Welcome to the 2013 Warn-on-Forecast and High Impact Weather Workshop!

Special Thanks

Linda McGuckin, NSSL

Tonia Rollins, NSSL

Dan Miles, NSSL

Session chairs: Steve Koch, Chris Velden

Panel Discussion Moderator: Kevin Kelleher

Panelists: D. Andra, R. Schneider, S. Weiss,
L. Rothfusz, T. Smith, B. Bunting

Agenda for Wednesday

Session 1: Warn-on-Forecast Overview and Status Reports

Lunch

Session 2: GOES-R Status and Applications
High Impact Weather Warnings

Agenda for Thursday

Session 3: WoF and Decision Support Services

Wrap-up Discussion

End by 12 pm

WiFi Access

“OUGuest”

NSSL's WoF Project

Lou Wicker
NSSL

NSSL's WoF Project

Lou Wicker
NSSL

Thanks to
Warn-on-Forecast partners
for their hard work and dedication!

Talk Outline

- What do we mean by Warn on Forecast?
- Evolution of the WoF vision?
- Highlights of NSSL WoF Activities for 2012

What is Warn on Forecast?

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What is FACETS?

Forecasting a Continuum of Environmental Threats

FACETs

Thursday morning talk!

Idea: Coalesce the disparate watch and warning activities into a single vision for a new threat forecasting paradigm that is…

- ***Modern***
- ***Effective***
- ***Scientifically robust***
- ***Holistic***
- ***Unifying***

Thursday morning talk!

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Lans Rothfusz

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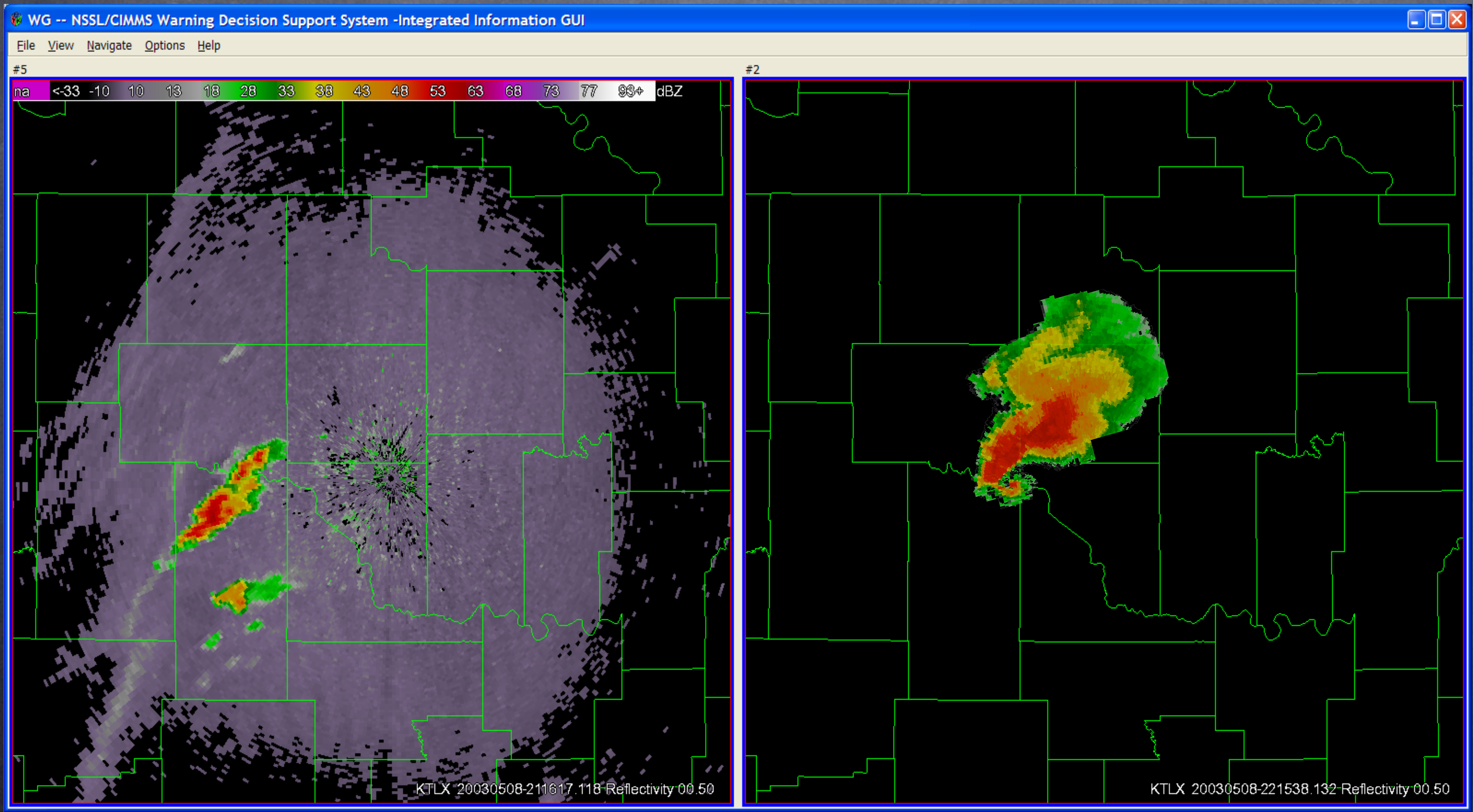
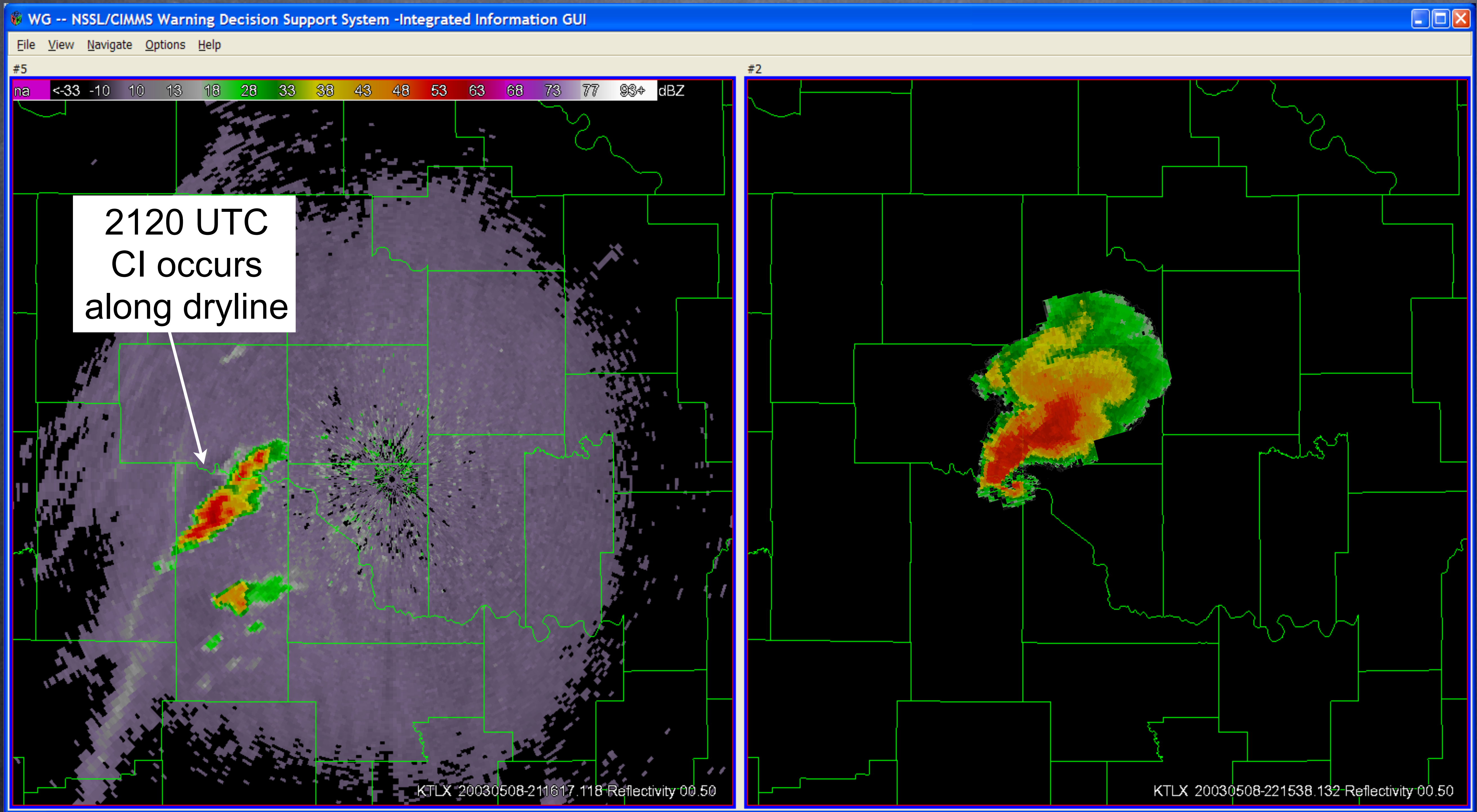
  - WoF-TTP is a specific capability which will be integrated into **FACETS** tornado threat products

Current T-Warning Process



Current T-Warning Process



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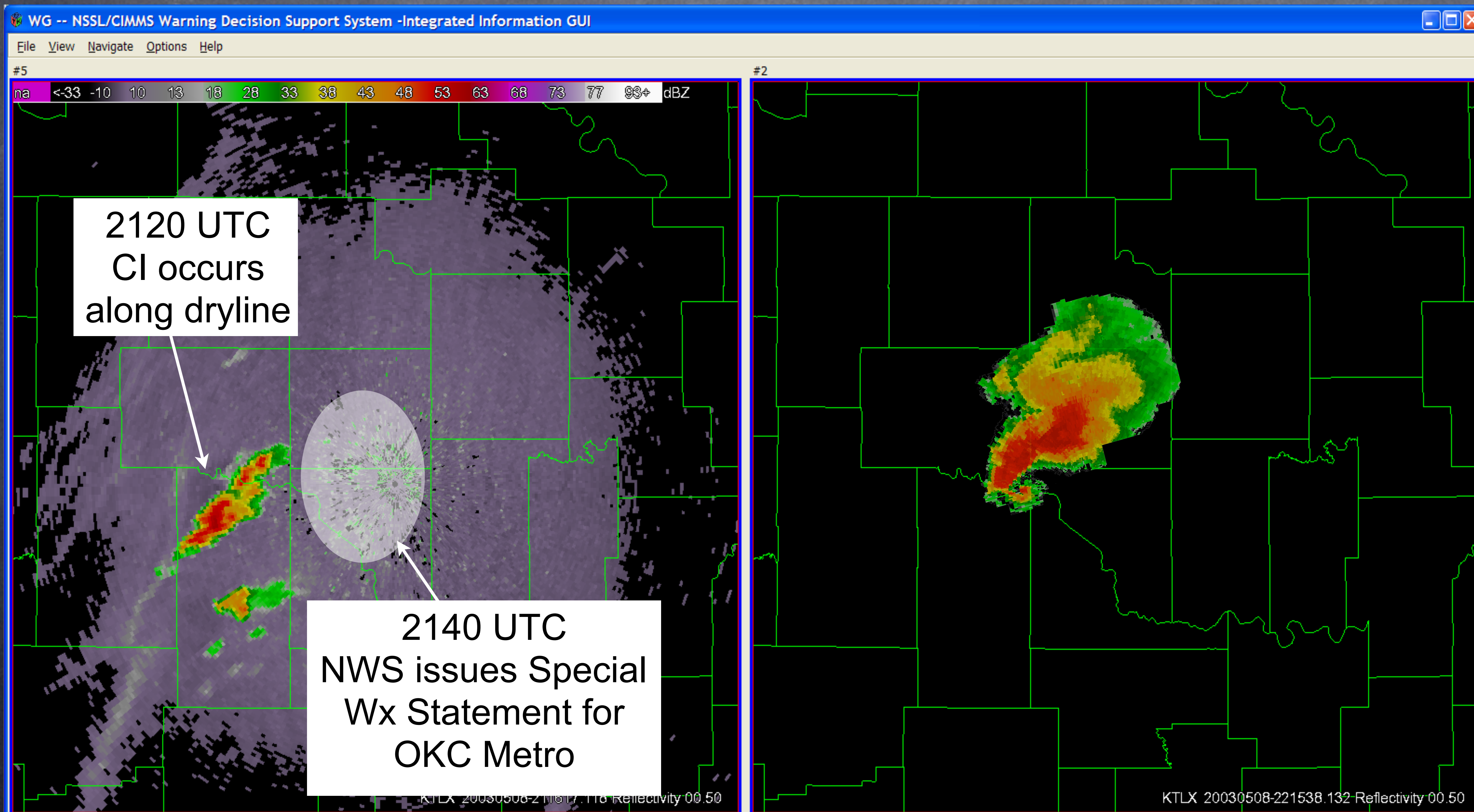

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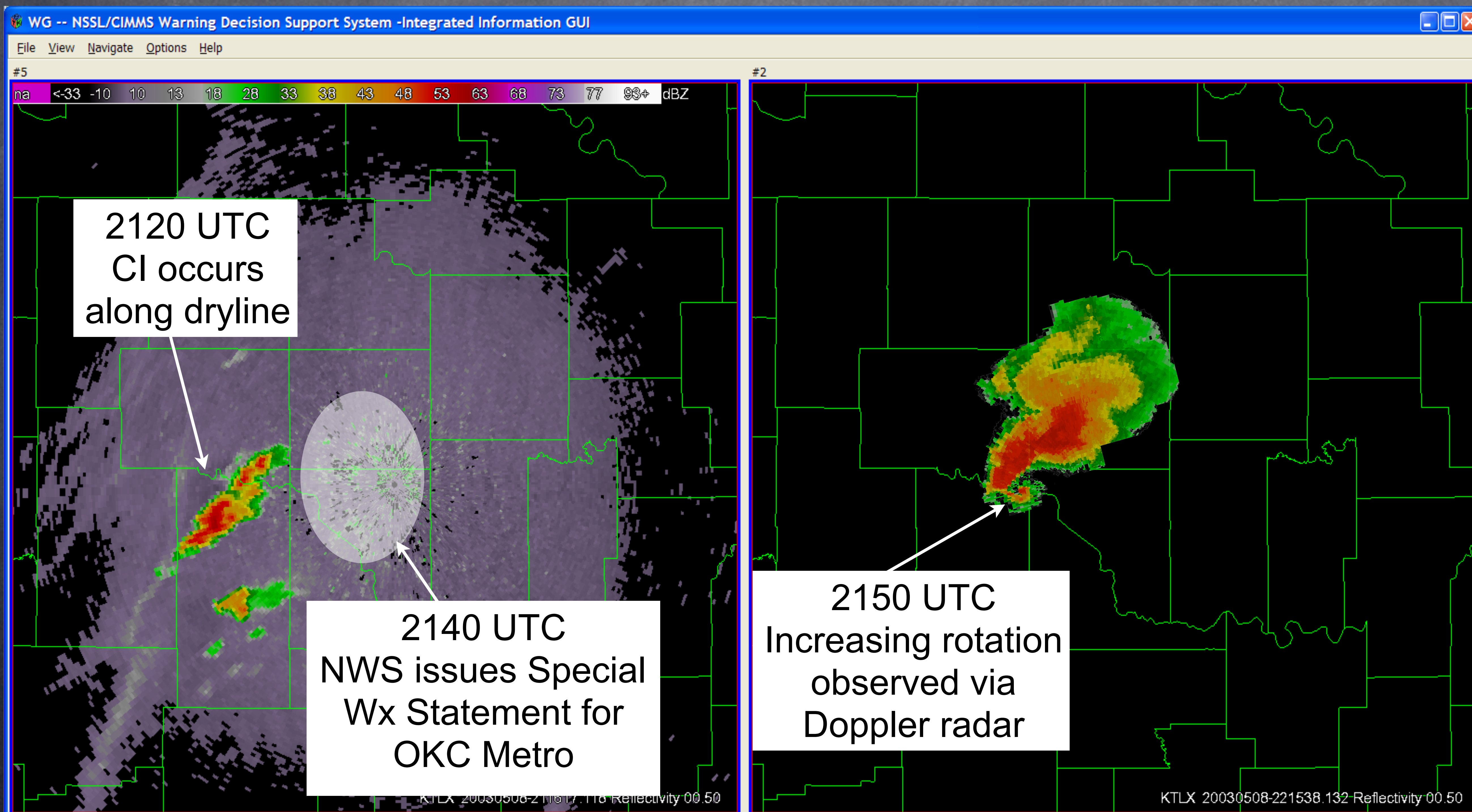

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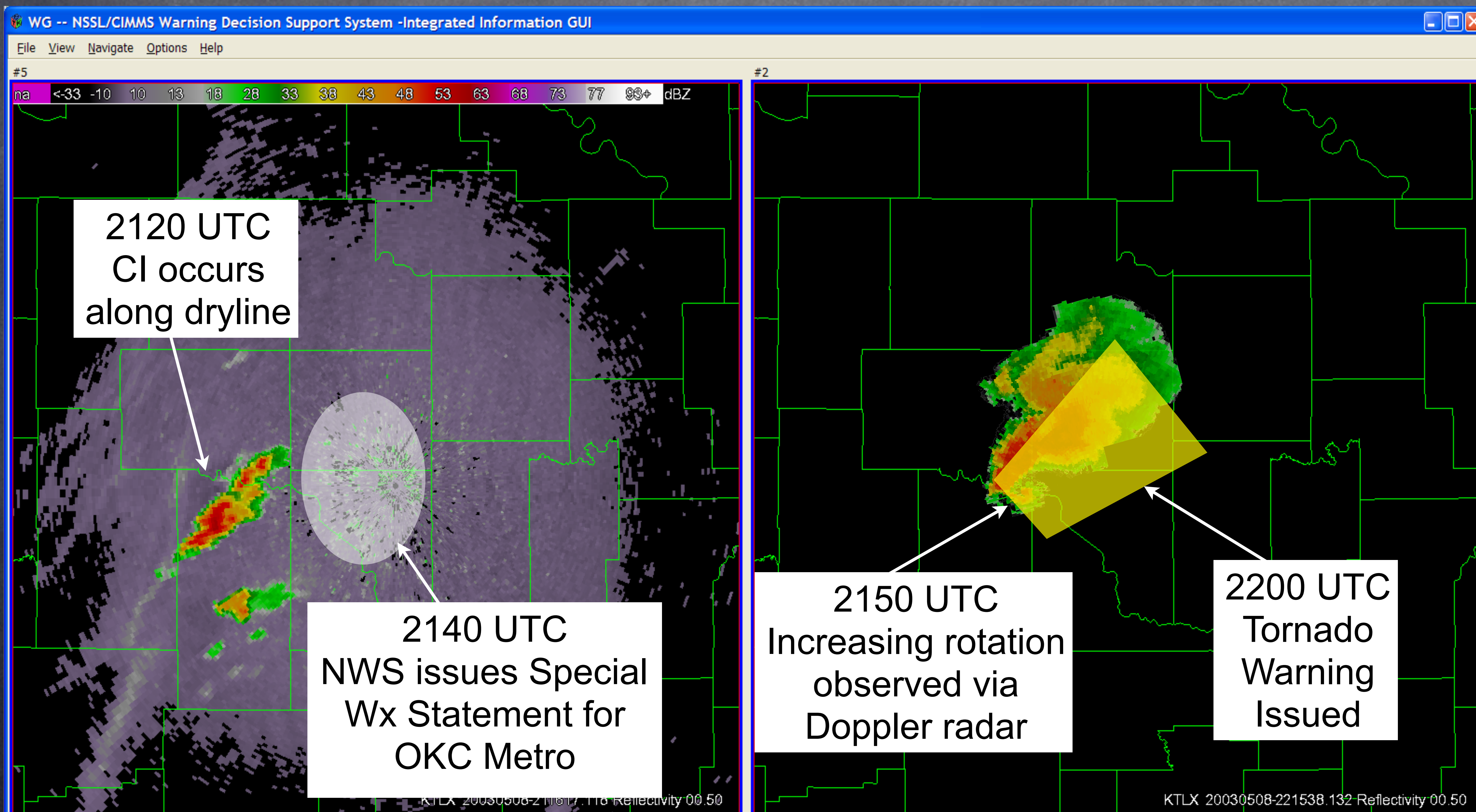
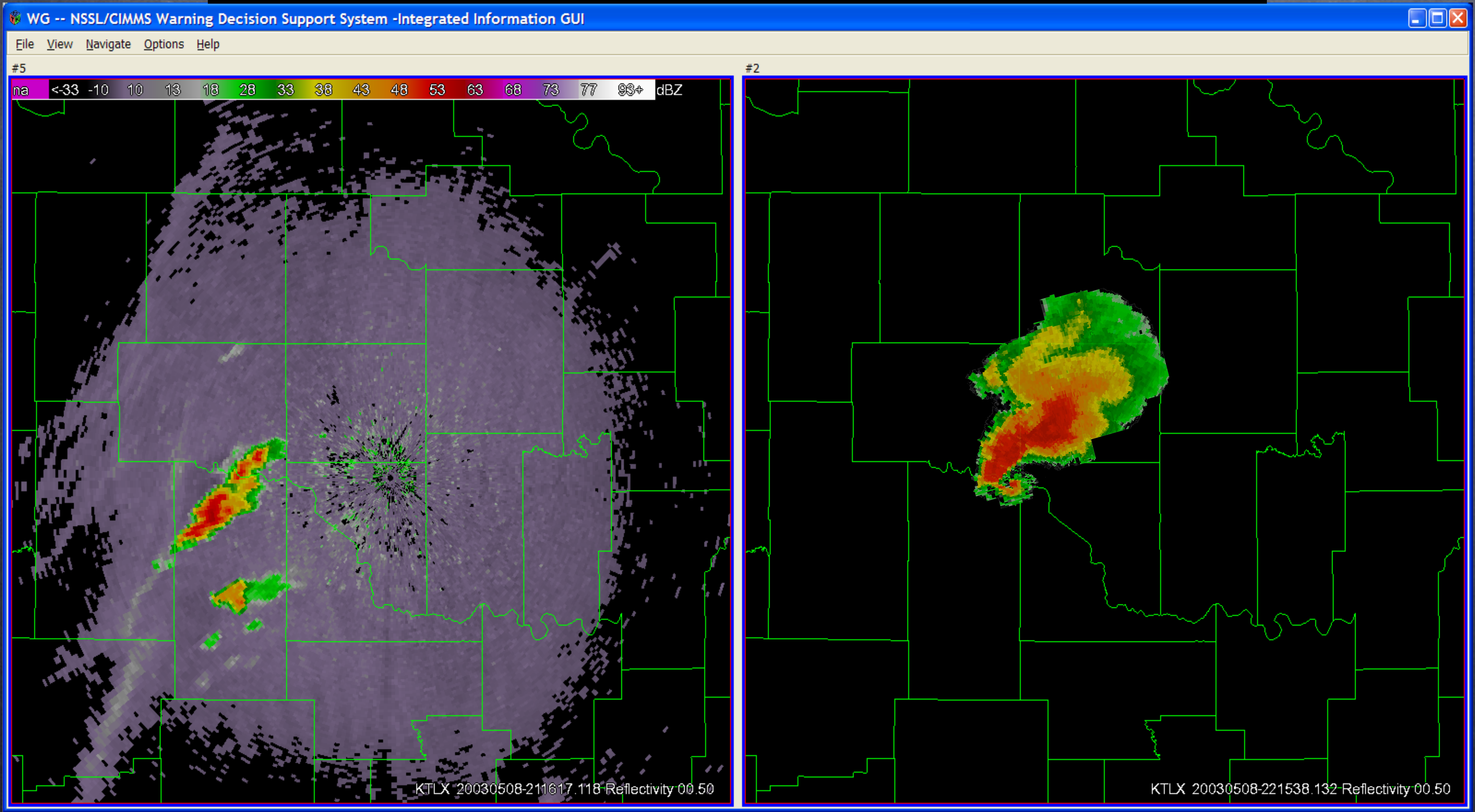


WoF-TTP Process

An ensemble of storm-scale NWP models predict the path of a potentially tornadic supercells during the next 40-60 min. The ensemble is used to create probabilistic tornado guidance.



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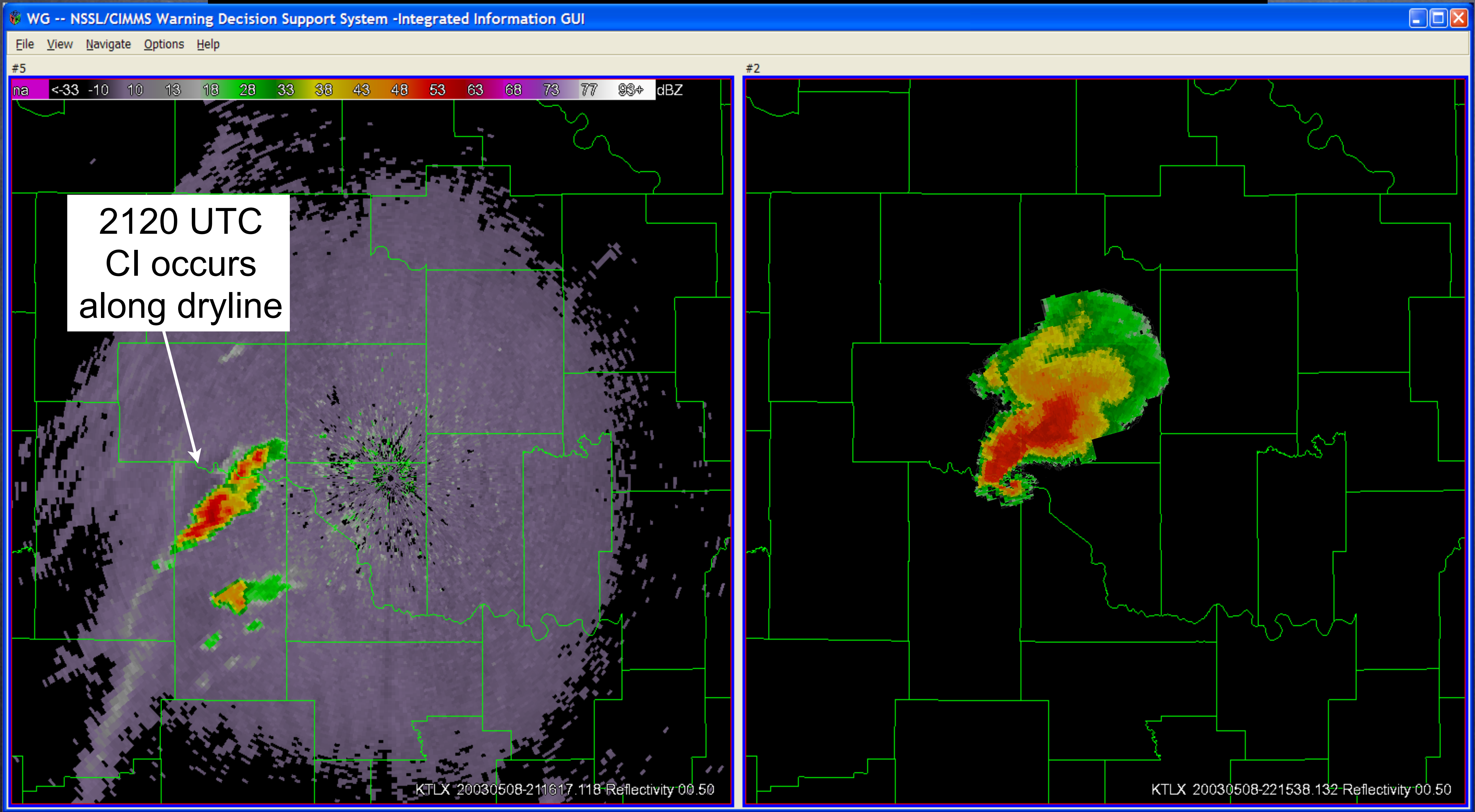

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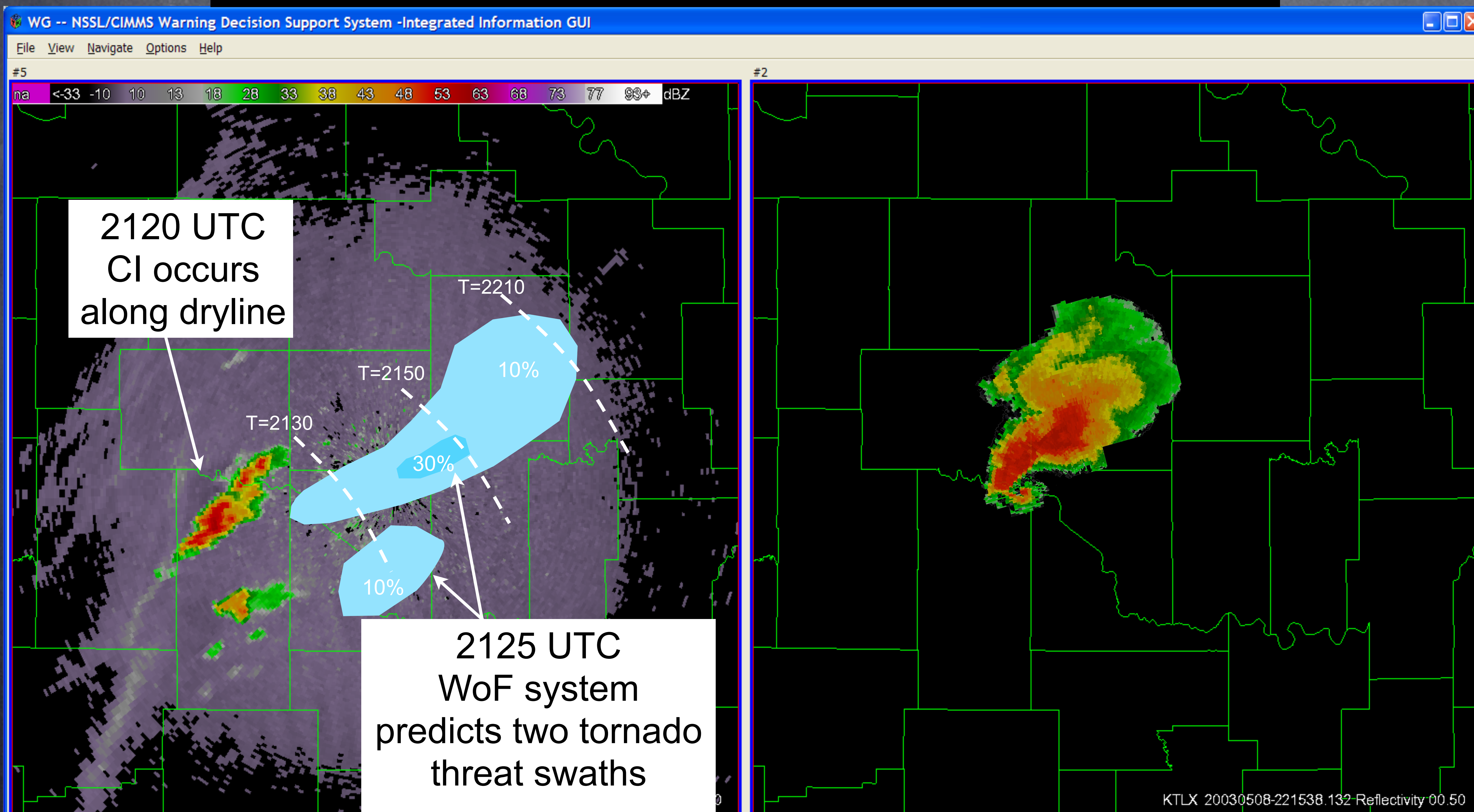

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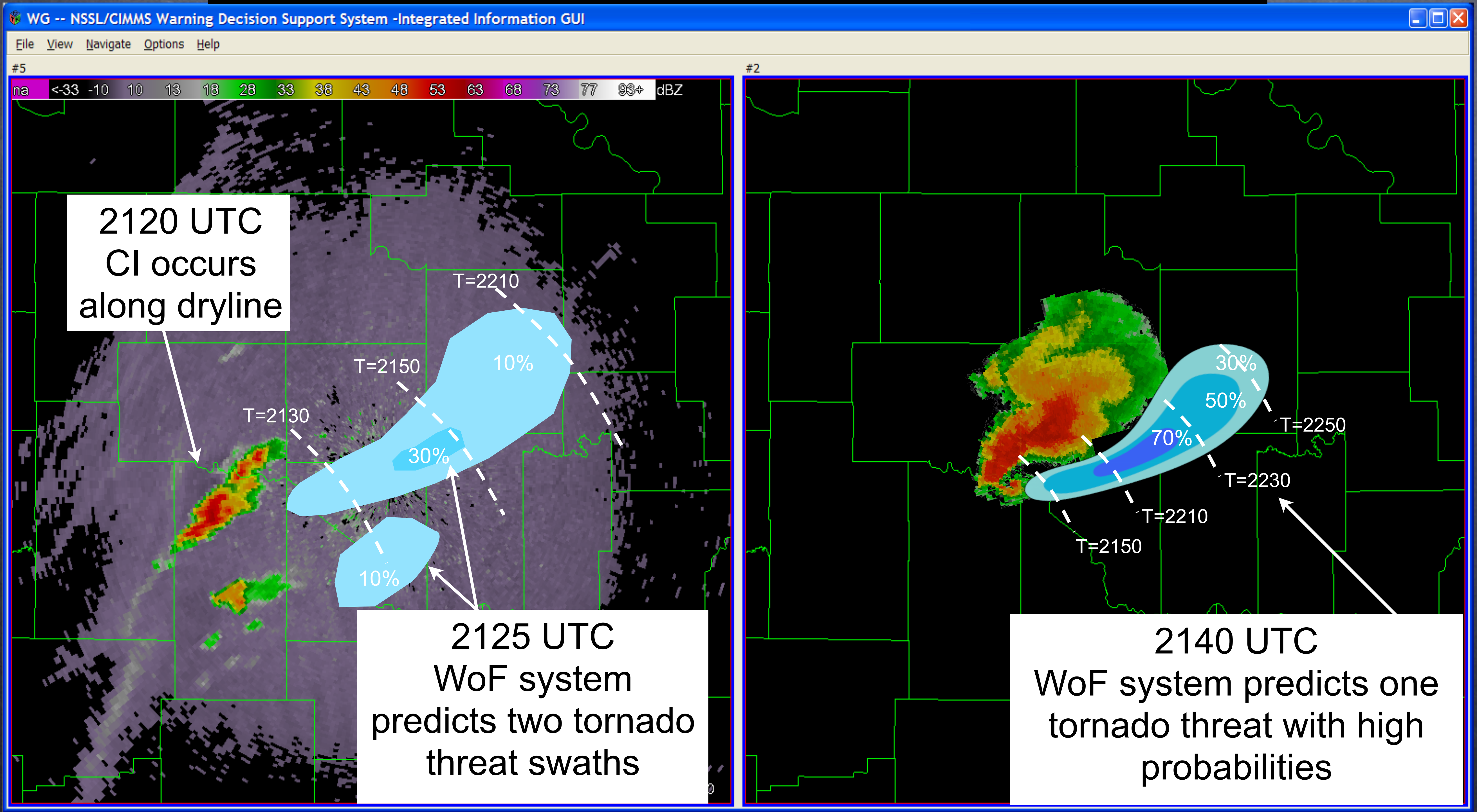

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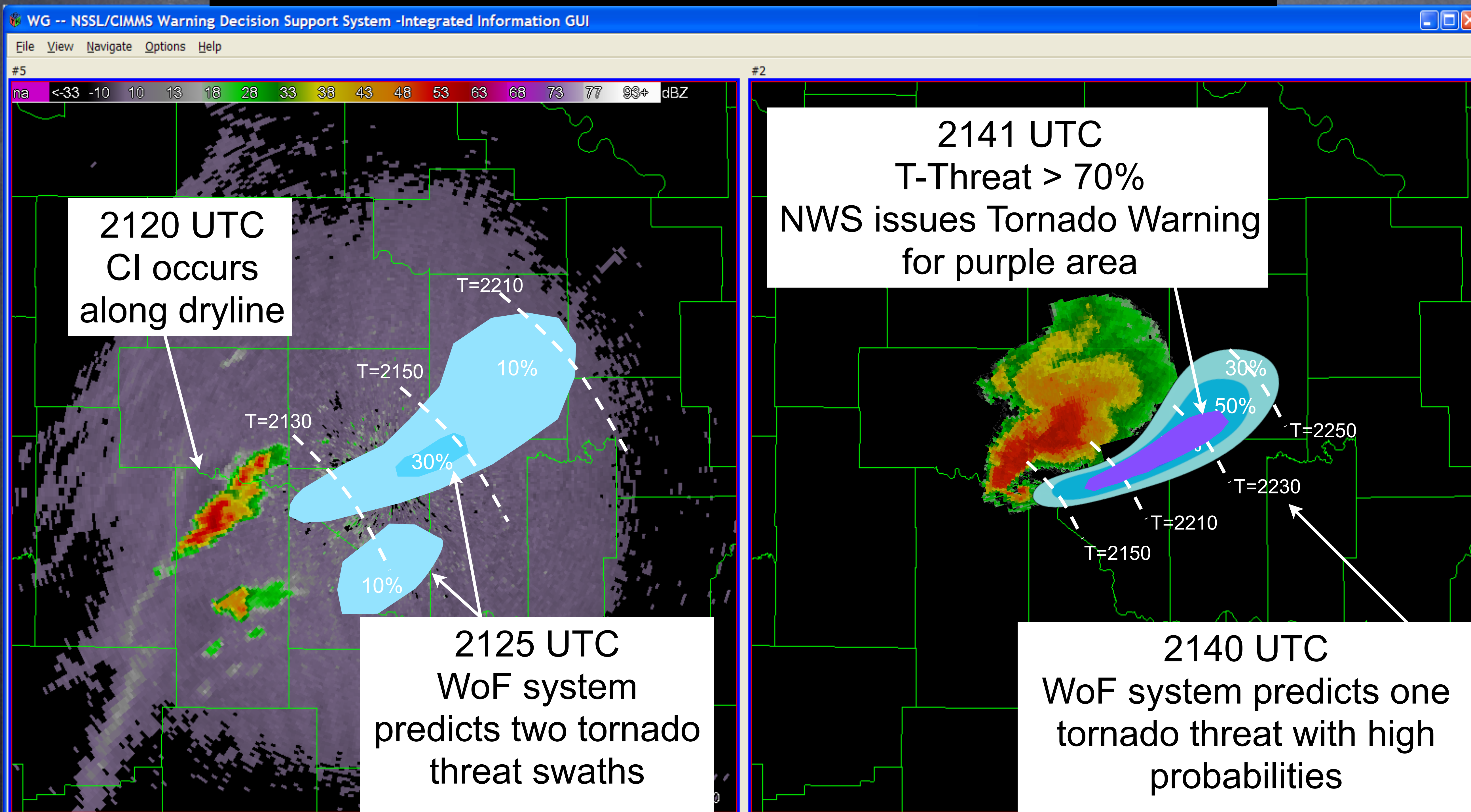

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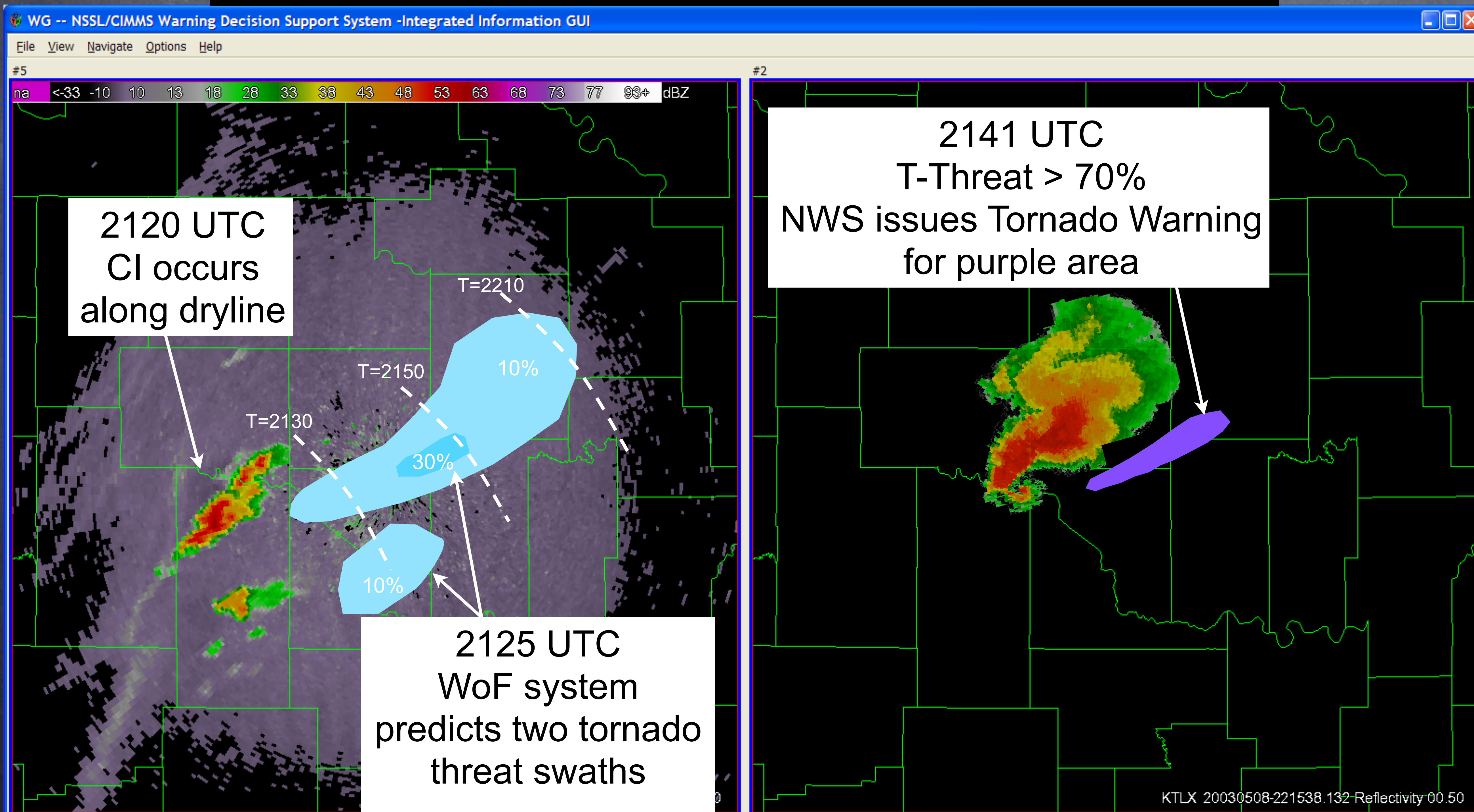

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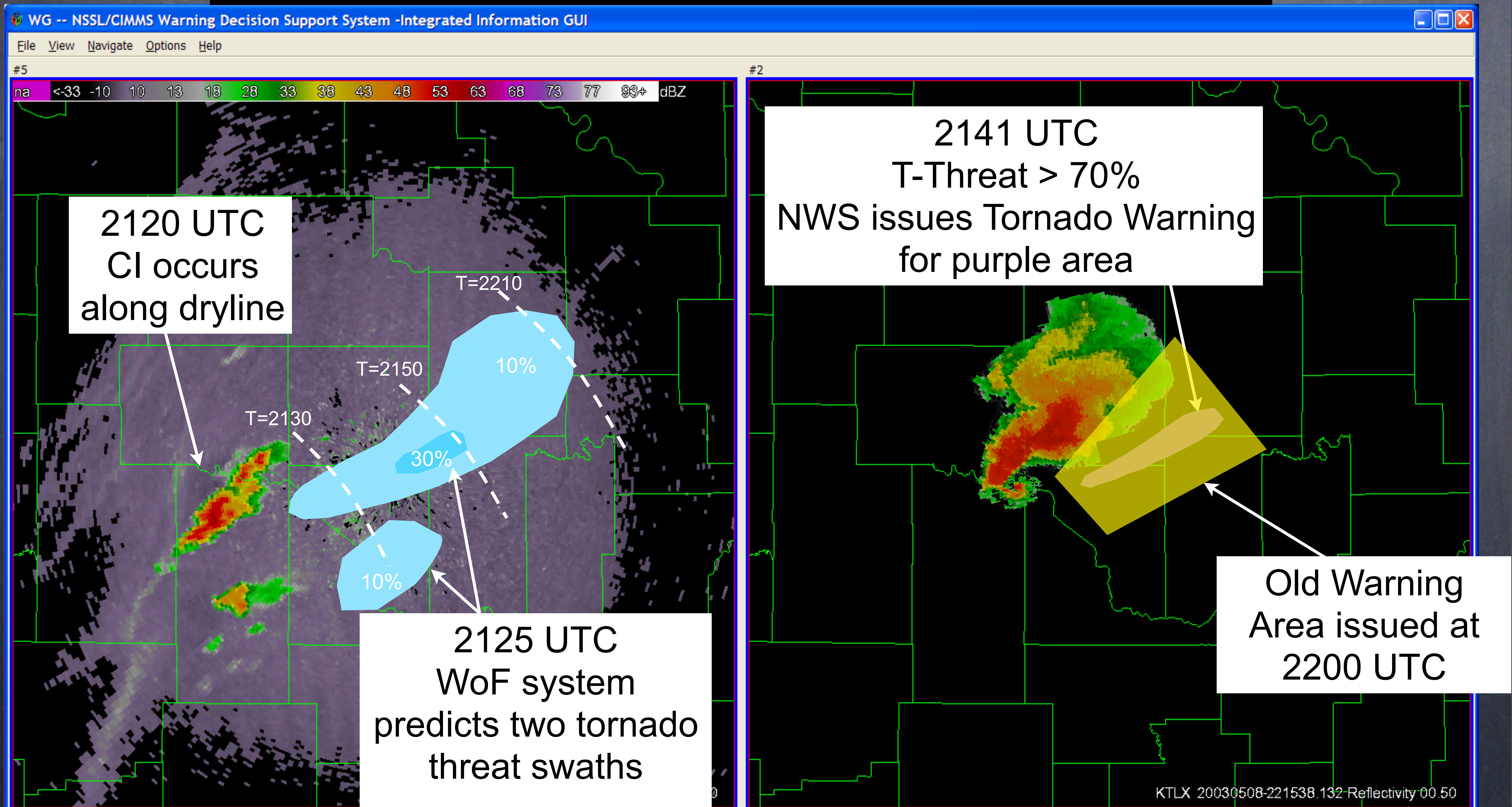


Relationship between NSSL's WoF-TTP and other projects

- Example: High Resolution Rapid Refresh ensemble (HRRRe)
  - 3 km resolution ensemble of HRRRs
  - New analysis & forecasts produced every hour
  - full DA capability including radar, satellite, etc!
- Great Idea! We love this! We want to work with GSD/EMC to see this happen!
- But its **NOT** WoF-TTP! Cannot forecast tornadoes at these resolutions
- A 3 km grid is <u>convection-permitting</u>, but not <u>convection-resolving!</u>
- WoF-TTP will require grid resolution 3-10x higher than this to reliably predict the internal dynamics of convective entities.
- Think of a HRRRe as the initial background fields for a WoF-TTP system

NSSL's WoF-TTP is a research project to develop a 0-1 hour, 1-km resolution ensemble-based NWP system to forecast individual convective storms and their tornadoes.

2012 NSSL Activities

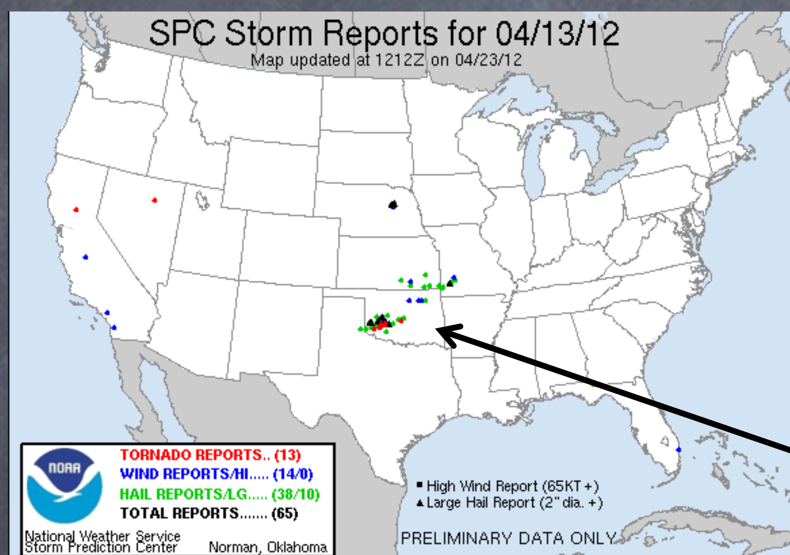
A Weather-Adaptive 3DVAR System used in HWT

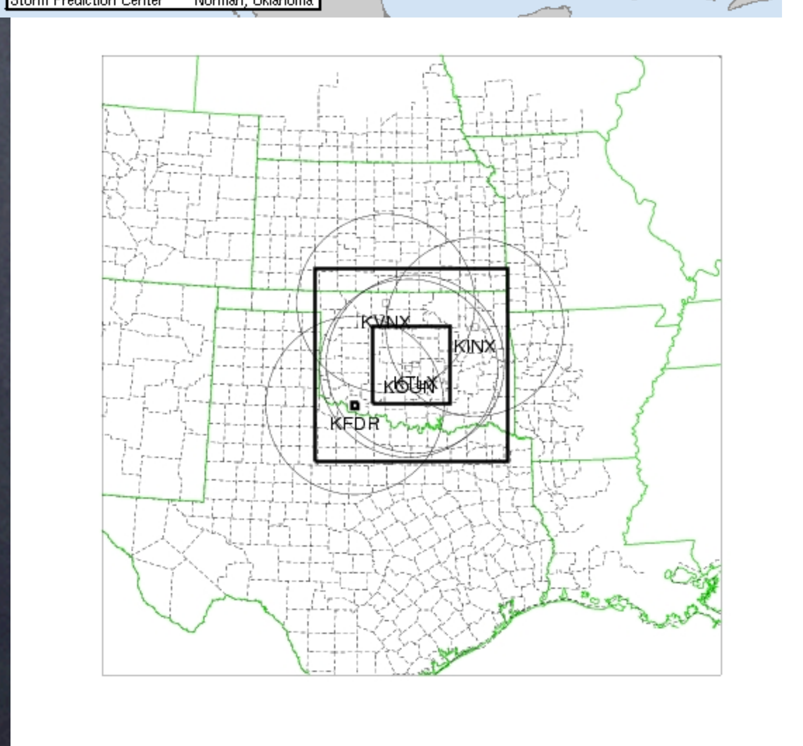
(J. Gao and collaborators)

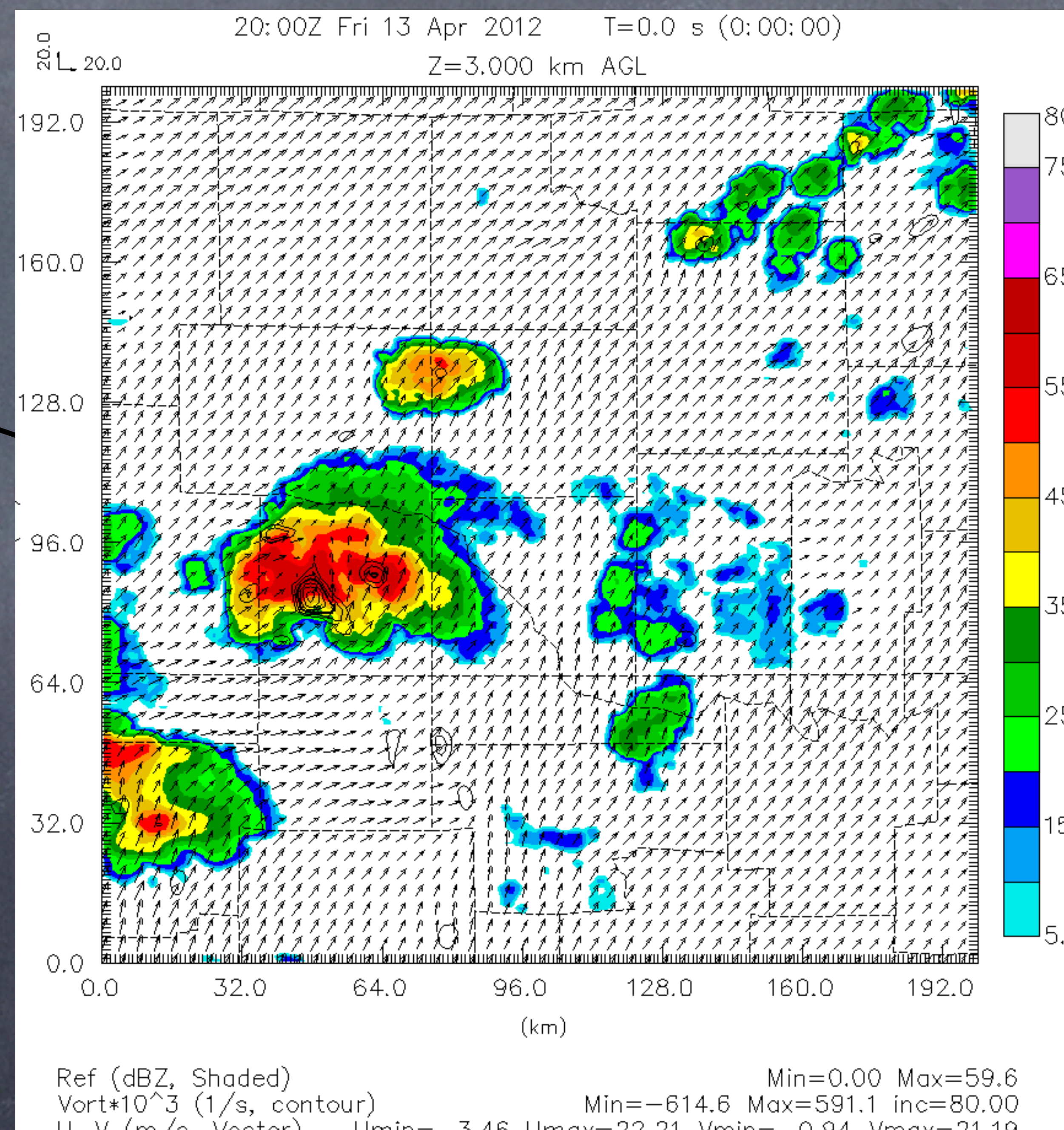
- Focus:
- Using the operationally available radar data from the 88D network to create realtime weather-adaptive 3DVAR analyses:
  - high horizontal resolution (200x200 km domain having 1 km grid)
  - high time frequency (new analysis every 5 min)
  - Up to five local adaptive domains run every 5 min.
- Analyses are used by forecasters to see if they add value regarding the hazardous weather threat.

Realtime 3DVAR Output
Norman Tornado, 13 April 2012

(J. Gao and collaborators)







Radar QC

(C. Karstens and collaborators)

- Goal: Interactive interface
  - Rapidly test different schemes and combinations of schemes
  - Rapidly process large amounts of data
  - Output formats:
    - WDSS2, M31, Foray, images, shapefiles
- (Soon) able to do data thinning via OPAWS
  - output to DART obs_seq
- Collaborators hopefully can access it later this year

8 May 2003: Multiscale experiment
EnKF (DART) used for multiple scales

Yussouf et al. 2013

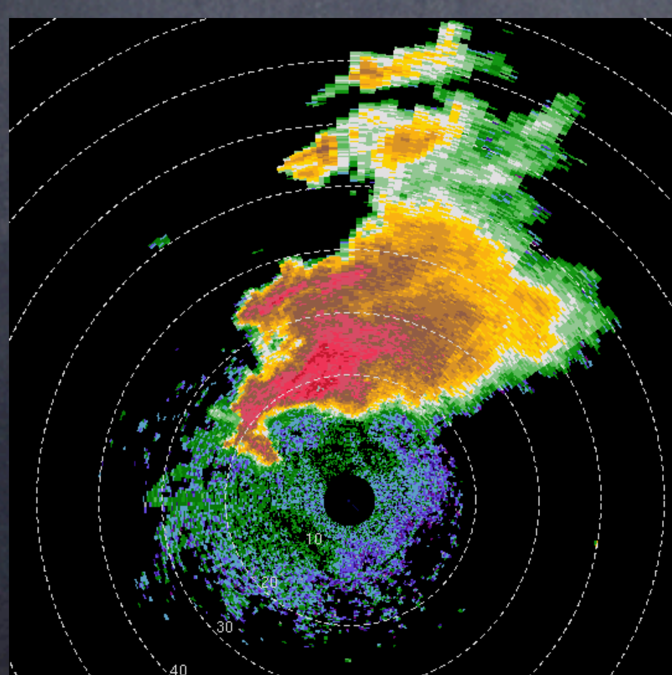
Mesoscale Ensemble

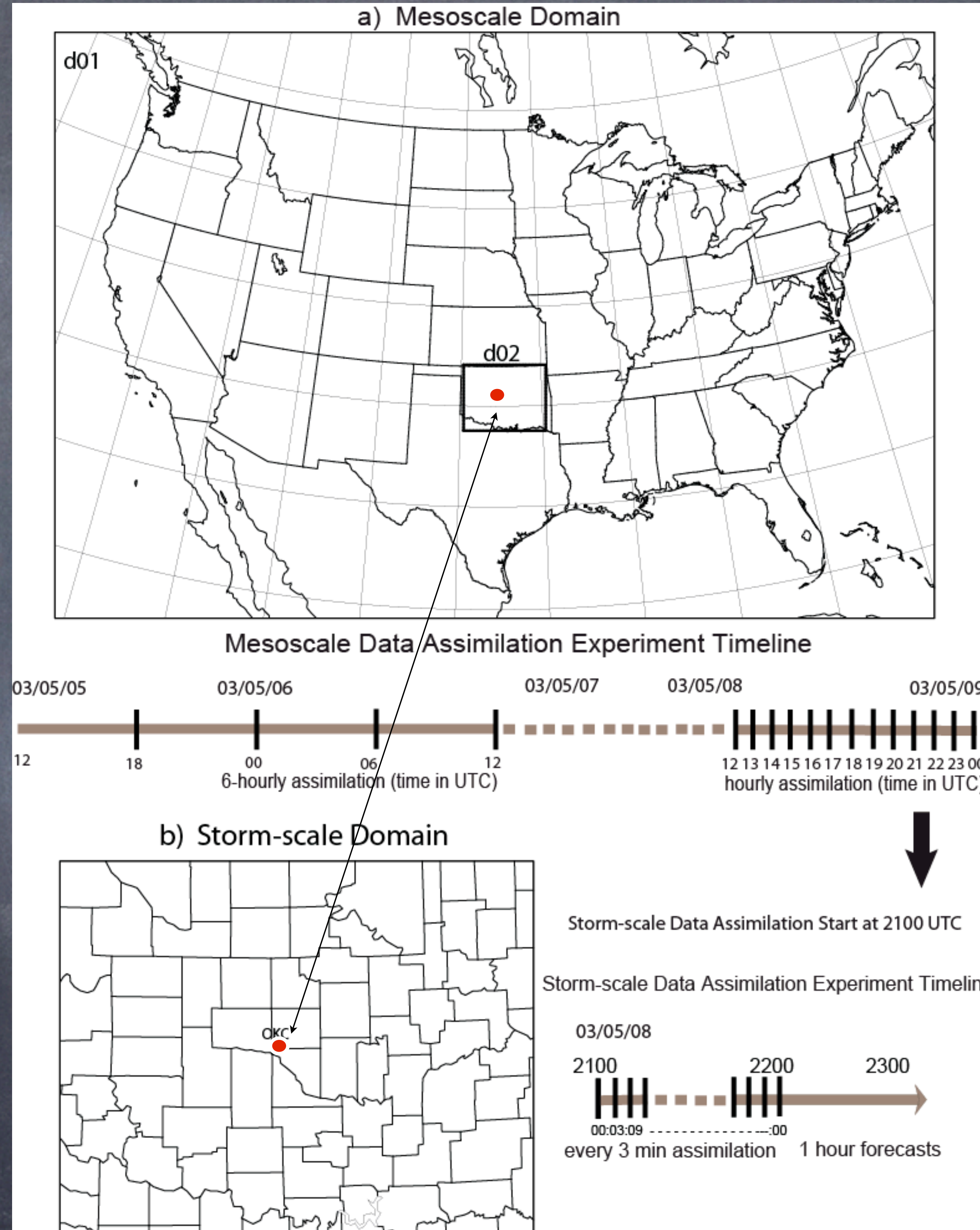
- 45 member WRF mesoscale ensemble at 18 km horizontal grid spacing
  over CONUS initialized from GFS
- 3 day cycling with assimilation of routinely available observations from
  metar, marine, radiosondes and ACARS using DART system
- Physics options used: MYJ, Thompson, Kain-Fritsch, Noah, Dudhia and RRTM

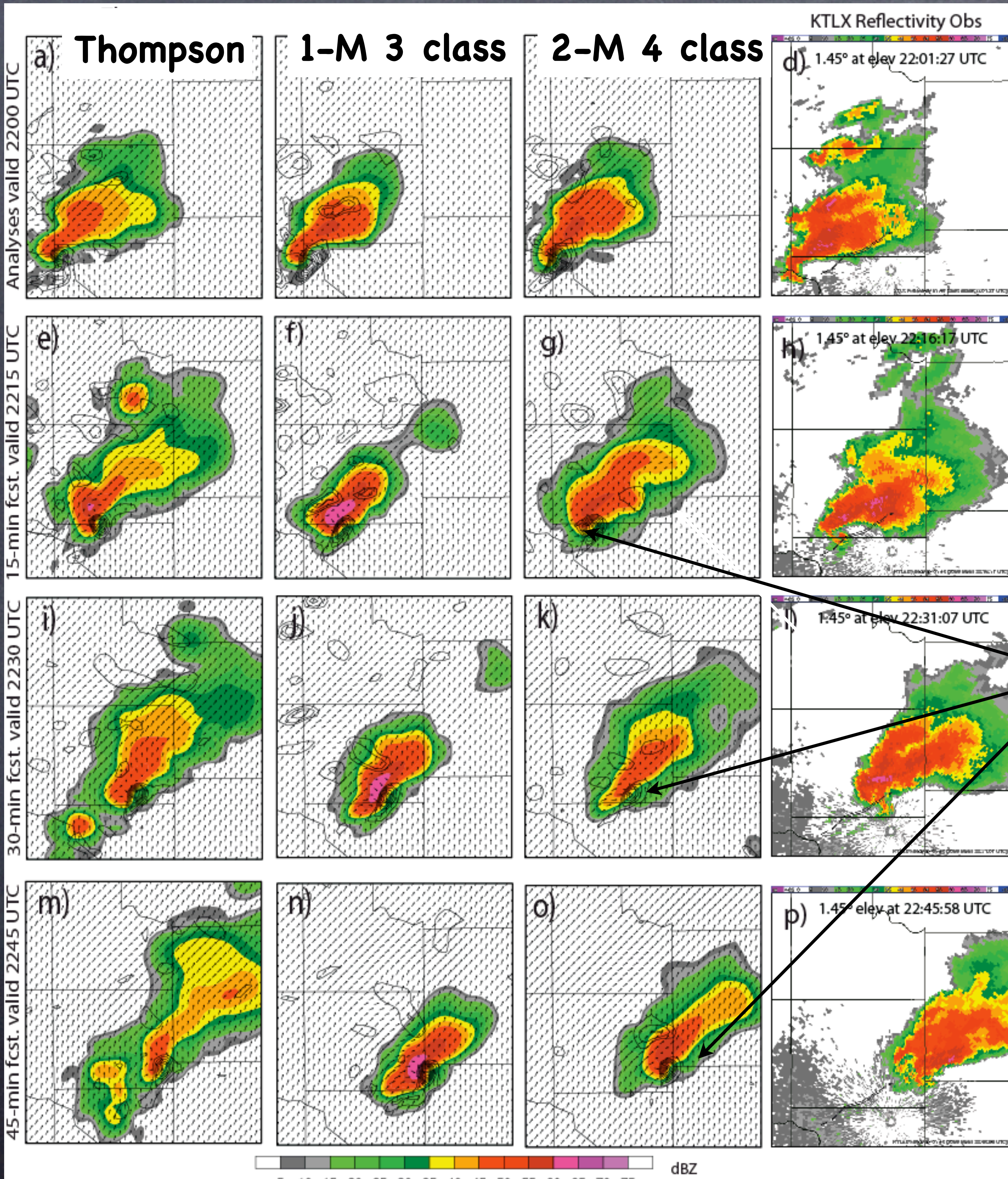
Storm-scale Ensemble

- 45 member storm-scale ensemble nested down from
  the 45 member mesoscale ensemble data system
- 2-km horizontal grid spacing, 225 x 180 x 50 grid points
- Assimilates KTLX radar radial velocity and reflectivity observations every 3-min for a one-hour period
- **Test multi-moment vs single moment microphysics**

8 May 2003 Oklahoma City Tornadic Supercell







Multi-scale DA showing sensitivity to microphysics param

Yussouf et al. 2013

Analysis

15 min FCST

Contours are rotation maxima

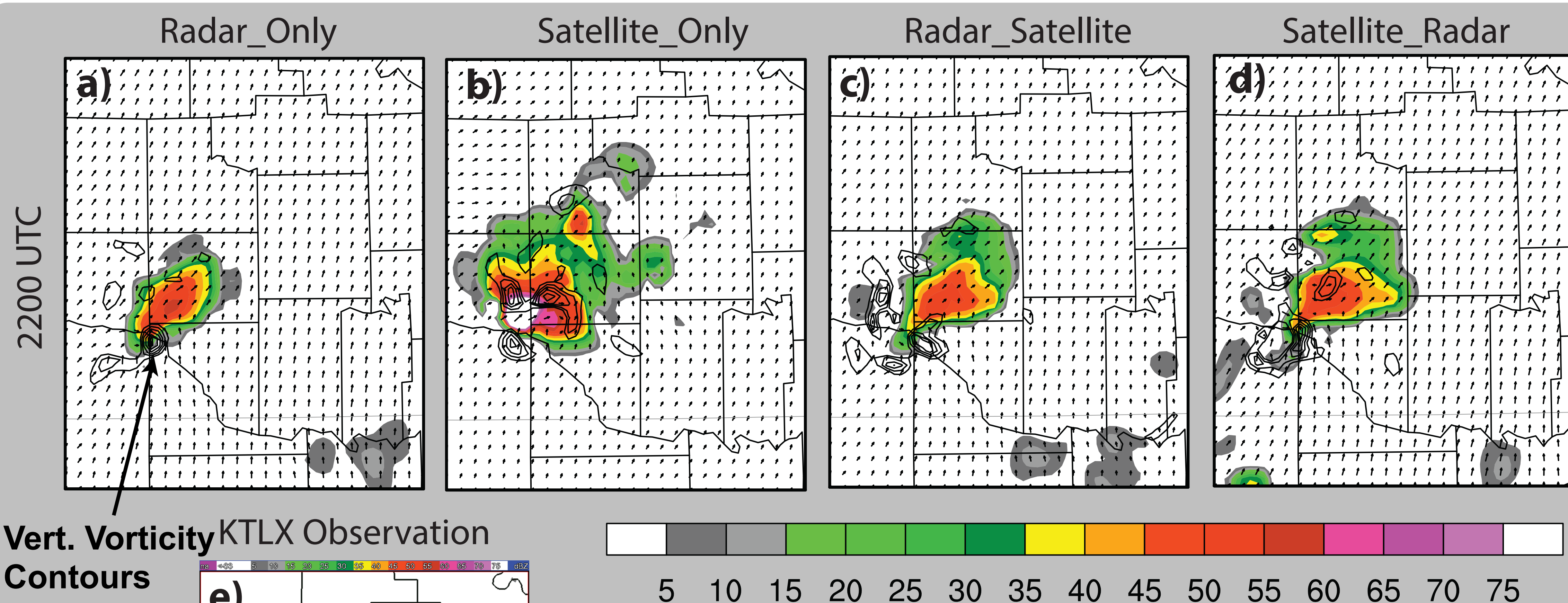
30 min FCST

45 min FCST

Ens Mean shown
3 microphysics schemes
dBZ and ζ @ z = 1 km

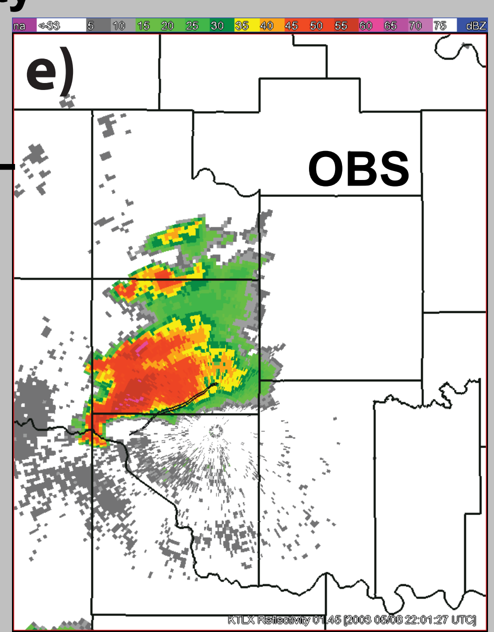
Extension: Multiscale EnKF using both Radar and Satellite Data

M. Vaughn, T. Jones, N. Yussouf



Vert. Vorticity Contours at z = 1km AGL

KTLX Observation



2200 UTC Analysis

Radar_Satellite = DA radar then CLWP

Radar_Satellite: Assim radar then Cloud Liq Water Path

Satellite_Radar: Assim Cloud Liq Water Path then radar

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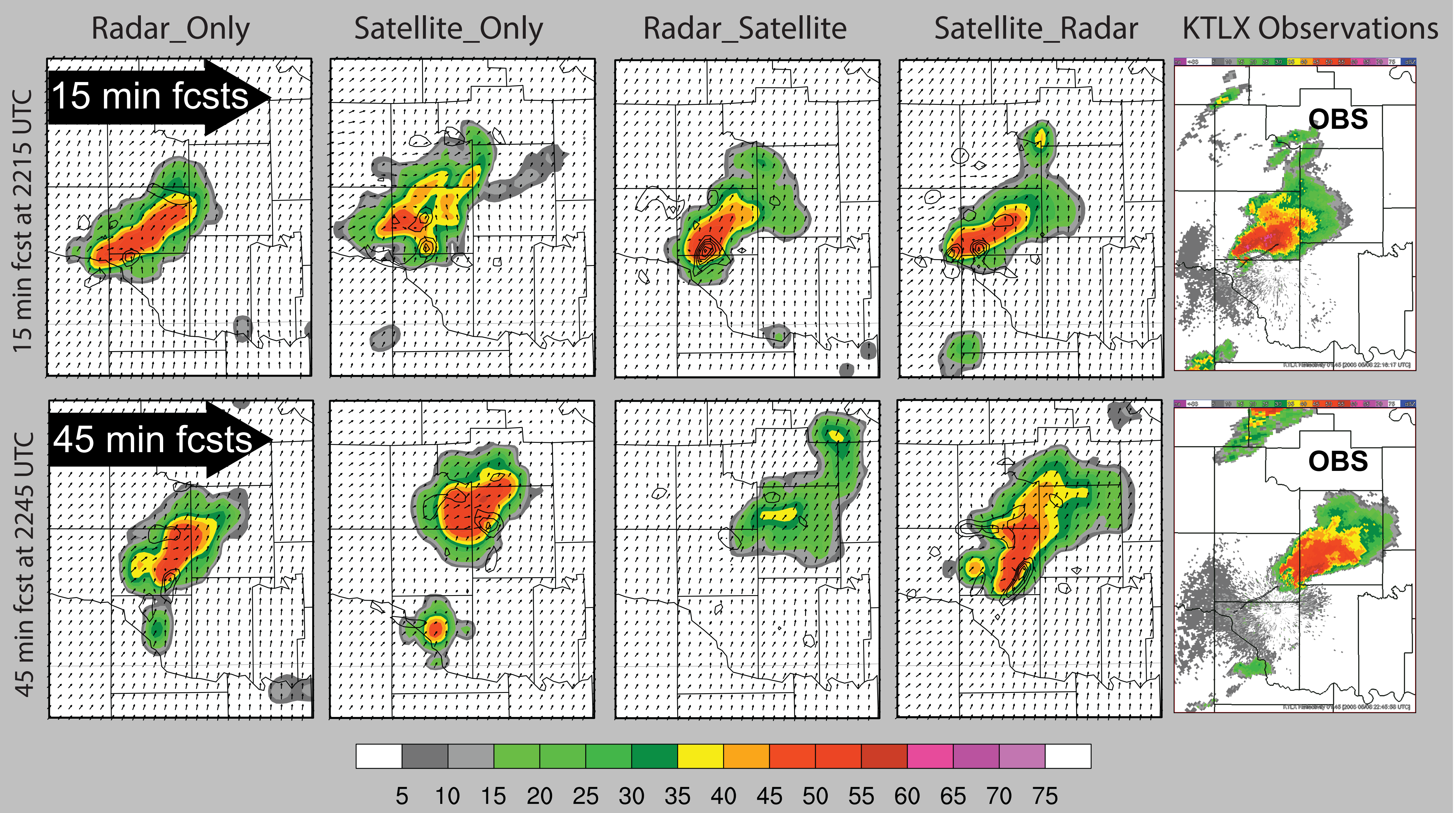
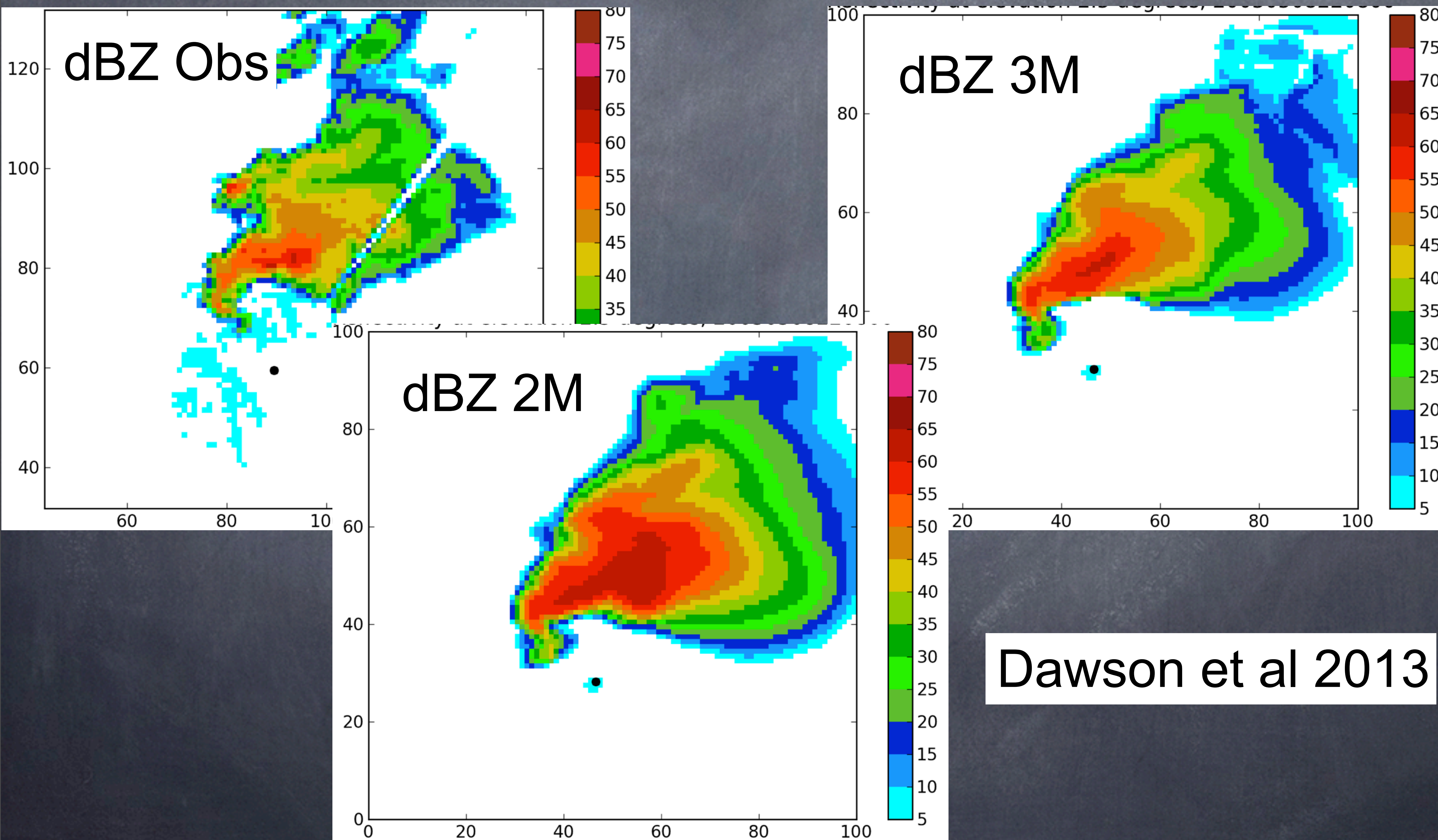


Dual-Pol Evaluation/Improvement of Microphysical Schemes

Dawson, Jung, Mansell, Wicker 2013

- Use Dual-Pol observations to access and improve microphysical parameterization
- DP Forward-operator is complicated - also microphysics scheme dependent
- CAPS forward DP operator (for M-Y scheme) converted to ZVD-2M/3M.
- 40 member EnKF analysis
  - only Vr observations are assimilated!!!!
  - cannot "touch" the hydrometeors in analysis
- Iterative process - considerable development in both DP-Op and microphysics.
  - bugs were found in both codes
  - improvements were made in both codes
  - DP-Op is very sensitive to assumptions about drop shapes

Dual-Pol Evaluation/Improvement of Microphysical Schemes (8 May 03 case)



Dawson et al 2013

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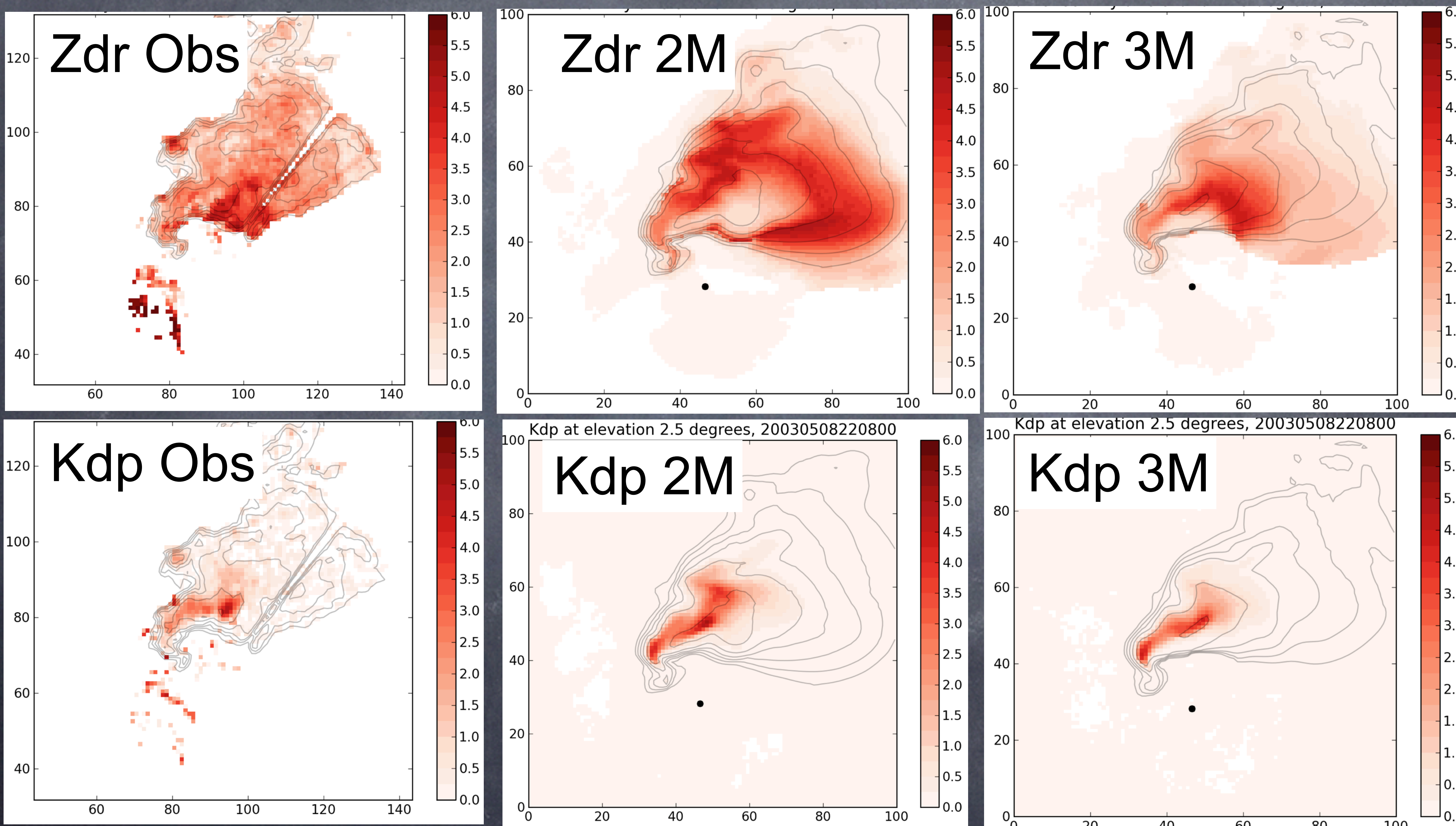
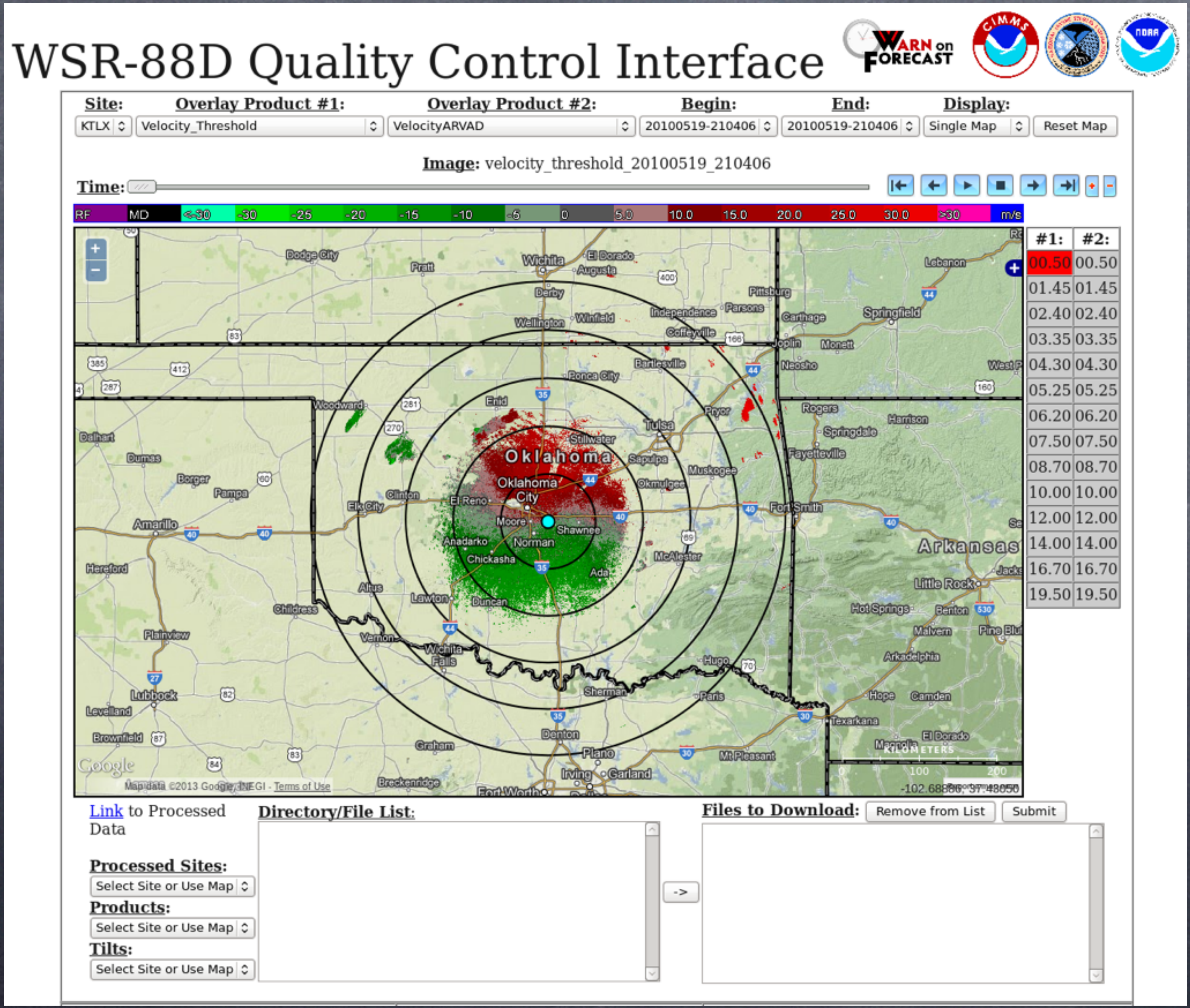


Dawson et al 2013

WSR-88D QC Test Environment
(C. Karstens and collaborators)



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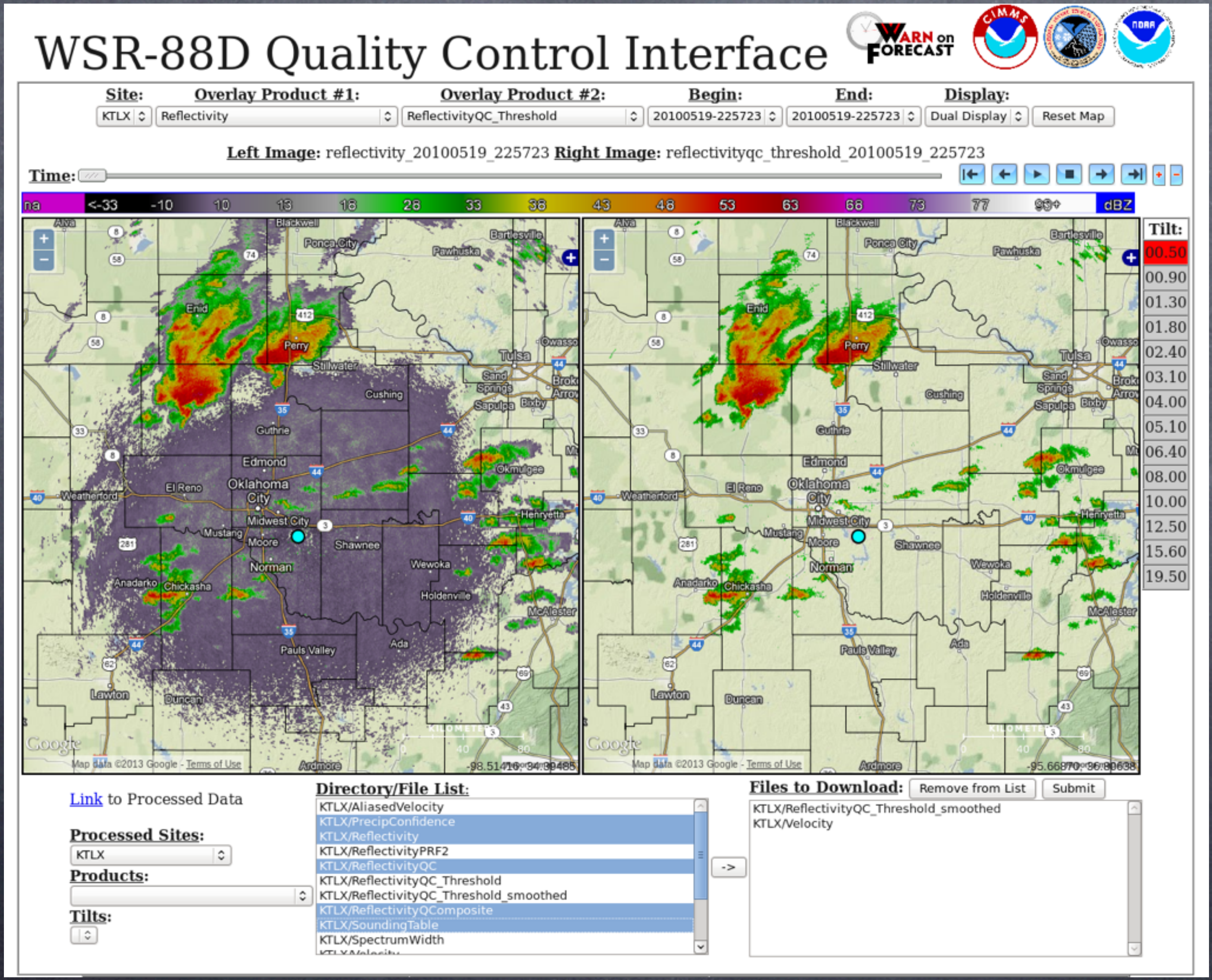
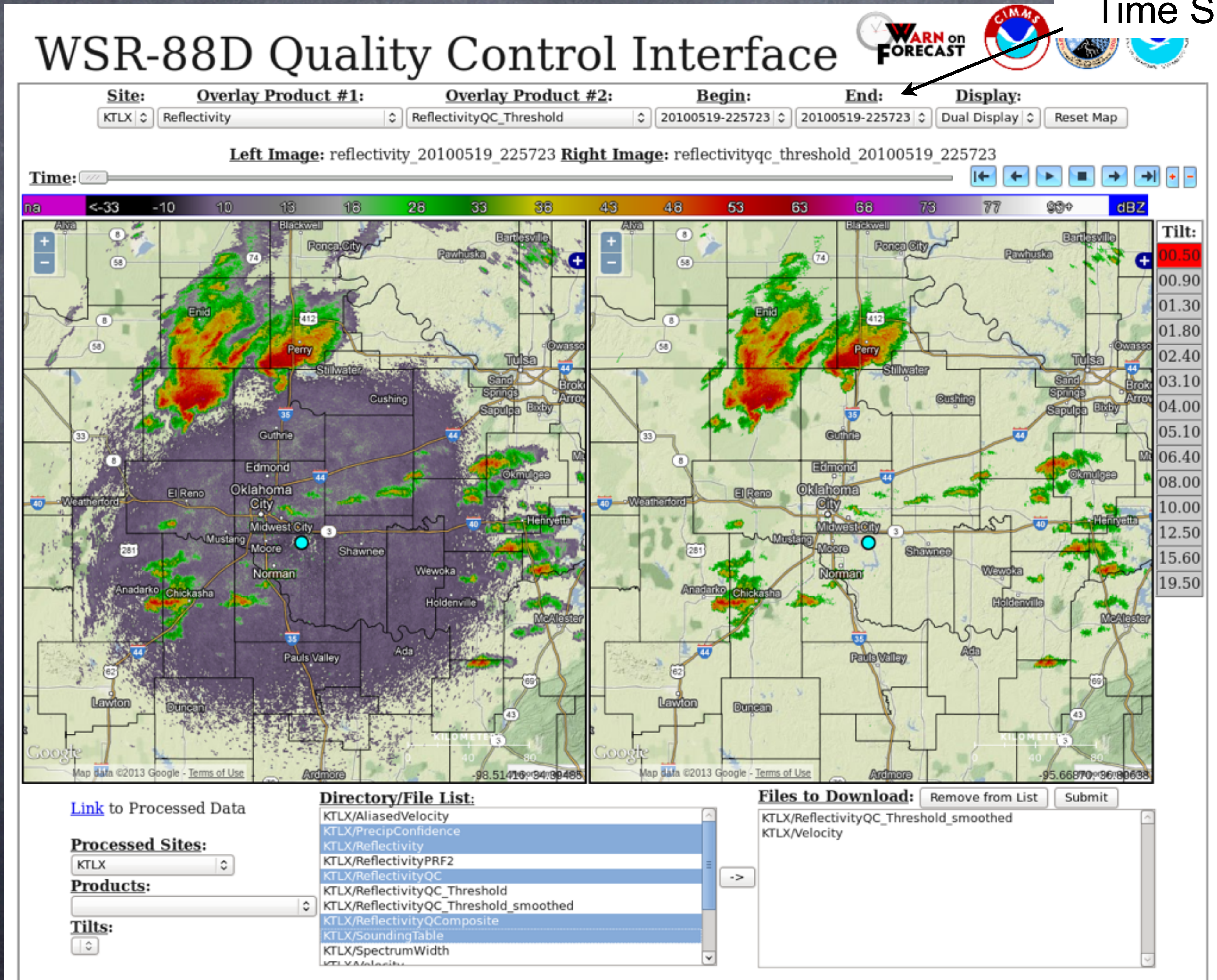


WSR-88D QC Test Environment

(C. Karstens and collaborators)

File/Display Mode
Time Selection

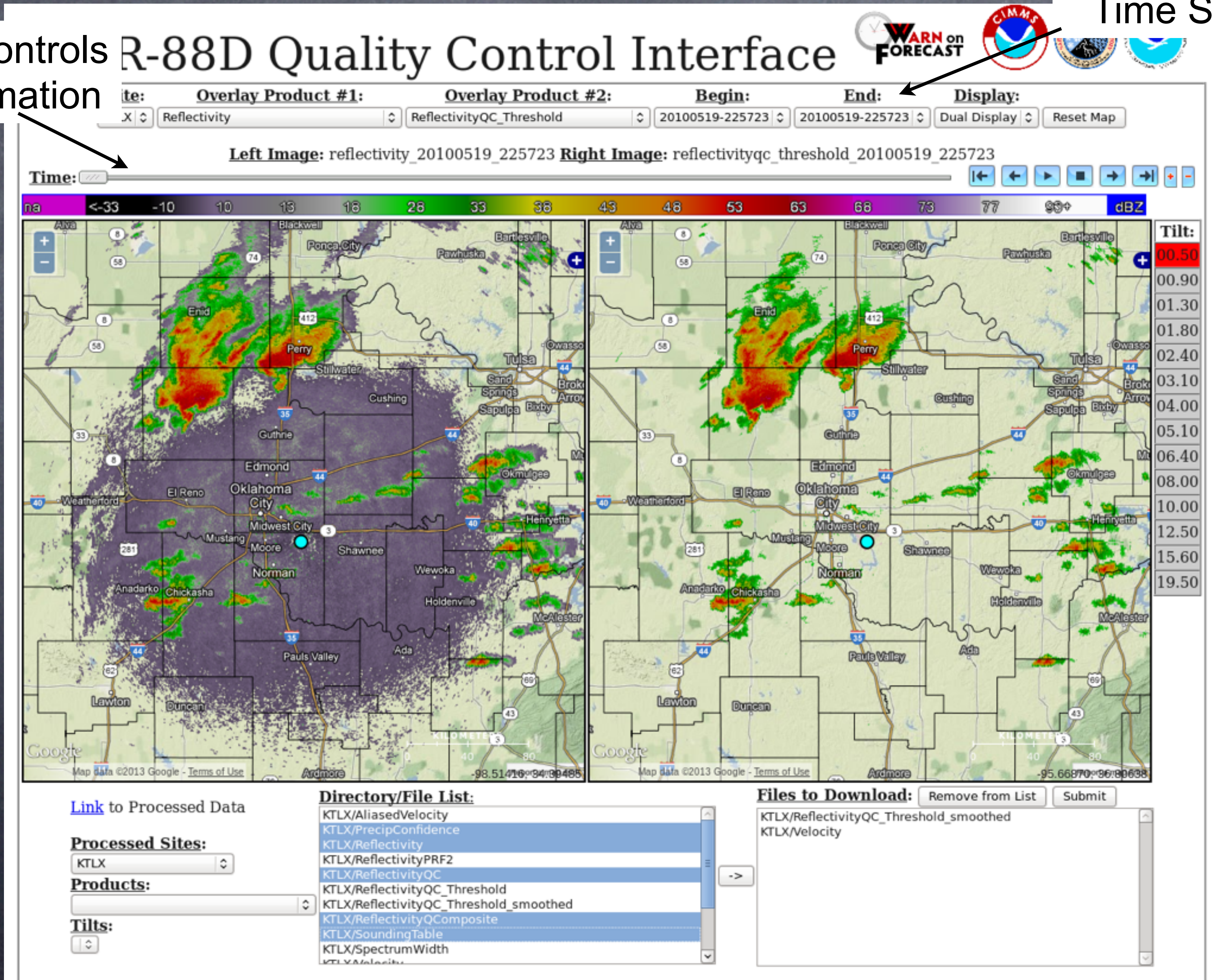


WSR-88D QC Test Environment

(C. Karstens and collaborators)

File/Display Mode Time Selection

Time Controls for Animation



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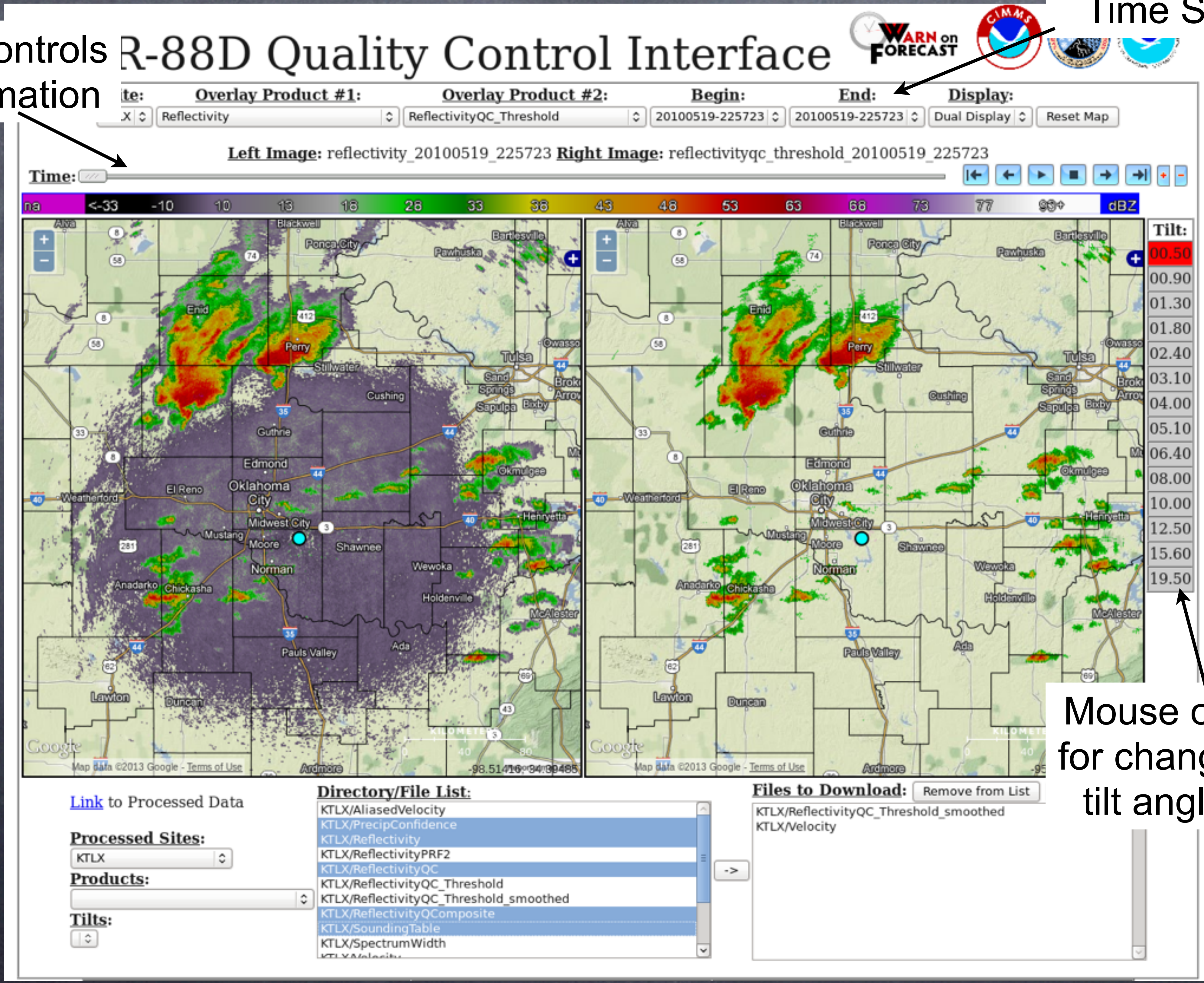

Time Controls for Animation

File/Display Mode Time Selection

Mouse over for changing tilt angles

WSR-88D QC Test Environment

(C. Karstens and collaborators)

File/Display Mode Time Selection

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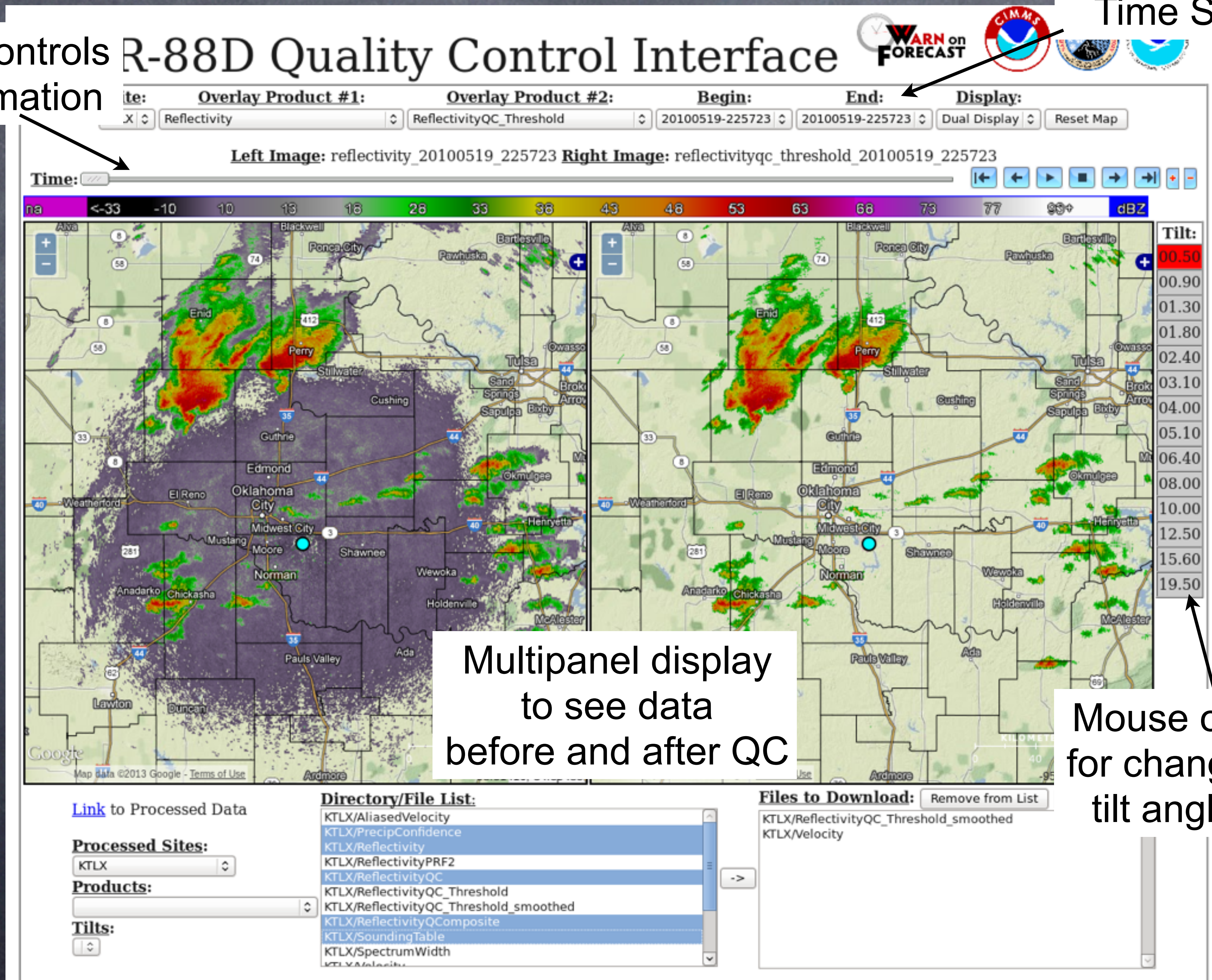
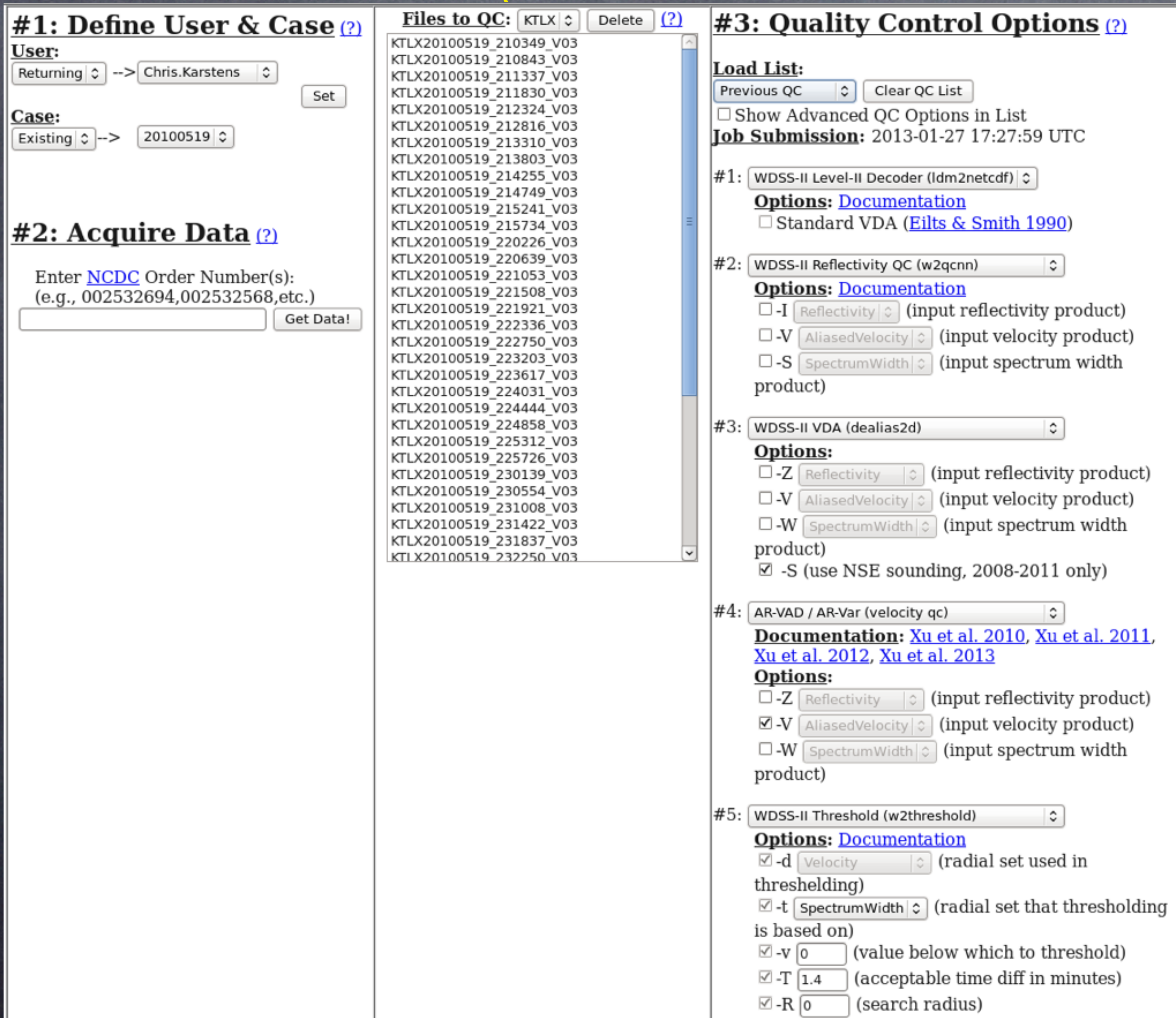


Multipanel display to see data before and after QC

Mouse over for changing tilt angles

WSR-88D QC Test Environment

(C. Karstens and collaborators)



WSR-88D QC Test Environment
(C. Karstens and collaborators)

Login to return to case

#1: Define User & Case (?)

User:
Returning --> Chris.Karstens
Set

Case:
Existing --> 20100519

#2: Acquire Data (?)

Enter NCDC Order Number(s):
(e.g., 002532694,002532568,etc.)
Get Data!

Files to QC: KTLX Delete (?)

KTLX20100519_210349_V03
KTLX20100519_210843_V03
KTLX20100519_211337_V03
KTLX20100519_211830_V03
KTLX20100519_212324_V03
KTLX20100519_212816_V03
KTLX20100519_213310_V03
KTLX20100519_213803_V03
KTLX20100519_214255_V03
KTLX20100519_214749_V03
KTLX20100519_215241_V03
KTLX20100519_215734_V03
KTLX20100519_220226_V03
KTLX20100519_220639_V03
KTLX20100519_221053_V03
KTLX20100519_221508_V03
KTLX20100519_221921_V03
KTLX20100519_222336_V03
KTLX20100519_222750_V03
KTLX20100519_223203_V03
KTLX20100519_223617_V03
KTLX20100519_224031_V03
KTLX20100519_224444_V03
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KTLX20100519_230139_V03
KTLX20100519_230554_V03
KTLX20100519_231008_V03
KTLX20100519_231422_V03
KTLX20100519_231837_V03
KTLX20100519_232250_V03

#3: Quality Control Options (?)

Load List: Previous QC | Clear QC List
☐ Show Advanced QC Options in List
Job Submission: 2013-01-27 17:27:59 UTC

#1: WDSS-II Level-II Decoder (ldm2netcdf)
Options: Documentation
☐ Standard VDA (Eilts & Smith 1990)

#2: WDSS-II Reflectivity QC (w2qcnn)
Options: Documentation
☐ -I Reflectivity (input reflectivity product)
☐ -V AliasedVelocity (input velocity product)
☐ -S SpectrumWidth (input spectrum width product)

#3: WDSS-II VDA (dealias2d)
Options:
☐ -Z Reflectivity (input reflectivity product)
☐ -V AliasedVelocity (input velocity product)
☐ -W SpectrumWidth (input spectrum width product)
☑ -S (use NSE sounding, 2008-2011 only)

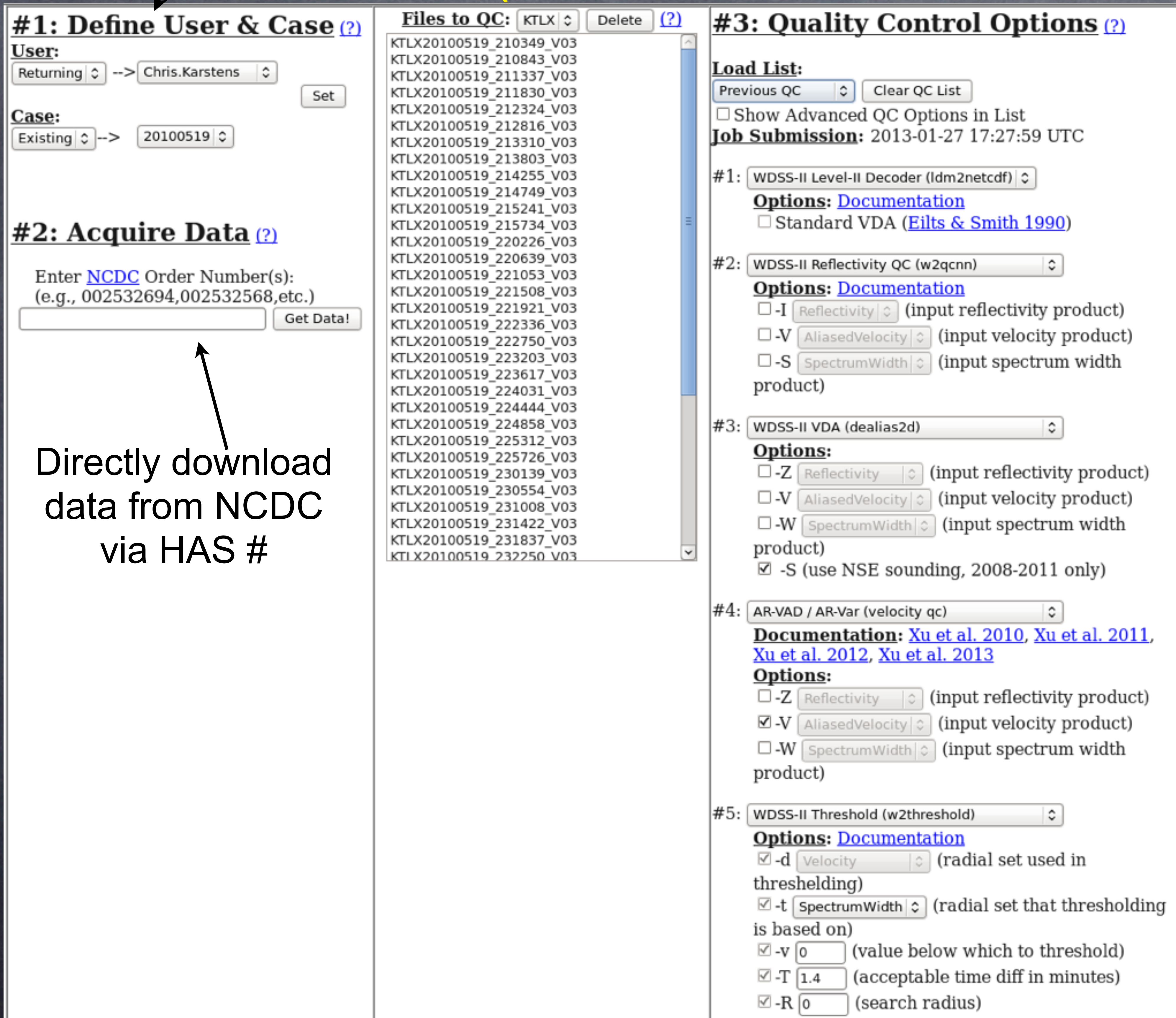
#4: AR-VAD / AR-Var (velocity qc)
Documentation: Xu et al. 2010, Xu et al. 2011, Xu et al. 2012, Xu et al. 2013
Options:
☐ -Z Reflectivity (input reflectivity product)
☑ -V AliasedVelocity (input velocity product)
☐ -W SpectrumWidth (input spectrum width product)

#5: WDSS-II Threshold (w2threshold)
Options: Documentation
☑ -d Velocity (radial set used in thresholding)
☑ -t SpectrumWidth (radial set that thresholding is based on)
☑ -v 0 (value below which to threshold)
☑ -T 1.4 (acceptable time diff in minutes)
☑ -R 0 (search radius)

WSR-88D QC Test Environment

(C. Karstens and collaborators)

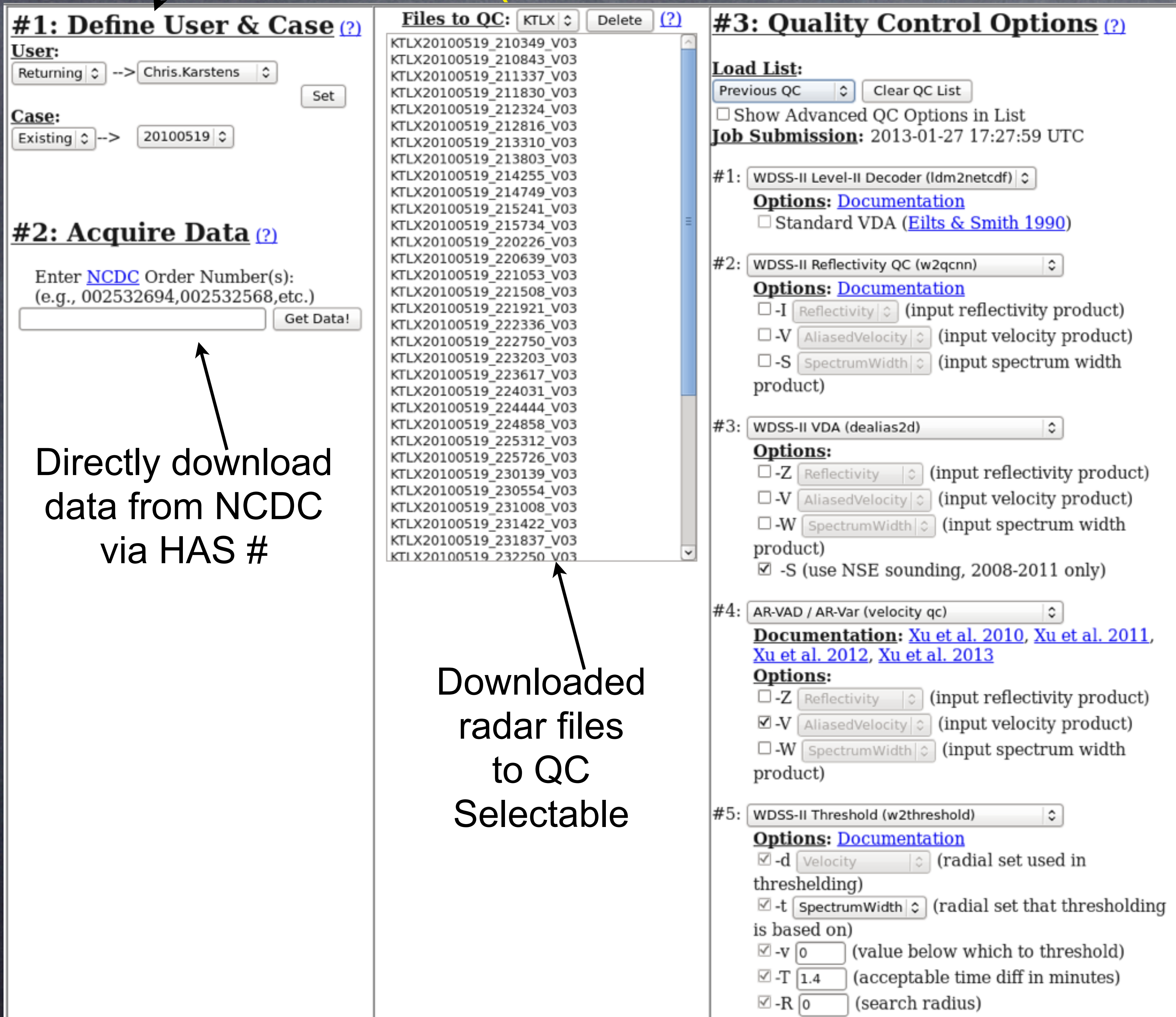
Login to return to case



WSR-88D QC Test Environment

(C. Karstens and collaborators)

Login to return to case



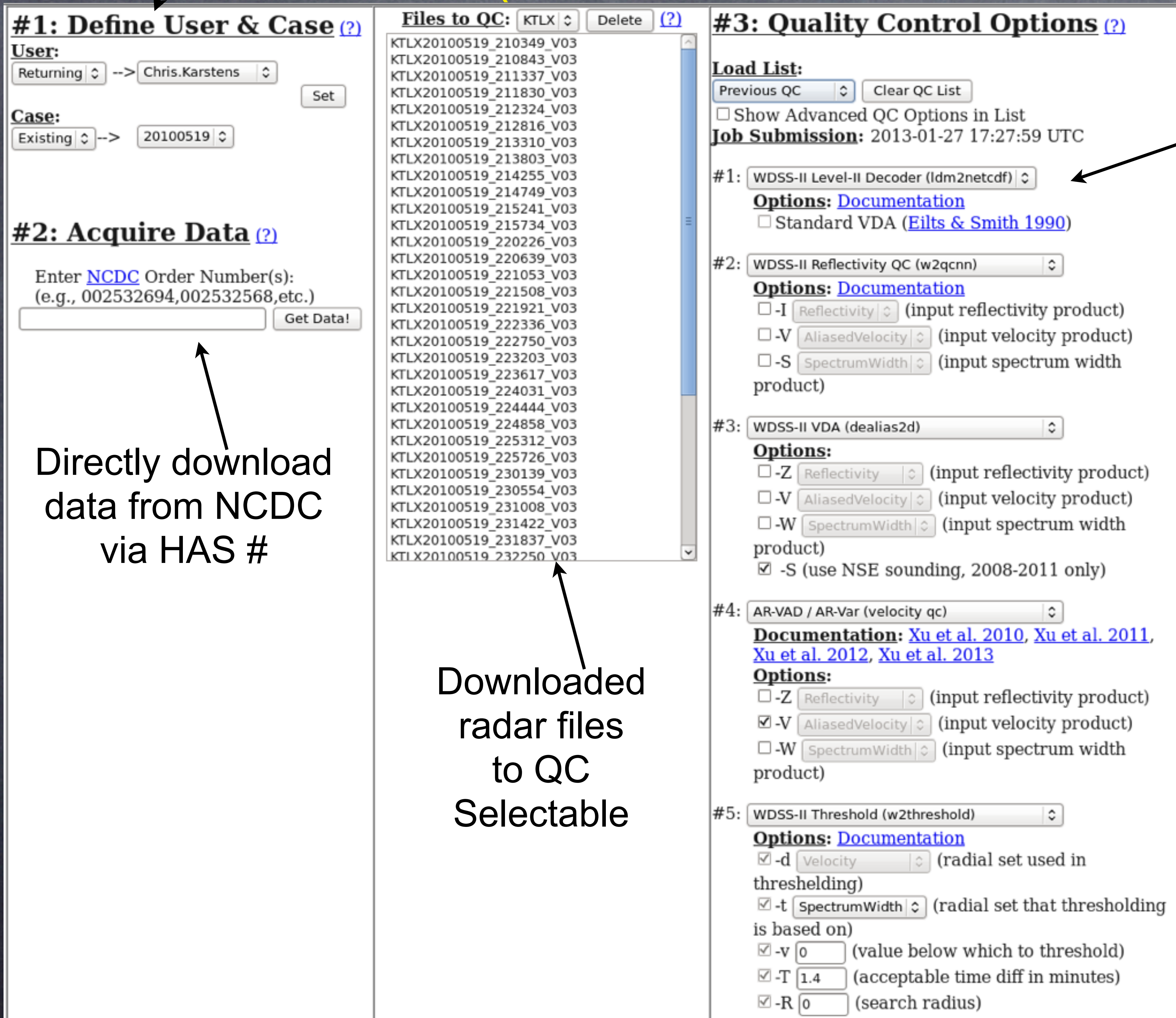
Directly download data from NCDC via HAS #

Downloaded radar files to QC Selectable

WSR-88D QC Test Environment

(C. Karstens and collaborators)

Login to return to case



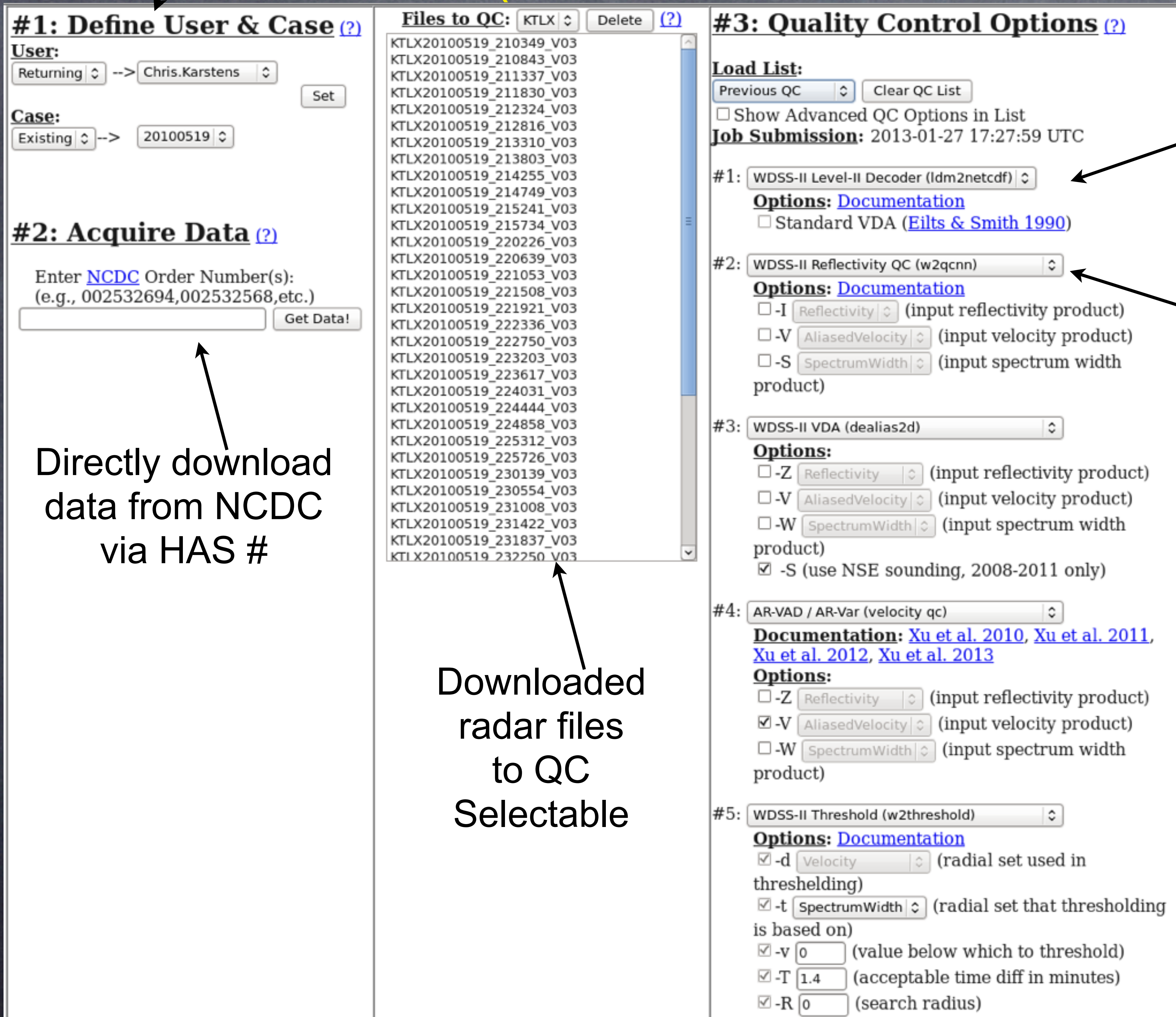
1st layer of QC

Wednesday, February 13, 13

WSR-88D QC Test Environment

(C. Karstens and collaborators)

Login to return to case

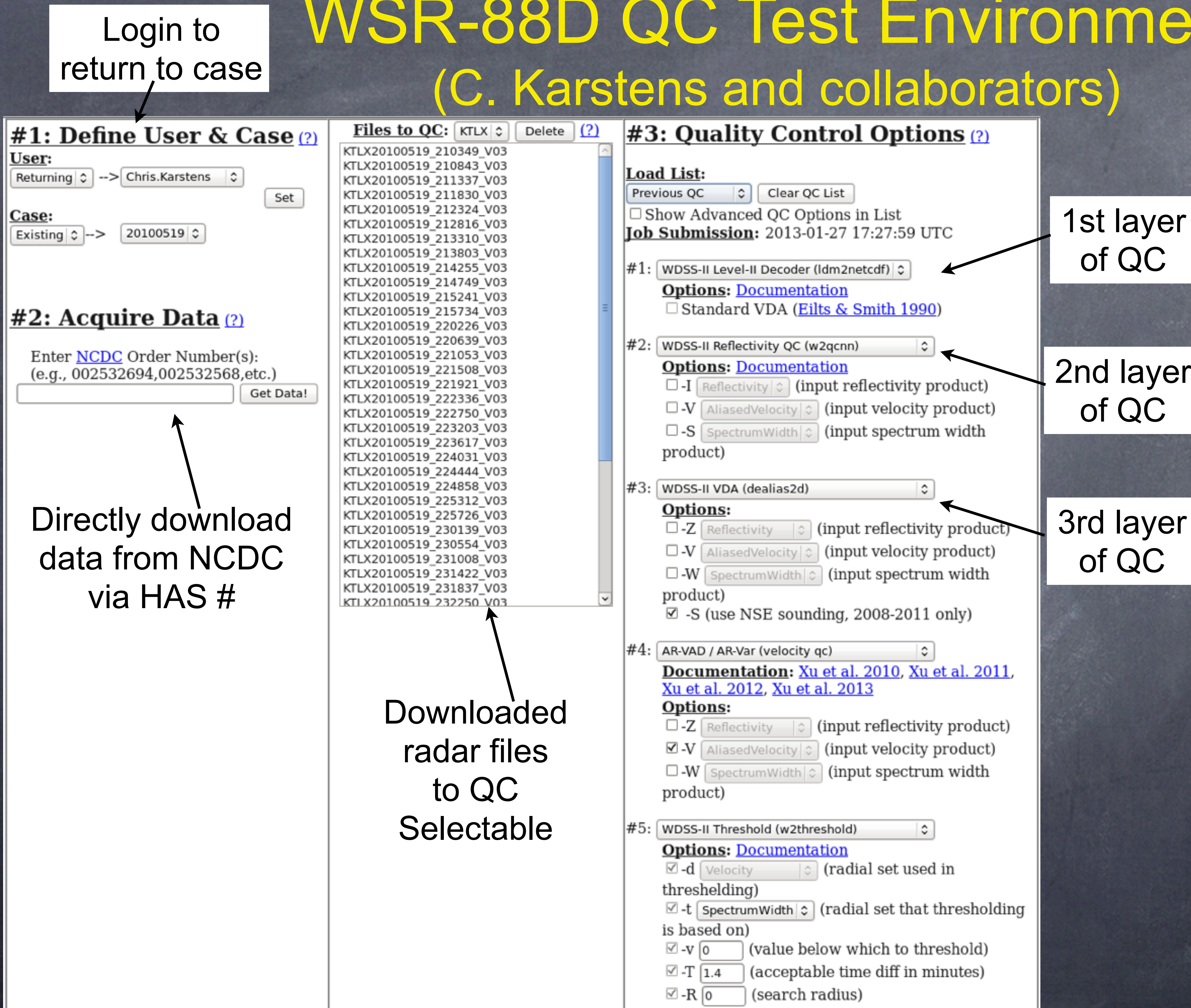


1st layer of QC

2nd layer of QC

WSR-88D QC Test Environment

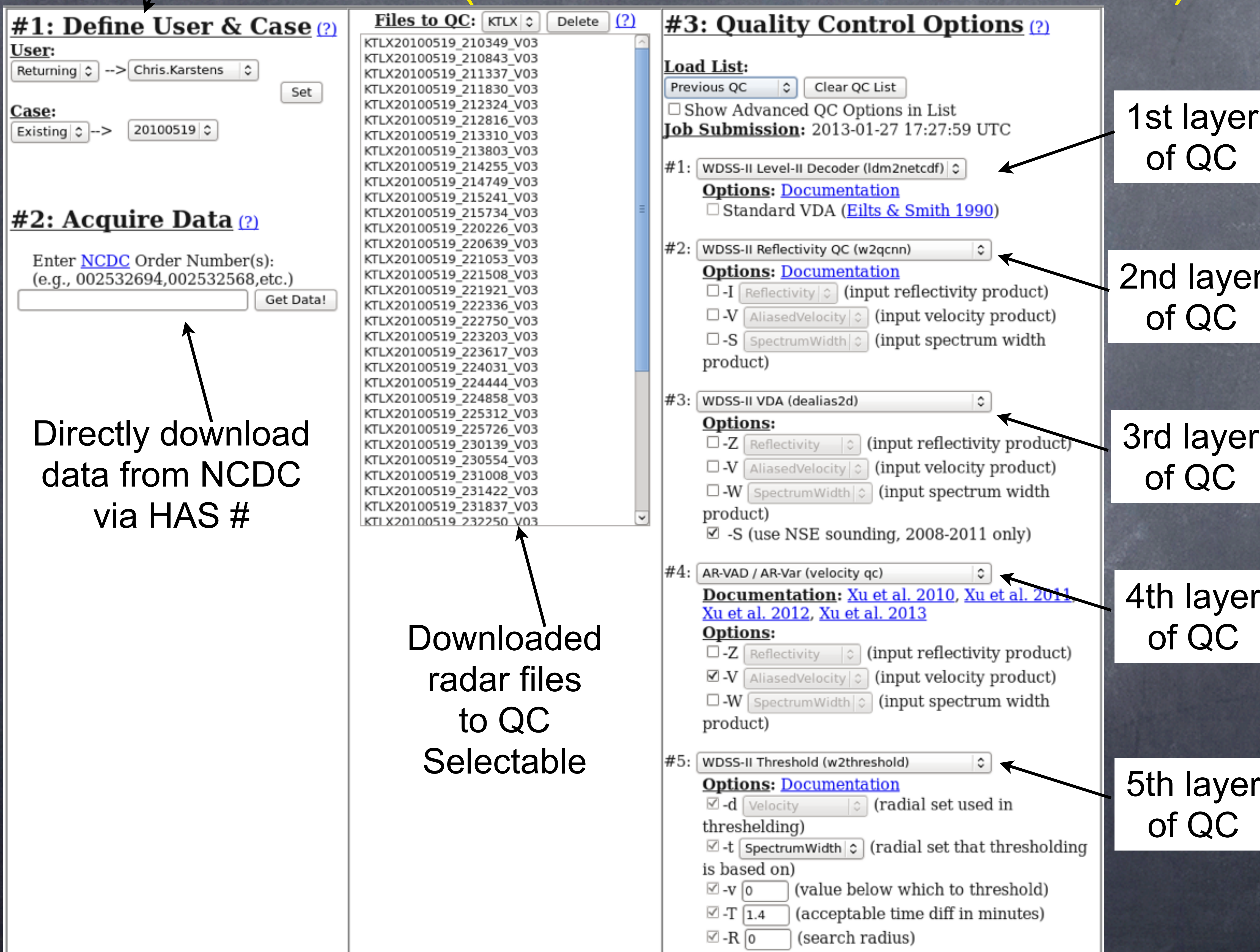
(C. Karstens and collaborators)



WSR-88D QC Test Environment

(C. Karstens and collaborators)

Login to return to case



WSR-88D QC Test Environment
(C. Karstens and collaborators)

Output Products:

- Reflectivity (#1)
- ReflectivityPRF2 (#1)
- AliasedVelocity (#1)
- SpectrumWidth (#1)
- ReflectivityQC (#2)
- ReflectivityQComposite (#2)
- PrecipConfidence (#2)
- Velocity (#3)
- VelocityARVAD (#4)
- Velocity_Threshold (#5)
- ReflectivityQC_Threshold (#6)
- Velocity_Threshold_Threshold (#7)
- ReflectivityQC_Threshold_smoothed (#8)

Output Format(s):

☑ WDSS-II NetCDF
☐ Nexrad Level-II (netcdf2ldm)
Reflectivity (input reflectivity product)
AliasedVelocity (input velocity product)
SpectrumWidth (input spectrum width product)
☐ Dorade Sweeps via sweep_trans
☐ Foray NetCDF via sweep_trans
☐ Foray NetCDF (Reflectivity) via W2toFORAY (Opaws)
Reflectivity (input reflectivity product)
☐ Foray NetCDF (Velocity) via W2toFORAY (Opaws)
AliasedVelocity (input velocity product)
☐ Reflectivity Point Shapefile (lowest tilts(s))
☑ -s (Sparse Grid)
☐ ReflectivityQComposite
☐ Reflectivity
☐ ReflectivityQC
☐ ReflectivityQC_Threshold
☐ ReflectivityQC_Threshold_smoothed

Other:

☑ Generate Images (Google Map Overlay or Other)
0.005 Pixel Resolution (Degrees)
☐ Generate World Files (.wld)

Start Quality Control

NSSL-Mesoscale-Ensemble (N-M-E)

D. Wheatley, K. Knopfmeier, G. Creager, D. Dowell
M. Coniglio, A. Clark, J. Kain

U.S. Department of Commerce | National Oceanic & Atmospheric Administration | NOAA Research

Warn-on-Forecast Research Model Output

Model: Warn-on-Forecast Mesoscale Ensemble Area: FULL DOMAIN Date: 29 May 2012 - 12Z

Model: Warn-on-Forecast Mesoscale Ensemble **Domain:** FULL DOMAIN **Date:** 29 May 2012 - 12Z

			Valid Time													
			Tue 12	Tue 13	Tue 14	Tue 15	Tue 16	Tue 17	Tue 18	Tue 19	Tue 20	Tue 21	Tue 22	Tue 23	Wed 00	
	All times	Loop	Forecast													
			00	01	02	03	04	05	06	07	08	09	10	11	12	
all fields			00	01	02	03	04	05	06	07	08	09	10	11	12	all fields
composite reflectivity [mean]	✔	✔		01	02	03	04	05	06	07	08	09	10	11	12	composite reflectivity [mean]
composite reflectivity [spread]	✔	✔		01	02	03	04	05	06	07	08	09	10	11	12	composite reflectivity [spread]
surface CAPE [mean]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	surface CAPE [mean]
surface CAPE [spread]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	surface CAPE [spread]
surface CIN [mean]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	surface CIN [mean]
surface CIN [spread]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	surface CIN [spread]
mixed-layer CAPE [mean]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	mixed-layer CAPE [mean]
mixed-layer CAPE [spread]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	mixed-layer CAPE [spread]
most unstable CAPE [mean]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	most unstable CAPE [mean]
most unstable CAPE [spread]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	most unstable CAPE [spread]
most unstable layer CAPE [mean]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	most unstable layer CAPE [mean]
most unstable layer CAPE [spread]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	most unstable layer CAPE [spread]
10m wind [mean]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	10m wind [mean]
10m wind [spread]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	10m wind [spread]
2m temp [mean]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	2m temp [mean]
2m temp [spread]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	2m temp [spread]
2m dew point [mean]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	2m dew point [mean]
2m dew point [spread]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	2m dew point [spread]
2m RH [mean]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	2m RH [mean]
2m RH [spread]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	2m RH [spread]
precipitable water [mean]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	precipitable water [mean]
precipitable water [spread]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	precipitable water [spread]
rh with respect to pw [mean]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	rh with respect to pw [mean]
rh with respect to pw [spread]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	rh with respect to pw [spread]
0-1 km shear [mean]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	0-1 km shear [mean]
0-1 km shear [spread]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	0-1 km shear [spread]
0-6 km shear [mean]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	0-6 km shear [mean]
0-6 km shear [spread]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	0-6 km shear [spread]
0-1 km helicity, storm motion [mean]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	0-1 km helicity, storm motion [mean]
0-1 km helicity, storm motion [spread]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	0-1 km helicity, storm motion [spread]
0-3 km helicity, storm motion [mean]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	0-3 km helicity, storm motion [mean]
0-3 km helicity, storm motion [spread]	✔	✔	00	01	02	03	04	05	06	07	08	09	10	11	12	0-3 km helicity, storm motion [spread]

U.S. Department of Commerce | National Oceanic and Atmospheric Administration
Earth System Research Laboratory | Global Systems Division
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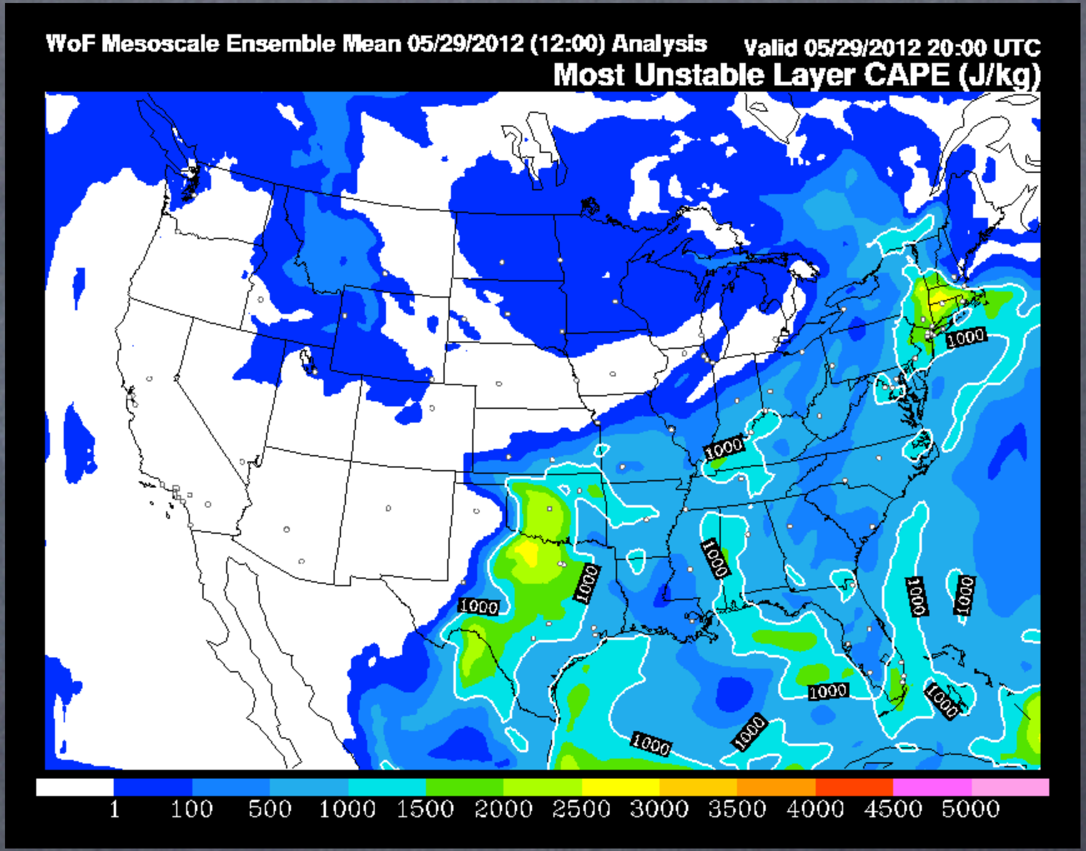
Web Contact: *webmaster-amb.gsd@noaa.gov*



N-M-E is a research project work in progress may not be always available

NSSL-Mesoscale-Ensemble (N-M-E)

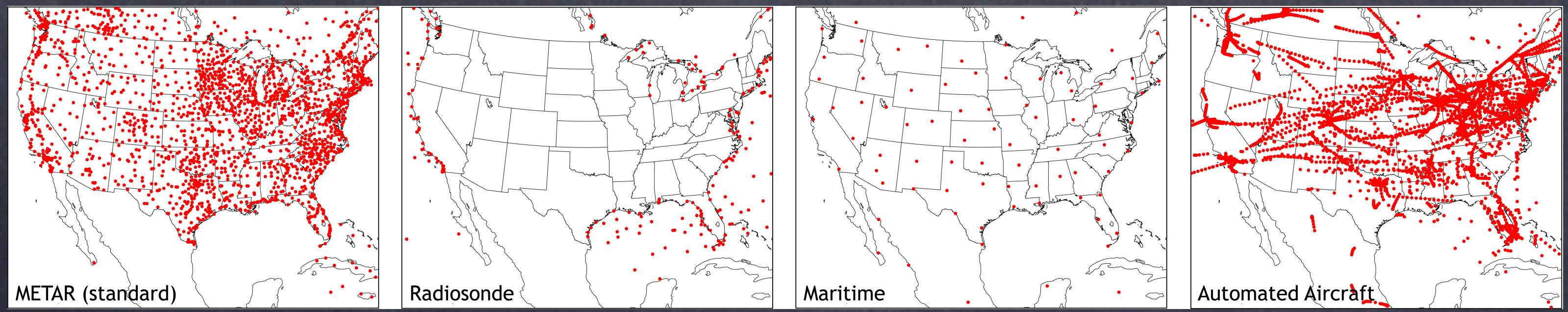
D. Wheatley, K. Knopfmeier, G. Creager, D. Dowell
M. Coniglio, A. Clark, J. Kain

- **Why bother doing this?**
  - wanted experience with running RT system in our group.
  - WoF-TTP is a multiscale problem: need BECs at stormscale
  - eventually will downscale to 3 km ensemble
    - in-house generation from N-M-E for new case studies
    - get ready for the GSD HRRRe system
  - enhance our collaboration with GSD

- **WRF (ARW)**
  - Mesoscale data assimilation on CONUS domain
  - 20-km horizontal grid spacing; 51 vertical levels
  - Mean initial and boundary conditions from the NAM forecast cycle starting at 1200 UTC

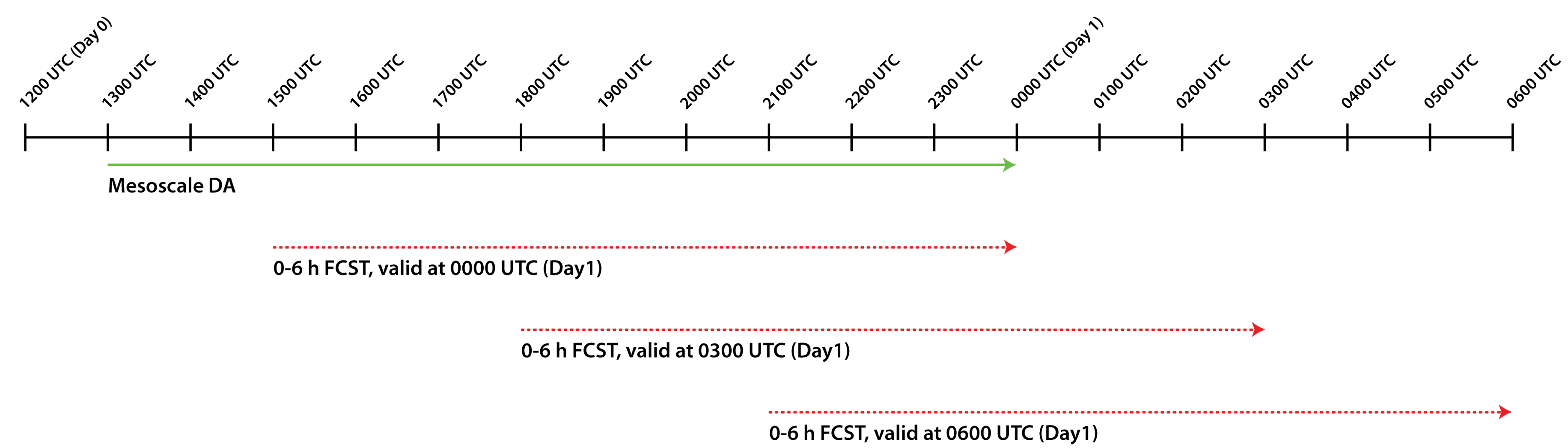
NSSL-Mesoscale-Ensemble (N-M-E)

- 36-member ensemble
  - Efforts made to mitigate initial condition uncertainty and model error…
  - IC/BC perturbations from WRF-Var (see Torn et al. 2006)
  - Physics diversity
    - Microphysics: NSSL 1-moment
    - Cumulus: Kain-Fritsch, Grell, Tiedtke
    - Land surface: Noah
    - Shortwav radiation: Dudhia
    - LW/SW radiation: RRTM/Dudhia, RRTMG/RRTMG, Goddard/Goddard
    - PBL: YSU, MYJ, MYNN, ACM
- Mesoscale data assimilation
  - p (land-surface altimeter), T, T_d, u, v (see observation platforms below)



NSSL-Mesoscale-Ensemble (N-M-E)

- Hourly mesoscale analyses from 1200 UTC (Day 0) to 0000 UTC
- Goal: 0-9 hour 20 km ensemble forecasts launched at 1500, 1800, and 2100 UTC



Other Work

- LETKF for radar assimilation
  - Thompson, Wang, Wicker
  - Better analyses/forecasts for Vr/dBZ assimilation than EnKF (not Vr only)
- Continued microphysics development (Mansell)
  - full 3M scheme
  - Lightning
  - Bin microphysics implemented

Summary

NSSL WoF Publications

(17 pubs/*in press for 2012*)

Clark, A., **J., Gao,** P. T. Marsh, T. M. Smith, J. S. Kain, J. Correia Jr., M. Xue, and F. Kong, 2012b: Tornado path length forecasts from 2011 using a 3-dimensional object identification algorithm applied to ensemble updraft helicity, *Wea. Foreacasting, in press.*

Coniglio, M.C., J. Correia Jr., P.T. Marsh, and F. Kong, 2012: Verification of convection-allowing WRF model forecasts of the planetary boundary layer using sounding observations. Wea. Forecasting, In press, DOI: http://dx.doi.org/10.1175/WAF-D-12-00103.1

Dawson II, D. T., Louis J. Wicker, Edward R. Mansell, Robin L. Tanamachi, 2012: Impact of the Environmental Low-Level Wind Profile on Ensemble Forecasts of the 4 May 2007 Greensburg, Kansas, Tornadic Storm and Associated Mesocyclones. Mon. Wea. Rev., 140, 696–716. DOI: http://dx.doi.org/10.1175/MWR-D-11-00008.1

Gao J., and D. J., Stensrud, 2012: Assimilation of reflectivity data in a convective-scale, cycled 3DVAR framework with hydrometeor classification: results from an idealized thunderstorm. *J. Atmos. Sci*., **69**, 1054-1065.

Ge, G., **J. Gao**, and M. Xue, 2012a: Incorporating Diagnostic Pressure Equations as a Weak Constraint into a Storm-Scale Three Dimensional Variational Radar Data Assimilation System--Simulated Data Experiments. *J. Atmos. Oceanic Technol*. **29**, 1075-1092.

Ge. G., **J. Gao**, and M. Xue, 2012b: Impact of Different Model Variables on Storm-scale Three-dimensional Variational Data Assimilation. *Mon. Wea. Rev.* In press.

Jones, T.A. and D. J. Stensrud, 2012a: Assimilating AIRS temperature and mixing ratio profiles using an Ensemble Kalman Filter approach for convective-scale forecasts. Wea. and Forecasting, 27(3), 541-564.

Jones, T.A. D. J. Stensrud, P. Minnis, and R. Palikonda, 2013a: Evaluation of a forward operator to assimilate cloud water path into WRF-DART. Mon. Wea. Rev. In Press (online).

Potvin, C. K., L. J. Wicker, D. Betten, M. I. Biggerstaff, and A. Shapiro, 2012: Comparison between storm-scale dual-Doppler and EnKF wind analyses: The 29-30 May 2004 Geary, Oklahoma, supercell thunderstorm. Mon. Wea. Rev., In press, DOI: http://dx.doi.org/10.1175/MWR-D-12-00308.1.

Potvin, C. K., L. J. Wicker, 2012: Comparison between dual-Doppler and EnKF storm-scale wind analyses: Observing system simulation experiments with a supercell thunderstorm. 140, 3972–3991, Mon. Wea. Rev., DOI: http://dx.doi.org/10.1175/MWR-D-12-00044.1.

Potvin, C. K., D. Betten, L.J. Wicker, M. I. Biggerstaff, K. Elmore, 2012: 3DVAR versus traditional dual-Doppler wind retrieval of a simulated supercell thunderstorm. 140, 3847–3494. Mon. Wea. Rev., DOI: http://dx.doi.org/10.1175/MWR-D-12-00063.1

Shimose K., M. Xue, R. D. Palmer, J. Gao, B. L. Cheong and D. J. Bodine, 2012: Two-dimensional Variational Analysis of Near-Surface Moisture from Simulated Radar Refractivity-Related Phase Change Observations, Adv. Atmos. Sci., in press

Stensrud, D. J., L. J. Wicker, M. Xue, D. T. Dawson II, N. Yussouf, D. M. Wheatley, T. E. Thompson, N. A. Snook, T. M. Smith, A. D. Schenkman, C. K. Potvin, E. R. Mansell, T. Lei, K. M. Kuhlman, Y. Jung, T. A. Jones, J. Gao, M. C. Coniglio, H. E. Brooks, K. A. Brewster, 2012: Progress and Challenges with Warn-on-Forecast. Atmospheric Research. European Conference on Severe Storms Special Issue. In press. DOI: http://dx.doi.org/10.1016/j.atmosres.2012.04.004

Tanamachi, R., L. Wicker, D. C. Dowell, H. B. Bluestein, and M. Xue, 2012: Assimilation of high-resolution, mobile Doppler radar data into EnKF analyses of the 4 May 2007 Greensburg, Kansas supercell storm. Mon. Wea. Rev., 141, 625-648, DOI: http://dx.doi.org/10.1175/MWR-D-12-00099.1

Thompson, T. E., L. J. Wicker, and X. Wang, 2012: Impact from a volumetric radar-sampling operator for radar velocity observations within EnKF supercell assimilation. J. Atmos. Ocea. Tech., 29, 1417-1427. DOI: http://dx.doi.org/10.1175/JTECH-D-11-00177.1

Wheatley, D. M., David J. Stensrud, David C. Dowell, Nusrat Yussouf, 2012: Application of a WRF Mesoscale Data Assimilation System to Springtime Severe Weather Events 2007–09. Mon. Wea. Rev., 140, 1539–1557. DOI: http://dx.doi.org/10.1175/MWR-D-11-00106.1

Yussouf, N., D. J. Stensrud, 2012: Comparison of Single-Parameter and Multiparameter Ensembles for Assimilation of Radar Observations Using the Ensemble Kalman Filter. *Mon. Wea. Rev.*, **140**, 562–586. DOI http://dx.doi.org/10.1175/MWR-D-10-05074.1

Questions?