Development of a prototype flash-flood prediction system for the Colorado Front Rang using the coupled WRF/Noah-Distributed Hydrometeorological Prediction System

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8th Annual WRF User's Workshop, June 14, 2007

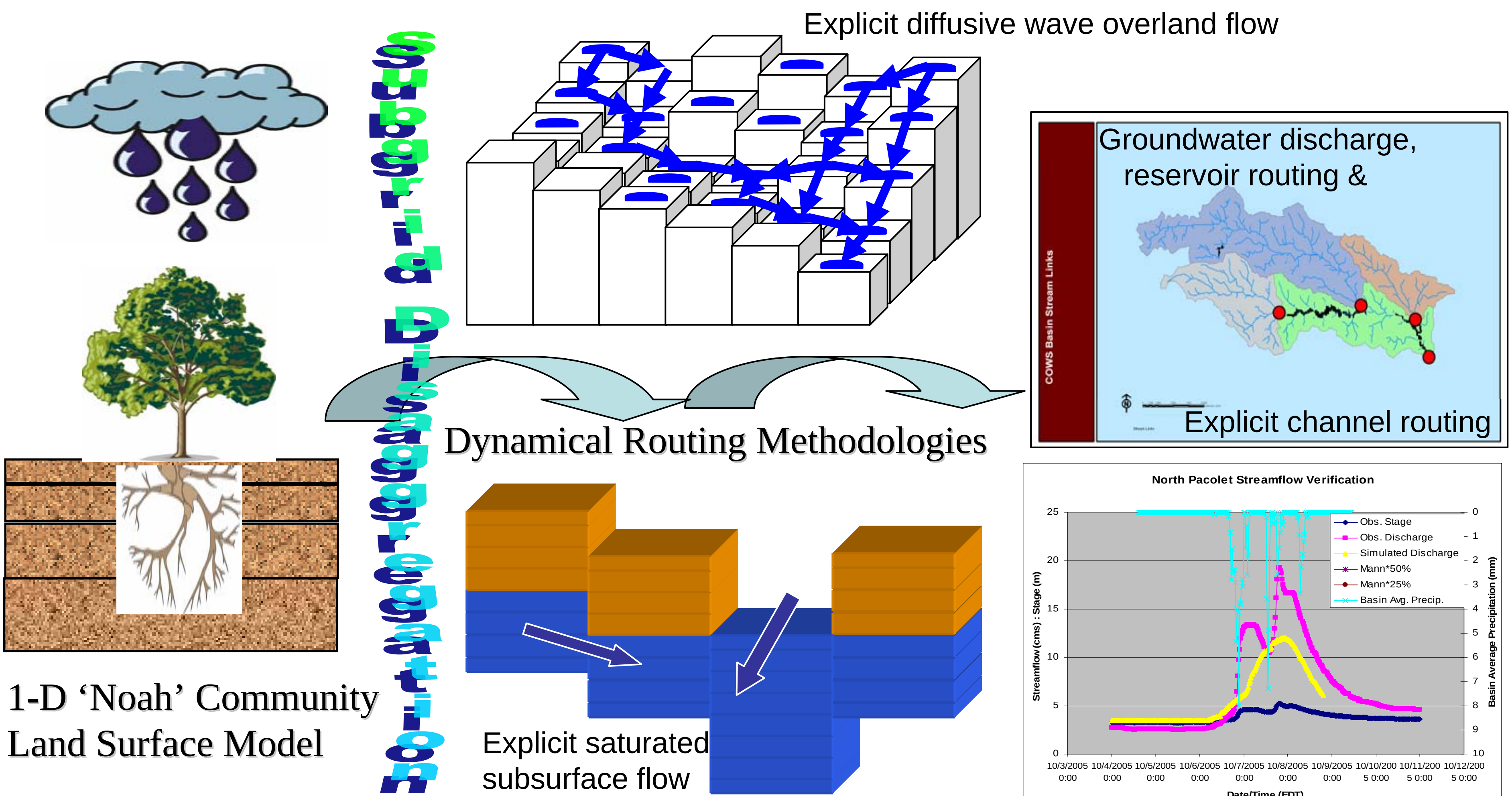
Critical needs and challenges for improved flash flood prediction

- USGS/FEMA Reports: Significant annual losses of life and property
- Spatial and temporal scale of flood generation processes *and* impacts necessitate very highly-resolved systems
- Regions of complex terrain can be particularly vulnerable due rapid collection and transport of flood waters in catchments
- The (*growing*) urban landscape also imparts significant challenges to traditional watershed modeling approaches
- Many events exhibit low predictability thus necessitating probabilistic approaches

Photo courtesy: Cornerstones Community Partnerships

The hydrologically-enhanced Noah-distributed Land Surface Model

(Gochis and Chen, 2003, NCAR Tech Note)



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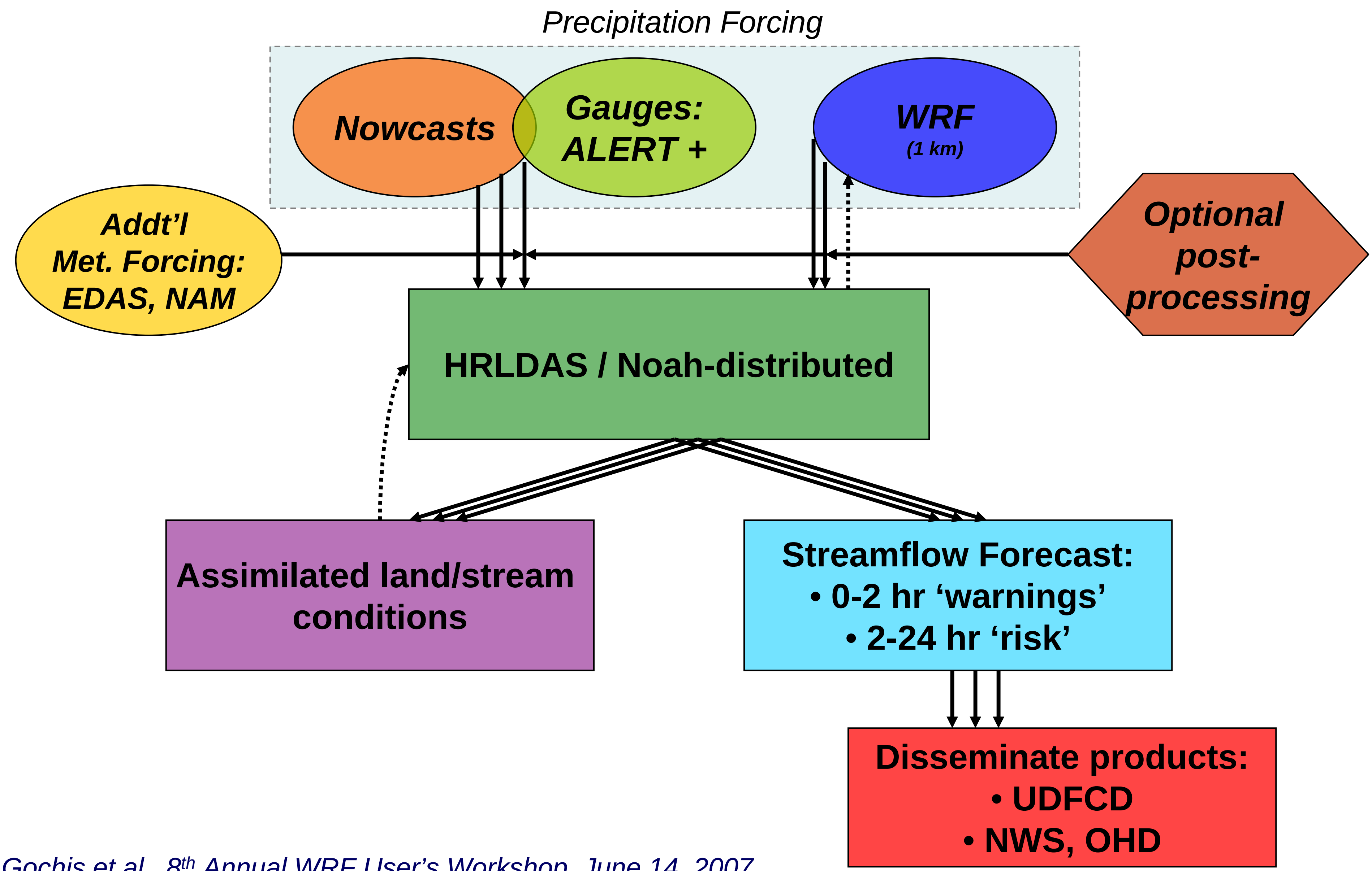
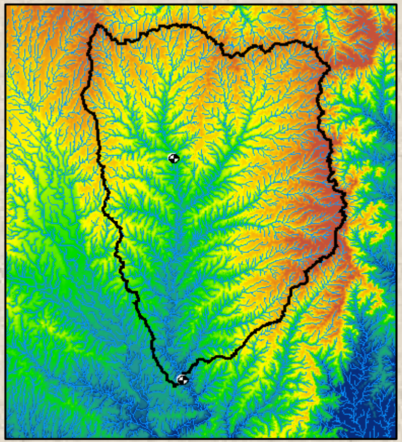
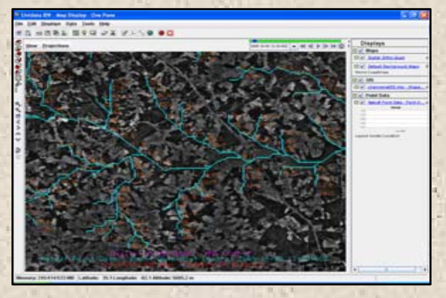
Coupled and Uncoupled Modeling Strategy:



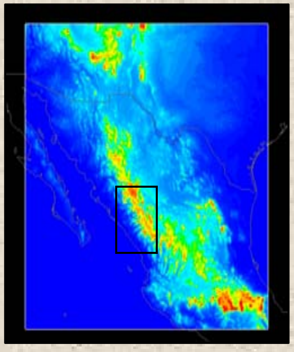
Current applications and deployments:



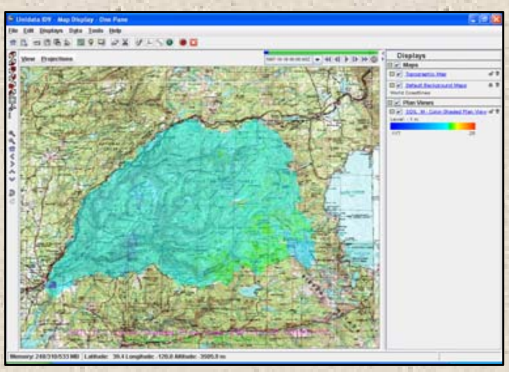
Walnut River Basin, KS, USA (land-atmosphere coupling)



Santee River Basin, SC, USA (land-falling Tropical storms)



North American monsoon, Mex. (monsoon hydrology)



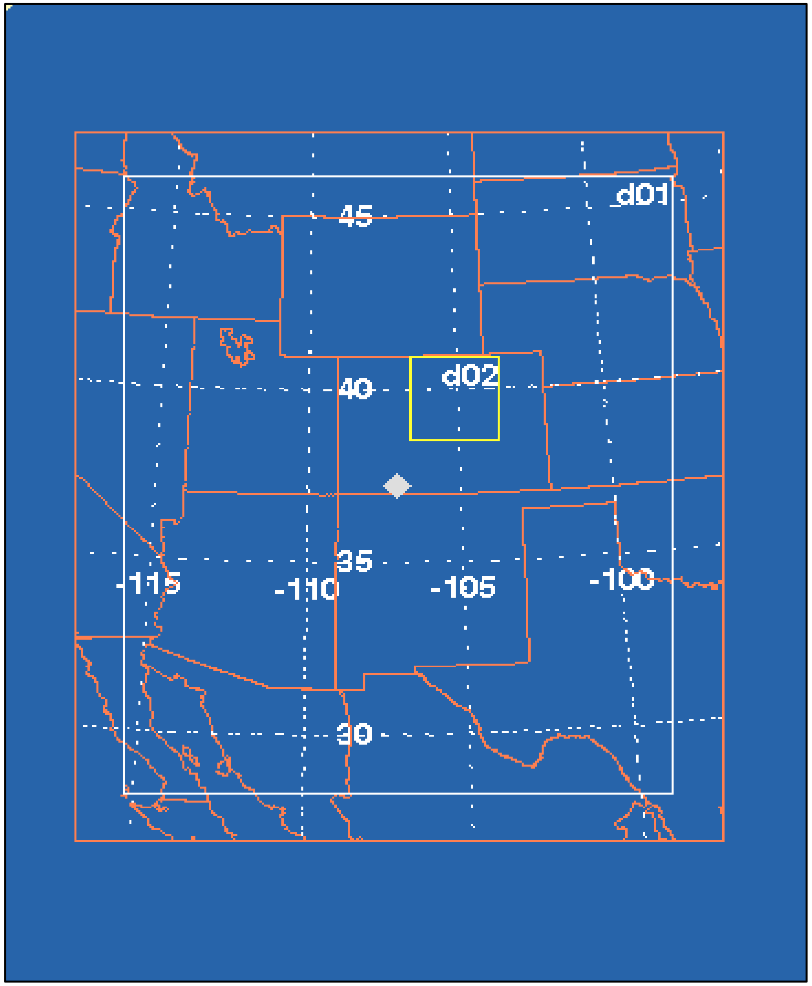
American River Basin, CA, USA (snowmelt hydrology)

Romanian operational hydrologic modeling

Coupled WRF-Hydro Flash Flood Forecasting in the Colorado Front Range:

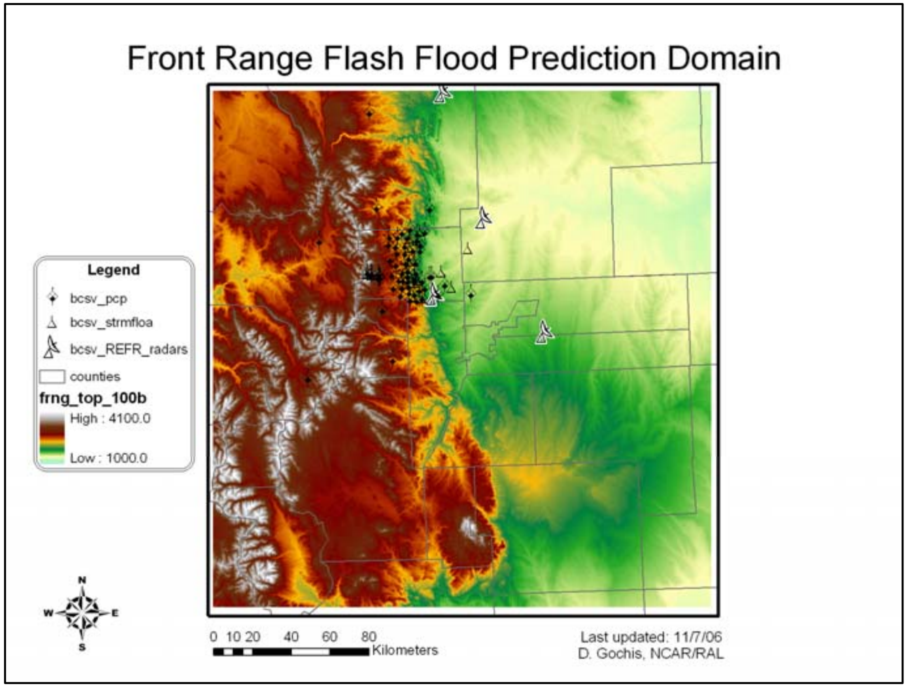
- WRF Model Options
  - No convection parameterization
  - Purdue/Lin 6-class microphysics
  - RRTM LW, Dudhia SW
  - Yonsei PBL, M-O sfc lyr
  - Noah land surface model w/ and w/out coupled Noah-distributed routing
  - Various initialization times

4 km and 1 km WRF Domains



Coupled WRF-Hydro Flash Flood Forecasting in the Colorado Front Range:

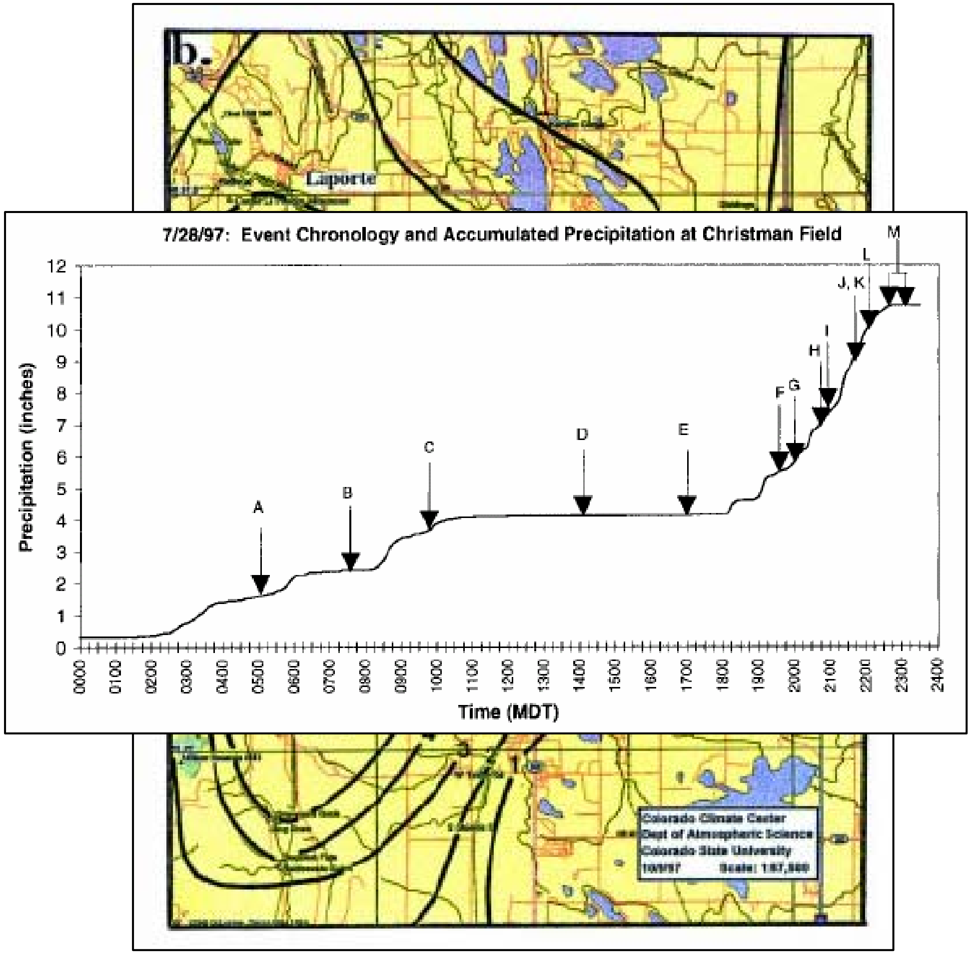
- Noah-distributed specifications:
  - 1 km Noah grid w/ 100m explicit terrain routing
  - NHDPlus 100m terrain
  - Trained stream network delineation based on NHDPlus 'blue-lines'
  - STATSGO 1km soils
  - USGS 1km land cover



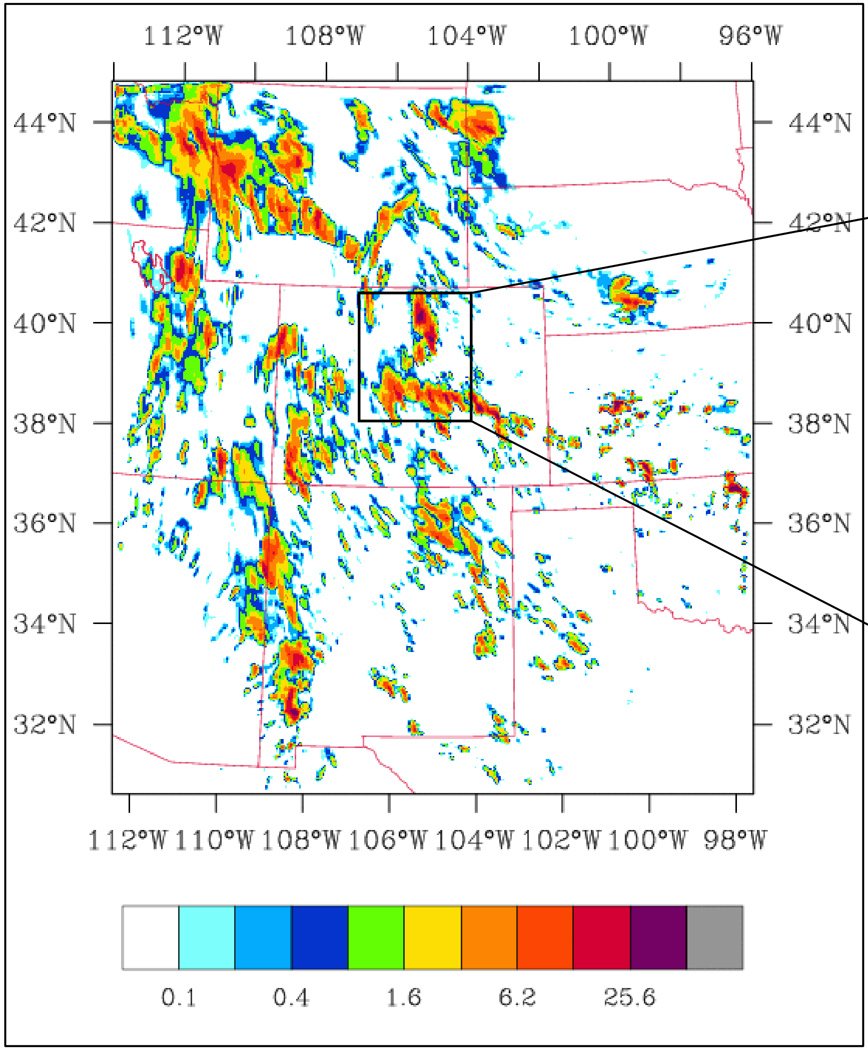
Case Study: 1997 Ft. Collins Flood Event (see Peterson et al. 1997 BAMS)

- July 28-29, 1997
- Max. accumulations > 10 in. (250 mm) in 6 hrs.
- 5 fatalities
- Over $200M in damages
- Warm season quasi-stationary convective event

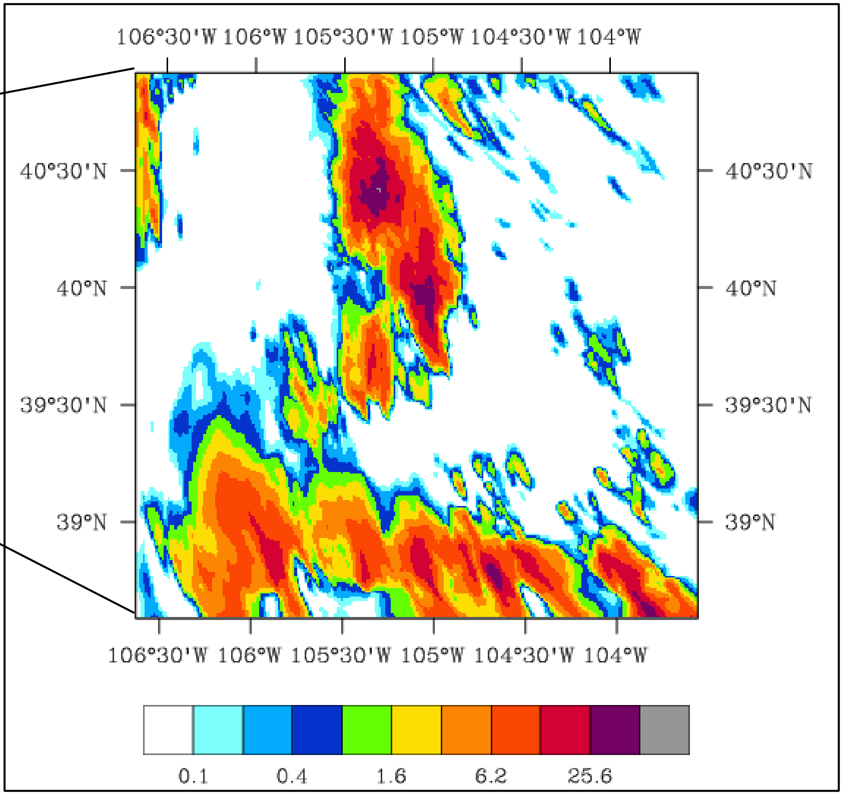
Accum. Precip. (in): 1730-2300 MDT Jul. 29, 1997



Case Study: 1997 Ft. Collins Flood Event



1 hr rain rates: Jul. 29, 1997 0100Z



1 km WRF

4 km WRF

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Case Study: 1997 Ft. Collins Flood Event Mesoscale Analysis

Observed Analysis

"Denver Cyclone"

1 km WRF-no routing:
Init. July 27 12z

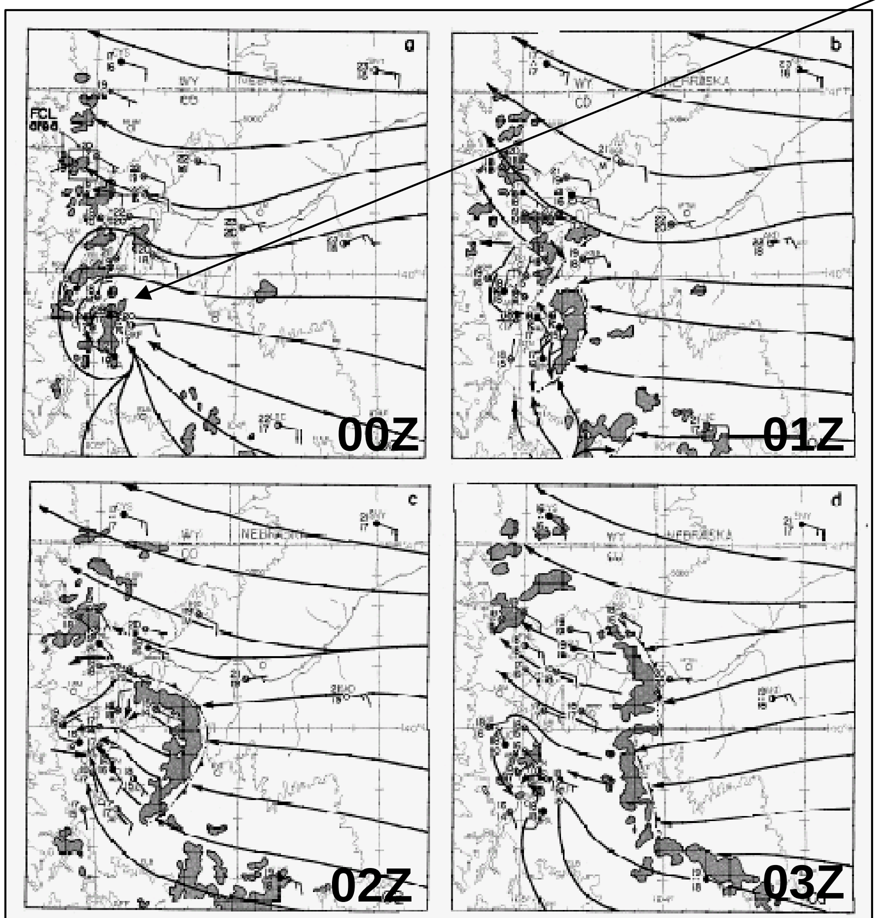
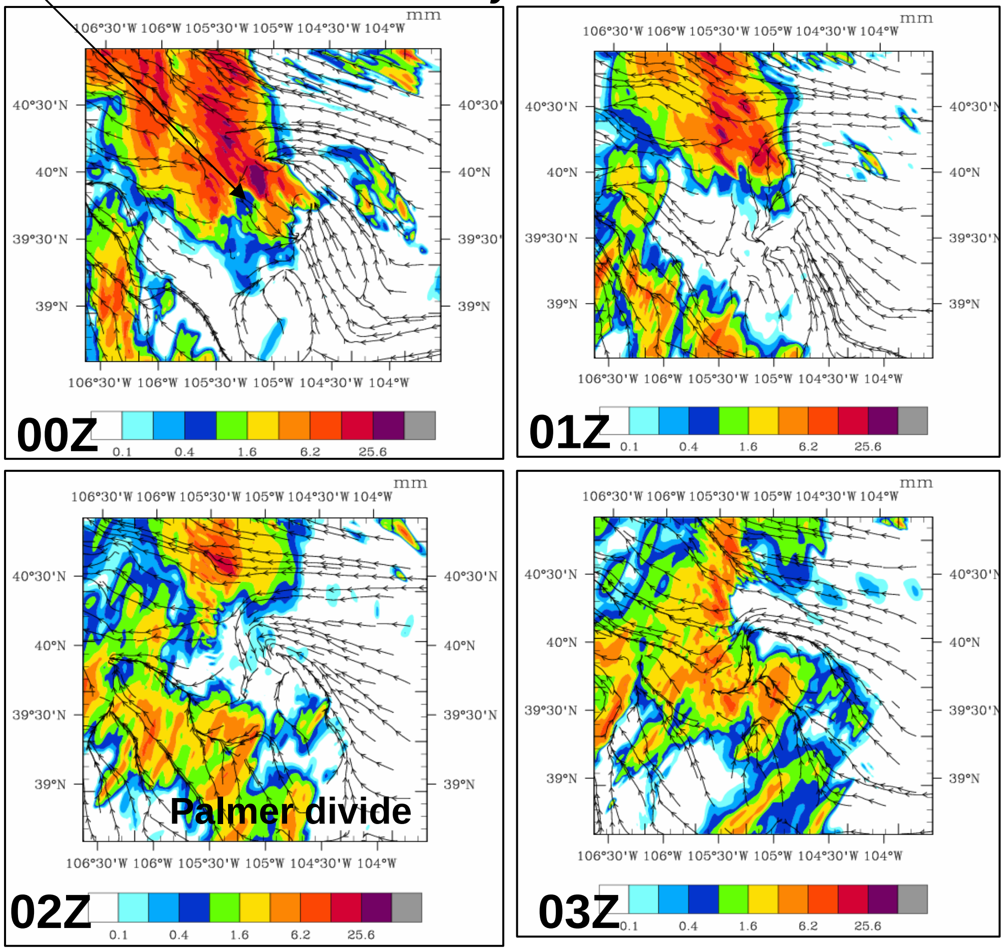


FIG. 7. Hourly mesoscale analyses for 1800–2100 MDT 28 July 1997 (0000–0300 UTC 29 July 1997). Surface streamlines are in solid arrows. Wind barbs plotted as in Fig. 6; temperature and dewpoints in °C. Mesoscale boundaries are indicated as in Fig. 5. Regions of radar reflectivity ≥ 35 dBZ are shaded: (a) 1800 (0000), (b) 1900 (0100), (c) 2000 (0200), and (d) 2100 MDT (0300 UTC).



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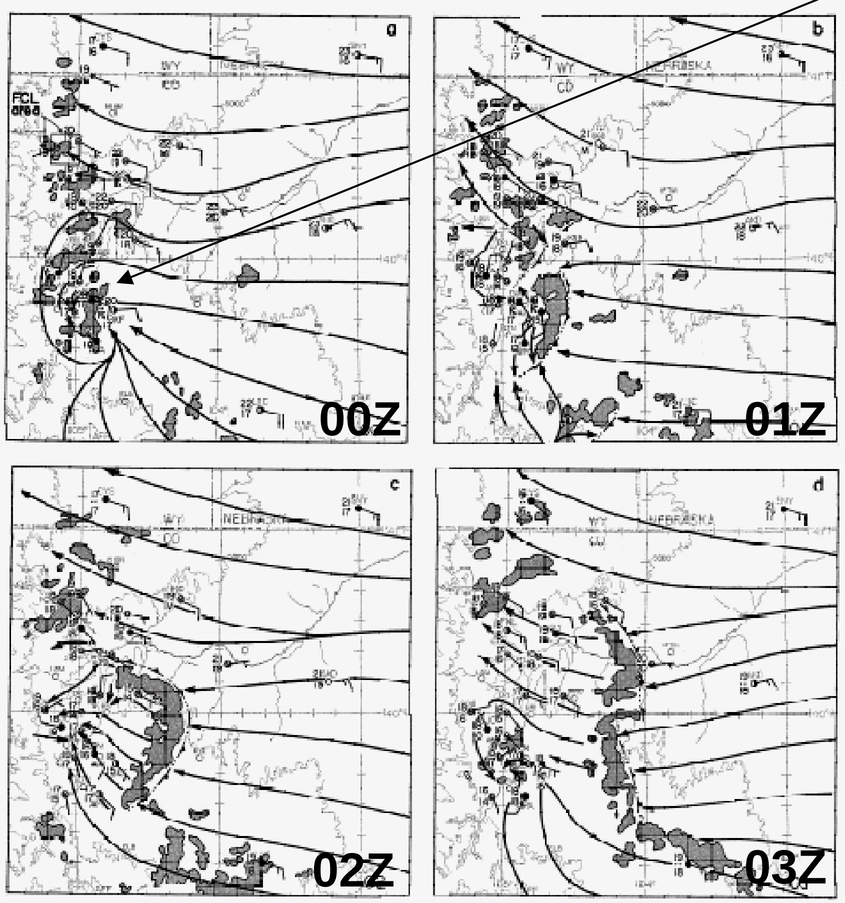
Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

Observed Analysis

"Denver Cyclone"

1 km WRF-w/ routing: Init. July 27 12z



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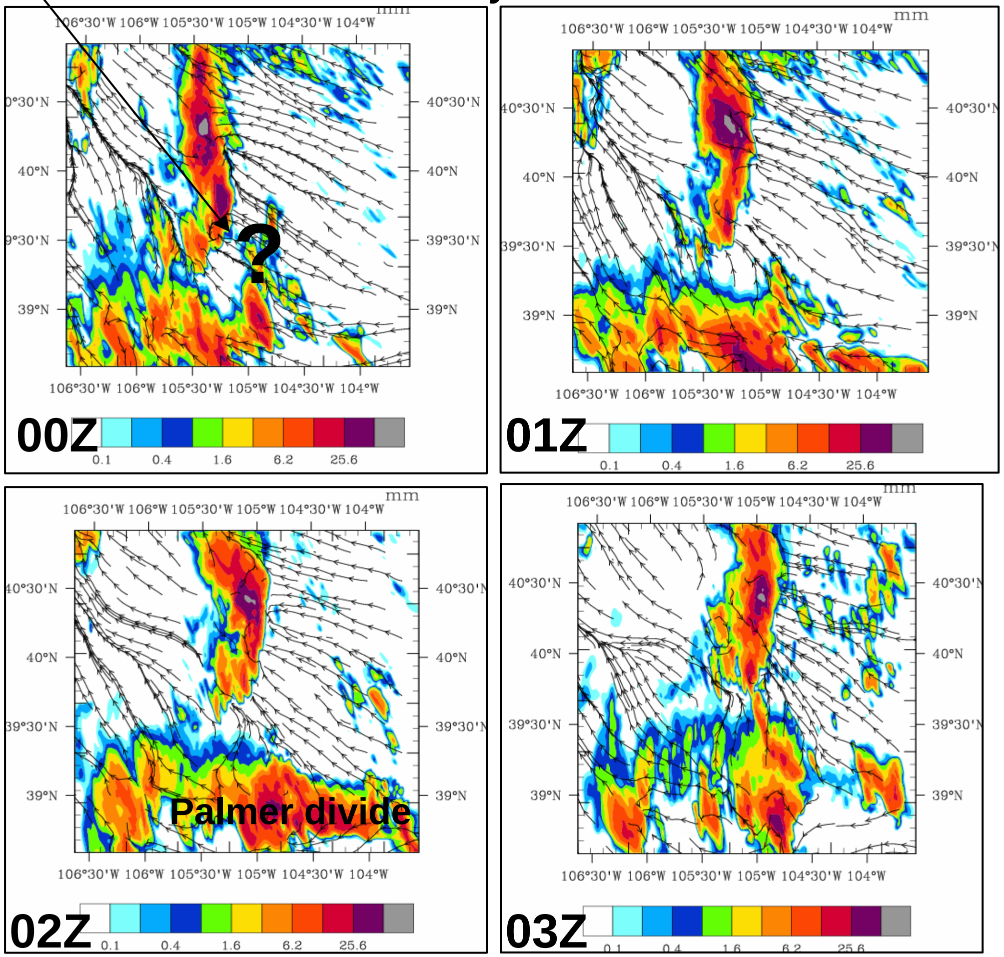

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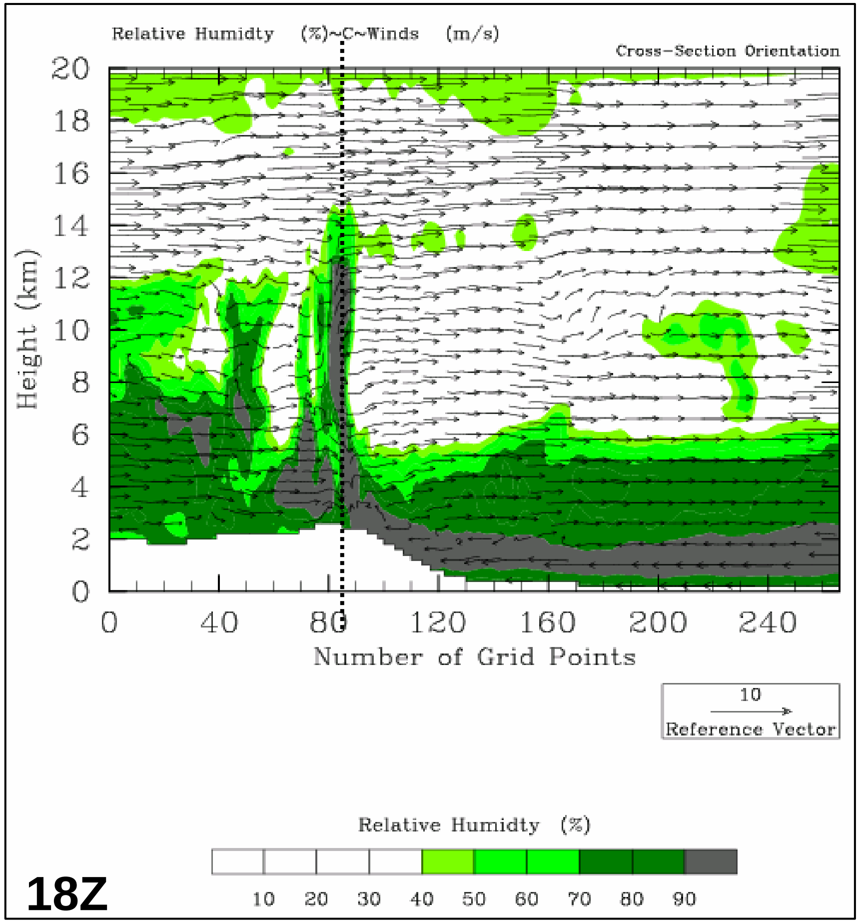
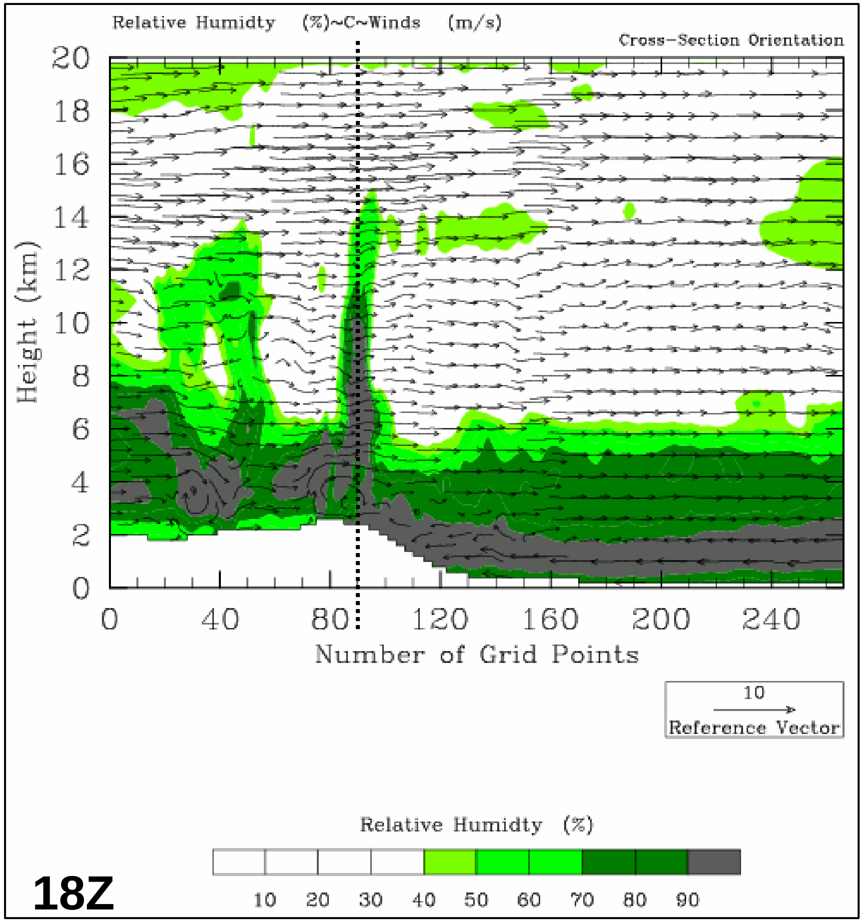
Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

1 km WRF-w/out routing:
Init. July 27 12z



1 km WRF-w/ routing:
Init. July 27 12z



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Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

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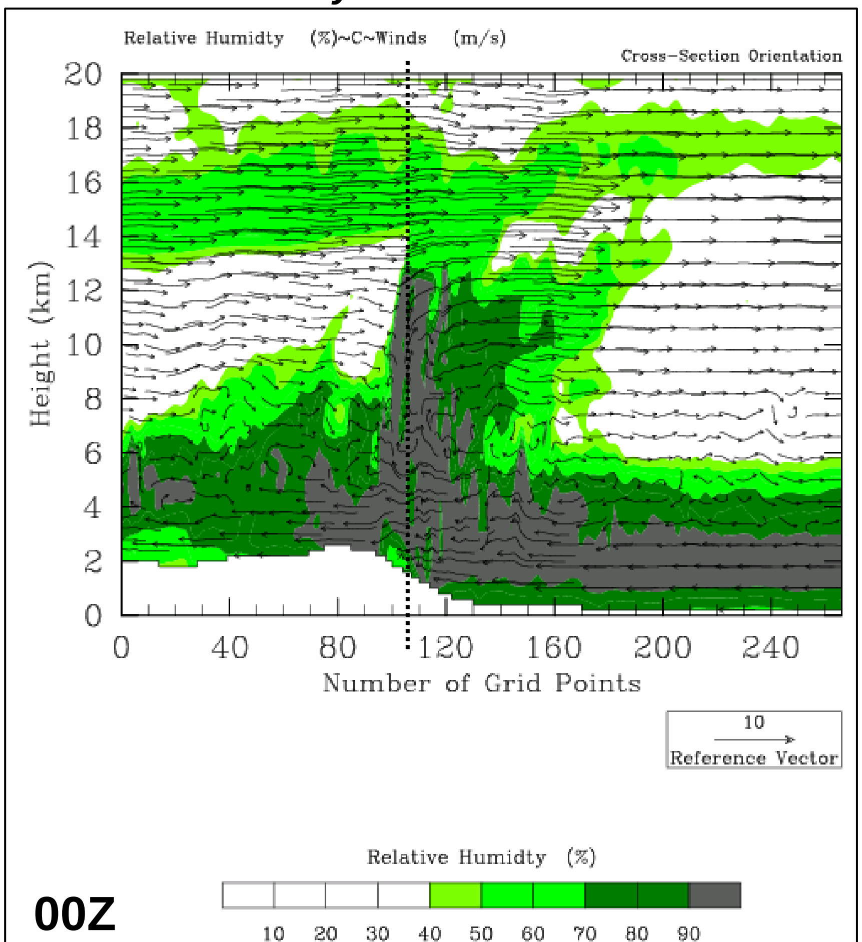
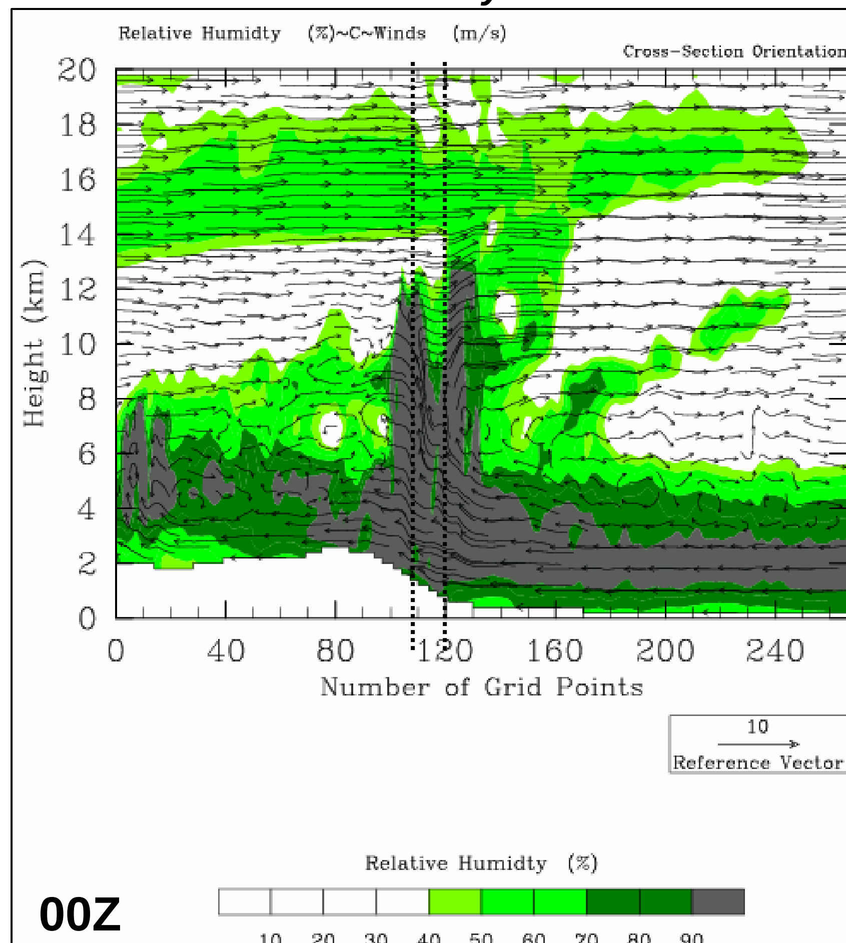
Init. July 27 12z



1 km WRF-w/ routing:
Init. July 27 12z



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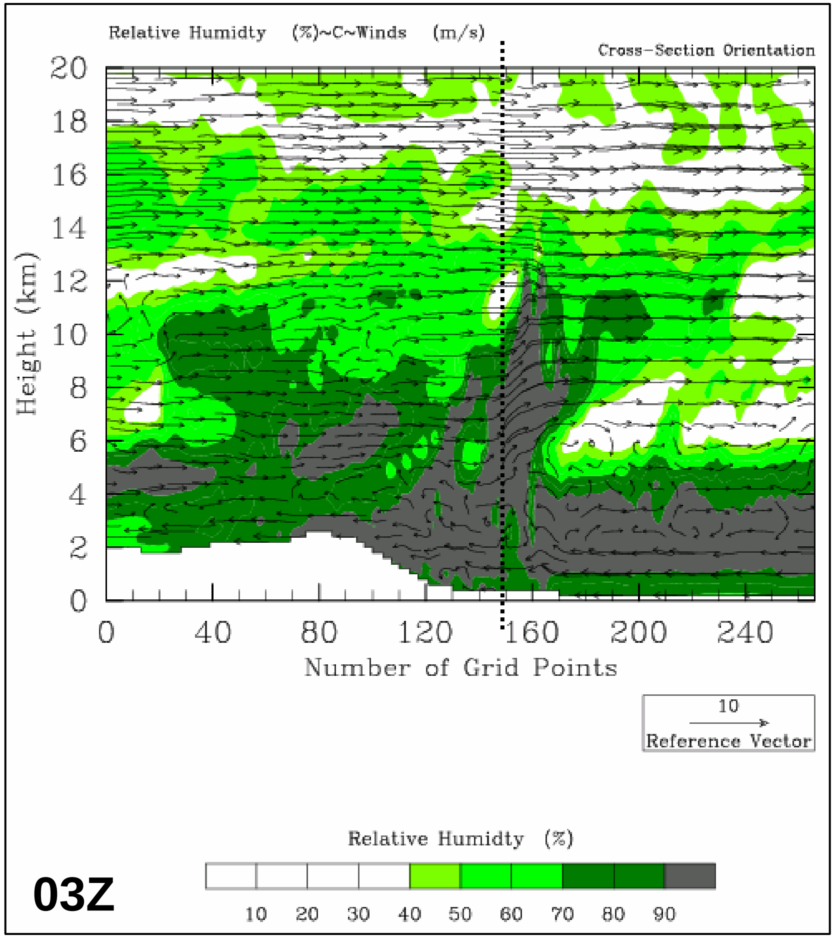
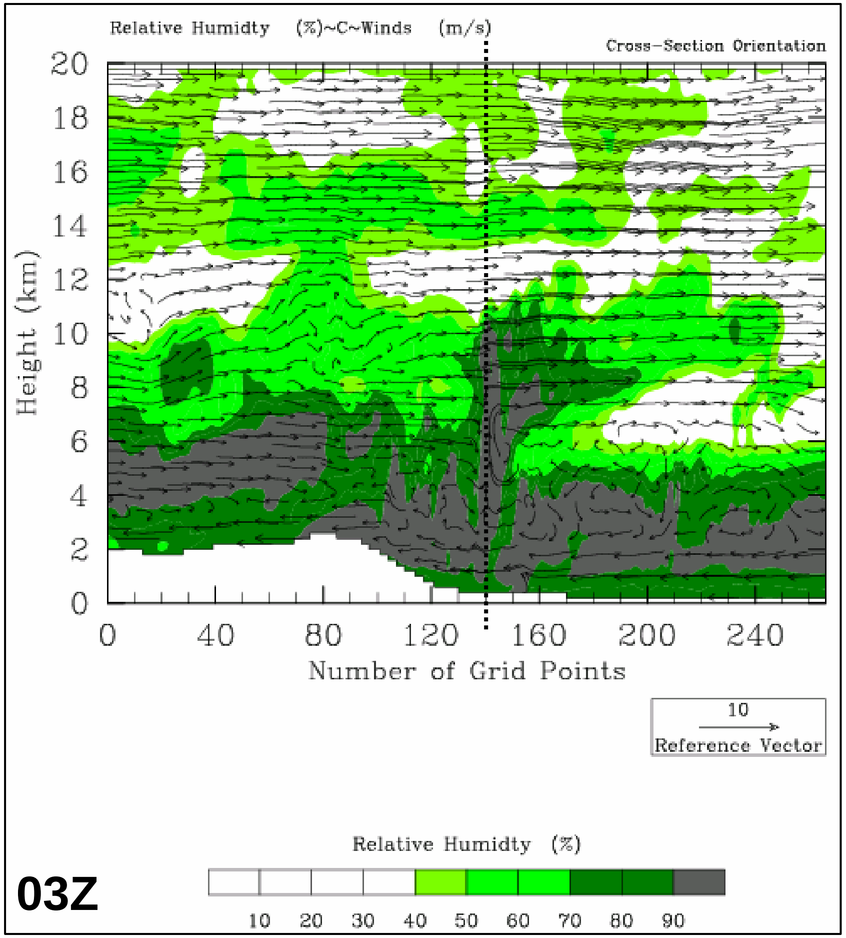
Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

1 km WRF-w/out routing: Init. July 27 12z



1 km WRF-w/ routing: Init. July 27 12z



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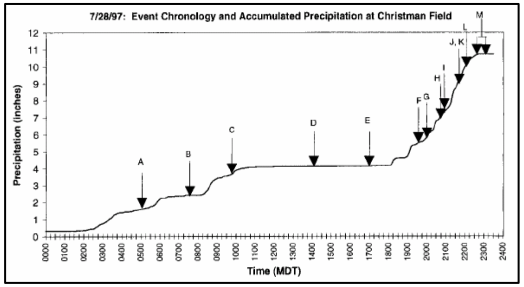
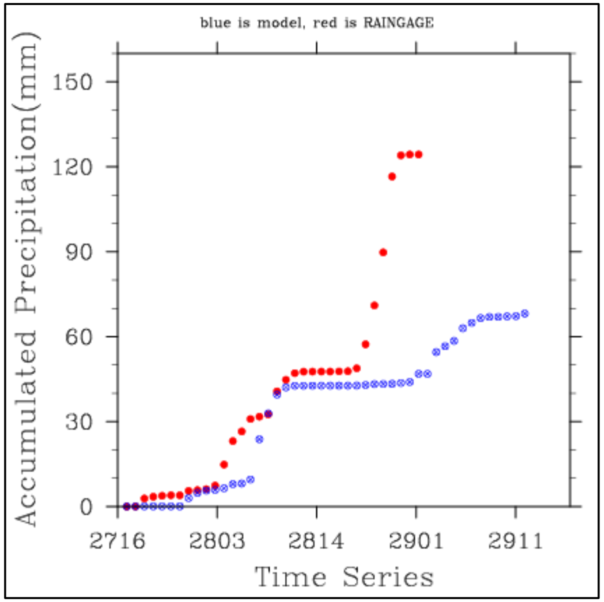
Case Study: 1997 Ft. Collins Flood Event

Accumulated Precipitation

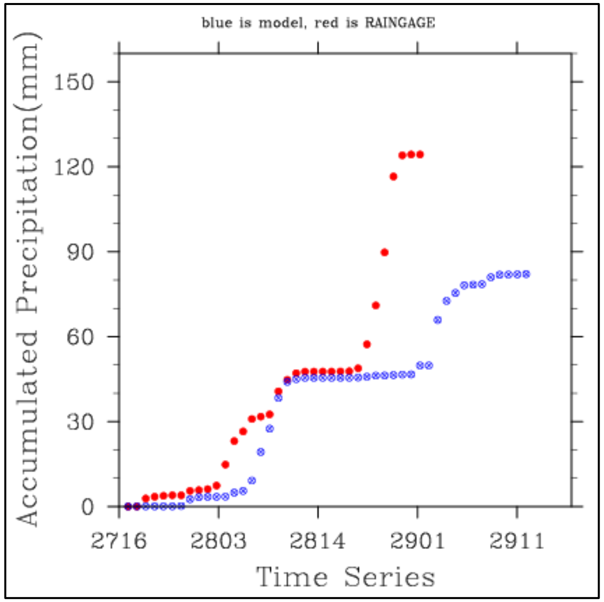


WRF vs. Rain Guages



1 km WRF-no routing: Init. July 27 12z

WRF vs. Rain Guages



1 km WRF-*with routing*: Init. July 27 12z

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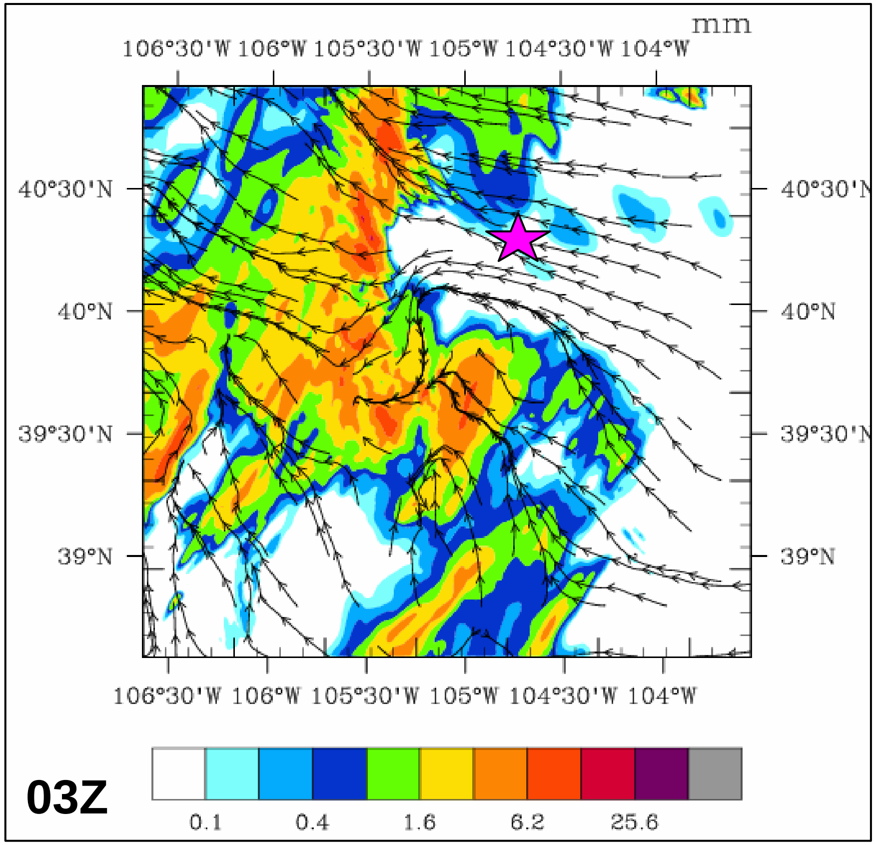
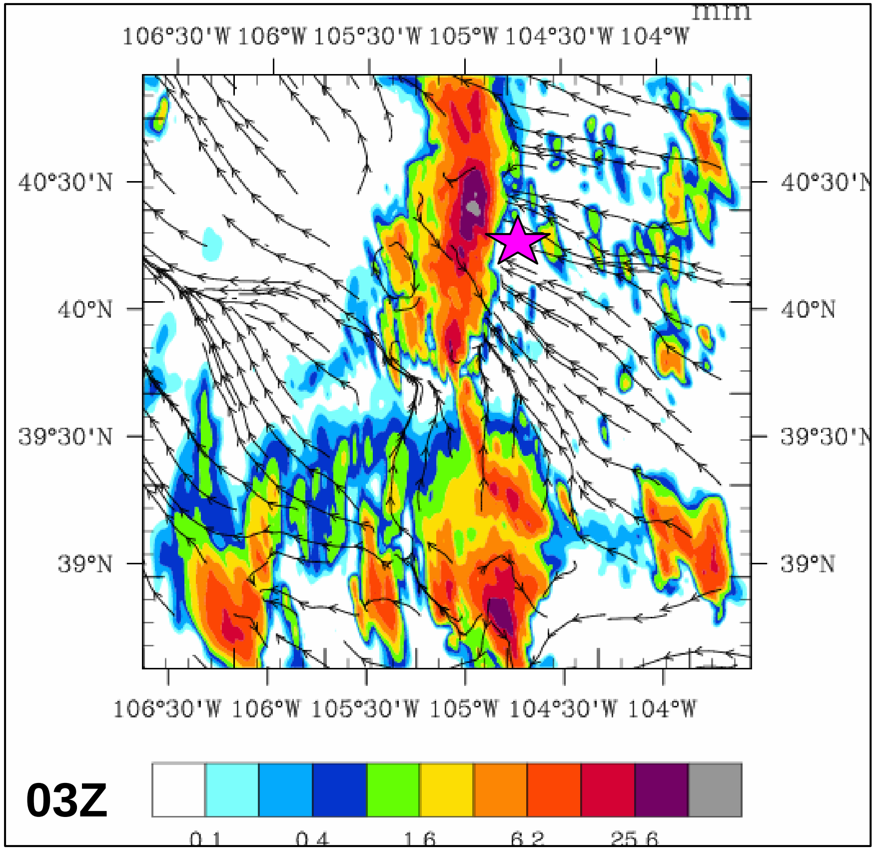
Case Study: 1997 Ft. Collins Flood Event
Mesoscale Analysis

1 km WRF-w/out routing:
Init. July 27 12z



1 km WRF-w/ routing:
Init. July 27 12z



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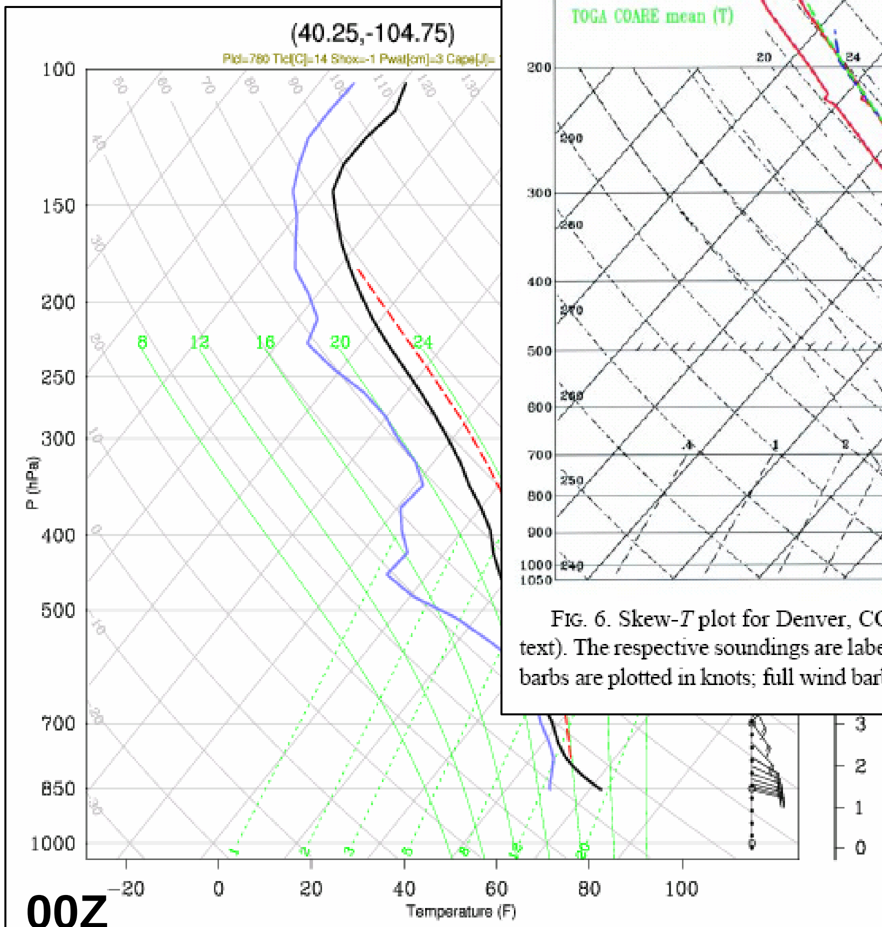
Case Study: 1997 Ft. Collins Flood Event

Mesos

1 km WRF-w/ou
Init. July 27 12z

km WRF-w/ routing:
it. July 27 12z



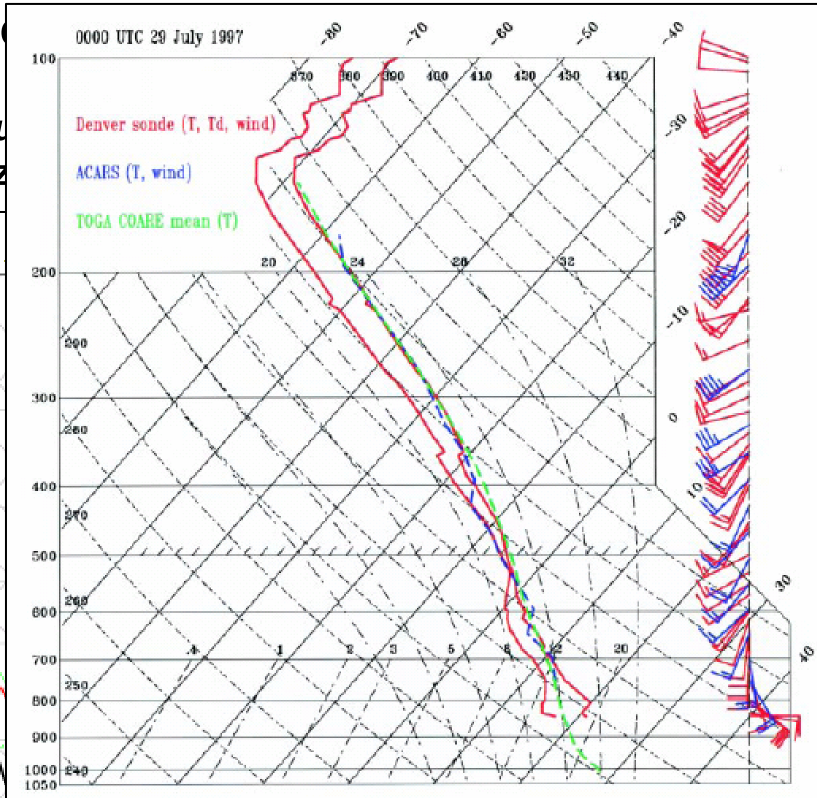
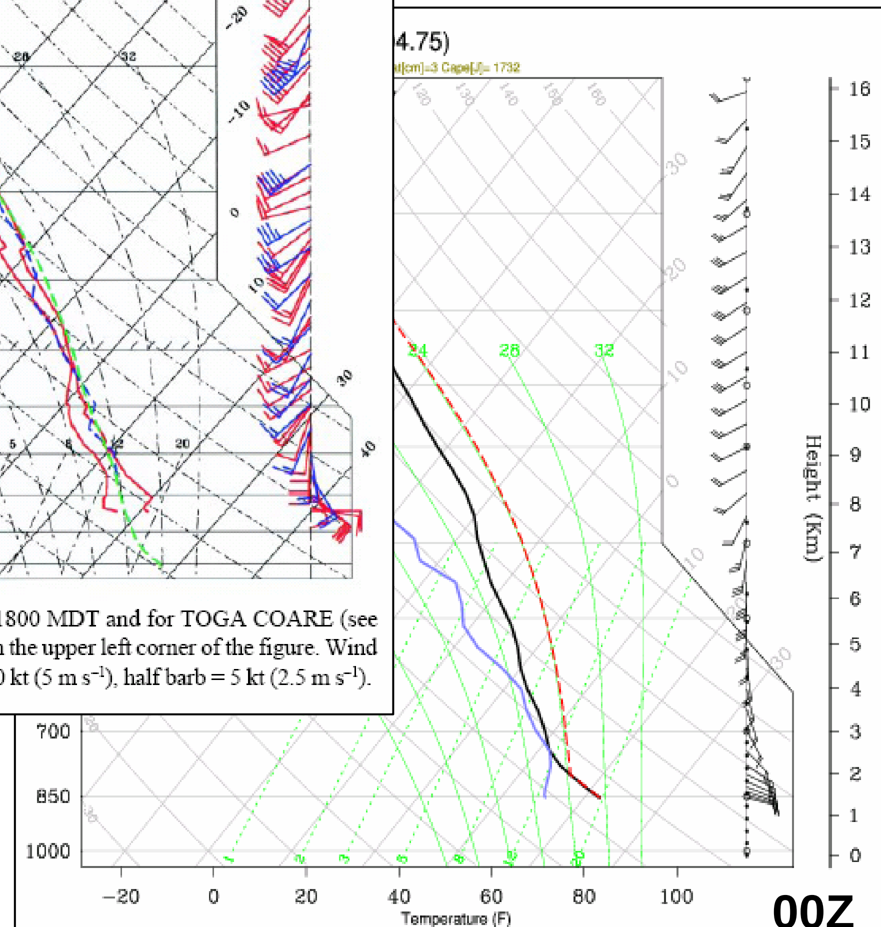


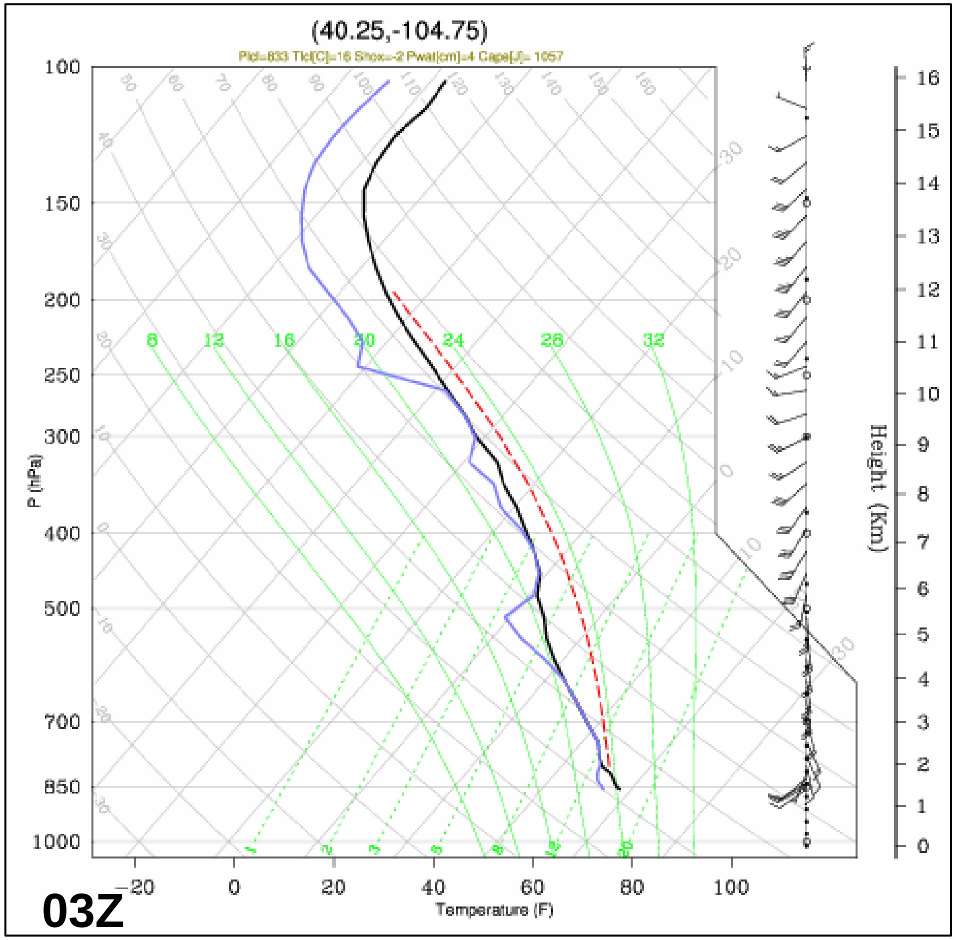
FIG. 6. Skew-*T* plot for Denver, CO, at 1800 MDT and for TOGA COARE (see text). The respective soundings are labeled in the upper left corner of the figure. Wind barbs are plotted in knots; full wind barb = 10 kt (5 m s^{-1}), half barb = 5 kt (2.5 m s^{-1}).



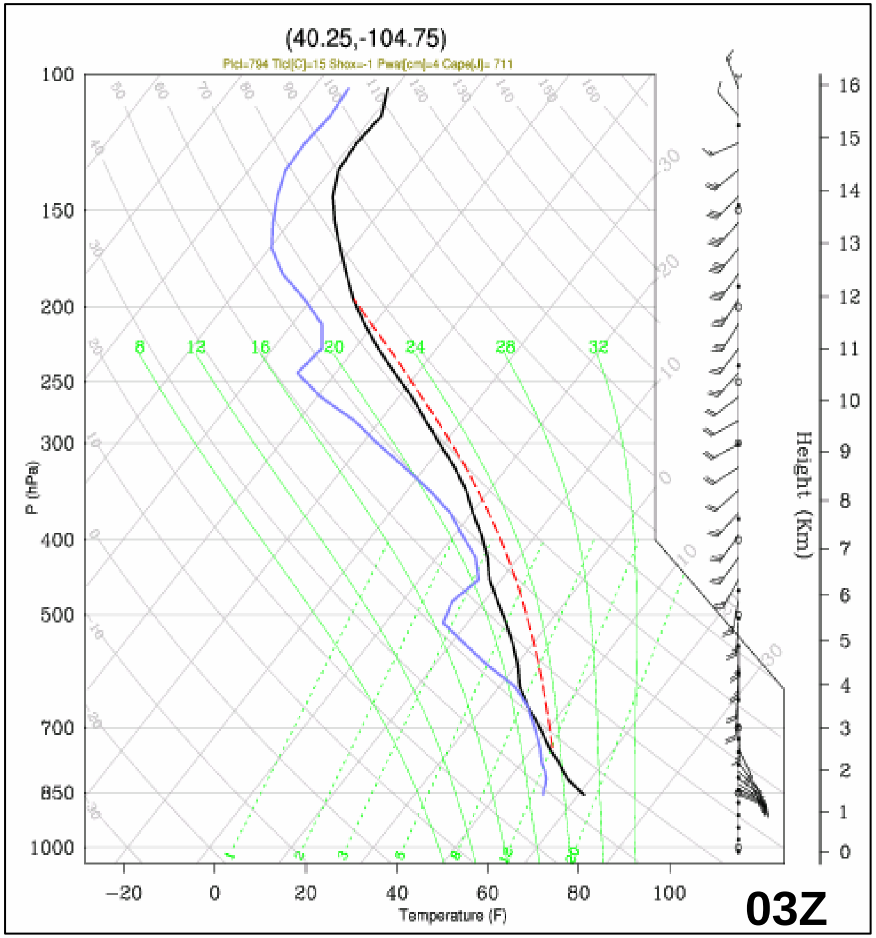
Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

1 km WRF-w/out routing:
Init. July 27 12z



1 km WRF-w/ routing:
Init. July 27 12z



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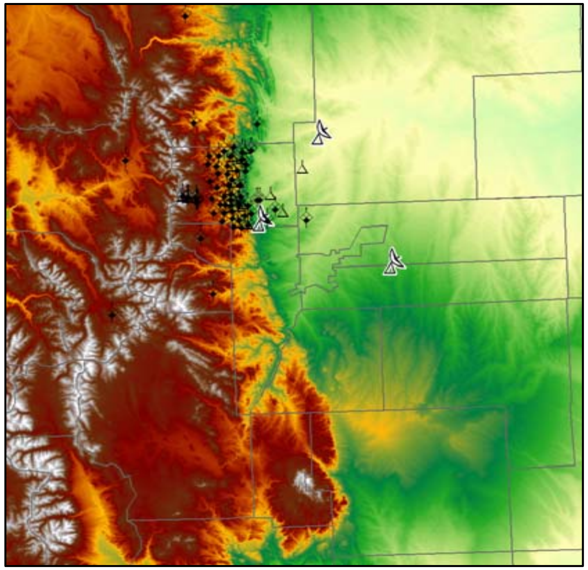
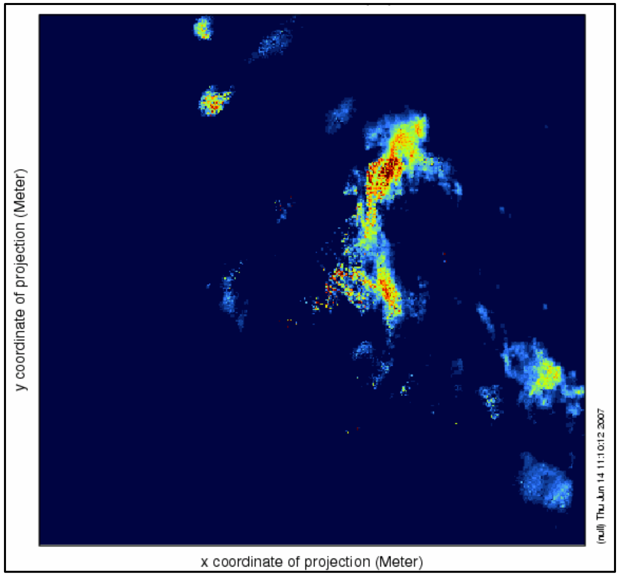
Hydrological Model Results

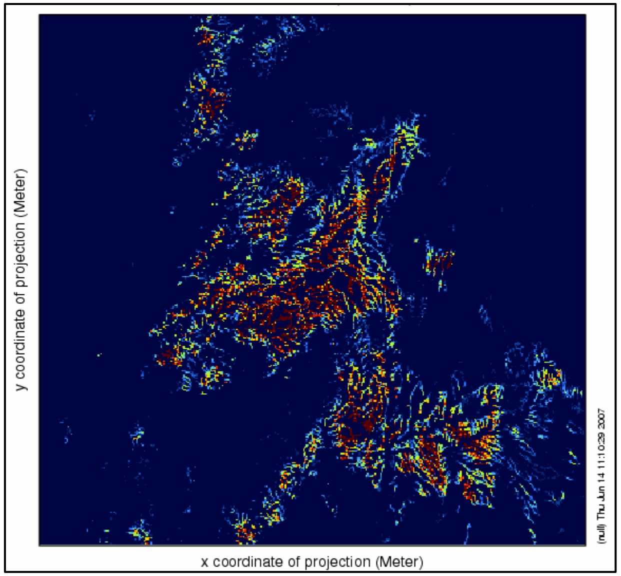
***1 km WRF-w routing:
Terrain Heights (m)***



***1 km WRF-w routing:
Init. July 15 0z - Top Layer
Surface water Depth (mm)***



***1 km WRF-w routing:
Init. July 15 0z -
Accum. Stream Inflow (mm)***



Concluding thoughts and future activities:

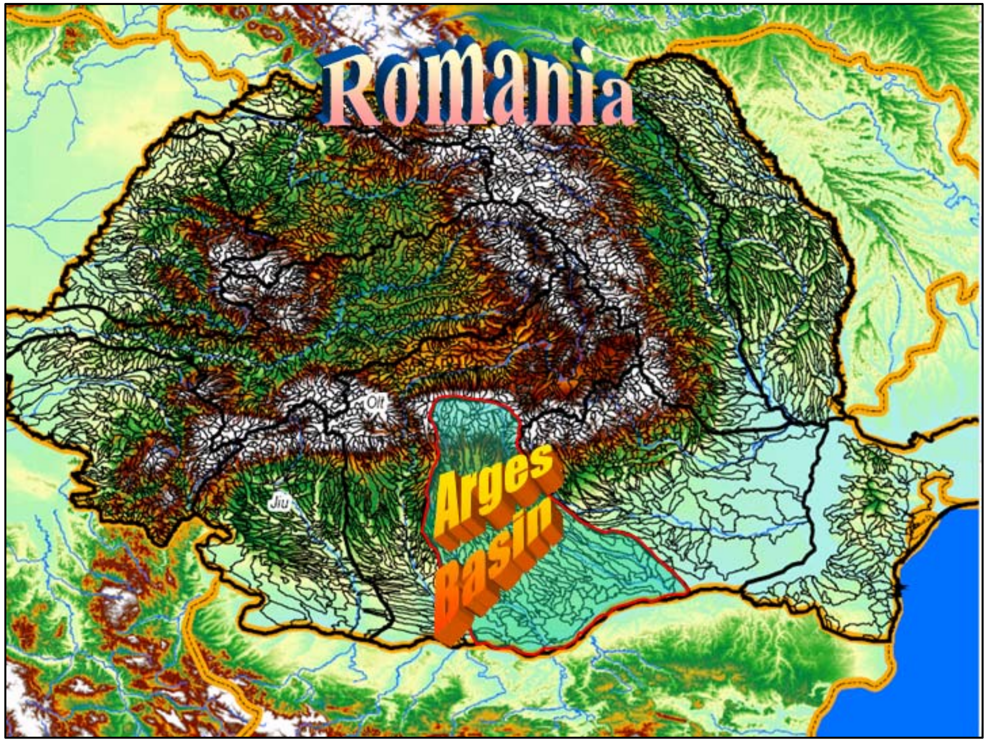
- Much work remains in analyzing the thermodynamic forcing of convection and precipitation in WRF runs:
  - Inclusion of routing component in Noah-WRF appears to have surprisingly significant effect Jul. 28-29 storm events
  - Early, intense, terrain convection in routing model case produces precipitation regime more like that observed over flooding domain
  - Significant interaction with propagating convection in the Denver area

- Need to complete control/spin-up runs for the hydrological model for Ft. Collins event:
  - Several unresolved issues related to estimation of precip. rates from Stage II radar data
  - Nowcast runs will follow directly
  - Stream/reservoir network over this large region needs to be completed for channel routing

The end: gochis@rap.ucar.edu

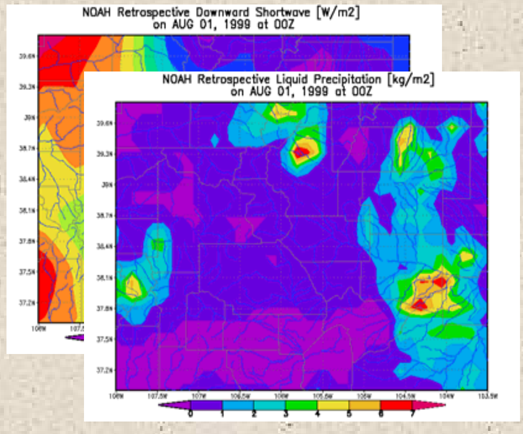
Romanian Operational Hydrological Modeling:

- DEStructive WATers Abatement Program
- World Bank funded project to support Romania's application to EU
- NCAR tasked to provide modeling support to Baron AMS and NASA-LIS team
- Implementation and real-time forecasts began Oct. 1, 2006



Framework for Hydrometeorological Prediction System Development

1. Obtain and Process Meteorological Forcing Data



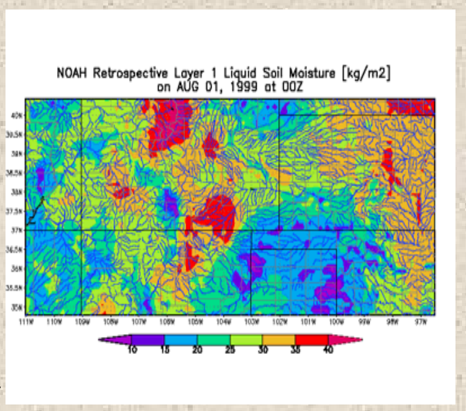
Observed Met. Forcing

Precipitation
Temperature
Humidity
Radiation
Wind
Pressure

2. Land Data Assimilation Cycling

Drive 'Offline' Land Surface Model NCAR-HRLDAS/ NASA-LIS

3. Weather and Climate Model Initialization



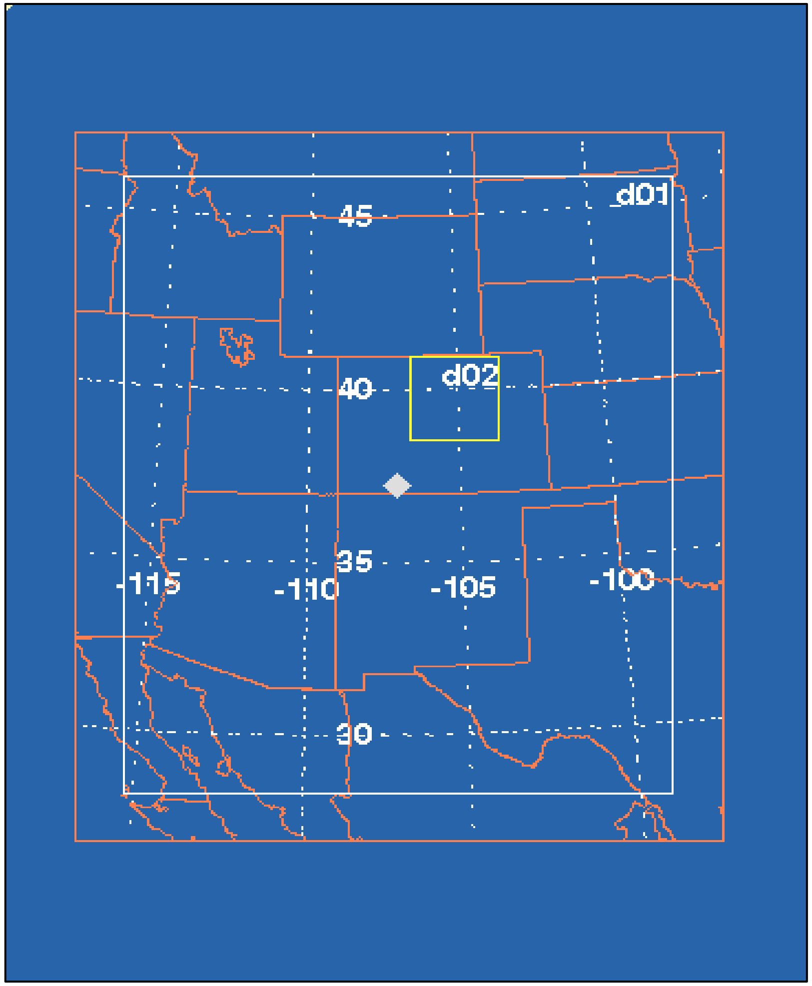
4. Generatation of Coupled Hydrometeorological Forecasts

5. Post-process data within Decision Support Systems

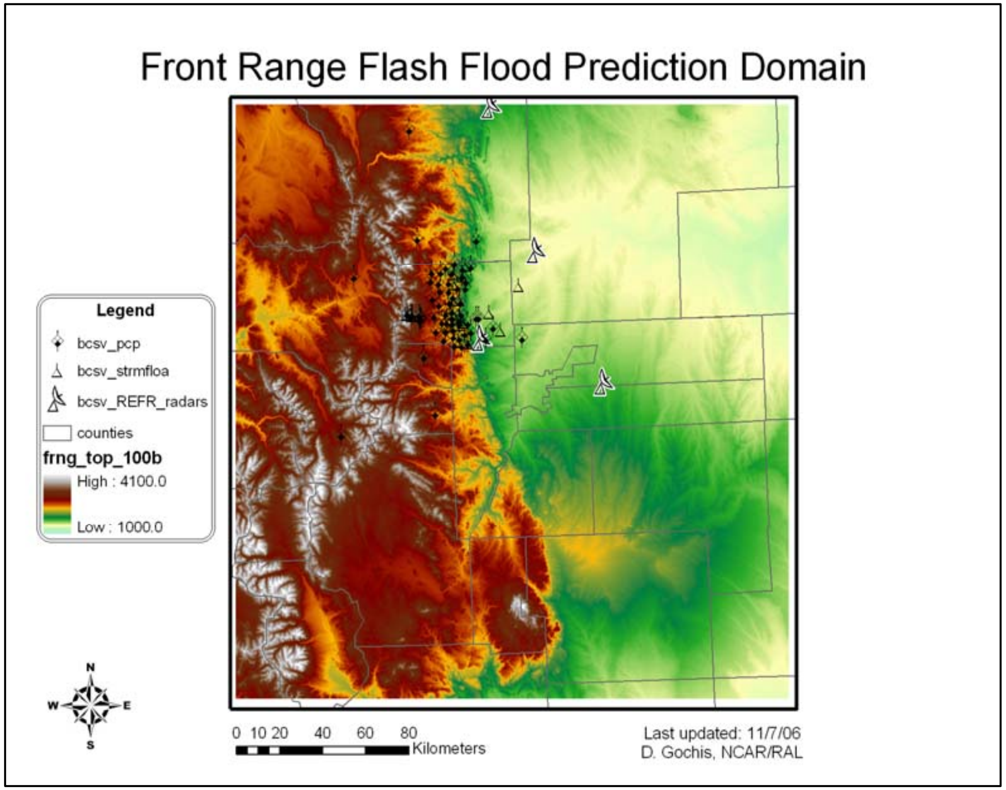
Emergency Management
Decision Support Systems

Coupled WRF-Hydro Flash Flood Forecasting in the Colorado Front Range:

4 km and 1 km WRF Domains



100m Topography on 1km Domain



USGS NHDPlus terrain

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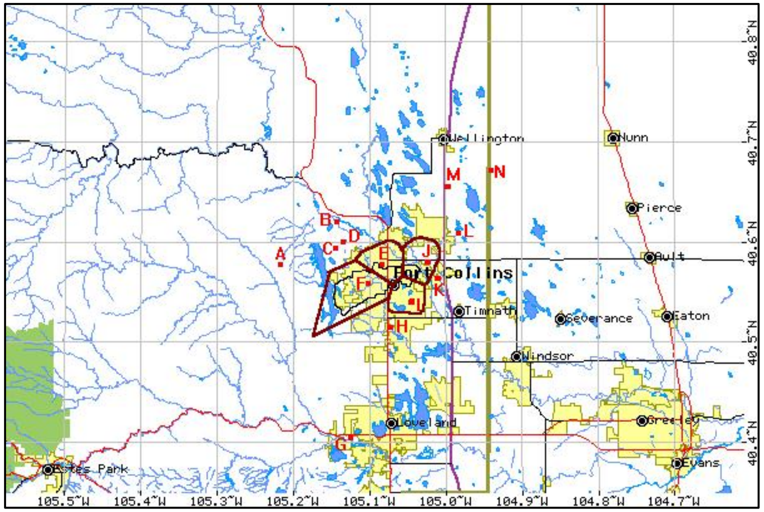
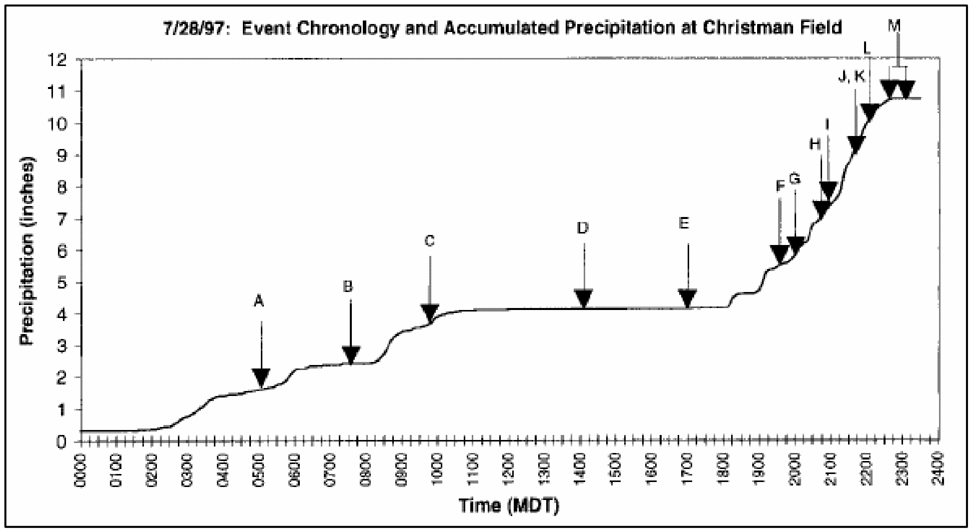
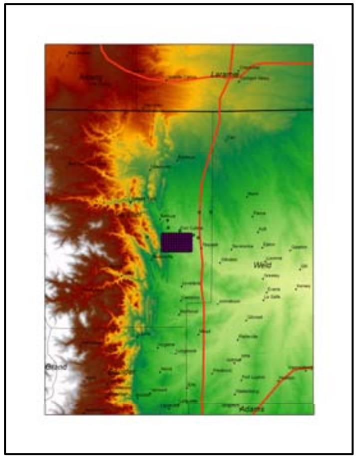
Case Study: 1997 Ft. Collins Flood Event

Ft. Collins rain gauge locations



Accumulated Precipitation

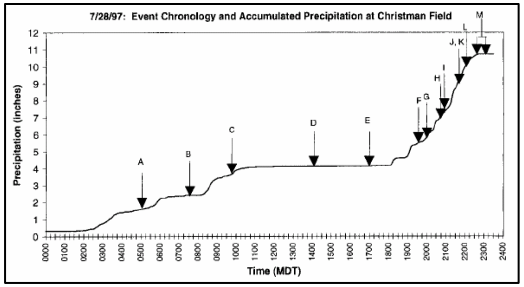




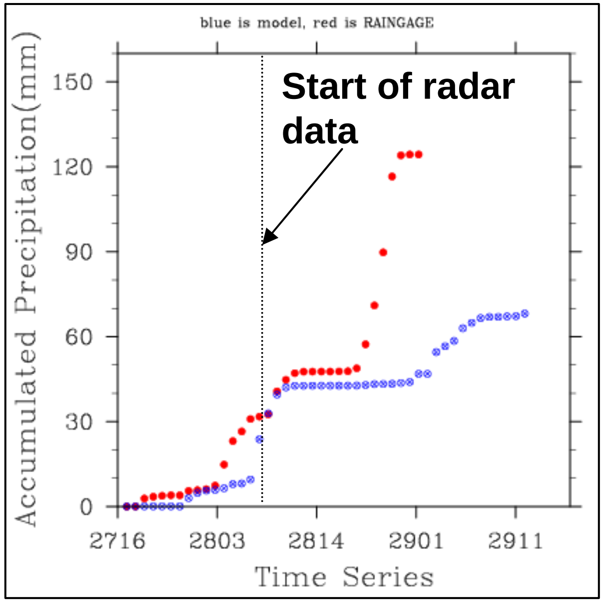
Spring Creek radar coverage

Case Study: 1997 Ft. Collins Flood Event

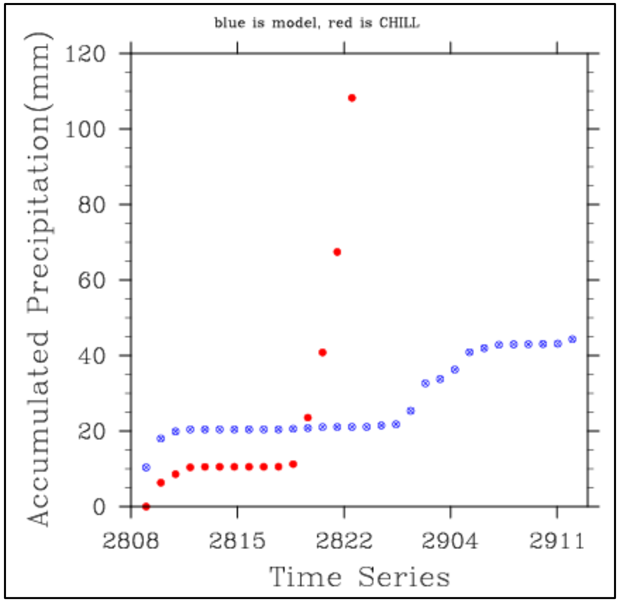
Accumulated Precipitation



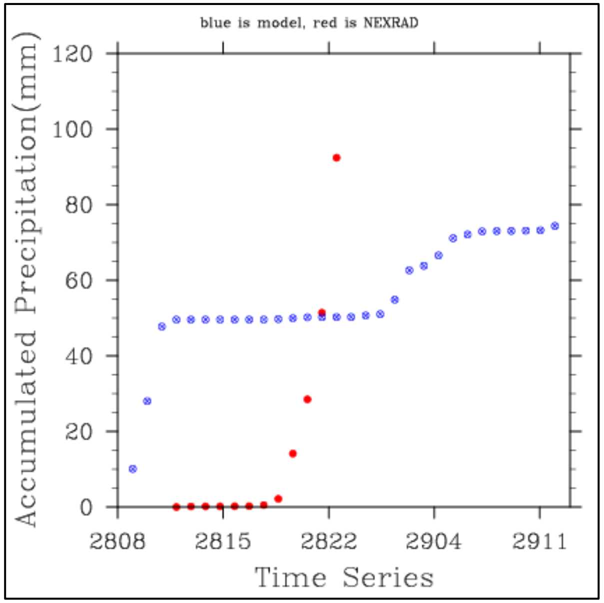
WRF vs. Rain Guages



WRF vs. CHILL



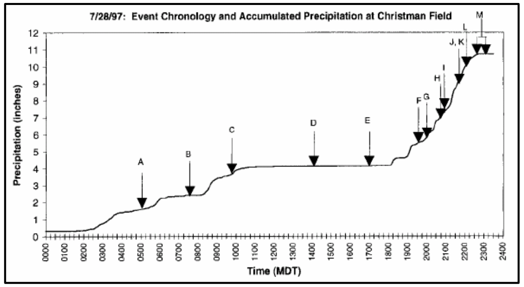
WRF vs. KCYS NEXRAD



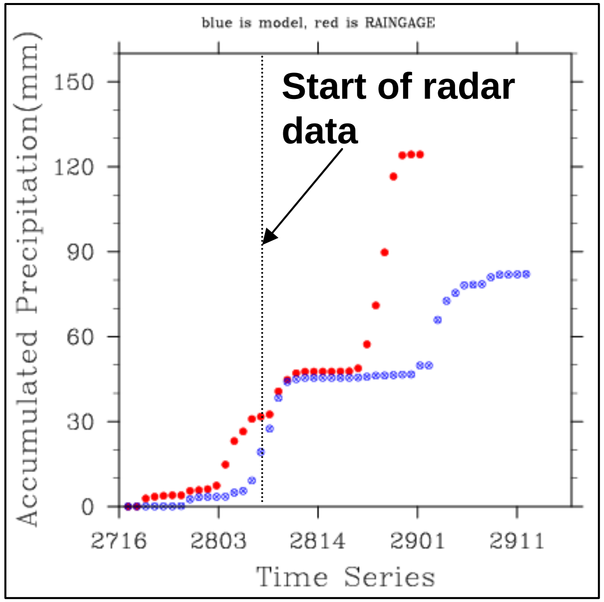
1 km WRF-no routing:
Init. July 27 12z

Case Study: 1997 Ft. Collins Flood Event

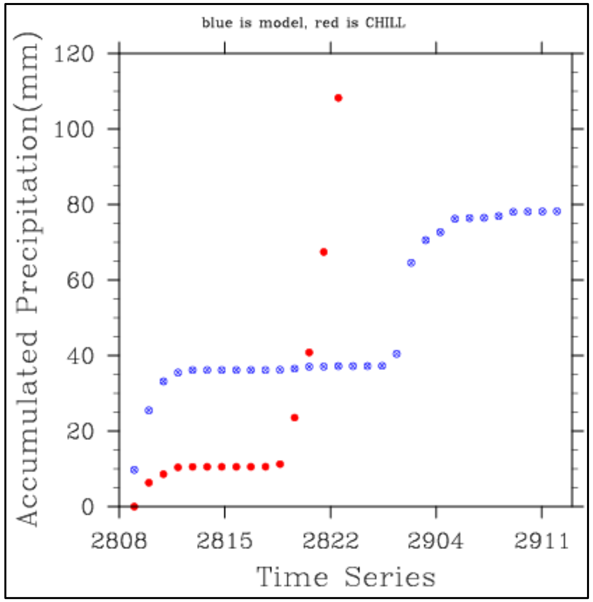
Accumulated Precipitation



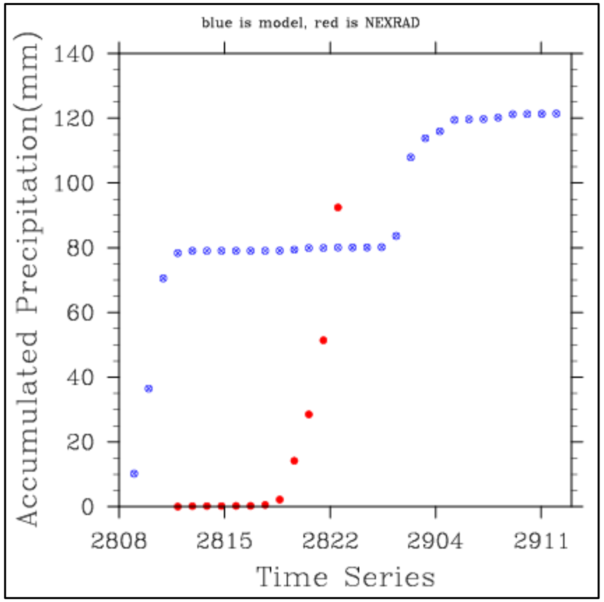
WRF vs. Rain Guages



WRF vs. CHILL



WRF vs. KCYS NEXRAD



1 km WRF-with routing:

Init. July 27 12z

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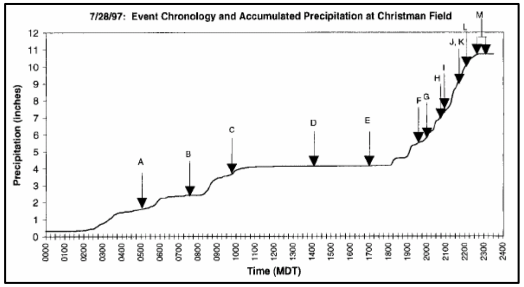
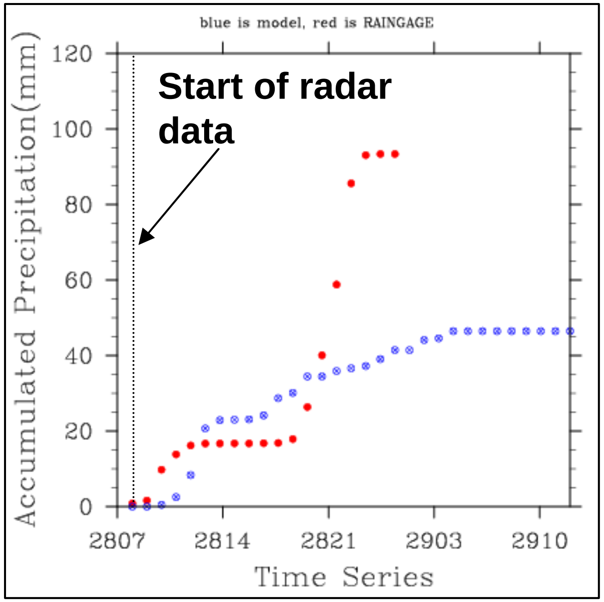
Case Study: 1997 Ft. Collins Flood Event

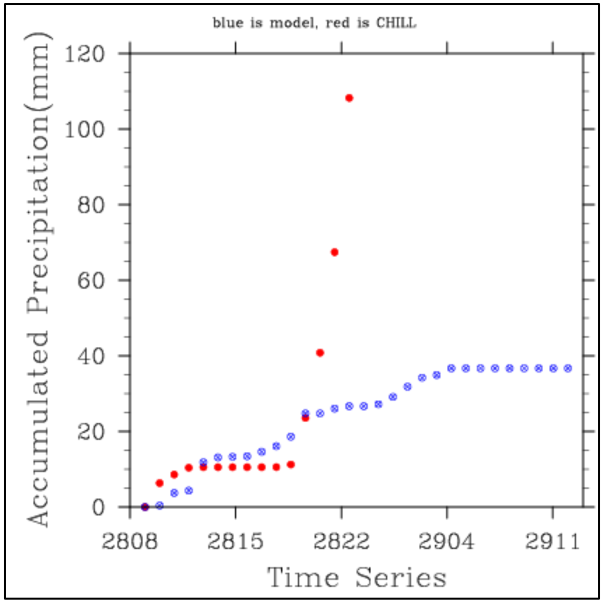
Accumulated Precipitation



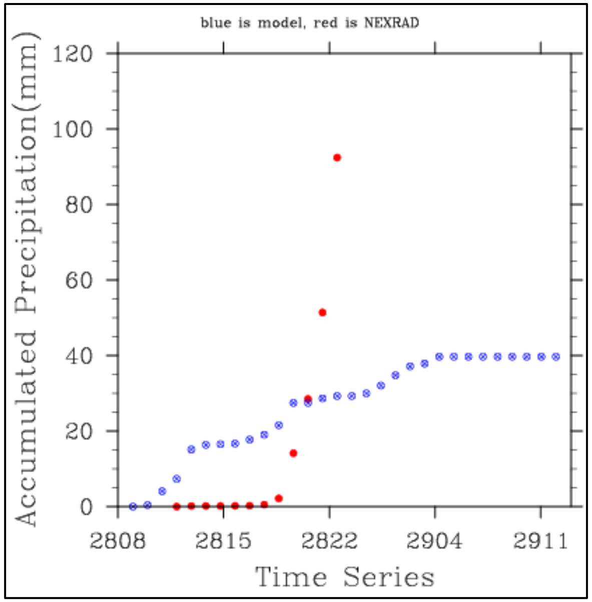
WRF vs. Rain Guages



WRF vs. CHILL



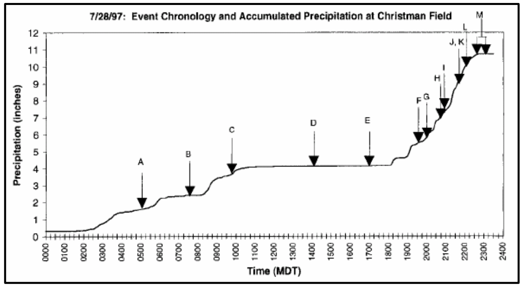
WRF vs. KCYS NEXRAD



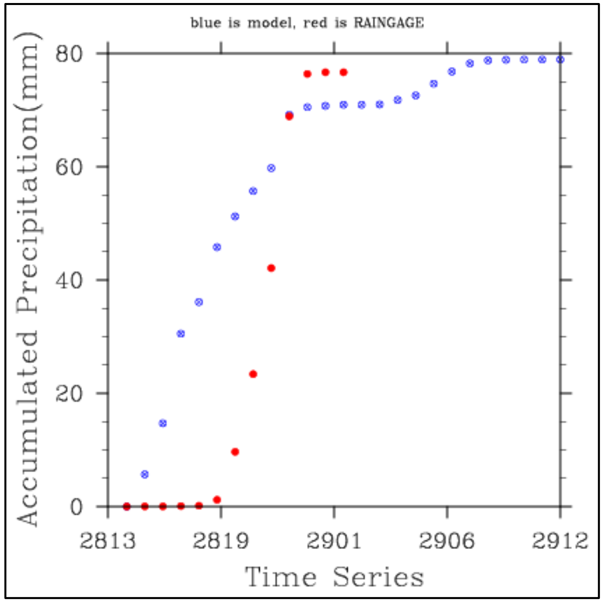
1 km WRF-no routing:
Init. July 28 06z

Case Study: 1997 Ft. Collins Flood Event

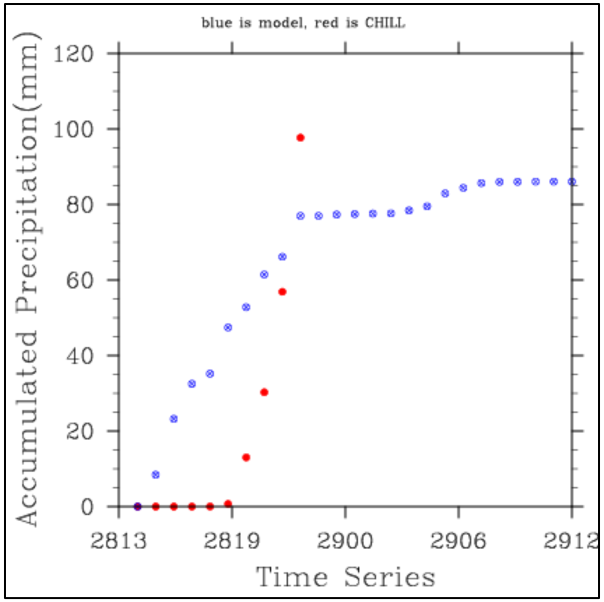
Accumulated Precipitation



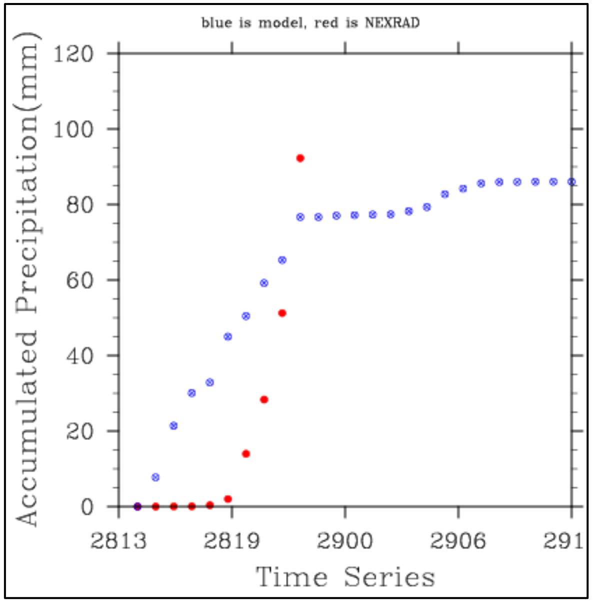
WRF vs. Rain Guages



WRF vs. CHILL



WRF vs. KCYS NEXRAD



1 km WRF-no routing:
Init. July 28 12z

Gochis et al., 8th Annual WRF User's Workshop, June 14, 2007

Case Study: 1997 Ft. Collins Flood Event Mesoscale Analysis

Observed Analysis

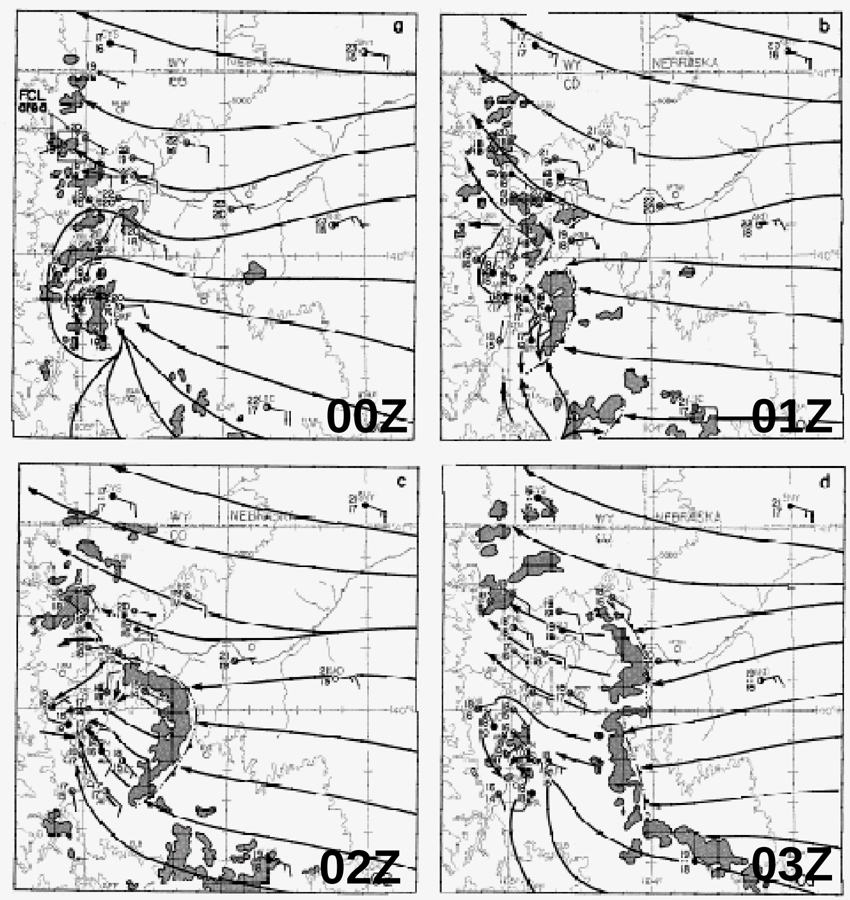
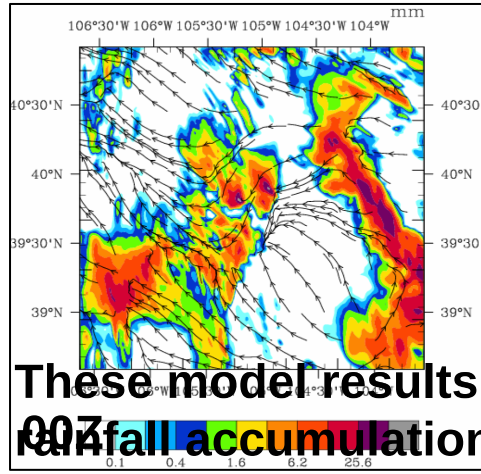
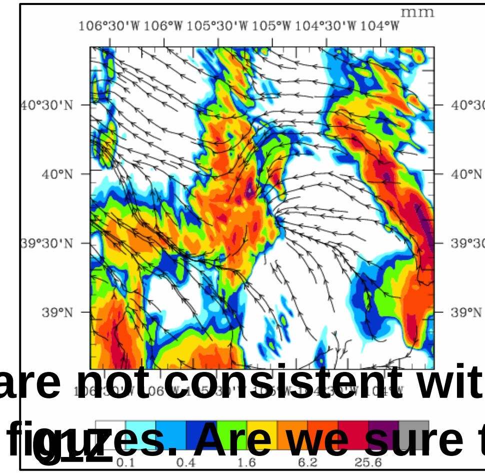


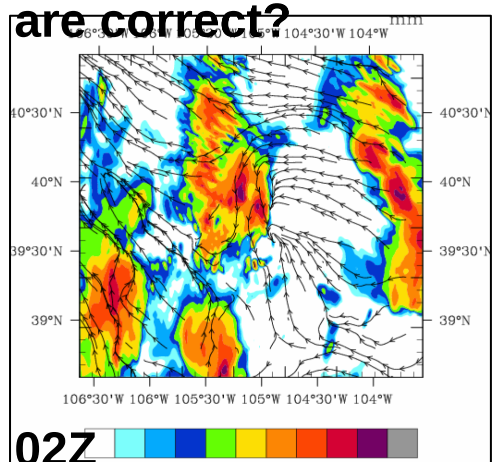
FIG. 7. Hourly mesoscale analyses for 1800–2100 MDT 28 July 1997 (0000–0300 UTC 29 July 1997). Surface streamlines are in solid arrows. Wind barbs plotted as in Fig. 6; temperature and dewpoints in °C. Mesoscale boundaries are indicated as in Fig. 5. Regions of radar reflectivity ≥ 35 dBZ are shaded: (a) 1800 (0000), (b) 1900 (0100), (c) 2000 (0200), and (d) 2100 MDT (0300 UTC).

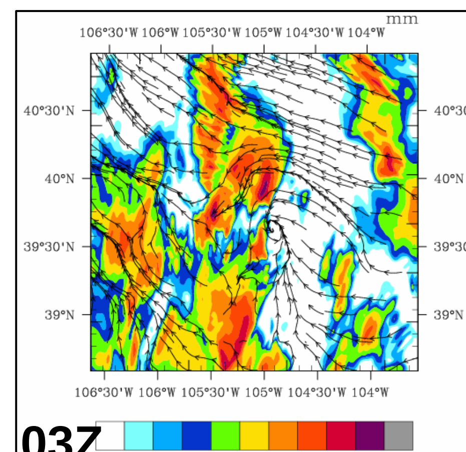
1 km WRF-no routing: Init. July 28 12z





These model results are not consistent with rainfall accumulation figures. Are we sure th are correct?

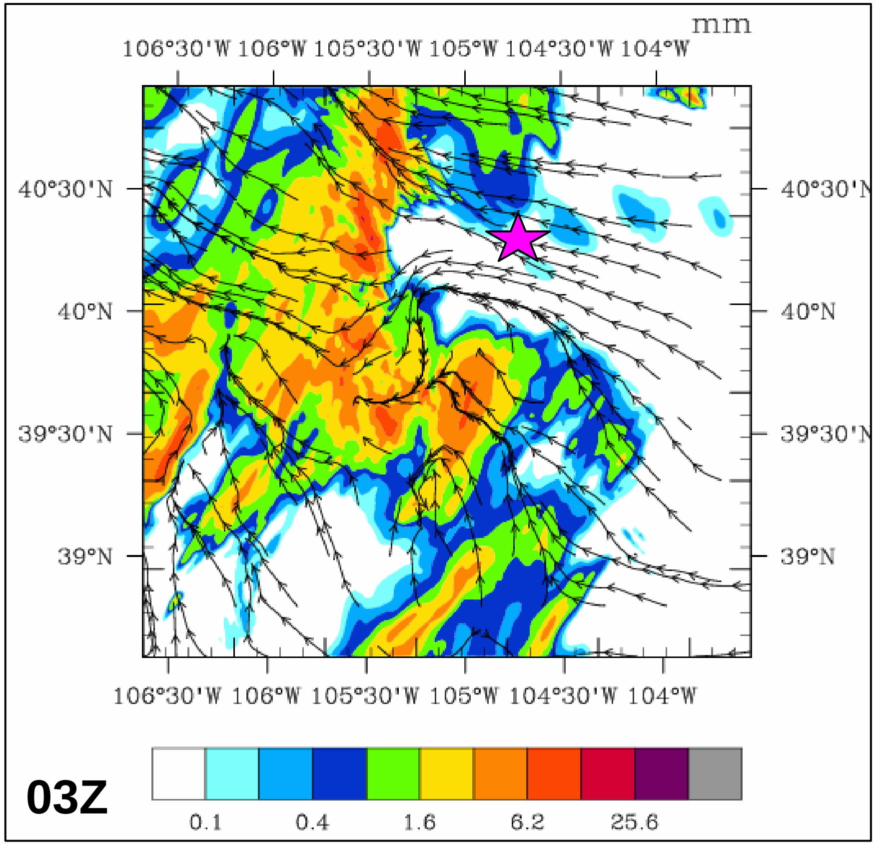




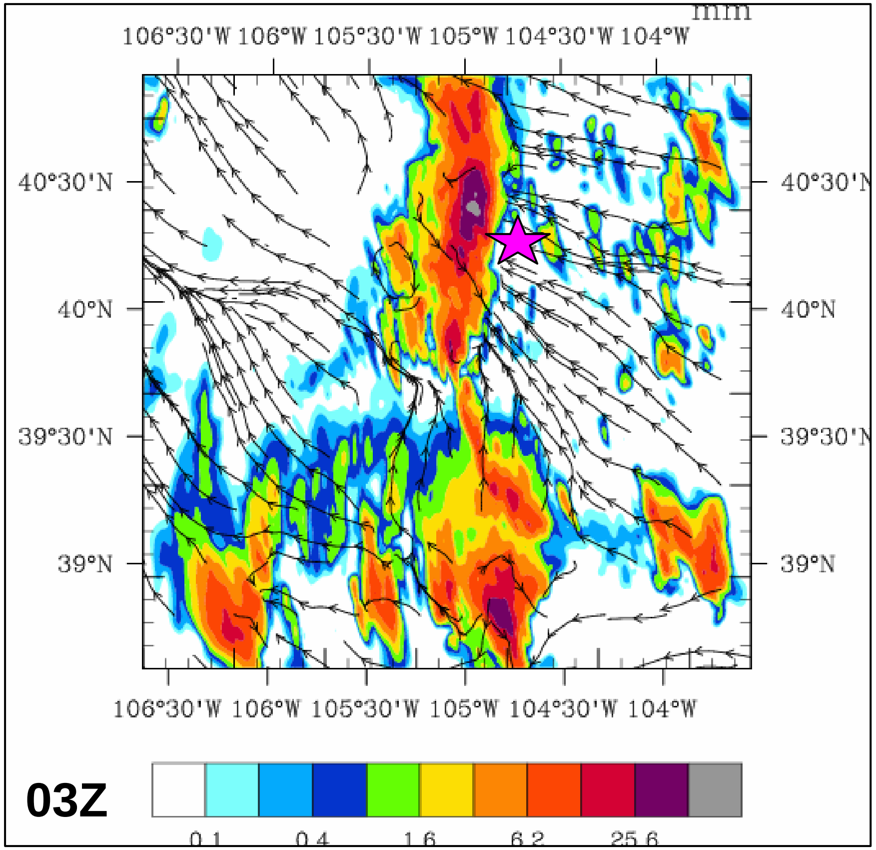
Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

1 km WRF-w/out routing:
Init. July 27 12z



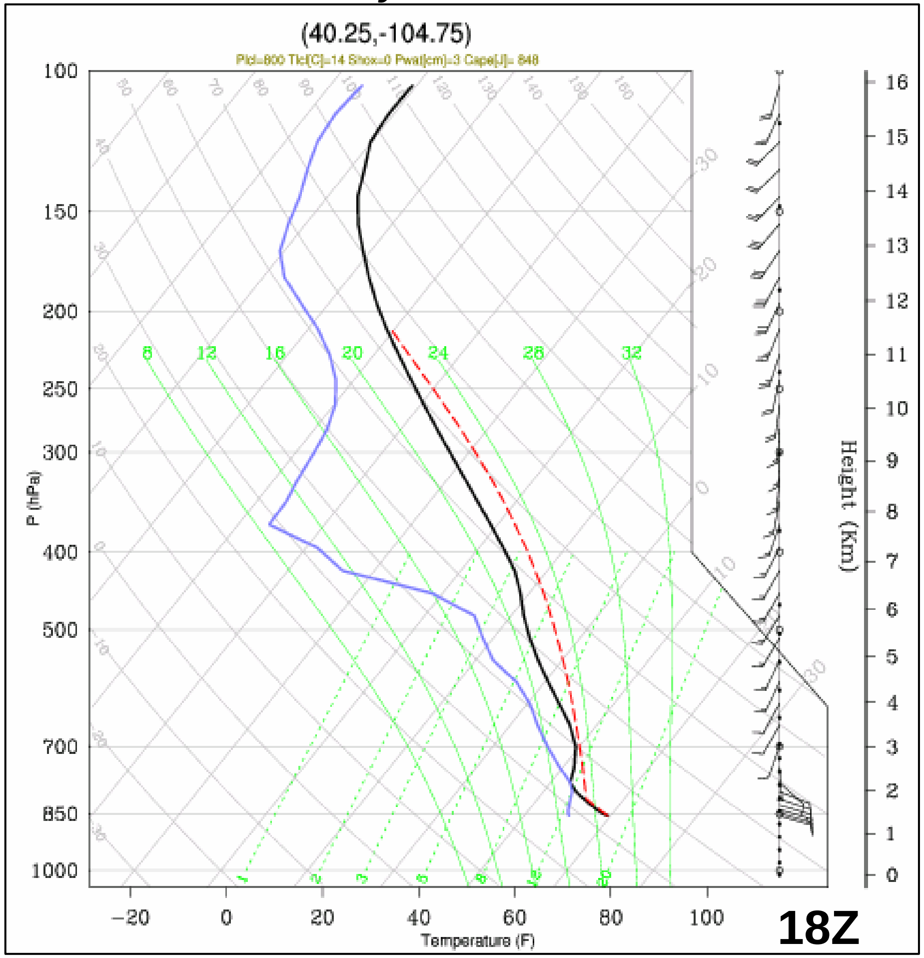
1 km WRF-w/ routing:
Init. July 27 12z



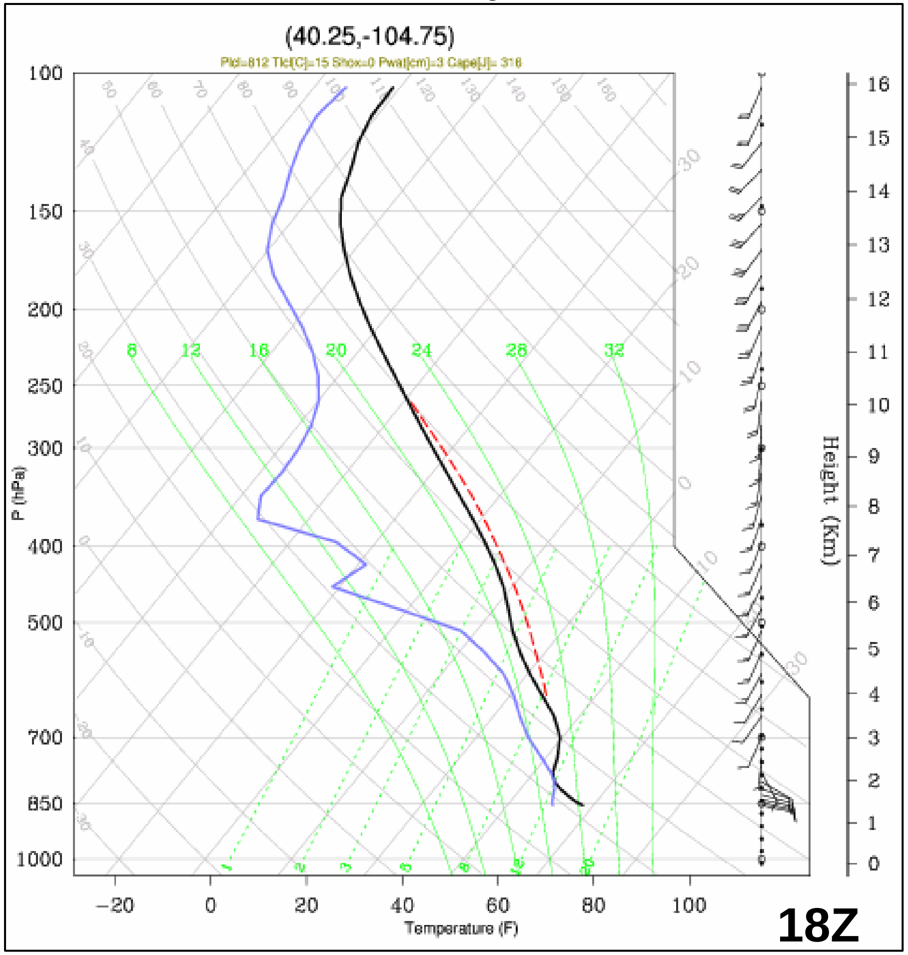
Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

1 km WRF-w/out routing:
Init. July 27 12z



1 km WRF-w/ routing:
Init. July 27 12z



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Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

1 km WRF-w/out routing:
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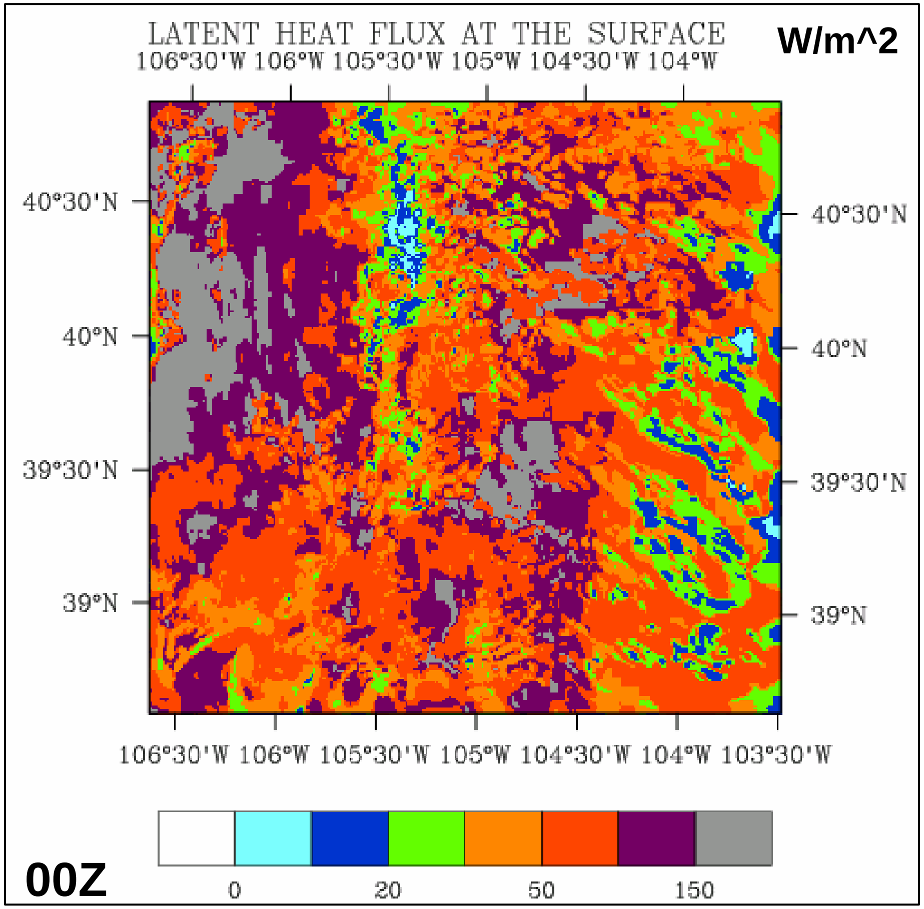
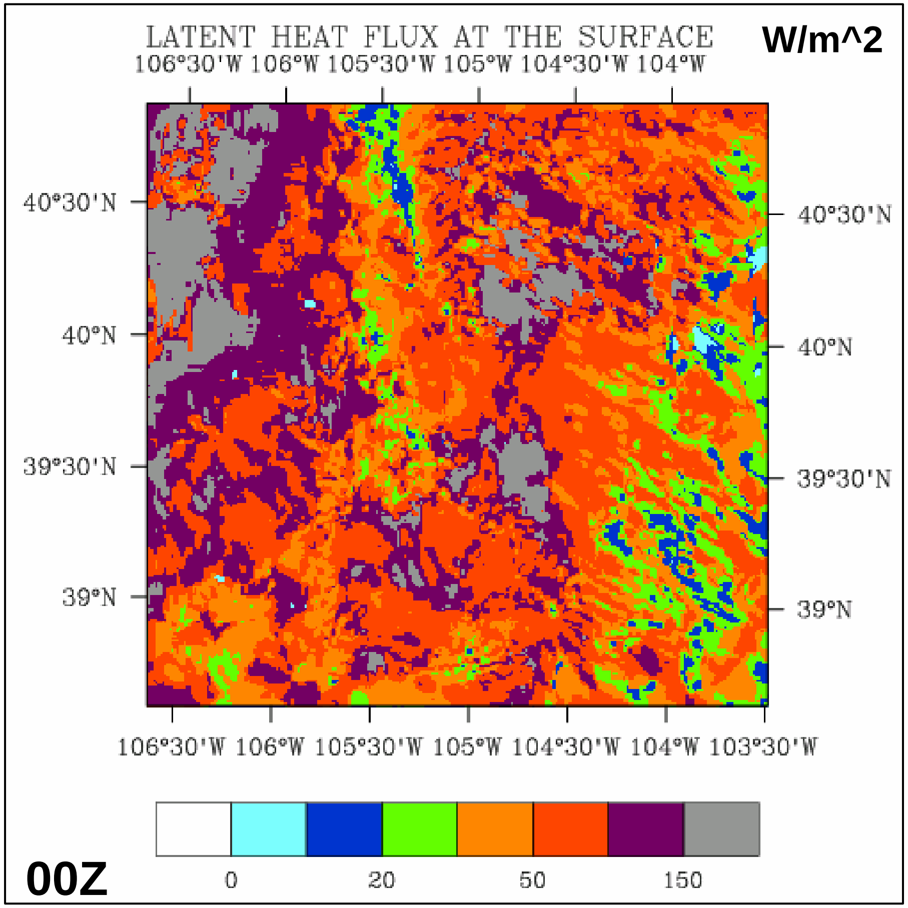


1 km WRF-w/ routing:
Init. July 27 12z



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Case Study: 1997 Ft. Collins Flood Event

Mesoscale Analysis

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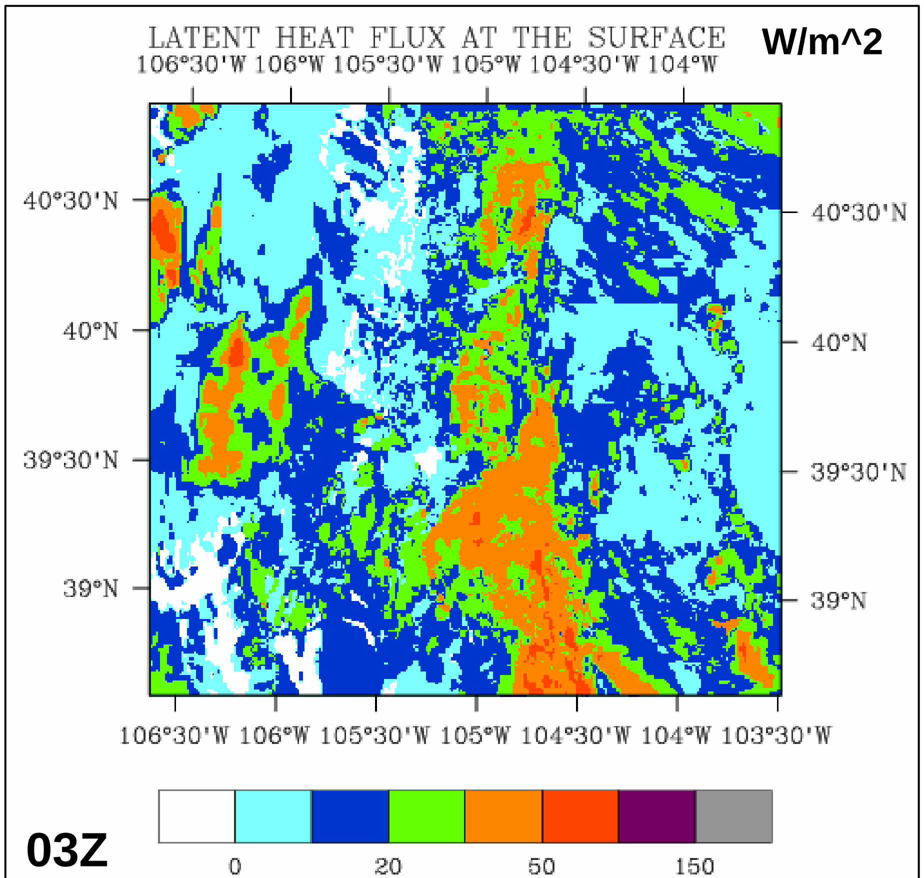
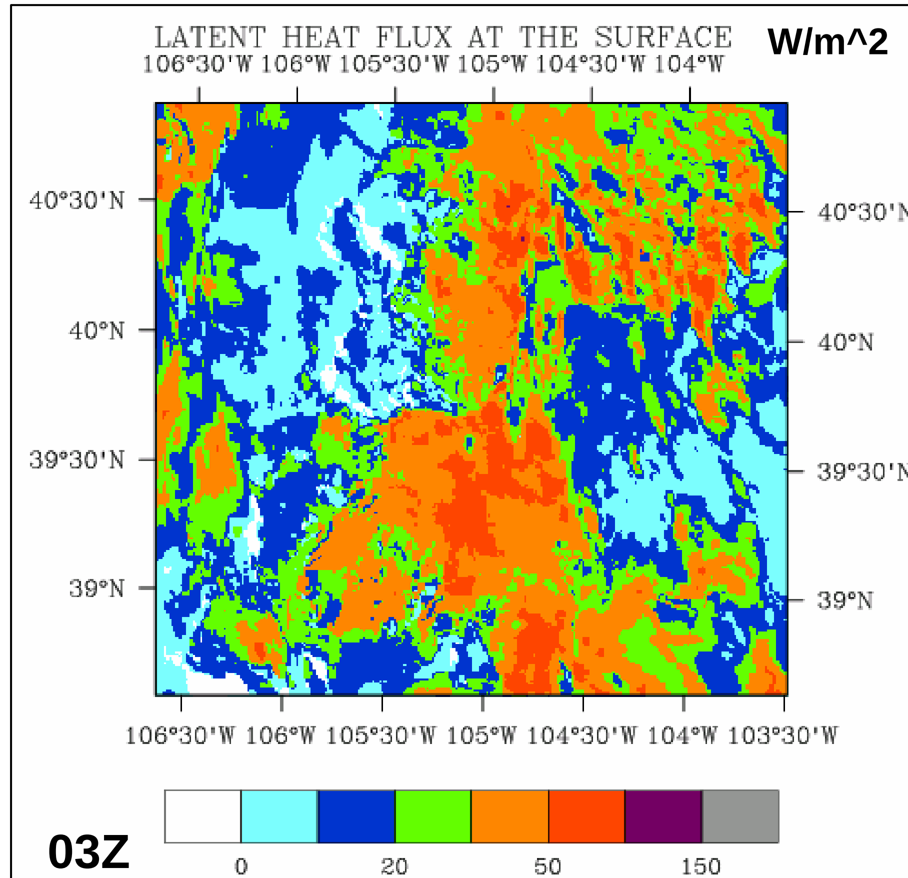


1 km WRF-w/ routing:
Init. July 27 12z



Gochis et al., 8th Annual WRF User's Workshop, June 14, 2007

Concluding thoughts and future activities:

- Need to complete control/spin-up runs for the hydrological model for Ft. Collins event:
  - David Yates is working on radar derived precip using MDV, working through some projection issues
  - Several unresolved issues related to estimation of precip. rates from Stage III radar data
  - Nowcast runs will follow directly
  - Stream/reservior network over this large region needs to be completed
- Much work remains in analyzing the thermodynamic forcing of convection and precipitation in WRF runs:
  - Inclusion of routing component in Noah-WRF appears to have significant effect on low-level circulation and precipitation. Need to determine exactly why.
- Continued benchmarking and case studies of coupled system to proceed this summer
  - Will likely look at May 29th 2007 event which resulted in widespread street flooding in Denver
  - Need to determine computational needs for operational work to initiate during Spring of 2008