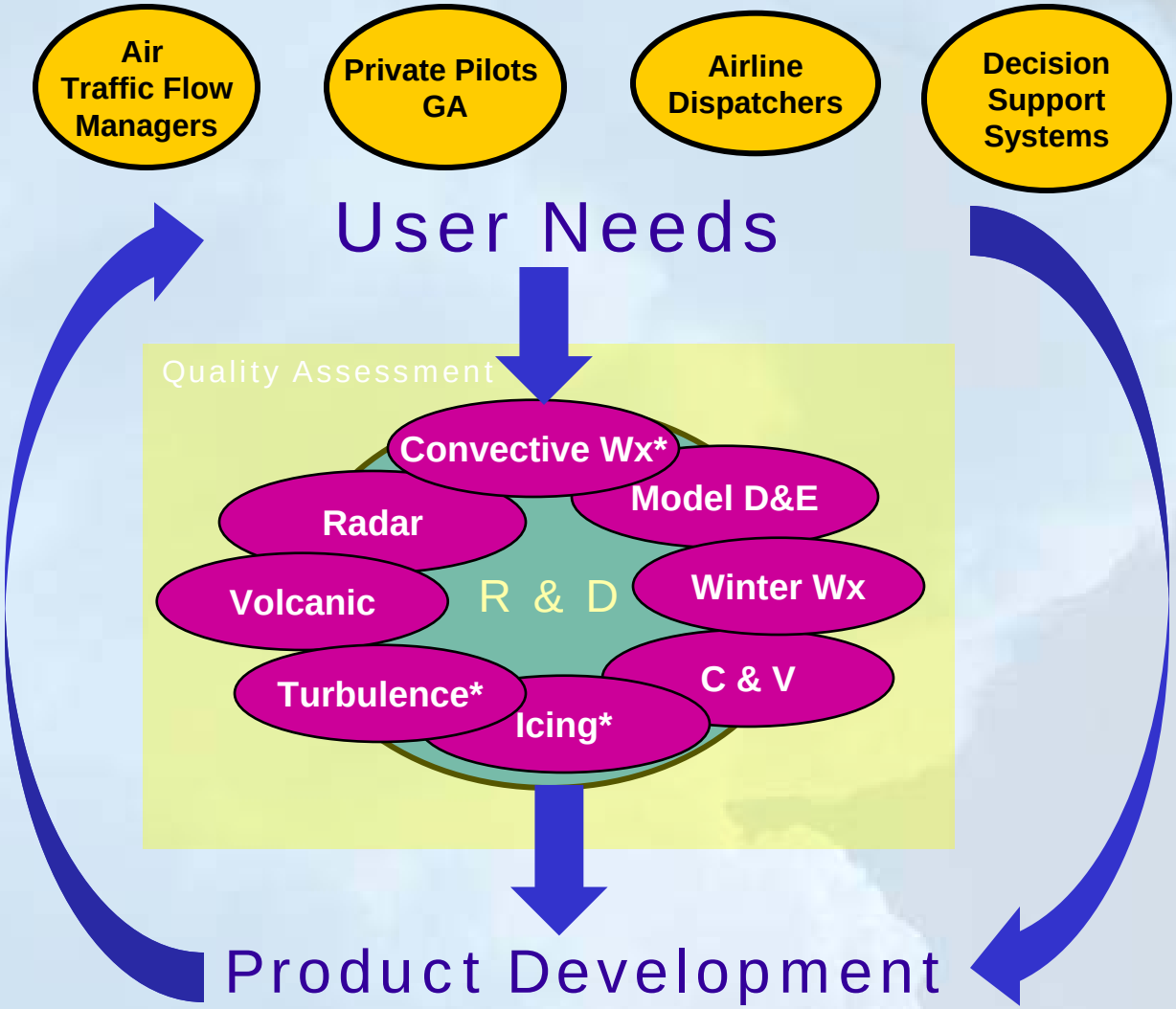
NCAR

16 April, 2009

Advances in Aviation Weather Hazard Detection and Prediction

James Pinto
Project Scientist
Research Applications Laboratory

National Center for Atmospheric Research

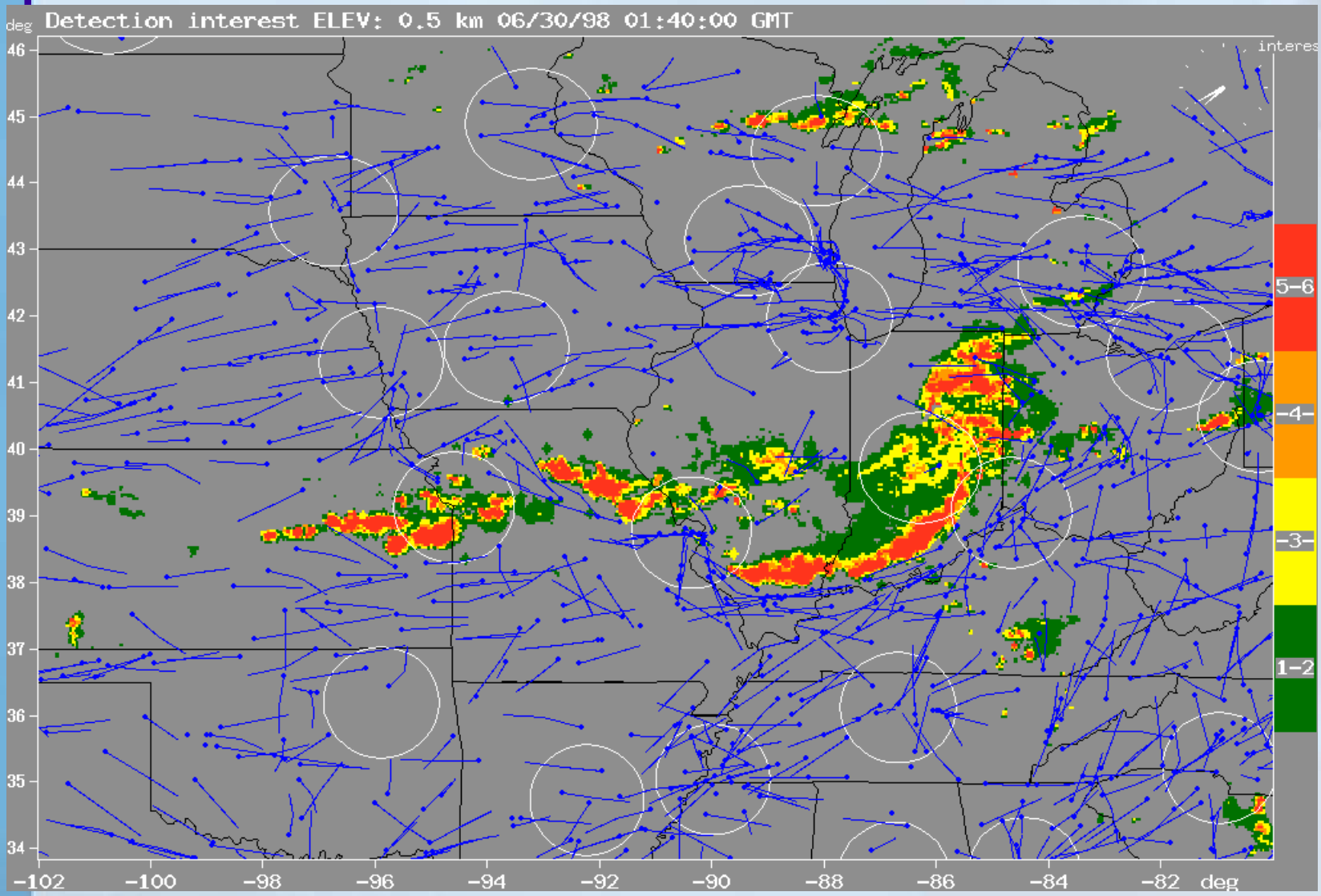


Hazard Detection and Forecast Product Generation Systems	
• Turbulence	• Temperature
• Icing	• Humidity
• Ceiling	• Noise Propagation
• Visibility	• Atmospheric Exhaust
• Radiation	• Volcanic Ash
• Winds	• Wake Vortex

Algorithmic Development & Analysis Techniques

- **data quality control**
- **data fusion**
- **data mining (Random Forest)**
- **fuzzy logic**
- **Storm tracking / characteristics (TITAN, VET)**
- **image processing (e.g., TITAN)**
- **regridding / reformatting (GRIB, netCDF)**
- **numerical modeling (HRRR)**
- **pattern recognition**
- **product verification and validation (Met Tool /MODE)**
- **Climatology development**

Impact of Aviation Weather Hazards

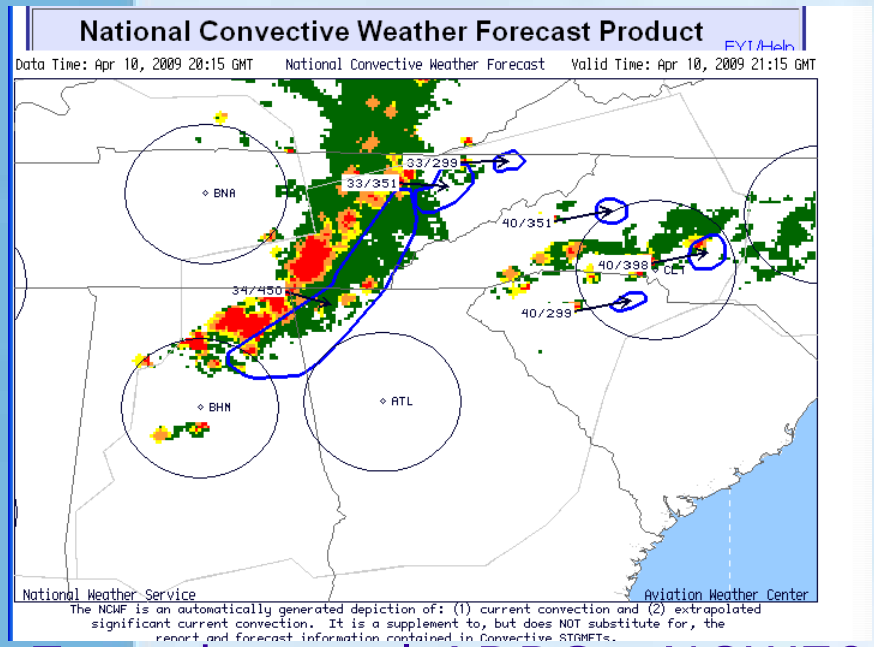


Convective Wx Research

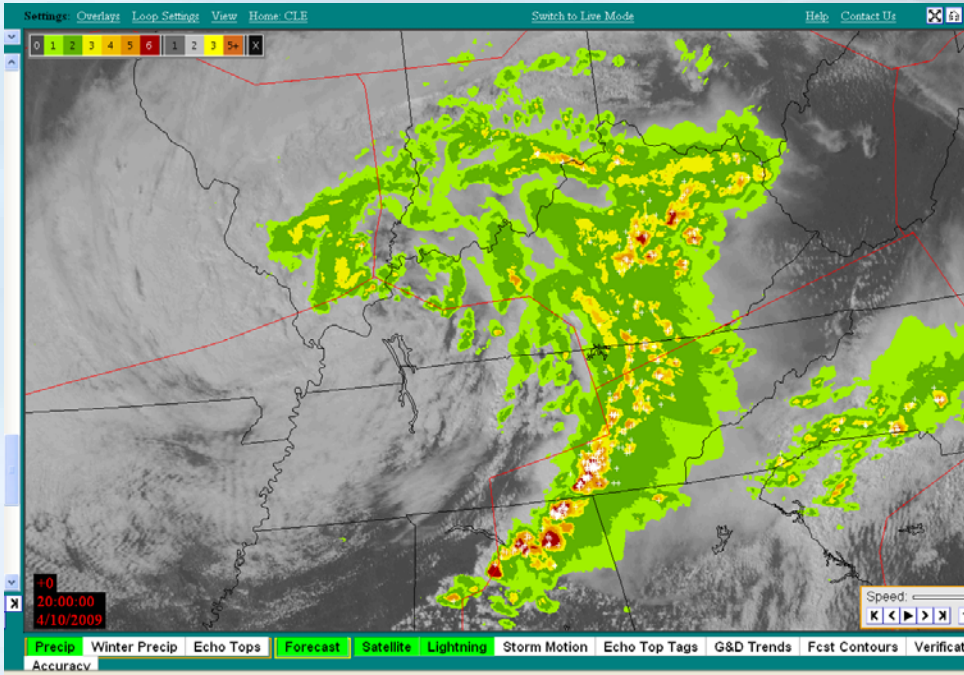
Collaboration between NCAR, MIT-LL and NOAA GSD
Additional Contributions from (NASA, NRL, and others)
Lead : Marilyn Wolfson (MIT-LL)

Convective Weather Team Products

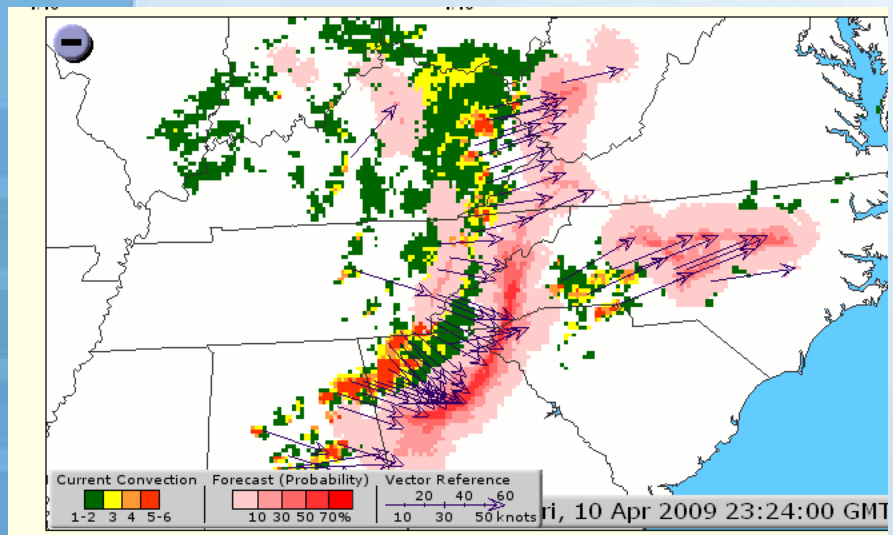
ADDS : NCWF -1



CIWS – MIT-LL Web Page



Experimental ADDS – NCWF2



In the pipeline ……..

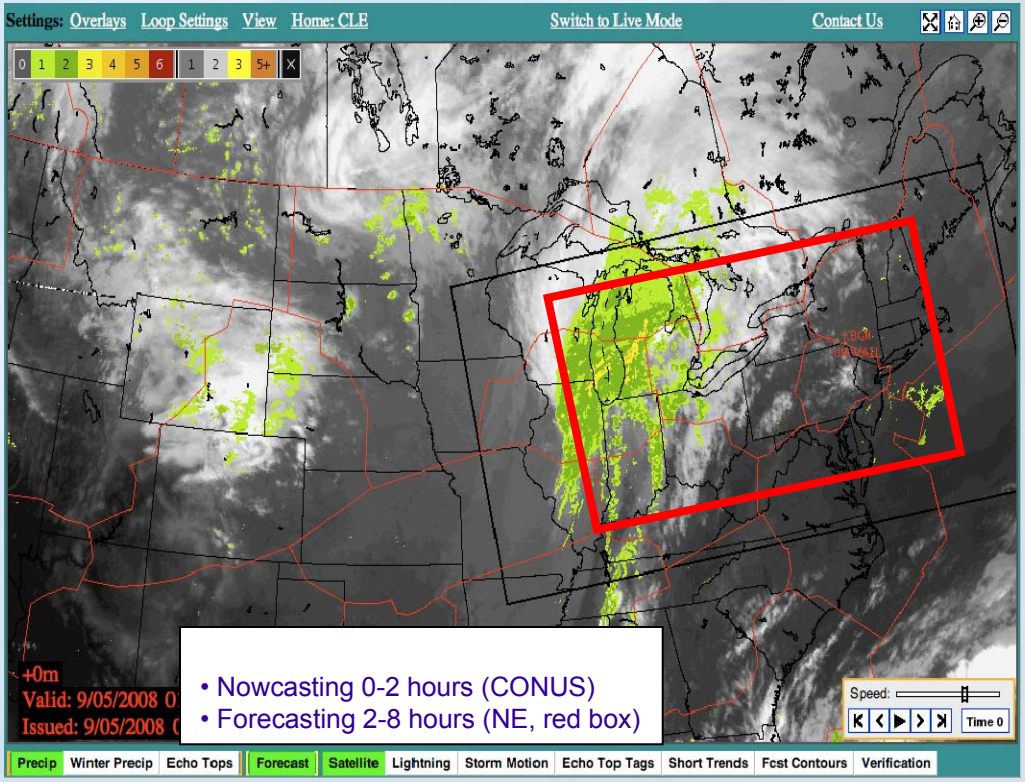
CoSPA
Collaborative Storm Prediction for Aviation

Goal:

• Collaborative effort between MIT-LL, GSD & NCAR that builds upon existing technologies at the labs & adding new technologies.

Major Focus Areas:

• Blending
• Statistical Optimization
• Forecast uncertainty
• User interaction
• Will populate the 4D data cube as part of the nextGen IOC in 2013.



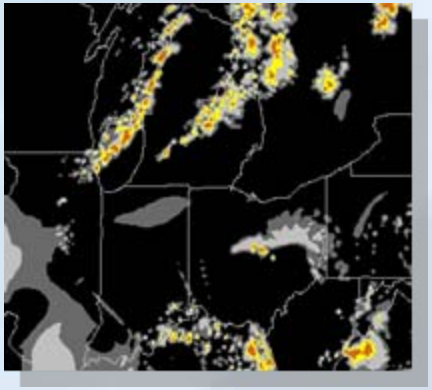
CoSPA – Blended 0-8 h forecast of storms

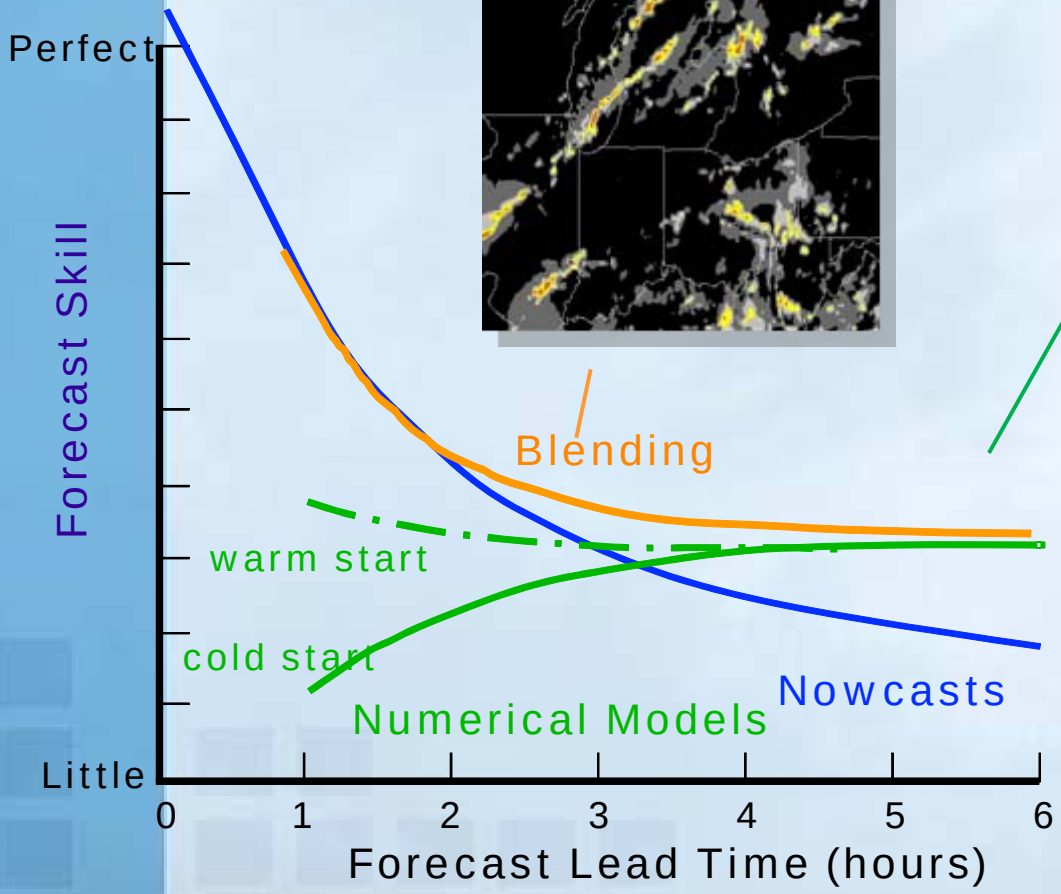
The National Center for Atmospheric Research
NCAR
sponsored by NSF

Blending

Earth System Research Laboratory
Serving Society through Science

Numerical Models





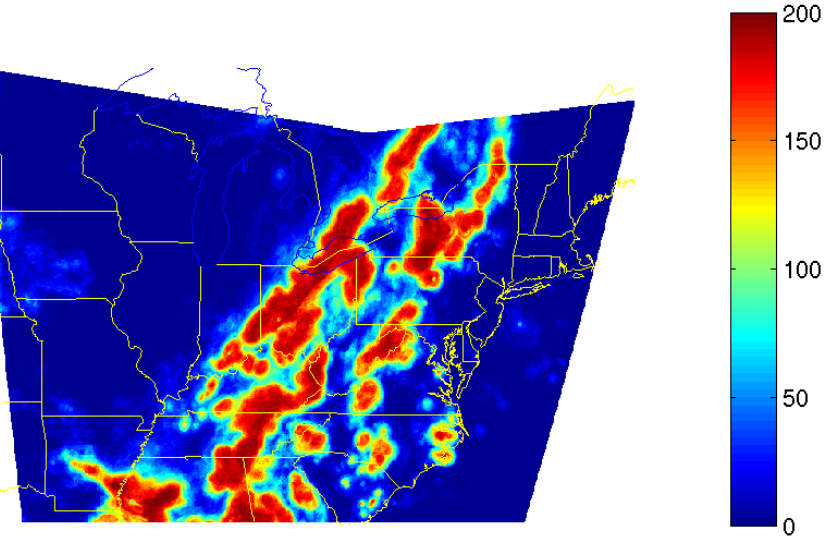
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Nowcasts

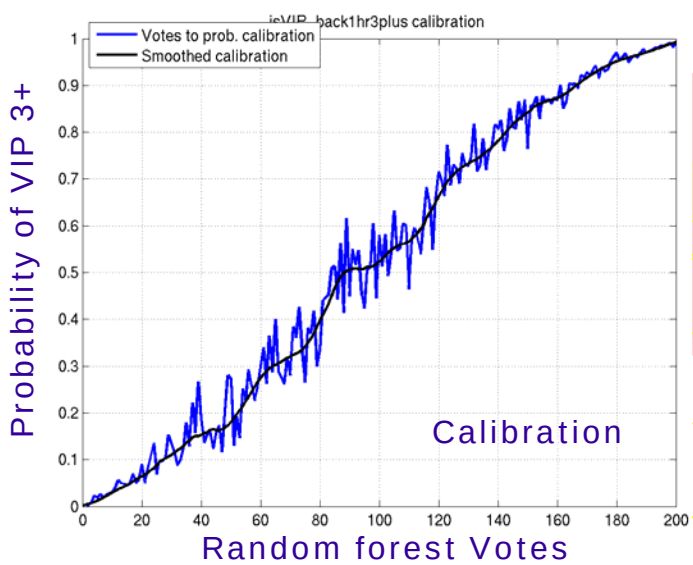
Additional contributions from NSSL, NRL and NASA

Random Forest Research – Optimization & Uncertainty

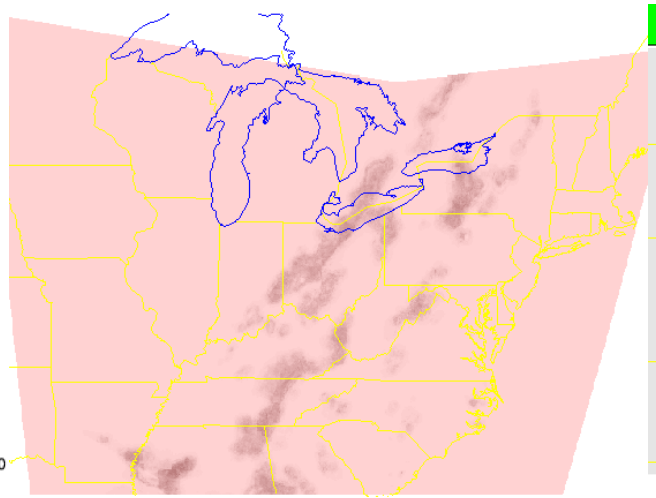
Votes for VIP ≥ 3 (var. WxType)



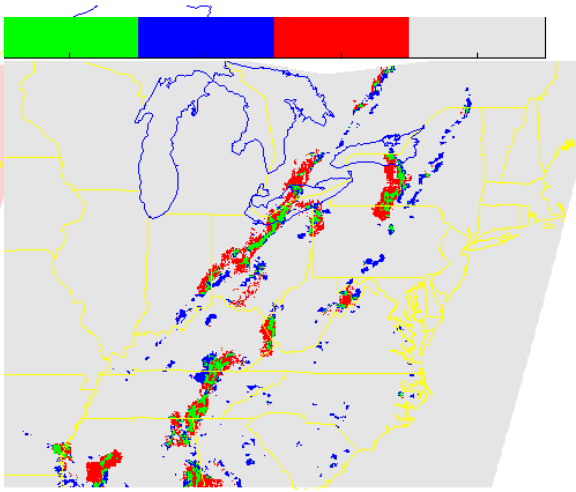
- **Statistical data mining technique**
- **Determine most likely storm regime**
- **Predictor field Importance**
  - Scale selection
- **Optimize CoSPA forecast logic**
- **Provide info on how to optimally combine various predictors.**
- **Can be used to convey fcts uncertainty**



Probability VIP of 3+

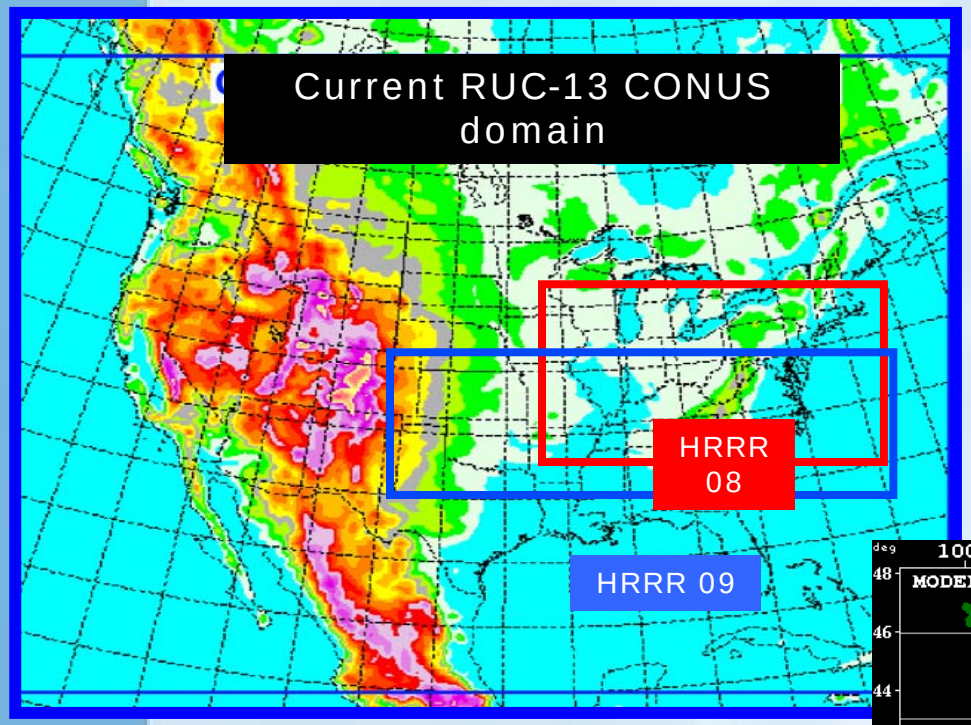


Hits Miss FA POD-No

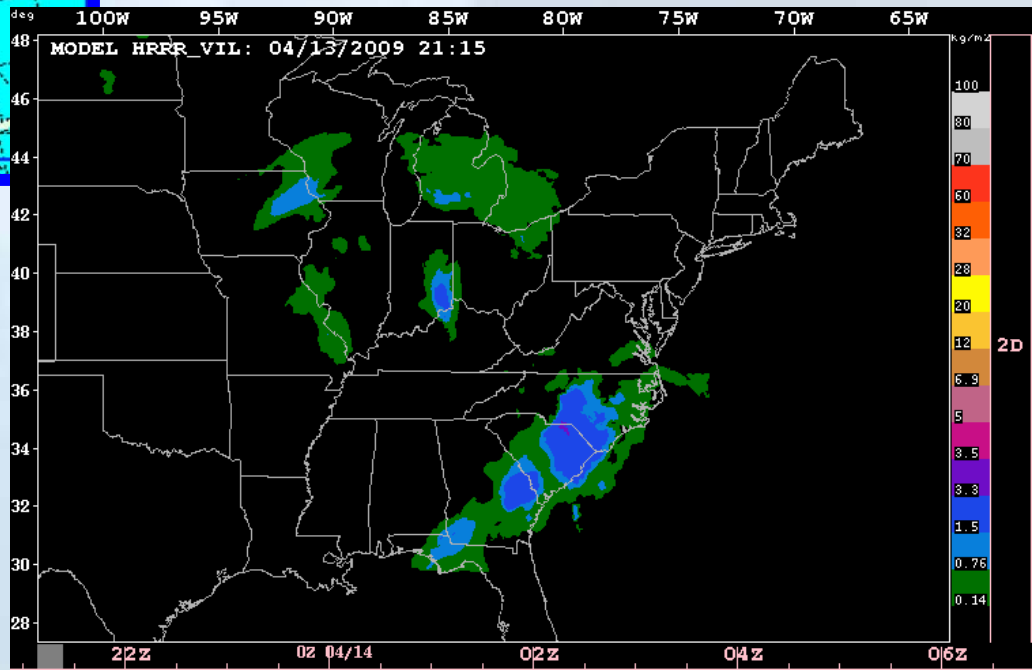


NWP Support for CoSPA

High Resolution Rapid Refresh (HRRR)



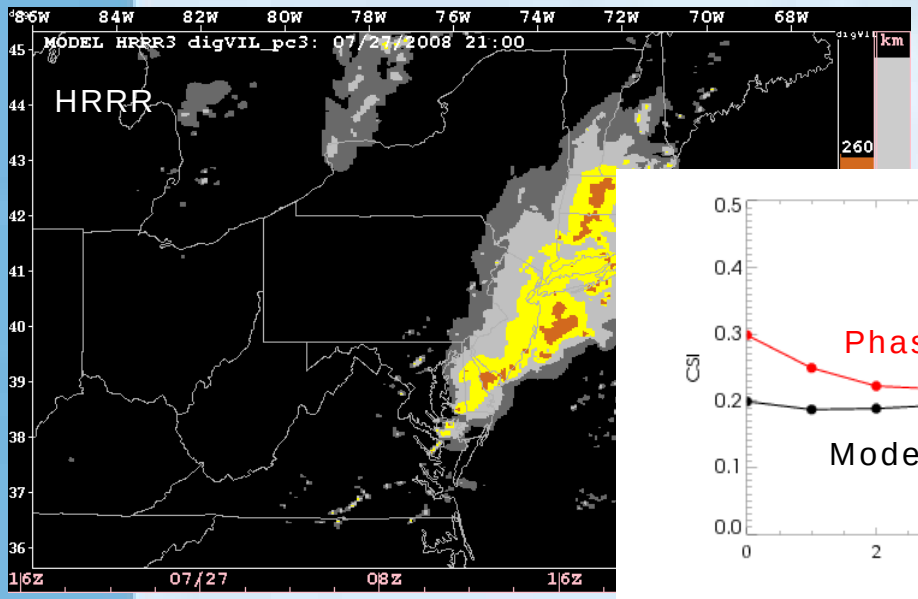
- Radar reflectivity assim.* into RUC13
- 1 hr update cycle (12 hour fcst)
- 3 km resolution.
- Special 15 min output freq
- 3 hour latency
- Small domain hindered simulation particularly to the south and west.

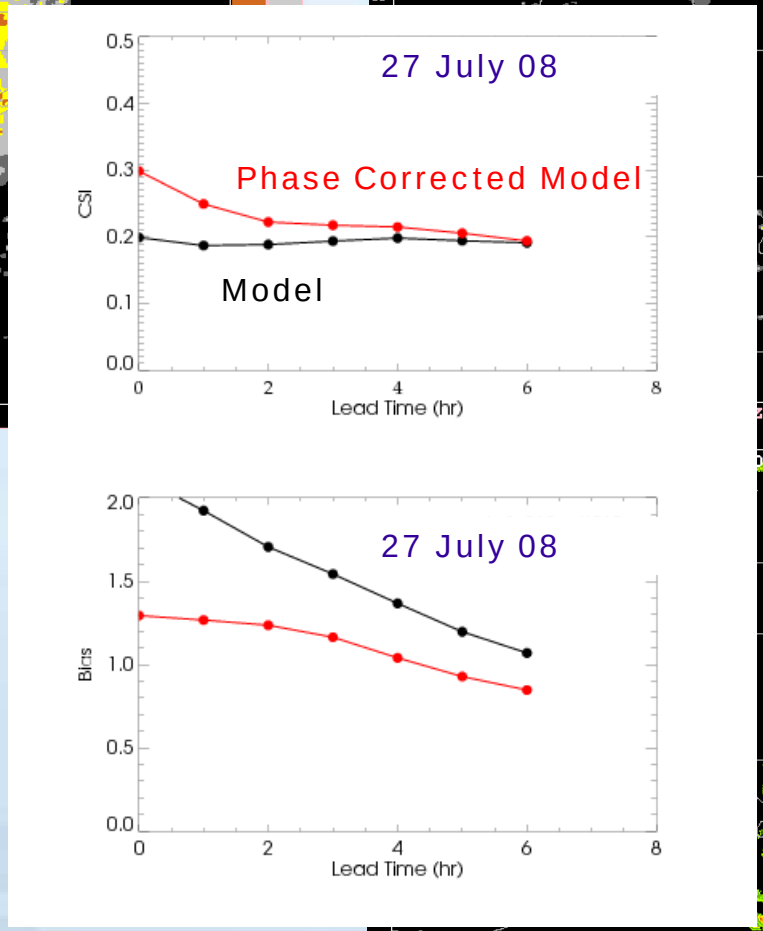


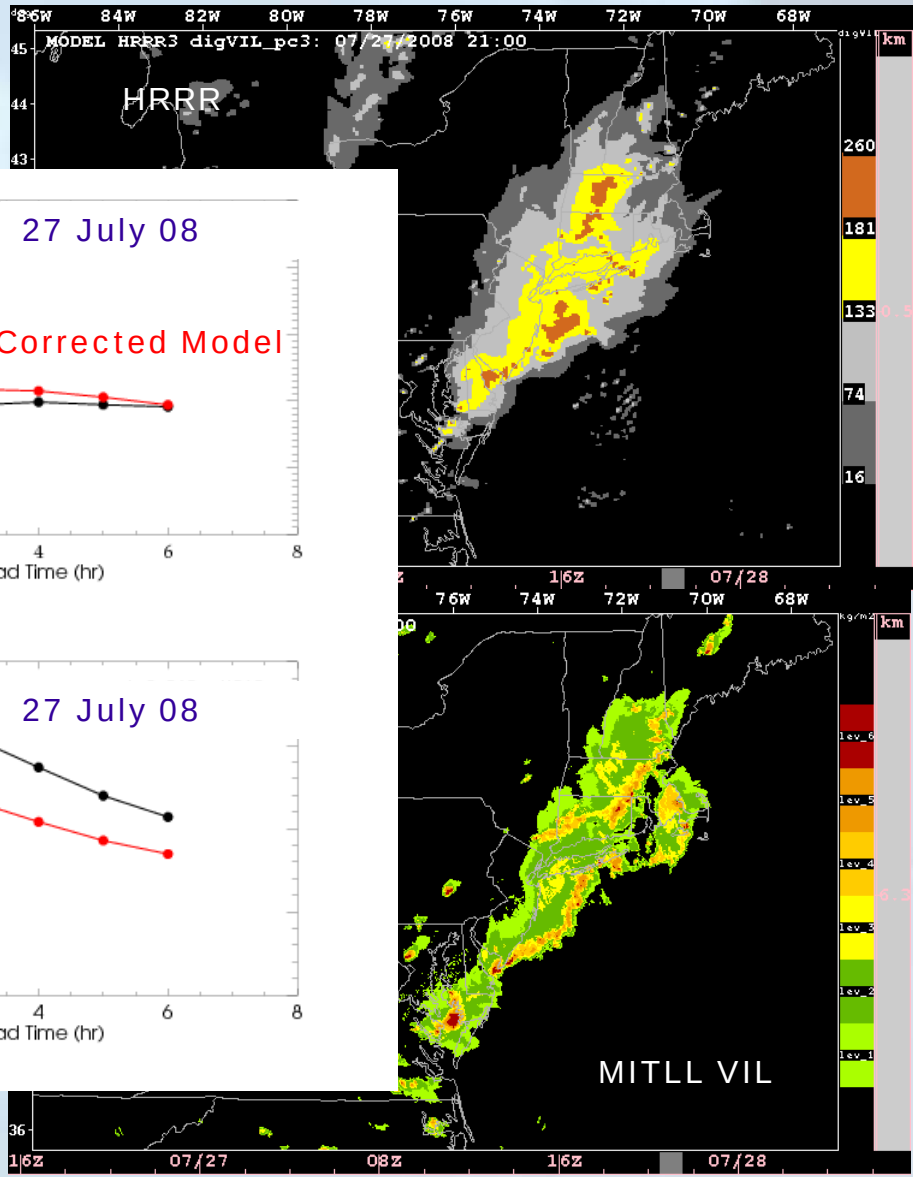
New for this summer:

- Expanded domain will improve performance and eliminate edge effects.
- Added 15 min echotops fcst

Model Phase-Error Correction





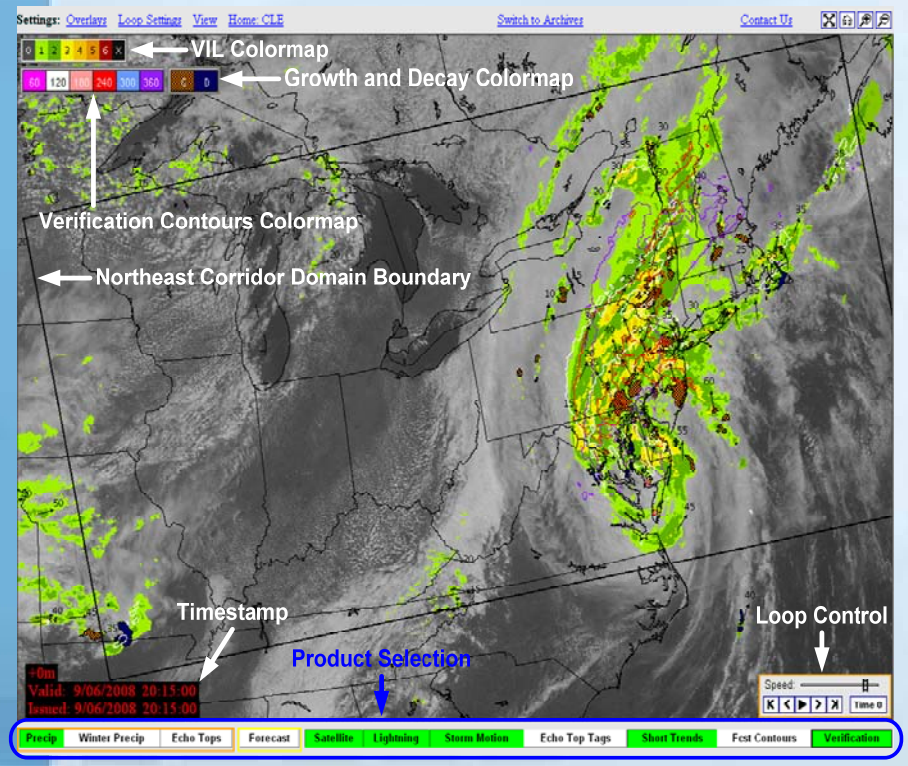


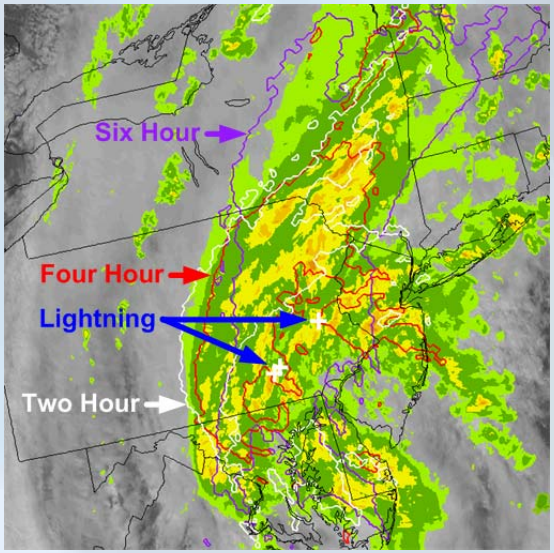
Phase Correction Research

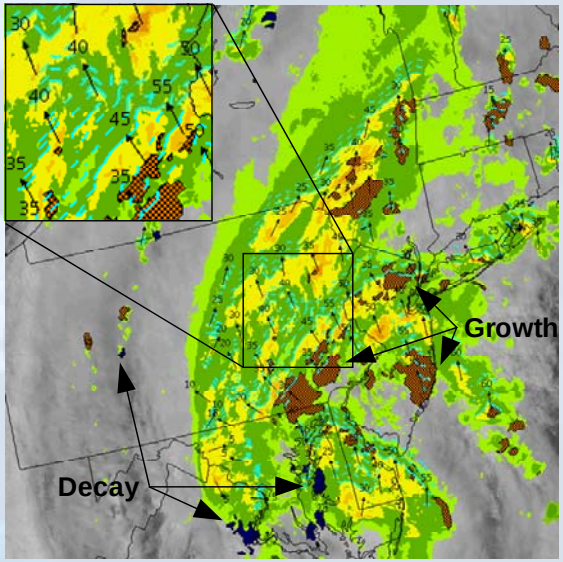
- Image processing technique
- Reduces phase errors in existing precip areas.
- Shows increased skill at lead times of up to 6 hours
- Improves storm morphology.

CoSPA Demonstration

- **FY09 24/7 Forecast Demonstration**
- **Gridded obs**
  - VIL, Etops, Ltg Satellite, Trends, Motion, Quicklook Verification
- **Gridded 0-8 h forecasts of intensity and echo tops**
  - Smooth transition from nowcast to NWP
  - 1 – 3 km resolution
  - Rapid Cycling : Forecast updated every 15 min



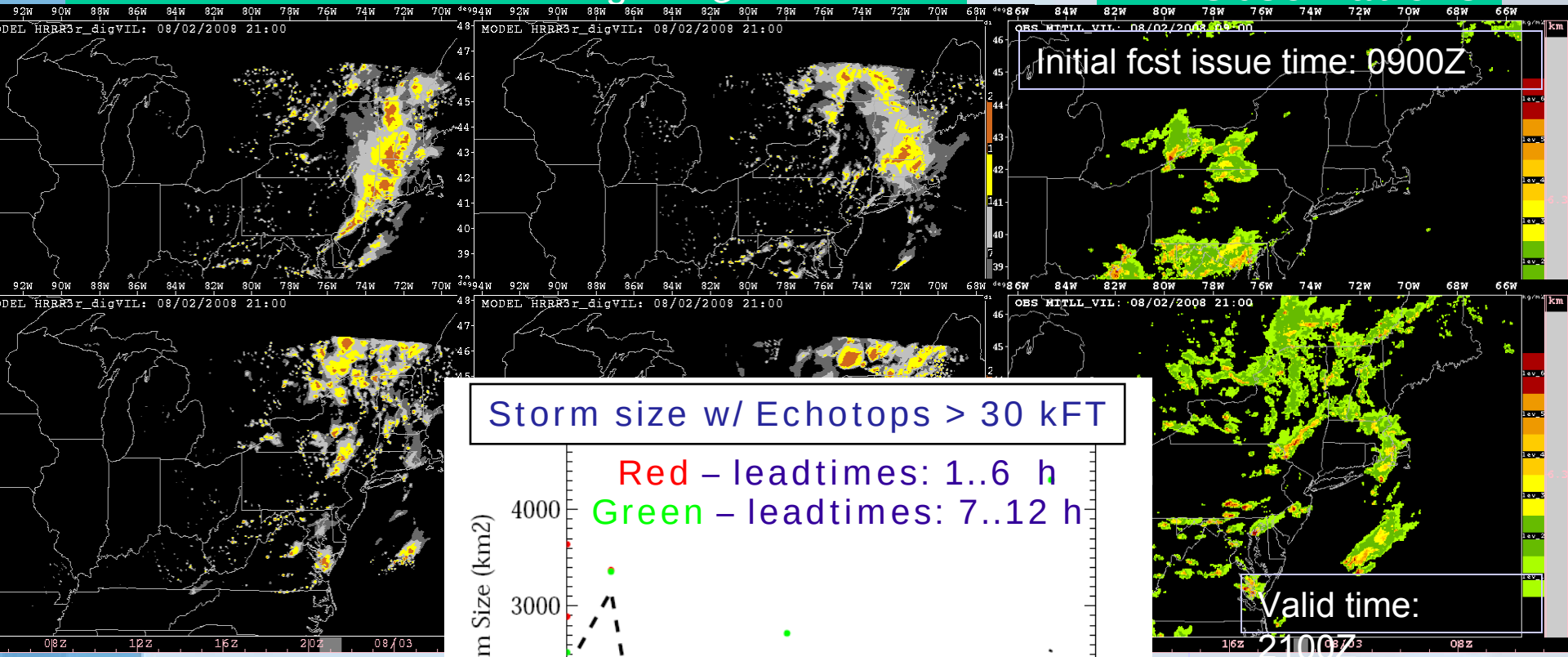




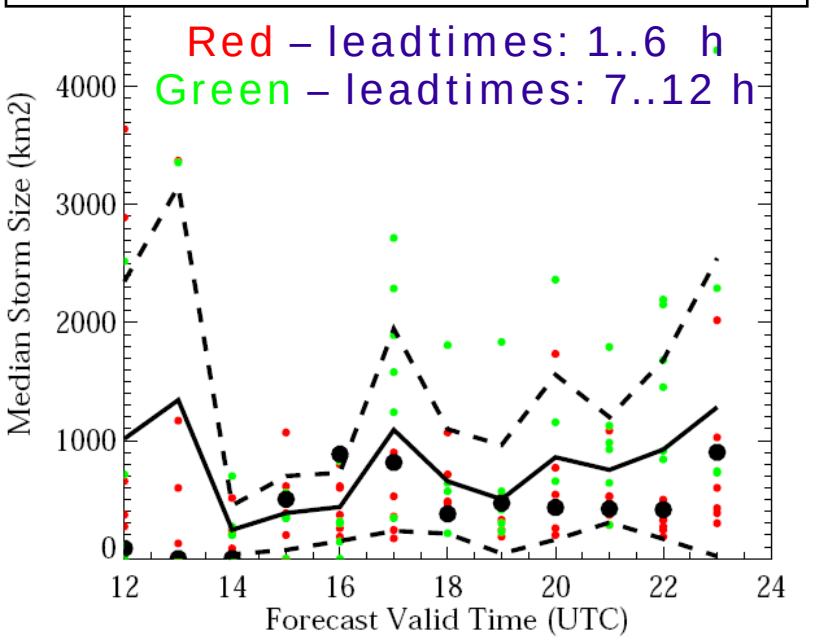
Time-Lagged Ensemble Example

HRRR Model Valid 02 Aug 08 @ 2100

VIL Observations



Storm size w/ Echotops > 30 kFT



Forecast Period 00 02 04 0 UTC

12h

8h

4h

2h

Turbulence Research Team

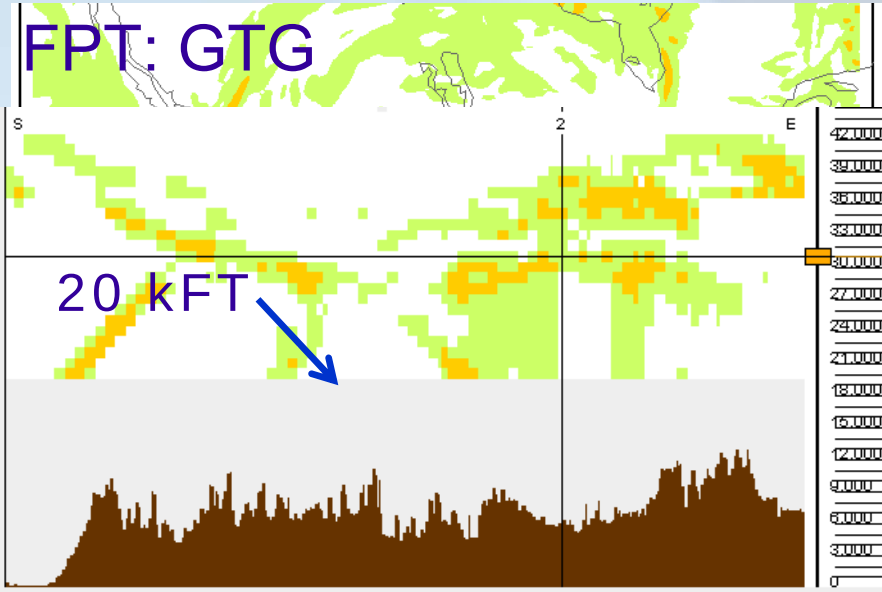
Lead: Bob Sharman, NCAR

Collaborations: NOAA/ESRL/GSD, UW CIMSS, UAH

Graphical Turbulence Guidance

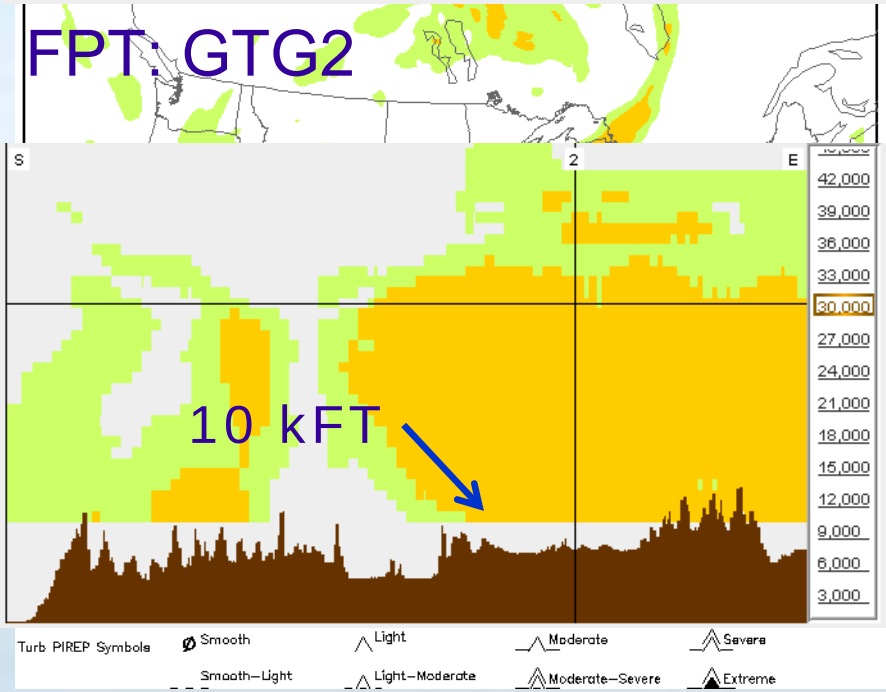
GTG

- Run operationally at the AWC
- Displayed on ADDS
- Diagnosis /12h prediction down to 20 kFT
- Includes PIREPS

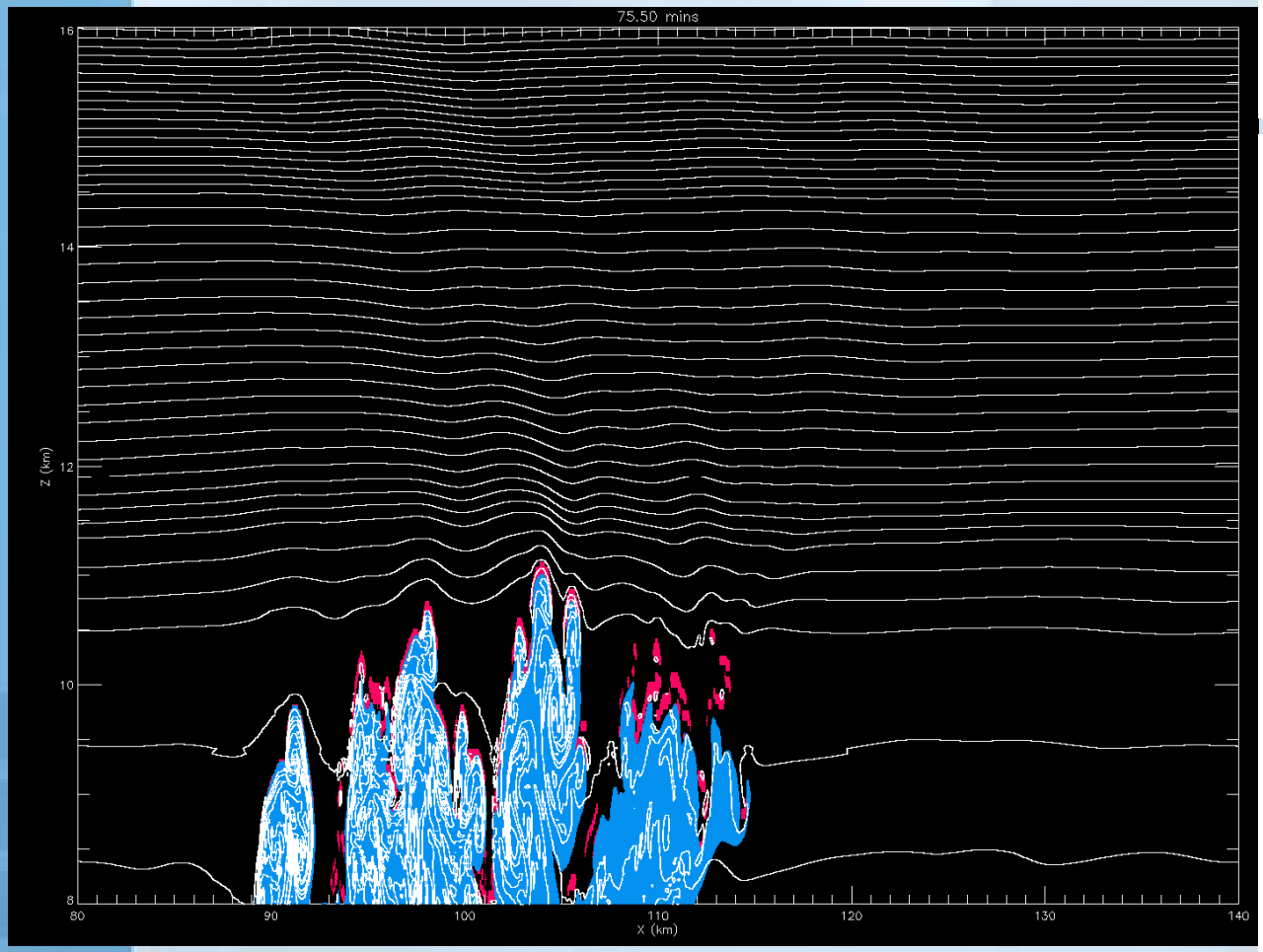


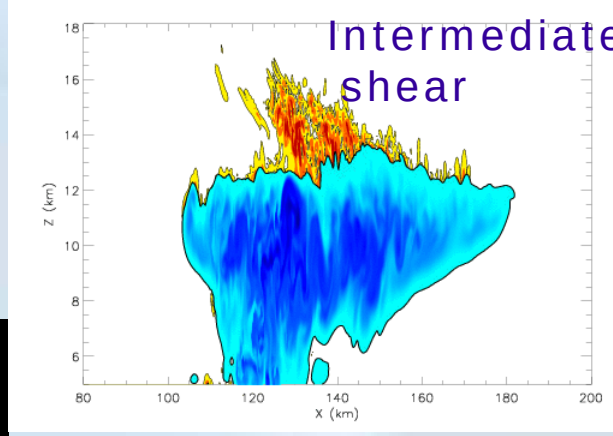
GTG2

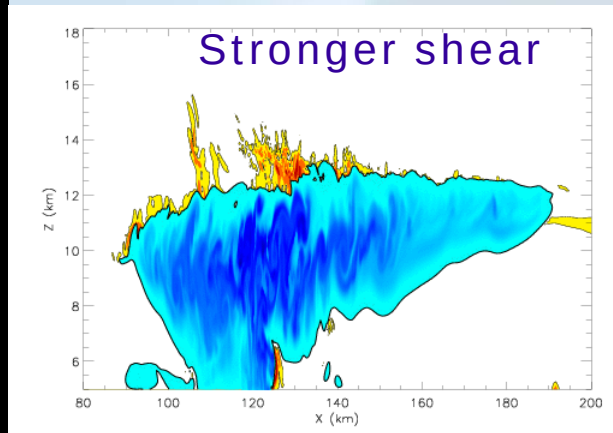
- Run experimentally at AWC
- On Experimental ADDS
- Detection & prediction
- Improved diagnostics
- Extend diagnosis/12-h prediction down to 10 kFT
- Includes PIREPS

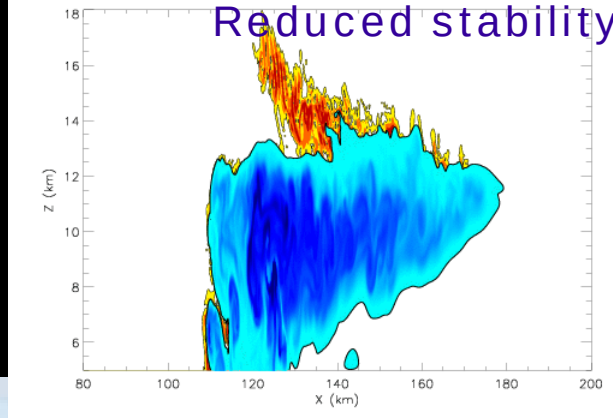


Numerical simulations of turbulence : Above-Cloud CIT





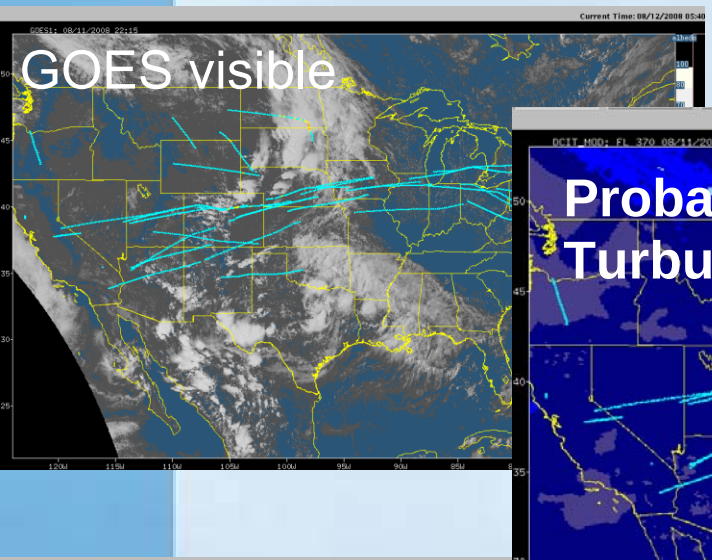


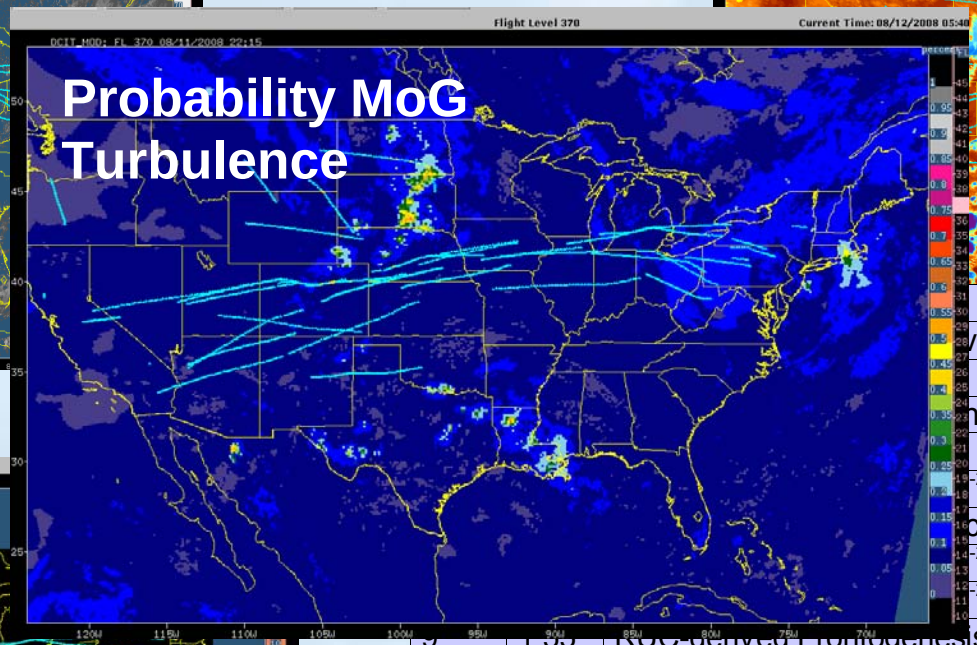


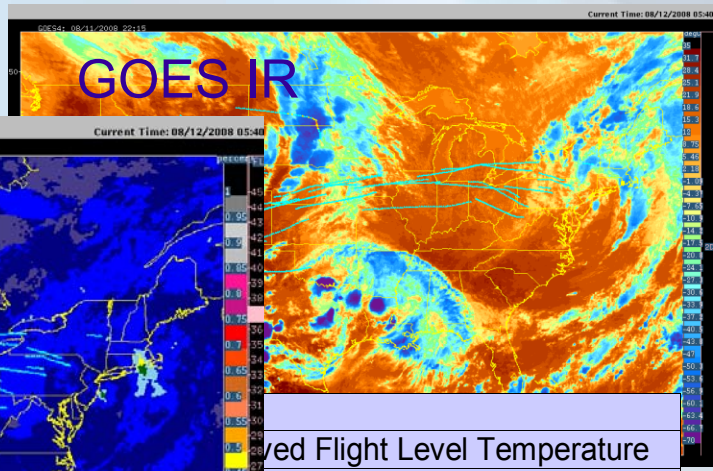
Courtesy Todd Lane U. Melbourne

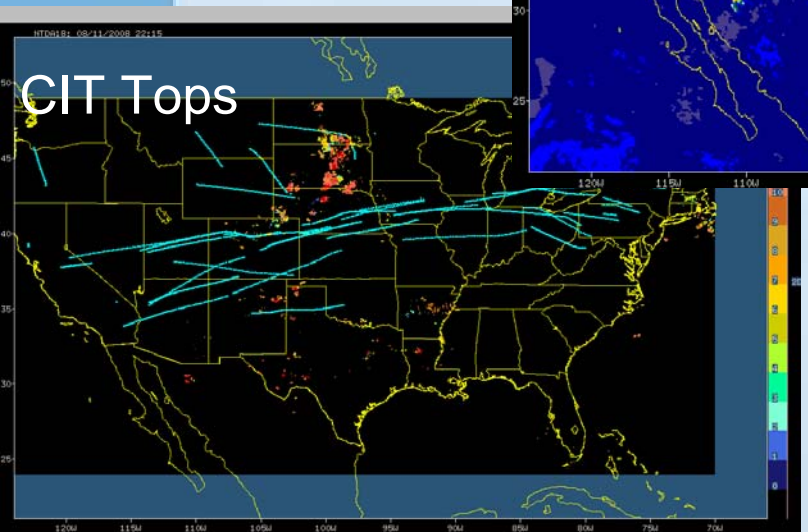
In the pipeline .....

Diagnosed Convection Induced Turbulence (DCIT)









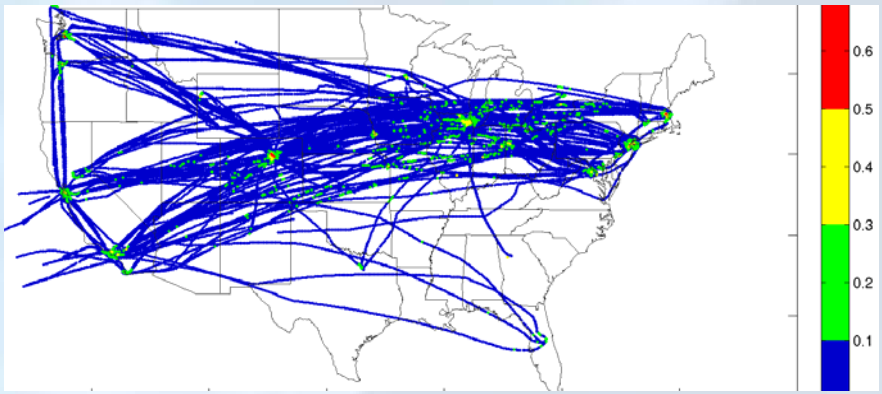
		ved Flight Level Temperature
		nction EDR
		$^{-2}$
		chardson Number
		$^{-2}$
		$^{-2}$
9	1.55	RUC-derived Frontogenesis Function
10	1.54	Distance to VIL > 12.0 kg m^{-2}
11	1.47	RUC-derived Vertical Shear
12	1.42	Distance to VIL > 30.0 kg m^{-2}
…		
22	0.78	RUC MSL Pressure minus RUC Flight Level Pressure
23	0.76	RUC Pressure
24	0.74	RUC-derived Temperature
25	0.73	NEXRAD Echo Top minus Geopotential Height

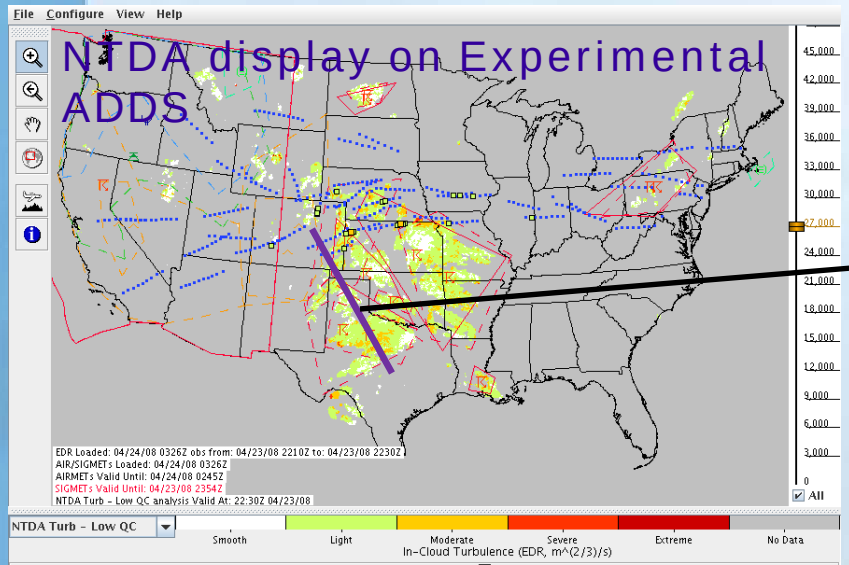
In the pipeline....

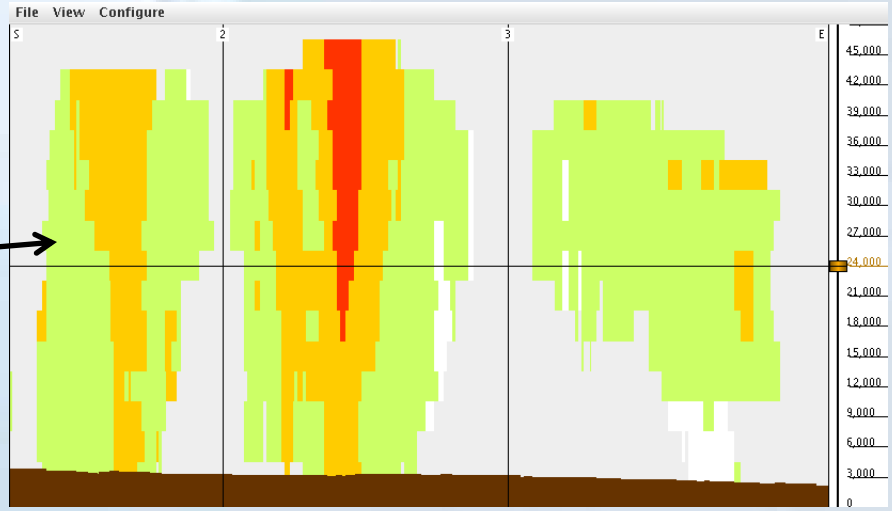
GTG-Nowcasting (GTG-N)

- **Observations driven**
  - In-situ EDR – Aircraft measurement of eddy dissipation rate (EDR).
  - NTDA EDR - Uses NEXRAD radar data : Doppler spectral width ⇒ EDR
- **Rapid updates (~15 min)**
- **To be Operational - 2011.**

24 hrs of UAL in situ EDR



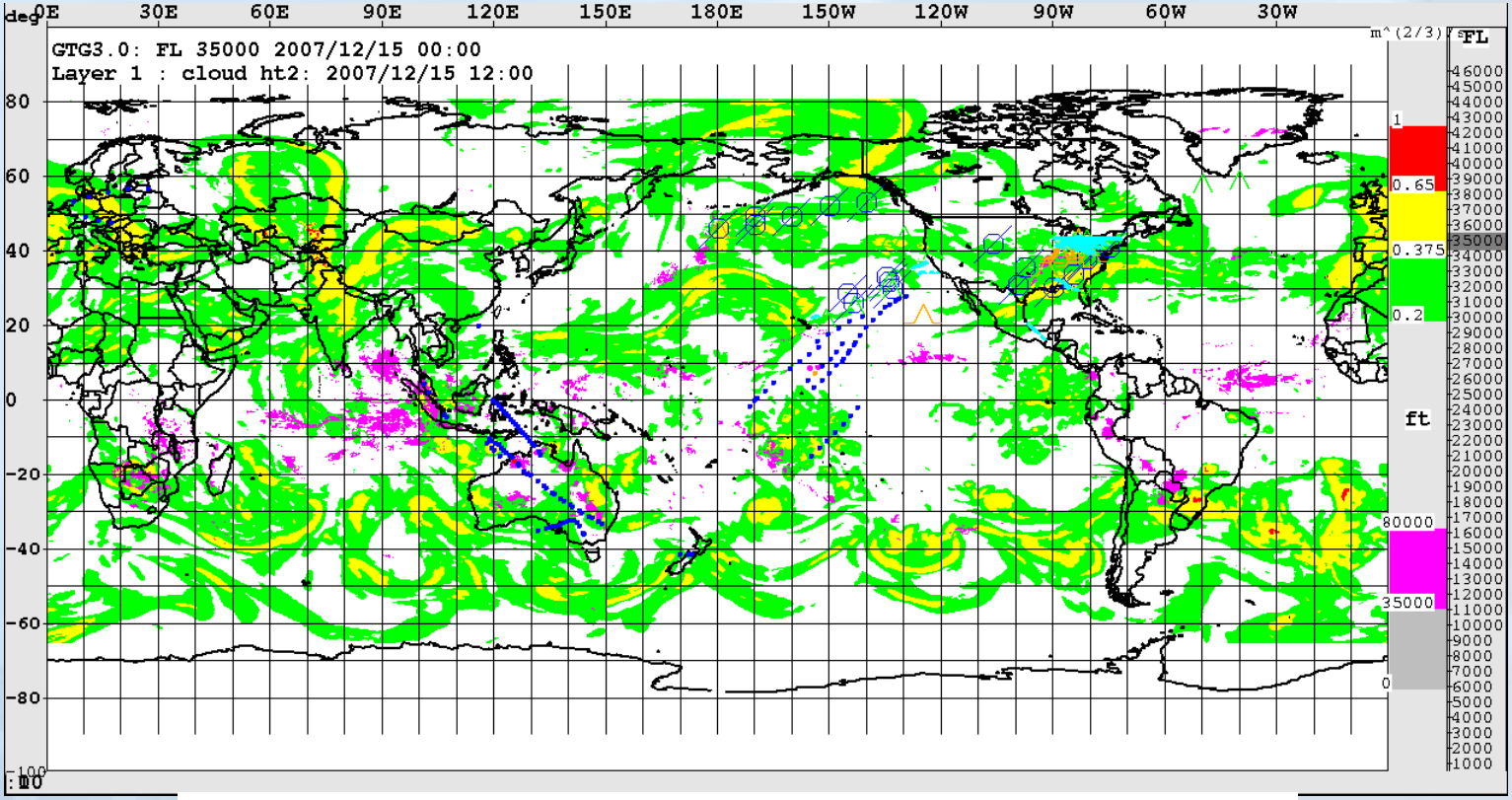




In the pipeline….

Global GTG

- GFS-based
- Output expected to populate SAS of the NextGen 4D virtual data cube



GFS GTG 12-hr fcst, magenta=cloud tops>35,000 ft, AIREPs, *in situ* turbulence measurements from Delta, United and Qantas aircraft, ± 90 min (blue =null, light, orange=moderate, red severe turbulence)

Icing Research Team

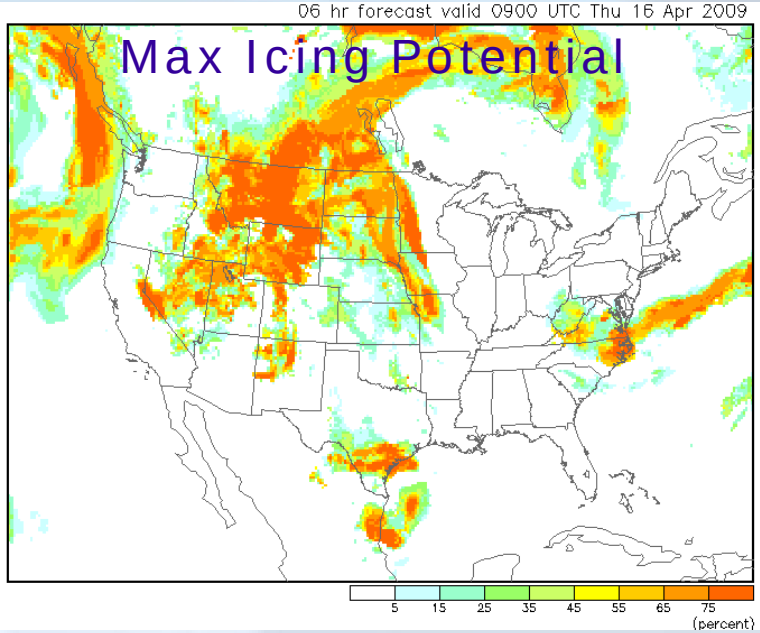
Lead: Marcia Politovich, NCAR

Collaborations: AAWC, NASA, GSD

Current/Forecast Icing Potential/Severity

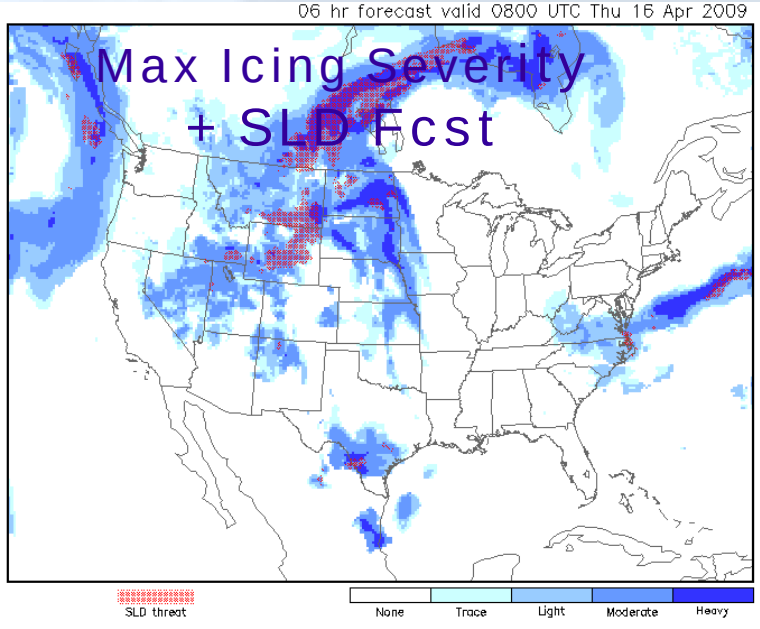
CIP/FIP on ADDS

- Diagnosed Icing Severity + SLD
- Fcst Icing Potential Only
- Forecast out to 12 hrs
- Based on RUC-13 and fuzzy logic algorithm

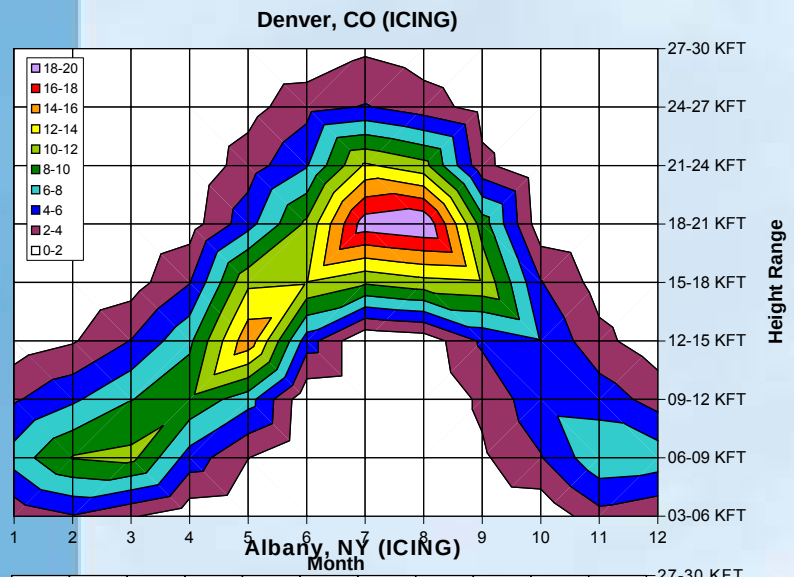


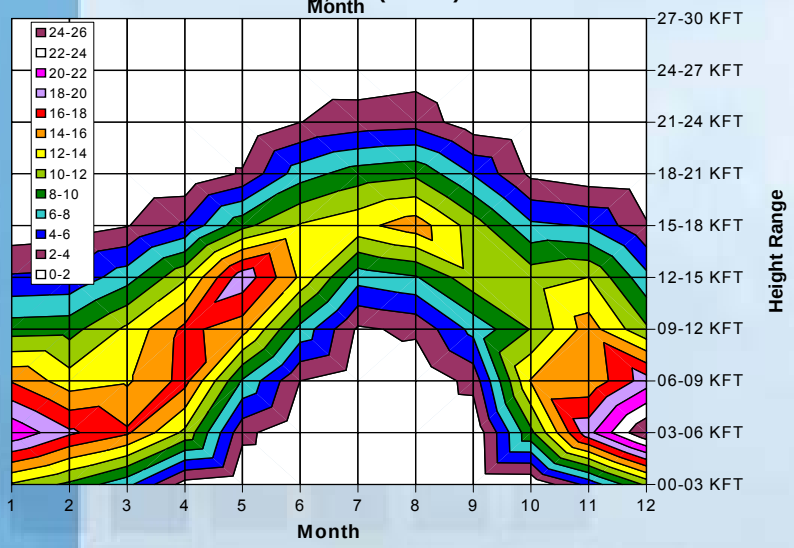
CIP/FIP on Experimental ADDS

- Calibrated CIP + FIP probabilities
- Added forecasts icing severity and SLD



Icing "climatologies"

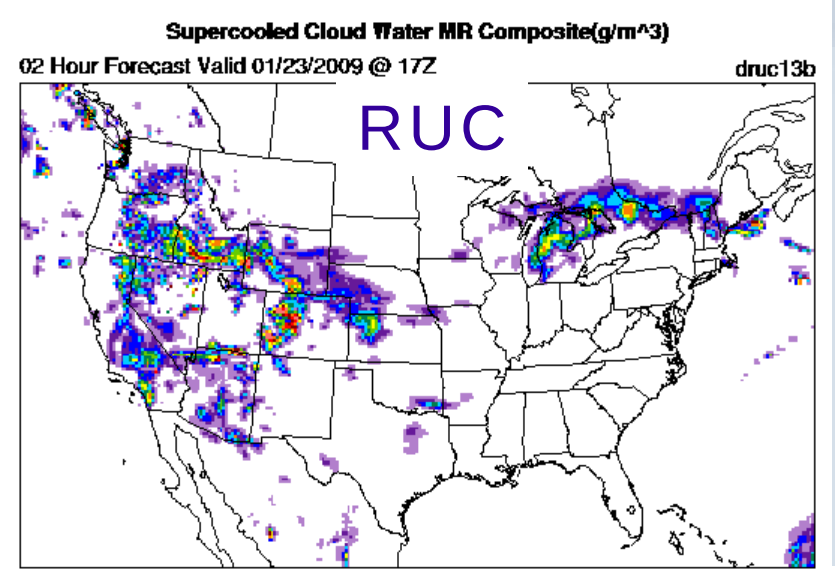


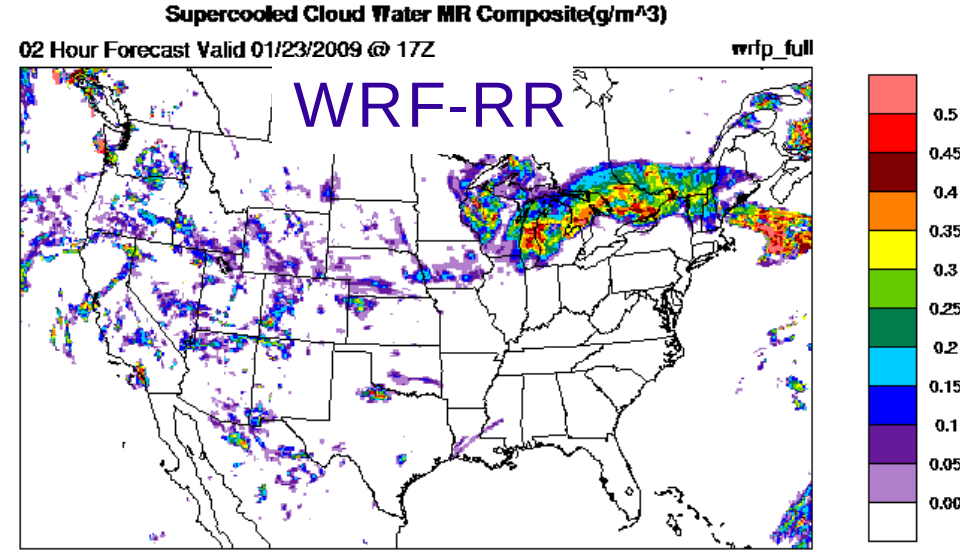


- **For major airports around country.**
- **Use soundings, CIP analyses, weather observation surrogates for the icing condition**
- **Wide variety of uses**
  - Appendix X
  - Field programs
  - Another CIP input?

Upcoming Improvements in FY09…

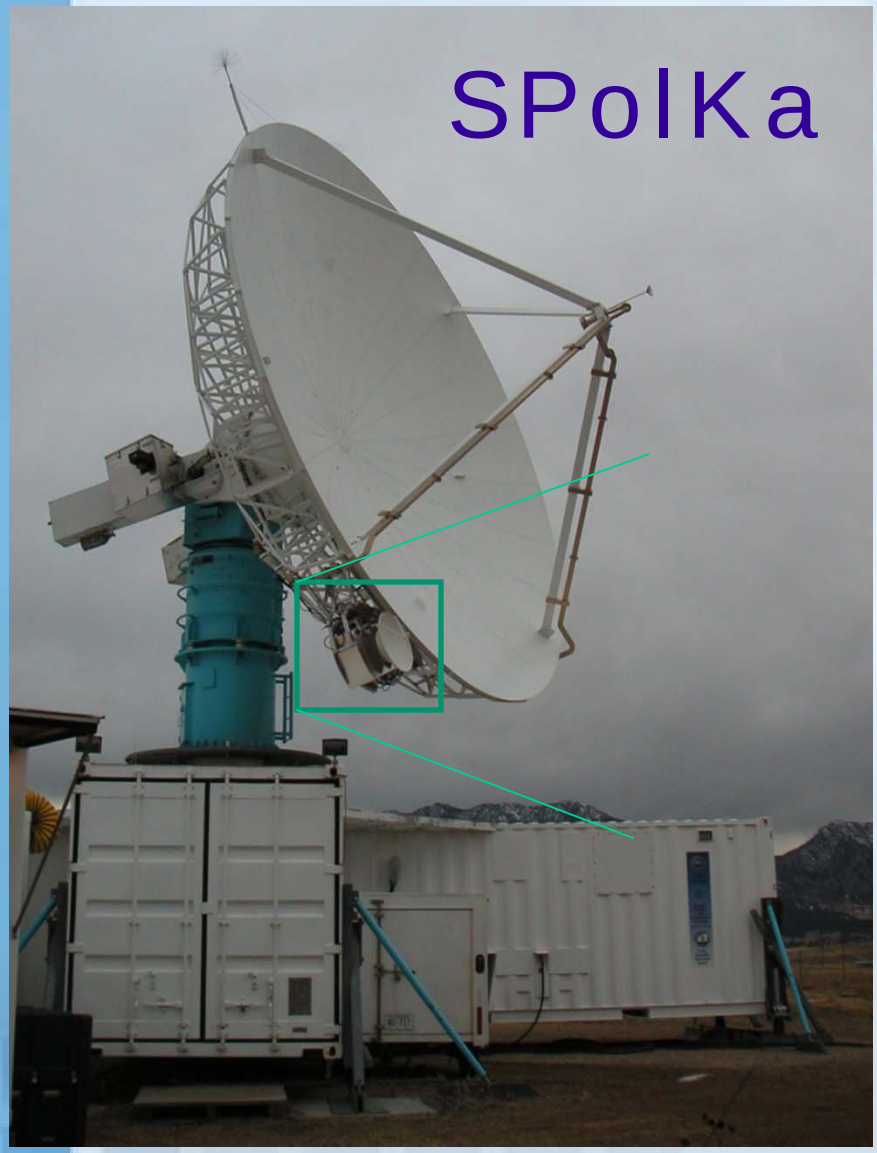
- **Testing FIP algorithms using WRF-RR**
- **Improve model microphysics**
- **Better understanding of freezing drizzle and rain formation**
- **More CloudSat analyses**
- **More Alaska case analyses**





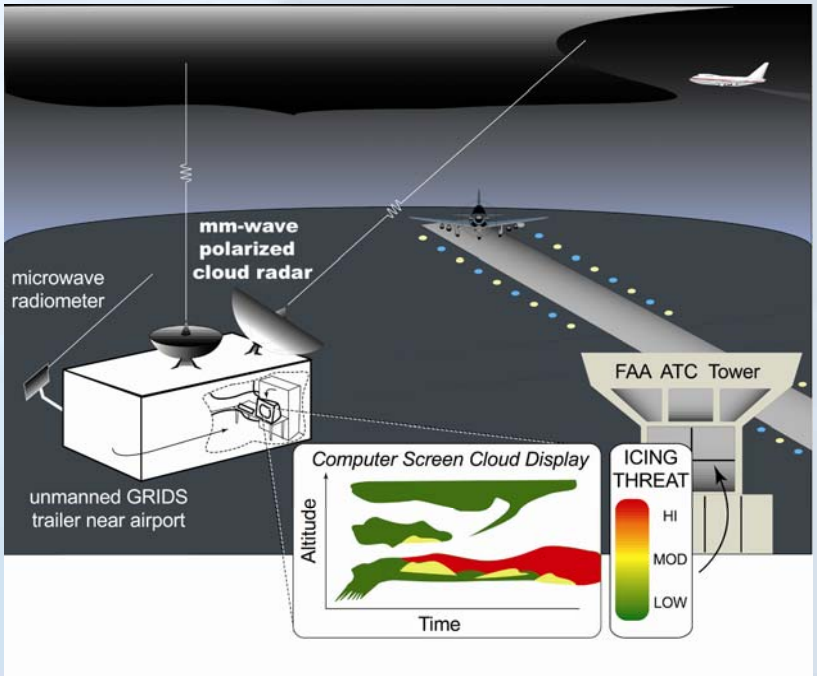
In the pipeline....

Polarmetric Radar



Products:
- Particle Phase
- LW mapping
- Dropsize Distributions
- SLD
- Icing Threat

Ground-Based Remote Icing Detection

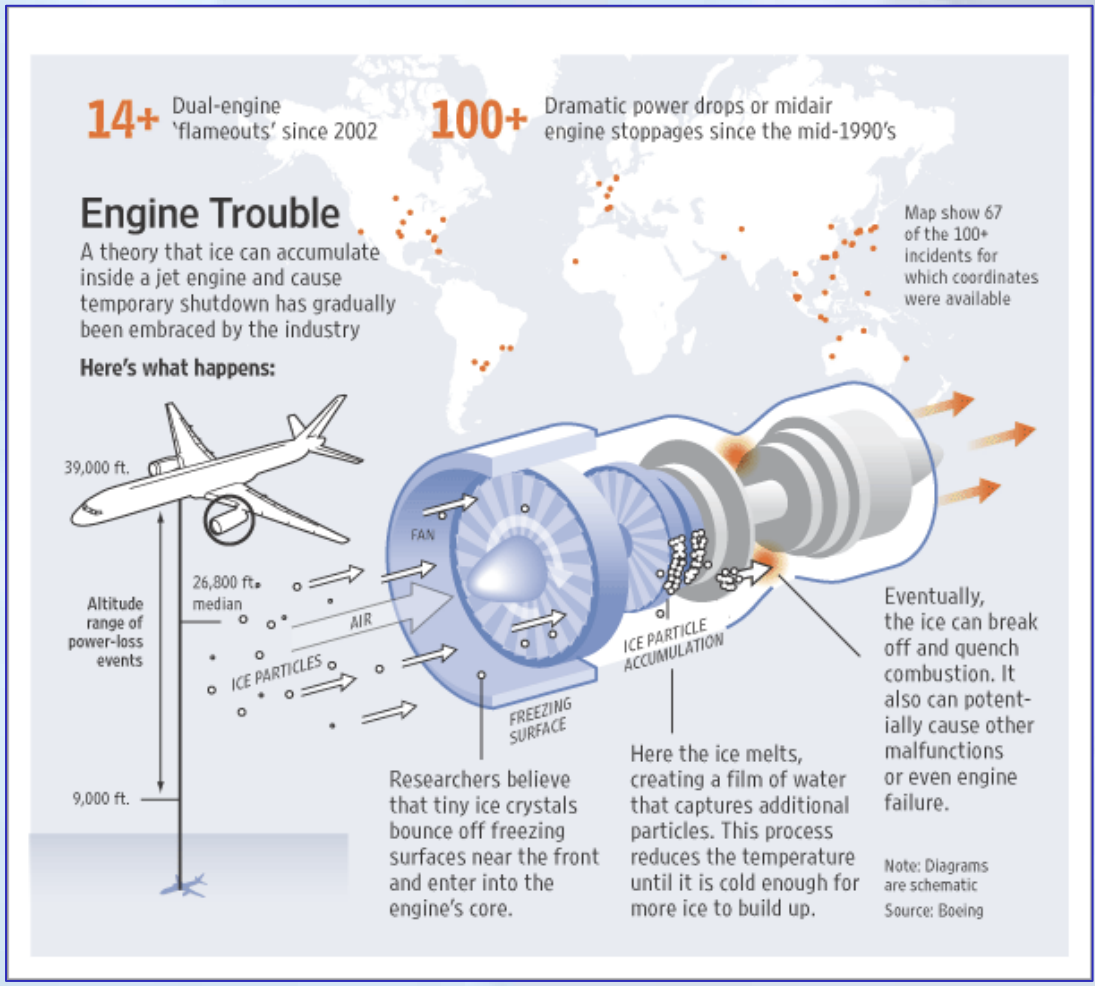


In the pipeline....

High Ice Water Content

Several incidents of late.

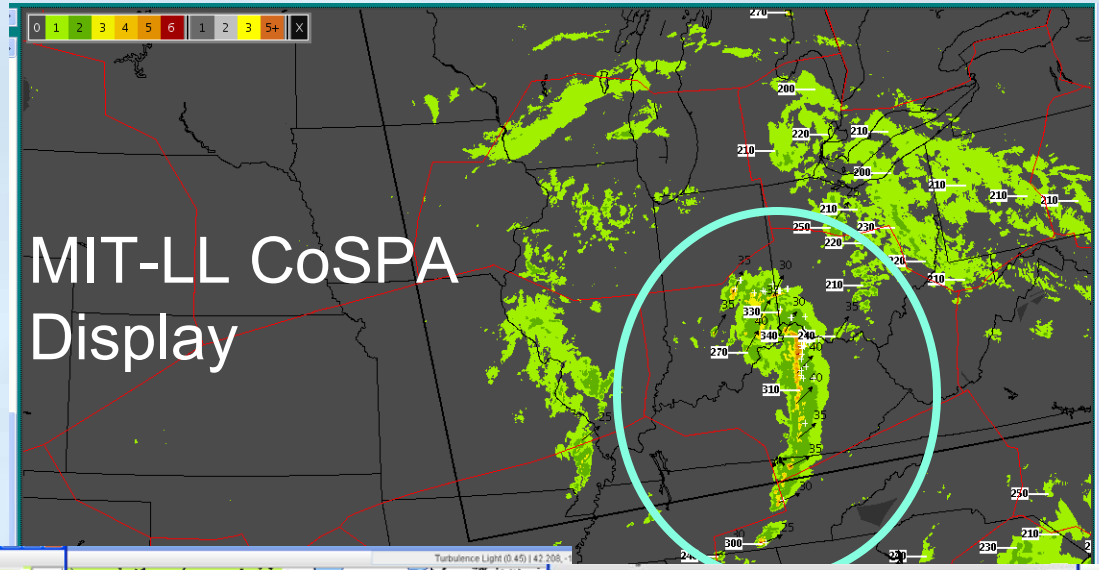
Build HIWC on-board warning tool based on available observations combined with up-to-date knowledge of the phenomenon.



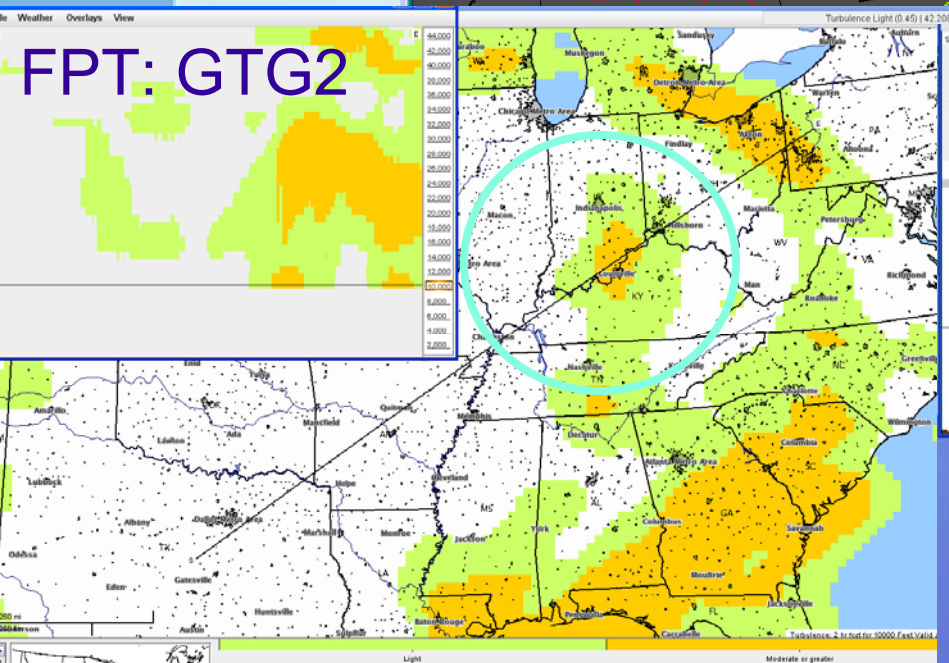
Wall Street Journal, 7 April 2008

Consistent Atmospheric Analysis

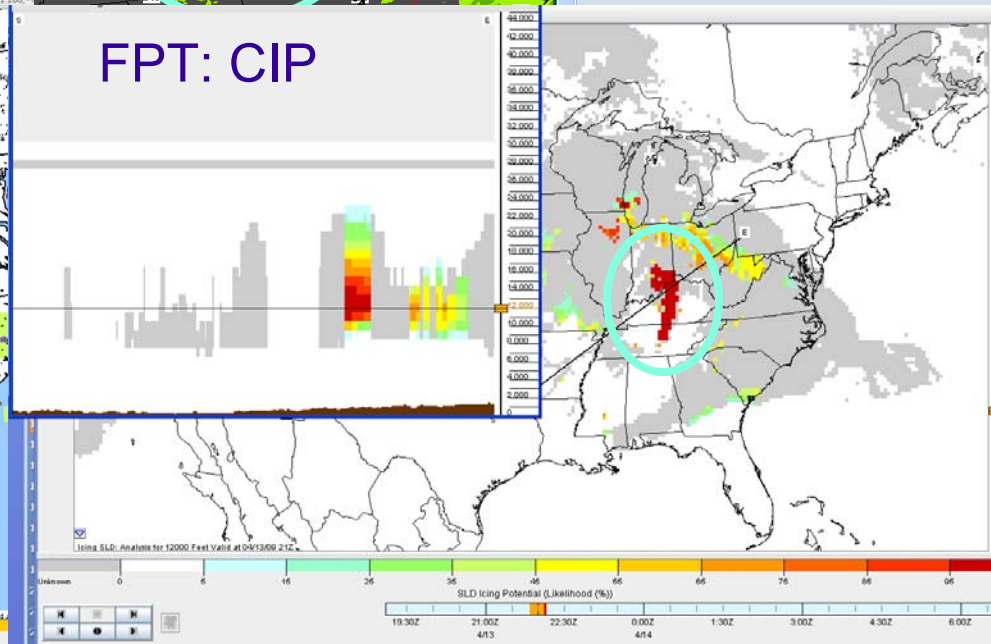
Precipitation Intensity & EchoTops



Turbulence



Icing



Questions ?????

Appendix / Details

Experimental Aviation Weather Hazard Products

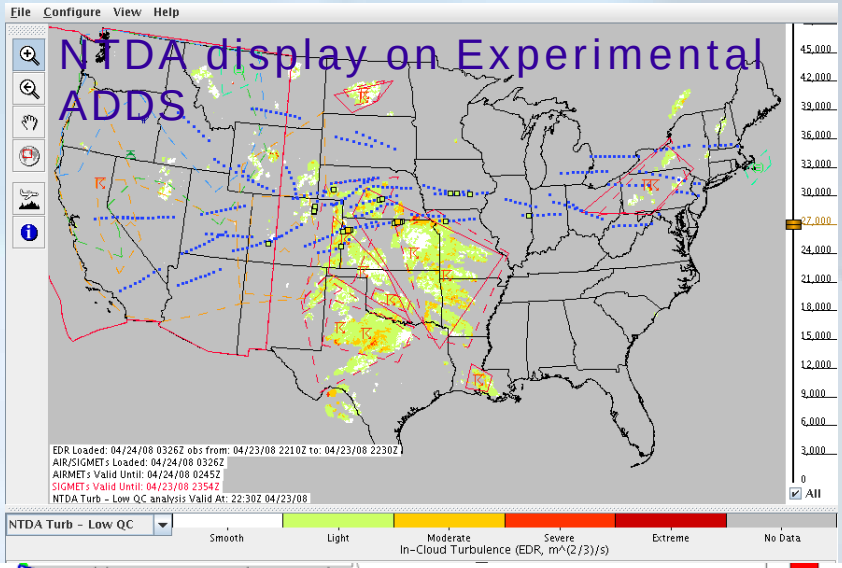
- **Links**
  - Winter Weather -- http://www.rap.ucar.edu/projects/winter/
  - Icing (CIP/FIP) - http://www.weather.aero/icing/
  - Turbulence (GTG)
  - Convective - http://www.weather.aero/convection/

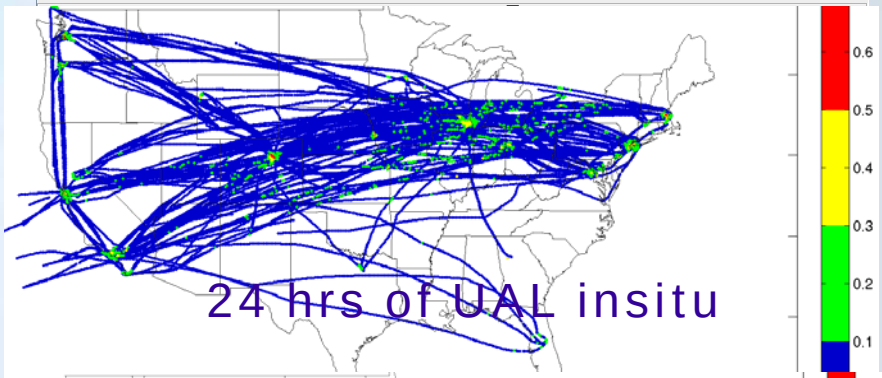
Turbulence Nowcast/Forecast Product: Graphical Turbulence Guidance (GTG)

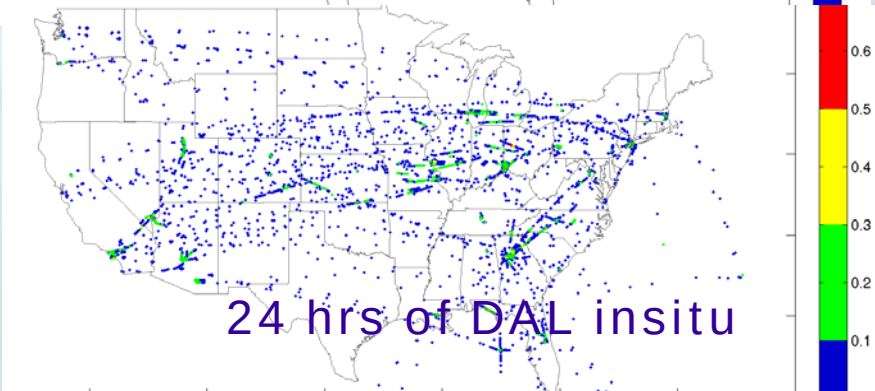
- **Based on RUC, GFS, or WRF NWP forecasts**
- **Current work areas:**
  - Optimal use of *in situ* reports
  - Probability of MOG,SOG > some EDR threshold
  - Improve forecasts of severe turbulence
  - Alternative combination methods
  - Explicit MWT, CIT diagnoses (DCIT) and forecasts
  - Global applications (global GFS, regional WRF)
  - Incorporate satellite-based feature detectors
- **GTG-N**
  - Rapid updates (~15 min)
  - Combines most recent observations, GTG, DCIT
- **Output expected to populate the SAS of the NextGen 4D virtual data cube**

New Observations : Turbulence

- **NEXRAD <u>in-cloud</u> Turbulence Detection Algorithm (NTDA)**
  - Uses NEXRAD radar data Doppler spectral width ⇒ EDR
  - NTDA-1 deployed on all NEXRADs in 2008 as part of ORPG Build 10
  - NTDA-2 Build 12 update (2010)
    - Prototype running in real-time at NCAR on Level II data from 133 NEXRADs
    - Experimental CONUS mosaic of in-cloud EDR produced every 5 min.
- **In situ measurements**
  - Provides atmospheric turbulence metric: eddy dissipation rate (EDR), actually $\varepsilon^{1/3}$ ($m^{2/3}$ / s)
  - 100 UAL 737s and 100 UAL 757s
  - 70 DAL 737-800s
  - 4 SWA aircraft in test evaluations (expect fleet implementation on ~ 280 737-700s in CY09)







In-Flight Icing Hazard Products Currently Available

- **CIP/FIP**
  - Gridded, 4-dimensional icing products
  - Icing severity, probability and SLD likelihood
- **CIP: combines observations and model output**
  - Fuzzy logic technique to pull out icing interest fields
  - Weighted and combined
- **FIP: similar to CIP but only weather models are used**
- **Both: 20km x 20km x 1000ft, issued hourly**
- **FIP Forecast lead times 1,3,6,9 h**

CONUS C&V Probabilistic Forecast

Features

- 1-12 h forecasts initially, later extended toward 24-30 h
- Consolidates NWP, MOS, & observations-based methods
- Rapid updating, major refresh hourly, minor refresh 15-min
- 0-h diagnosis - probabilistic C&V in observation gap areas
  - uses previous 1-h probability forecast information in gap areas
  - constrained to match observations at observing points

“This research is in response to requirements and funding by the Federal Aviation Administration (FAA). The views expressed are those of the authors and do not necessarily represent the official policy or position of the FAA.”