# Comparing different wall heat transfer packages of MARS-KS, TRACE, and SPACE.

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## Introduction

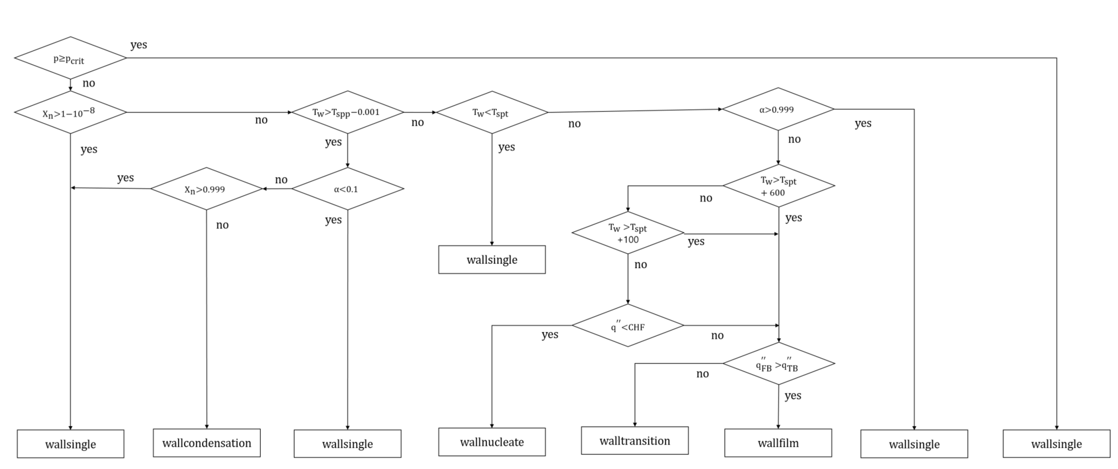
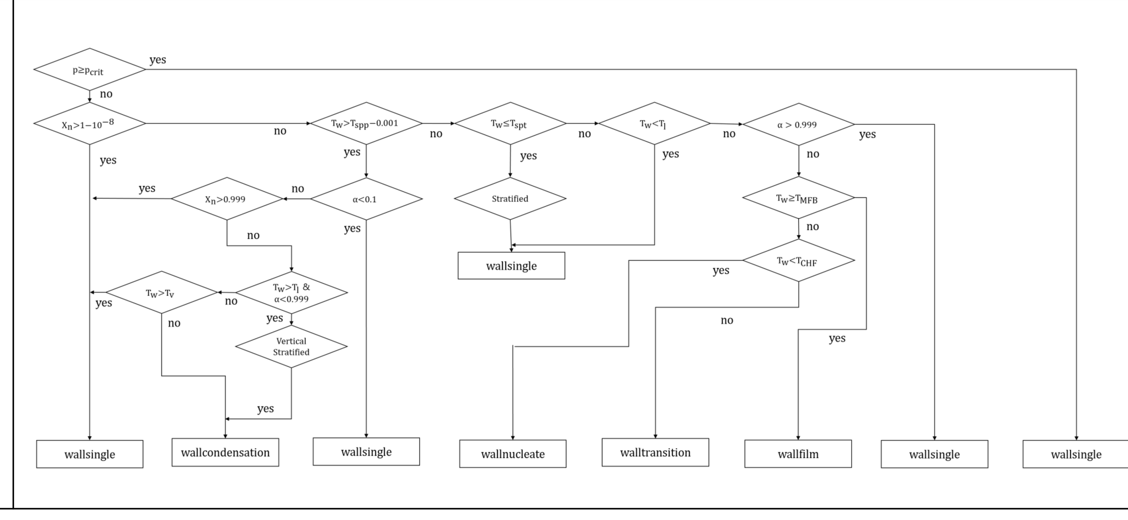
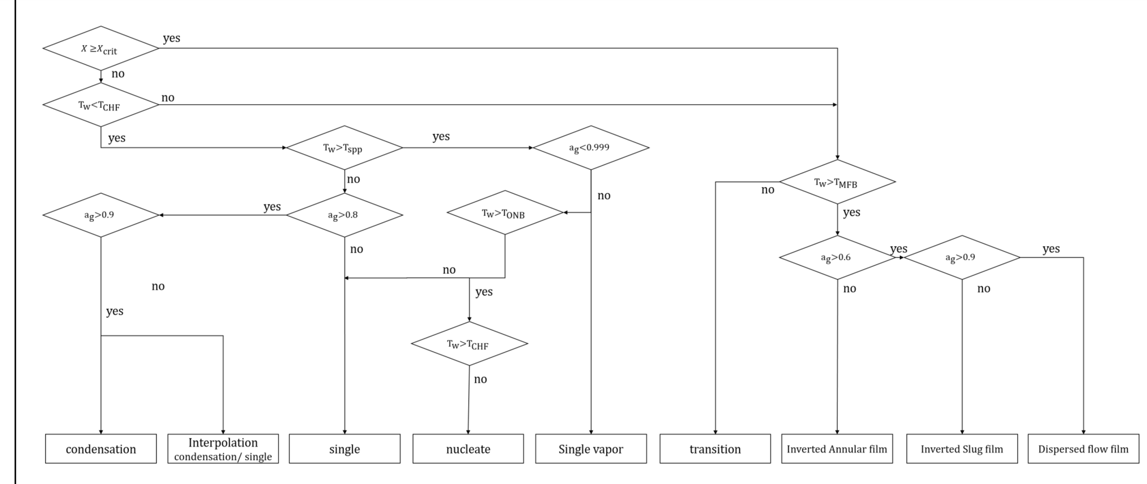
- System thermal hydraulic analysis codes (MARS-KS, TRACE, SPACE, etc.) are commonly used for reactor simulation to analyze and evaluate the safety of a nuclear power plant
- These system thermal hydraulic analysis code's composition: of governing equations, physical models and correlation packages. Due to the use of different equations and models, it is expected that some differences in the code calculations can be observed.
  Major physical models: wall heat transfer (HT), wall & interfacial friction, interfacial heat transfer packages, etc.
- Object: To analyze different wall HT packages between MARS-KS v1.4, TRACE v5.0, and SPACE v3.0by comparing heat transfer coefficients (HTC) calculated in wall HT packages.

## Method

1. By using manual & source code, compare how to calculate HTC → Methods2.
2. Make In-house HT package codes, which can compute HTC according the specified variables.
   It is because that it is difficult to make the same condition in each code.
   To make In-house code, use MATLAB & REFPROP v8.
   specified variables: pressure(p), liquid & vapor temp(Tl, Tg), liquid & vapor velocity(vl, vg), quality(x)
3. Verify In-house code. (using same material properties with MARS-KS, TRACE & SPACE)
4. Analyze which parts have big HTC differences in whole Tl, Tg, Tl, & x sections.
5. In this parts, compare HTC differences by using MARS-KS, TRACE & SPACE.

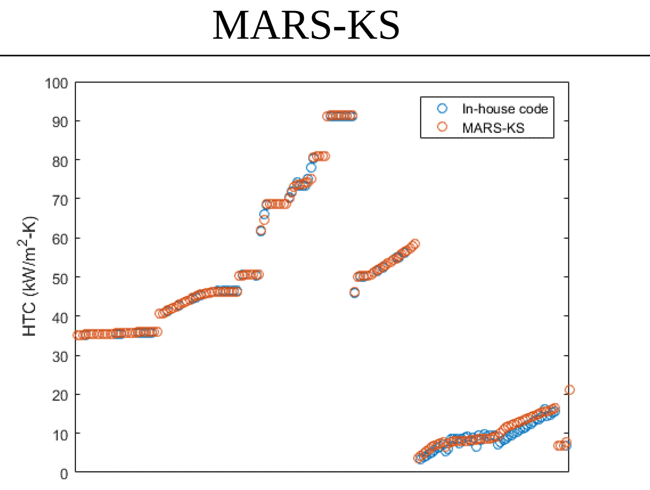
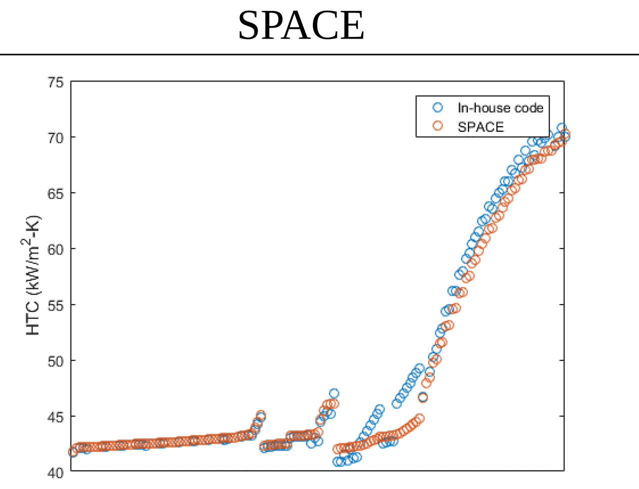
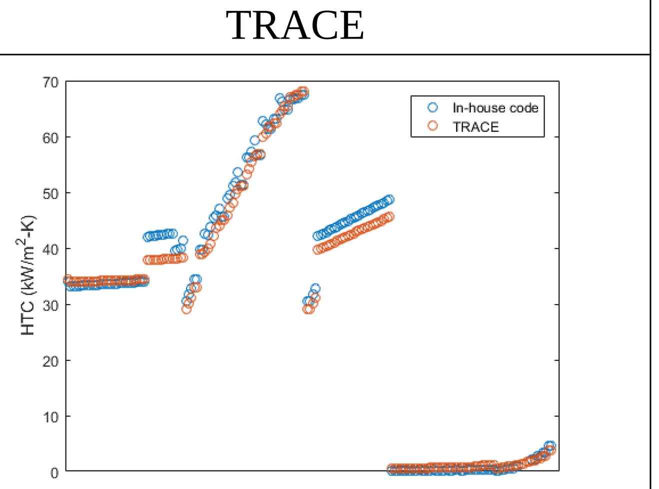
## Method2: Compare of wall HT packages & correlations

- **Wall HT package configuration**: HT mode transition map & HT models and correlations

| | | MARS-KS | SPACE | TRACE |
|---|---|---|---|---|
| HT regime logic diagram | |  |  |  |
| Single phase (Turbulent) | | Dittus-Boelter $Nu = 0.023\,Re^{0.8}Pr^{0.4}$ | | Gnielinski $Nu = \frac{(f/2)(Re-1000)Pr}{1+12.7(f/2)^{0.5}(Pr^{2/3}-1)} \times \left(\frac{Pr}{Pr_w}\right)^{0.11}$, $f = [1.58\ln Re - 3.28]^{-2}$ |
| Nucleate boiling | | Chen $q''_{wl} = h_{mac}(T_w - T_l) + h_{mic}(T_w - T_{sat})$, $h_{mac} = h_{sg}F$, $h_{mic} = 0.00122\frac{k_l^{0.79}c_{pl}^{0.45}\rho_l^{0.49}}{\sigma_l^{0.5}\mu_l^{0.29}h_{fg}^{0.24}\rho_v^{0.24}}(\Delta T_w)^{0.24}(\Delta p)^{0.75}s$ | | Chen $q''_{wl} = h_{FC}(T_w - T_l) + h_{PB}(T_w - T_{sat}) - q''_{sat}$, $h_{PB} = \left(\frac{5600F_P}{20000^n}\right)^{1/(1-n)}(T_w - T_{sat})^{n/(1-n)}$ |
| Film boiling | IAFB | Bromley, Dittus-Boelter, Sun $h = h_{con} + h_{cov} + h_{rad}$ | Groeneveld 2001 film boiling LUT | Self-developed $h = h_{con} + h_{rad,l}$, $h_{rad,l} = \frac{\sigma(T_w^2 + T_l^2)(T_w + T_l)}{1/\varepsilon_f(1-\alpha)^{1/2} + 1/\varepsilon_w - 1}$ |
| | ISFB | | | Interpolation between IAFB and DFFB |
| | DFFB | | | $h = h_{cov} + h_{rad}$ |

## Results & Discussions

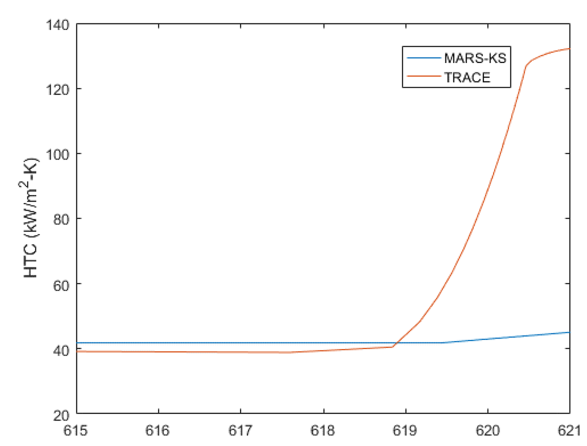
- **In-house code verification**

| MARS-KS | SPACE | TRACE |
|---|---|---|
|  |  |  |
| $Error_{max}$ = 2.796 kW/m²-K | $Error_{max}$ = 4.530 kW/m²-K | $Error_{max}$ = 4.529 kW/m²-K |

- Conditions

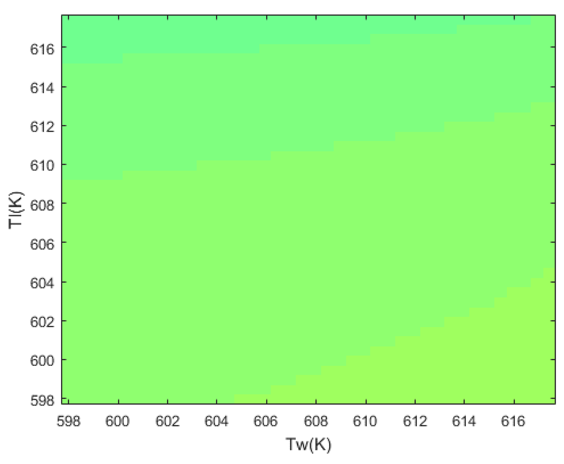
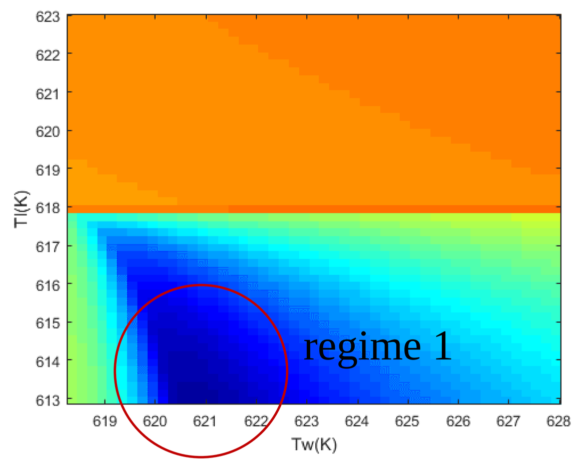
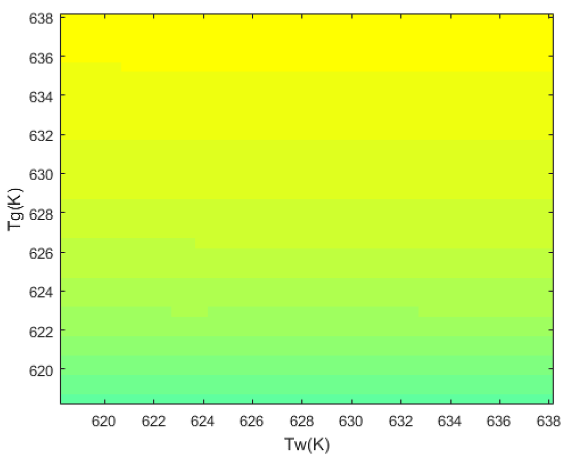
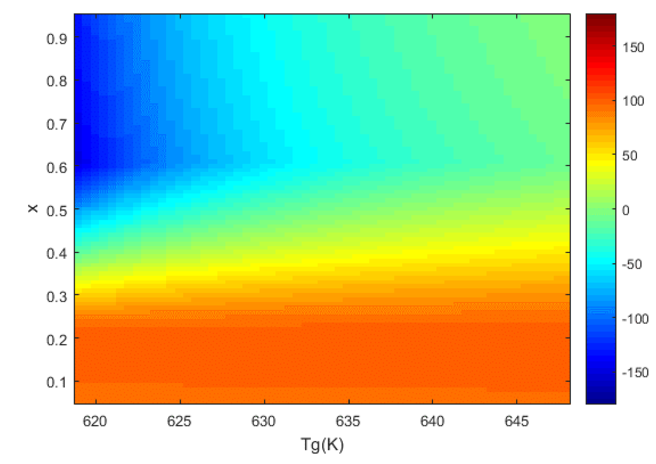
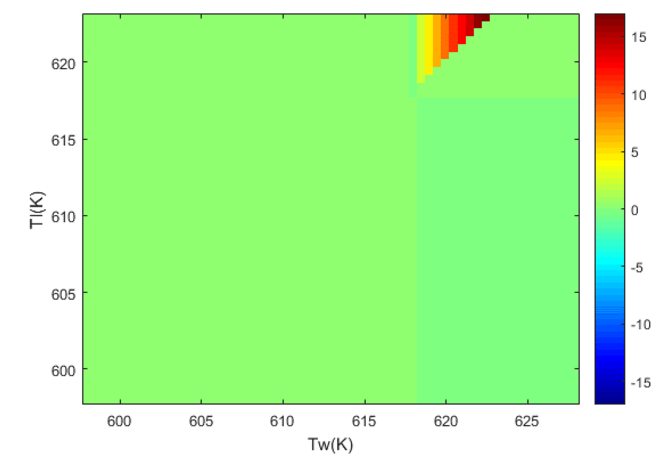
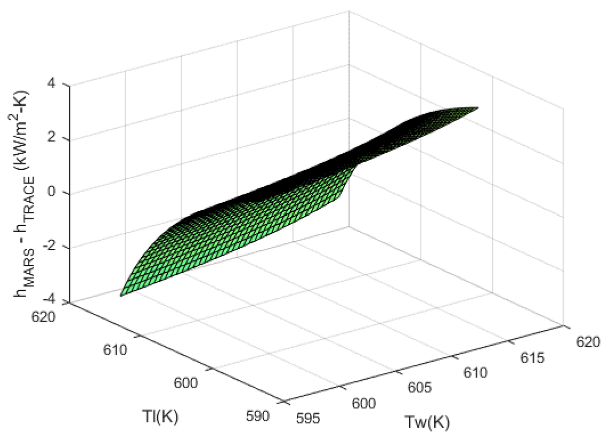
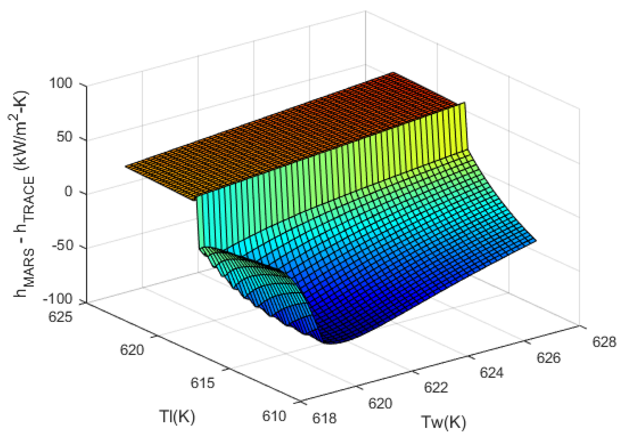
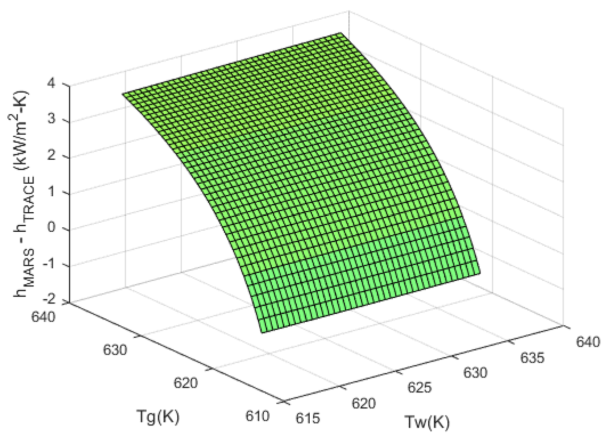
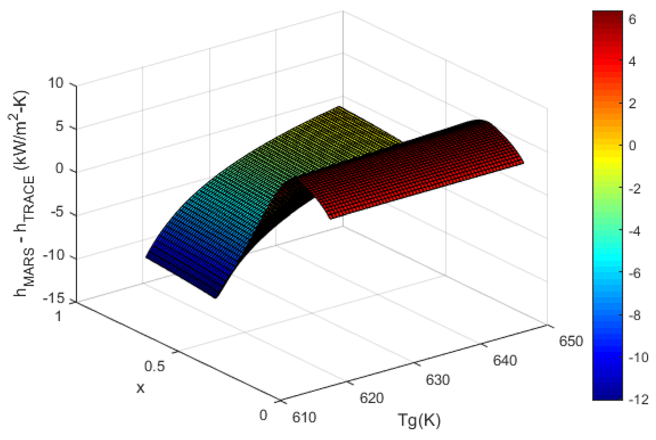
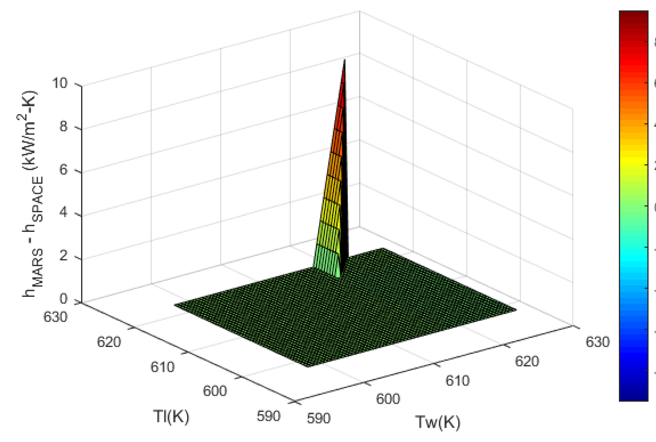
| P (MPa) | Dh (m) | vl (m/s) | vg (m/s) | vd (m/s) | Tl (K) | Tg (K) | Tw (K) | x |
|---|---|---|---|---|---|---|---|---|
| 15.5 | 0.012 | 6 | 6 | 6 | controlled | | | |

- Regime 1. (Tl = 613 K) code calculation.
  After $T_{ONB}$, HTC in TRACE increase dramatically. In correlation, $h_{PB}$ increase and is converged
  , then Tw and HTC also is converged.




- **Comparison HTC between MARS-KS and TRACE**

1. Single liquid, Single vapor: there is little HTC difference
2. Nucleate boiling
   - Subcooled : near regime 1, there is big HTC difference ($HTC_{MARS-KS} < HTC_{TRACE}$) → Regime 1. (Tl = 613 K) code calculation.
   - Saturated : have almost certain HTC difference ($HTC_{MARS-KS} > HTC_{TRACE}$)
3. Film boiling : there is big relative difference near the Tg = Tsat & 0.5 < x < 1 ($HTC_{MARS-KS} < HTC_{TRACE}$) or 0 < x < 0.3 ($HTC_{MARS-KS} > HTC_{TRACE}$). But, not big absolute difference.

| MARS-KS vs TRACE | | | | MARS-KS vs SPACE |
|---|---|---|---|---|
| Single liquid | Nucleate boiling | Single vapor | Film boiling | Single liquid + nucleate boiling |
| 》 Relative difference : $(HTC_{MARS-KS} - HTC_{TRACE}) / HTC_{MARS-KS} * 100$ (%) | | | | : There is a little HTC difference |
|  |  regime 1 |  |  |  |
| 》 Absolute difference : $HTC_{MARS-KS} - HTC_{TRACE}$ (kW/m²-K) | | | | |
|  |  |  |  |  |