IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Faire avancer la sûreté nucléaire

(Assessment of) radionuclide wash-off from contaminated watersheds

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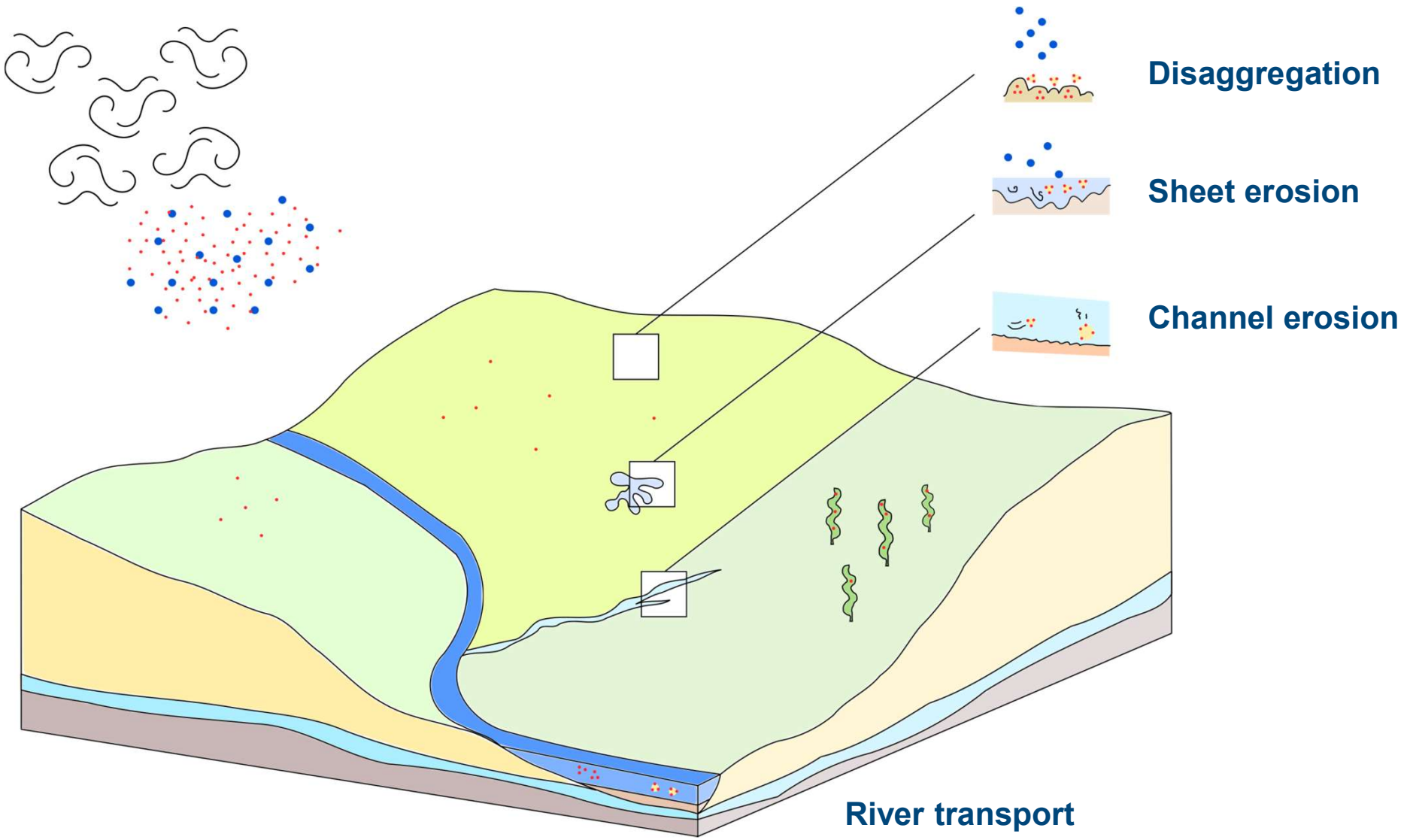
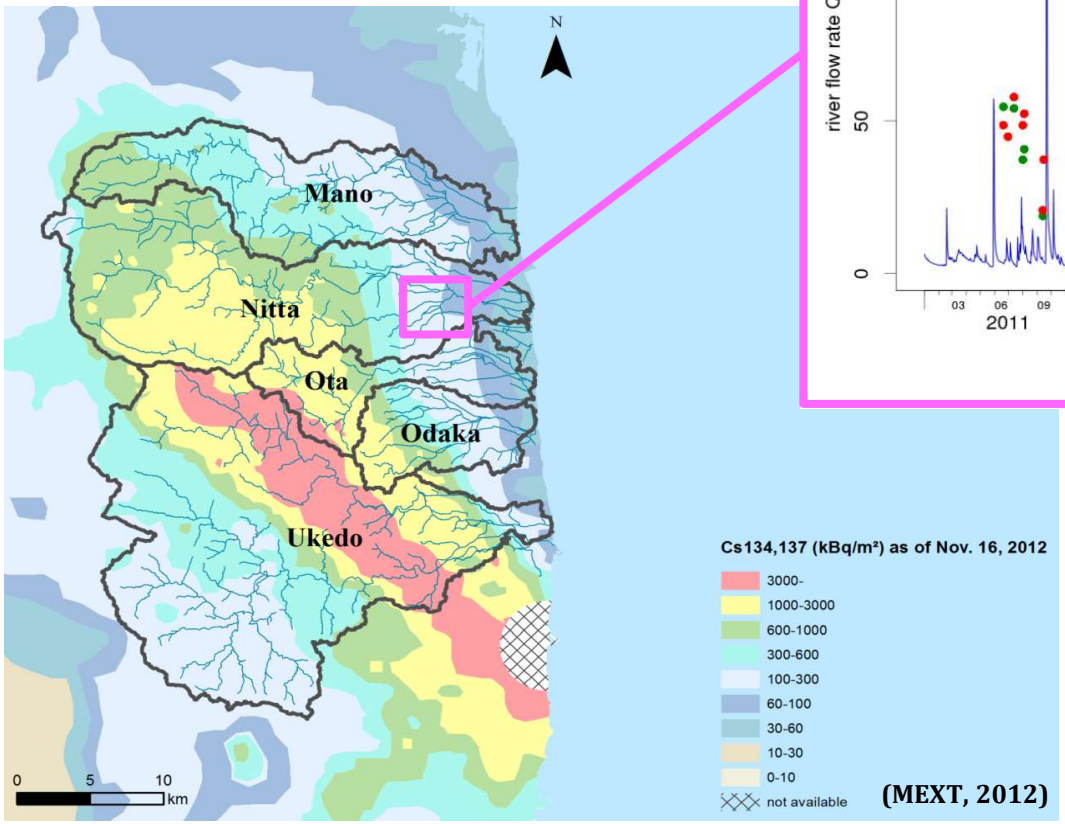
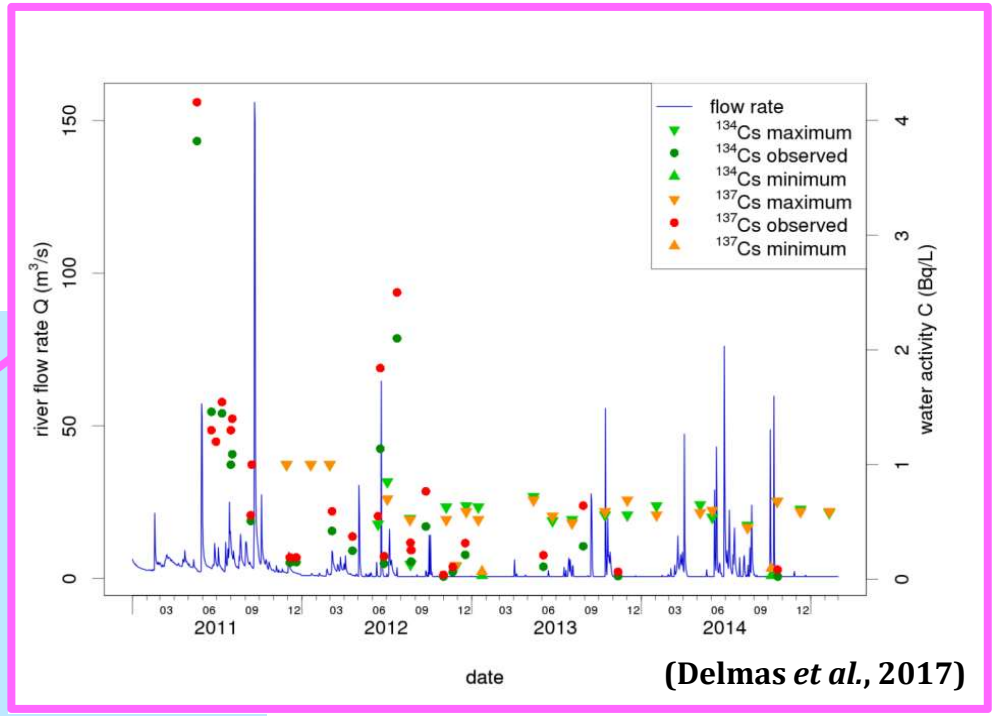
WATERSHED WASH-OFF: PROCESSES AND SCALES



WATERSHED WASH-OFF: ISSUES



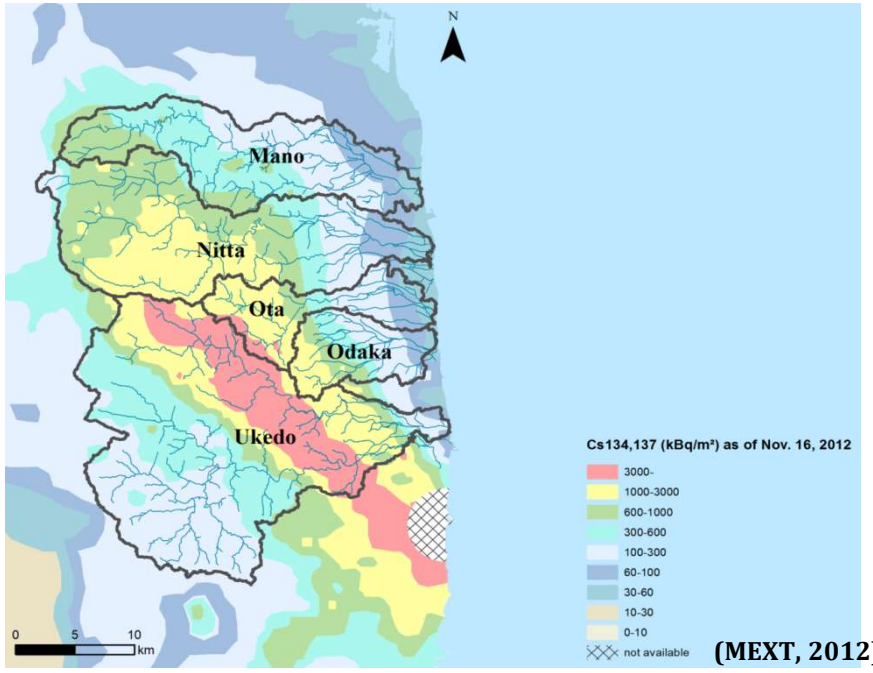
(MEXT, 2012)



(Delmas *et al.*, 2017)

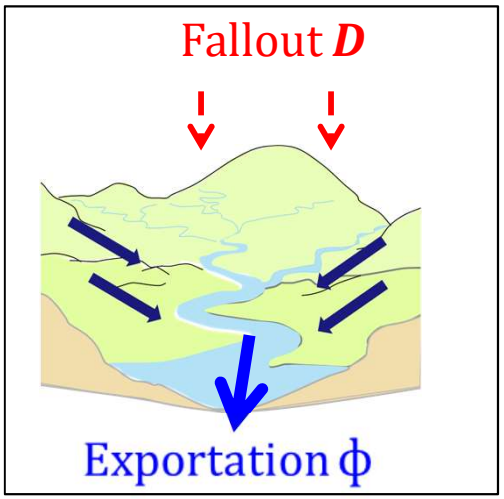
- Objectives
  - Estimate ^{134}Cs, ^{137}Cs fluxes to the sea around Fukushima
  - Improve existing models of radionuclide wash-off

- Lines of research
  - **1. Modified Transfer function (Nitta catchments)**
  - **2. Similarity of catchments responses (meta-analysis)**
  - **3. Mass Response Function (4 monitored catchments, NIES)**

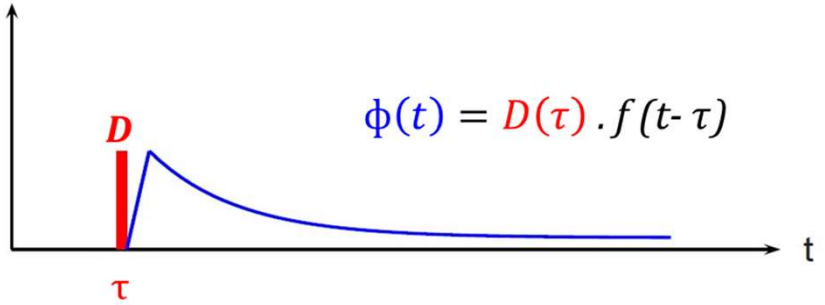


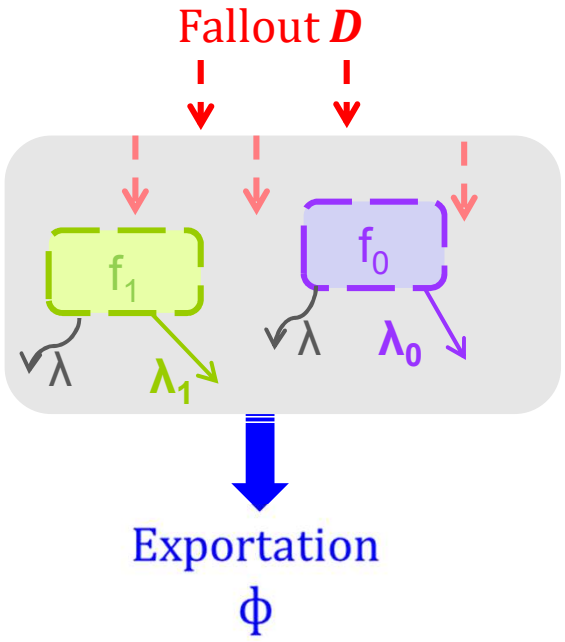
(MEXT, 2012)

ASSESSMENT OF WATERSHED WASH-OFF



Transfer function approach





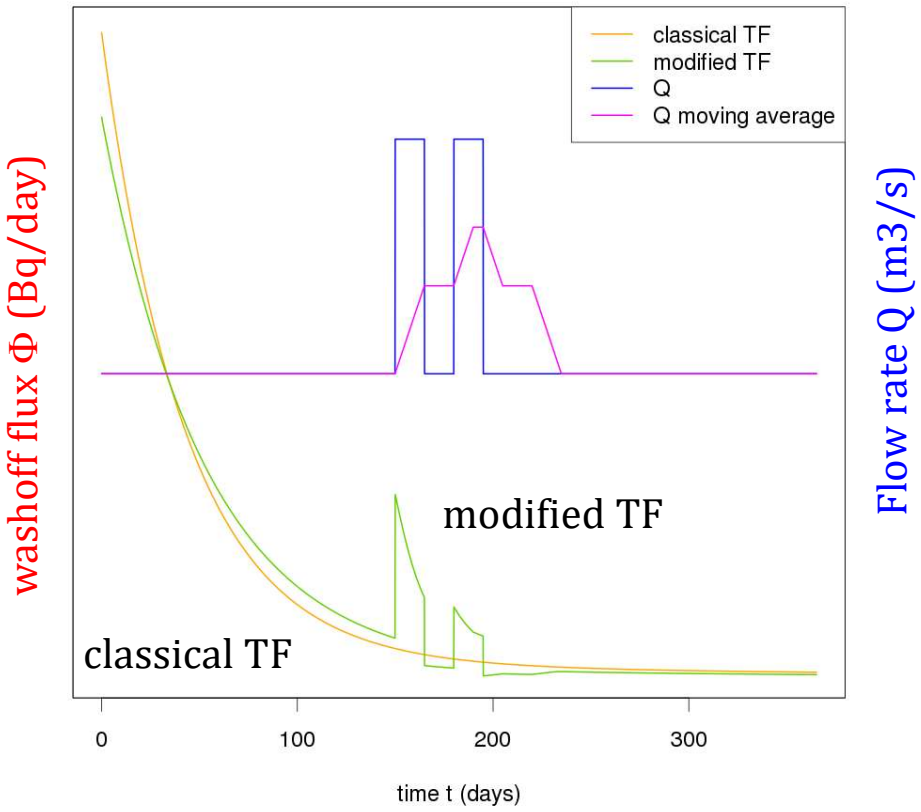
Classical formulation

$$\phi = D.\left(\lambda_0 f_0 . e^{-(\lambda+\lambda_0)t} + \lambda_1 f_1 . e^{-(\lambda+\lambda_1)t}\right)$$

Helton *et al.* (1985); Dominik *et al.* (1987); Monte *et al. (1995);* Smith *et al.* (2000)

MODIFIED FORMULATION

$$\phi(t) = D(\tau)\, G(t)\, f(t_C - \tau)$$



Effect of flow rate (Q) fluctuations

Integrating the recent history of flow rate :

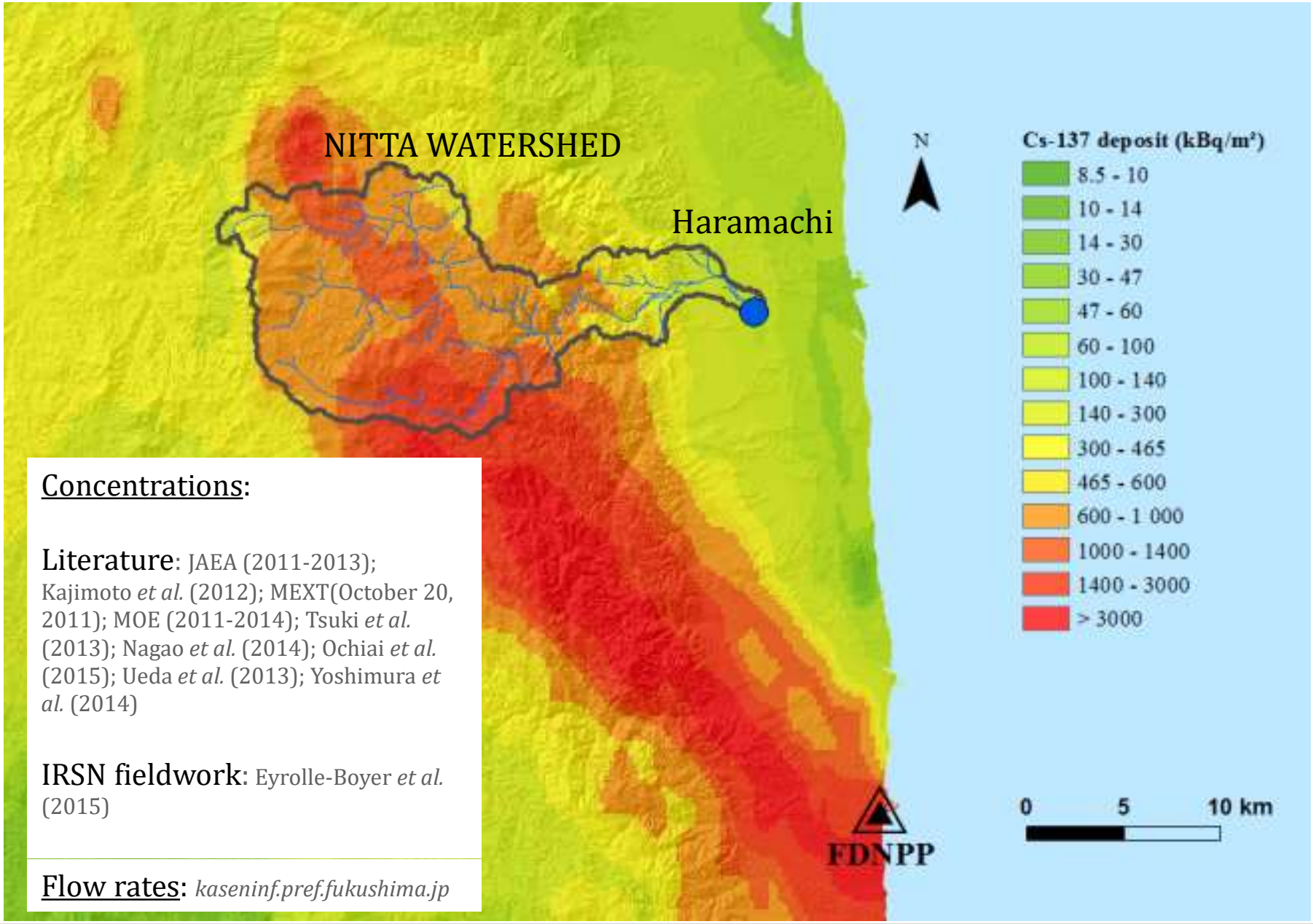
$$G = \frac{Q(t)}{Q_{22d}(t)} \exp\left(-\frac{Q_{85\%}}{Q_{22d}(t)}\right)$$

Effect of runoff volume

Time corrected with exported water volume (t_C) (Rhode et *al.*, 1996)

$$t_C = \frac{\int_0^t Q(\tau).\, d\tau}{\bar{Q}}$$

MONITORING DATA



Concentrations:

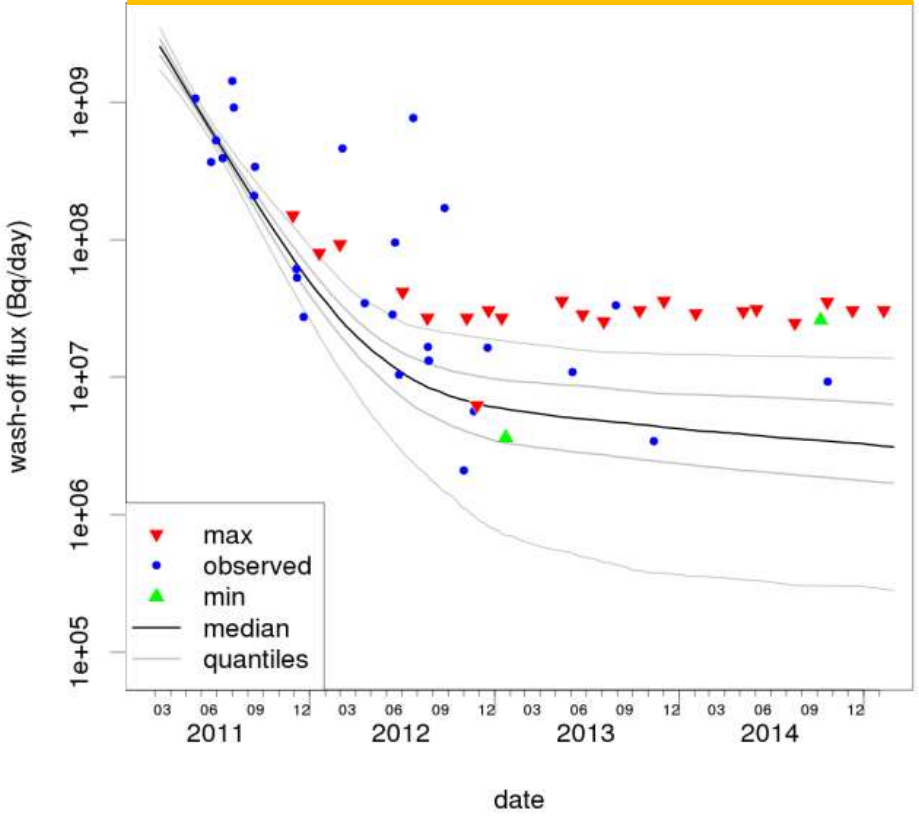
Literature: JAEA (2011-2013); Kajimoto *et al.* (2012); MEXT(October 20, 2011); MOE (2011-2014); Tsuki *et al.* (2013); Nagao *et al.* (2014); Ochiai *et al.* (2015); Ueda *et al.* (2013); Yoshimura *et al.* (2014)

IRSN fieldwork: Eyrolle-Boyer *et al.* (2015)

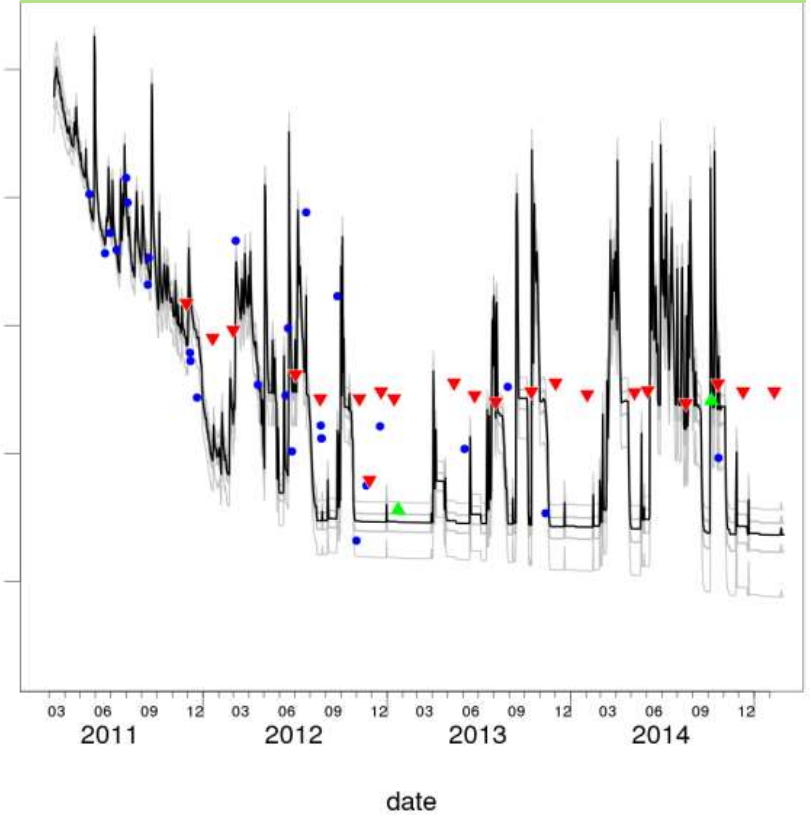
Flow rates: *kaseninf.pref.fukushima.jp*

RECONSTRUCTED FLUXES AFTER CALIBRATION

Classical formulation



Modified formulation

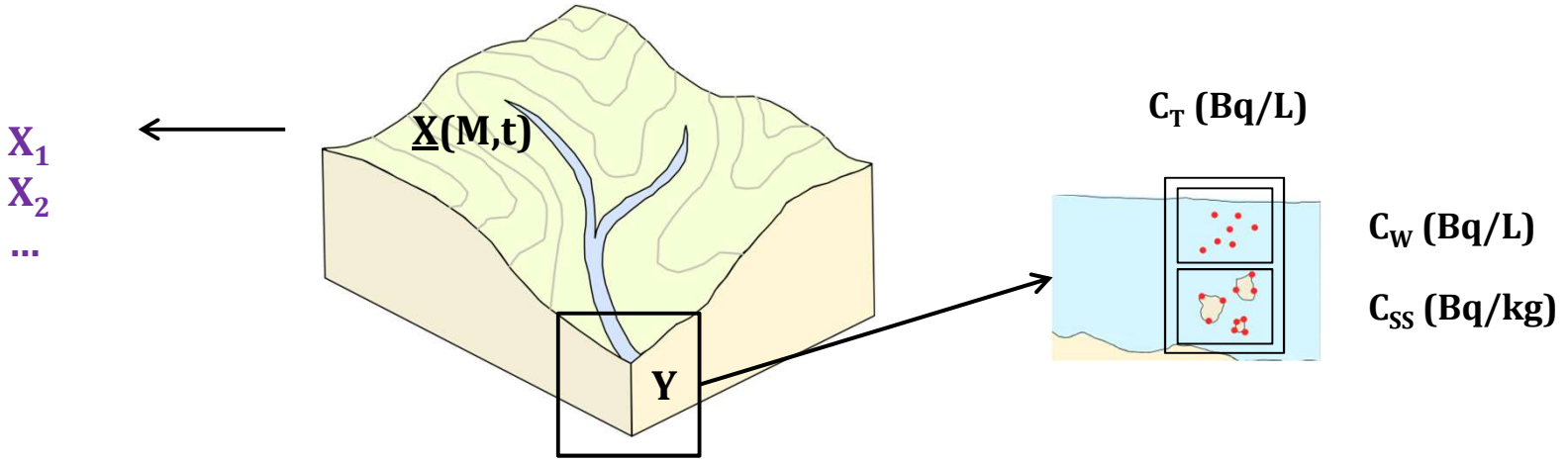


META-ANALYSIS: OVERVIEW

Conditions (X)
(scalar variables)

Experimental units
(catchments)

Observations Y(t)



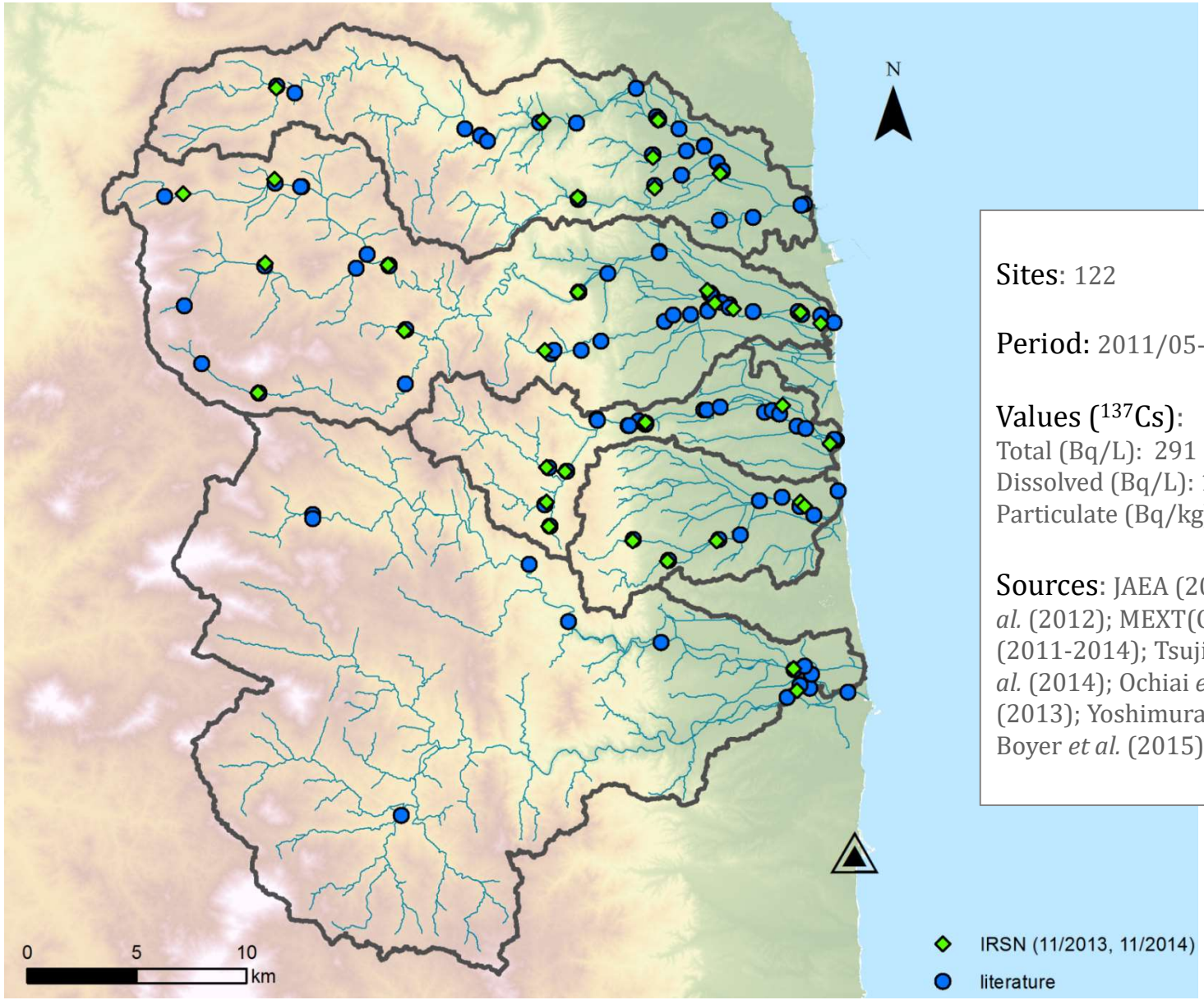
Variability

Variable selection
(regression)

$$Y = f(X_1, X_2 \ldots, X_p) + \varepsilon$$

Y	f	$(X_1, X_2 \ldots, X_p)$	ε
$\log C_T$ (Bq/L) $\log C_W$ (Bq/L) $\log C_{SS}$ (Bq/kg)	linear	$\log D_0$ $\log D_l$; Season ; $\log D_{l+d}$ Time Slope Land-cover ...	least-squares

OBSERVATIONS (Y): ^{137}Cs RIVER CONCENTRATIONS



Sites: 122

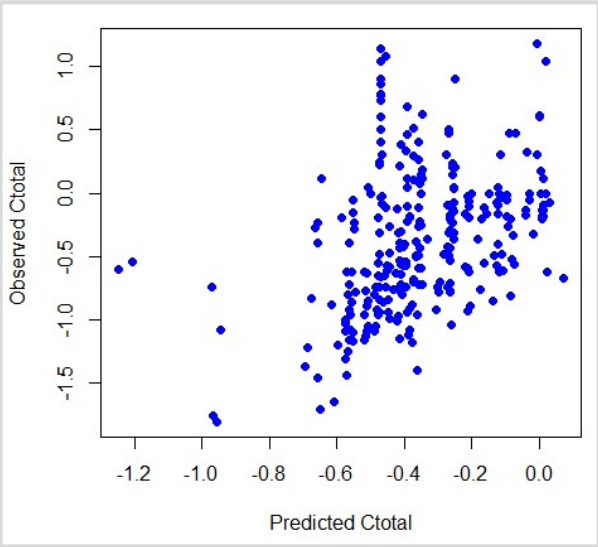
Period: 2011/05- 2014/10

Values (^{137}Cs):
Total (Bq/L): 291
Dissolved (Bq/L): 109
Particulate (Bq/kg): 255

Sources: JAEA (2011-2013); Kajimoto *et al.* (2012); MEXT(October 20, 2011); MOE (2011-2014); Tsuji *et al.* (2013); Nagao *et al.* (2014); Ochiai *et al.* (2015); Ueda *et al.* (2013); Yoshimura *et al.* (2014); Eyrolle-Boyer *et al.* (2015)

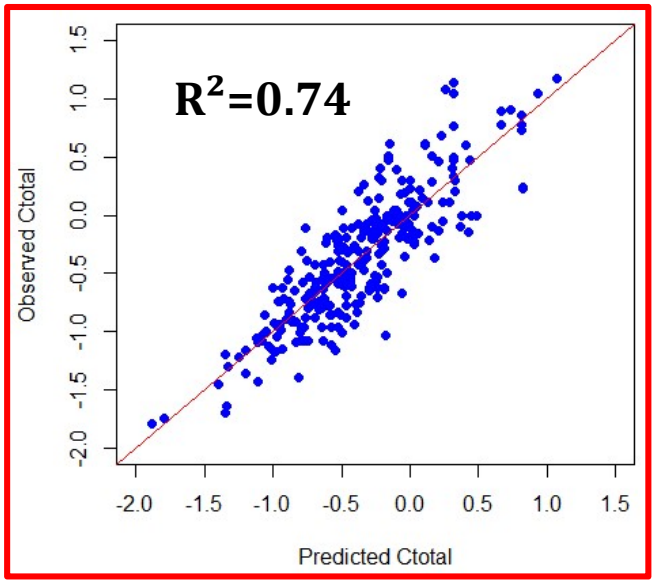
CRITICAL VARIABLES

C_T (Bq/L)

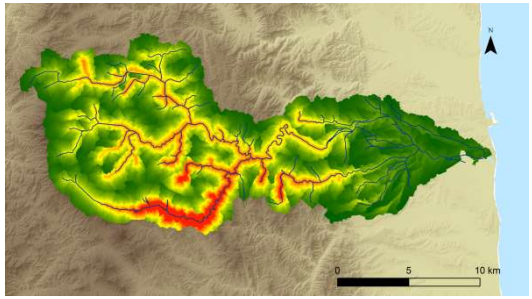


Selected variables

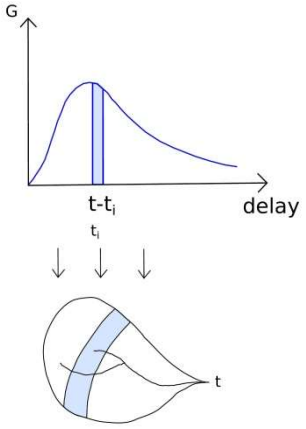
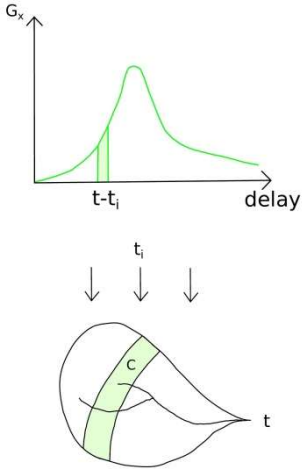
Model performance criterion	Value
R^2	0.74
GSE	1.91
Cross validation results	**RPD values**
mean RPD	1.80
median RPD	1.76
Selected variable	**p-value**
D_l	< 2.2e-16
τ	< 2.2e-16
Season	2.54E-10
SL	8.67E-07
SL_G	1.05E-06
R90d	1.47E-05
LC_{for}	8.67E-05
SL_S	2.32E-04
LC_{agri}	1.17E-03
R30d	5.56E-03



D_l



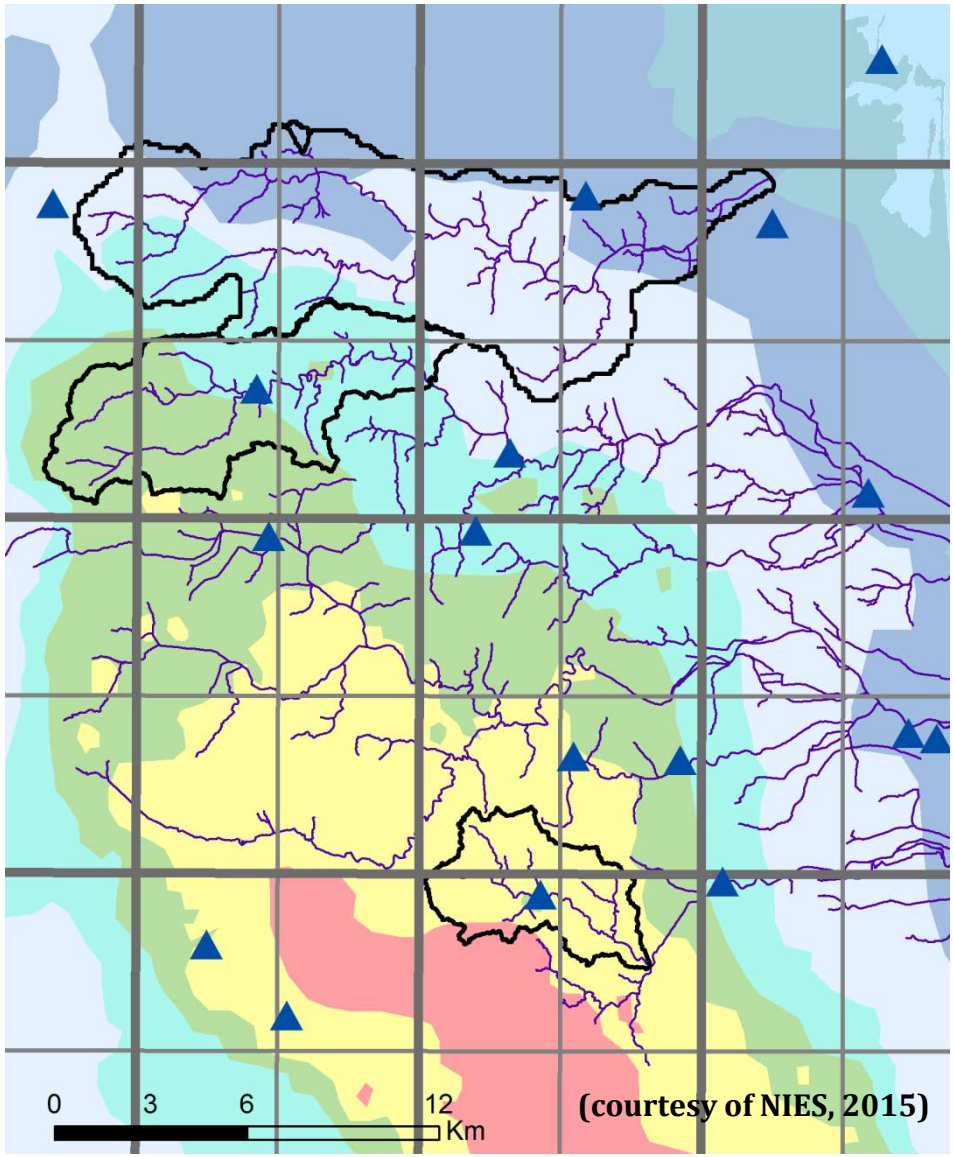
MASS RESPONSE FUNCTIONS

	production	transfer	equations
Water (w)	not resolved		$Q_w = \int_0^t G(t-\tau)\, i(\tau)\, d\tau$
Radionuclide (x)	Mass-balance $\frac{\partial C(t-\tau,\tau)}{\partial t} = \ldots$		$Q_x = \int_0^t G_x(t-\tau)\, i(\tau)\, d\tau$ $G_x(t-t-i,\tau) = C(t-\tau,\tau)\, G(t-\tau)$

(after Rinaldo & Marani, 1989)

4 STUDIED CATCHMENTS

- NIES Monitorings (2011-2016)
  - Flow rate
  - Turbidity/Suspended matter load
  - Particulate concentration (Bq/kg)
  - Dissolved concentration (Bq/L)
- Complementary data
  - Rainfall stations (JMA, prefecture)
  - Global rainfall maps (Aphrodite, JAXA)
  - Contamination maps (MEXT)



CONCLUSIONS/PERSPECTIVES

- Improve integrated assessments
  - wash-off
  - river transport…
- Validation with existing datasets
  - Fukushima (IAEA Modaria II, WG4.2)
  - Chernobyl: « runoff » database (FGT, 2000)
- Compare approaches
  - based on transfer functions
  - physically-based models (e.g. STREAM, MIKE-SHE)
- Turn into operationnal tools
  - typology of catchments from big datasets
  - ready-to-use wash-off parameters
  - preparing input information around NPPs