



GSA-5859 / PCA-5017

SIG em Software Livre

Modelos Digitais de Elevação

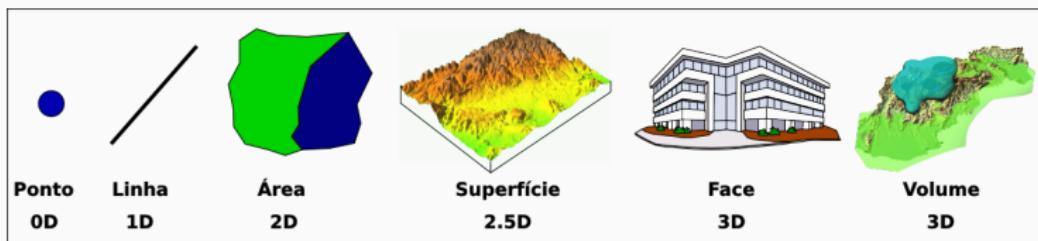
Carlos H. Grohmann

2021

Instituto de Energia e Ambiente
USP

Representação de uma superfície em SIG

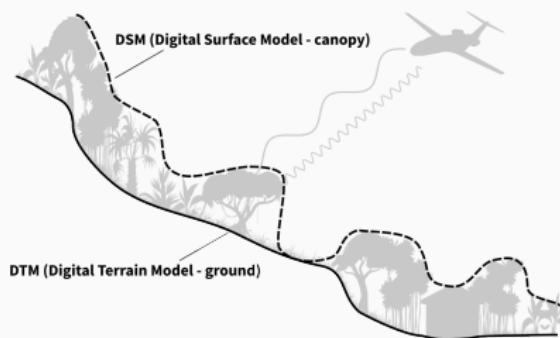
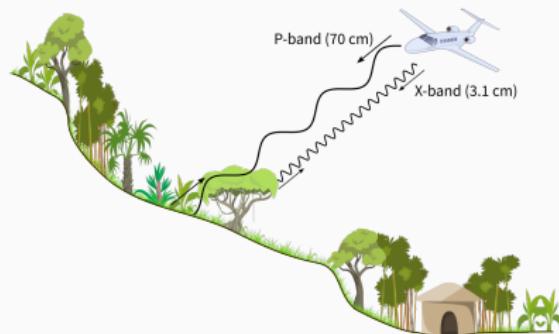
- Raster (MDE, MDT, MDS...)
- Vetor (TIN, malha (mesh))
- “2.5D”



MDE/MDT/MDS ??

- MDE, DEM – Modelo Digital de **Elevação**
 - termo mais genérico
- MDT, MNT, DTM – Modelo Digital de **Terreno**
 - representa o relevo real
- MDS – Modelo Digital de **Superfície**
 - representa a superfície do dossel, de construções, etc

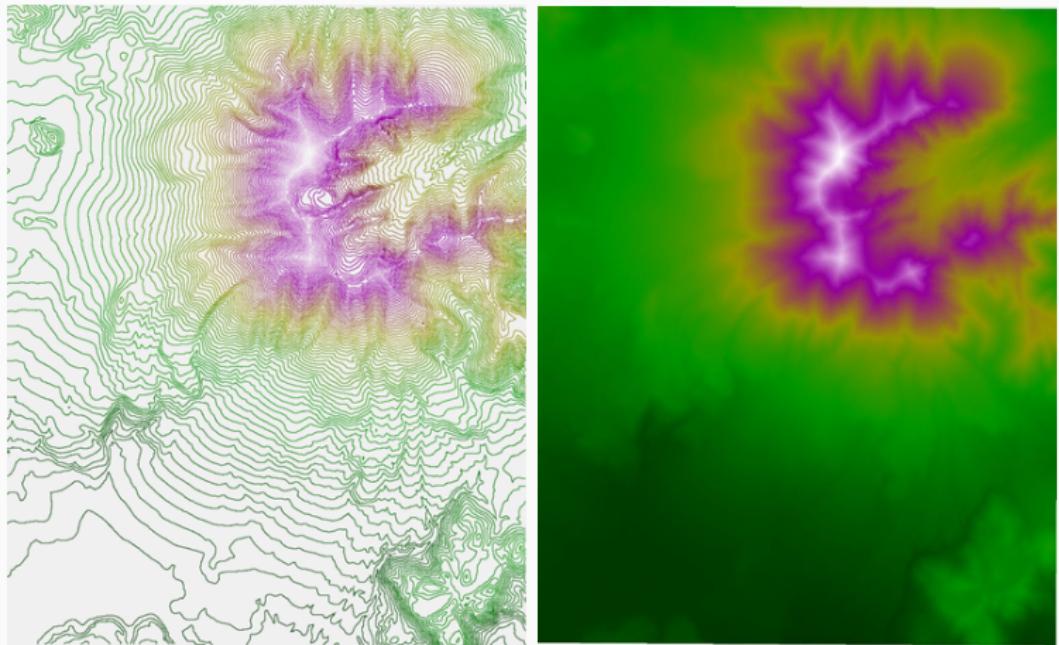
MDE/MDT/MDS ??



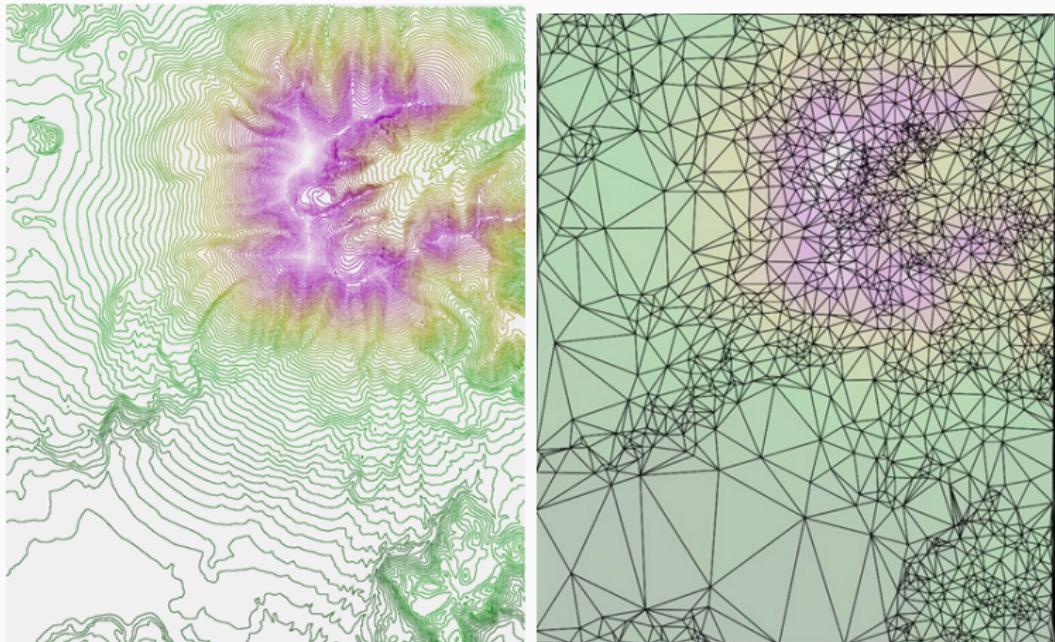
Construção de MDEs

- Interpolação de dados vetoriais
 - curvas de nível
 - pontos cotados
 - curvas + pontos
 - soft breaklines, hard breaklines
- Sensoriamento remoto
 - fotogrametria
 - interferometria de radar
 - LiDAR

Interpolação de dados vetoriais para raster

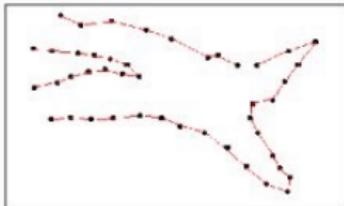


Interpolação de dados vetoriais para TIN

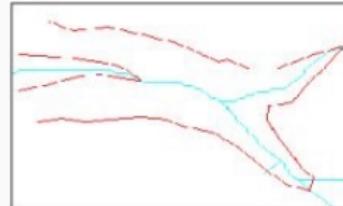


Interpolação – Breaklines

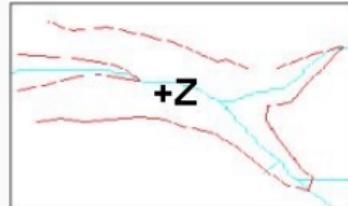
no breakline



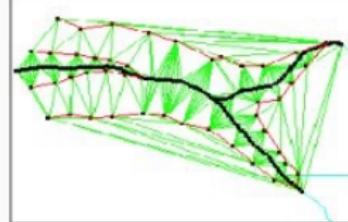
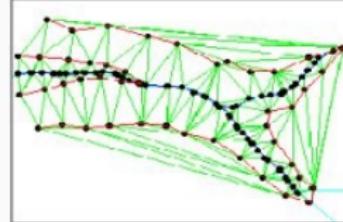
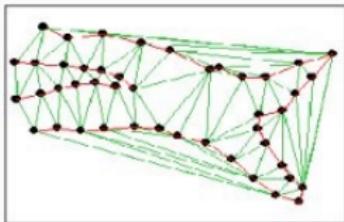
soft breakline



hard breakline

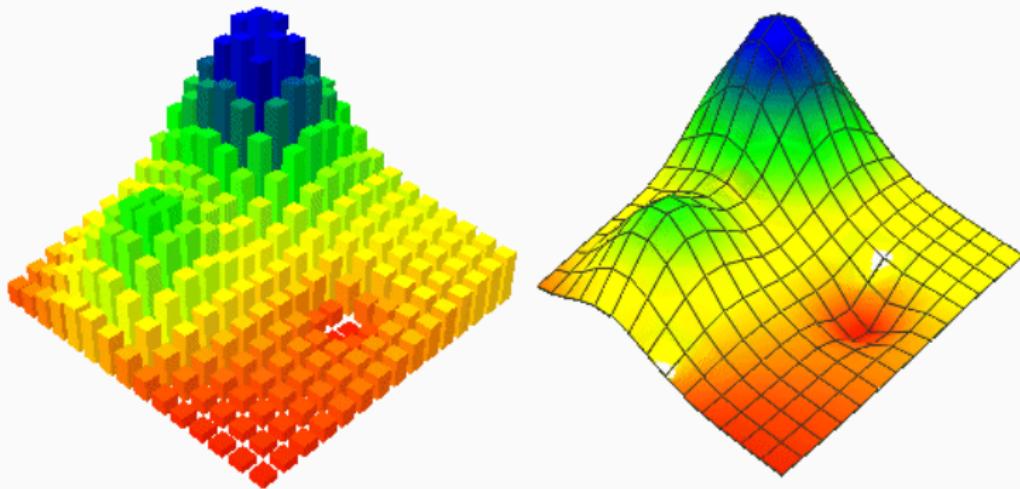


+Z



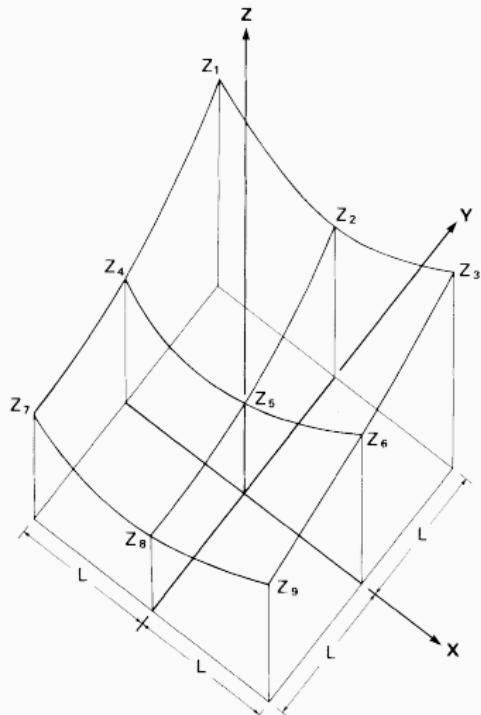
Representações Discretas x Contínuas

pixel-is-area x pixel-is-point

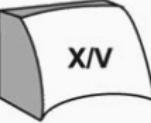
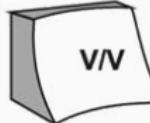


Derivadas da Superfície

- Declividade (slope)
 - 1^a derivada vertical
- Orientação de vertentes (aspect)
 - 1^a derivada horizontal
- Curvatura de perfil
 - 2^a derivada vertical
- Curvatura tangencial
 - 2^a derivada horizontal



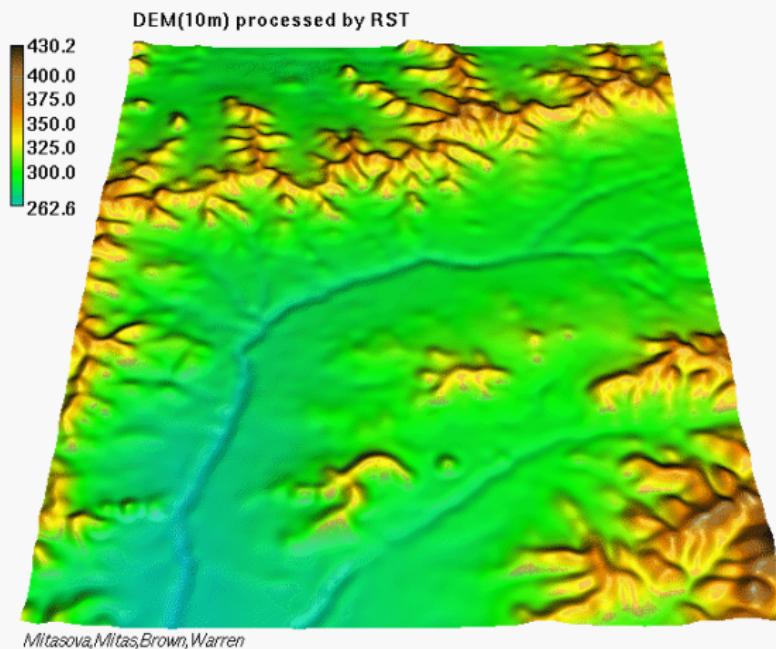
Curvaturas

		profile curvature		
		convex	profile-straight	concave
tangential curvature	convex			
	tangential-straight			
	concave			

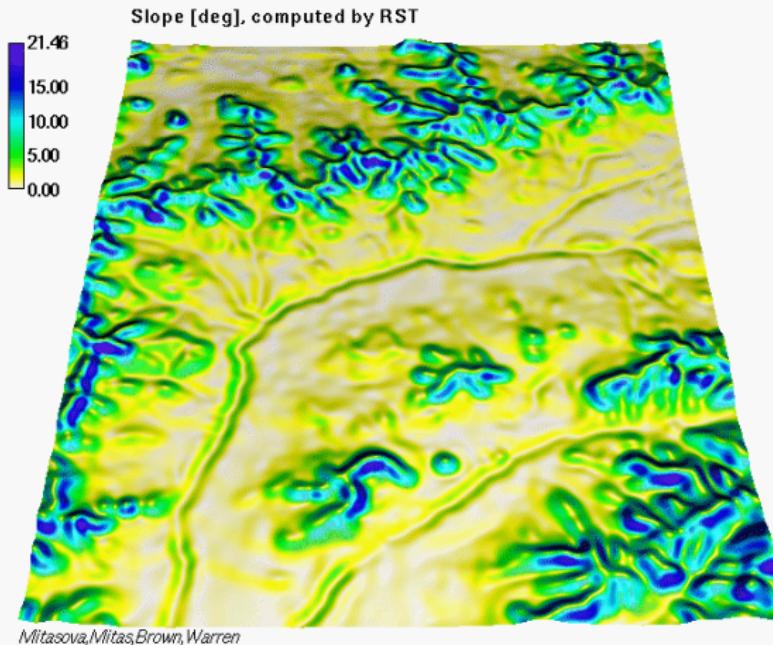
Curvaturas

Contour	Block	
		Divergent Shoulder
		Convergent Shoulder
		Divergent Backslope
		Convergent Backslope
		Divergent Footslope
		Convergent Footslope
		Level

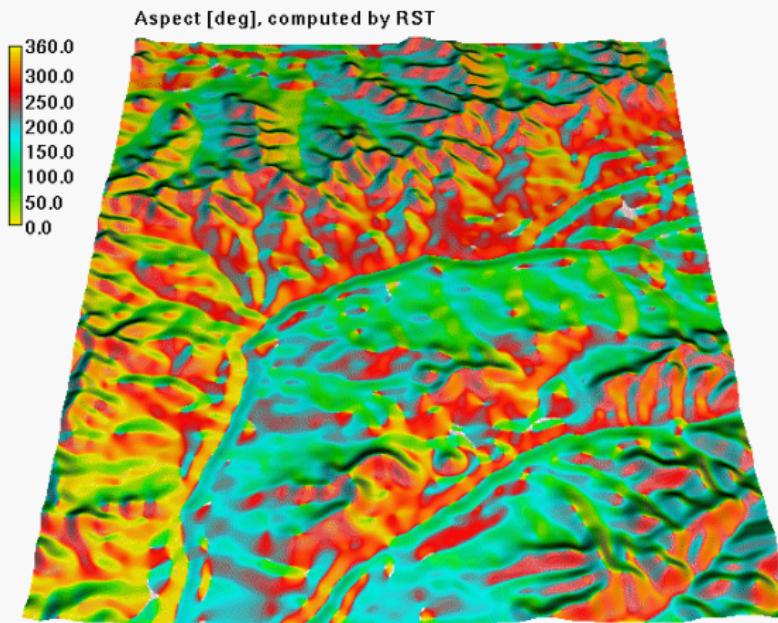
MDE / DEM



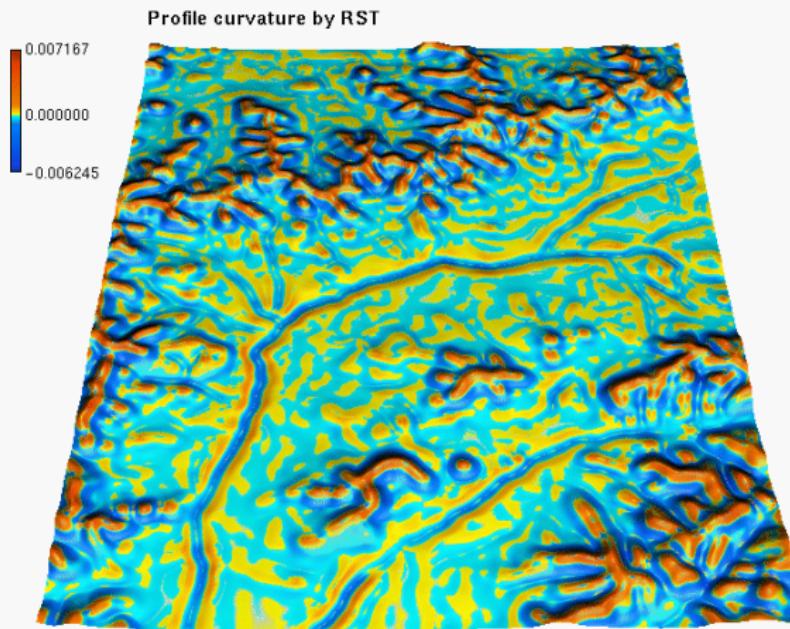
Declividade / Slope



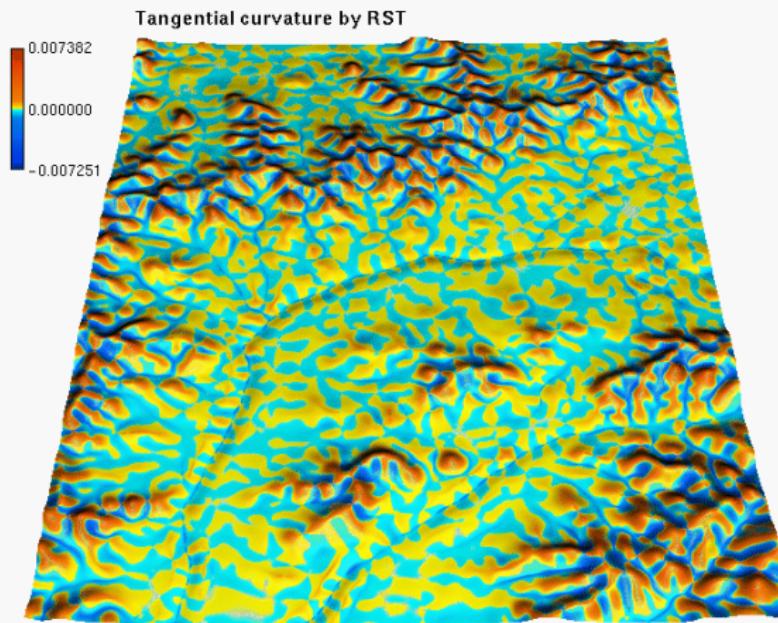
Orientação de Vertentes / Aspect



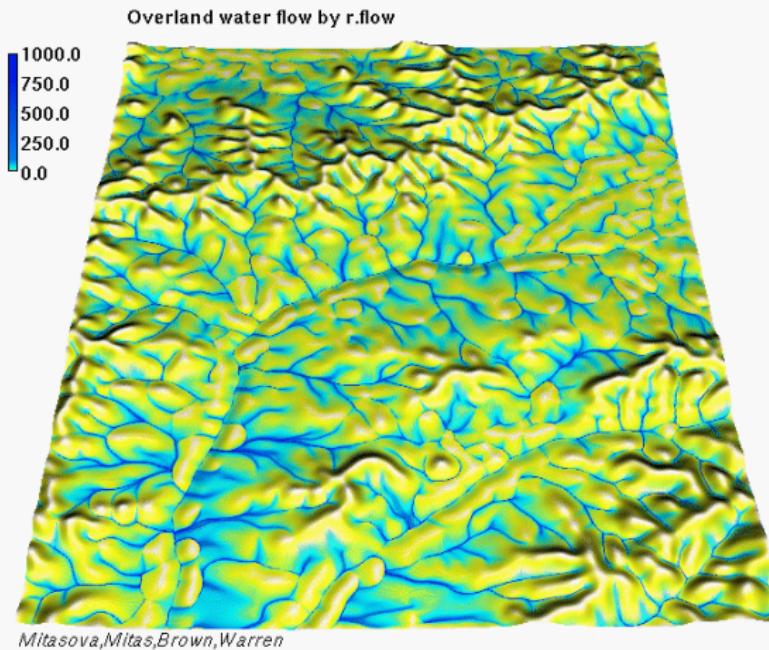
Curvatura Perfil / Profile Curvature



Curvatura Tangencial / Tangential Curvature

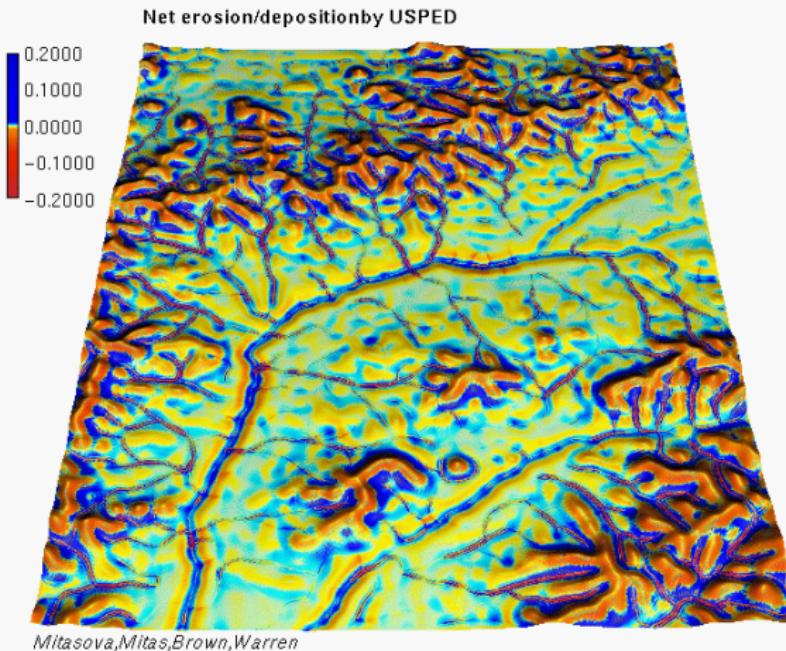


Fluxo / Flow



Mitasova,Mitas,Brown,Warren

Erosão/Deposição



Principais MDEs (semi-) Globais

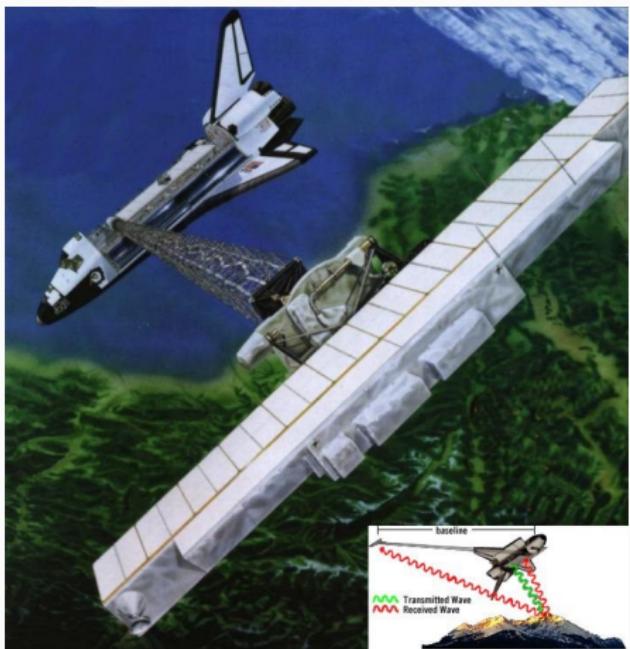
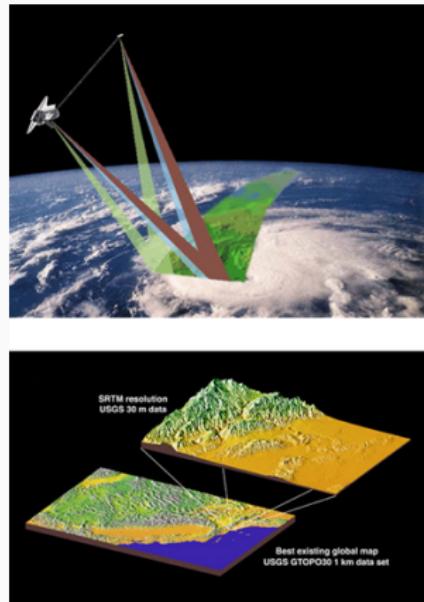
Shuttle Radar Topography Mission - SRTM

- MDEs gerados por interferometria de radar, com abrangência de 80% da superfície terrestre
- Inicialmente:
 - Estados Unidos – resolução de 1" (aprox. 30m)
 - O resto do Mundo – resolução de 3" (aprox. 90m)

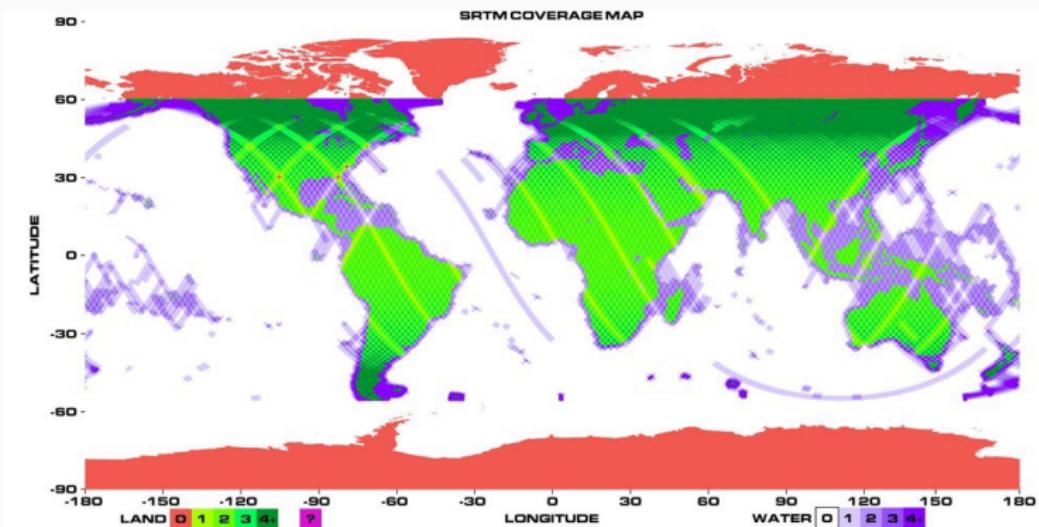
Farr, T. G., Rosen, P. A., Caro, E., Crippen, R., Duren, R., Hensley, S., Kobrick, M., Paller, M., Rodriguez, E., Roth, L., Seal, D., Shaffer, S., Shimada, J., Umland, J., Werner, M., Oskin, M., Burbank, D., Alsdorf, D., 2007. The Shuttle Radar Topography Mission. *Review of Geophysics*, 45:RG2004.

<https://doi.org/10.1029/2005RG000183>

SRTM



SRTM

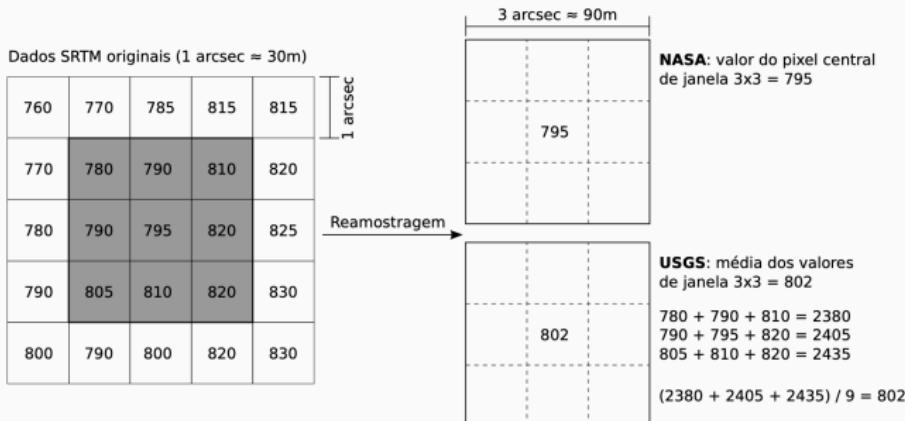


Versões dos dados SRTM

- NASA SRTM V1 - 2003
- NASA SRTM V2 e V2.1 - "Finished version"(2005)
 - SRTM Water Body Data - SWBD
 - Embrapa - Brasil em Relevo (2005)
- CGIAR-CSI SRTM V4.1 - 2008
- DLR SRTM X-SAR - 30m - 2010
- NASA SRTM V3 - 2013/2014 (01" para mundo todo)
 - <https://lpdaac.usgs.gov/products/srtmgl3v003/>
 - <https://portal.opentopography.org/datasets?group=global>

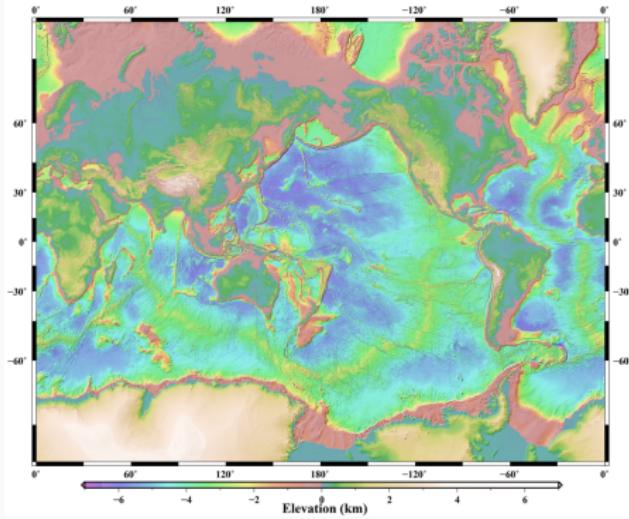
Reamostragem dos dados SRTM

- NASA SRTM V3 (90m)
 - SRTMGL3 - média de janela 3x3
 - SRTMGL3S - sub-sampled



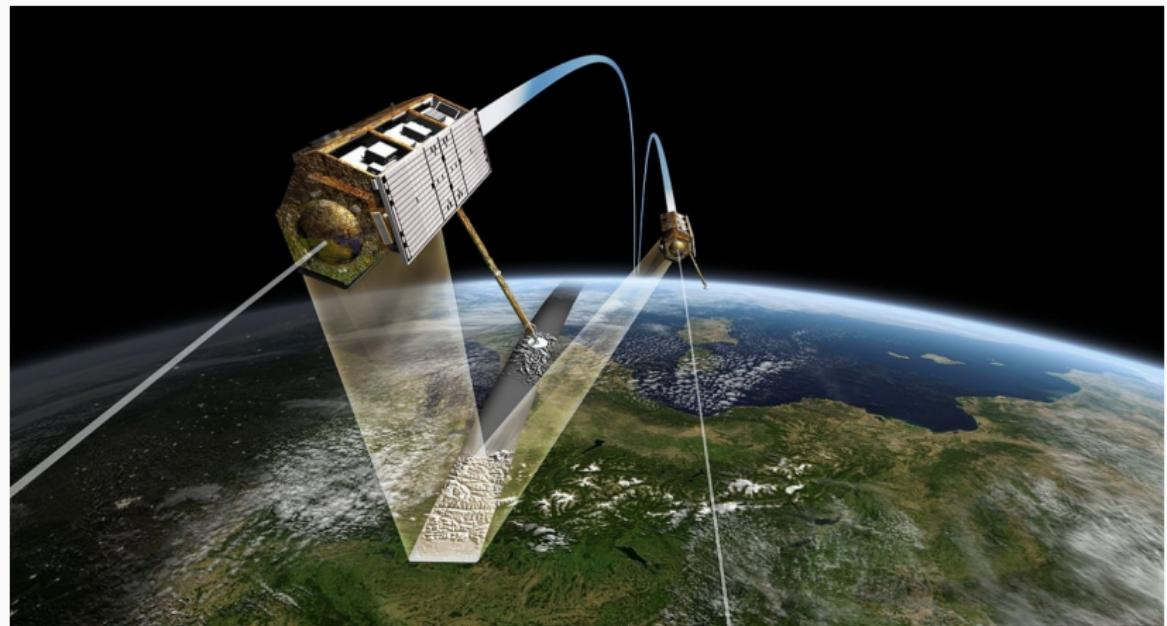
SRTM15+

- Resolução de 15" (aprox. 500m)
- Continentes e Oceanos (global)
- https://topex.ucsd.edu/www_html/srtm15_plus.html

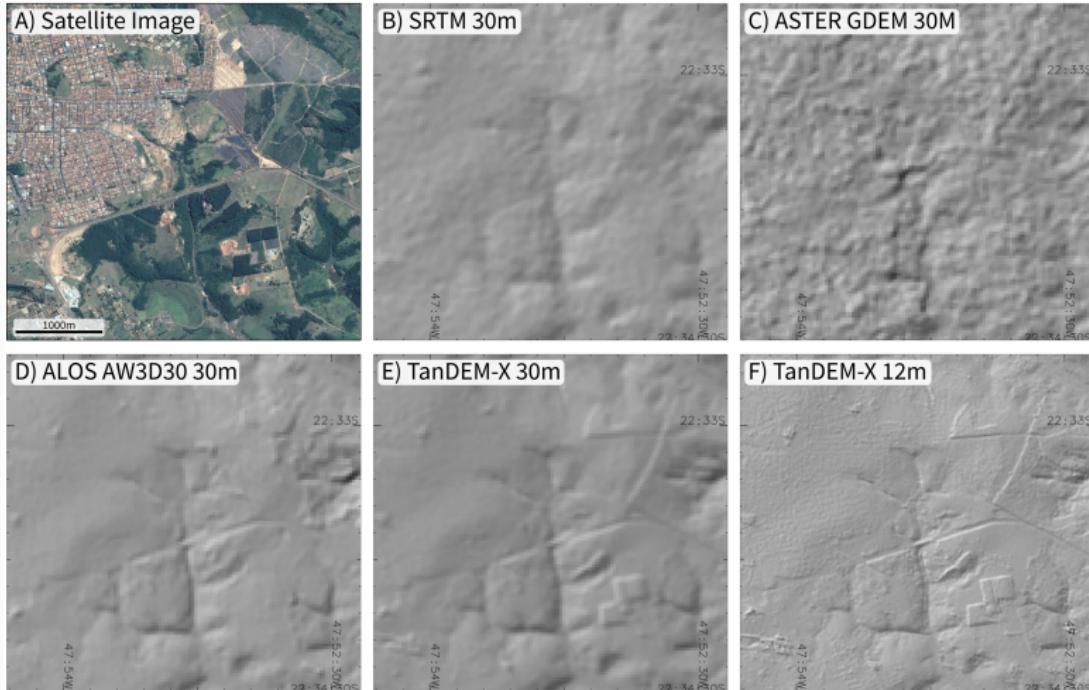


- TerraSAR-X add-on for Digital Elevation Measurement
- Dois satélites com sensores idênticos em formação (tandem)
- Banda X (quase sem penetração no dossel)
- 12m resolução (comercial, WorldDEM - Airbus)
- MDS com 90m gratuito
- <https://tandemx-science.dlr.de/>
- <https://geoservice.dlr.de/web/dataguide/tdm90/>

TanDEM-X



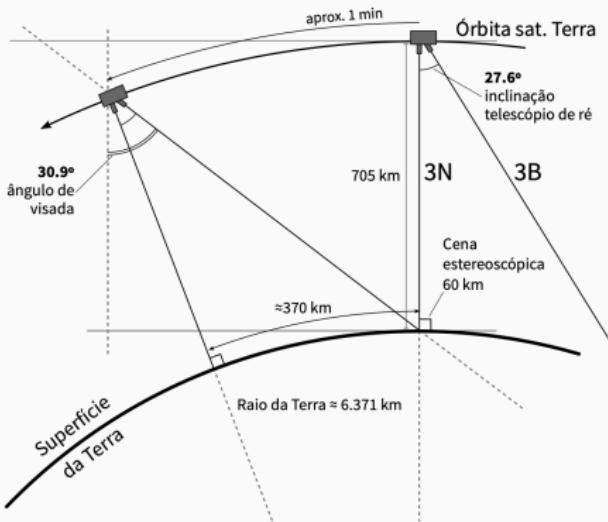
TanDEM-X



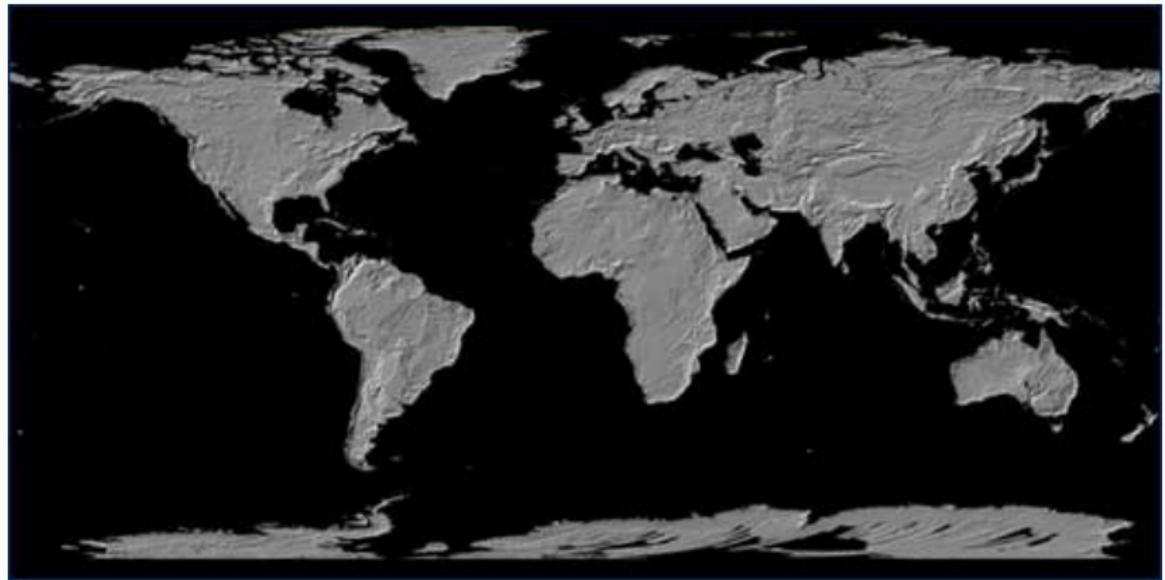
Grohmann, 2018. RSE. <https://doi.org/10.1016/j.rse.2018.04.043>

ASTER GDEM

- Advanced Spaceborne Thermal Emission and Reflection Radiometer
- ASTER GDEM v.1 – 2009
- ASTER GDEM v.2 – 2011
- ASTER GDEM v.3 – 2019
- 30m (teóricos)
- DSM
- Global



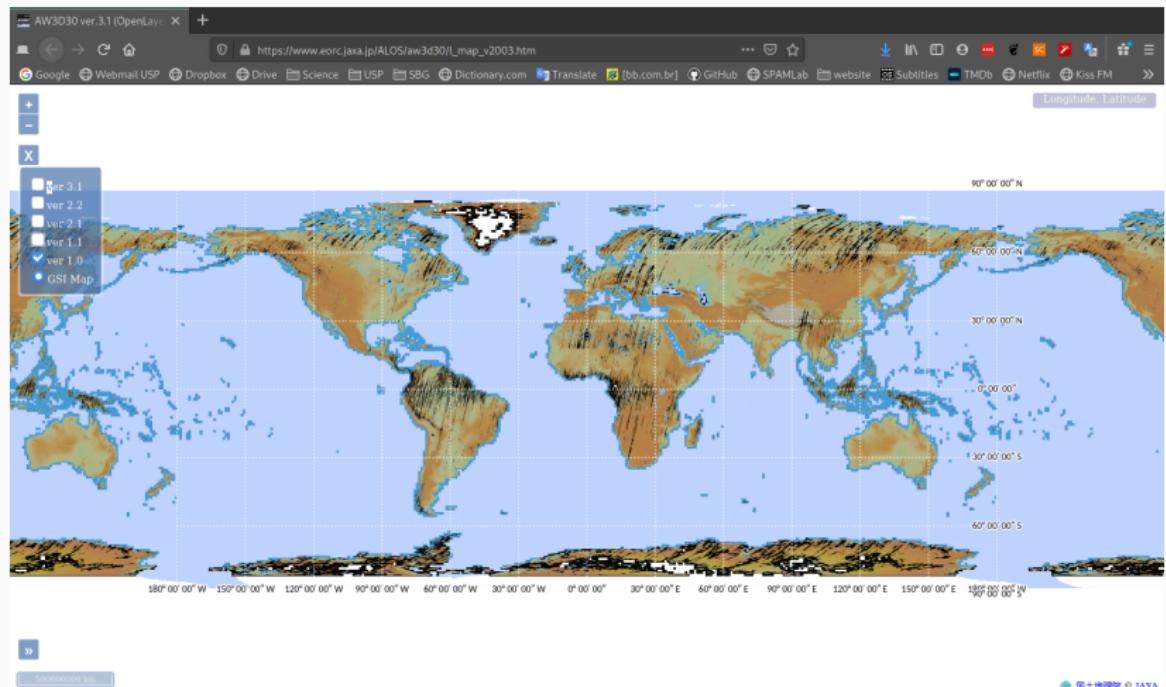
ASTER GDEM



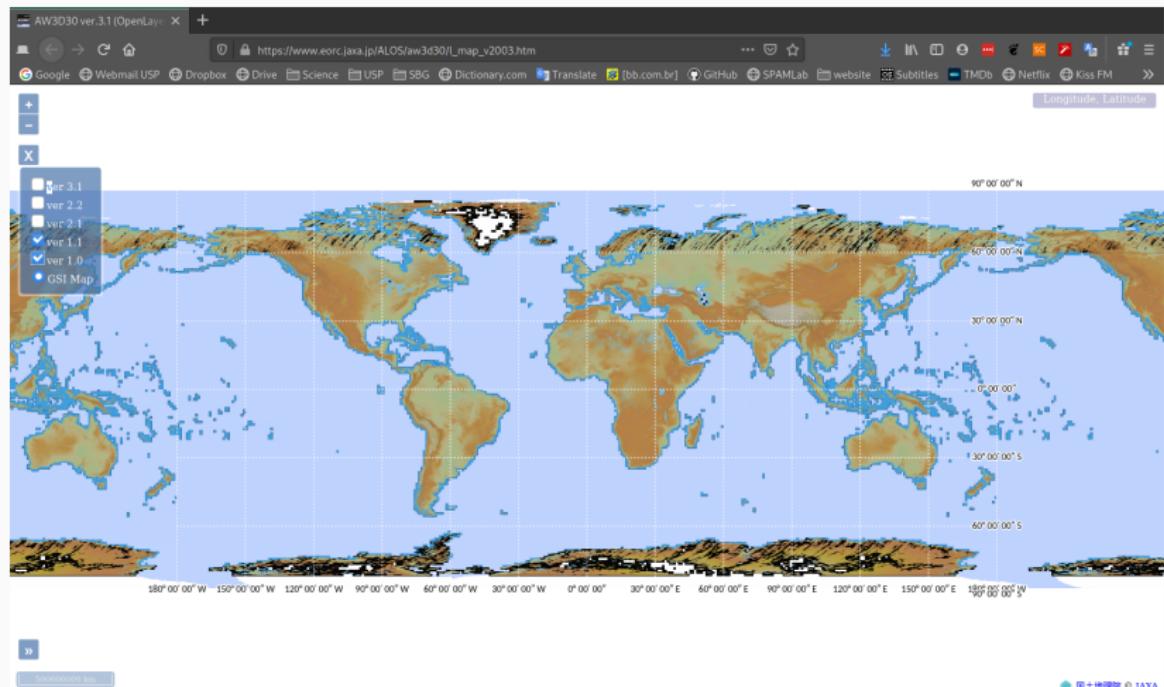
ALOS PRISM AW3D30

- Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM)
- Modelo comercial com 5m resolução
- Modelo gratuito com 30m resolução
- ALOS AW3D30 v.1.0 – 2016
- ALOS AW3D30 v.1.1 – 2017
- ALOS AW3D30 v.2.1 – 2018
- ALOS AW3D30 v.2.2 – 2019
- ALOS AW3D30 v.3.1 – 2020
- 30m (teóricos)
- DSM
- Global

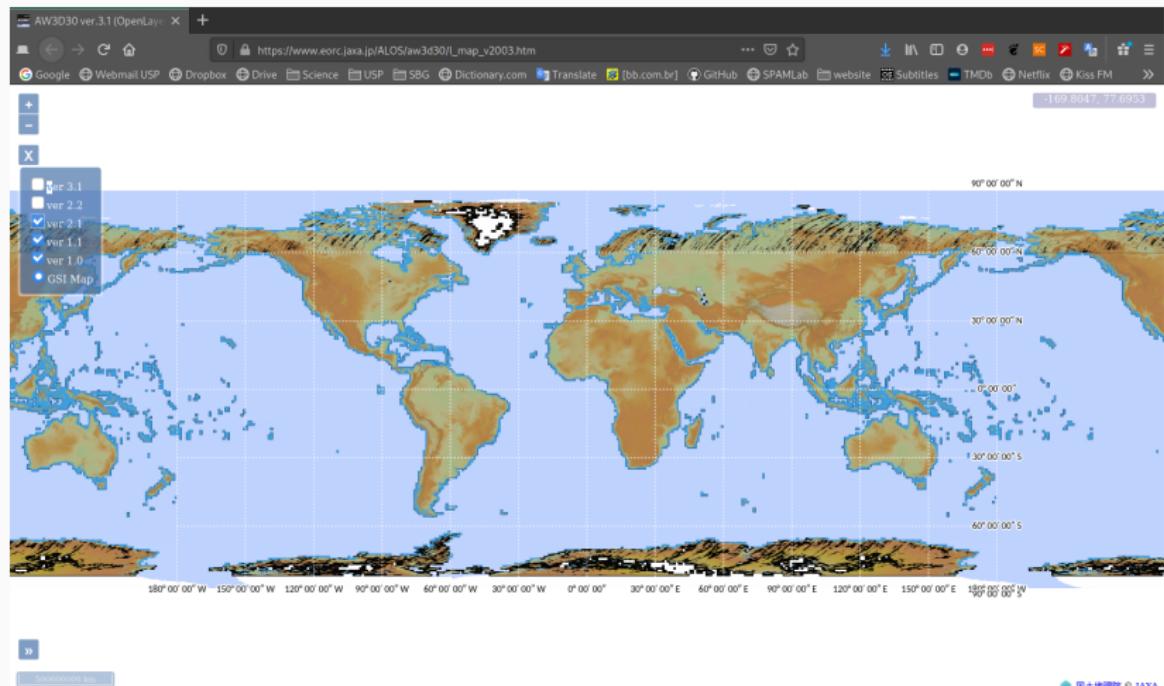
ALOS PRISM AW3D30 - v1.0



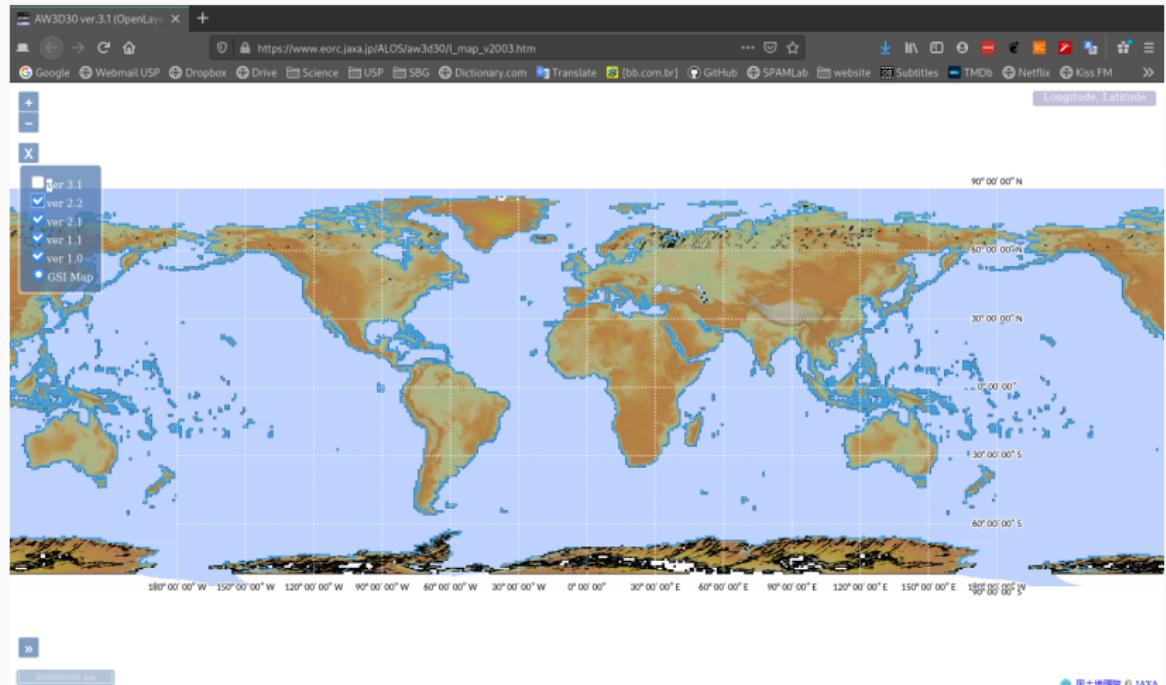
ALOS PRISM AW3D30 - v.1.1



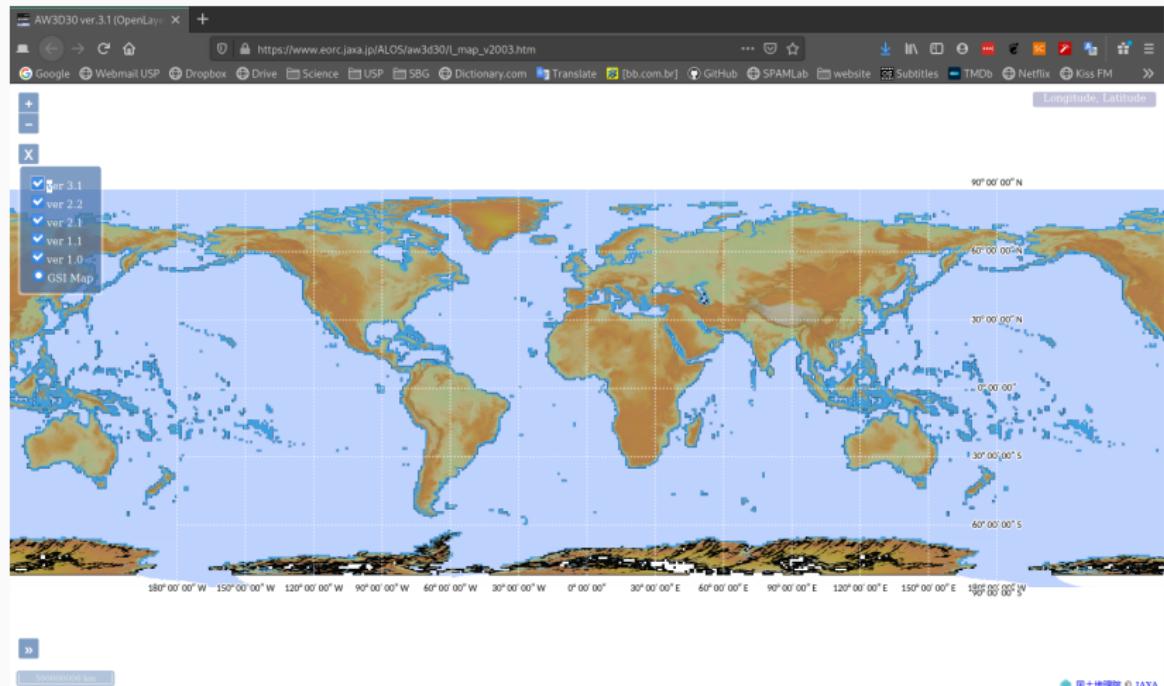
ALOS PRISM AW3D30 - v.2.1



ALOS PRISM AW3D30 - v.2.2

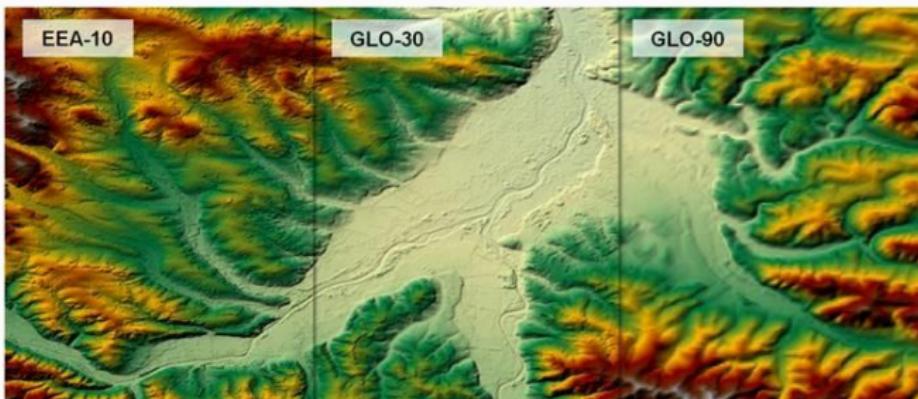


ALOS PRISM AW3D30 - v.3.1



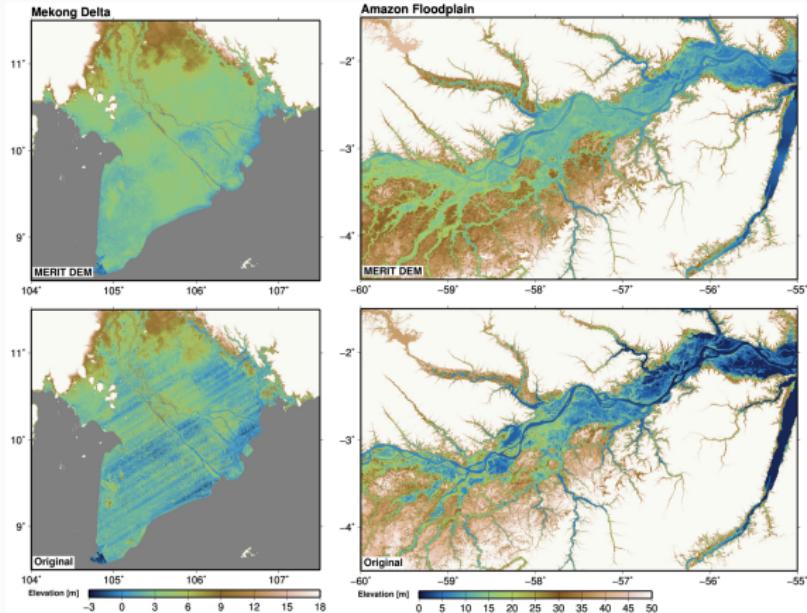
Copernicus DEM

- Produzido a partir do TanDEM-X
- [https://spacedata.copernicus.eu/fr/dataset-details?
articleId=394198](https://spacedata.copernicus.eu/fr/dataset-details?articleId=394198)
- [https://spacedata.copernicus.eu/fr/web/cscda/
data-access/registration](https://spacedata.copernicus.eu/fr/web/cscda/data-access/registration)



MERIT DEM

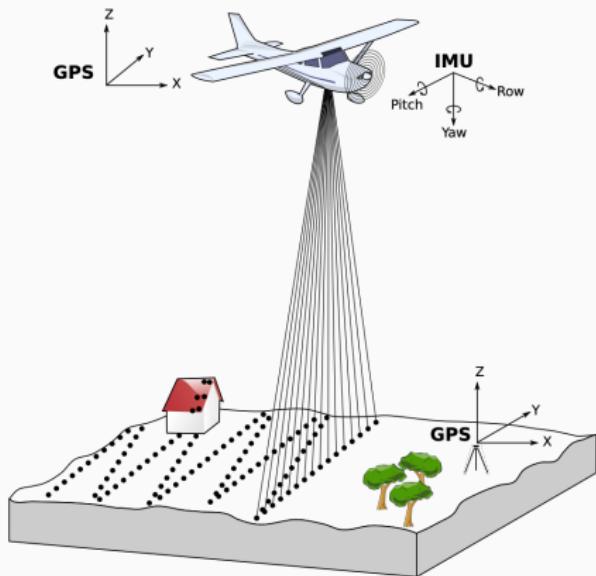
- MERIT DEM: Multi-Error-Removed Improved-Terrain DEM
- http://hydro.iis.u-tokyo.ac.jp/~yamadai/MERIT_DEM/



MDEs de alta resolução espacial

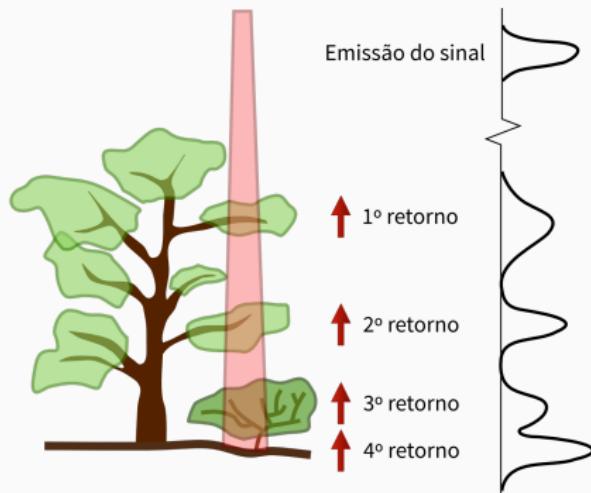
LiDAR

- LiDAR – Light Detection and Ranging
- Aeroportado ou Terrestre (TLS)
- Densidade de pontos absurdamente elevada
- DGPS + IMU + Laser
- Múltiplos retornos – múltiplas superfícies

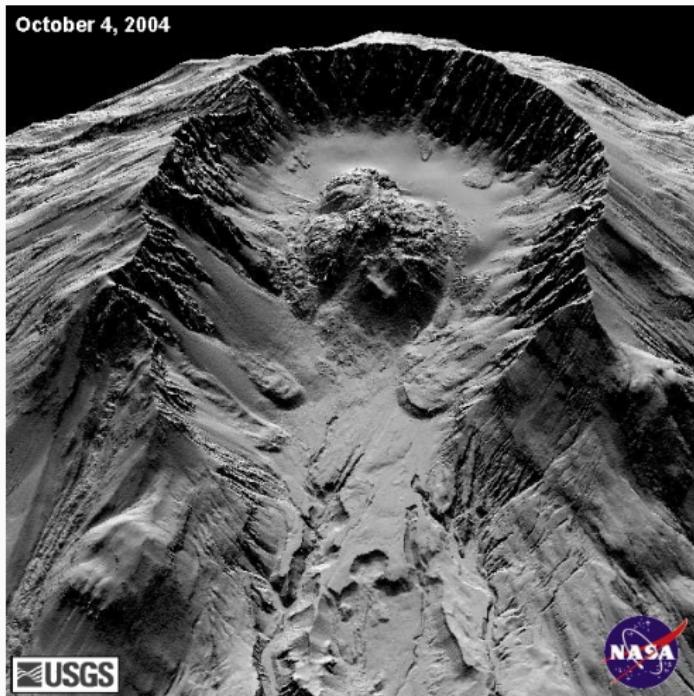


LiDAR - retornos

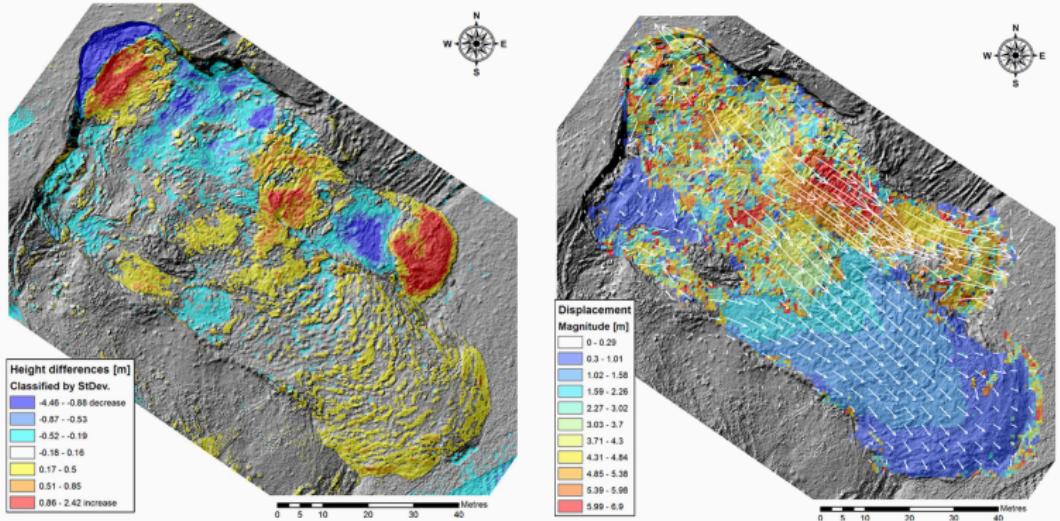
- Múltiplos retornos do pulso de laser
 - Filtragem de superfícies (solo, dossel)
- Full Waveform



LiDAR - Monte Santa Helena



LiDAR - Análise temporal



Lucieer et al., 2014. Progress in Physical Geography.

<https://doi.org/10.1177/0309133313515293>

LiDAR - São Paulo



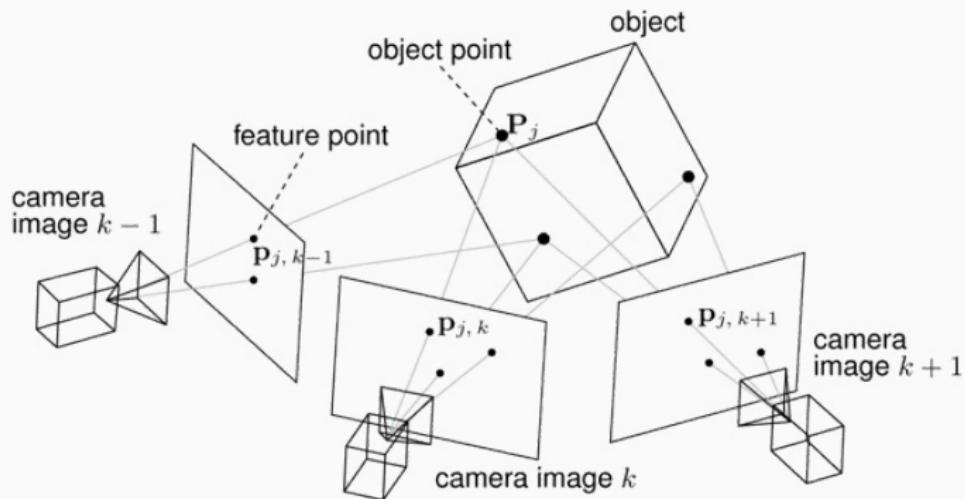
http://geosampa.prefeitura.sp.gov.br/PaginasPublicas/_SBC.aspx
https://spamlab.github.io/blog/pmsp_lidar/

LiDAR - São Paulo



http://geosampa.prefeitura.sp.gov.br/PaginasPublicas/_SBC.aspx

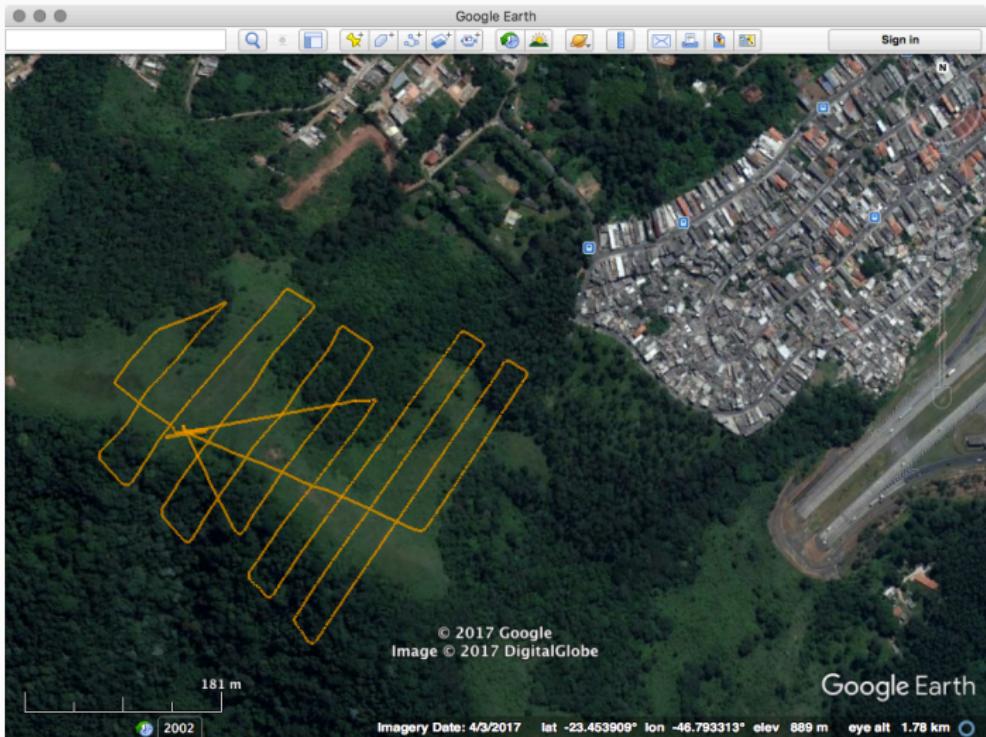
Structure from Motion Multi-View Stereo – SfM-MVS



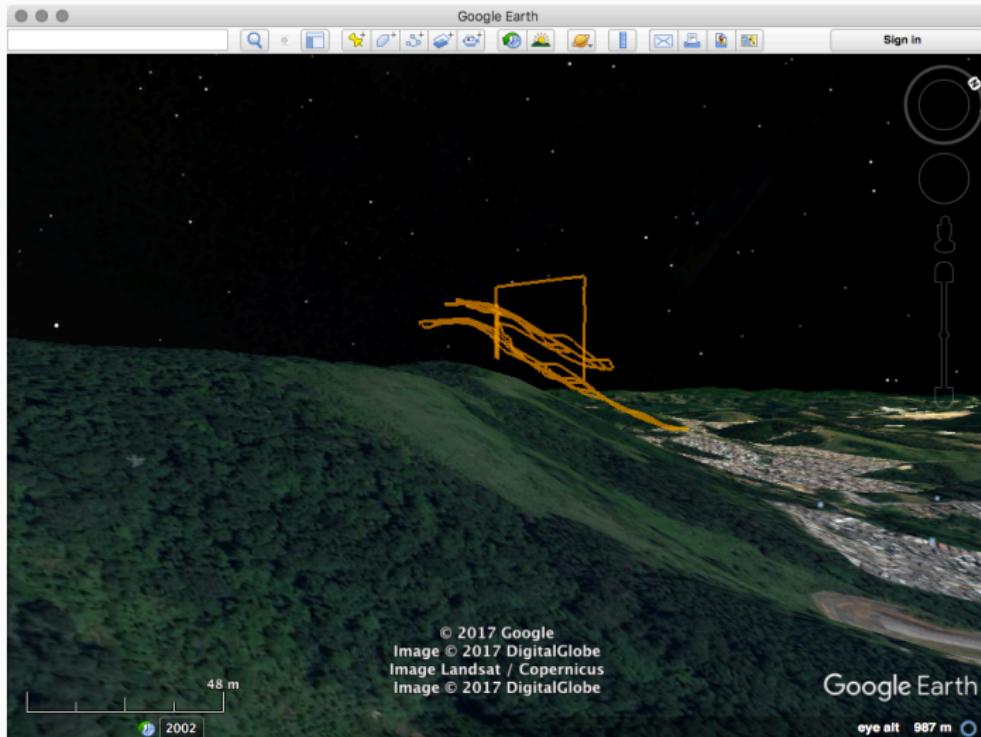
Kurz et al., 2011. Journal of Virtual Reality and Broadcasting

<https://doi.org/10.20385/1860-2037/8.2011.2>

SfM-MVS - São Paulo



SfM-MVS - São Paulo



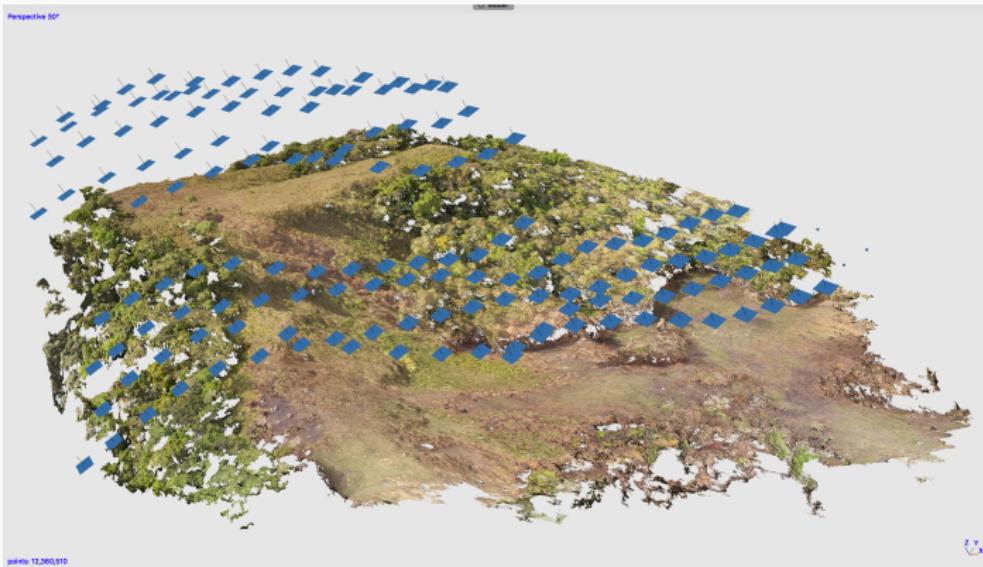
Santos & Grohmann, 2019. SBSR (link)

SfM-MVS - São Paulo



Santos & Grohmann, 2019. SBSR ([link](#))

SfM-MVS - São Paulo

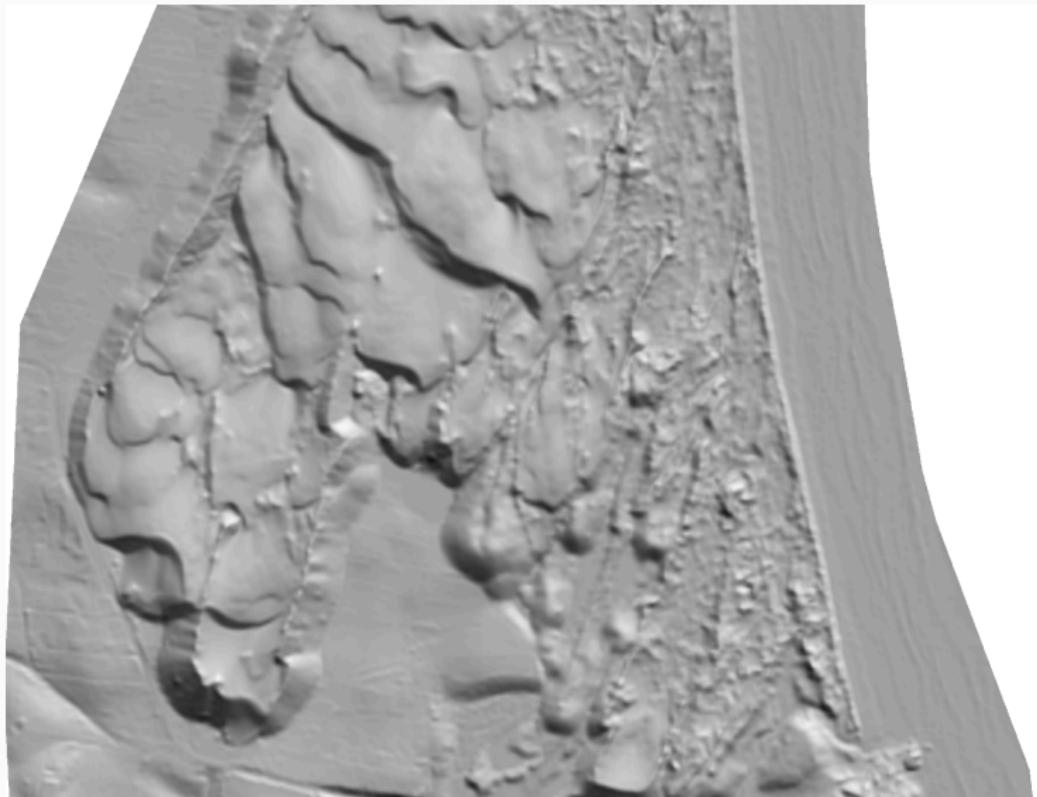


Santos & Grohmann, 2019. SBSR ([link](#))

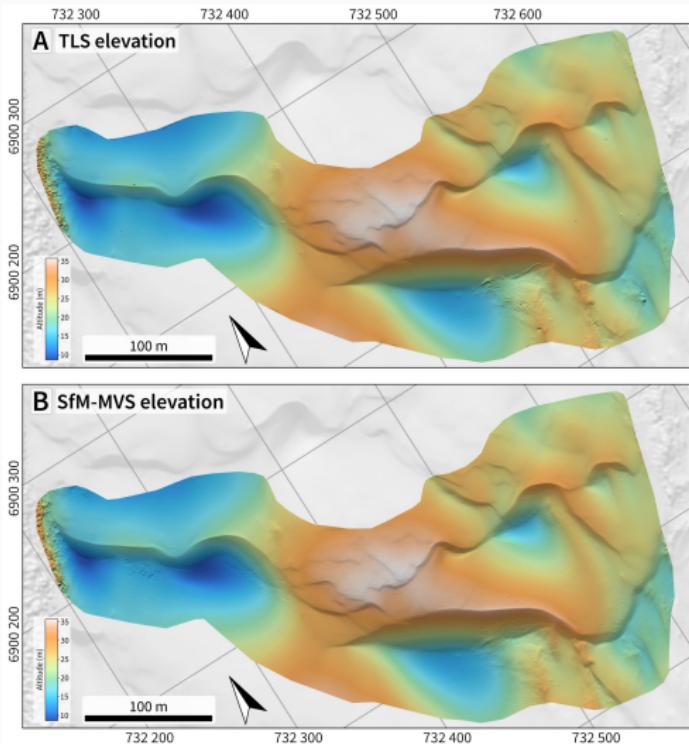
LiDAR x SfM-MVS – Imagem intensidade LiDAR



LiDAR x SfM-MVS – MDT LiDAR



LiDAR x SfM-MVS (LiDAR terrestre)



Grohmann et al., 2020. CAGEO <http://doi.org/10.1016/j.cageo.2020.104569>

LiDAR x SfM-MVS – MDT LiDAR

