NOWCASTING – NOW AND THEN

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Acknowledgements:
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Oct. 8 2014, 3:45 pm SIMULATED / OBSERVED CLOUD IMAGE

OUTLINE / SUMMARY

- **Current status**
  - Traditional nowcasting methods empirically / statistically based, subjective
  - NWP not ready yet - Last frontier
- **Satellite-derived products** fill gap in support of nowcasting
  - Products of opportunity derived directly from selected set of observations
  - Fragmented approach
    - Disconnected observations, methods, production streams, teams
- **NWP-based nowcasting**
  - Synthesize all obs. & NWP data into common reference state (5D analysis)
  - Derive all user products from common reference state
  - Comprehensive, potentially high quality & consistent guidance
- **Examples**
  - Simulated Weather IMagery (SWIM)
  - Probabilistic tornado indicators
- **Challanges / opportunities**
  - Quality and timeliness of 5D analysis

NOWCASTING

- **Definition**
  - Fine scale analysis and ~ 0-3 hour forecast
- **Context**
  - Larger spatial / longer timescales covered by dynamical (NWP) approach
- **Traditional** approach to **nowcasting**
  - "A human given the latest radar, satellite and observational data will be able to make a better analysis of the small scale features present and so will be able to make a more accurate forecast for the following few hours"

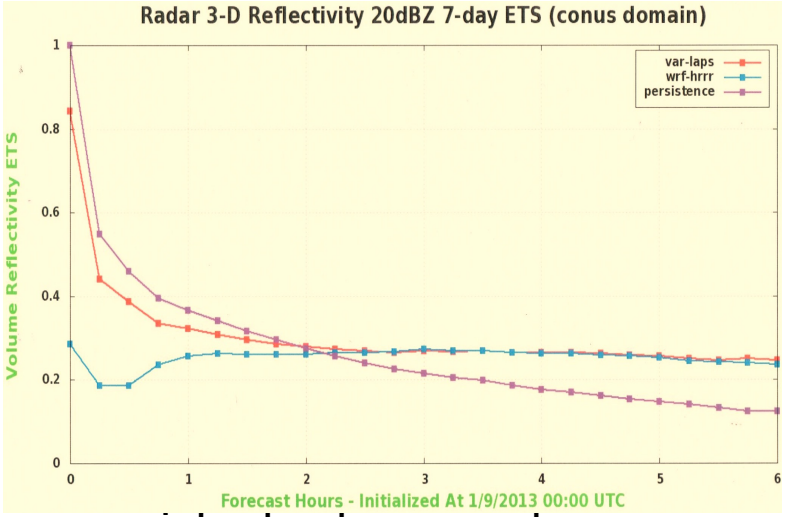
Wikipedia on Nowcasting, 2017

- **Dynamical nowcasting**
  - What's the holdup? Model or its initialization?

NWP PARADOX

- **NWP basics**
  - Initial value problem – most accurate info about system at initial time
    - Due to chaos, forecast skill should gradually drop with lead time
  - Most weather forecasts beyond ~6 hrs based on NWP

- **Reality**
  - Paradoxically, fine scale measures of *forecast skill increase w lead time*



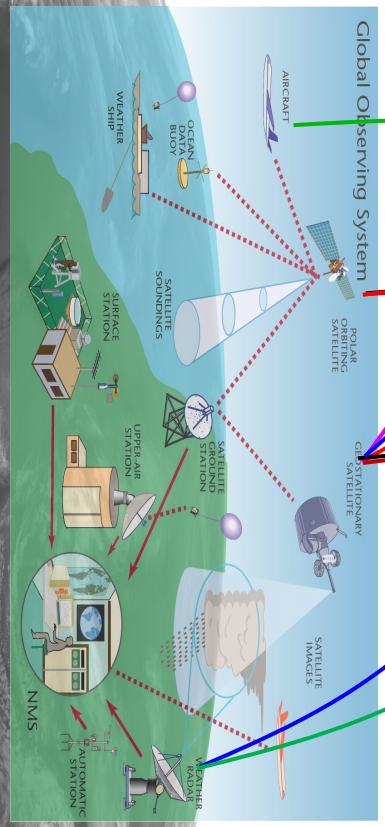
- **Explanation**
  - **Large scales**
    - Analyzed well in initial condition
    - Skill drops with lead time
  - **Fine scales**
    - **Not or poorly analyzed / initialized**
    - Model forecast creates fine scale motions consistent w large scales
      - Not a "forecast" per se but a "simulation"
    - => Skill initially increases with lead time

Primary problem with initial value, not model

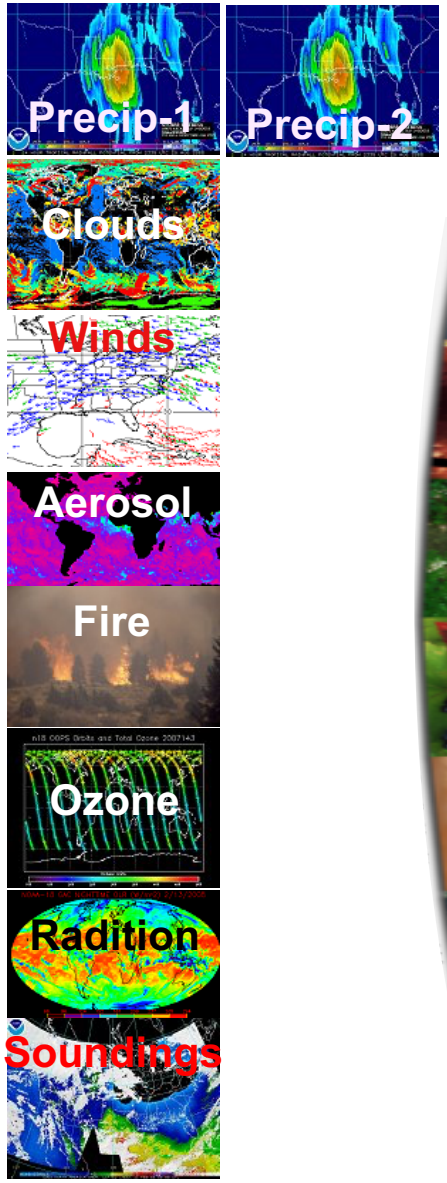
TRADITIONAL NOWCASTING TECHNIQUES

- **Observations**
  - In-situ, radar, satellite
- **Analysis**
  - Manual (or computer aided) analysis of selected observations
  - Spatial mosaic of observations (eg, radar)
  - **Derived products** (eg, satellite)
- **Forecast**
  - Subjective extrapolation
  - Advection of existing systems
    - Trend in recent past can be considered
  - Statistical enhancements to advection & trends
- Short of a theoretically founded NWP solution to Nowcasting
  - Traditionally generated nowcast products fill void

PRODUCT GENERATION SCHEMATIC



OBSER-VATIONS



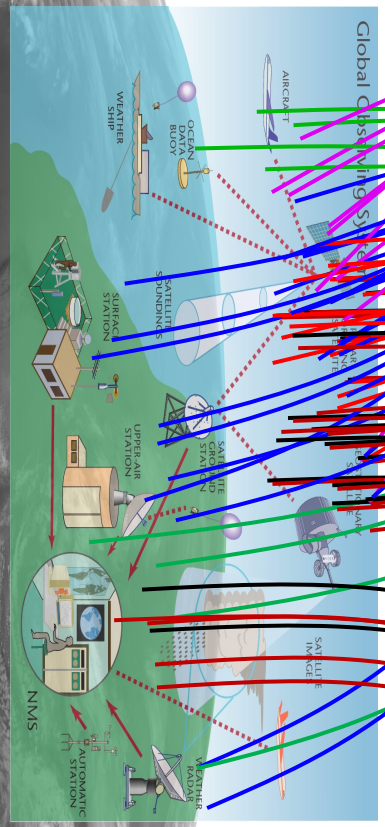
USER PRODUCTS

APPLI-CATIONS

Lacking theoretically sound NWP solution, traditional nowcast product generation proliferates

NATURE

PRODUCT GENERATION - REALITY



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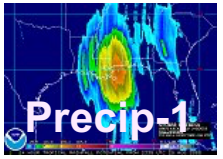
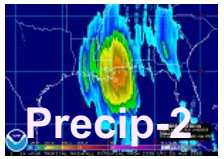
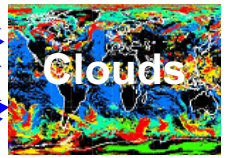
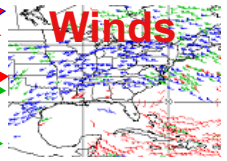
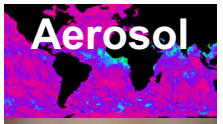
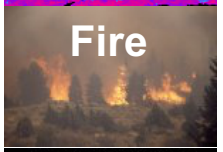


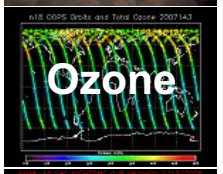


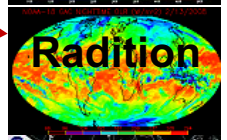


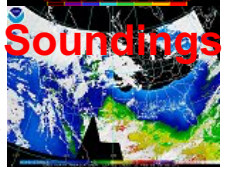












USER
PRODUCTS

APPLI-
CATIONS

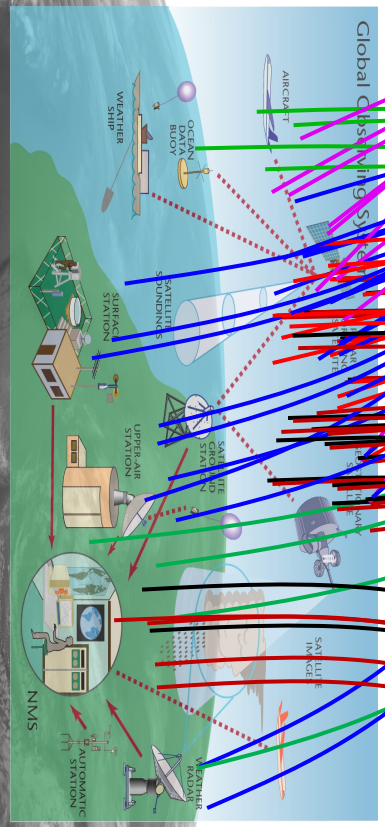
NATURE

TRADITIONAL PRODUCT GENERATION

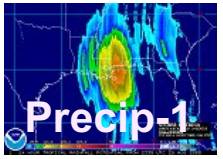
- **Knowledge base -** Invaluable
  - Direct relationships (physical and/or statistical) between
    - Selected set of observations (& possibly NWP background)
    - Specific user products (variables or phenomena of interest) – Products of opportunity
      - Cloud drift winds, cloud top pressure, overshooting cloud tops, cloud optical depth, etc
- **Input data** - Only selected / individual observations used
  - Multiple versions of same product
  - Suboptimal products
  - Inconsistency across & in quality of products
- **Methods** - Large set of disconnected algorithms w partially overlapping functionalities
  - Inefficiencies in development, operations, maintenance
- **Workflow – S^3**
  - Stand-alone / segmented / stove piped

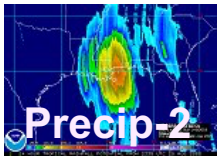
Resources scattered across stovepipes, benefitting indiv. products

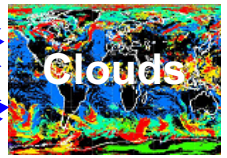
PRODUCT GENERATION - REALITY

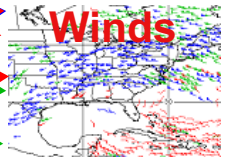


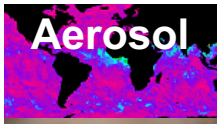
OBSER-VATIONS

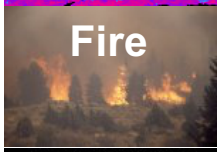


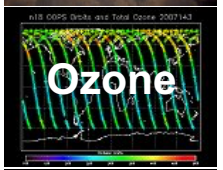


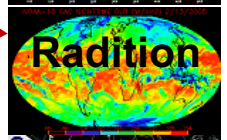


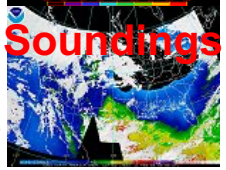












Is there an alternative?

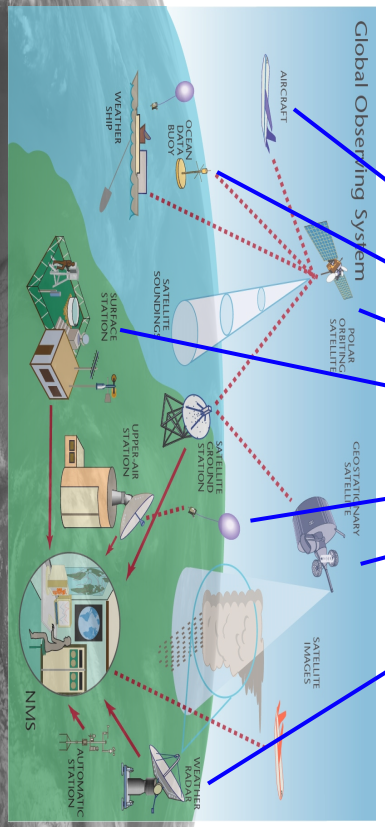
NATURE

Numerical Weather Prediction (NWP)

USER PRODUCTS

APPLI-CATIONS

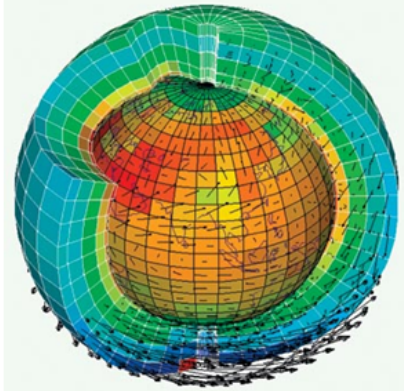
NWP-BASED PRODUCT GENERATION



OBSER-VATIONS

OBSERVATION OPERATORS

NWP
DA + MODEL



SIMULATED NATURE
Incl.atm. chemistry, land, ocean, ice, etc

Object Oriented Repositories for Obs Opers, DA schemes, Numer. Models, Product Generators

PRODUCT GENERATORS

NATURE

USER PRODUCTS

APPLI-CATIONS

NWP-BASED PRODUCT GENERATION

- **Modularize by methodology -** Not by individual obs. or products
  - Transparent design, systematic & simplified approach, efficiency
    - Potential for faster progress, clearer focus, integration, enhanced collaboration

All resources come to bear on common problems, benefitting all

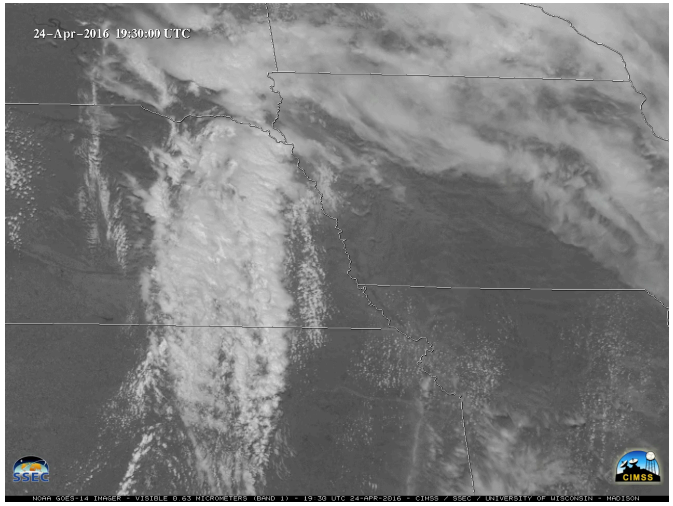
- **Simulate nature** - Digital representation (common reference state)
  - Synthesize all observations using NWP first guess & DA methods
    - Comprehensive 5D dataset - 3D in space, 1D in time & across variables
  - Elements of product generation algorithms to be used in obs. operators
  - Some pre-generated products can be "assimilated" for expediency
    - Products result of translucent filter of obs – Variational use of obs preferred

- **Derive all products** from simulated nature (common reference state)
  - Potentially improved quality due to use of all obs. & model constraints
  - Consistency across products
  - Elements from "product generation" algorithms can be reformulated & used

WILL IT WORK?

- **Challanges**
  - High fidelity
    - Use of spatially/spectrally detailed obs. (multiscale approach), balance
  - Short latency
    - Efficient DA (multiscale approach); adequate computational resources
  - Streamlined workflow
    - Realign satellite community, reconfigure traditional algorithms into repositories

- **Examples**
  - All-weather imagery from 5D cloud analysis
  - Tornado warning – NSSL
  - Radar reflectivity nowcasting – OU, LAPS
  - Visibility around topography



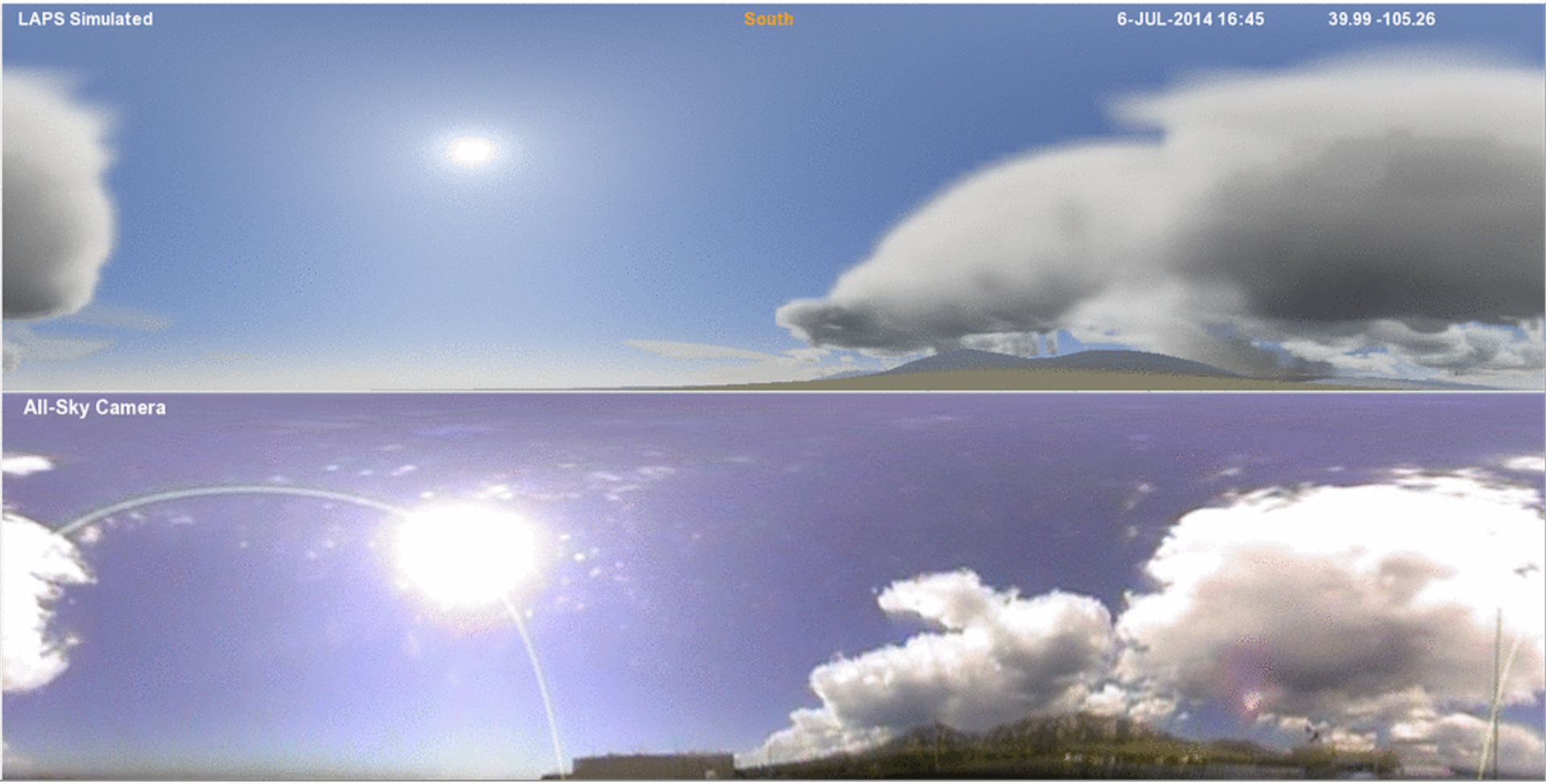
- **Practical approach**
  - Gradually shift resources from traditional to NWP "product generation"
    - Focus developmental resources on NWP-based approach
  - Establish repositories, adopt Object Oriented design
    - Obs operators, DA – JCSDA; Model – NGGPS; Product generation - ?
  - Maintain traditional schemes until NWP approach supercedes them

3D 500 m CLOUD ANALYSIS

Courtesy Steve Albers

NOWCASTING WITH LOCAL ANALYSIS AND PREDICTION SYSTEM – **LAPS**

Clouds as seen from top of DSRC building in Boulder by ***LAPS ANALYSIS***

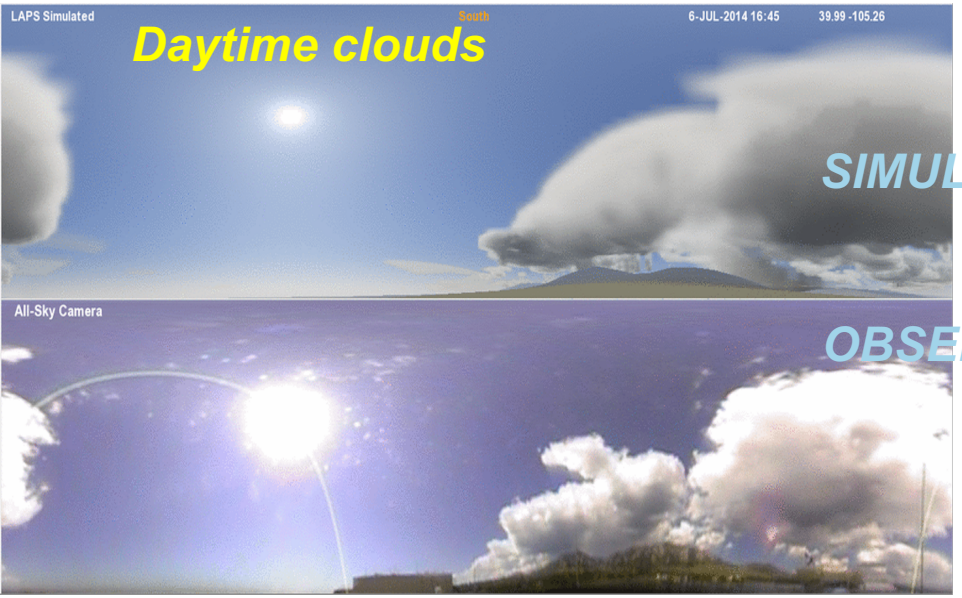


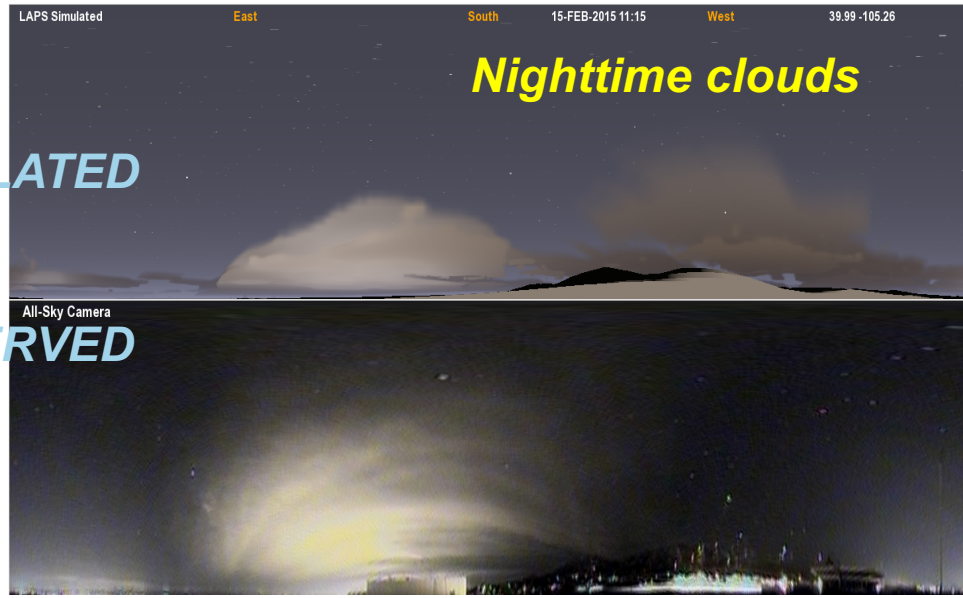
16:45 UTC Jul 6, 2014

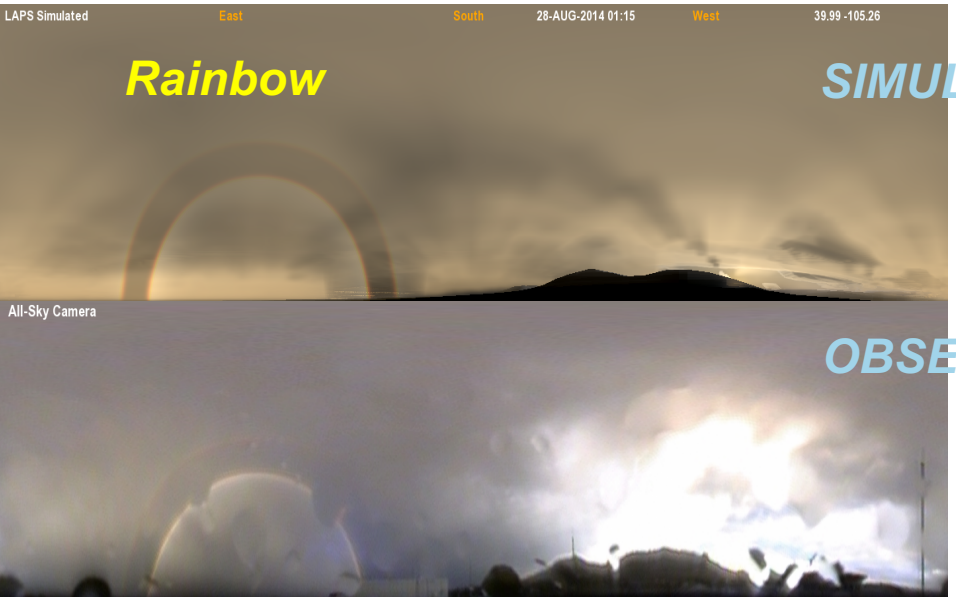
Camera images as independent validation

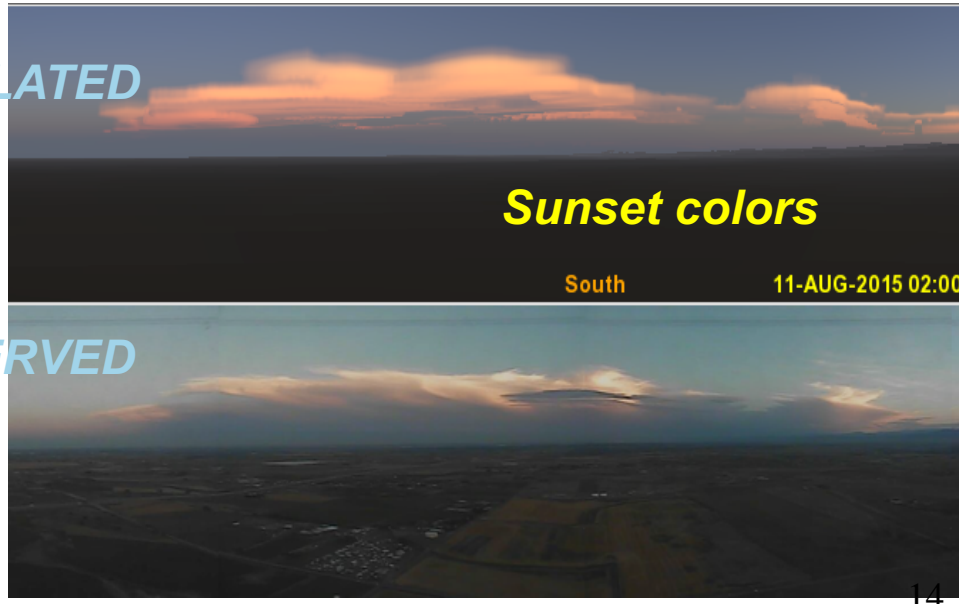
ALLSKY CAMERA

SIMULATED WEATHER







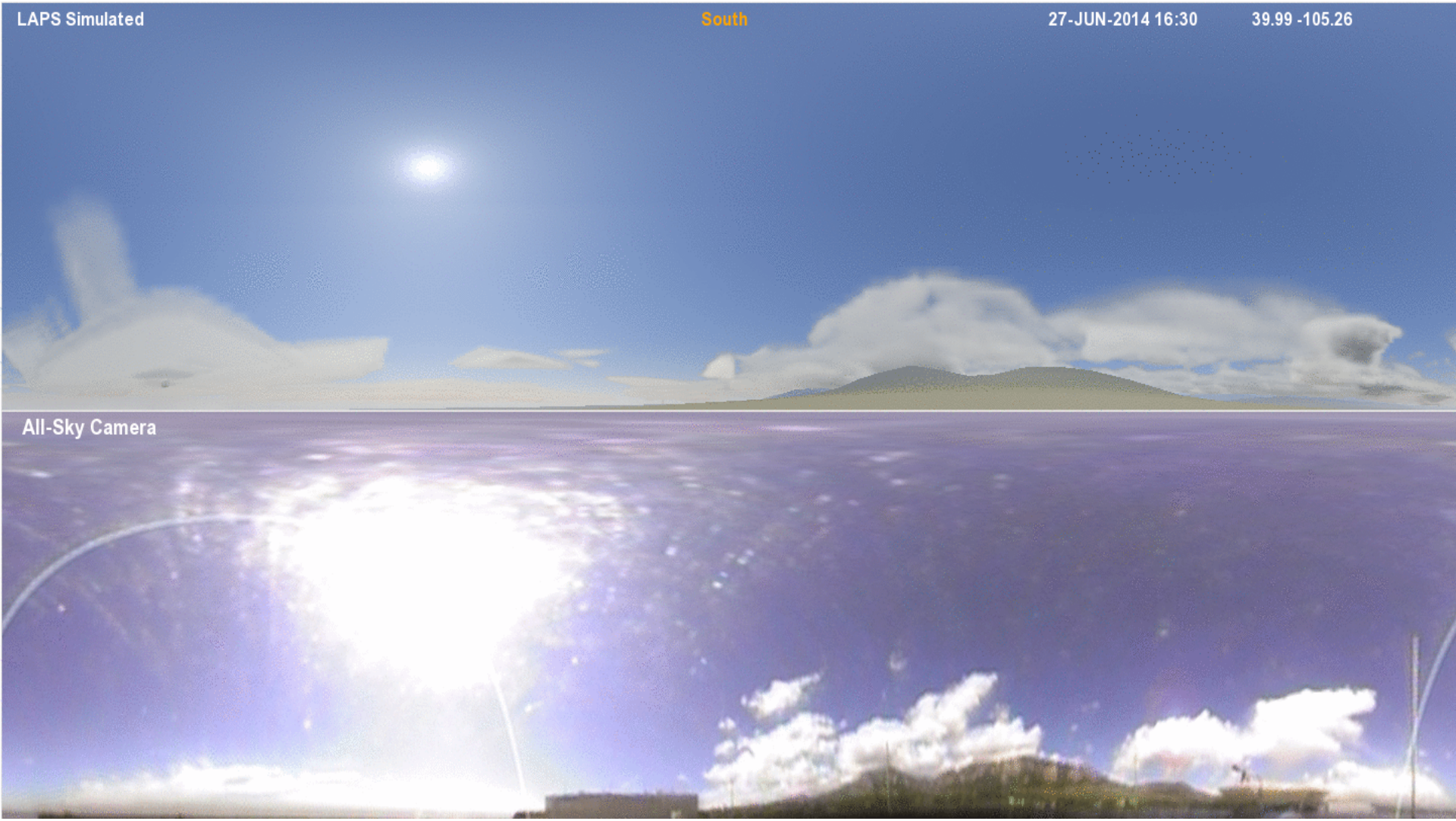


Courtesy Steve Albers

3D 500 m CLOUD ANALYSIS - LOOP

Courtesy Steve Albers

Unique feature of LAPS, critical for WOF, Nextgen, etc



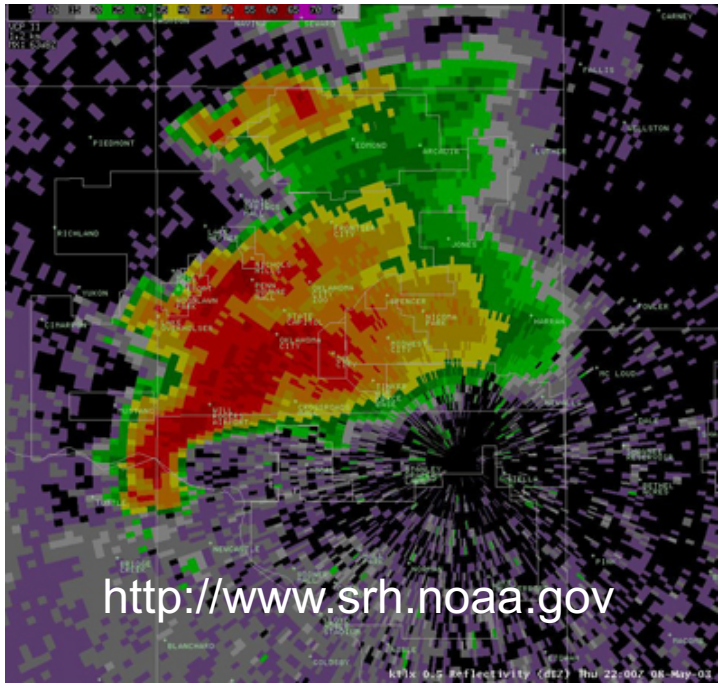
16:30-18:45 UTC June 27, 2014, 15-min frequency

ALLSKY CAMERA

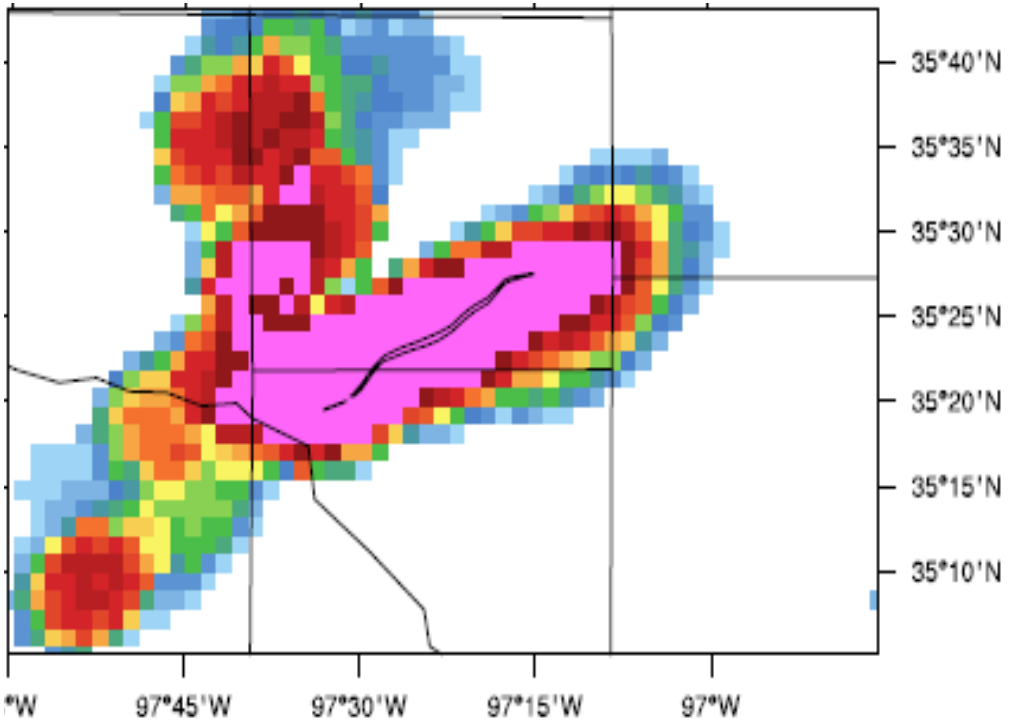
GSI hybrid DA for May 8th 2003 OKC Tornadic Supercell

Xuguang Wang *et al., 2015, MWR, to be submitted*

Radar reflectivity 22:00 UTC



1-hr Prob. fcst. Initialized 2200 UTC

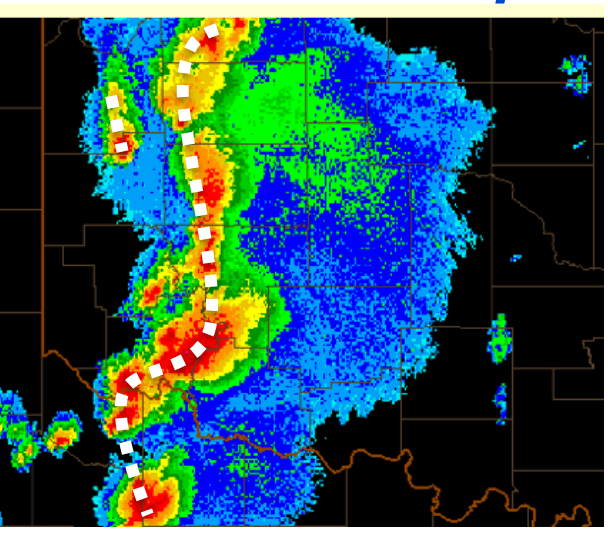


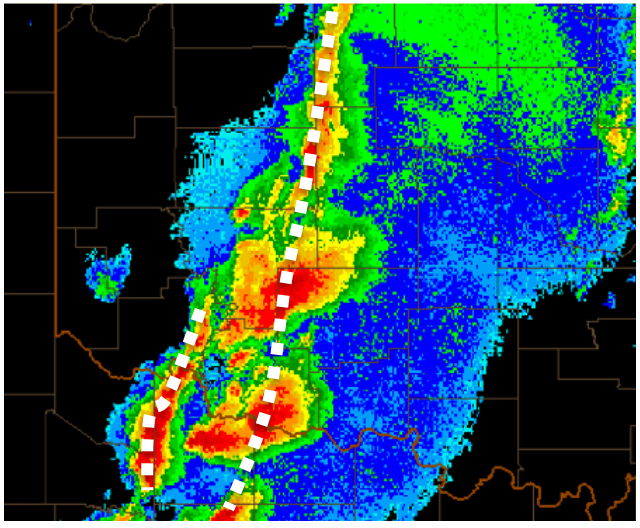
Isolated supercell 2210 – 2400 UTC with F-4 tornadoes in Moore & Oklahoma City (OKC) between 2210—2240 UTC

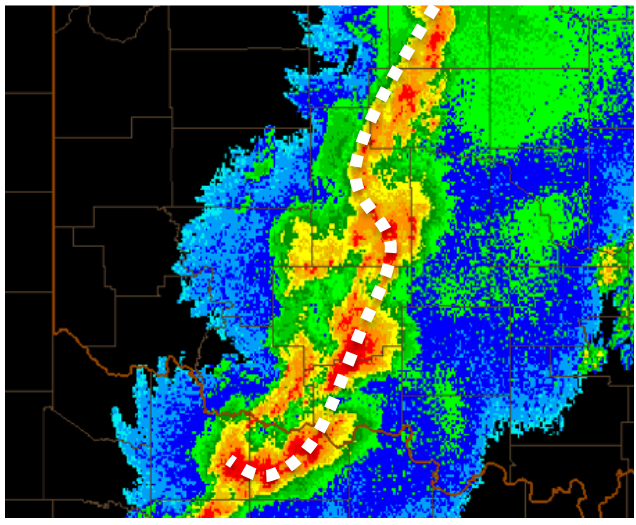
SW OK TORNADO, 16 MAY 2015

Wheatley & Wicker

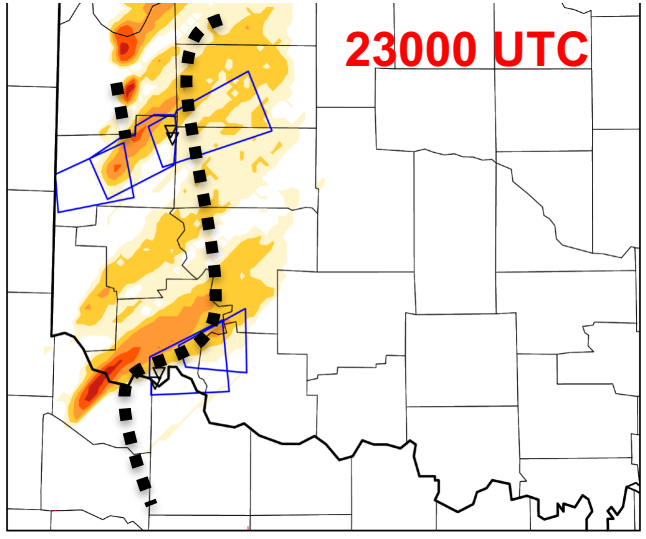
Observed Composite Radar Reflectivity

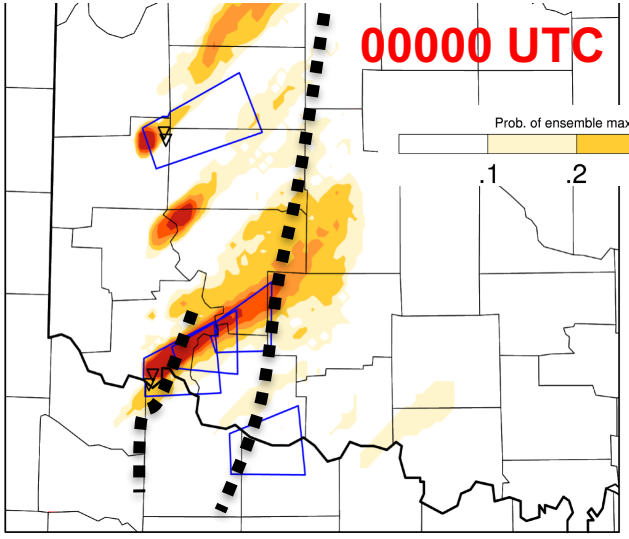


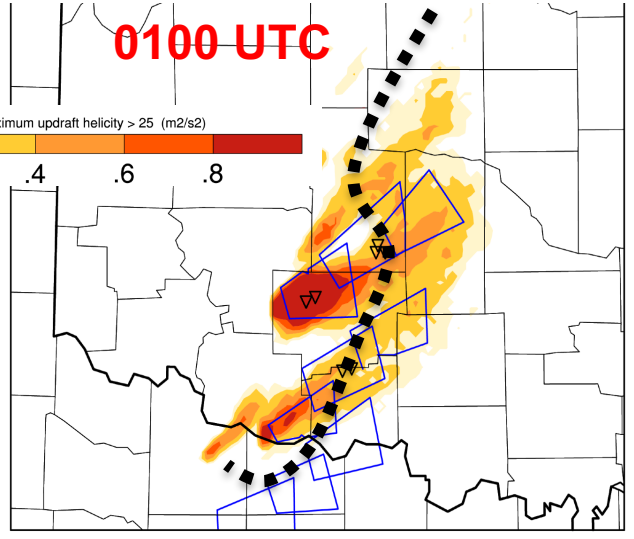




3km radar+satellite 15-min update EnKF initialization







Real-time 90-min Prob. Updraft Helicity Forecast (>25m^2/s^2)

OPPORTUNITIES / PROMISING AREAS

- **Observational operators**
  - Harvest possible schemes from satellite product generation algorithms (CRTM, etc)
- **Data assimilation**
  - Thermodynamically balanced microphysical / aerosol parameters
  - Adjoint-based 4DVar w ensemble-based covar. – Success at ECMWF
  - Multiscale technique
- **Numerical models – R^3**
  - Resolution (space), resolution (physics), resolution (probabilities)
- **Product generation**
  - Reuse elements of traditional product generation algorithms
  - Expand UPP

OBSERVATIONS LEAD THE WAY

- **Which way?**
  - Disjoint suboptimal products based on subsets of observations
    - “React to individual snippets of nerve impulses”
  - Integrated, holistic, digital depiction of reality
    - ”Process totality of sensory input & form view before reacting”

- **Invest in advanced use of observations**
  - Modular NWP-based approach to nowcasting
  - Rational study of observational needs in that context

BACKGROUND