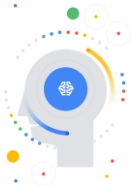
Deep Learning Bise Wind Prediction at ZRH airport

Pawel Kampczyk, PhD

AMLD 2022

Contents

Bise POC Success Criteria



First ML Model

First ML model for Bise created

Outperform existing Approaches

ML model to beat heuristics in precision, recall, f1 score .

Extend Model Timeframe

Extend model to 6h horizon + beat heuristics

Make it easy with Technology

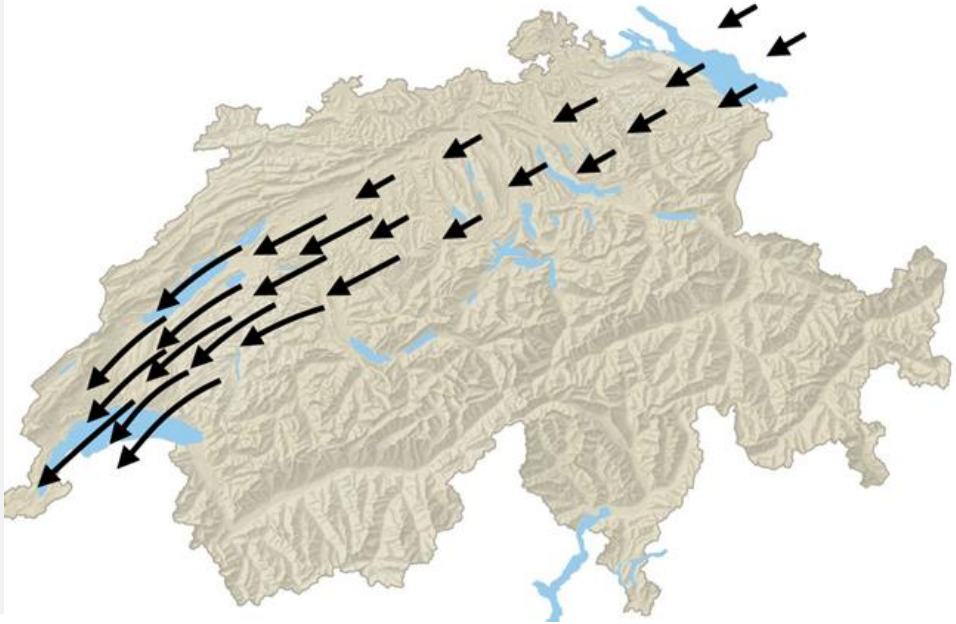
Evaluate new VertexAI time series technology

Contents

What is BISE?

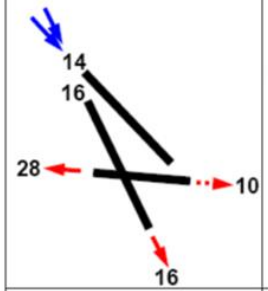
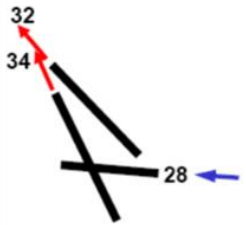
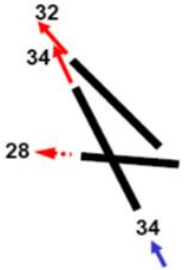
- Cold, mostly dry wind from the north-east to south-west
- Canalization through the Alps and the Jura Mountains towards the west
- Summer: good weather
- Winter: high fog, strong haze
- Strongest at Lake Geneva: Wind speed: avg. 60 km/h, Gust peak: >100 km/h

→ 30% decrease of the ZRH airport capacity for landings & take-offs



What does this mean for the ZRH airport?

30% decrease in the ZRH airport capacity
Potential delays - on departure and arrival

Nordanflugkonzept	Ostanflugkonzept	Südanflugkonzept
Landungen von Norden, Starts Richtung Westen und Süden, bei Bise Richtung Osten Landungen: Piste 14 und 16 Starts: Piste 28 und 16 Piste 10 (Bise)	Landungen von Osten, Starts Richtung Norden Landungen: Piste 28 Starts: Piste 32 und 34	Landungen von Süden, Starts Richtung Norden und Westen Landungen: Piste 34 Starts: Piste 32, 34 teilweise Piste 28
		
Generelle Anwendung: • 07:00 - 21:00 Uhr Mo - Fr • 09:00 - 20:00 Uhr Sa und So, baden-württembergische Feiertage ➔ bei Biswind auch morgens und abends	**Generelle Anwendung:** • 21:00 - 23:30 Uhr Mo - Fr • 20:00 - 23:30 Uhr Sa und So, baden-württembergische Feiertage ➔ bei Westwind auch tagsüber	**Generelle Anwendung:** • 06:00 - 07:00 Uhr Mo - Fr • 06:00 - 09:00 Uhr Sa und So, baden-württembergische Feiertage ➔ abends, wenn Ostanflüge nicht möglich sind (Bise, schlechte Sicht etc.) oder tagsüber wenn weder Nord- noch Ostanflüge möglich sind

Forecasting Approaches

1. Numerical weather forecasting

- Global optimization
- Run every couple of hours + time to compute
- Lead time in days

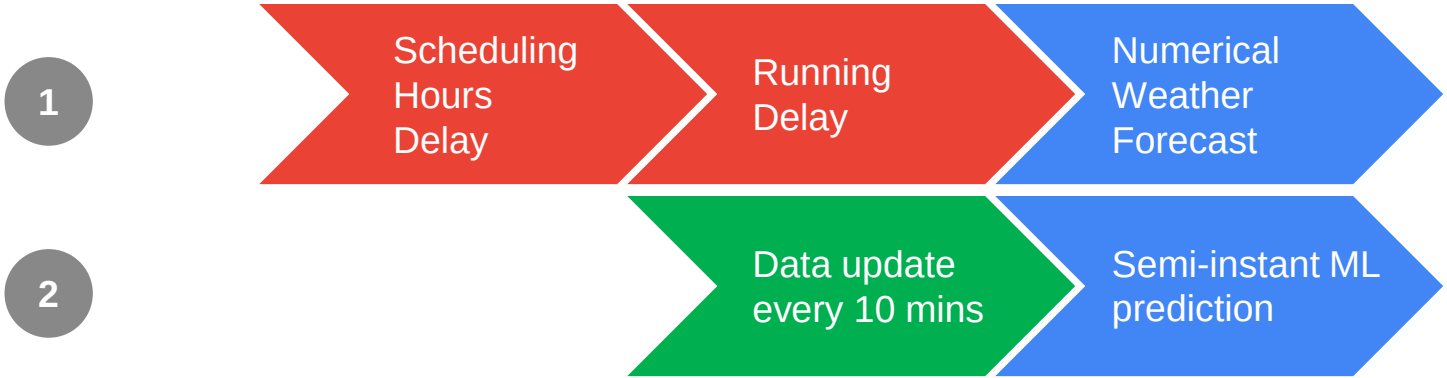
Forecasting Approaches

1. Numerical weather forecasting

- Global optimization
- Run every couple of hours + time to compute
- Lead time in days

2. ML time series prediction

- Focus on local optimization (ZRH airport)
- Semi-instant forecast (only initial training of the model takes hours)
- Lead time in hours



Contents

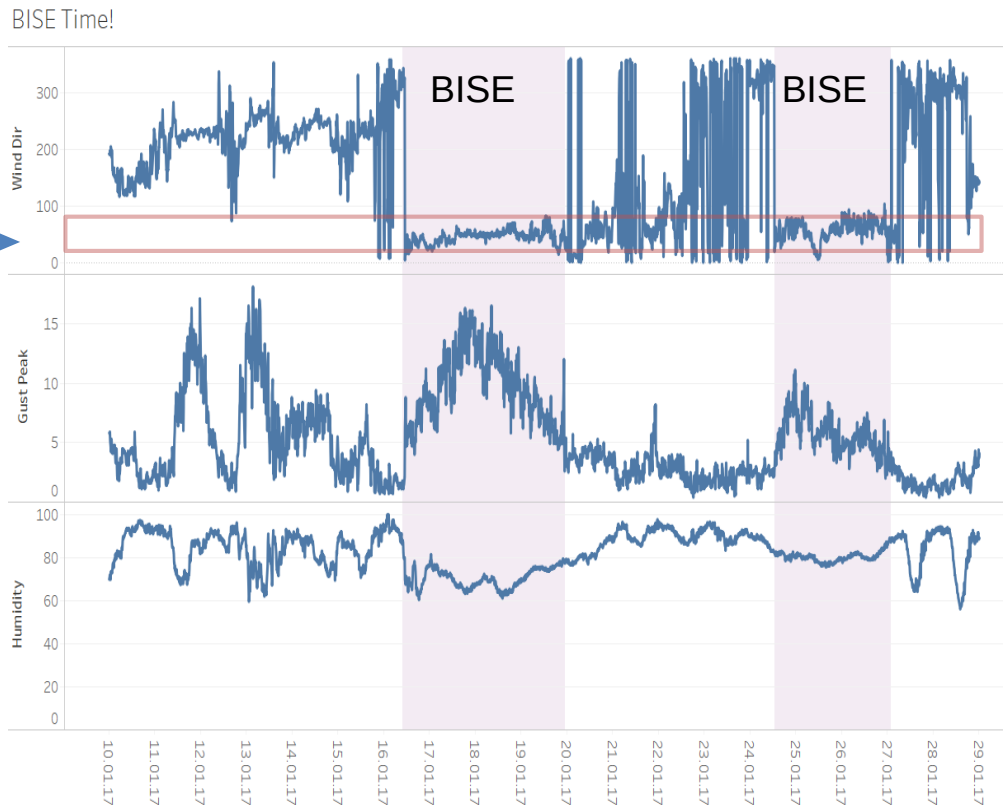
Weather Data

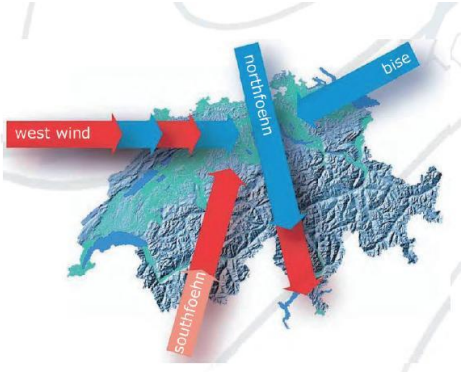
Wind direction Change to:

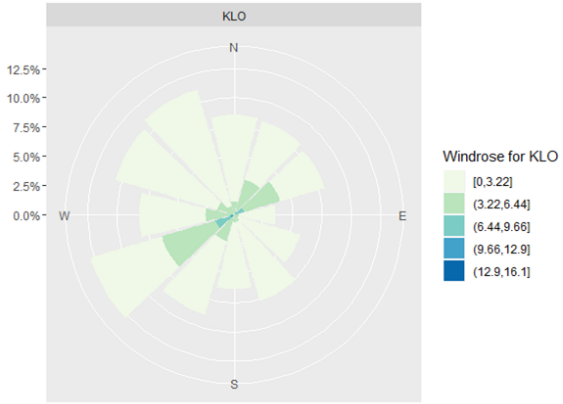
N-E

Increase in wind peaks.

Often decrease in humidity.





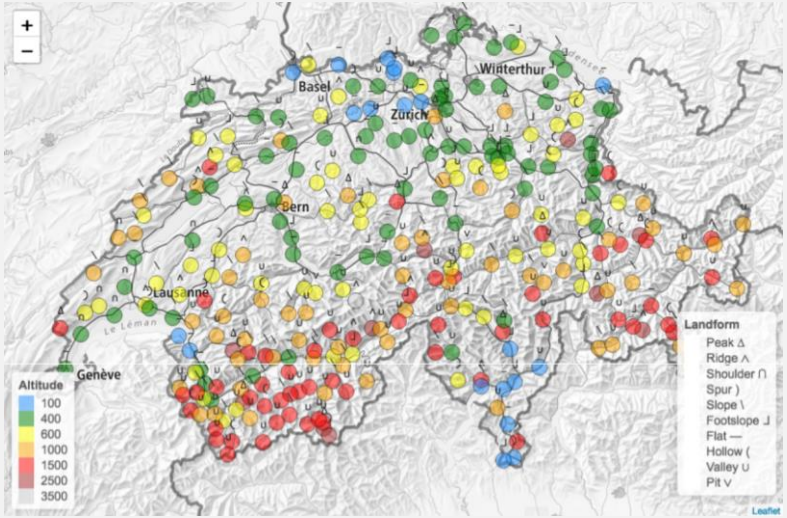


Weather Data

Current prediction based on pressure difference between two points (from MeteoSwiss simulation)

Project idea: Create a machine learning system to predict Bise wind in ZRH

Idea for the future implementation:
Utilize information from actual measurements to create more granular prediction with a model based on historical data.



Inputs

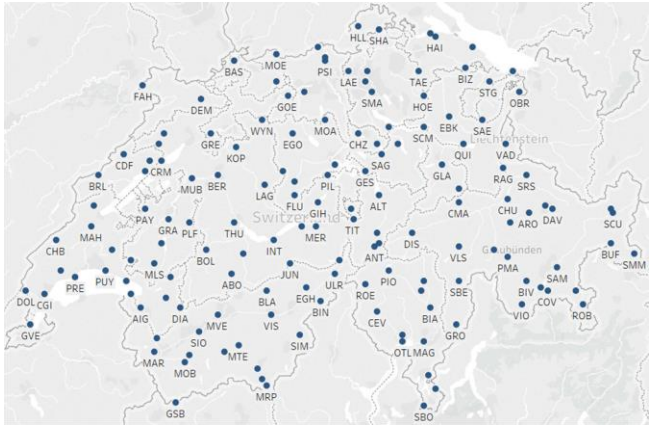
1 Meteorological data

- Wind:
  - Direction
  - Strength
  - Gusts
- Pressure (3 different fields)
- Temperature
- Humidity

5 years of data, 10 min resolution

2 Station location data (~150)

- Name
- Position (2 / 4 fields)
- Altitude
- Available measured parameters



Statistics

- High impact, but a rare event – imbalanced sample.
- Depending on the selection criteria for the Bise, it can be in range of 0.6% to 3.2%.

Bise according to >10knots headwind on runway 10

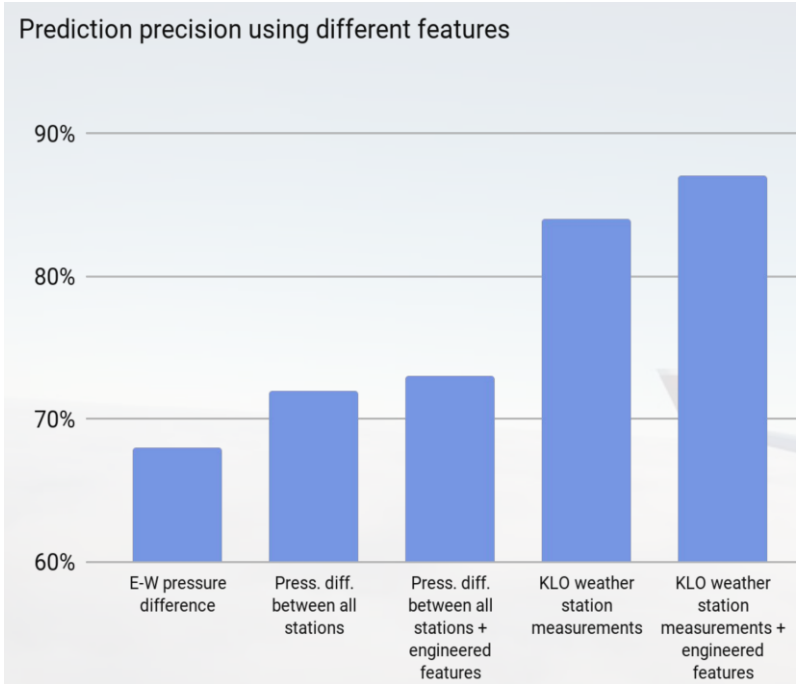
windSpeedDir100gt5.15	
Null	129
False	261,194
True	1,478

Bise according to >10knots headwind gust on runway 10

windGustDir100gt5.15	
Null	129
False	254,284
True	8,388

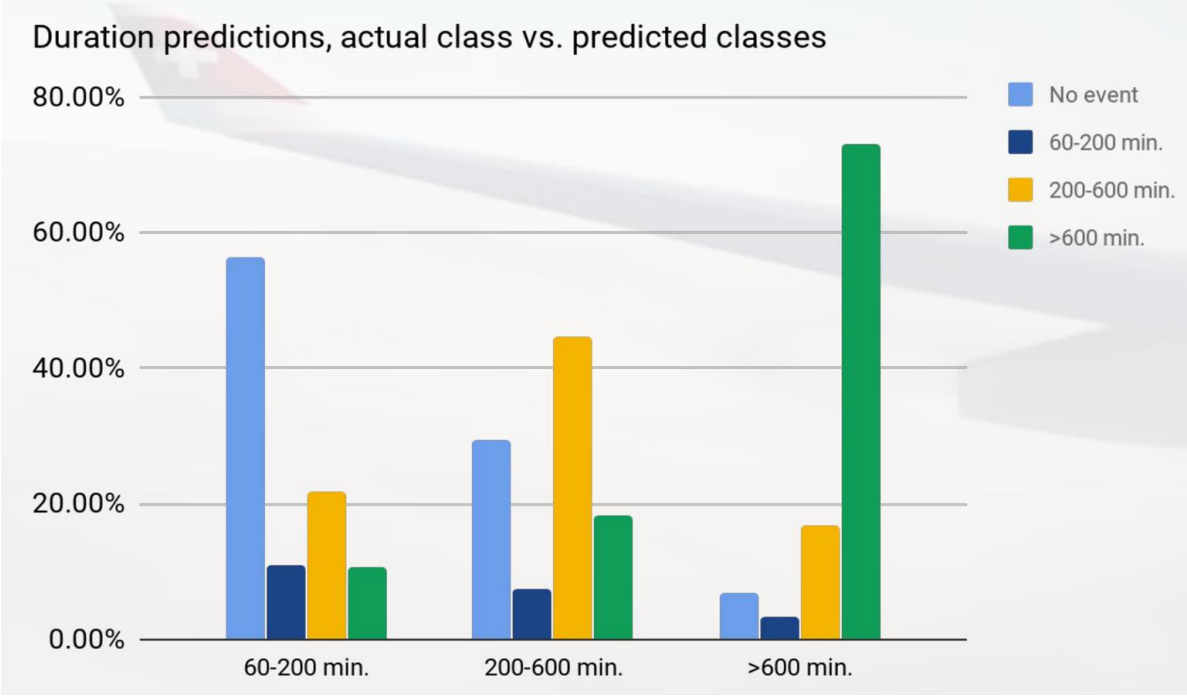
What can we predict?

Next time steps – wind / wind gust values along runway or binary classification



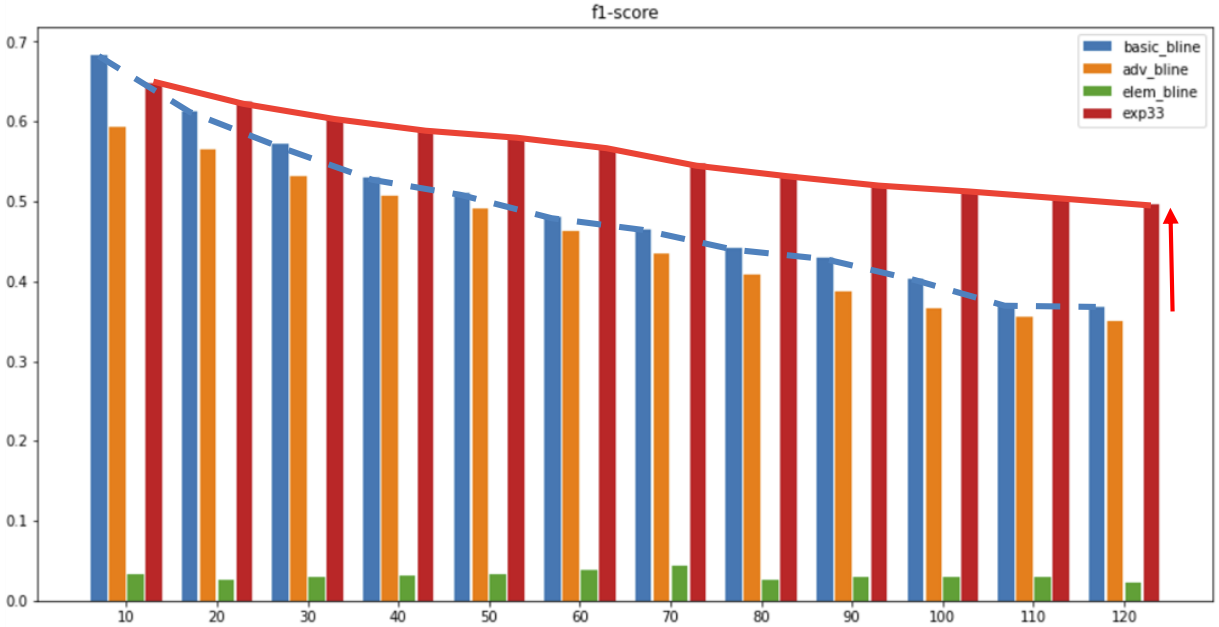
What can we predict?

Event duration



Contents

Results - F1 Score 2 hrs

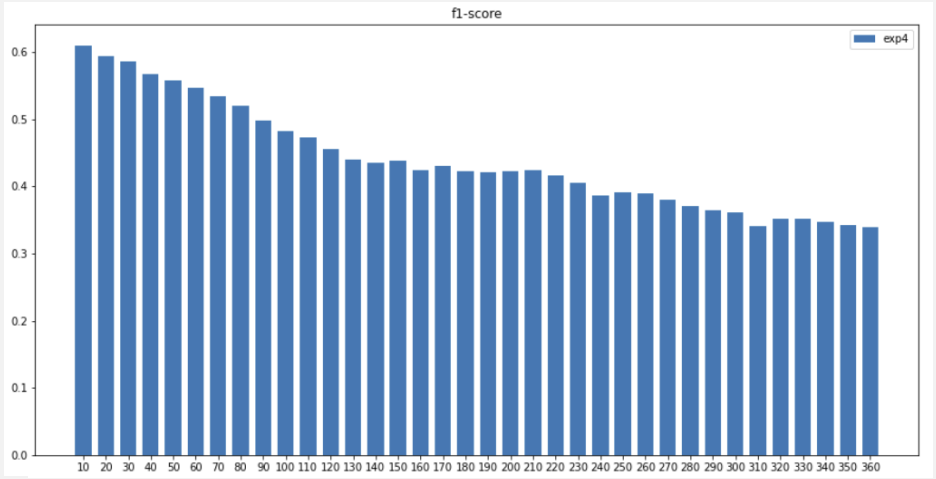


Precision answers " out of all the times gives bise how often is it actually a Bise?".
Since Precision/recall are inversely correlated trade-offs: F1 score is the harmonic mean of precision and recall

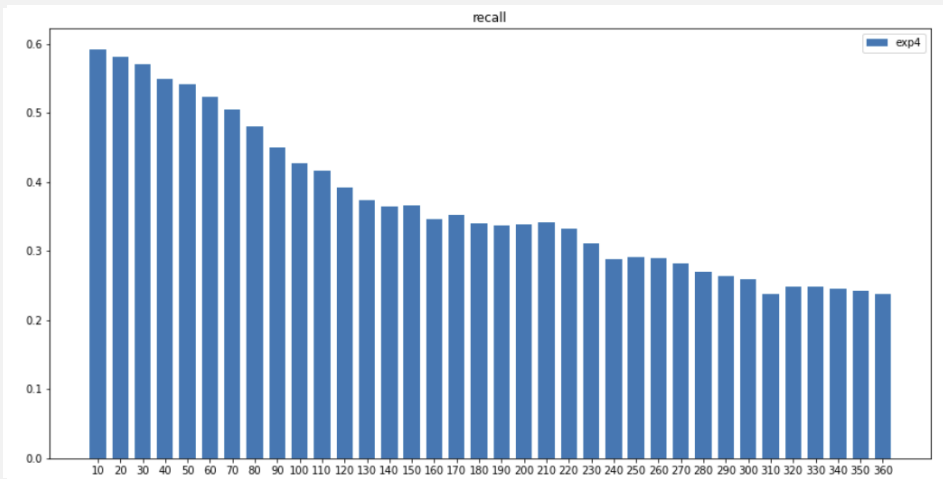
$$\text{Precision} = \frac{tp}{tp + fp}$$
$$\text{Recall} = \frac{tp}{tp + fn}$$

- Predicting Bise with ML is possible
- Good overall precision and recall
- The longer the time scale, the bigger advantage of DL models over baseline

Results - 6 hours



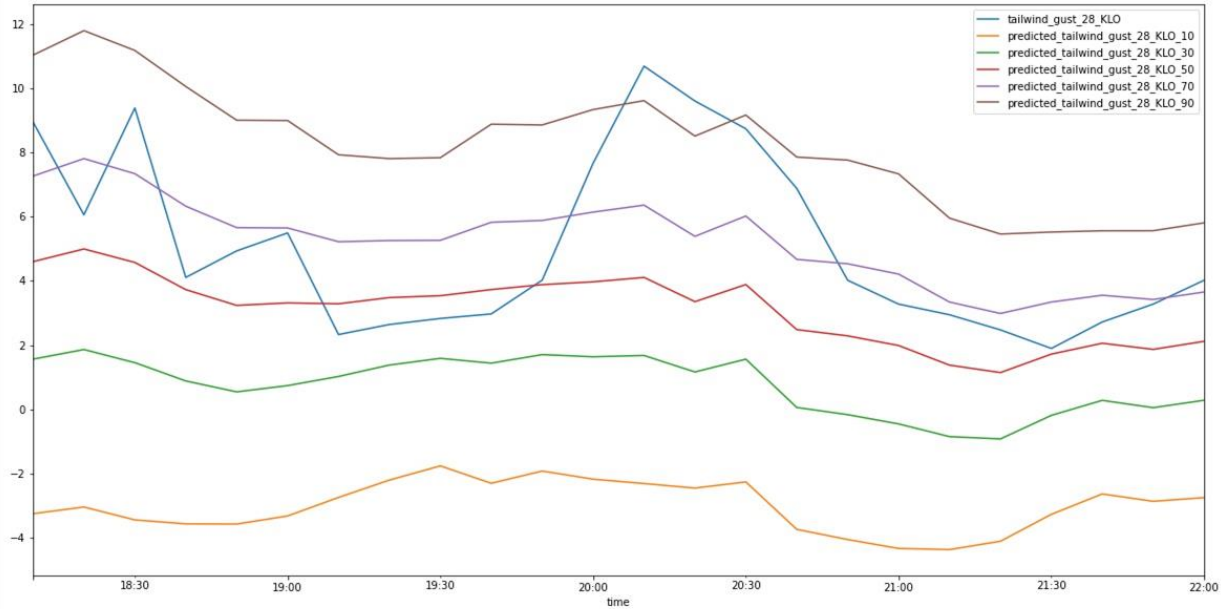
F1-Score



Recall

- Extension beyond 2 hours - works, strong performance at 3h
- The longer the time scale, the bigger advantage of DL models over baseline

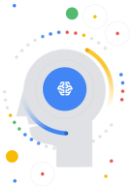
Model Learning Wind Movements - 2 hrs in advance



Behind the Scenes:

- Model uses Wind prediction to determine Bise
- Wind direction predicted 90%+ of times two hrs ahead

POC Success Criteria



First ML Model

First ML model for Bise created

Outperform existing Approaches

ML model to beat heuristics in precision, recall, f1 score .

Extend Model Timeframe

Extend model to 6h horizon + beat heuristics

New Technology

Evaluate new VertexAI time series technology

Contents

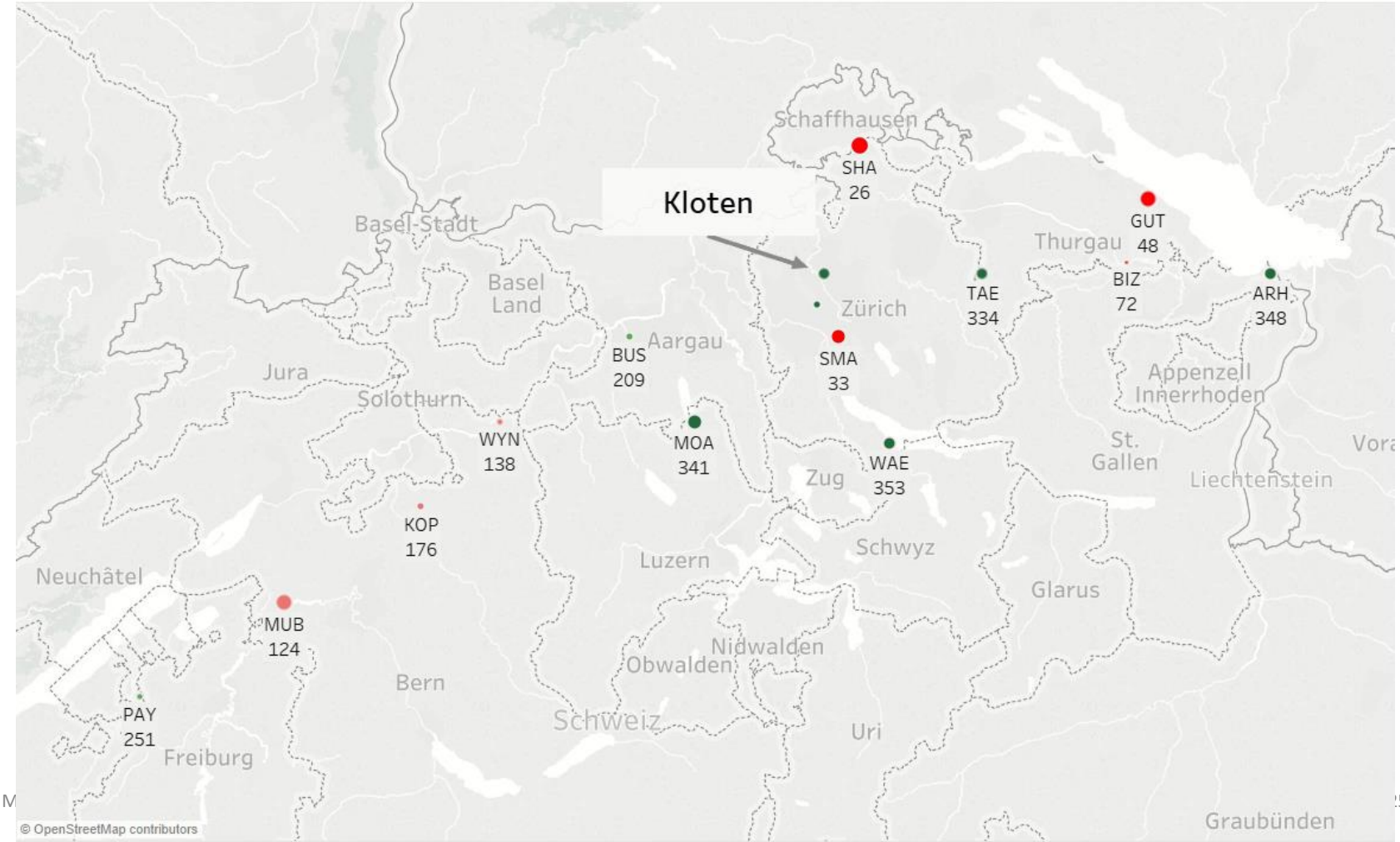
Next Steps

1. Productionalization [from **POC to MVP**]
2. Possible implementation as a **dashboard** for operators
3. Usability / **user acceptance** needs to be assessed
4. Approach scalable to other **time series** problems


Thank you very much
for your attention


Backup slides

Bise - 16.01.2017 10:00:00



Data – legend files

Parameter

Einheit Beschreibung
dkl010z0 ° Windrichtung; Zehnminutenmittel
fkl010z0 m/s Windgeschwindigkeit skalar; Zehnminutenmittel
fkl010z1 m/s Böenspitze (Sekundenböe); Maximum
pp0qffs0 hPa Luftdruck reduziert auf Meeresniveau (QFF); Momentanwert
pp0qnhs0 hPa Luftdruck reduziert auf Meeresniveau mit Standardatmosphäre (QNH); Momentanwert
prestas0 hPa Luftdruck auf Stationshöhe (QFE); Momentanwert
tre200s0 °C Lufttemperatur 2 m über Boden; Momentanwert
ure200s0 % Relative Luftfeuchtigkeit 2 m über Boden; Momentanwert

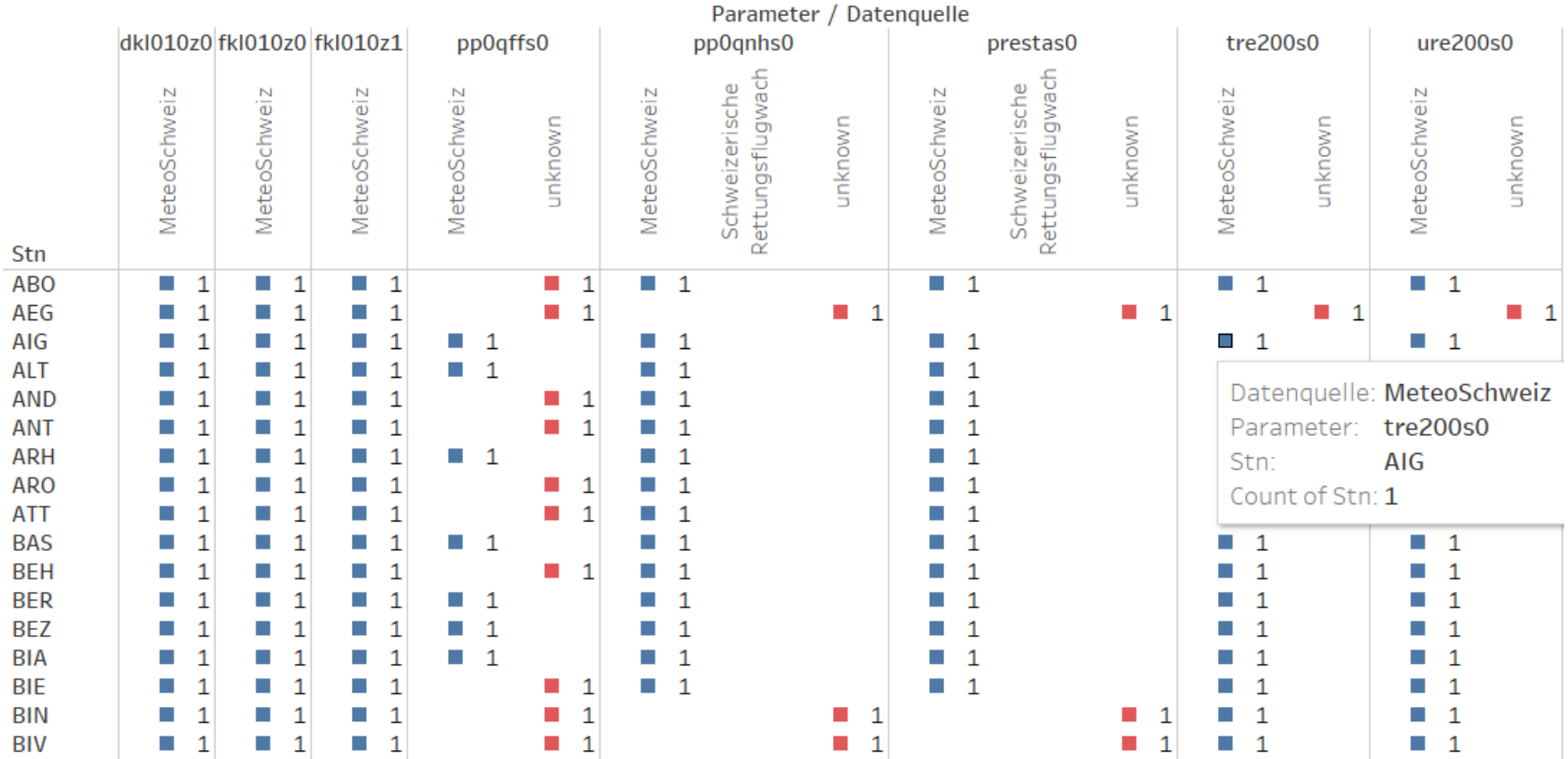
Data – legend files

Stationen

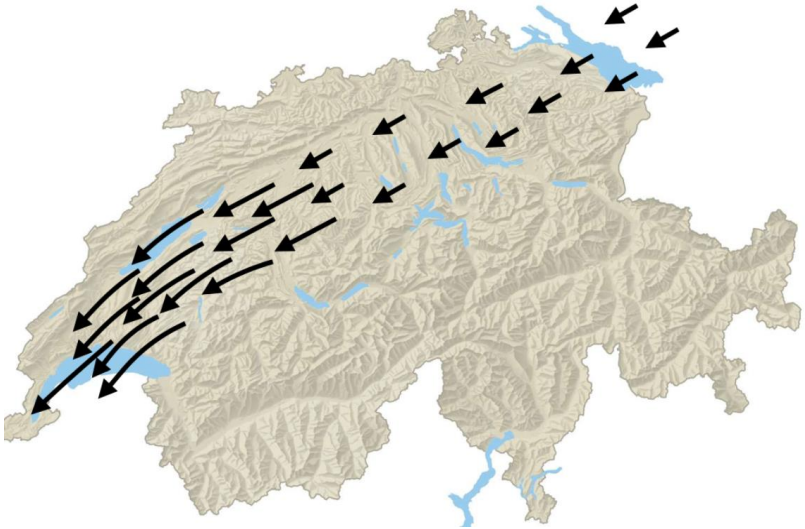
---

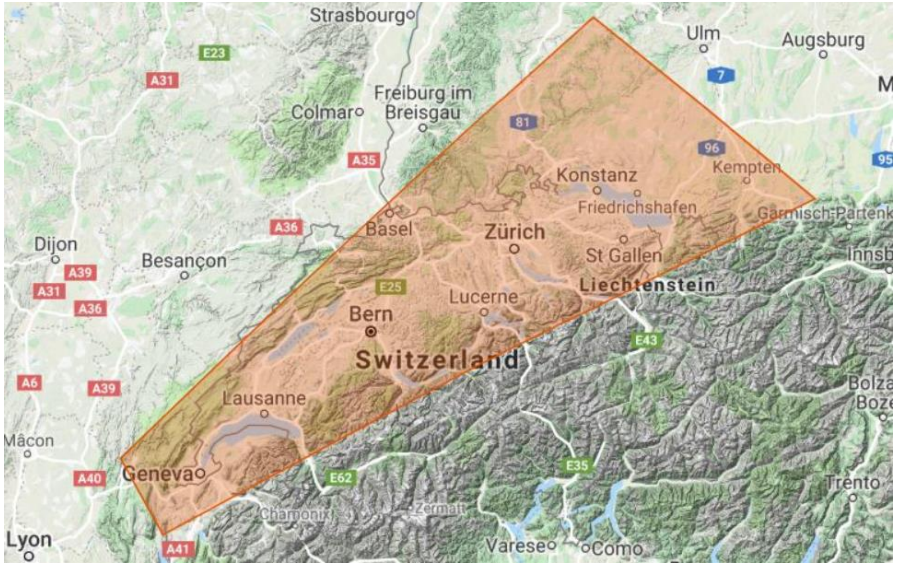
stn	Name	Parameter	Datenquelle	Länge/Breite	Koordinaten [km]	Höhe ü. M. [m]
VIO	Vicosoprano	dkl010z0	MeteoSchweiz	9°38'/46°21'	768485/135866	1089
VIO	Vicosoprano	fkl010z0	MeteoSchweiz	9°38'/46°21'	768485/135866	1089
VIO	Vicosoprano	fkl010z1	MeteoSchweiz	9°38'/46°21'	768485/135866	1089
VIO	Vicosoprano	pp0qnhs0	MeteoSchweiz	9°38'/46°21'	768485/135866	1089
VIO	Vicosoprano	prestas0	MeteoSchweiz	9°38'/46°21'	768485/135866	1089
VIO	Vicosoprano	tre200s0	MeteoSchweiz	9°38'/46°21'	768485/135866	1089
VIO	Vicosoprano	ure200s0	MeteoSchweiz	9°38'/46°21'	768485/135866	1089
VIO	Vicosoprano	pp0qffs0	MeteoSchweiz	9°38'/46°21'	768485/135866	1089
VLS	Vals	dkl010z0	MeteoSchweiz	9°11'/46°38'	734016/165551	1242
VLS	Vals	fkl010z0	MeteoSchweiz	9°11'/46°38'	734016/165551	1242
VLS	Vals	fkl010z1	MeteoSchweiz	9°11'/46°38'	734016/165551	1242
VLS	Vals	pp0qnhs0	unknown	9°11'/46°38'	734016/165551	1242
VLS	Vals	prestas0	unknown	9°11'/46°38'	734016/165551	1242
VLS	Vals	tre200s0	MeteoSchweiz	9°11'/46°38'	734016/165551	1242
VLS	Vals	ure200s0	MeteoSchweiz	9°11'/46°38'	734016/165551	1242
VLS	Vals	pp0qffs0	unknown	9°11'/46°38'	734016/165551	1242

Data


Parameter / Datenquelle
dkl010z0
fkl010z0
fkl010z1
pp0qffs0
pp0qnhs0
prestas0
tre200s0
ure200s0
MeteoSchweiz
unknown
Schweizerische Rettungsflugwach
Stn
ABO
AEG
AIG
ALT
AND
ANT
ARH
ARO
ATT
BAS
BEH
BER
BEZ
BIA
BIE
BIN
BIV
Datenquelle: MeteoSchweiz
Parameter: tre200s0
Stn: AIG
Count of Stn: 1

Project proposal





Es wird diskutiert wie man von der Meteoprognose zu einem Entscheid kommt, der dann das DCB Verfahren auslöst. Aus Sicht von Eugen Müller stellt heute das TAF, welches auf einem deterministischen Modell basiert, das am besten geeignete Produkt dar. In Zukunft könnte man auch Prognosen auf Basis von Ensamble Modellen verwenden, die dann auch Eintretenswahrscheinlichkeiten berechnen können. Das TAF wird alle 3h aktualisiert und umfasst einen Prognosezeitraum von 30h. Zum Zeitpunkt der Nachmittagstelefonkonferenz hätte man somit eine Prognose für die Betriebszeit des nächsten Tages. Anhand der TAF Daten würde man dann die Wahrscheinlichkeit, dass das Runway Konzept Bise zur Anwendung kommt ableiten und in Kategorien einteilen.
Beispiel:

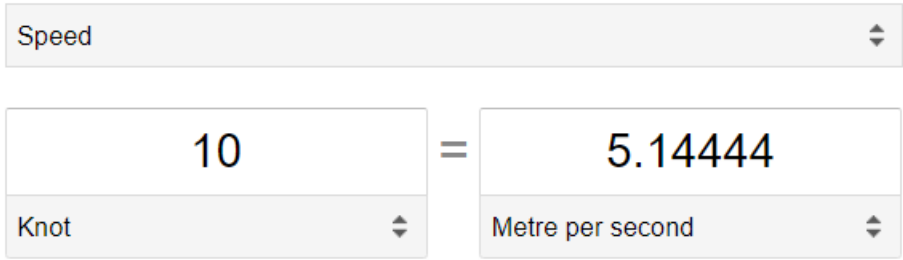
Time	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500
Bise Risk										
Bise Key		NIL		Low		Medium		High		Very High

Mit «Bise Risk» ist in dem Zusammenhang das Runway Konzept gemeint.

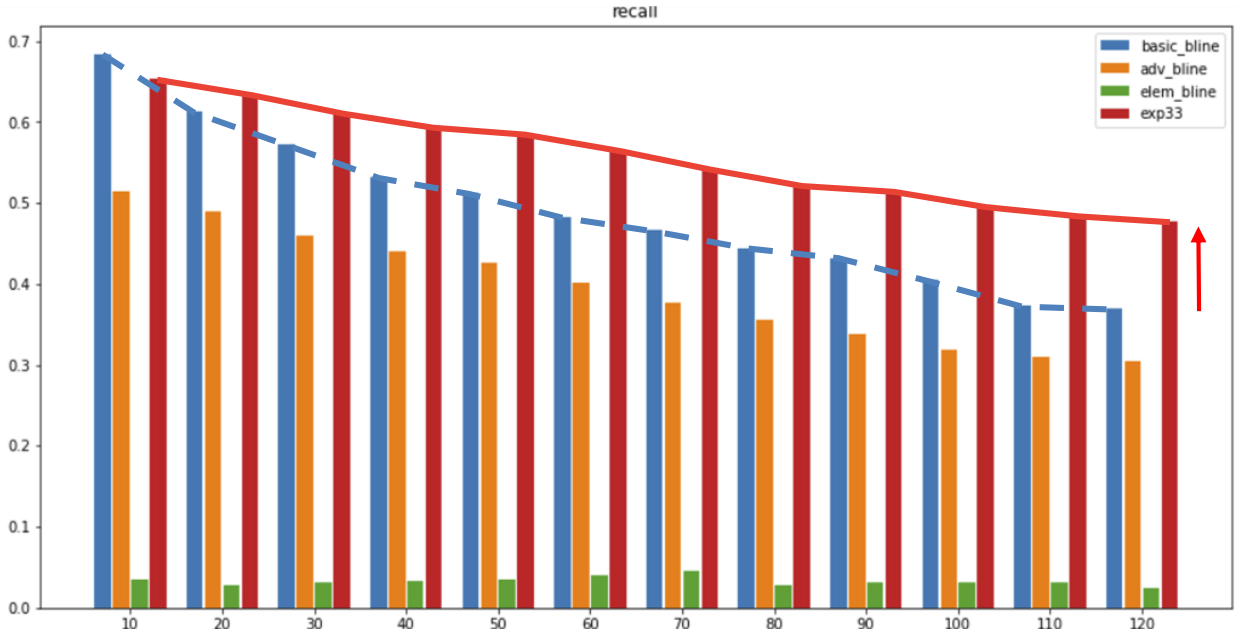
Die Einteilung in die Gruppen würde auf Basis der TAF Windinformation und der daraus abgeleiteten Rückenwindkomponente für RWY 28 erfolgen. Am Meeting wurde sich initial auf folgende Einteilung verständigt.

- Very High: TWC RWY 28 ≥ 12kt
- High: TWC RWY 28 ≥ 8kt
- Medium: TWC RWY 28 ≥ 4kt
- Low: TWC RWY 28 ≥ 0kt
- NIL: TWC RWY 28 < 0kt

Der DCB Bisenprozess würde dann ausgelöst werden, wenn zum Beispiel das Risiko für Bisenkonzept High oder



Results - Recall 2 hrs

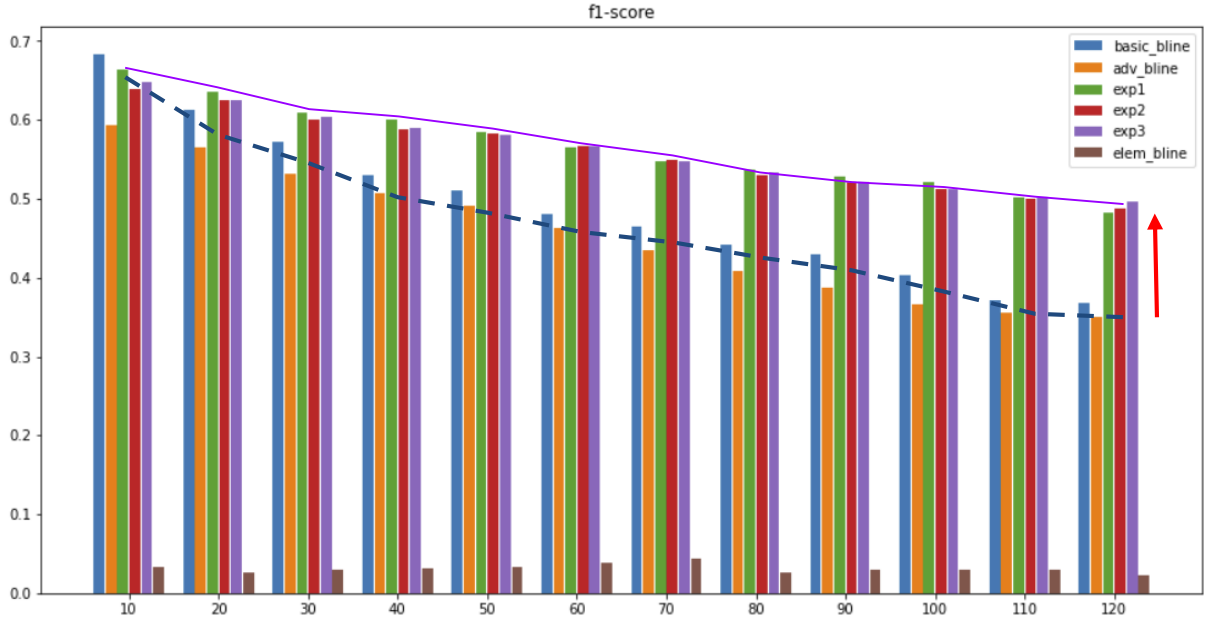


Recall is the number of correct results divided by the number of results that should have been returned.
“What %age of the actual bise periods did were caught?”

$$\text{Precision} = \frac{tp}{tp + fp}$$
$$\text{Recall} = \frac{tp}{tp + fn}$$

- Predicting Bise with ML is possible
- Good overall precision and recall (+10-11 points over heuristics on average- better for longer forecasts)
- The longer the time scale, the bigger advantage of DL models over baseline

Results - F1 Score



Precision answers " out of all the times gives bise how often is it actually a bise?".
Since Precision/recall are inversely correlated trade-offs: F1 score is the harmonic mean of precision and recall

$$\text{Precision} = \frac{tp}{tp + fp}$$
$$\text{Recall} = \frac{tp}{tp + fn}$$