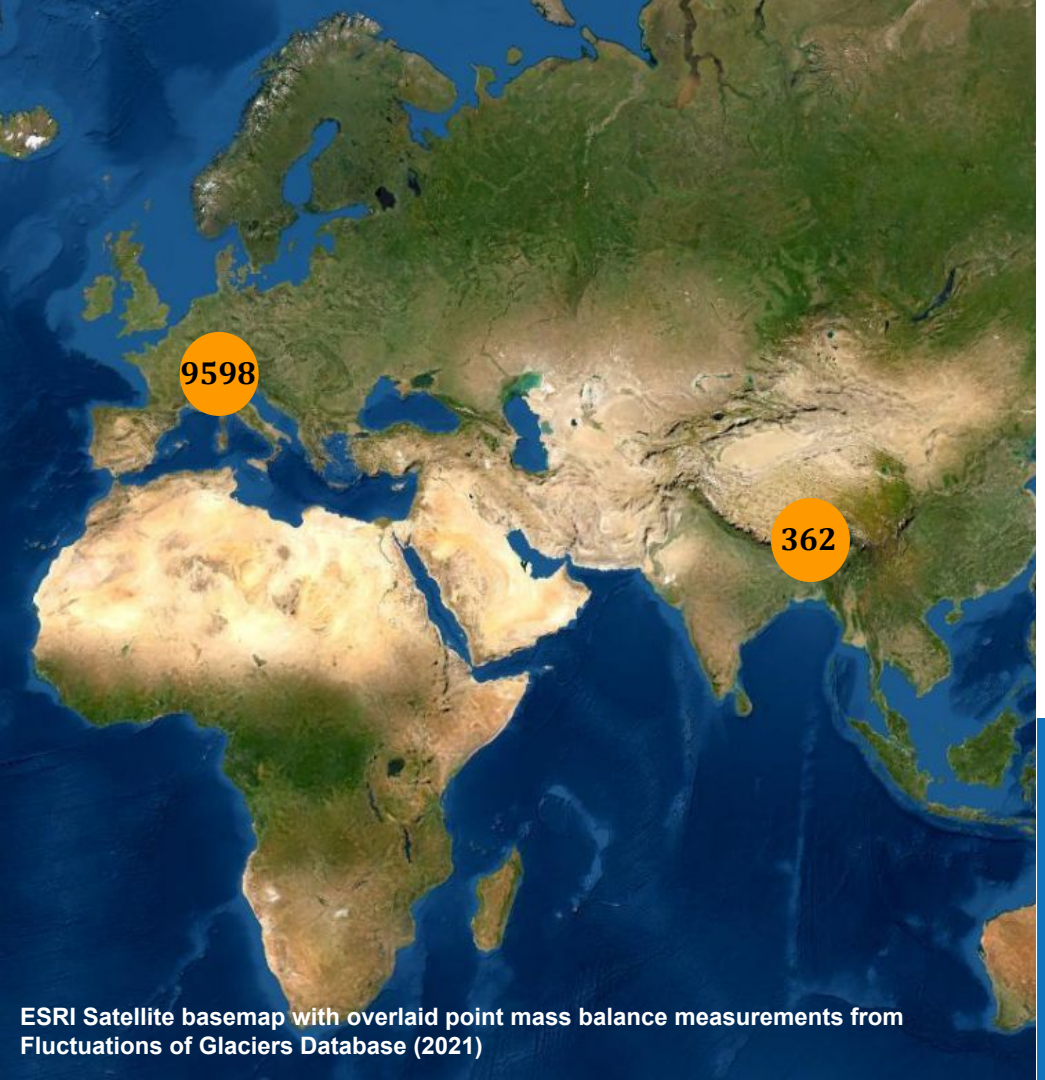


ESRI Satellite basemap with overlaid point mass balance measurements from Fluctuations of Glaciers Database (2021)

EGU22-5317

Point Mass Balance Regression using Deep Neural Networks:

A Transfer Learning Approach

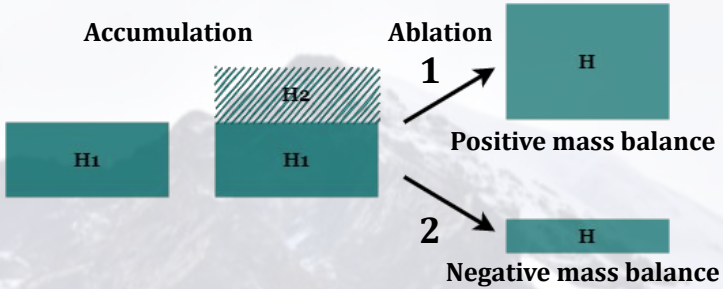
Ritu Anilkumar, Rishikesh Bharti and Dibyajyoti Chutia
r.anilkumar@iitg.ac.in

Sharing is encouraged

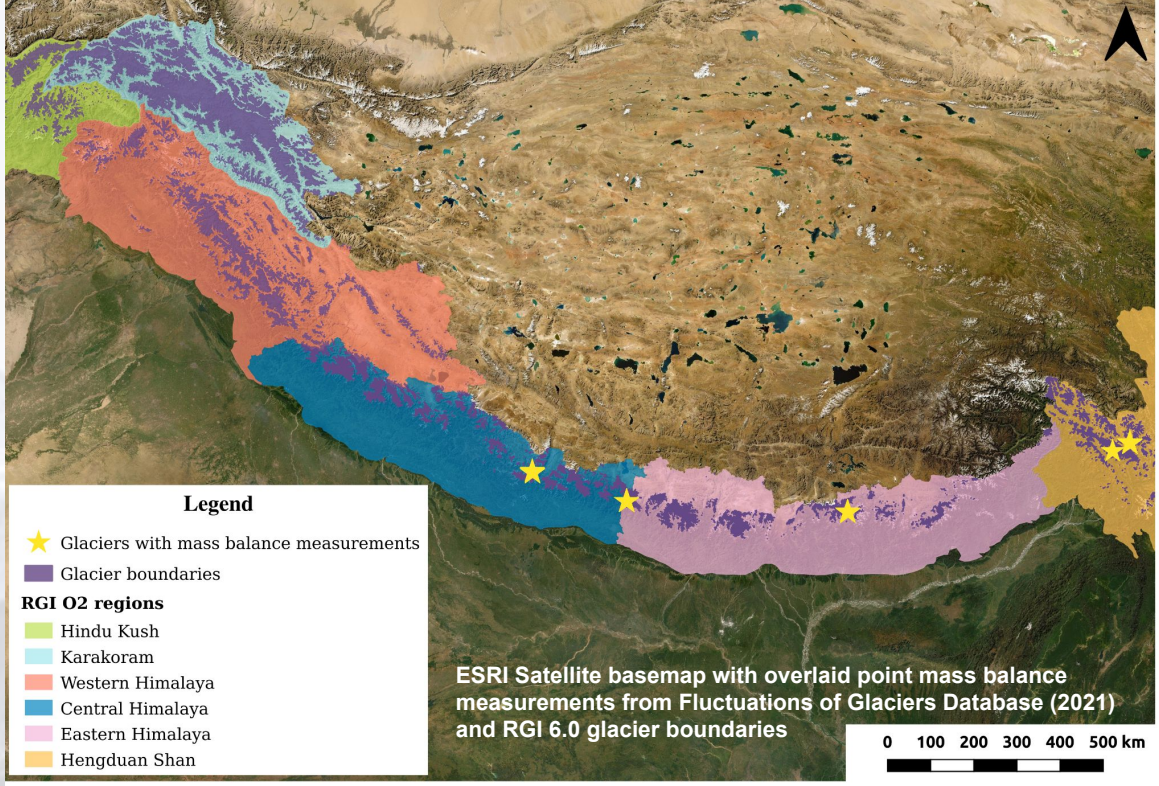
This presentation participates in OSPP

Outstanding Student & PhD candidate Presentation contest

Motivation



- Several tens of thousands of measurements available globally
- Very few in-situ measurements available in Himalaya region
- Applicability to data driven techniques directly over Himalayas is thereby restricted

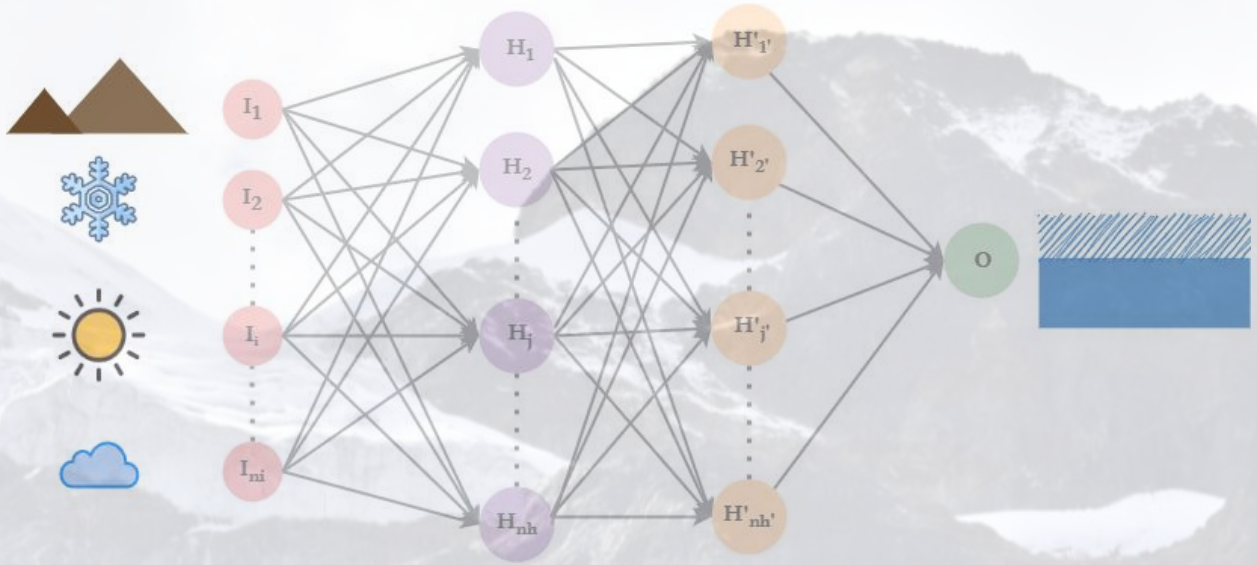


- Can machine learning be effectively utilized as a proxy for mass balance measurements?
- How do we address limited real world data availability in complex architectures?

Data Driven Methods for Mass Balance Estimation: Problem Formulation

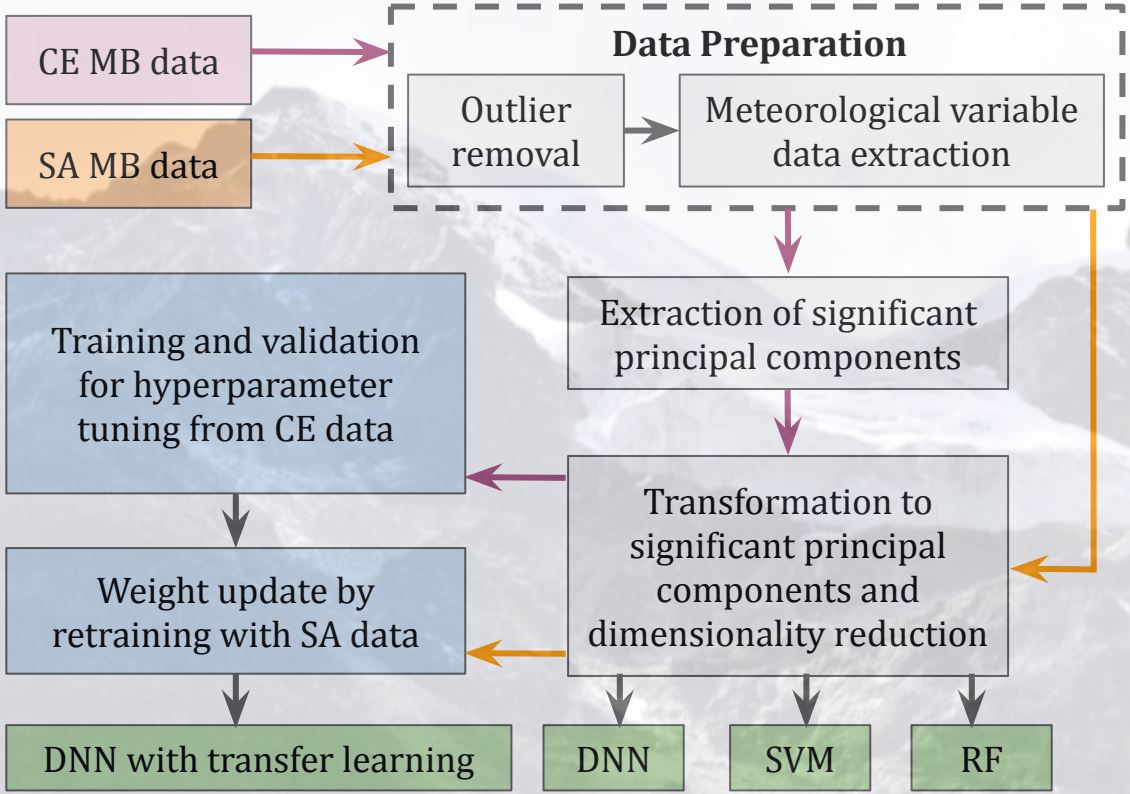
Invert the problem:

- Standard formulation: use rules to derive the data
- Data-driven formulation: use data to derive the rules



- **Inputs used:** Monthly mean of 14 meteorological variables
- **Labels:** Fluctuation of Glaciers database of point mass balance estimates
- **Algorithms considered:** Support Vector Machine, Random Forest and Deep Neural Network
- **Handling limited data:** Transfer learning and dimensionality reduction

Data and Methods

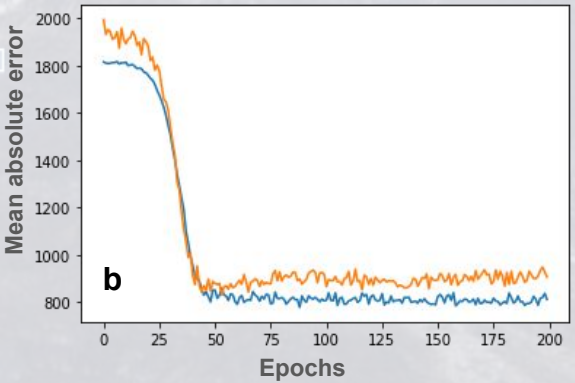


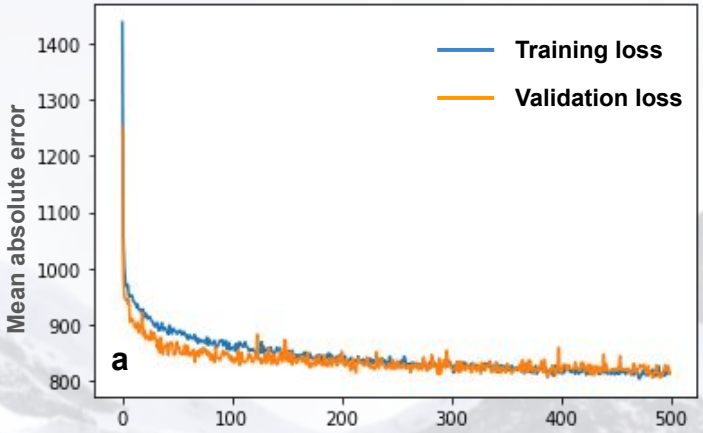
MB: Mass Balance; **CE:** Central Europe; **SA:** South Asia;
DNN: Deep Neural Network; **SVM:** Support Vector Machine; **RF:** Random Forest

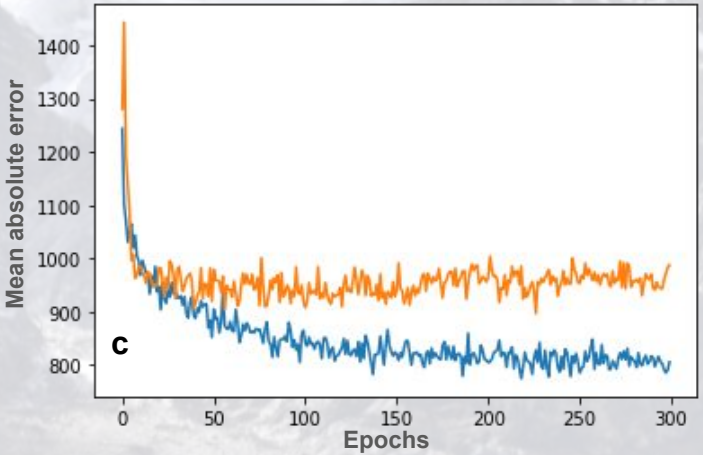
Input features (ERA5 Land M.Avg)	
Temperature 2m	Snow density
Snow temperature	Surface net solar radiation
Total Precipitation	Forecast albedo
Surface pressure	Surface net solar radiation downwards
Snowfall	Surface net thermal radiation
Snowmelt	Surface Sensible Heat Flux
Snow depth	Surface Latent Heat Flux

Results

- **Data split:** 70-15-15
- **Loss functions:** MAE, MSE, Smooth MAE
- **Activations:** ReLU, Tanh, Sigmoid
- **Optimizers:** SGD, Adadelta, Adam





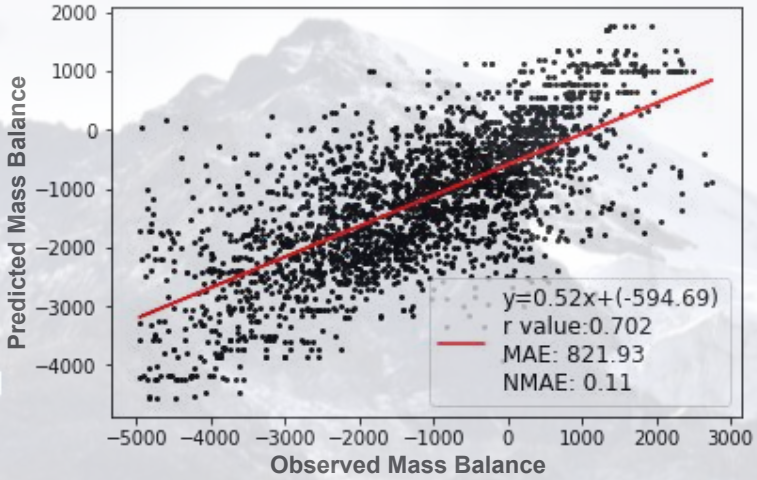


Training and validation loss characteristics (a) CE dataset and (b) SA without transfer learning and (c) SA with transfer learning

Best Model

Hyp.param.	Selected
Loss function	L1 loss
#hidden lyr	5
#hidden nodes	25,30,40,20,10
Activation	Leaky ReLU
Optimizer	Adadelta with lr 1
Batchnorm	Yes
Epochs	500
Model MAE	0.805 m we
Mini-batch	32

Results



Sample scatter plot of Random Forest regressor for Central Europe

Regressor	Choice of Hyperparameters	L1 Loss (mwe)
Large Datasets		
SVM	Kernel: Radial Basis Function; C=10	0.842
RF	**Number of trees = 200**	**0.821**
DNN	5 layers (25,30,40,20,10 neurons) with Adadelta optimizer and Leaky ReLU activation	0.858
Small Datasets		
SVM	Kernel: Radial Basis Function; C=1	0.878
RF	Number of trees = 100	0.886
DNN	**5 layers (25,30,40,20,10 neurons) with Adadelta optimizer and Leaky ReLU activation**	0.974
DNN (TL)		**0.828**

Conclusion

- For large training datasets, machine learning algorithms may effectively be used for estimation of point mass balance
- For fewer training datasets, machine learning regressors such as SVM and Random Forest continue to perform well as compared to complex neural network architectures
- An improvement in performance of complex architectures on limited datasets is observed when using transfer learning
- Useful technique particularly for filling spatial and temporal gaps in field data

- Downscaling of meteorological data can be attempted for fine tuning results
- Recurrent structures in the network architecture to incorporate long term temporal effects

Selected References

- Kuhn, M, E Dreiseitl, S Hofinger, G Markl, N Span, and G Kaser. 1999. “Measurements and models of the mass balance of Hintereisferner.” Geografiska Annaler: Series A, Physical Geography 81 (4): 659–670.
- Steiner, Daniel, Andreas Walter, and H. J. Zumbühl. 2005. "The application of a non-linear back-propagation neural network to study the mass balance of Grosse Aletschgletscher, Switzerland." Journal of Glaciology 51(173) : 313-323.
- Bolibar, Jordi, Antoine Rabatel, Isabelle Gouttevin, Clovis Galiez, Thomas Condom, and Eric Sauquet. 2020. “Deep learning applied to glacier evolution modelling.” The Cryosphere 14(2): 565–584.
- Bolibar, J., Rabatel, A., Gouttevin, I., Zekollari, H., & Galiez, C. (2022). Nonlinear sensitivity of glacier mass balance to future climate change unveiled by deep learning. Nature Communications, 13(1), 1-11.

Thank You

In case of queries, please contact me at

r.anilkumar@iitg.ac.in