Analyzing Surface Weather Conditions on the Mesoscale

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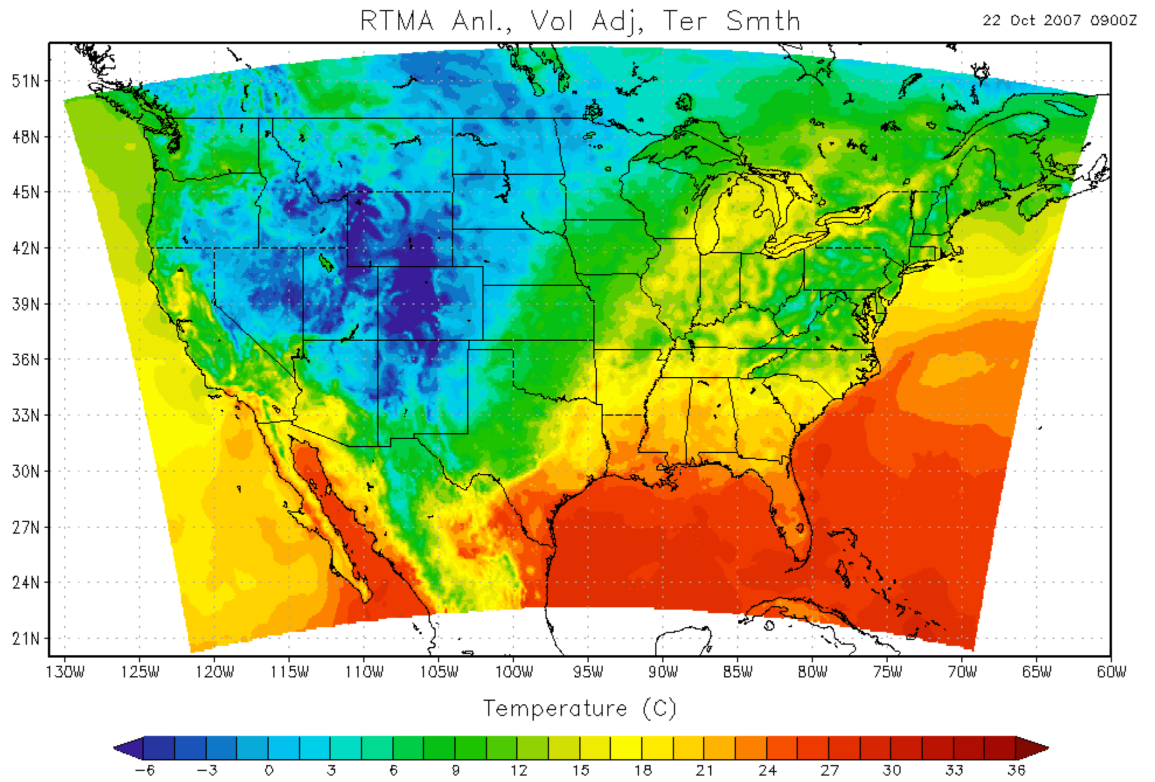

- Acknowledgements
  - Dan Tyndall & Xia Dong (Univ. of Utah)
  - Manuel Pondeca (NCEP)
- References
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Class Discussion Points

- Why are analyses needed?
  - Application driven: data assimilation for NWP (forecasting) vs. objective analysis (specifying the present or past)

- What are the goals of the analysis?
  - Define microclimates?
    - Requires attention to details of geospatial information (e.g., limit terrain smoothing)
  - Resolve mesoscale/synoptic-scale weather features?
    - Requires good prediction from previous analysis

- How is analysis quality determined? What is truth?
  - Evaluating analysis by withholding observations

Discussion Points (cont.)

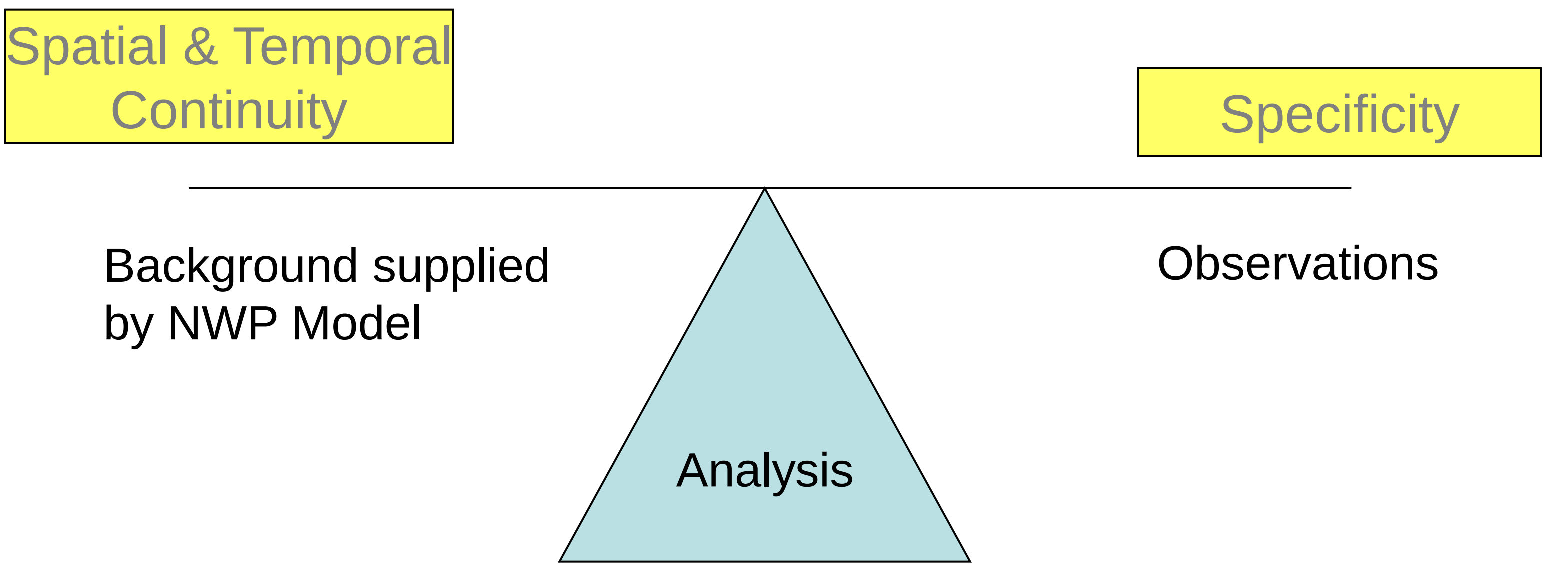
- What causes large variations in surface temperature, wind, moisture, precipitation over short distances?
  - Terrain, convection, etc.
- How well can we observe, analyze, and forecast conditions near the surface?
  - What errors should we tolerate?
- To what extent can you rely on surface observations to define conditions within 2.5 x 2.5 or 5 x 5 km^2 grid box?
  - Do we have enough observations to do so?

Review

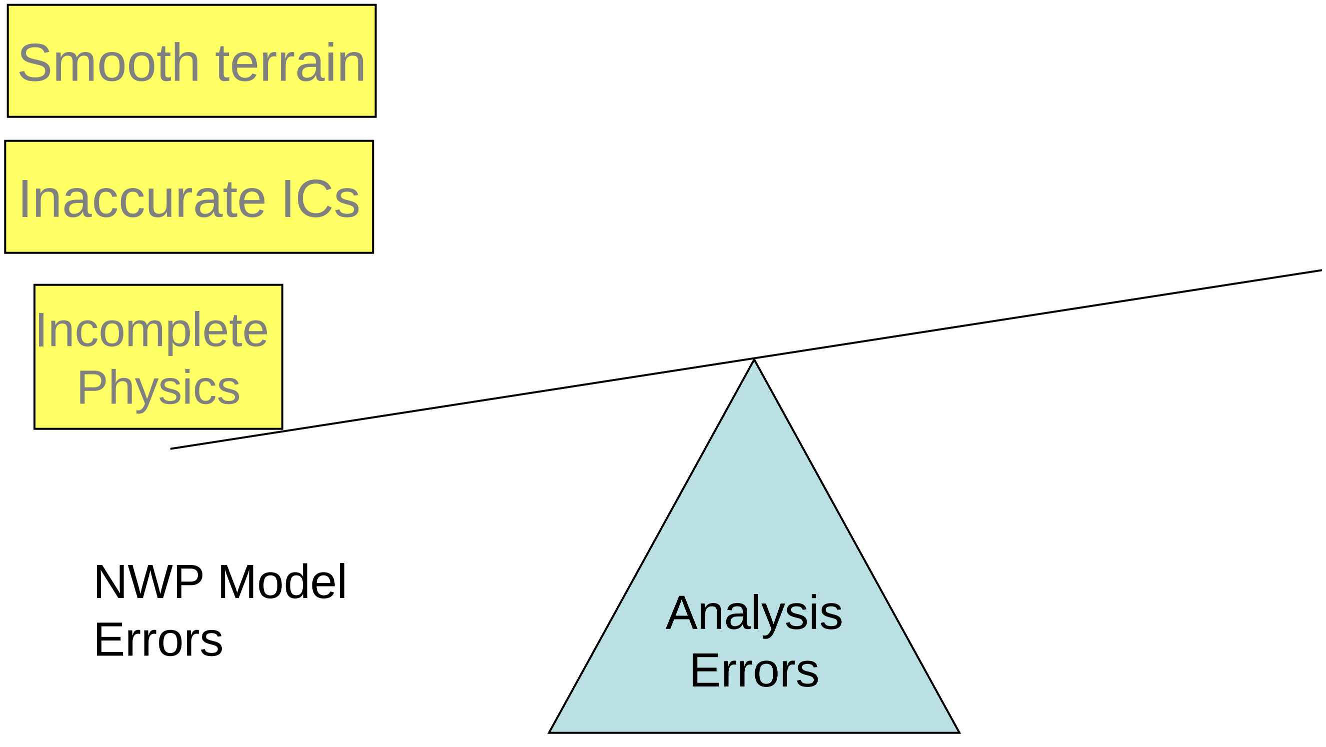
Analysis value = Background value + observation Correction

- An analysis is more than spatial interpolation
- A good analysis requires:
  - a good background field supplied by a model forecast
  - observations with sufficient density to resolve critical weather and climate features
  - information on the error characteristics of the observations and background field
  - appropriate techniques to translate background values to observations (termed “forward operators”)

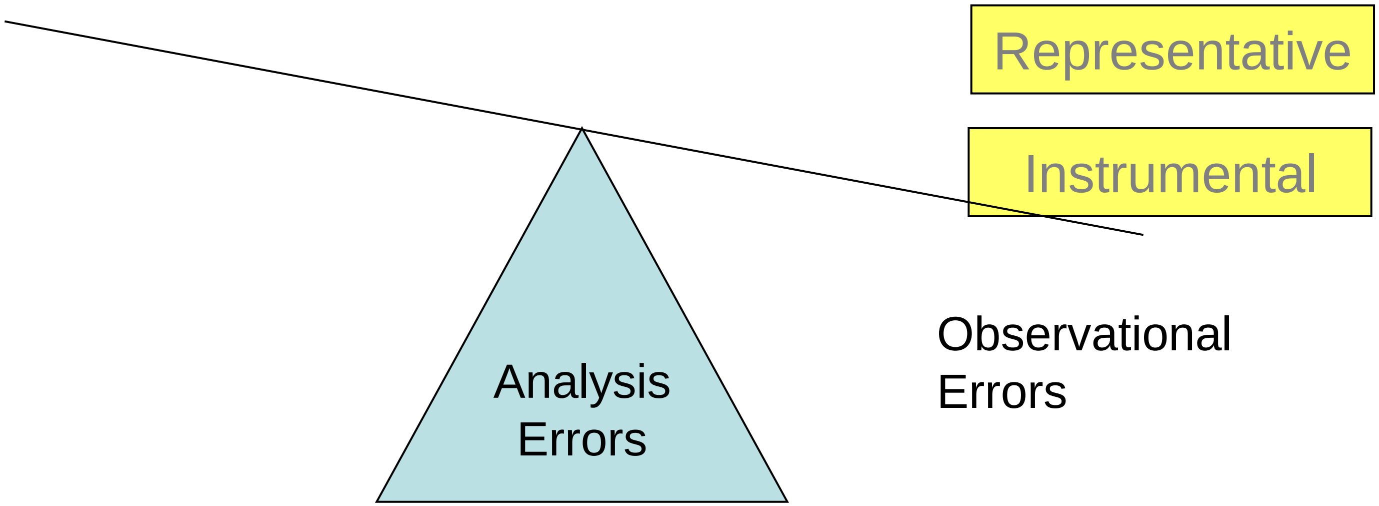
Need for balance…
Models or observations cannot independently define weather and weather processes effectively



Recognition of Sources of Errors



Recognition of Sources of Errors



Background Values

- Obtained from an analysis:
  - Climatology or analysis from prior hour
  - An objective analysis at a coarser resolution
  - Short term forecast
- Most objective analysis systems account for background errors but approaches vary

Some of the National & Regional Mesonet Data Collection Efforts

Planning for a National "Networks of Networks" underway
NAS report, August 2009 AMS Community Meeting

MADIS

IEM

NJ Weather & Climate NETWORK

CoCoRaHS
Community Collaborative Rain, Hail & Snow Network

Weather Underground

RAWS

National Weather Service

Homeland Security Weather Network

NOAA Regional Climate Centers

FAWN Florida Automated Weather Network

Northwest Atmospheric Modeling System

Citizen Weather Observer Program APRSWXNET

MesoWest

Oklahoma Mesonet

Arizona Cooperative Extension
AZMET

West Texas Mesonet

Observations

- Observations are not perfect…
  - Gross errors
  - Local siting errors
  - Instrument errors
  - Representativeness errors
- Most objective analysis schemes take into account that observations contain errors but approaches vary

Representativeness Errors

- Observations may be accurate…
- But the phenomena they are measuring may not be resolvable on the scale of the analysis
  - This is interpreted as an error of the *observation* not the analysis
- Common problem over complex terrain
- Also common when strong inversions
- Can happen anywhere

Sub-5km terrain variability (m)
(Myrick and Horel, WAF 2006)

Incorporating Errors

- Basic example:

$$T_a = T_b + W(T_o - T_b) \qquad W = \frac{\sigma_b^2}{\sigma_b^2 + \sigma_o^2}$$

σ_b = background error variance

σ_o = observation error variance

W = 0, distrust observation

W = 1, trust observation

Analyses of Record (AOR)

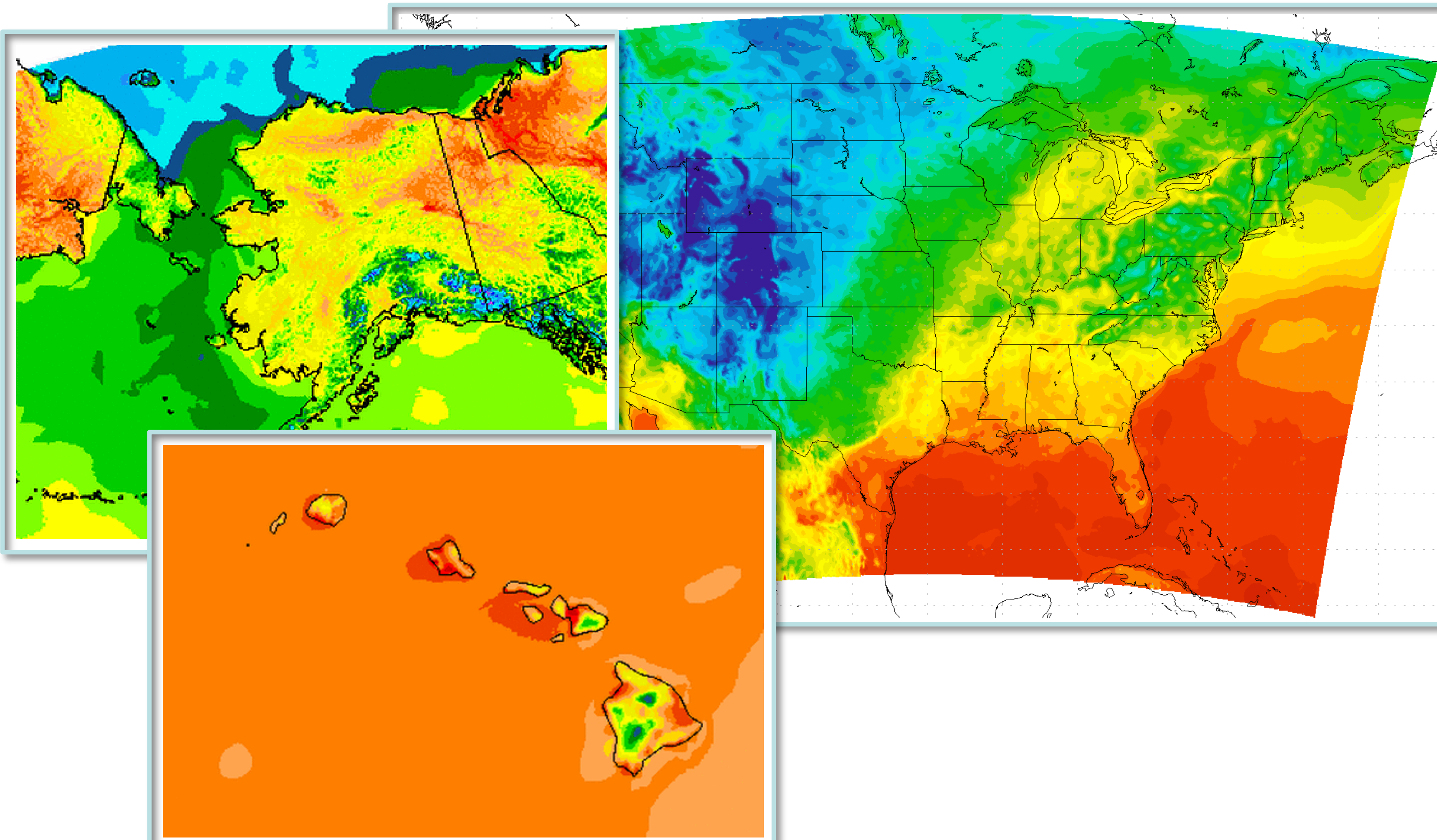
- Many needs for high resolution analyses
  - Research and education
  - Localized weather forecasting
  - Gridded forecast verification
  - Climatological applications
- AOR program established in 2004 by NWS
  - Three phases
    1. Real Time Mesoscale Analysis
    2. Delayed analysis: Phase II
    3. Retrospective reanalysis: Phase III

Real-Time Mesoscale Analysis (RTMA)

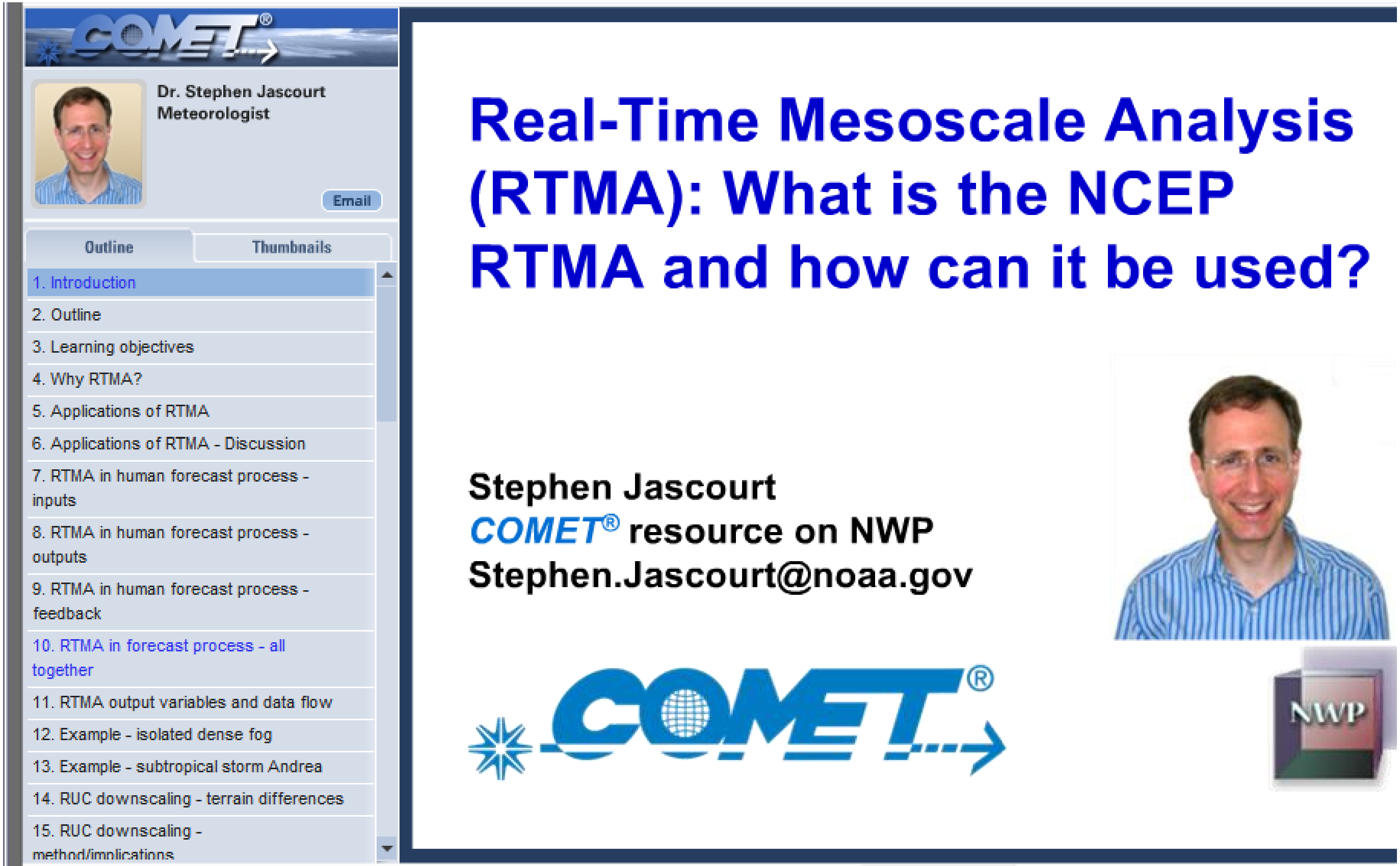
- Fast-track, proof-of-concept intended to:
  - Enhance existing analysis capabilities at the NWS and generate near real-time hourly analyses of surface observations on domains matching the NDFD grids.
  - Background errors can be defined using characteristics of background fields (terrain, potential temperature, wind, etc.)
  - Provide estimates of analysis uncertainty

- Developed at NCEP, ESRL, and NESDIS
  - Implemented in August 2006 for CONUS (and southernmost Canada) & recently for Alaska, Guam, Puerto Rico
  - Analyzed parameters: 2-m T, 2-m q, 2-m Td, sfc pressure, 10-m winds, precipitation, and effective cloud amount
  - 5 km resolution for CONUS with plans for 2.5 km resolution

The Real-Time Mesoscale Analysis



More Info… www.meted.ucar.edu



The Real-Time Mesoscale Analysis

- Several layers of quality control for surface observations
- Two dimensional variational surface analysis (2D-Var) using recursive filters
- Utilizes NCEP’s Gridpoint Statistical Interpolation software (GSI)
- Uses 1-h RUC forecast as background
- Uses surface observations and satellite winds
  - METAR, PUBLIC, RAWS, other mesonets
  - SSM/I and QuikSCAT satellite winds over oceans

The actual ABCs…

- The RTMA analysis equation looks like:

$$\left(\vec{P}_b^{\,T} + \vec{P}_b^{\,T}\vec{H}^T\vec{P}_o^{-1}\vec{H}\vec{P}_b\right)\vec{v} = \vec{P}_b^{\,T}\vec{H}^T\vec{P}_o^{-1}\left[\vec{y}_o - \vec{H}\left(\vec{x}_b\right)\right]$$

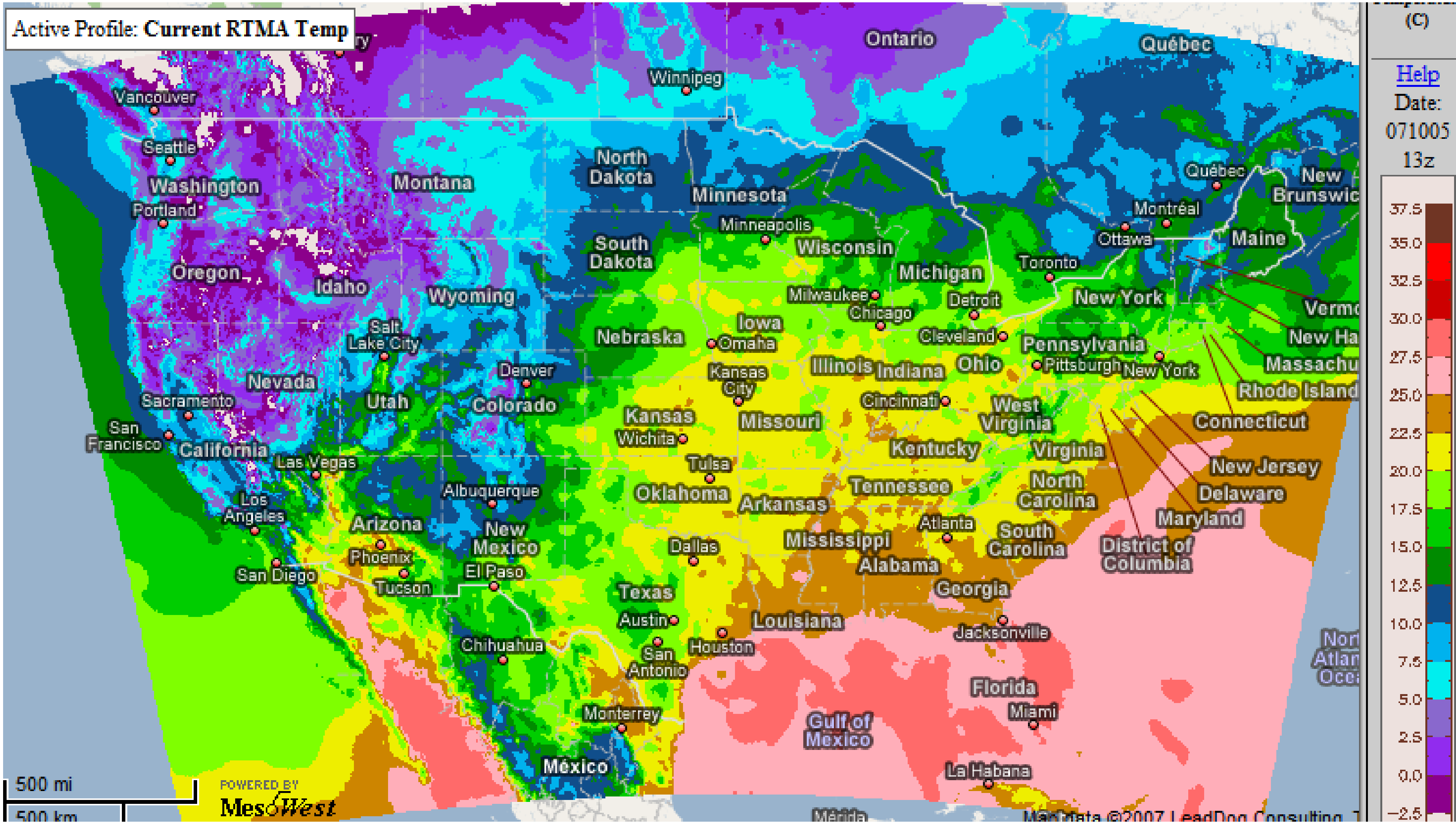
$$\vec{x}_a = \vec{x}_b + \vec{P}_b\vec{v}$$

- Covariances are error correlation measures between all pairs of gridpoints
- Background error covariance matrix can be extremely large
  - 2,900 GB memory requirement for continental scale
  - Recursive filters significantly reduce this demand

Estimation of Observation and Background Error Covariances

- Temperature errors at two gridpoints may be correlated with each other
- Error covariances specify the influence of observation innovations upon surrounding gridpoints
- RTMA used decorrelation lengths of:
  - Horizontal (*R*): 40 km
  - Vertical (*Z*): 100 m
  - Now increased to ~80 km and 200 m respectively
- *Significant limitation to specify error covariances rather than determine them through ensemble methods*

RTMA CONUS Temperature Analysis



RTMA Demo

- http://mesowest.utah.edu/class/unidata/
- Part 1: online RTMA resources
- Part 2:
  - download RTMA from U/U THREDDS server
  - OR
  - use Workshop RAMADDA page

Local Surface Analysis

- RTMA experiments run on NCEP’s Haze supercomputer but limited computer time available
- Development of a local surface analysis (LSA)
  - Same background field
  - Same observation dataset, but without internal quality control
  - Similar 2D-Var method, but doesn’t use recursive filters
  - Smaller domain
- Tyndall et al. (2009) Submitted to WAF

Local Surface Analysis

- Solving linear system of form Ax=b using GMRES- generalized minimal residual method

$$\left(\overrightarrow{P_b}' + \overrightarrow{P_b}'\overrightarrow{H}'\overrightarrow{P_o}^{-1}\overrightarrow{H}\overrightarrow{P_b}\right)\vec{v} = \overrightarrow{P_b}'\overrightarrow{H}'\overrightarrow{P_o}^{-1}\left(\overrightarrow{y_o} - \overrightarrow{H}\left(\overrightarrow{x_b}\right)\right)$$

$$\overrightarrow{x_a} = \overrightarrow{x_b} + \overrightarrow{P_b}\vec{v}$$

- In matlab x= gmres(A,b)

Local Surface Analysis Lab

- http://mesowest.utah.edu/class/unidata/lab.html

- Steps
- 1. Download observations from MesoWest
- 2. Download downscaled RUC 1-h forecast background
- 3. Run local surface analysis in matlab
- 4. display observations, background, & analysis in IDV

Summary

- Improving current analyses such as RTMA requires improving observations, background fields, and analysis techniques
  - Increase number of high-quality observations available to the analysis
  - Improve background forecast/analysis from which the analyses begin
  - Adjust assumptions regarding how background errors are related from one location to another
- Future approaches
  - Treat analyses like forecasts: best solutions are ensemble ones rather than deterministic ones
  - Depend on assimilation system to define error characteristics of modeling system including errors of the background fields
  - Improve forward operators that translate how background values correspond to observations