Analysis and prediction of VFR vs IFR traffic behavior to support uncrewed aircraft operations at regional airports

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Motivation

Challenge – Uncrewed Aircraft (UA) integration with existing IFR and VFR operations
IFR – predictable with high precision; VFR – more uncertain in space and time and intent prediction

UA cargo and Advanced Air Mobility operations in airspace with significant proportion of VFR traffic

How to limit the probability of interaction with VFR traffic?
thereby reducing the frequency of activation of conflict resolution and collision avoidance systems

Research Gap – *Lack of VFR traffic analysis and prediction methods*

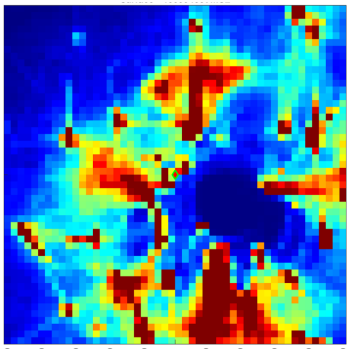
IFR – Instrument Flight Rules, VFR – Visual Flight Rules, UA – Uncrewed Aircraft

Research Goal

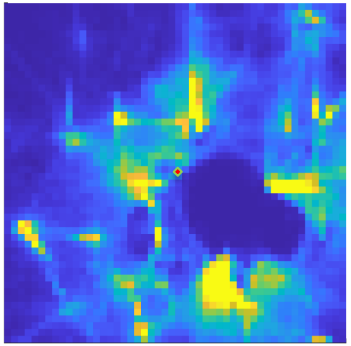
Characterize VFR traffic behavior and build predictive models to inform and support UA flight operations

Methodology

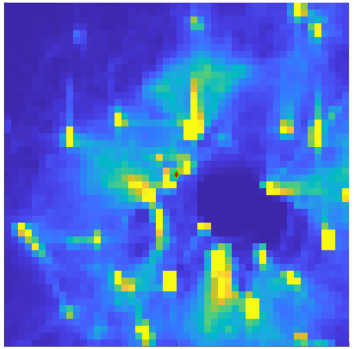
Grid the study region around a regional airport and analyze historical data to produce –



Spatial Density Heat Map
(# of track points in each cell)



Occupancy Map
(probability of interaction)



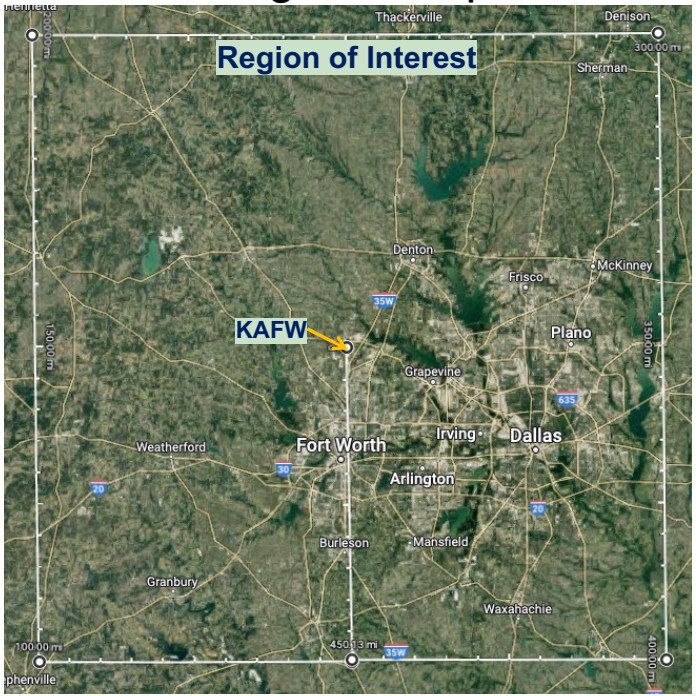
Predictive Occupancy Map
(conditional probability)

Rest of Presentation: *Results presented in relation to an example study region*

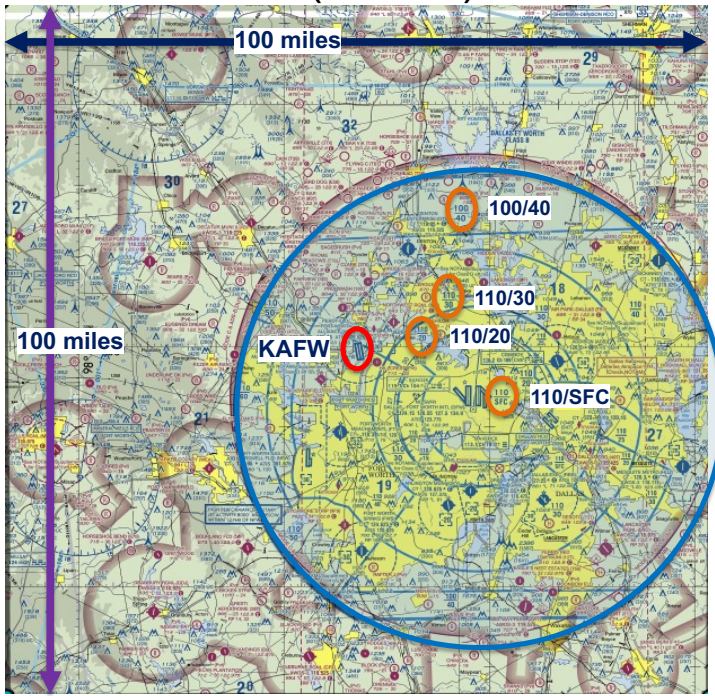
Data – Track points for September and October 2022
September data used to build the statistical models,
Predictions made for October, and October data used to validate predictions

Study Region

Regional Airport – Fort Worth Alliance (KAFW)



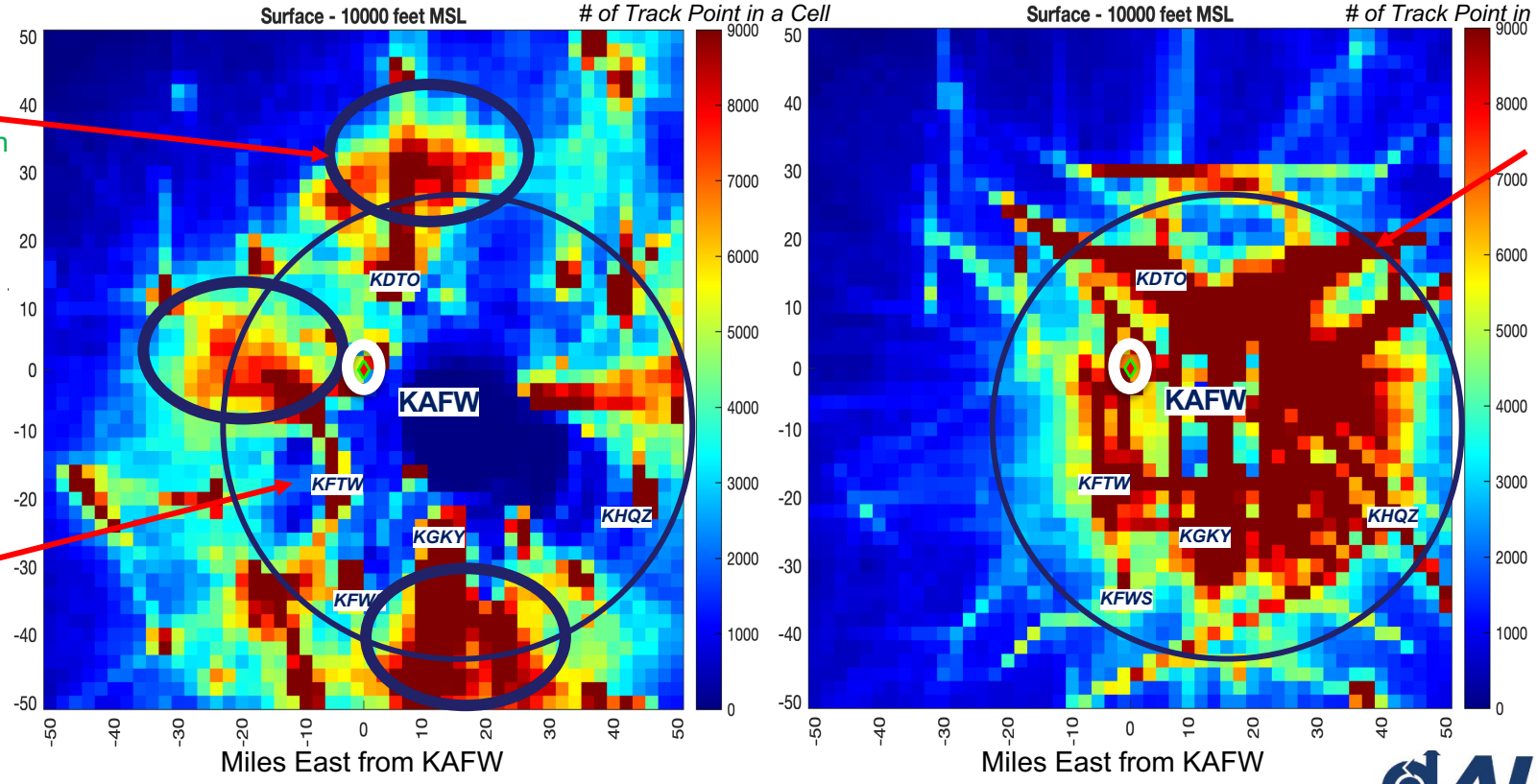
Imagery ©2023 Landsat/Copernicus, Imagery ©2023 TerraMetrics, Map data ©2023 Google



Class B Airspace

FAA Sectional Chart for Dallas-Fort Worth Area https://www.faa.gov/air_traffic/flight_info/aeronav/productcatalog/VFRCharts/Sectional/, 2023. Images produced by the U.S. Government and in the public domain.

Spatial Density Heat Maps



Low Population Areas

Miles North from KAFW

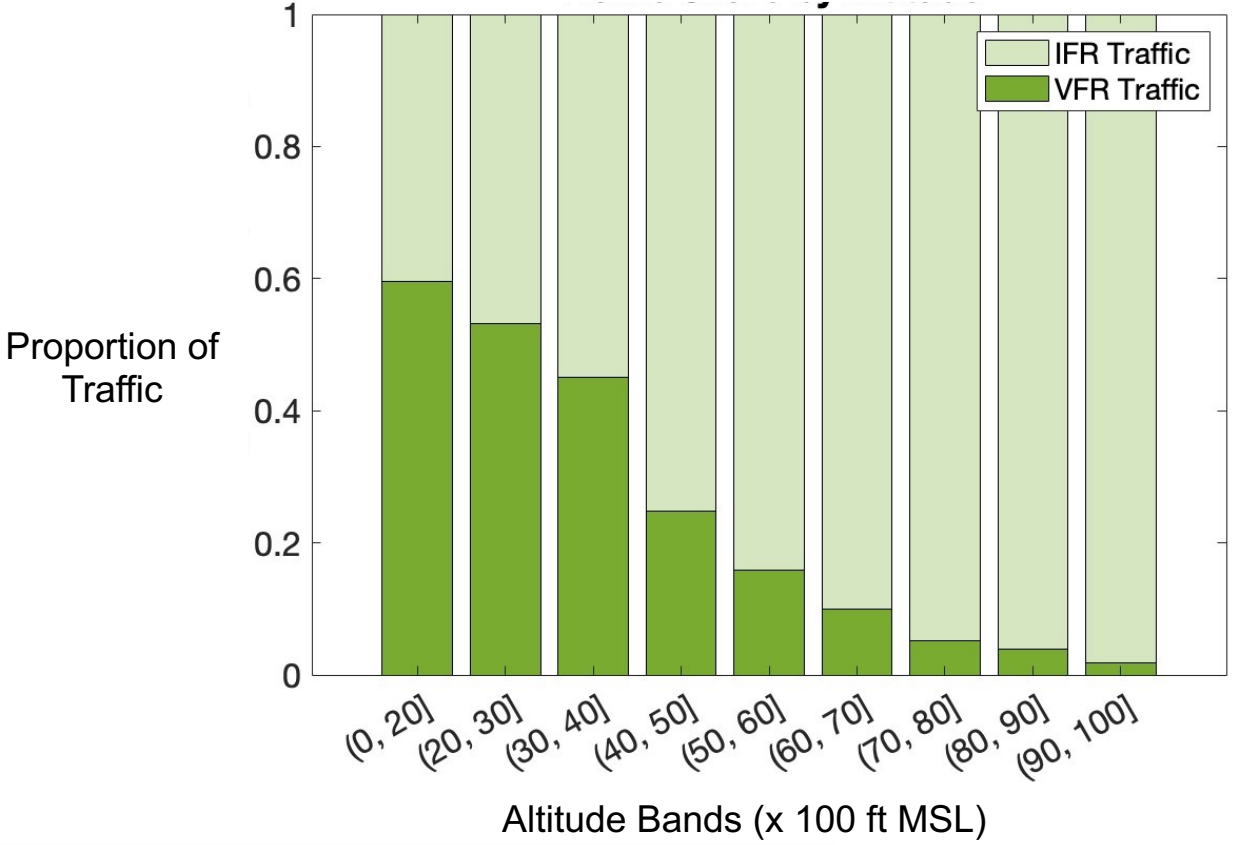
Class D Airports

Within Class B, Arr/Dep Routes, Highly Structured

VFR

IFR

VFR vs IFR Traffic Share by Altitude

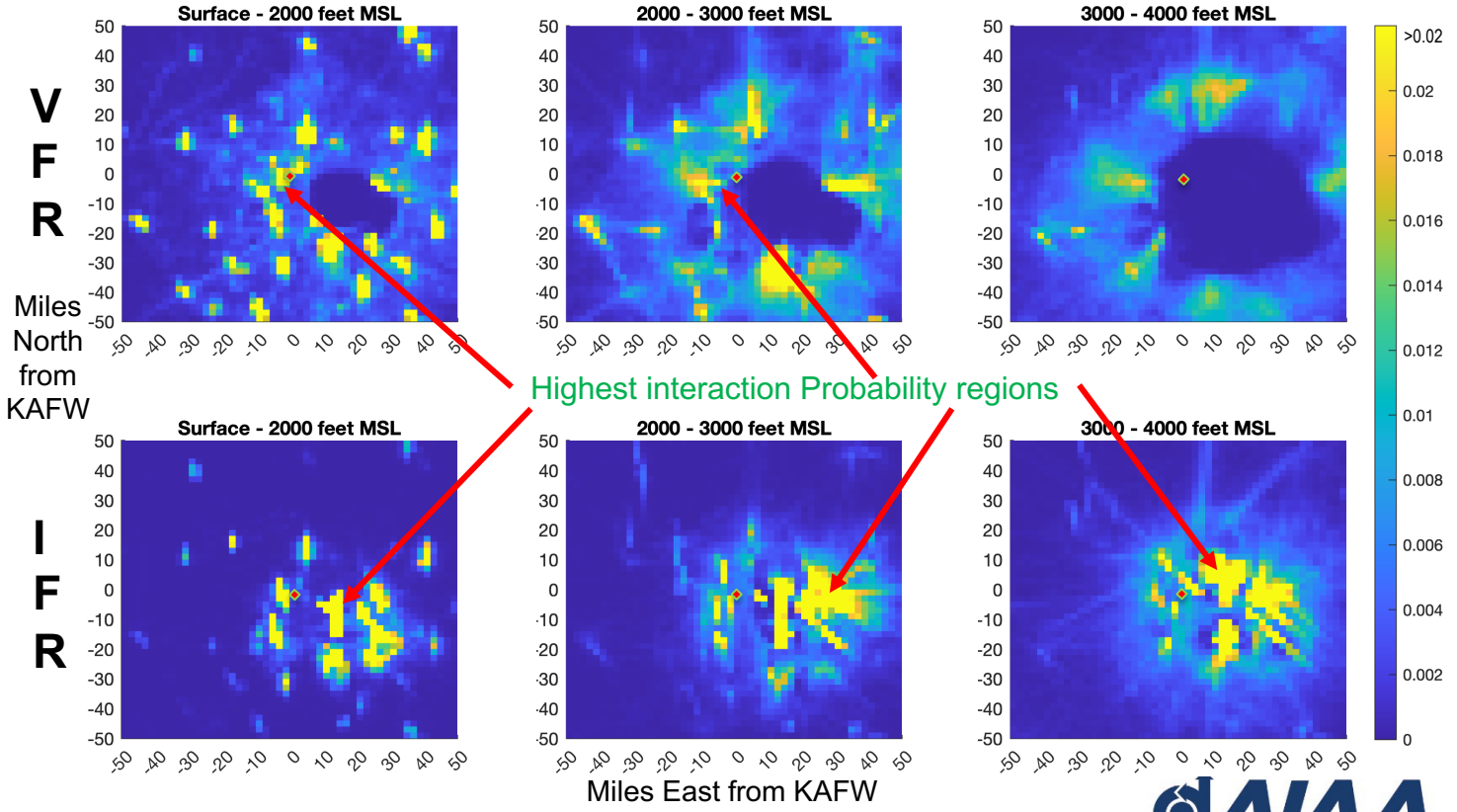


Occupancy Map

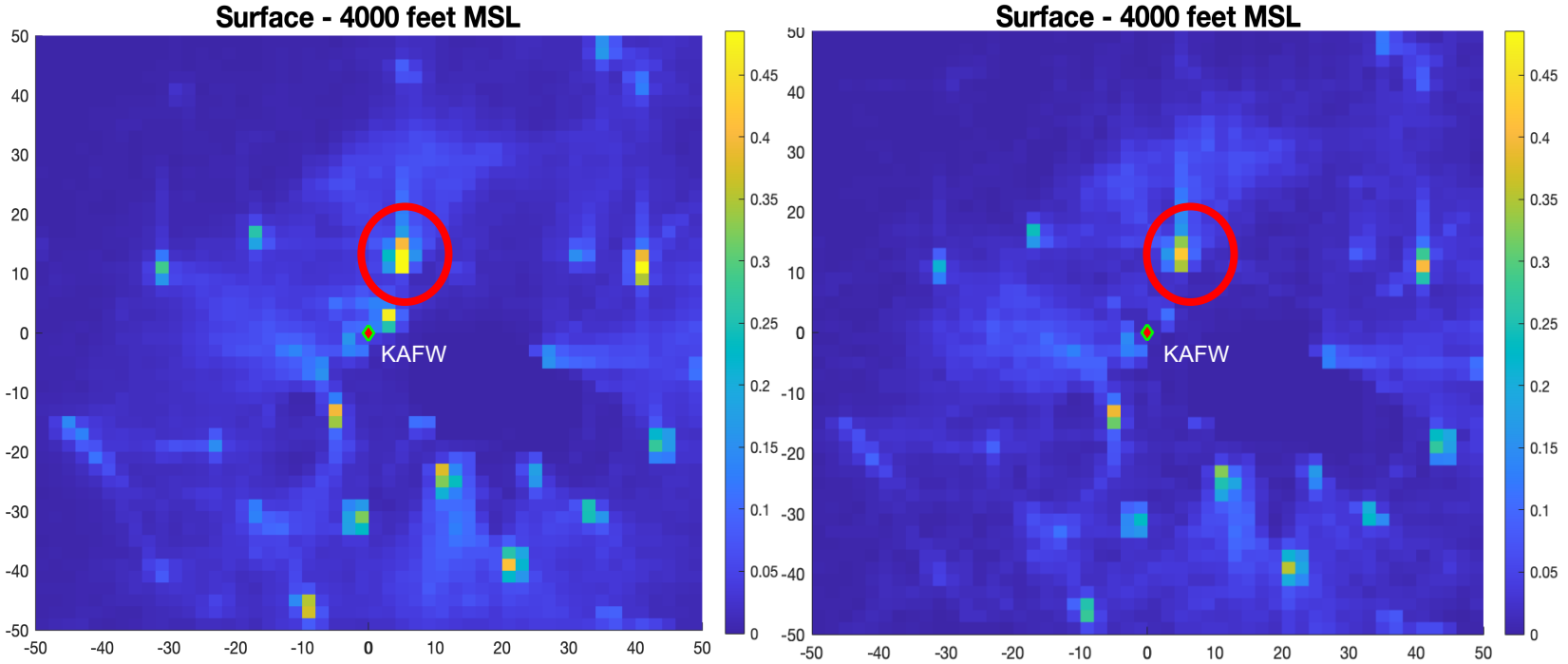
P (>1 Ac) =
Ratio of *Number of time steps with at least 1 Aircraft* to *Total time steps in data*

VFR insights
- Concentrated below 4000 ft MSL
- Interaction risk dispersed and low

IFR insights
- Concentrated in approach departure routes and within class B
- Interaction risk concentrated and high



Prediction based on Time of Day (at 8a)

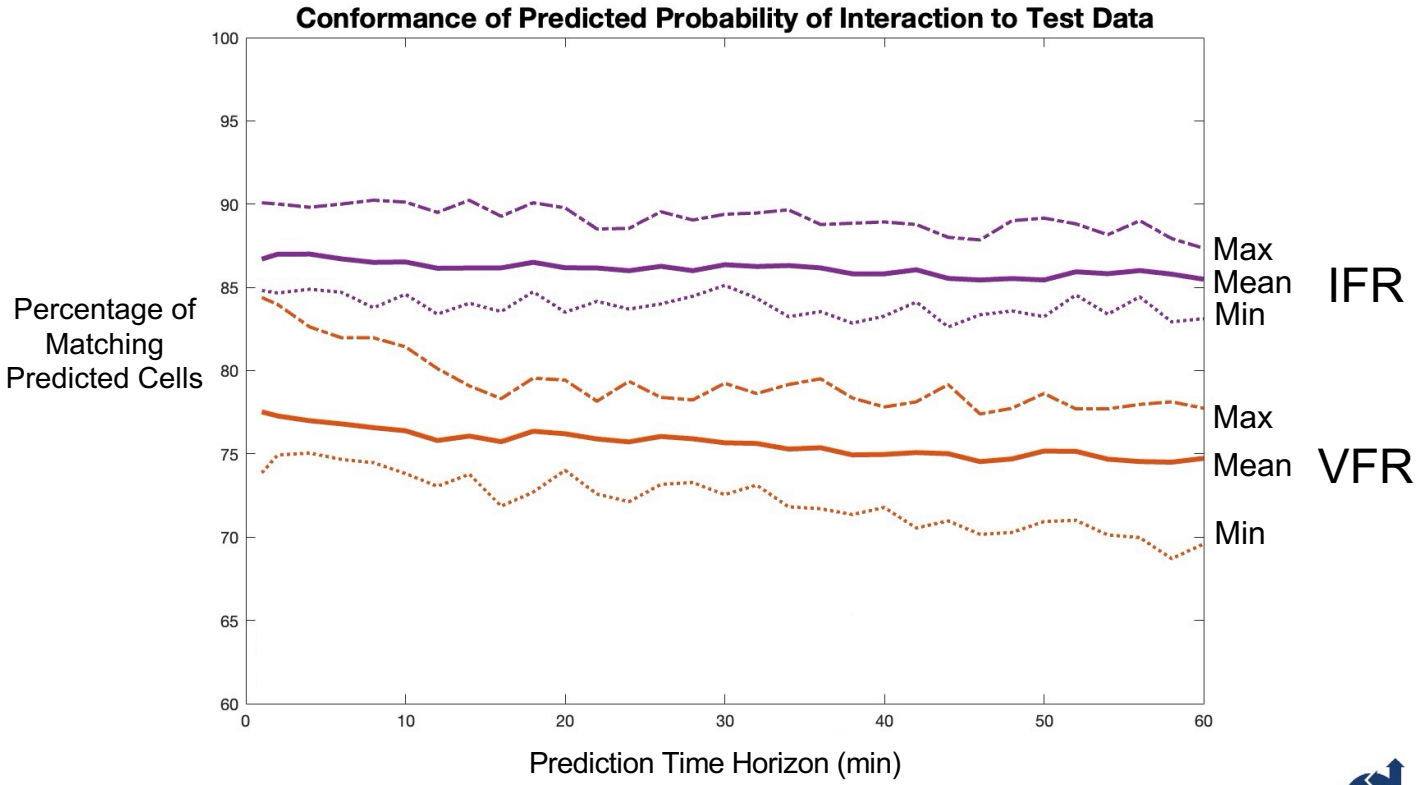


1 min later

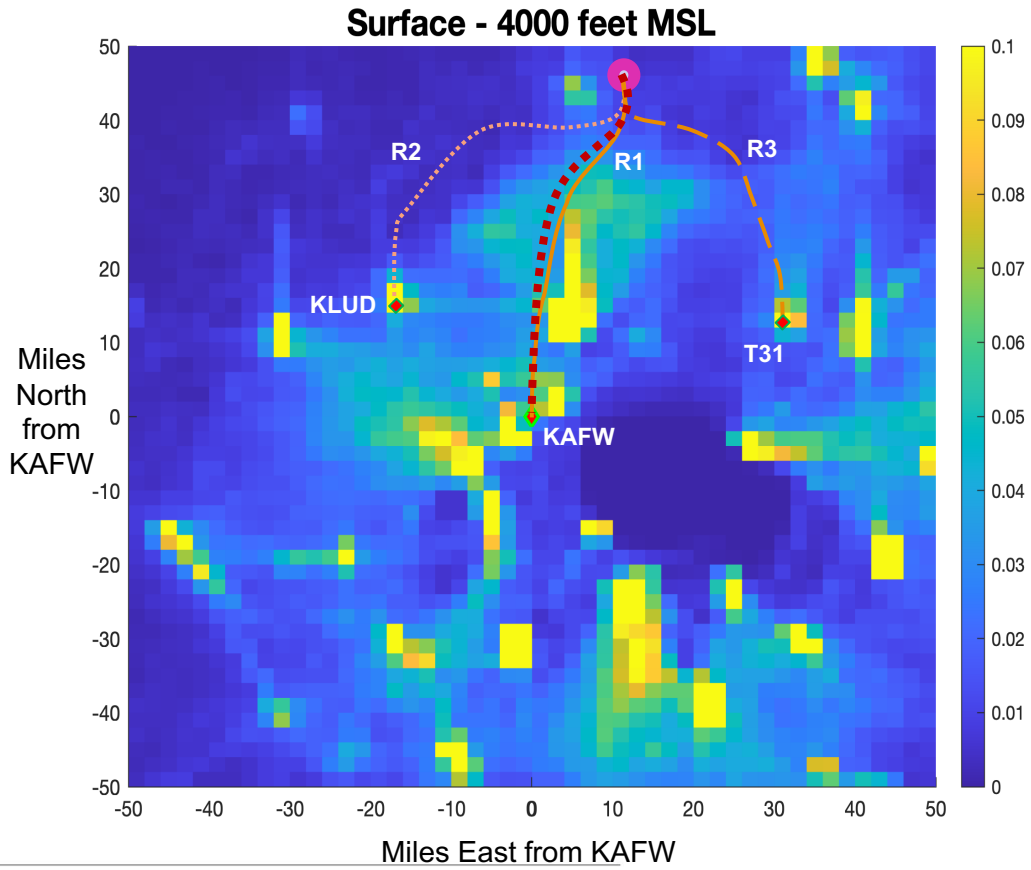
5 min later

Traffic moves further on longer time horizon

Accuracy of Predictions (8a to 6p)



Sample Application – Contingency Management



Conclusions

- Developed method to characterize VFR traffic
- VFR traffic interactions more dispersed but less severe compared to IFR traffic
- Used statistical modeling to predict aggregate traffic behavior
  - VFR behavior was predictable with 75-85% accuracy
  - IFR behavior was predictable with 80-90% accuracy
- Prediction method enables identification of UA routes around regional airports with minimal risk of interaction with VFR traffic

Future Work

- Can Machine Learning models improve prediction accuracy?
  - Use Machine Learning to predict VFR trajectories (DASC 2024 - predictions in terminal area)
  - Compare prediction accuracies

- Develop additional metrics to quantify risk based on VFR traffic characterization

Questions/Comments/Suggestions?

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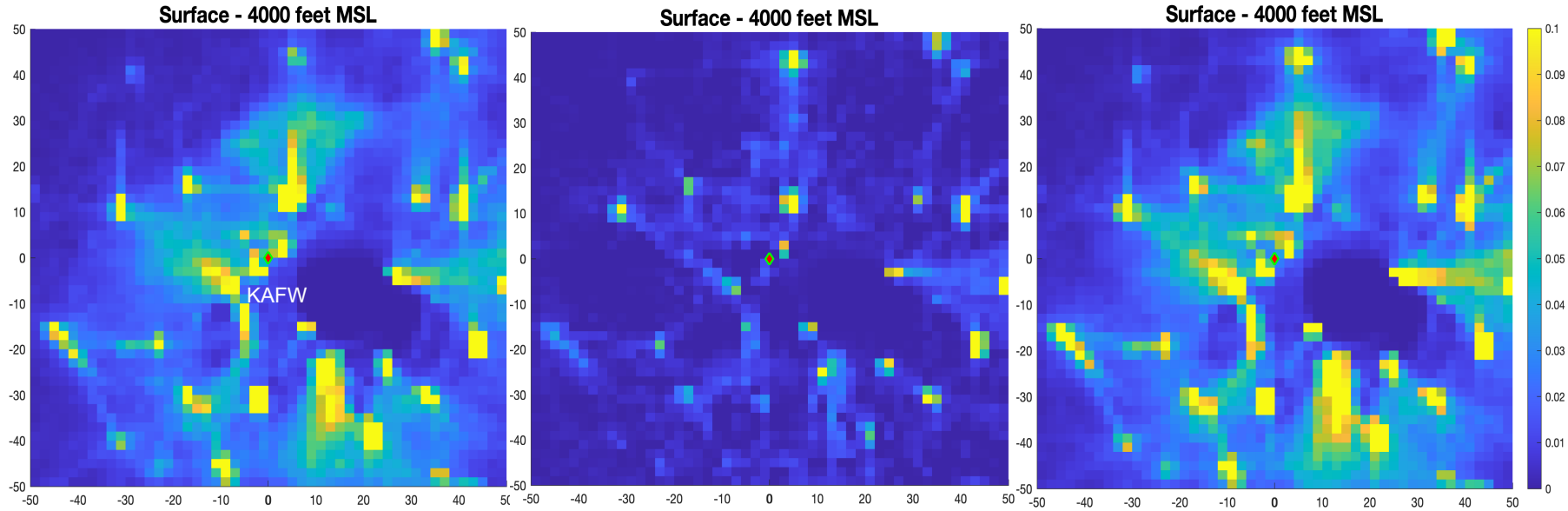
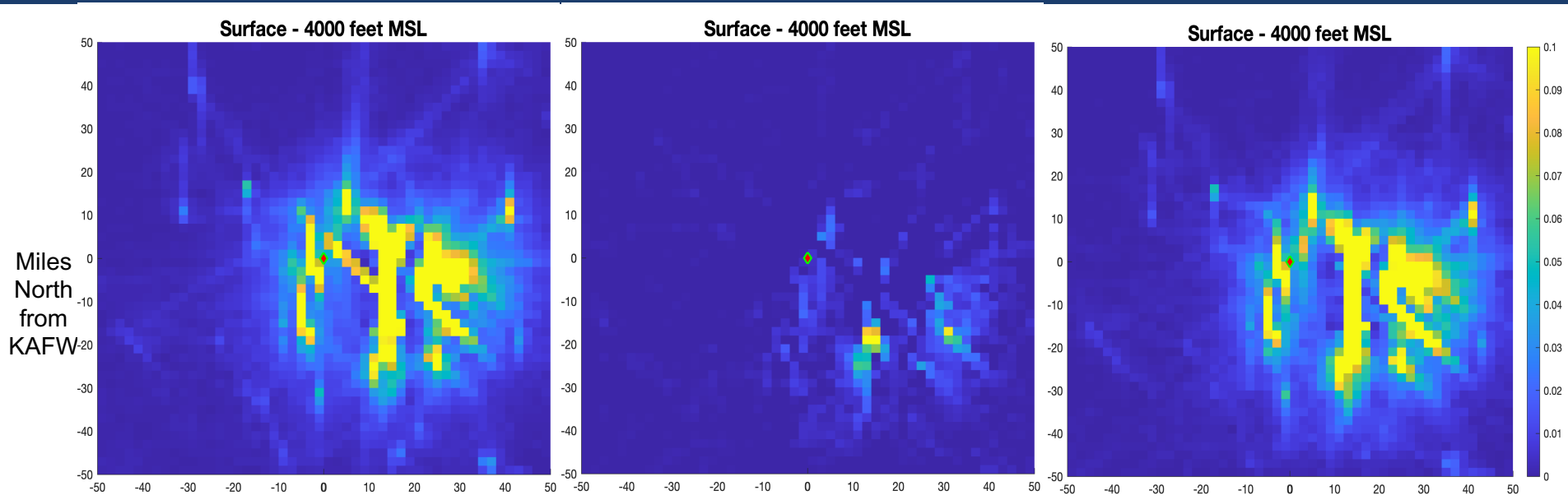
Data –
VFR track points – 10268185 (~342K per day)
IFR track points – 20350864 (~678K per day)

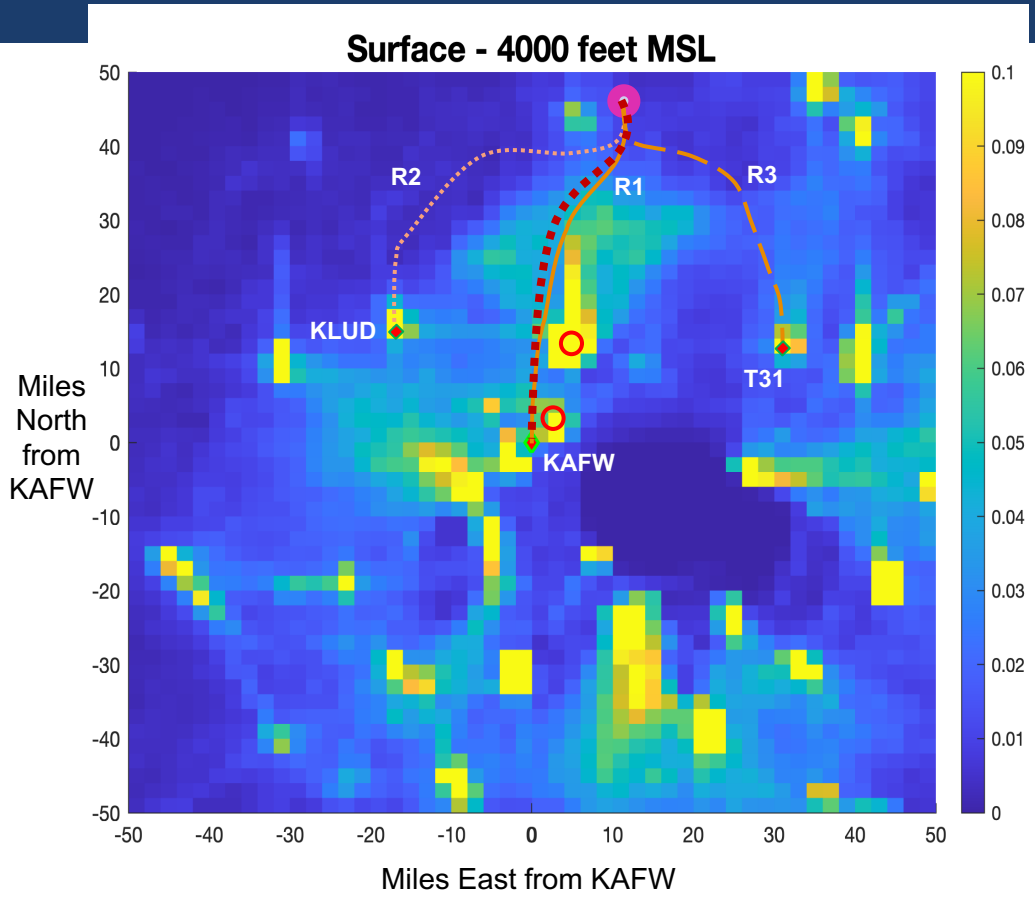
VFR flights – Total: 25784 (~860 per day), At KAFW: 10901 (~360 per day)
IFR flights – 61764 (~2058 per day), At KAFW: 24407 (~814 per day)

Traffic Distribution by Altitude (ft MSL)

Prctile	99	96	90	84	50	40	30	20
VFR	10000	7000	5600	5000	3600	3200	2800	2500
IFR	43000	40000	37000	35000	20500	18500	16800	13500


Surface - 4000 feet MSL
Surface - 4000 feet MSL
Surface - 4000 feet MSL
KAFW
Miles North from KAFW
Miles East from KAFW


Surface - 4000 feet MSL
Surface - 4000 feet MSL
Surface - 4000 feet MSL
Miles North from KAFW
Miles East from KAFW


Surface - 4000 feet MSL
R2
R1
R3
KLUD
KAFW
T31
Miles North from KAFW
Miles East from KAFW
50
40
30
20
10
0
-10
-20
-30
-40
-50
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0