GSA-5859 / PCA-5017
SIG em Software Livre

Modelos Digitais de Elevação

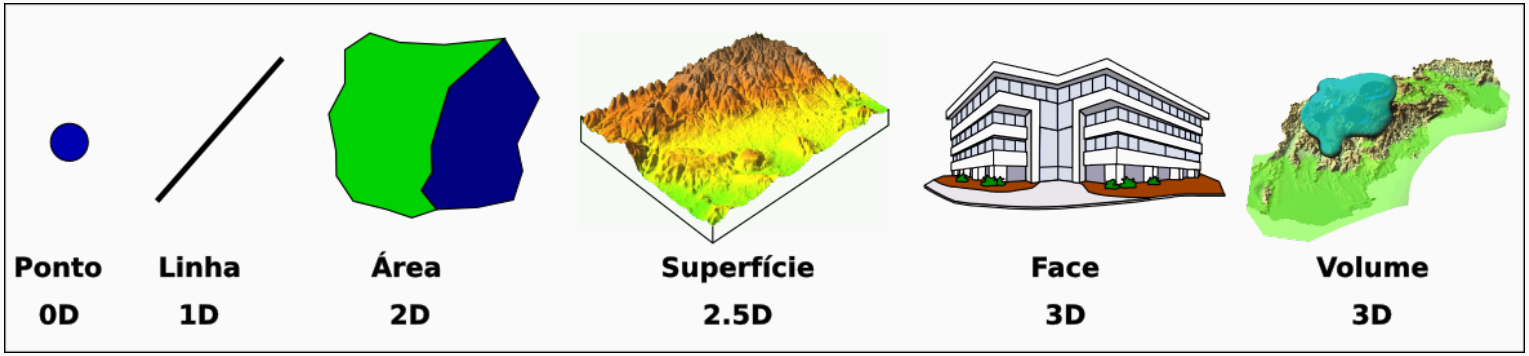
Carlos H. Grohmann

2021

Instituto de Energia e Ambiente
USP

Representação de uma superfície em SIG

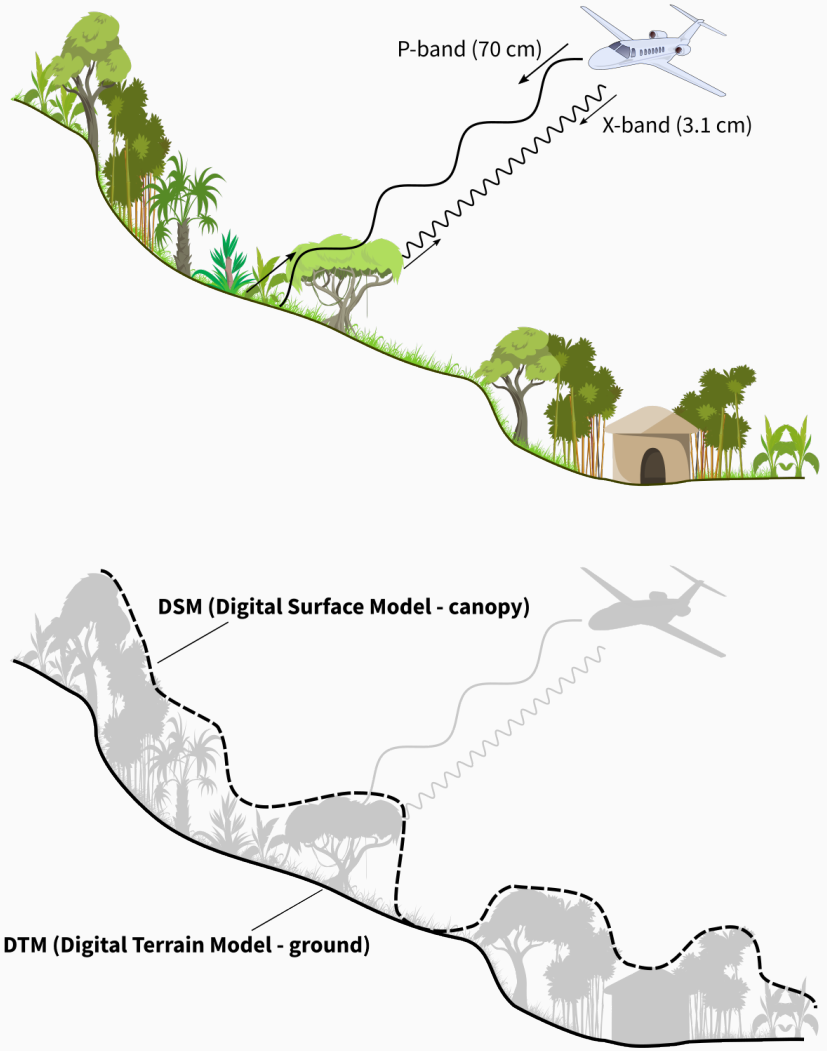
- Raster (MDE, MDT, MDS...)
- Vetor (TIN, malha (mesh))
- “2.5D”



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

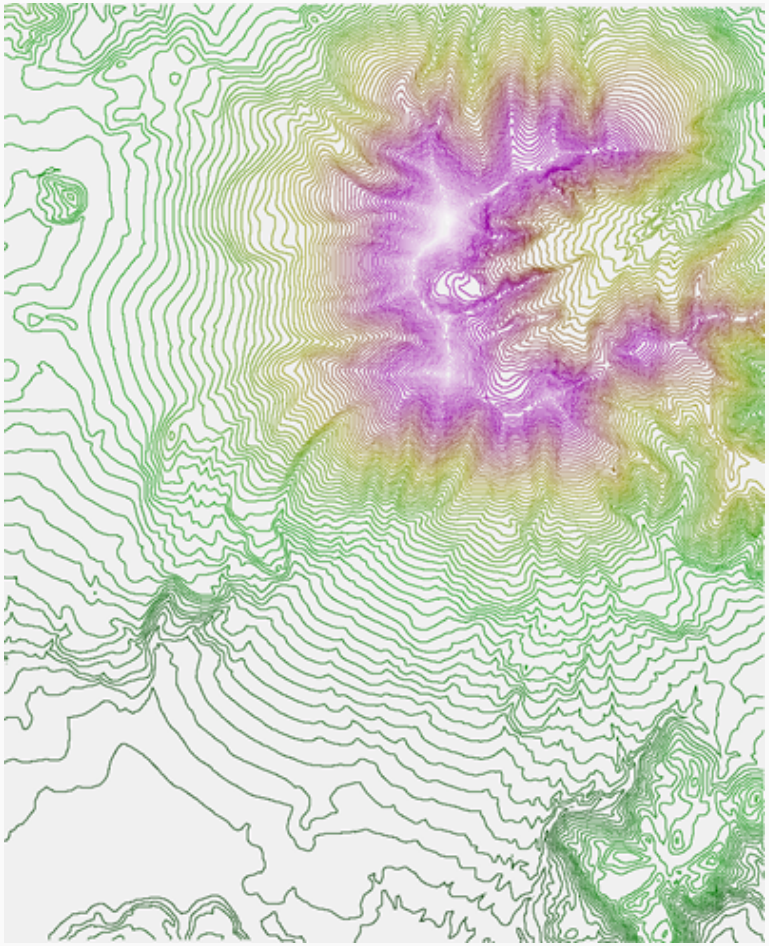
MDE/MDT/MDS ??

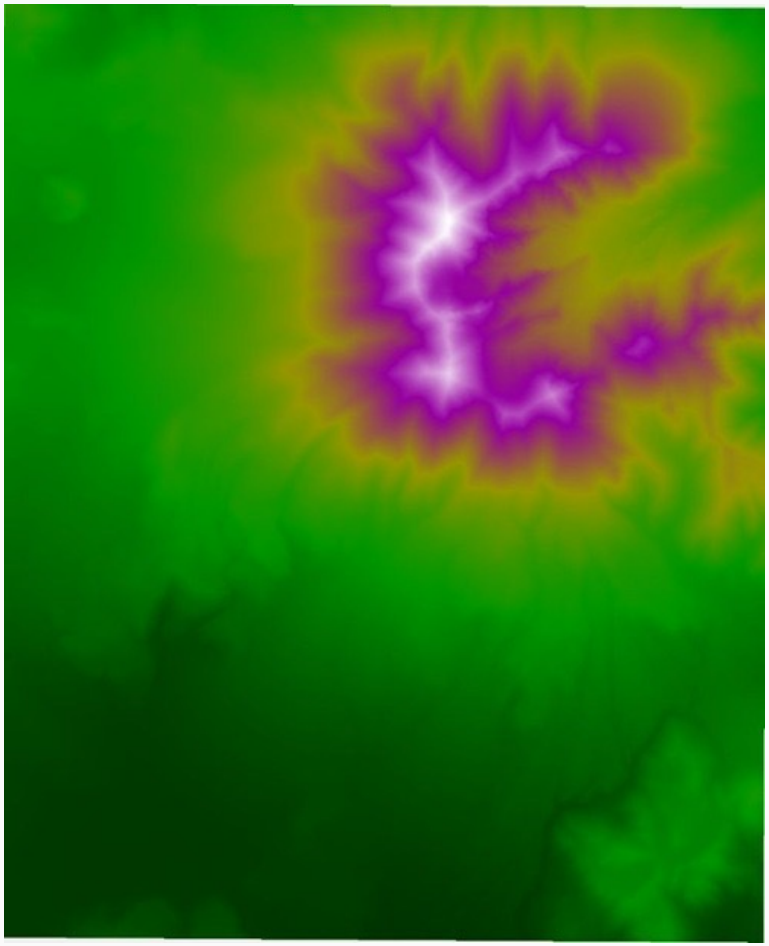

P-band (70 cm)
X-band (3.1 cm)
DSM (Digital Surface Model - canopy)
DTM (Digital Terrain Model - ground)

Construção de MDEs

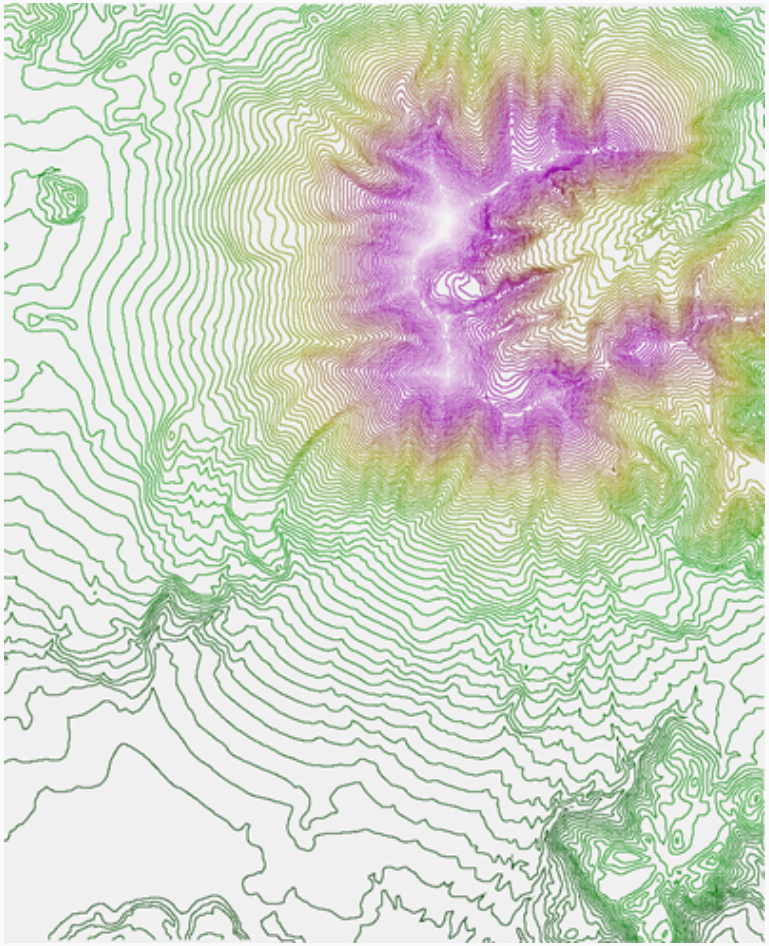
- Interpolação de dados vetoriais
  - curvas de nível
  - pontos cotados
  - curvas + pontos
  - soft breaklines, hard breaklines
- Sensoriamento remoto
  - fotogrametria
  - interferometria de radar
  - LiDAR

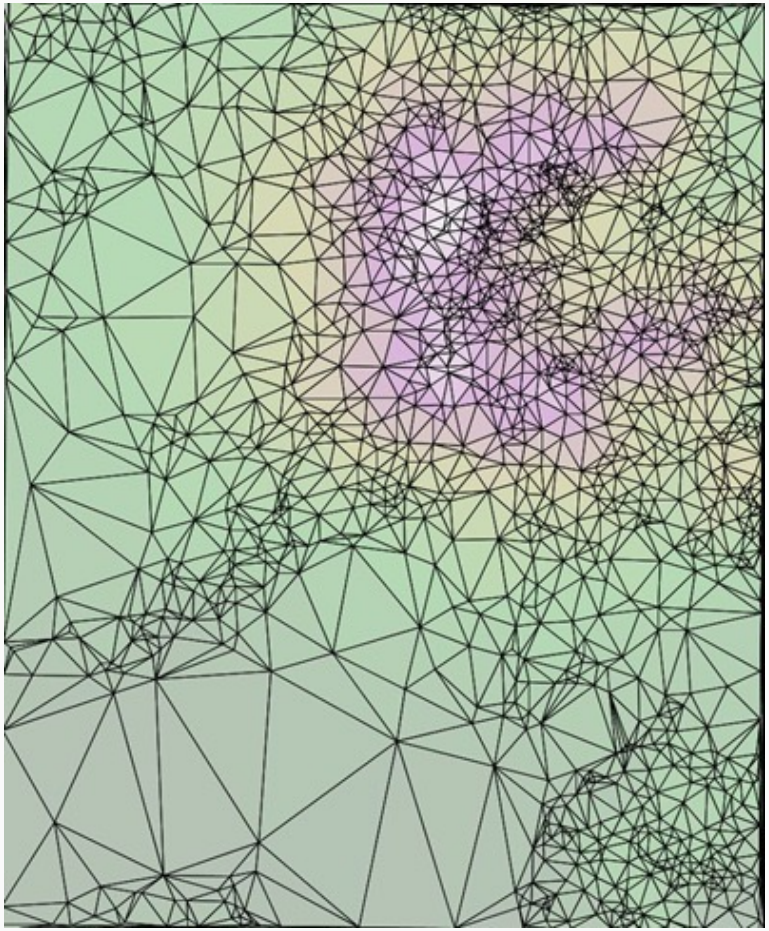
Interpolação de dados vetoriais para raster



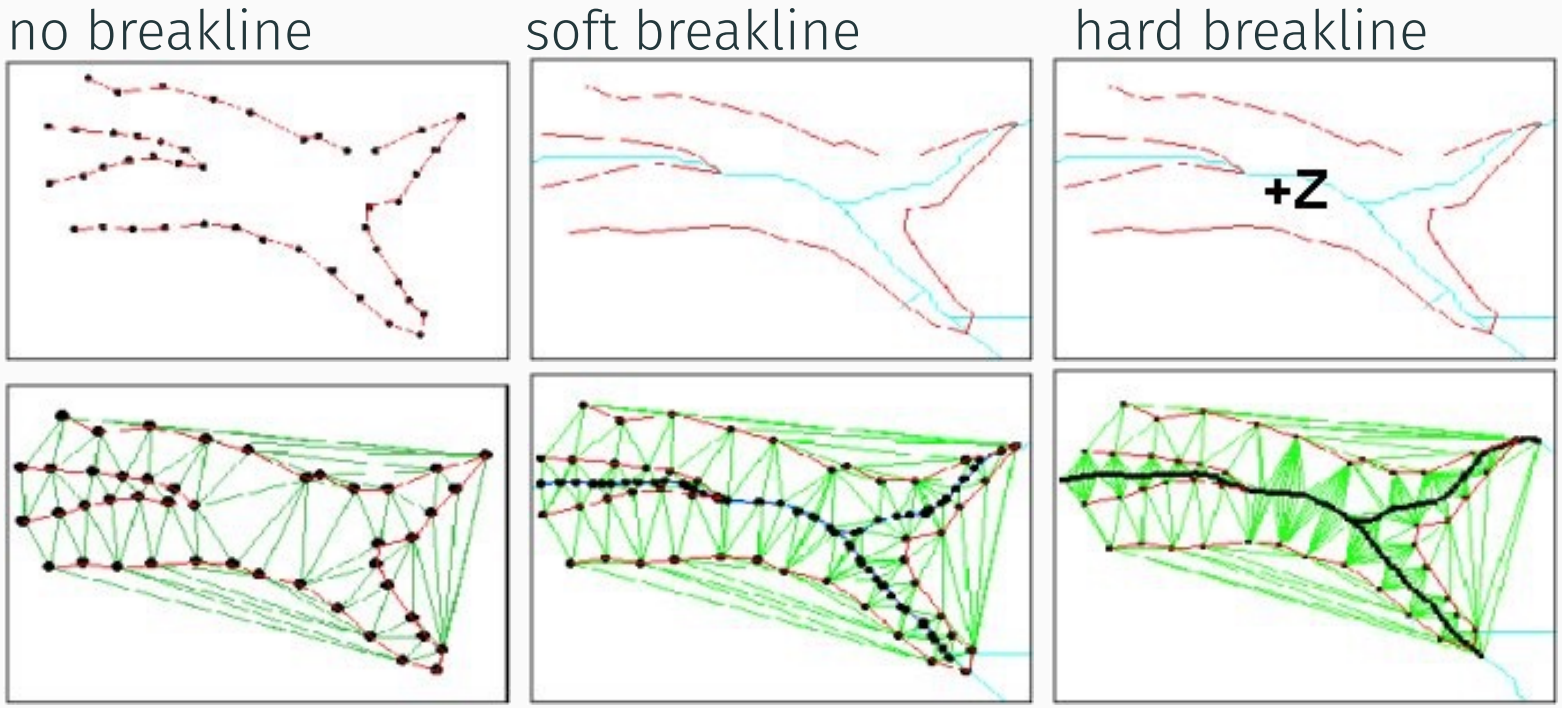


Interpolação de dados vetoriais para TIN



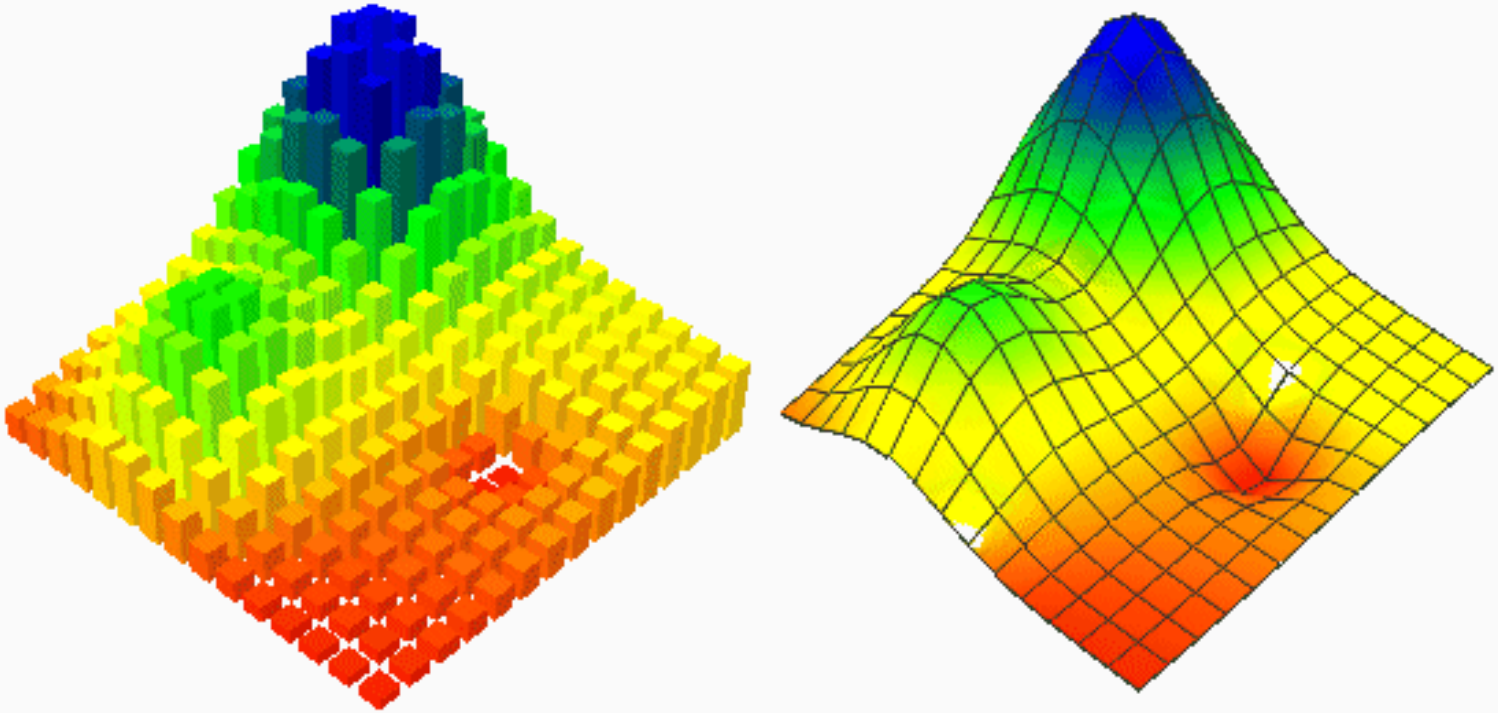


Interpolação – Breaklines

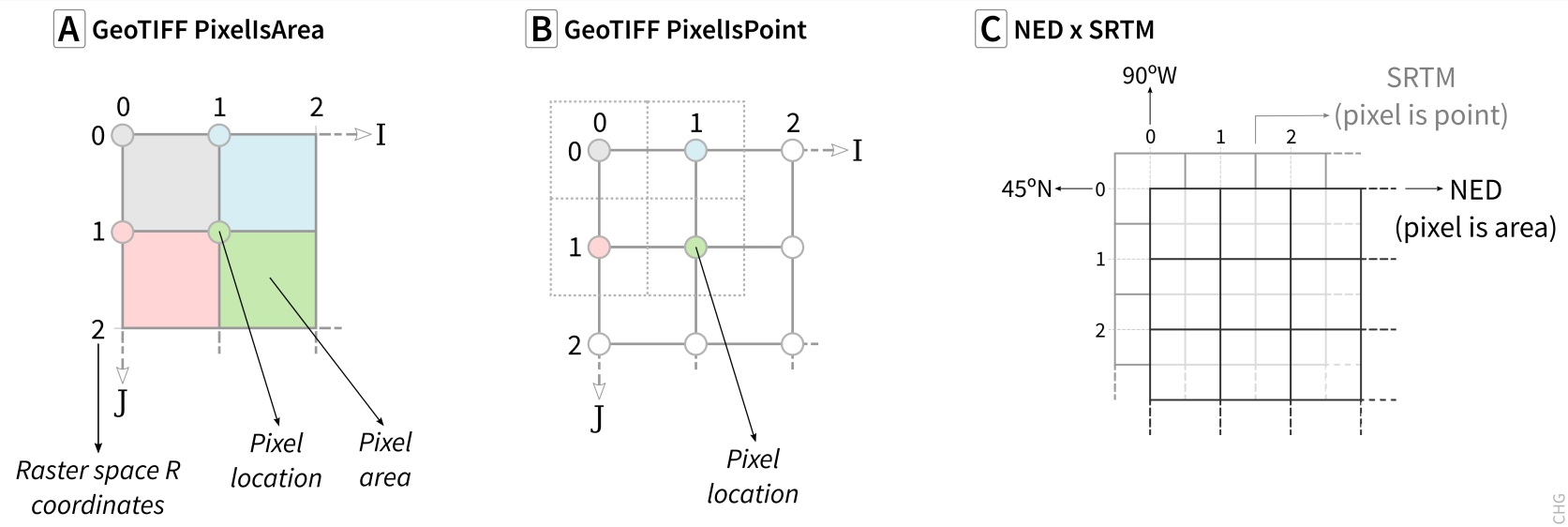


Representações Discretas x Contínuas

pixel-is-area x pixel-is-point

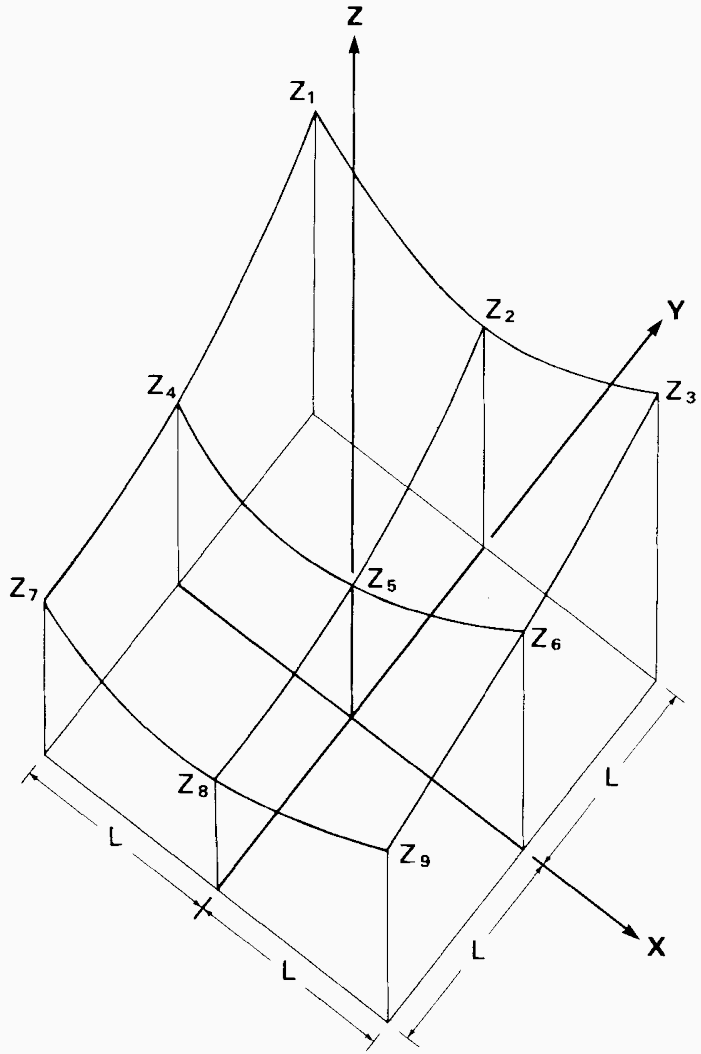


Pixel-is-area x Pixel-is-point

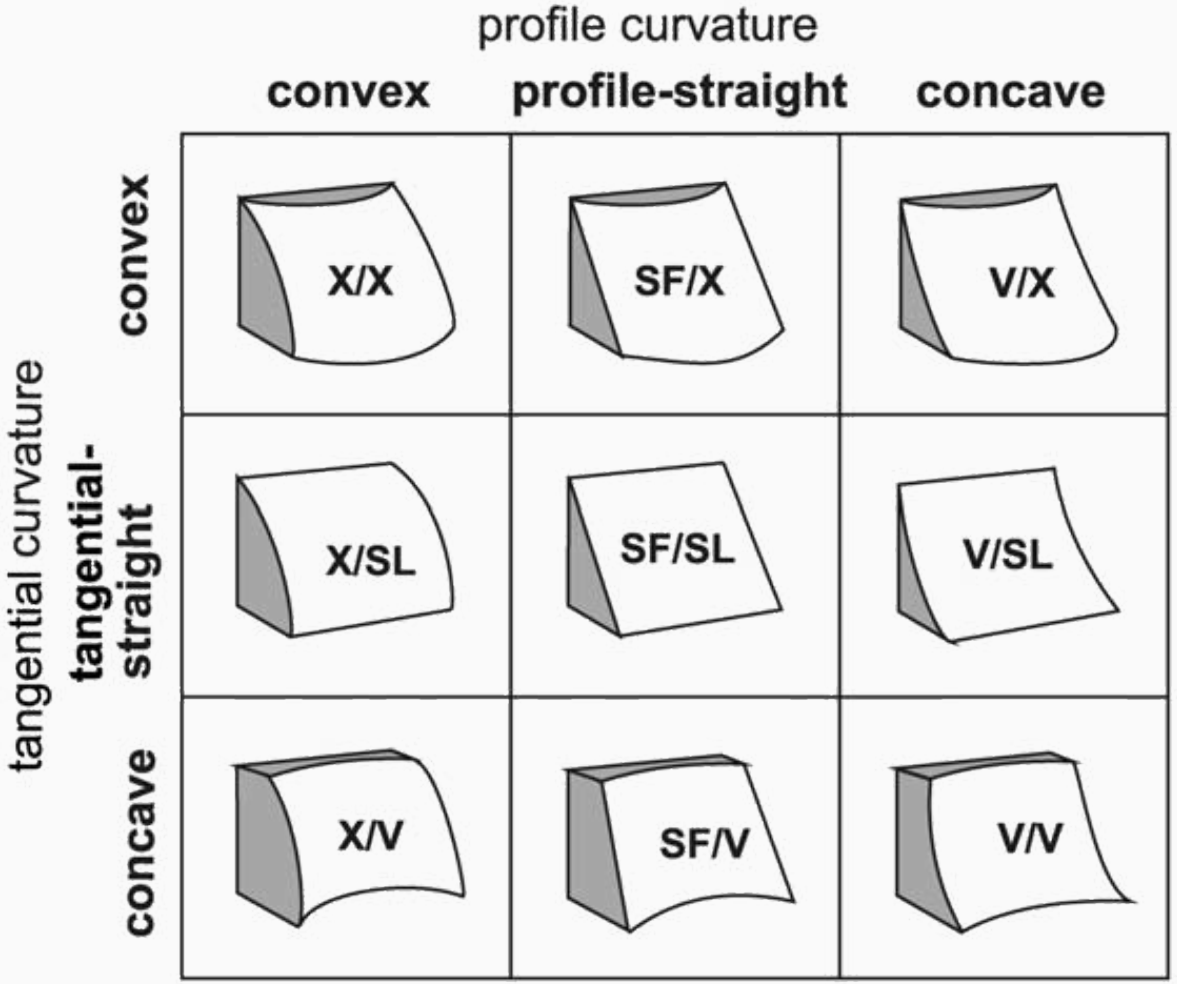


Derivadas da Superfície

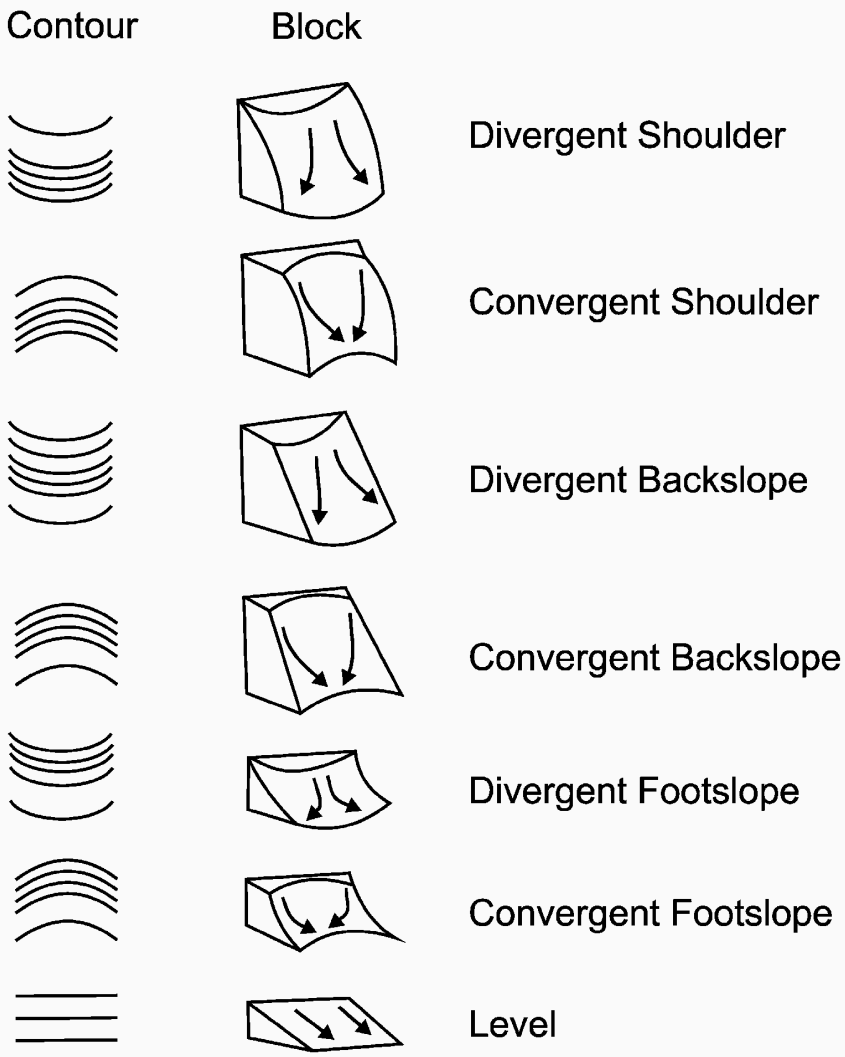
- Declividade (slope)
  - 1^a derivada vertical
- Orientação de vertentes (aspect)
  - 1^a derivada horizontal
- Curvatura de perfil
  - 2^a derivada vertical
- Curvatura tangencial
  - 2^a derivada horizontal



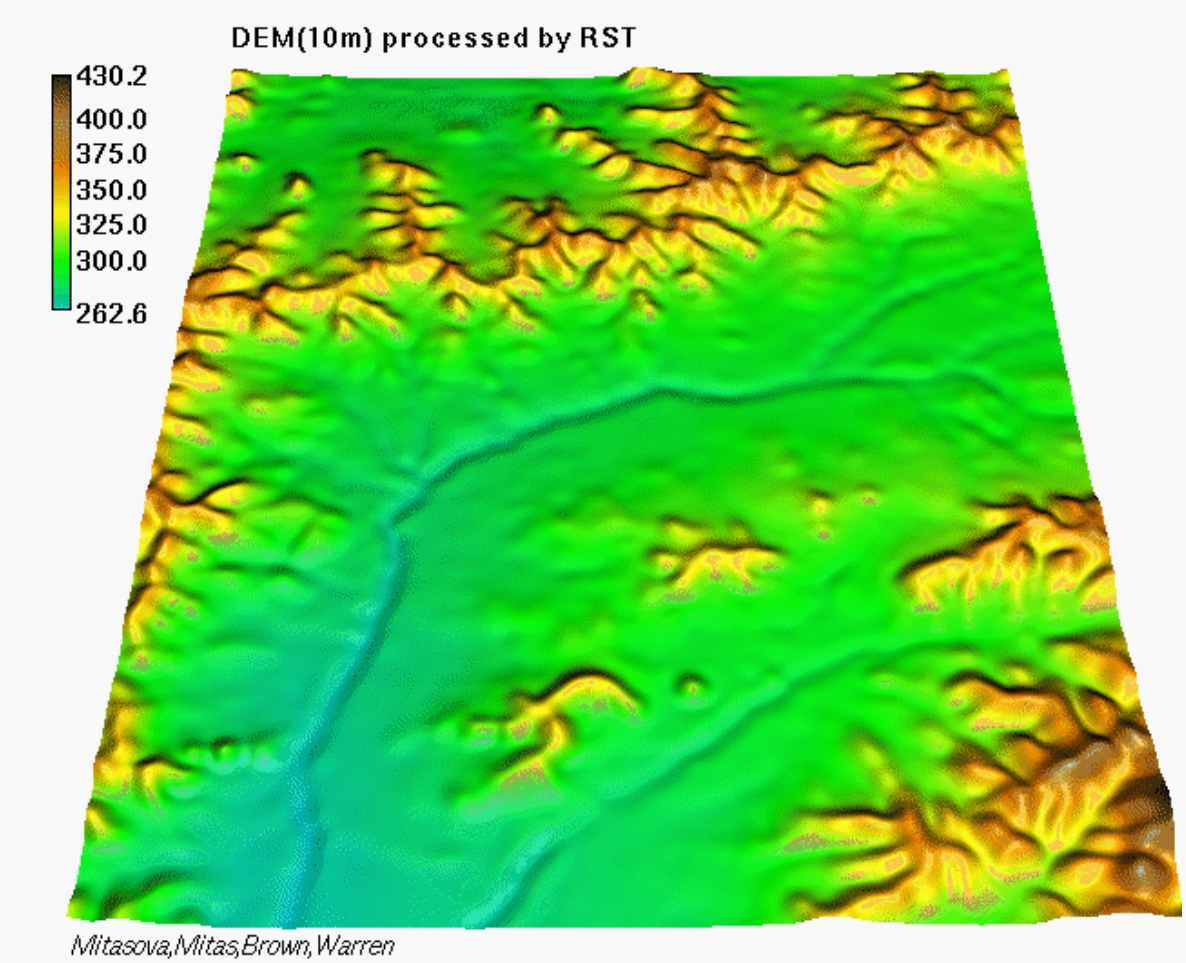
Curvaturas


profile curvature
convex
profile-straight
concave
tangential curvature
convex
tangential-straight
concave
X/X
SF/X
V/X
X/SL
SF/SL
V/SL
X/V
SF/V
V/V

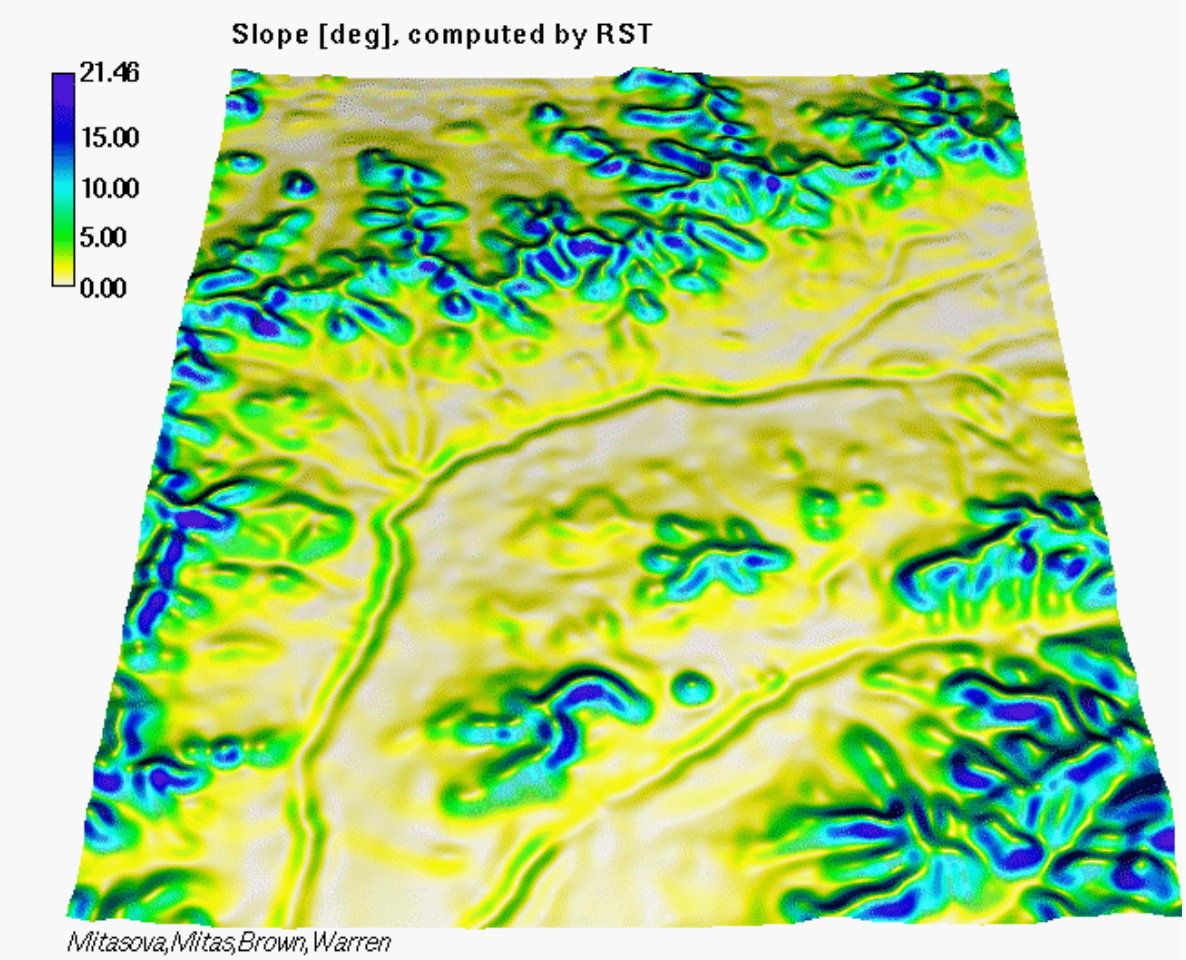
Curvaturas


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

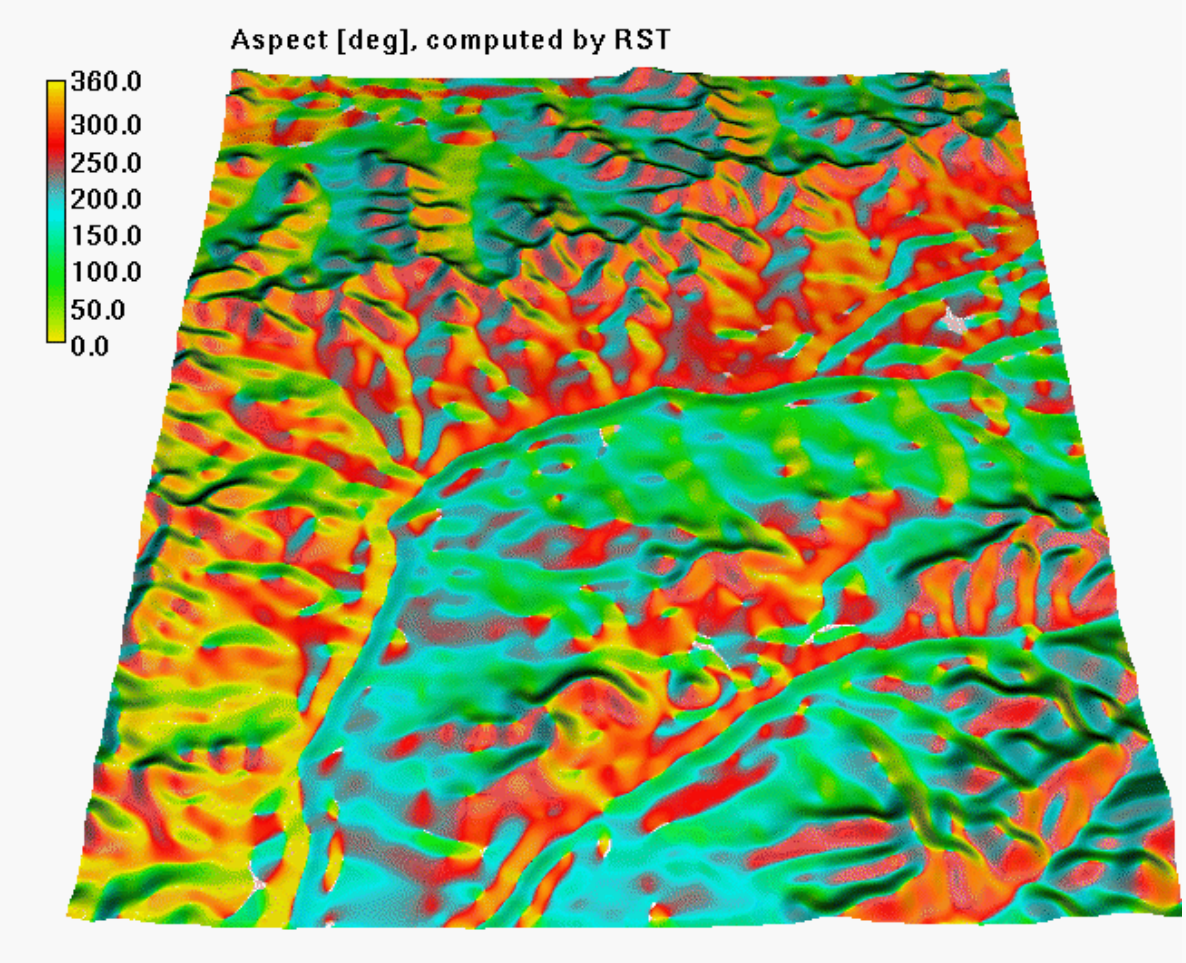
MDE / DEM


DEM(10m) processed by RST
430.2
400.0
375.0
350.0
325.0
300.0
262.6
Mitasova,Mitas,Brown,Warren

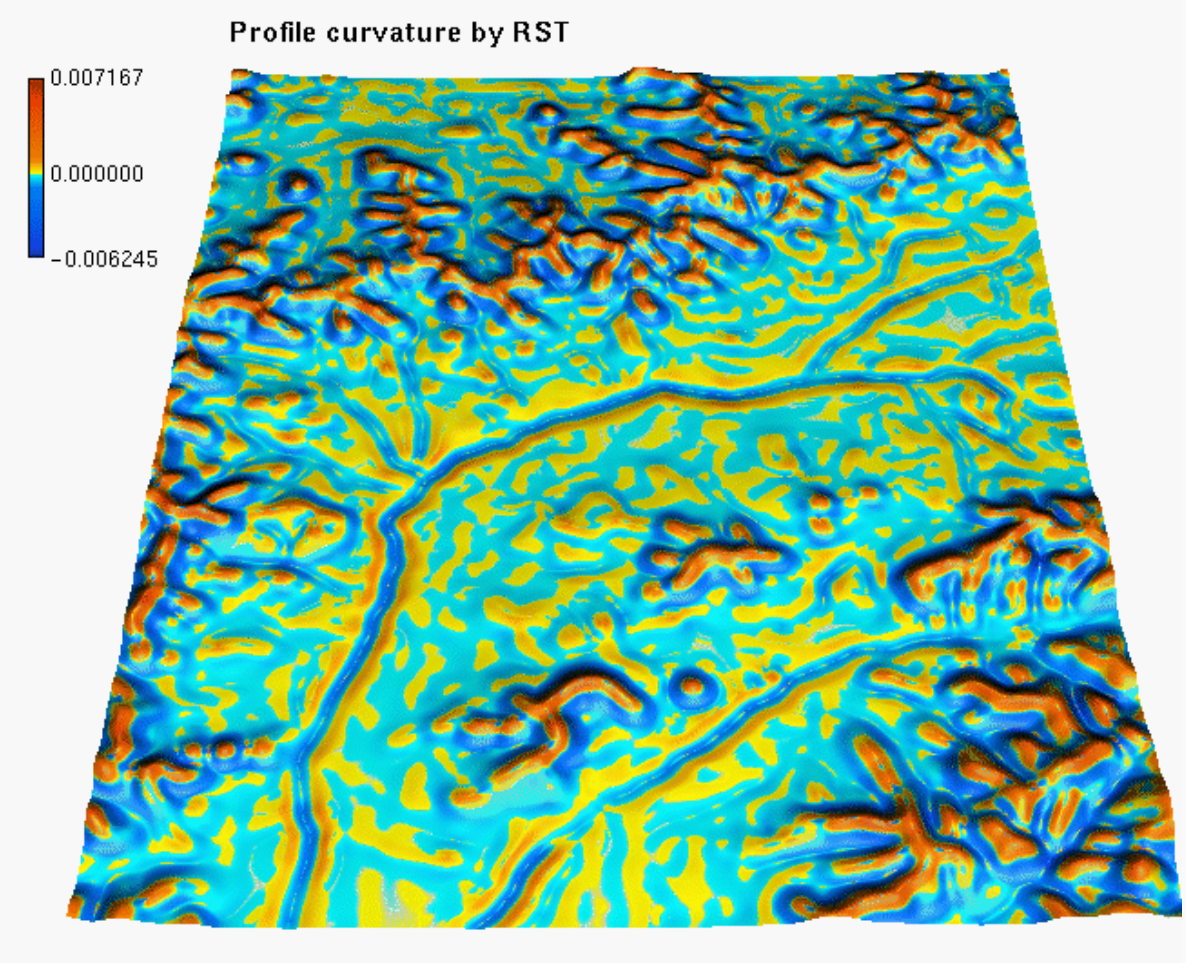
Declividade / Slope



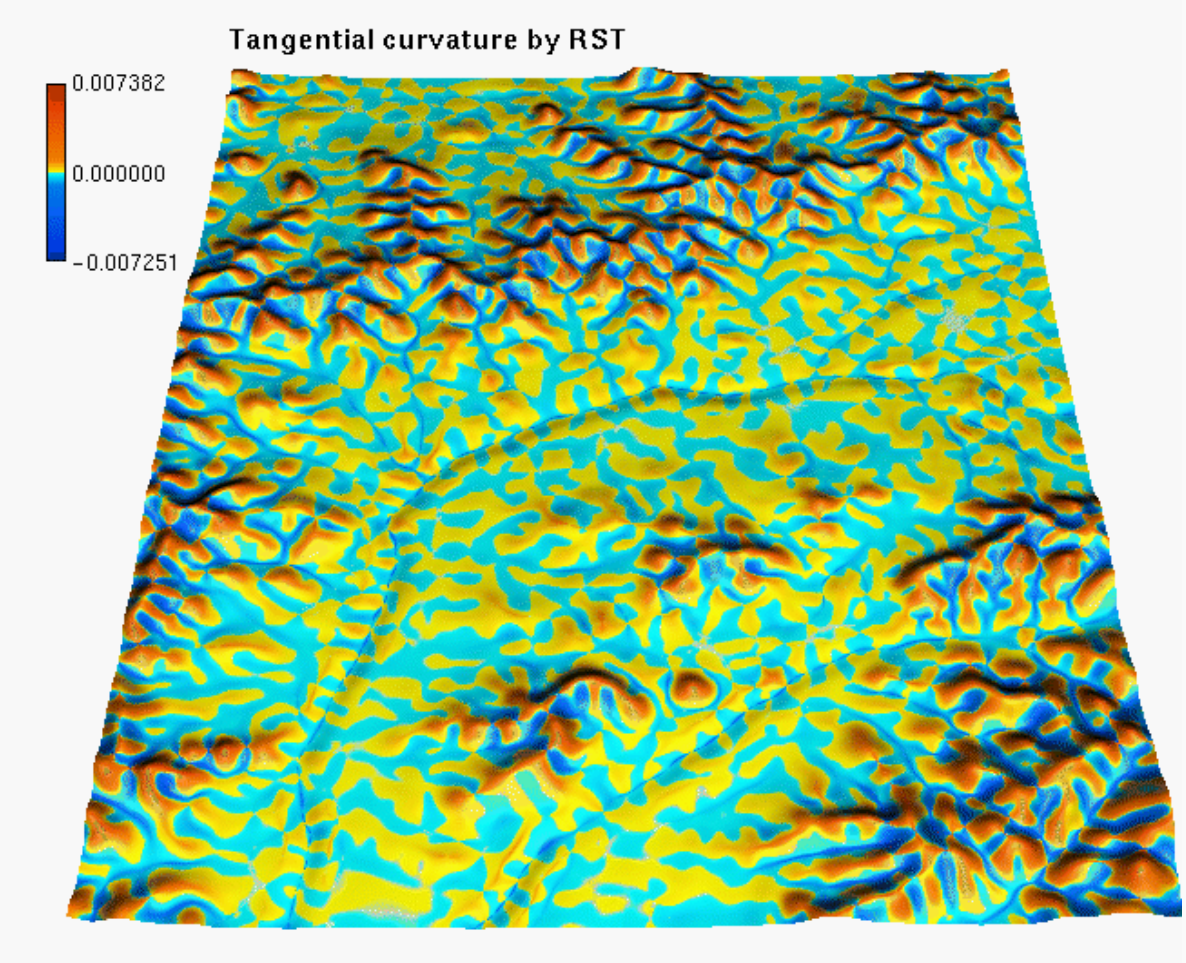
Orientação de Vertentes / Aspect



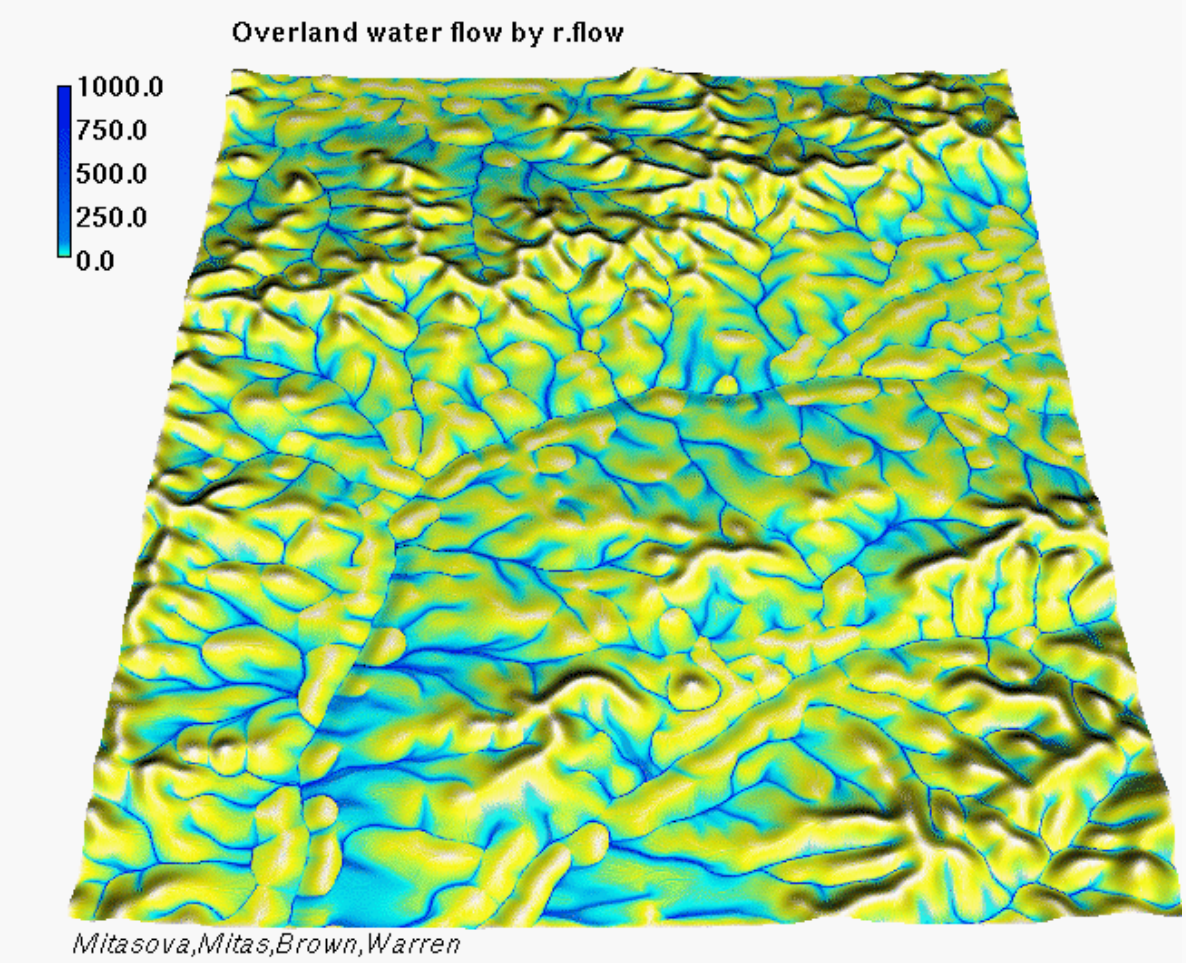
Curvatura Perfil / Profile Curvature



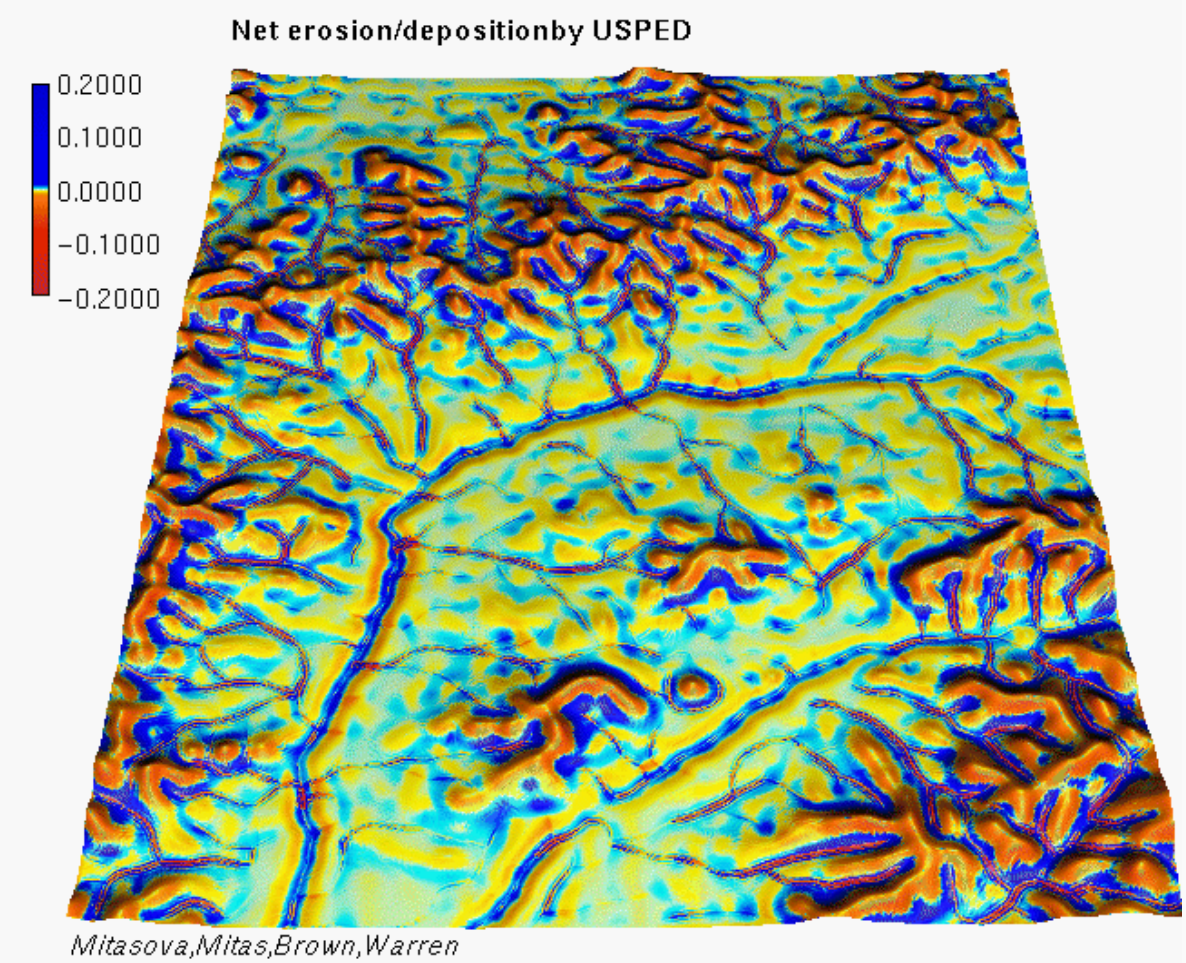
Curvatura Tangencial / Tangential Curvature



Fluxo / Flow


Overland water flow by r.flow
1000.0
750.0
500.0
250.0
0.0
Mitasova,Mitas,Brown,Warren

Erosão/Deposição



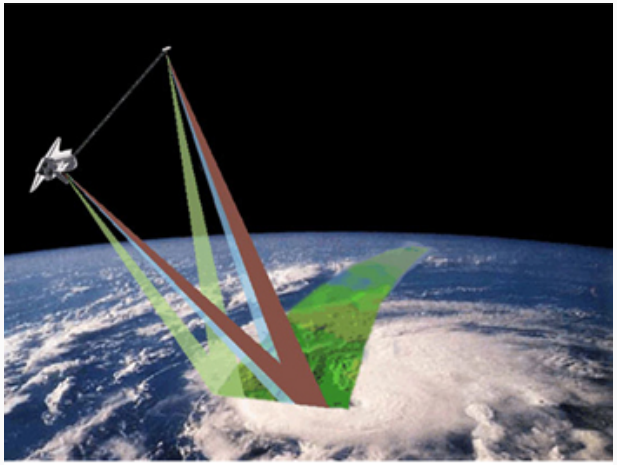
Principais MDEs (semi-) Globais

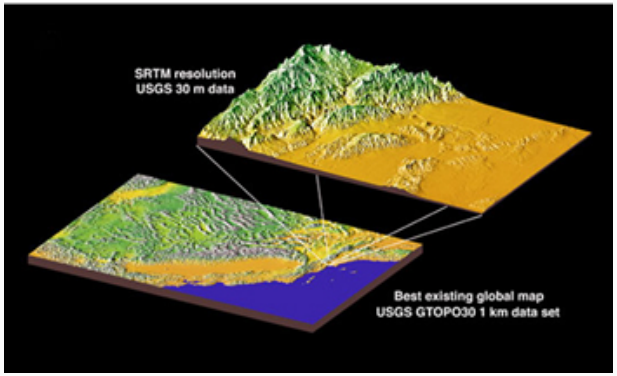
Shuttle Radar Topography Mission - SRTM

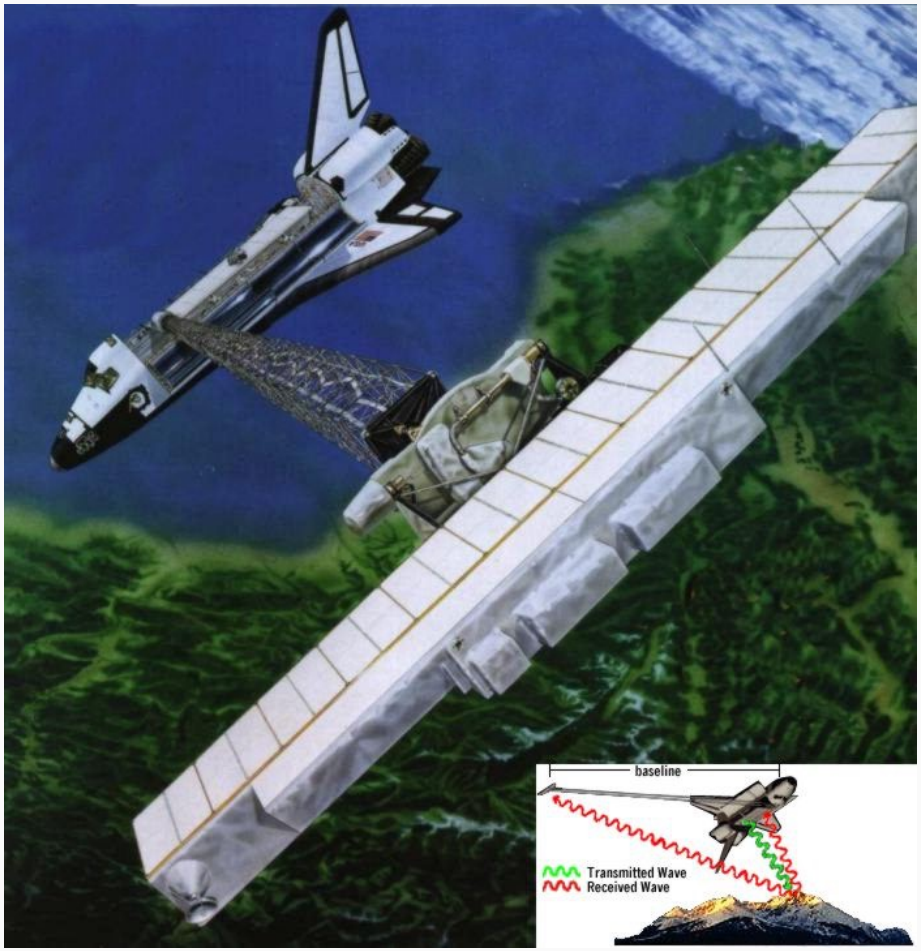
- MDEs gerados por interferometria de radar, com abrangência de 80% da superfície terrestre
- Inicialmente:
  - Estados Unidos – resolução de 1” (aprox. 30m)
  - O resto do Mundo – resolução de 3” (aprox. 90m)

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

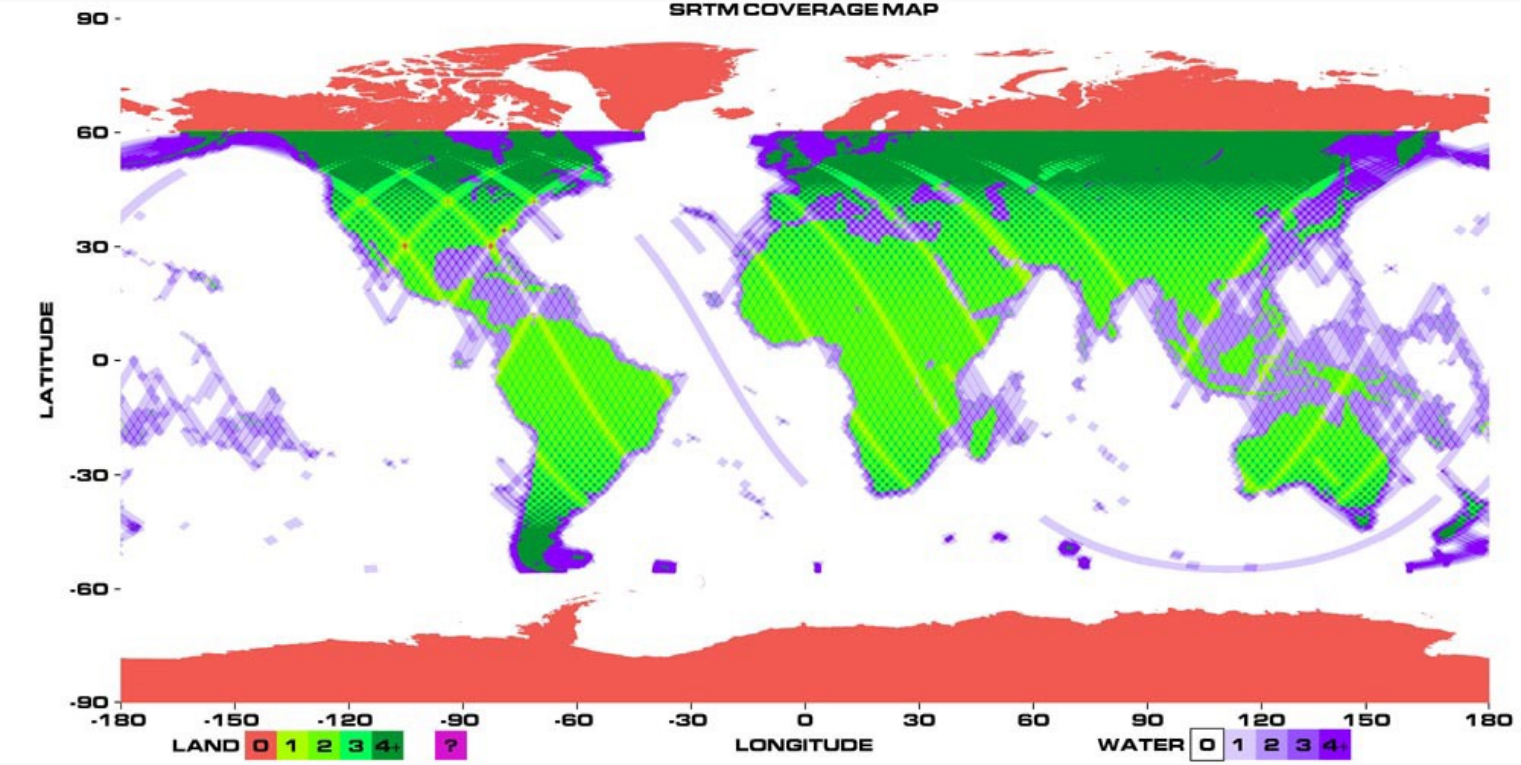
SRTM




SRTM resolution
USGS 30 m data
Best existing global map
USGS GTOPO30 1 km data set


baseline
Transmitted Wave
Received Wave

SRTM

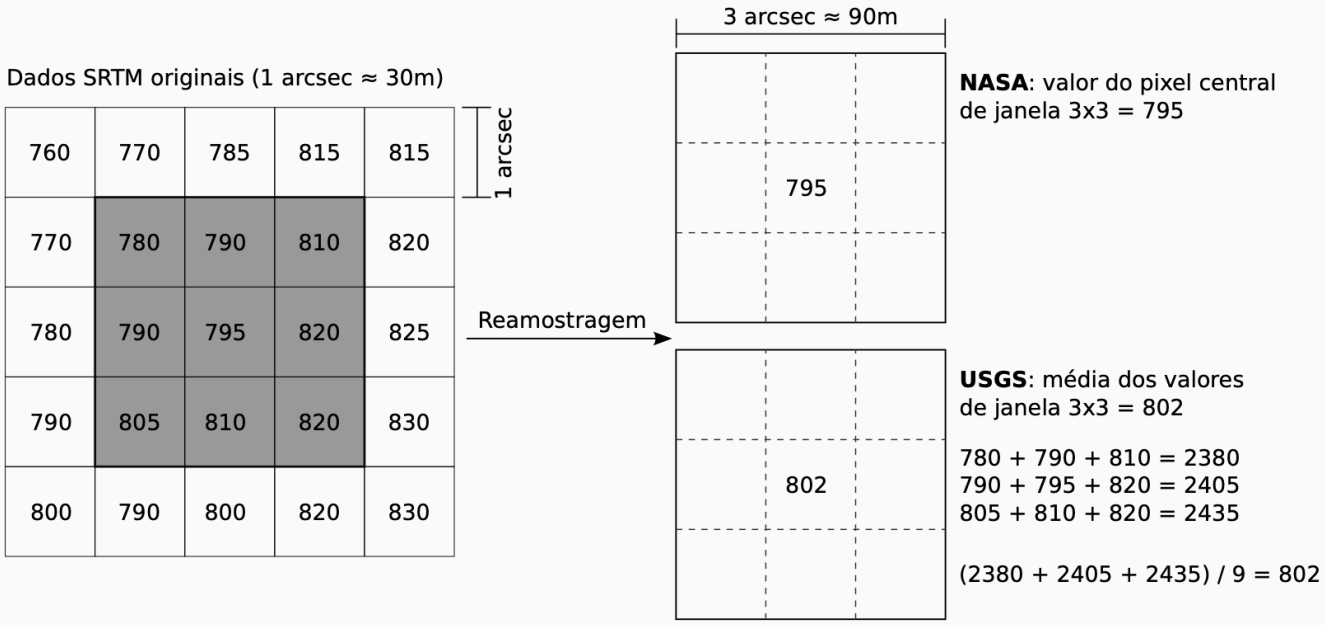

SRTM COVERAGE MAP
90
60
30
0
-30
-60
-90
LATITUDE
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
LONGITUDE
LAND 0 1 2 3 4+
?
WATER 0 1 2 3 4+

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`

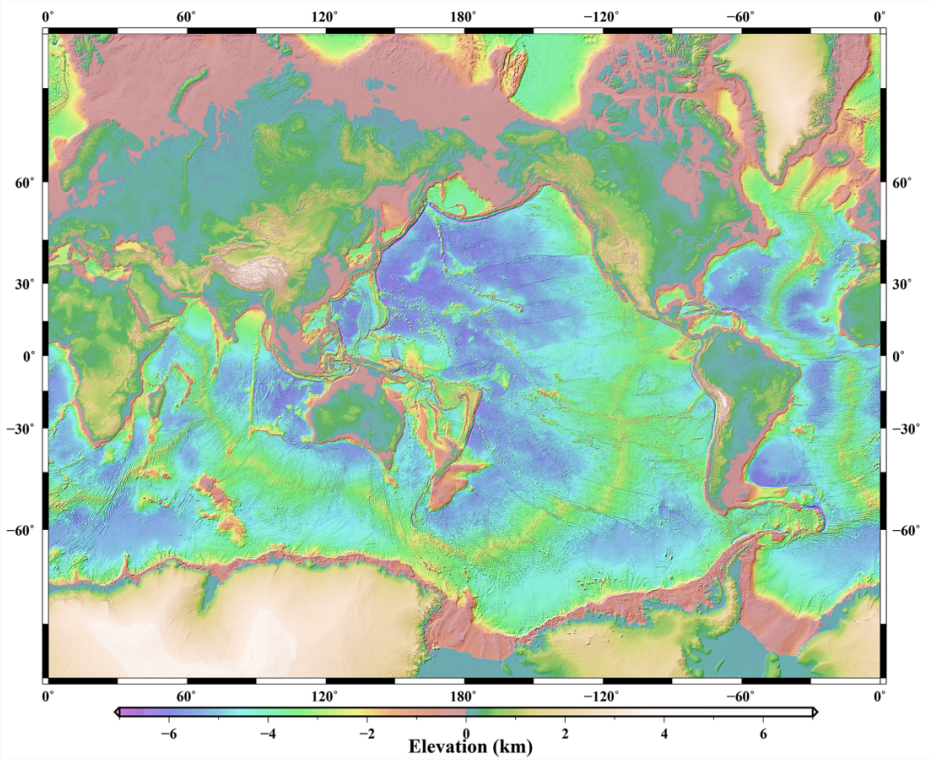
Reamostragem dos dados SRTM

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



SRTM15+

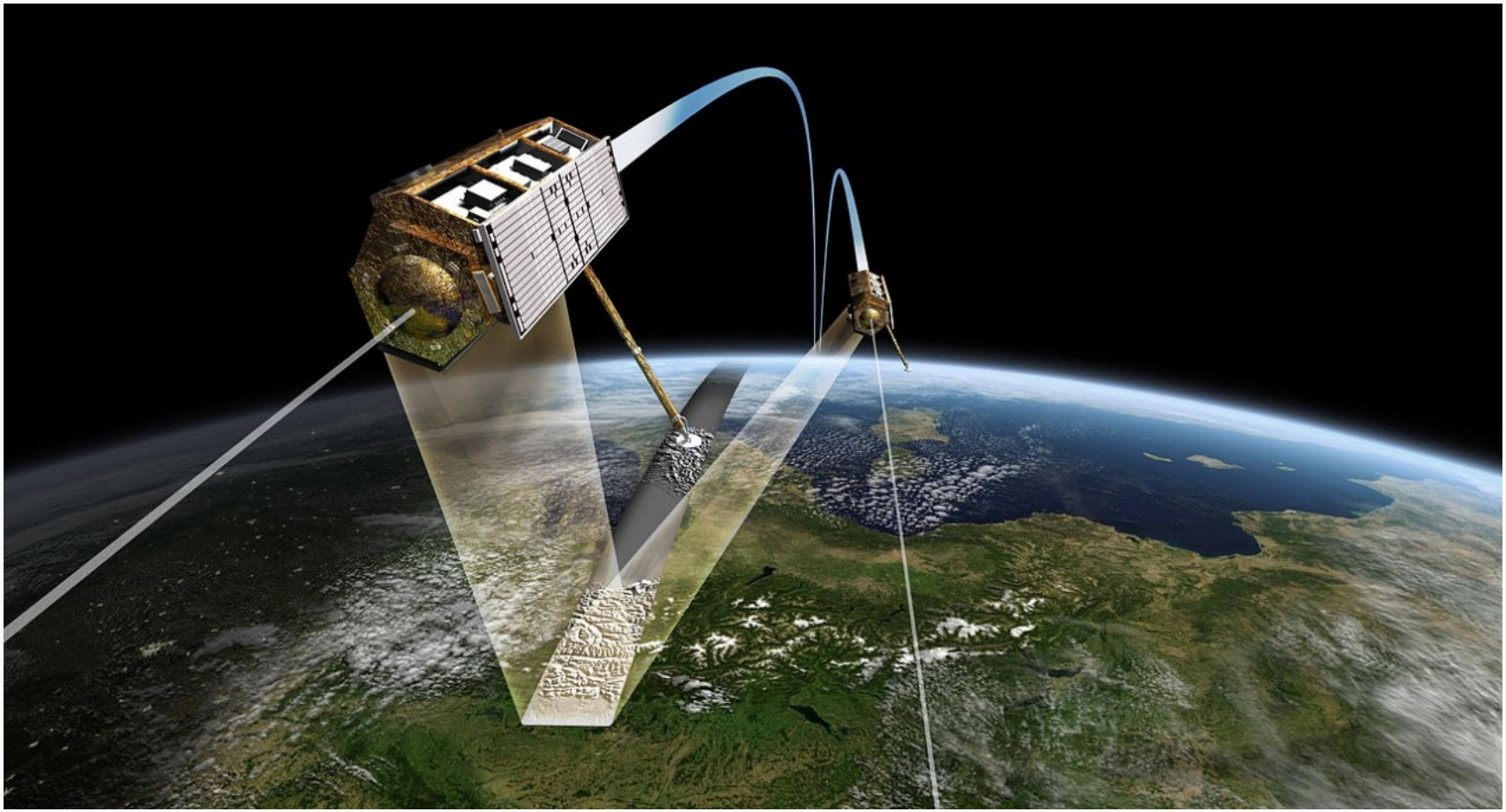
- Resolução de 15” (aprox. 500m)
- Continentes e Oceanos (global)
- `https://topex.ucsd.edu/WWW_html/srtm15_plus.html`



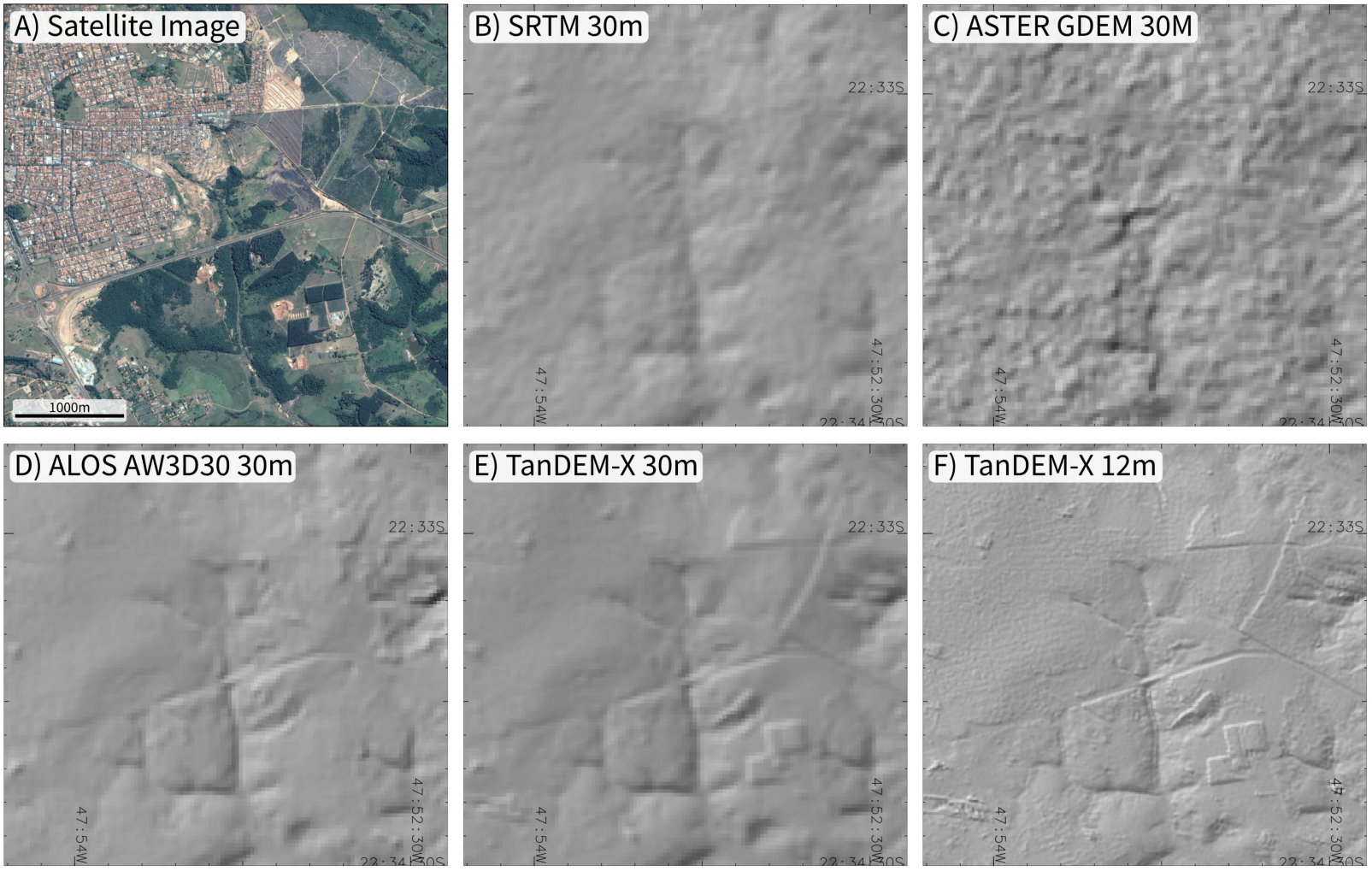
TanDEM-X

- 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



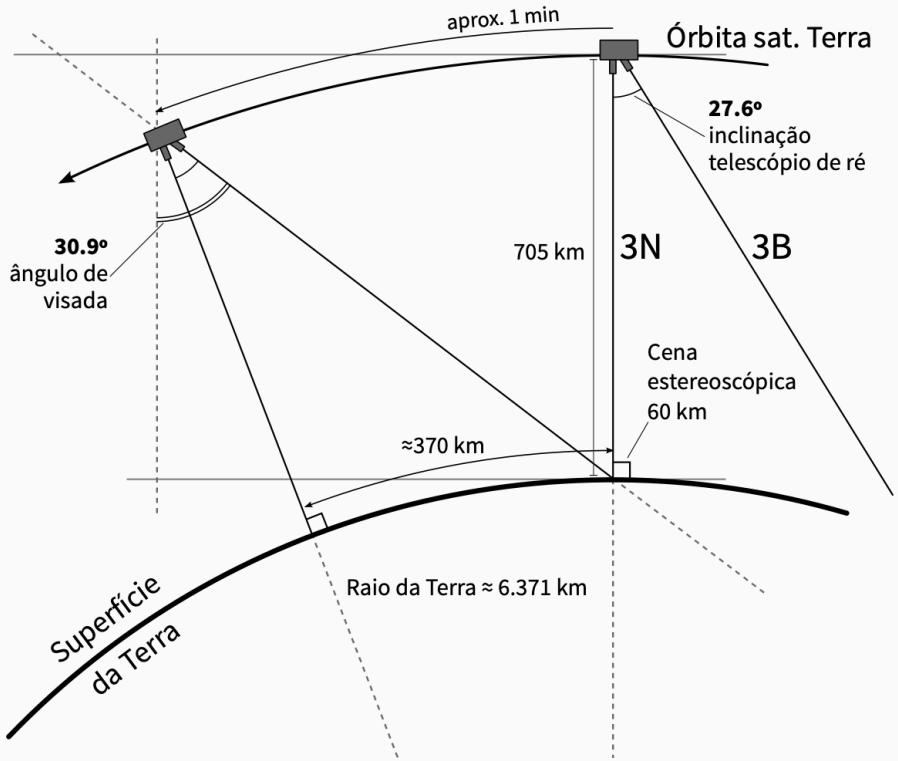
TanDEM-X



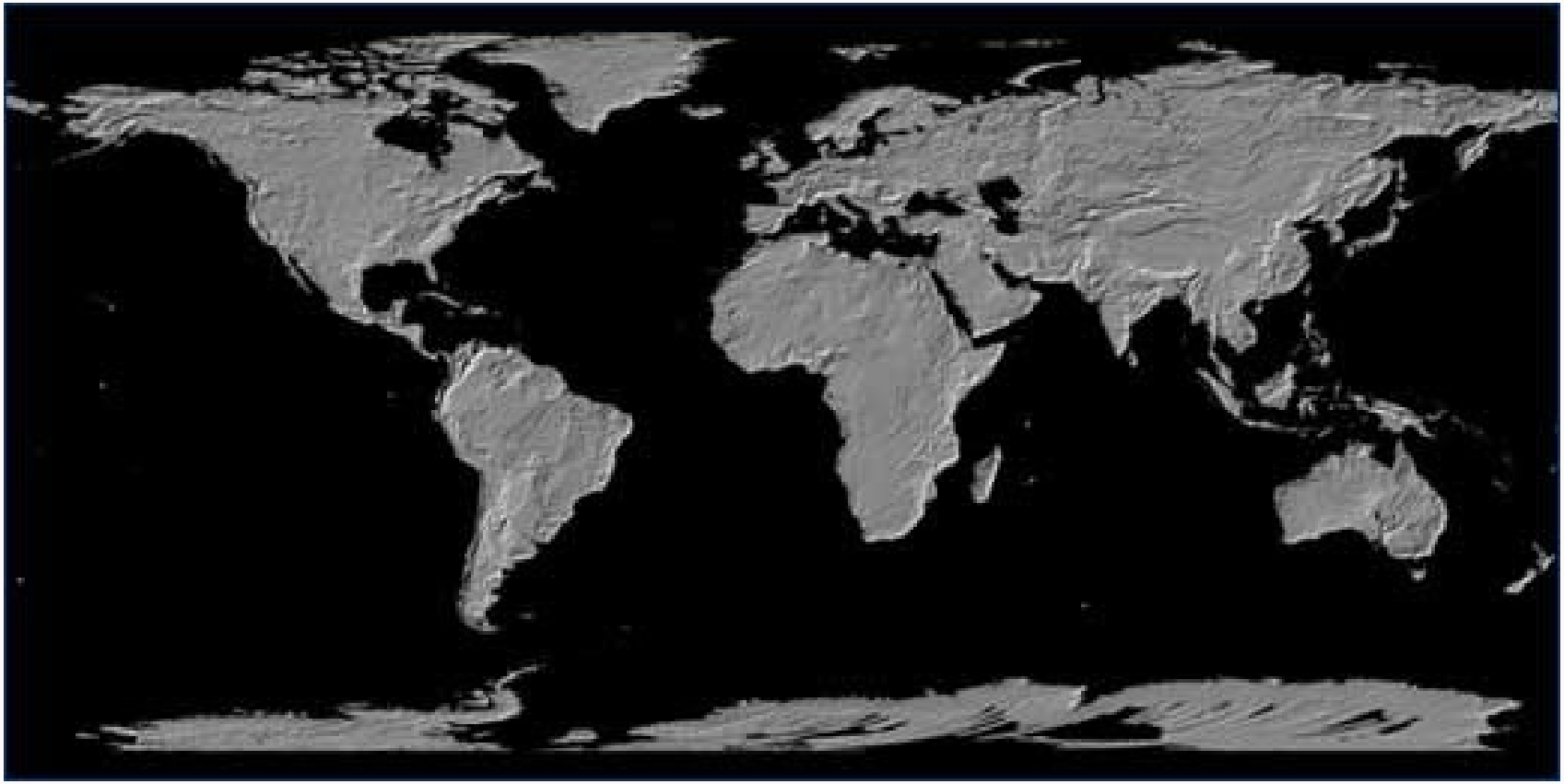
Grohmann, 2018. RSE. https://doi.org/10.1016/j.rse.2018.04.043

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



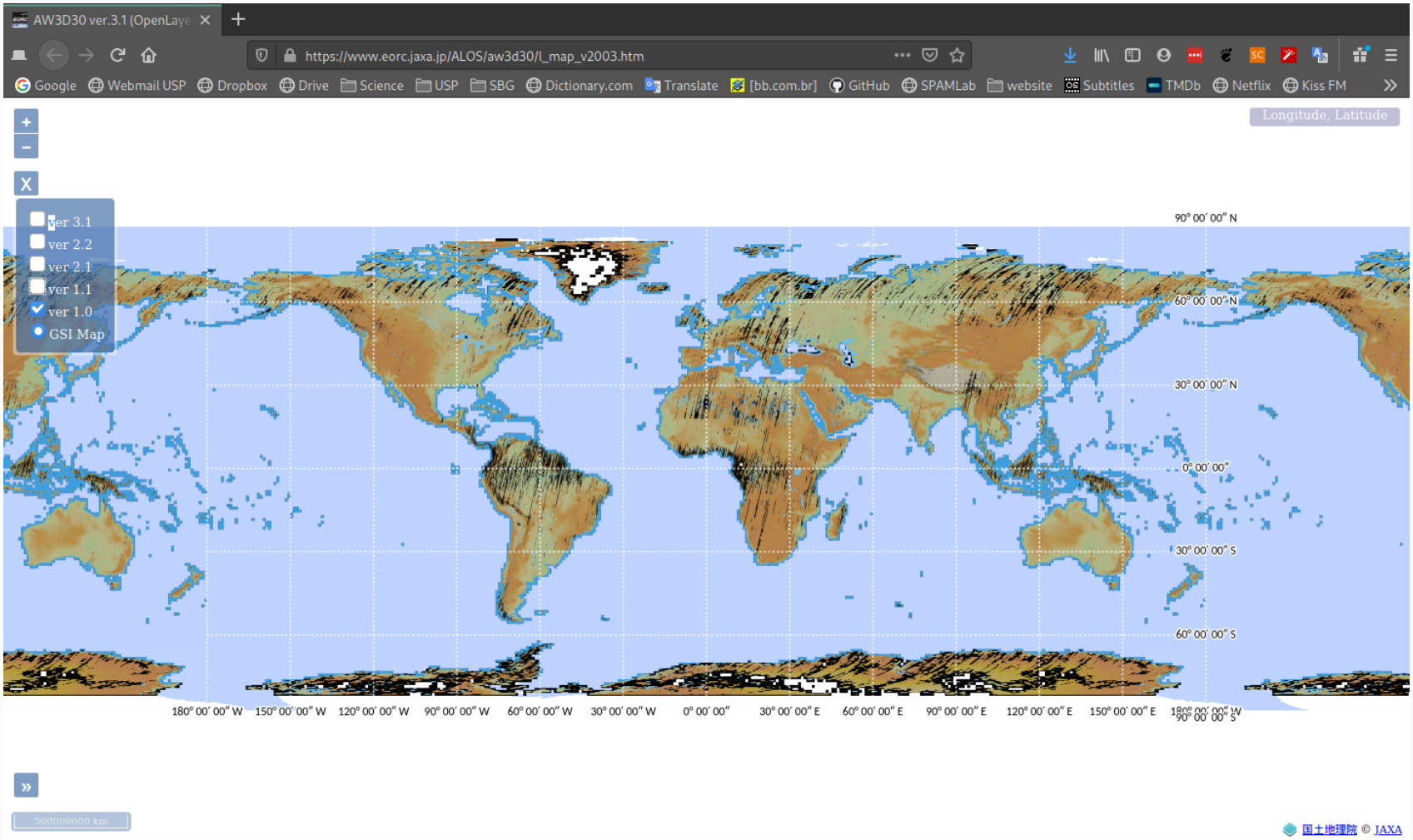
ALOS PRISM AW3D30

- Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM)
- Modelo comercial com 5m resolução
- Modelo gratuito com 30m resolução

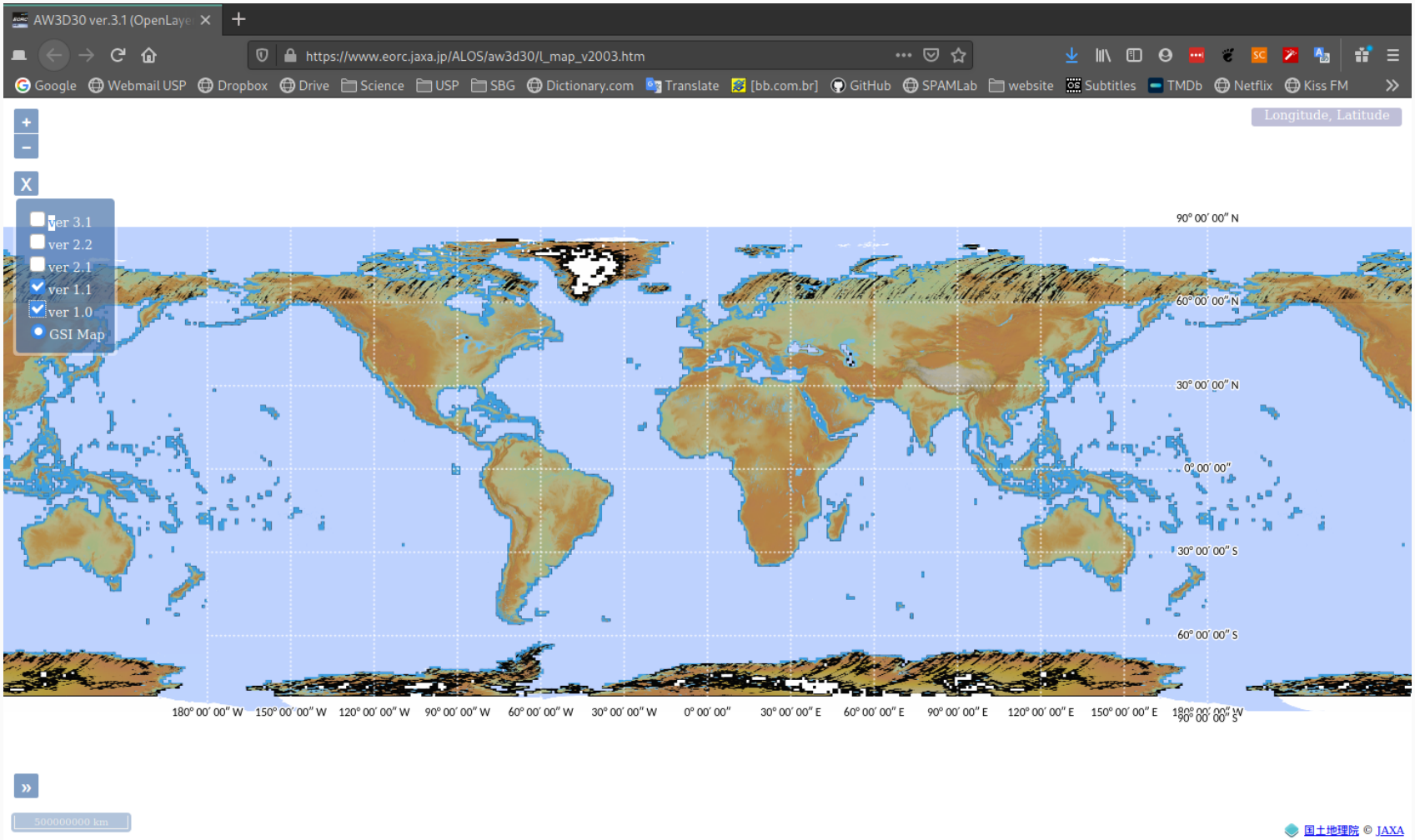
- ALOS AW3D30 v.1.0 – 2016
- ALOS AW3D30 v.1.1 – 2017
- ALOS AW3D30 v.2.1 – 2018
- ALOS AW3D30 v.2.2 – 2019
- ALOS AW3D30 v.3.1 – 2020

- 30m (teóricos)
- DSM
- Global

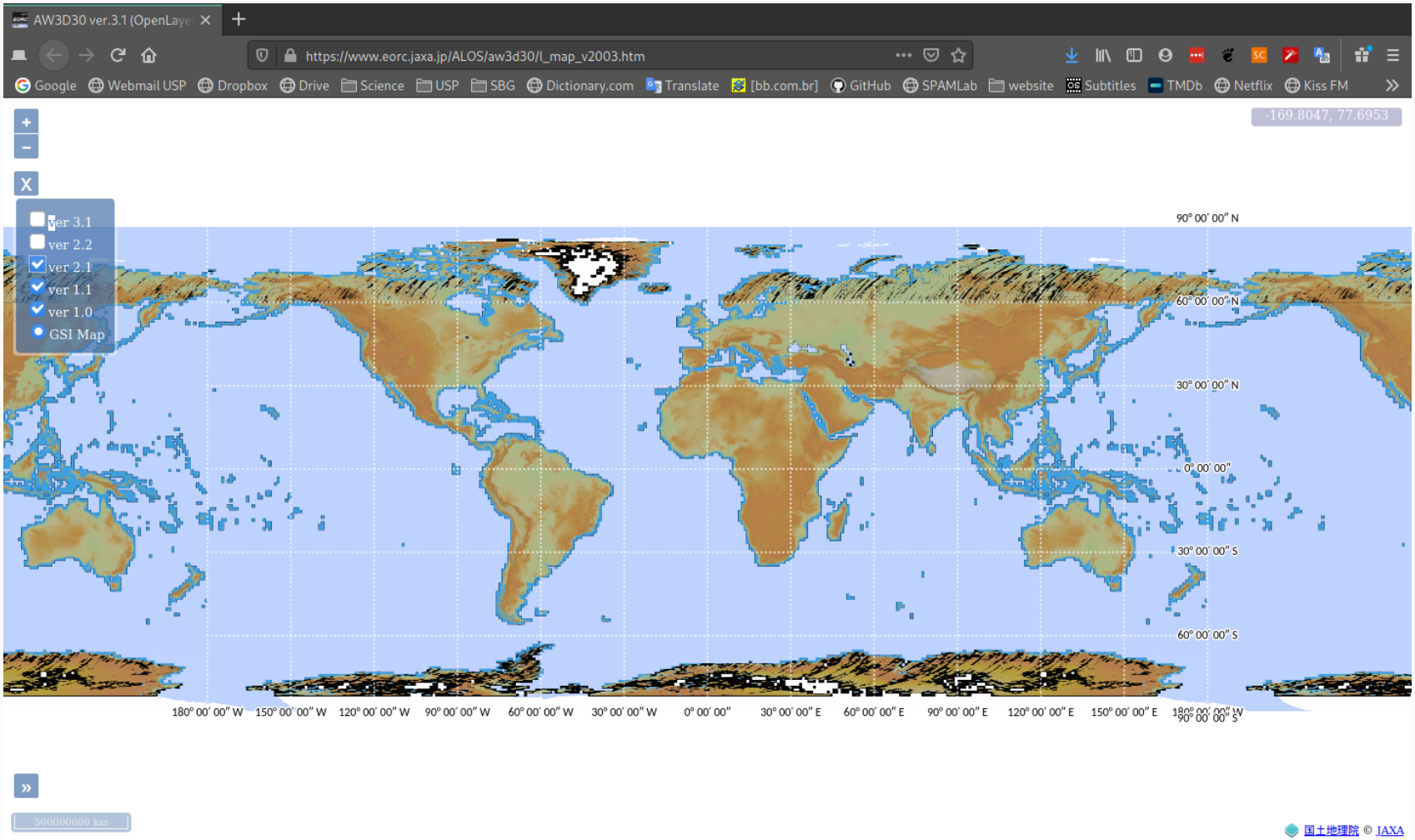
ALOS PRISM AW3D30 - v.1.0



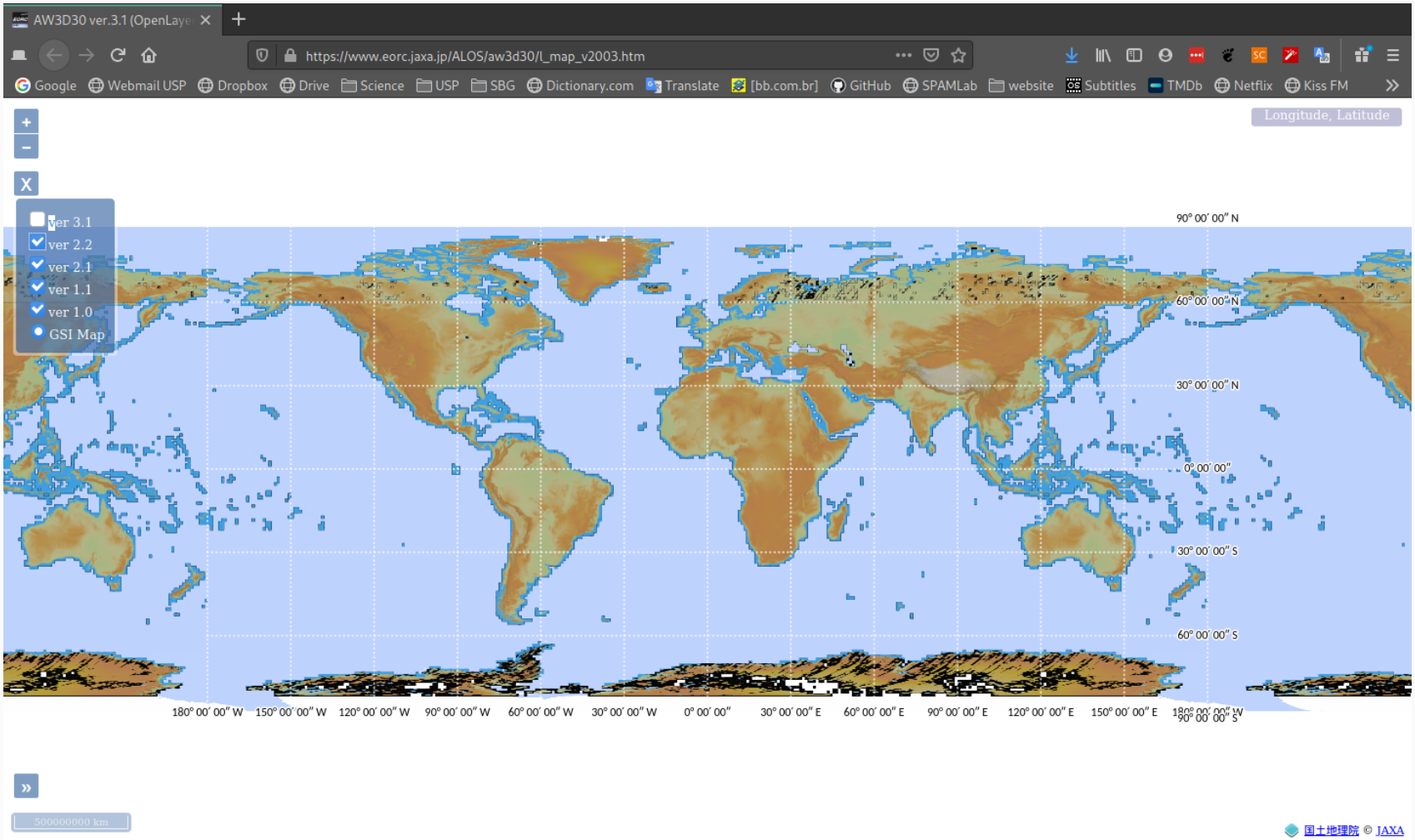
ALOS PRISM AW3D30 - v.1.1



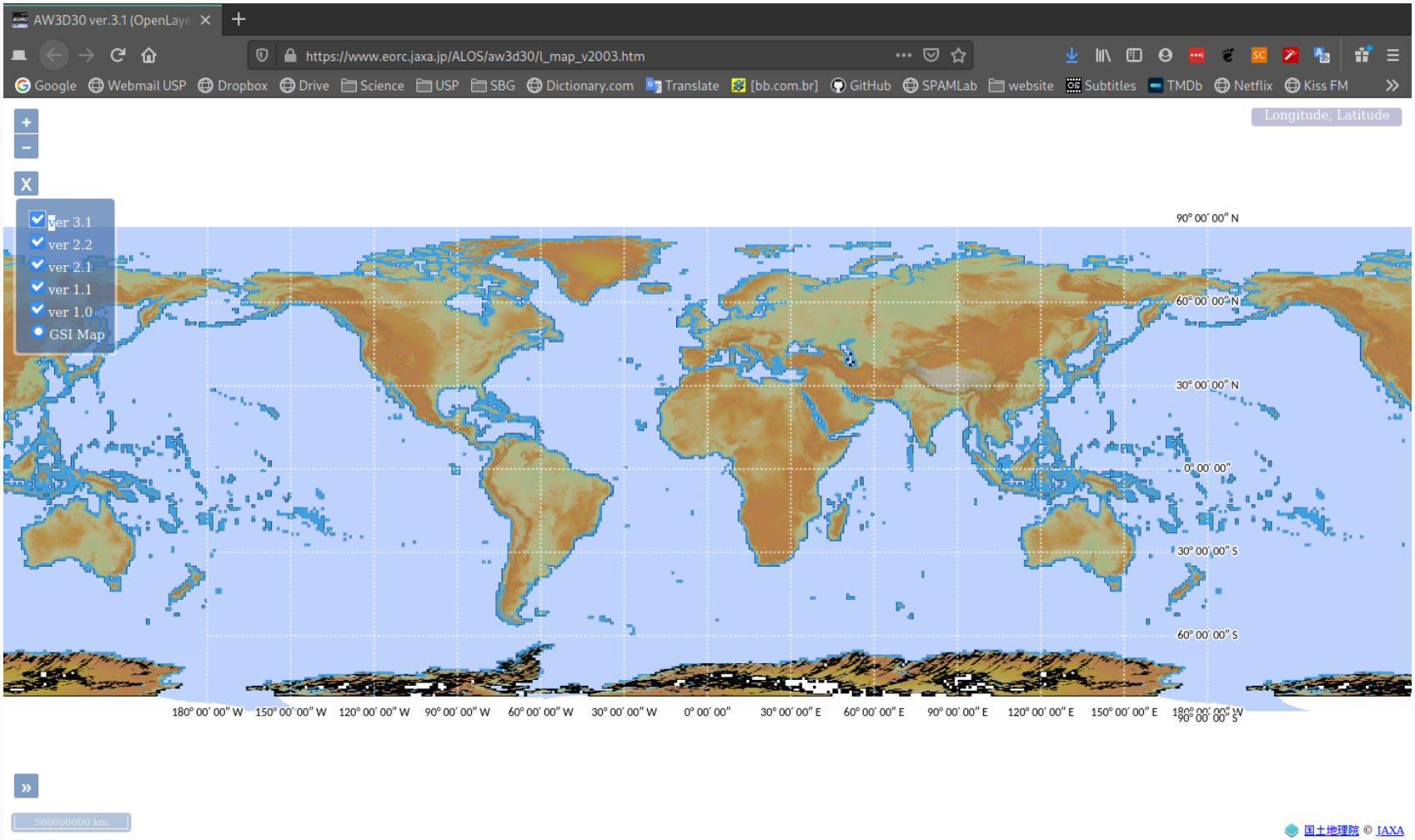
ALOS PRISM AW3D30 - v.2.1



ALOS PRISM AW3D30 - v.2.2

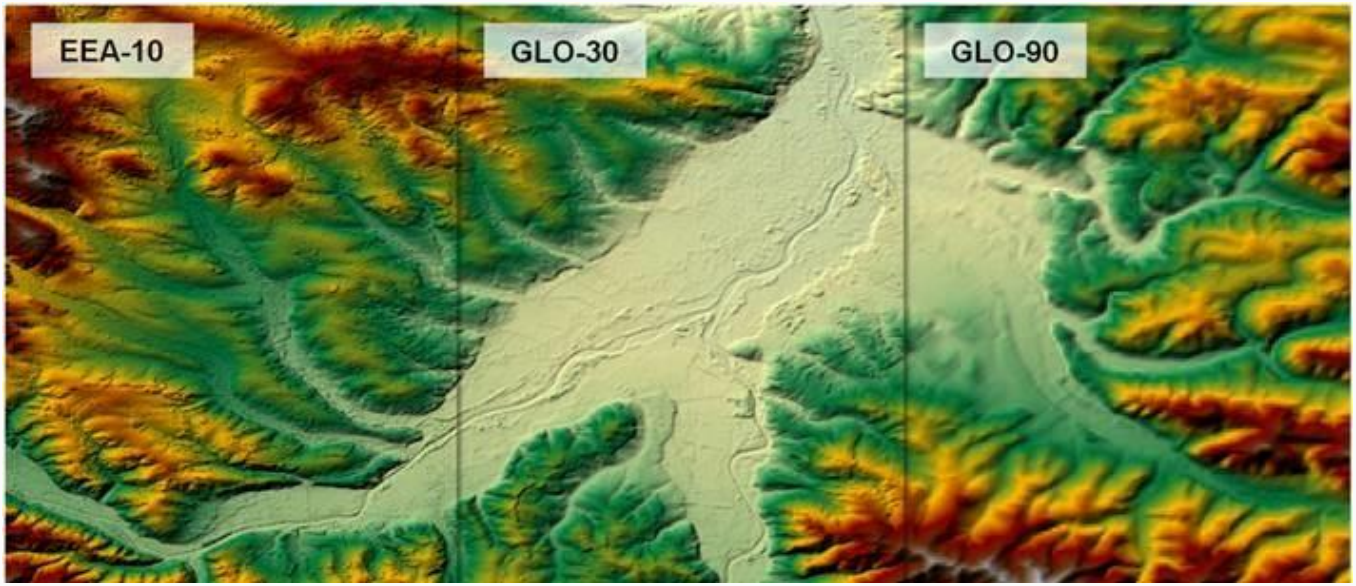


ALOS PRISM AW3D30 - v.3.1



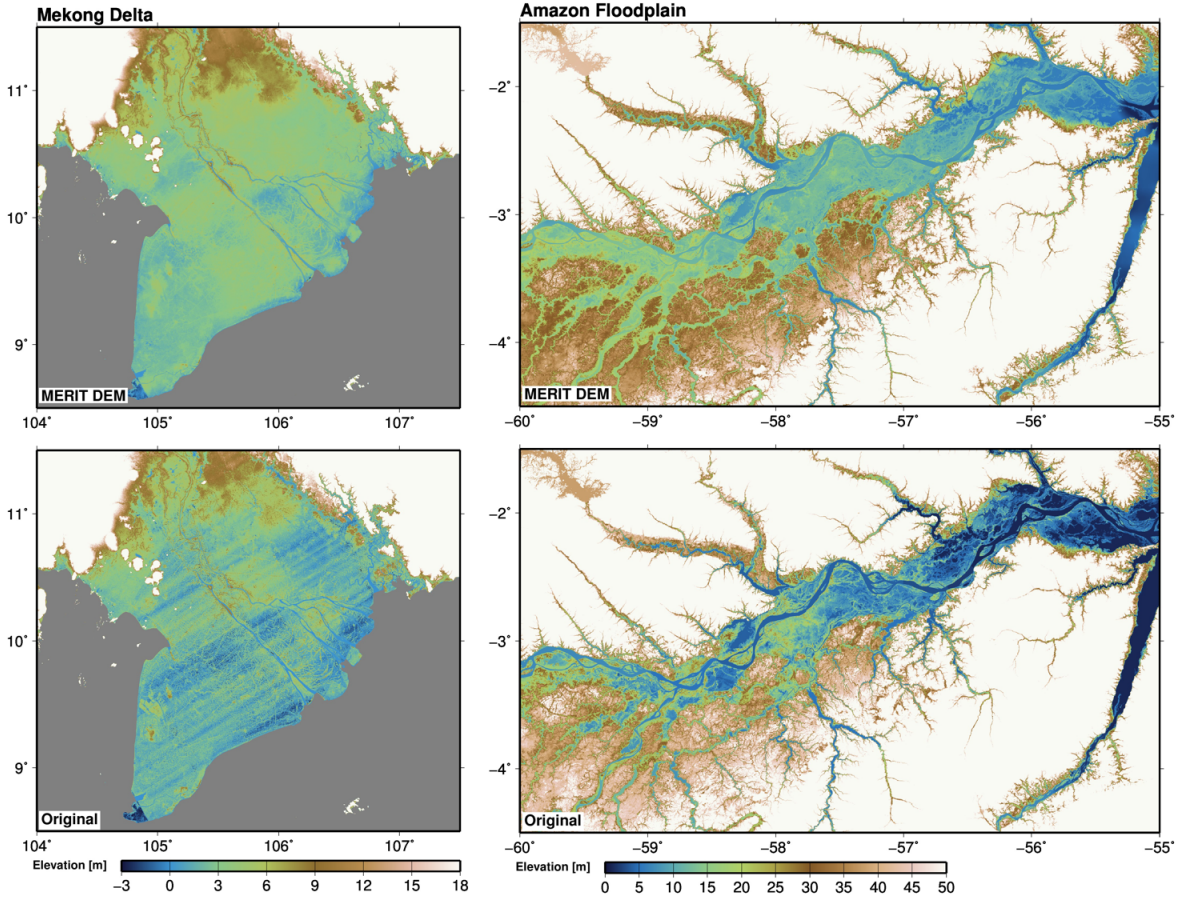
Copernicus DEM

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



MERIT DEM

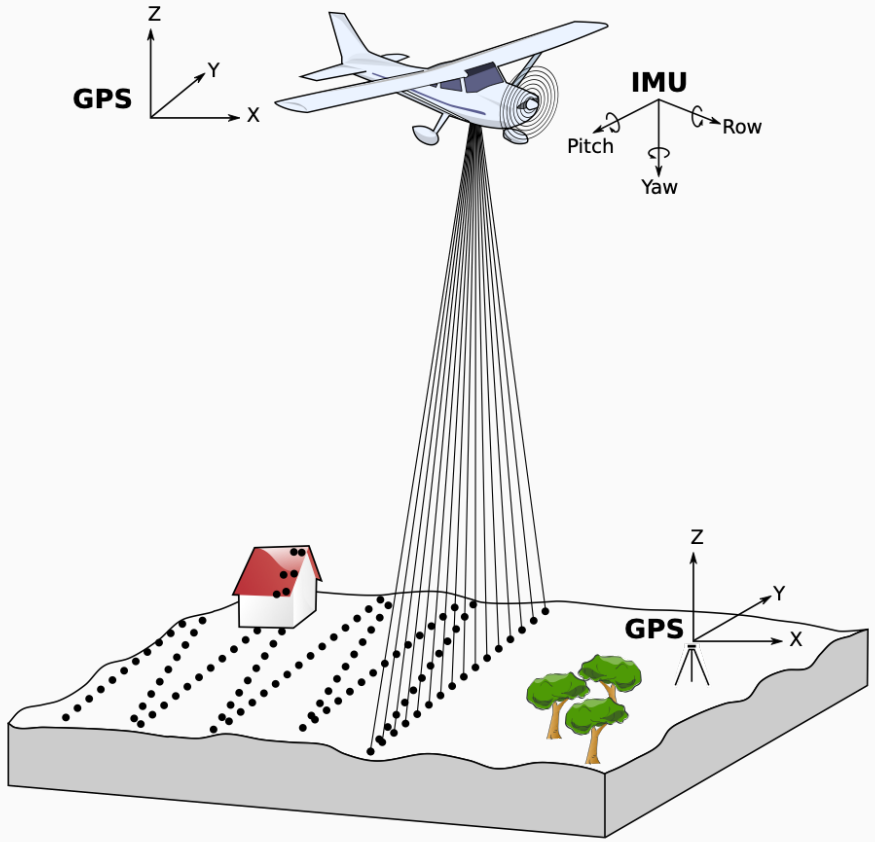
- MERIT DEM: Multi-Error-Removed Improved-Terrain DEM
- `http://hydro.iis.u-tokyo.ac.jp/~yamadai/MERIT_DEM/`



MDEs de alta resolução espacial

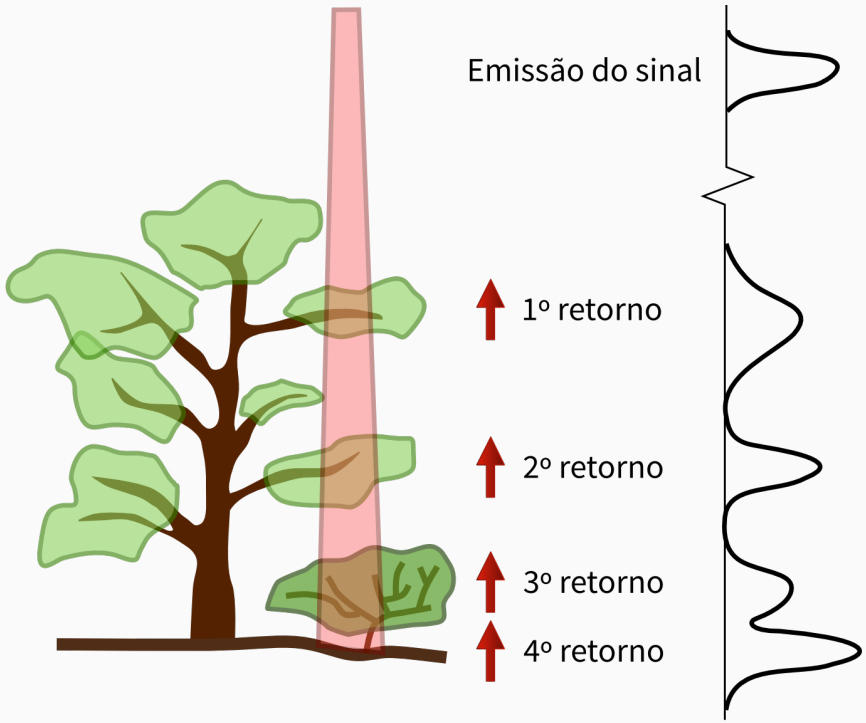
LiDAR

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

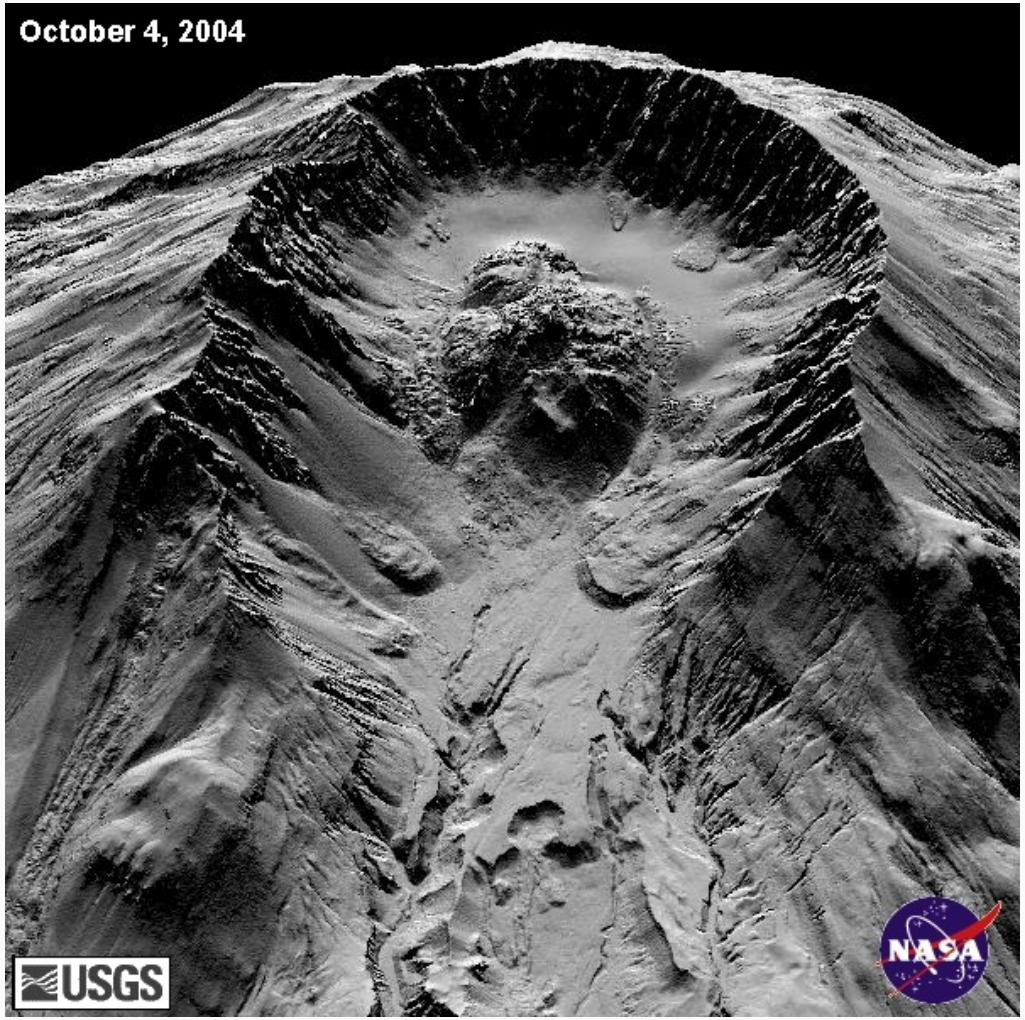


LiDAR - retornos

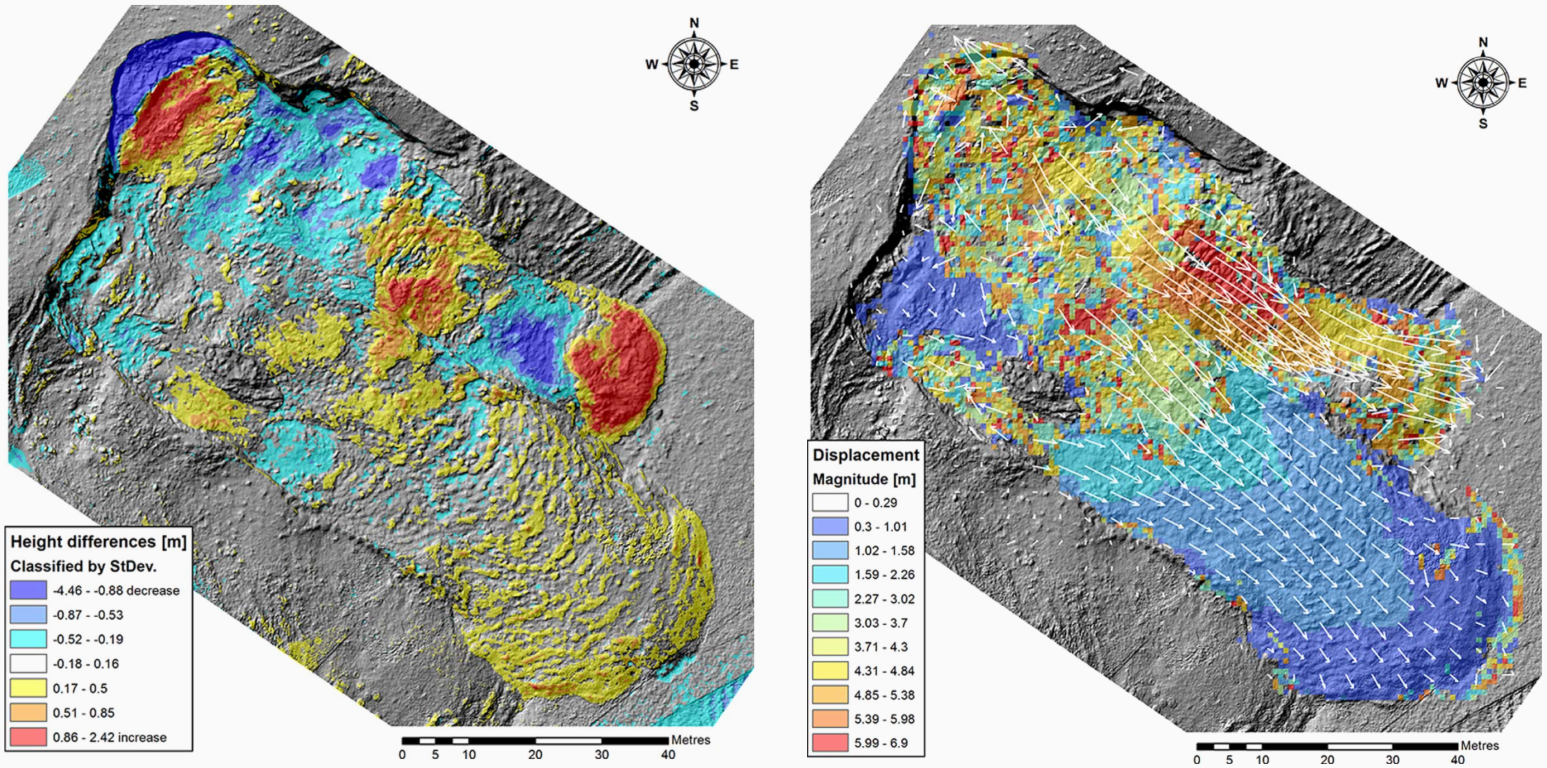
- Múltiplos retornos do pulso de laser
    - Filtragem de superfícies (solo, dossel)
- Full Waveform



LiDAR - Monte Santa Helena



LiDAR - Análise temporal



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

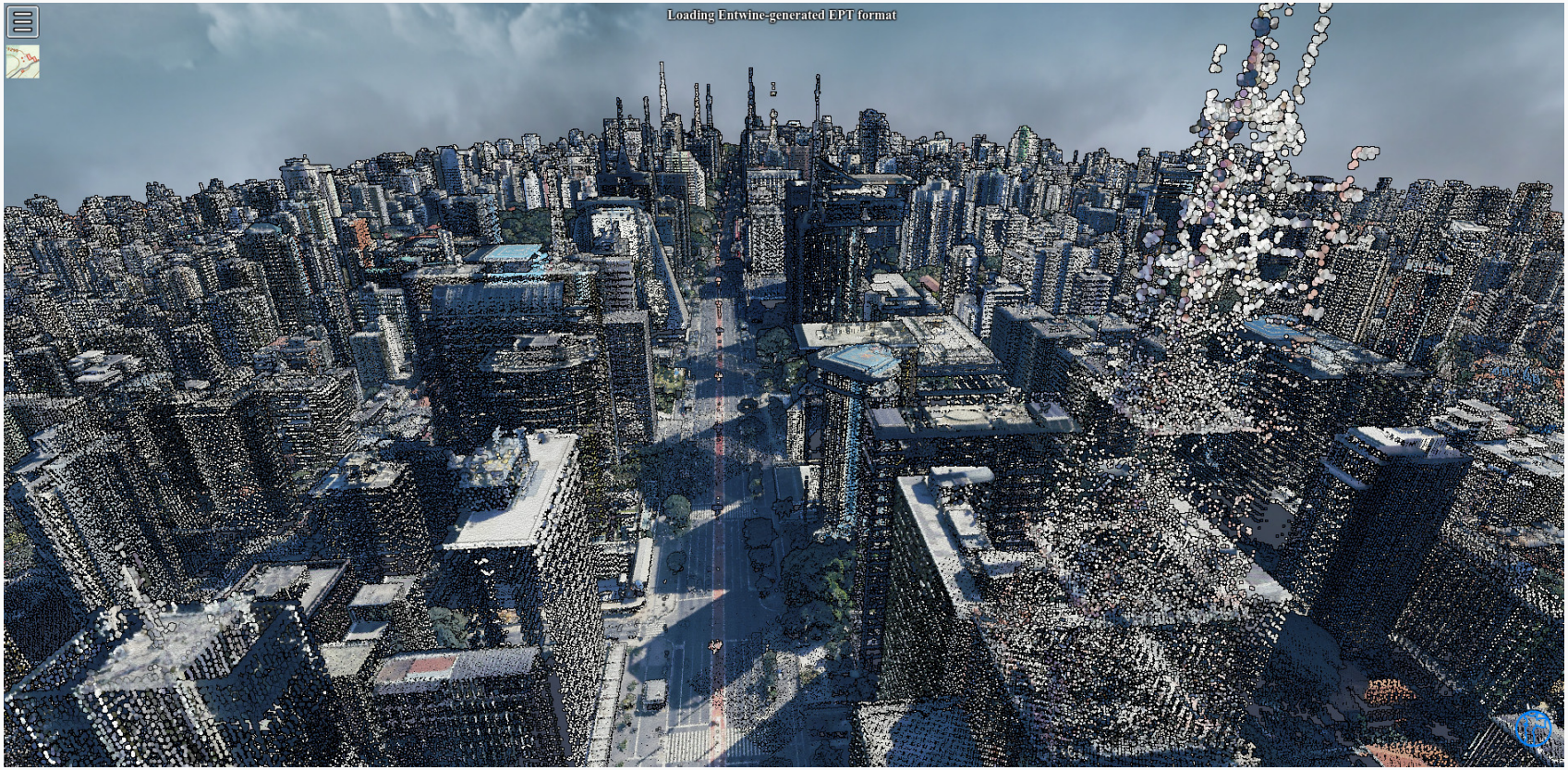
`https://doi.org/10.1177/0309133313515293`

LiDAR - São Paulo

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

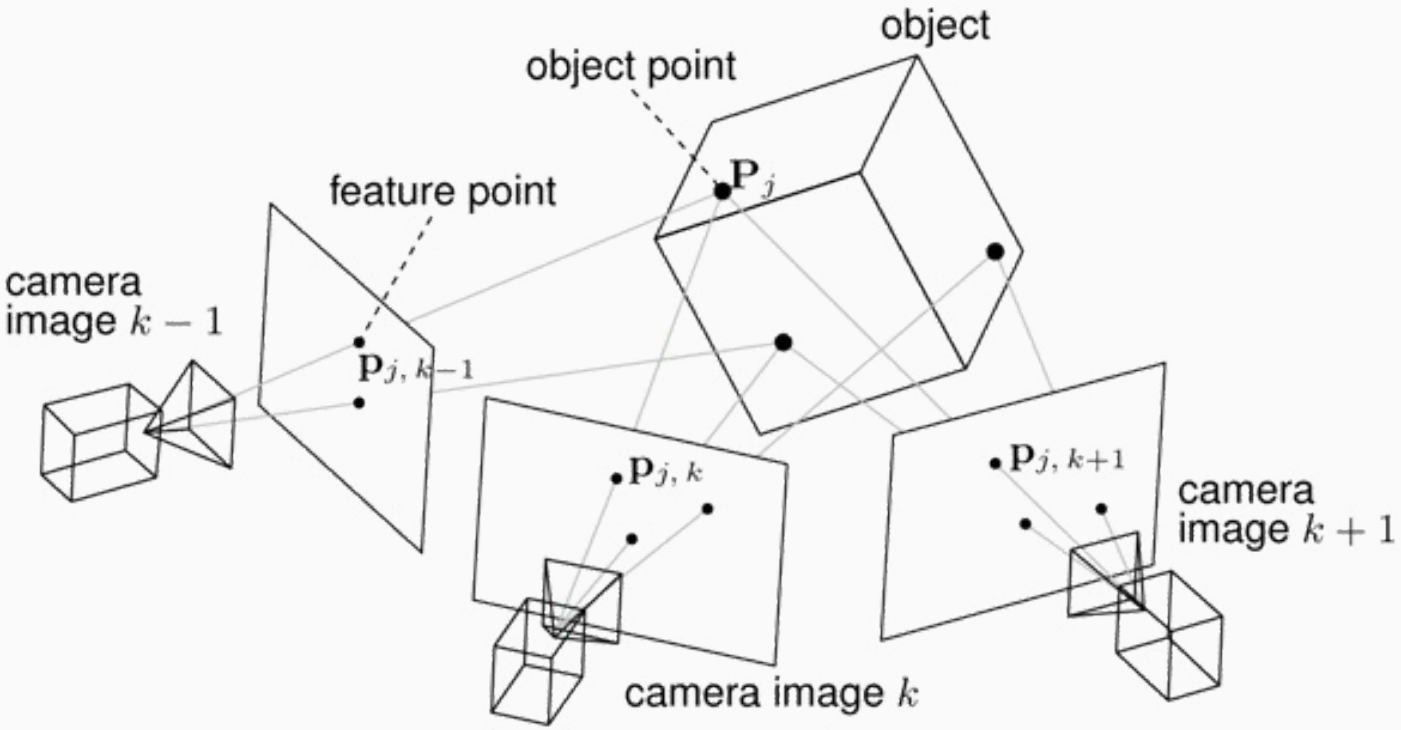
https://spamlab.github.io/blog/pmsp_lidar/

LiDAR - São Paulo



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

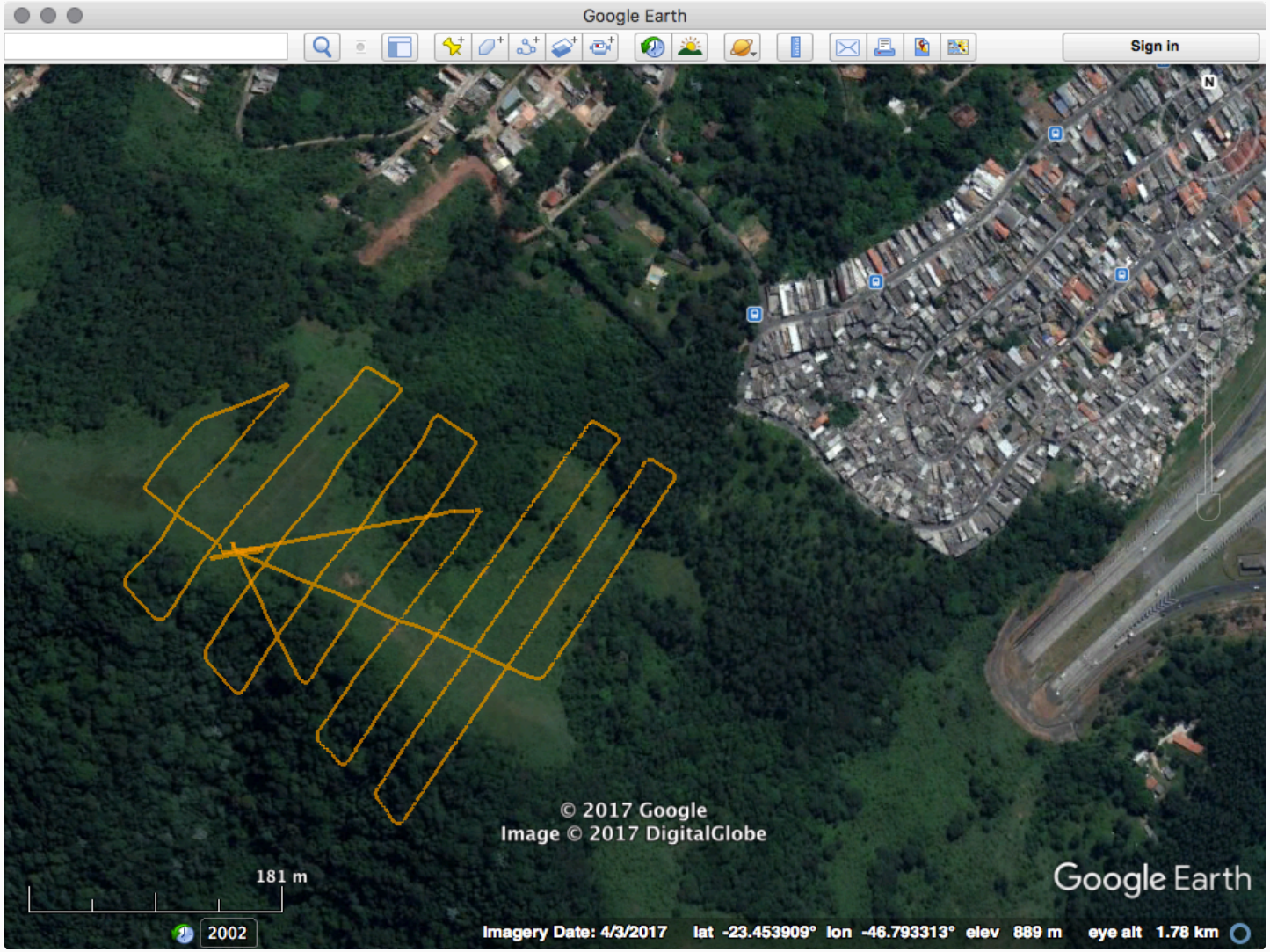
Structure from Motion Multi-View Stereo – SfM-MVS



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

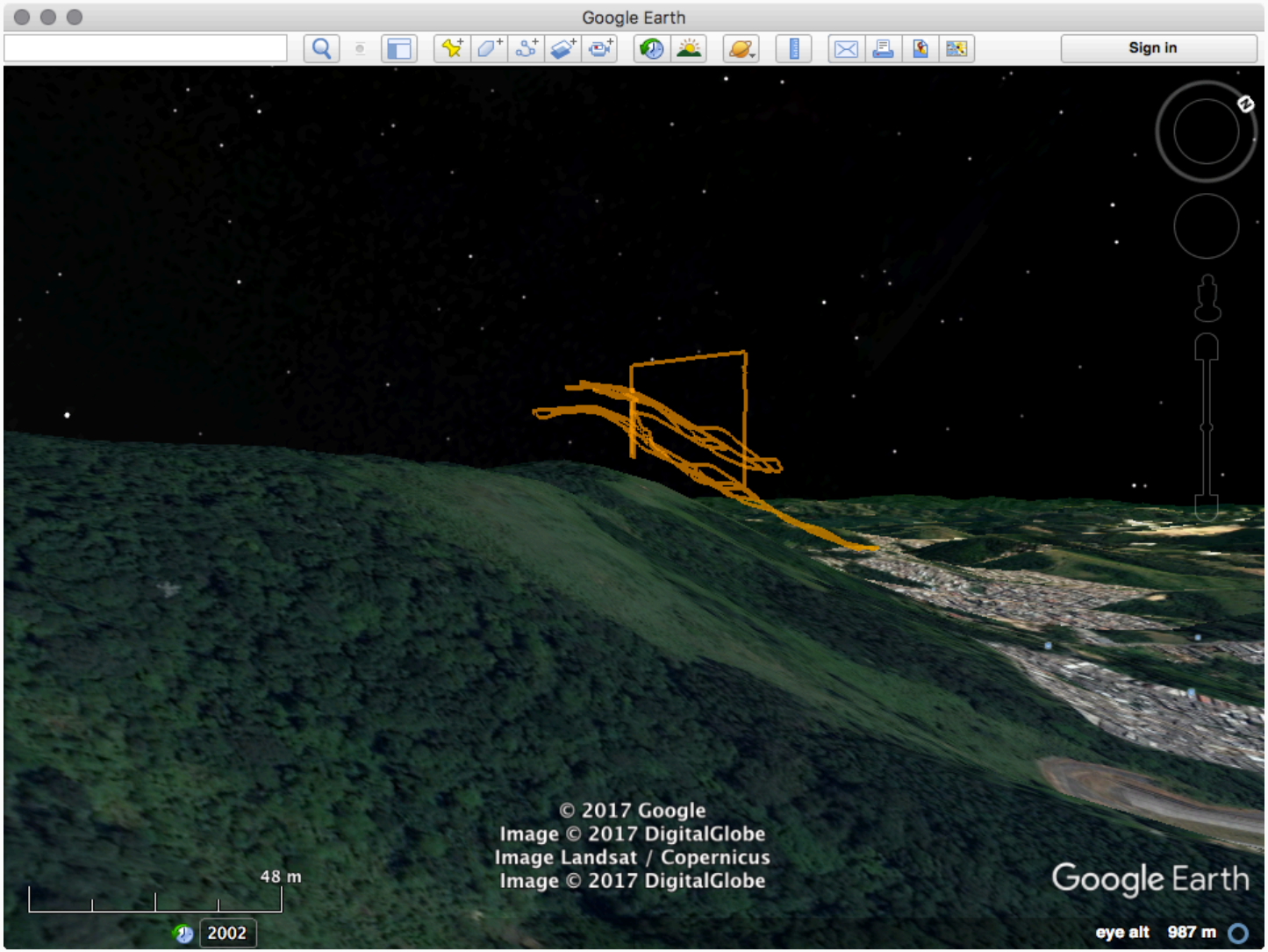
`https://doi.org/10.20385/1860-2037/8.2011.2`

SfM-MVS - São Paulo



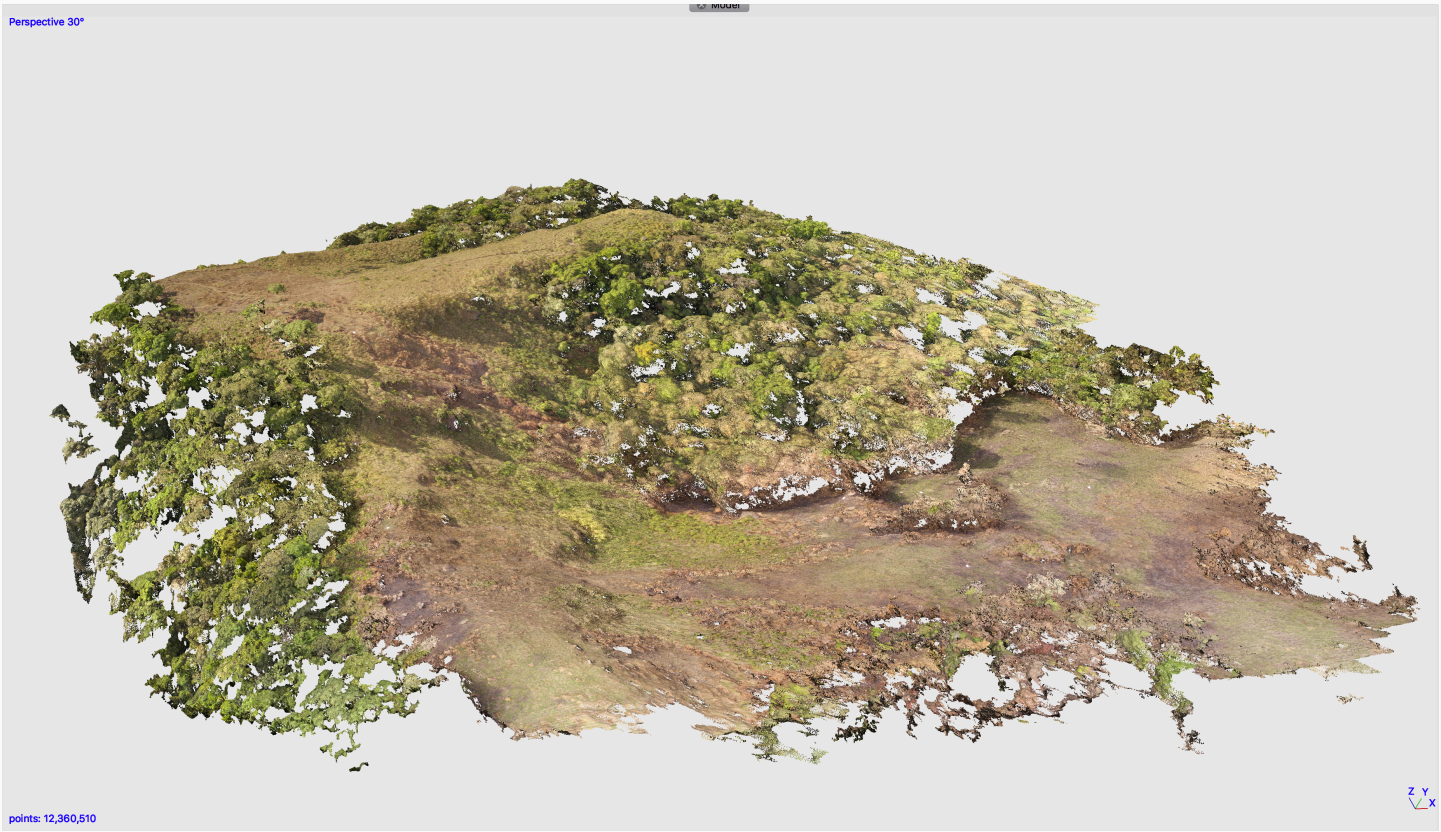
Santos & Grohmann, 2019. SBSR (link)

SfM-MVS - São Paulo



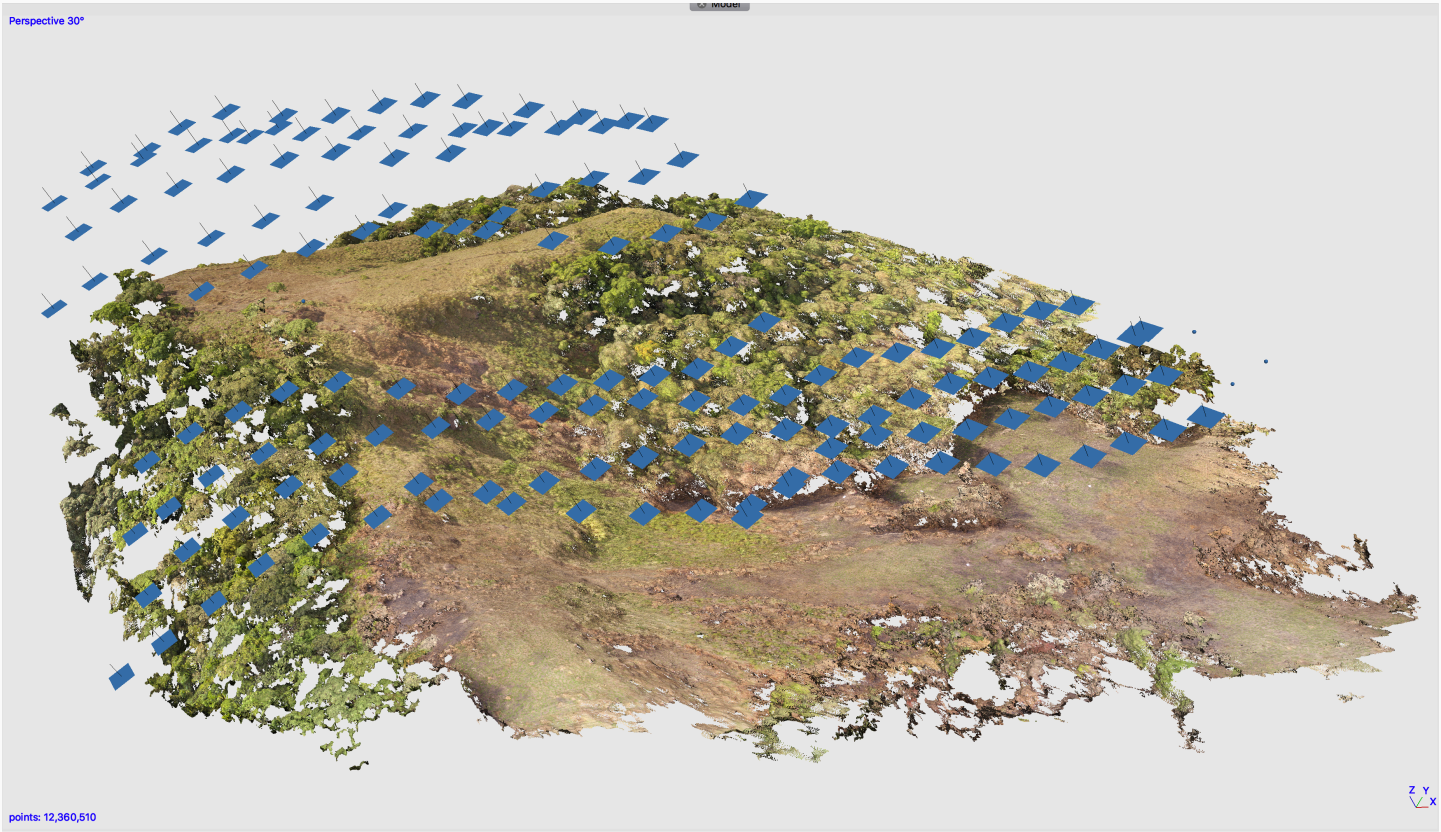
Santos & Grohmann, 2019. SBSR (link)

SfM-MVS - São Paulo



Santos & Grohmann, 2019. SBSR (link)

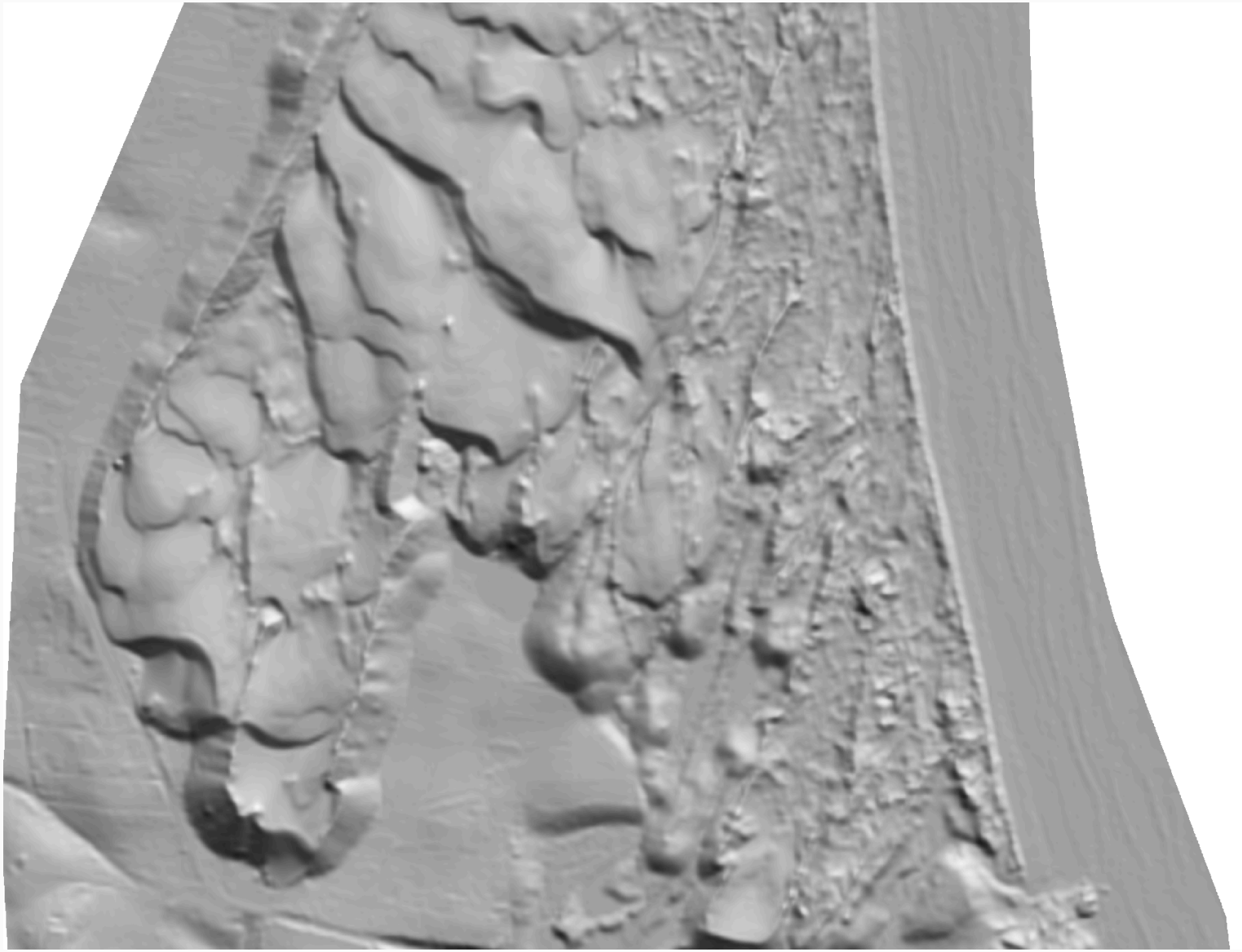
SfM-MVS - São Paulo



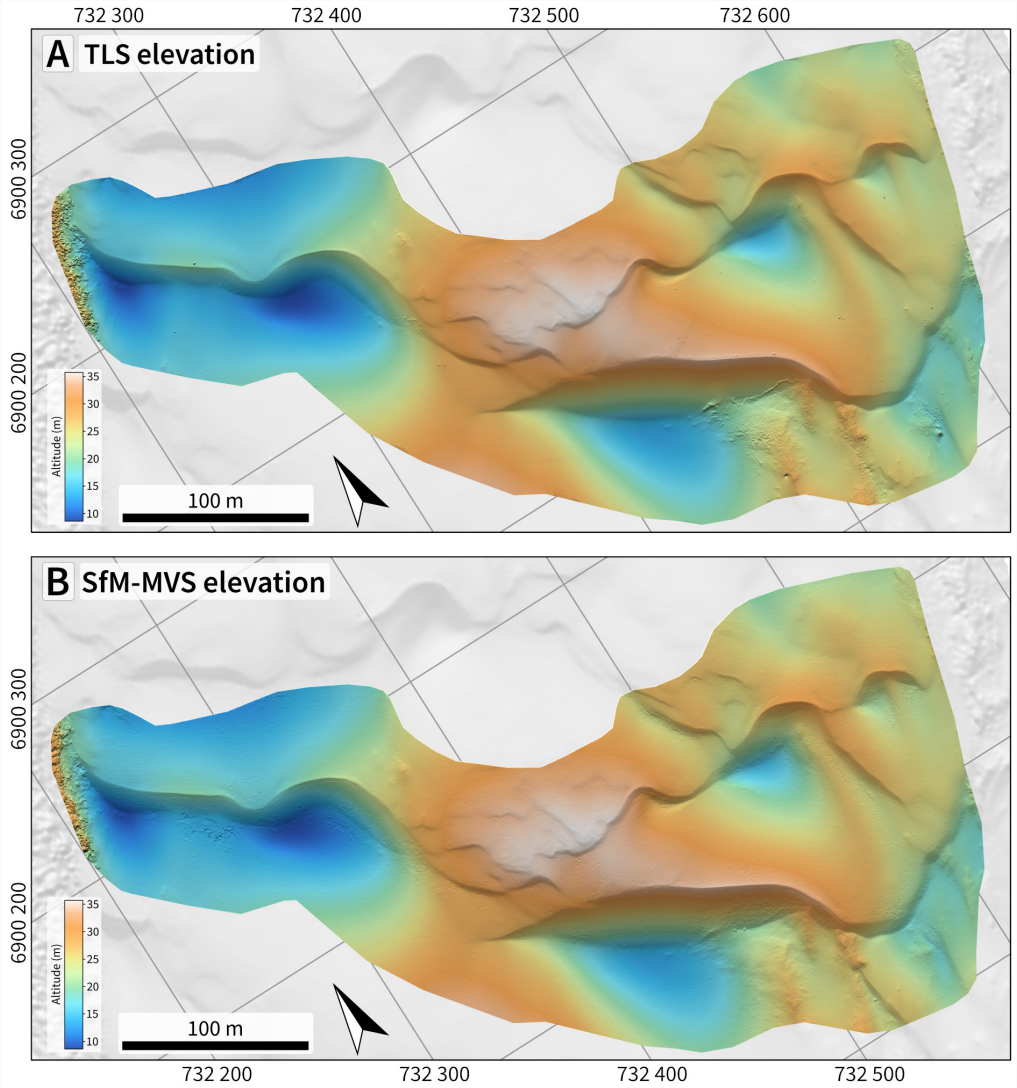
Santos & Grohmann, 2019. SBSR (link)

LiDAR x SfM-MVS – Imagem intensidade LiDAR

LiDAR x SfM-MVS – MDT LiDAR



LiDAR x SfM-MVS (LiDAR terrestre)



Grohmann etal., 2020. CAGEO `http://doi.org/10.1016/j.cageo.2020.104569`

LiDAR x SfM-MVS – MDT LiDAR