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Modelling glaciers in the JULES Integrated Impacts Model (JIM)

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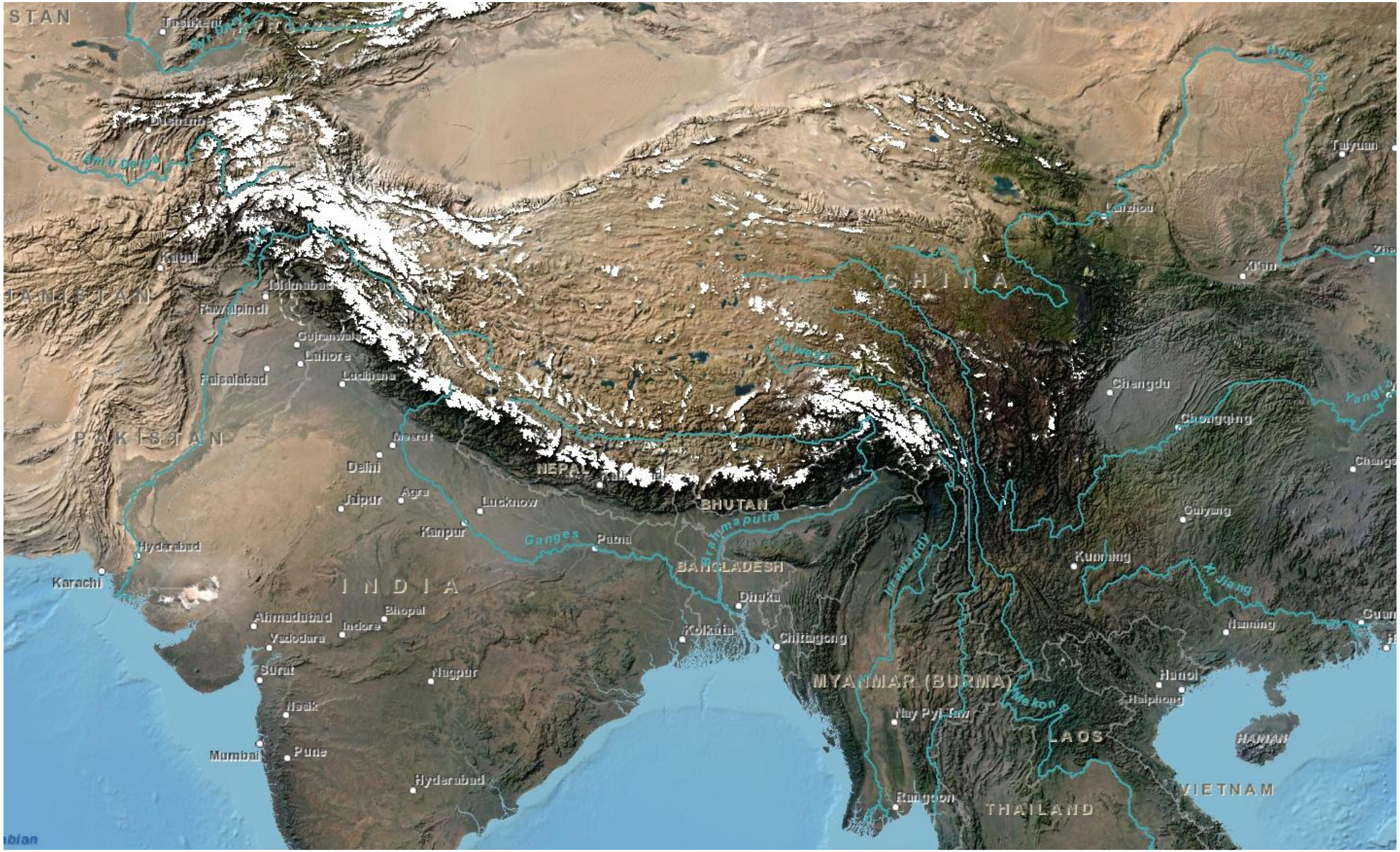
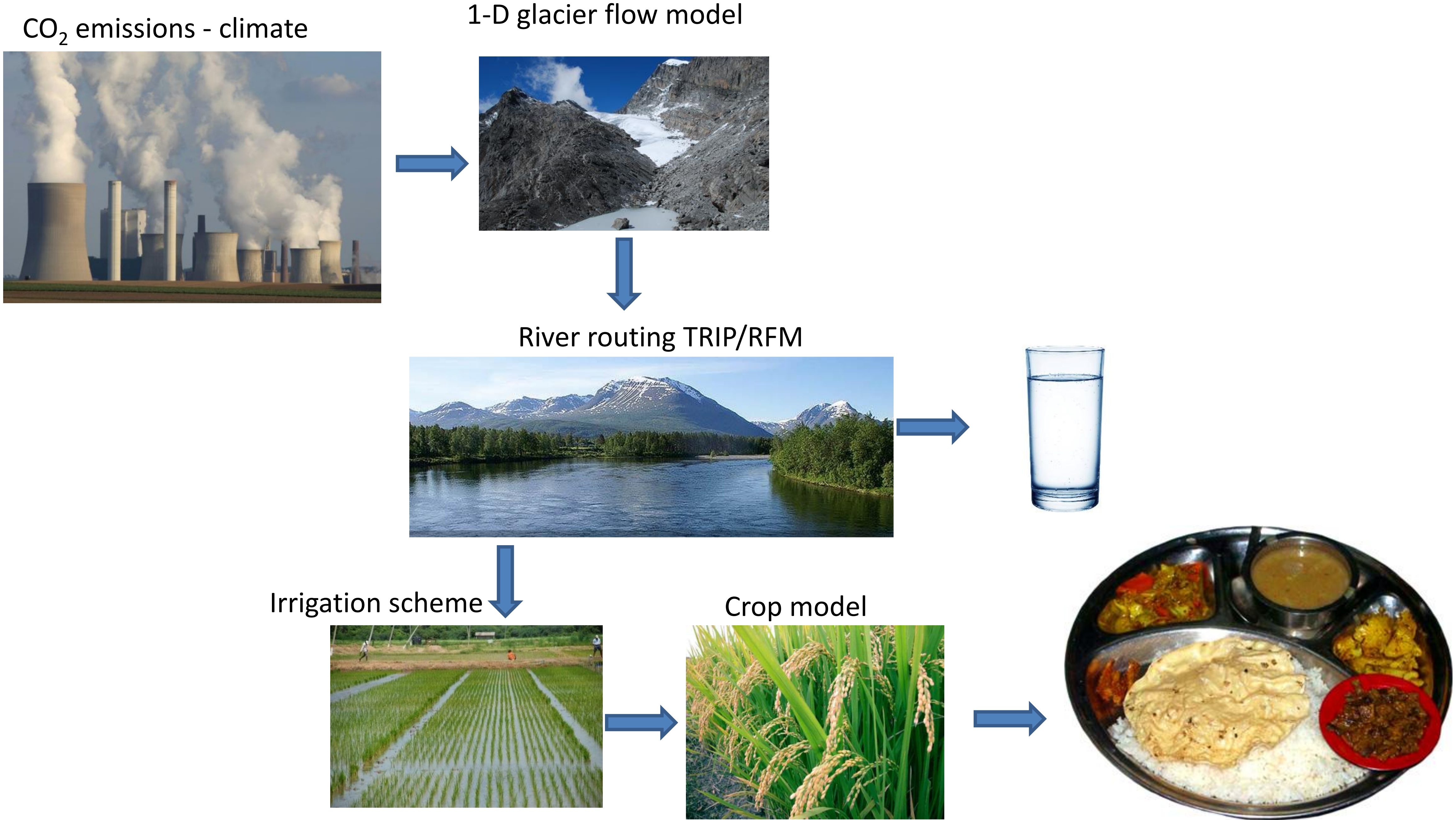
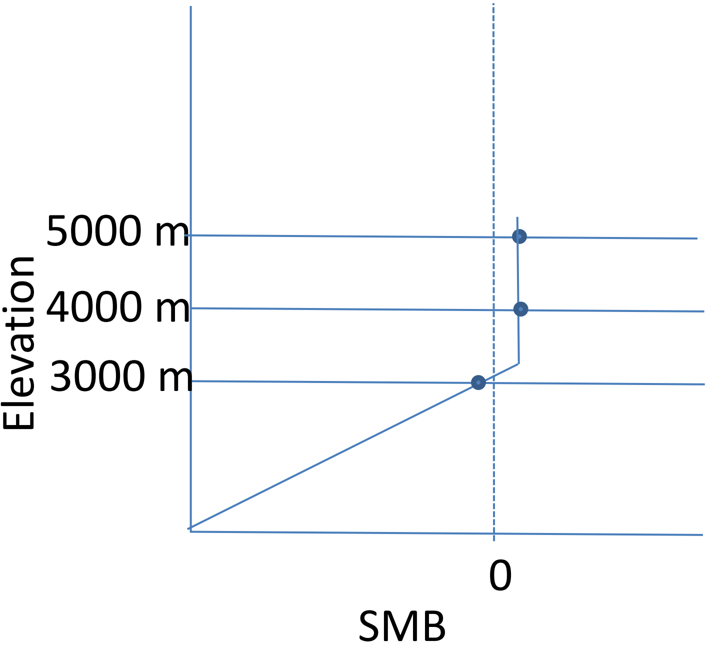


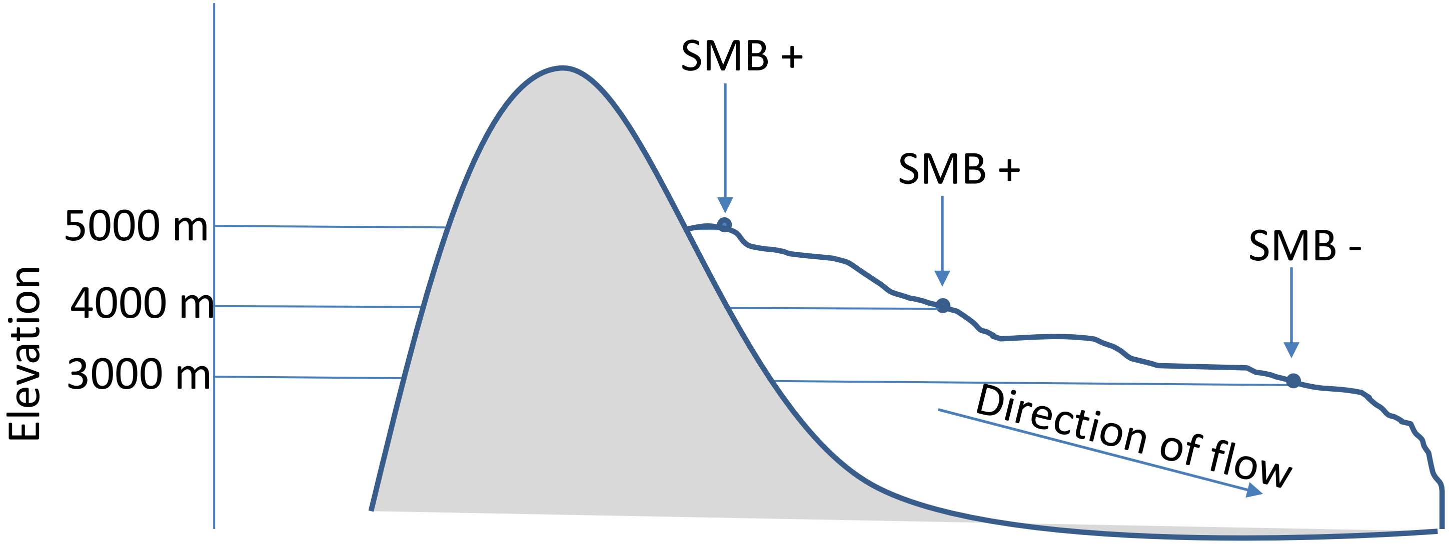
*…glaciers in the Himalayas are receding faster than in any other part of the world, and if the present rate continues, the likelihood of them **disappearing by the year 2035** and perhaps sooner is very high if the Earth keeps warming at the current rate."* Intergovernmental Panel on Climate Change *4th Assessment report 2007*

JULES-integrated impacts model (JIM)



Glacier model

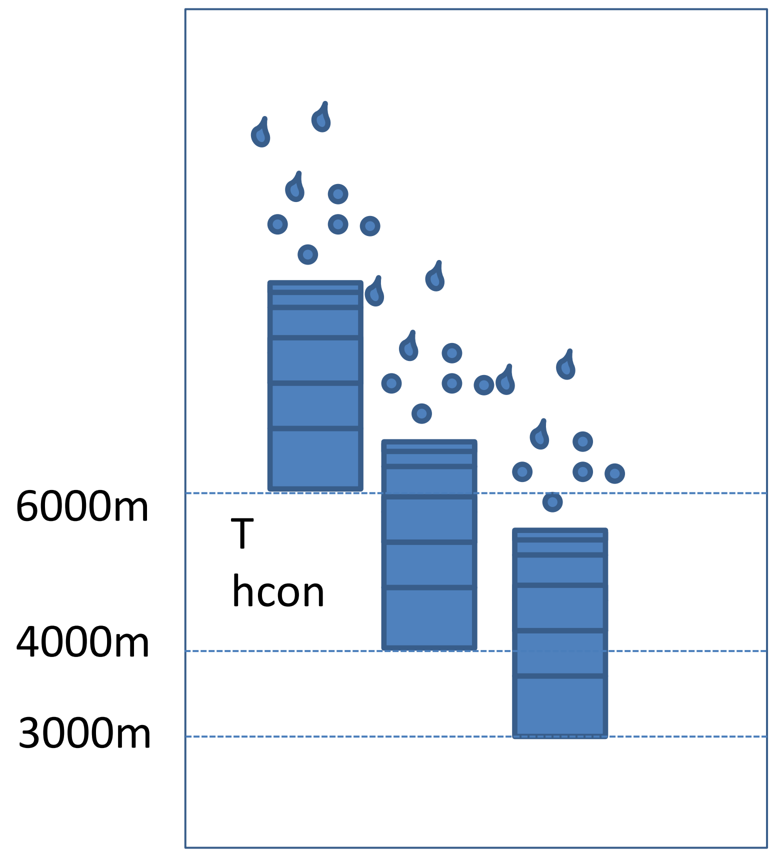




- 1-D depth-integrated SIA flowline model (Vieli & Payne, 2005).
- Gravitational driving stress = basal traction
- Simulates thickness change along the centre flow line of glacier.
- Inputs:
  1. **Surface mass balance (SMB) as a function of elevation – JULES**
  2. **Initial ice thickness distribution**
  3. **Digital elevation model**

Modifications to JULES to calculate surface mass balance

1 JULES grid box



Representing sub-grid orography

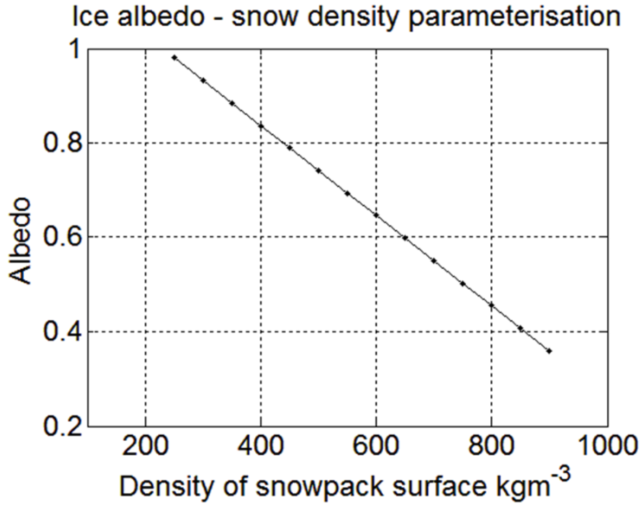
- Use existing multi-level snow scheme
- New surface type which are given multiple elevations above sea-level. A way to represent sub-grid orography.
- Elevated tiles have their own subsurface.
- Surface forcing data is adjusted for elevation levels
    - Surface **air temperature** is lapse rate corrected
    - **Rainfall** is converted to snowfall if the wet bulb temperature is below freezing.
    - **Downward longwave radiation** is adjusted for elevation

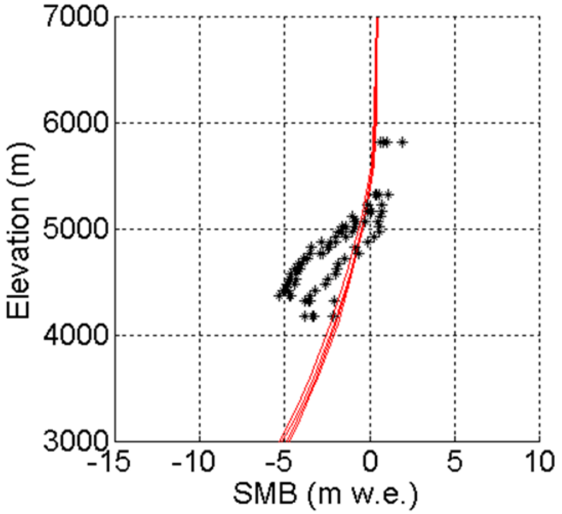
$$LW \downarrow = \varepsilon_{cs} \sigma T^4$$

where ε_{cs} is the clear sky emissivity (1), σ is Stefan-Boltzmann constant and T is the lapse rate corrected surface air temperature.

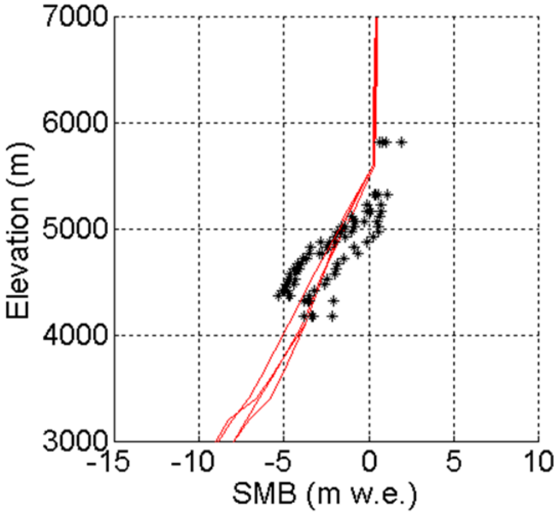
- SMB = accumulation – snow melt – sublimation

Modifications to JULES: Ice albedo parameterisation





SMB for Chhota Shigri with no ice albedo parameterisation. Observations from WGMS



SMB for Chhota Shigri with the ice albedo parameterisation

- Glacier ice albedo not accounted for in the existing prognostic albedo model (snow darkens with age, albedo ~grain size)

- Gardner & Sharp 2010

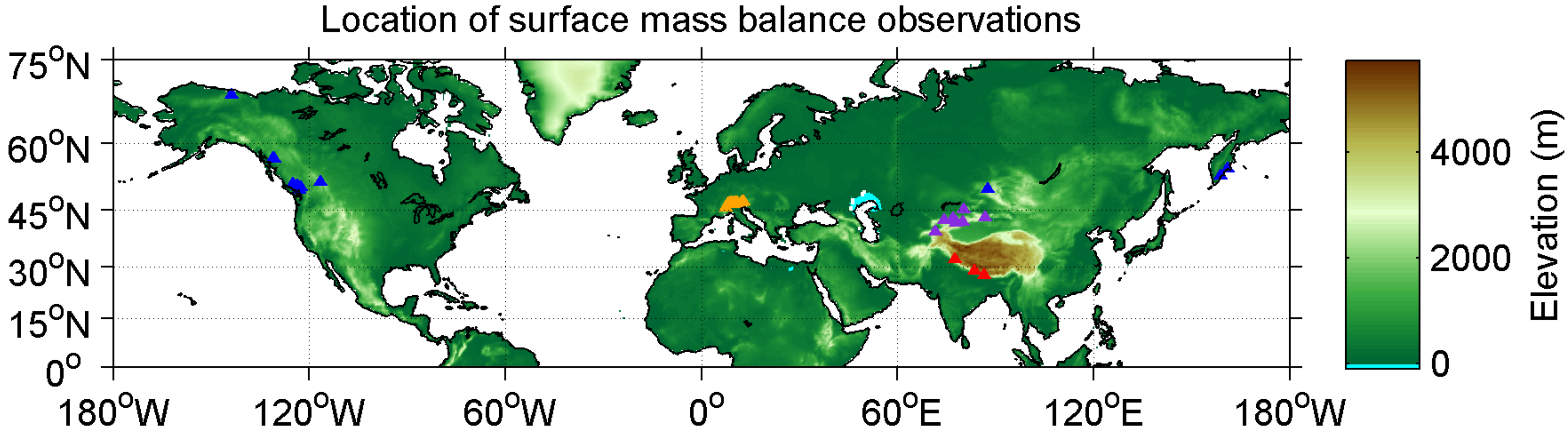
$$\alpha = \alpha_i + (\boldsymbol{\rho_{ss}} - \rho_i)\left(\frac{\alpha_s - \alpha_i}{\rho_s - \rho_i}\right)$$

- $\boldsymbol{\rho_{ss}}$ is the density of the surface layer of the snowpack, α_s maximum albedo of fresh snow (0.98 0.7), α_i albedo of ice (0.36 0.25), ρ_s is the density of fresh snow ($250 kgm^{-3}$)and ρ_i is the density of ice ($910 kgm^{-3)}$

- Run with WFDEI 0.5 x 0.5.

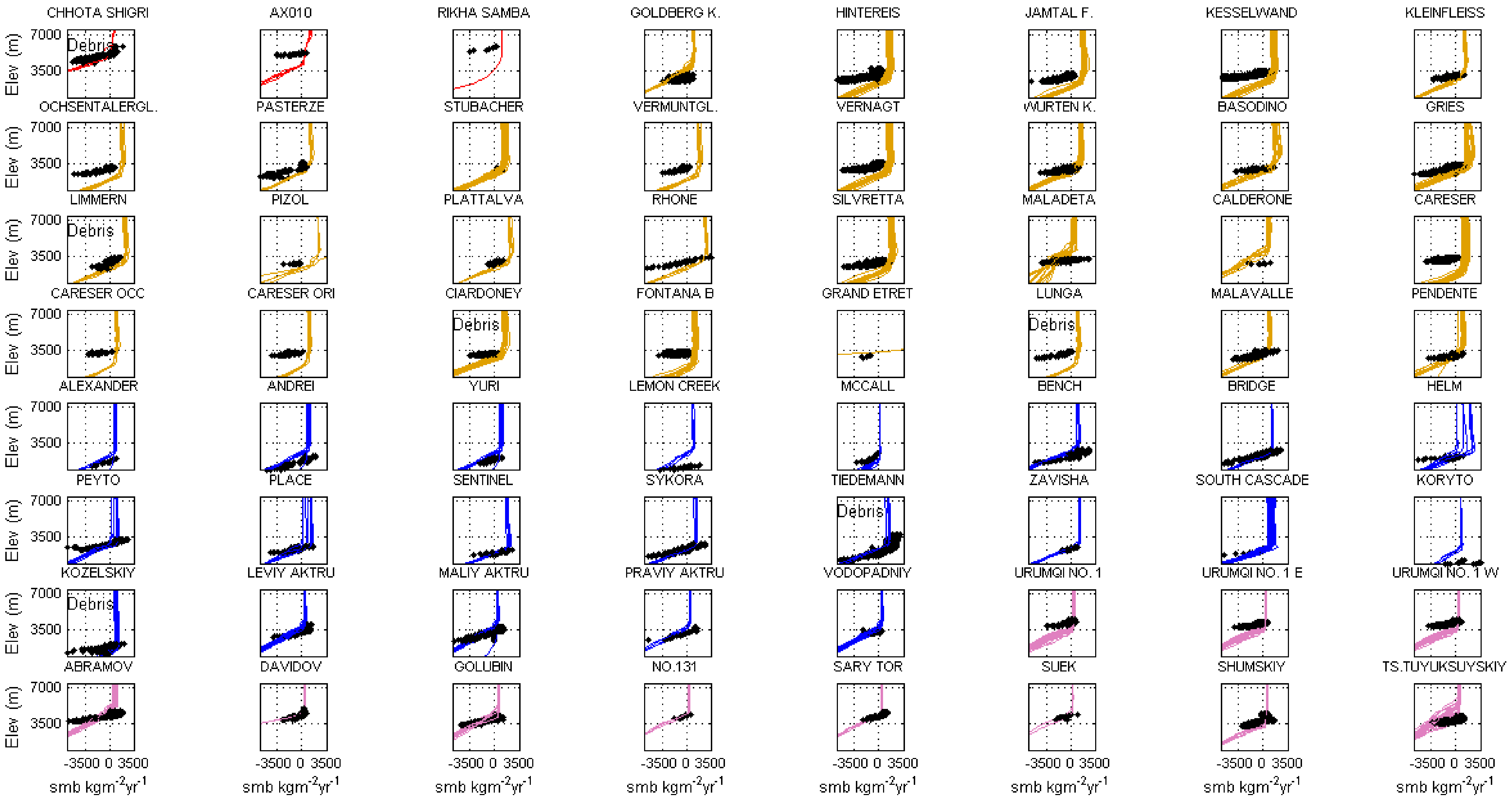
- Parameterisation lowers the albedo at low elevations, enhances melting and improves match with observations.

Validation of glacier surface mass balance



- The location of sites where glacier surface mass balance has been observed. Data from the World Glacier Monitoring Service (WGMS).

- Stake measurements repeated at elevations along the glacier.



- WATCH forcing data
- 0.5 x 0.5 ERA-interim
- 20 elevation levels
- Underestimates accumulation
- Underestimates melting
- Forcing data quality?

Missing processes

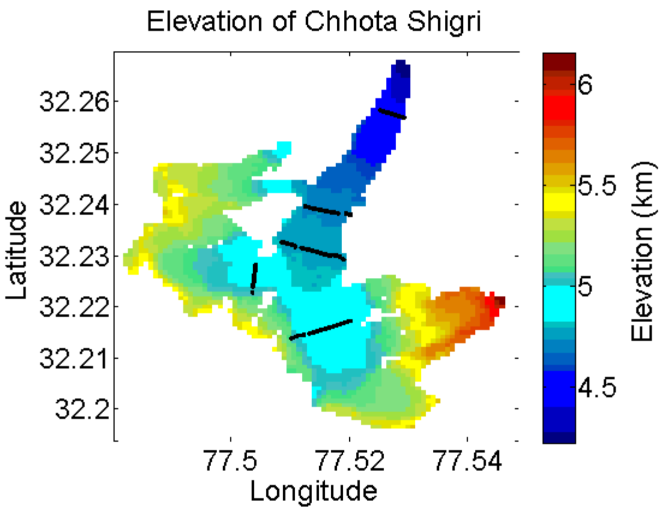
Avalanching

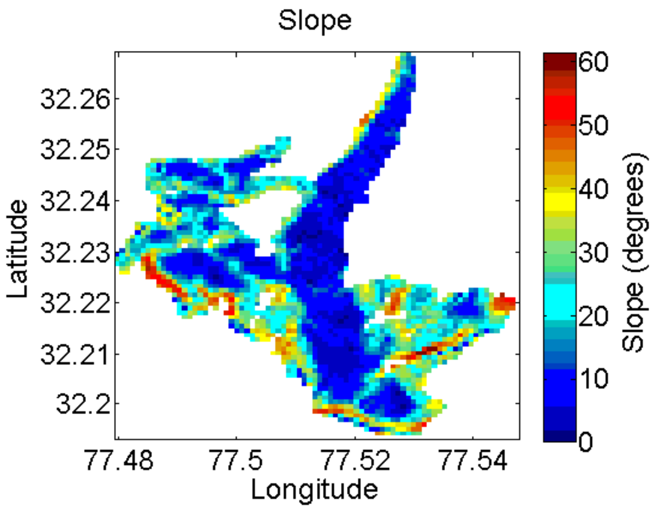
Contributes to accumulation

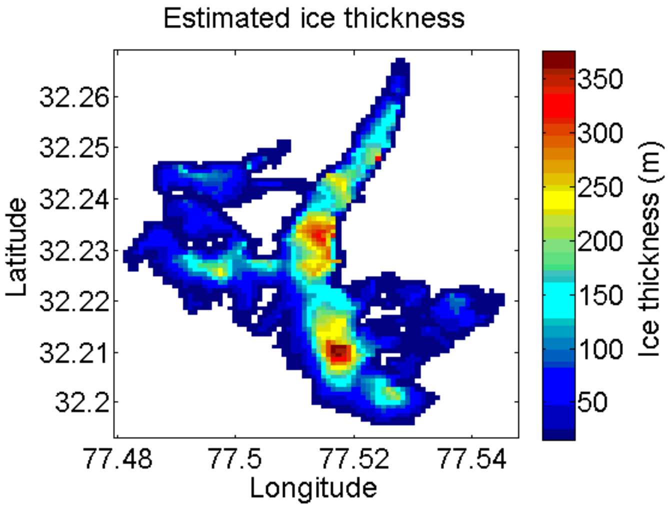
Debris cover

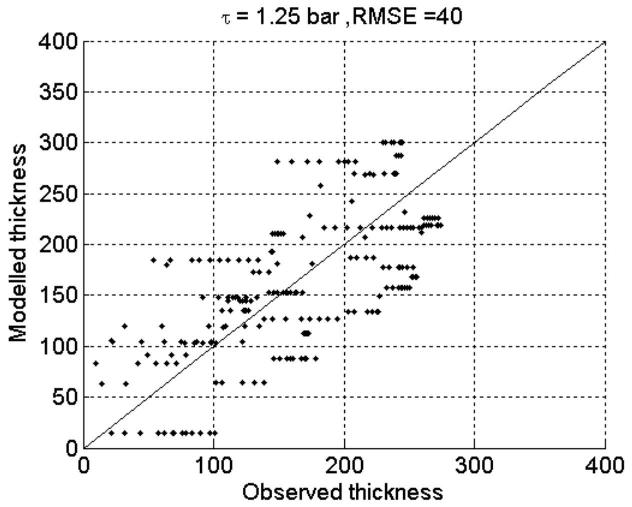
Thin layer enhances melting, thick layers insulate the glacier and prevent melting. Aspect not included

Estimating ice thickness









- Use a 90m digital elevation model and glacier outlines from the Randolph glacier Inventory.
- Overlay the glacier outlines on the DEM to get elevation and slope
- Thickness at the random points is

$$h = \tau / f \rho g Sin \alpha$$

τ is the basal shear stress, g the gravitational acceleration, α is the slope and f a shape factor is 0.8 (typical value for valley glaciers).

- Interpolate thickness between random points using inverse distance weighing.
- GPR observations provided by Mohd. Farooq Azam

What next?

- Science
  - Tune model parameters to improve modelled SMB
  - Glacier flow simulations for individual glaciers
  - Test an alternative initial ice thickness dataset (ITEM technique which will be used by glacierMIP)
- Model development
  - Add code to calculate SMB into JULES trunk – standalone version
  - Add the glacier model. Link volume change to hydrology
  - Full coupling of glacier model to the UM
  - Benchmarking glacier model