University of Utah Surface Analysis System

Dan Tyndall and John Horel
Department of Atmospheric Sciences, University of Utah

Introduction

- High resolution analyses (1-5 km) are needed for NWS forecast verification, fire weather and wind power applications, and forecaster situational awareness
- The National Centers for Environmental Prediction (NCEP) developed the Real-Time Mesoscale Analysis (RTMA), which is a two-dimensional variational (2DVar) surface analysis to meet this need
- The RTMA is run at both 5-km and 2.5-km resolution over the CONUS domain, and assimilates ~15,000 observations from various mesonets every hour
- Tyndall et al. (2008) assessed appropriate decorrelation length scales used to build the background error covariance matrix and appropriate observation to background error variance ratios
  - That research utilized a 2DVar local surface analysis (LSA) written in MATLAB that could only run over a limited domain (4°×4°) due to memory requirements
- This study has developed a new parallelized, cross-platform, 2DVar analysis with increased memory efficiency through computational and mathematical simplification methods

Analysis Methodology

- The University of Utah Surface Analysis System (UU2DVar) utilizes the standard variational cost function:

$$J(\vec{x_a}) = (\vec{x_a} - \vec{x_b})^{T} P_b^{-1} (\vec{x_a} - \vec{x_b}) + [H(\vec{x_a}) - \vec{y_o}]^{T} P_o^{-1} [H(\vec{x_a}) - \vec{y_o}] \quad (1)$$

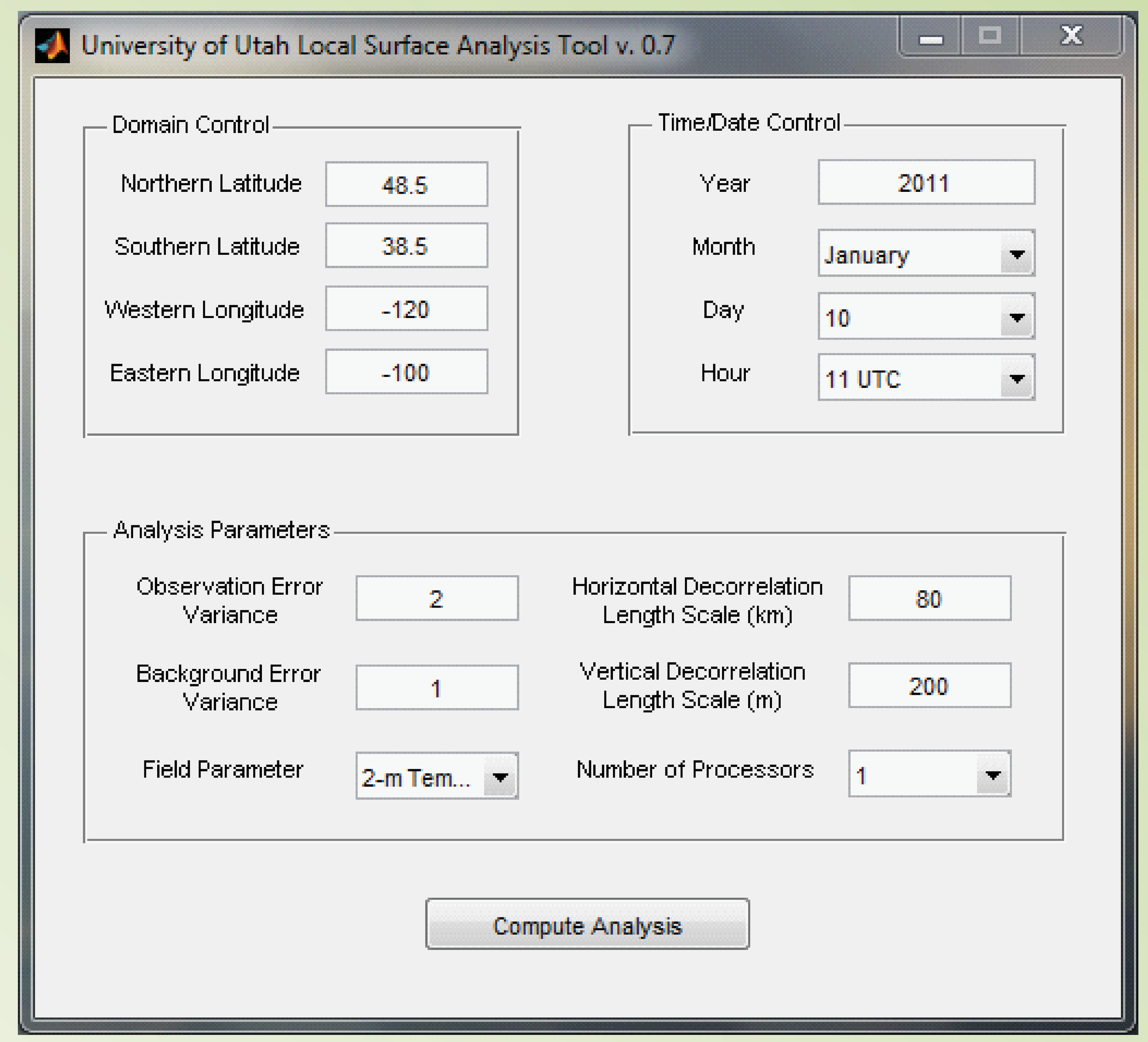
- This function is solved in observation space using the PSAS technique (Lorenc 1986)
- Solving the equation in observation space yields the equations:

$$\vec{y_o} - H(\vec{x_b}) = (HP_bH^{T} + P_o^{-1})\vec{\eta} \quad (2) \qquad \vec{x_a} = \vec{x_b} + P_bH^{T}\vec{\eta} \quad (3)$$

- Equation 2 is solved for $\vec{\eta}$ iteratively using the Generalized Minimum Residual technique, and then $\vec{\eta}$ is inserted into equation 3 to yield the analysis grid
- The background error covariance matrix (P_b) is difficult to store, due to its size (square of the number of gridpoints)
- UU2DVar reduces the computation time and storage of P_b by:
  1. Usage of variational localization and sparse matrices, and elements of the matrix are zeroed at a distance of 3.75 horizontal decorrelation length scales
  2. Computing only rows of P_b which share row indices of nonzero elements of H, reducing the number of computations by two orders of magnitude
  3. Storing the array P_bH^{T}, which has the size oft he number of gridpoints multiplied by the number of observations
  4. Parallelizing computation of P_bH^{T} with near perfect speedup
- Analysis error information can be generated by sequentially removing each observation while using all others utilizing the same P_bH^{T} matrix for each analysis
  - Matrix can be reused in data denial analyses by setting observation innovation to zero and its observation error very large, which causes the analysis to ignore the observation
  - Re-solving equation 3 takes approximately a second for a 5-km CONUS analysis with order 10,000 observations

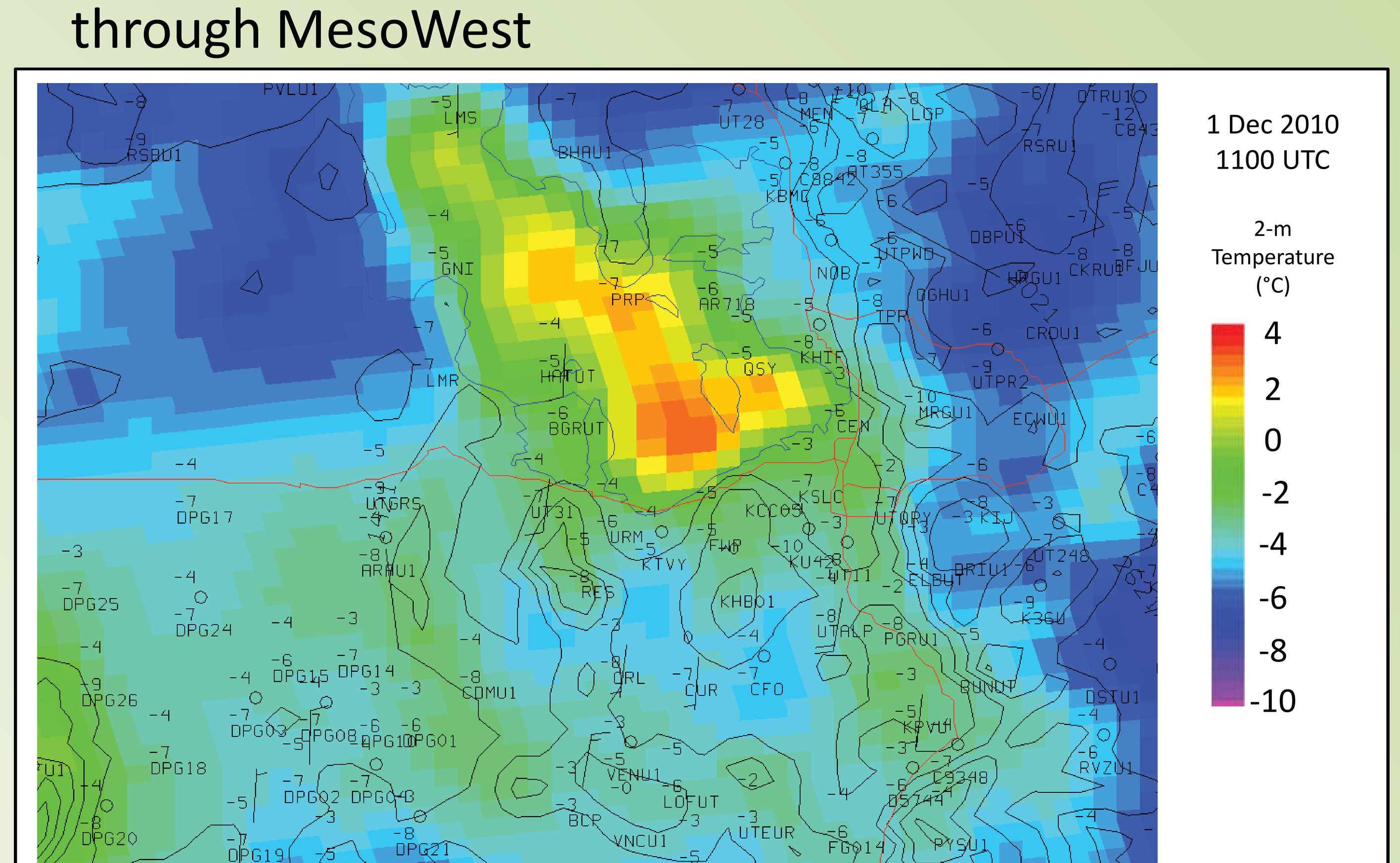
UU2DVar Software

- UU2DVar written entirely in MATLAB
  - Takes advantage of built-in parallelization and efficient matrix computation algorithms
- Includes a graphical user interface which can be used to run the analysis
- Analyses are outputted as NetCDF files which can be easily viewed in Unidata's Integrated Data Viewer
- Software is compiled using the MATLAB Compiler, allowing it to be run on Windows, OS X, and Linux on computers without MATLAB



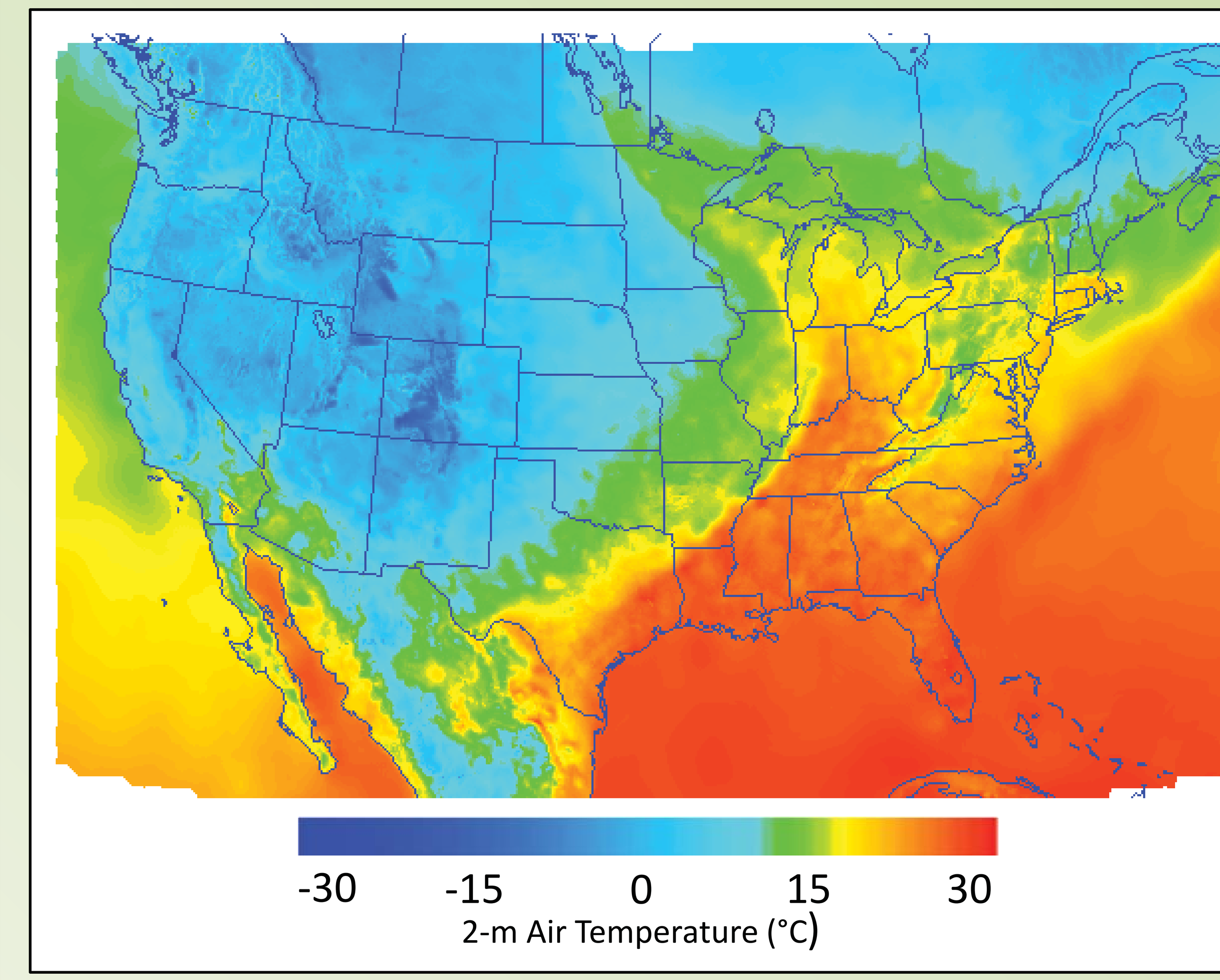
Persistent Cold Air Pool Study (PCAPS)

- UU2DVar is being used to help analyze cold air pools tha orm over the Salt Lake Valley during PCAPS
- UU2DVar is run over a smaller domain centered over northern Utah, run at 2.5 km resolution
  - System utilizes high resolution background field used by experimental version of RTMA
- Additional experiment observations downloaded through MesoWest



CONUS Hourly Analysis

- UU2DVar is run routinely every hour over the CONUS domain using a 5-km analysis grid:
  - 5-km downscaled Rapid Update Cycle 1-h forecast as background
  - MesoWest observations within a ±15 minute window about the analysis hour
  - Only gross error check quality control measures are utilized
- Analysis grids are publicly available from the University of Utah THREDDS server
  - 2-m temperature grids available currently; 2-m dew point, 10-m winds, and surface pressure coming soon
- Figure below depicts UU2DVar 2-m temperature analysis on 1400 UTC 27 Oct 2010 over CONUS domain



Future Work and Further Information

- Evaluate uncertainty information as a function of observation density by assessing background grid errors
- Implement strong and weak constraints into the analysis
- Increase the resolution of the hourly analysis to 2.5 km
- For more information on how UU2DVar was developed, and how to use MATLAB to develop parallelized, cross-platform GUI applications, see J7.3 20Ed/27IIPS, Tuesday, 11:45 am

Contact Information and Poster Download

- Email: d.tyndall@utah.edu
- Website: http://www.inscc.utah.edu/~dtyndall/

Scan me with any QR barcode reader on your smart phone.

Scan me with Microsoft Tag on your smart phone. Don't have the free reader? Visit http://gettag.mobi