Development and Application of Methodologies for Source Term Analysis

IEM on Strengthening Research and Development Effectiveness
in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant
(IEM8)

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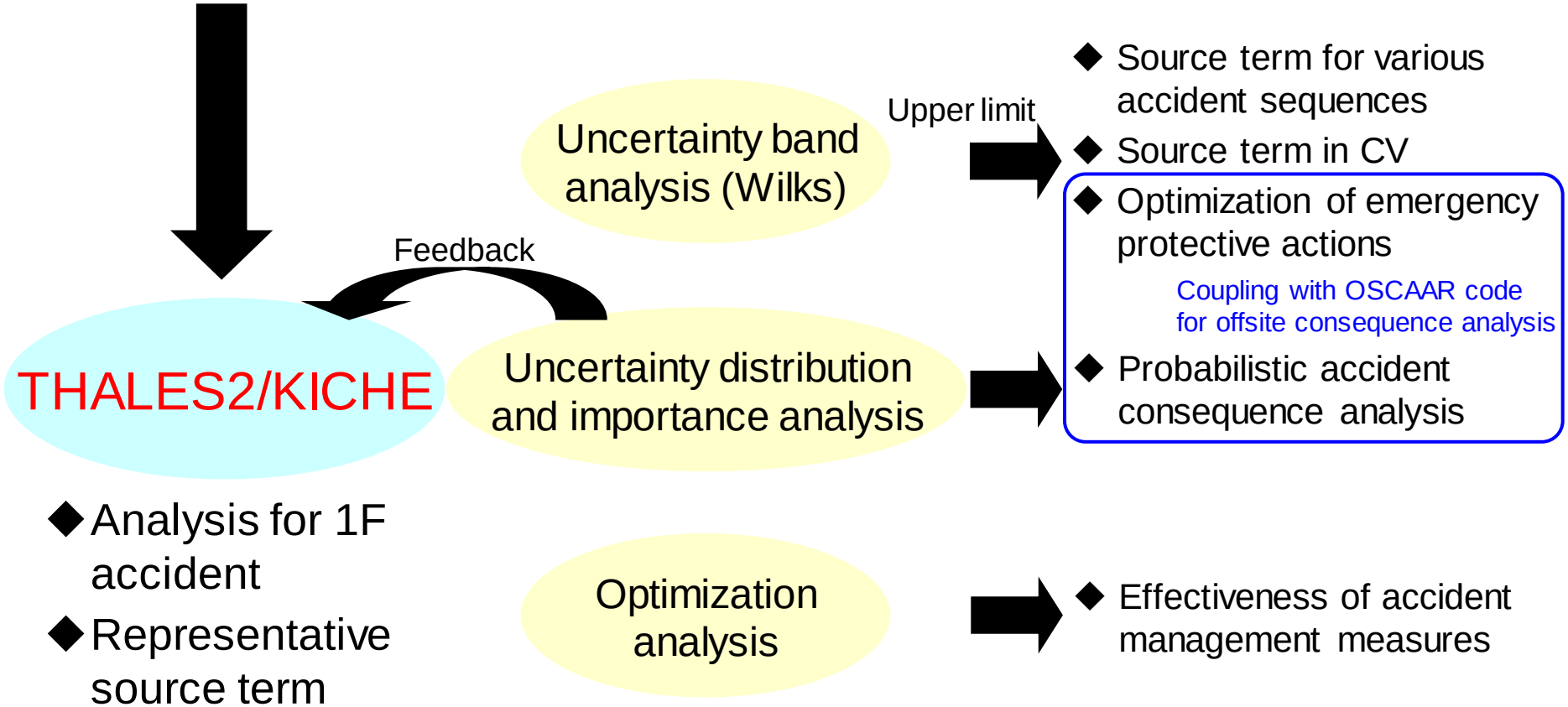
Outline of Presentation

- Approach and target of study
- Overview of main tool for source term analysis
- Application to analysis of Fukushima Daiichi nuclear power plant (1F) accident
- Recent accomplishments
- Summary

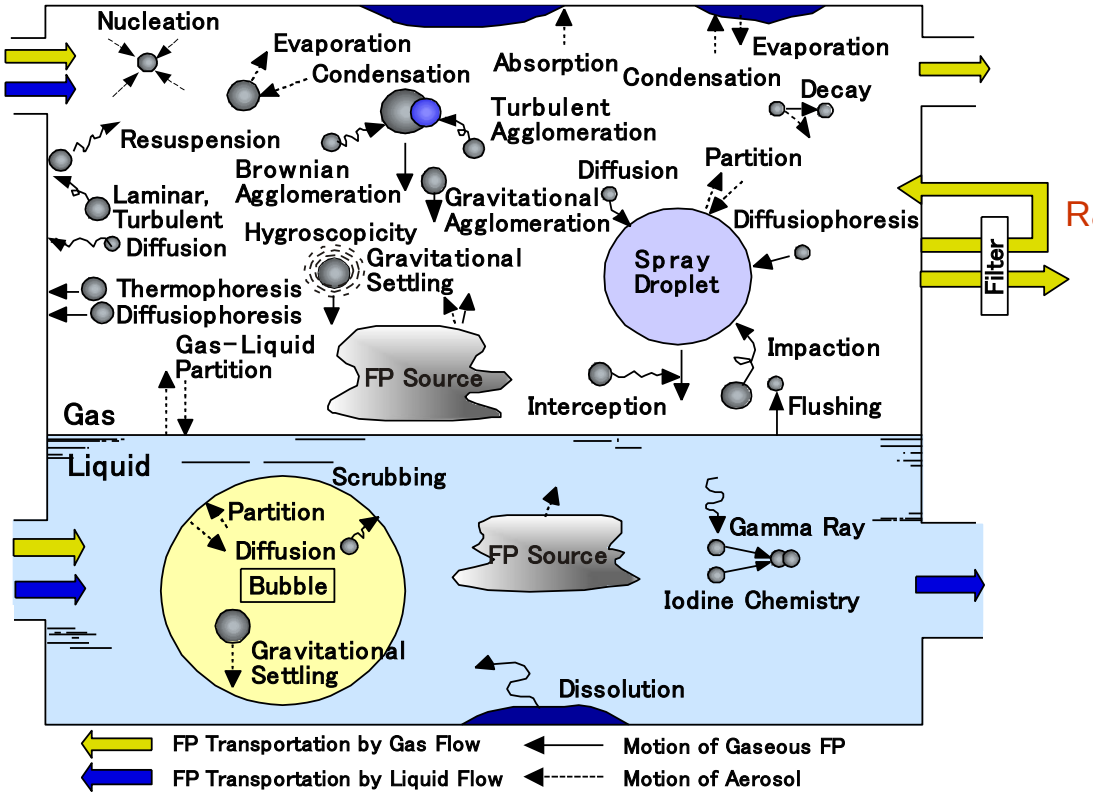
Approach and Target of Study

- State-of-the-art knowledge for improvement of methodologies for source term analysis including international cooperation

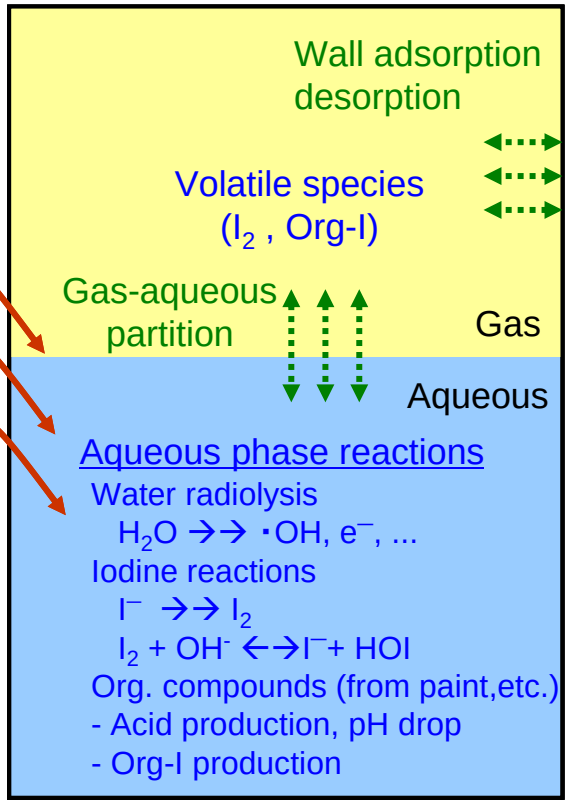


Brief Description of THALES2/KICHE Code

- Fast running capability (THALES2)
  - Simplified modeling for thermal-hydraulics and core melt progression
- Covering major phenomena for in-vessel and ex-vessel transportation of radioactive materials (THALES2)
- Mechanistic modeling for iodine chemical reaction kinetics in aqueous phase (KICHE)



Radiation

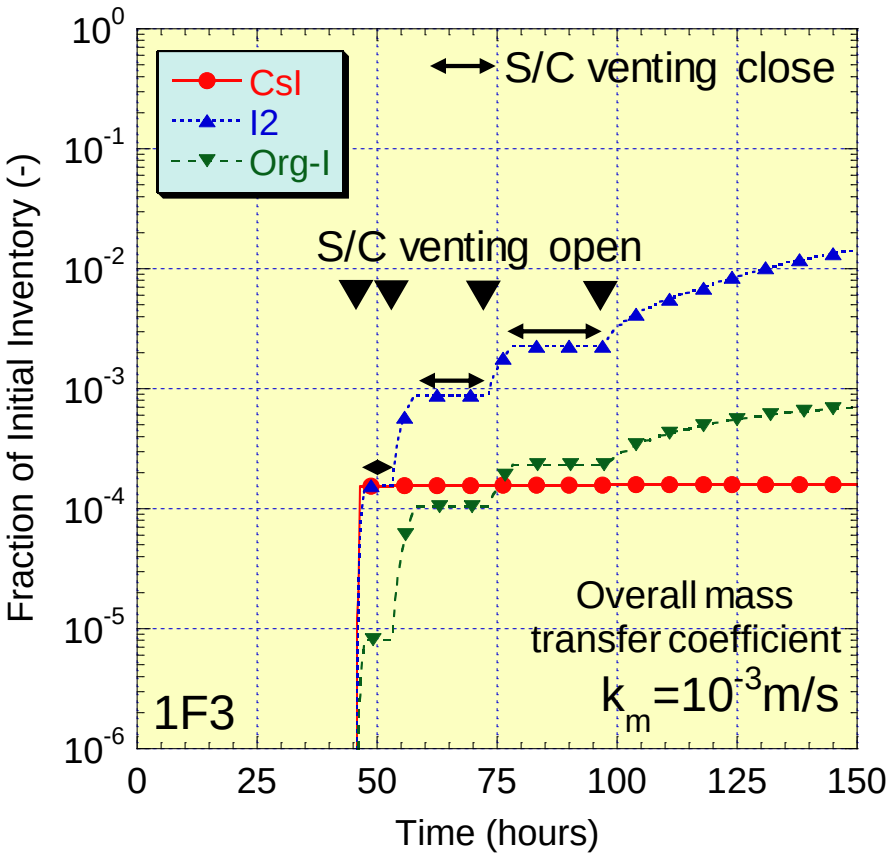


Application to Analysis of 1F Accident

- Analysis for units 1 through 3 in framework of OECD/NEA BSAF (Benchmark Study of the Accident at the Fukushima Daiichi Nuclear Power Station) project
  - Core melt progression and source term
- Release of volatile iodine species (I_2 and organic iodine) due to operation of containment vessel (CV) venting through suppression chamber (S/C)
  - Air sampling data at JAEA indicating “gaseous iodine >> particulate iodine”

THALES2/KICHE Code Analysis for Unit 3

Iodine Release from S/C



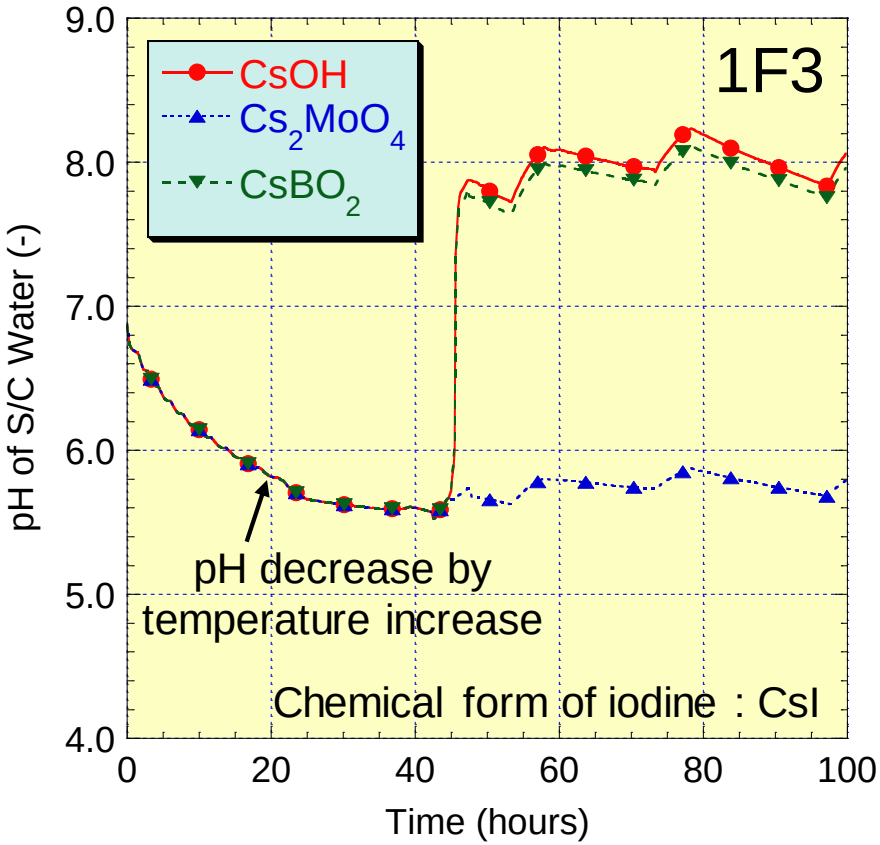
Limitations of Analysis

- Insufficient modeling and lack of technical knowledge
  - Predictability for pH of aqueous phase
    - In-vessel chemical forms of Cs and I
    - B_4C oxidation to form CO_2 and boric acids
    - Formation of HCl due to radiation degradation of cable covering
  - Gas-liquid mass transfer of volatile iodine species under anticipated two-phase flow conditions including flushing
  - Impact of seawater on iodine chemistry in aqueous phase
  - Adsorption of I_2 onto aerosol

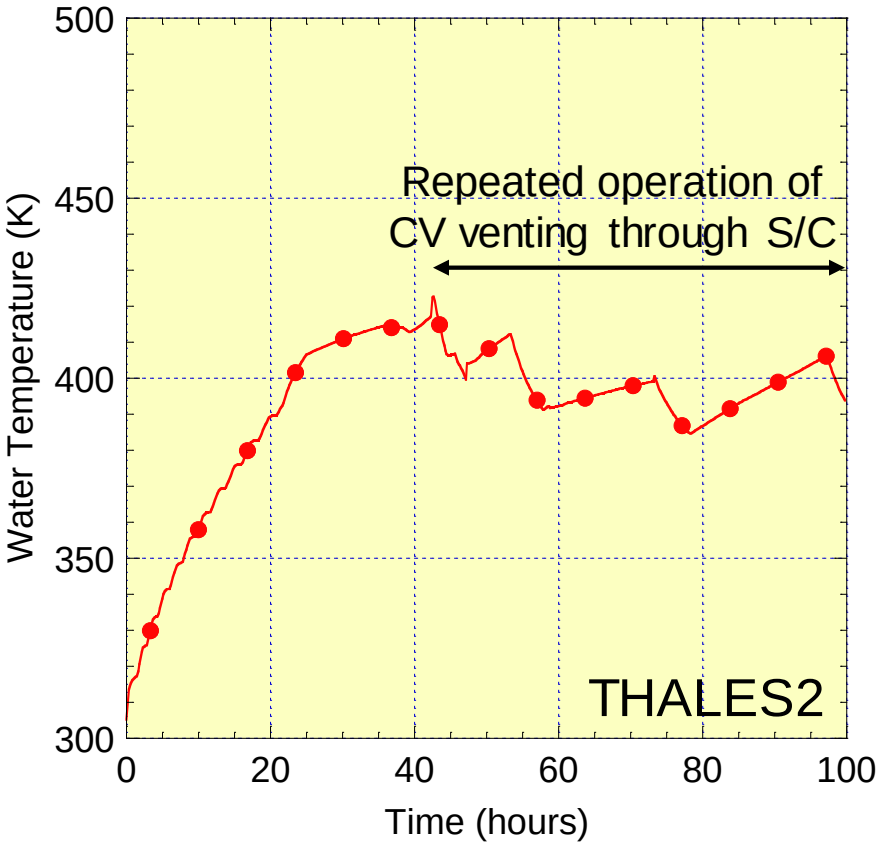
- Significant release of gaseous iodine due to operation of CV venting
  - Qualitatively consistent with the air sampling data at JAEA
- Large sensitivities to pH variation and gas-liquid mass transfer coefficient

Influence of Cs Chemical Forms

pH Variation



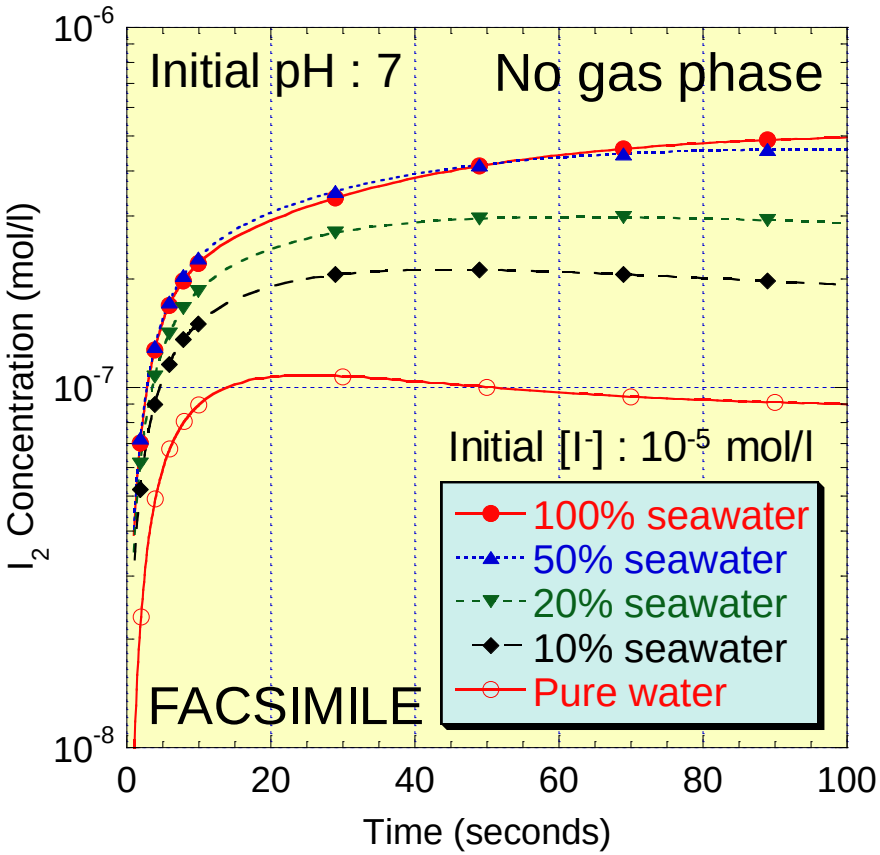
Temperature Variation



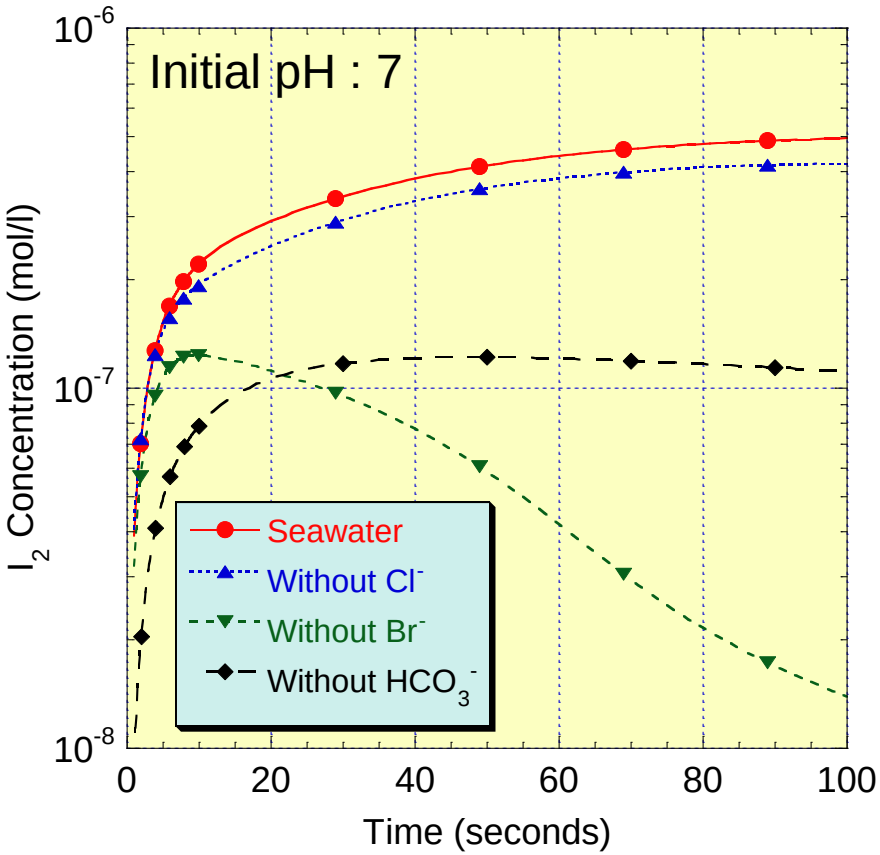
- Evaluation of pH taking into account temperature dependences of dissociation constants for water and Cs species
  - ◆Measurable impact of Cs chemical forms on pH of aqueous phase
  - ◆Further pH decrease expected in case that considerable amount of HI is generated

Preliminary Analysis for Impact of Seawater

I_2 Formation



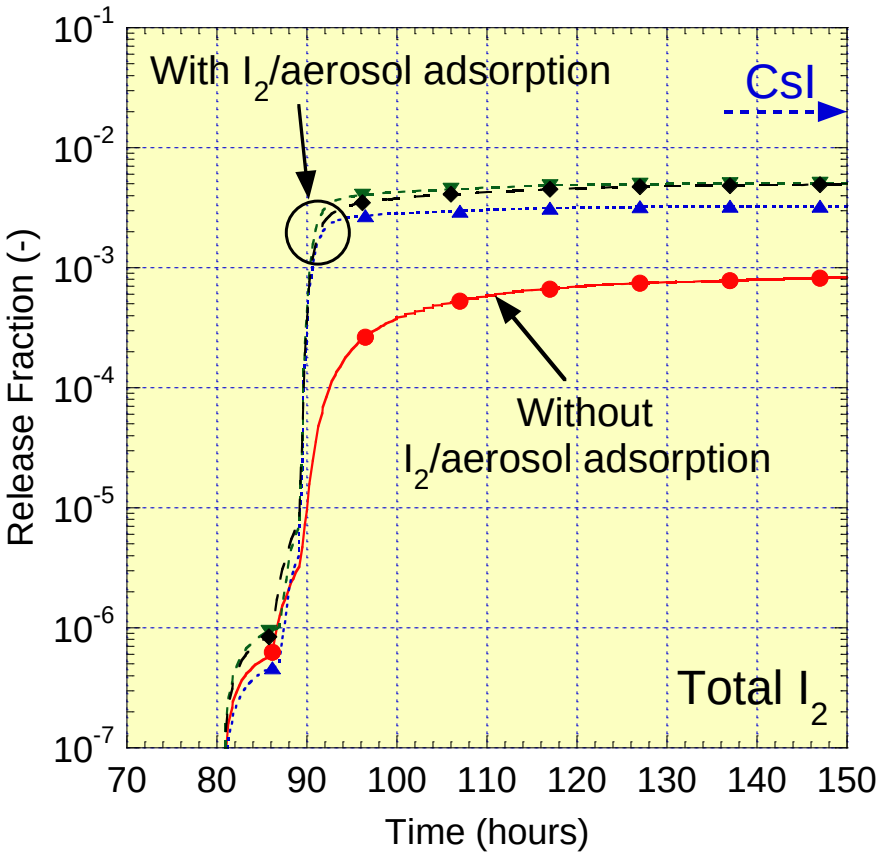
Effects of Constituents



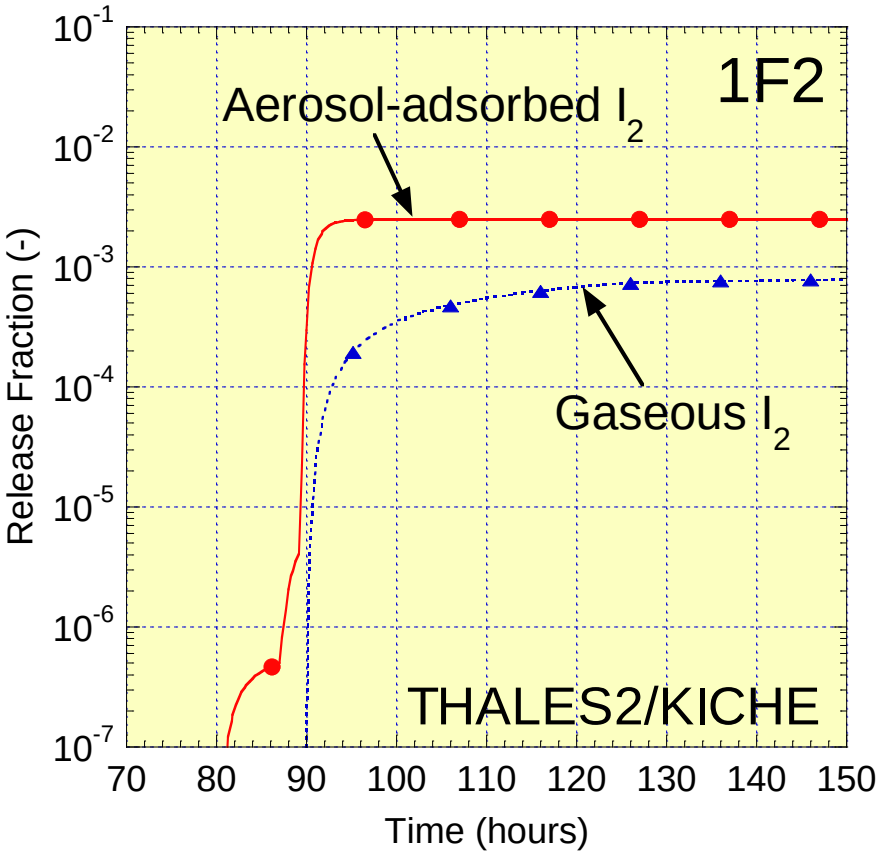
- Large impact of seawater constituents (especially, Br^- and HCO_3^-) on I_2 formation in aqueous phase
  - Indication of continuous or intermittent volatilization to gas phase in case of CV failure or operation of CV venting

Influence of I_2 Adsorption onto Aerosol

Release of I_2

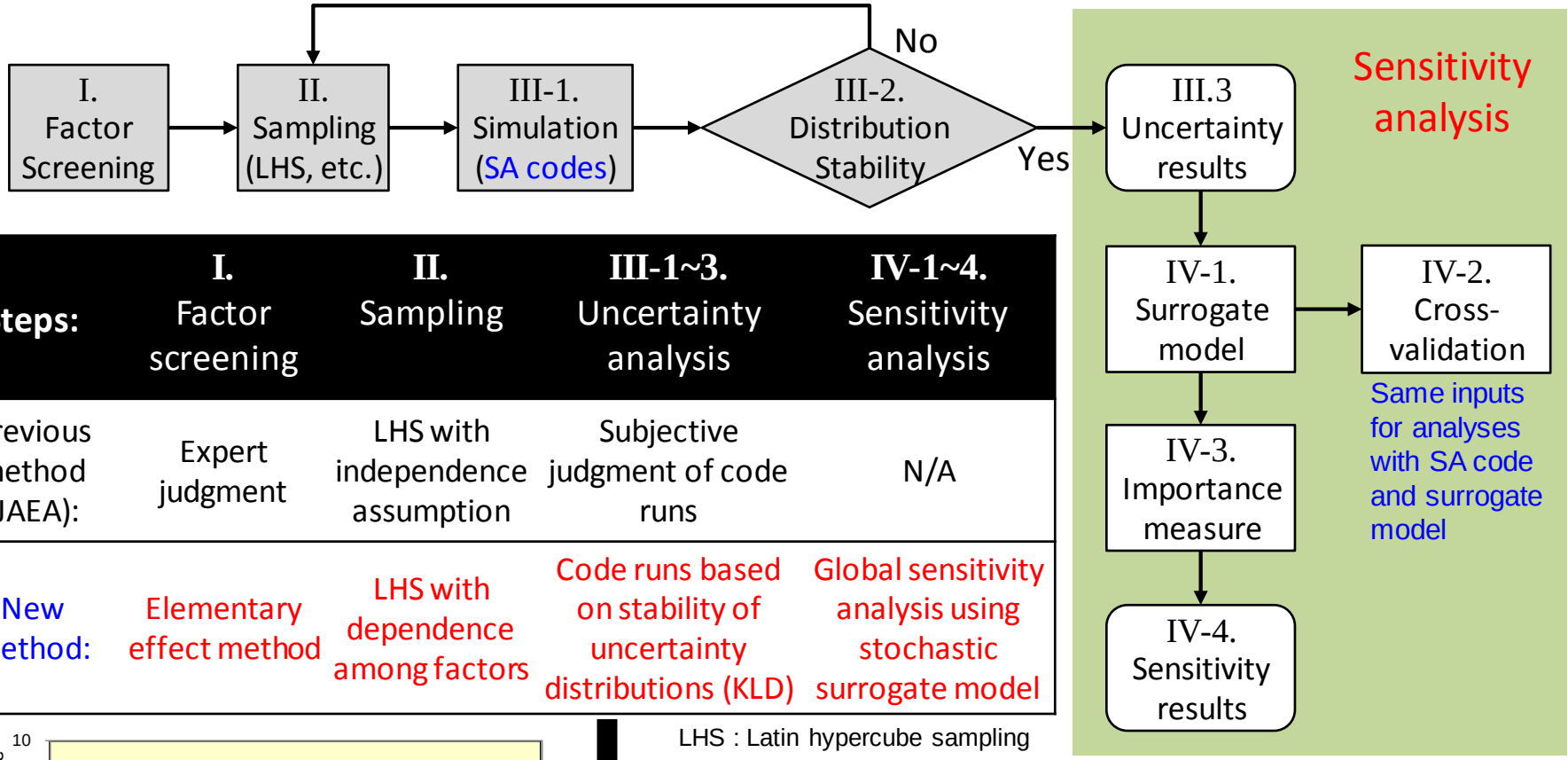


Forms of I_2



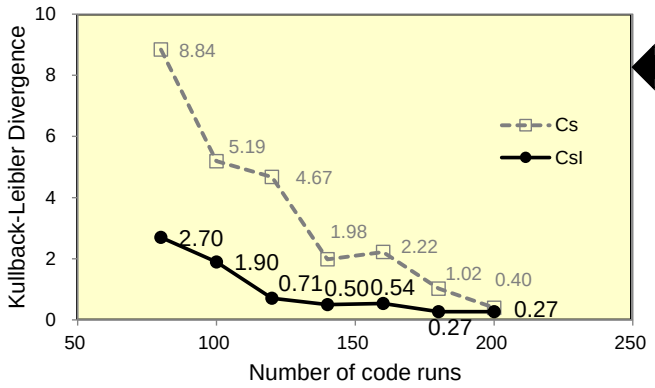
- Adsorption velocity of I_2 onto aerosol based on experiments in OECD/NEA THAI-2 project
- Increase of I_2 release by considering I_2 adsorption onto aerosol
  - Mainly in adsorbed form onto aerosol

Methodology for Uncertainty Analysis



Steps:	**I.** Factor screening	**II.** Sampling	**III-1~3.** Uncertainty analysis	**IV-1~4.** Sensitivity analysis
Previous method (JAEA):	Expert judgment	LHS with independence assumption	Subjective judgment of code runs	N/A
New method:	Elementary effect method	LHS with dependence among factors	Code runs based on stability of uncertainty distributions (KLD)	Global sensitivity analysis using stochastic surrogate model

LHS : Latin hypercube sampling
KLD : Kullback-Leibler divergence

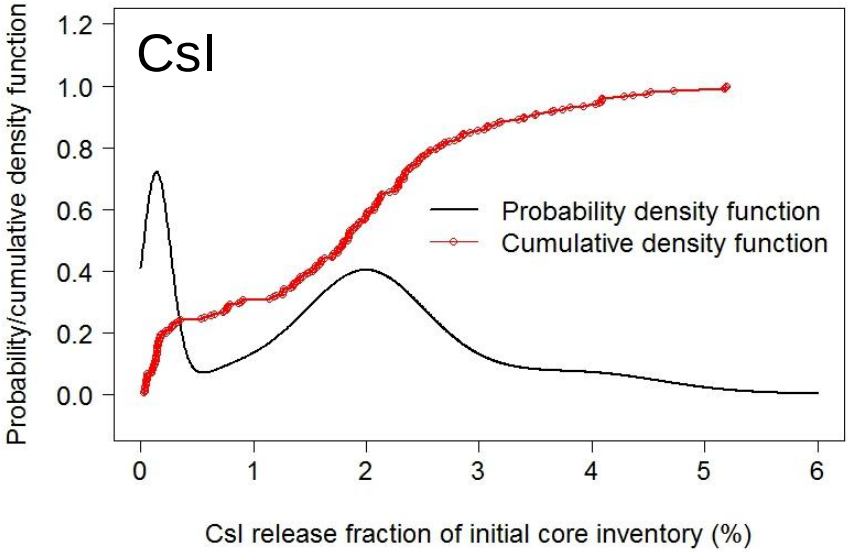


- Need of enormous code runs for global sensitivity analysis
  - Development of stochastic surrogate model based on Bayesian nonparametric approach

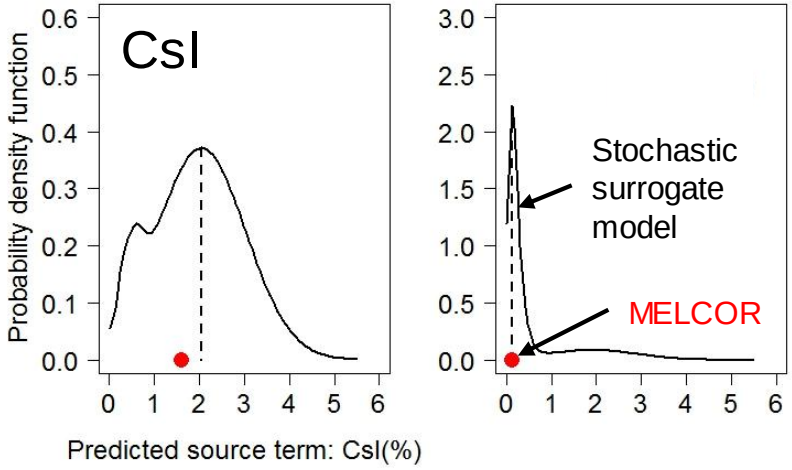
Uncertainty and Sensitivity Analyses

- Severe accident sequence
  - Similar to that occurred at unit 2 of 1F
- Uncertain inputs
  - 10 selected from 92 based on factor screening process
- Uncertainty analysis
  - 200 runs with MELCOR 1.8.5 code
- Sensitivity analysis
  - 21000 runs with stochastic surrogate model

Uncertainty Distribution



Examples of Cross-validation



Global Sensitivity Analysis

Inputs	Sobol' index	Importance ranking
TZXMX	0.802	1
DELDIF	0.736	2
TRDFAI	0.725	3
SC7155(1)	0.556	4
…	…	…
TSPCB	0.467	9
TPFAIL	0.402	10

Summary

- Efforts are being made for the improvement of THALES2/KICHE code for source term analysis.
- Key methodologies (uncertainty/sensitivity and optimization analyses) have been developed to effectively use THALES2/KICHE code.
- Source term analysis including that for 1F accident is currently underway with THALES2/KICHE code and the methodologies developed.
- Experimental studies are planned for in-vessel chemistry and transportation of fission products and gas-liquid mass transfer of volatile species under two-phase flow conditions.