Time Series Analysis On Snow Depth In the Alps

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Motivation

Understand and use SAFRAN CROCUS datasets

Conduct Time Series Forecasting

Find a model independent from weather forecast

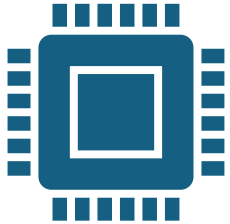
Study snow depth during peak season

Novelty

No models on snow depth,

only snowfall

Search of a hybrid model,
adapted to winter season



Model would predict
up to 1 year

Dataset

- **1975 => 2019**, 1 log/day, 212 day/year
- Source: MeteoFrance's **SAFRAN-CROCUS** dataset
- Stations to study:
  - Les 2 Alpes: Highest, glacier ~**3000m**
  - Tignes: north-facing, stable snowpack ~**2600m**
  - Serre Chevalier: south-facing, unstable snowpack ~**2100m**
  - Col de Porte: Lowest, humid, perfect data source ~**1300m**

- Measurements are grid-generalized per station
- Processed Day Metrics : HS = > qc(HS) => **gapfill(qc(HS))**

Literature – Primary Data Source

Matiu, M., Crespi, A., Bertoldi, G., Carmagnola, C. M., Marty, C., Morin, S., Schöner, W., Cat Berro, D., Chiogna, G., De Gregorio, L., Kotlarski, S., Majone, B., Resch, G., Terzago, S., Valt, M., Beozzo, W., Cianfarra, P., Gouttevin, I., Marcolini, G., Notarnicola, C., Petitta, M., Scherrer, S. C., Strasser, U., Winkler, M., Zebisch, M., Cicogna, A., Cremonini, R., Debernardi, A., Faletto, M., Gaddo, M., Giovannini, L., Mercalli, L., Soubeyroux, J.-M., Sušnik, A., Trenti, A., Urbani, S., and Weilguni, V.: **Observed snow depth trends in the European Alps: 1971 to 2019**, The Cryosphere, 15, 1343–1382, https://doi.org/10.5194/tc-15-1343-2021, 2021.

Literature – Gap filling / Meaning

Use of the models Safran-Crocus-Mepra in operational avalanche forecasting, Coléou C* , Giraud G, Danielou Y, Dumas J-L, Gendre C, Pougatch E CEN, Météo France, Grenoble, France

Version 3.0 of the Crocus snowpack model, Matthieu Lafaysse1 , Marie Dumont1 , Basile De Fleurian1 , Mathieu Fructus1 , Rafife Nheili1 , Léo Viallon-Galinier1 , Matthieu Baron1 , Aaron Boone2 , Axel Bouchet1 , Julien Brondex1,4 , Carlo Carmagnola1 , Bertrand Cluzet1 , Kévin Fourteau1 , Ange Haddjeri1,4, Pascal Hagenmuller1 , Giulia Mazzotti1,4, Marie Minvielle2 , Samuel Morin1 , Louis Quéno1,5, Léon Roussel1 , Pierre Spandre1 , François Tuzet1 , and Vincent Vionnet1,3

Literature - Models

Aschauer, J., Bavay, M., Begert, M., and Marty, C.: **Comparing methods for gap filling in historical snow depth time series**, EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020–17211, https://doi.org/10.5194/egusphere-egu2020-17211, 2020.

Introduction to Time Series and Forecasting – Third Edition,

By Peter J. Brockwell Richard A. Davis, 2016

Durbin, James, and Siem Jan Koopman. 2012. **Time Series Analysis by State Space Methods: Second Edition.** Oxford University Press.

Work Done – Naïve Model

- Average of past Same Days:
  - NS(y, m, d) = $\frac{1}{y-1}\sum_{k=1}^{y-1} ds[k, m, d]$
  - NMAE = $\frac{MAE}{season\_mean}$
  - 2 Clear groups performance-wise
- Note: 10 first years without cross-validation

STATION NAME	MAE	NMAE
Tignes	30.822	0.395
Les 2 Alpes	48.345	0.404
Serre-Chevalier	25.076	0.82
Col de Porte	32.797	1.125

Work Done – (AR)(I)(MA) Model

- AR : Auto Regression – Past values
- I: Integration – Past trends
- MA: Moving Average – Past errors

- Stations with big snowfalls perform Worst, and need error correction (MA)

- Limitations: Needs a seasonal parameter, least worst performing ARIMA are smoothing ones

Worse Accuracy

Better Accuracy

STATION NAME	MAE	NMAE	p, d, q
Tignes	44.769	0.52	1, 0, 1
Les 2 Alpes	64.701	0.521	1, 0, 1
Serre-Chevalier	33.173	0.905	1, 0, 0
Col de Porte	42.711	0.946	1, 0, 0

Work Done – (AR)(I)(MA) Model

- $AR_{m,d}(\text{p}) = C + \sum_{k=1}^{p} \Phi_k * ds[t\text{-}1]$
- $I_{m,d}(\text{d}) = \nabla^d * ds[t]$
- $MA_{m,d}(\text{q}) = C + \sum_{k=1}^{q} \theta_k * \varepsilon_{t-k}$

- Note: We add white noise shock

For every member ε_t

Worse Accuracy

Better Accuracy

STATION NAME	MAE	NMAE	p, d, q
Tignes	44.769	0.52	1, 0, 1
Les 2 Alpes	64.701	0.521	1, 0, 1
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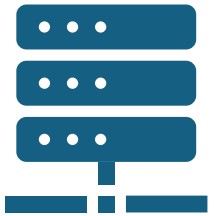
CONCLUSION – What's next

(S)ARIMA

Another, improved, custom model



Kaggle integration for bigger hyperparameters

Thank you for your time !

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https://github.com/PapayaSupreme/snow-depth-time-series-analysis-model