Numerical Simulation System for Environmental Studies: SPEEDI-MP

Research Group for Environmental Science,
Japan Atomic Energy Agency

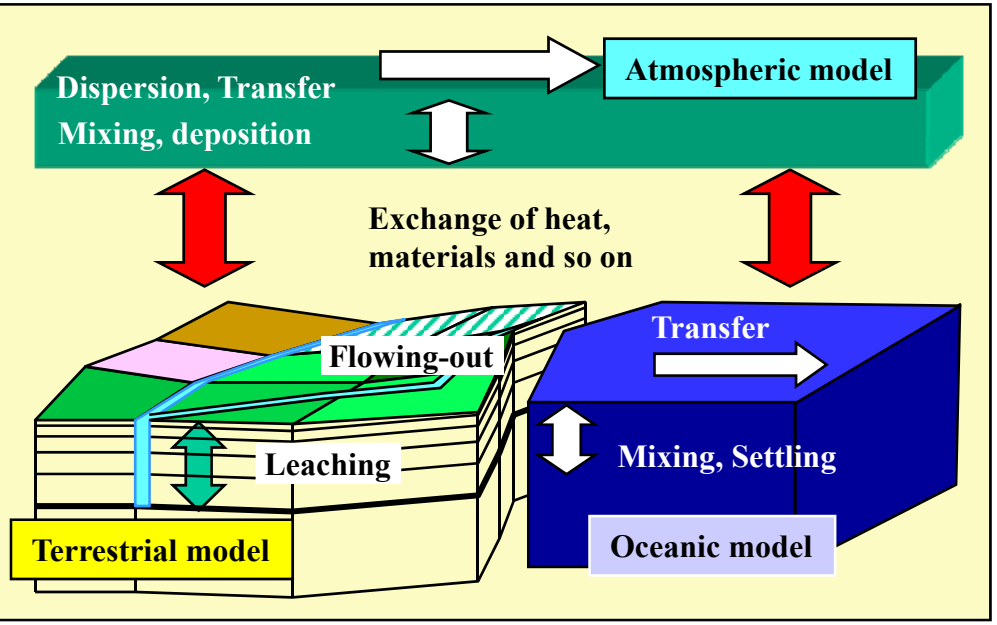
Development of SPEEDI-MP

Simulations in a multiple environment

Changes and needs of the society

- Diversification of nuclear activities and complication of release conditions
  → Advance in nuclear fuel cycle, increase of nuclear facilities in East Asia, and so on
- General environmental problems to be solved by science and technology
  → water cycle problems (desertification, tidal wave), global warming, and so on

Expansion: elucidation of the behavior of materials in a multiple environment



Use of results (Nuclear problems)

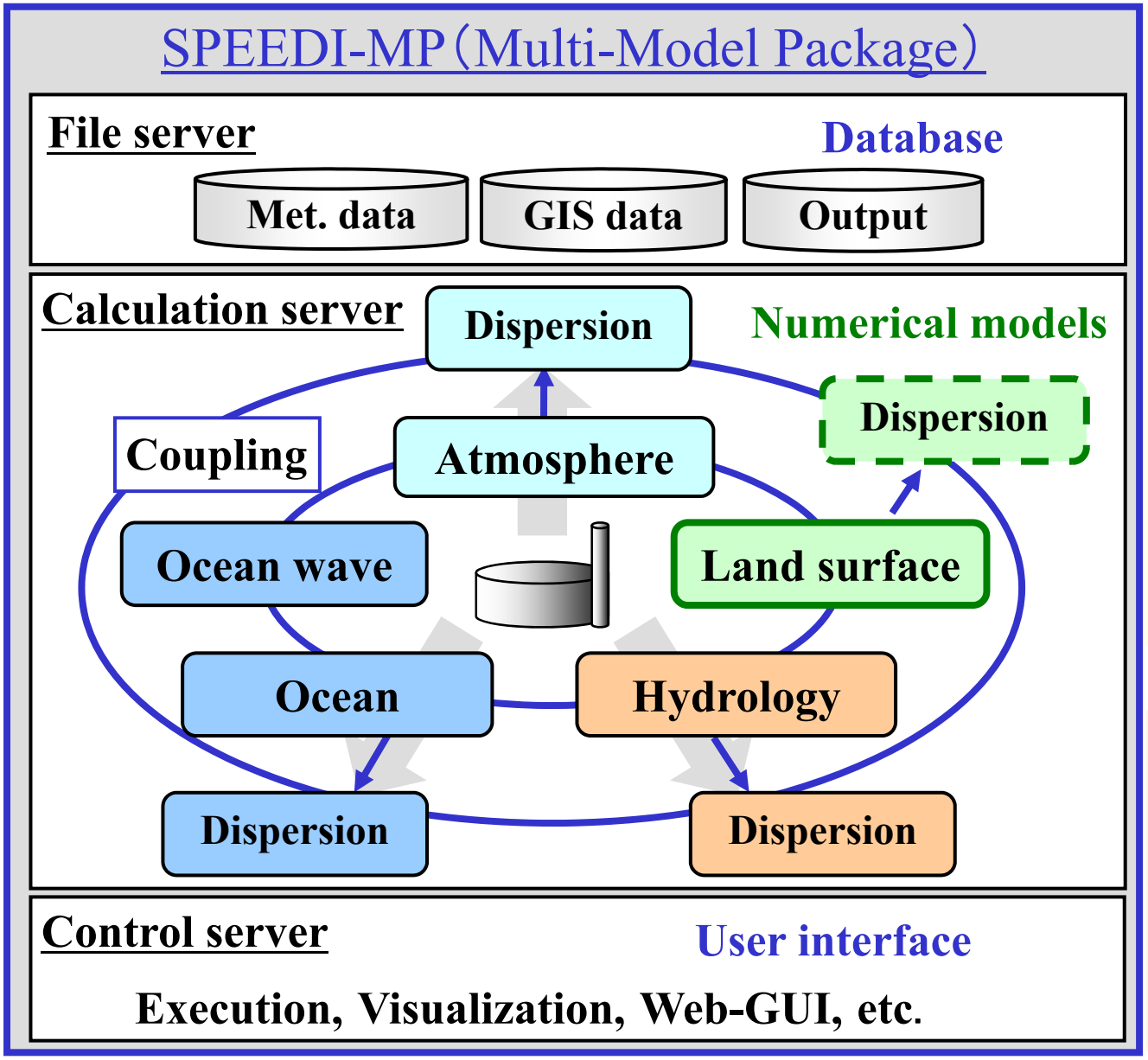
- Nuclear emergency responses in an early stage and environmental surveys in middle/late stages
- International collaboration on accidents of environmental pollution
- Responses to environmental problems peculiar to the Japan Sea

Ripple effects (general problems)

- Water cycle problems
  → Simulations on possibility/effects of tree-planting in deserts
  → Simulations on storm surges/waves
- Global warming
  → Study on CO_2 exchange in forests

Development of SPEEDI-MP

Structure of the system



Development of SPEEDI-MP for nuclear problems

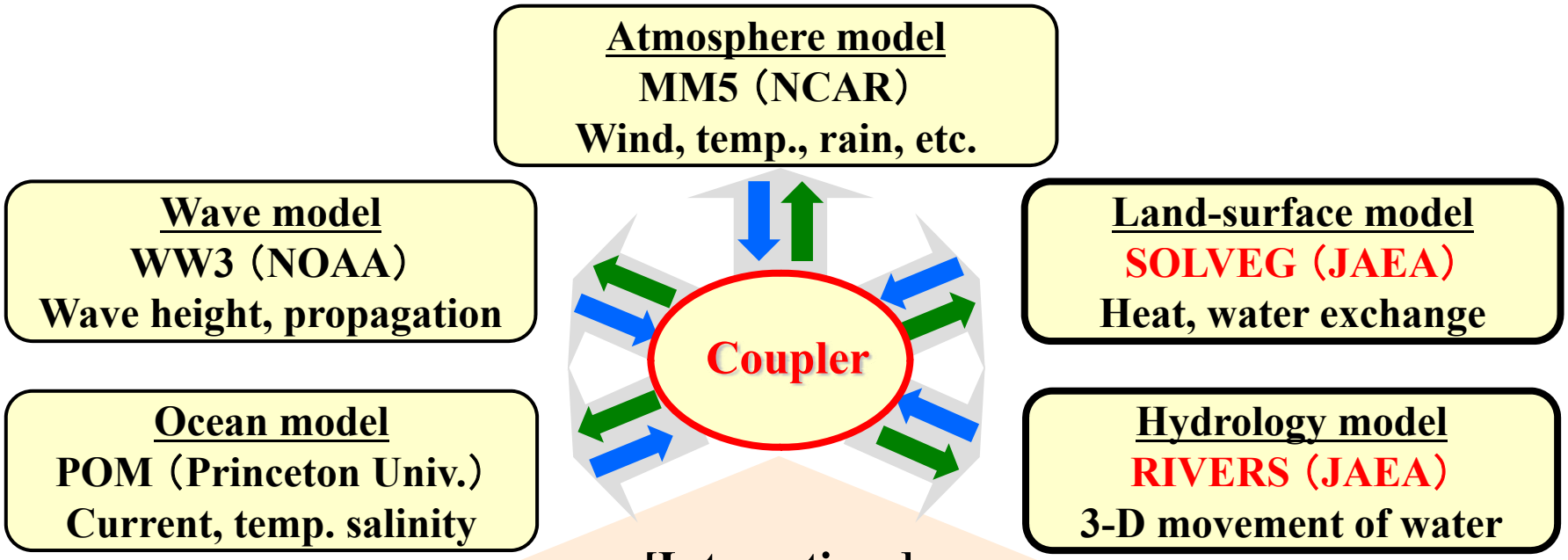
- Numerical models
  - Physical models
  - Dispersion models
- Model coupling
  - Water cycle & dispersion
- Utility tools
  - Web-GUI
  - Visualization

Application to environmental problems

- Water problems
- Climate change

Development of SPEEDI-MP

Coupled water cycle model



[Interactions]

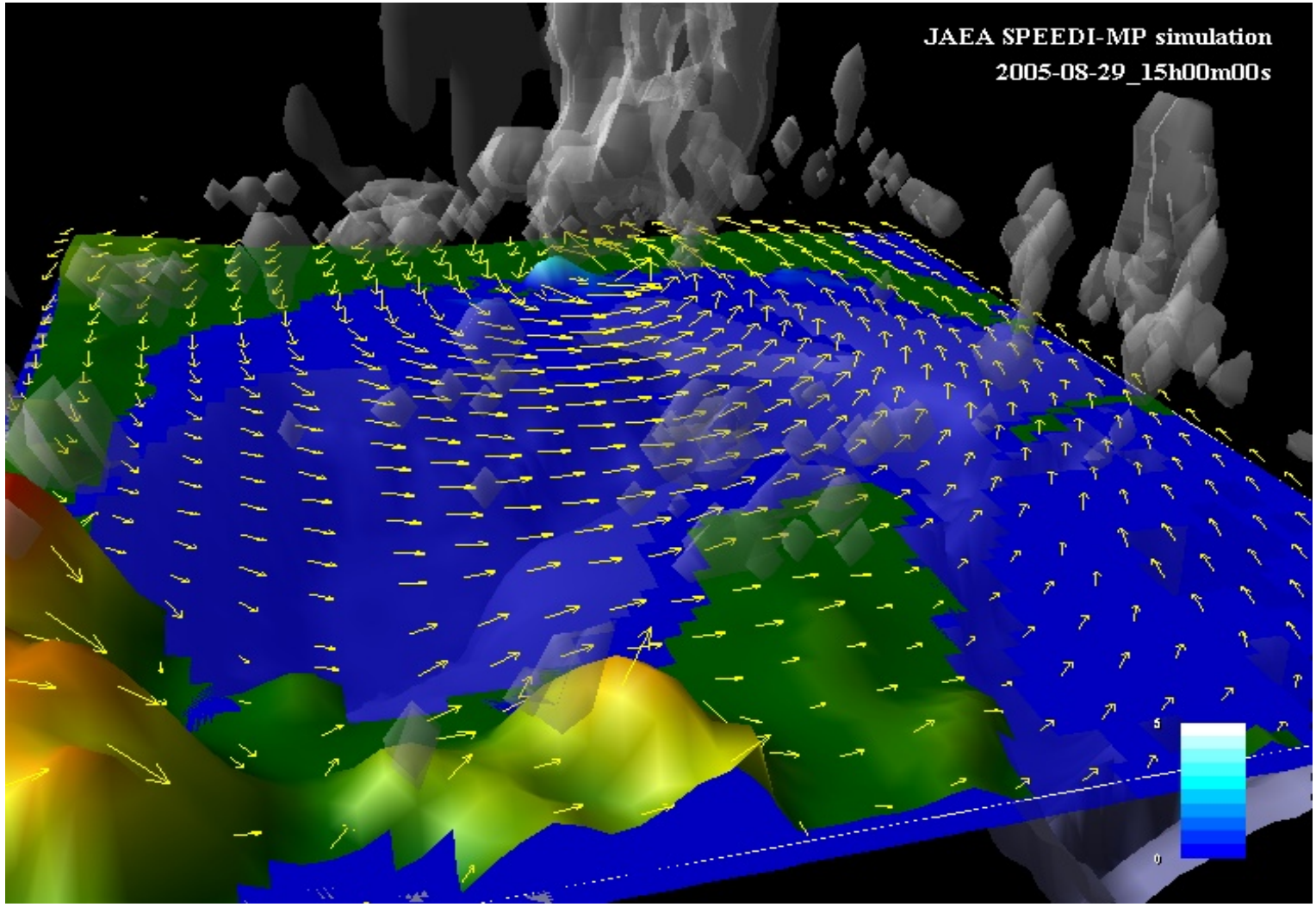
MM5: wind, pressure	⇒	POM: current, elevation	WW3: wave generation
surface met. field	⇒	SOLVEG: upper boundary condition	
WW3: wave break stress	⇒	POM: current	MM5: surface roughness
POM: current, SST	⇒	WW3: wave generation	MM5: SST
SOLVEG: surface fluxes	⇒	MM5: boundary condition	RIVERS: surface water
RIVERS: land water movement	⇒	SOLVEG: run-off	POM: river flow

Realization of complete atmosphere, land, ocean dynamical coupling

Application of coupled water cycle model

■ Simulation of storm surge caused by Hurricane Katrina in Aug. 2005.

[Visualization] MM5: surface wind, cloud, POM: sea surface elevation



Coupling

MM5 ↕ WW3 ↕ POM

Elevation

5 m

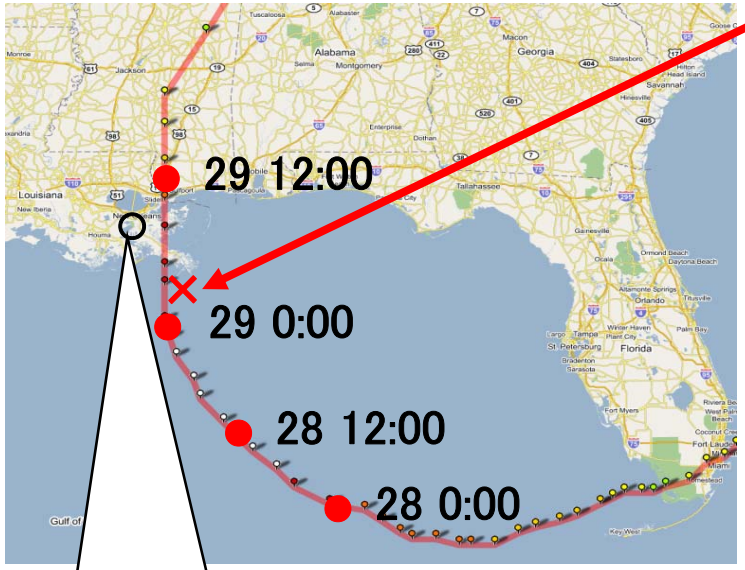
0 m

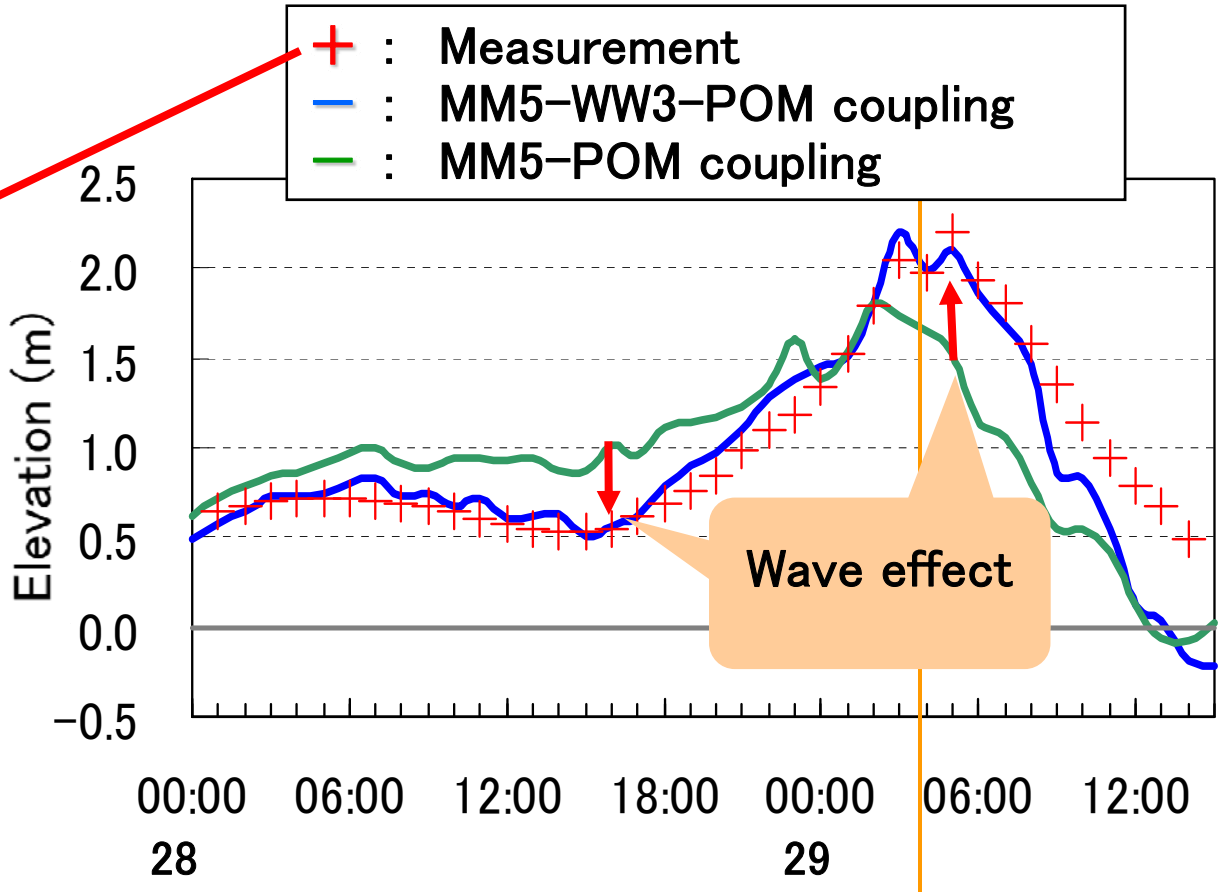
Application of coupled water cycle model

- Coupled model simulated the storm surge successfully.
- Calculation was improved by considering wave effect.

⇒ **Validation of the atmosphere, ocean-wave, and ocean-current coupling**

Hurricane track





Development of SPEEDI-MP

Application of coupled water cycle model

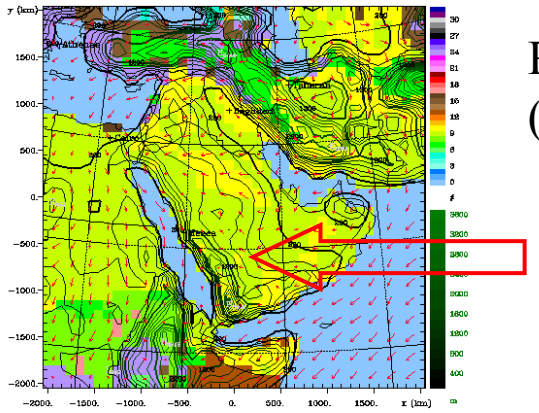
"Advanced Numerical Model System and Countermeasure Technology for Regional- and Meso-scale Water Cycle" by Kyoto Univ. and MHI

[Objectives]

- Development of regional climate model to combine engineering and agriculture fields
- Prediction of water cycle change by wide greening

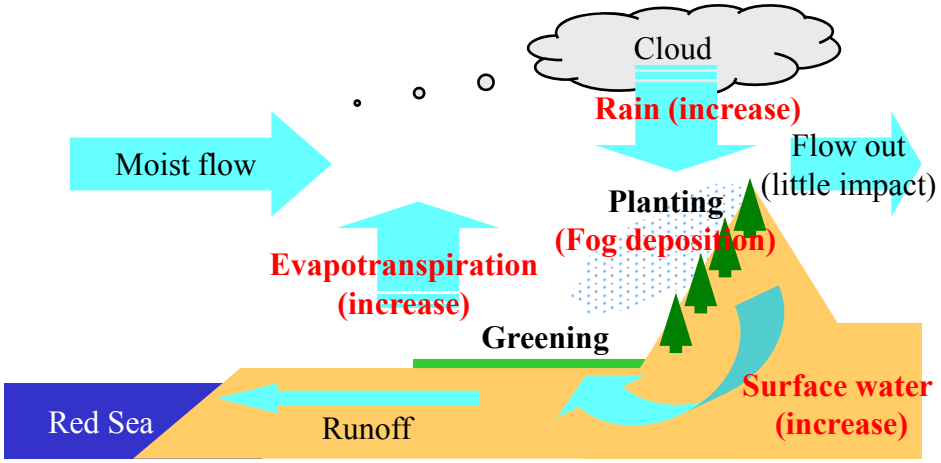
[Subject of JAEA]

- Development of models for air-vegetation-soil exchanges
- Development of model coupler
- Coupling of air, sea, and land models



Research Area (mountainous region in south-west Saudi Arabia)

Desert greening plan of this study:
Acceleration of local water circulation



Application of coupled water cycle model

■ Simulation of flash flood after heavy rainfall at desert area (Nagai et al. 2005)

⇒ **Validation of atmosphere, land-surface, and hydrology coupling**

MM5-SOLVEG-RIVERS coupling

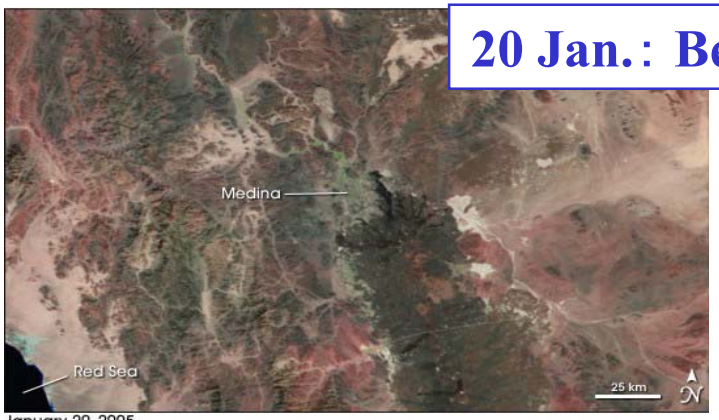
MM5: wind field, cloud, rain

RIVERS: surface water

Simulated and observed flood area

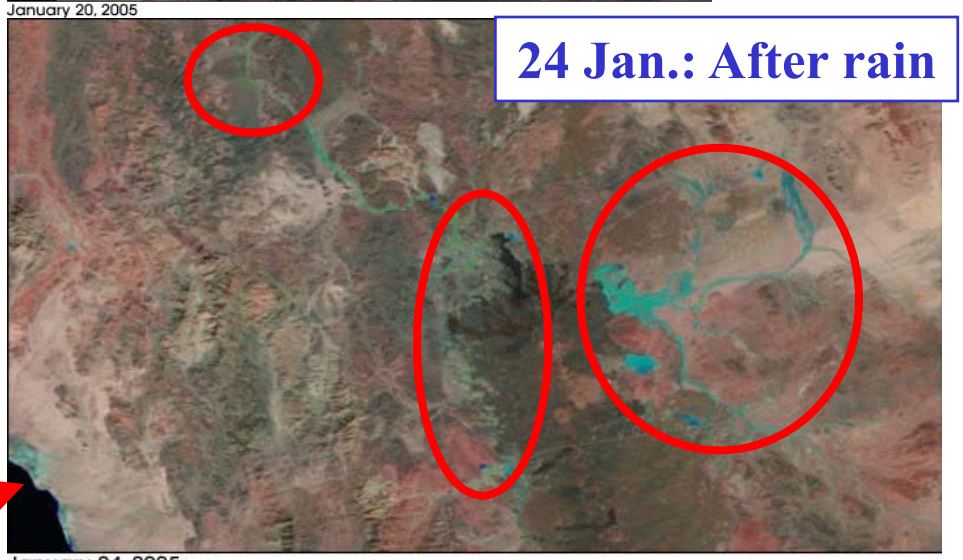
Satellite image

20 Jan.: Before rain



January 20, 2005

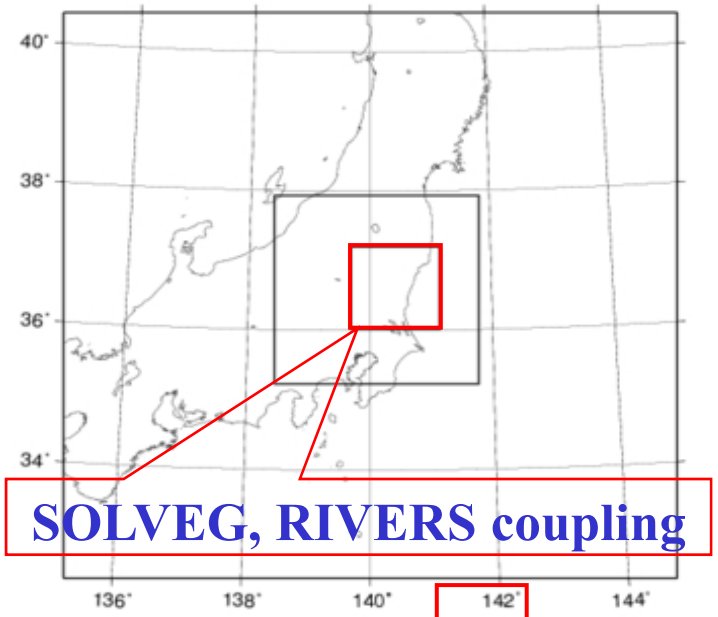
24 Jan.: After rain



January 24, 2005

Five model coupling test

MM5 (3-domain nesting)



[MM5]

- DOM1,2 : Grid 100 × 100 × 23
  DX= 9, 3km DT= 27, 9s
- DOM3 : Grid 130 × 130 × 23
  DX= 1km DT= 3s

[SOLVEG, RIVERS]

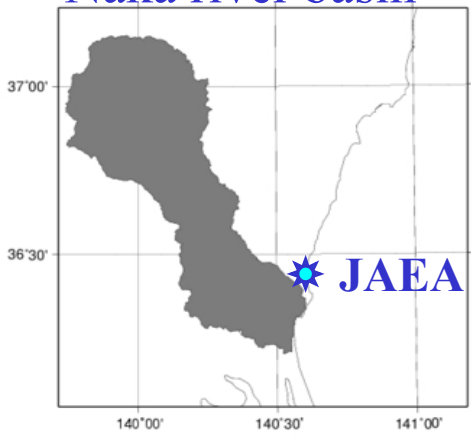
- Same as MM5-DOM3 DT= 6s

[POM, WW3]

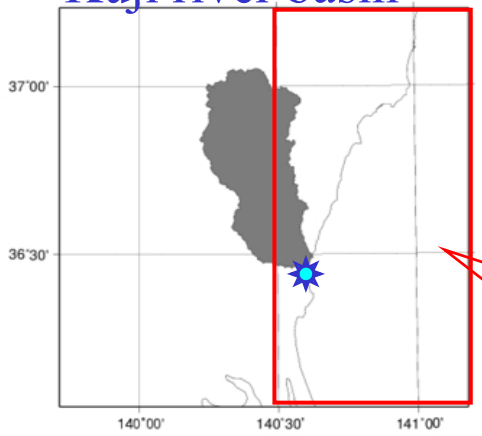
- Grid 26 × 54 × 21 DX= 3km DT= 60s

Data exchange: time step of each model

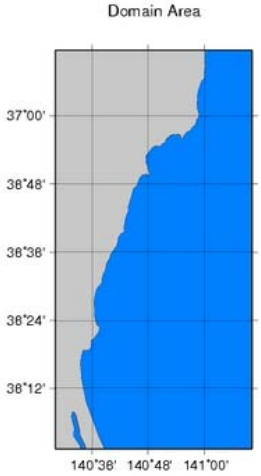
Naka river basin



Kuji river basin

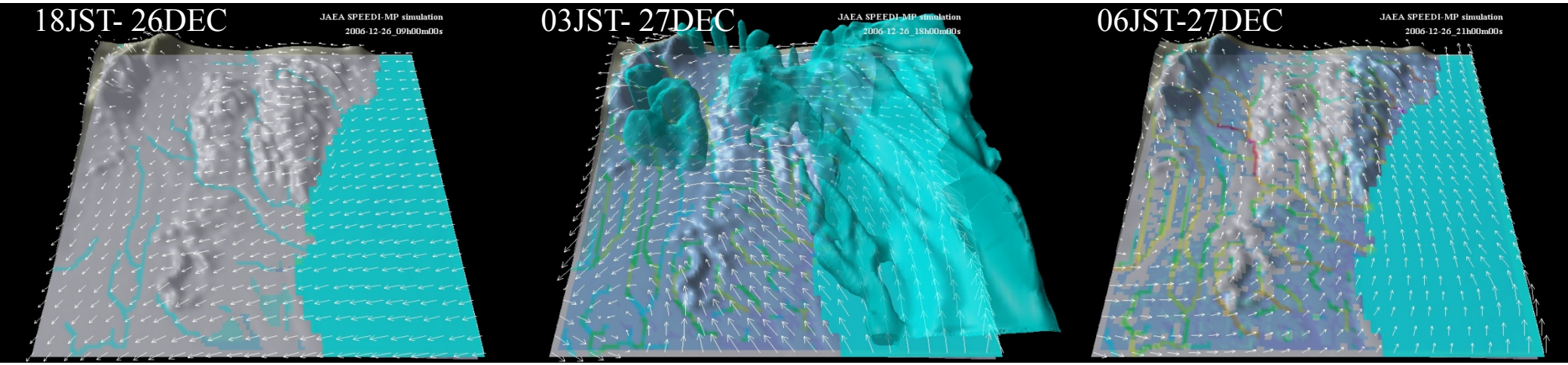


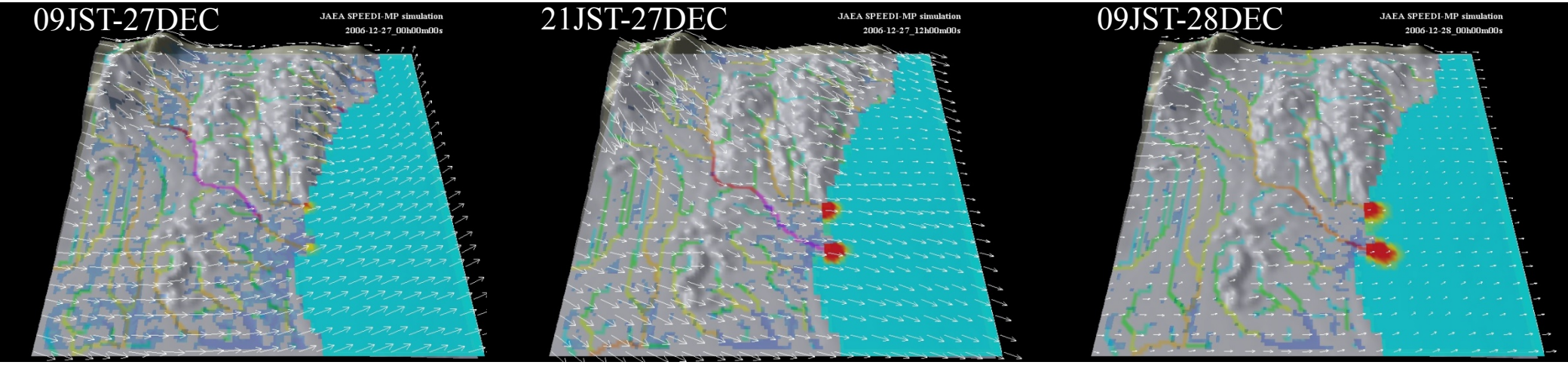
POM, WW3 coupling



Development of SPEEDI-MP

Five model coupling test



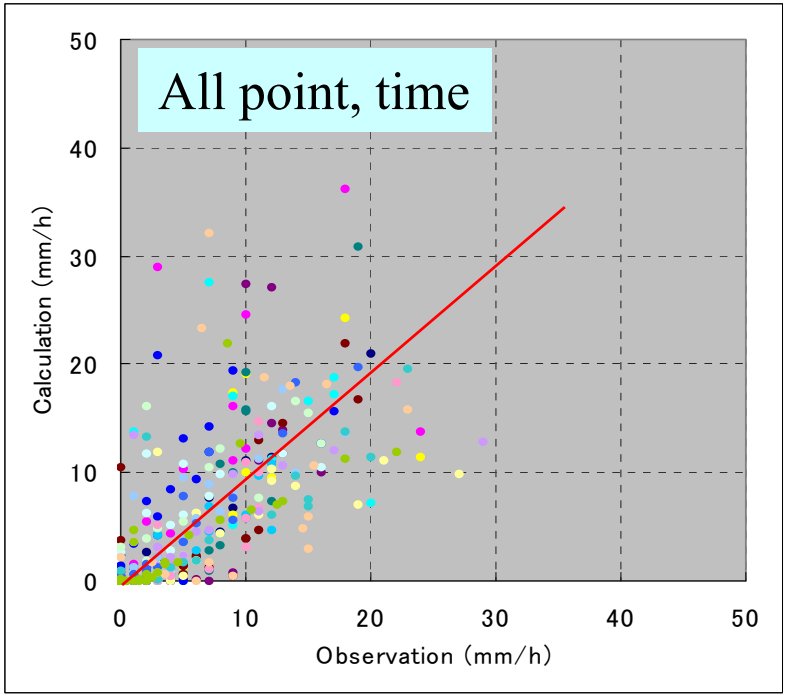


[Test case] Swelling of Naka and Kuji rivers after heavy rainfall on 26-27 Dec. 2006

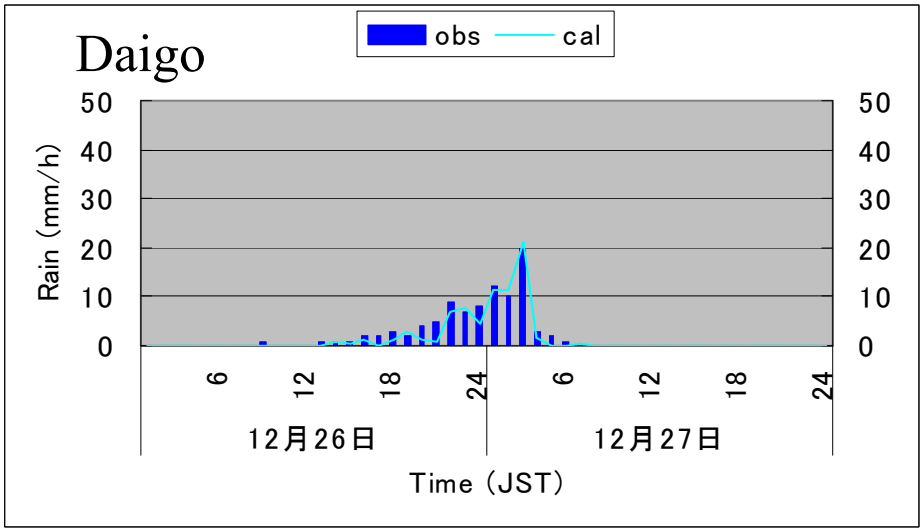
[Visualization] MM5: surface wind field, 3-D rain water, SOLVEG: surface water, RIVERS: river flow rate, POM: salinity (decrease by flesh water from river)

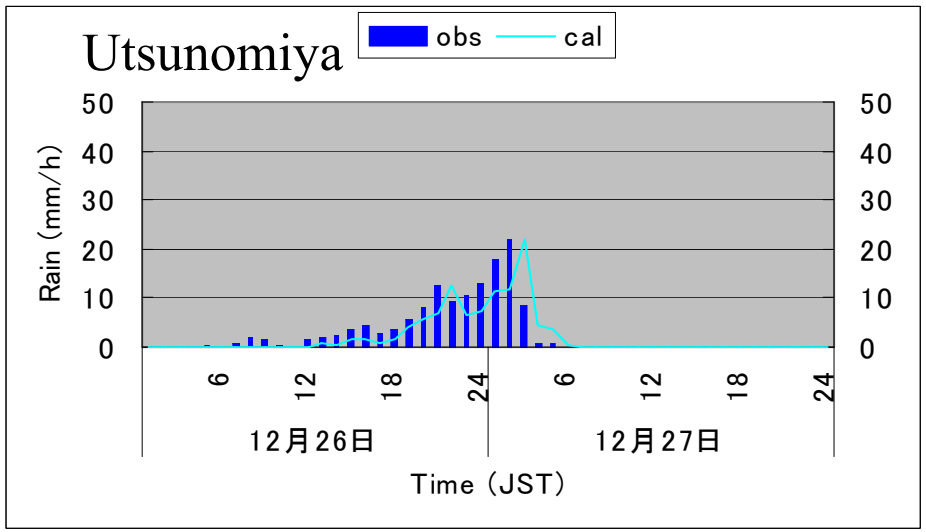
Development of SPEEDI-MP

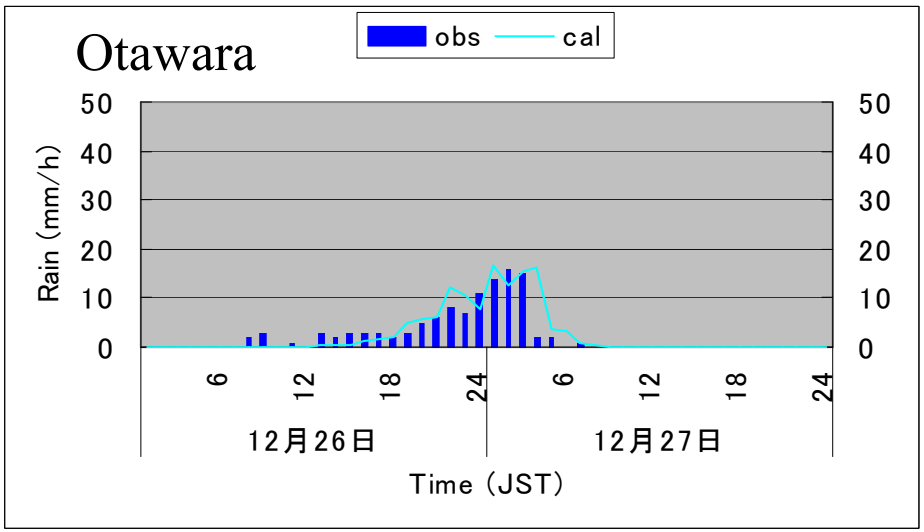
Five model coupling test



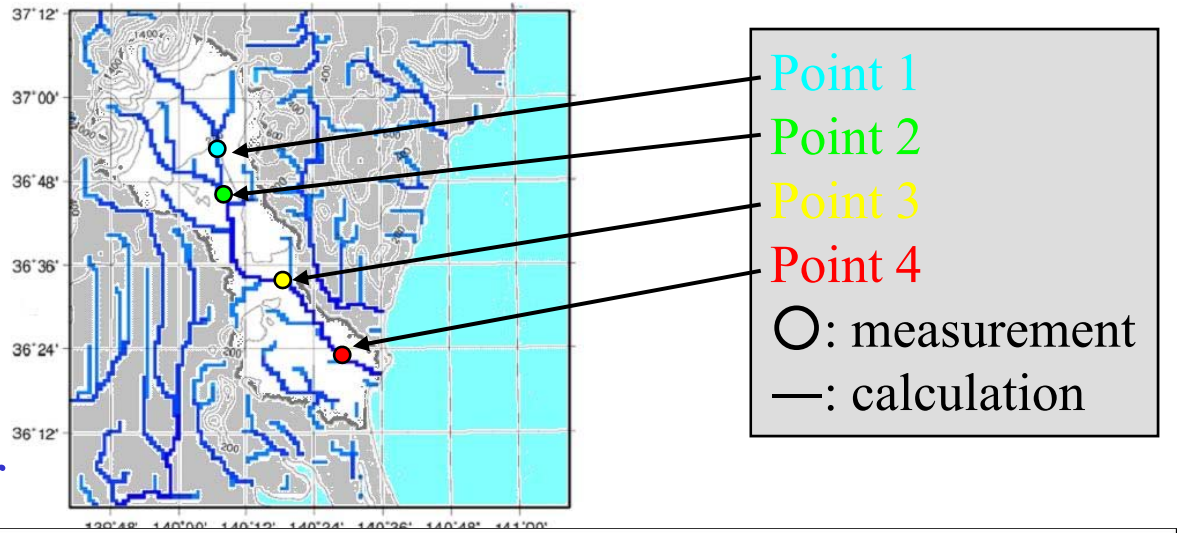
Comparison with AMeDAS rain



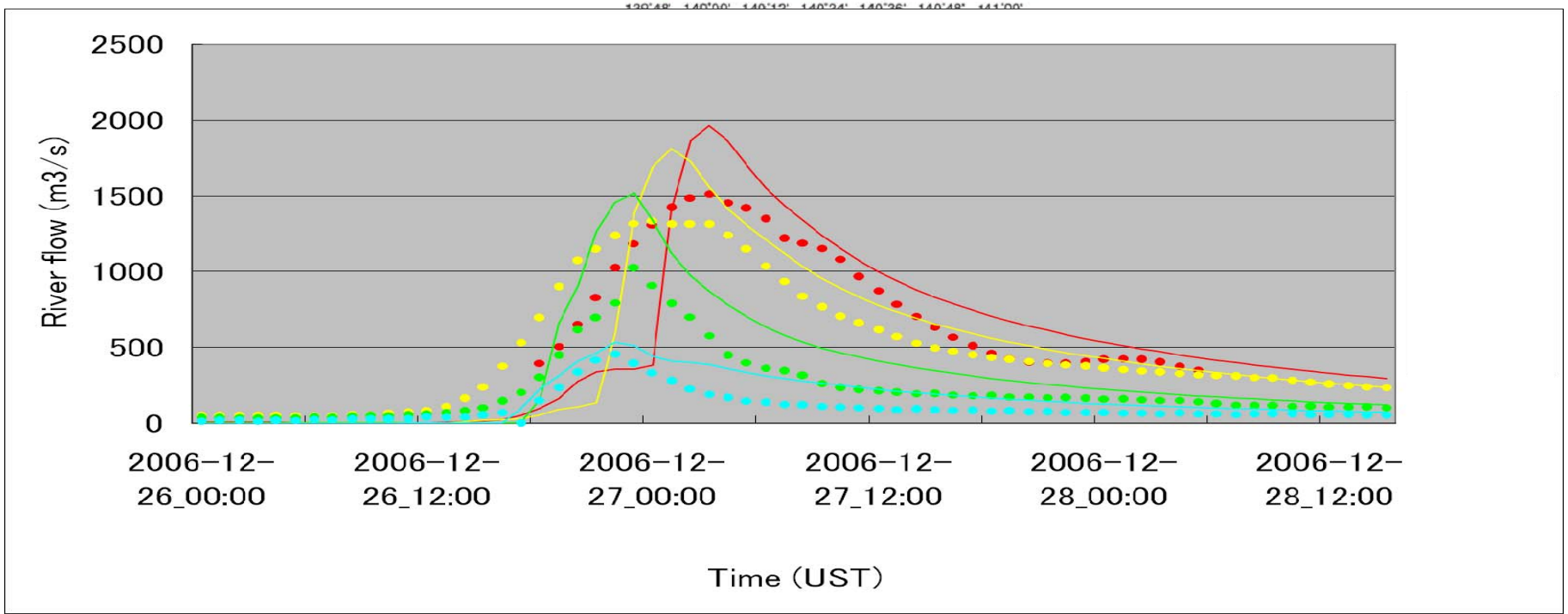




Five model coupling test



River flow at Naka river



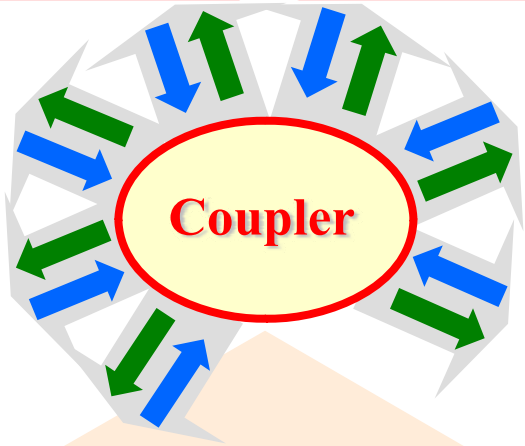
Development of SPEEDI-MP

Coupled water cycle & dispersion model

Atmosphere model
MM5（NCAR）
Wind, temp., rain, etc.

Dispersion model
GEARN（JAEA）
Air conc., deposition, dose

Wave model
WW3（NOAA）
Wave height, propagation



Land-surface model
SOLVEG（JAEA）
Heat, water exchange

Ocean model
POM（Princeton Univ.）
Current, temp. salinity

Hydrology-transport model
RIVERS（JAEA）
3-D movement of material

Dispersion model
SEA-GEARN（JAEA）
Conc., dose

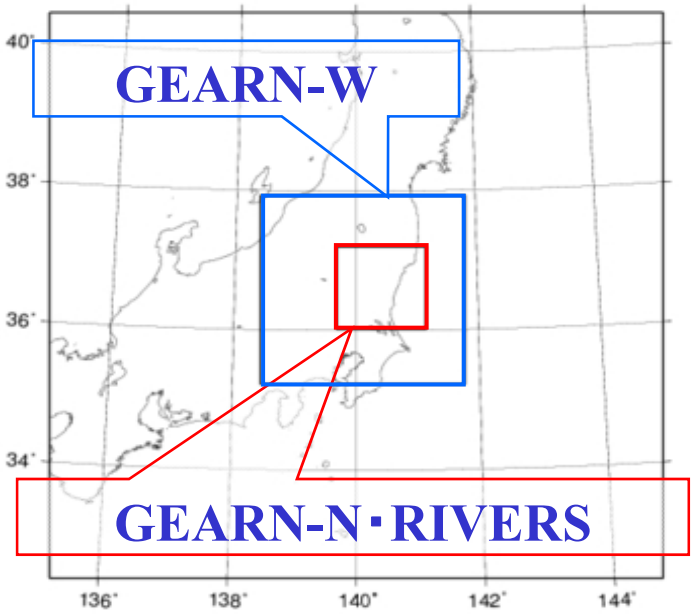
[Interactions]

MM5: 3-D met. Field ⇒ GEARN: dispersion, deposition
rain, water flux ⇒ RIVERS: upper boundary condition, re-emission
GEARN: particle transport ⇒ GEARN: particle in/out
deposition ⇒ RIVERS: particle input to surface
RIVERS: surface conc., re-emission ⇒ GEARN: deposition change, re-emission

Coupled calculation of 2-way exchange between atmosphere and land

Coupled dispersion model

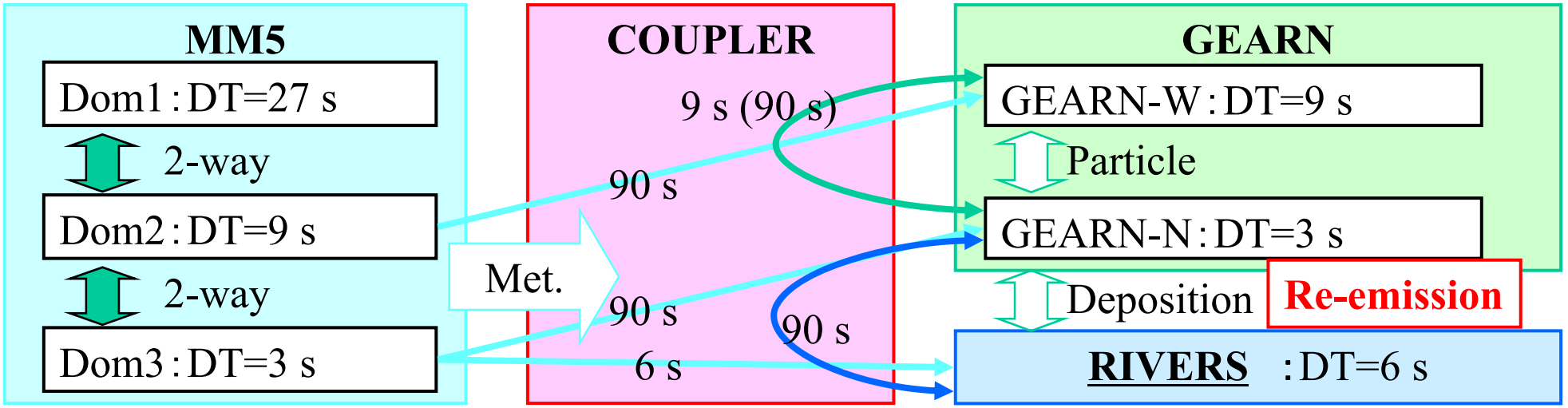
MM5 (3-domain nesting)



[MM5]
- DOM1,2 : Grid 100 × 100 × 23
  DX= 9, 3km DT= 27, 9s
- DOM3 : Grid 130 × 130 × 23
  DX= 1km DT= 3s

[RIVERS]
- Same as MM5-DOM3, DT= 6s

[GEARN-W/GEARN-N]
- Same as MM5-DOM2/3, DT= 9/3s



Development of SPEEDI-MP

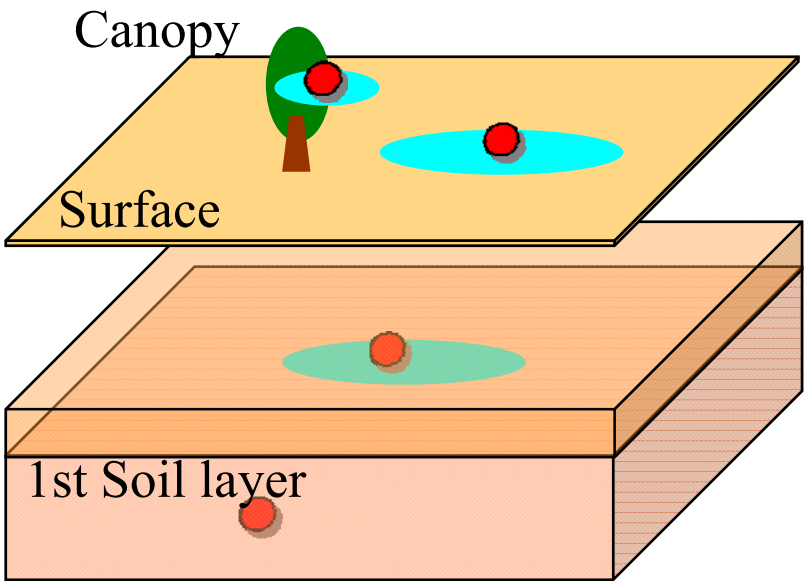
HTO re-emission process (deposition)

RIVERS : Particle dispersion

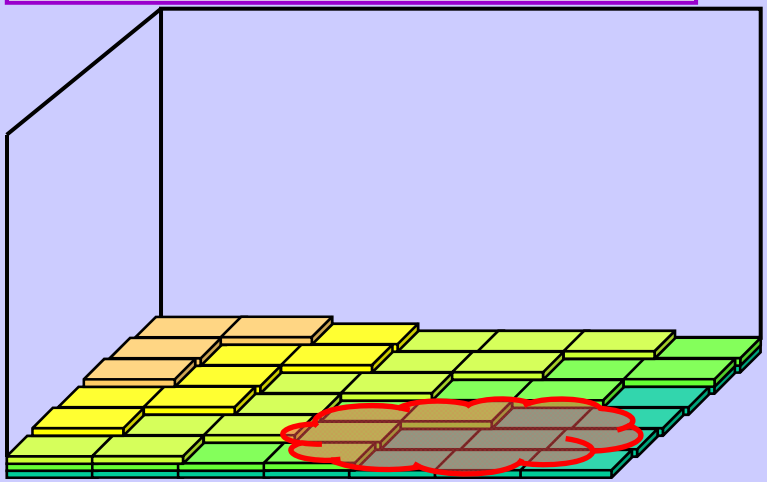
Particle generation : based on deposition
- Put particle at soil surface
- Add radioactivity to each particle

Particle transport :
- Transport with water (dissolved)
- 3-D movement at surface, soil, river
- Decrease of radioactivity by decay

COUPLER
Deposition



GEARN : Particle dispersion



HTO re-emission process (re-emission)

RIVERS : Particle dispersion

Re-emission rate for each step (6s):

$FQ=\sum_i Q(i) \times r(i)$ ・・・accumulate for re-emission area

Q(i) : radioactivity of each particles

r(i)=q/v : emission rate for each particle

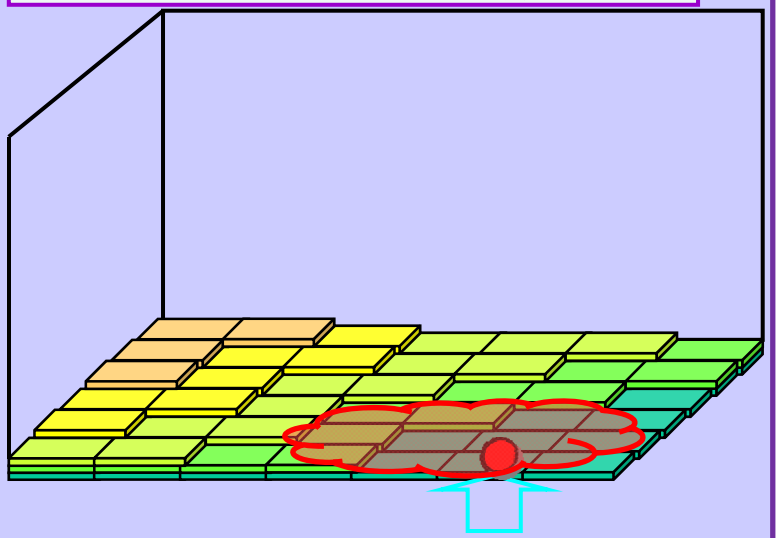
q : water vapor to atmosphere ←MM5

v : water content

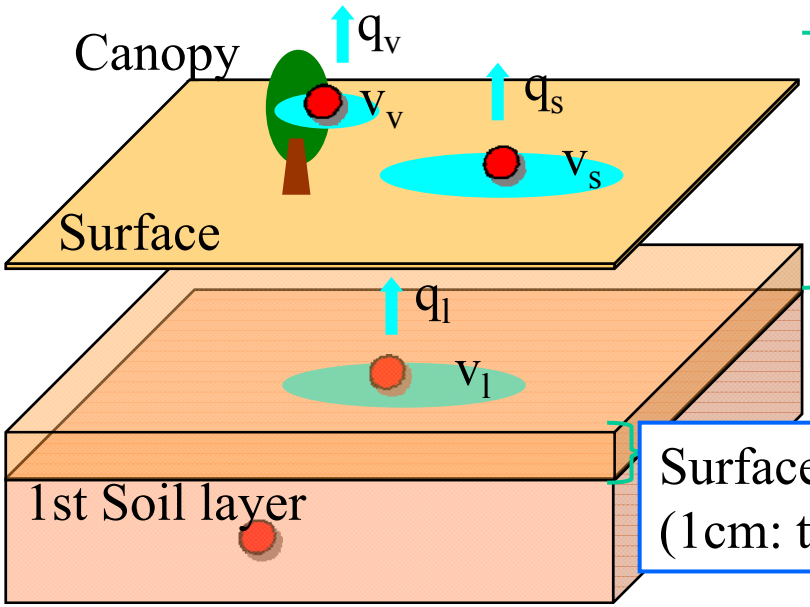
Accumulate for exchange step (90s)

COUPLER
Re-emission rate

GEARN : Particle dispersion



Release particle at each cell for every exchange step (90s)
(1 particle for each: temporally)



Re-emission area

Surface layer (1cm: temporally)

Development of SPEEDI-MP

HTO re-emission calculation

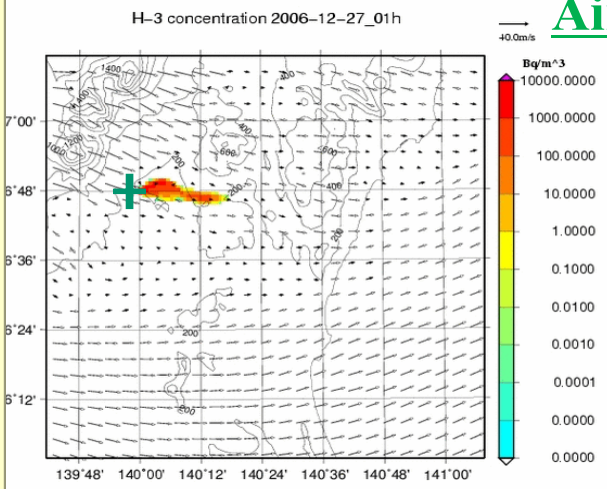
[Test calculation]
Fictitious release
Point: N36.8° E140.0°
Height: 50m
Term: 27DEC00UTC～6h
Radionuclide: HTO
Release rate: 10^{13}Bq/h

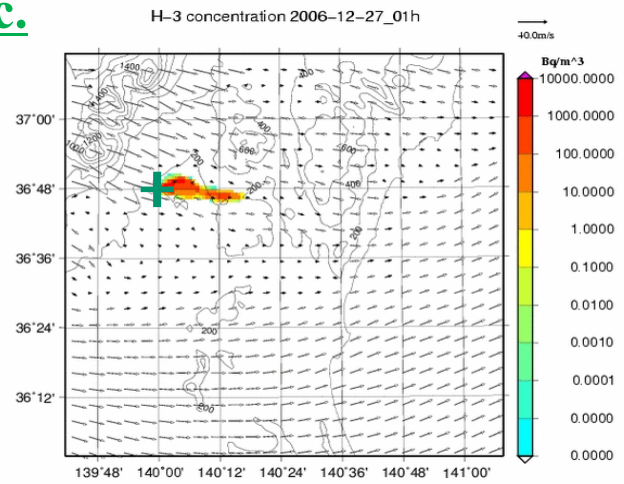
Calculation period:
27DEC2006～31DEC
(Met. cal.: 24DEC～)
NW wind is continued after heavy rainfall

[Visualization]
MM5: surface wind vector
GEARN: air concentration, deposition

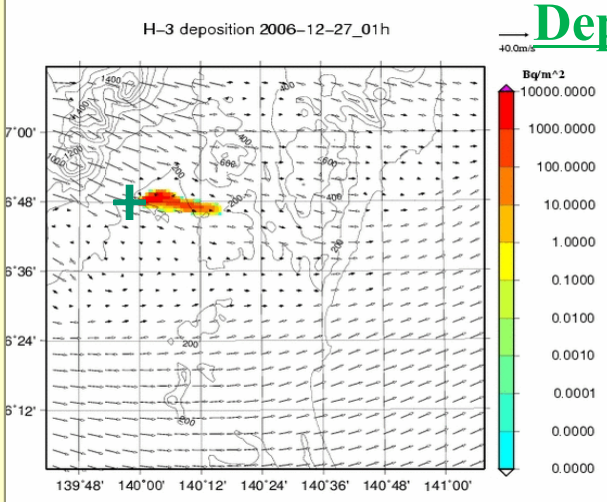
No re-emission | **Re-emission**

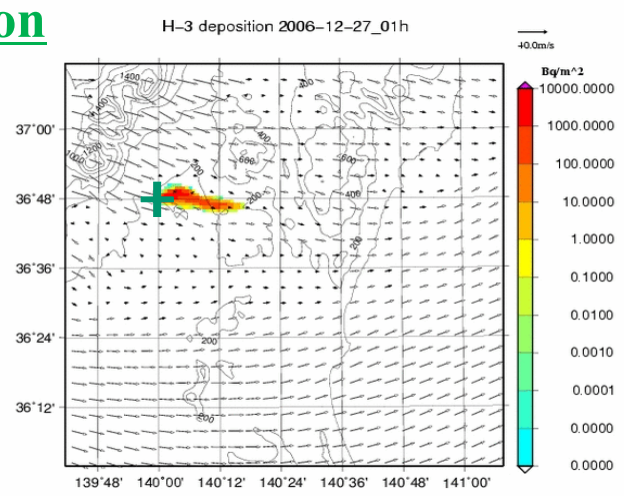
Air conc.





Deposition





HTO re-emission: deposition