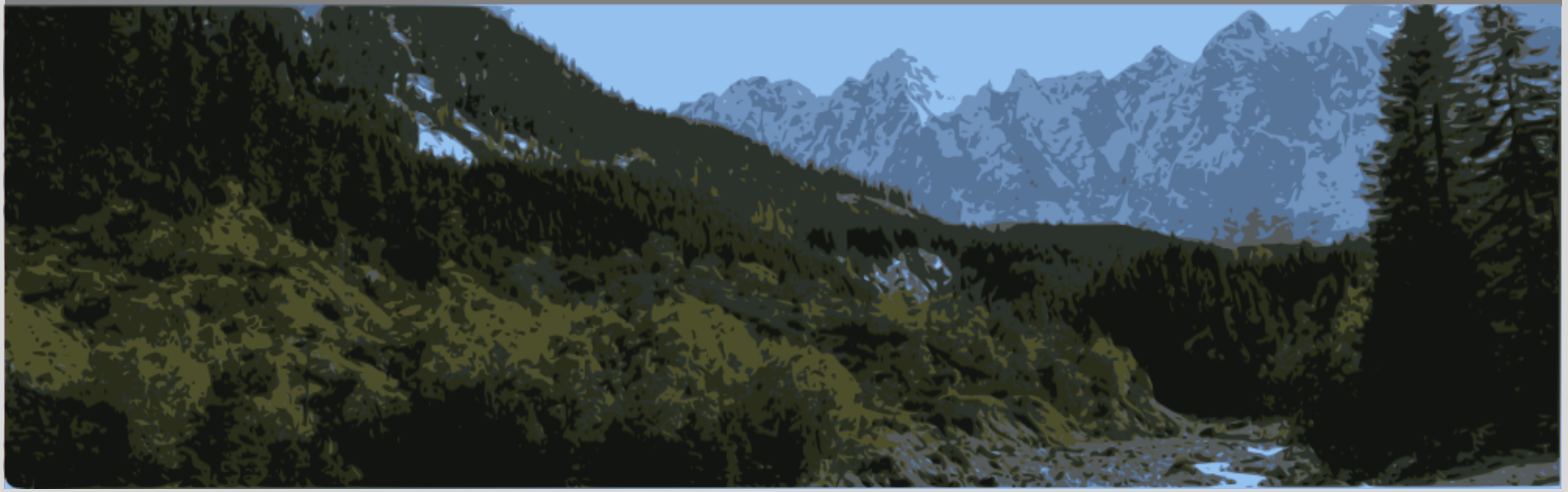
Karlsruhe Institute of Technology

Model systems for closed regional atmospheric and terrestrial water balance analyses

Benjamin Fersch, Thomas Rummler, David Gochis (NCAR), Harald Kunstmann

REKLIM Workshop Bremerhaven, 29.-30.03.2011

INSTITUT FÜR METEOROLOGIE UND KLIMAFORSCHUNG (IMK-IFU), GARMISCH-PARTENKIRCHEN



Objective

Can alterations in small scale surface and subsurface processes impact atmospheric properties, in particular precipitation characteristics?

Objective

Fast land-use change (China)

How does land-use change affect the
long-term atmospheric water budget of a region?

Feedback Analysis

Sensitivity of

Land surface properties
Lateral interactions

via

Soil moisture
100m - 1km

on

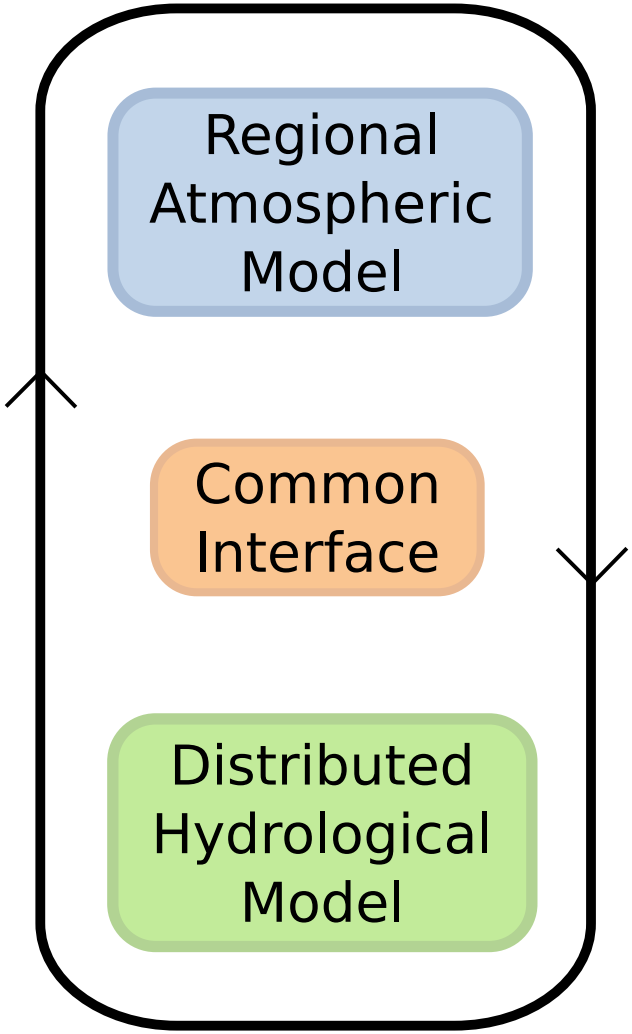
Atmosphere
Water budget
Precipitation

Short term feedback

E.g. Ammer (~700km²)

Concept

Fully integrated compartment crossing approach



radiation
precipitation
evapotranspiration

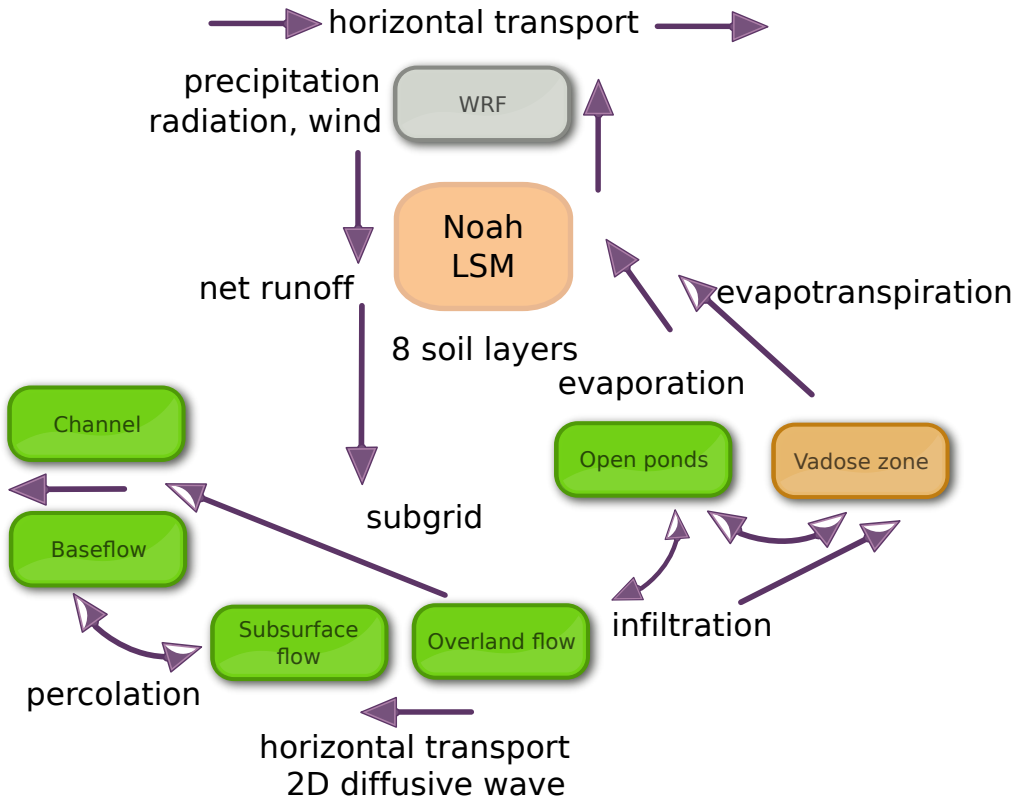
compatible formulation of water and energy fluxes

surface runoff
infiltration
groundwater flow

WRF/NDHMS

NCAR distributed hydrological modeling system

(Gochis et al. 2010)



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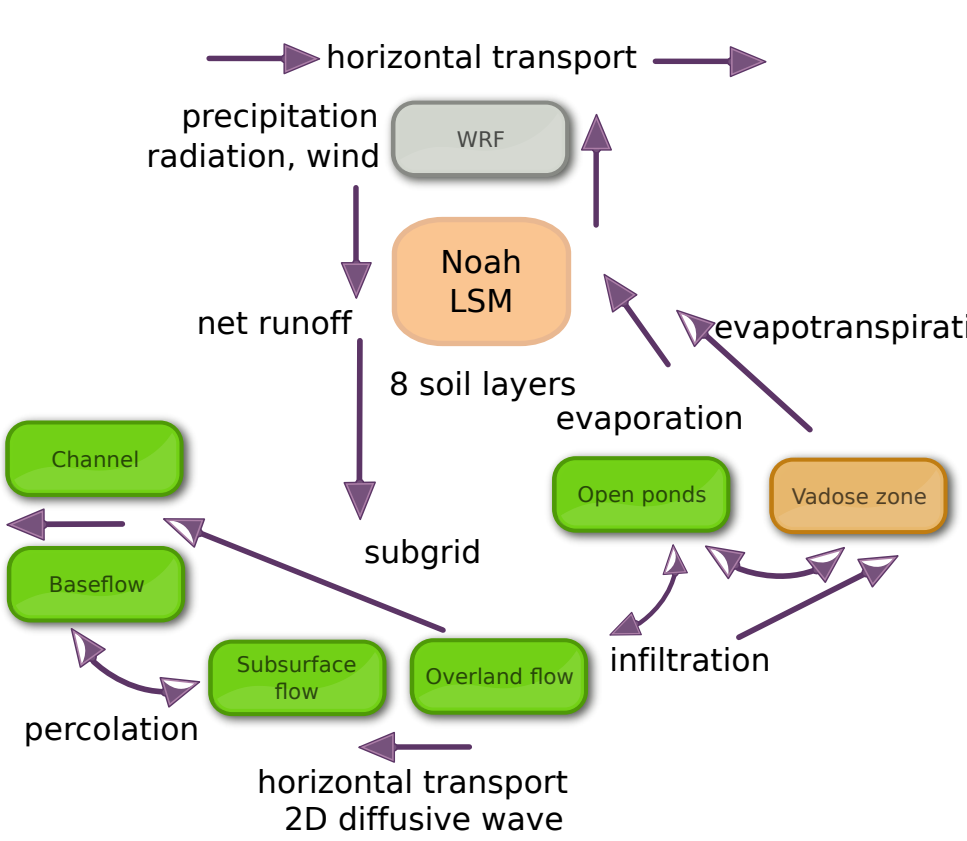

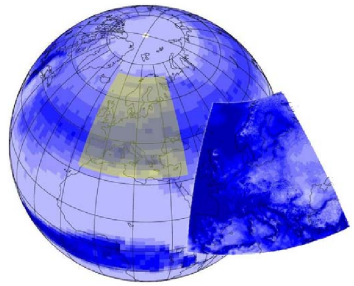

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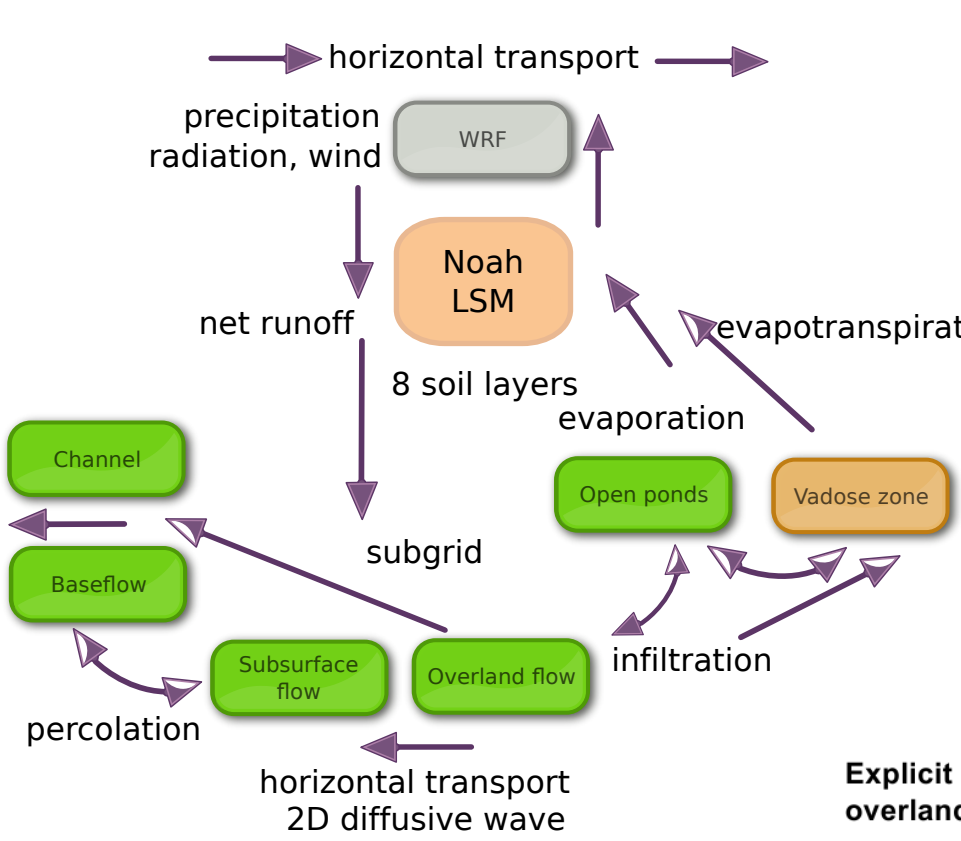
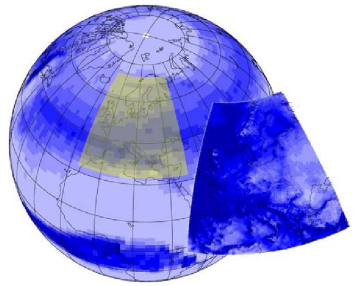
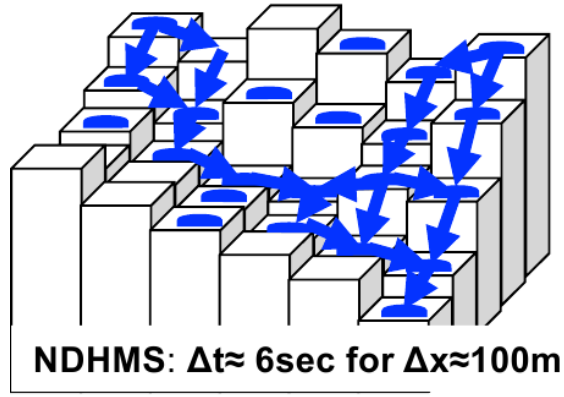




Explicit diffusive wave overland flow:



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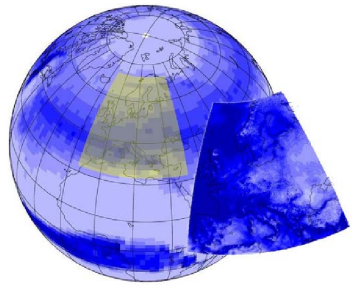
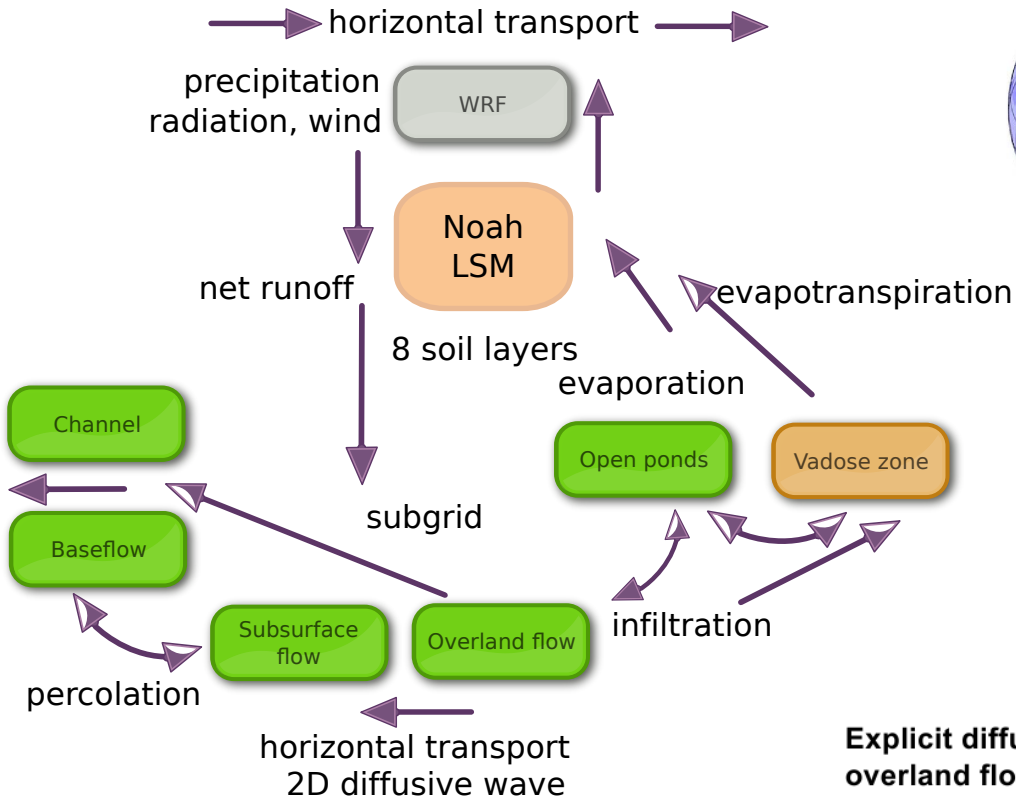
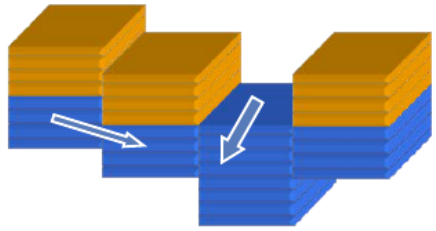


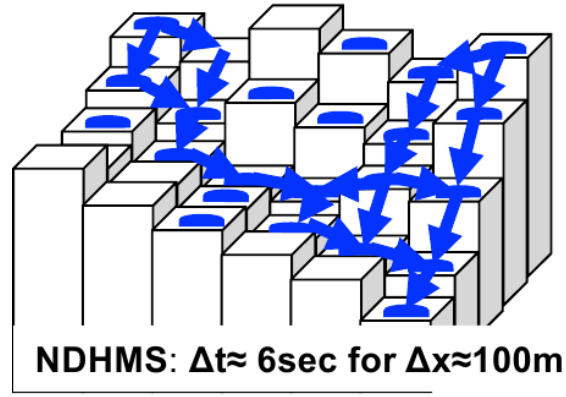


Explicit saturated subsurface flow:



subgrid ~ 100m

Explicit diffusive wave overland flow:



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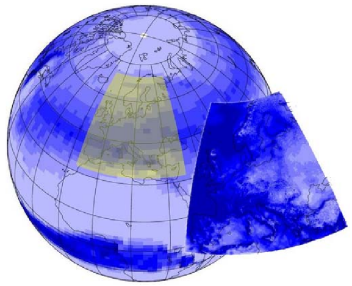
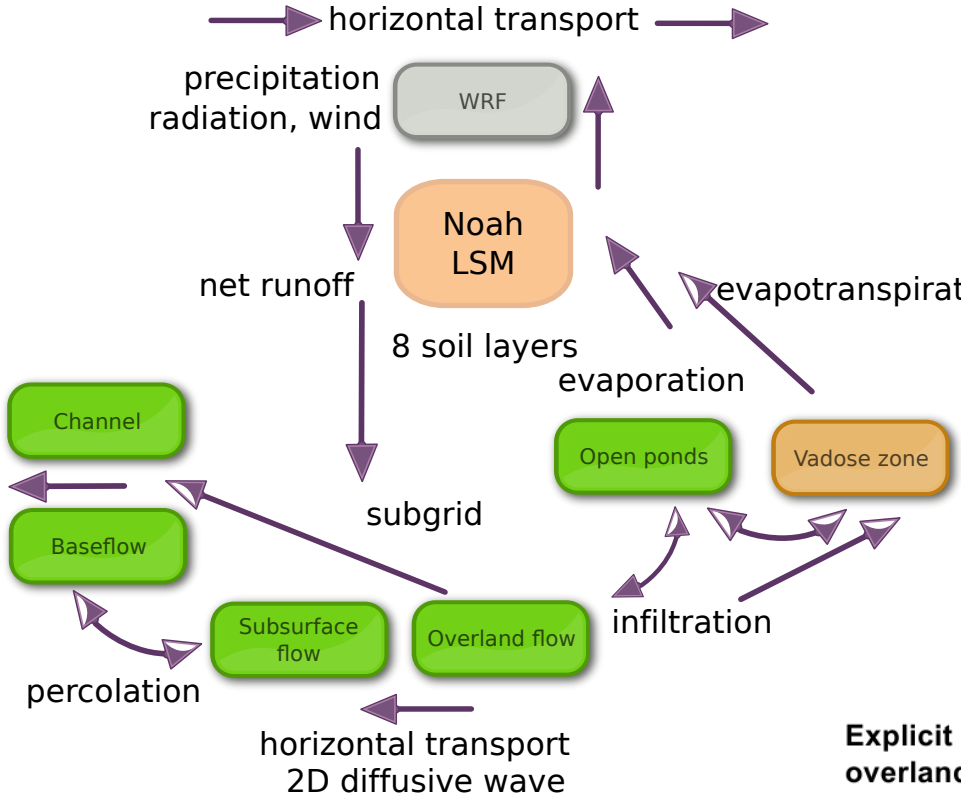
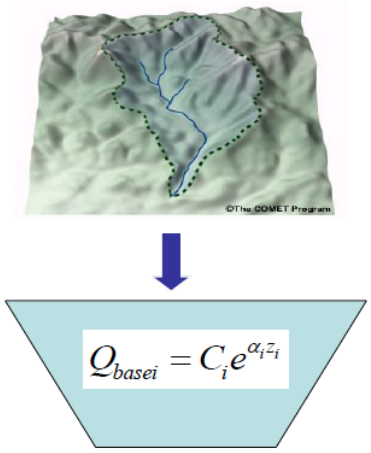
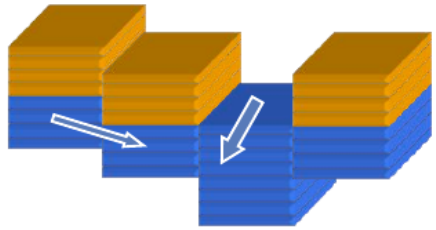




Groundwater bucket model

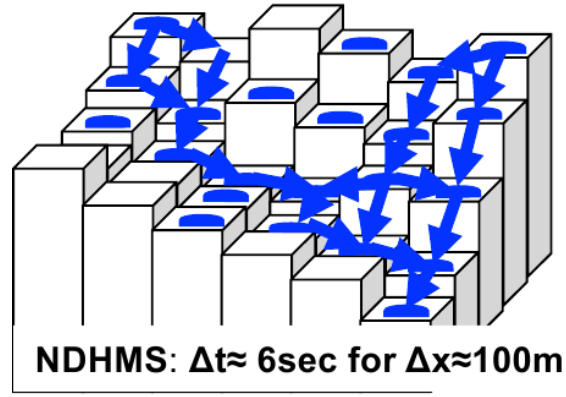


Explicit saturated subsurface flow:

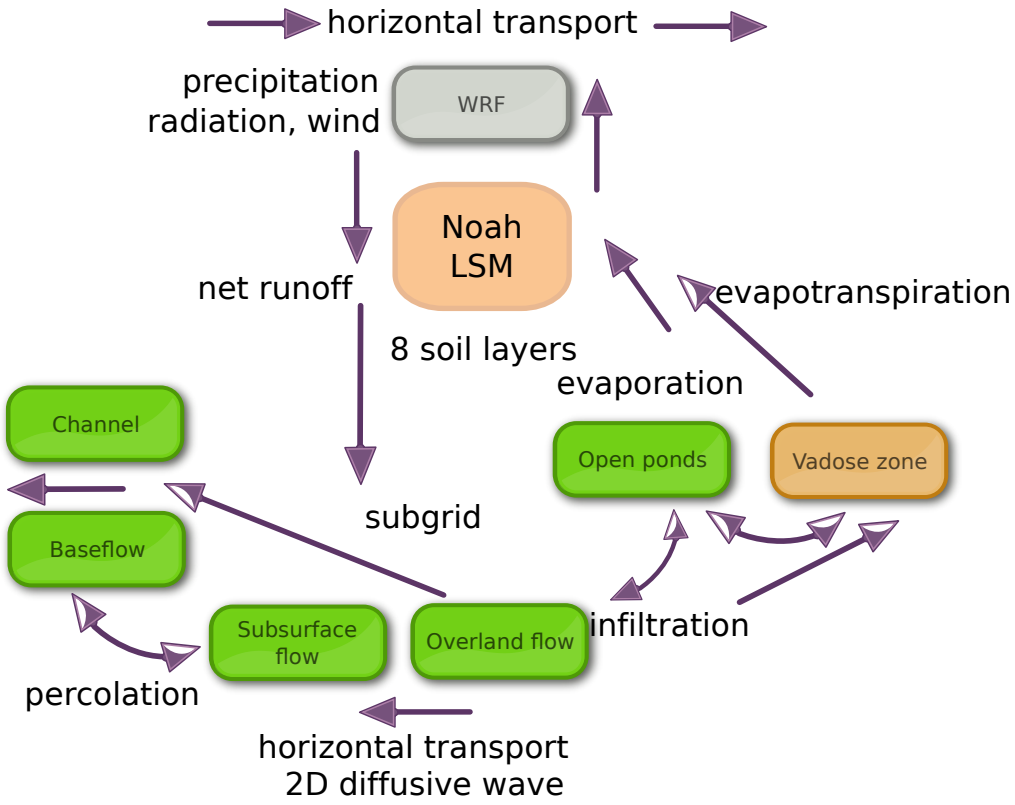


subgrid ~ 100m

Explicit diffusive wave overland flow:

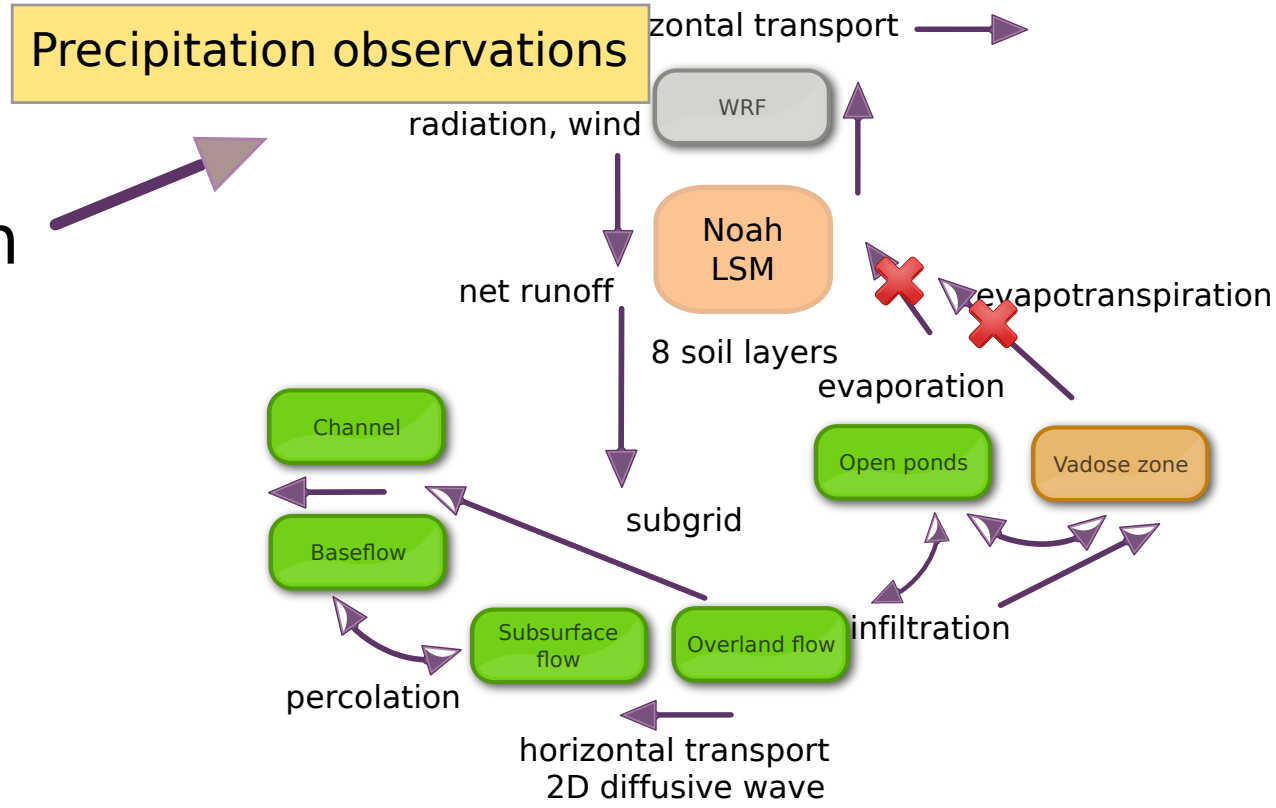


NDHMS Modes


horizontal transport
precipitation
radiation, wind
WRF
Noah
LSM
net runoff
8 soil layers
evapotranspiration
evaporation
Channel
Open ponds
Vadose zone
subgrid
Baseflow
Subsurface
flow
Overland flow
infiltration
percolation
horizontal transport
2D diffusive wave

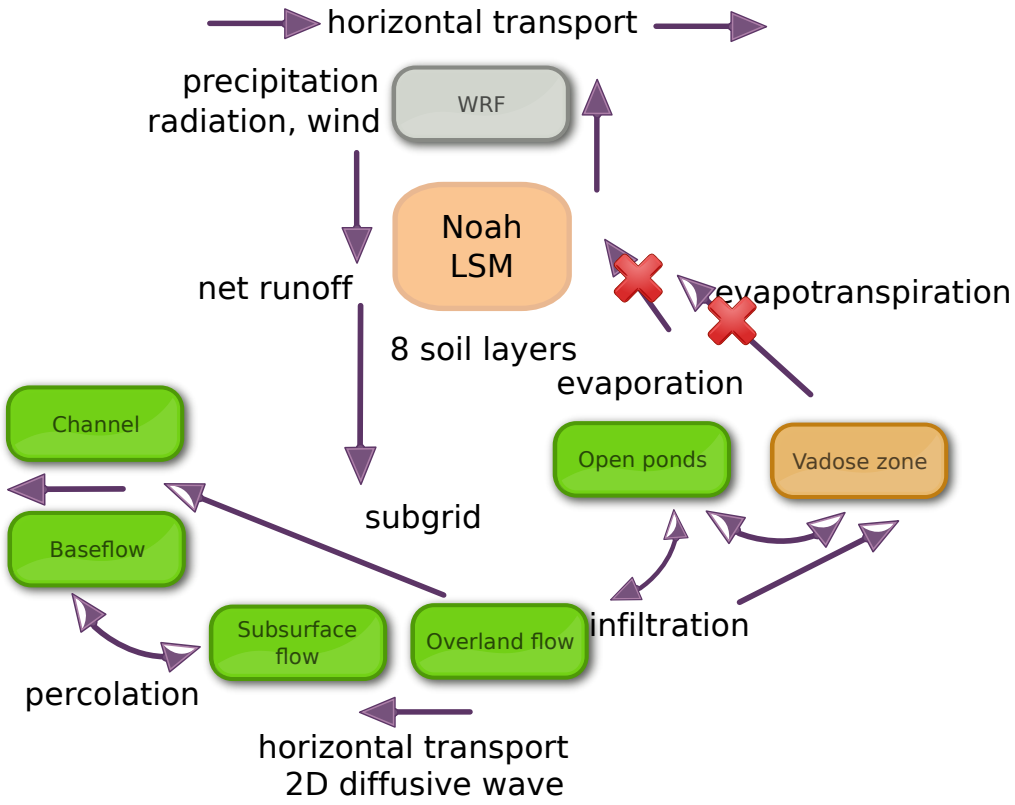
NDHMS Modes

1) Observation driven



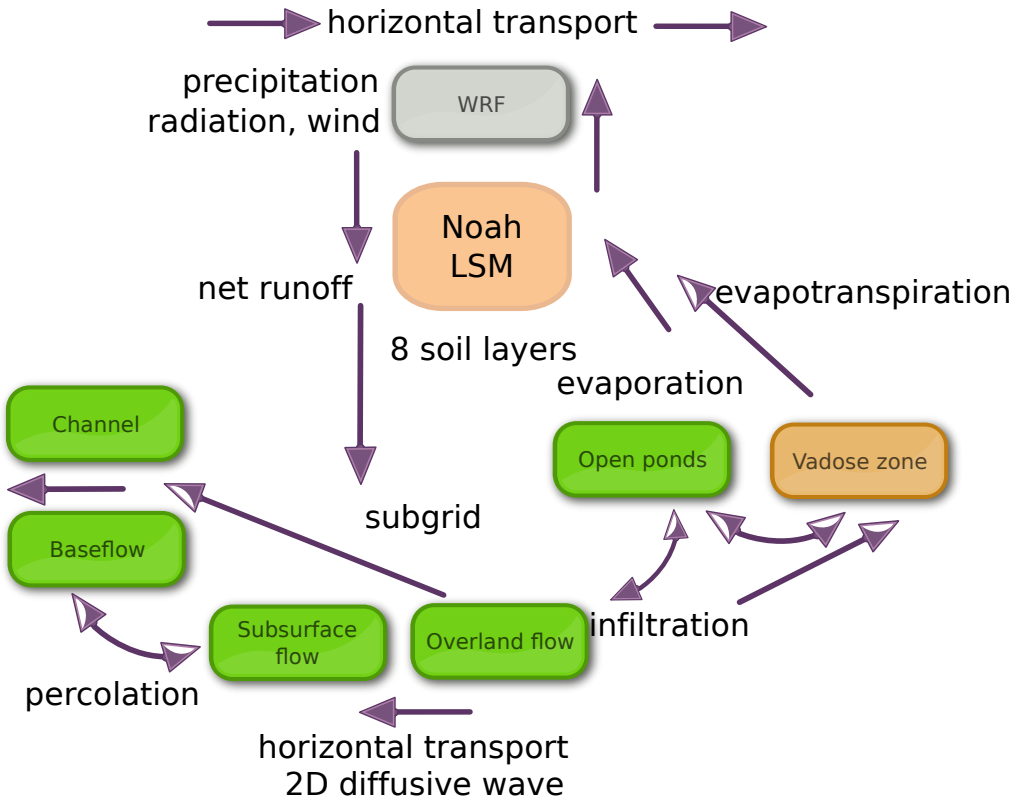
NDHMS Modes

2) One way coupled



NDHMS Modes

3) Two way coupled

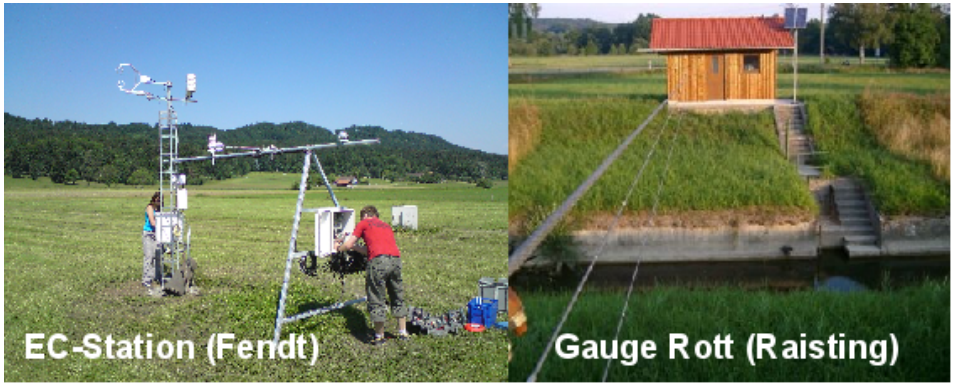


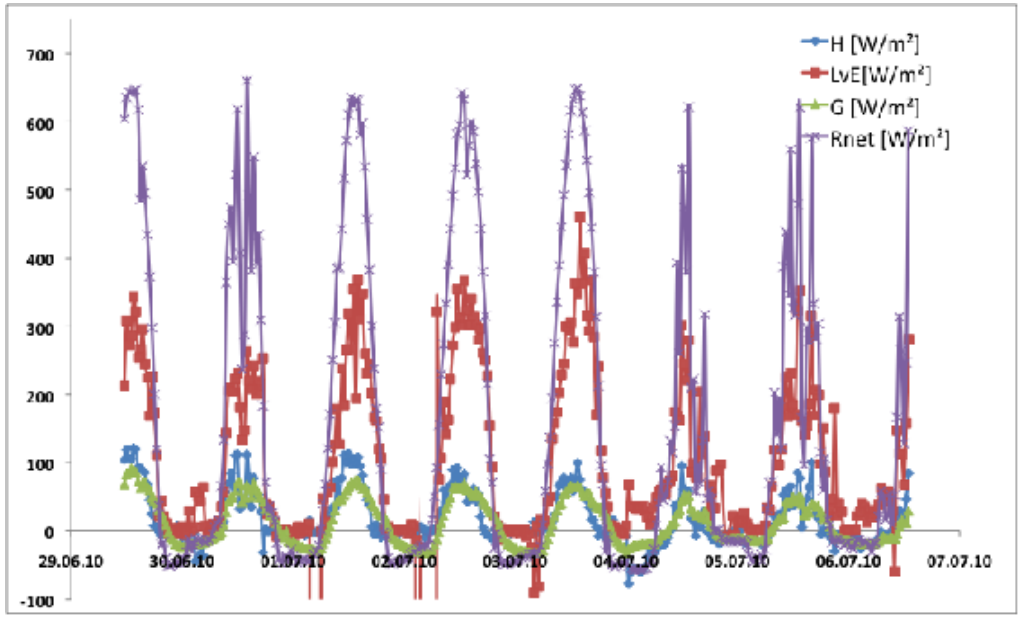
WRF/NDHMS

High Resolution Joint Atmospheric-Terrestrial Water Balance Estimations in a Prealpine Environment

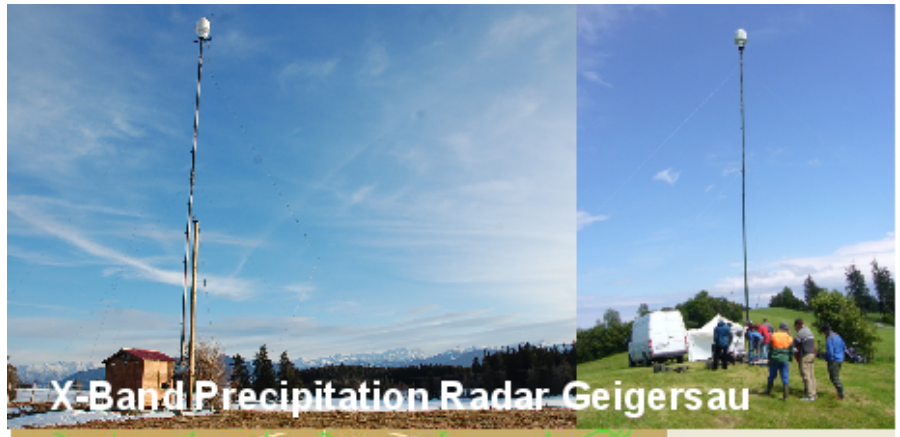
(Diploma Thesis by Thomas Rummler, 2011)

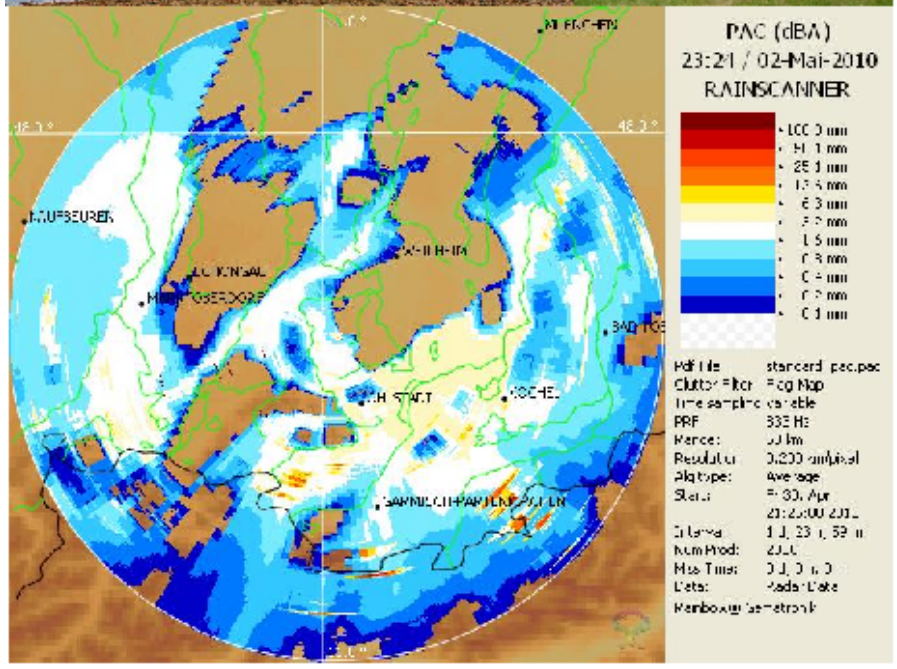
TERENO Pre-Alpine (Ammer)





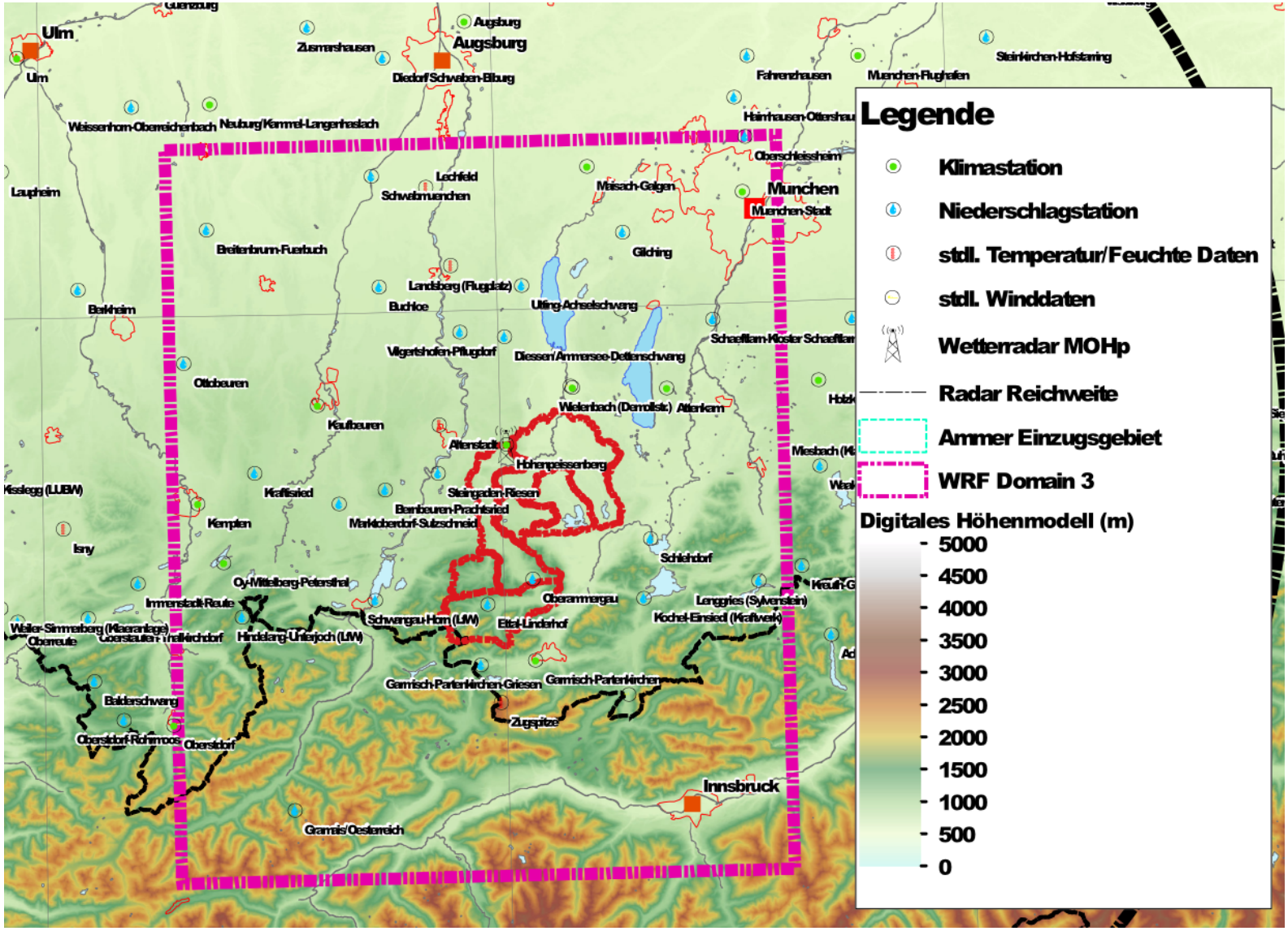
[Measurement: M. Mauder, KIT/IMK-IFU]





Joint water and energy flux observations, e.g. Rott (Ammer catchment)

WRF-NDHMS Ammer



WRF domain and Ammer catchment

WRF Configuration

Discretization 3 WRF domains

D01: dx= 15km
D02: dx= 5km
D03: dx= 1km
44 vertical layers

Routing subgrid

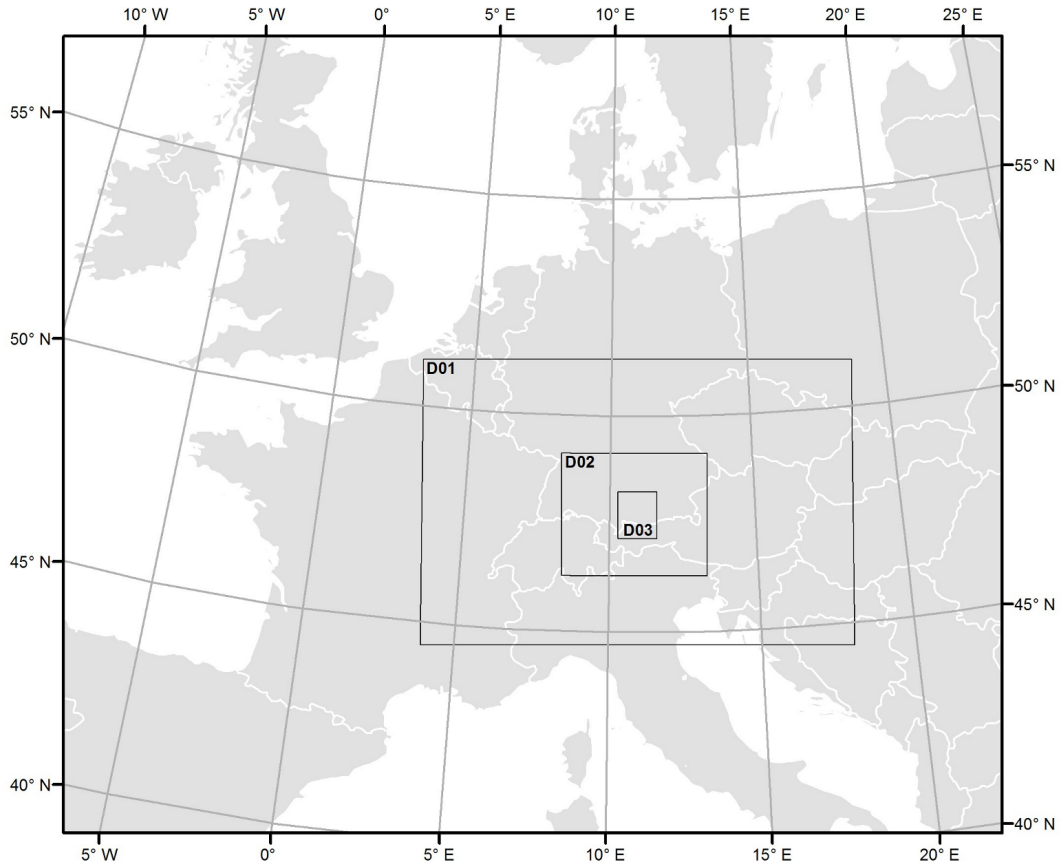
dx=100m

Global driving

ERA-INTERIM

Period

Jun-Aug 2005
August flooding
(20.-23.8.2005)

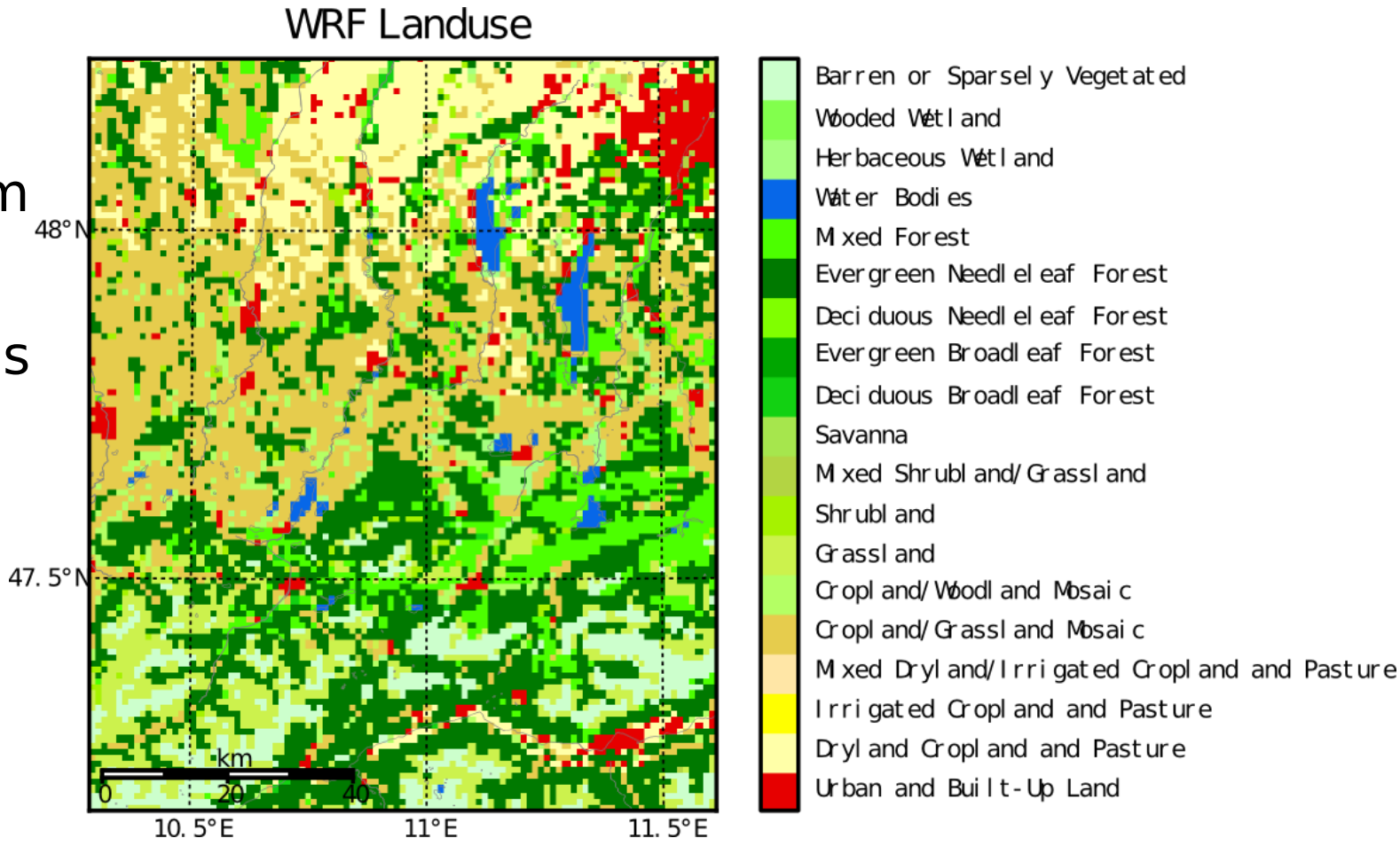


WRF Land Use

CORINE European land cover, 100m (2006)
http://www.corine.dfd.dlr.de

Aggregated 1km

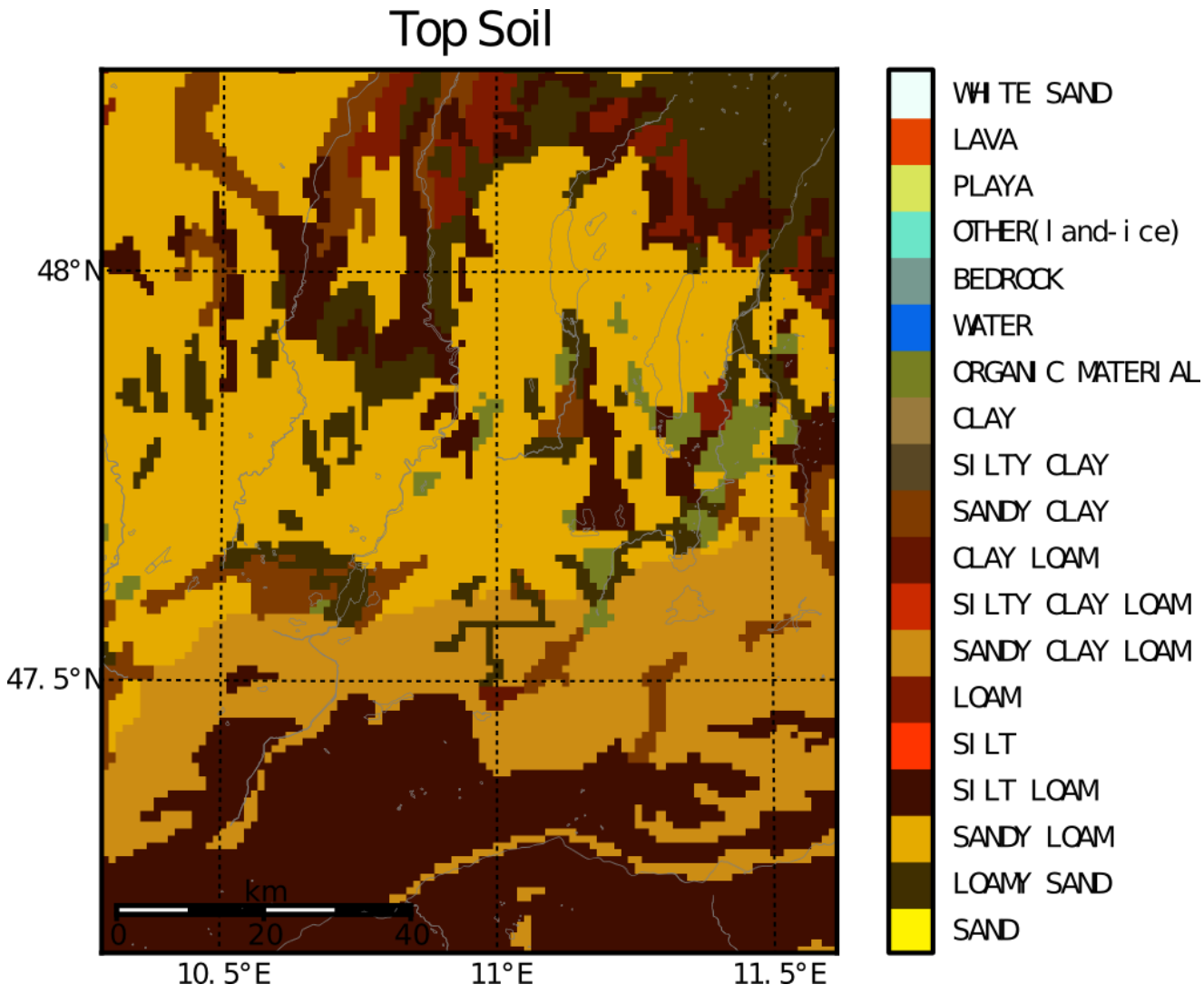
Converted into
19 USGS classes



WRF Soil Type

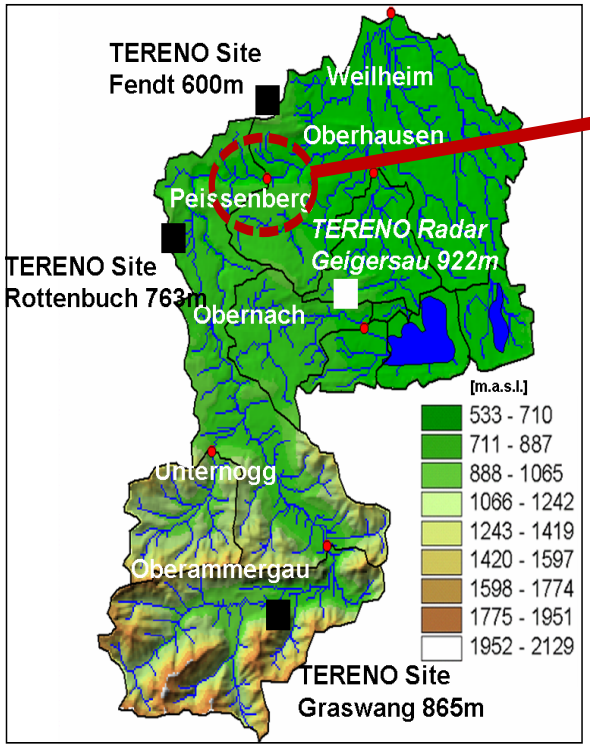
Harmonized world soil database, 1km (FAO)

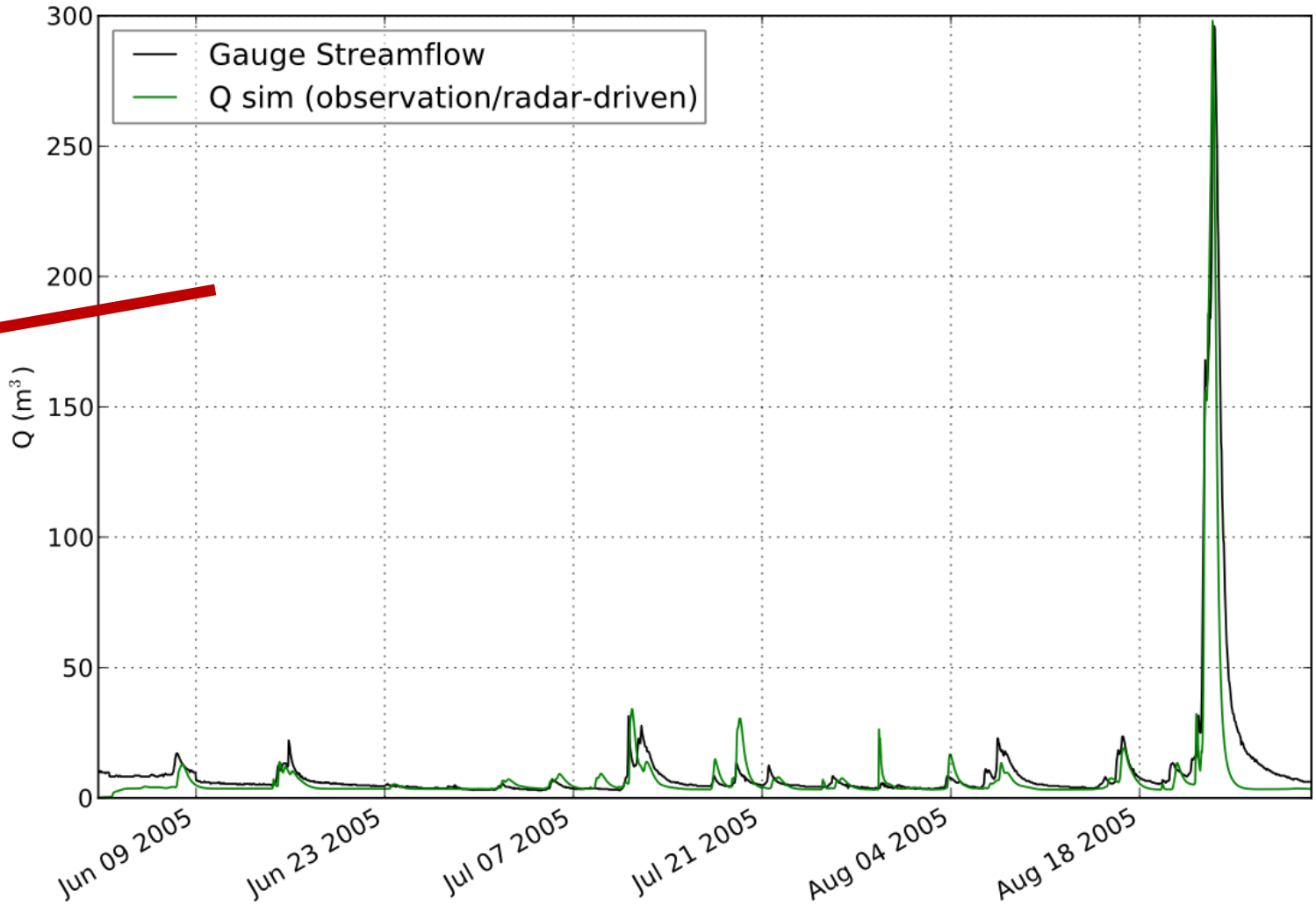
Refined with local data



Results

Observation driven NDHMS





Results

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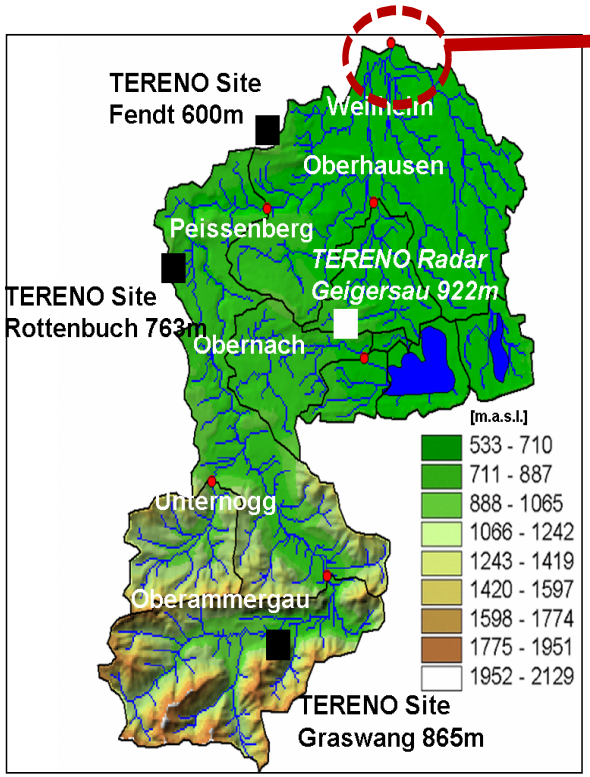

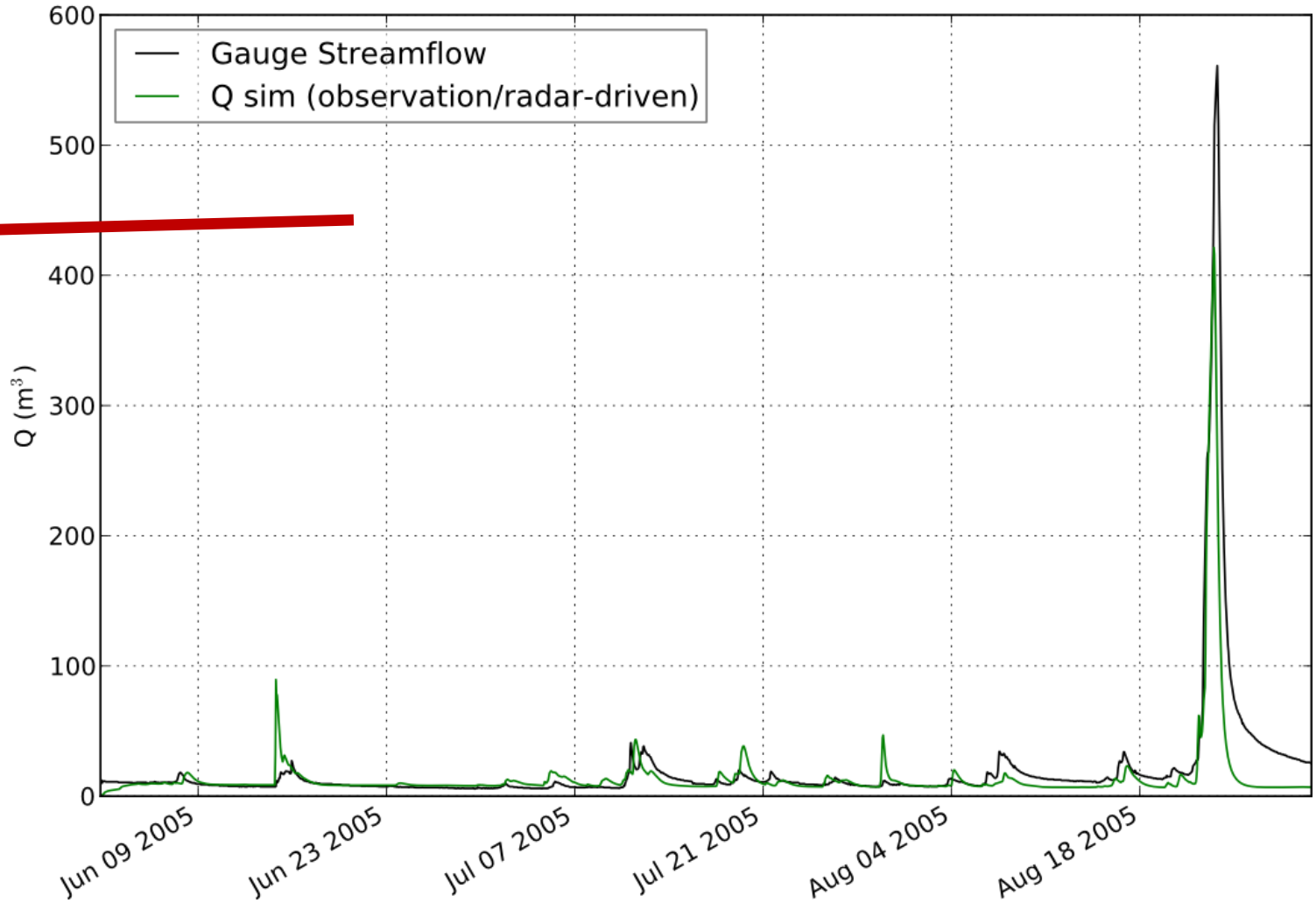

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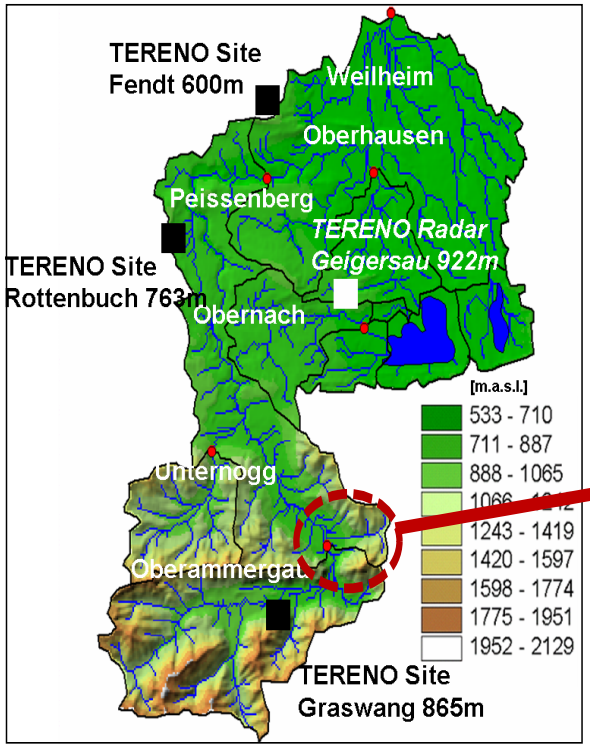

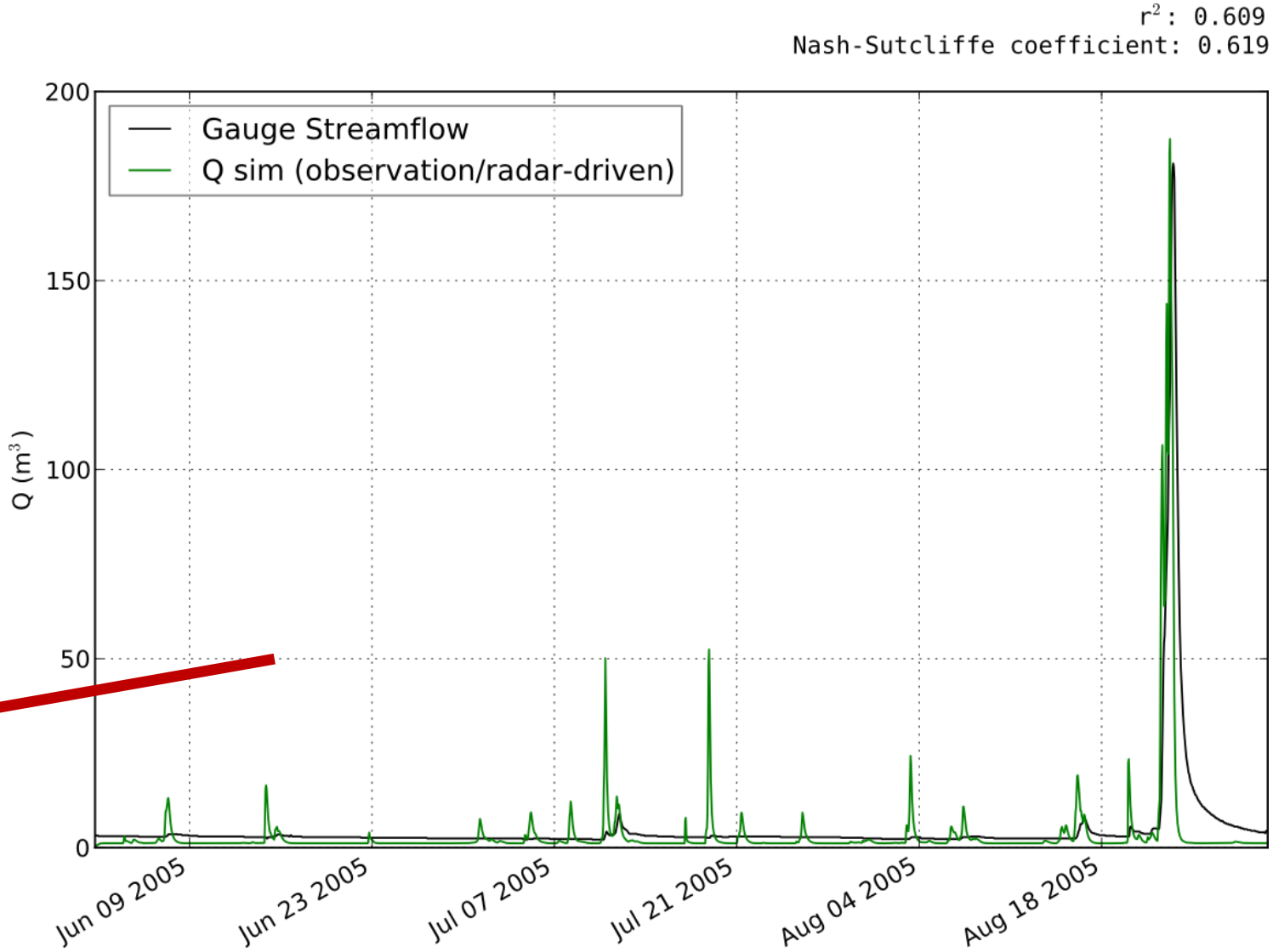

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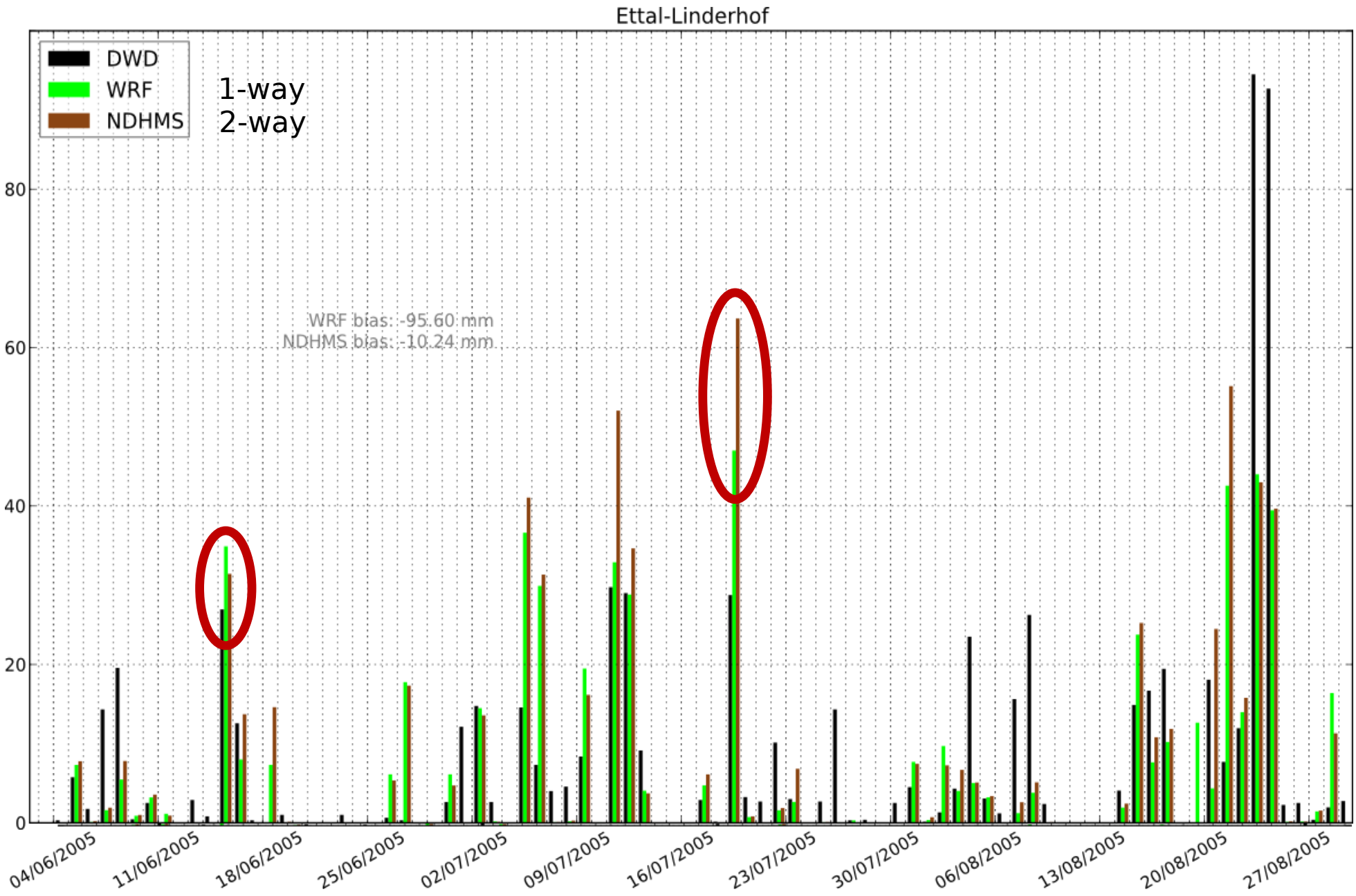
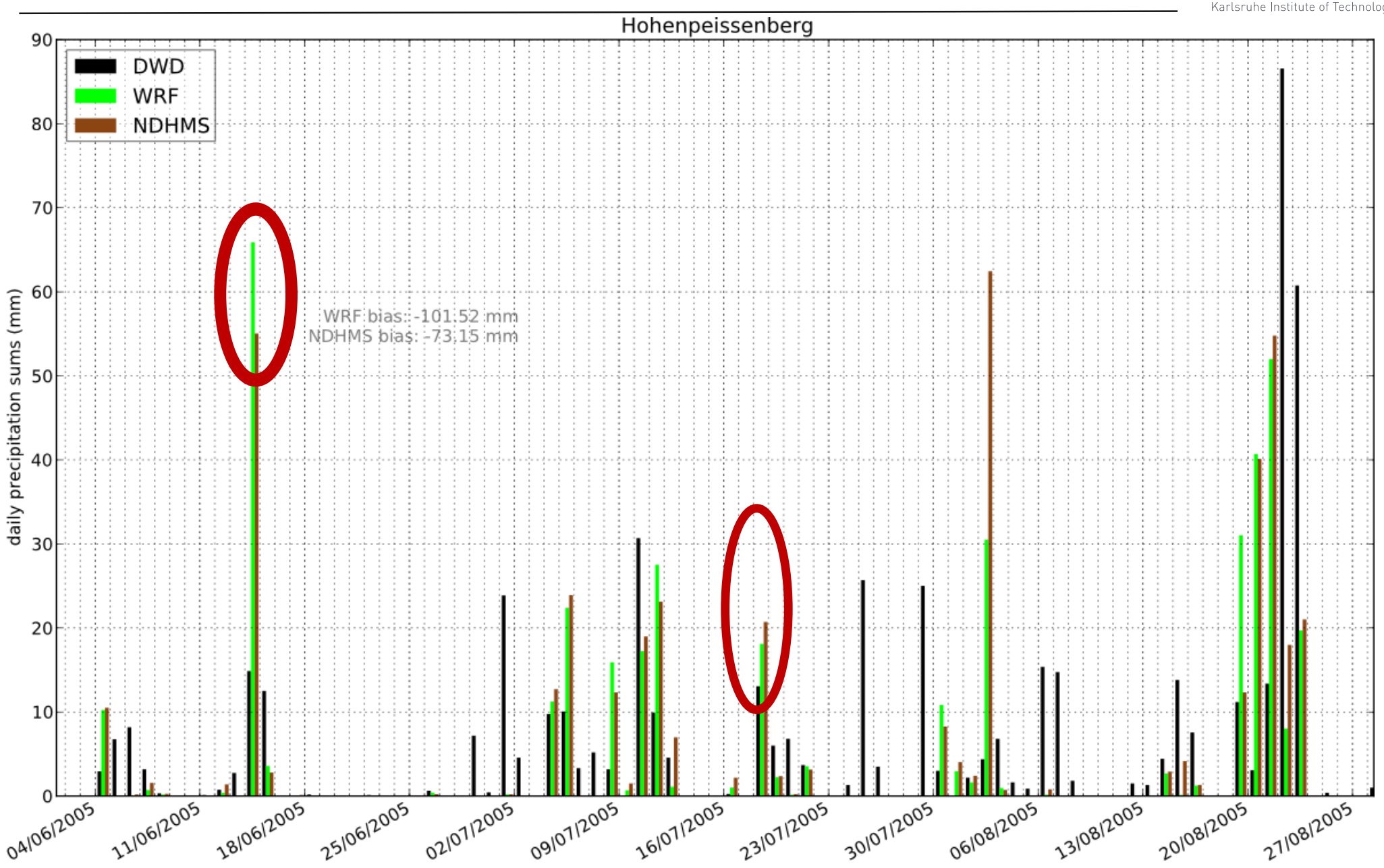
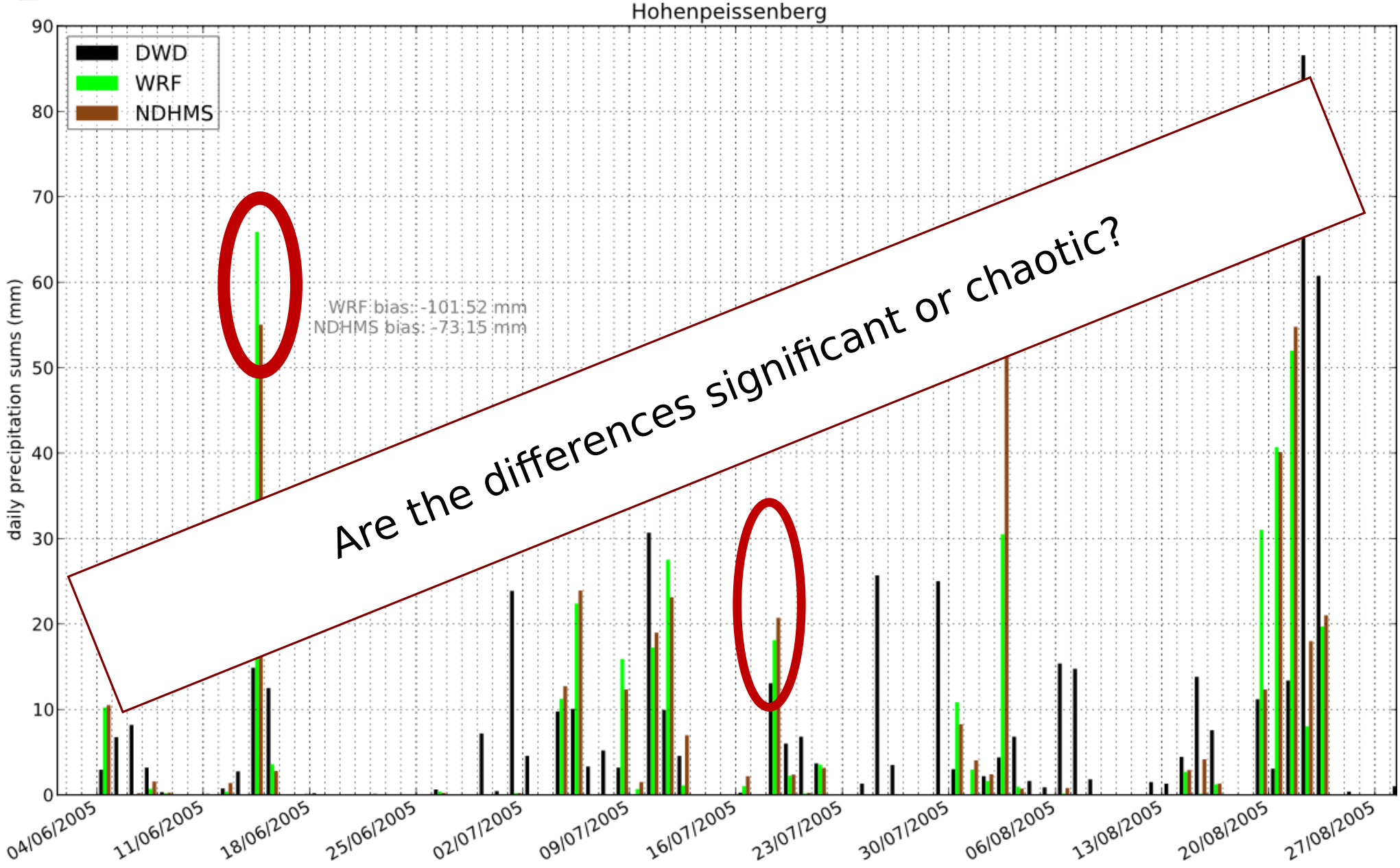

Ettal-Linderhof
DWD
WRF
NDHMS
1-way
2-way
WRF bias: -95.60 mm
NDHMS bias: -10.24 mm
0
20
40
60
80
04/06/2005
11/06/2005
18/06/2005
25/06/2005
02/07/2005
09/07/2005
16/07/2005
23/07/2005
30/07/2005
06/08/2005
13/08/2005
20/08/2005
27/08/2005

Results


Hohenpeissenberg
DWD
WRF
NDHMS
WRF bias: -101.52 mm
NDHMS bias: -73.15 mm
daily precipitation sums (mm)
0
10
20
30
40
50
60
70
80
90
04/06/2005
11/06/2005
18/06/2005
25/06/2005
02/07/2005
09/07/2005
16/07/2005
23/07/2005
30/07/2005
06/08/2005
13/08/2005
20/08/2005
27/08/2005

Results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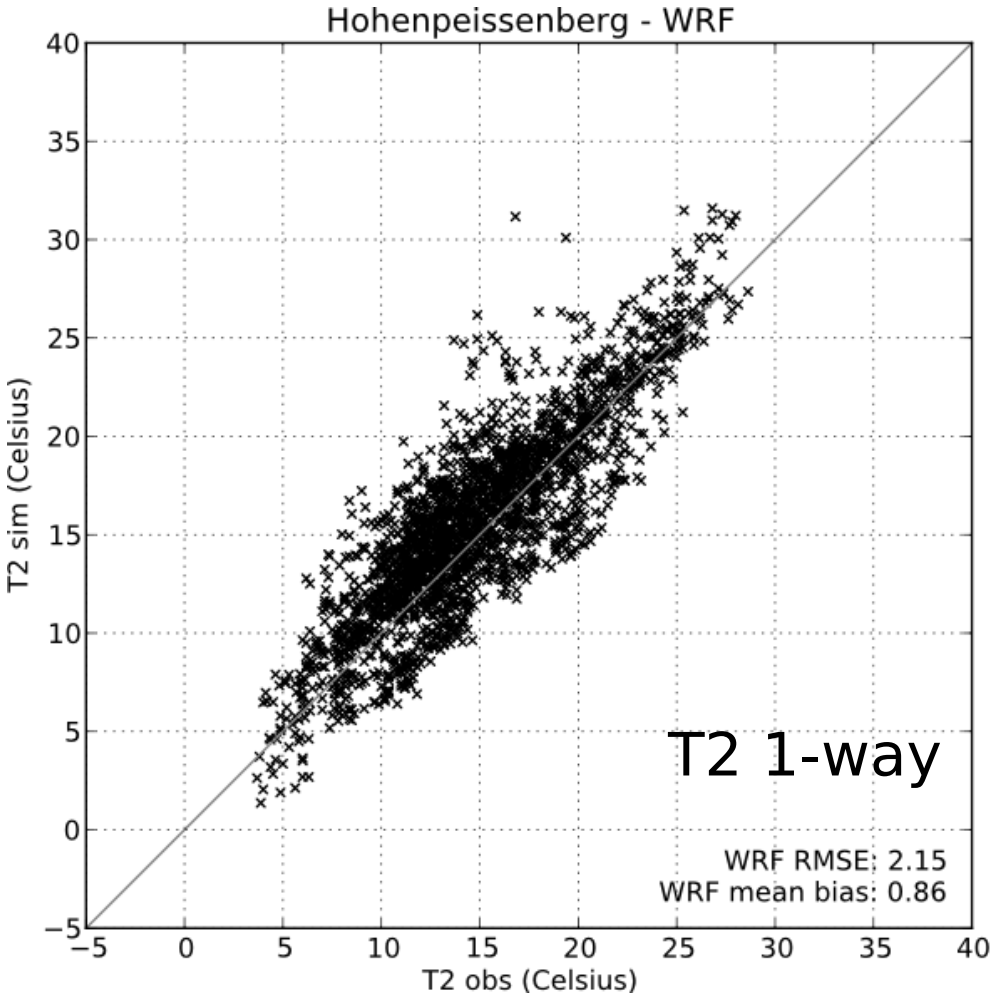
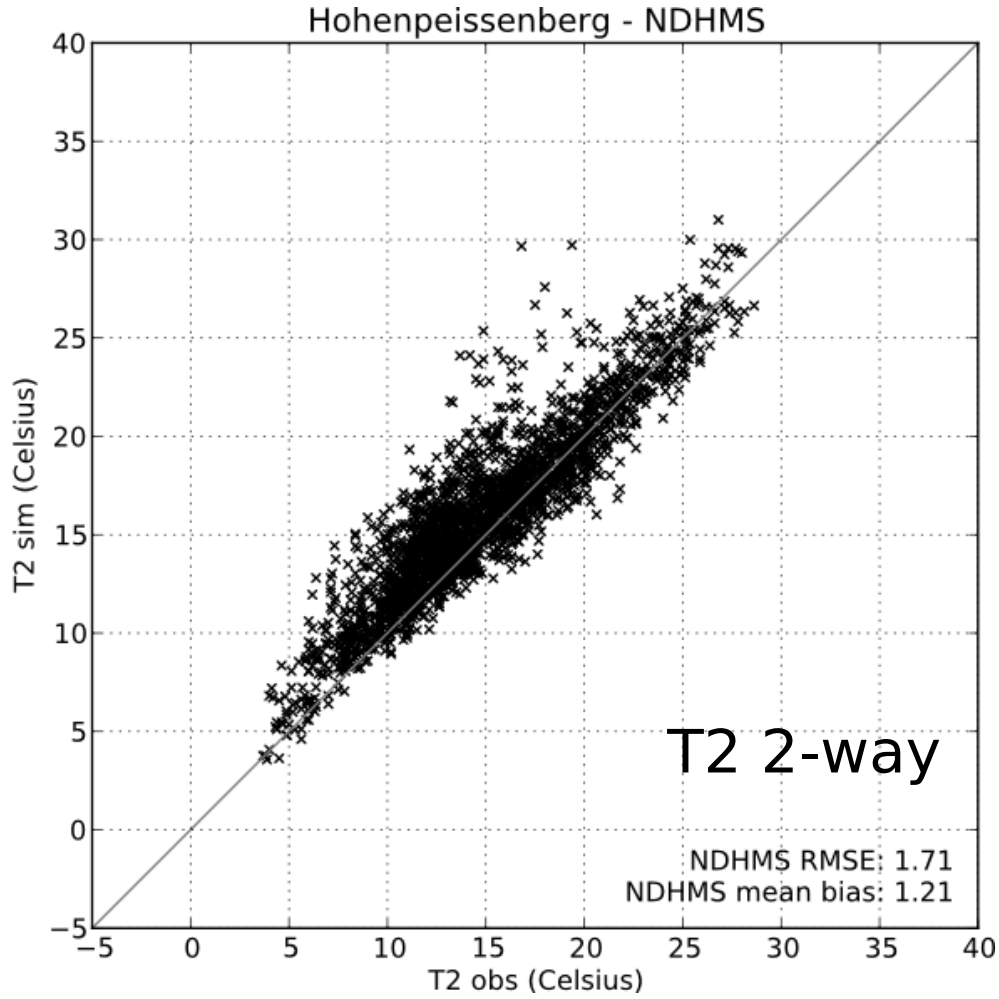
09/07/2005
16/07/2005
23/07/2005
30/07/2005
06/08/2005
13/08/2005
20/08/2005
27/08/2005
Are the differences significant or chaotic?

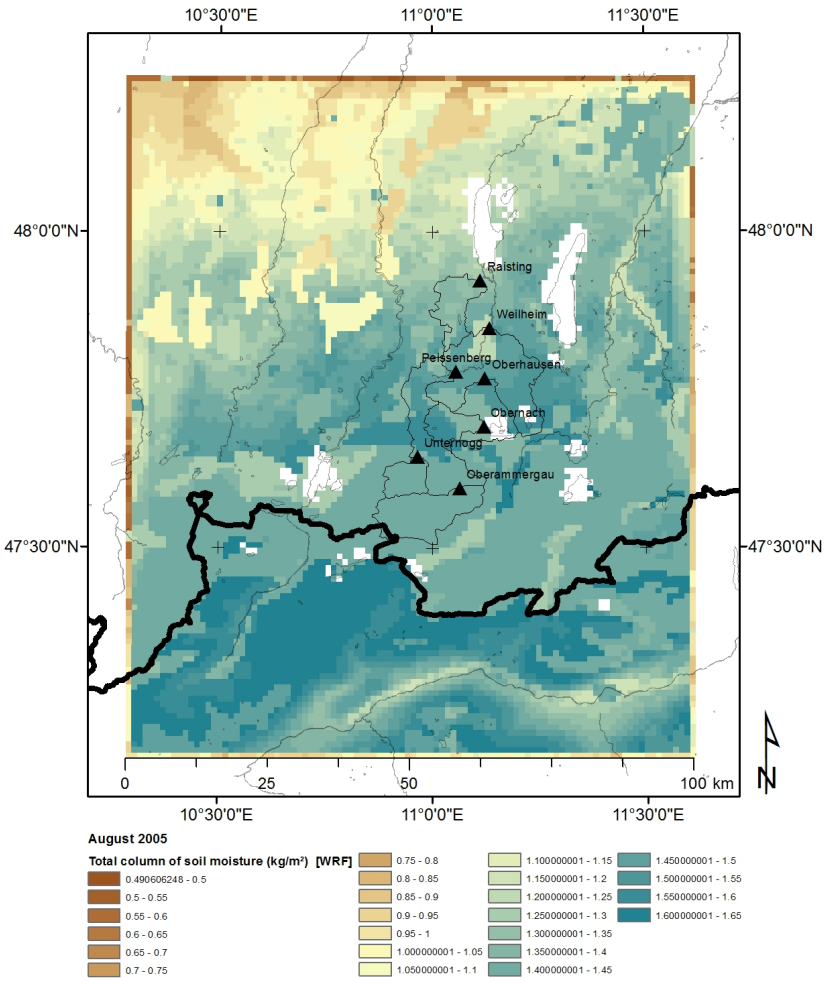
Results


Hohenpeissenberg - WRF
T2 sim (Celsius)
T2 obs (Celsius)
T2 1-way
WRF RMSE: 2.15
WRF mean bias: 0.86

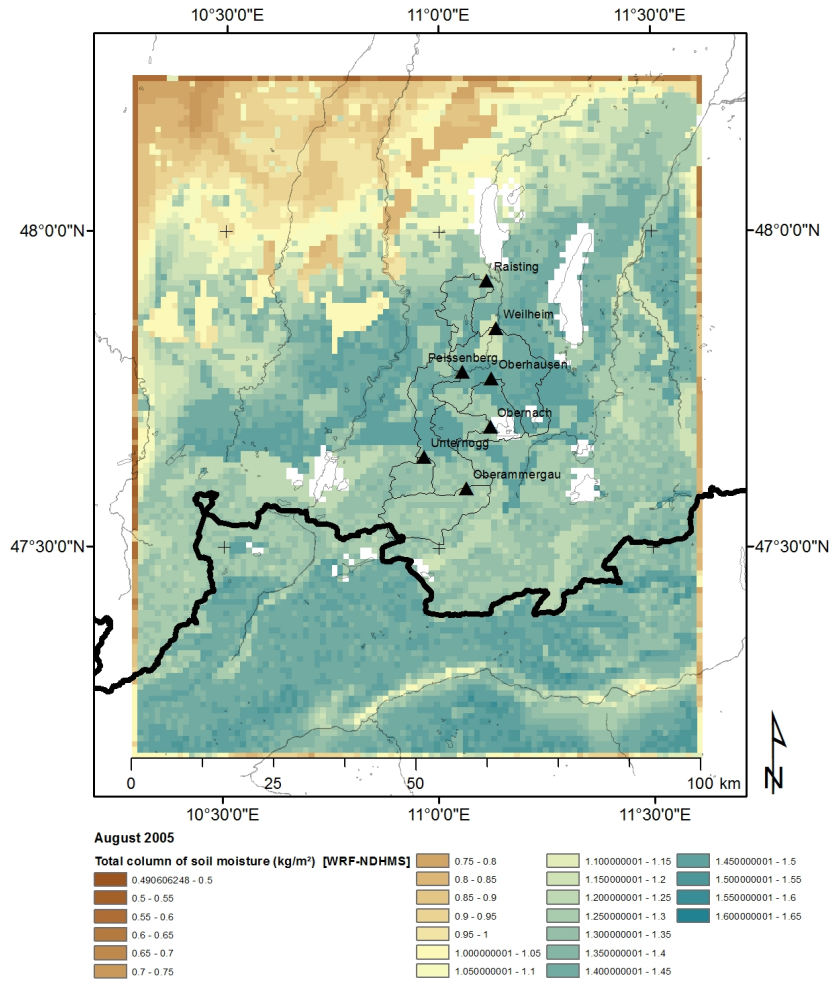

Hohenpeissenberg - NDHMS
T2 sim (Celsius)
T2 obs (Celsius)
T2 2-way
NDHMS RMSE: 1.71
NDHMS mean bias: 1.21

Results

Soil water content



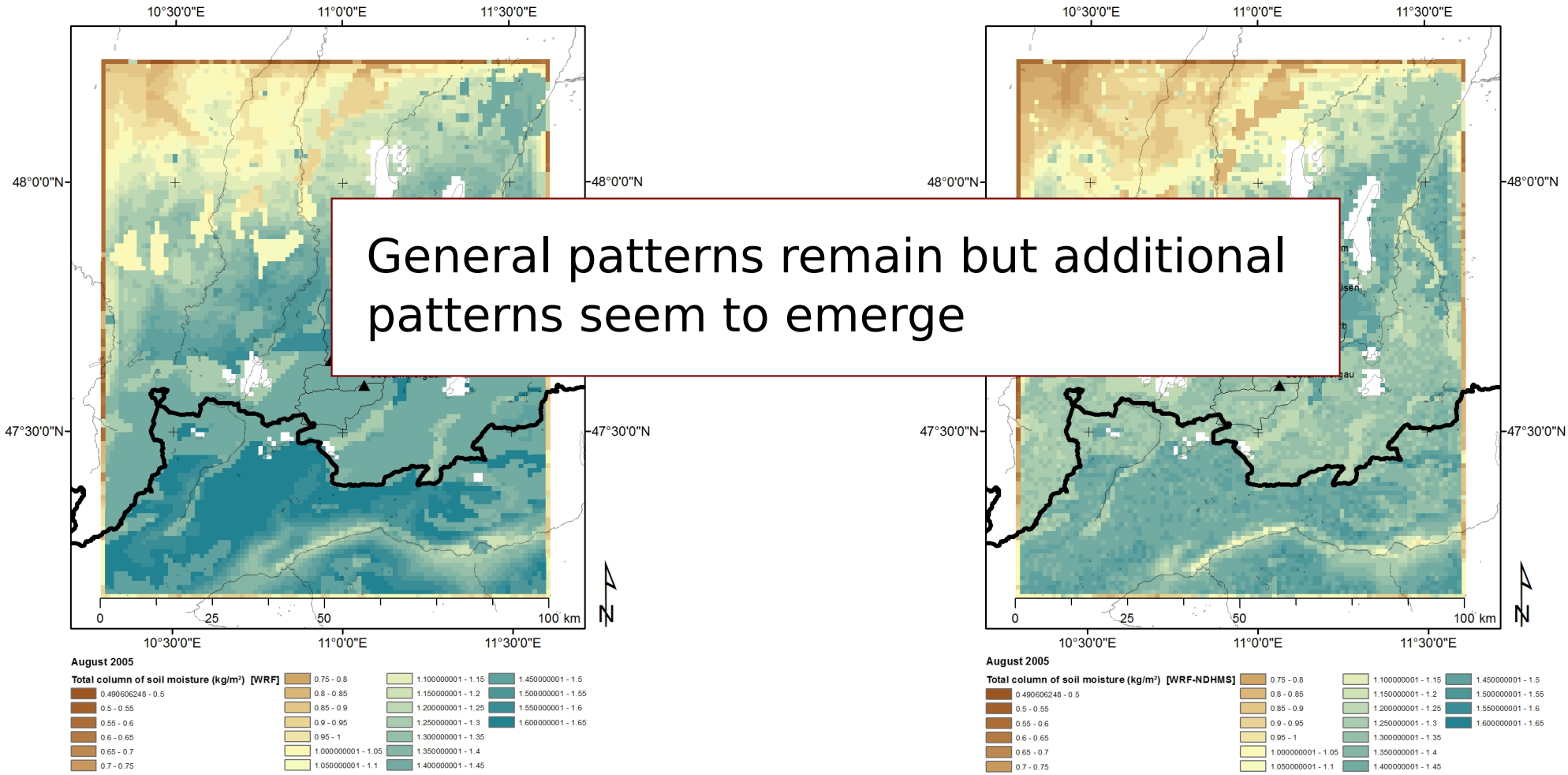
1-way coupling



2-way coupling

Results

Soil water content



General patterns remain but additional patterns seem to emerge

1-way coupling

2-way coupling

Summary and Outlook

WRF/NDHMS

- Compartment crossing model system, feedback effects, sub-grid scale
- Enhanced validation possibilities (satellite, ground based)
  - Energy
  - Soil moisture
  - Discharge

TERENO
Terrestrial Environmental Observatories

- Different response for one-way and two-way coupled versions
- Indication that enabling of lateral transport impacts atmospheric properties

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TERENO
Terrestrial Environmental Observatories

- Different response for one-way and two-way coupled versions
- Indication that enabling of lateral transport impacts atmospheric properties

Are the differences significant or chaotic?

Summary and Outlook

WRF/NDHMS

TODOs & Ideas

- Energy fluxes, comparison with GEOTOP study (Ammer)
- Enhancement of base flow / groundwater
- Application in climate mode
- Inclusion of vegetation parametrization models
- Application e.g. for TERENO Bode catchment

EARLY-CAREER SCIENTIST WORKSHOP (ECSW)

16-17 September 2011, Mercure Hotel
Challenges and chances of interdisciplinary collaboration in Land Ecosystem - Atmosphere Processes (LEAP) science

POST-CONFERENCE WORKSHOP (PCW)

25--26 September 2011, IMK-IFU, KIT
Challenges and chances of integrated long-term LEAP observatories
This event is by invitation only. For more information, please contact HaPe.Schmid@kit.edu.

IMPORTANT DATES

~~15 Mar 2011~~	~~Deadline for abstract submission~~
15 May 2011	Confirmation of abstracts
30 Jun 2011	Deadline for early-bird registration
30 Jun 2011	Deadline for ECSW registration
30 Jun 2011	Deadline for PCW registration
16-17 Sep 2011	Early-Career Scientist Workshop (ECSW)
18-23 Sep 2011	iLEAPS Science Conference
25-26 Sep 2011	Post-conference workshop (PCW)

3rd iLEAPS Science Conference

Integrated Land Ecosystem-Atmosphere Processes Study

Abstract Deadline 15 April 2011

Garmisch-Partenkirchen
Germany
18 – 23 September 2011

SATELLITE EVENTS

Several satellite events are planned during the conference, contact ipo@ileaps.org.

SPONSORS AND EXHIBITION

We warmly invite institutions, companies, and publishing houses to fully attend our event. For details, please see the conference website, contact HaPe.Schmid@kit.edu and ipo@ileaps.org.

SOCIAL PROGRAM

Ice breaker	18 September 2011
Excursion/s	21 September 2011
Conference dinner	21 September 2011

Ice breaker and conference dinner will be included in the conference fee. iLEAPS will arrange half-day excursions on 21 September 2011 which you can book together with your conference registration. For more details, please see conference website.

www.ileaps.org/science_conf_2011

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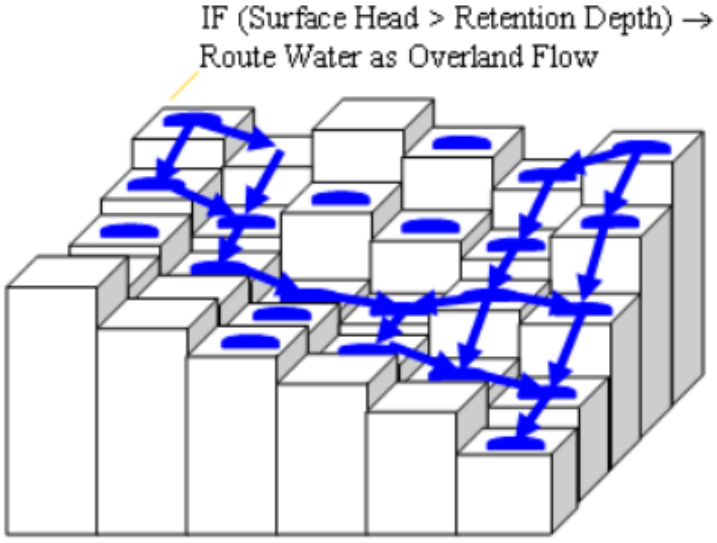
www.ileaps.org/science_conf_2011

Thanks for your attention!

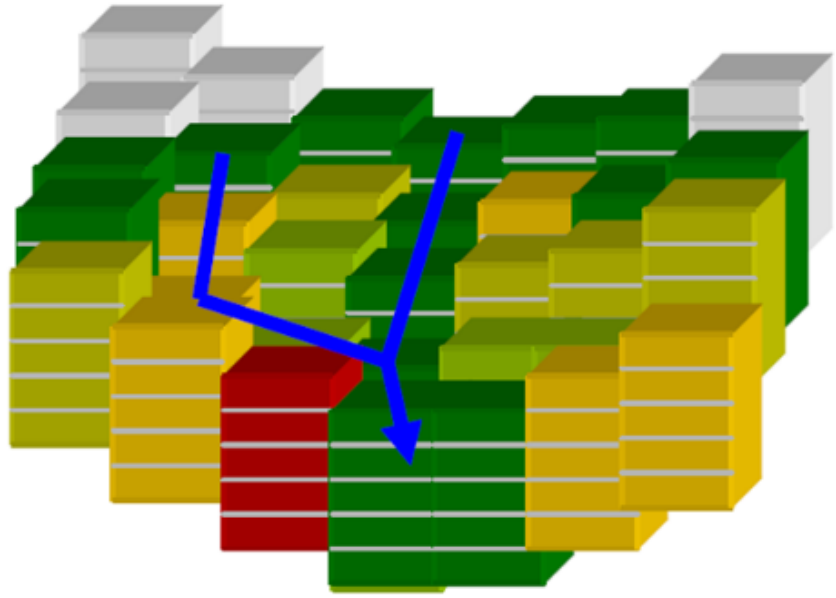
WRF-ARW Setup

WRF 3.1.1
forcing: ECMWF ERA-Interim (6 hourly)
3 one-way nesting configuration
Horizontal grid resolution: 15 - 5 - 1 km
Routing horizontal grid resolution: 100m
44 vertical levels (smaller spacing at lower boundary)
Model top: 10 hPa
Fixed time step: 48 - 12 - 3 s
Microphysics scheme: RUN1: WSM6 RUN2: Thompson
Shortwave radiation scheme: Dudhia scheme
Longwave radiation scheme: RRTM scheme
PBL parametrization: Yonsei University scheme
Cumulus parametrization: Kain-Fritsch scheme for domain 1 and 2 only
Surface Layer: Noah LSM + NDHMS
NDHMS: 8 soil layers (2m)
WRF: 4 soil layers (2m)
Custom soil dataset for domain 3
Changes to NDHMS parameter files:
GWBUCKPARM.TBL (groundwater bucket parametrization)
VEGPARM.TBL (surface roughness length)
CHANPARM.TBL (Mannings roughness parameter)

Surface overland flow



1- or 2-Dimensional
Diffusive Wave
Overland Flow Routing
Ogden, 1997



- Surface overland flow is calculated using a diffusive wave formulation
- Two methods implemented
  - 2d (x,y direction)
  - 1d (steepest descent or 'D8')

- Flow is routed across terrain elements until it intersects a "channel" grid cell indicated by the blue line where it becomes „in-flow" to the stream channel network.

(Gochis, 2010)

Saturated Subsurface Routing

- Following Wigmosta et al. (1994)
- Calculated prior to the routing of overland flow to include the updated values for surface head
- 8 soil layers, each depth can be manually specified
  - Currently the depths of the individual soil layers are constant throughout the entire model domain
- Lateral flow is calculated by a quasi 3d flow representation, which include effects of:
  - Topography
  - Saturated soil depth (layers)
  - Lateral saturated hydraulic conductivity

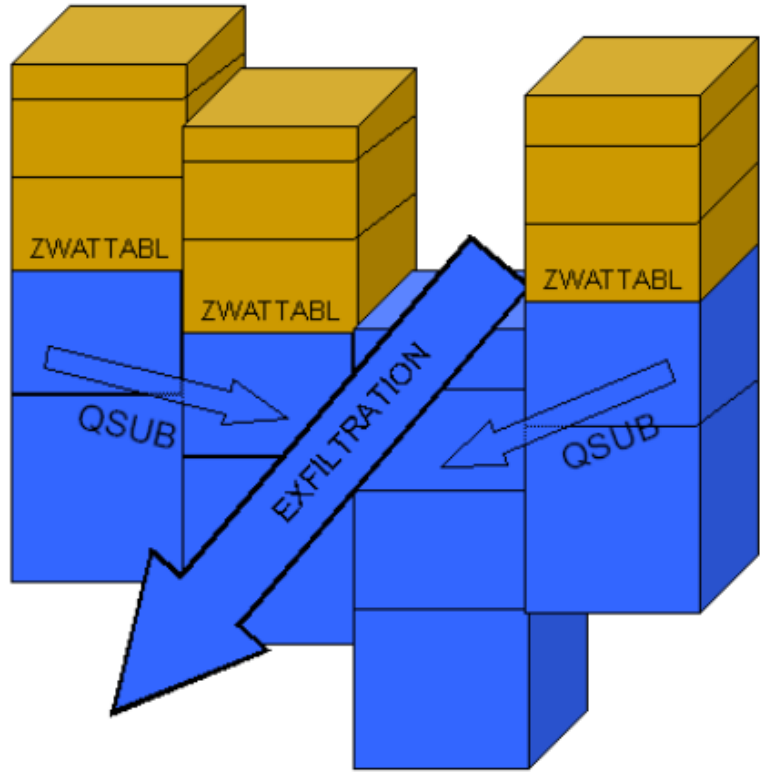
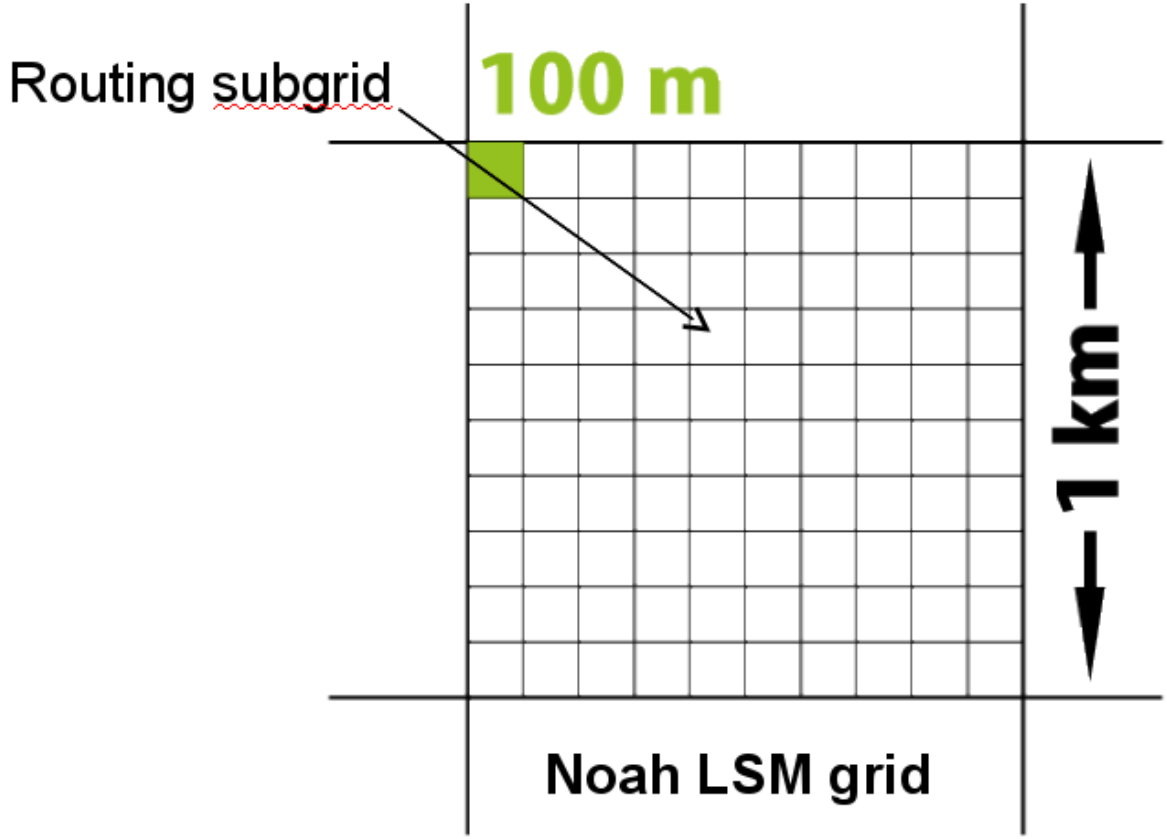


Figure 6: Saturated Subsurface Flow Processes in Noah-router

(Gochis, 2010)

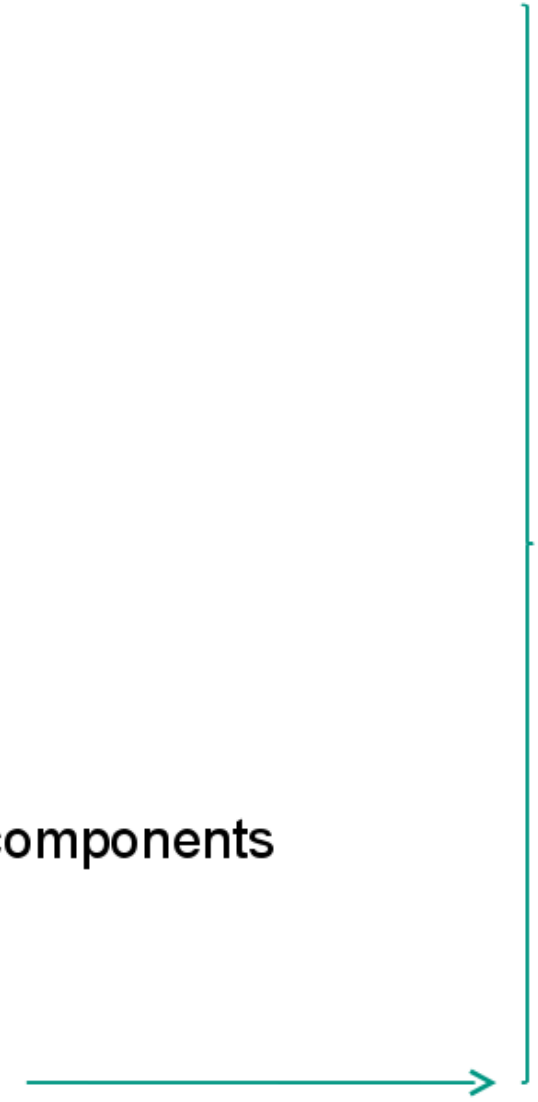
Subgrid Aggregation / Disaggregation

- Activated when routing of overland flow or subsurface flow is selected and the routing grid is different from the LSM grid
- Only routing is represented within the subgrid
- Also possible to run both the LSM and the routing with the same grid size
- Typical resolutions:
  - LSM: 1-4km
  - Subgrid: 30-100m



Forcing data

- Incoming shortwave radiation
- Incoming longwave radiation
- Specific humidity
- Air temperature
- Surface pressure
- Near surface wind in U and V components
- Liquid water precipitation rate



1km WRF domain, downscaled ECMWF Reanalysis

Hourly station data, spatial interpolated to 1km grid