Climate and Weather of South America

1. **Climate of South America and the South American Monsoon System**
2. **Impact of Climate on the Environment**
   - Amazon discharge
   - Glacial retreat
   - Lake levels on the Central Andean Plateau
3. **Weather and Climate of the NW Argentine Andes**

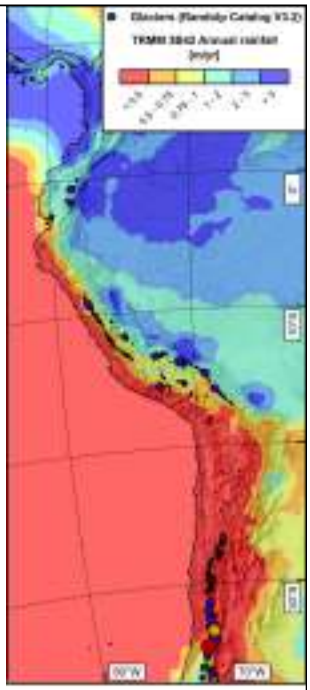
Erosion and Climate in the Central Andes

1. **Linkages between Erosion and Climate**
   - Rates of sediment flux
   - Millennial-scale Erosion rates and their spatial pattern
2. **Tectonic Processes**

Glaciers in South America



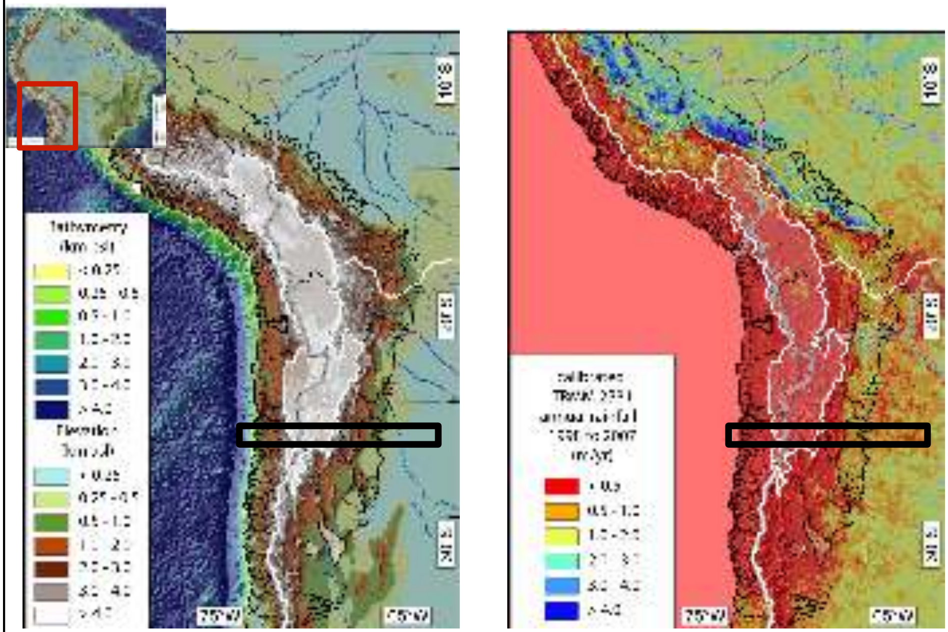
Topography and glacier locations (RGI V4).



TRMM 3B42 V7 mean annual rainfall.

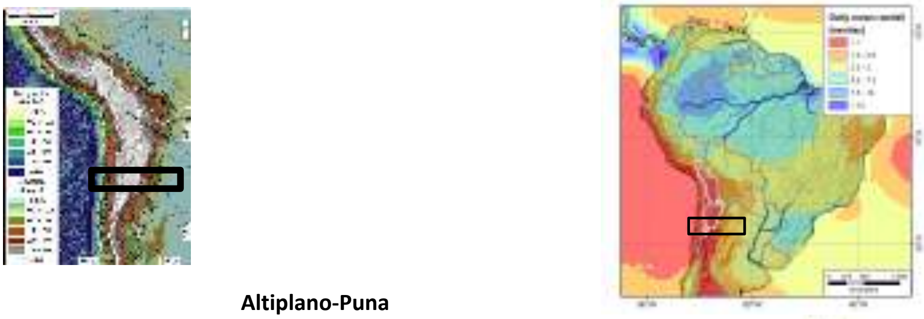
Bookhagen, 2015, *Glaciers and Monsoon Systems* in **The Monsoons and Climate Change**, Springer

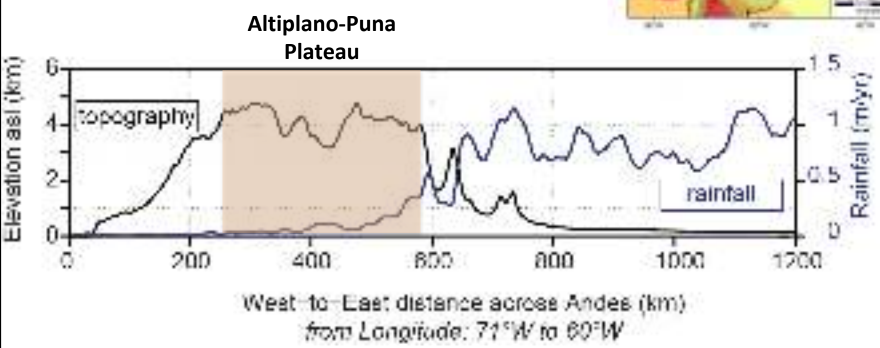
Climatic Gradients in the Central Andes



Bookhagen and Strecker, 2008 , 2012

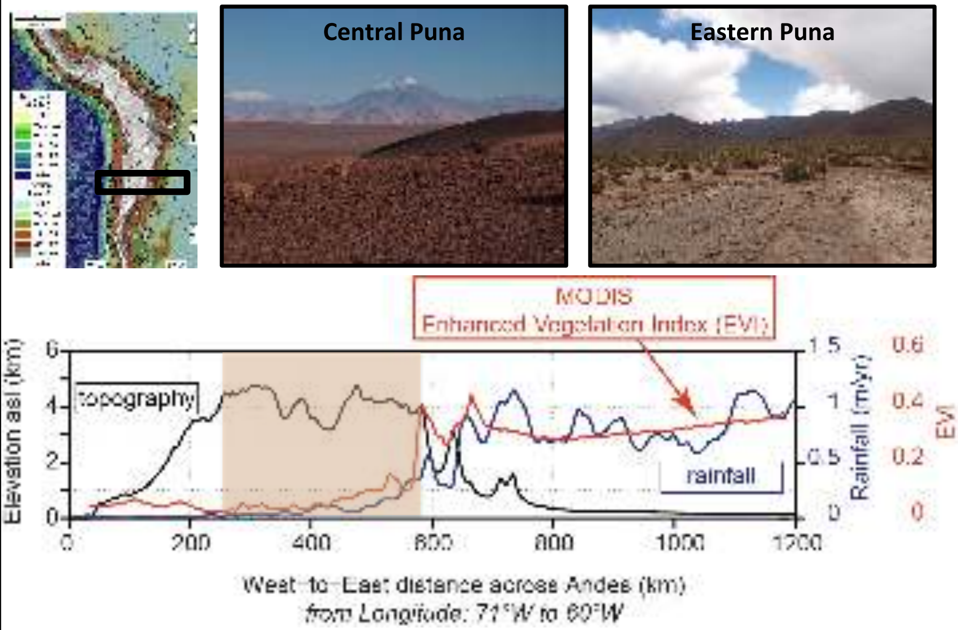
Climatic Gradients in the Southern Central Andes





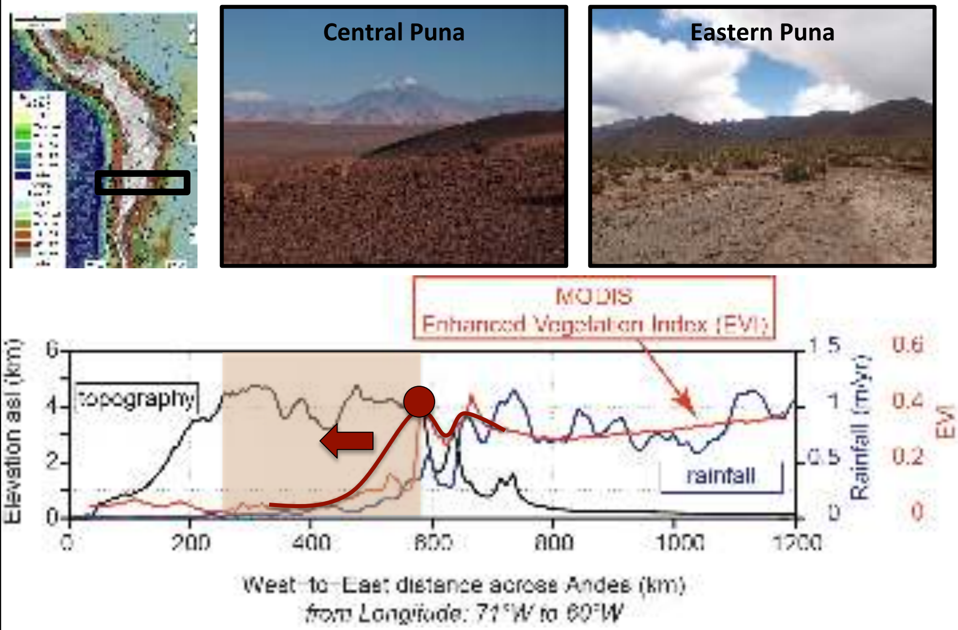
Bookhagen and Strecker, in preparation

Climatic and Vegetation Gradients in the S. Central Andes



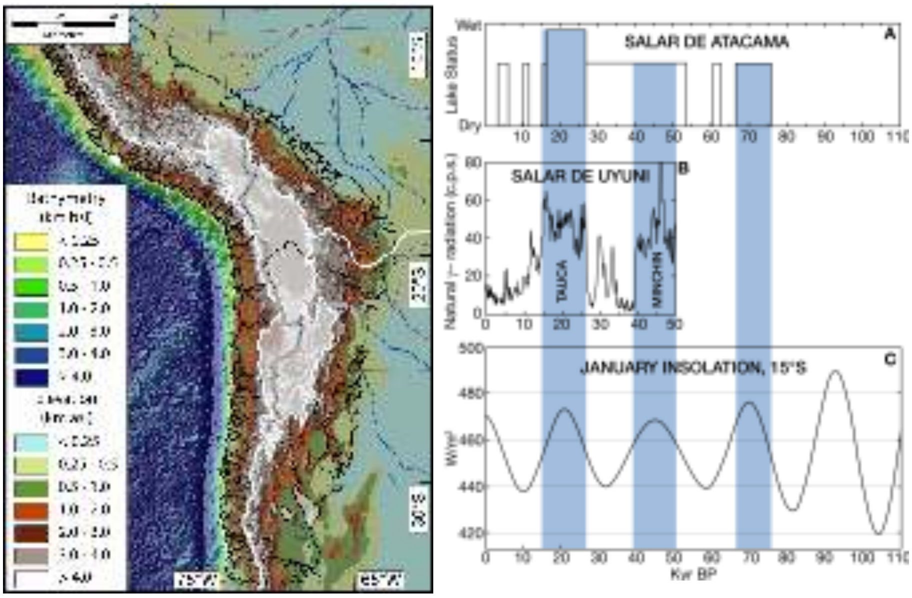
Bookhagen and Strecker, in preparation

Climatic and Vegetation Gradients in the S. Central Andes



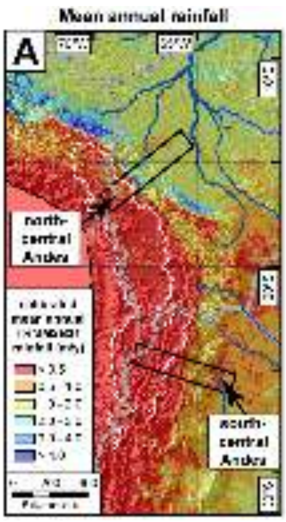
Bookhagen and Strecker, in preparation

Pleistocene-Holocene lake-level highstands in the Central Andes: paleoclimatic proxy record

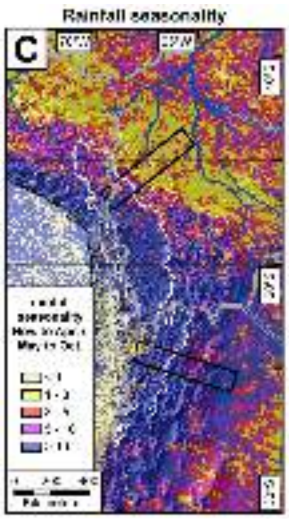


Bobst et al., 2001

Northern and Southern Central Andes



- **<u>Steep climatic gradient</u>: north-central Andes are wetter**
- **<u>High Contrast in Seasonality</u>: south-central Andes have much higher seasonal rainfalls**



Erosion and Climate in the Central Andes

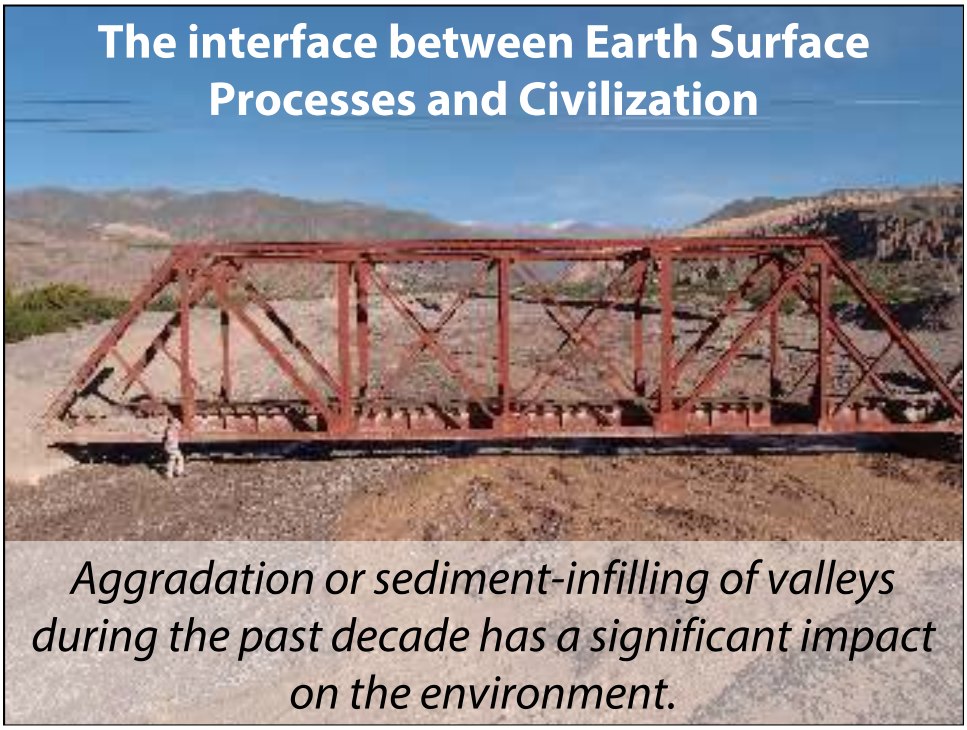
1. Linkages between Erosion and Climate

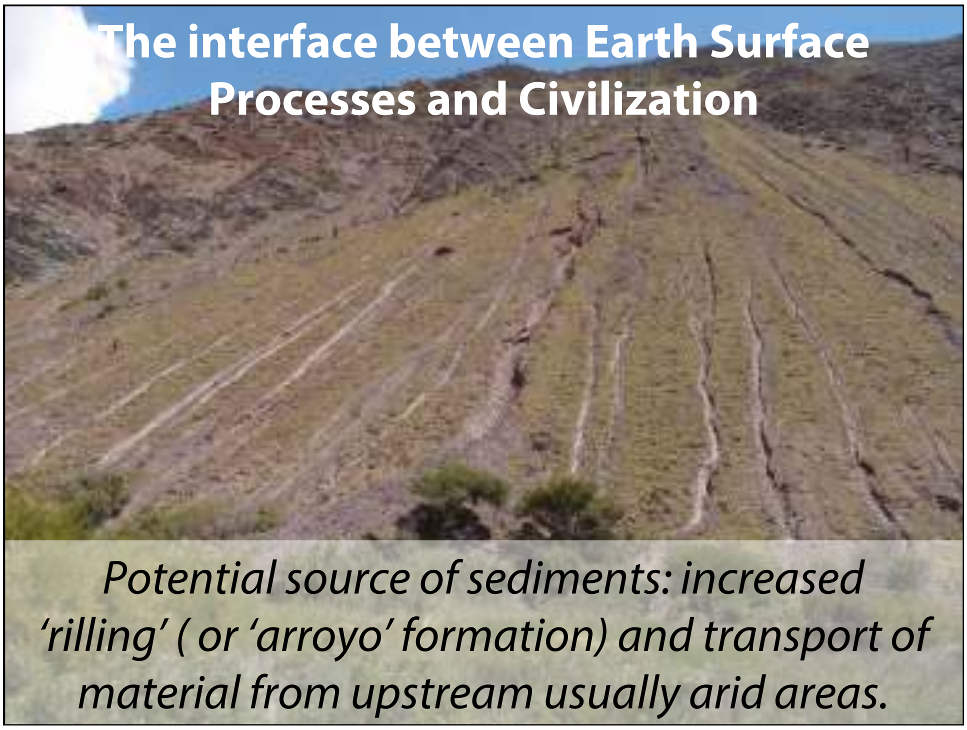
- Rates of sediment flux
- Millennial-scale Erosion rates and their spatial pattern

2. Tectonic Processes

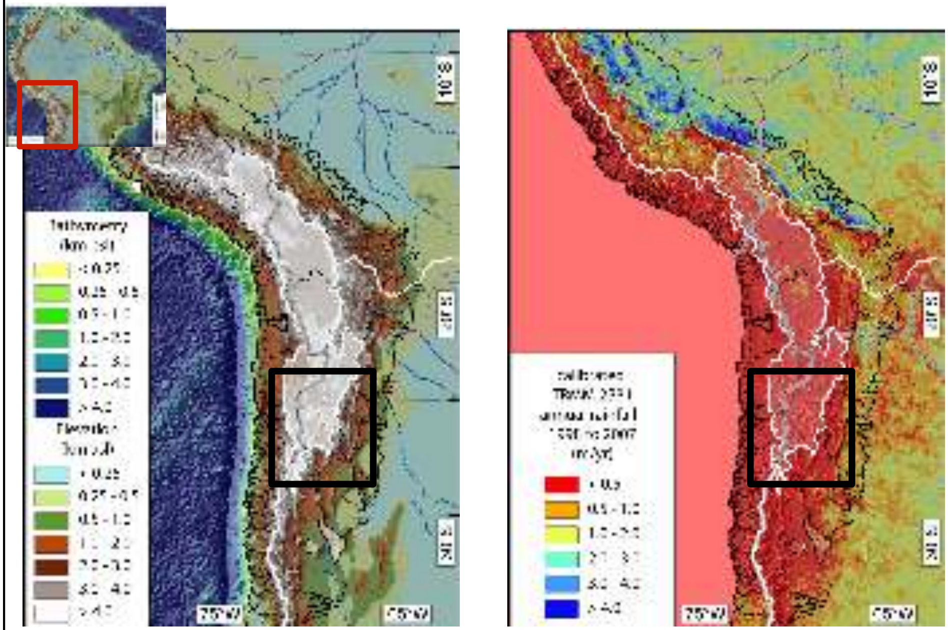
The interface between Earth Surface Processes and Civilization

Why do we care about mass-transport processes?


The interface between Earth Surface
Processes and Civilization
Aggradation or sediment-infilling of valleys
during the past decade has a significant impact
on the environment.


The interface between Earth Surface
Processes and Civilization
Potential source of sediments: increased
'rilling' (or 'arroyo' formation) and transport of
material from upstream usually arid areas.

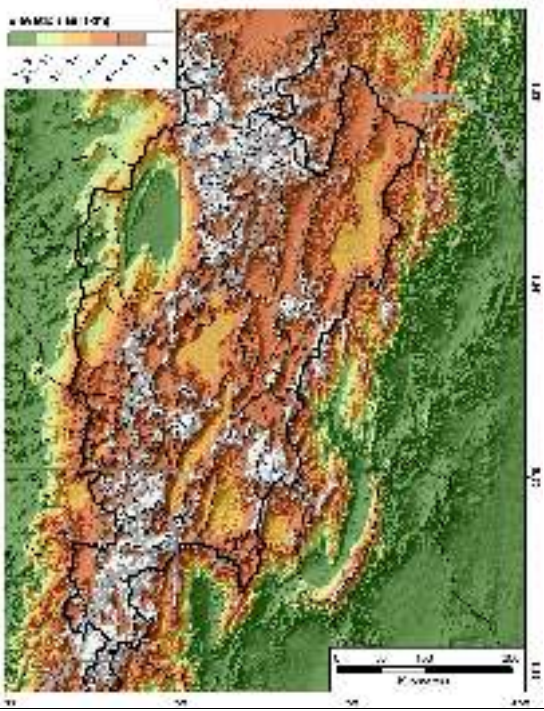
Climatic Gradients in the Central Andes



Bookhagen and Strecker, 2008 , 2012

Southern Central Andes –

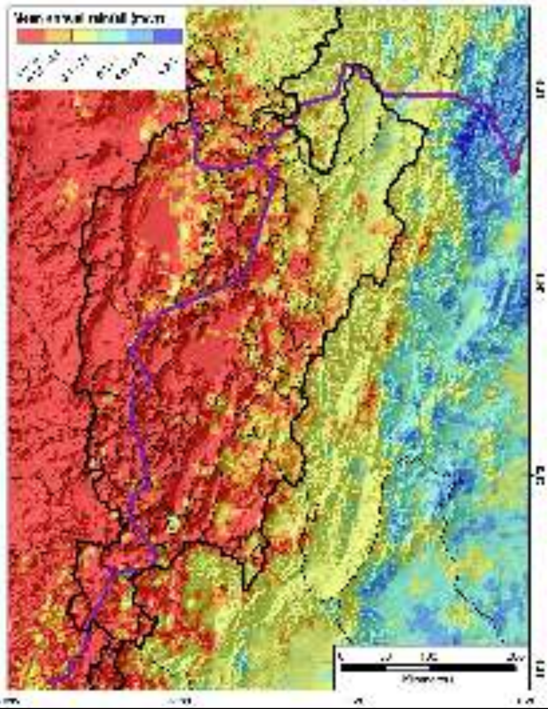
Southern Central Andes – Hydrologic Catchments of the Puna de Atacama



Southern Central Andes – Hydrologic Catchments of the Puna de Atacama

The Puna is separated into hydrologically disconnected catchments with variable sizes.

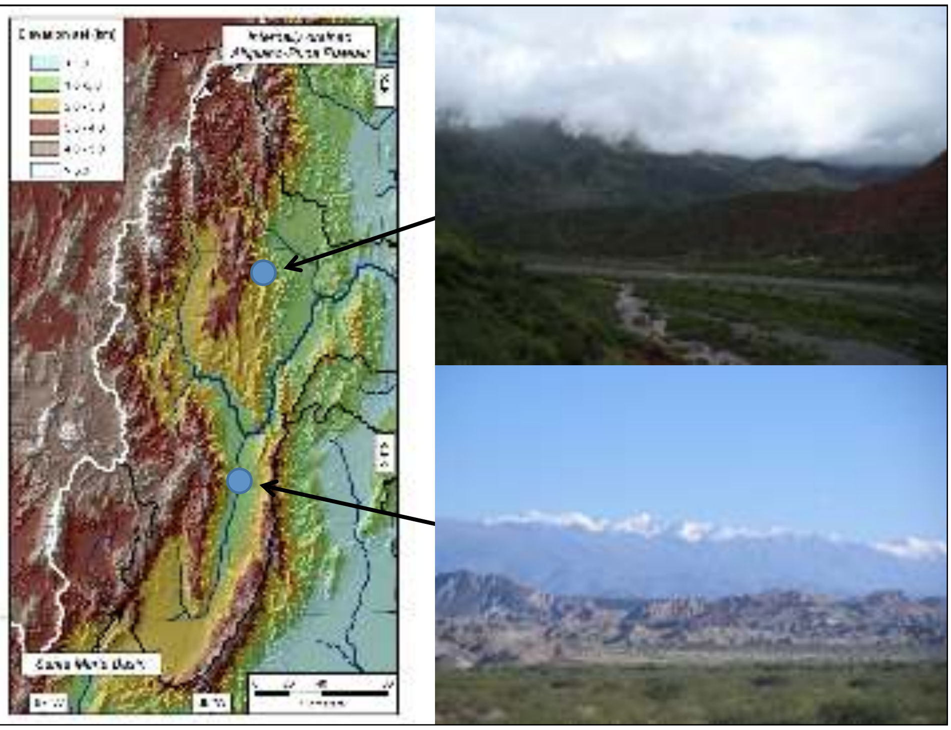
Bookhagen and Strecker, in preparation



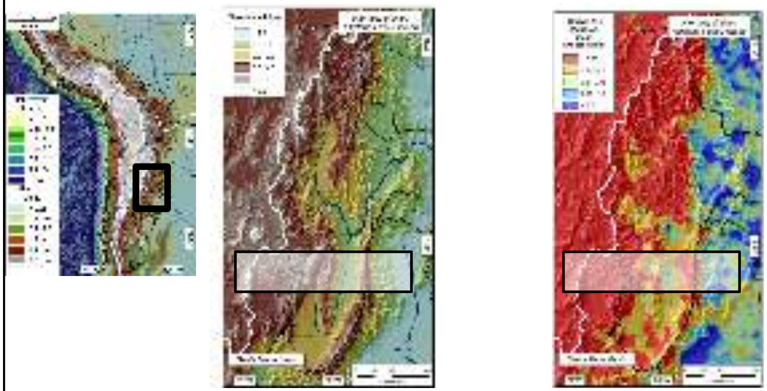
Southern Central Andes – Mean Annual rainfall (1998-2013)

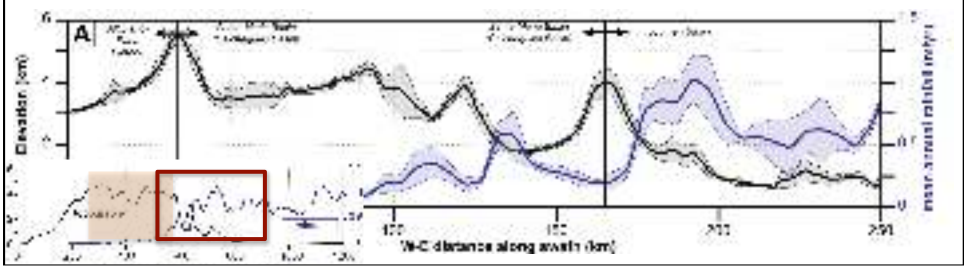
Mean annual rainfall from TRMM2B31 and 2A25 show a ~10-fold rainfall gradient from the eastern foreland to the Altiplano.

Bookhagen and Strecker, 2008; Bookhagen and Strecker, in preparation



Rainfall and Topographic Swath Profile I



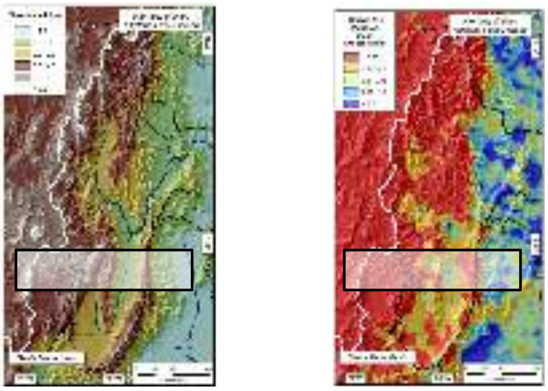


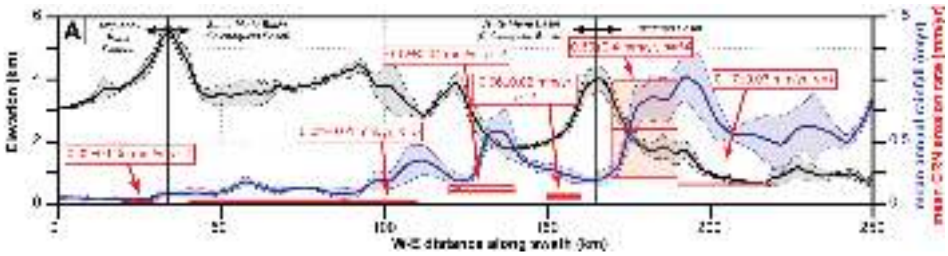
Bookhagen and Strecker, 2012

Rainfall and Topographic Swath Profile II

40 Cosmogenic-nuclide erosion rates across a climatic gradient

Deciphering spatial erosion-rate distribution



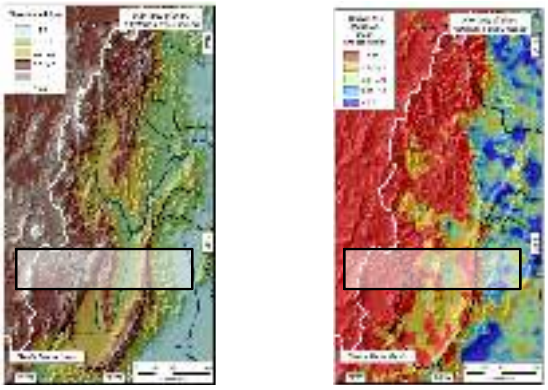


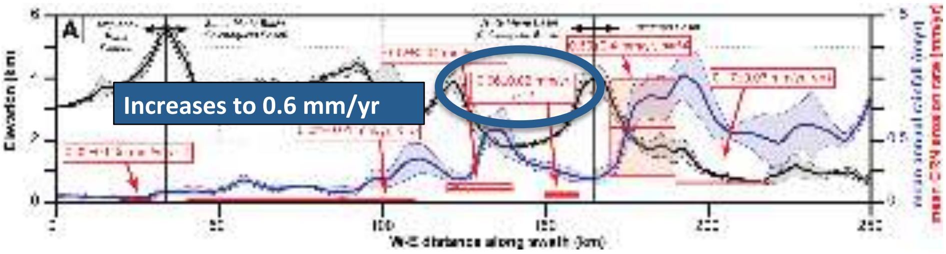
Bookhagen and Strecker, 2012

Modern and Paleo-erosion rates during pluvial periods

Sediment budget quantified from a landslide-dammed lake in the Santa Maria Basin

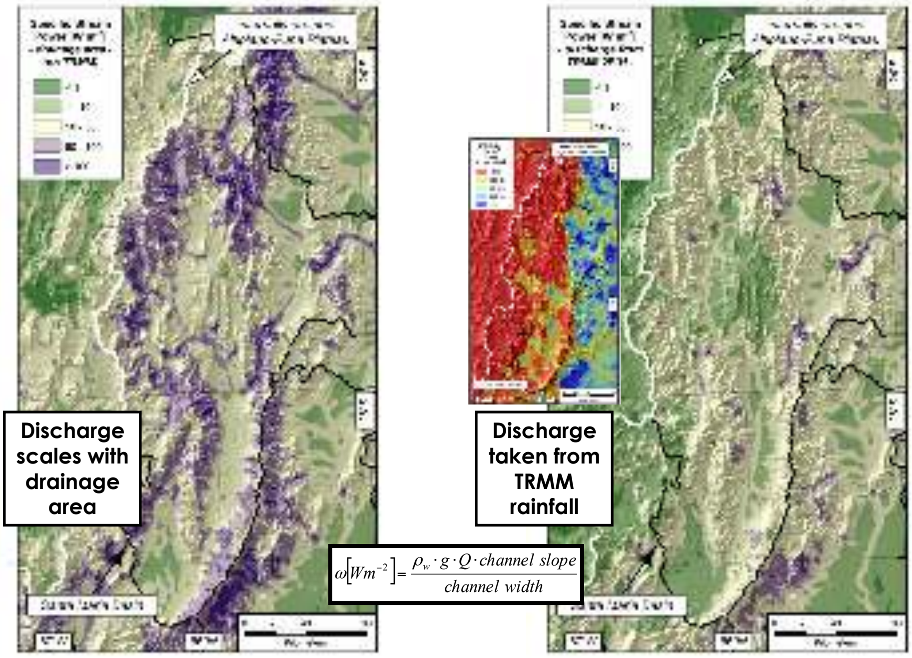
Erosion rates increased 10-fold (one order of magnitude)





Bookhagen and Strecker, 2012

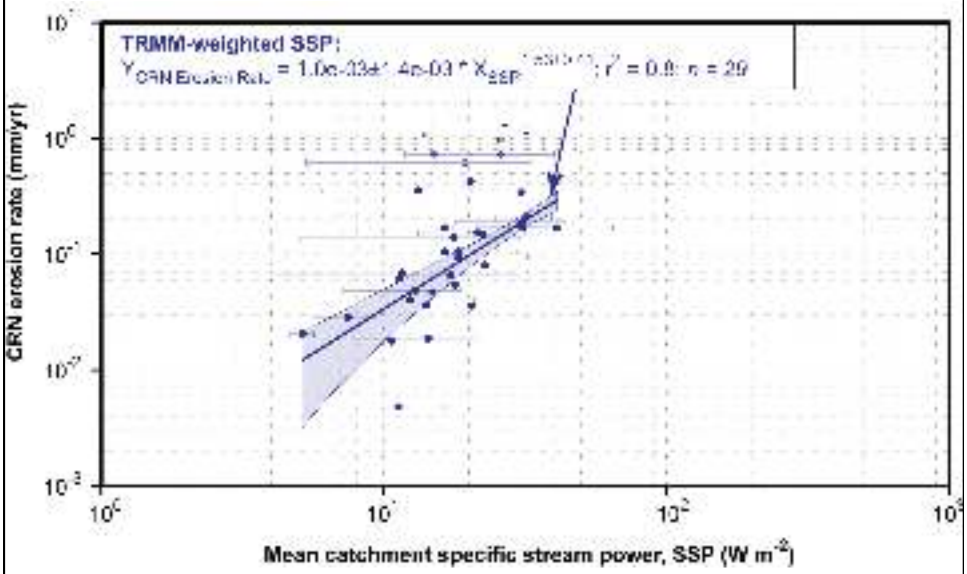
Rainfall Gradient and Specific Stream Power II



$$\omega\left[Wm^{-2}\right] = \frac{\rho_w \cdot g \cdot Q \cdot channel\ slope}{channel\ width}$$

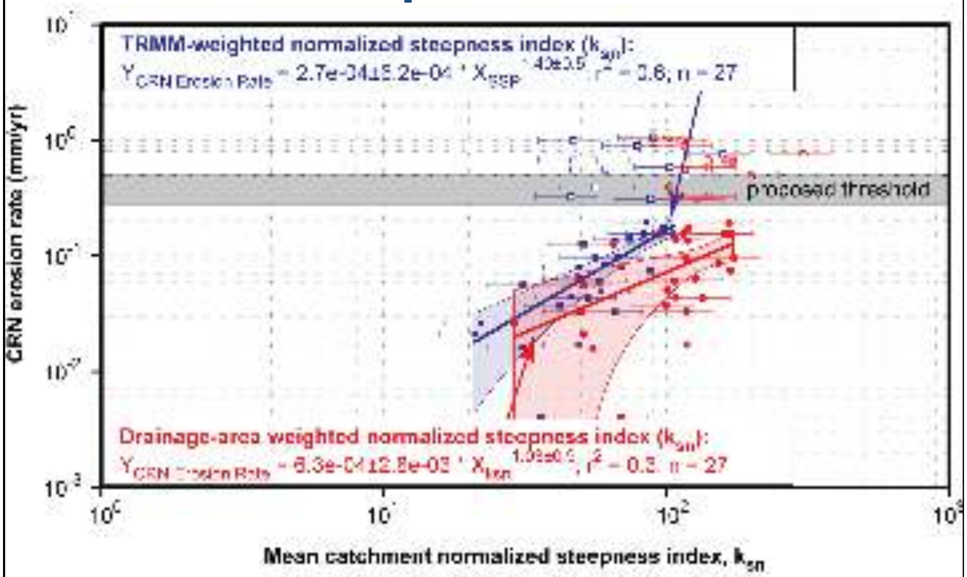
Bookhagen and Strecker, 2012

‘Erosion Mapping’ with Specific Stream Power I



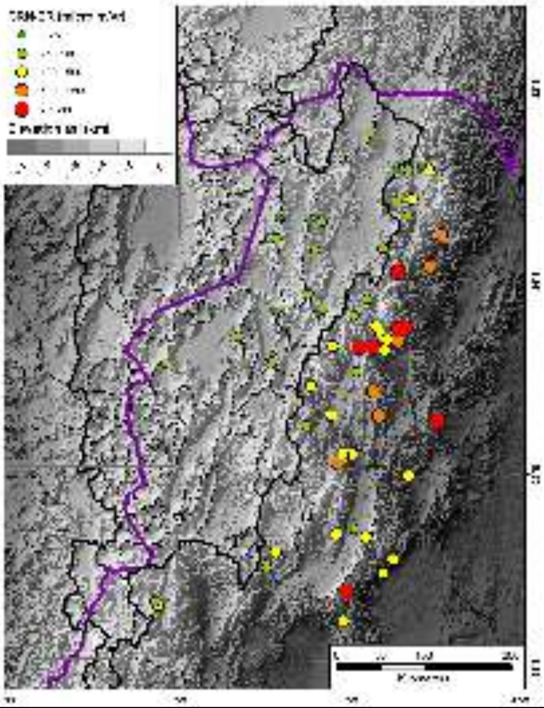
Bookhagen and Strecker, 2012

‘Erosion Mapping’ with the channel steepness index



Bookhagen and Strecker, 2012

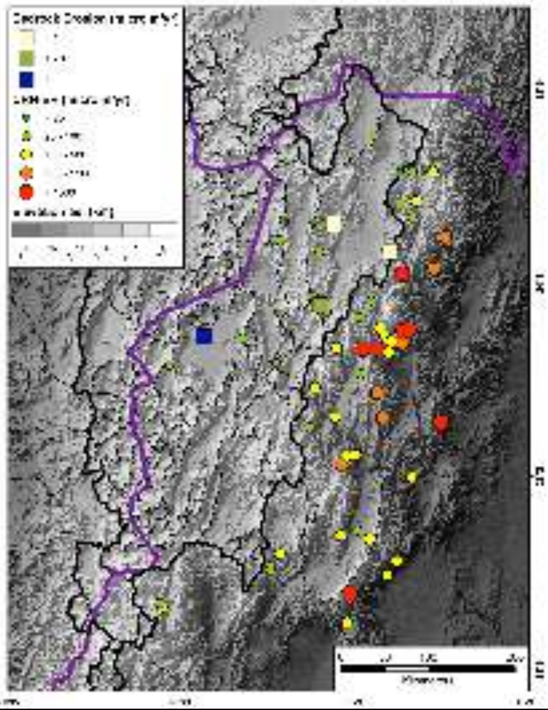
Southern Central Andes – CRN erosion rates



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

Bookhagen and Strecker, 2012; Bookhagen and Strecker, in preparation

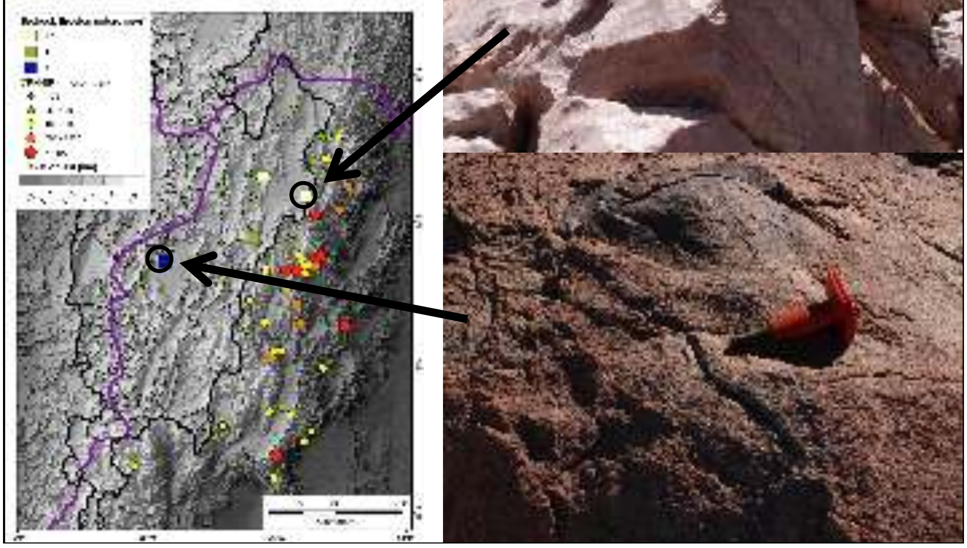
Southern Central Andes – CRN erosion rates



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

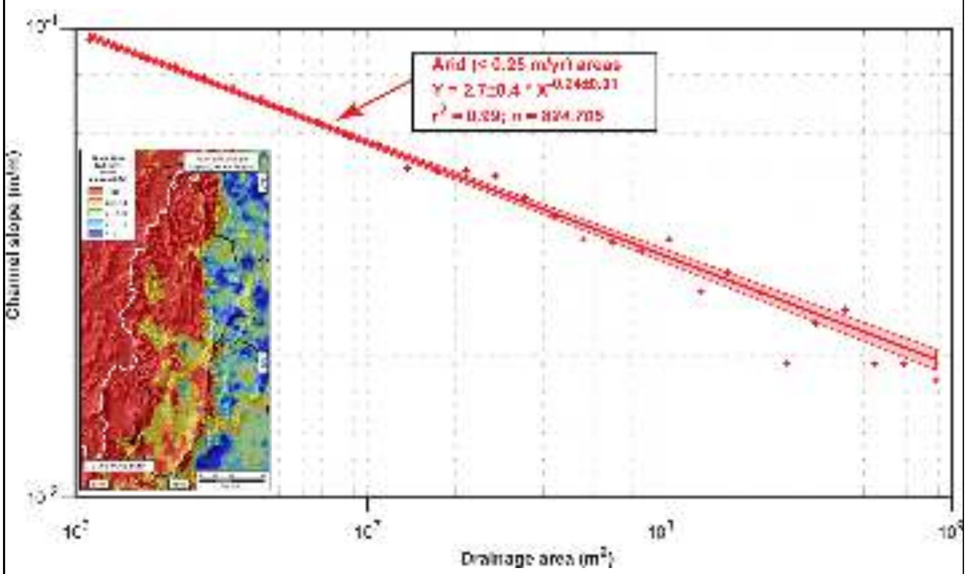
Bookhagen and Strecker, in preparation

Significant Aeolian Erosion on the Puna Plateau



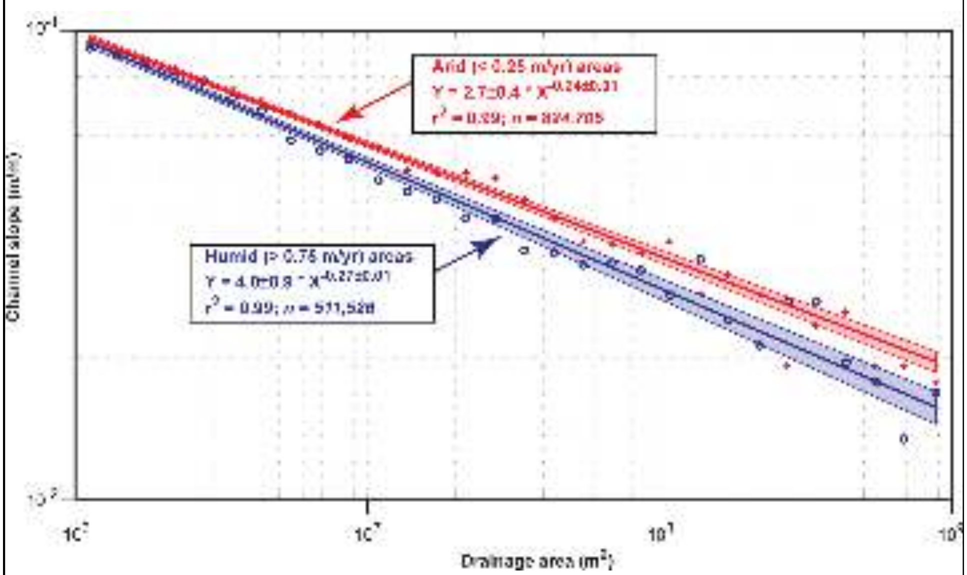
Climatic Impact on Channel Slopes

Climatic Impact on Channel Slopes I



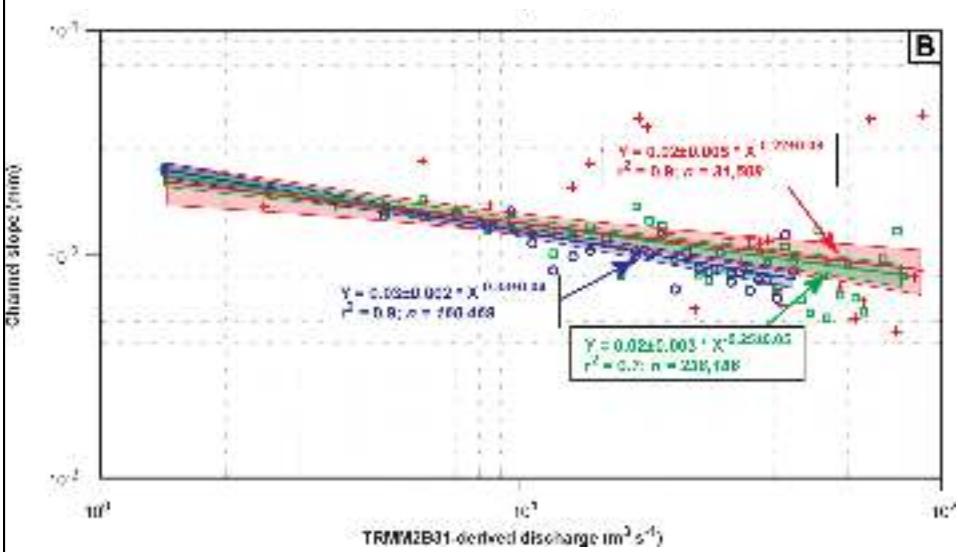
Bookhagen and Strecker, 2012

Climatic Impact on Channel Slopes II



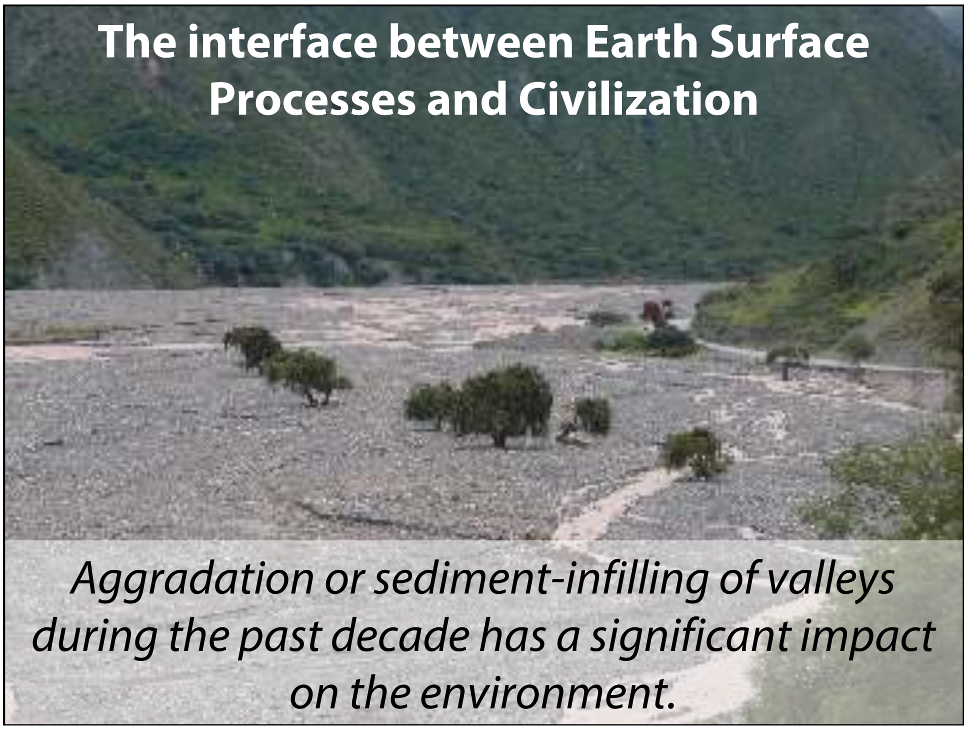
Bookhagen and Strecker, 2012

Climatic Impact on Channel Slopes III

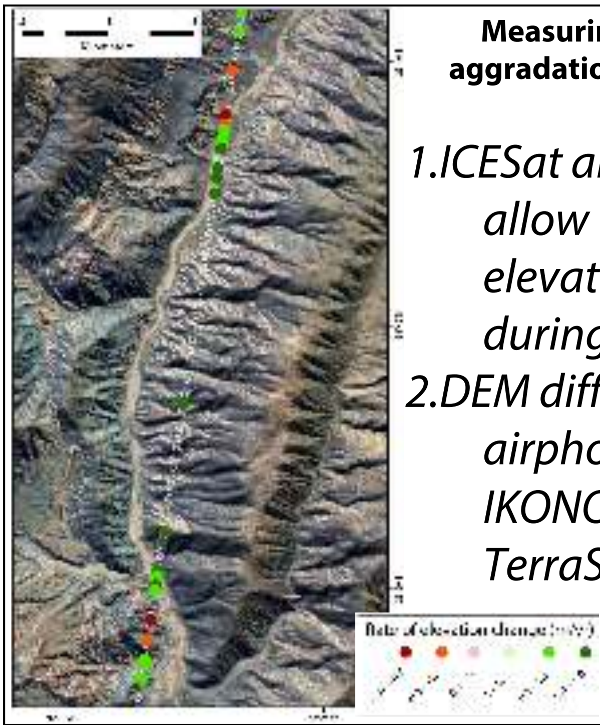


Bookhagen and Strecker, 2012

The interface between Earth Surface Processes and Civilization



Aggradation or sediment-infilling of valleys during the past decade has a significant impact on the environment.

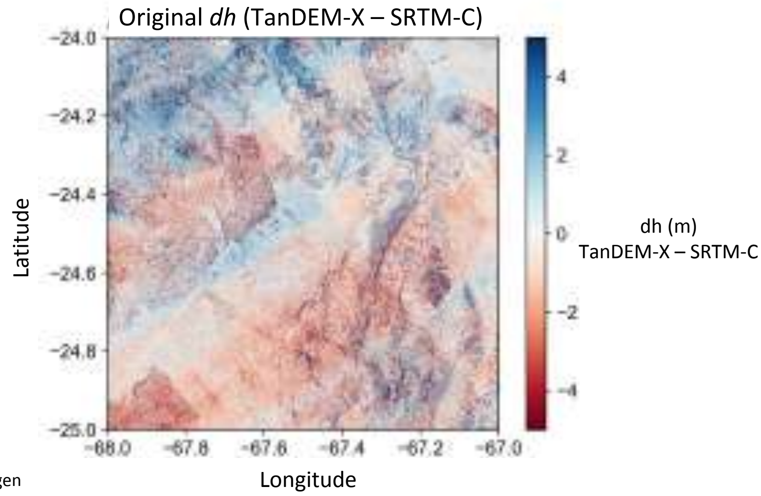


Measuring and Quantifying aggradation (sediment infilling)

1. *ICESat and SRTM data allow to measure elevation change during the past decade.*
2. *DEM differencing (stereo airphotos, ASTER, SRTM, IKONOS, GeoEye, TerraSAR-X)*

Bookhagen, in preparation

Example Correction Applied to SRTM-C (2000) Using TanDEM-X (~2015) as Control Surface



Purinton & Bookhagen (2018) – Earth Surface Dynamics

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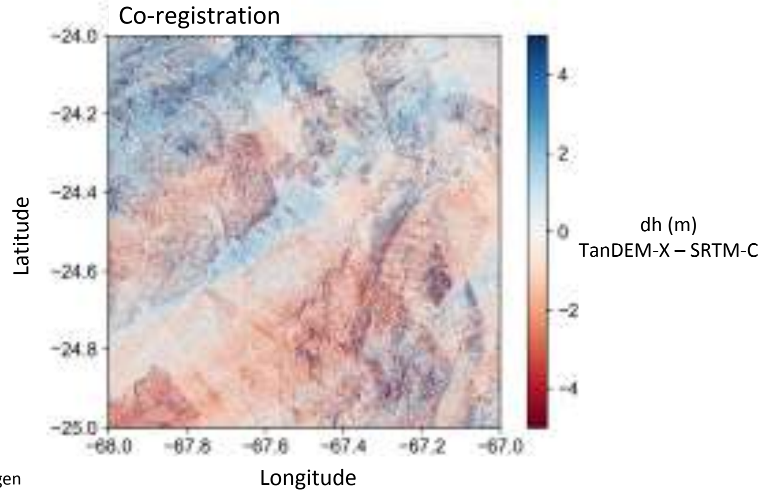

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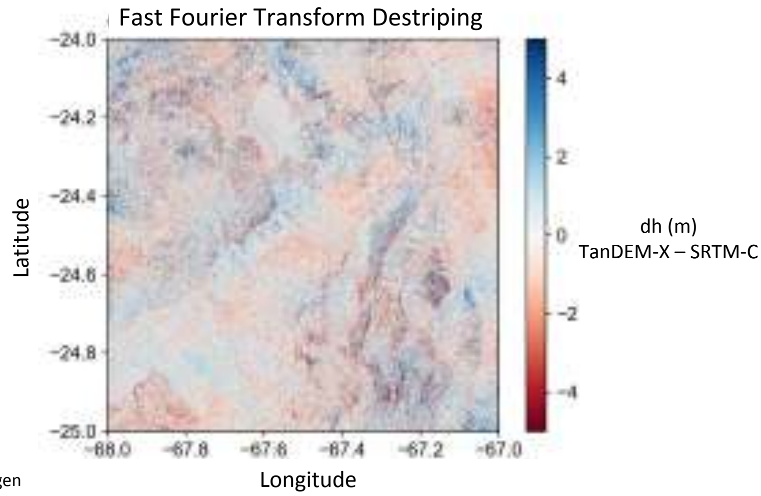

Purinton & Bookhagen (2018) – Earth Surface Dynamics

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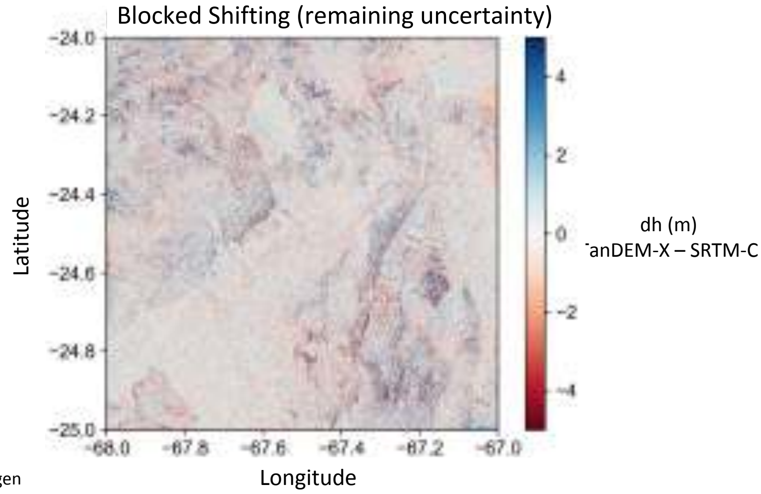
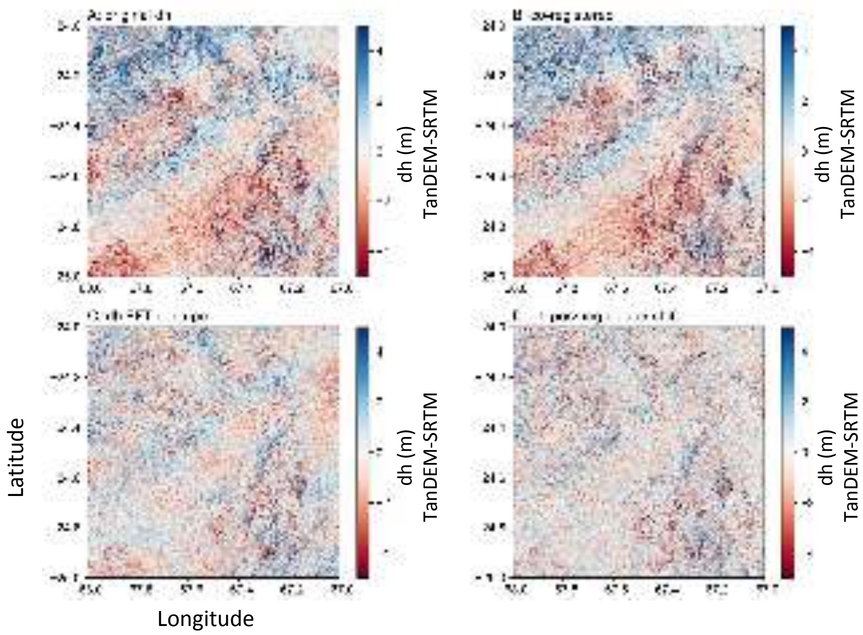


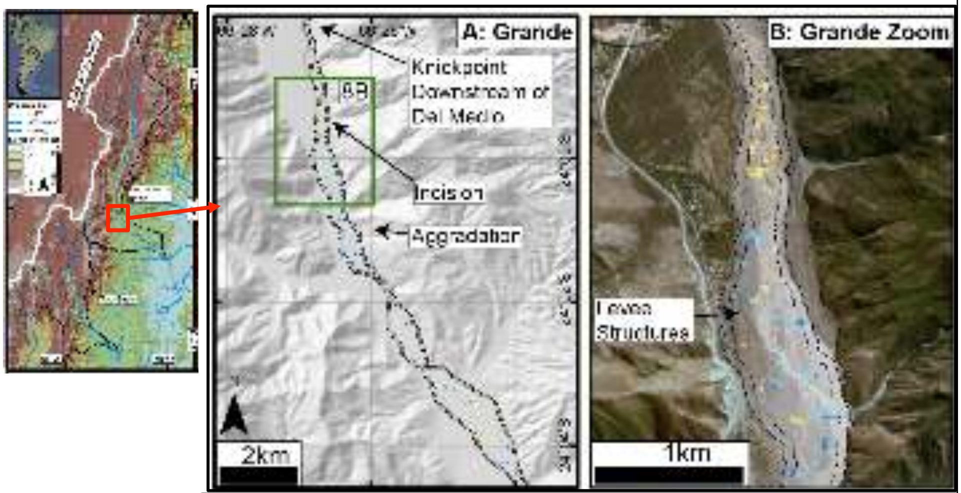
Purinton & Bookhagen (2018) – Earth Surface Dynamics

Example Correction Applied to SRTM Tile S25 W68



Purinton and Bookhagen, in preparation

TanDEM-X – SRTM-C (corrected) Gravel-Bed River Aggradation/Incision



Purinton & Bookhagen (2018) – Earth Surface Dynamics

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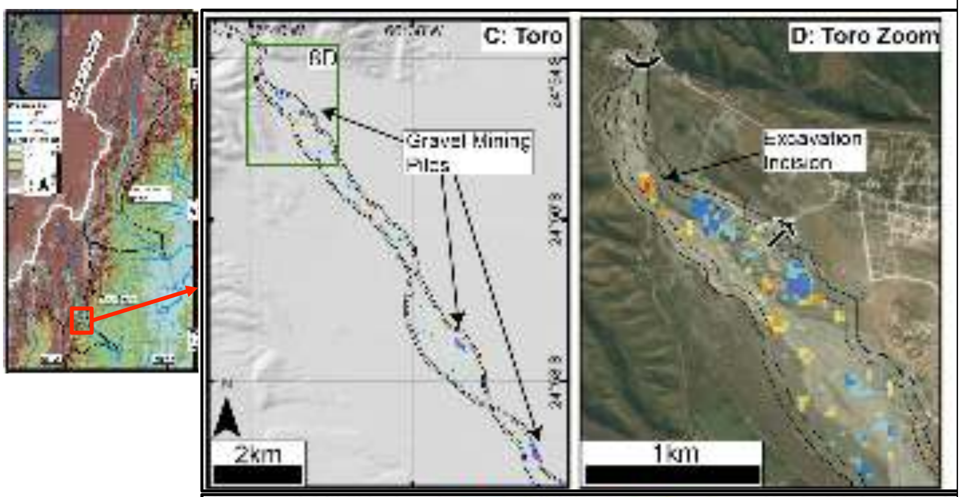
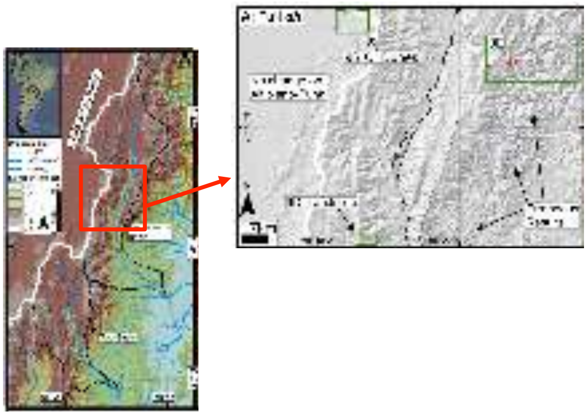


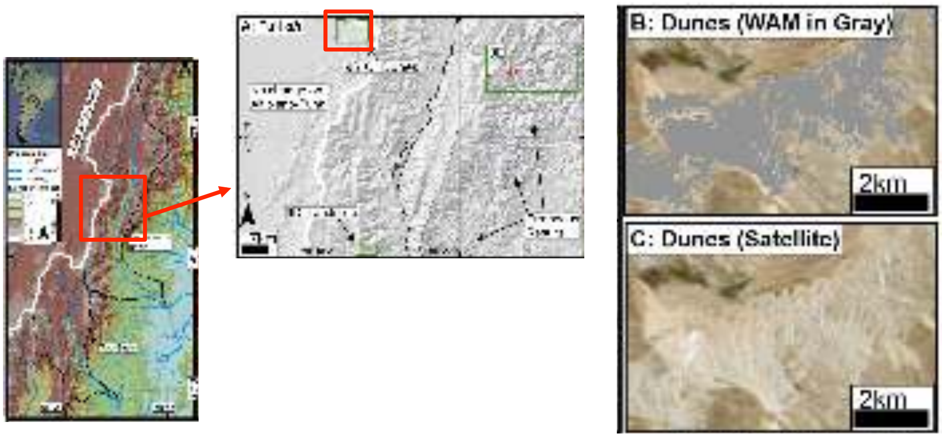
Purinton & Bookhagen (2018) – Earth Surface Dynamics

TanDEM-X – SRTM-C (corrected) Landscape Change



Purinton & Bookhagen (2018) – Earth Surface Dynamics

TanDEM-X – SRTM-C (corrected) Landscape Change



Purinton & Bookhagen (2018) – Earth Surface Dynamics

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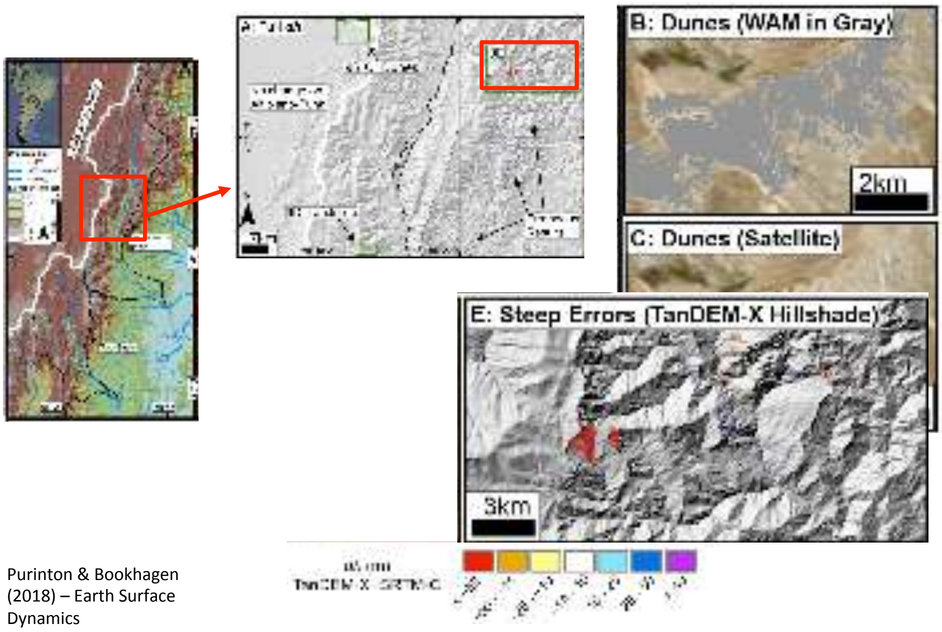

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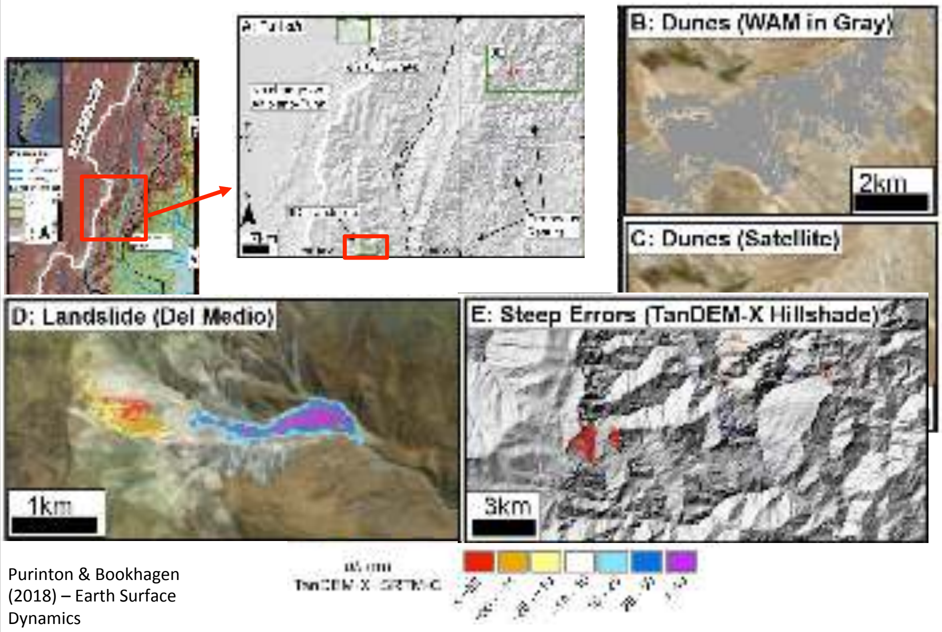
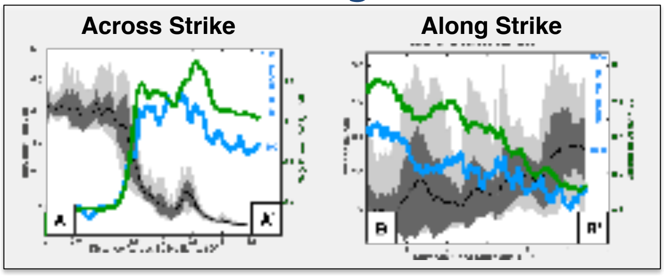
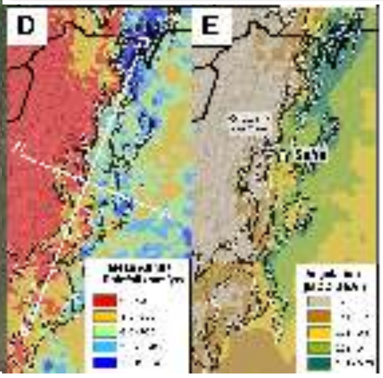


Purinton & Bookhagen (2018) – Earth Surface Dynamics

E-W and N-S climatic gradients

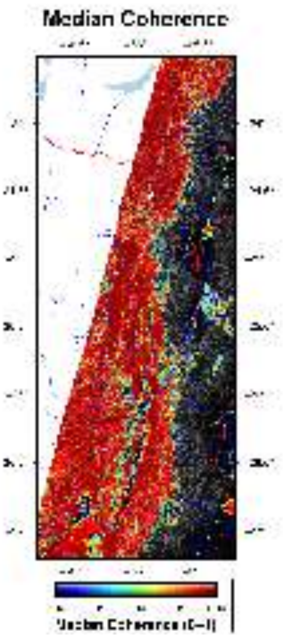


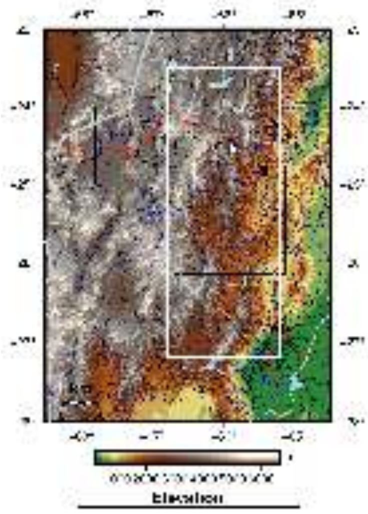


- Large across-strike gradient in precipitation and vegetation
- Graduate along-strike gradient in precipitation and vegetation

Olen and Bookhagen, in preparation

E-W and N-S climatic gradients



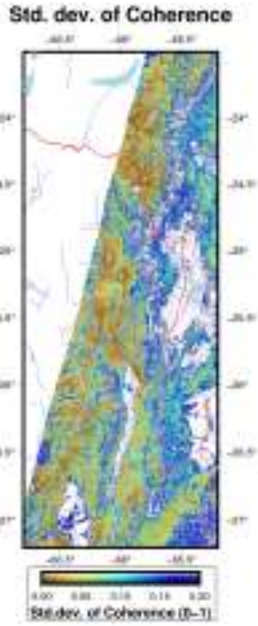


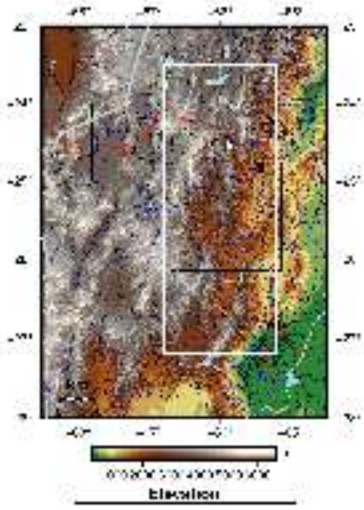
Median SAR coherence averaged over two years (n=305 interferogram pairs):

- Blue colors (or dark colors): unstable terrain
- Red colors: stable terrain

Olen and Bookhagen, in preparation

E-W and N-S climatic gradients

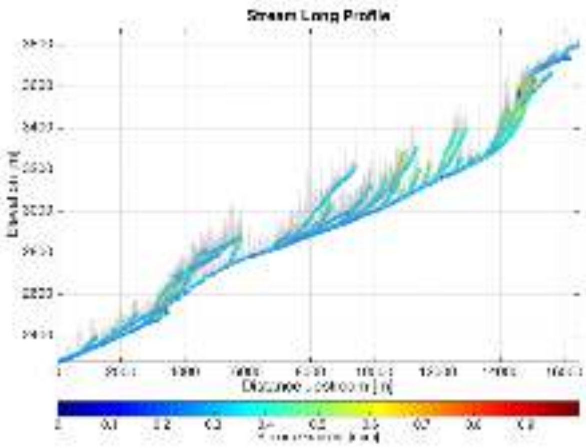


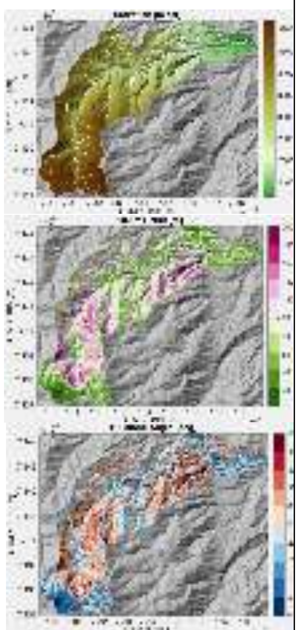


- Changes of SAR coherence averaged over two years (n=60 pairs of interferograms):
  - brown/yellow colors indicate stable terrain
  - blue colors are areas with seasonal differences

Olen and Bookhagen, in preparation

Coherence as a Proxy for Geomorphic Activity: **Santa Maria Basin**





Olen and Bookhagen, in preparation

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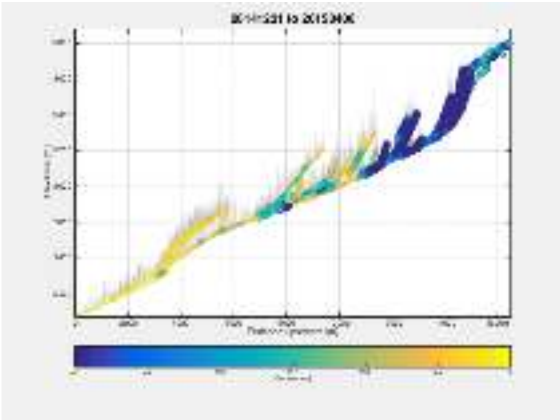
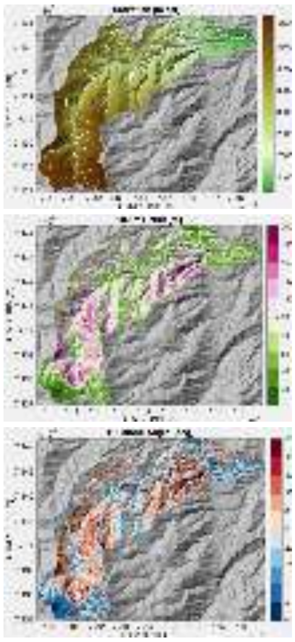
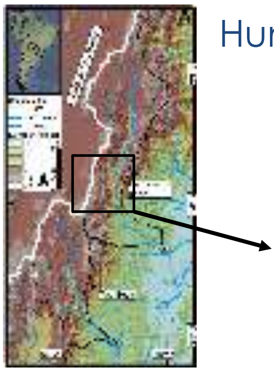
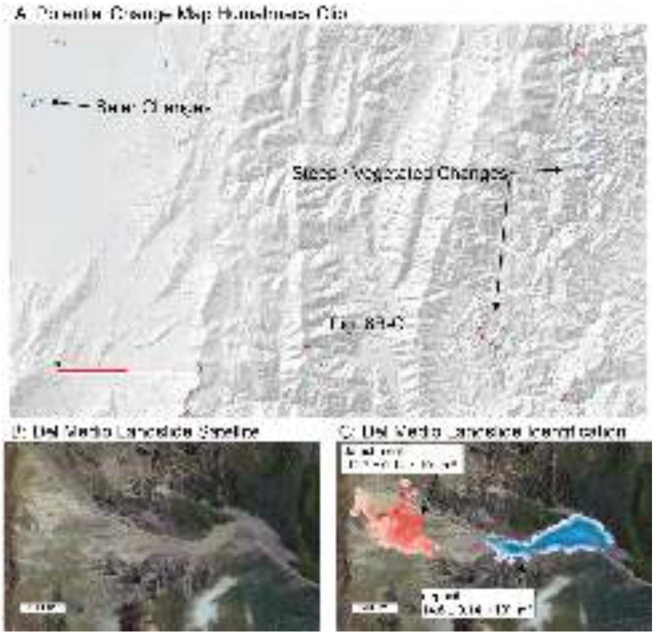




Olen and Bookhagen, in preparation

Humahuaca Basin Del Medio Landslide





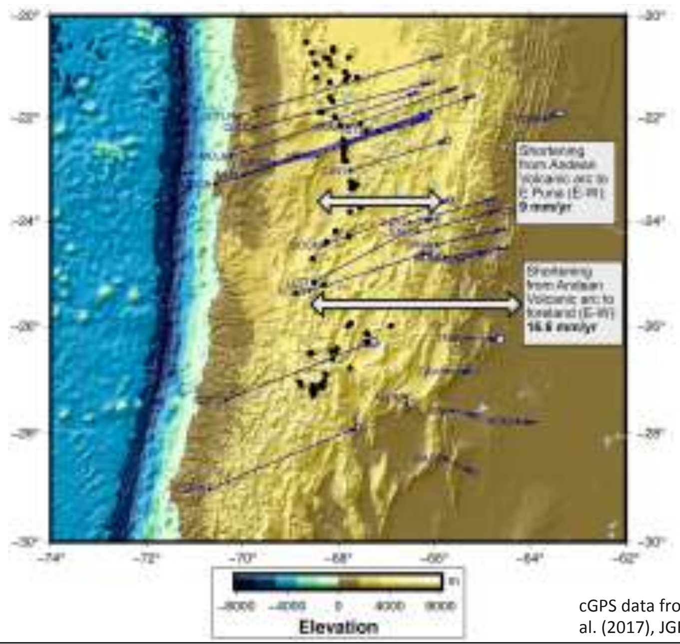
Erosion and Climate in the Central Andes

1. Linkages between Erosion and Climate

- Rates of sediment flux
- Millennial-scale Erosion rates and their spatial pattern

2. Tectonic Processes

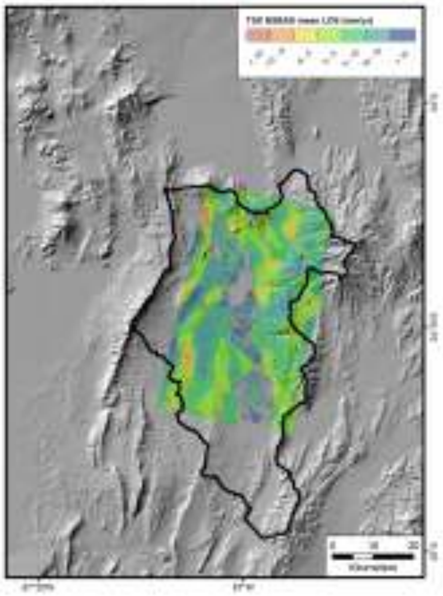
cGPS-based shortening across the south-central Andes



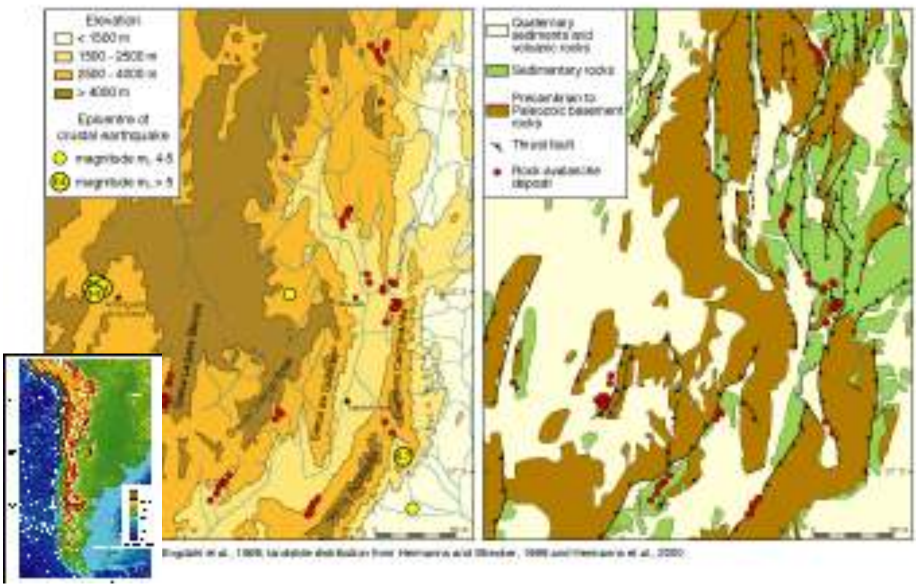
cGPS data from: McFarland et al. (2017), JGR-Solid Earth

TerraSAR-X InSAR: Pocitos (East)

- TSX: 28 SAR scenes, 177 interferograms between 2012-09-17 and 2014-10-25
- Mean LOS deformation using NSBAS shows short- and long-wavelength surface deformation



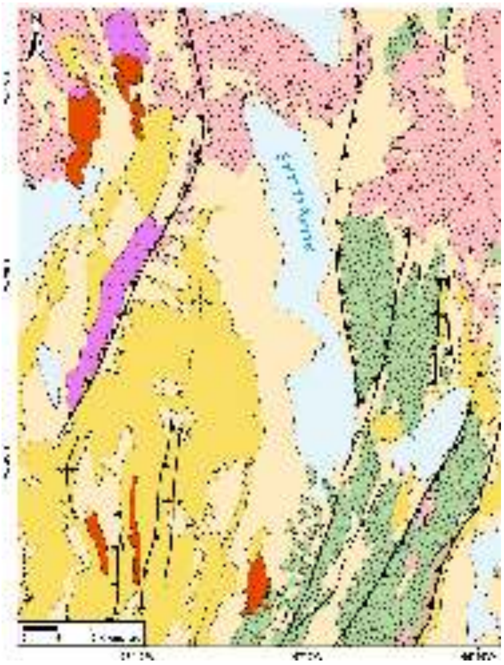
Recognizing and assessing secondary effects of active tectonism: Voluminous mass movements: seismic vs. climatic triggers



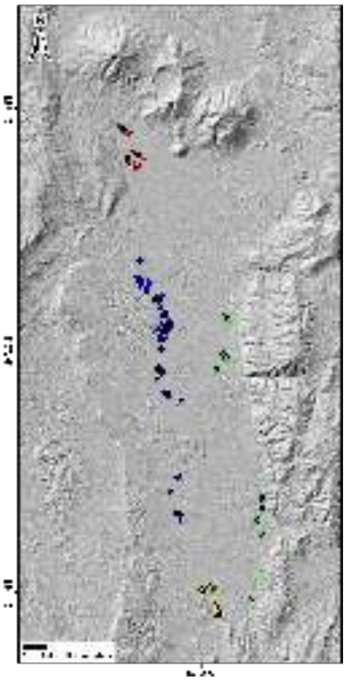
Assessing trigger mechanisms of landsliding

Understanding structural predisposition of landsliding

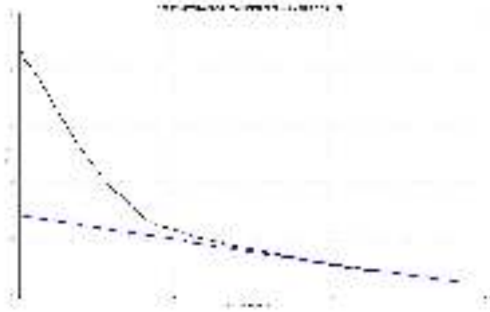
Using lacustrine sediments of different ages as strain markers to determine deformation rates: “geodetic“ vs. “geologic“ timescales



Salar de Pocitos



Gently sloping pediments, river profiles and lacustrine shorelines/base levels



E – W Pocitos basin dGPS transsect

Asymmetry in E & W positions of shorelines