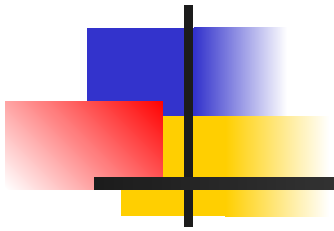

Flight Safety Event Prediction with Flight Density and Event Complexity in the Airspace

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Outline

- Introduction
- Data Processing and Cleaning
- Proposed Methodology
- Results
- Discussion

Background

- Flight event recordings are post-processed by ATAC using track data, including the spatial-temporal coordinates of each flight event.
- Both normal events and safety-related events are detected and documented.
- The prediction of safety-related flight event occurrence could enhance the flight operation safety while providing guidance for daily aviation operations.

Introduction

- From individual level to systemic level:
  - The previous work study the individual level impact of convective weather on flight trajectories.
  - The current objective is to do systemic level flight event and traffic density prediction.

Table 1. Meaning of different event types

Event Type	Counts	Meaning
EV_MOF	279645	Mode of flight. A flight record in vertical domain such as descending level, climbing level. Also known as vertical trajectory.
EV_XING	250173	Crossing event from one sector to another sector. Indicate which space volume are you in and which one are you crossing to other column.
EV_USER	134956	User event. The definition is flexible includes times you go into a center, different volume definitions. It's a user based concept.
EV_TRNS	75086	Transition from above or below altitude. Not often used.
EV_PXCP	52892	Unknown.
EV_INIT	50934	Detail on the begin of flight tracks. Smaller set on facility recorded by the surveillance system.
EV_STOP	50934	The last track point of the aircraft.
EV_LOOP	41118	Indication of holding pattern. The flight circle around in the trajectory.
EV_TOC	25467	Top of climb. Reach cruise altitude. Overlap with MOF.
EV_TOD	25467	Top of descend. Start to descent from cruise altitude
EV_RRT	20692	Reroute. New flight plan change compared to old flight plan.
EV_LND	19526	Landing event. Recorded when arrival aircraft pass the arrival runway threshold.
EV_TOF	14697	Take off event. It's defined geometrically when the aircraft cross the departure runway threshold (wheels come off the pavement).
EV_STOL	5174	Stop holding. Finish EV_LOOP Event.
EV_GOA	1814	Go around. About to land but pull up and circle back, turn around again. A possible safety concern.

Safety Concern

Data Preparation

- Two types of data in Sherlock Data Warehouse.
  - Flight recording: ZTL from Aug 1st, 2019 to Aug 28th, 2019
  - Flight event occurrence recording: ASDEX+ATL from Aug 1st, 2019 to Aug 28th, 2019
- Data processed:
  - Traffic flow heatmap generator:
    - time_interval = 60s, range_latlon=[[-88, -78], [32, 38]], range_time=[12pm, 4pm]
  - Event occurrence generator for all flight event types and only safety-related event types:
    - time_interval = 60s, range_latlon=[[-88, -78], [32, 38]], range_time=[12pm, 4pm]
  - Smoothing the discrete scatter plot around its nearest neighbors.
- Large-scale data processing techniques deployed:
  - SparkSQL, SparkRDD for efficient querying of the flight recordings.
  - GeoSpark extensions for efficient geospatial query.
  - Reduce computational complexity with R-tree/KD-tree for accelerated query indexing with amortized cost O(logn).

```
rectangular_query = "SELECT COUNT(acId) " \
                    "FROM spatialdf " \
                    "WHERE ST_Contains(ST_PolygonFromEnvelope({}, {}, {}, {}), geom)" \
.format(lat[index_lat], lon[index_lon], lat[index_lat+1], lon[index_lon+1])
```

Data Preparation

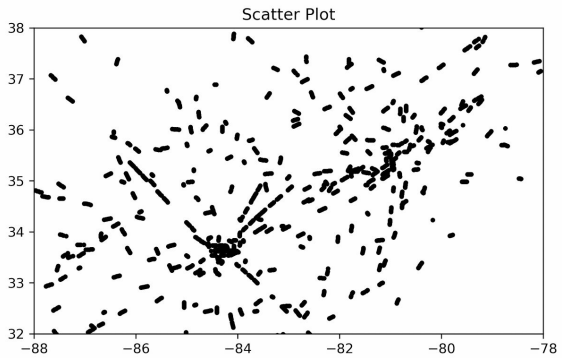
- Multiple set of data are generated based on the following parameters,
  - Resolution: [32, 64, 128] // The resolution of generated image.
  - Smoothing: [4, 16, 32] // Smoothing around k-nearest neighbors.
  - Horizon: [0, 60, 120, 180, 240] // The time horizon shifting among dataset.

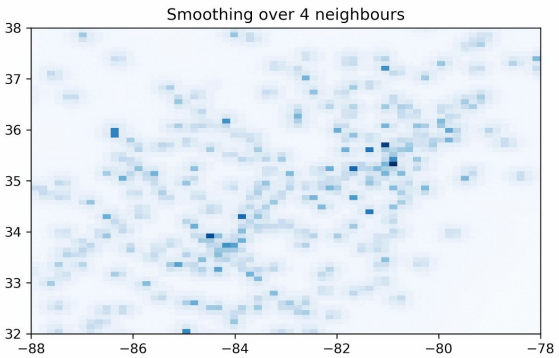
- The processed data are organized into a data warehouse.

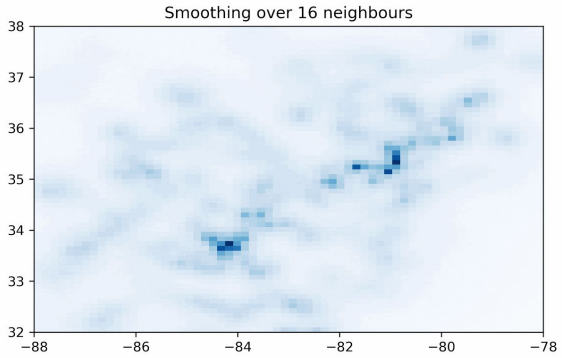
- Processed 27 days data.

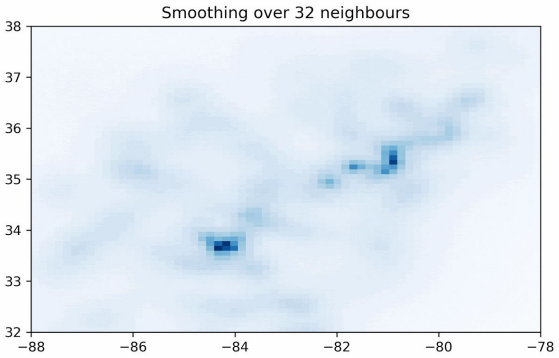
Data Visualization

Flight Density

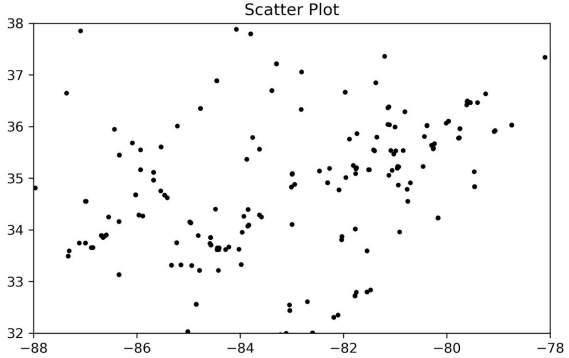


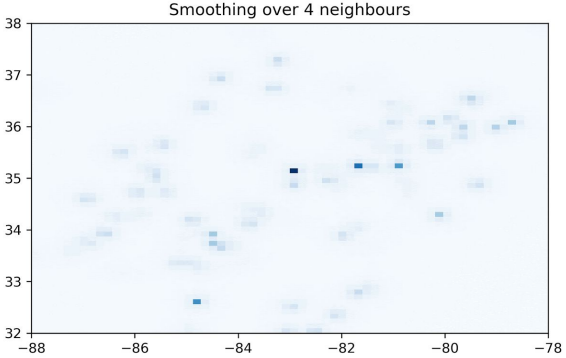


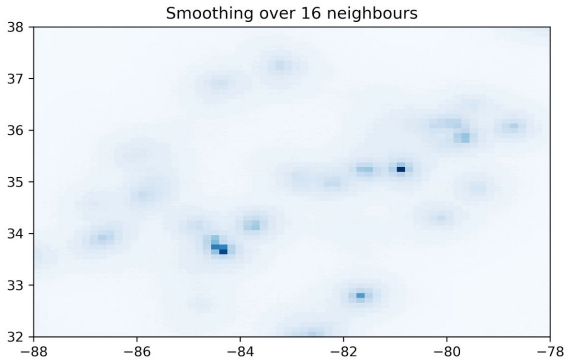


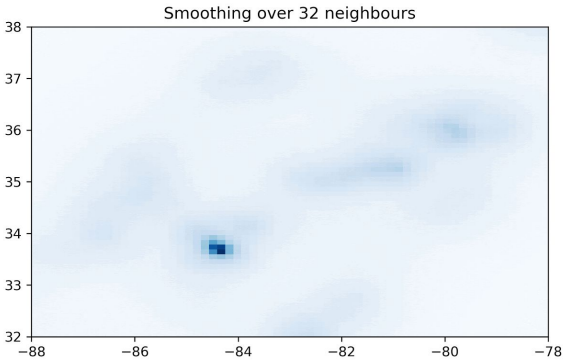


Event Complexity



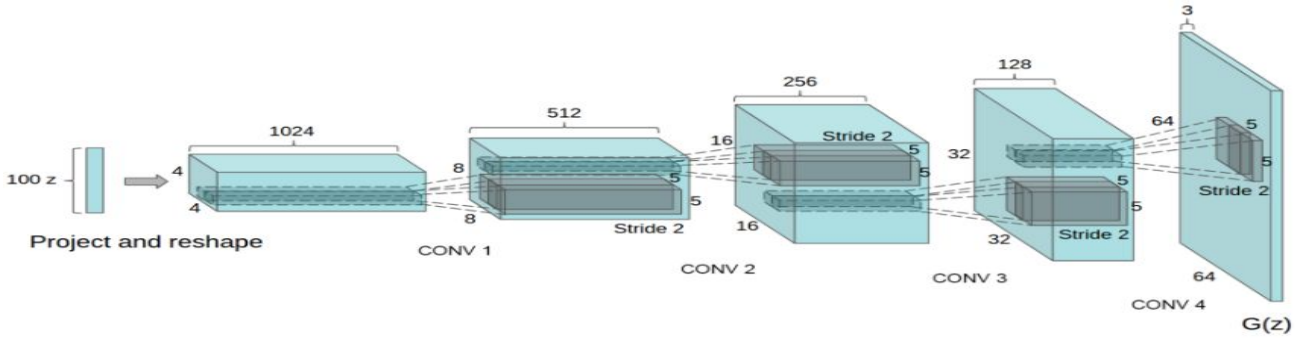






Proposed Methodology

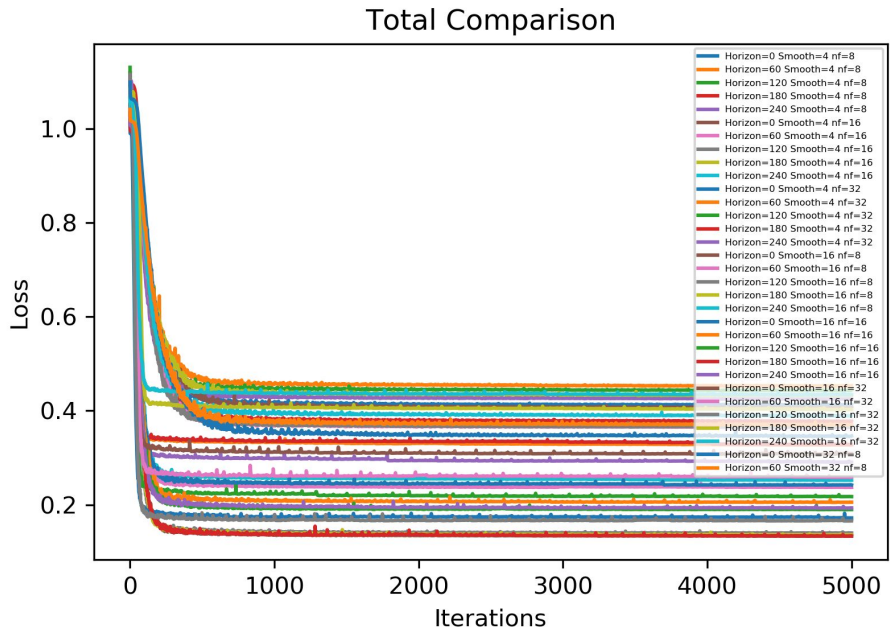
- We want to predict safety-related events:
  - Predict the occurrence of EV_LOOP and EV_GOA based on the traffic flow density and flight event density
- We tried to use two models,
  - Deep-convolutional Autoencoder (DCAE)
    - Synthetic data generation
  - Deep-convolutional general adversarial networks (DCGAN)[1]
    - capture the training data's distribution and generate new data from that distribution



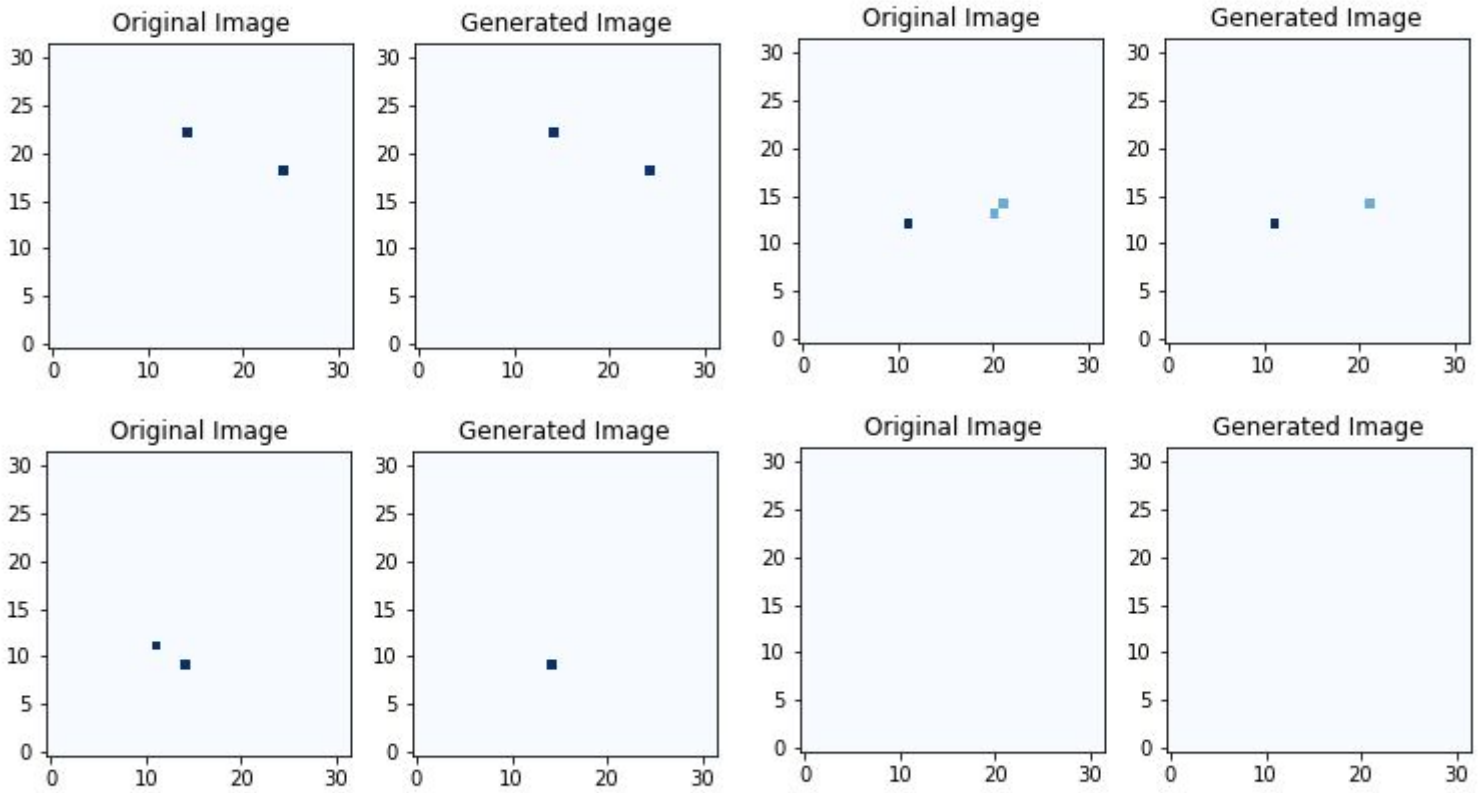
[1] Radford, A., Metz, L., & Chintala, S. (2015). Unsupervised representation learning with deep convolutional generative adversarial networks. arXiv preprint arXiv:1511.06434.

Results

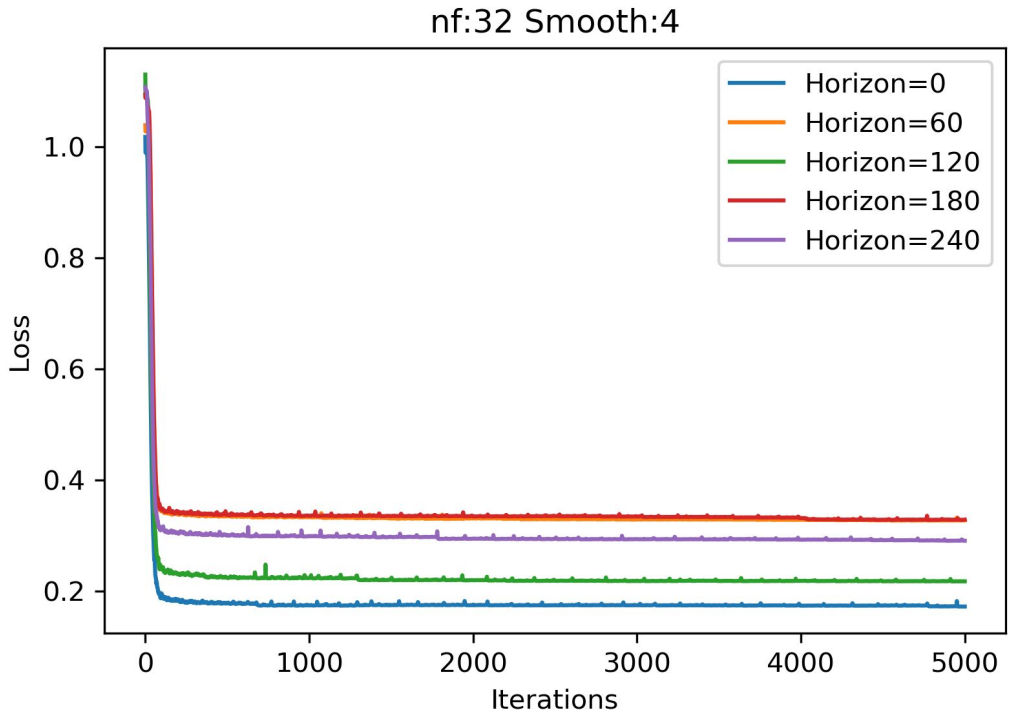
- Result are shown with,
  - input dimension: 32x32x2
  - output dimension: 32x32x1
- We will also try different input-output resolution combinations,

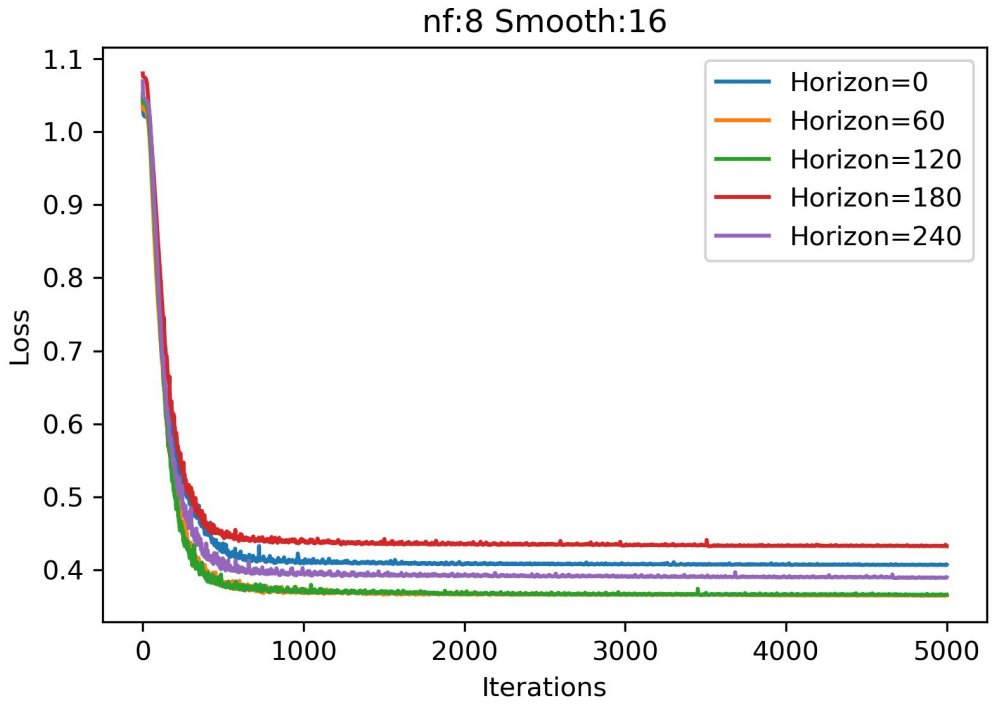


Results Visualization

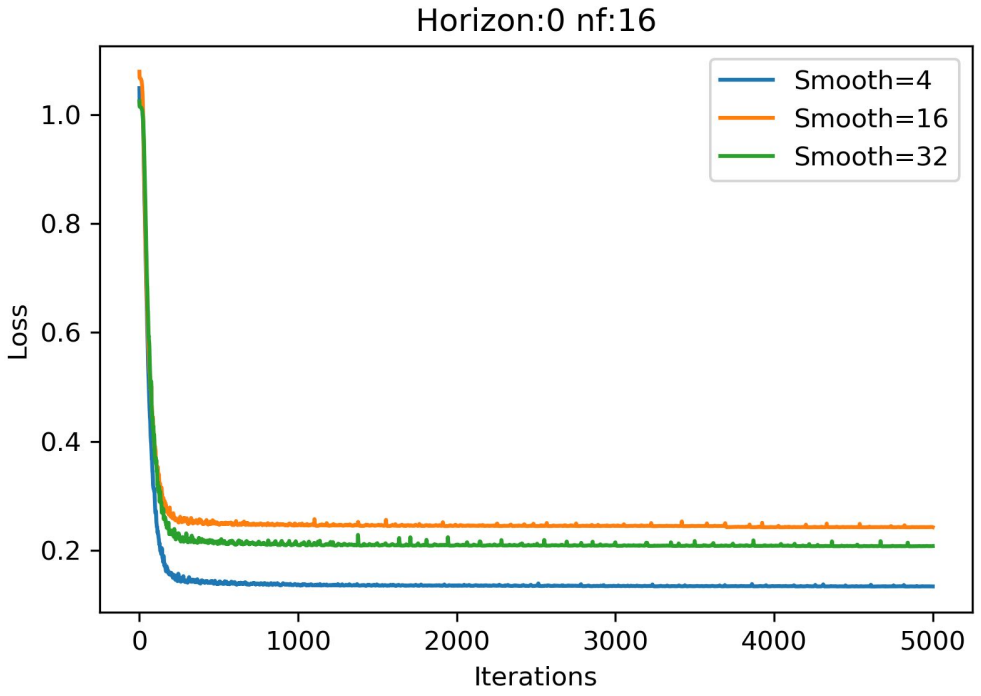


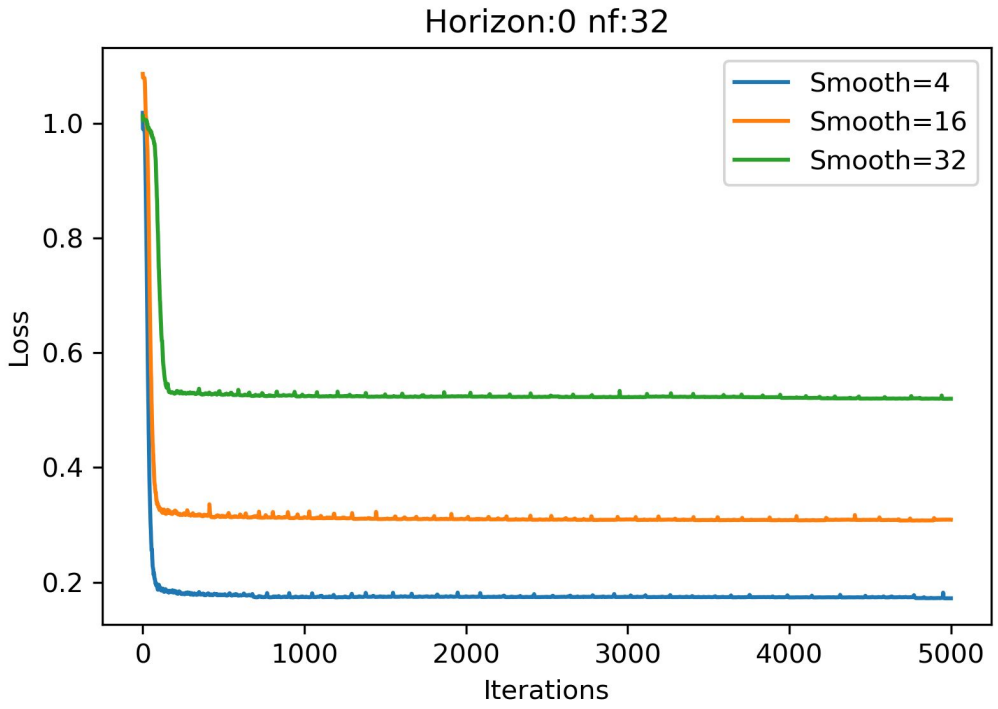
Impact on time horizon



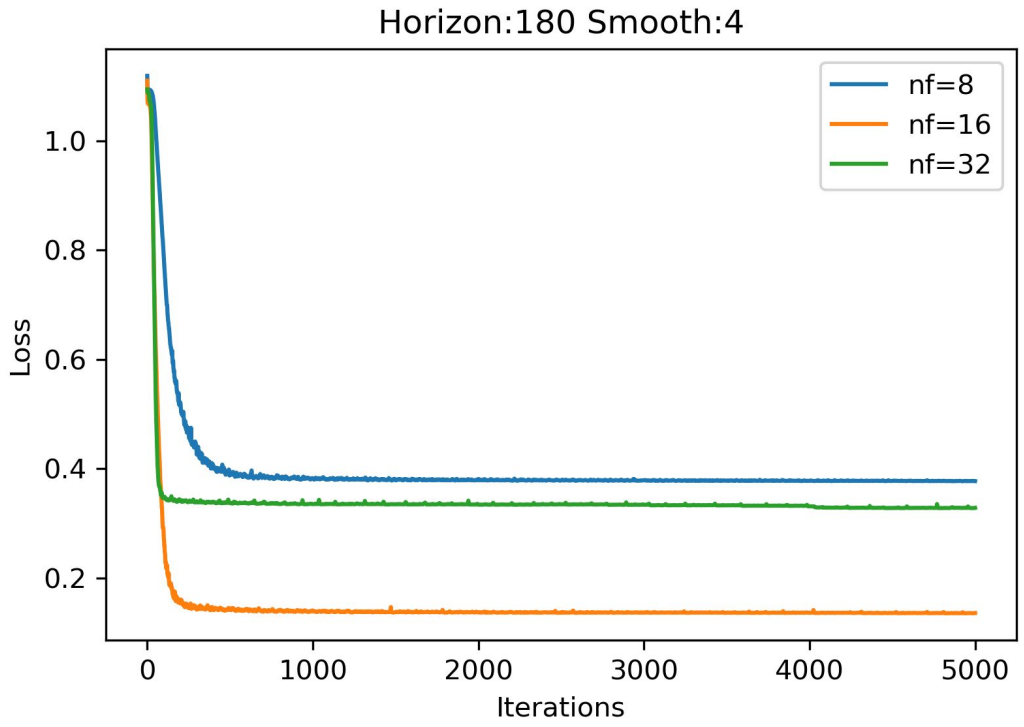


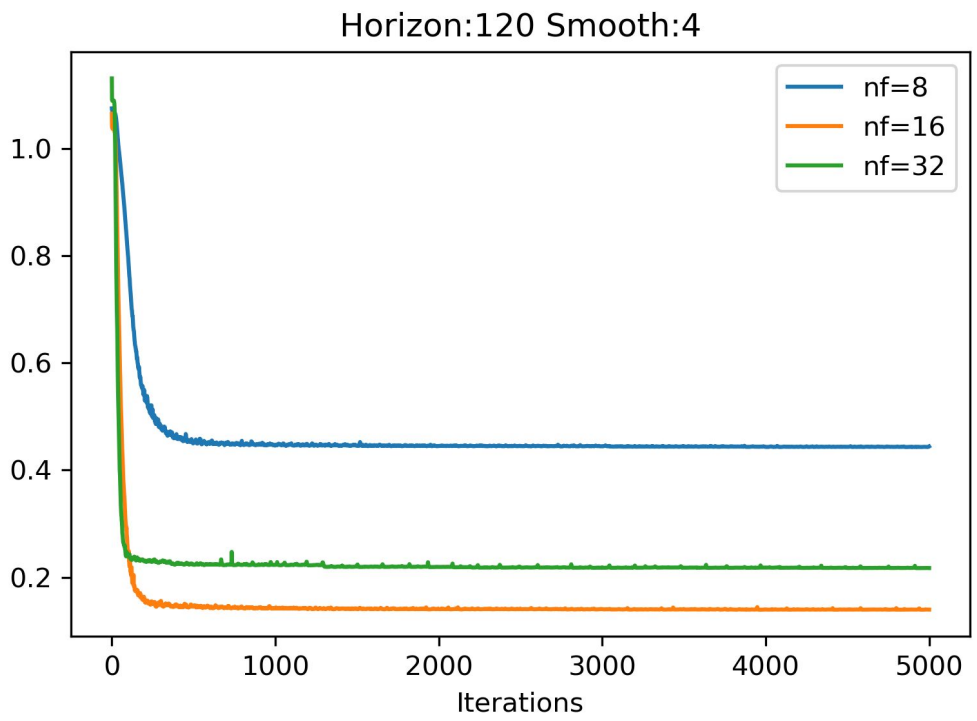
Impact on Smoothing

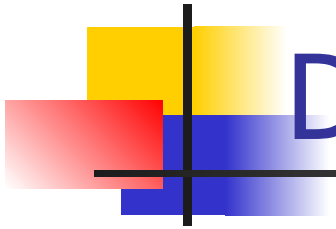




Impact on feature dimension







Discussion

- The feature dimensions 16 and smoothing around 4 nearest neighbors seems the best.
- The model has overfitting on the test images.