Investigation of cryo-geohazards in Langtang Valley, Nepal

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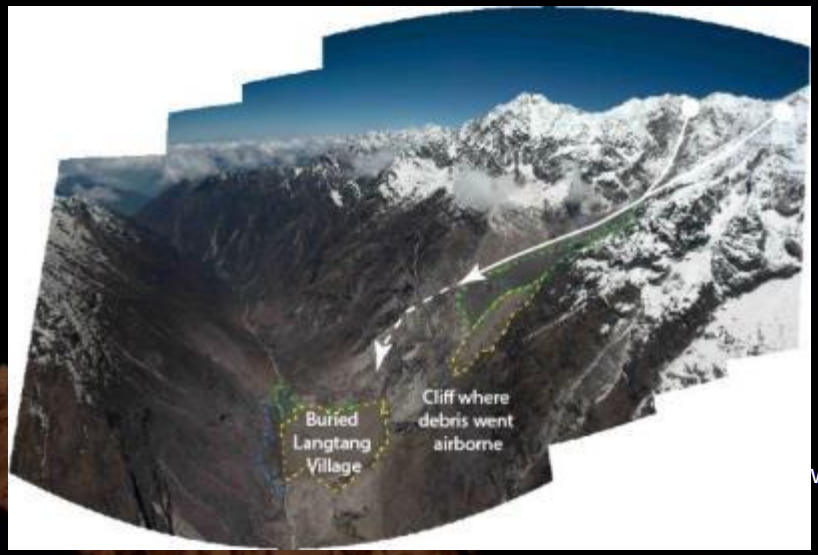
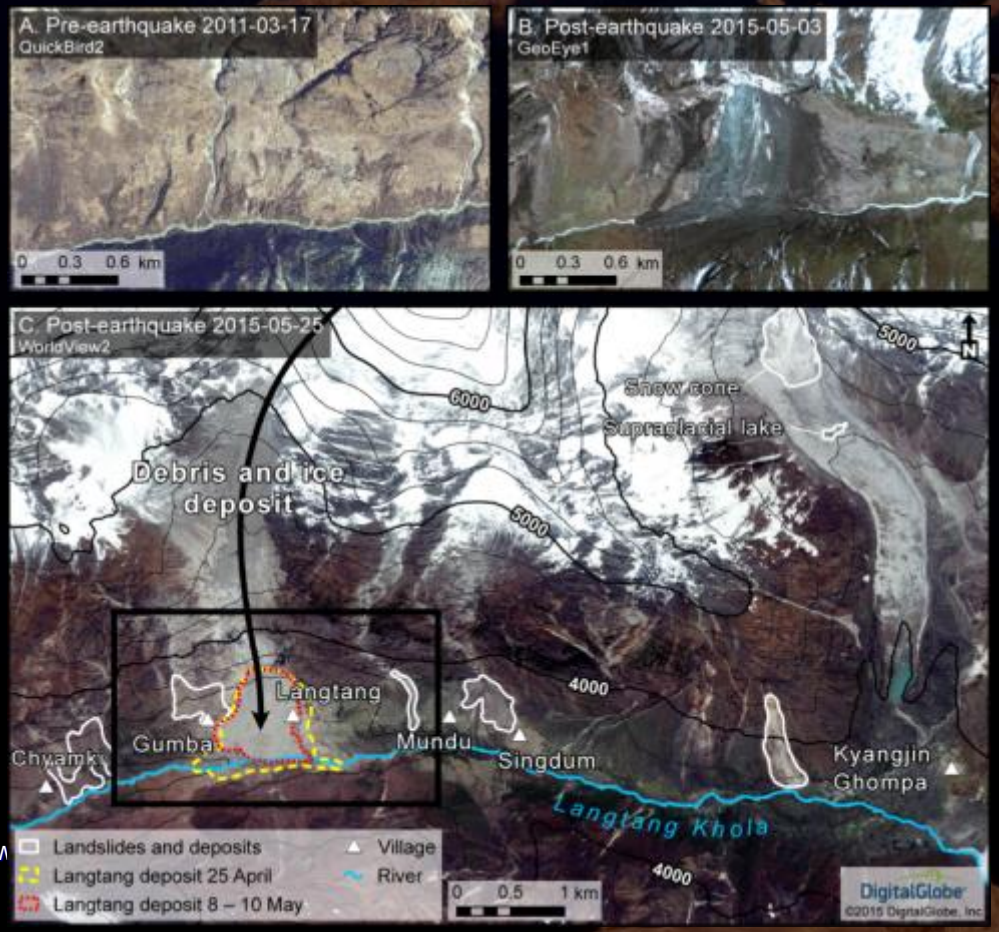
Kargel+ (2016Science)

Langtang Tragedy

- Death toll & missing ~300
  - 178 villagers
  - Many trekkers, guides & porters
  - Only 10 survivors





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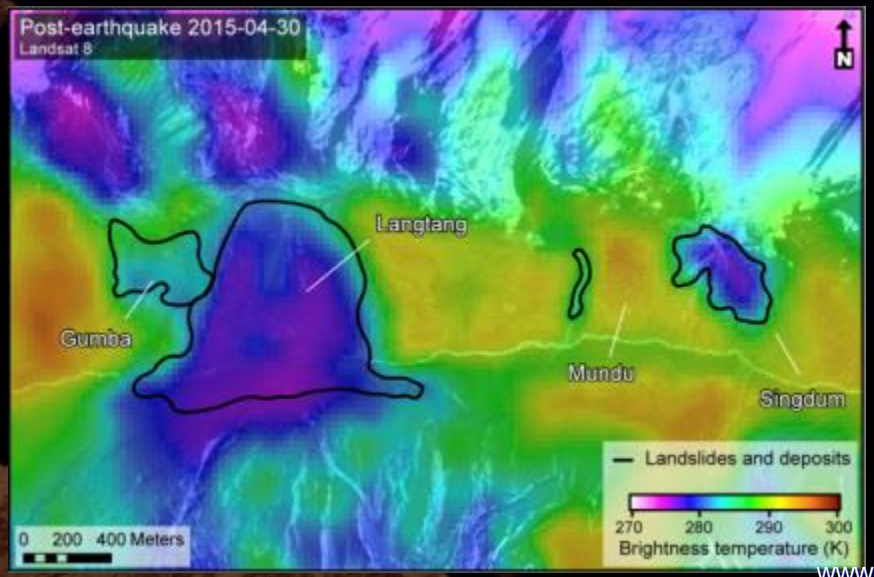
Avalanche Attacked the Village

- Huge amount of ice and rocks



Thermal image of Landsat8

Photos by D.F. Breashears/GlacierWorks

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Blast

- More than 63 m s^{-1} at the village
  - Alternative estimate ~ 100 m s^{-1}

www.cryoscience.net

Photos by D.F. Breashears/GlacierWorks

Initial Survey

- Photos by Rijan/Langtang Plan in June
- This slide will be updated.

What Can We Do?

- Glacier research led by Nagoya Univ. in Langtang since 1981
  - Ice core drilling / Hydrological observation / Glacier change
- Collaboration with
  - NIES, Niigata U., TMU, DHM, ICIMOD, Utrecht U.

Purpose 1

- Measuring debris amount covering village
  - ✓ Extent known by RS data
  - Volume & distribution unknown
  - Materials such as snow, ice, and rock
- Three digital elevation models created
  - Pre-event: ALOS-PRISM images (2.5 m)
  - Post-event: Aerial photos (<1 m)
  - Post-monsoon: Aerial photos by UAVs & helicopter (<1 m)

Purpose 2

- Refining avalanche simulation
  - Validation with debris extent and amount

- Creating avalanche hazard map
  - Polynomial chaotic quadrature method

Analysis for Mt. Fuji by K. Tsunematsu & K. Nishimura

Challenges

- Few operation at high elevation

- Multicopter aka drone (T. Izumi, TMU)
  - No obs. at high elevation
- Fixed wing UAV (H. Inoue, NIES)
  - ✓ Previous study at 4500 m in Langtang (ETH/UU)
    - eBee: expensive
  - Handmade UAV
    - Cheap but difficult to operate

PRODRONE at Nagoya

- Dedicated supports
  - Light weight by carbon fiber
  - Brand-new high-power mortars
- Free-rented three bodies
  - 2 quadcopter, 1 hexacopter

Test flight at 2700-m Norikura

ネパール地震の被害調査

山岳ドローン活躍

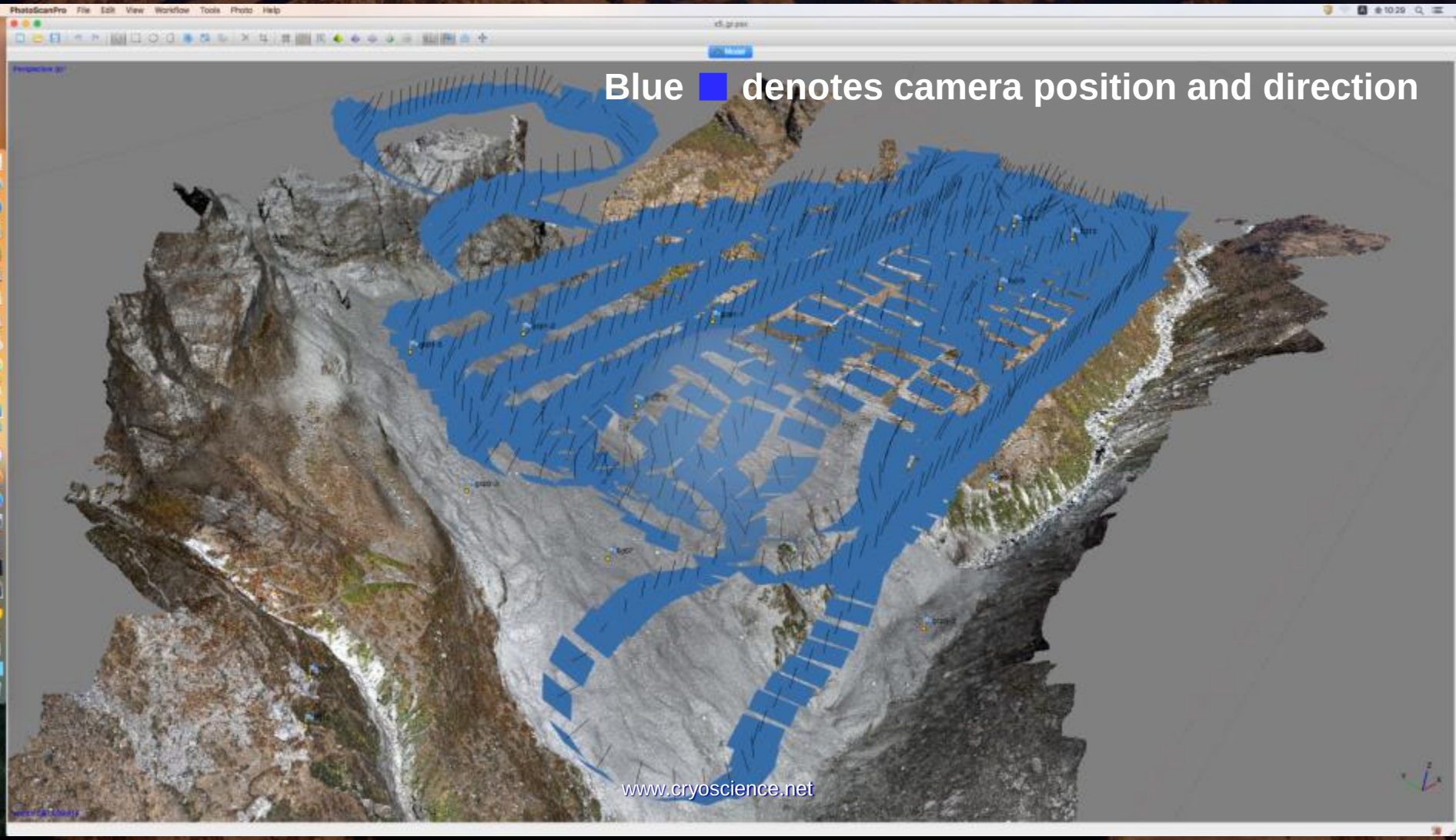
名古屋のメーカー特製

2015/11/23 中日新聞

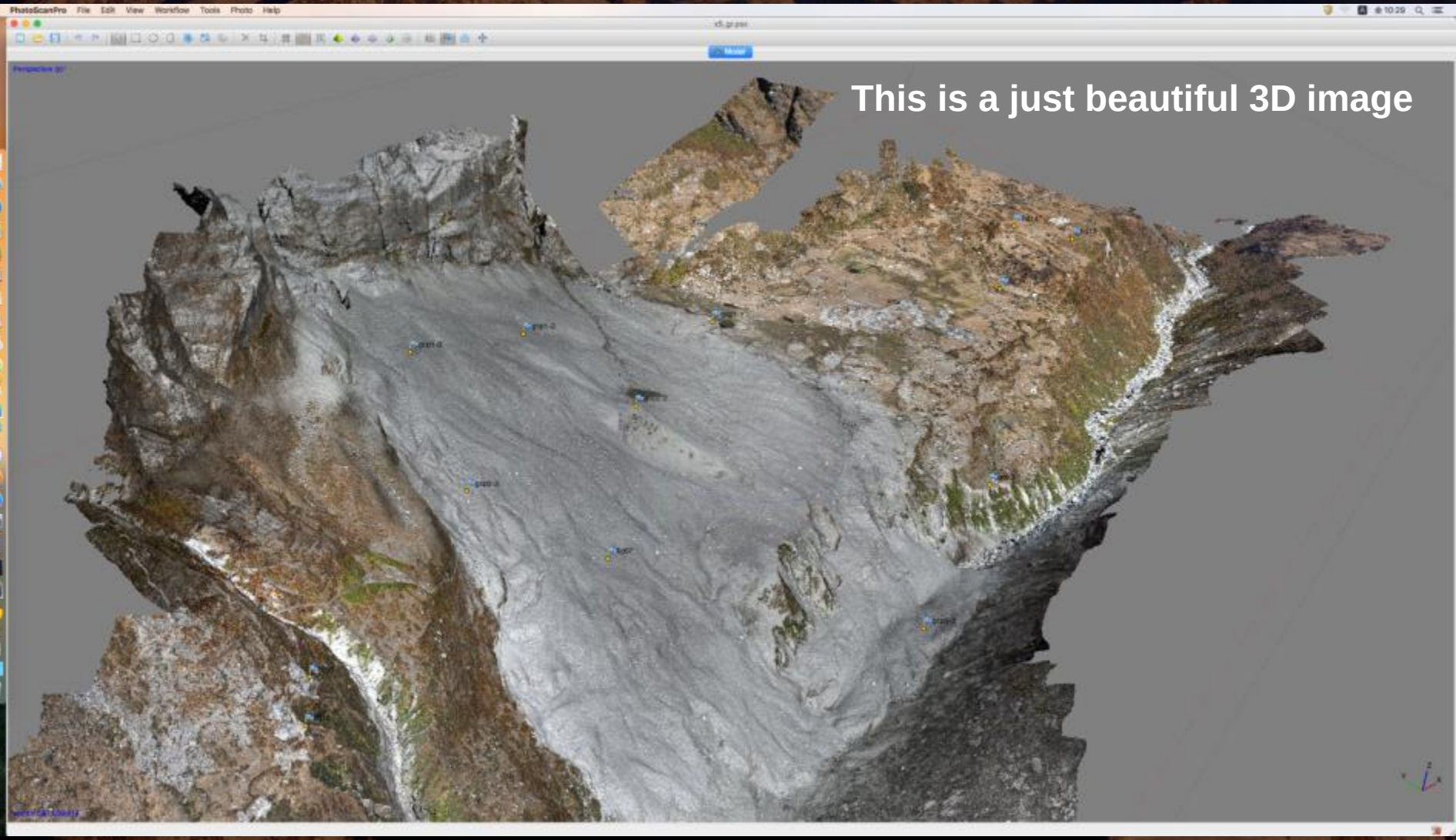
UAV Operations

- A dozen successful flights
  - PRODRONE
  - Skywalker X-5
  - eBee (Utrecht U/ICIMOD)

Structure from Motion Analysis



Structure from Motion Analysis



Result

- X-5 with Ricoh GR (reso. 0.06 m)

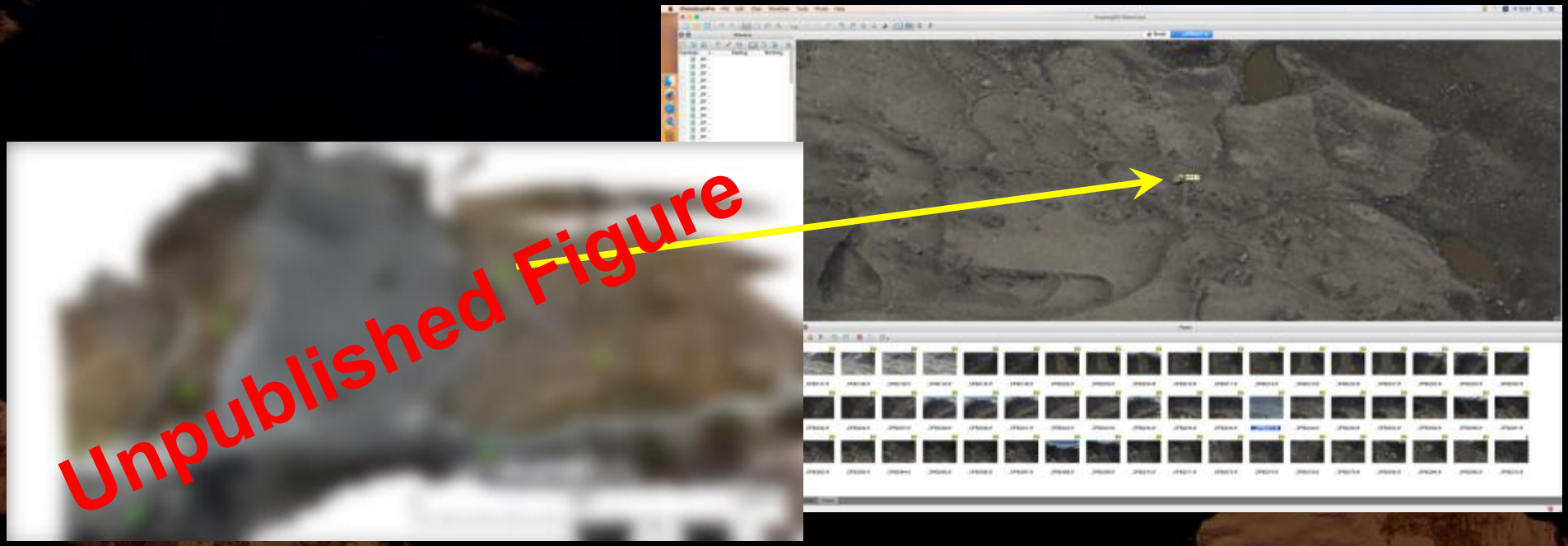
Launch Site

Unpublished Figure

Processing Helicopter Photos

- D.F. Breashears/GlacierWorks: 7 and 10 May
- Japan Landslide Society: 1 June

- Put "tie point" from 23 Oct. UAV-DEM/Ortho



Pre-event DEM

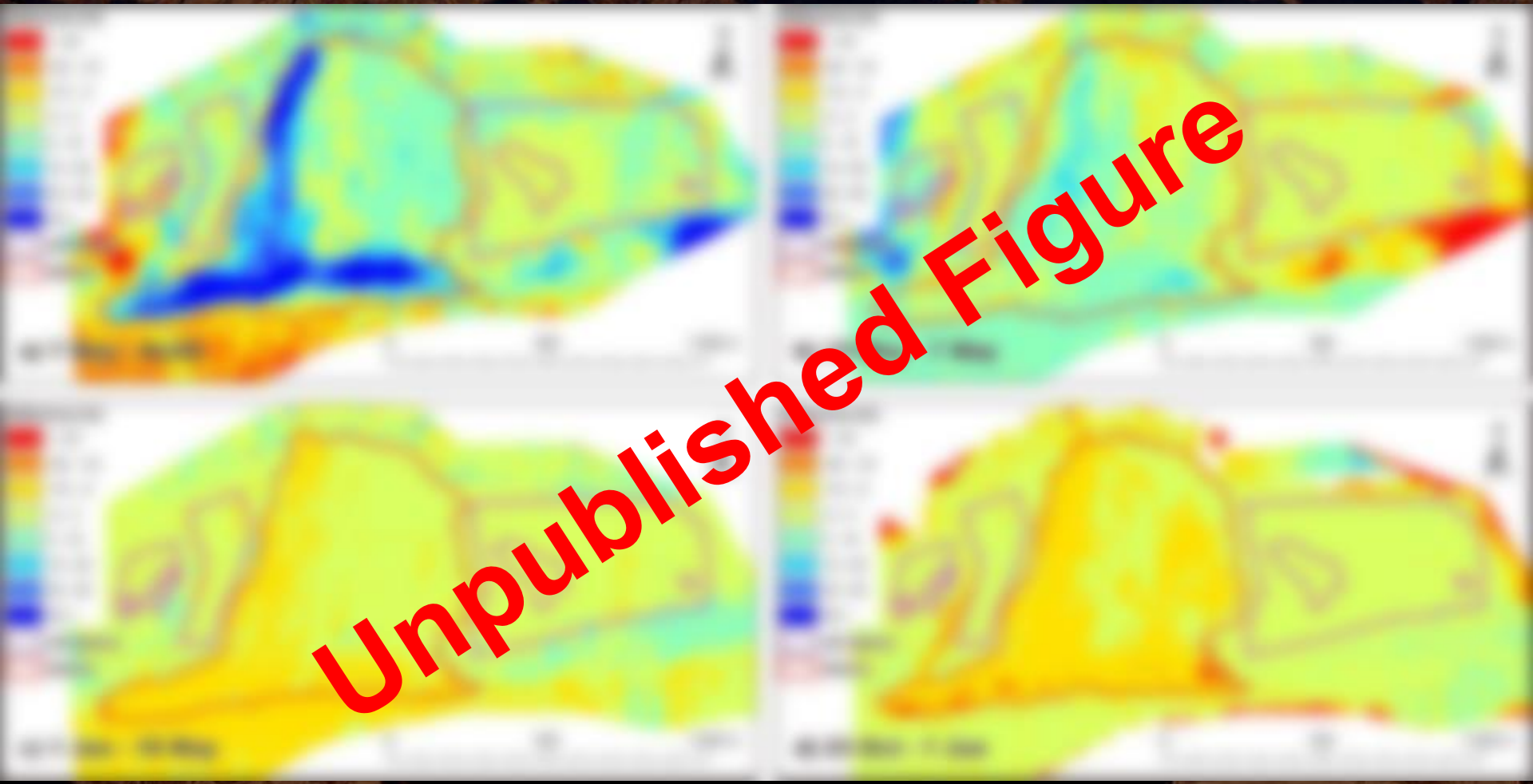
- UAV (6-cm) vs. "High-reso." ALOS (2.5-m)

Accuracy Evaluation

- DEM-GPS on the off-debris area
  - SDs of 0.3 ~ 1.5 m
  - Offset of –4.81 m with ALOS-DEM
  - No horizontal offset with ALOS-DEM

Orthoimages

Elevation Differences



Collapse of Glacier

- Glacier ice contributes a few % to the total

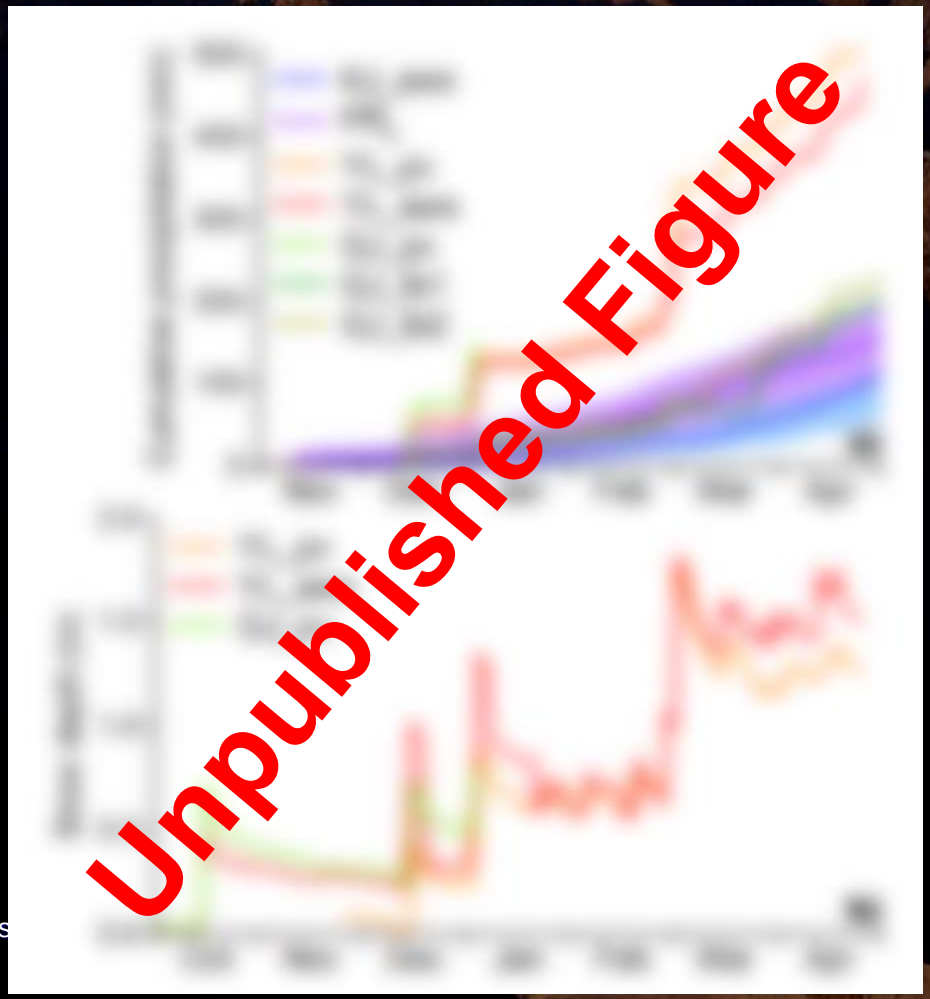
Snow, ice and rock

- Ice-rock boundary is clear
- No large-size rock within ice
- Clear ice balls in dirty ice

- These have different sources and timings

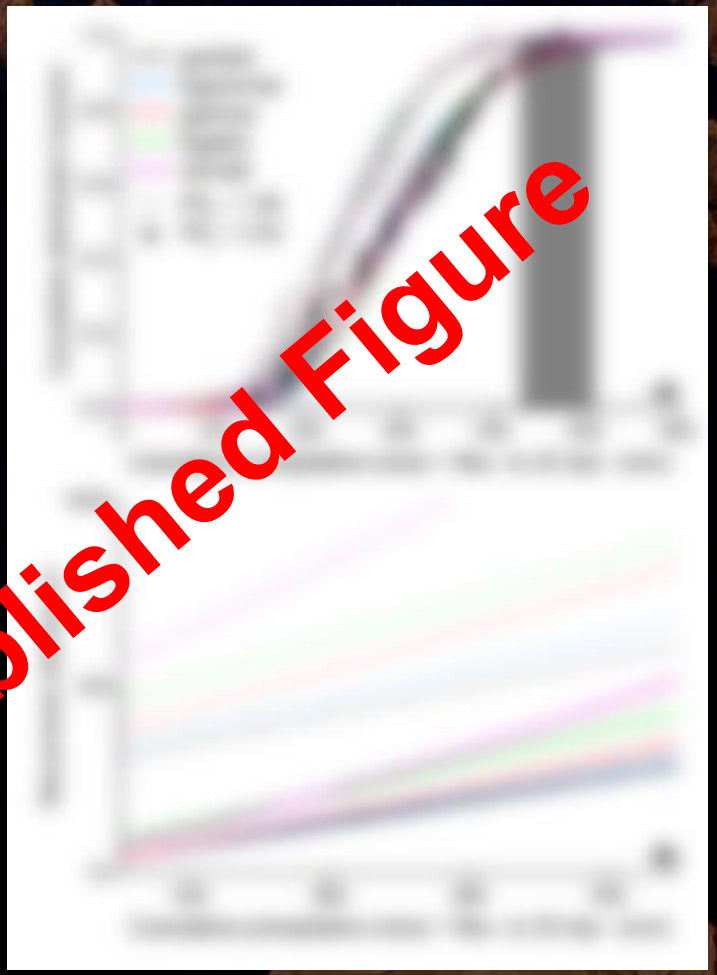
Precipitation & Snow Depth

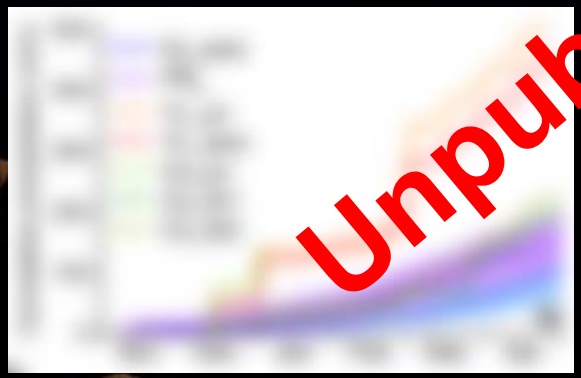
- V(6.55Mm^3)/A(8.4km^2) =0.78 m in ice
- ~1.56m = Yala!!
  - snow dens. 450kg m^{-3}



How Rare Event?

- Aphrodite prec. data (29a, Yatagai+, 2012)
- Prec. lapse rate (0.053% m^{-1})
  - PR_{YL}/PR_{KY} (dz ~ 1000m)
    - 1.66 (Immerzeel+, 2014WRR)
    - 2.00 (Seko, 1987BGR)
- T_{ri} > 18 ~ 100 a
- T_{eq} (80a) x T_{ri} (20a) > 1600a!!





Unpublished Figure

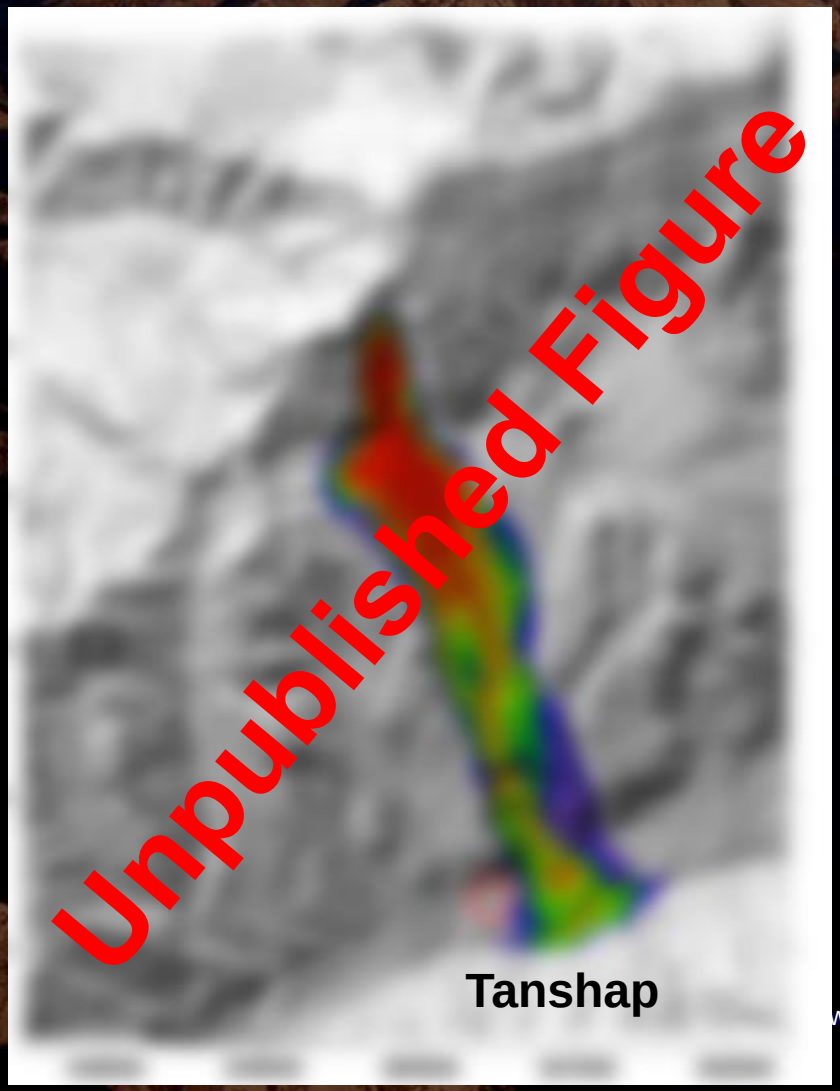
Avalanche Simulation

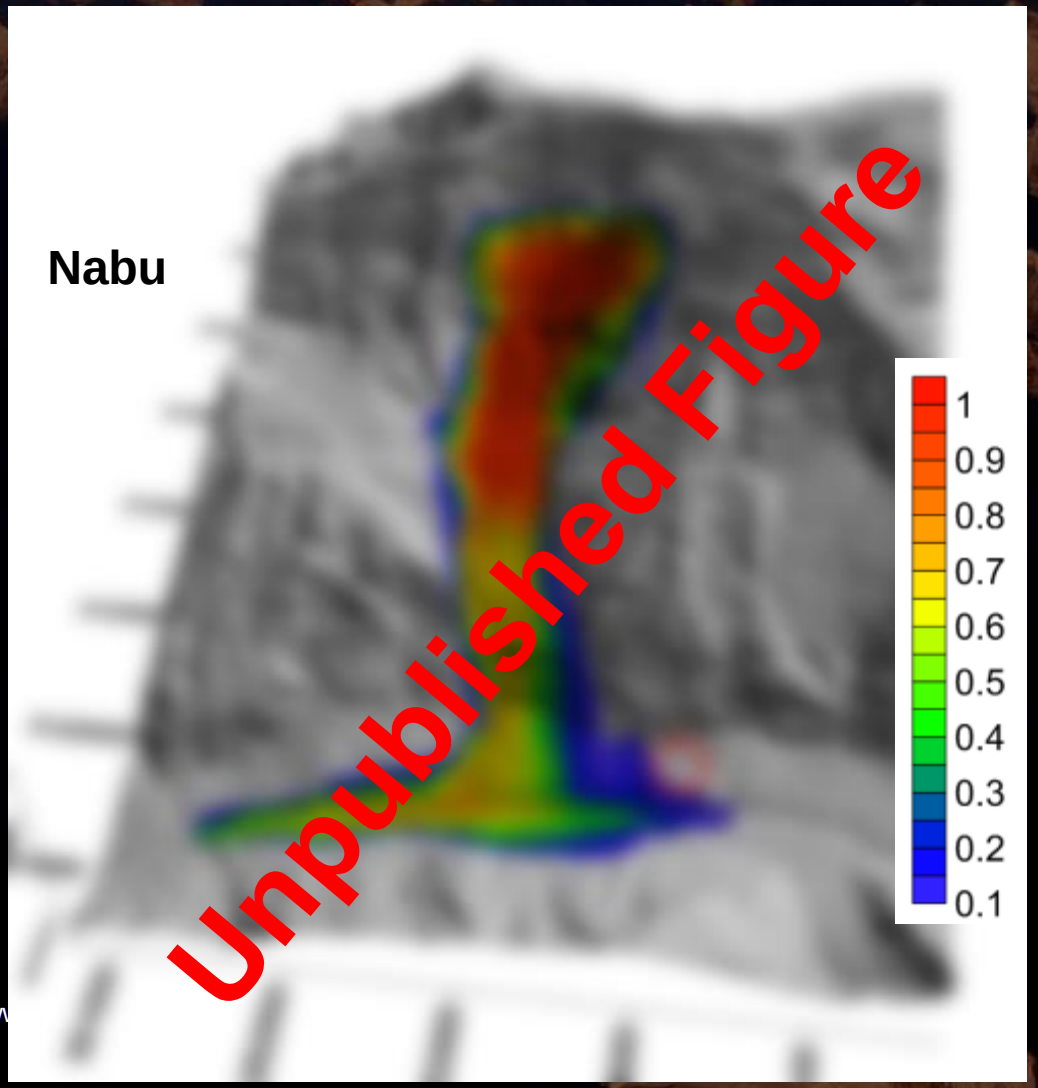
- Validation with
  - debris extent / amount / stone movement / tree damage
- Creating avalanche hazard map

Unpublished Figure

Y. Ito, S. Yamaguchi & K. Nishimura

Avalanche Hazard Map





Summary

- Earthquake is the main trigger, but,,,
- Anomalous winter snow amplified the tragic hazard

- For villagers
  - Fast outcomes required
  - Not only scientific, but also "practical" solutions and suggestions
  - Long-term supports necessary