WRF-Hydro: A hydrological modeling extension package and version 2 updates (WRF-Hydro 2.0.1)

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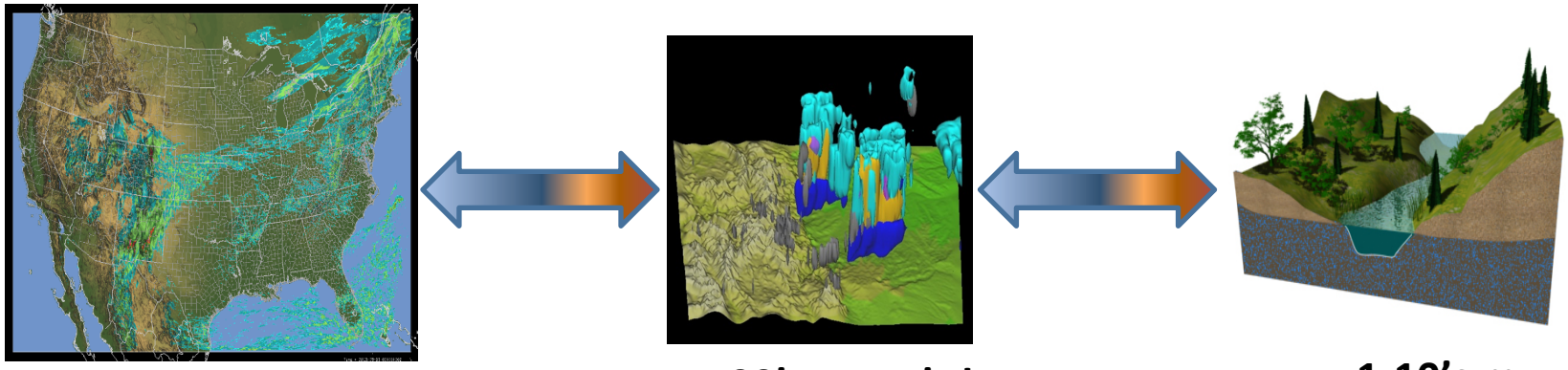
National Center for Atmospheric Research

Outline

- Description of WRF-Hydro
  - Hydrological process of WRF-Hydro
  - WRF-Hydro system features
  - Software features
- Prediction Application
  - Flash flooding forecast capability
- Recent and ongoing enhancement

Motivation for WRF-Hydro:

- Scientific Needs:
  - Based on community support requests it was evident that there was a need integrated modeling capabilities for conservative prediction for complete predictions of the water cycle…climate impacts
  - Need multi-scale framework…bridge atmosphere-hydro application scales….



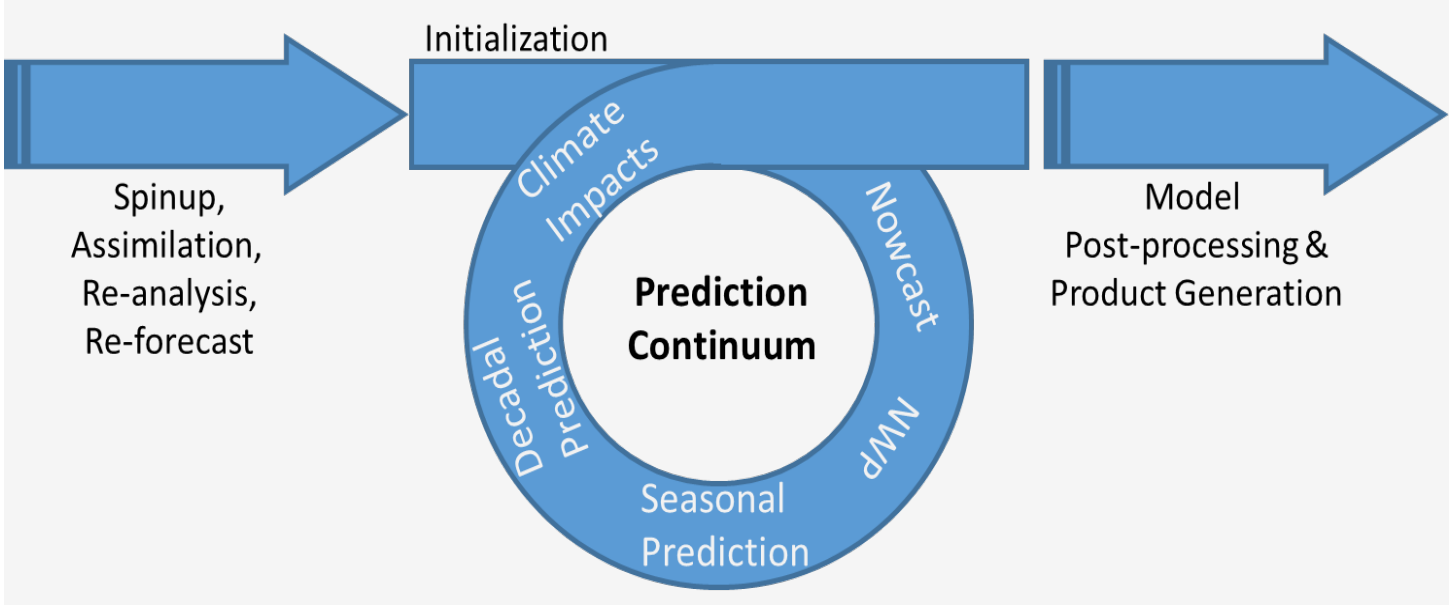
1-10's km

100's m - 1's km

1-10's m

Motivation for WRF-Hydro:

- Prediction System Needs:
  - Need rapid pathway to operational deployment… Seamless hydrometeorological modeling tools for continuum prediction:

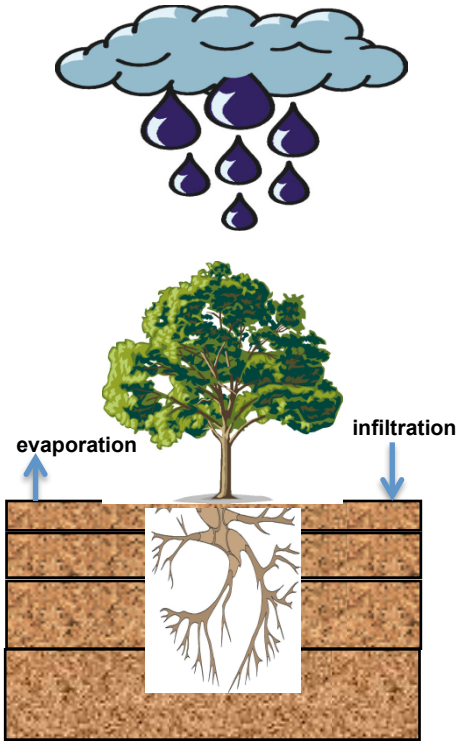


  - Linkage to ensemble forecasting methodologies…
  - Utilization of HPC (on both local and distributed/cloud architectures…)

WRF- Hydro Description

Snow melting

Single Column

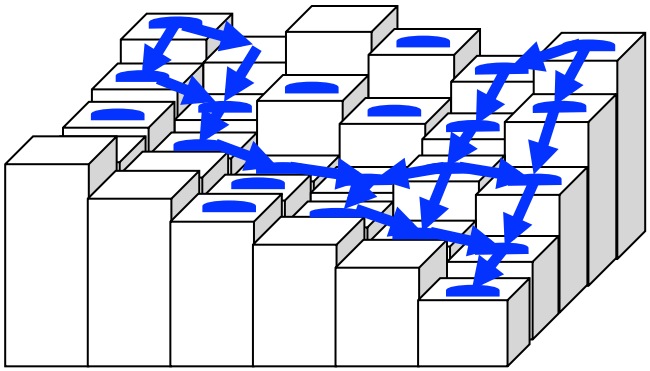


1-D Land Surface Models (e.g. 'Noah')

Run off

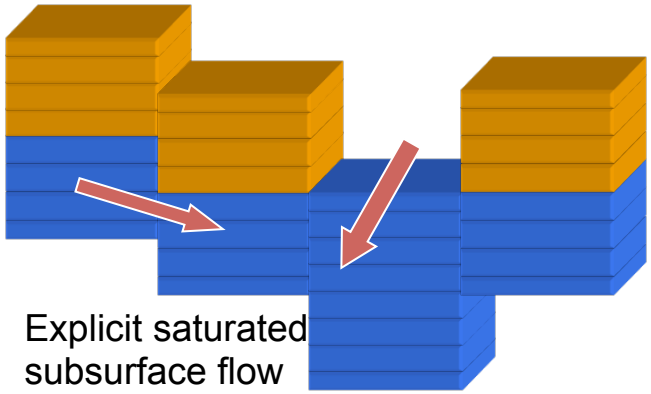
Land Surface Routing

Explicit diffusive wave overland flow



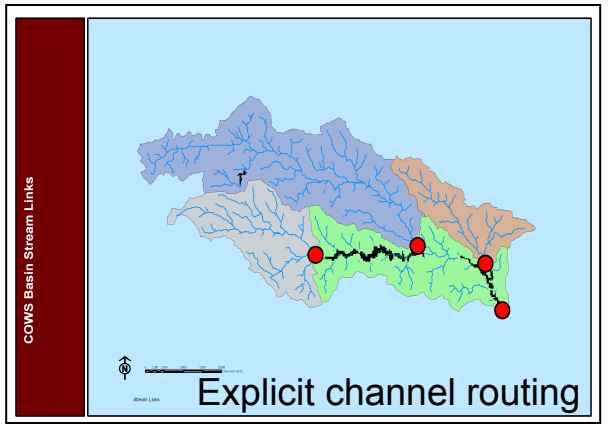
Base flow

Subsurface Routing



Explicit saturated subsurface flow

Channel Routing



Three major components for river forecasting :
Snow melting, base flow and run off

WRF-Hydro System: General Attributes

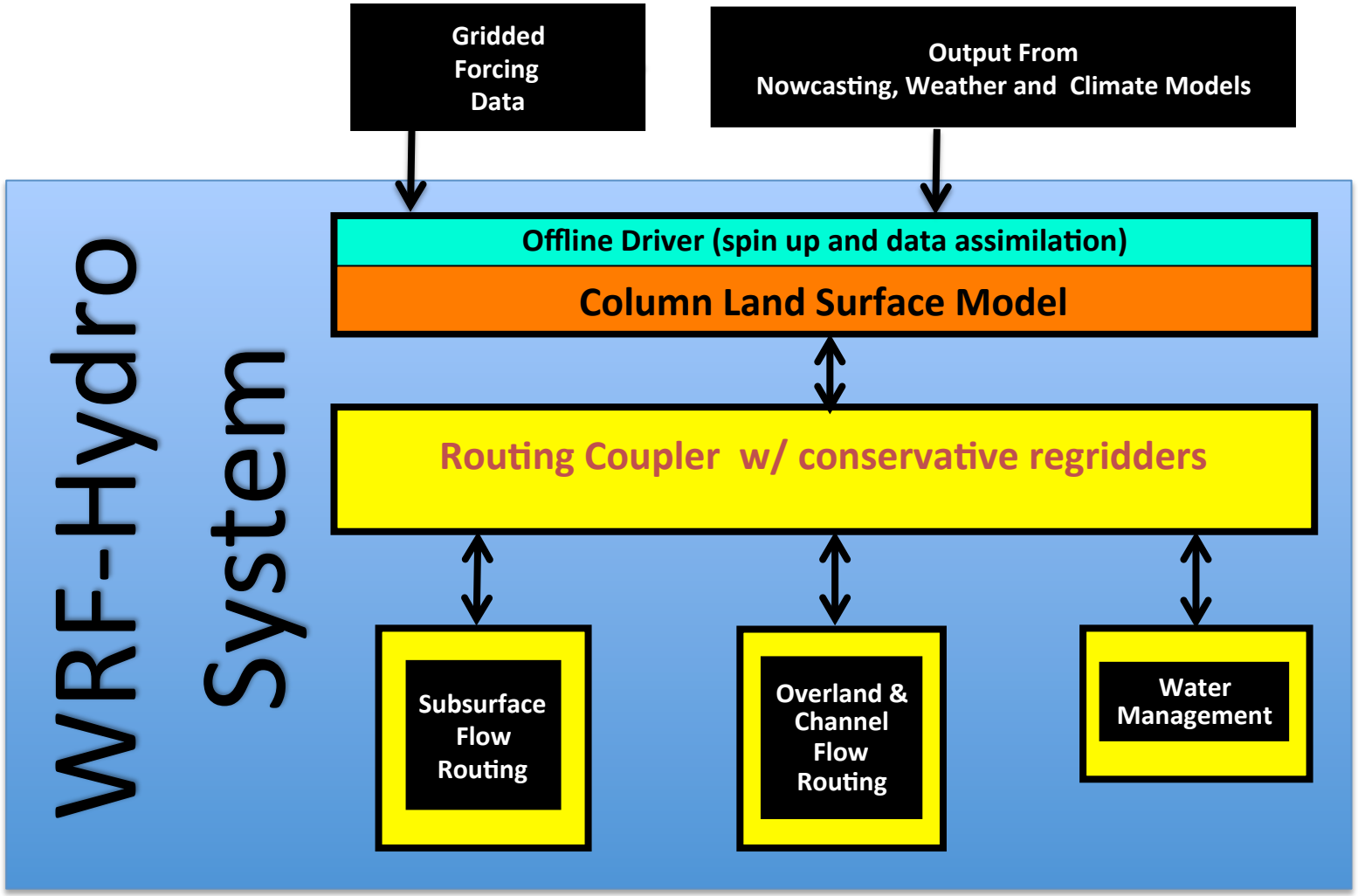
- Runs coupled or uncoupled to WRF
- Open source, community-contributed code
- Readily extensible for multiple physics options
- Multi-scale/multi-resolution
- Supported, documented, multiple test-cases
- Portable/scalable across multiple computing platforms
- Standards based I/O
- Pre-/Post-processing Support
  - ArcGIS pre-processing tool

System Function Overview

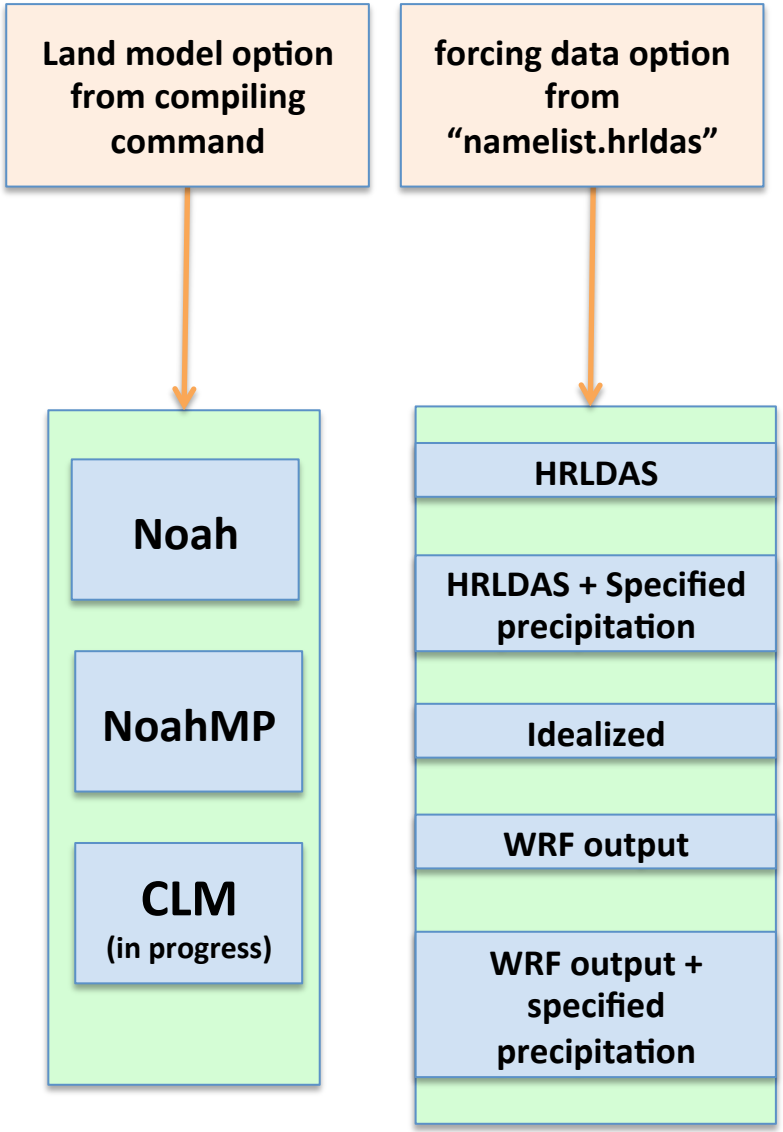
- WRF-Hydro offline
  - Noah and NoahMP two drivers
    - spin-up (data assimilation)
    - Forecasting
- WRF-Hydro fully coupled system
  - WRF model
    - with Land model option **Noah** and **NoahMP**
- Work in progress
  - LIS and CESM
  - Hydrologic data assimilation with DART and GSI

Conceptualization of WRF-Hydro Off-line

- Multi-scale/Multi-physics modeling…



WRF-Hydro Offline Physical Process Options



Namelist.hrldas

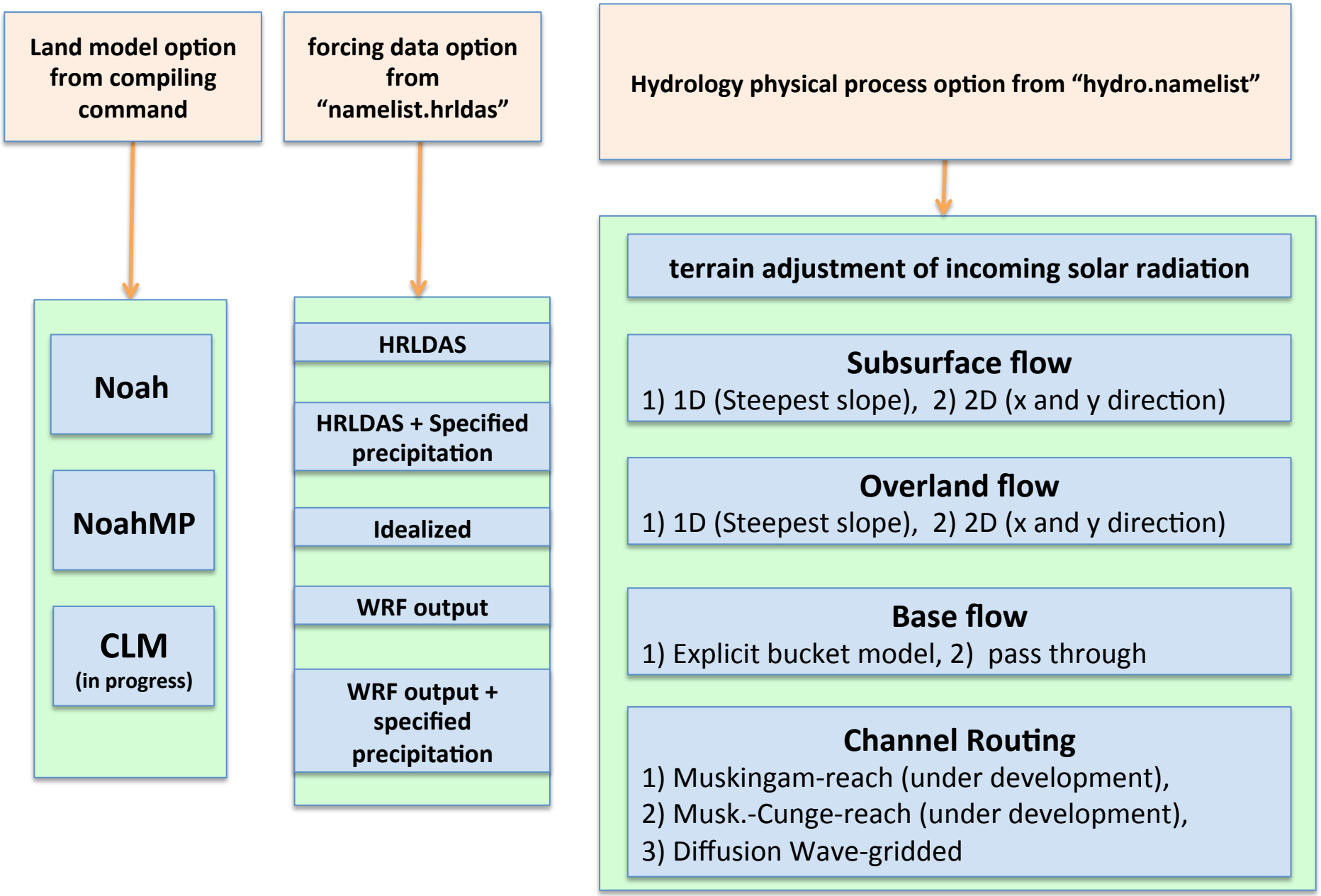
INDIR = '/d2/weiyu/wrf_release/EXE/wrf_run_noah/thomson_org'

FORCING_TIMESTEP = 3600

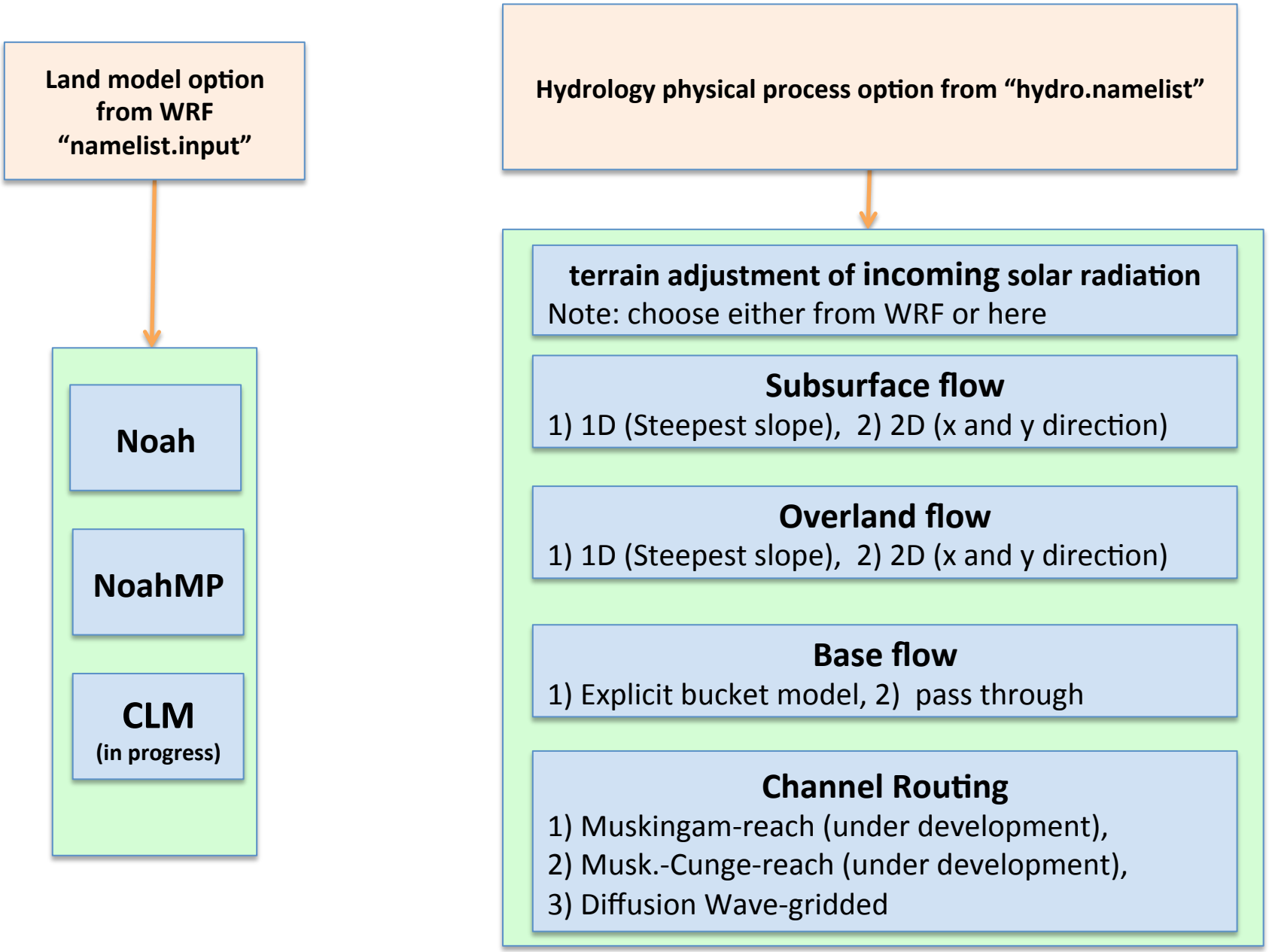
!Specification of forcing data: 1=HRLDAS-hr format, 2=HRLDAS-min format, 3=WRF, 4=Idealized, 5=Ideal w/ Spec.Precip., 6=HRLDAS-hrly format w/ Spec. Precip, 7=WRF w/Spec. Precip

FORC_TYP = 3

WRF-Hydro Offline Physical Process Options



WRF-Hydro Fully Coupled Physical Process Options



Hydro.namelist

```
!!!! SYSTEM COUPLING !!!!
!Specify what is being coupled:  1=HRLDAS (offline Noah-LSM), 2=WRF, 3=NASA/LIS, 4=CLM
 sys_cpl = 1

!!!! MODEL INPUT DATA FILES !!!
!Specify land surface model gridded input data file...(e.g.: "geo_em.d03.nc")
 GEO_STATIC_FLNM = "DOMAIN/geo_em.d03.nc"

!Specify the high-resolution routing terrain input data file...(e.g.: "Fulldom_hires_hydrofile.nc"
 GEO_FINEGRID_FLNM = "DOMAIN/Fulldom_hires_hydrofile_ohd_new_basns_w_cal_params_full_domain.nc"

!Specify the name of the restart file if starting from restart...comment out with '!' if not...
! RESTART_FILE  = 'HYDRO_RST.2012-07-21_12:00_DOMAIN2'

!!!! MODEL SETUP AND I/O CONTROL !!!!
!Specify the domain or nest number identifier...(integer)
 IGRID = 3

!Specify the restart file write frequency...(minutes)
 !rst_dt = 360
 rst_dt = 30

!Specify the output file write frequency...(minutes)
 out_dt = 15 ! minutes

!Specify if output history files are to be written...(.TRUE. or .FALSE.)
 HISTORY_OUTPUT = .TRUE.

!Groundwater/baseflow mask specified on land surface model grid...
!Note: Only required if baseflow bucket model is active
 gwbasmskfil = "DOMAIN/basn_msk1k_frng_ohd.txt"
```

Coupling

```
hydro% ls -1 CPL/
CLM_cpl/
LIS_cpl/
NoahMP_cpl/
Noah_cpl/
WRF_cpl/

hydro% ls -1 WRF_cpl/
Makefile
Makefile.cpl
module_wrf_HYDRO.F
wrf_drv_HYDRO.F
```

Data Grids

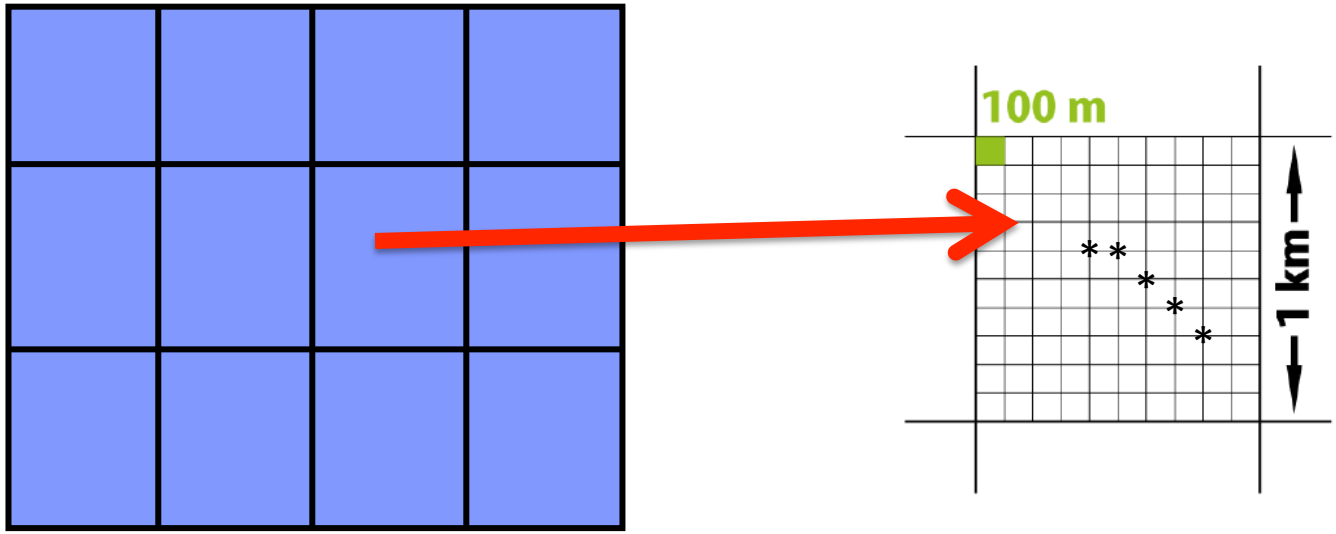
- Three Types of Data Grids

  Land Grids: (ix, jx), (ix, jx, n_soil_layer)

  Land Routing: (ixrt, jxrt), (ixrt, jxrt, n_soil_layer)

  Channel Routing: (n_nodes), (n_lakes)
- Parallel Scheme
  - Two dimensional domain decomposition
  - Distributed system (MPI) only

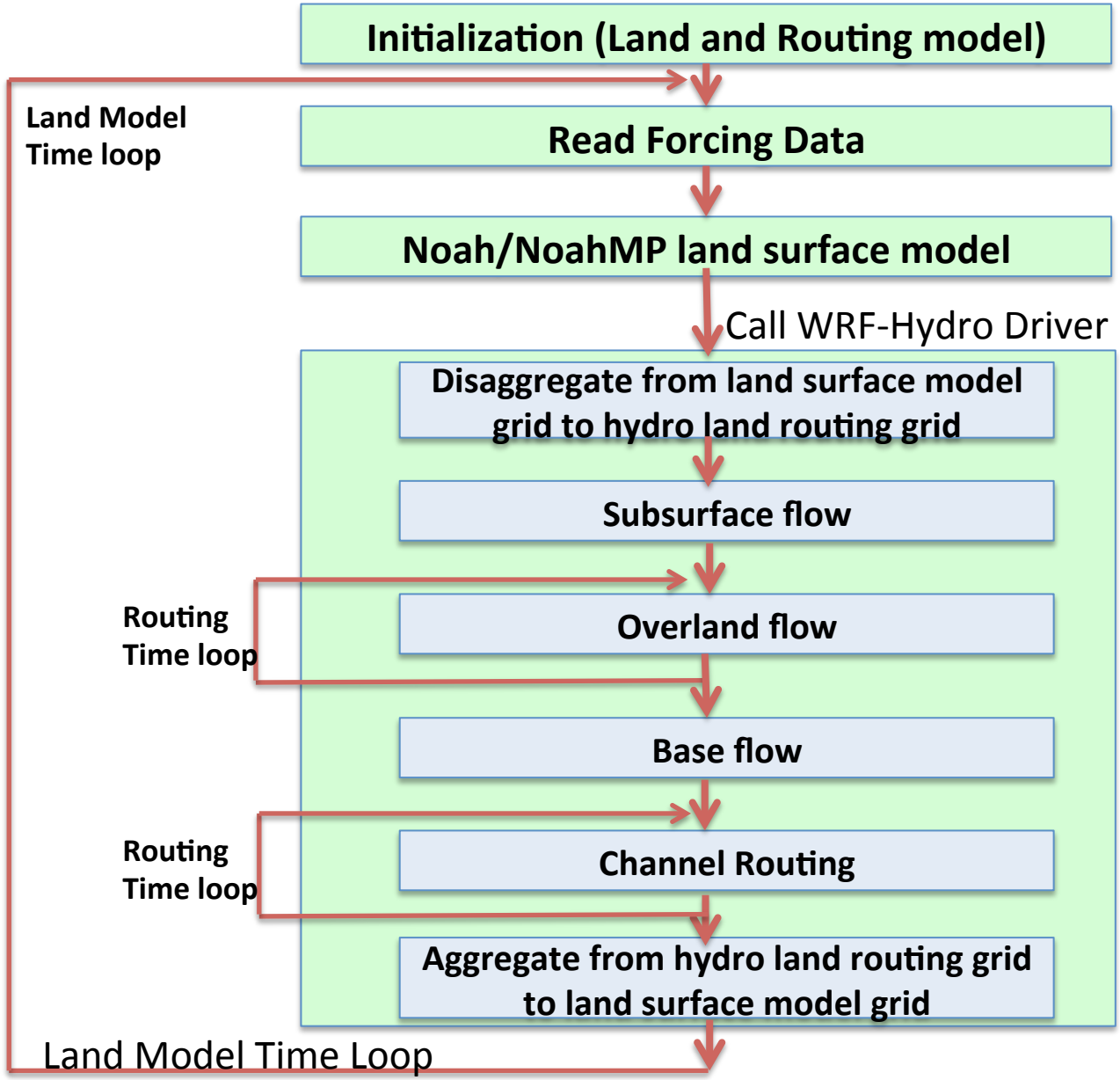
WRF-Hydro Multi-Grids Domain



1 km Land grid

Land routing and
Channel routing grid: regridding

WRF-Hydro Execution Flow Chart (example)



Compiling

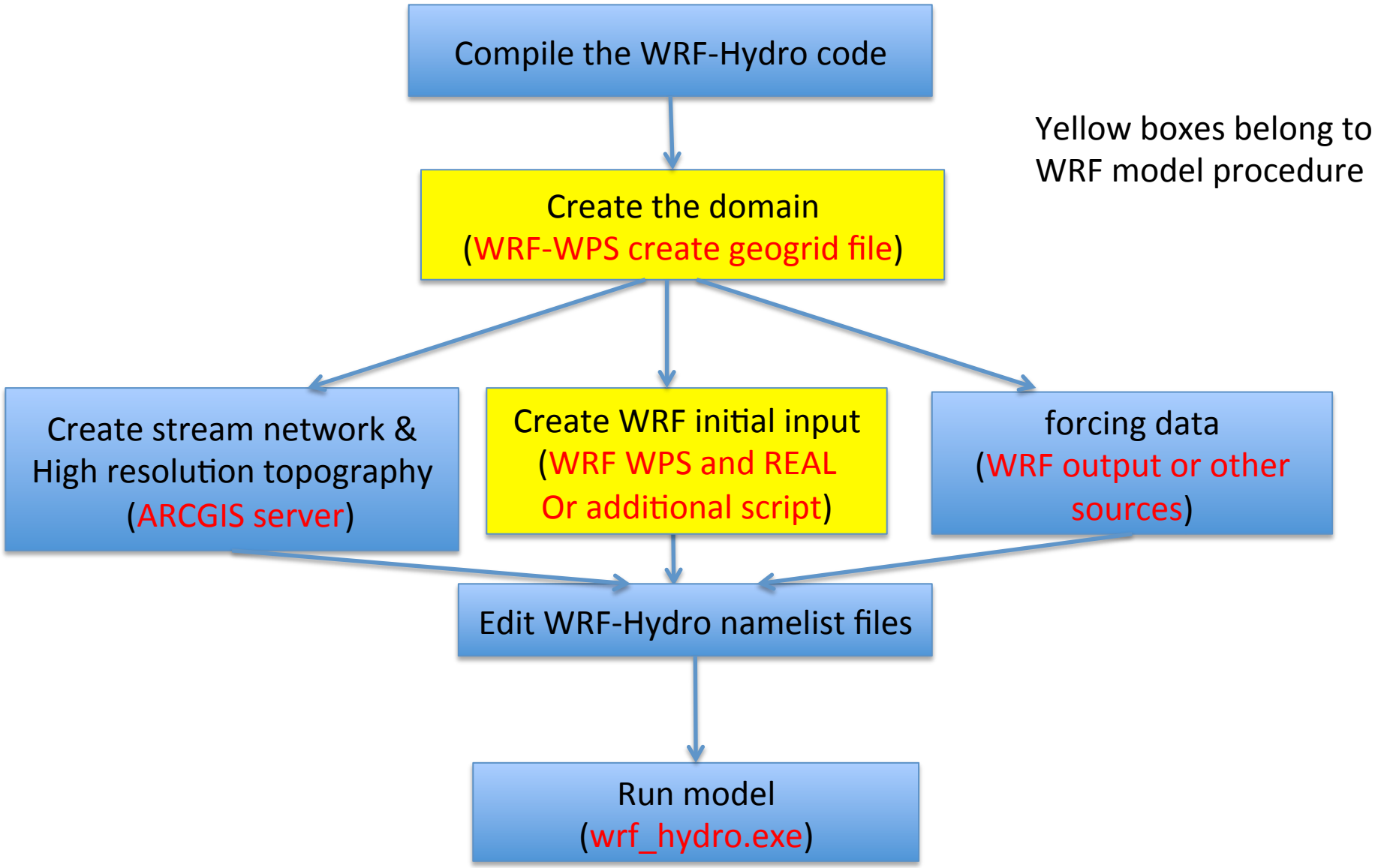
- Environment
  - netcdf library
  - setenv WRF_HYDRO 1
  - setenv HYDRO_D 1
- Offline
  - Directory: WRFV3/hydro
  - Choose compiler options (./configure)

```
WRFV3/hydro% ./configure
Please select from following supported options.

  1. Linux PGI compiler sequential
  2. Linux PGI compiler dmpar
  3. IBM AIX compiler sequential, xlf90_r
  4. IBM AIX compiler dmpar
  5. Linux gfort compiler sequential
  6. Linux gfort compiler dmpar
  7. Linux ifort compiler sequential
  8. Linux ifort compiler dmpar
  0. exit only

Enter selection [1-8] :
```

Compiling

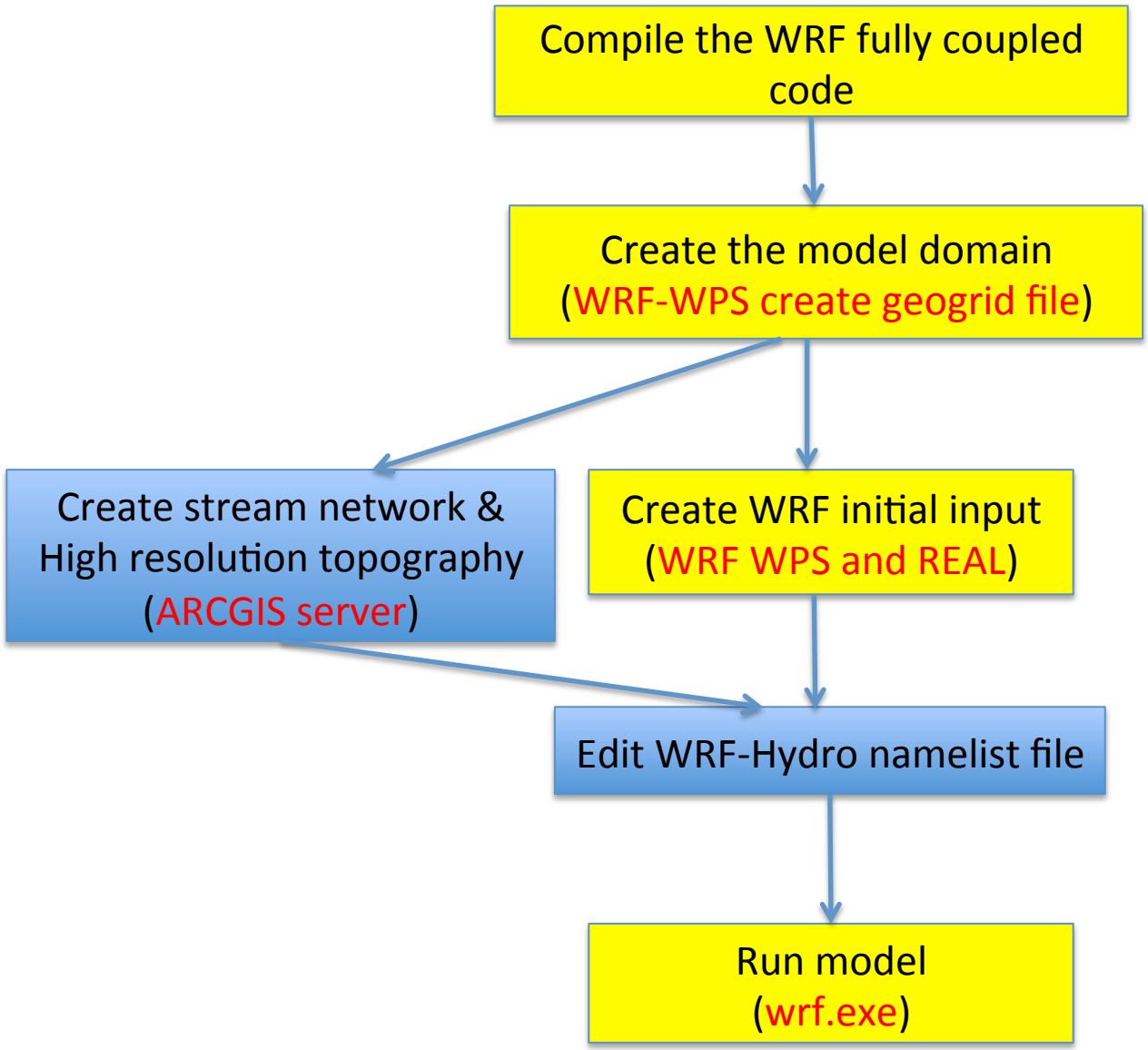
- Environment
  - netcdf library
  - setenv WRF_HYDRO 1
  - setenv HYDRO_D 1
- Offline
  - Directory: WRFV3/hydro
  - Choose compiler options (./configure)
  - Building WRF-Hydro
    - with Noah (./compile_offline_Noah.csh)
    - With NoahMP (./compile_offline_NoahMP.csh)
- WRF fully coupled
  - setenv WRF_HYDRO 1

Running WRF-Hydro Offline



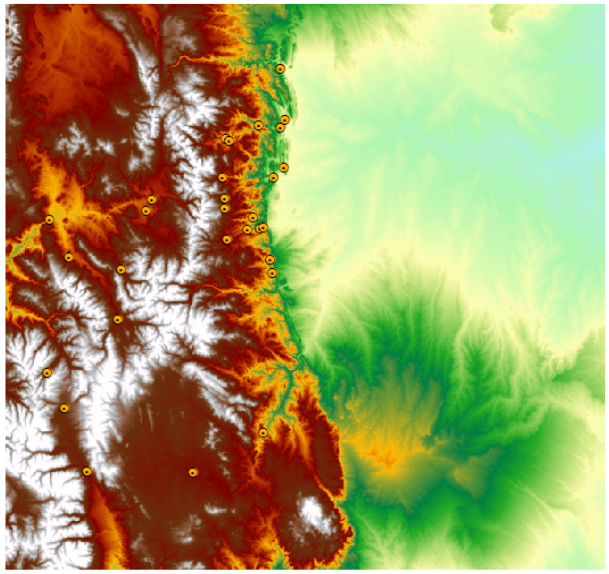
Yellow boxes belong to
WRF model procedure

Run WRF-Hydro Fully Coupled



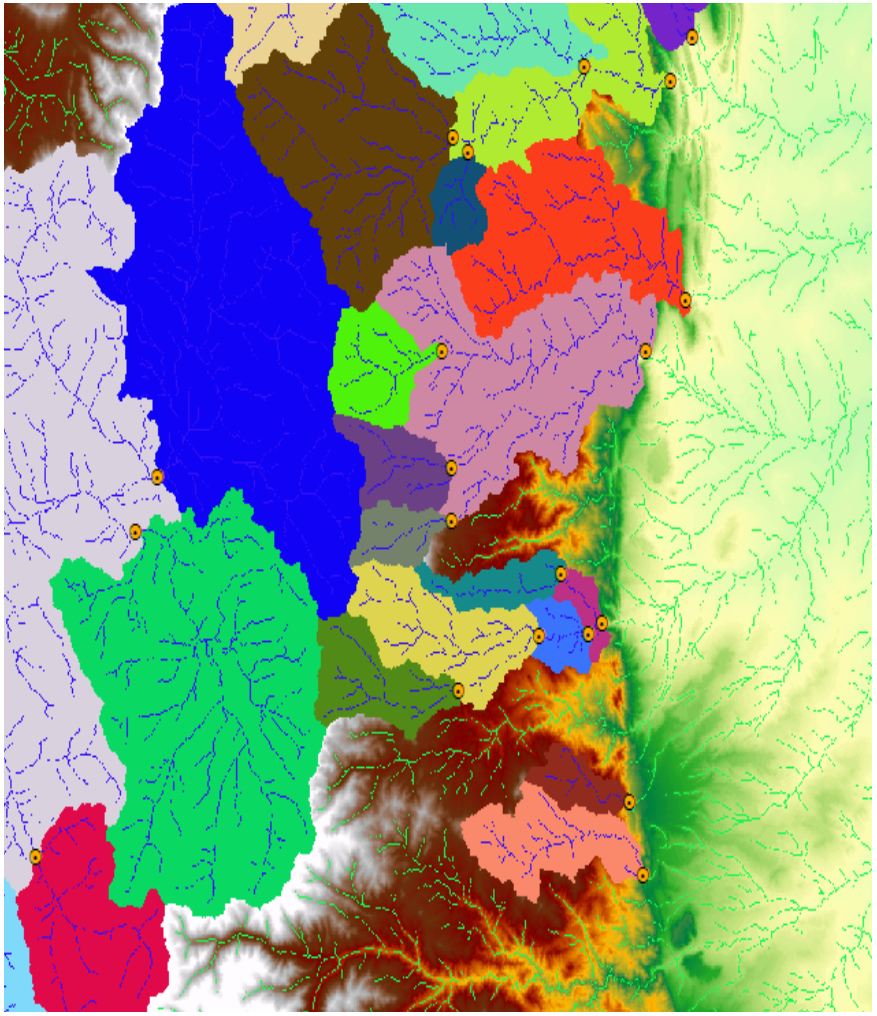
Yellow boxes belong to WRF model procedure

WRF-Hydro ArcGIS Pre-processing Tool: K. Sampson - developer



Import:
WRF-geogrid terrain

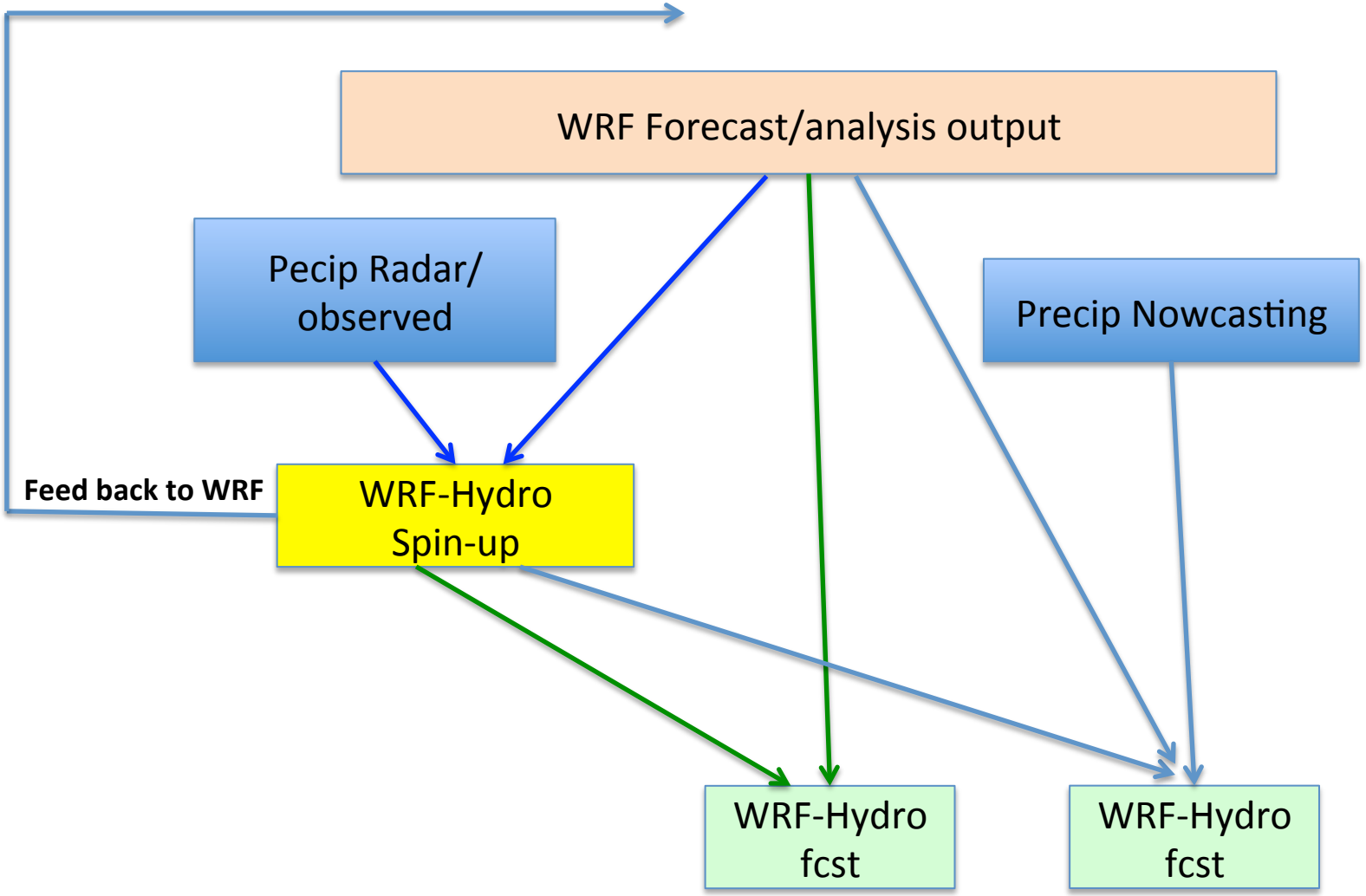
Create:
Hydrologi
cal
routing
grids



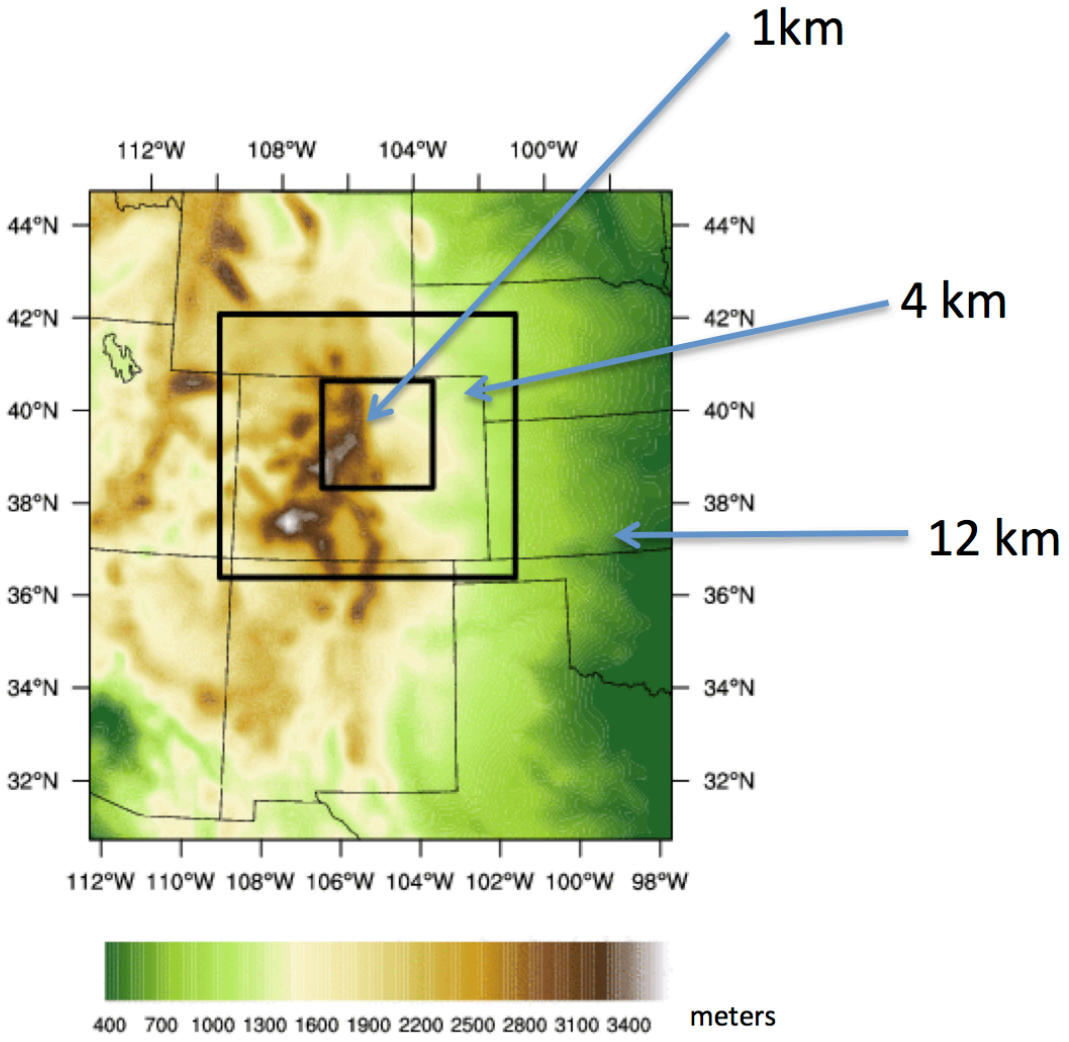
Tips for Running Fully Coupled WRF-Hydro on New Machine

- Compile offline first
- Running the testing case
- Compile and run WRF only
- Compile fully coupled WRF/WRF-Hydro model
- Running the testing case with WRF only
- Running the testing case with fully coupled WRF/WRF-hydro model

WRF-Hydro Prediction System:
Example Modes of Operation



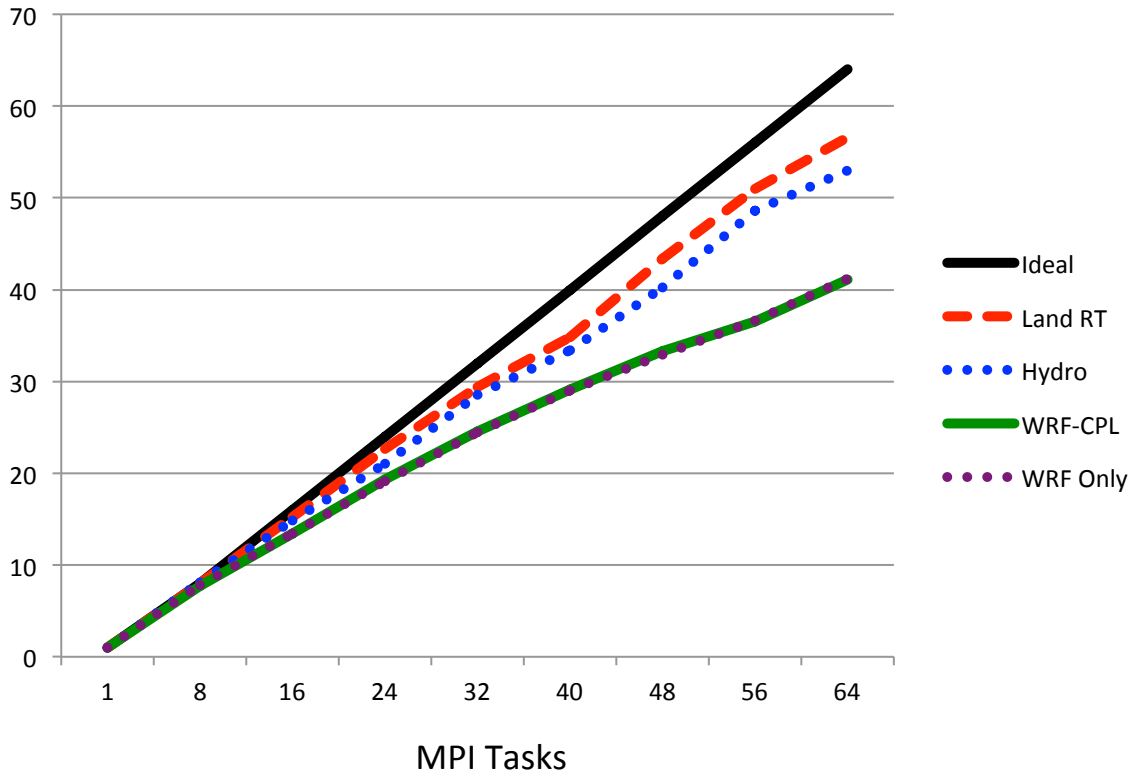
Benchmarking WRF-Hydro: Front Range Model Domain



WRF-Hydro Performance Speedup

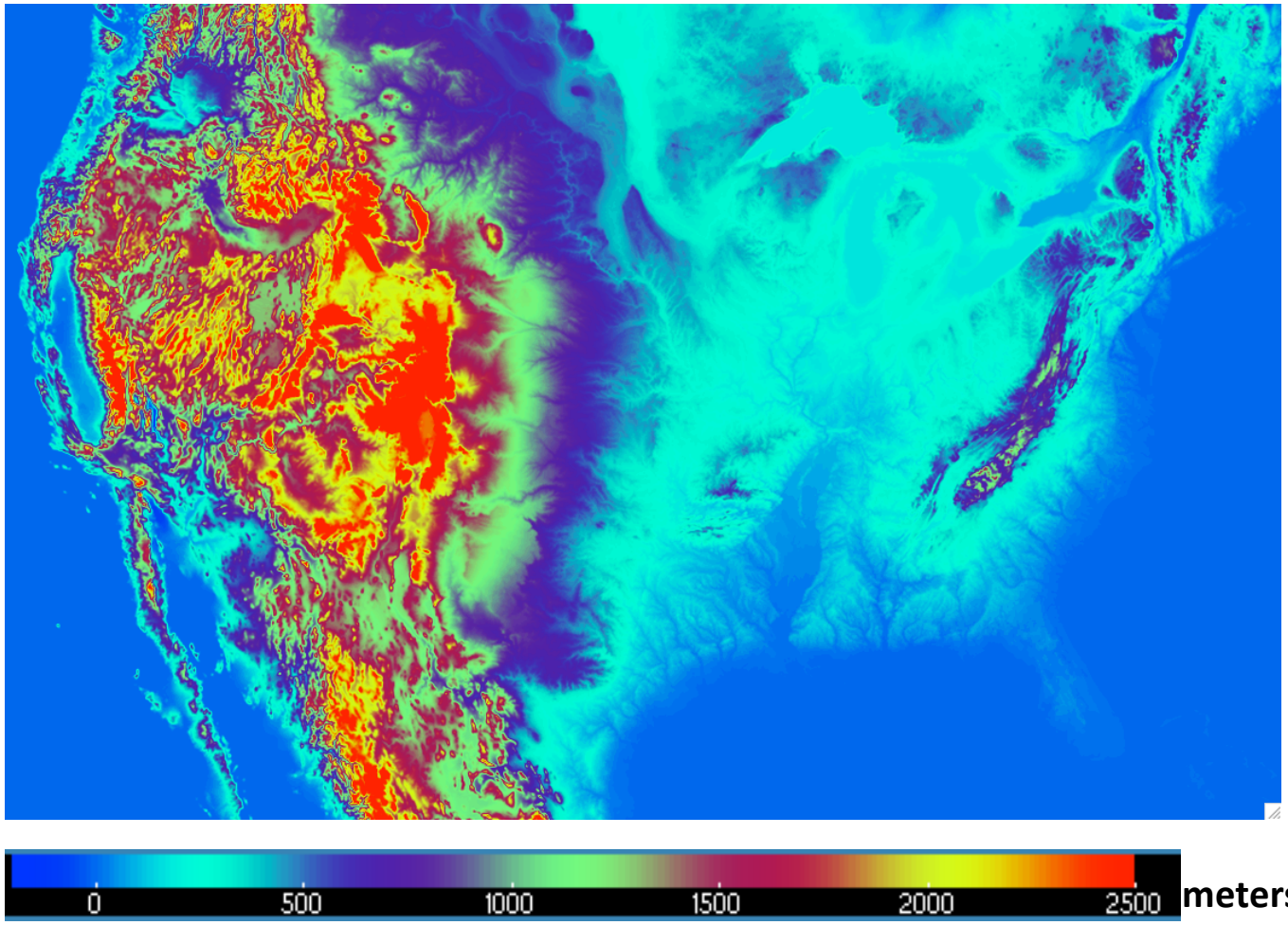
Time of Sequential Run

Time of Parallel Run



Hydro running time: 10%-20% of WRF run

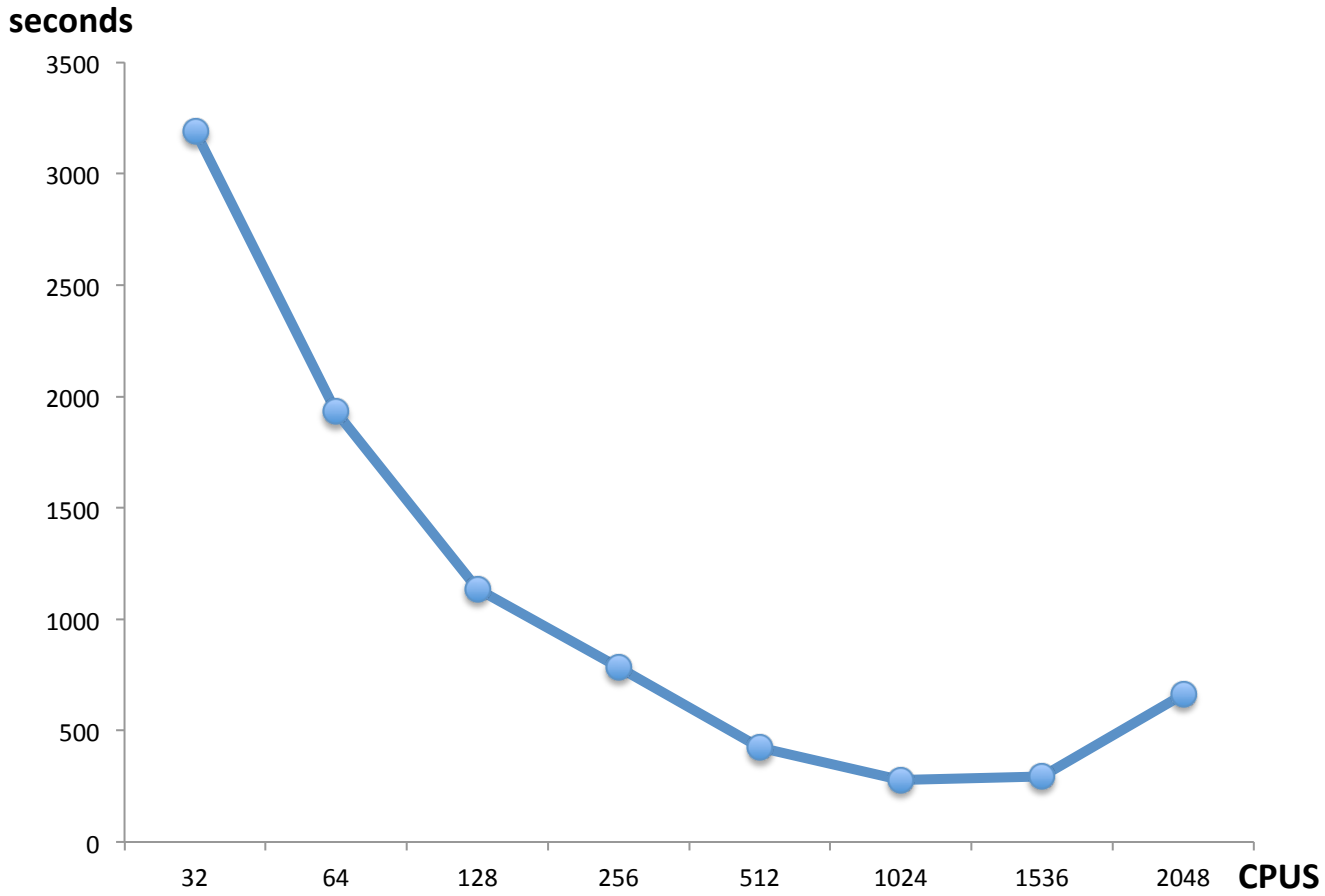
CONUS Domain 4km horizontal resolution
Land Routing 500 meter resolution



Grid numbers: 9024 X 5760

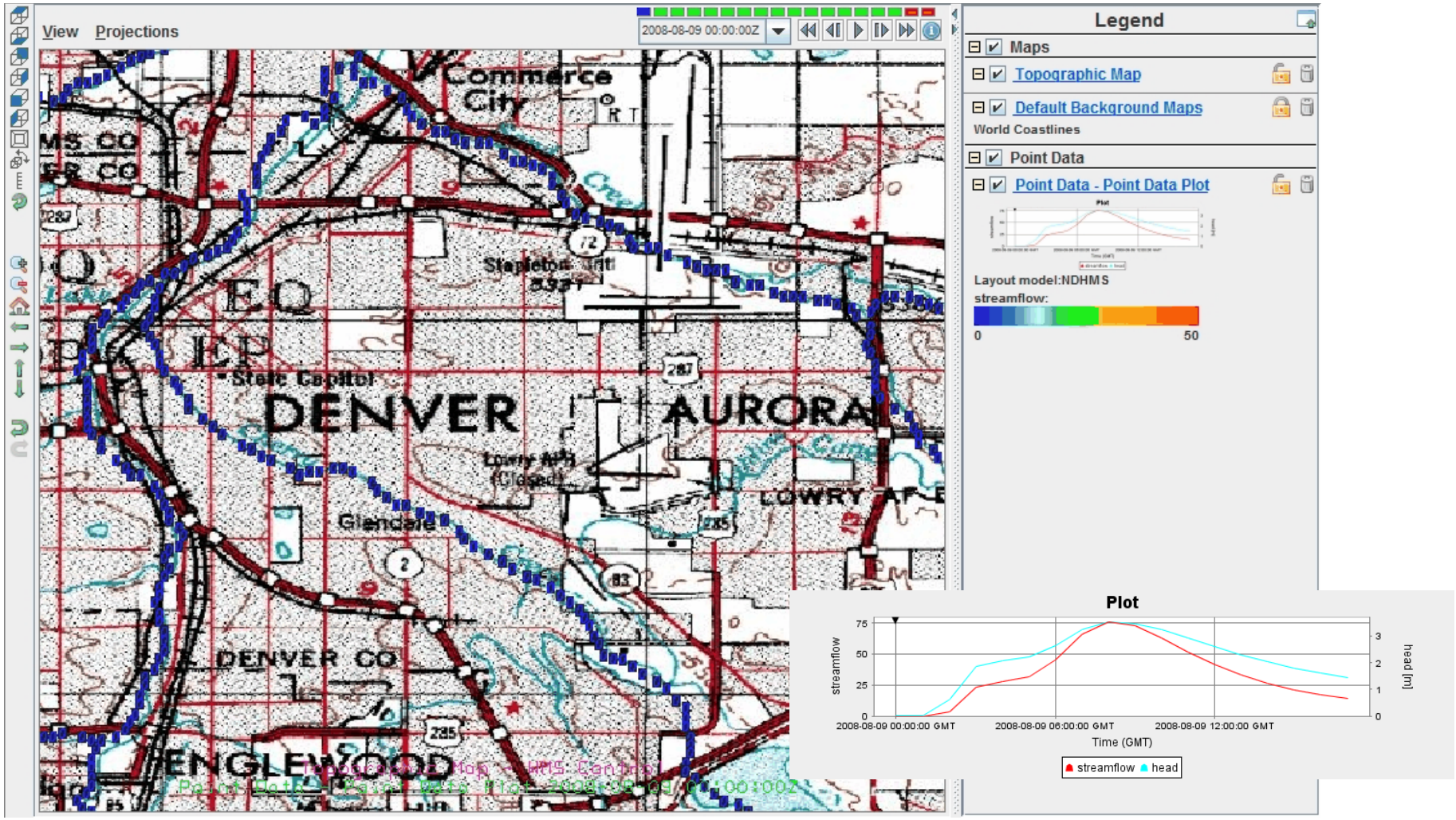
2 hours offline forecast with CONUS domain

MPI tasks	wall clock time seconds
32	3189.3
64	1932.7
128	1136.6
256	784.8
512	423.9
1024	277
1536	294
2048	662.4



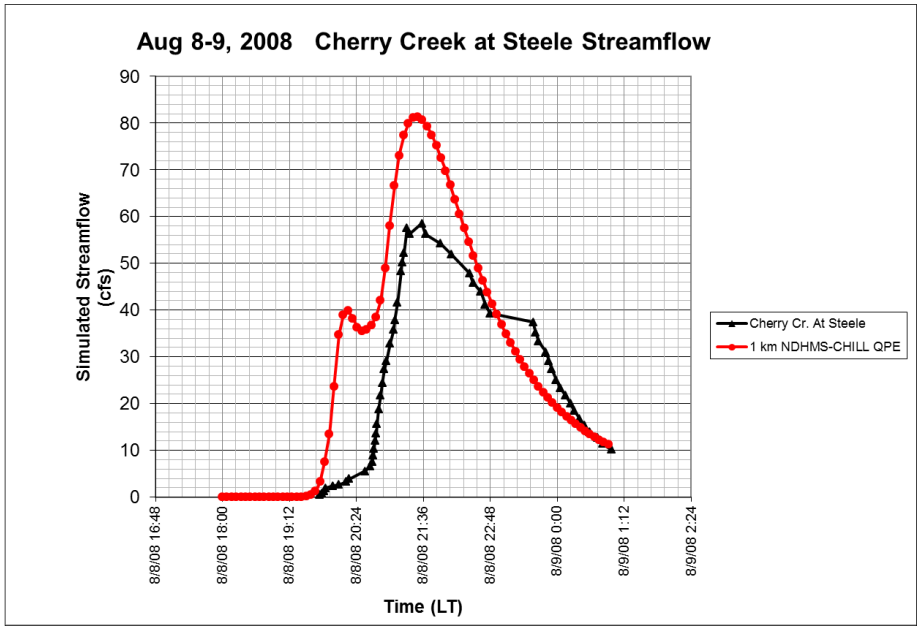
Initial Results: WRF-Hydro Simulations

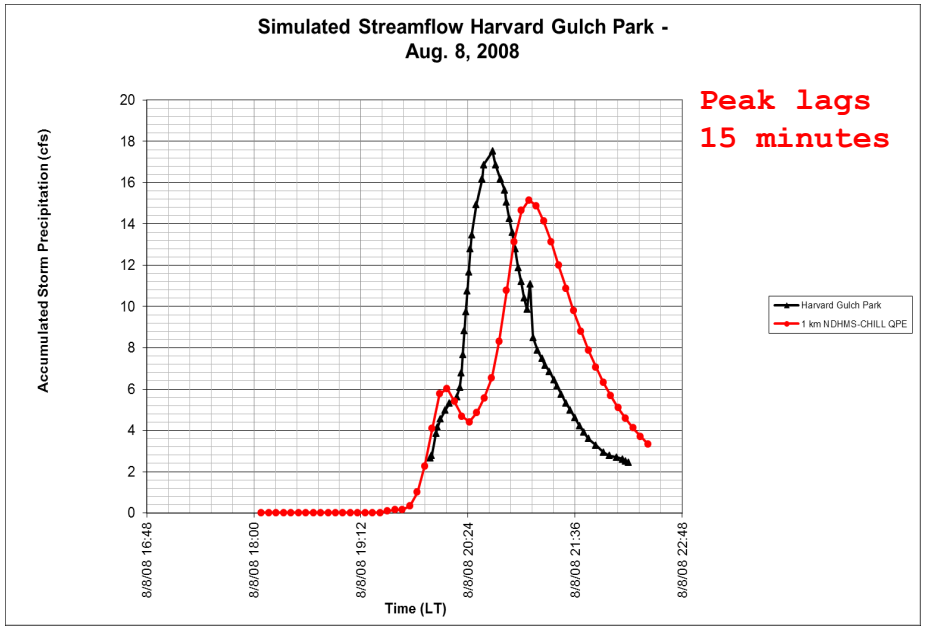
- Evaluation of simulated streamflow using multiple precipitation products: Aug. 8, 2008



Initial Results: WRF-Hydro Simulations

- Evaluation of simulated streamflow using multiple precipitation products: Aug. 8, 2008

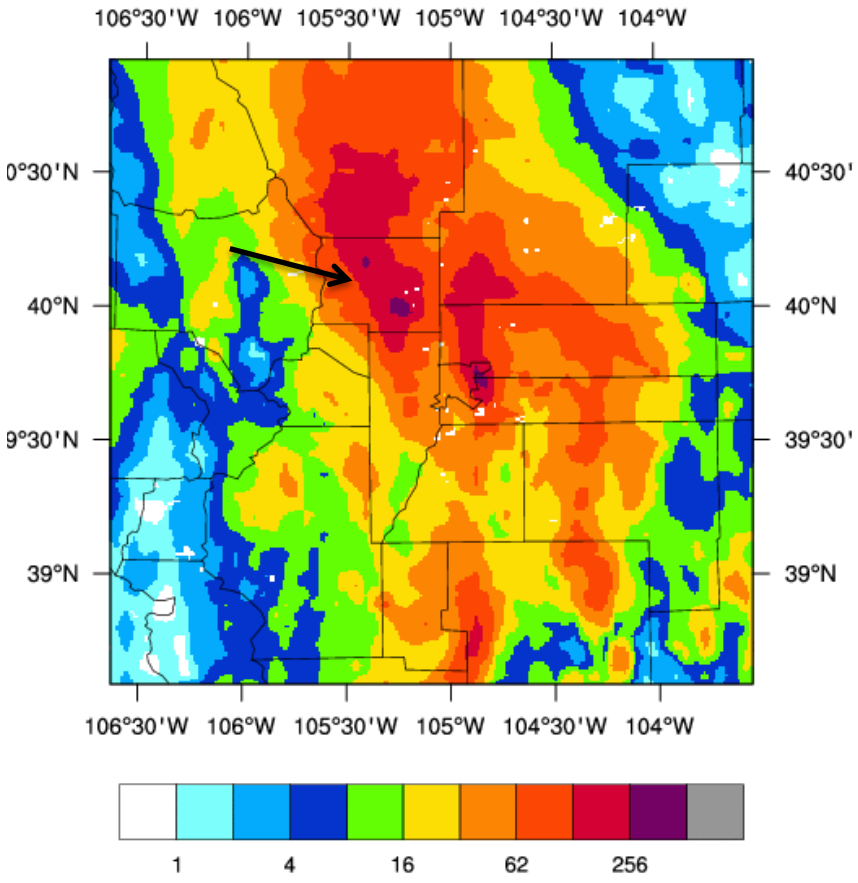




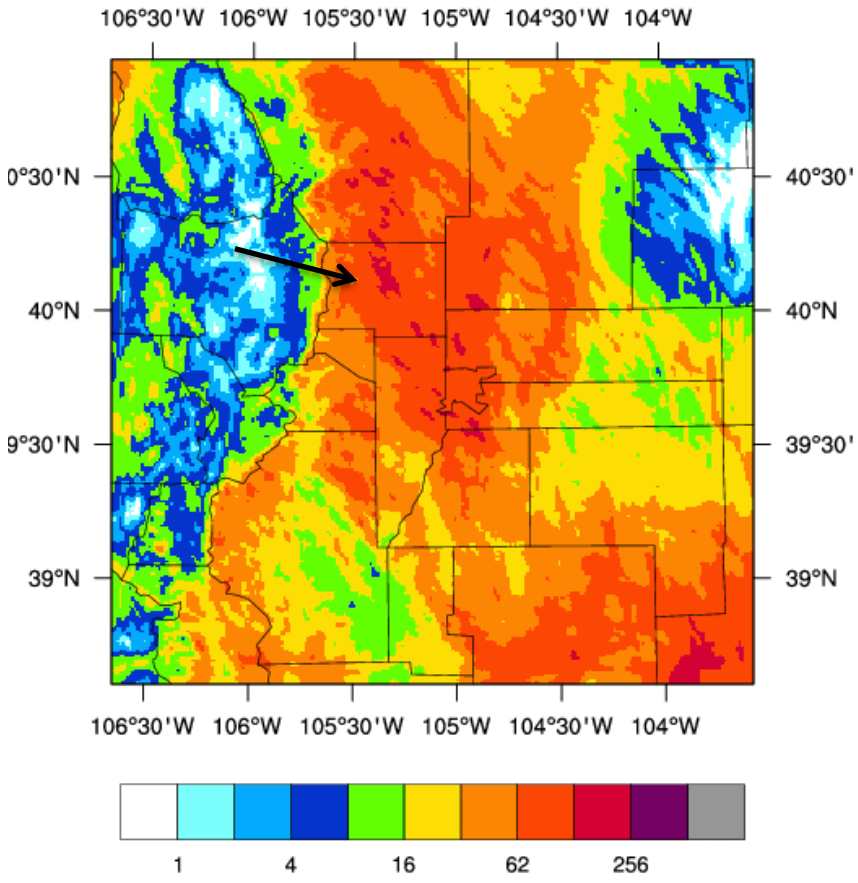
- Here the QPE is provided by the CSU-CHILL dual-polarimetric radar.
- Noah and CHILL QPE precipitation on a 1km grid, NDHMS routing executed on a 100m
- NDHMS-Noah is un-calibrated
- LIS-NDHMS coupling near complete…

48 hr accumulated Pcp validated at 2013091300Z

Multiple sensor precipitation Estimation (MPE)

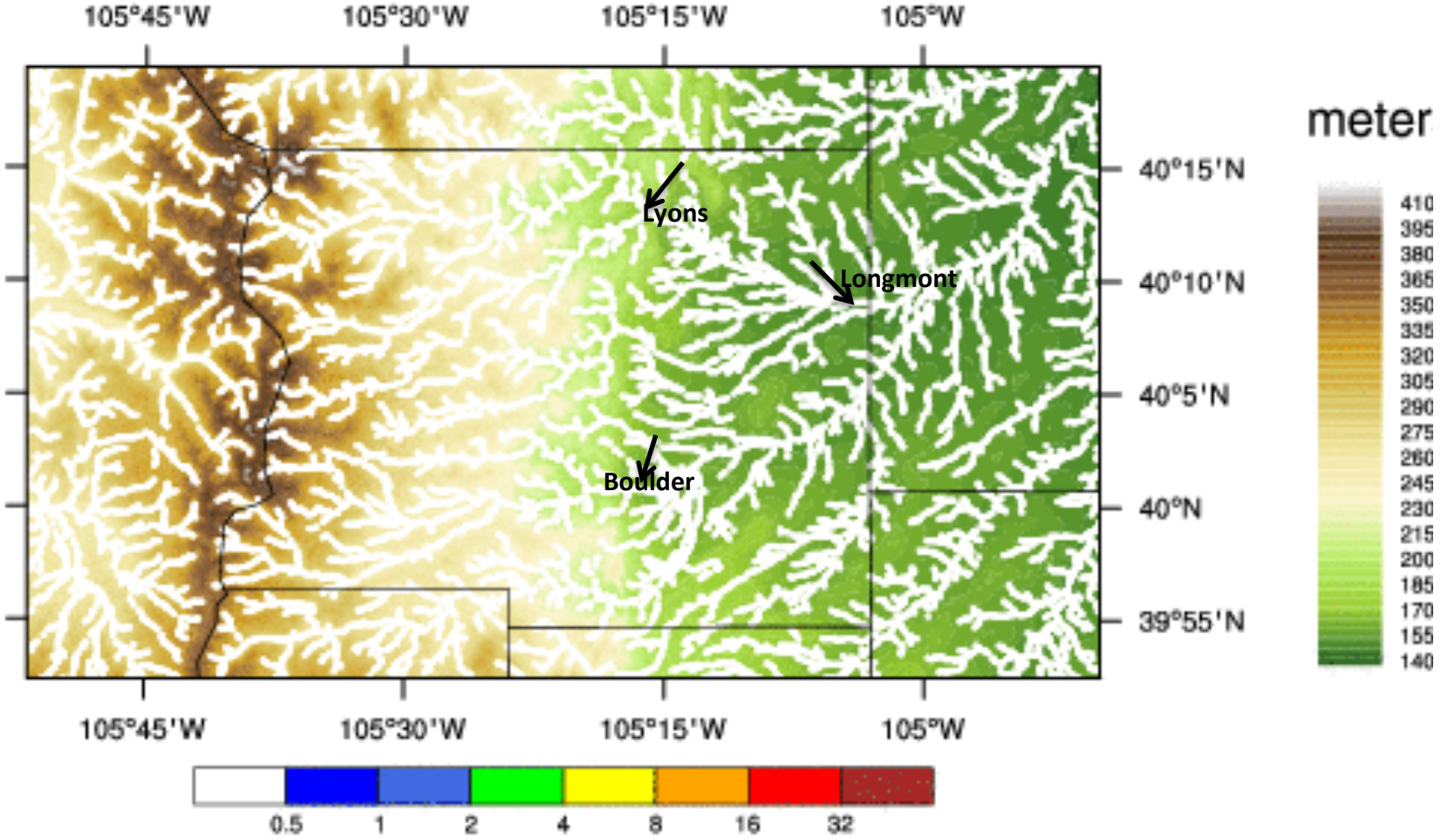


WRF



Stream Flow Forecast

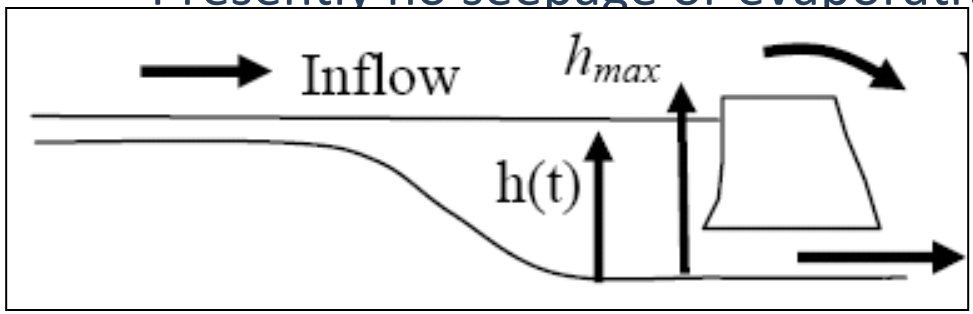
2013091100Z – 2013091300Z



Streamflow (cms)

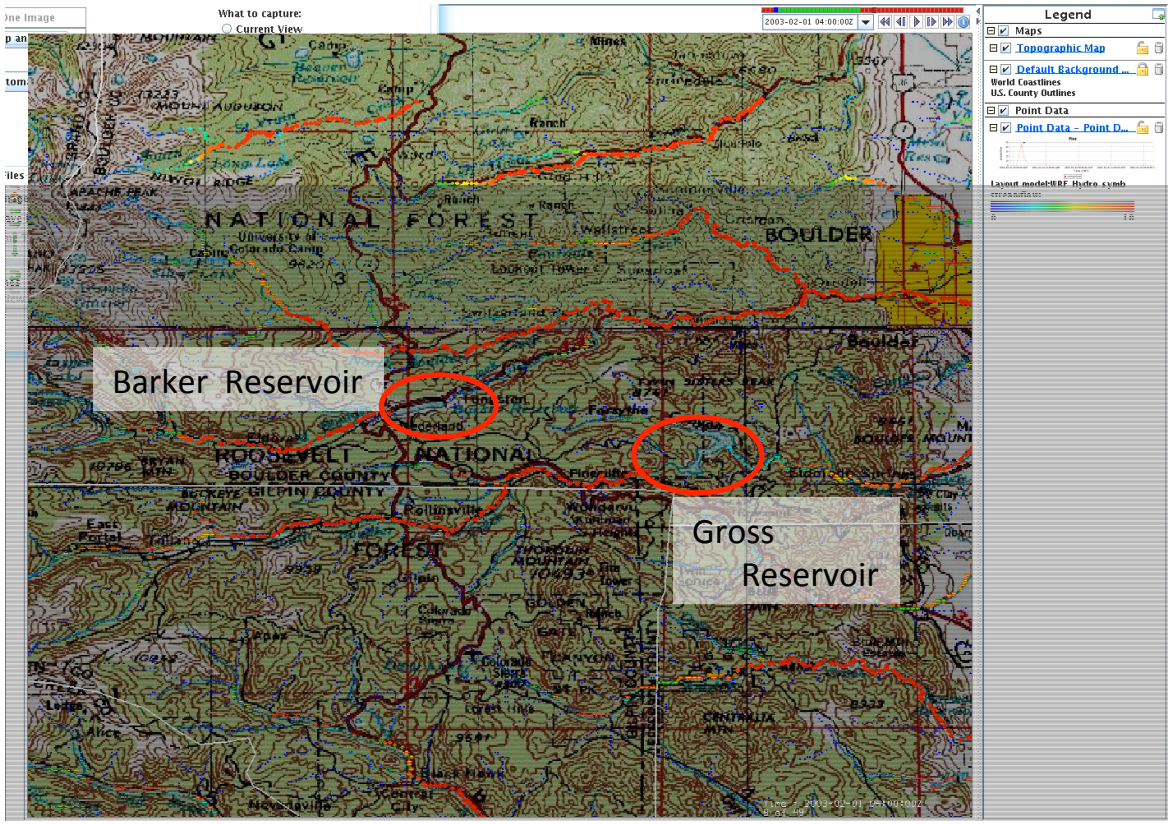
WRF-Hydro v2.0 Physics Components:

- Optional lake/reservoir model:
  - Level-pool routing (i.e. no lagging of wave or gradient in pool elevation)
  - Inflows via channel and overland flow
  - Discharge via orifice and spillway to channel network
  - Parameters: lake and orifice elevations, max. pool elevation, spillway and orifice characteristics; specified via parameter table
  - Active management can be added via an operations table
  - Presently no seepage or evaporative loss functions



Implementing lakes and reservoirs in WRF-Hydro

Visualization of lake impacts



WRF-Hydro Ongoing Activities

- Hydrologic Data Assimilation within WRF-Hydro (in progress):

1. Interfacing with multi-agency GSI (Gridpoint Statistical Interpolation system) for support of variational methods and WRF-embedded applications
2. Interfacing with NCAR DART (Data Assimilation Research Testbed) for support of ensemble-based DA methods

WRF-Hydro Ongoing Activities

- **Expanded Support, Documentation & Training:** Remains a fundamental challenge under current project- based support structure… but an area where there is substantial groundwork

  - Full website with downloads, documentation and test cases
  - Creating pdf's of past training seminars
  - Expanding library of pre-/post-processing scripts

Thank you !

Contributions:

NCAR Internal:

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Wei Yu (Lead Software Engineer)

David Yates (Water Resources Lead)

A. Wood (Advising Scientist)

M. Clark (Advising Scientist)

J. McCreight (Post-doc)

K. Sampson (GIS Specialist)

K. Ikeda (Data Analyst)

R. Rasmussen (Sr. Advising Scientist)

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- A. Parodi and E. Fiori (CIMA-Italy)
- NCAR STEP team
- Amir Givati and Erik Fredj (Israeli Hydr. Service)
- K. Mahoney (CU-CIRES)
- Col. State Univ. CHILL-team
- Logan Karsten (NOHRSC)
- Sujay Kumar (NASA-Goddard)

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- **NASA-IDS**
- **DOE-ESM**