Thank you. First we thank you for the invitation. It's an honor for us to be invited in Japan. We have already seen many interesting sites and many interesting regions, sure it will continue. The [Unclear] for us now.

For this seminar I will first present our institute. We are both from the IRSN, which is in French, Institut de Radioprotection et de Sûreté Nucléaire, which means Institute for Radioprotection and Nuclear Safety. First, I will present this institute and then some general works and results. Afterwards, Frédéric will focus on [Unclear] based on the previous experience. We suggest that there could be questions at each part of the seminar.

IRSN Identity

- A public body with industrial and commercial activities**, under the joint supervision of the Minister of State, the Minister of Ecology, Energy, Sustainable Development and Planning, the Minister of the Economy, Industry and Employment, the Minister of Higher Education and Research, the Minister of Defense and the Minister of Health and Sport.**
- **Research, assessment and public service missions**
- **1700 employees, including more than 1000 specialists: researchers, Ph.D. students, post-docs and engineers**
- **A budget of €301 million in 2009, with 45% committed to research**
- **11 establishments in France, including 3 major sites: Fontenay-aux-Roses, Cadarache and Le Vésinet**

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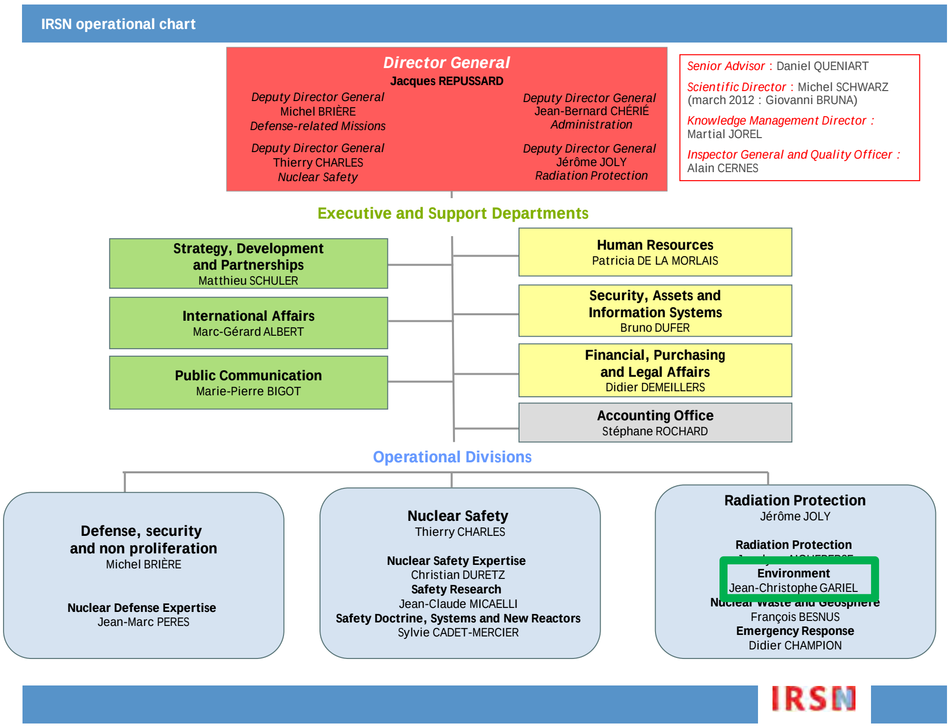
IRSN is a public institute. We depend on multiple ministries. Our missions are research, assessment, being an expert, public support to the government and public service missions. We are 1700 people working for IRSN, and among these 1700 people there are more than 1000 researchers, PG students, postdocs, and engineers, mainly scientists in the staff and lots of information about the budget. You can see that research is important in the budget and in the missions of IRSN.

It is a French institute located in different places in France. This is Paris. Paris is here. This is Paris and the main place is near Paris. Then another important location is here, Cadarache. It is north of Marseille. Marseille is here, close to Aix-en-Provence. We are here in this place, both of us.



This is the operational chart of IRSN. It is quite new because the organization changed recently. The General Director is Jacques Repussard. We are under the discussion that Jacques Repussard for IRSN and University of Tsukuba might sign a memorandum of understanding. These are the divisions.

This one is about radiation protection including radiation protection for humans. This is research for human medicine, environment, nuclear waste, and emergency response including the crisis management. This one is about nuclear safety, and this one is about defense. We are in this operational division. This operational division is organized in three services, three parts, and we are one of these three parts.

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Faire avancer la sûreté nucléaire

Overview of

Division Research & Expertise on Environmental Risks

Système de management de la qualité IRSN certifié

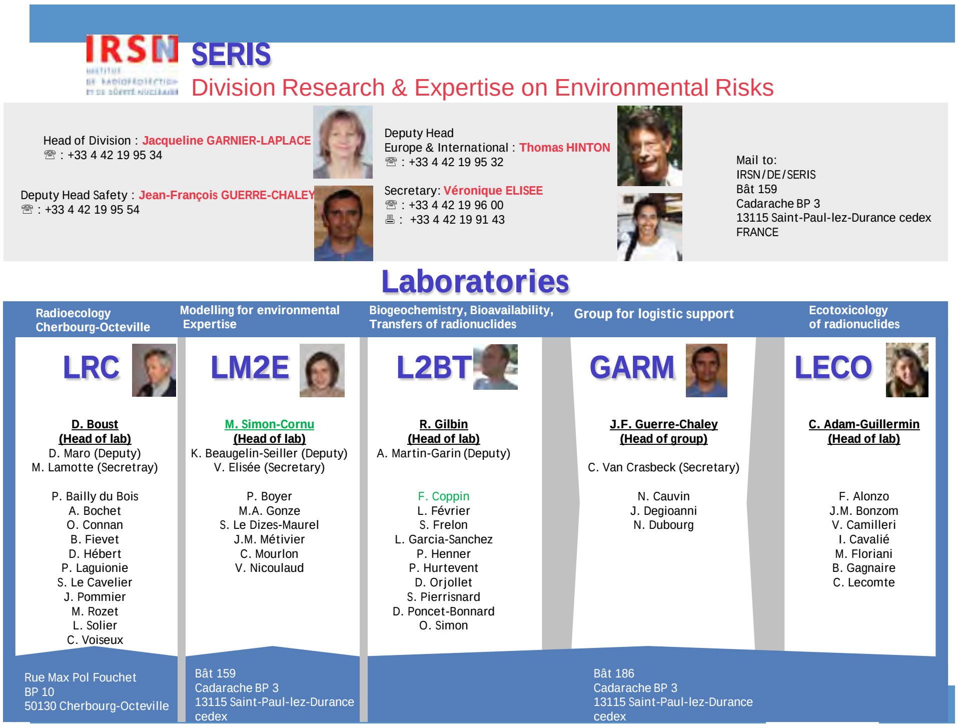
Now I will focus on our division which is about research and expertise on environmental risks. These are horses, very famous in Cadarache, the place in the South of France where we are. There are many wild things.

Key features for our division in 2012

- **Total budget :** 6 M€ including 65 % permanent & temporary staff
  25 % ressources extérieures (1.4 M€)
- **Clients :** European commission, nuclear industry (EdF, ANDRA, AREVA)
  ANR (national research agency), other national agencies
  Private companies (véolia, total)
- **Collaborators :** 50 (12 technicians, 3 secretaries, 35 engineers-researchers – (=18 FullTime researchers)
- **PhD students :** 12 // **Post-Doc:** 2 (+3 vacant positions)
- **Links for education & training with universities in environmental sciences:** Aix-Marseille, Montpellier, Nancy/Metz, Bordeaux, Toulon/var, Rouen, Grenoble, Caen, Brest…
- **Publications in international peer-reviewed journals in 2011:** 26
- **On going projects:** ANR (AMORE, INOGEV, VEGDUD, MESONNET, StMalo, FREE BIRD); CEA (Transrad); MEDDTL (DEVIL); EC (STAR); EdF (GGPe); ANDRA ; GNR Trasse
- **Main partners:** INERIS, CEA, CNRS, IFREMER, INRA, CEH (UK), SSM (Sweden), NRPA (Norway), CIEMAT (Spain), SCK (Belgium), STUK (Finland), BfS (Germany), CNSC (Canada), Univ. Laval (Canada)…

This is our division. A lot of us are in this division. It is 50 people plus Ph.D. students and postdocs. This is the total budget. We are here in 2012. Our main mission is research. You can see the publications in journals and we are involved in projects funded by the French funding agency, which is the ANFR which funds the research projects. One of these projects is FREEBIRD which is dedicated to birds in the Fukushima prefecture.

Of course we have many partners in France and at the international level. We lead the consortium of research institutes in Europe about geoecology, the science of protection in the environment.



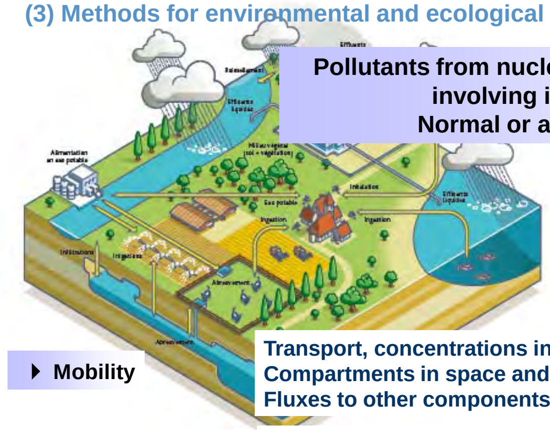
This is the organization of this research expertise on environmental waste. The total is 50 people and it is organized in laboratories. I am the Head of the Modeling for Environmental Expertise Laboratory. We have very close contacts with this laboratory of biochemistry, biorelativity, transfer of radionuclides which is led by Rodolphe Gilbin whom you met and Frederic [Unclear] belongs to this laboratory. The other laboratories – these ones are also in Cadarache and also involved in research like Fukushima Prefecture. This laboratory leads the FREEBIRD project about birds in Fukushima and here we continue about the toxicity of radionuclides on biota, non-human species in the environment. These four labs are in Cadarache in the South of France. This one is in Normandy, in the north of France. They are mostly involved in research about atmospheric transportation of radionuclides and the marine dispersion of the radionuclides and they are close to the sea.

Our activities in brief

(1) Dynamic behaviour of radioactive substances in the biosphere (alone or in mixture, natural or anthropogenic origins)

(2) Effects on animals and plants health : Ecological consequences

(3) Methods for environmental and ecological risk assessments.



Pollutants from nuclear industries and activities involving ionising radiation
Normal or accidental releases

- **Mobility**

Transport, concentrations in abiotic
Compartments in space and time
Fluxes to other components

- **Bioavailability**

Uptake through biological membranes
Bioaccumulation, depuration

- **Ecotoxicity**

External Irradiation

Internal Irradiation
Chemotoxicity

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The main activities concerned behavior of frequencies [ph] in the biosphere, the effects on animals and plant health and methods for risk assessment to assess risk for humans and for biota, non-human species. Our scope are pollutants from nuclear industries and activities involving ionizing radiation under normal or accidental releases.

These are the key words of the research; mobility, availability, ecotoxicity, toxicity to non-human species.

Our Platform specificities:

- **modeling skills and tools**: speciation-bioavailability relationships, dose-effects relationships, mixture exposure and effects models, PBPK models, individual to population extrapolation, ecological risk; human dosimetric impact; SAUA toolbox
- **integrated technical plateau** (analytical (bio)chemical characterization in various sample types with multi-element metrology, radioactive metrology, biochemical/genotoxicity characterization, histology/imagery, freshwater/marine organisms husbandry, greenhouses, exposure laboratories). This plateau allows: to perform experiments under controlled conditions for various biological models while using (or not) radioactive tracers and/or ionising radiation, and/or any chemical elements such as metals.
- **a unique tool with the *MICADOLab* equipment** (chronic external gamma irradiator). The later allows investigating external gamma dose(rate) / effects relationships covering 6 orders of magnitude of dose rates in a large-scale experimental hall (50x7 m2)

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In Cadarache and in Normandy we have the facilities, laboratories with many specificities, modeling skills and tools applied to many applications, facilities which enable to perform experiments in the laboratory. These experiments could include external irradiation. This is very new and very [Unclear].

Knowledge and tools to support EIA and ERA

Human Radioprotection and Environmental Radioprotection :

radiological impact/risk assessment for accidental, post-accidental or routine releases (and/or occurrence) of radioactive substances into the environment

For Human Risk Assessment, the environment is only seen as multiple sources of human population exposure.

(bio)(geo)chemistry, biology, ecology, (eco)toxicology, radiobiology, genetics, Physics…etc

For Ecological Risk Assessment, the environment is considered *per se* with multiple protection targets (ecosystem, communities, populations, individuals)

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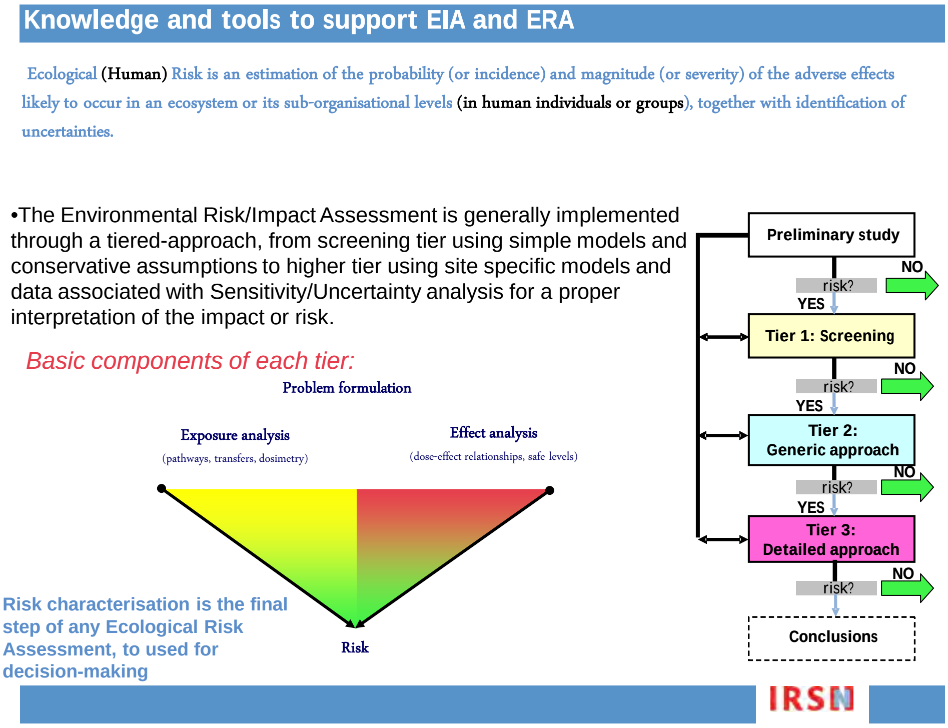
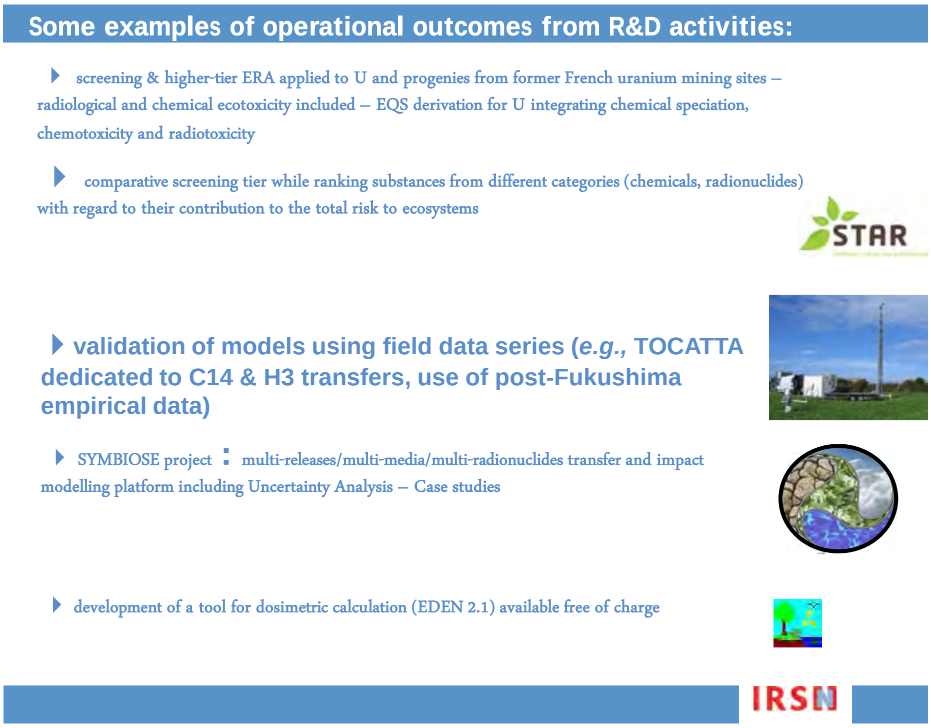
The applied objective of our research is to support, to provide science for radioprotection of humans and biota, environmental impact assessment, ecological risk assessment. To support these assessment studies we've developed research using all these facilities. Of course we continue the process until risk assessment [Unclear].



These are in slightly more detail about the activities. I think that may be not necessary that we spend a long time about that.

This is the process of assessment; different tiers, different steps when we assess risk of system of nuclear facility emitting the substances in environment to the risk for biota. We open these methods. These methods are based on calculating exposure. Exposure means calculating the transfers from the system to the target, the target being either the human or the non-human and dosimetry of course and the effect analysis is usually expressed [Technical Difficulty] those affect relationships of ecological protection.



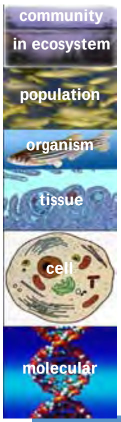
These are some of the tools that we developed and we present you SYMBIOSE, which is a software that we developed which enabled to perform assessment of transfer and impact of multiple radionuclides and multiple media for multiple places.

The ENVIRHOM-Eco programme

[E]NVIRHOM-Eco

- Knowledge on chronic internal exposure of living organisms (including humans) and on the biological responses at the individual level (e.g. growth, reproduction, behaviour) and at higher level potentially involved by this exposure is still too scarce.

Objectives :



Understand the mobility and bioavailability of radionuclides from exposure sources (soil, sediment, water, air, food)

Identify the Sensitivity of life history traits, impact on physiology, metabolism and population dynamics

Highligth the modes of action at the molecular, cellular and tissular level

Determine the consequences on the structure and functioning of ecosystems : adaptation, acclimation, community diversity…

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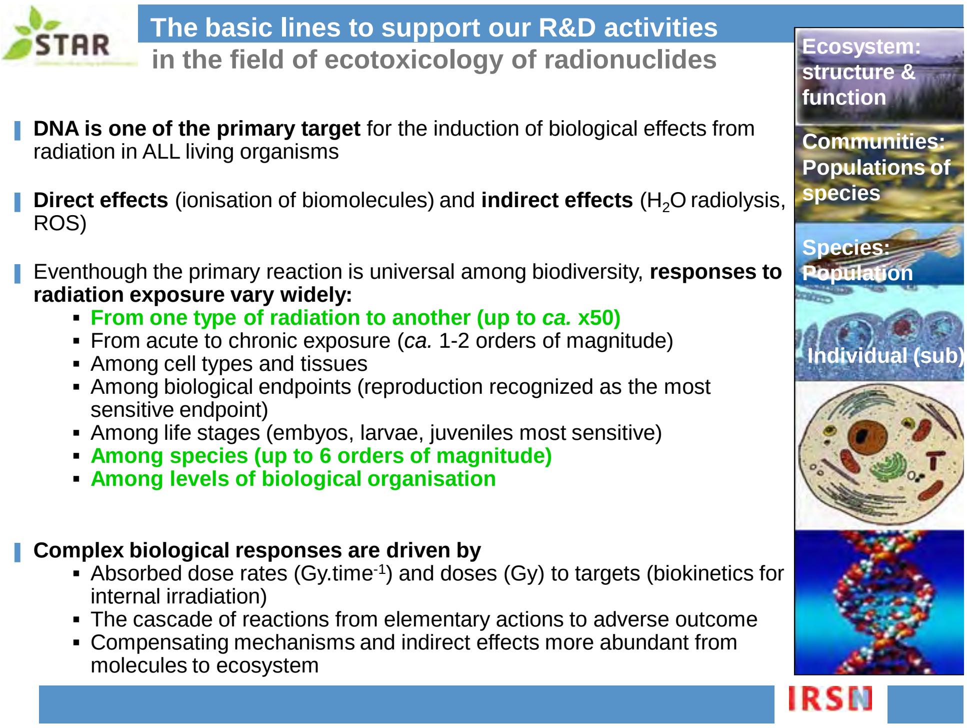
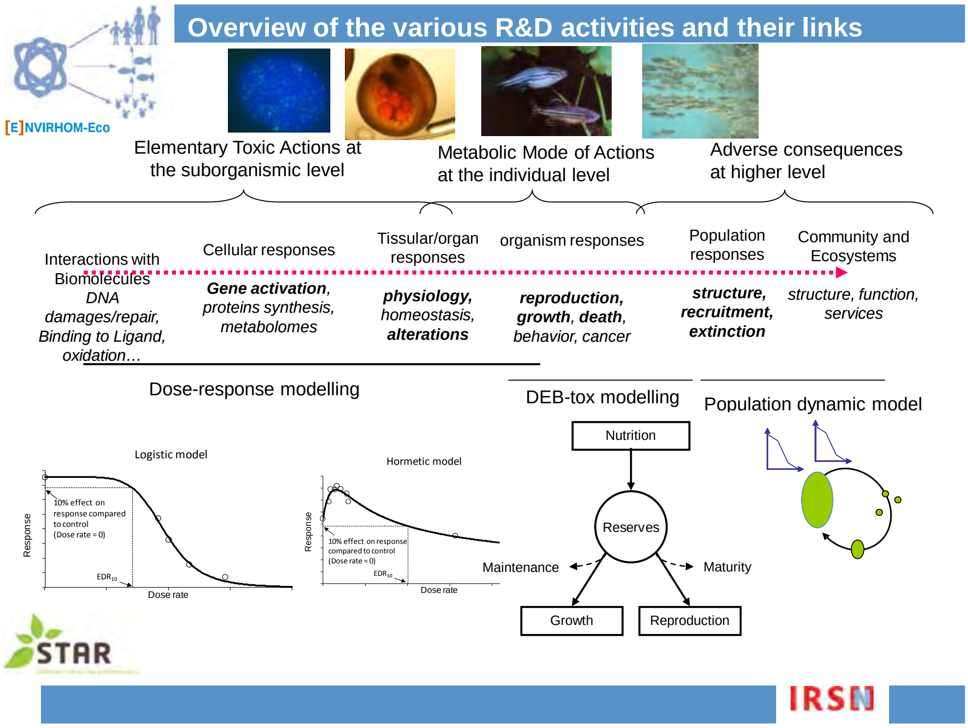
This is slightly more detailed about ecotoxicity. I don't think it is necessary to enter in much detail about ecotoxicity.



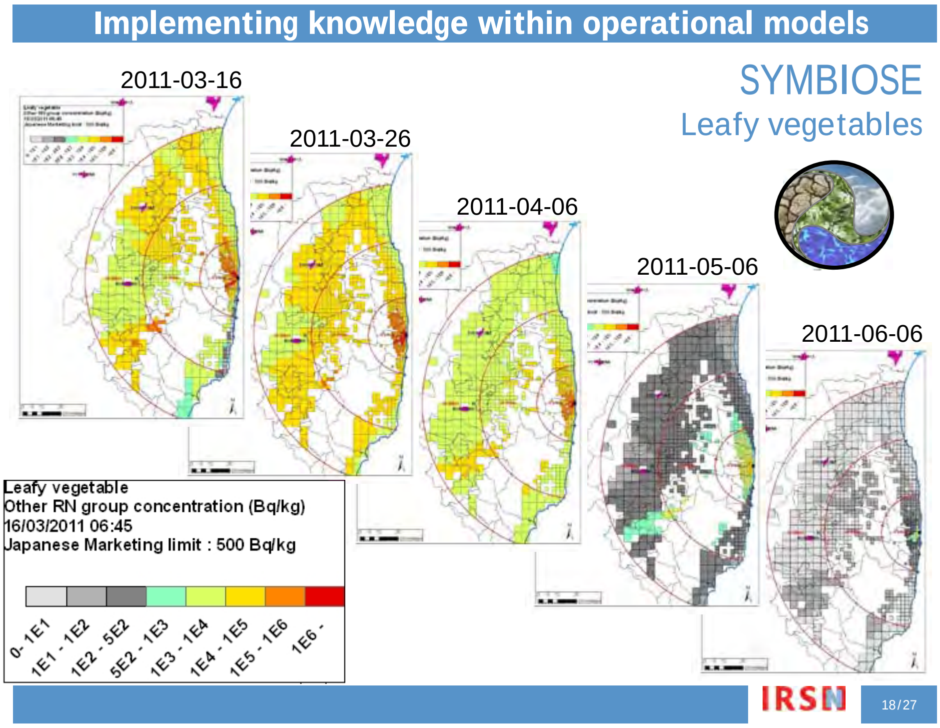
These are the main activities in this field of toxicity to species and communities and ecosystems.



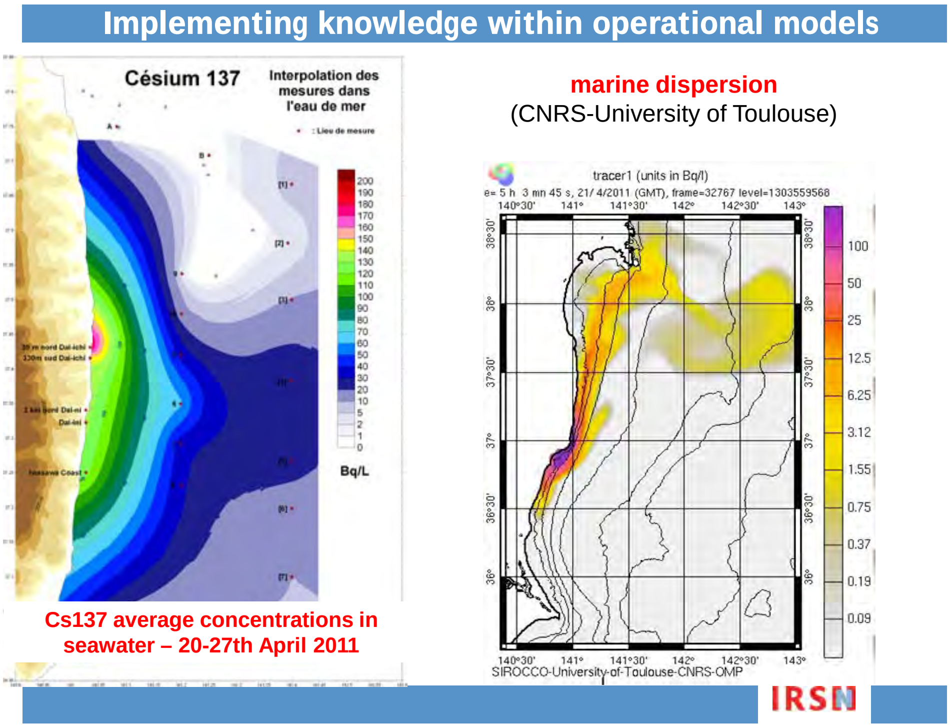
Laboratory studies are based on the level of individuals, one fish or some fishes in the laboratory. Of course we extend to population responses or even to community and ecosystem, which consist of models.

These are some illustrations of our facilities in the lab and [Unclear] model we have and the species that we have.

We also have a field monitoring and field experiments. This is our colleagues from Cherbourg doing atmospheric transportation experimentation.



This is an example of calculation we did with SYMBIOSE 1 year ago. At the end of March 2011 I will present to them in more details afterward.



These are the marine dispersion; dispersion of cesium in the ocean. These were modeled by IRSN. This is the result of the collaboration.

One sample representative of our team….

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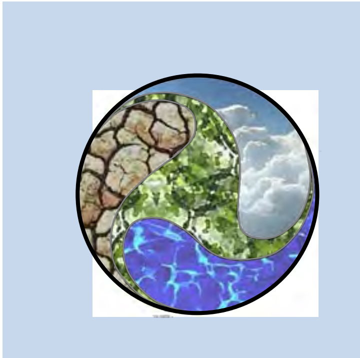
Overview of SYMBIOSE



Système de management de la qualité IRSN certifié

This was the very quick presentation of our institute. I prefer not to spend too much time about this overall presentation. I'll accept the questions and might continue with these professional tool and we can have questions afterward.

A Modeling and Simulation Platform for Environmental Radiological Risk Assessments

- Purpose: Risk assessment calculations
  - Fate and transport of radionuclides in ecosystems
  - Dose to man
- Flexible approach to deal with a wide range of situations
  - Multiple radioactive releases (atmospheric, fluvial, and/or marine) from nuclear facilities under normal, incidental or accidental conditions
  - Multi-media (atmospheric, terrestrial, freshwater and marine) and interfaces
  - Multiple exposure routes (external, inhalation, ingestion…)
- Calculations
  - Reference Data Bank with generic versus site-specific data
  - Dynamical (physically-based) and spatially-distributed modeling
  - Deterministic or probabilistic calculations (Monte Carlo)
  - Specific models to deal with hydrogen, carbon and chlorine
  - Include radioactive filiations

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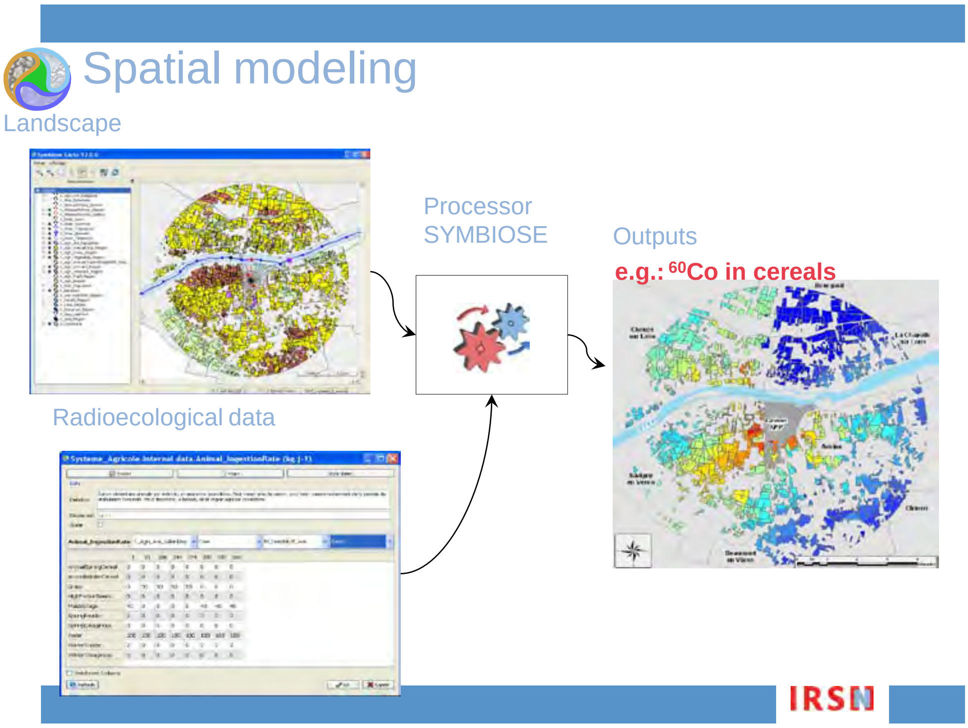
SYMBIOSE is a platform. It's a software that we developed to assess transportation of radionuclides in the environment and useful to assess dose to man and can also be used to assess dose to non-humans. The main purpose is risk assessment calculation in support to risk management decisions. This software is quite flexible and enables to be applied in a wide range of situations. It's possible to have a source [ph] [Unclear] in the atmosphere, in the river, in the sea or all of them together. It is possible to model that and it is appropriate for normal conditions or accidental conditions. Different media are modeled in the same process which enables to have interfaces between the media and atmosphere. The continental biosphere including agriculture and freshwater and pond and the sea. This enables to calculate dose to man who have multiple exposure, which includes external exposure and internal exposure through inhalation and food intake.
Of course it's based on data bank. The data bank includes generic data and some site-specific data. Of course the user can provide data to the site-specific calculation. The process is dynamical which means that we solve at each step differential equations. It is not an analytical calculation. It is based on a solver of differential equations, which enables to produce the temporal availability. It is especially distributed which means that on a map we cannot save our calculations in different places on the map. We can do deterministic calculations, which means normal calculations, but also probabilistic calculations taking into account uncertainty for multi [Unclear] sampling of data. The main equations are like, all radionuclides except the free ones. Of course we have different parameters for cesium and strontium and iodine and so on. But for these radionuclides we have specific models. We have one model for tritium, one model for carbon 14 and one model for chlorine 36. Of course our calculations include radioactive variations, which mean that we explicitly model the daughters of each radionuclide, and the daughters of the daughters and so on.

Multi-media modelling

SOURCE	Release	Release	Release			
	ATMO	Deposition		Deposition		Inhalation External
		RIVER		Watering Irrigation	Collecting	Inhalation External
			MARINE		Collecting	Inhalation External Acc. ingestion
				AGRI	Collecting	Inhalation External
				Feeding	FOOD/FEED	Ingestion
						DOSE TO MAN

This is the way to represent what is the currently modeled in SYMBIOSE. These are the compartments. This can be the source term, and then the atmosphere, the river, fresh water, the sea, the agriculture. We explicitly modeled food and feed for animals and then those two. These are the compartments on the diagram. Then the other places of interactions. For example, this is an interaction between the term source and the atmosphere because it is released from this facility to the atmosphere or released to river or released to the sea. If there is a plume in the atmosphere the plume can deposit on to agricultural soils or on to the river. It can especially model this deposition on to river and on to agriculture. Of course in the river and the seas there are fishes that fishermen can collect and then they are collected and they are ingested by man. These are all the exposure routes, all the ways that one man can be exposed to the radionuclides through food and through inhalation and through agricultural soil and through the sea and through the river. Accidental ingestion of sand if small children eats the sand on the beach and of course external ingestion.



I mentioned that it is especially explicit which means that we remodel the land-use. This is an example around the nuclear power station. This is in Loire, a French river. This is one nuclear power station. This is the landscape of 5 kilometers around the nuclear power station. We describe in which places there are crops, in which places there are animals, in which places there are people living in villages. We described the landscape this way; landscape meaning land-use and ecological network. We have ecological data. This is the calculation. This is one example of output. Here it is cobalt 60 in series [ph]. This is the nuclear power station and you can see that the crops are more or less contaminated by the radionuclides emitted by this nuclear power station under normal conditions; taking into account the winds and taking into account the impact of the rivers. The river flows this way; the ocean is here. If the nuclear power station releases radionuclides in the river, it goes this way, so this part is more contaminated than this one, which is not contaminated through the river, but only through the plume, the winds.

Data in SYMBIOSE

Radioecological parameters (default values proposed), eg.:

- 1624 transfer factors for root uptake (58 elements x 14 types of plants x 2 types of soil),
- 464 transfer factors to animal products (58 elements x 8 types of products, incl. Cow milk, Pork meat, Hen egg, …)
- 58 Kd (freshwater),
- 116 Kd (soils) (58 elements x 2 types de sols)
- …

Site-specific data to be specified for each scenario.

- Source term : radionuclides, quantities and conditions
- Weather, characteristics of the river
- Landscape (land use)
- Agricultural data (e.g. feed intake by animals…)
- Human data (food intake, where do people spend time…)

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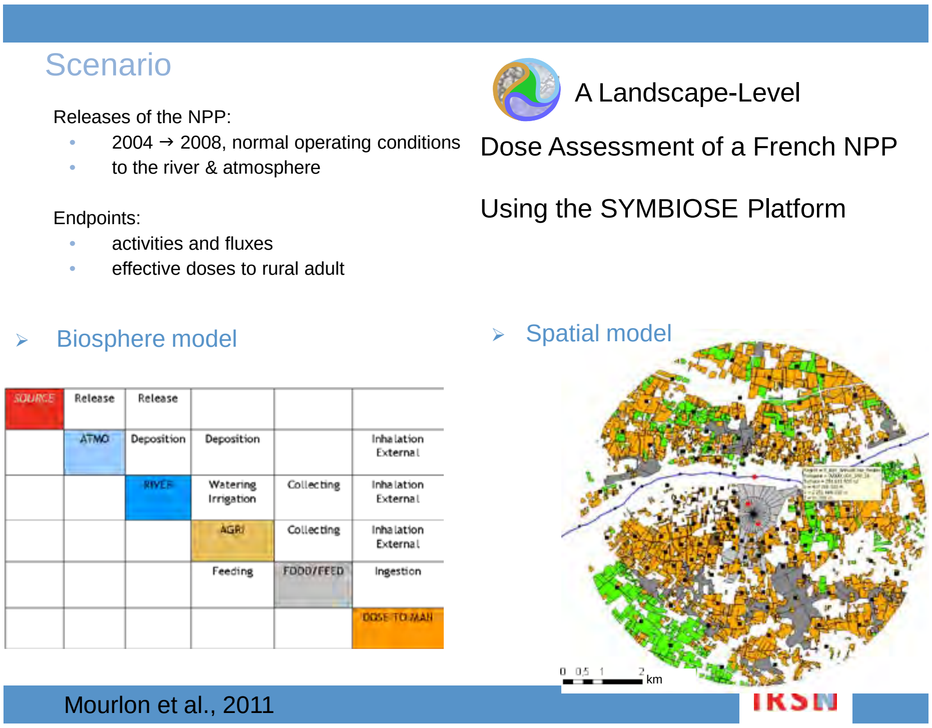
Of course there is a huge data bank for each transfer factor. We propose default values and most default values come from the IAEA, International Agency, and in the technical books. These are the examples of parameters proposed in the system. Of course the user can change the factor if the user has better information, site-specific information. Of course it's better to use site-specific information than default international [Unclear] value. For each calculation the user has to describe its scenario using the – describing the source term, which radionuclides were emitting, in which quantities, which conditions, the weather, the land-use, and so on.



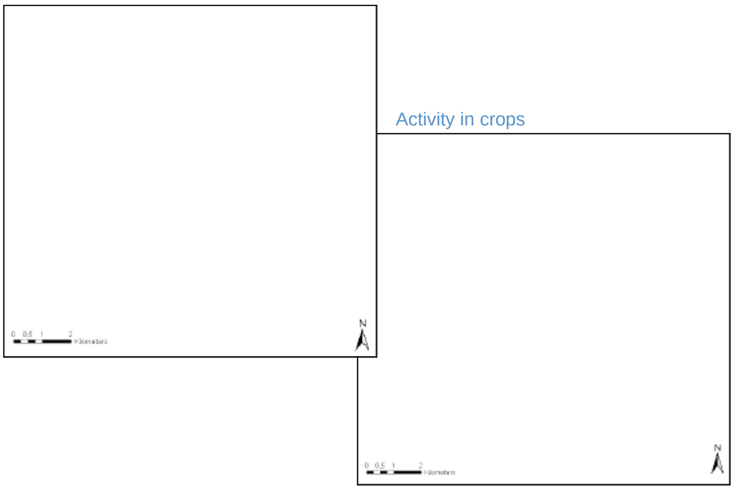
It is an example of application of this SYMBIOSE platform on a nuclear power station in normal conditions, which otherwise releases in the atmosphere and in the river. You recognize the same nuclear power station we already saw. This is the river. We describe the landscape around – it was based on true values of over 5 years. We use the real amounts of releases to the river and to the atmosphere. We calculated becquerel per kilogram of each compartment and doses on [Unclear] to adult living in this place which is a rural place, man living in a company. All these mechanisms were described.

SYMBIOSE

Activity in milk

Annual dose

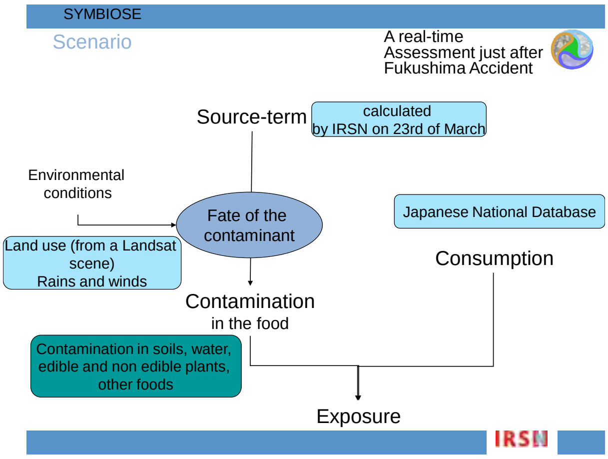
Activity in crops



Mourlon et al., 2011

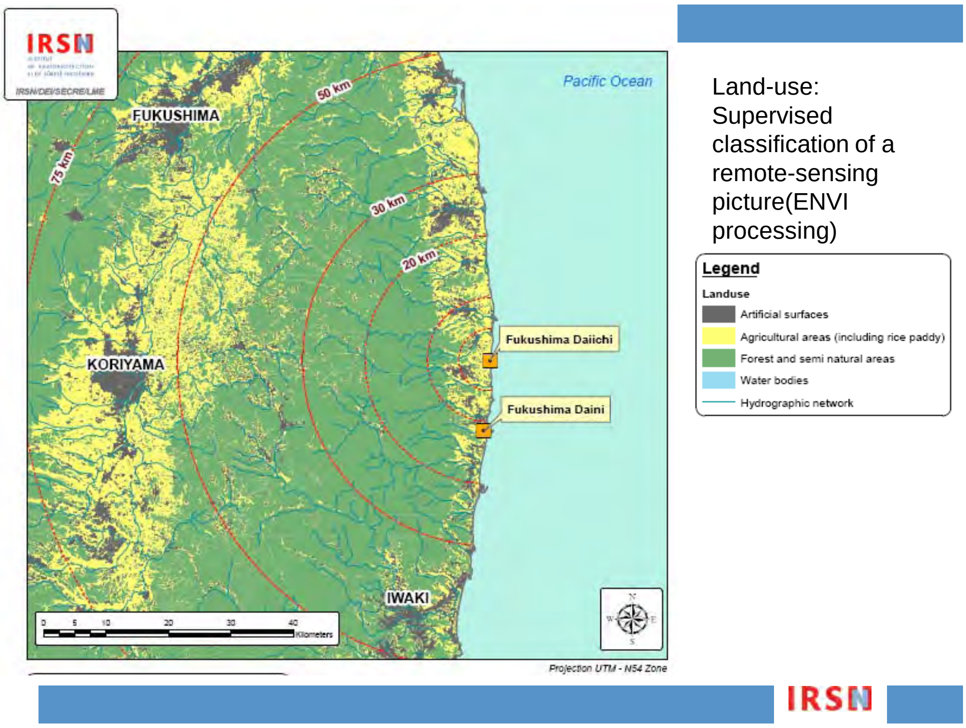
As we have solver of different calibrations, we can take into account the temporal availability. This is an example of overtime, the differences in becquerel per liter of milk. You can see a difference between winter and summer because in winter the cows are not eating the grass outside. They eat the grass and that's the difference of course. These are the villages around the nuclear power station. In each village we describe where the populations spend their time, where do they go in the day, where do they spend the time, where do they collect their water to drink, where do they collect animal products. For animal products we describe for each animal population where water is collected for the animals to drink and where are the crops cultivated for feed for animals in the winter and where are the cows in the summer, where do they eat grass. All these special interactions are modeled and it enables to differentiate which town or which village had the highest dose.

Nice translation. I'll continue. It will be a very modest presentation, very preliminary information, calculation, but of course I am sure that all of you [Unclear] aware and concerned by the data that I will present on ourselves. Please excuse any error or mistakes in the results because we were not here during the events. Since yesterday I've already learned much more than in 1 year.

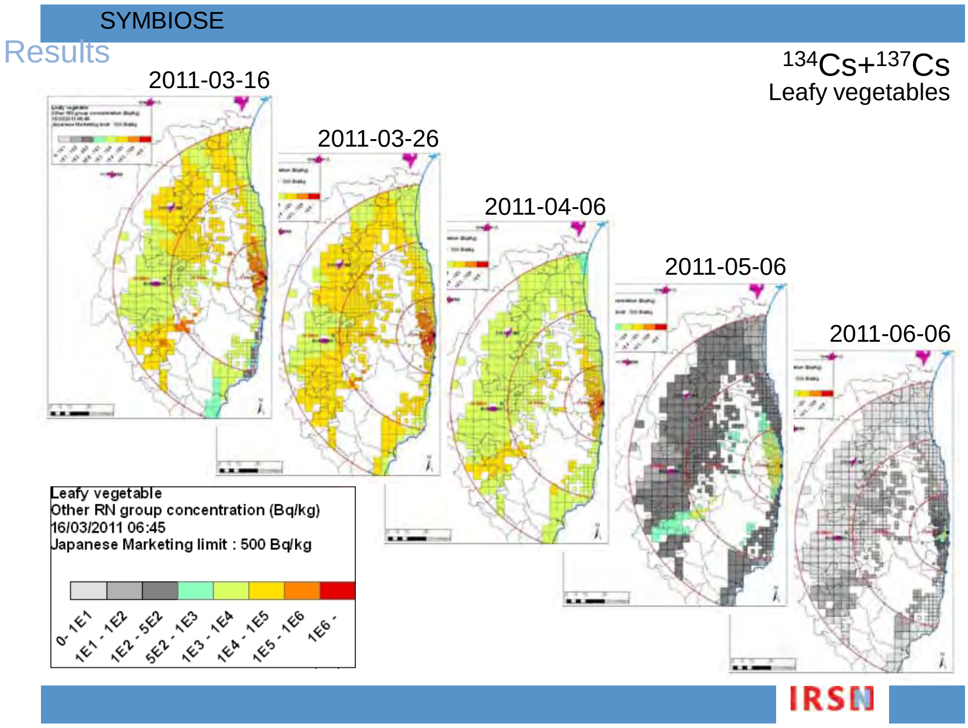


In the very few days after the accident the Technical Center for Crisis Management in IRSN was open actually the day of the events of March. The Technical Center for Crisis Management in IRSN was opened. It was opened to answer for questions of the French government and to answer questions of the Ambassador of France in Japan. Of course the IRSN only works to answer questions and the questions from these official bodies. In this context we propose that some calculations which were of course not dedicated to the crisis management itself, but mostly to train ourselves, to test what we could have done if it had happened in France.

What I will present here was not presented outside of IRSN. It's the first time that it's presented outside of IRSN. It was just for our own experiment to try what we could have done in rare conditions. It was very different. This is first calculation at the end of March last year. We used the source terms, so the amounts of radionuclides that I myself calculated that were emitted the 11th of March and 23rd of March. This was the stage of the knowledge of IRSN at these dates. Of course since these dates the knowledge has evolved [Technical Difficulty] we use this. We use the meteorological information, rains and winds, and we now know that the rains and winds that we used at that time were right We showed it because it was not rain, but snow. We also tried to understand the land-use. Of course we didn’t know the regions, so we interpreted the [Unclear] and we continue the calculation and the contamination in the sea. We did not go further, but if we had been in France we could have continued further by taking into account that the base we found some of Japanese data, but we didn't use them. We tried to use [Unclear] the French-based database consumption to calculate the exposure. We compared with data produced by the Japanese government.



This is the very, very first work that we presented. This is our view of the land-use on the nuclear power station. We used then [Unclear] long-SAT picture to try and understand the region because we didn't know that there are many forests here and [Unclear] picture. It was our understanding at that time of the green is the settlement, the cities and towns and villages. The yellow was supposed to be agricultural areas including these white spaces [ph] and green are forests. We also added the rivers. Now we know that this map was not perfect, but we did it in a very few days. It was the best that we could do at that time.



Using this and using the information about what IRSN thought to be emitted and using the rains and the winds that we had at that time we did these calculations, so starting on 11th of March and calculating – this is the cesium in leafy vegetables such as spinach. We predicted a way what could be the levels. This green is 500 becquerel per kilograms. The white zones are places where we thought there were mostly forests. It was not useful to predict spinach in places where there is plenty of forest. We indentified from this way, so [Unclear] and we thought there was another plume this way which wasn't [Unclear]. We didn't take into account that very probably most spinach in Fukushima Prefecture are under [Unclear] hut houses. This doesn't take into account hut houses and of course in March there were very few spinaches outside of hut houses.

SOIL ACTIVITY MONITORING

MEXT monitoring data

- ☐ I-131, Cs-134/136/137, Te-129/129m, Ag-110m (+ others not studied)
- ☐ About 150 stations in inhabited (& cropland) areas
- ☐ Irregularly distributed in the 20-50km region
- ☐ (Some) time series of activity in the about top-5cm layer (Bq.kg^{-1}) -> up to 3000 spatio-temporal values, March-September
- ☐ Description of sampling and analytical protocol not published (in English)?

Japanese UNIVersity monitoring

- ☐ Maps and raw data: I-131, Cs-134/137
- ☐ Maps only: Te-129, Ag-110m…
- ☐ About 2200 stations in inhabited (& cropland) open areas
- ☐ Regularly distributed from 0 to 100km
- ☐ Surface activity in the top-5cm layer (Bq.m^{-2}) in June-July 2011 (1st campaign)

Objectives

- ☐ Analyzing MEXTtime series to detect the signature of other processes than natural decay (i.e. downward migration, run-off/water erosion, etc.)
- ☐ Establishing maps of surface activity through time extrapolation to 15 March + geostatical treatment
- ☐ Checking the spatial consistency between MEXT and UNIV data sets

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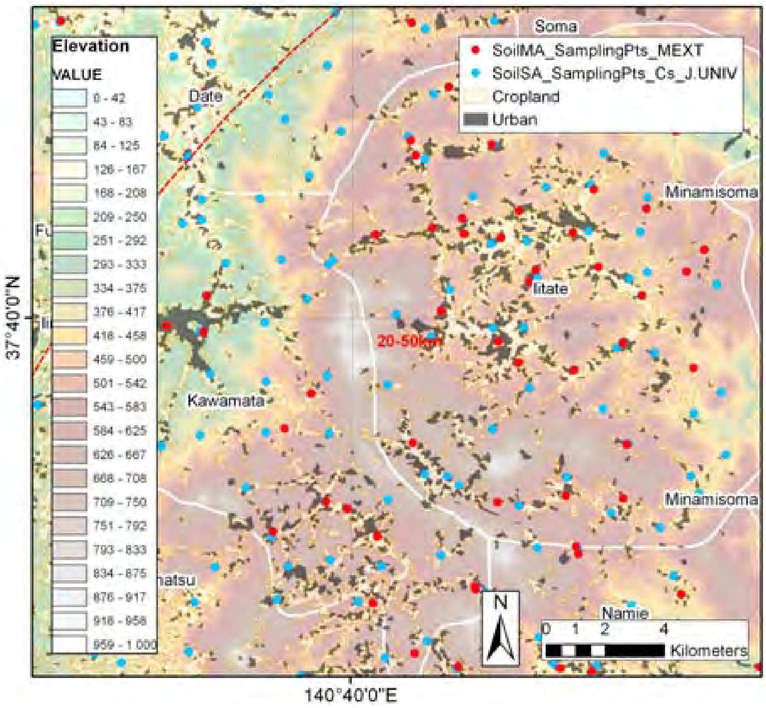
These were very, very preliminary results, end of March last year. Then over time we analyzed many data especially the data that were privileged by the government on the internet. All of you know very, very well this data, first-hand knowledge. Thus we of course were appreciated very much by this report of accurate and interesting information about becquerel per square meter. We also analyzed the data published by the Ministry of Science. We used them in this presentation and we used value for March to September. These data were not published with the objective of scientific research, and so there is much less accuracy in the description of the protocol and I guess, in the application. What I will present is based on analysis of this data.



Above sea level altitude (meters)

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This is the map where you can see in blue, the dots where you sampled and in the red the places where Ministry of Science sampled and we could observe that they are mostly sampled in villages or around the villages, but not in the forest. The assets were mostly not in the forest.

SOIL ACTIVITY : TIME ANALYSIS

Method

- Massic to surface activity conversion : coefficient ~ 65 $kg.m^{-2}$ (i.e. ~1300 $kg.m^{-3}$)
- Non linear time regression, for each radionuclide at each station :
- $$Ln[A_s(t)] = Ln[A_s(t1)] - a \times (t - t1) + \varepsilon(t)$$

$As(t_1)$: initial activity after deposition (+ standard error σ_A) ($Bq.m^{-2}$)
α : estimate slopes (d^{-1})
ε : residual error ($Bq.m^{-2}$)

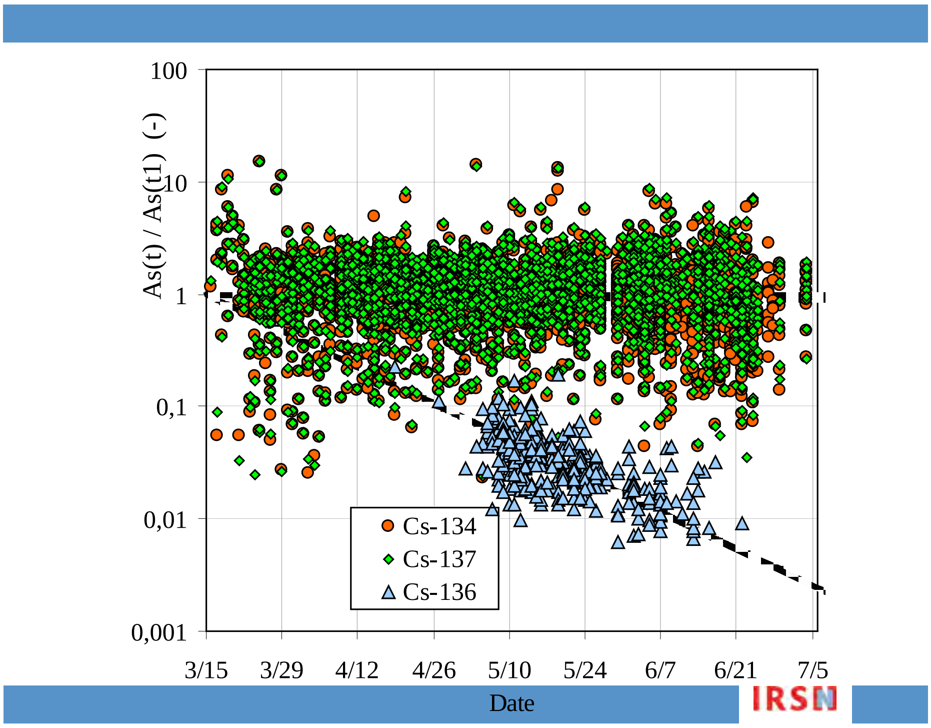
From March to September 2011
Remark: for Te-129 analytical relationship accounts for Te-129m

Results

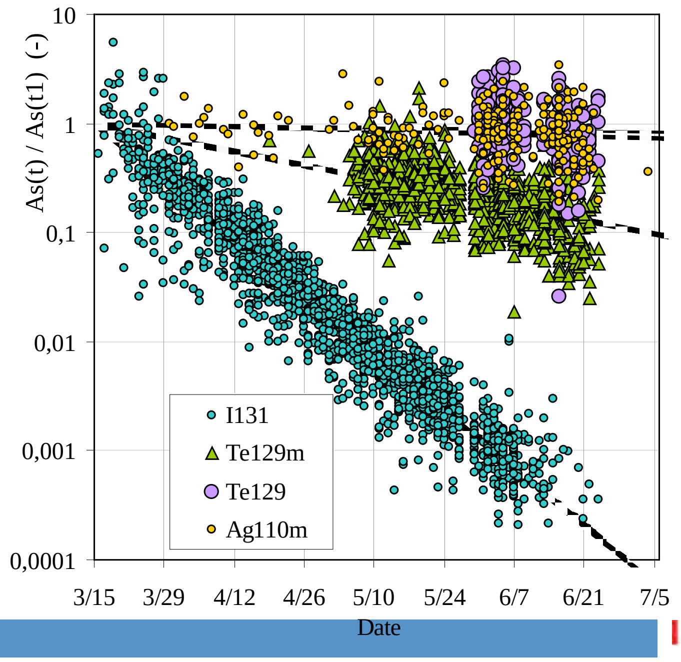
No statistical evidence that $\alpha \neq$ radioactive decay (at any station & any radionuclide) -> enables time extrapolation to t_0 March 15 of activity: $As(t1) \pm \sigma_A$
Important time-independent residual variability
MSE range from 0.25 to 0.35 $\log_{10}(Bq/m^2)$ -> small scales spatial variability of soil properties and activity sampling height “error”, intrinsic error measurement

IRSN

Under data of the Ministry of Science, we have data from March to September continuously, so with some calculation of the evolution and the type just to check what is the behavior on this timeframe, which is only from March to September. It appears that those data are quite noisy, but today the slope is not different from radioactive decay which means that the contamination has not moved from 5 per centimeters. You know that cesium has [Unclear] centimeters. It’s [Unclear] to do statistical calculation using old data and getting back to the 15th of March as a reference date to do geostatistical analysis.



These are the data. In this case they are divided by the estimate of the first value from 15th of March. You can see that it is very noisy but the tendency is constant for the cesium, etcetera, cesium 136.



IRSN

It's the same for iodine and tellurium, and [Unclear].

SOIL ACTIVITY : SPATIAL ANALYSIS

Geostatistical Method

MEXT data : Non Systematic Error Kriging -> accounting for local σ_A
UNIV data : Ordinary Kriging
Log-transformed activity -> increased kriging performance (i.e. normality)

Results

Consistency between both data sets : semi-variogram (*i.e.* spatial auto-correlation function), mean isotope ratios, spatial distribution
But difference in I-131 and Cs-134/137 mean activities : MEXT $\approx 2 \times$ UNIV -> sampling height error, bias induced by difference in experimental protocol

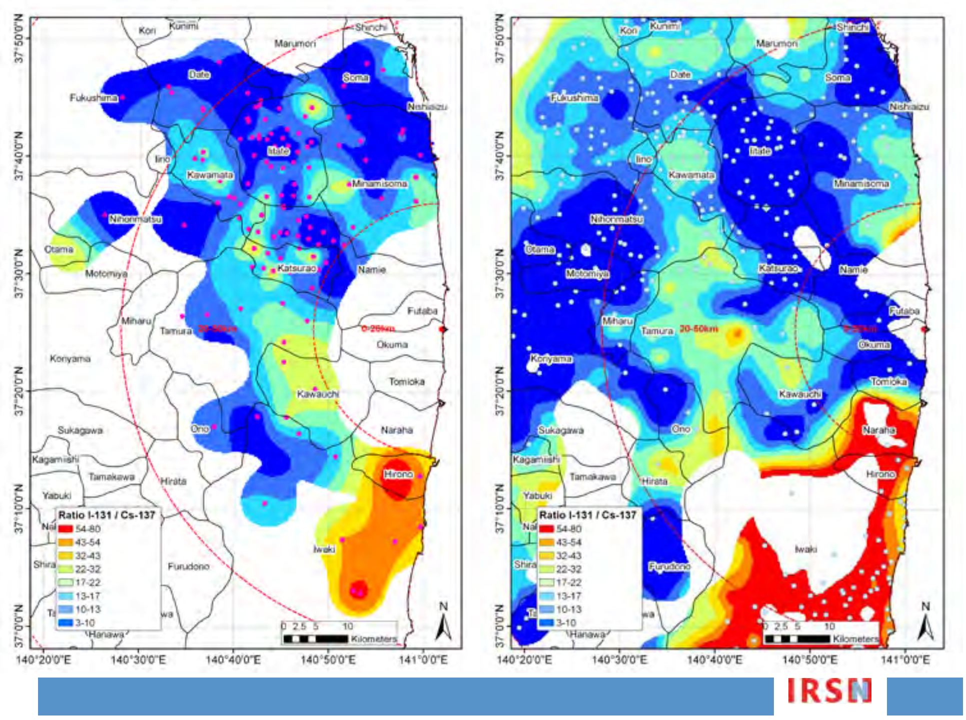
IRSN

This enabled us to do geostatistical calculation presented [Unclear] transformed the becquerel per kilogram. We could see much consistency between the dataset of the Ministry of Science and your dataset. Of course the dataset of the Ministry of Science is much more noisy, but there is some consistency concerning, for example, the ratios. We'll check that.

Activity ratios	MEXT	UNIV	IRSN Source Term (15/16 Mars)
Cs-134/Cs-137	0.9±0.05	0.99±0.03	1.3
Cs-136/Cs-137	0.4±0.2		0.4
I-131/Cs-137	12±4.5 (NW trace) 49±7 (South trace)	12.5±7 (NW trace) 75±55 (South trace)	9.5
Te-129m/Cs-137	1.7±0.6		0.6
Te-129/Cs-137	0.25±0.2		0.4
Ag-110m/Cs-137	0.05±0.06		

IRSN

This is the average ratio over the 80 kilometers from the nuclear power station. There is consistency between both datasets and also there is consistency with the source term of IRSN.



We did the geostatistical interpolations, which enabled us to predict data between two points. If we have data here and data here, we predict what is between the two points only based on the particular principle of geostatistics. When it is white, it means we don't have enough data to do this interpolation. These are the ratios between iodine and cesium on 15th of March.

WEEDS ACTIVITY MONITORING

MEXT monitoring data

- ☐ I-131, Cs-134/137 (+ others not studied)
- ☐ Fine time series of activity in the aerial part ($Bq.kg^{-1}$ fw), March -> Nov 2011
- ☐ 10 stations in inhabited (& cropland) areas, of varying elevation (from 15 to 550m)

No ecological information

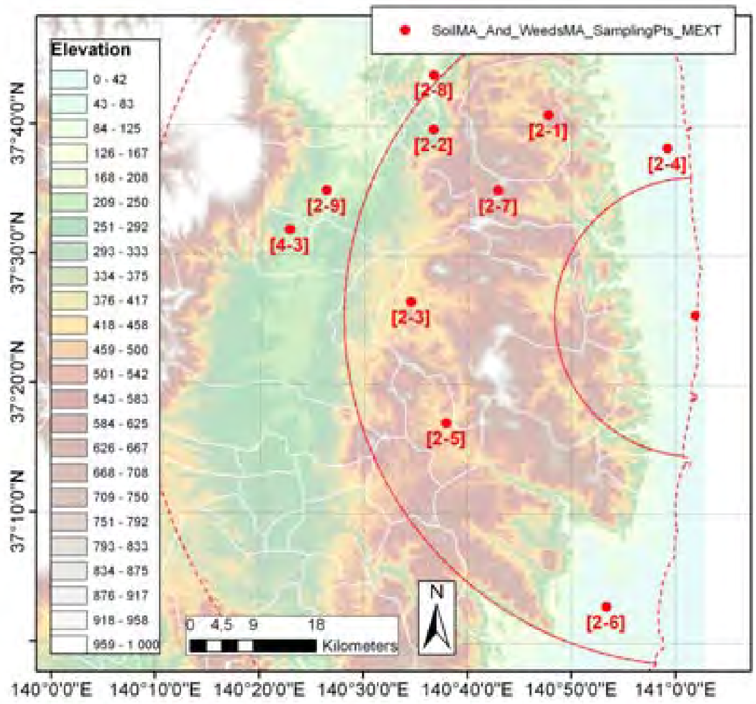
- ☐ Biocenose : grass-like vs broadleaf species, annual, biennial or perennial species, plurispecific canopies with interactions/competitions, plant growth stage, etc. ?
- ☐ Biotope : soil texture, climate, environment (i.e. gardens, road areas, semi-natural, crops), etc. ?

But, general information exist :

- ☐ in-situ studies of weeds in upland fields of Fukushima region (Kobayashi et al.),
- ☐ weed-weed & crop-weed competition models (Kropff et al., Colbach et al.) -> prediciting weed growth (in progress)

IRSN

Also we are interested in a series of data published by the Ministry of Science about weeds. We don’t know exactly what it was meant, but we suspect it was grass along the walls [ph] because it seems it was collected in the power plant, but not in the pots just along the water. Data were published in becquerel per fresh weight kilogram in November of three radionuclides.
We don't have any information about which plant is where. Yesterday I took many pictures of all possible weeds in the region.

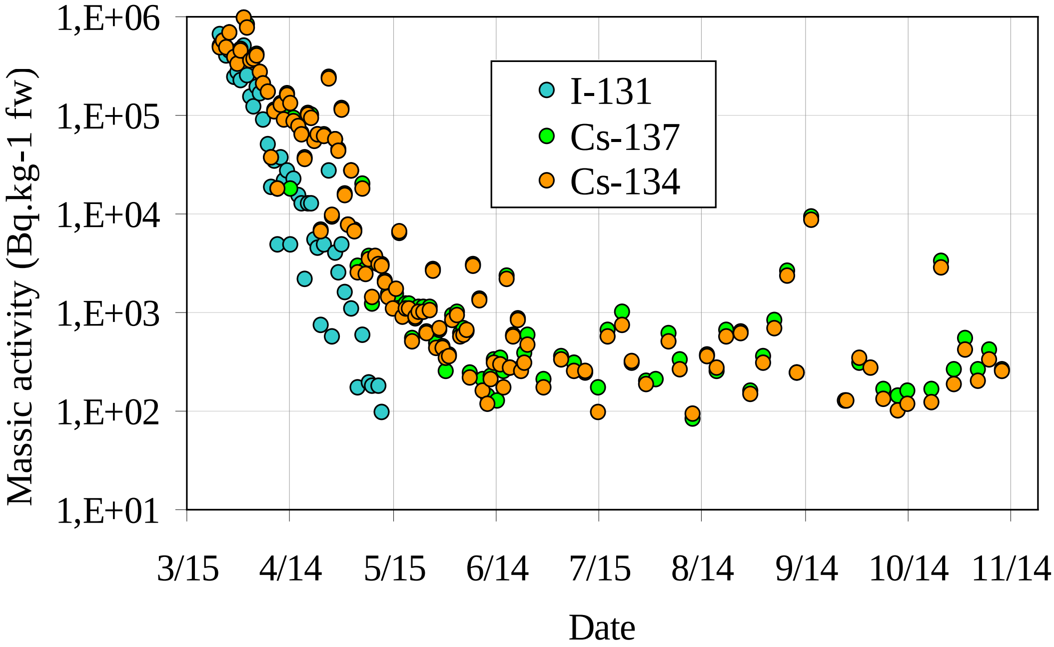


IRSN

Even in absence of such information we could do some conclusion over that. These are the places where they were sampled by the Ministry of Science and we see very different behaviors between the places, the different behaviors of course due to the fact that the depositions were not the same obviously, but also that the elevation, the altitude above the sea level is not the same so the growth of plants from March to November was not the same.

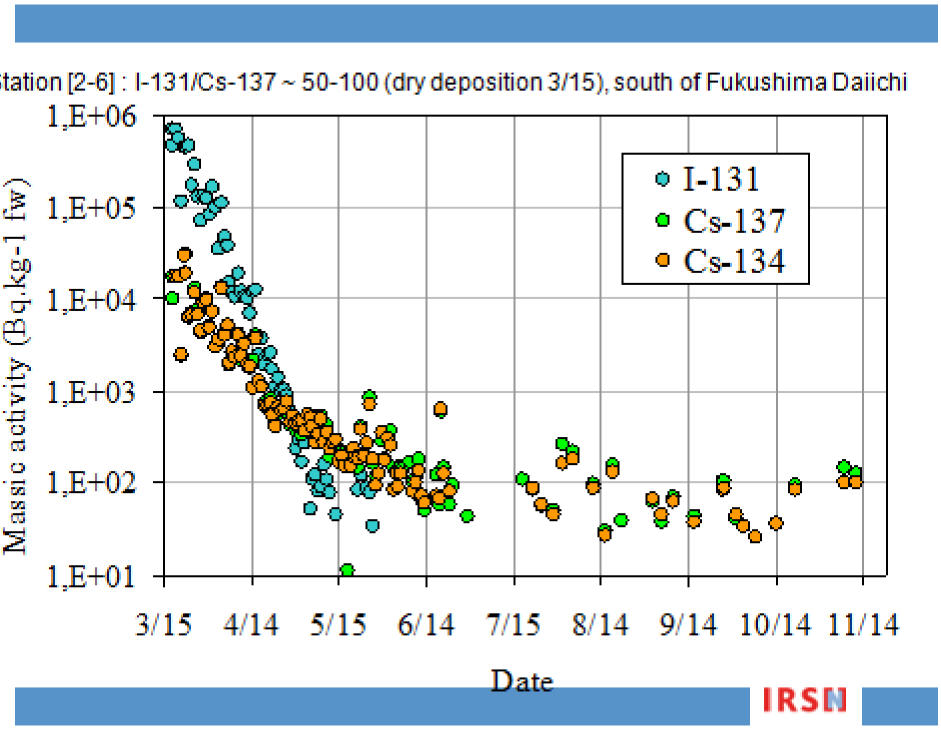
Station [2-4] : I-131/Cs-137 ~100 (dry deposition 3/12), north of Fukushima Daiichi

pass



1,E+06
1,E+05
1,E+04
1,E+03
1,E+02
1,E+01
Massic activity (Bq.kg-1 fw)
I-131
Cs-137
Cs-134
3/15
4/14
5/15
6/14
7/15
8/14
9/14
10/14
11/14
Date

pass


Station [2-6] : I-131/Cs-137 ~ 50-100 (dry deposition 3/15), south of Fukushima Daiichi
1,E+06
1,E+05
1,E+04
1,E+03
1,E+02
1,E+01
Massic activity (Bq.kg-1 fw)
I-131
Cs-137
Cs-134
3/15
4/14
5/15
6/14
7/15
8/14
9/14
10/14
11/14
Date
IRSN

pass

Weed growth model : assesses time evolution of total root/shoot biomass + LAI, following:
A seasonally-dependent (logistic-like) growth model,
Outputs of a physiologically-based weed & weed-crop competition model (Colbach *et al*., INRA France)

Simplified analytical formulation (under some assumptions)

Massic activity in the aerial system:
where:
: initial activity after deposition on March 15 ($Bq.kg^{-1}$ fw)
l^{j} : decreasing rate of the *j* pool (d^{-1})
α^{j} : proportion of activity involved in the *j* pool (-)
l : radioactive decay rate (d^{-1})
At least 2 pools (cf Fig. 1)
- Fast
  - Cs: λ^{fast} = 0.115±0.045 d^{-1} α^{fast} ~ 1
  - I: λ^{fast} = 0.08±0.02 d^{-1} α^{fast} ~ 1

Driving processes : high spring biomass growth + rainfall weathering (for Cs)
- Slow (for Cs) :
  - Cs: λ^{slow} = 0.001 to 0.01 d^{-1} α^{slow} = 0.0001 to 0.01 (high variability)

Driving processes : low summer biomass growth + root-to-shoot translocation
- No clear evidence for root uptake & rainsplash & (cf Fig. 2 TF) : partly due to a low Cs bioavailability for root (downward migration, unploughed soil, etc.)

Unexplained station-to-station variability : possibly due to interspecific variability and/or climatic conditions

IRSN

pass

I-131

Fast decreasing pool (~60d)

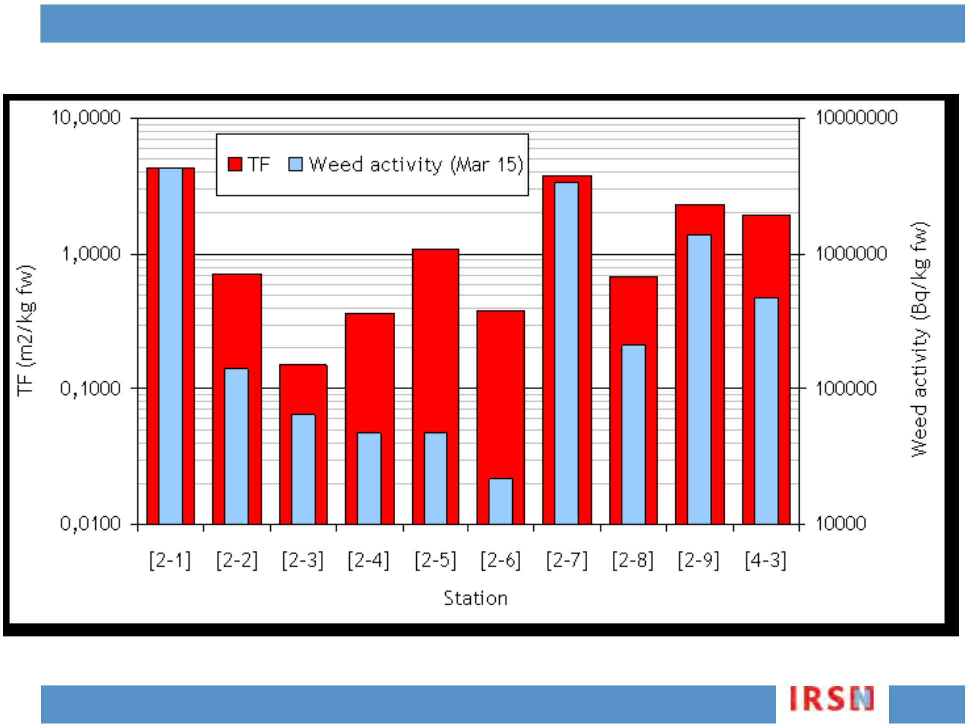
Slow decreasing pool

Cs-134

This is again the normalized activities, so becquerel per kilogram along the time divided by becquerel per kilogram on 15th of March, which means that [Unclear] one. For iodine we identify mostly of fast decreasing pool [ph]. These are different stations. You see the symbols of different places on the map. There are different behaviors between the stations. For cesium we have a much longer behavior of course. This is first day and then a slow step, which is mostly explained by the fact that in summer the growth of the plants is less and in this part the plants grow very fast, which makes dilution of cesium in the plants. Once again there were much differences between two places which could be explained by the elevation or [Technical Difficulty] explanation.

Transfer factor (Cs)= Weed activity / Soil activity
(September 15)

pass


TF
Weed activity (Mar 15)
TF (m2/kg fw)
Weed activity (Bq/kg fw)
10,0000
1,0000
0,1000
0,0100
10000000
1000000
100000
10000
[2-1]
[2-2]
[2-3]
[2-4]
[2-5]
[2-6]
[2-7]
[2-8]
[2-9]
[4-3]
Station

pass

LEAFY VEGETABLES

MHLW monitoring data
I-131, Cs-134/137 (+ others not studied)
Activity in the edible food($Bq.kg^{-1}$ fw), at various date from March 2011
Data reported at county level
At field or local market collecting

No clear correlation between vegetable and soil surface activities, when activities are spatially averaged over the inhabited and agricultural areas in each county -> collected vegetables may have circulated !
-> Working at the prefecture level

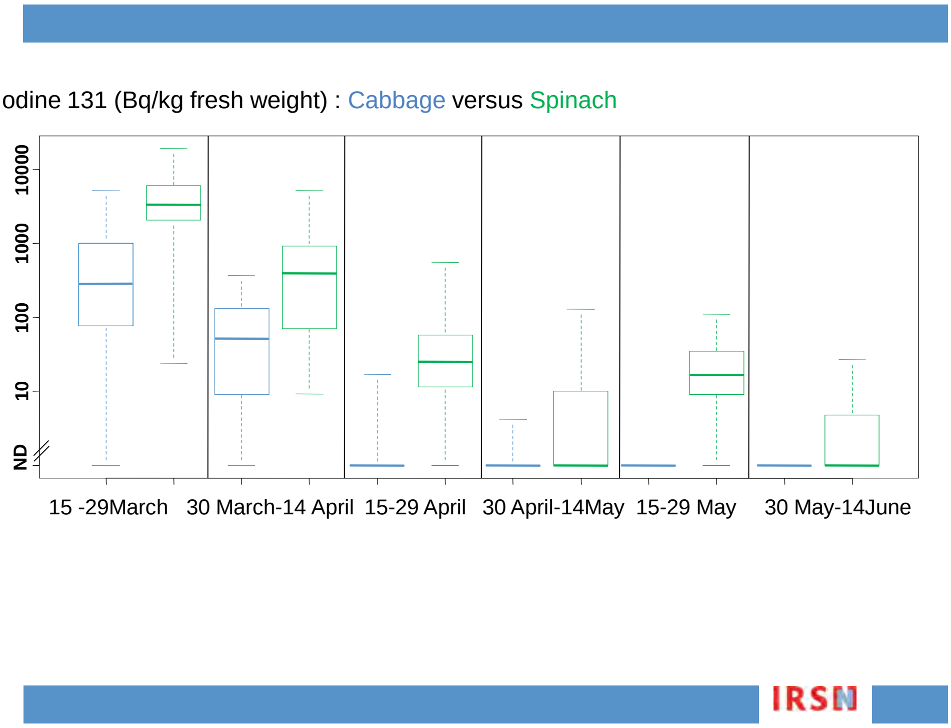
Objectives
Bringing some insights into our understanding of the observed inter-sepcific variability

$$Activity(t1) \propto LAI(t1)/biomass(t1)$$

IRSN

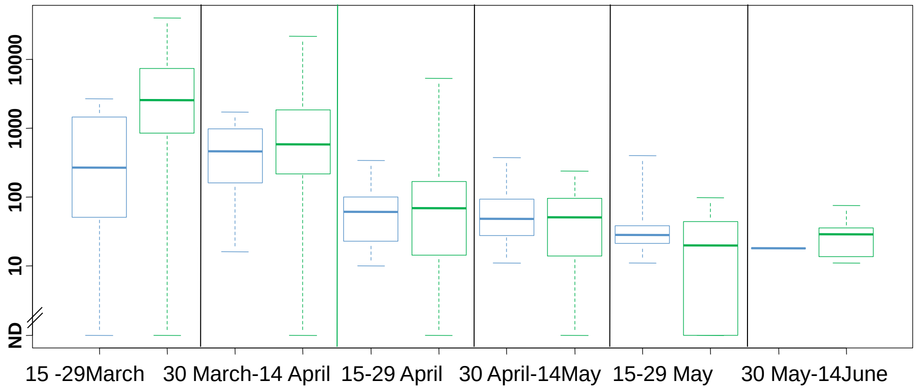
Concerning the leafy vegetables such as spinach for example, we used data published by the Ministry of Health. They published mainly data about foods.

Iodine 131 (Bq/kg fresh weight) : Cabbage versus Spinach



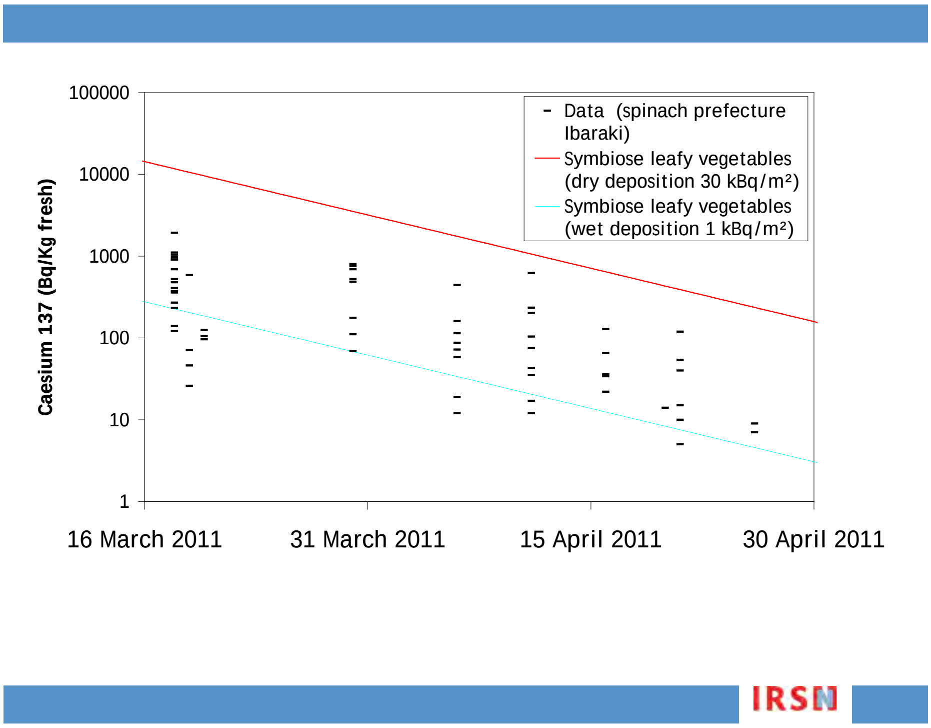
Last time I counted it was more than 104,000 data about all sorts of food products and in this case we checked the leafy vegetables such as spinach, which was interesting for us. For example to see that – this is in the Fukushima Prefecture. It was very obvious that the becquerel per kilogram in spinach were different from other leafy vegetables such as broccoli or cabbage. This is very well explained by common knowledge about [Unclear]. It was interesting for us to see that because in our operational software in SYMBIOSE we consider all leafy vegetables together and the same transfer factor for all leafy vegetables together and obviously it's wrong to do that way. For each period, which is the end of March, mid of April, end of April, and so on For each 15-day period, this is the minimum, maximum, median, 25th percentile, which means there are 25% of the data below and 75% above and the 75th percentile. You can see that [Unclear] becquerel levels of spinach are always higher than the [Unclear] becquerel level of cabbage, which is very well explained by the leaf area index or the fact that for the same number of kilograms of cabbage and spinach, we have much more leaves in spinach than cabbage.

Caesiums 134+137 (Bq/kg fresh weight) : Cabbage versus Spinach

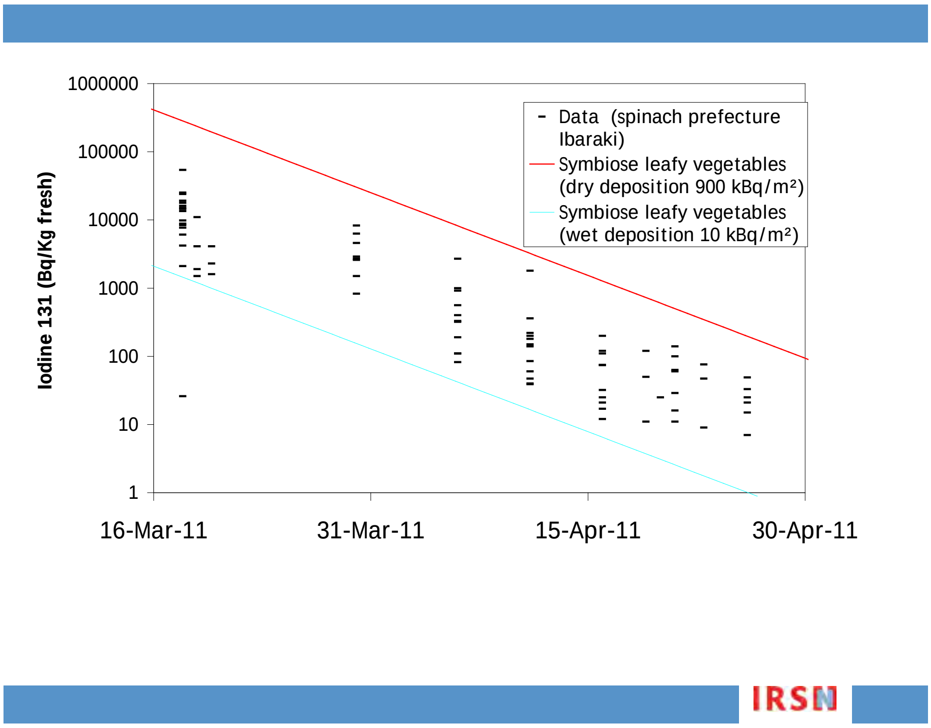


IRSN

I think the same for cesium.



In the Prefecture of Ibaraki, we collected all data about spinach and it seems that in the Prefecture of Ibaraki there were some spinach outside of hut houses, outside of tenants in the [Unclear] each data is becquerel per kilogram of cesium 137. In one sample of spinach over the Prefecture of Ibaraki and the blue one is the low prediction using SYMBIOSE, not taking into account [Unclear] protection, not taking into account the [Unclear]. We saw low hypothesis, which is wet deposition of 1 kilogram becquerel per square meter of cesium, which seems reasonable for the less contaminated parts of the Prefecture of Ibaraki and this is the high hypothesis. You can see that the high hypothesis is dry deposition and the low hypothesis is wet deposition because the models predict that with the same deposition there will be more contamination in the case of dry deposition than in the case of wet deposition.



This is the same for iodine. The behavior is explained both by decay of iodine and by the growth of the plants. The general behavior that we had for spinach is consistent with the data.

Project to be funded 2013-2020

SOURCE	Release	Release	Release			
	ATMO	Deposition	Deposition	Deposition		Inhalation External
		RIVER LAKE	Export	Watering Irrigation	Collecting	Inhalation External
			MARINE		Collecting	Inhalation External Acc. ingestion
		Erosion		AGRI FOREST	Collecting	Inhalation External
				Feeding	FOOD/FEED	Ingestion
						DOSE TO MAN

IRSN

Now our prospects are to continue research and improving our operational models and improving our knowledge to go further the operational models for better understanding of the processes. This is why we are preparing a project to be funded from next year to 2020. The main processes to be studied in this group project will include ecotoxicity, toxicity to animals such as birds, and also transfers in the environment including especially transportation in the atmosphere and deposition. Transportation in the rivers and water-soil erosion from soils to river, and also for rivers to the sea. Of course as we discussed before we have much more to improve our operational models about agriculture taking into account bigger plants than spinach and especially taking into account the forest. This project will be dedicated to research about understanding the processes and also research about applying this knowledge in the software in the operational tools to be used by IRSN and some parts of this project will be concerned by application through Fukushima data to validation of the data for model measures [Unclear] reason and toward the experience of using these operational tools in real situations. These are the main objectives of this project.

IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Faire avancer la sûreté nucléaire

Système de management
de la qualité IRSN certifié

TRANSFERS


Alimentation
en eau potable
Milieu végétal
(sol + végétation)
Inhalation
Eau potable
Ingestion
Ingestion
Infiltrations