Dobré ráno

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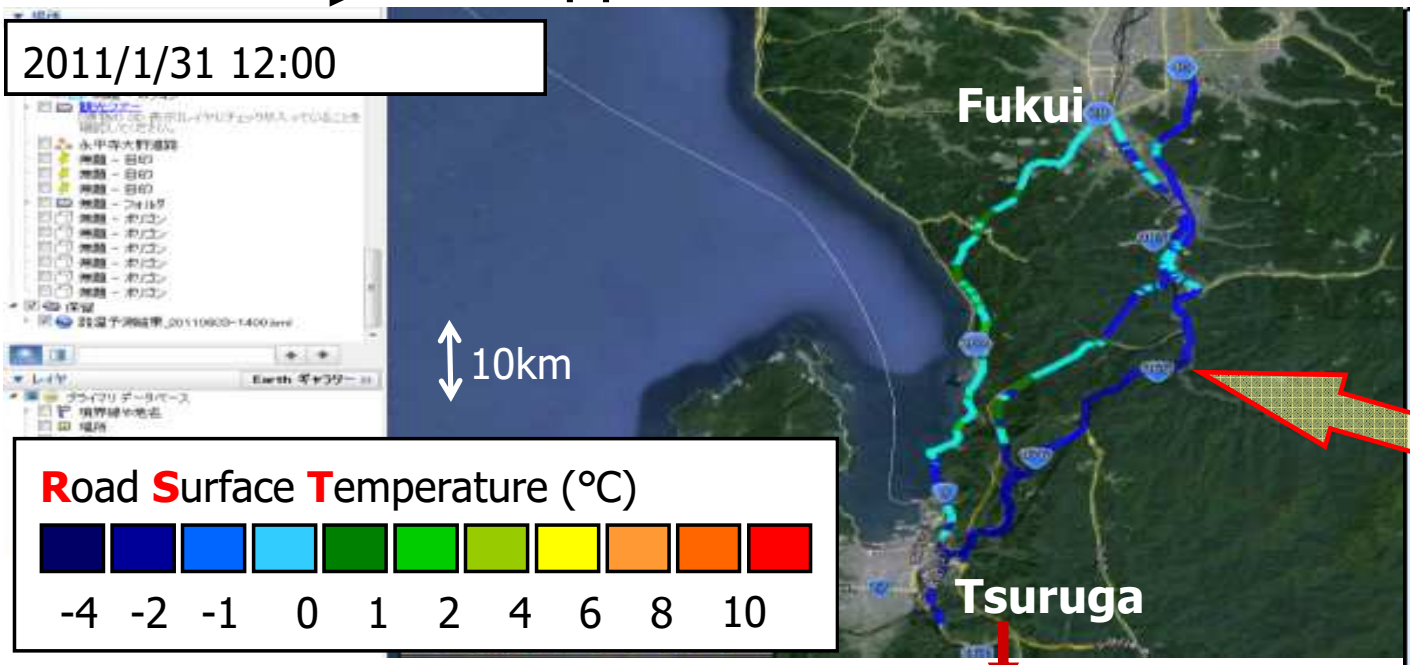
Session： Advances In Road Weather Forecasting (2)

A Route-Based Forecasting Model of Road Surface Friction and Snow/Ice Conditions

Purpose of study

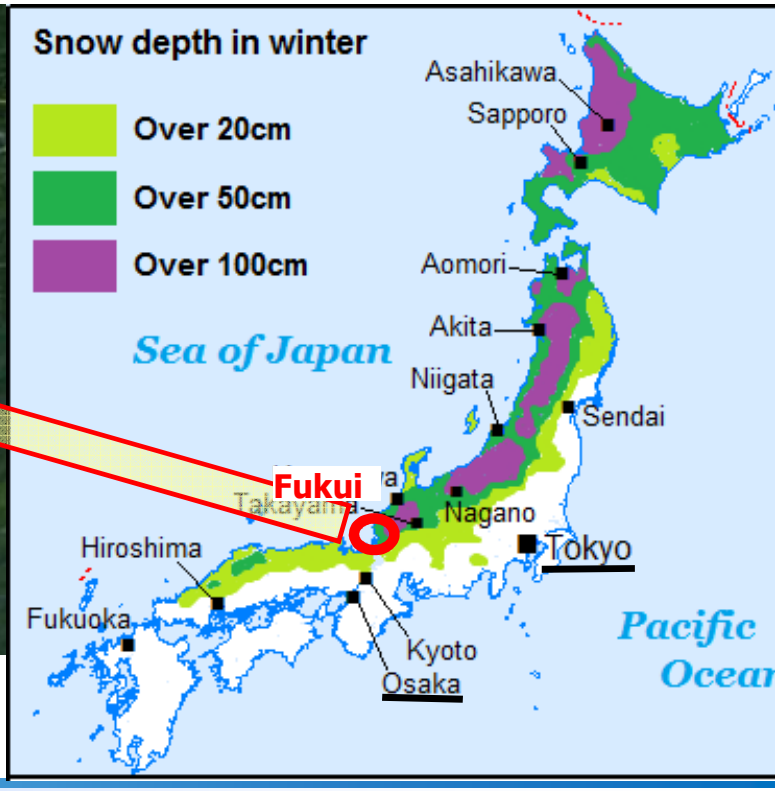
◆SAFF-II model: A ***RST & μ*** **forecasting** model along a road net work

To support a safe winter road management



To Osaka or Nagoya

Example of forecast result in Fukui prefecture, Japan



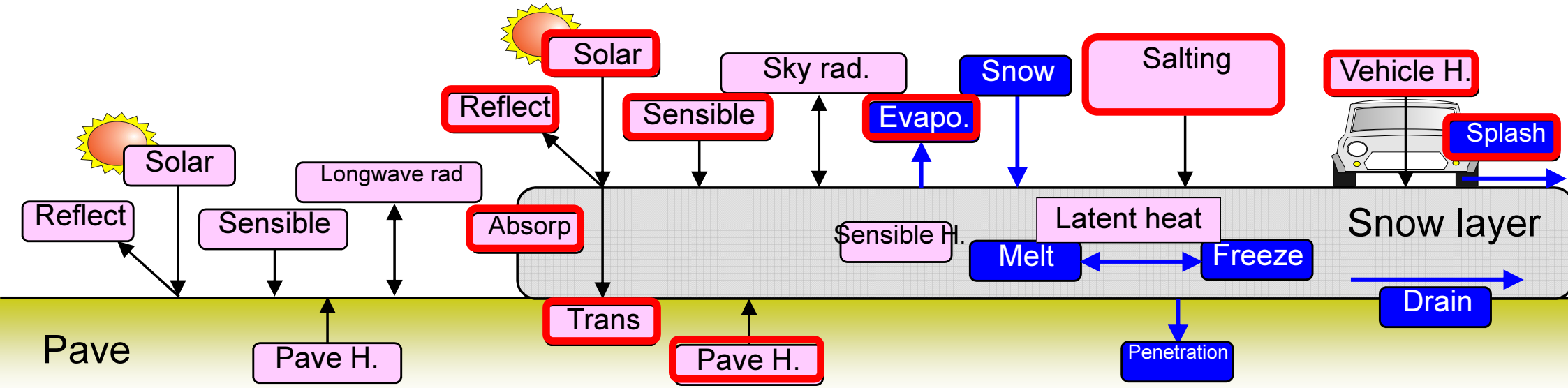
μ-forecasing model

Conventional

Heat balance model

Proposed

Heat & mass balance model



Output

RST

Output

Snow/ice state

μ

How to build a route-based road surface friction forecasting model?

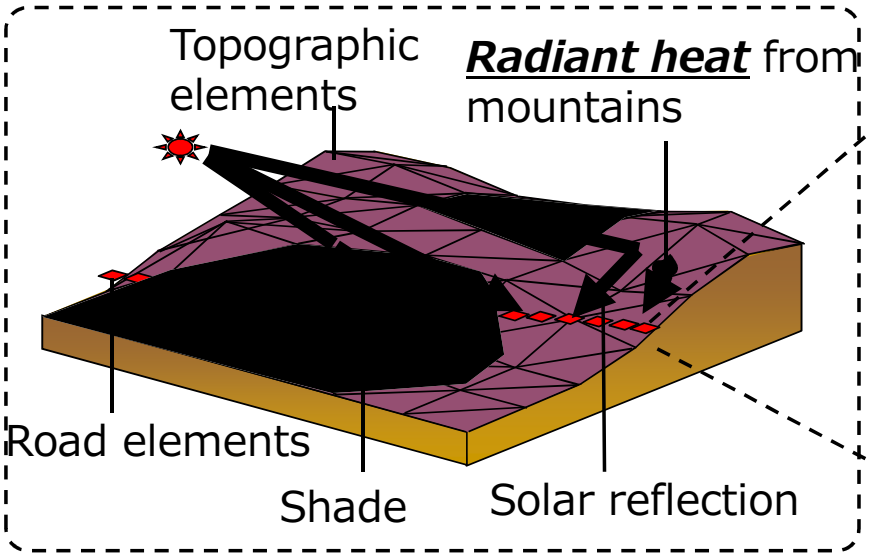
SAFF Ⅱ model ⇒ A heat and mass/volume balance method using a **digital surface model (DSM)**

What we did was

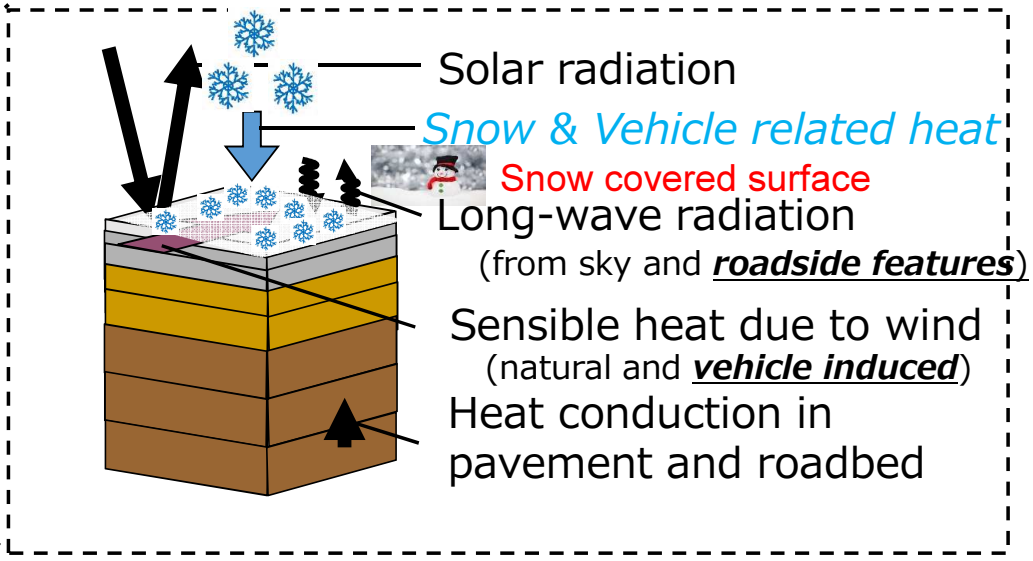
The validity of the SAFF-Ⅱ model ⇒ By comparing the calculated and measured spatial variations in ***RST*** and ***HFN*** **(Halliday Friction Number)**

SAFF Ⅱ model

Road weather calculation

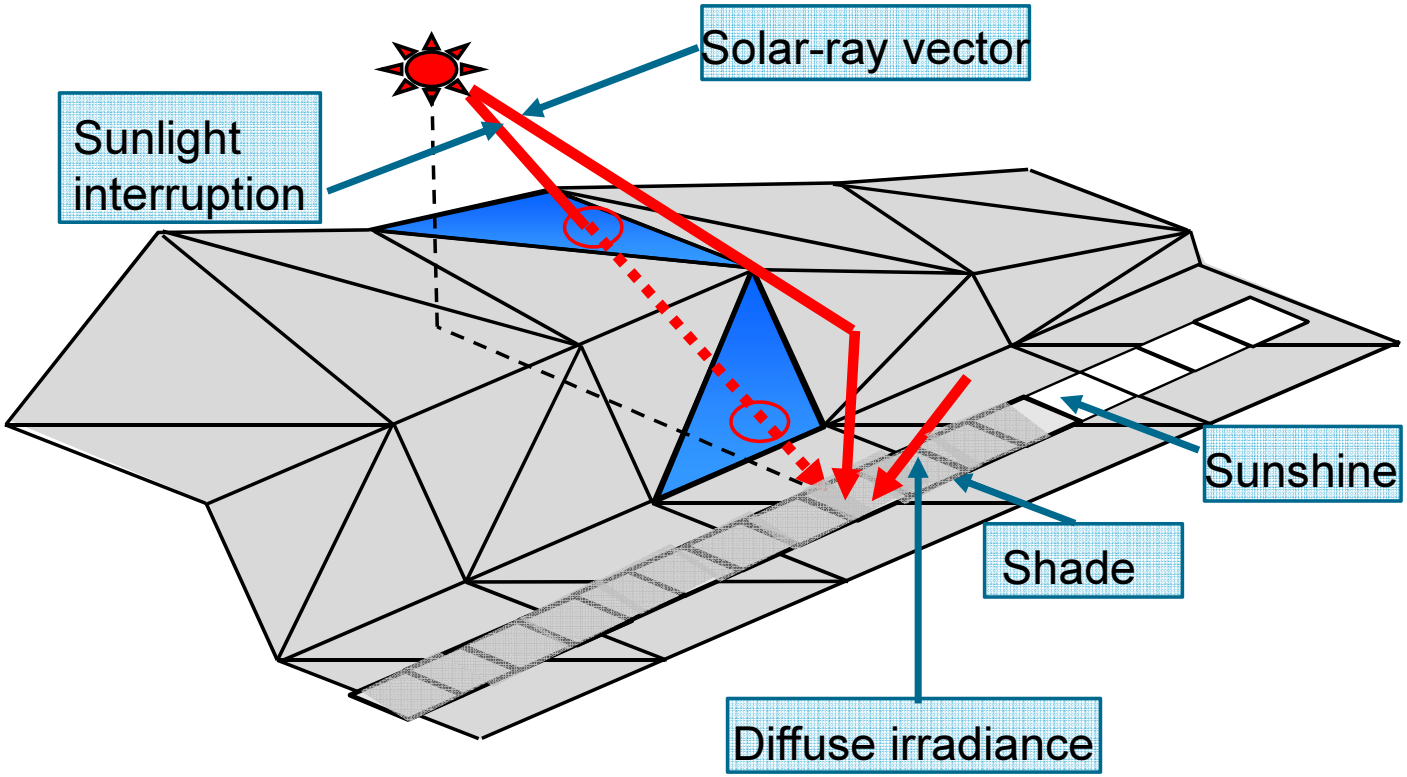


Heat & mass balance on the road surface



Calculation of road weather using the DSM

Solar radiation



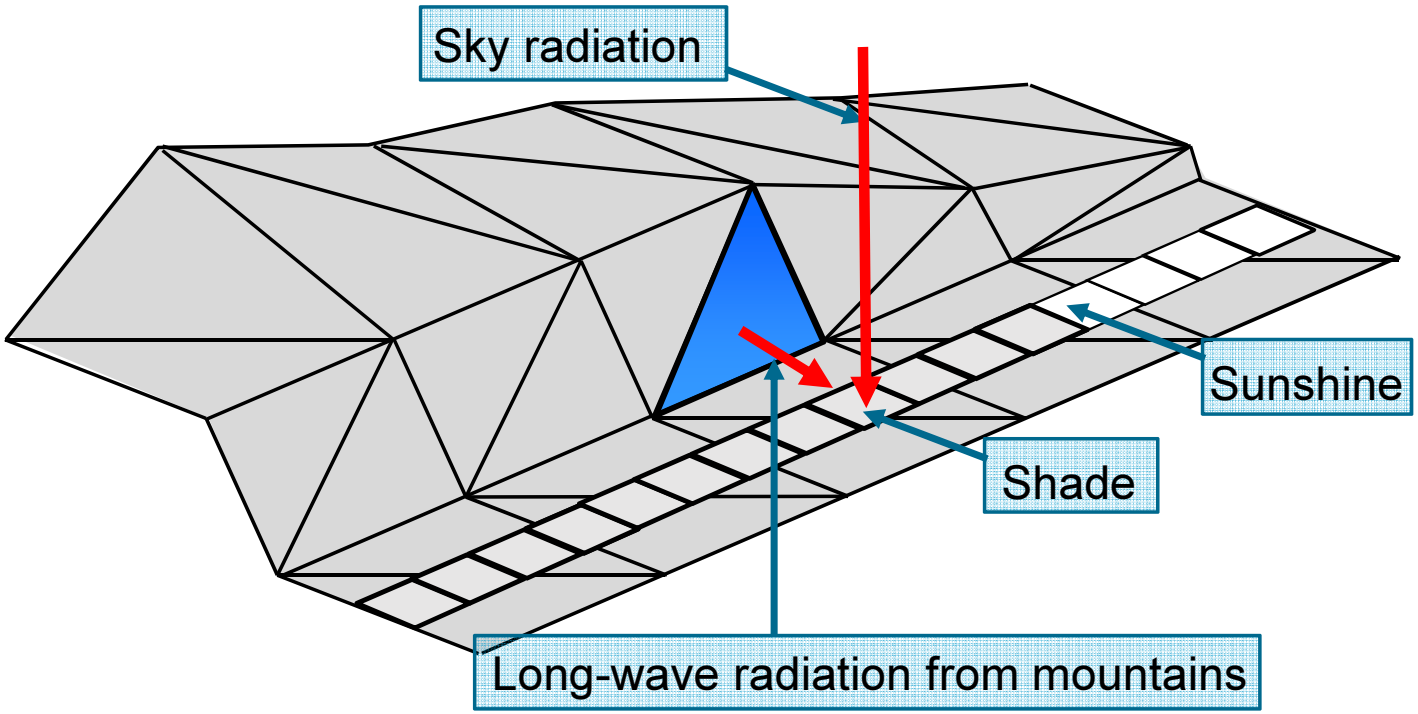
Solar radiation flux on the surface of road element:

$$q_{sd} = Sq_{sdr}\cos\theta + (1 - f_{all})q_{sdf} + q_{sr}$$

- S : Discrimination value of solar radiation (1 or 0)
- q_{sdr} : Direct solar radiation flux
- θ : Solar altitude
- f_{all} : View factor
- q_{sdf} : Diffuse solar radiation flux
- q_{sr} : Reflective solar radiation flux

Calculation of road weather using the DSM

Long-wave radiation



Long-wave radiation flux on the surface of road element:

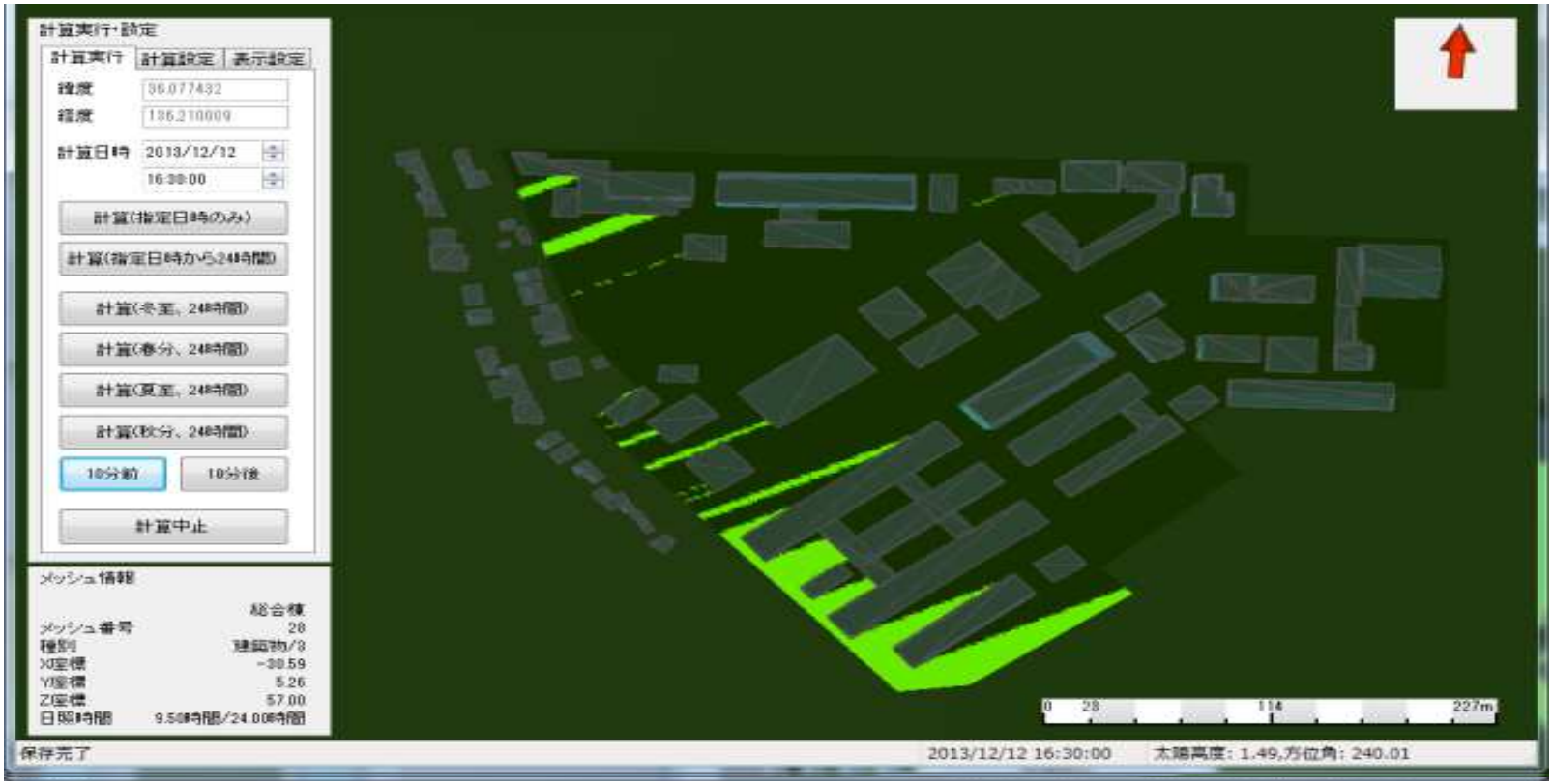
$$q_{ld} = (1 - f_{all})q_{ld\,0} + q_{ls}$$

f_{all} : View factor

q_{ld0} : Sky radiation flux

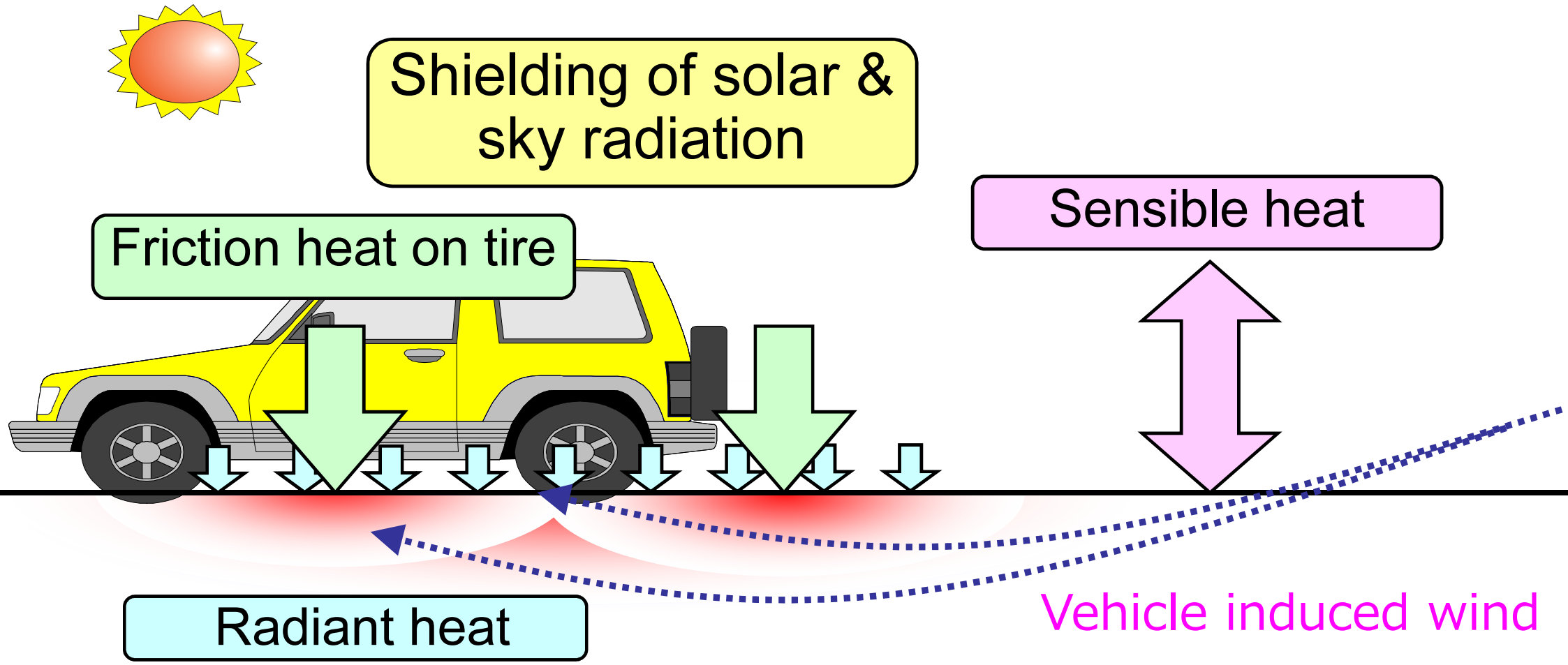
q_{ls} : Long-wave radiation flux from mountains and buildings

Shadow calculation by SAFF-II model



Shadow calculation at University of Fukui (2013/12/12)

Vehicle related heats



Calculation of road weather using the DSM

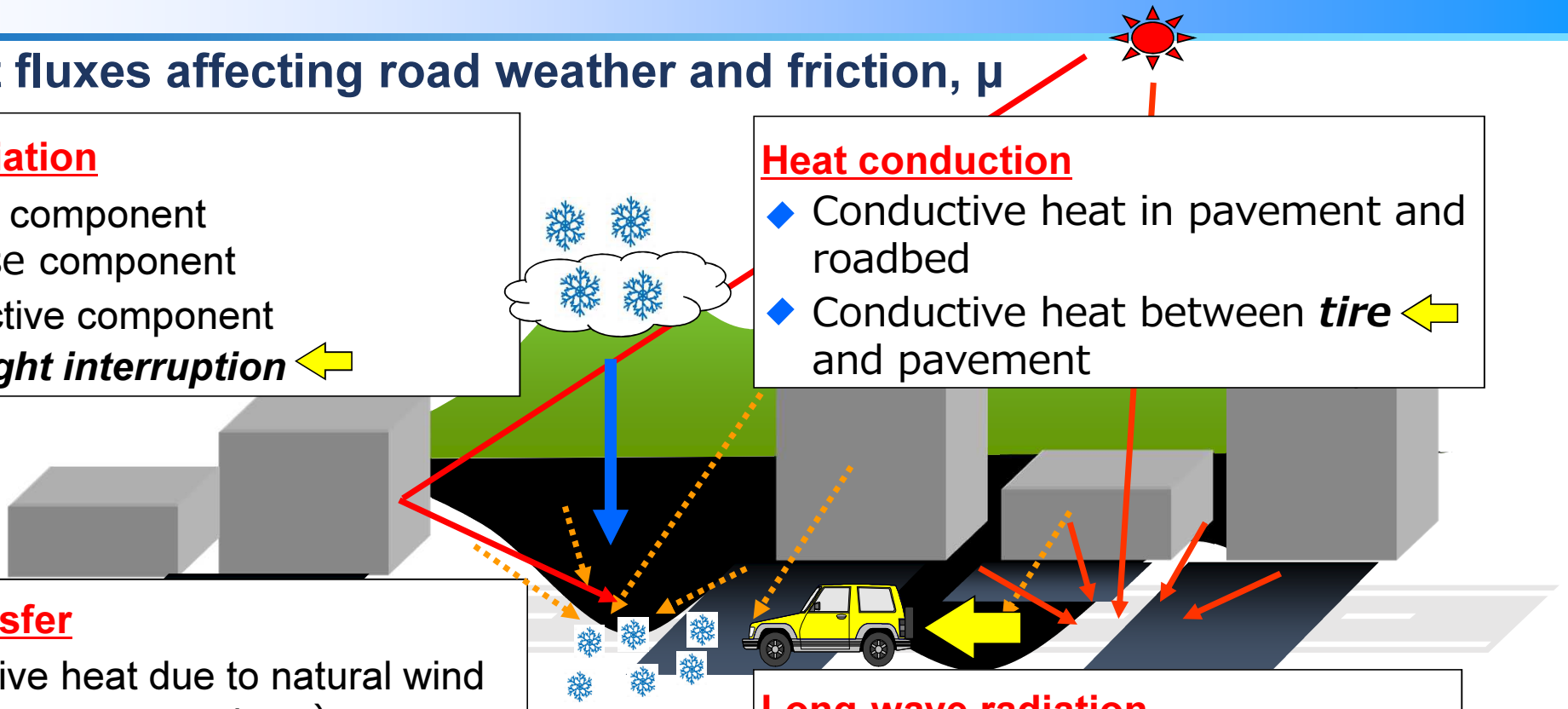
Major heat fluxes affecting road weather and friction, μ

Solar radiation

- Direct component
- Diffuse component
- Reflective component
- ***Sunlight interruption*** ⇦

Heat conduction

- Conductive heat in pavement and roadbed
- Conductive heat between ***tire*** ⇦ and pavement



Heat transfer

- Sensitive heat due to natural wind (pavement-atmosphere)
- Sensitive heat due to ***vehicle induced wind*** ⇦

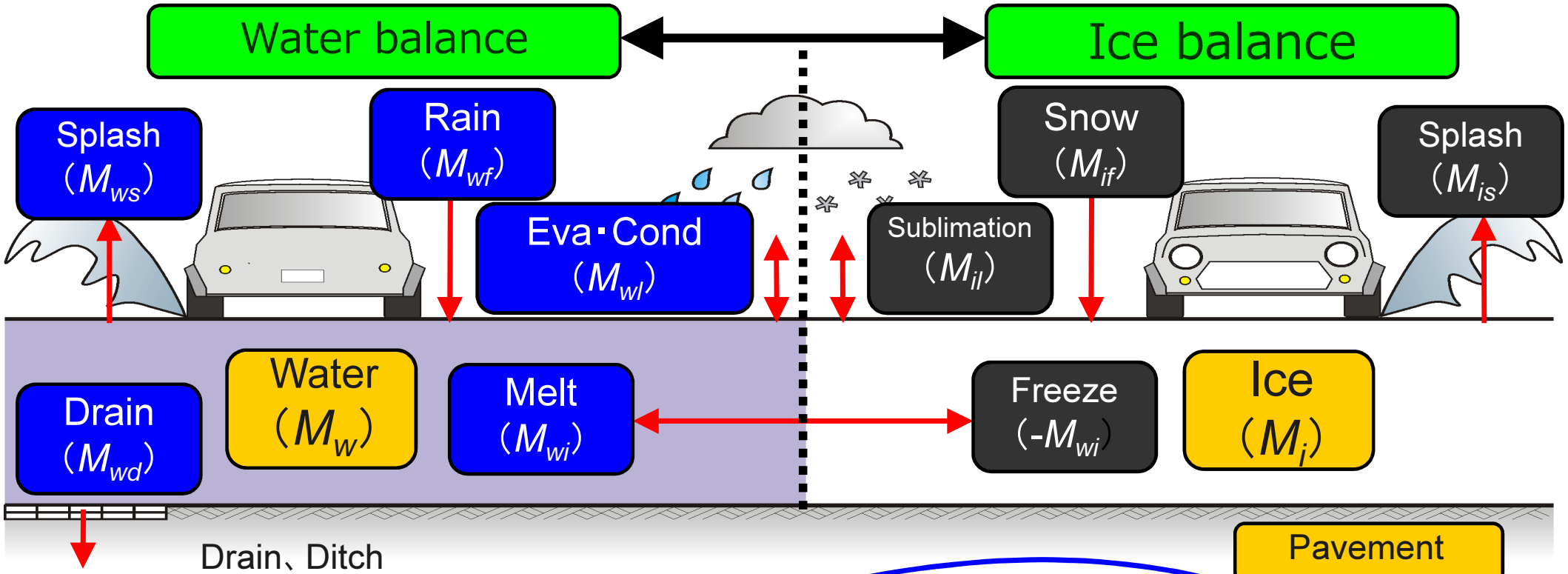
Long-wave radiation

- From *roadside features* and sky
- From ***vehicle bottom*** ⇦

Mass and volume balance equations of snow

Slash { ice, water, air }

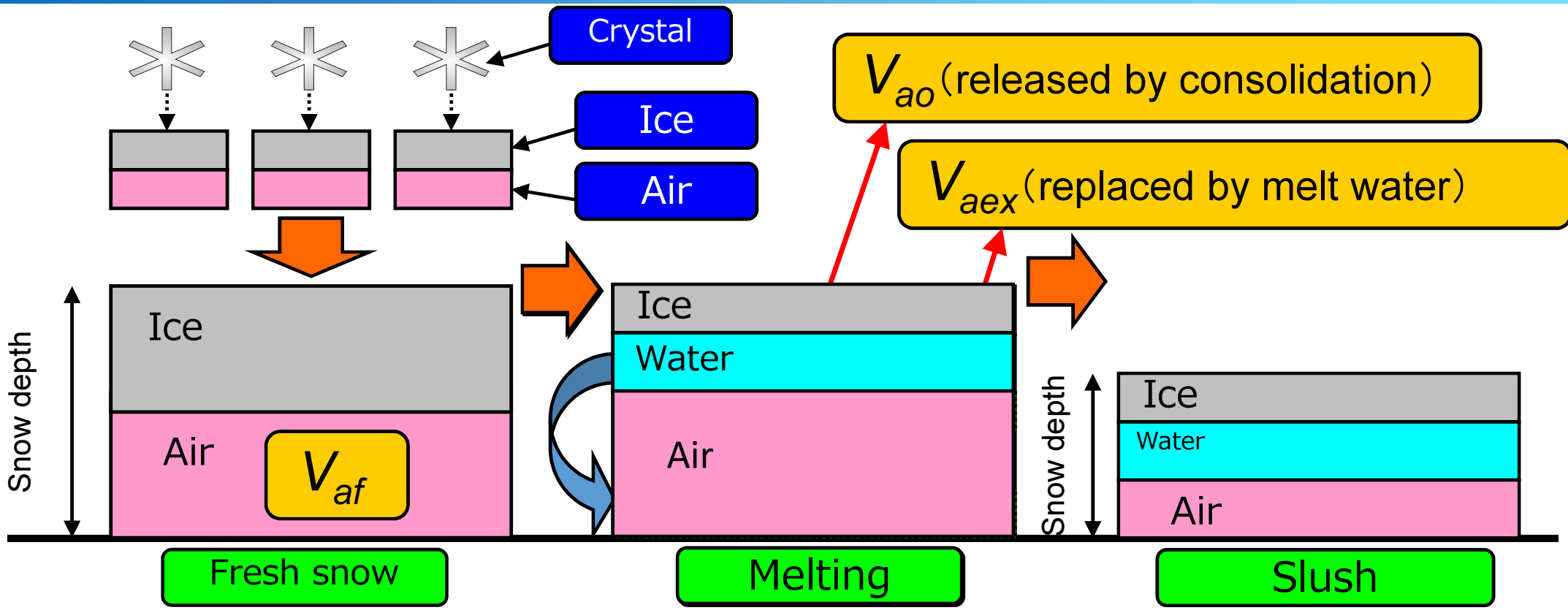
Water and ice balances



$$\frac{\partial M_w}{\partial t} = M_{wf} + M_{wl} + M_{wi}$$

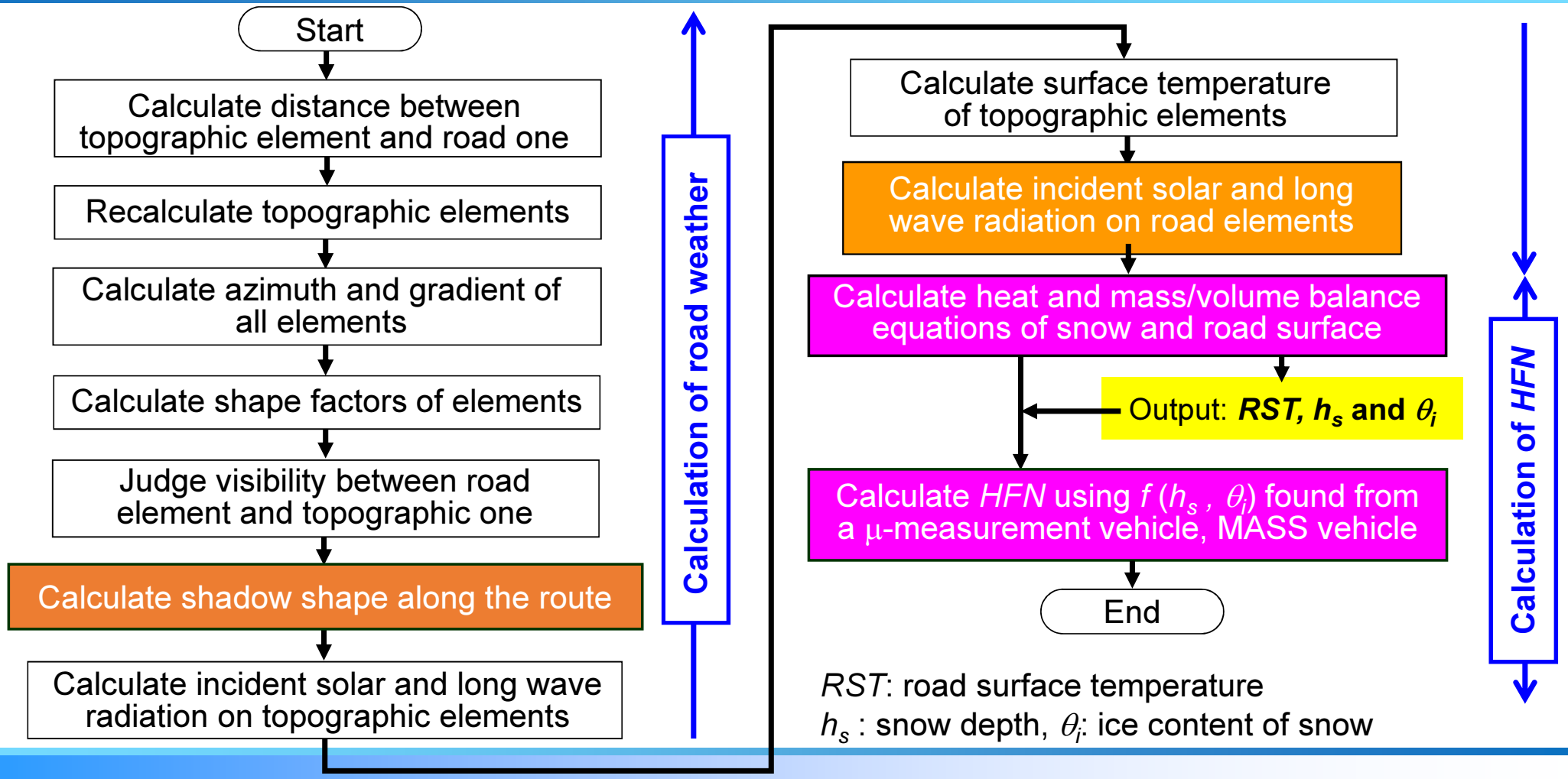
$$\frac{\partial M_i}{\partial t} = M_{if} + M_{il} - M_{wi}$$

Air volume balance



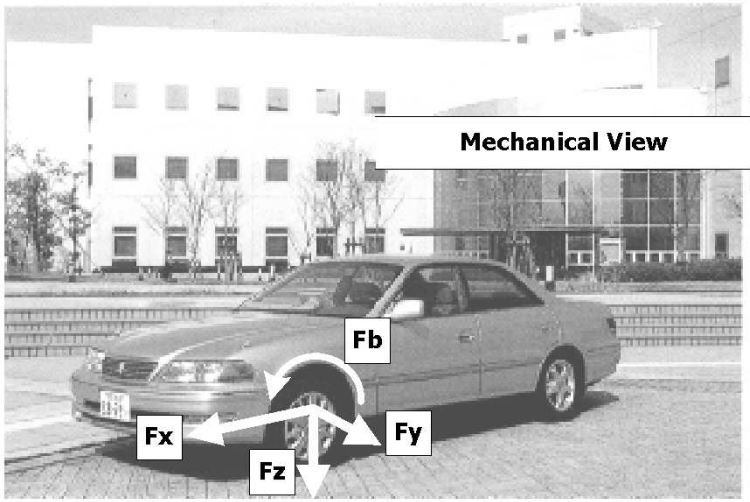
$$\frac{\partial V_a}{\partial t} = V_{af} - V_{aex} - V_{ao}$$

Computational Flow to obtain HFN (Halliday Friction Number)



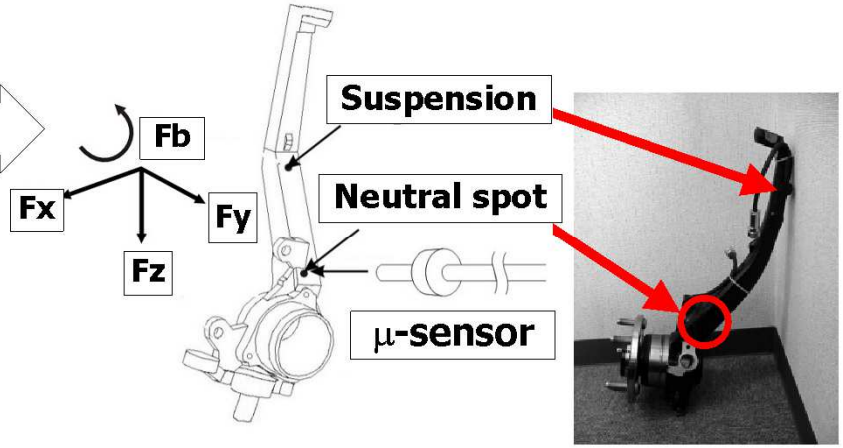
RST: road surface temperature
h_s : snow depth, θ_i: ice content of snow

μ-Measurement Vehicle, MASS Vehicle



MULTI-AXIAL SENSING SYSTEM (MASS) VEHICLE

Four-axial direction sensing device mounted in the suspension



F_x : longitudinal force
F_y : Lateral force
F_z : Vertical force
F_b : Breaking force

$$\mu = \frac{F_x}{F_z}$$

μ – Measurement Test

1. Before passage

Passage of MASS vehicle

2. Measurement of μ

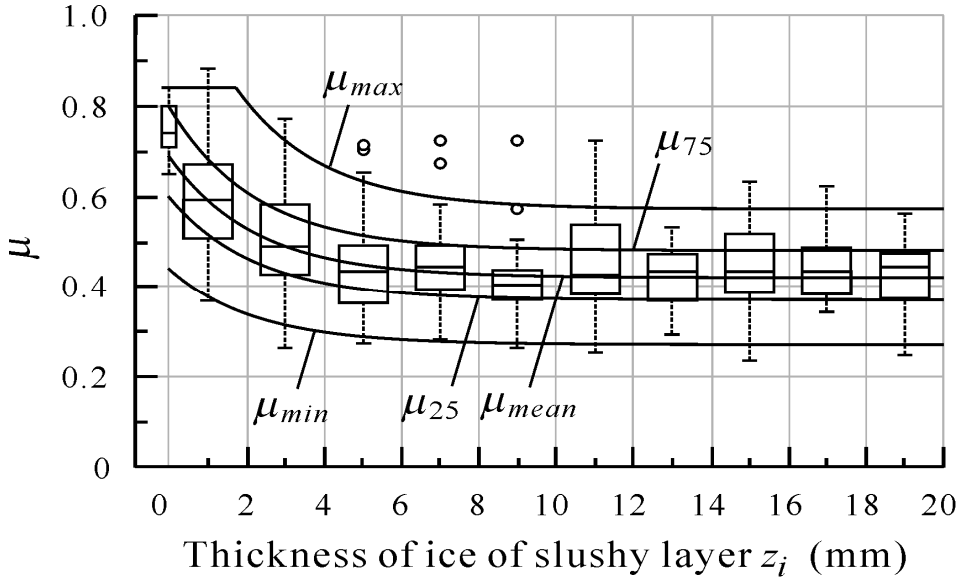
3. After passage

MASS vehicle

4. Measurement of ice mass content

5. Measurement of thickness of slush layer

Relationship between μ and the thickness of ice component in the slush



$$\mu = d\exp(ez_i) + f$$

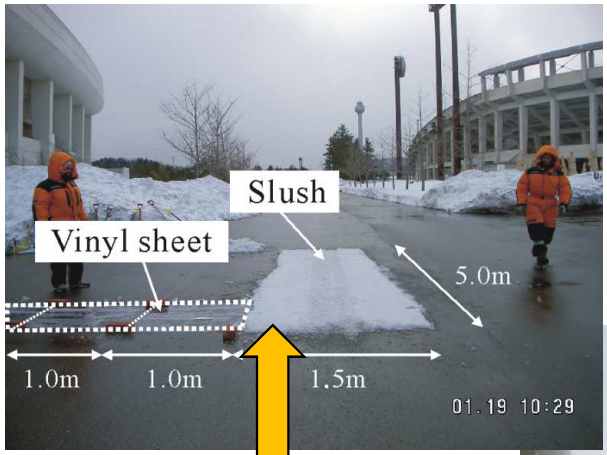
μ	d	e	f
μ_{max}	0.57	-0.45	0.57
μ_{75}	0.32	-0.45	0.48
μ_{mean}	0.27	-0.45	0.42
μ_{25}	0.23	-0.45	0.37
μ_{min}	0.17	-0.45	0.27

$$HFN = HFN_w - 86.8 + 64.8(\theta_i h_s)^{-0.154}$$

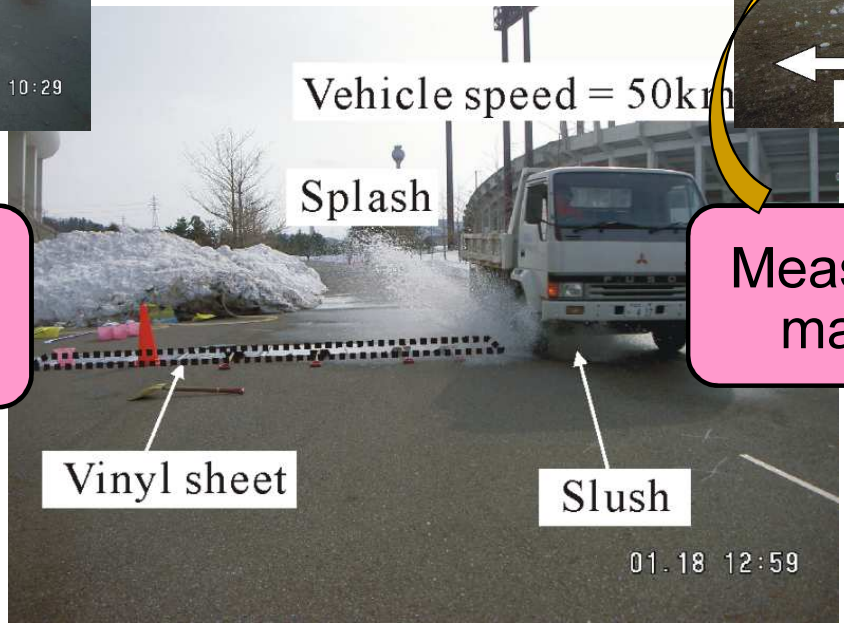
The thickness of ice component in the slush is the most appropriate factor.

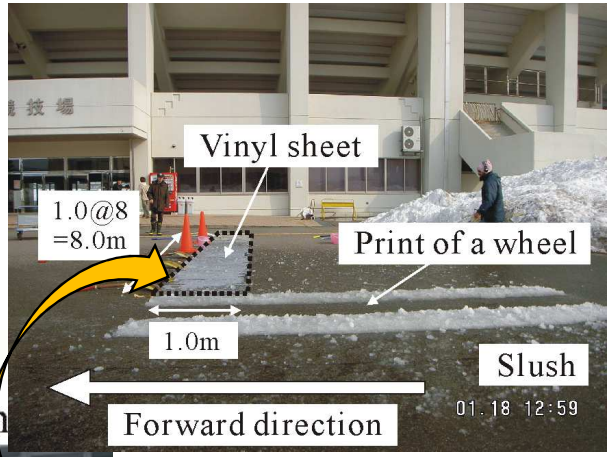
$$z_i = \frac{z_s \cdot \rho_s \cdot \theta_i}{\rho_i}$$

Experiment on scattering of slush due to vehicle passage



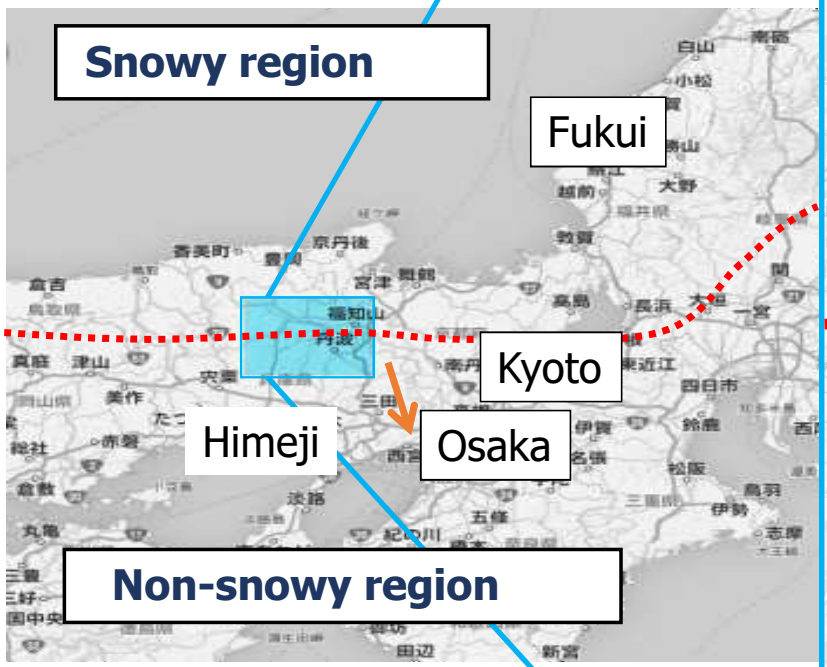
Measurement of ice mass content and thickness of slush

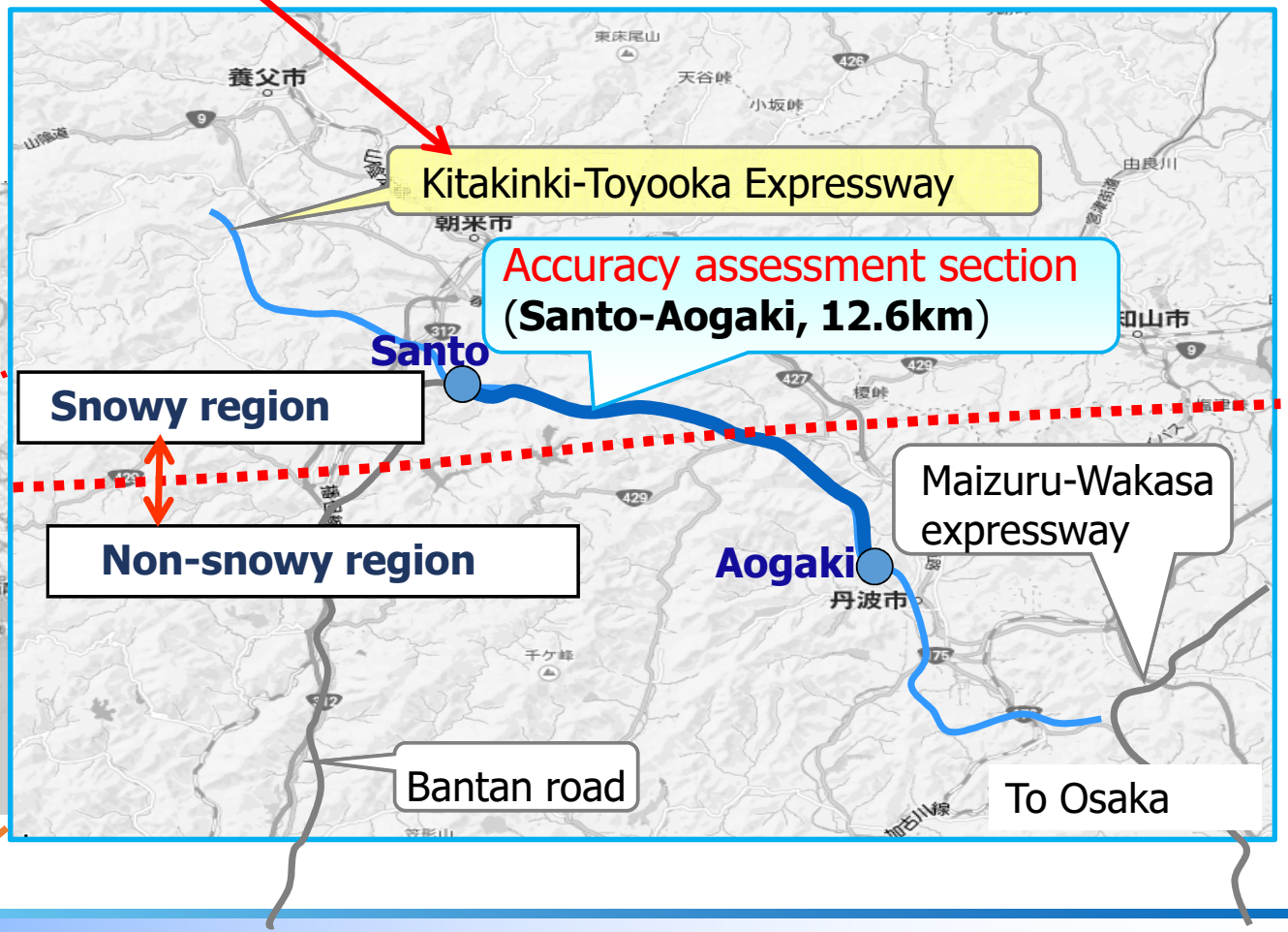




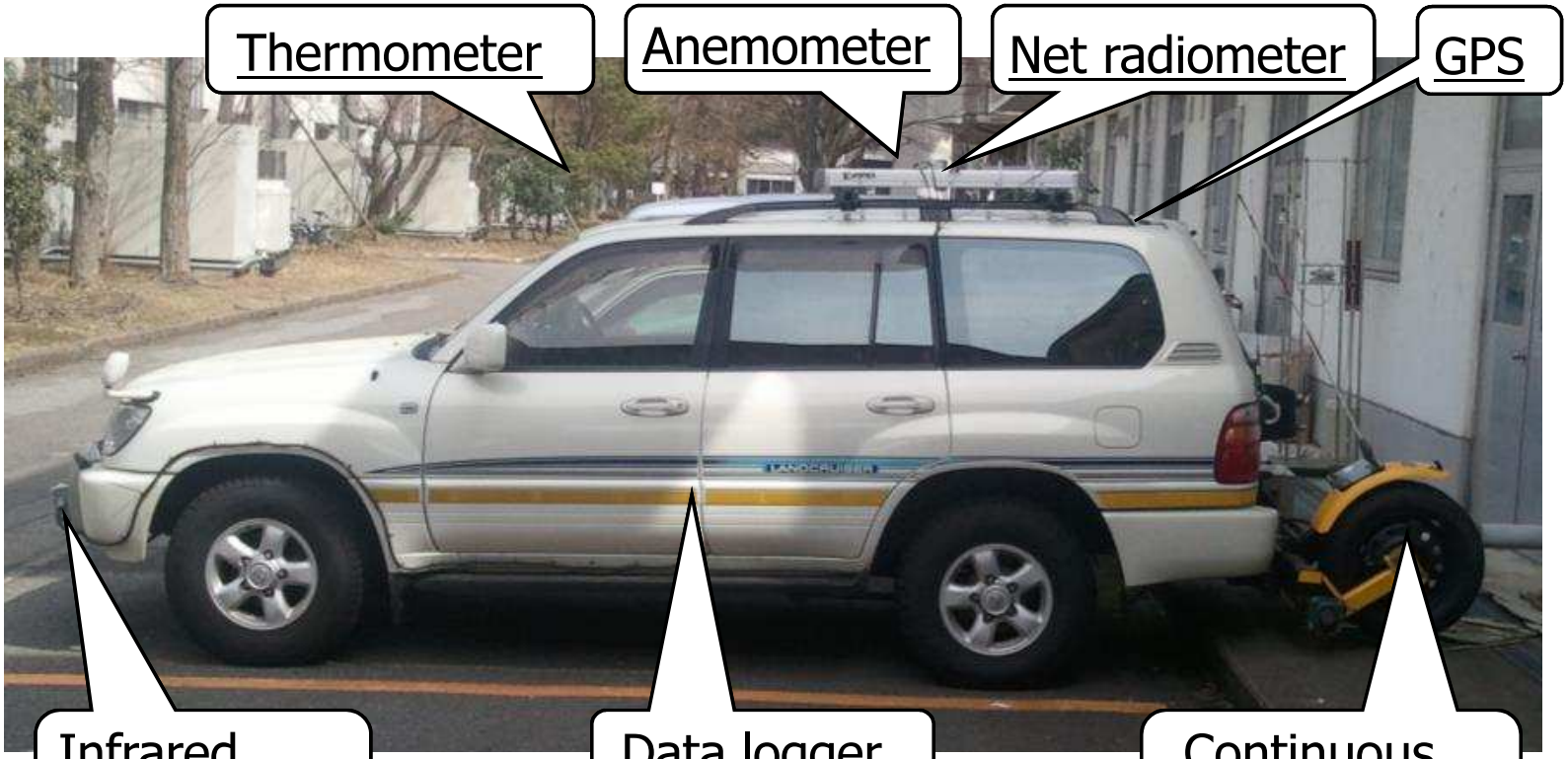
Measurement of length and mass of splashed slush

Accuracy assessment of SAFF-II model performed on Kitakinki-Toyooka expressway





Road weather measuring vehicle



(RST)

(HFN)

Accuracy assessment of SAFF-II model performed on Kitakinki-Toyooka expressway

Computation period:

2012/1/25 15:00~1/26 15:00

Analysis domain:

Kitakinki-Toyooka Expressway, Aogaki ~Santo IC & surroundings within 1km range of the route

Outputs:

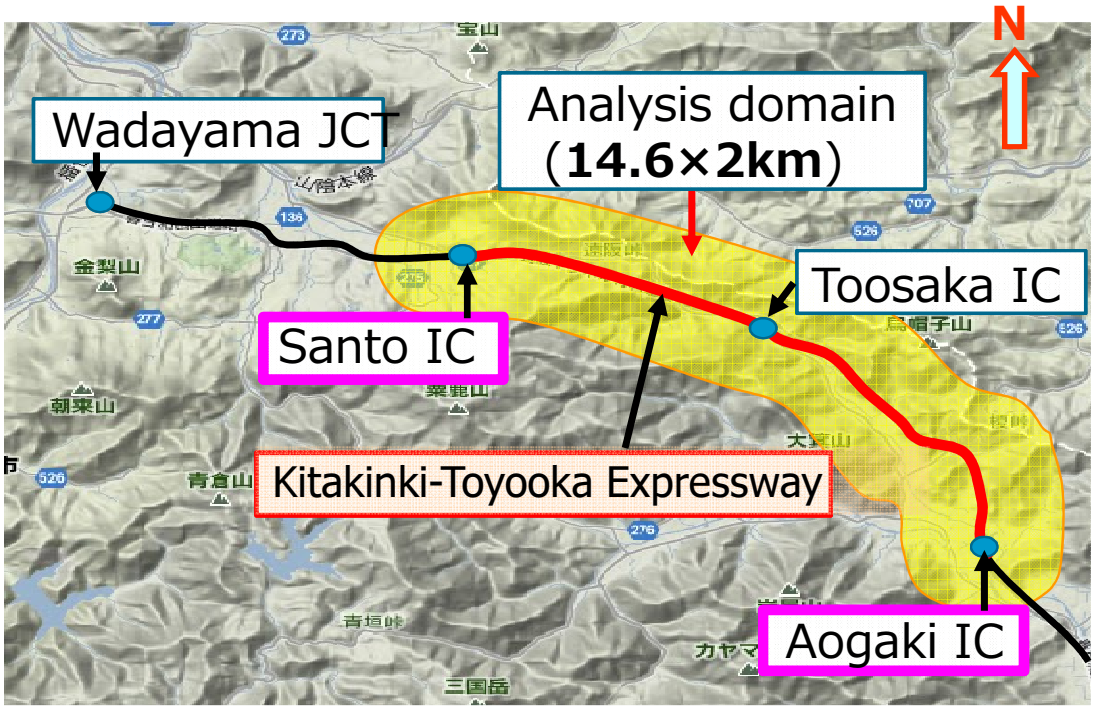
- **RST** and **HFN**
- **Solar radiation and long-wave radiation** fluxes
- **Sunshine or shade** & View factor

Meteorological data:

Observed data at Aogaki IC and Santo IC

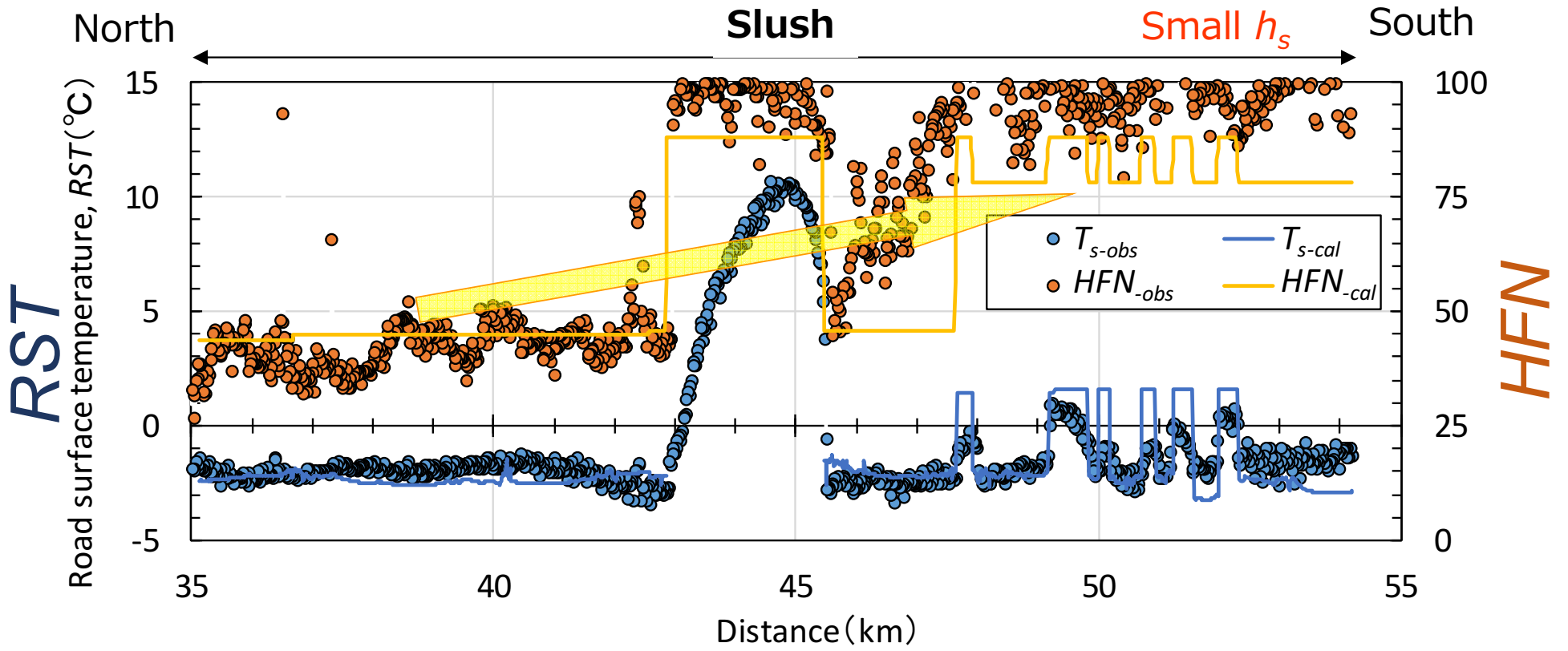
Resolution of DSM:

50m~400m



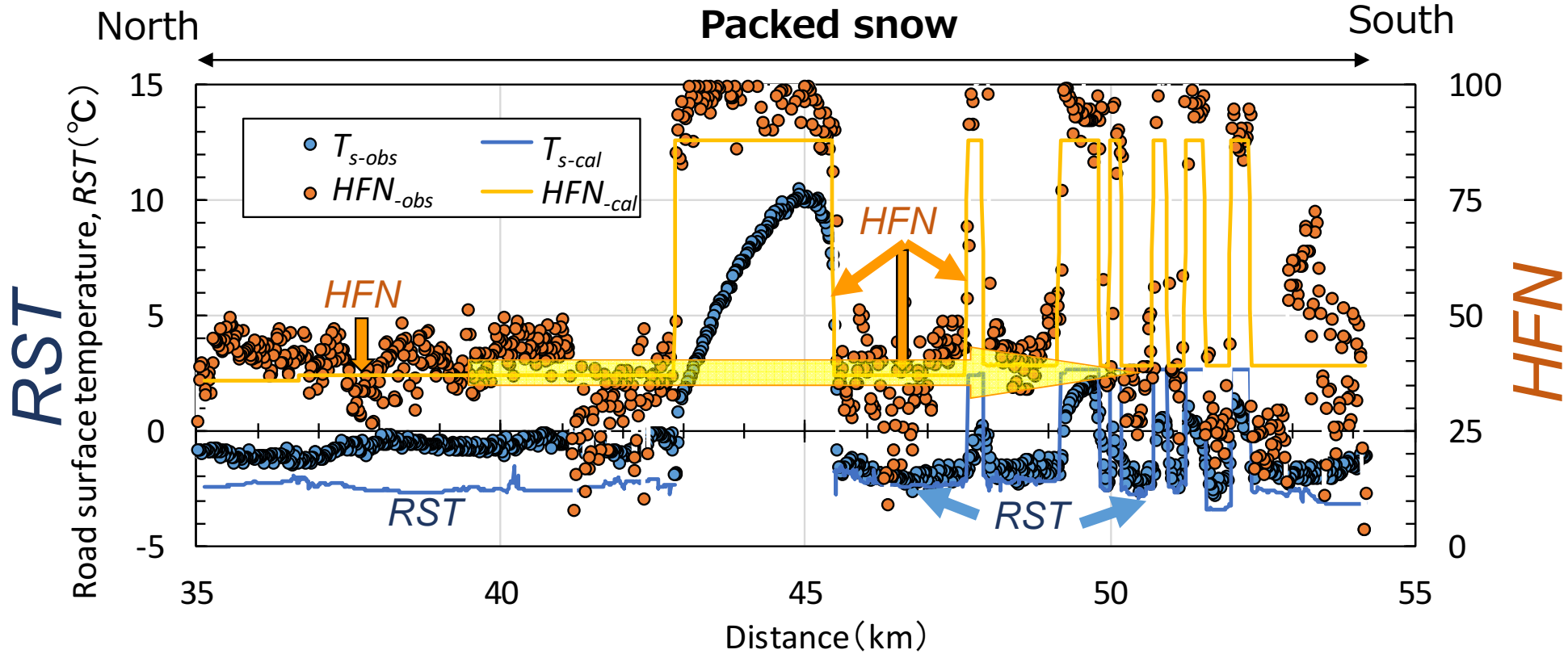
Analysis domain

RESULTS(1): Road surface temperature (*RST*) and *HFN* profiles on a slushy surface



(2012/1/26 2:00)

RESULTS(2): Road surface temperature (*RST*) and *HFN* profiles on a packed snow surface



No difference in snow condition

(2012/1/26 6:30)

Conclusions

- Calculated **road surface friction** (HFN) is in **good agreement** with the measured HFN profile along the expressway.
- The forecast model has a lower RST accuracy **at several spots in the daytime.**
- Small terrains, buildings and trees could increase the risk of **misjudging sun shine/shading portions** on a road surface.
- Mean error of road surface temperature is **1.4°C.**

Thank you for your attention!

Ďakujem

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