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Statistical Prediction of Flight Behavior in the Vicinity of Convective Weather

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Some Numbers

- 2 of 3 events correctly predicted
- 1 of 4 alerts are false alarms

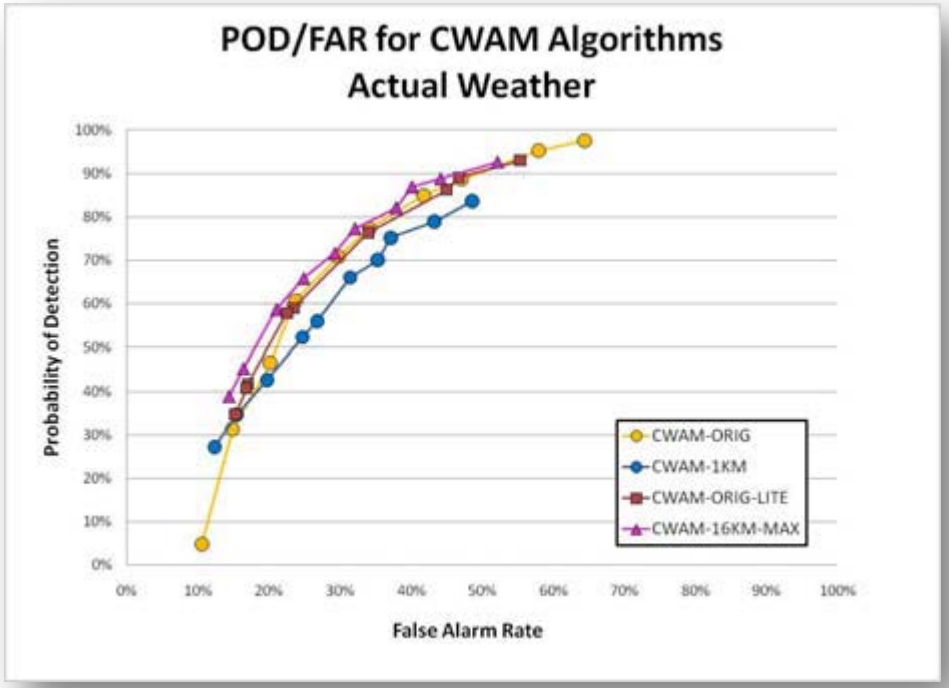

Figure reproduced from Matthews, M., DeLaura, R., "Evaluation of Enroute Convective Weather Avoidance Models Based on Planned and Observed Flight", 14th Conference on Aviation, Range, and Aerospace Meteorology (ARAM), *Amer. Meteor. Soc.*, Atlanta, GA, Jan 2010.

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All you have to do is…

Gaussian Copula Likelihood Approximation for Arbitrary Feature Vector Data

- Putting it all together …

$$\Pr\{\mathbf{y}|x\} \approx \underbrace{\prod_{i=1}^{m} \frac{\frac{1}{\sigma_x^{(i)}} f_x^{(i)}\left(\frac{y^{(i)}-\mu_x^{(i)}}{\sigma_x^{(i)}}\right)}{\varphi\left(\Phi^{-1}F_x^{(i)}\left(\frac{y^{(i)}-\mu_x^{(i)}}{\sigma_x^{(i)}}\right)\right)}}_{\text{non-gaussianity-}\mathcal{N}(\mathbf{0},\mathbf{C}_x)\text{ Jacobian correction term}} \cdot \underbrace{\frac{1}{\sqrt{\det 2\pi\mathbf{C}_x}} \exp\left(-\frac{1}{2}\left[\mathbf{\Phi}^{-1}\mathbf{F}_x\left(\frac{\mathbf{y}-\boldsymbol{\mu}_x}{\boldsymbol{\sigma}_x}\right)\right]^{tr} \mathbf{C}_x^{-1}\left[\mathbf{\Phi}^{-1}\mathbf{F}_x\left(\frac{\mathbf{y}-\boldsymbol{\mu}_x}{\boldsymbol{\sigma}_x}\right)\right]\right)}_{\mathcal{N}(\mathbf{0},\mathbf{C}_x)\text{ density evaluated at }\Phi^{-1}F_x((\mathbf{y}-\mu_x)/\sigma_x)}$$

$\frac{y^{(i)}-\mu_x^{(i)}}{\sigma_x^{(i)}}$ = standardized data

$f_x^{(i)}$ = p.d.f. of $\frac{Y^{(i)}-\mu_x^{(i)}}{\sigma_x^{(i)}}$

$F_x^{(i)}$ = c.d.f. of $\frac{Y^{(i)}-\mu_x^{(i)}}{\sigma_x^{(i)}}$

30

John Frank Stevens

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Just a little infrastructure

High resolution weather information w/ minimal latency

Conditioned flight dataset

Integrated analysis environment

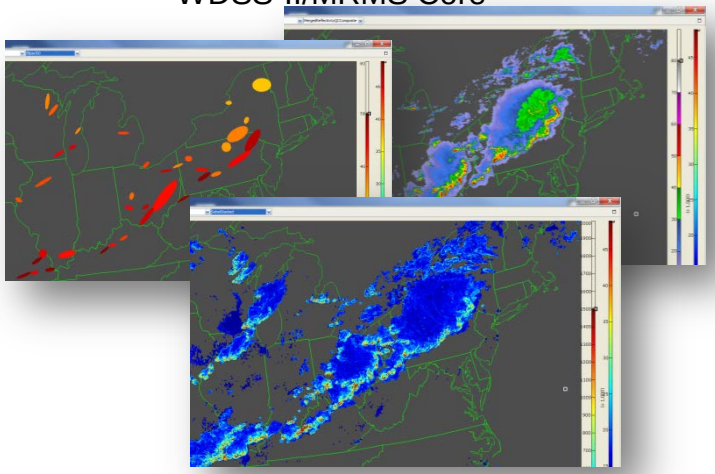
Clear definitions for weather-related flight deviation

Automated identification of deviations when they occur

Project Areas

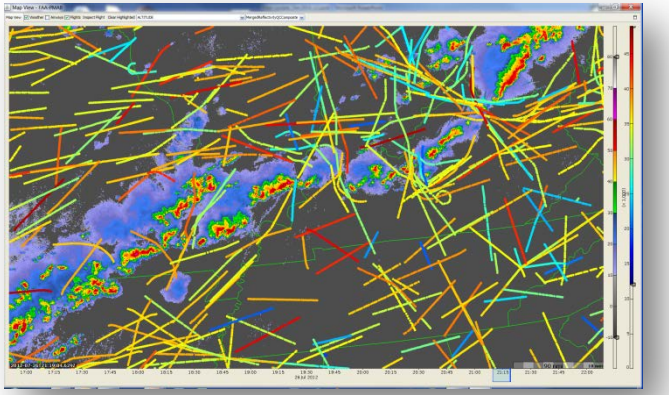
High Resolution 3D CONUS-wide Weather Feature Mosaics

New feature extraction routines built on FAA/NWS WDSS-II/MRMS Core



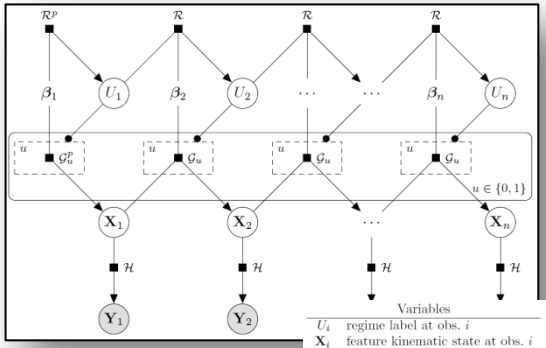
PDARS – Wx Analysis Environment - Flight View

Built using Java and OpenGL.
Specifically designed for rapid visual analysis of very large multi-dimensional data sets



Markov Switching Model for Flight Deviation Detection

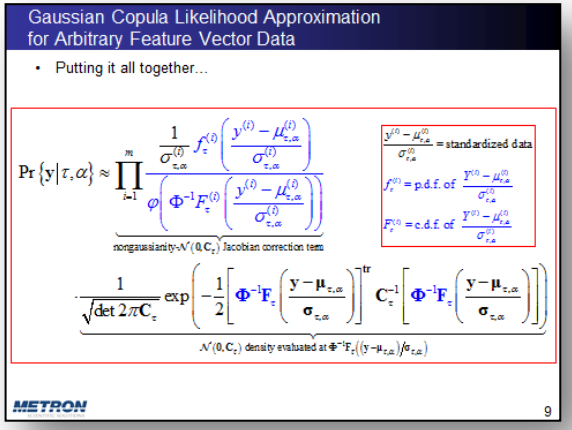
Implemented in Java for scalable processing of large data sets. Approximately 1 minute to process 30,000 flights



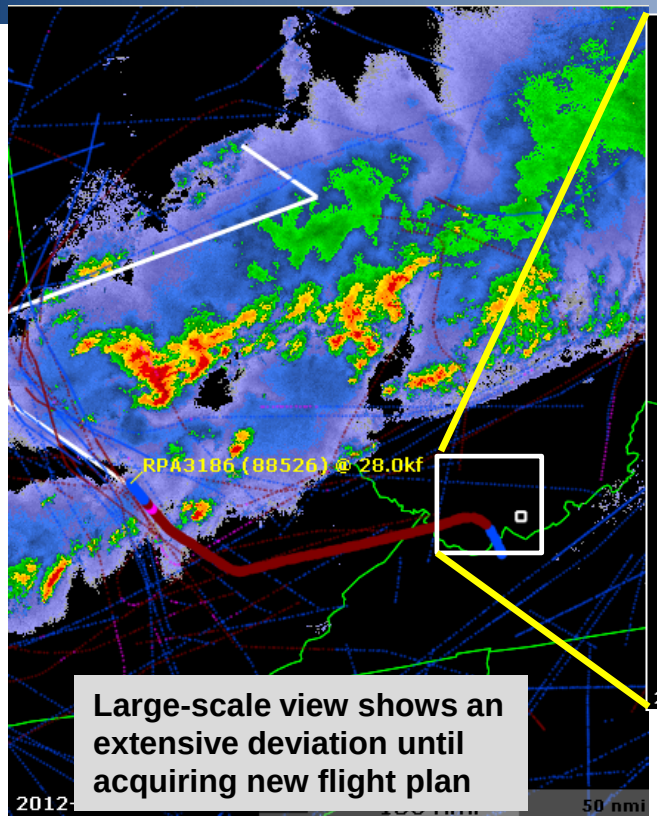
Variables		Factors	
U_i	regime label at obs. i	$\mathcal{G}_u^p$	state prior for regime u
$\mathbf{X}_i$	feature kinematic state at obs. i	$\mathcal{G}_u$	state transition kernel for regime u
$\mathbf{Y}_i$	observed feature value at obs. i	$\mathcal{R}^p$	regime label prior
$\boldsymbol{\beta}_i$	exogeneous variables at obs. i	$\mathcal{R}$	regime transition kernel
		$\mathcal{H}$	observation model

Gaussian Copula-based Classifier

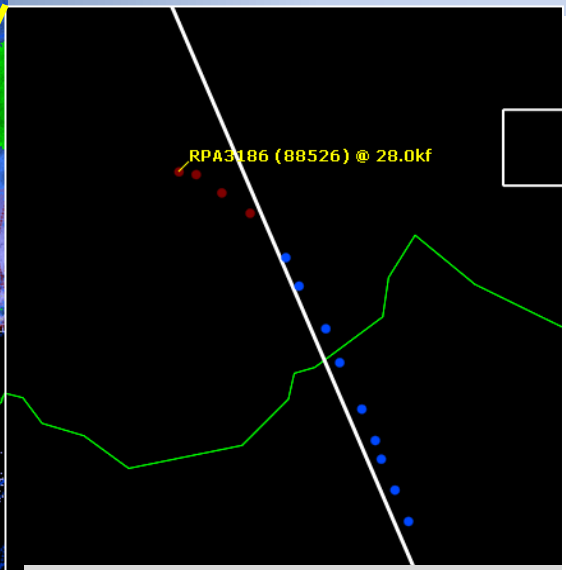
Implemented in Java. Adaptable to arbitrary feature data, including non-Gaussian data



Automated Flight Deviation Detection

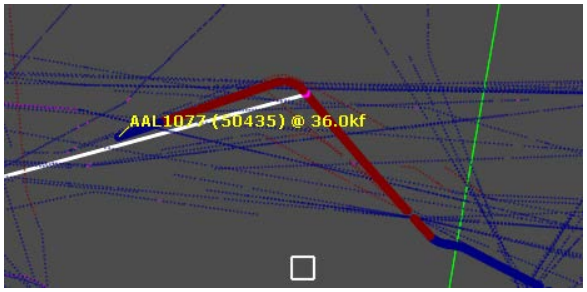


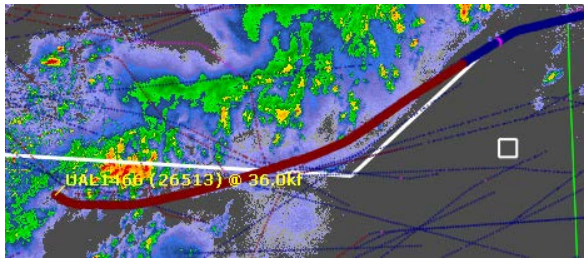
Large-scale view shows an extensive deviation until acquiring new flight plan



Acceleration away from path is flagged as deviant (distance of first deviant posit is ~1 km)

Examples of correct behavior during flight plan crossings





	7/26/12 (severe)		6/8/12 (mostly benign)	
	Strategy		Strategy	
Statistic	Conservative	Aggressive	Conservative	Aggressive
Deviations near weather	3,172	5,728	746	1,451
Deviations not near weather	1,391	2,979	1,182	2,849
All deviating flights	3,849	6,821	1,819	3,913
Terminal deviations near weather	1,238	2,568	629	1,270
Terminal deviations not near weather	1,398	3,133	1,464	3,517
Total number of flights		29,424		29,707

Declared as Deviation

Declared as Non-deviation

For comparison, published CWAM training/test data set captured a total of 1,564 deviations over 5,235 events

Comparison of Approaches

	CWAM	PMAB-CW
Data Set	*5,000 Interactions*	*2,400,000 Flights*
ARTCCs	*3*	*All*
Deviation Detection	*Lateral Distance & Manual Review*	*Automated Markov Switching Model*
Potential for Performance Gains	*Low*	*High*
Output Type	*Geographic*	*Trajectory + Geographic** *(* future add)*
Airline Specific Classifiers	*No*	*Yes*
Aircraft Type Classifiers	*No*	*Yes*
Classifiers by Region	*No*	*Yes*
Classifiers by Season	*No*	*Yes*
Classifiers by Day/Night	*No*	*Yes*

Metron's Scalable Approach Provides Flexibility & Increases Feasibility for New Applications

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Benefits to the NAS