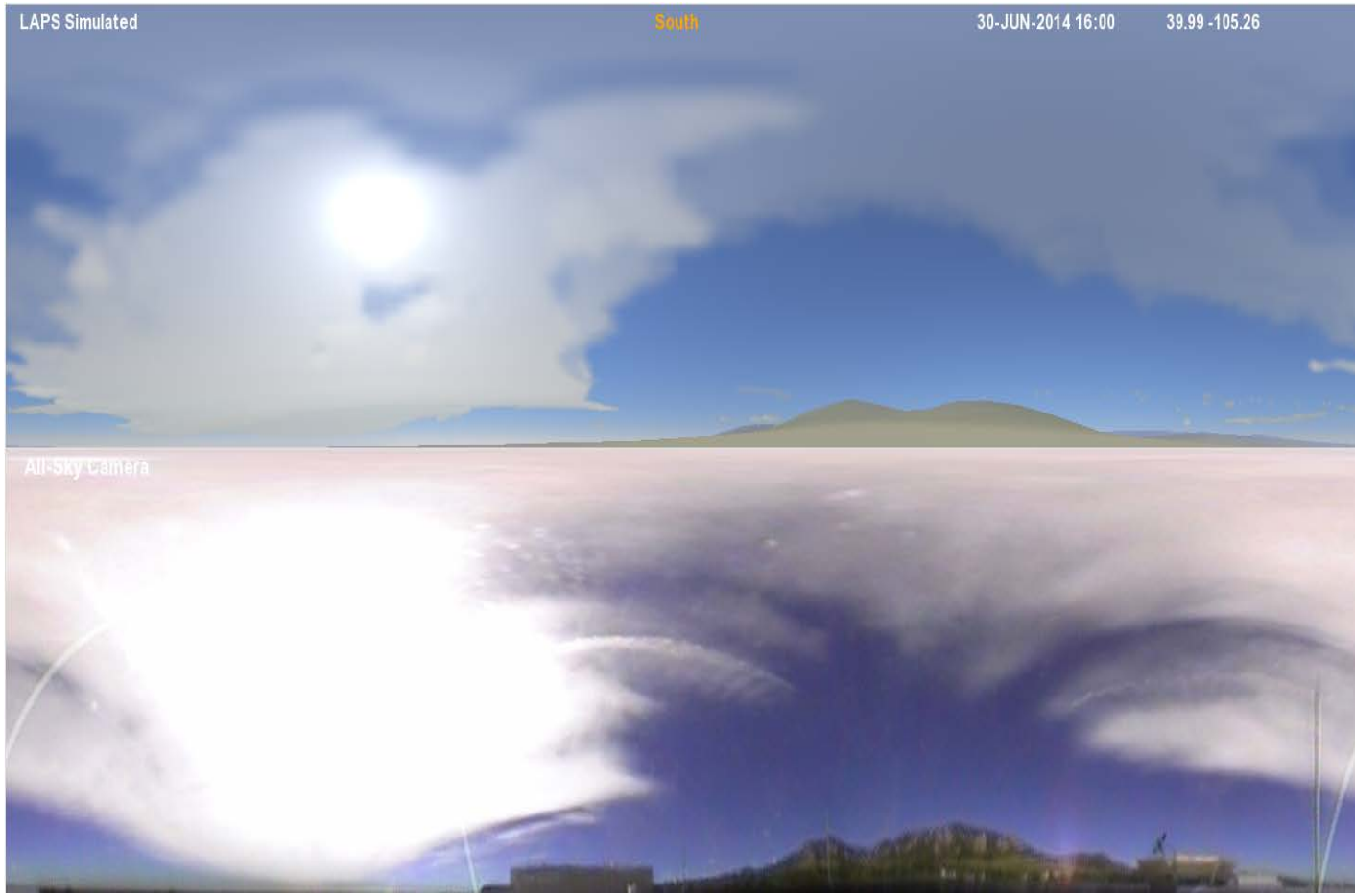
NOWCASTING WITH THE LOCAL ANALYSIS AND PREDICTION SYSTEM (LAPS)

Zoltan Toth,
Yuanfu Xie, Steve Albers[1], Hongli Jiang[1], and Craig Hartsough[2]

Global Systems Division
NOAA/OAR/ESRL

[1] CIRA at GSD
[2] CIRES at GSD



Acknowledgements:
Drs. Steve Koch &
Louis Uccellini

VLAB Seminar – 30 June, 2014 – 16:00 UTC CLOUD IMAGE

OUTLINE / SUMMARY

- **LAPS history & user base**
  - 1989 – 2011 – multi-pass Barnes analysis
  - 2012 – Multiscale variational approach
  - Used operationally by 20+ US, private, international agencies
- **Qualities of LAPS**
  - Fidelity to reality (observations)
  - Consistency between situational awareness & NWP analyses
  - Nowcast (forecast) skill
  - Speed – Low latency, high frequency, high resolution
- **Drivers for change in use of LAPS**
  - Need for more coordination, cloud computing, WRN
- **VLab path to Nowcasting with LAPS**
  - Monitoring
    - 2.5 km / 15-min frequency CONUS & OCONUS 2/3D analysis
  - Nowcasting
    - For high impact events – Relocatable domain
    - 1km/5-15 min freq. 3D analysis, 1hr freq. 3-6 hr WRF forecast
  - Approach
    - Run on IDP server; Test off-line, in Testbeds, OPG
    - Engage with broader DA / user communities – LAPS Workshop, User Group

HISTORY OF LAPS

- Wind analysis & radar remapping (V, Z) 1989
- Cloud analysis / Hotstart 1991
  - Major innovation – 150+ citations
- T-LAPS - Terminal-LAPS at 40 ITWS/FAA sites 1992
  - Major advancement
  - 5-min update at 2km, **20+ years ahead of national guidance**
- O-LAPS – System adapted at OU / CAPS 1990s
- K-LAPS - Technology transfer to KMA 1990s
- Cloud analysis / hot start elements in other systems 1995-2005
  - ADAS, RUC, etc
- LAPS operationally used at NWS WFOs (AWIPS) ~1995
- New 2DVar surface analysis – multiscale STMAS 2004
- NOAA Tech Transfer Awards 2005, 2008
- Variational LAPS based on STMAS => AWIPS-II 2013
- Multiscale approach in hybrid GSI & other systems 2013 - 2014
- Variational LAPS transitioned to FAA operations 2012 - 2015

LAPS USER BASE

- NOAA
  - ~120 WFOs (via AWIPS), ARL, NESDIS
- Other US Agencies
  - DHS, DoD, FAA, CA DWR, GA Air Qual.
- Academia
  - Univ of HI, Athens, Arizona, CIRA, UND, McGill

Courtesy Steve Albers

- Private Sector
  - Weather Decision Tech., Hydro Meteo,
  - Precision Wind, Vaisala, Telvent
- International agencies (10+ countries)
  - **KMA, CMA, CWB, Finland (FMI)**, Italy, Spain
  - BoM (Australia), Canary Islands, HKO
  - Greece, Serbia, Nanjing Inst. of Met.

SOME KEY LAPS PARTNERS

Institute	Role	Contributions
IHR, CMA	LAPS POC in China	Satellite data, cloud analysis
FMI, Finland	LAPS POC in Europe	Cloud and Arctic apps
KMA	User, developer	Typhoon apps, parallelization, nowcasting
CMA and IUM	User, developer	MICAPS
Univ. Belgrade	User, developer	Dual-polarization radar
Vaisala US	User, developer	Lightning DA
NOAA ESRL	Central repository, main developer	Terrain following, cloud, parallelization, balance
NOAA WFOs	Principal users	Feedback on LAPS
CWB, Taiwan	User, developer	Typhoon, satellite data
FAA, US	User	Nowcasting
Toyota Racing	User, developer	Cloud analysis
Army Research Laboratory	User, developer	Nowcasting, balance

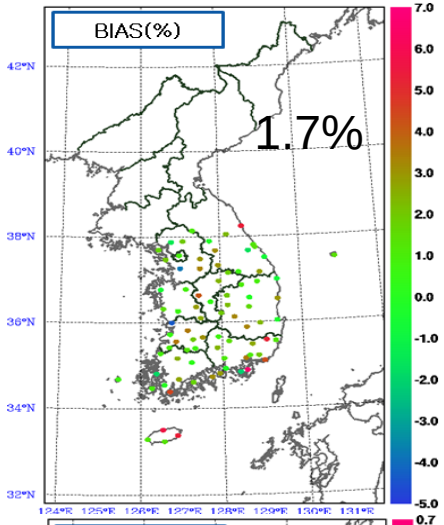
LAPS QUALITIES

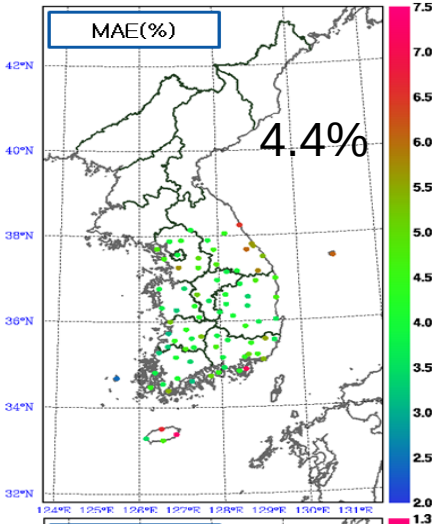
- **Fidelity to reality** (observations)
  - Due to use of Laplacian (instead of recursive) filter
    - Only gradients (not values) used from background near observations
- **Consistency** between situational awareness & nowcasting tools
  - Situational awareness analysis is used to initialize NWP nowcast/forecast model
    - After scales / features not resolved by model filtered out
- **Nowcasting skill**
  - Due to fidelity to observations
    - Significantly higher ETS for 0-3 hr reflectivity
- **Speed**
  - 18-times faster than GSI
    - Due to multi-scale formulation
    - Low latency, high update frequency, high resolution

FIT TO INDEPENDENT OBSERVARIONS - KMA

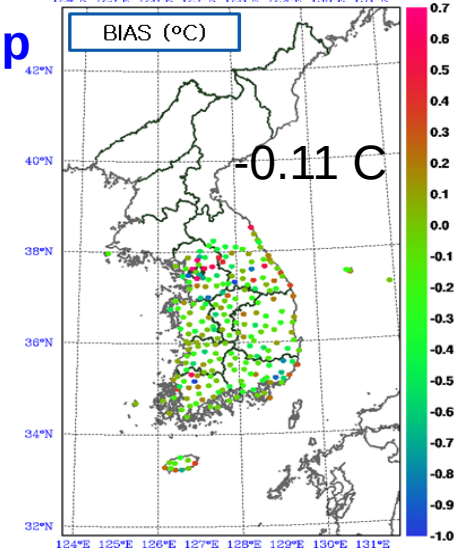
2009.1.1 ~ 12. 31 HOURLY ANALYSIS – 2 Million + INDEPENDENT OBSERVATIONS

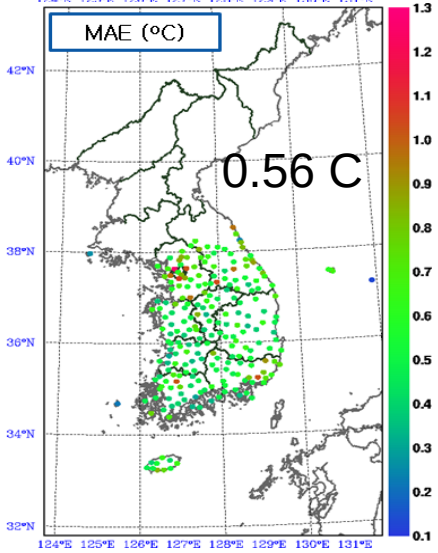
2m RH



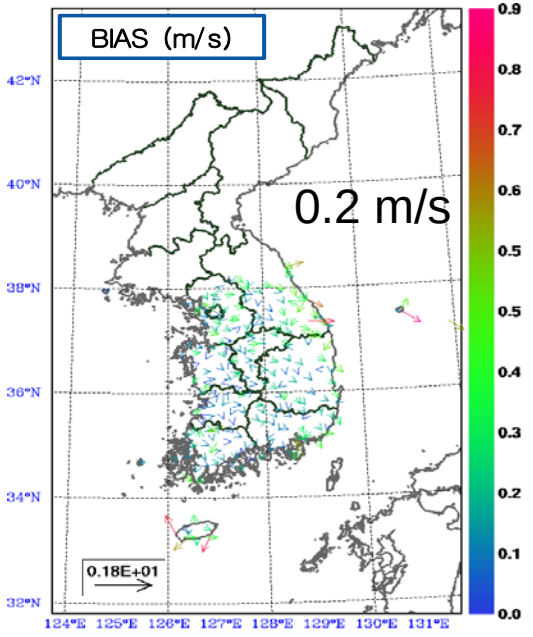


2m Temp





10m Wind Speed



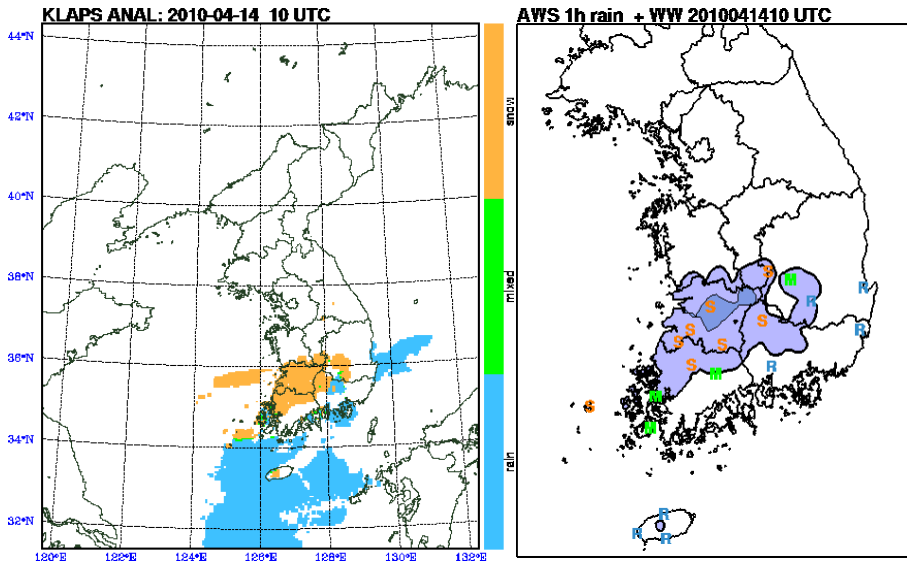
Courtesy YongHee Lee

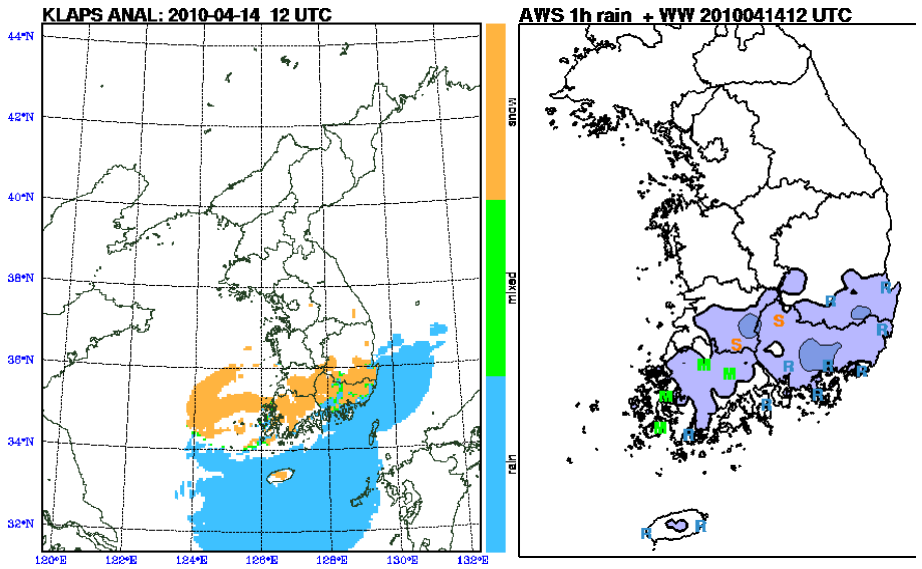
기상청

World Best 365

PRECIPITATION TYPE ANALYSIS - KMA

- Based on wet bulb temp & thicknesses
  - Relationship tuned
- Analyzed precip type at 76 sites with independent obs
  - **Matches independent observations 90% of time**





Courtesy YongHee Lee

기상청

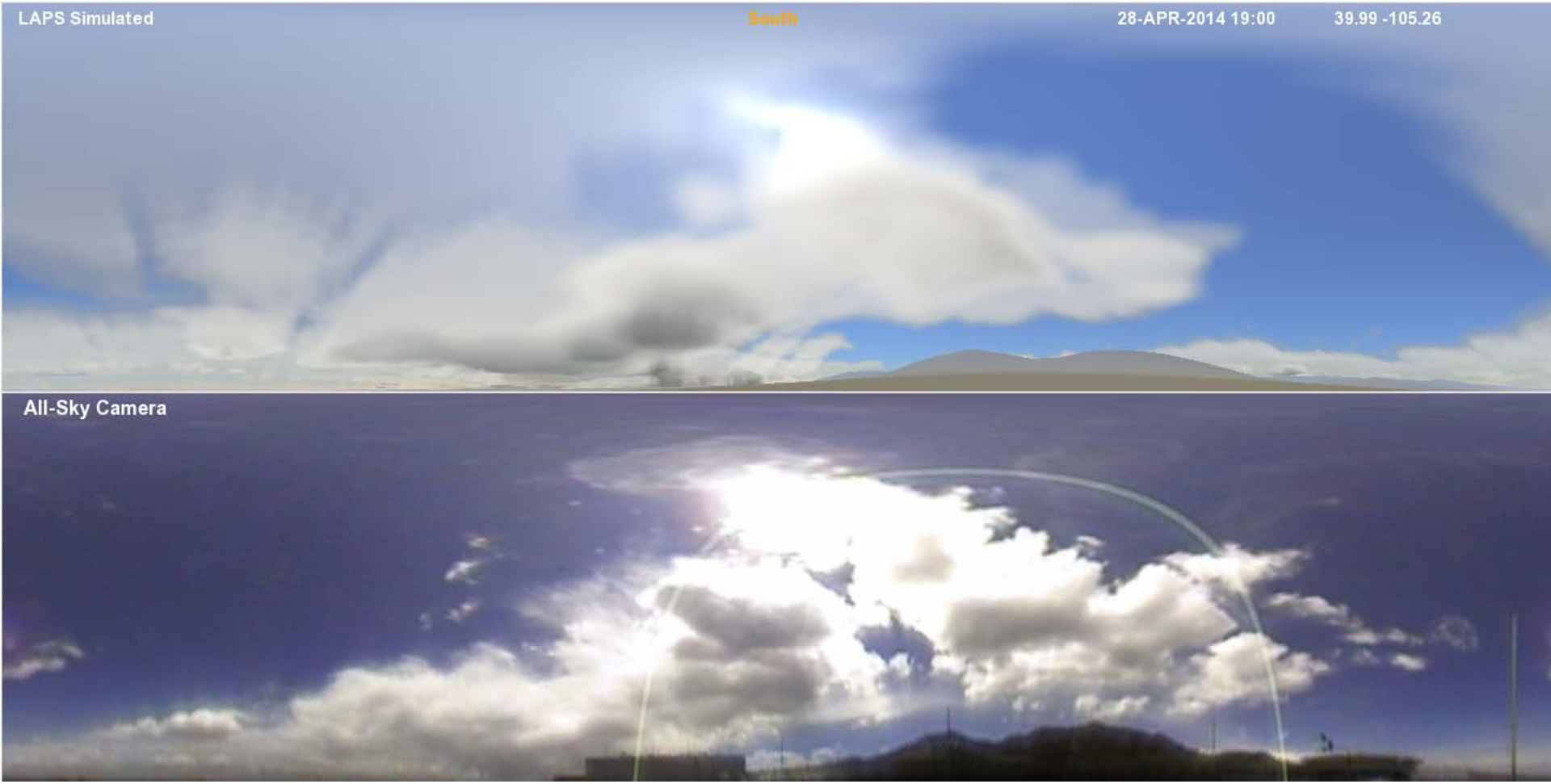
World Best 365

3D 1 km CLOUD ANALYSIS

Courtesy Steve Albers

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

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



19:00UTC Apr 28, 2014

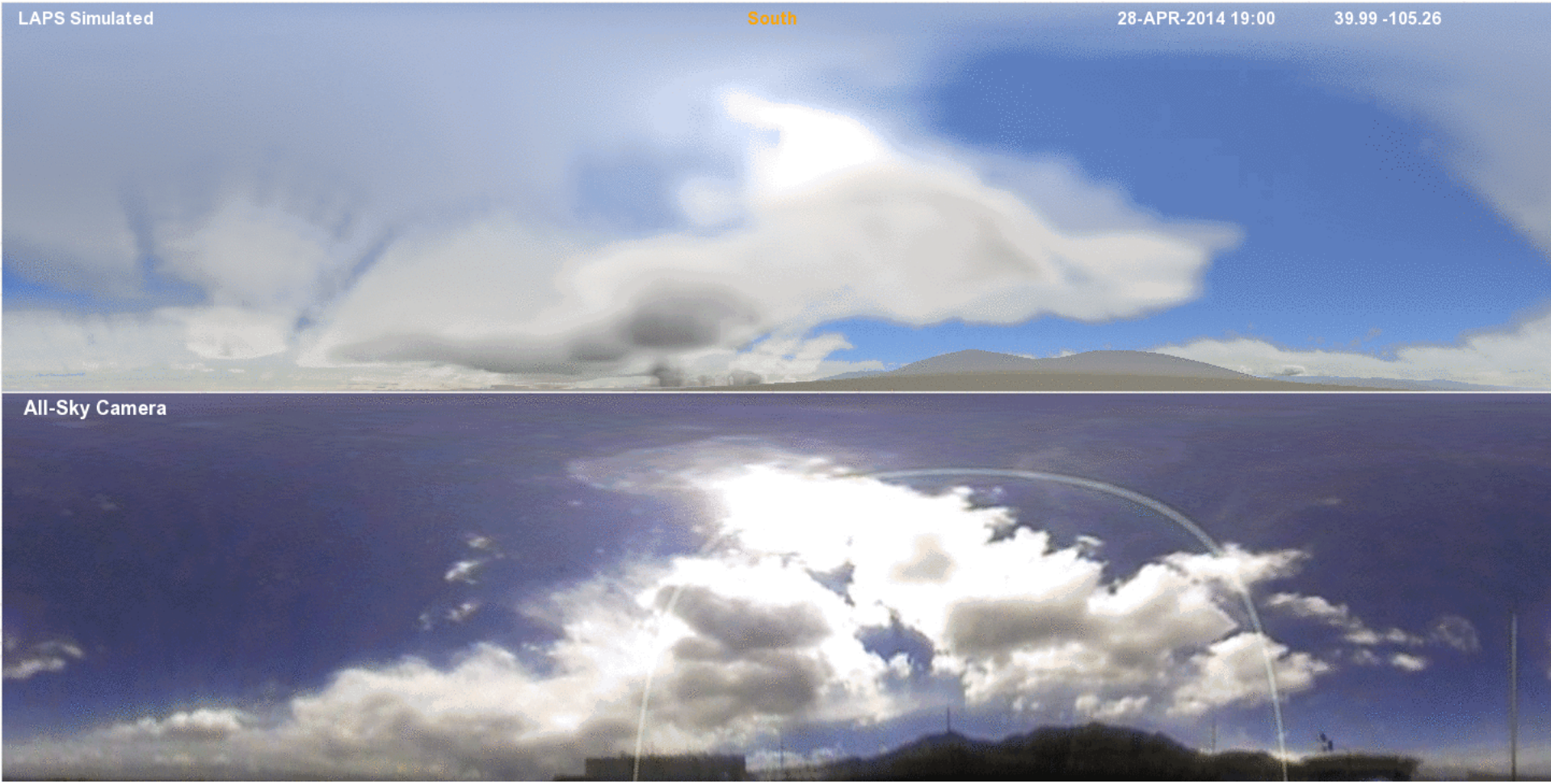
ALLSKY CAMERA

3D 1 km CLOUD ANALYSIS - LOOP

Courtesy Steve Albers

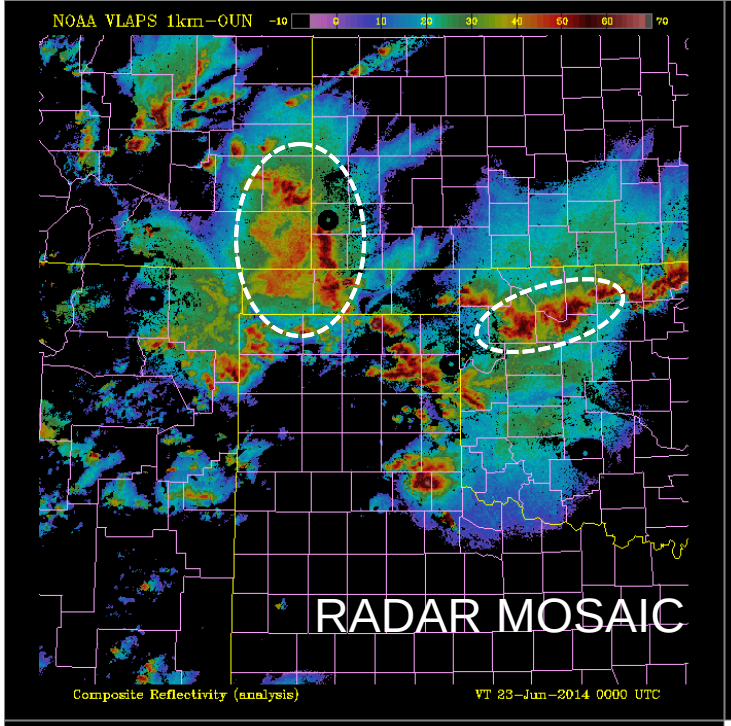
Unique feature of LAPS, critical for WOF, Nextgen, etc

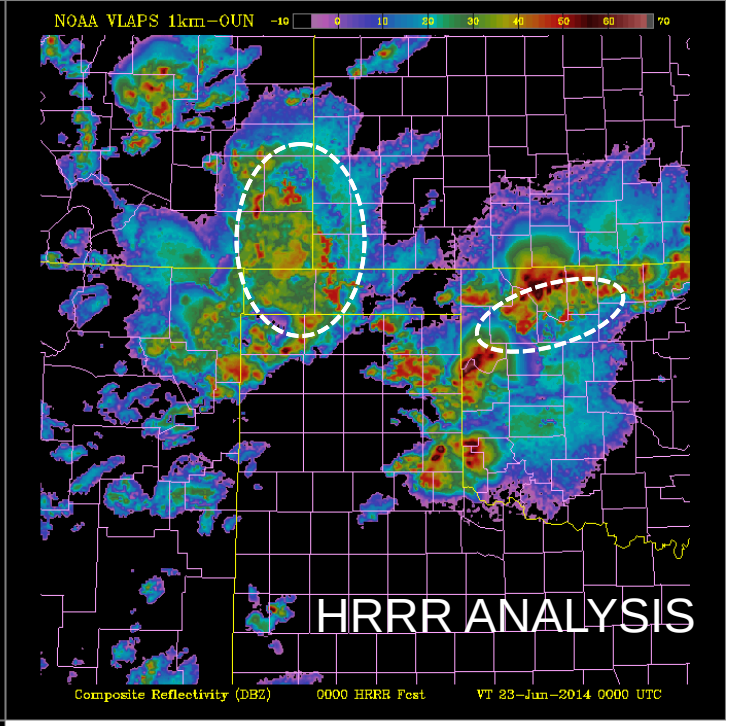
Clouds as seen from top of DSRC building in Boulder by ***LAPS ANALYSIS***

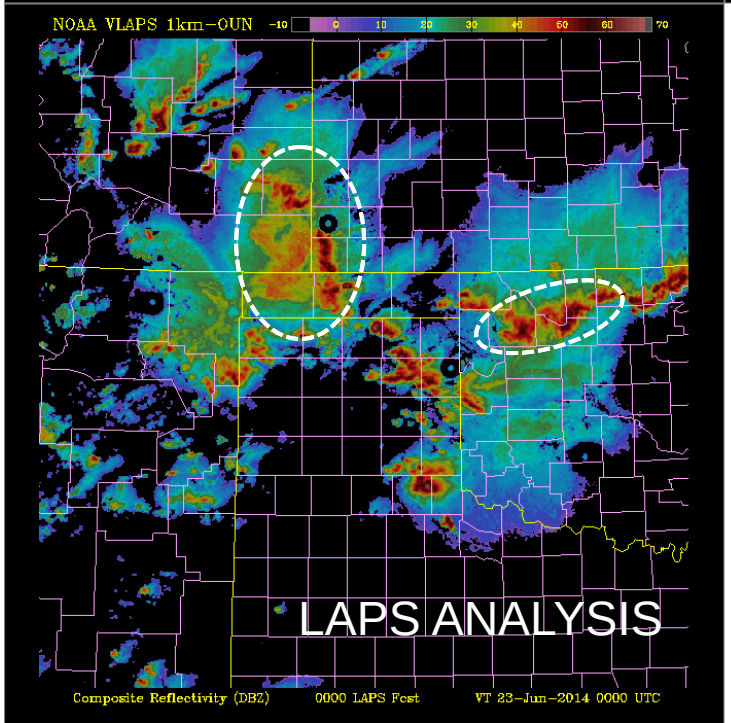


19:00-21:00 UTC Apr 28, 2014, 15-min frequency

ALLSKY CAMERA







COMPARISON OF LAPS RADAR MOSAIC WITH LAPS & HRRR COMPOSITE REFLECTIVITY ANALYSIS

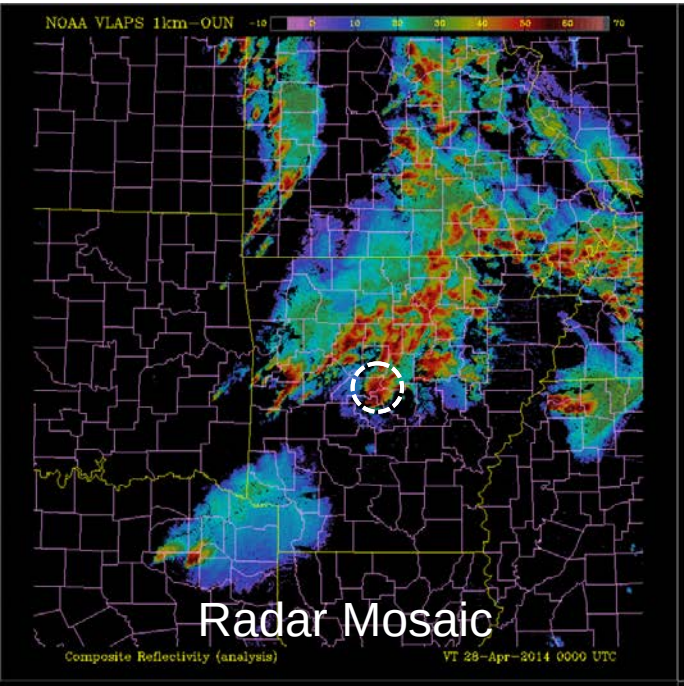
0000 UTC, 23 June, 2014

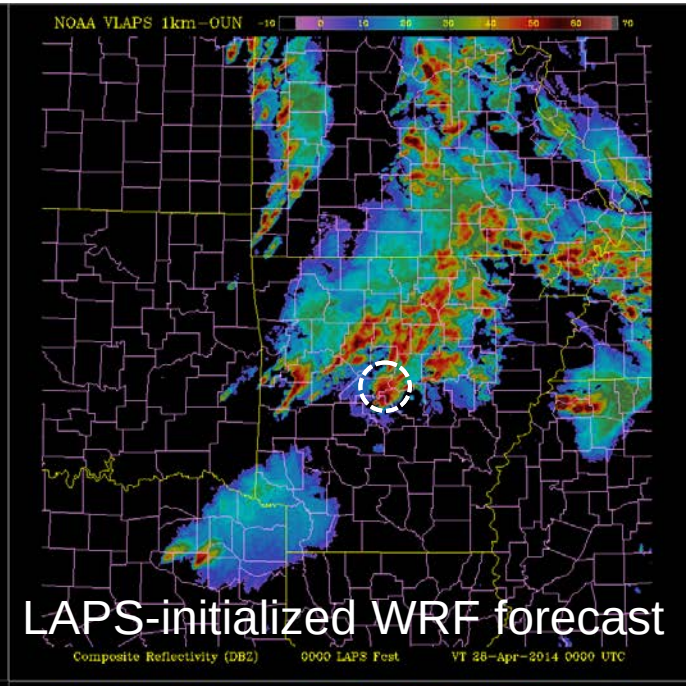
CONSISTENCY BETWEEN MONITORING & NOWCASTING

- High fidelity to reality for **monitoring**
  - Capture all scales / phenomena resolved on grid
    - 2D LAPS analysis
    - NDFD project making 2D & 3D LAPS analyses consistent
- **Initialize WRF ARW model** w 3D LAPS analysis
  - After filtering out scales/physics not resolved by WRF

- Inconsistency between
  - Initial model state & analysis used for monitoring
    - May render numerical guidance for nowcasting suspect

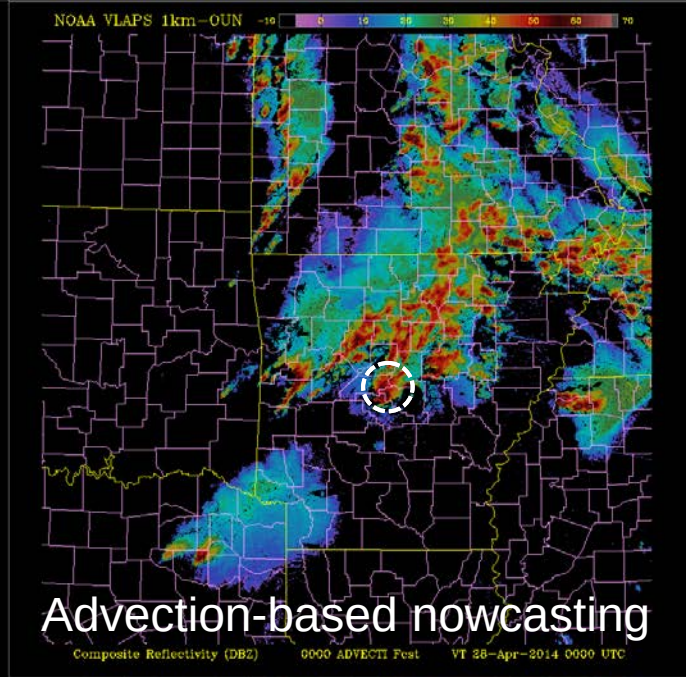
RADAR REFLECTIVITY FOR MAYFLOWER, AR TORNADO





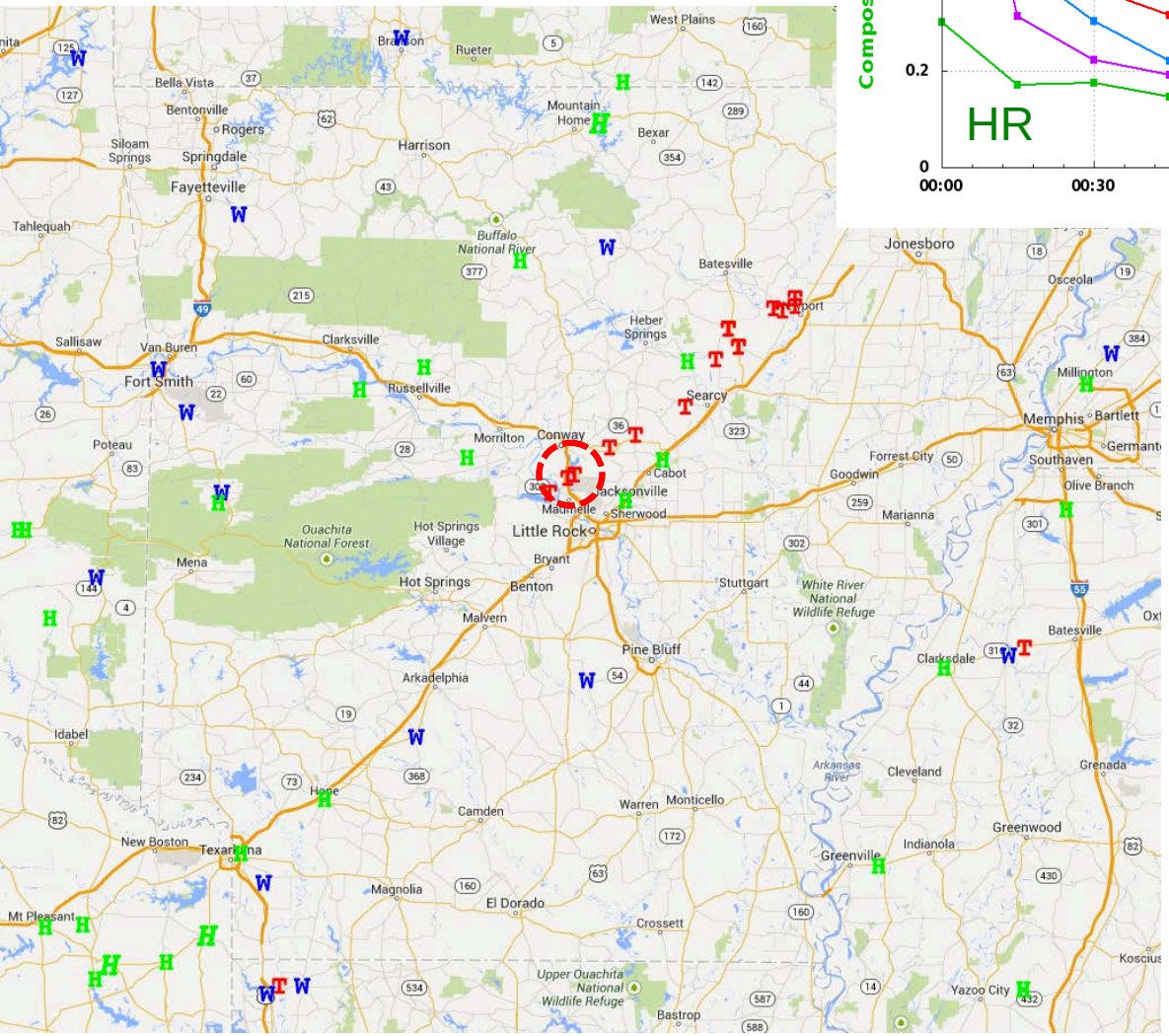
00:00 – 03:00 UTC
April 28, 2014
15-min frequency loop

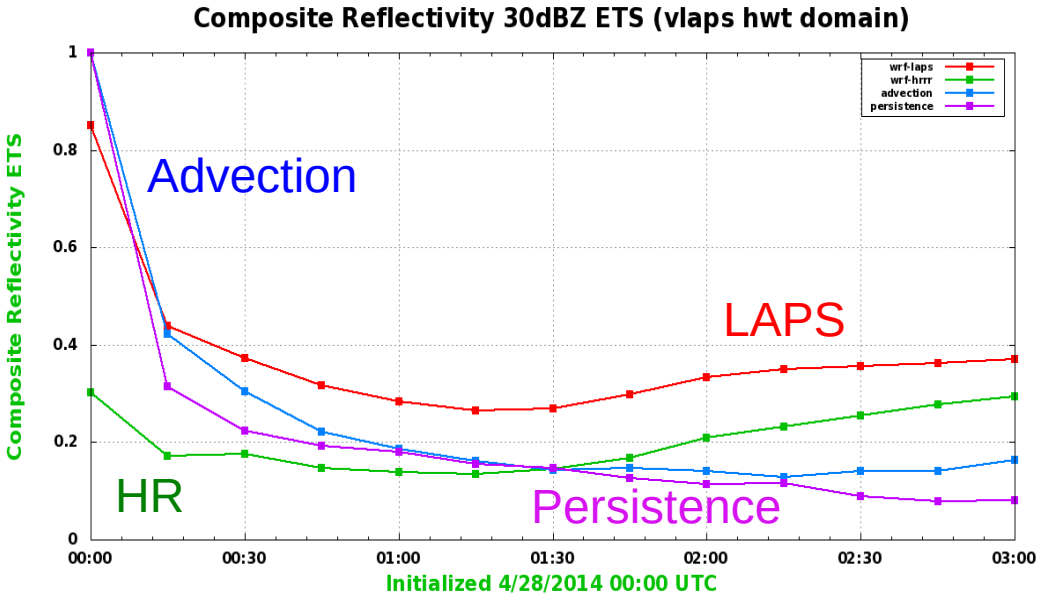
HR-initialized WRF forecast



Touchdown at
00:34 UTC
28 April, 2014

MAYFLOWER, AR TORNADO

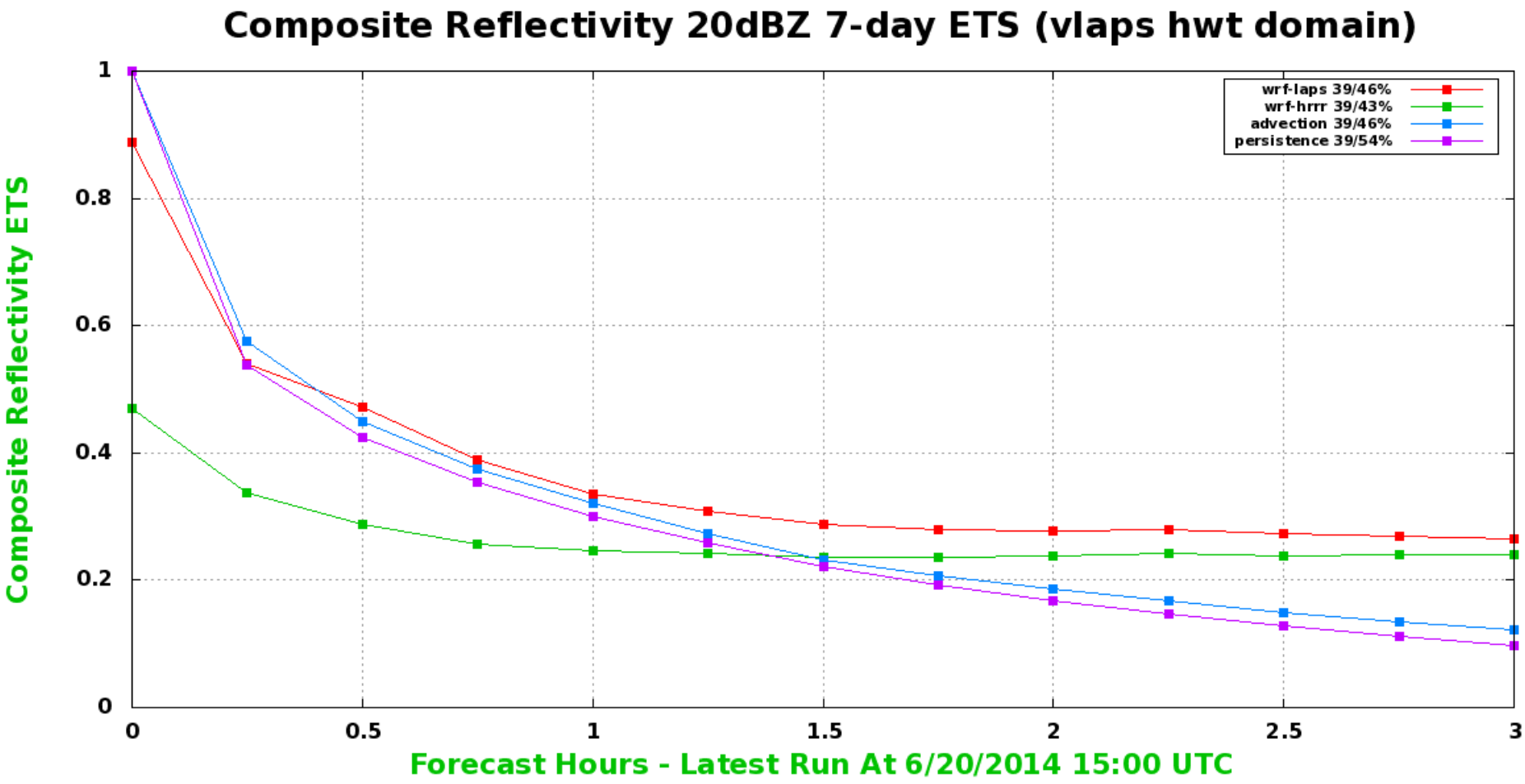




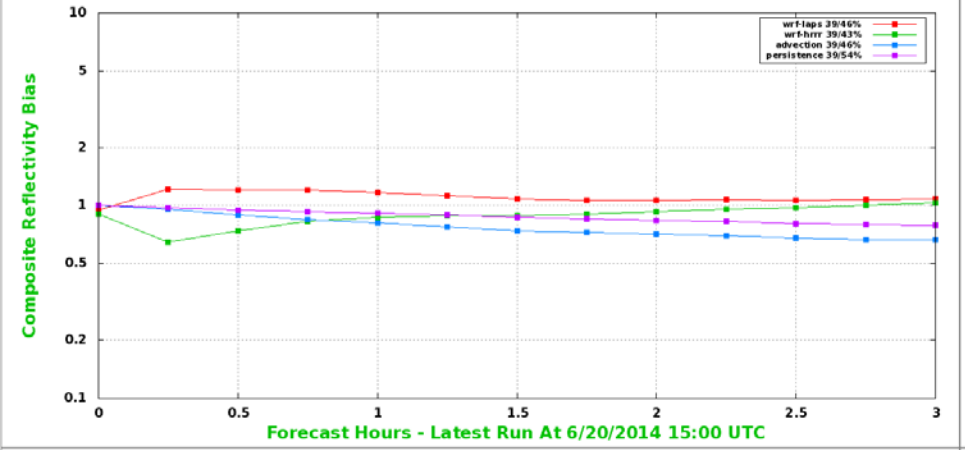
0.3-0.4 ETS score for LAPS Nowcasting

Ranking / scores consistent with 7-day mean results

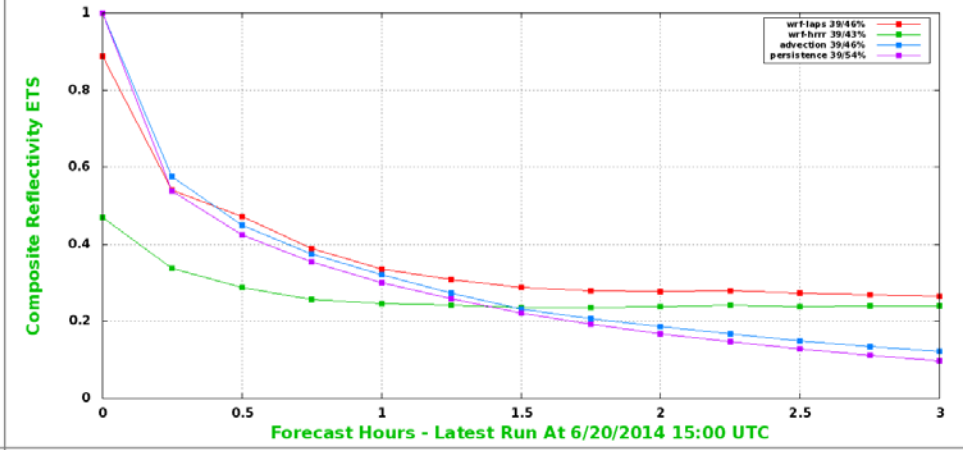
NOWCASTING SKILL



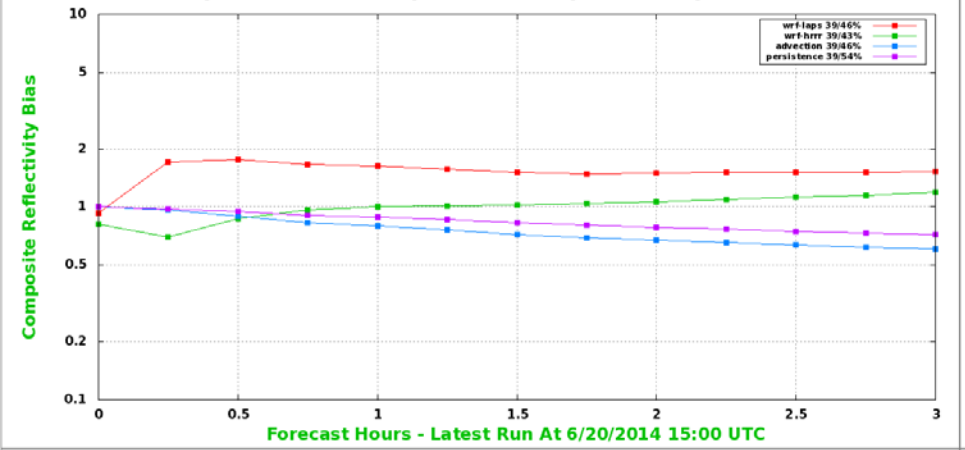
Composite Reflectivity 20dBZ 7-day Bias (vlaps hwt domain)



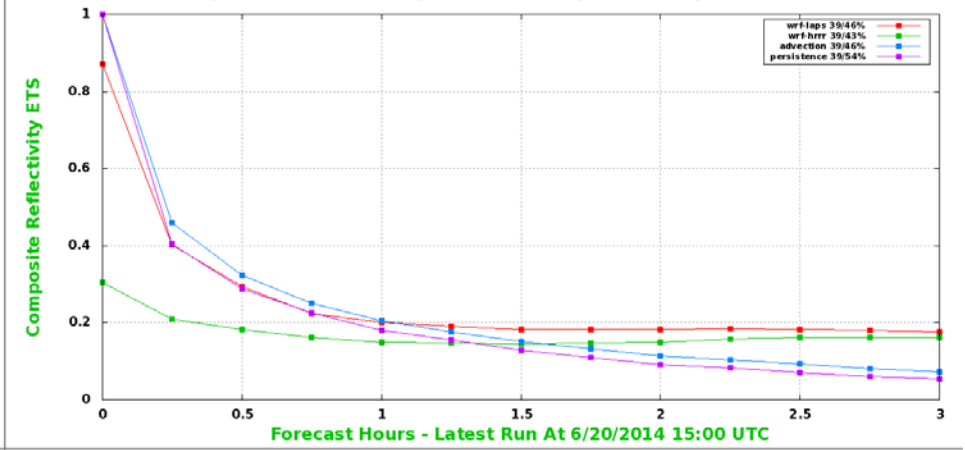
Composite Reflectivity 20dBZ 7-day ETS (vlaps hwt domain)



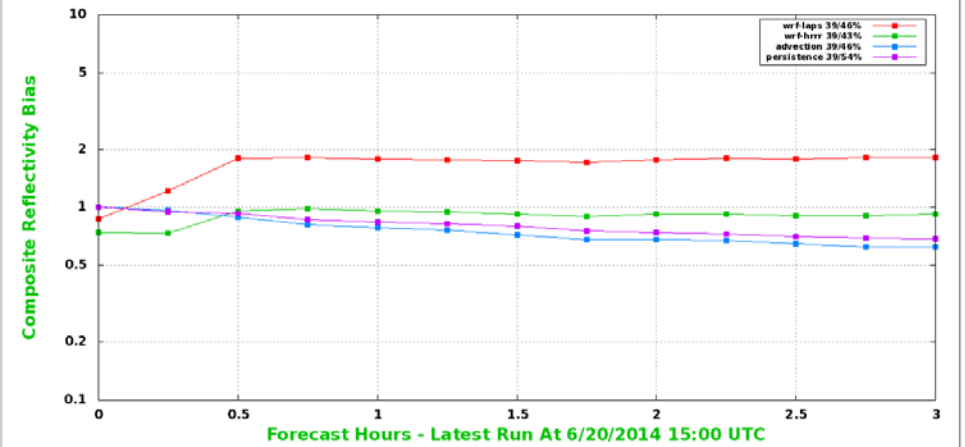
Composite Reflectivity 30dBZ 7-day Bias (vlaps hwt domain)



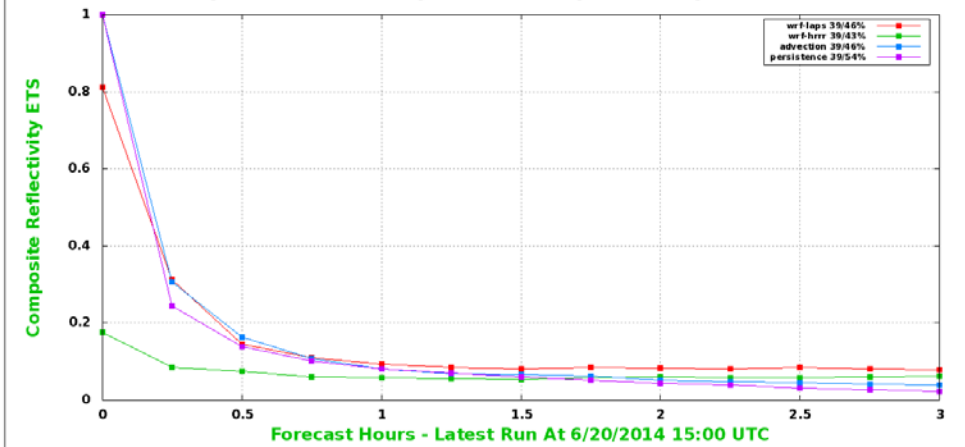
Composite Reflectivity 30dBZ 7-day ETS (vlaps hwt domain)



Composite Reflectivity 40dBZ 7-day Bias (vlaps hwt domain)



Composite Reflectivity 40dBZ 7-day ETS (vlaps hwt domain)



LAPS COMPUTATIONAL EFFICIENCY

Comparison with GSI by T. Schlatter, LAPS vs RAP (uses GSI)

- Configuration
  - Observations - Comparable types / amount
  - Resolution
    - LAPS – 12 km, 41 levels
    - RAP – 13 km, 50 levels
  - Domain
    - LAPS – CONUS
    - RAP – North America (3.5 times larger
  - Execution time
    - LAPS – 4 min on single Zeus processor
    - RAP – 5 mins on 64 Jet processors
- Considering all these factors:

$$64 \times \left(\frac{13}{12}\right)^2 \times \frac{41}{50} \times \frac{1}{3.5} = 17.6\,,$$

  - LAPS is about 18 times more efficient computationally
    - Due to use of multi-grid minimization algorithm

KEY FEATURES OF VARIATIONAL LAPS

FEATURE	METHOD	BENEFIT	SOURCE / REFERENCE
Variational Draws close to obs.	3DVAR and future 4DVAR Laplacian filter	Balance, remote obs. Use for monitoring/nowc.	3DVAR/4DVAR literature
Multiscale in space	Multigrid, Incorporate successively finer scales	Multiscale analysis	Briggs (2003), Xie et al. 2005, 2011. Li, et al 2008
Multiscale in time	Multigrid in time as well. Control variables at multiple time levels	4-dimensional extension of 3dvar. Take advantage of temporal information	Xie et al 2011
Choice of control variables	U and V	Best use of obs, efficient and avoid boundary issue	Xie and MacDonald 2011
Preconditioning minimization of cost function	In observational terms	efficiency	VLAPS surface document for MIT LL
Diabetic initialization ("hot start")	Dynamical, Physical & microphysical constraints	WoF, situation awareness and convective initiations	In progress
Nonlinear minimization	Nonlinear minimization algorithm and nonlinear 3-4 DVAR formulation	Without tangent linear, faster convergence and better minimizer	Fletcher R 1987, Xie and Byrd 1999
Thinning of observations	To nearest grid-points	Scale, terrain, & flow dependent; improved condition number	New version of surface LAPS
Object oriented design	Fortran 2003	Maintenance, collaboration, and portability	BAMS in preparation

RECENT LAPS PUBLICATIONS

- Cimini D., E. Campos, R. Ware, S. Albers, G. Giuliani, J. Oreamuno, P. Joe, S. Koch, S. Cober, E. R. Westwater 2011: Thermodynamic Atmospheric Profiling during the 2010 Winter Olympics Using Ground-based Microwave Radiometry, *IEEE Trans. Geosci. Rem. Sens.*, accepted, DOI 10.1109/TGRS.2011.2154337.
- Marquis, M., S. C. Albers and E. C. Weatherhead, 2011: For Better Integration, Improve the Forecast. *Solar Today*, **25**, 52-53.
- Xie, Y. F., and A. E. MacDonald, 2011: Selection of Momentum Variables for a Three-Dimensional Variational Analysis. *Pure and Applied Geophysics*, DOI 10.1007/s00024-011-0374-3.
- Xie, Y. F., S. Koch, J. McGinley, S. Albers, P. Beringer, M. Wolfson, and M. Chan, 2011: A Space-Time Multiscale Analysis System: A Sequential Variational Analysis Approach. Monthly Weather Review, 139, 1224-1240.
- Toth, Z., S. Albers, Y. Xie, 2012: Analysis of finescale weather phenomena. Bull. Amer. Meteor. Soc., 93 (3), ES35–ES38, doi:10.1175/BAMS-D-11-00148.1
- Toth, Z., M. Tew, D. Birkenheuer, S. Albers, Y. Xie, and B. Motta. 2013: Multi-scale data assimilation and forecasting. BAMS, Multiscale Data Assimilation and Forecasting. Bull. Amer. Meteor. Soc., 95, ES30–ES33.
- Jiang, H., S. Albers, Y. Xie, I. Jankov, Z. Toth, M. Scotten, J. Picca, G. Stumpf, D. Kingfield, D. Birkenheuer, and Brian Motta, 2014: Real-time Applications of the Variational Version of the Local Analysis and Prediction System (LAPS). BAMS, under review.
- Xie, Y., S. Albers, H. Jiang, and Z Toth, 2014: A New Variational Version of the Local Analysis and Prediction System (LAPS). Draft, available upon request.
- Toth, Z., Y. Xie and co-authors: Community Data Assimilation Development. Draft, available upon request.

USE OF LAPS IN NWS

- **AWIPS Operational Requirements** (2009)
  - 3D LAPS analysis needed "to properly assimilate an increasing number of data sources into [the forecasters'] decision making process"
  - Single 3/4D gridded data
    - ***Synthesis of all observational information***
    - ***From which all products can be derived***

- WFO application areas - NWS **LAPS survey** & AWIPS requirements
  - Monitoring
    - Severe weather & convective potential
    - Pre-storm & near-storm environments - 3D thermodynamic & kinematic analysis
    - Frontal / wind / synoptic forcing analysis
    - Winter weather / melting layer / mixed precipitation
    - Ongoing monitoring of current conditions
    - Moisture / temperature analysis / trends
    - Aviation forecasting – low level windshear
    - Coastal forecasting – intrusion of marine layers
  - "Local high resolution model initialization" – Nowcasting
    - LAPS GUI does not support this in AWIPS

DEFAULT LAPS CONFIGURATIONS ON AWIPS

- **2009**
  - 10 km, 1-hr frequency WFO domain 3D analysis
  - Schedule driven
  - Serves single WFO
  - Runs on AWIPS
- **2014**
  - 2.5km, 1-hr (?) frequency WFO domain 3D analysis
  - Schedule driven
  - Serves single WFO
  - Runs on AWIPS-II
- **Future configuration** – How should we design?

DRIVERS FOR CHANGE IN NWS USE OF LAPS

- Desire for more **coordinated forecast process**
  - WFOs work together to cover evolving high impact events
  - Close LAPS user – developer loop
- Government directive to **reduce # of data centers**
  - Servers or “thin clients” at WFOs?
- **Cloud computing**
  - Reassess where LAPS & AWIPS runs
    - Local machine or central / cloud facility?
- **Weather Ready Nation** (WRN)
  - Digital guidance needed for decision making support

PROPOSED CONFIGURATION FOR LAPS ANALYSIS & NOWCASTING (LAN)

- **Analysis** for monitoring
  - 2.5 km, 15-min frequency CONUS 3D analysis
  - Schedule driven
  - Serves all WFOs – *Coordination made easier*
- **Nowcasting**
  - On demand, for selected high impact events
  - Serves *group of WFOs coordinating* event response
    - 1km 15-min freq., relocatable domain 3D analysis
    - 1km 1-hr freq. 6-hr forecast
- **Platform**
  - Run on NWS central IDP servers
    - Space, data access, cpu, etc offered for testing

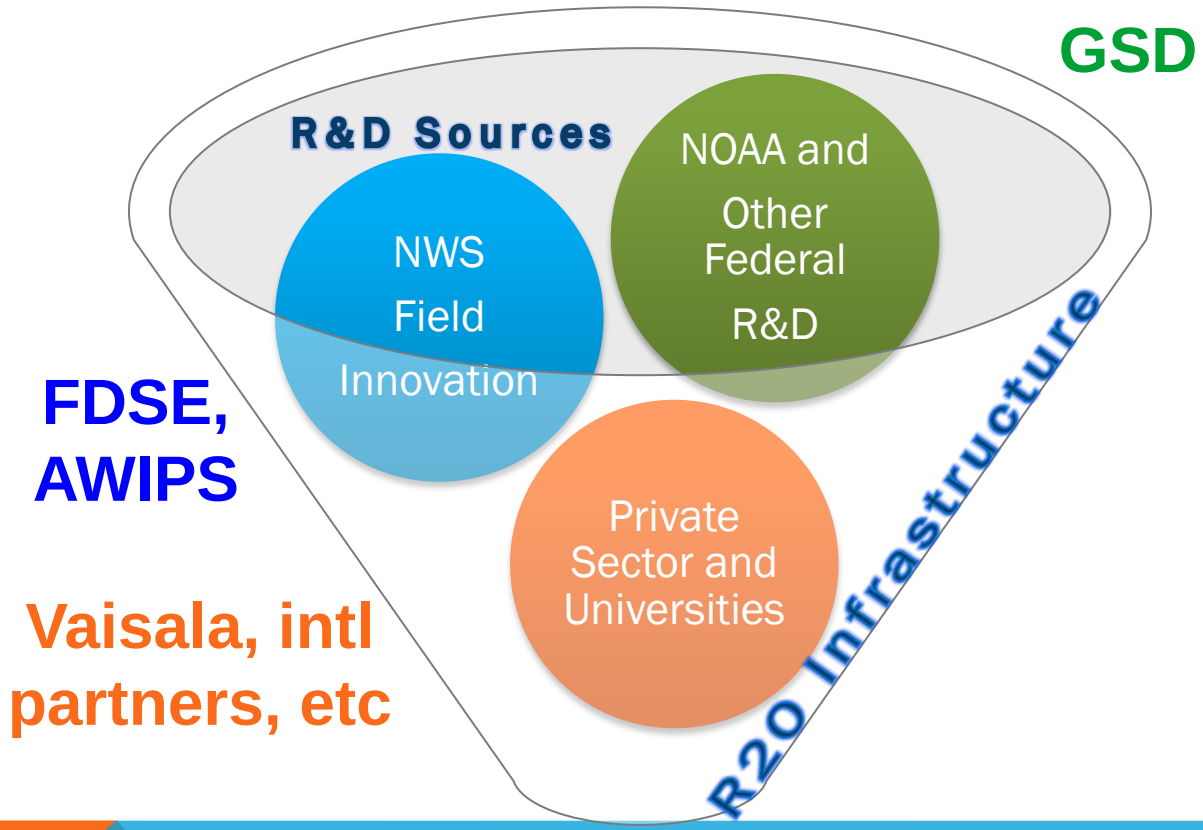
"LOCAL" IN LAPS

- **NWP strongly constrained by CPU**
  - Must sacrifice resolution on global / CONUS scales
  - Can run more sophisticated applications regionally
- **LAPS example**
  - ***~20-year advantage*** over high impact areas
    - 2 km local guidance in 1994
      - Terminal LAPS (T-LAPS – ITWS) for FAA
    - 3km CONUS guidance in 2014?
      - HR implementation scheduled at NCEP
- **Need for finer resolutions never goes away**
  - Do not wait until global / CONUS solution possible
  - Run **finer resolution regional applications** for
    - Tornadoes (WoF), flash flood, urban events, etc

LAPS ANALYSIS & NOWCASTING (LAN)

- **Forecasters' role**
  - Analysis
    - Local (WFO) QC of obs. for CONUS analysis
  - Nowcasting
    - Groups of WFOs / NCEP Service Centers
      - Request application
      - Define regional domain
      - Define non-default setup
- **Can serve needs of other agencies -** consistency
  - FAA – Nowcasting for CIWS (with MIT Lincoln Lab)
  - USAF – Range Standardization and Automation
  - SF Public Utility Commission, SF Bay Area Consortium

NWS R2O



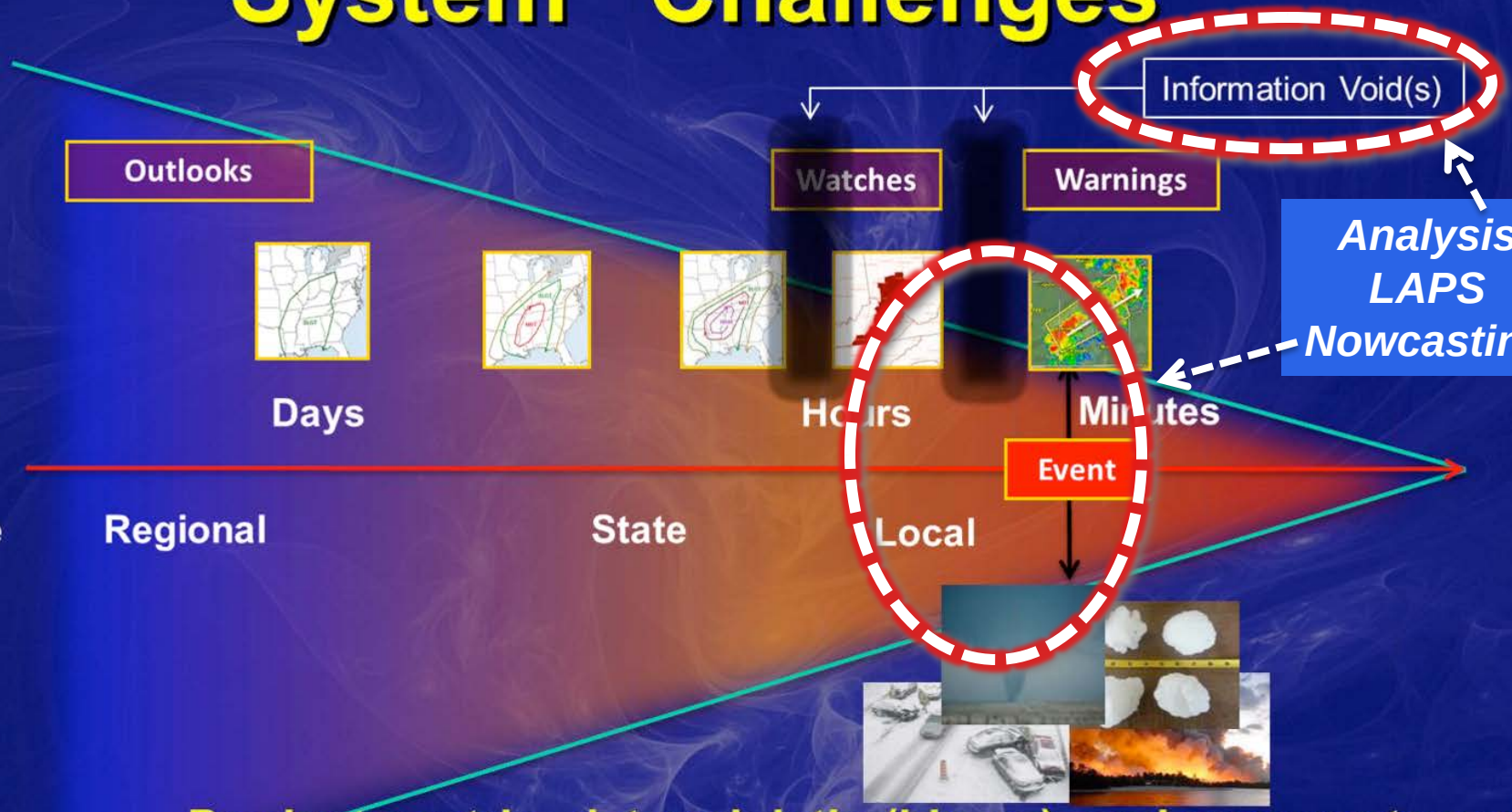
NWS Operations

After Stephan Smith

KEY PARTNERSHIPS

- **MRMS**
  - N-LAPS to use extensive radar QC etc from MRMS
  - MRMS to use microphysics analysis, precip over orography, & radar – gage relationships from LAPS
- **FACETS**
  - Role of LAN in end-to-end probabilistic warning
    - Gridded probabilistic warning guidance
- **SOOs from WFOs and Service Centers**
  - Contribute to design / development / testing
    - FDSE – Boise, Boulder; GOES-R 1-min scans, NUCAPS soundings, etc
- **Training Division**
  - Link with WRF Environmental Modeling System (EMS)
    - WRF model for WFO use
      - Bob Rozumalski et al

Current Watch/Warning System "Challenges"



- Product-centric, deterministic (binary), and presumptuous.
- More information needed.
- More information available.

After Lans Rothfusz

Adapted from Dr. Heather Lazrus (NCAR)

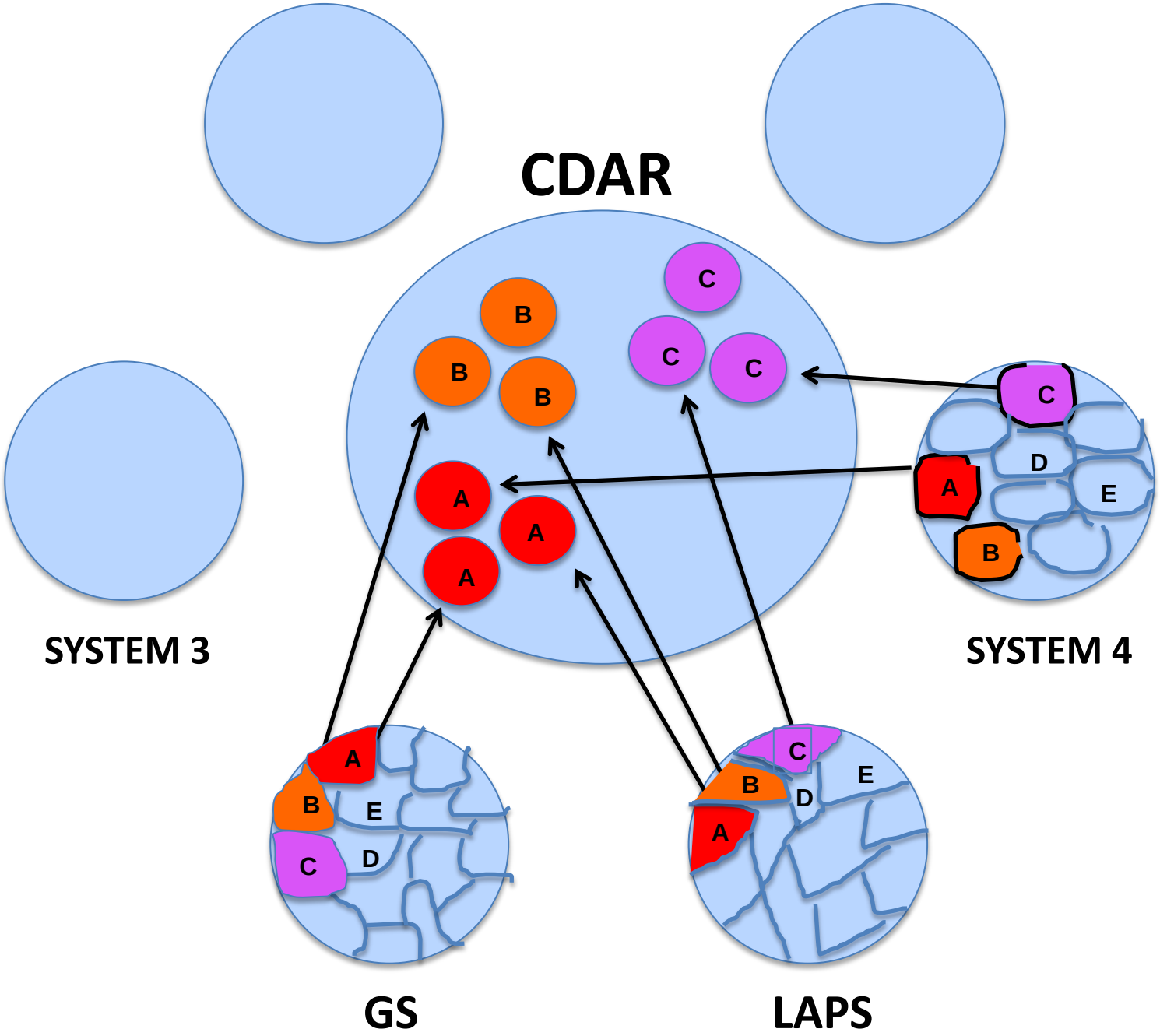
WHAT DISTINGUISHES DATA ASSIMILATION SCHEMES?

- **Scientific aspects**
  - Collection of methods based on 10-20 choices
    - Variational or ensemble filter, interpolation, minimization algorithm, QC, etc
  - Assembled to accomplish objectives in targeted appls.
- **Software engineering realization**
  - Process oriented design
    - Traditional, “hardwired” approach for particular application
    - Hard to modify / generalize
  - Object oriented design
    - Best suited for
      - Wide range of applications
      - Distributed development

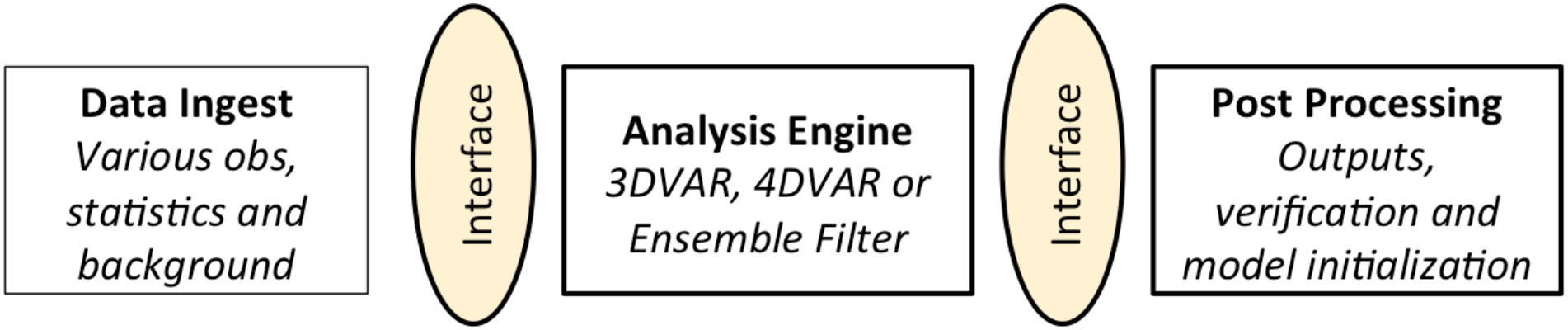
COMMUNITY DEVELOPMENT

- **Mature US data assimilation systems**
  - GSI, WRFDA, LAPS, DART, NAVDAS, etc – in their separate repositories
    - Only ideas exchanged – independent software development
    - Algorithms must be recoded & retested
      - Waste of national resources
- **Concept of Community Data Assimilation Repository (CDAR)**
  - **Agree upon use of Object Oriented Software Design** principles (OOSD)
  - **Share DA techniques** with community
    - Techniques from GSI, LAPS, etc available for direct use
      - Developers exchange software – *Accelerated advances in DA*
      - Users configure their DA according to their needs
        - » *Improved DA applications*
    - Concept paper ready for community review (BAMS)
- **Operational Centers**
  - Configure and test subsets of CDAR to meet their needs for various applications
    - Benefit from faster development and range of techniques
  - **National leveraging**
    - Links with JCSDA, ESMF, NUOPC, DTC - Integrated development
- **Gradual adoption of OOSD**
  - Newly developed methods adhere to OOSD
    - Other elements made compliant when changes required

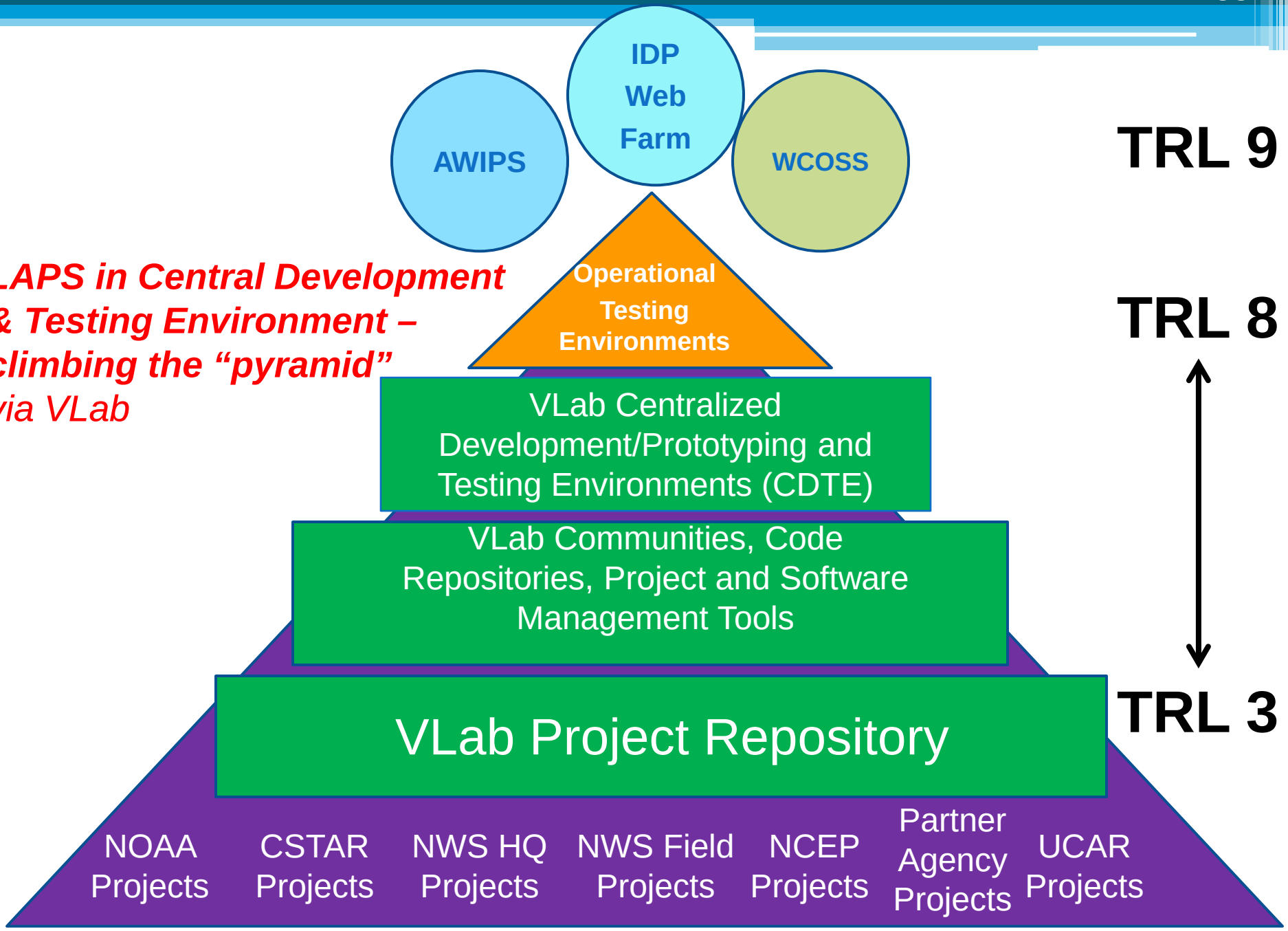
COMMUNITY DATA ASSIMILATION REPOSITORY (CDAR)



DA - OBJECT ORIENTED DESIGN



LAPS in Central Development & Testing Environment – climbing the "pyramid" *via VLab*



FIRST / NEXT STEPS

- LAPS project started in **vLab**
  - LAPS repository established (under GIT)
  - vLab seminar on LAPS Nowcasting
  - Distributed development
- **Close user – developer loop**
  - 3rd LAPS User Workshop – October 21-23, 2014
  - Form LAPS User Group to steer process
  - Links with MRMS, FACETS, etc
- **Test of concept**
  - LAPS Analysis / Nowcasting on IDP central servers
    - 2.5km 15-min frequency 2/3D CONUS analysis
    - 1km 15-min freq. 3D analysis & 1-hr freq 3-6 hr forecast
      - On demand relocatable domain for high impact events
- **NOAA Testbeds**
  - Testing / development in
    - HWT, HMT – Flash Flood / Winter Weather, AWT
- **Operational Proving Ground**
  - End-to-end evaluation

NOWCASTING VISION

- Build on **existing capabilities**
  - LAPS 3D analysis, WRF ARW, MRMS
- **Pathfinding** approach – What can we do today?
  - Plan in context of FACETS
  - Work with partners on concept / operations
    - Serve needs of field to respond to high impact events
      - Fire weather, severe weather, incident response, etc
    - On demand, flexible, quick response
      - Observationally driven analysis for monitoring
      - Forecast consistent w analysis for nowcasting
  - LAPS designed & developed to fill these needs

CONCLUSIONS

- **Objective**
  - Best nowcasting system attainable now for WRN
    - Will use whatever techniques provide desired features / best metrics
- **Community effort**
  - We engage in VLab
  - Invite others to join
    - Inclusive effort – LAPS & broader community
- **Readiness**
  - Necessary tools are there today
  - Use what's available now – Improve later

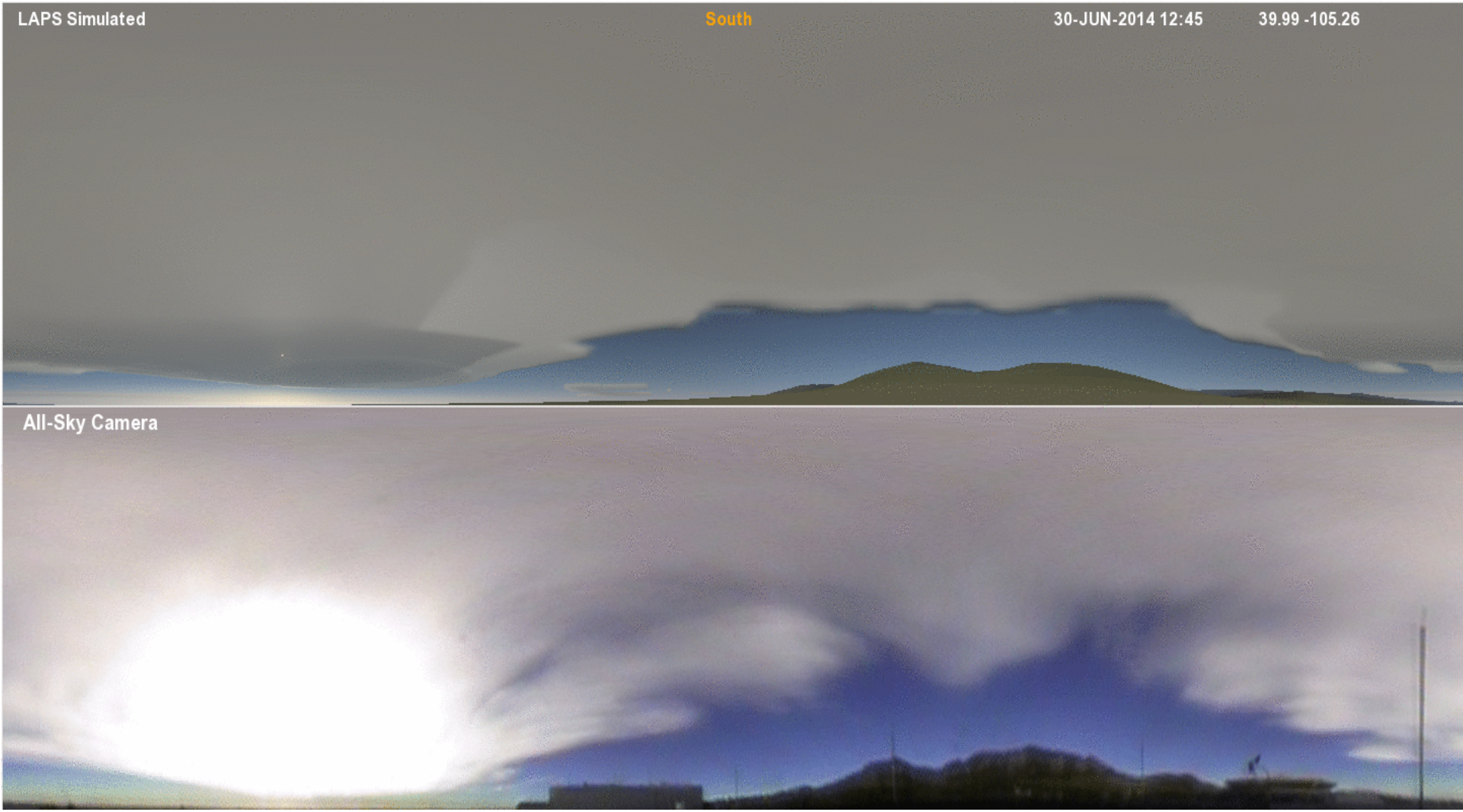
OUTLINE / SUMMARY

- **LAPS history & user base**
  - 1989 – 2011 – multi-pass Barnes analysis
  - 2012 – Multiscale variational approach
  - Used operationally by 20+ US, private, international agencies
- **Qualities of LAPS**
  - Fidelity to reality (observations)
  - Consistency between situational awareness & NWP analyses
  - Nowcast (forecast) skill
  - Speed – Low latency, high frequency, high resolution
- **Drivers for change in use of LAPS**
  - Need for more coordination, cloud computing, WRN
- **VLab path to Nowcasting with LAPS**
  - Monitoring
    - 2.5 km / 15-min frequency CONUS & OCONUS 2/3D analysis
  - Nowcasting
    - For high impact events – Relocatable domain
    - 1km/5-15 min freq. 3D analysis, 1hr freq. 3-6 hr WRF forecast
  - Approach
    - Run on IDP server; Test off-line, in Testbeds, OPG
    - Engage with broader DA / user communities – LAPS Workshop, User Group

3D 500 m CLOUD ANALYSIS - LOOP

Courtesy Steve Albers

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



12:45-16:00 UTC June 30, 2014, 15-min frequency

ALLSKY CAMERA

3D 500 m CLOUD ANALYSIS

Courtesy Steve Albers

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

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

18:00UTC May 29, 2014

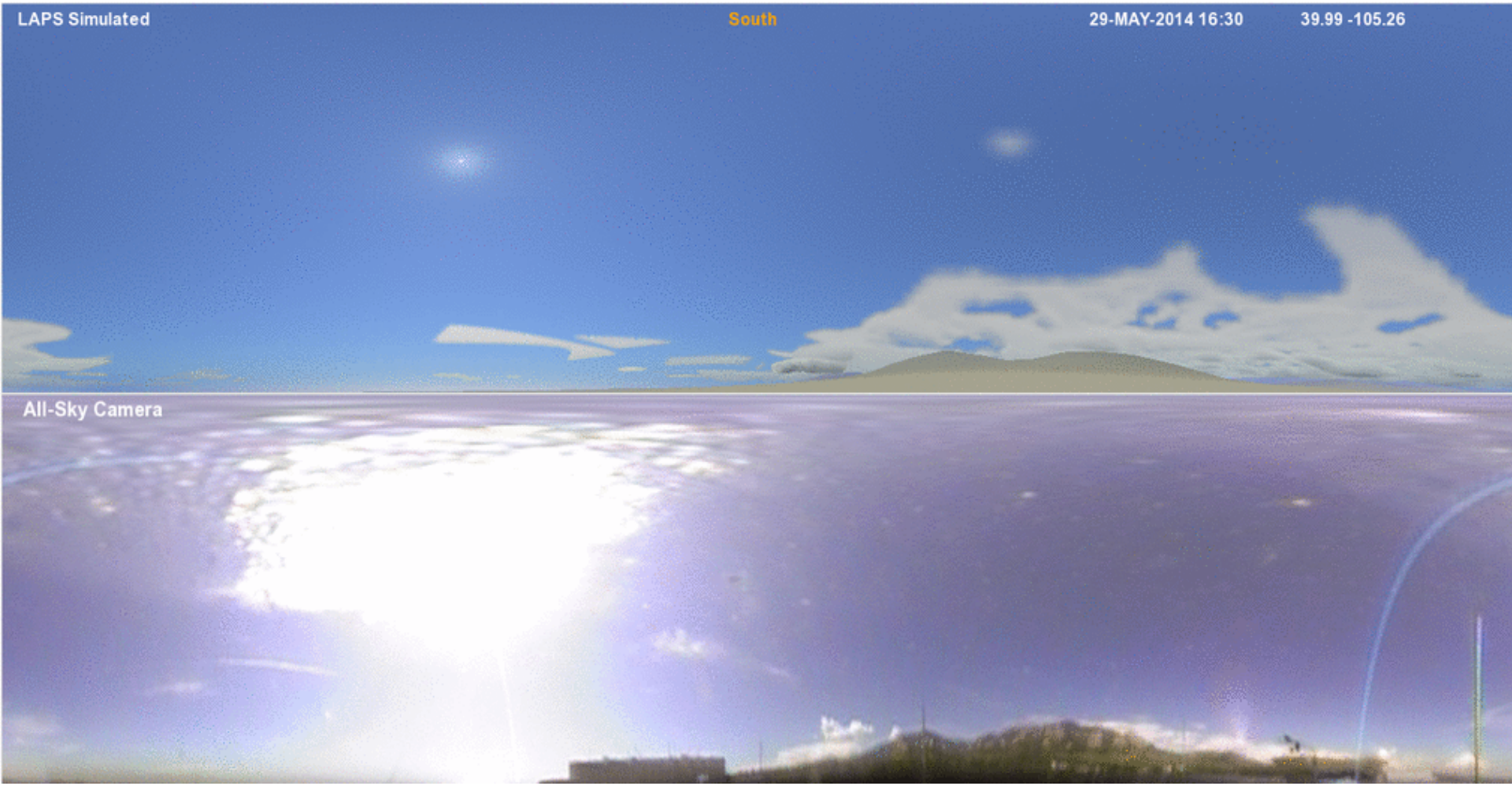
ALLSKY CAMERA

3D 500 m CLOUD ANALYSIS - LOOP

Courtesy Steve Albers

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

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



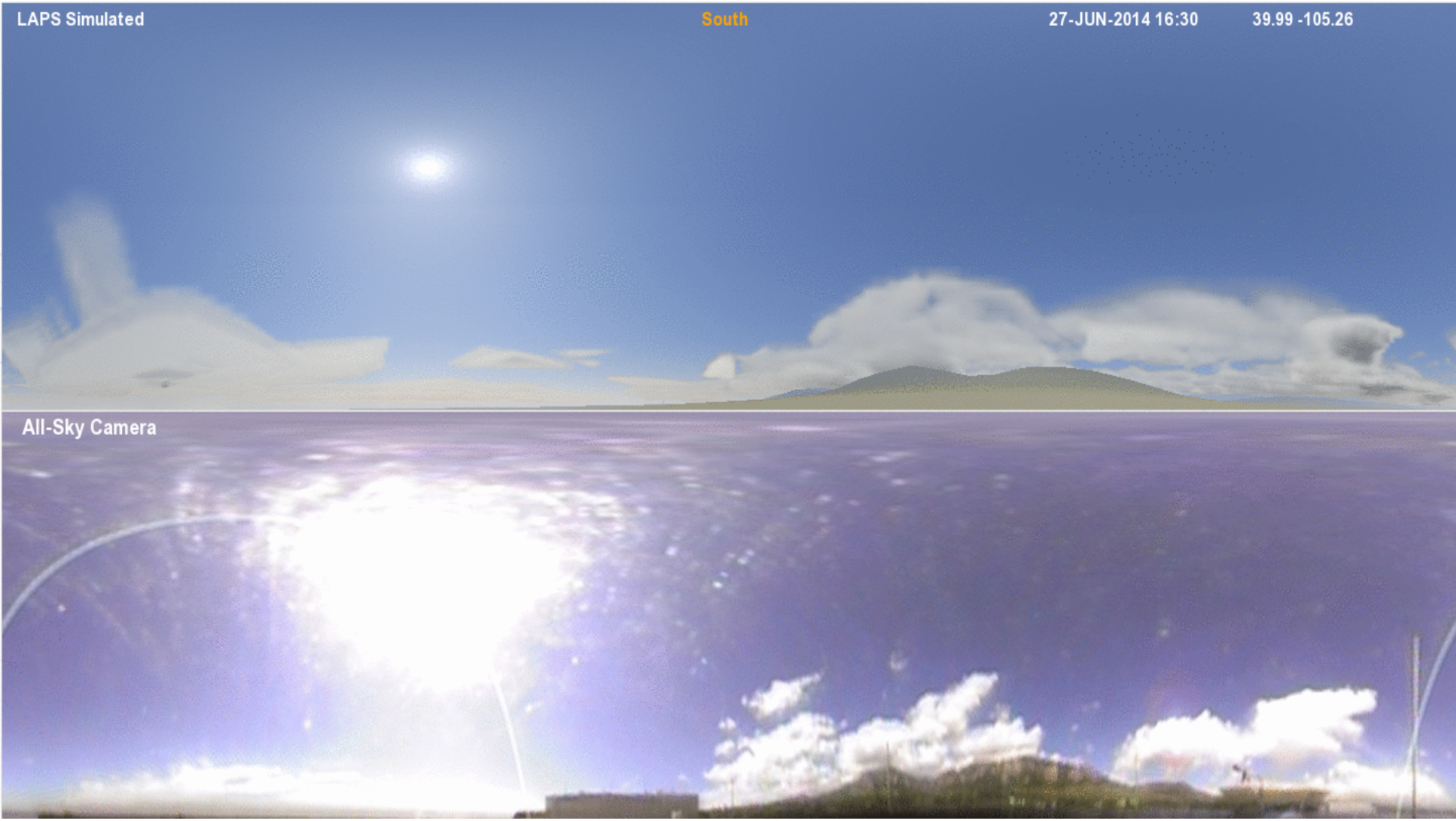
16:30-19:45 UTC May 29, 2014, 15-min frequency

ALLSKY CAMERA

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

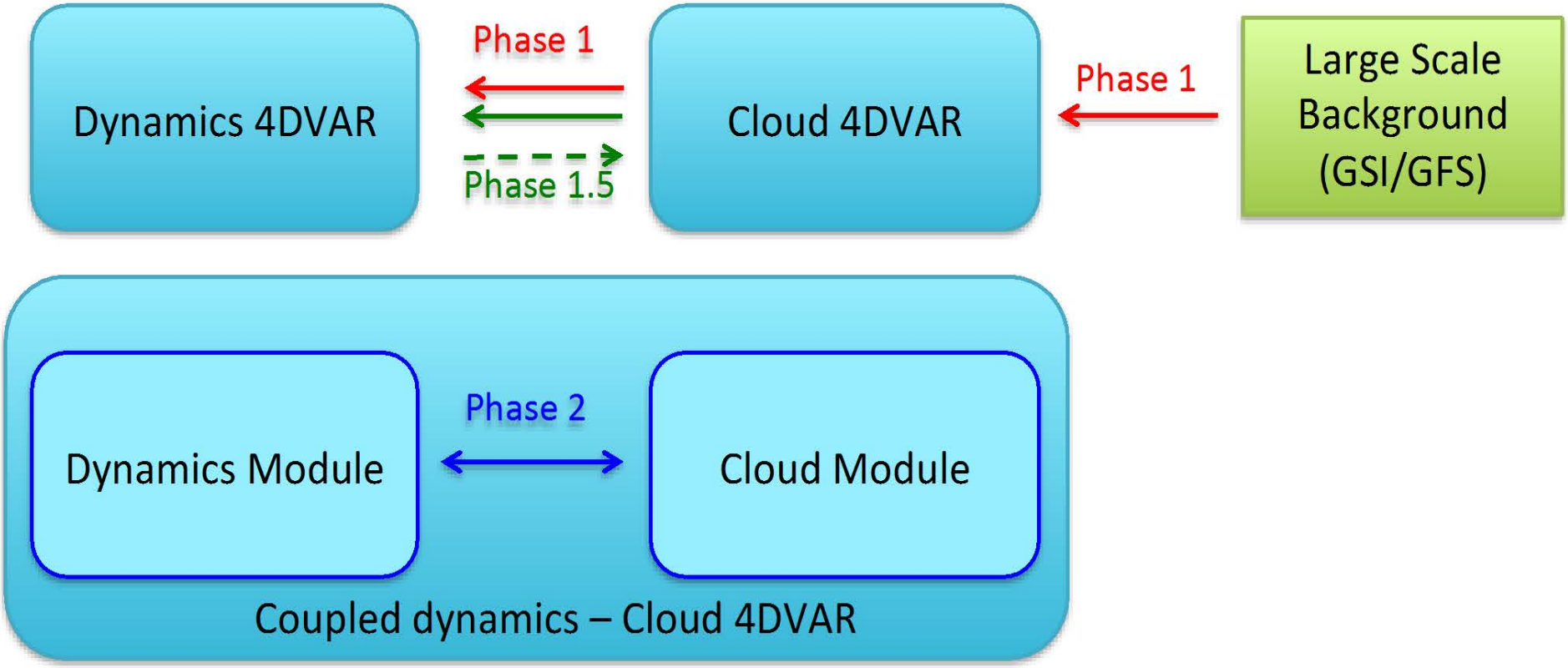
ALLSKY CAMERA

BACKGROUND

GSD DA TECHNIQUES

- **RUC (1994) – RAP (2013) – HRRR (2014?)**
  - CONUS scale applications, 60 / 13 / 3 km, 15 hrs & beyond
    - NCEP operations
  - GSI-hybrid, radar etc data added to GSI-hybrid, DFI for imposing balance
- **LAPS (early 1990s)**
  - Local / regional applications, 2/1/0.5 km, 0-3 hrs, nowcasting
    - NWS WFO operations
  - Multiscale variational approach
- **GSD internal assessment** (Schlatter 2013)
  - Value in both approaches
    - Continue both development path
    - DTC should distribute LAPS
- **Global cloud analysis**
  - LAPS & HRRR groups work together on 4DVar approach
    - For initialization of NIM, MPAS, NMMb

4DVAR CLOUD ANALYSIS

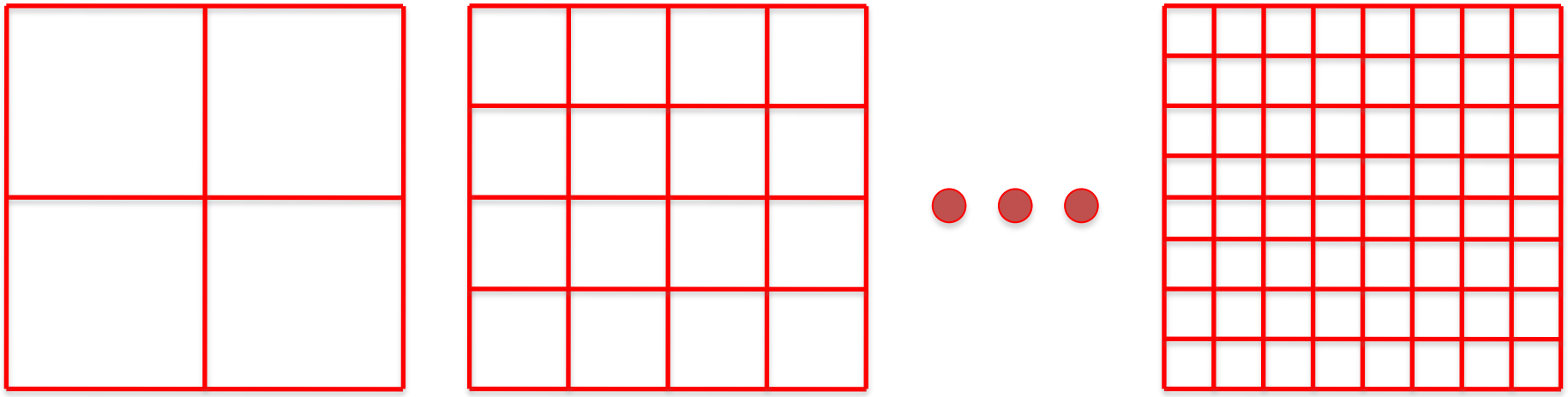


MULTISCALE DATA ASSIMILATION

- **Scales of phenomena to capture**
  - Planetary, synoptic, sub-synoptic, meso, convective
    - Factor of ~1000
- **Localized observations**
  - Reflect motions on all (multiple) scales
- **DA challenge**
  - How to extract observational info on multiple scales?
    - How to spatially spread observational info?

MULTIGRID APPROACH

Long waves → Short waves



Solve a sequence of 3-4DVARs with proper balance constraints

$$\min J = \frac{1}{2}\left(X - X^b\right)^T B^{-1}\left(X - X^b\right)` + \frac{1}{2}\left(H(X) - Y^o\right)^T O^{-1}\left(H(X) - Y^o\right)$$

A Space–Time Multiscale Analysis System: A Sequential Variational Analysis Approach. ***Xie, et al., 2011 MWR***

Hayden, and Purser, 1995: *J. Appl. Meteor. also shows a 3DVAR is equivalent to one LAPS pass*.

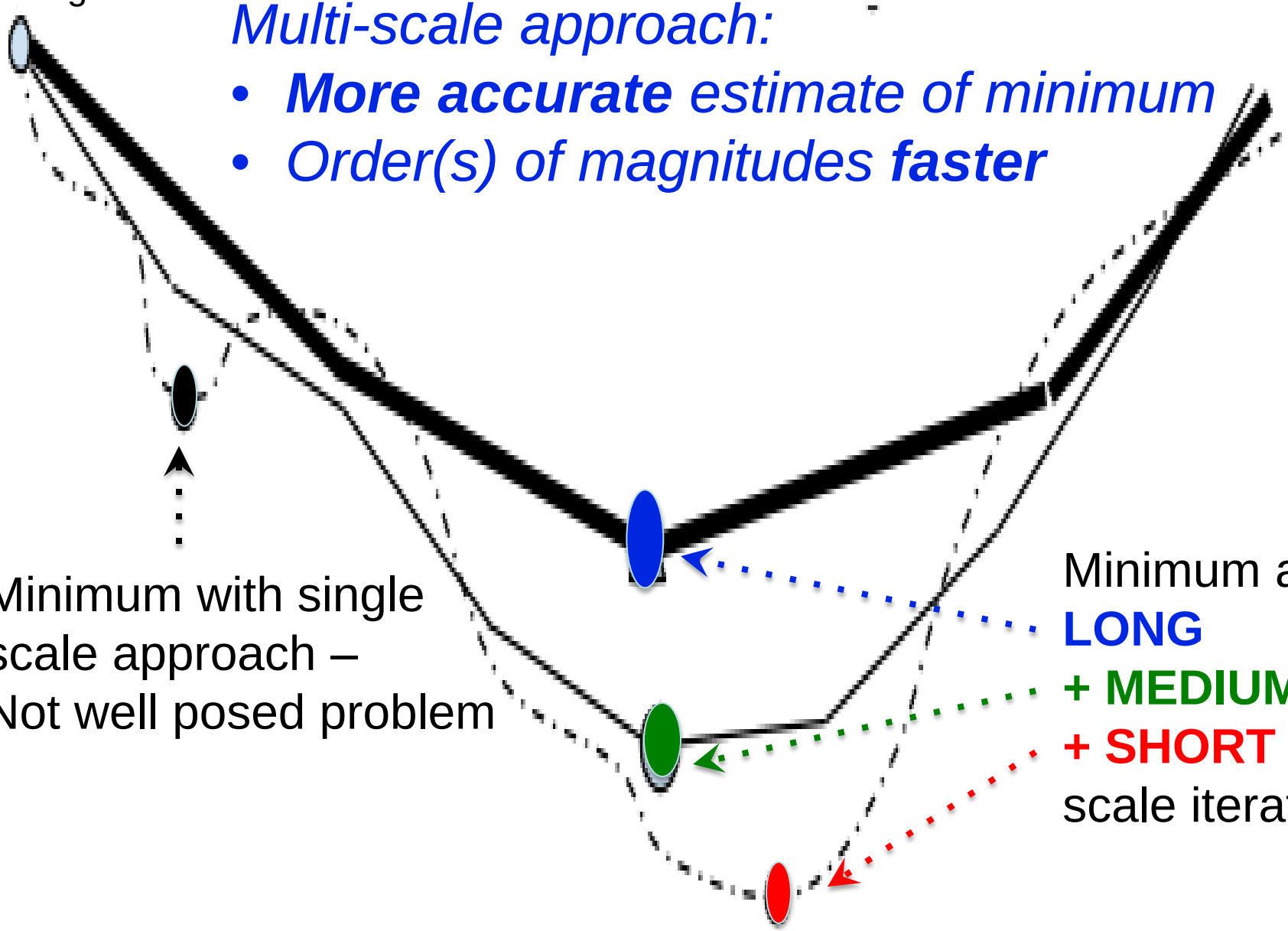
Ackn.: Koch & Uccellini

SINGLE VS MULTI - SCALE MINIMIZATION

Background

Multi-scale approach:

- ***More accurate** estimate of minimum*
- *Order(s) of magnitudes **faster***

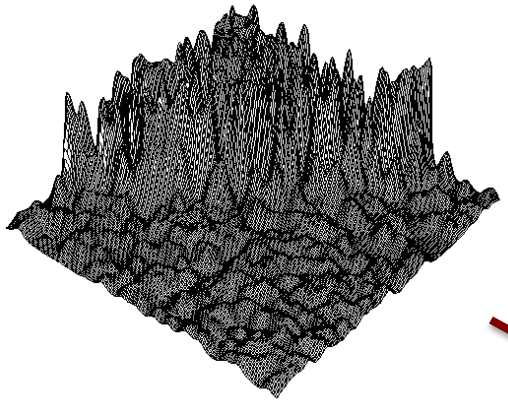


Minimum with single scale approach – Not well posed problem

Minimum after
LONG
+ MEDIUM
+ SHORT
scale iteration

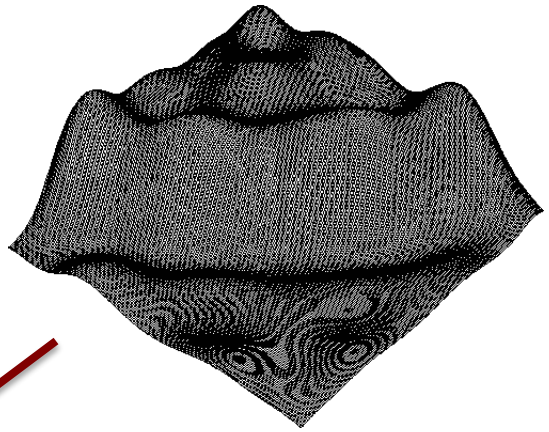
OSSE EXPERIMENTS

DENSE OBSERVATIONAL NETWORK

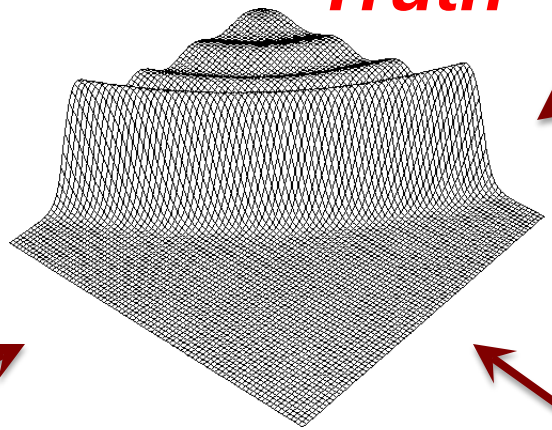


***3DVAR** with **short-scale** correlations*

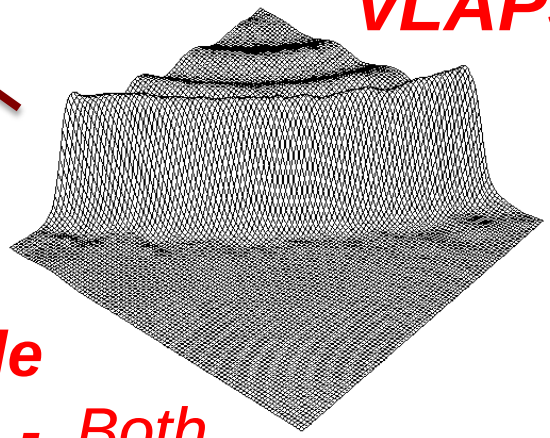
***3DVAR** with **long-scale** correlations*

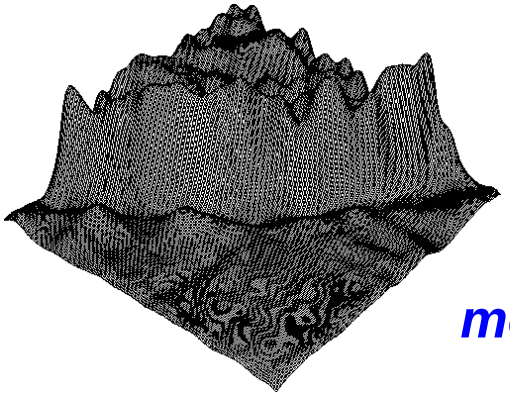


Truth



vLAPS

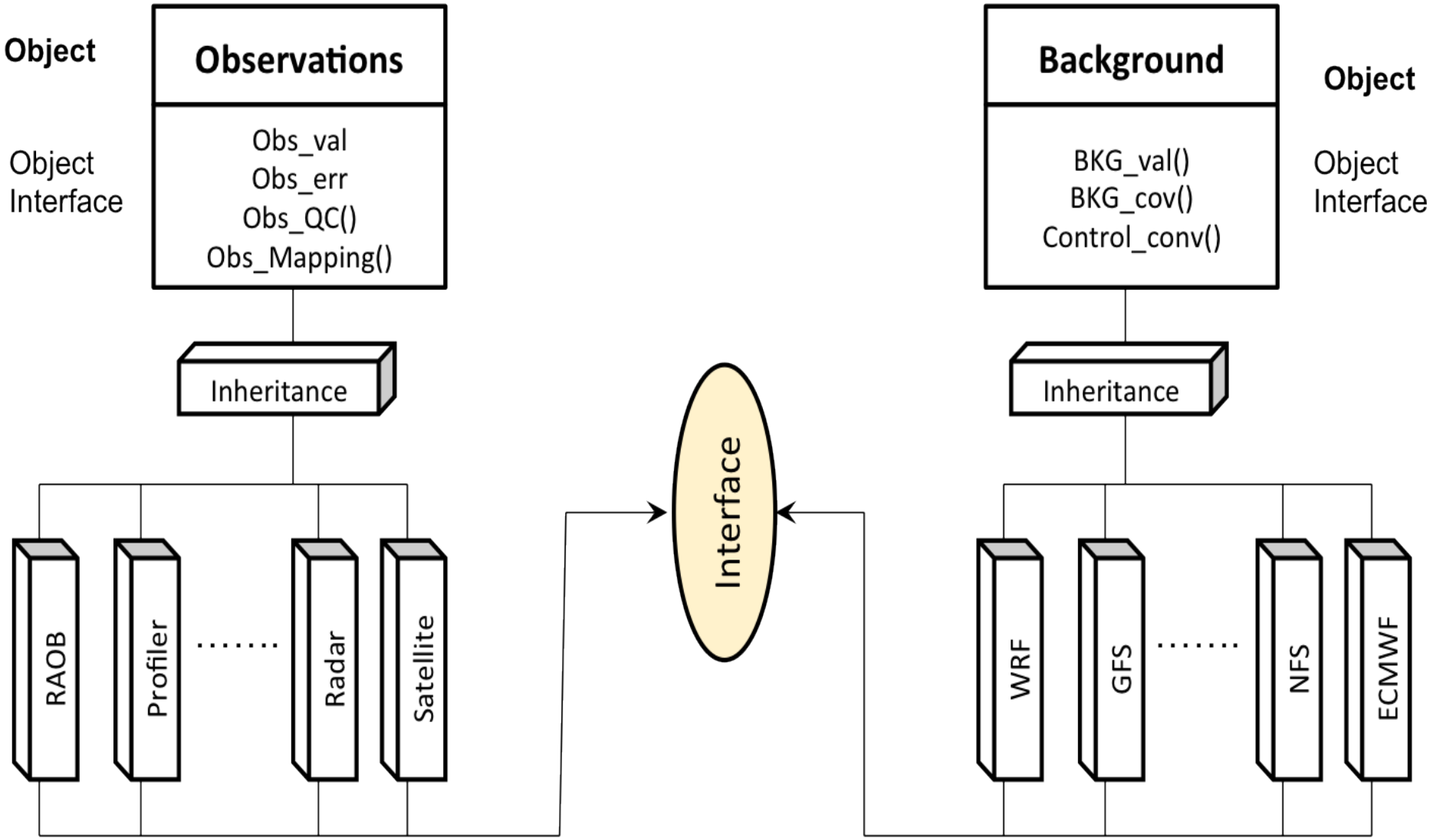




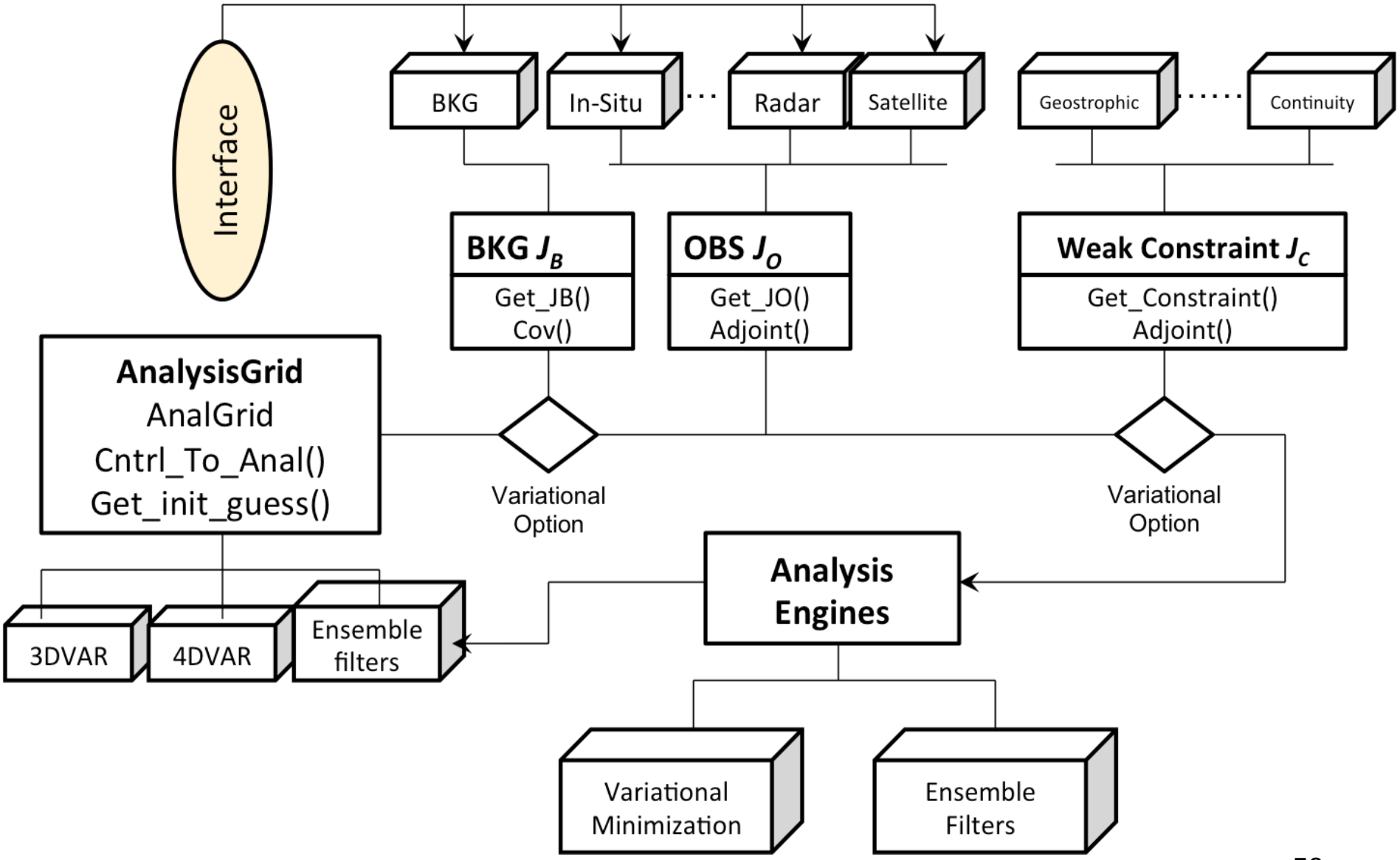
***3DVAR** with **medium-scale** correlations*

Multiscale** approach - Both **large & fine scales captured

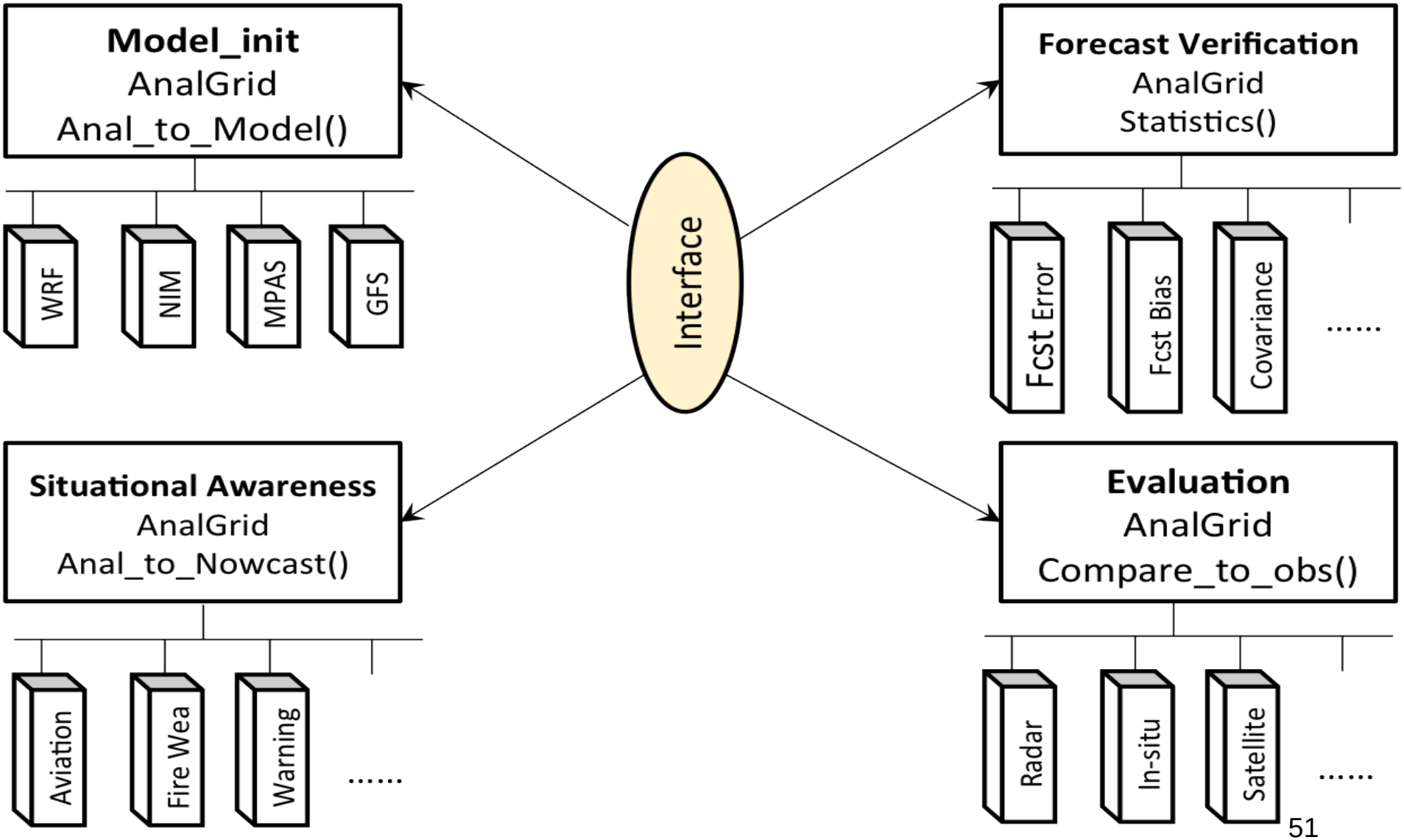
DA – DATA INGEST



DA ENGINE


Interface
BKG
In-Situ
Radar
Satellite
Geostrophic
Continuity
BKG J_B
Get_JB()
Cov()
OBS J_O
Get_JO()
Adjoint()
Weak Constraint J_C
Get_Constraint()
Adjoint()
AnalysisGrid
AnalGrid
Cntrl_To_Anal()
Get_init_guess()
Variational Option
Variational Option
Analysis Engines
3DVAR
4DVAR
Ensemble filters
Variational Minimization
Ensemble Filters

DA – POST-PROCESSING



LAPS BACKGROUND

- "**Traditional LAPS**"
  - Multiscale Barnes analysis used 1989-2012
- I joined GSD in 2009
  - Caretaker, not inventor
  - Saw value, great scientists, dedicated group
- **Renewal of LAPS**
  - Reconnect with community
    - 2 LAPS User Workshops (2010, 2012)
    - Active partnership with KMA, CMA, CWB, FMI, etc
  - Upgrade with state-of-the-art techniques
    - Variational multiscale approach based on STMAS (**Xie et al**) – "**variational LAPS**"

LAPS IN AWIPS-II – FY13 COMPLETED TASKS

- Ongoing support of LAPS in AWIPS II; Annual delivery of upgraded code to NWS
- Direct data ingest from the EDEX database to remove reliance on AWIPS-I data space & capture more data
- Datasets modified were:
  - **METAR data**
  - **Background forecast**
  - **Maritime data**
  - **Aircraft Observations**
  - **Profiler data**
  - **ACARS data**
  - **RAOB data**
- Basic LAPS GUI and short user guide to allow forecasters to:
  - Determine which observations were used by the analyses
  - Re-define the LAPS analysis domain, including:
    - Center latitude and longitude of the LAPS grid
    - Grid resolution (in km)
    - Number of gridpoints
- Delivery of LAPS, including reading data from EDEX database, and LAPS GUI is targeted for build 14.4.1 in July 2014.

LAPS IN AWIPS-II – FY14 ONGOING TASKS

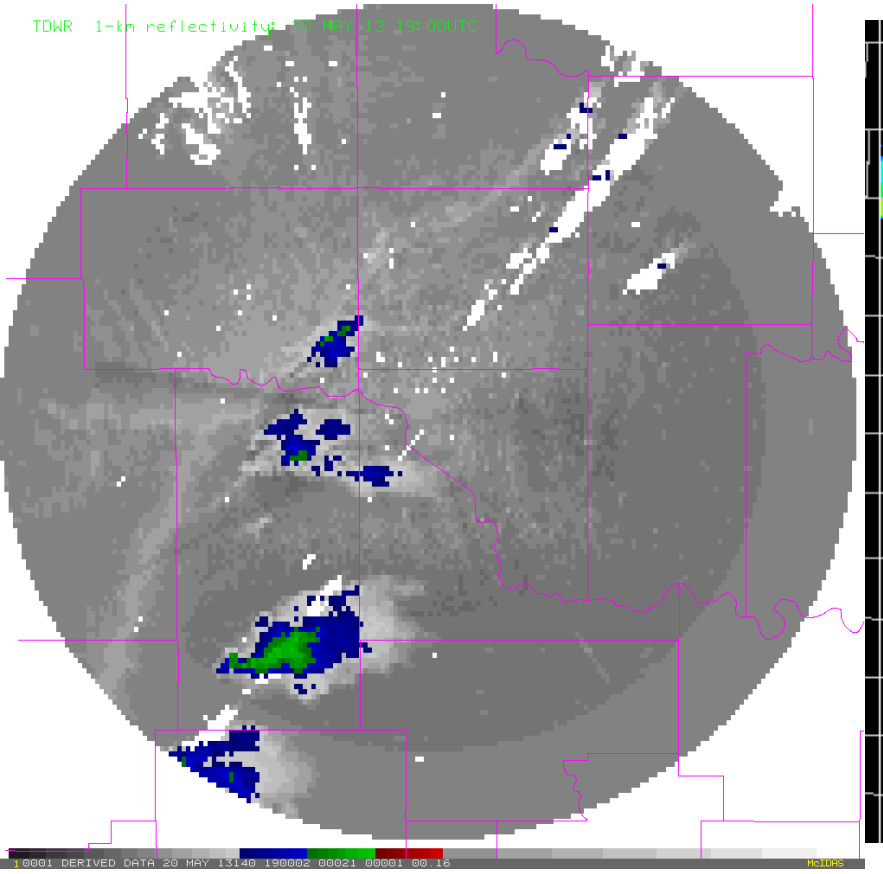
- Ongoing support of LAPS in AWIPS II; Annual delivery of upgraded code to NWS
- Ingest satellite data directly from the EDEX database to remove reliance on AWIPS-I data space (ongoing).
- Pull metadata for background models directly from EDEX database –
  - This will allow ingestion of higher resolution background forecasts (ongoing)

- Other tasks (priority / scope being finalized):
  - Direct ingest of radar data from the EDEX database – more data vertically
  - Further enhancements to LAPS GUI as requested by AWIPS-II users

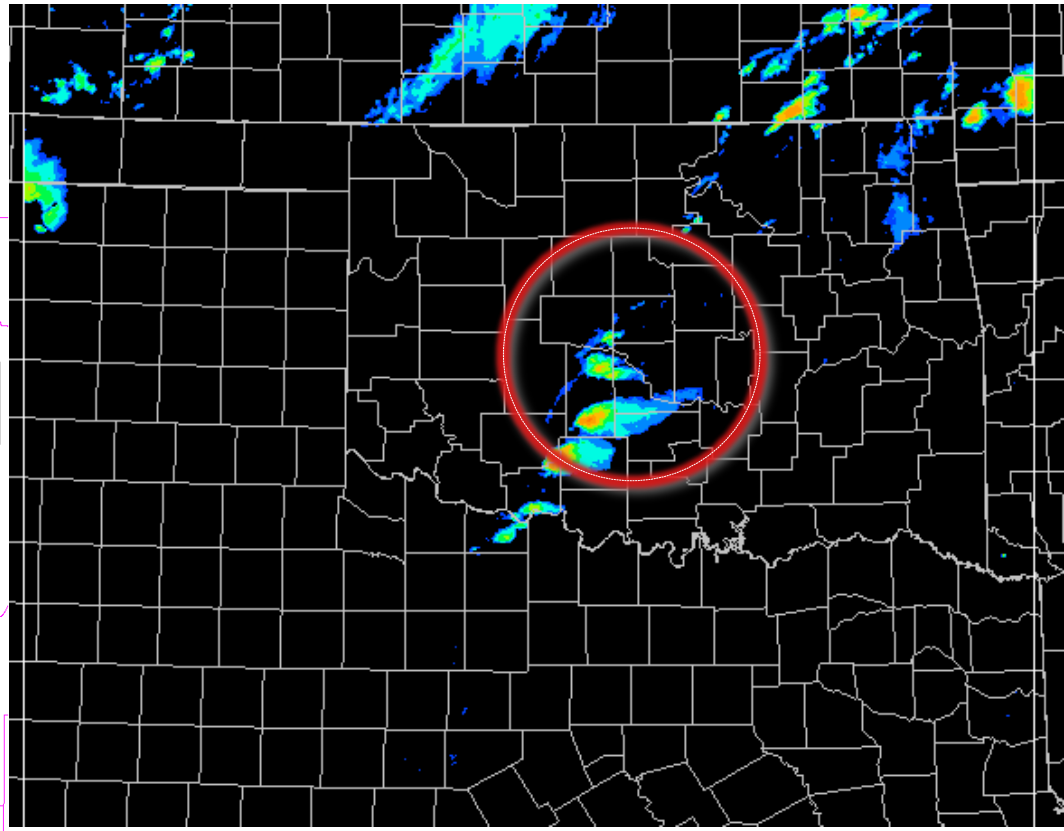
vLAPS 1-km Forecast for Moore Tornado

- vLAPS 2 h forecast initialized at 1900 UTC, 5 min intervals
- Touch down at 19:56 UTC, dissipated around 20:35 UTC

TDWR



LAPS Composite Reflectivity forecast



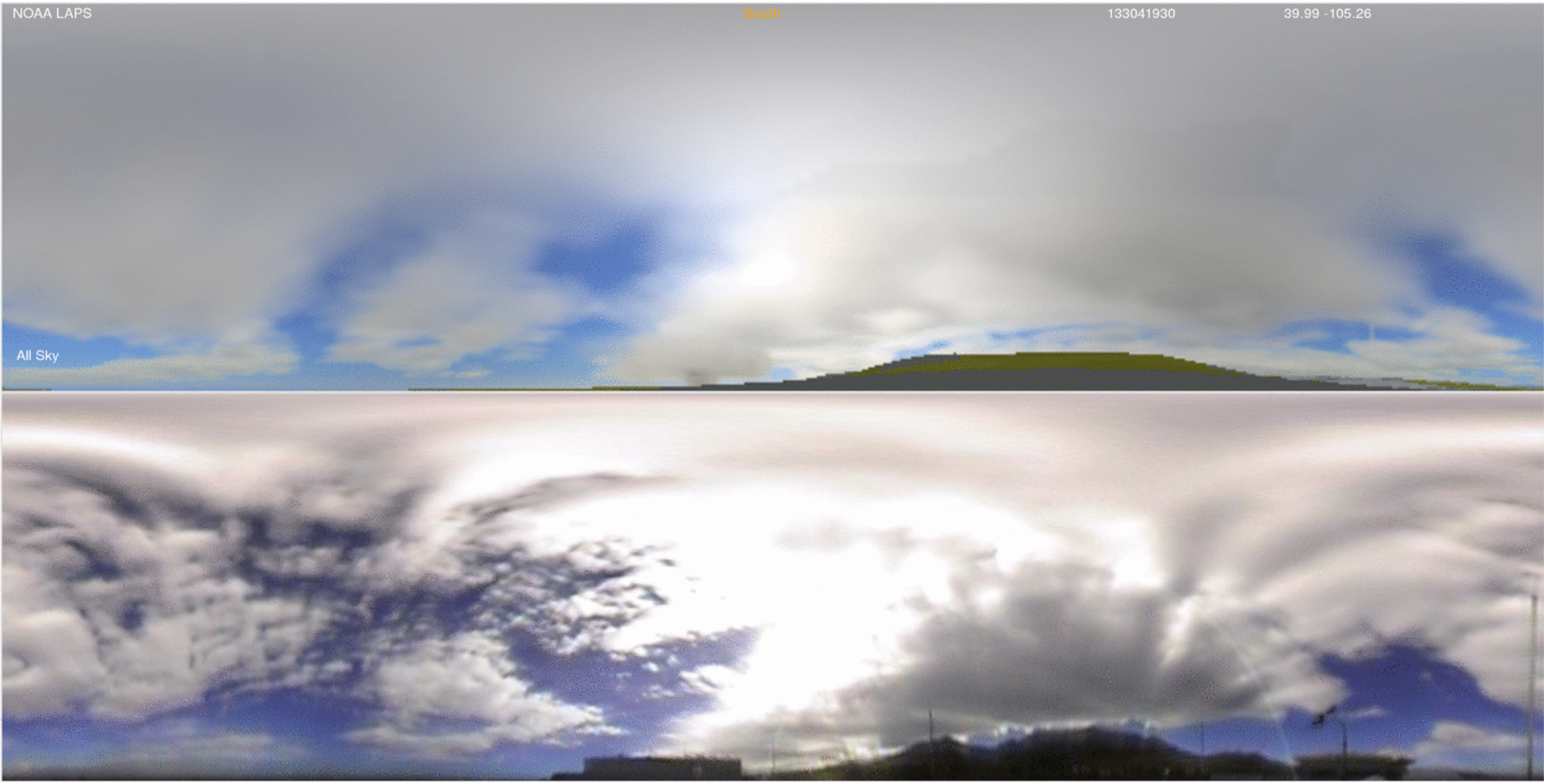
(B. Rabin)

3D 1 km CLOUD ANALYSIS LOOP

Courtesy Steve Albers

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

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



19:30-21:15 UTC Oct 31, 2013, 15-min frequency

ALLSKY CAMERA

WINDSOR, CO TORNADO SIMULATION

generated from 3-D cloud analysis

Cylindrical all-sky image forecast initialized at 1700 UTC 2008 05 22

1.7 km resolution LAPS, 1-min output frequency, out to 17 minutes

Courtesy Steve Albers

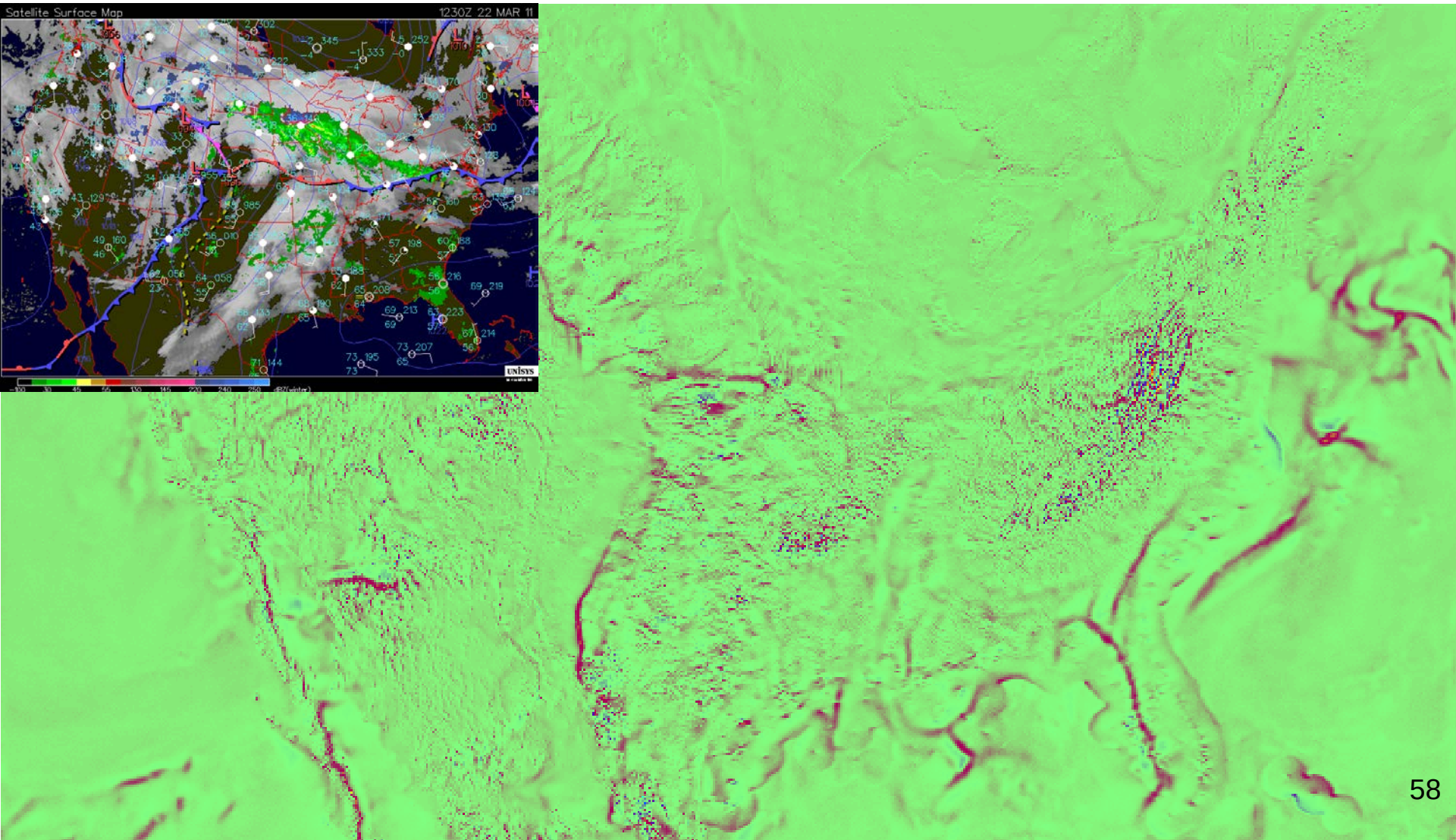
Loop starts ~45 mins before tornadic winds touched ground.
Supercell approaching from South

vLAPS DIVERGENCE ANALYSIS

Continental US

(note the frontal boundaries indicated in the inset)

24-hr Loop for Mar. 23, 2011



BACKGROUND - 2

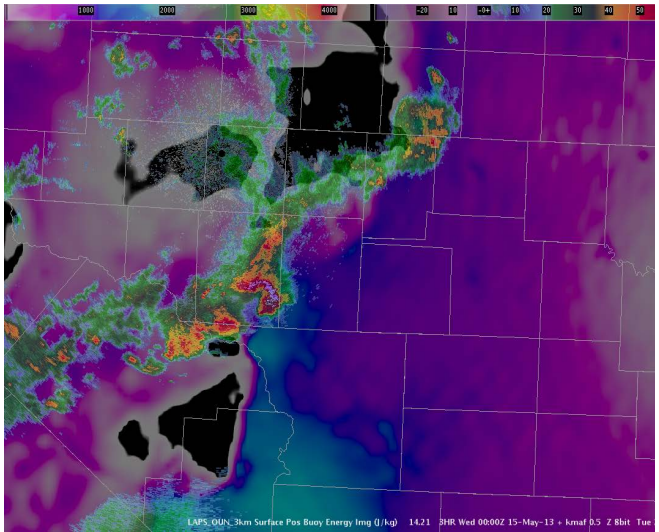
EWP 2013 Real-time blog posted on 13 May 2013

``LAPS again. Higher CAPE, bow echo. Lower CAPE, bye bye bow echo."

"In my opinion, ***the LAPS surface-based CAPE product was one of the stars of the day.***

Consistently, storms lived and died based on entering and exiting the higher **CAPE** values which extended north and northeast from the Big Bend area for most of the day. Lower left image shows the **LAPS surface-based CAPE** at 00Z, and the **radar** at the same time…. Note that the storm is still in the tongue of 1000+ J/kg of CAPE as noted on LAPS. One hour later, the storm is exiting and entering a less favorable instability regime. And predictably, it starts to weaken.

00Z

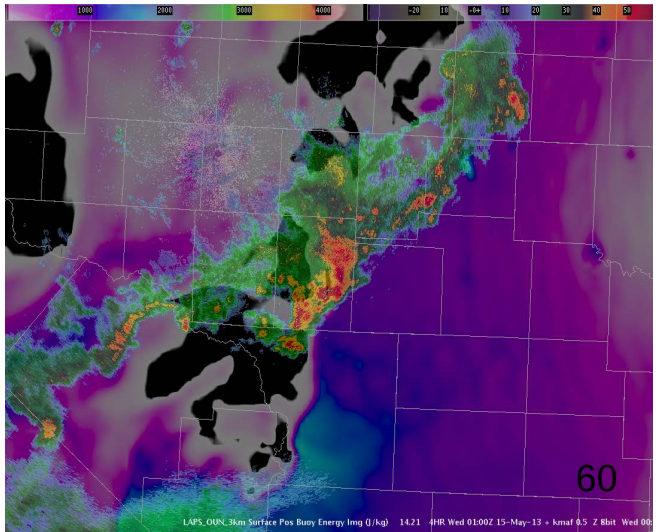


Any questions?

LAPS nailed it."

(courtesy of Chris Leonardi WFO RLX)

01Z



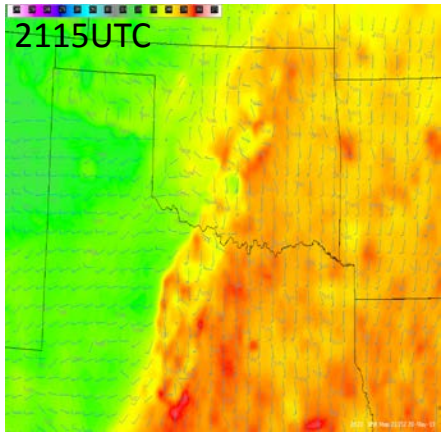
After Moore Tornado Real-time Blog Posted **20 May 2013**

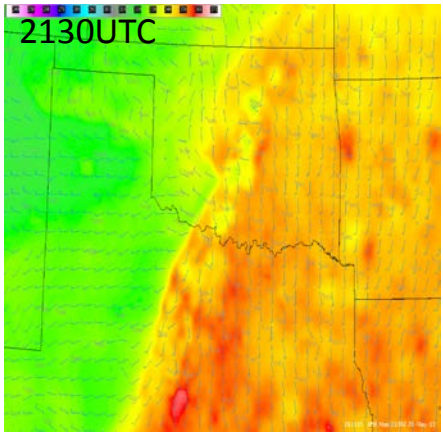
LAPS Observations and Determining Future Storm Development…

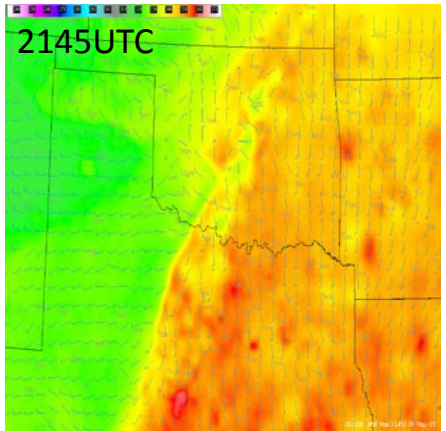
"Just a quick post about observations of the LAPS theta-e field this afternoon. It was interesting to see the near stationary aspect of the θ_e ***boundary in assoc/w the dryline*** to our south across portions of north Texas this afternoon. This suggests that continued development is possible late this afternoon especially across northern Texas, where the gradients have been sustained and have even increased lately. However, notice that the gradients have decreased generally across much of Oklahoma where convection and related effects (rain cooled air, cloud shield) have helped to stabilize the environment."

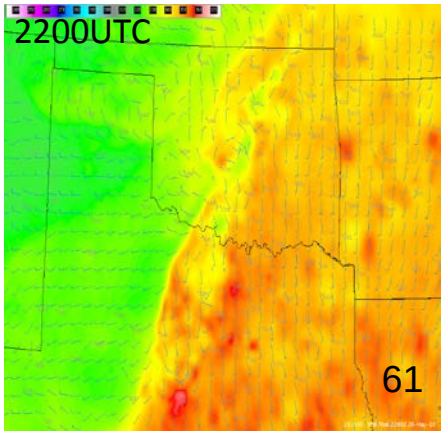
"The 15-minute temporal resolution of the product can be very useful for diagnosing locations of continued convection especially in rapidly developing convective situations." (courtesy of G. Garfield)

Surface θ_e (K, shades) and wind vector



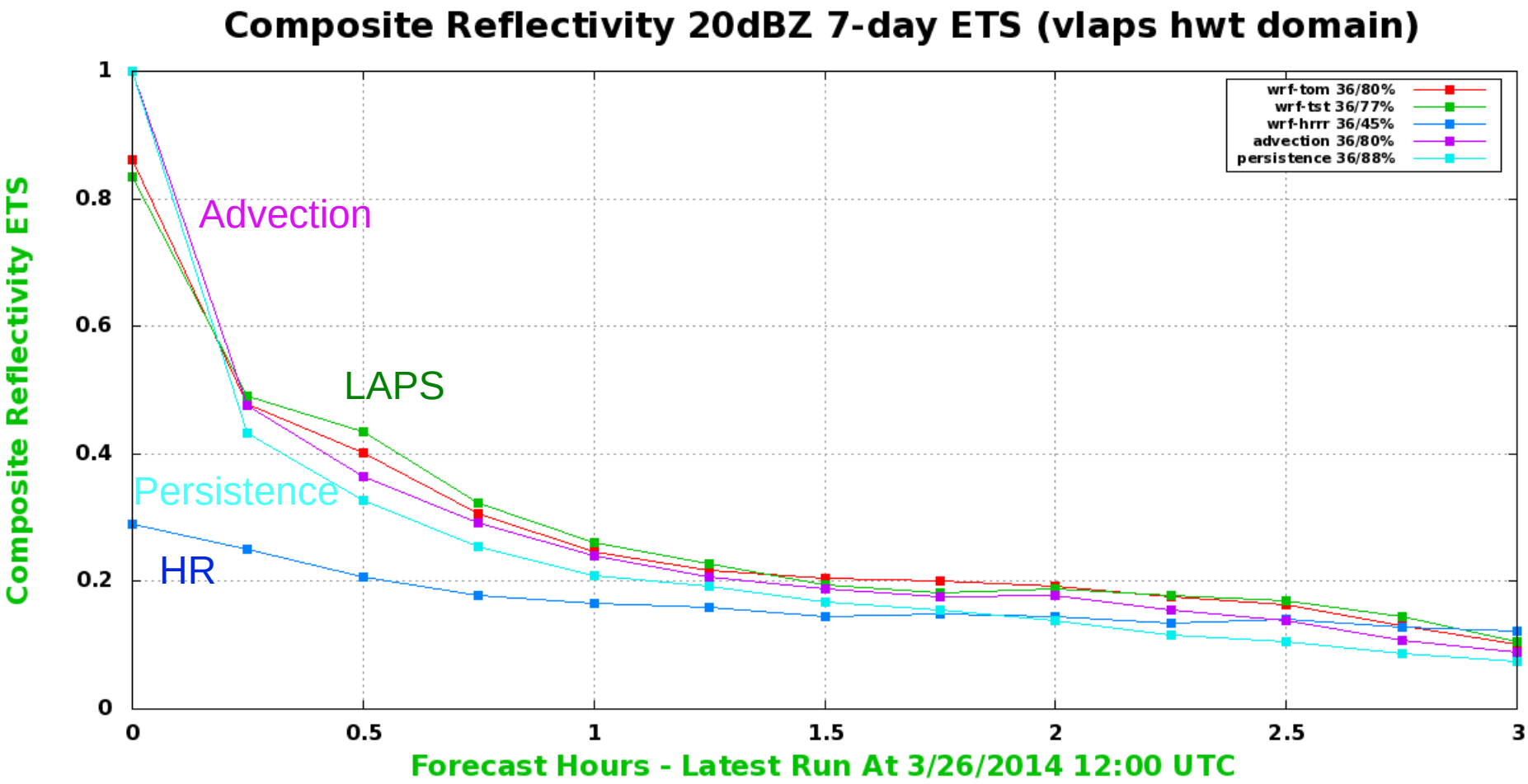






vLAPS vs PERSISTENCE & HR (7-days)

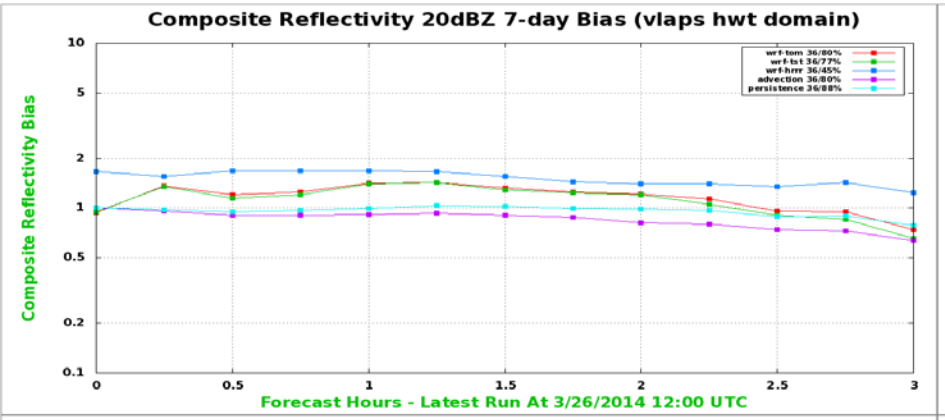
Quality of very short range forecast is indicator of analysis quality

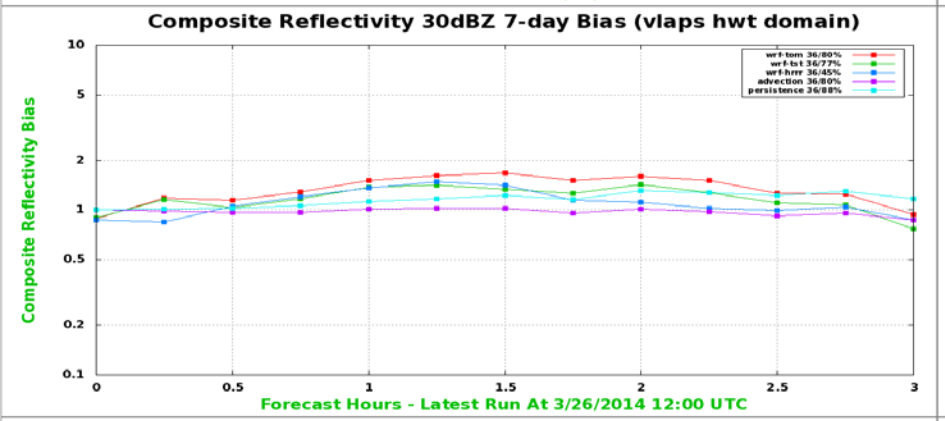


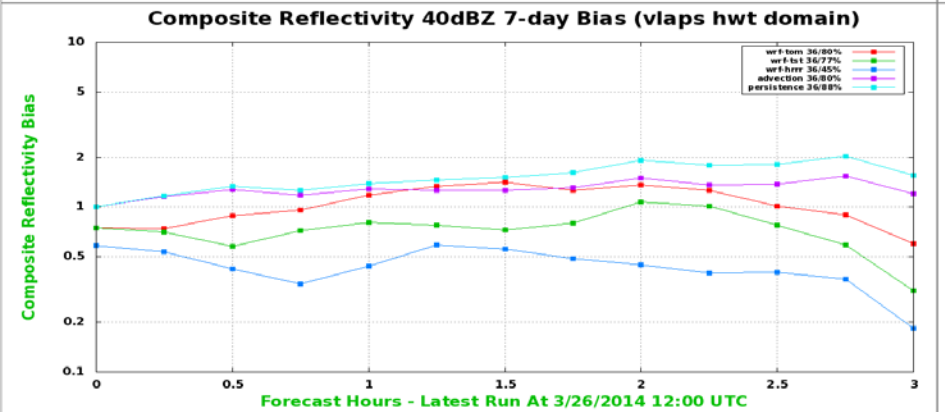
Courtesy Steve Albers

7-DAY MEAN RADAR COMPOSITE REFLECTIVITY SCORES

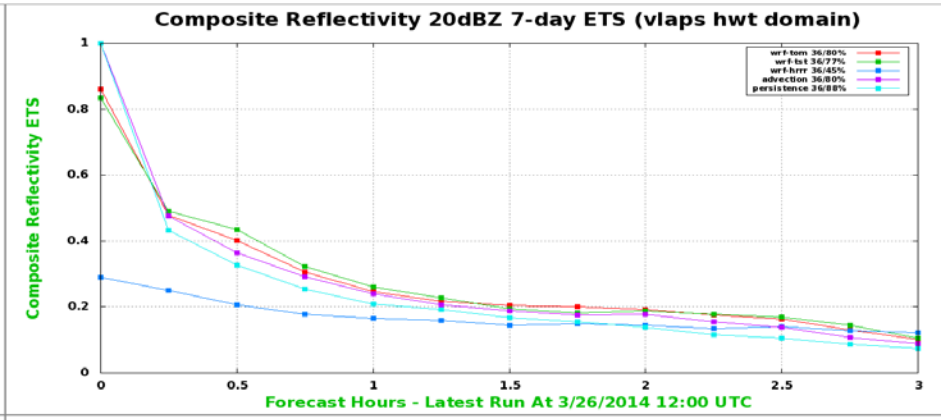
BIAS

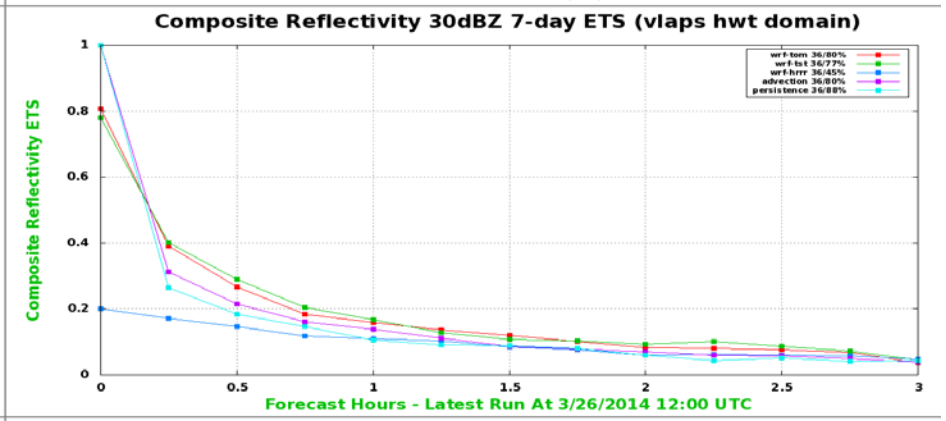


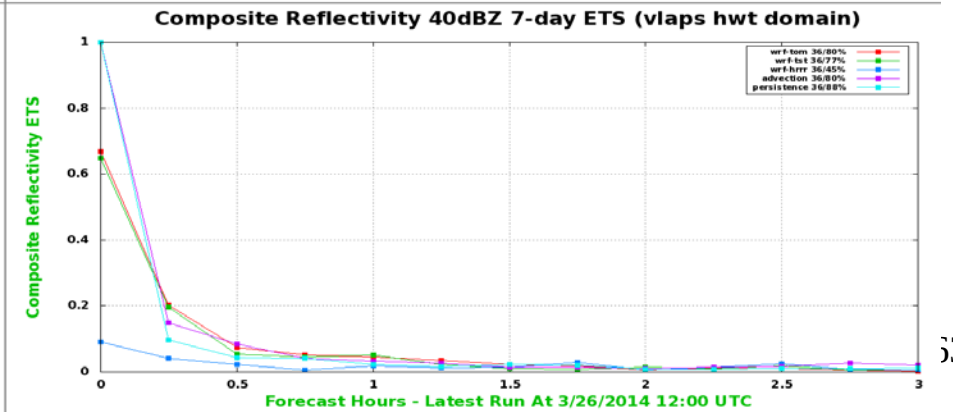




EQUITABLE THREAT SCORE







LAPS IN VLAB

- **Resources offered** in VLab / on IDP Server Farm
  - Space, data access, cpu, potential SOO participation
- **LAPS repository established in VLab**
  - Recommended revision control tool (GIT) used
- **VLab Forum**
  - LAPS briefing scheduled for 18 June
- LAPS group excited about what VLab offers
  - **Community / distributed development** at new level
- VLab LAPS project in planning phase
  - **Seeking input, identifying / developing links**, etc

LAPS IN CDTE

- Central Development and Testing Environment
  - **Climbing the "pyramid" of CDTE** via VLab

- GSD / community
  - Development and **off-line testing**
- **NOAA Testbeds**
  - Testing / development in
    - HWT, HMT – Flash Flood / Winter Weather, AWT
  - Forecaster control
    - Configuration – choice of events, domain, etc
    - Local Quality Control of observations
- **Operational Proving Ground**
  - End-to-end evaluation
- Potential implementation
  - **Operations on IDP Server Farm**

NOWCASTING WITH THE LOCAL ANALYSIS AND PREDICTION SYSTEM (LAPS)

Zoltan Toth,
Yuanfu Xie, Steve Albers[1], Hongli Jiang[1], and Craig Hartsough[2]

Global Systems Division
NOAA/OAR/ESRL

[1] CIRA at GSD
[2] CIRES at GSD

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