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A study on Linear Reduced-order Model based on PIV Data of Flow Field around Airfoil

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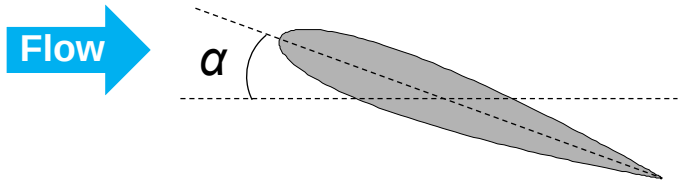
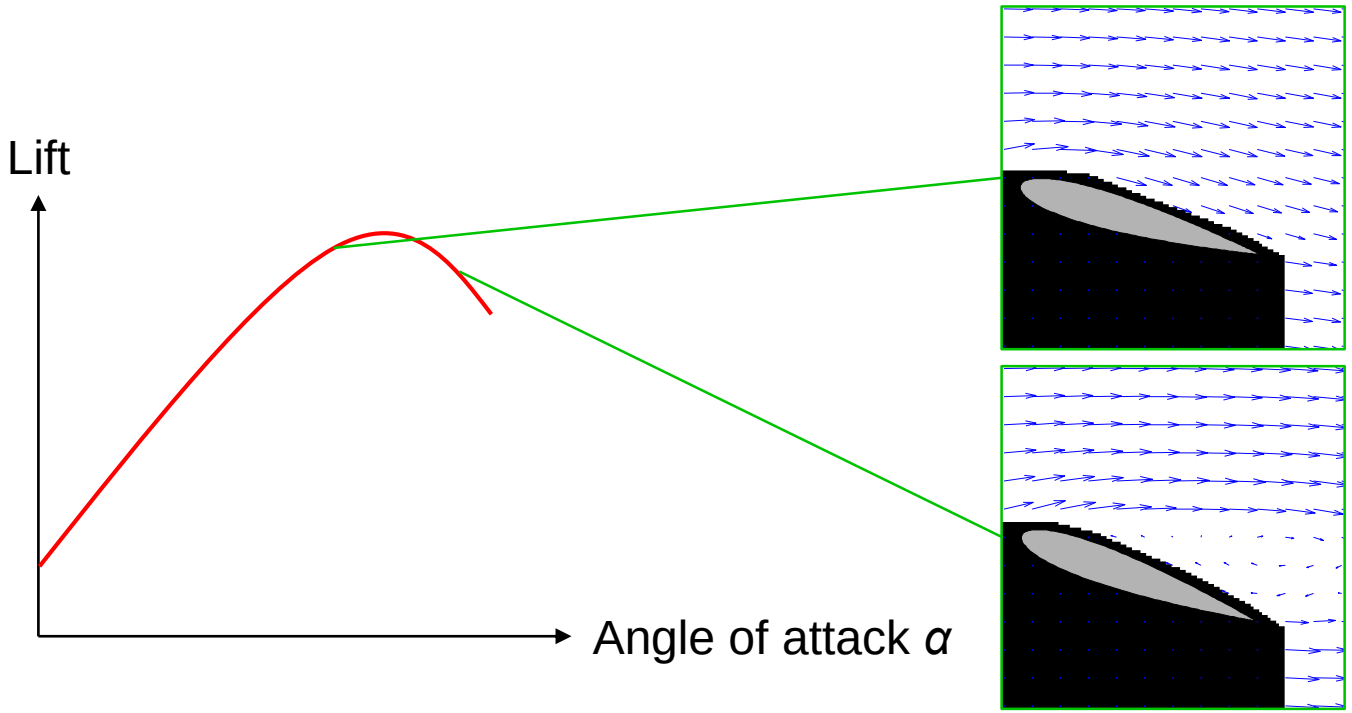
Flow field around airfoil

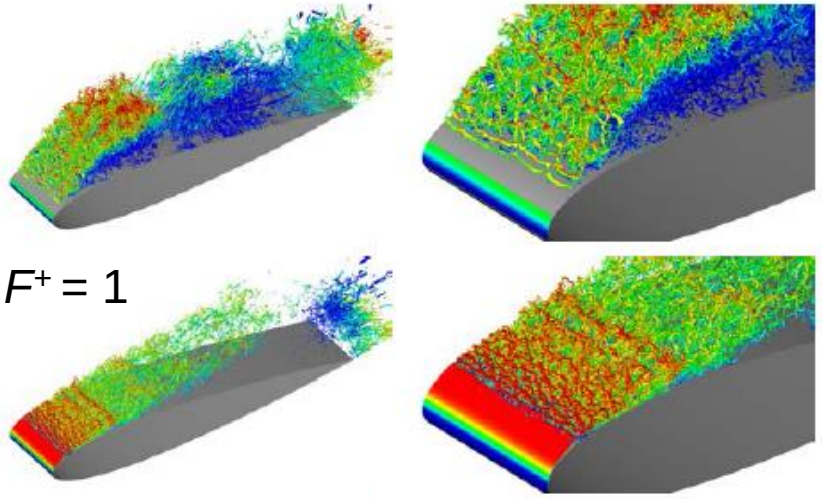
- Flow separation (stall)
  - ✓ Decrease in lift
  - ✓ Increase in drag





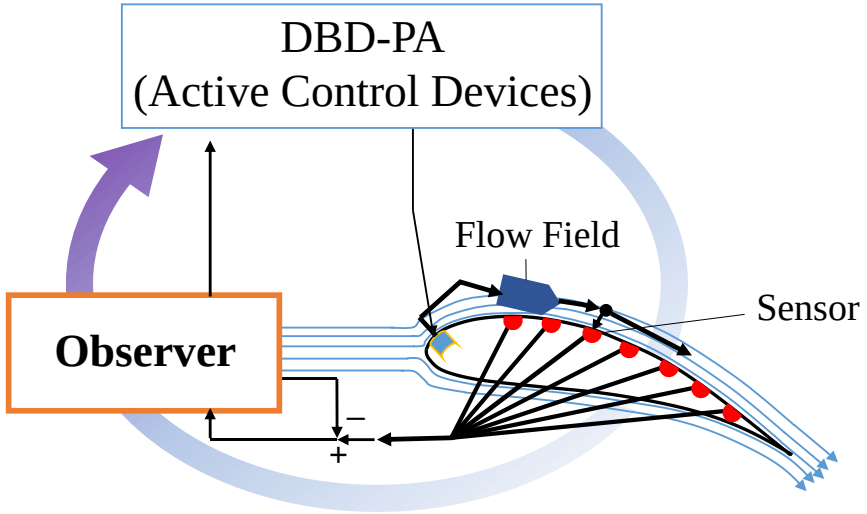
Active flow control

- Separation control using PA
  - ✓ Lift enhancement
  - ✓ Drag reduction
  - ✓ Various control input
    - – Voltage
    - – Frequency
    - – Burst frequency (F^+)
- Feedback control
  - ✓ Control input based on output
  - ✓ High robustness
  - ✓ Necessary to know state of flow fields



Aono et al., AIAA J., 2017

A model which estimates the time advancement of flow fields is necessary



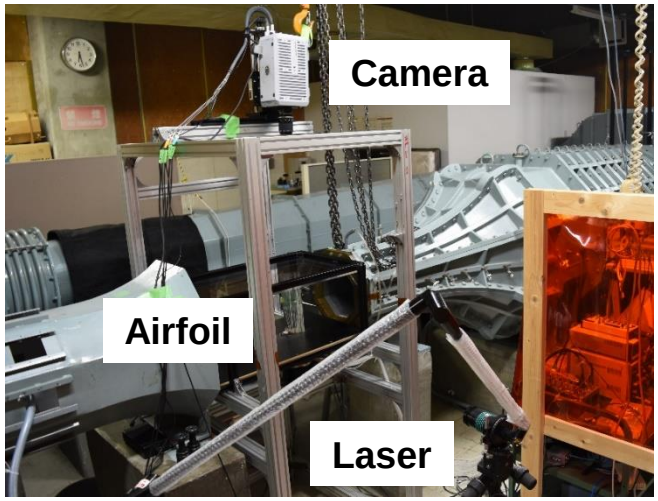
Objective

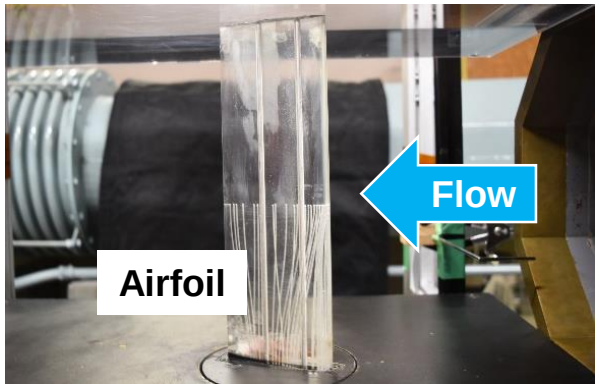
Construct the model of flow fields around an airfoil based on experimental data

- ✓ Experiment (Wind tunnel testing)
- ✓ Order reduction of data
- ✓ Modeling by a linear equation

Experiment

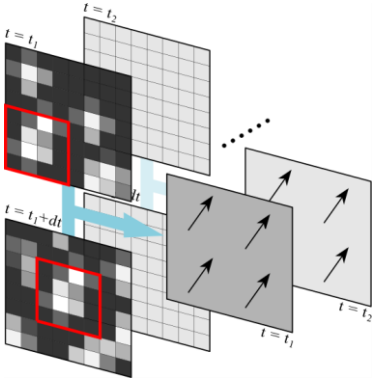
- Wind tunnel testing

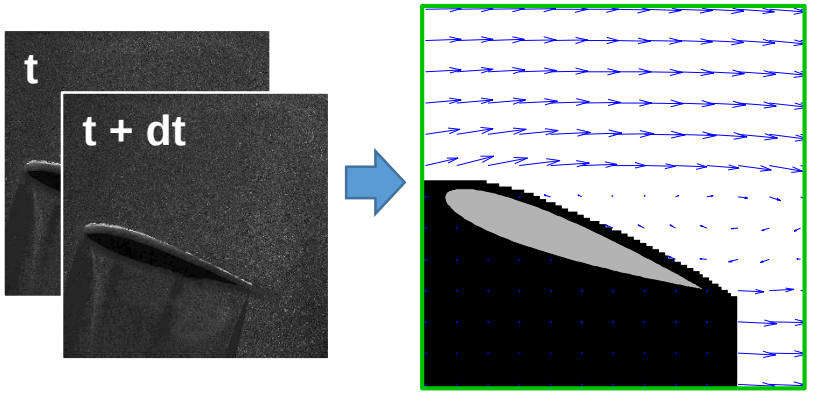




Experimental setup (at IFS, Tohoku university)

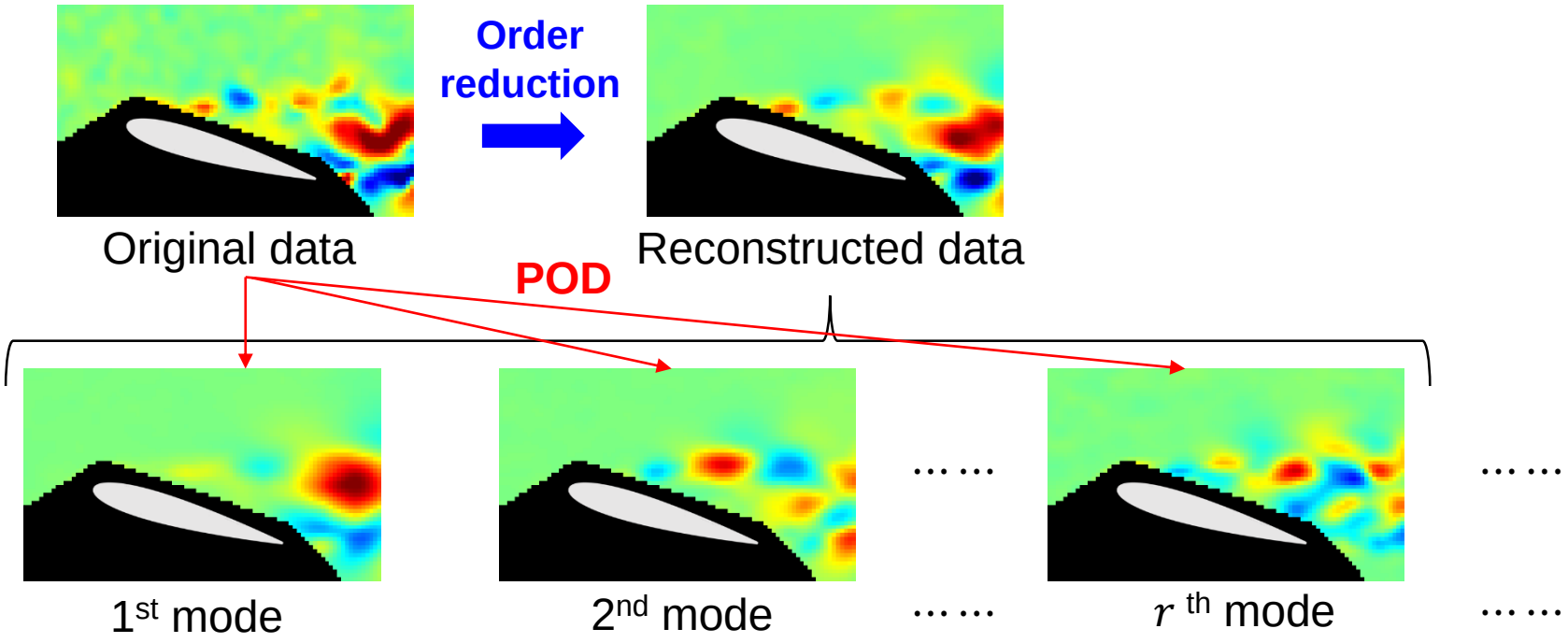
- ✓ Particle image velocimetry (PIV)





Modeling approach

- Order reduction of data using POD technique



- Modeling using linear equation

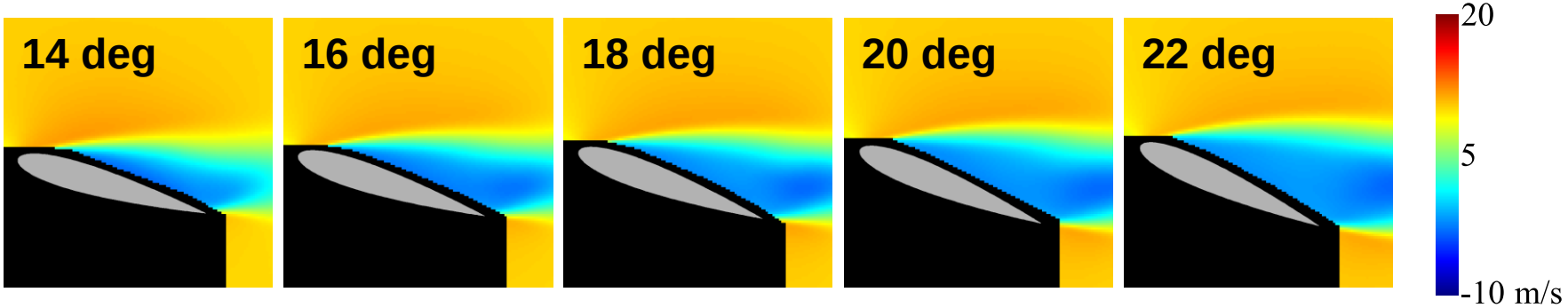
$$z_{n+1} = Az_n$$

z_n : Flow field at *n*th time step
A : Coefficient matrix

A is calculated from experimental (PIV) data

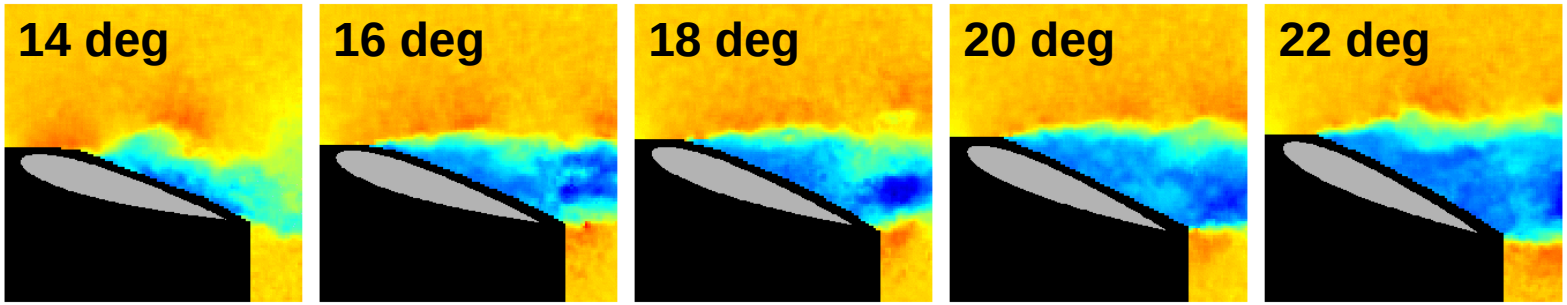
Results

- PIV measurements
  - ✓ Time-averaged velocity fields



  - ✓ Time-resolved velocity fields

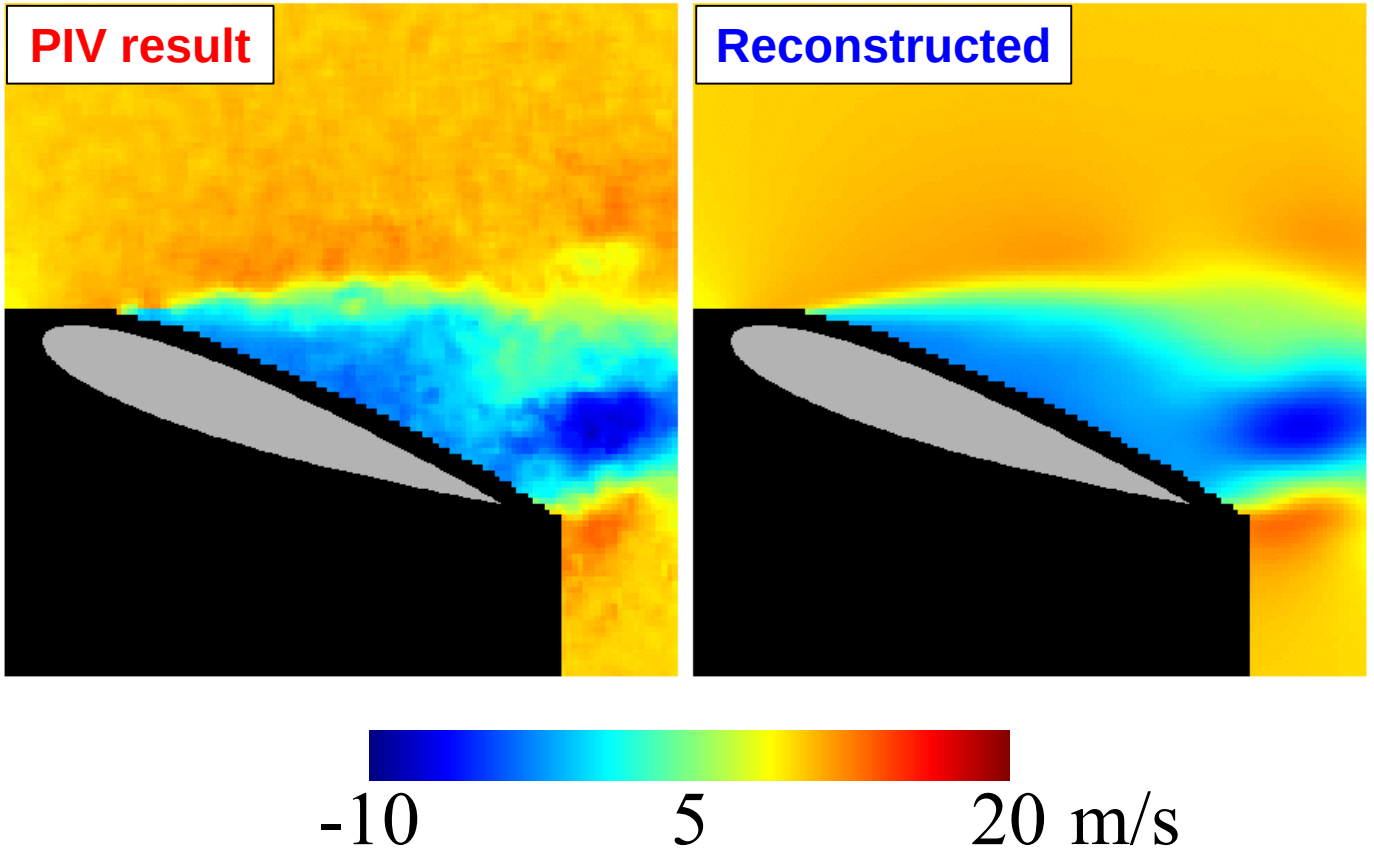
$tU/c = 0.02$



Results (α = 18 deg)

- Reconstruction of fluid data using POD

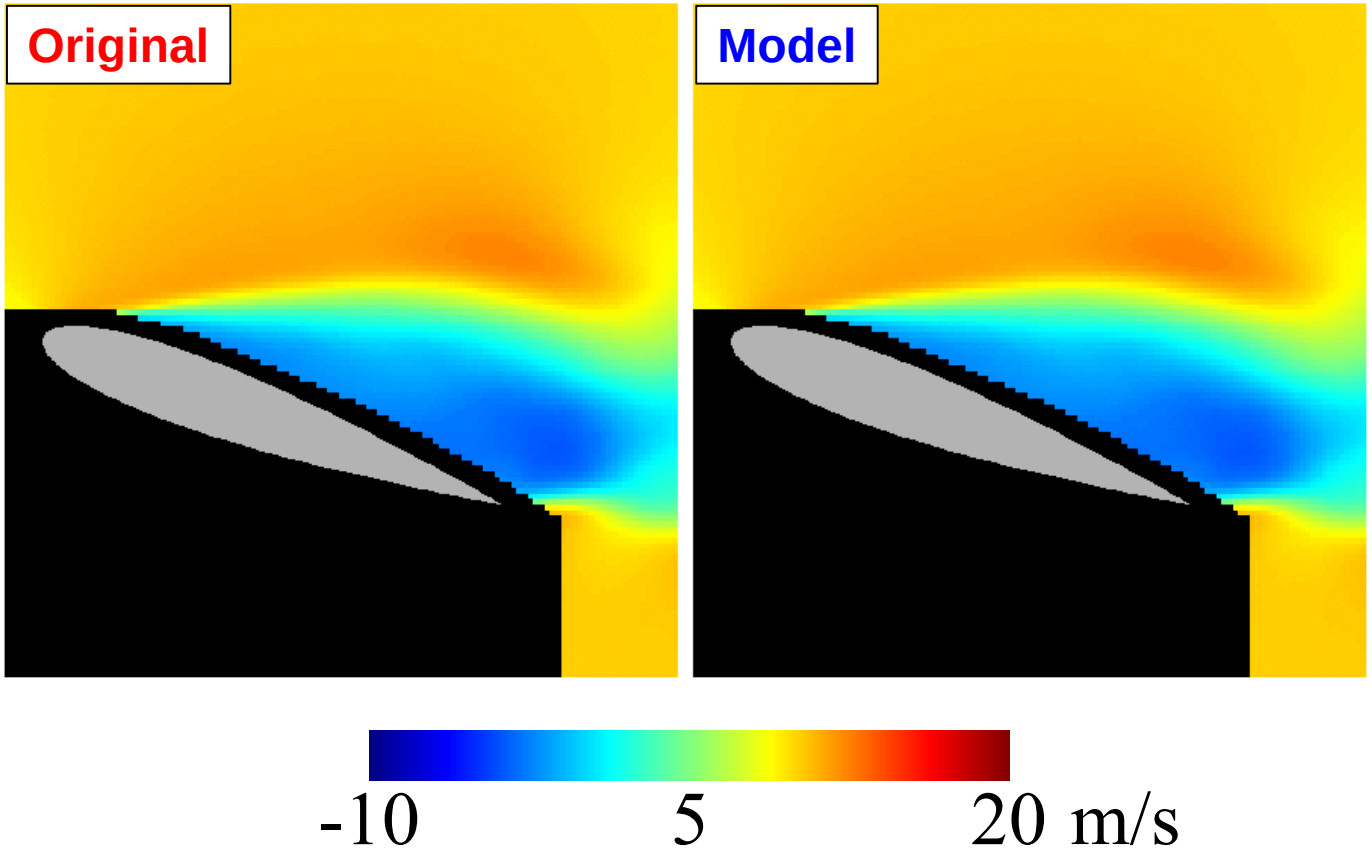
$tU/c = 0.02$



Results (α = 18 deg)

- Temporal estimation by the model

$tU/c = 0.02$



Conclusions

The linear reduced-order model of flow fields around the airfoil was constructed based on experimental data

- ✓ Experiment (Wind tunnel testing)
  - – Velocity fields data were acquired by PIV
- ✓ Order reduction of data
  - – The order of fluid data was reduced drastically by POD
- ✓ Modeling by a linear equation
  - – The model can reproduce the original data with low computational cost