EPFL Summer Experience

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1/25/16

Summer Experience

- EPFL in Lausanne, Switzerland
  - Dr. Fernando Porté-Agel
- July 17th - September 1st
- Surface Flow Convergence

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

How?

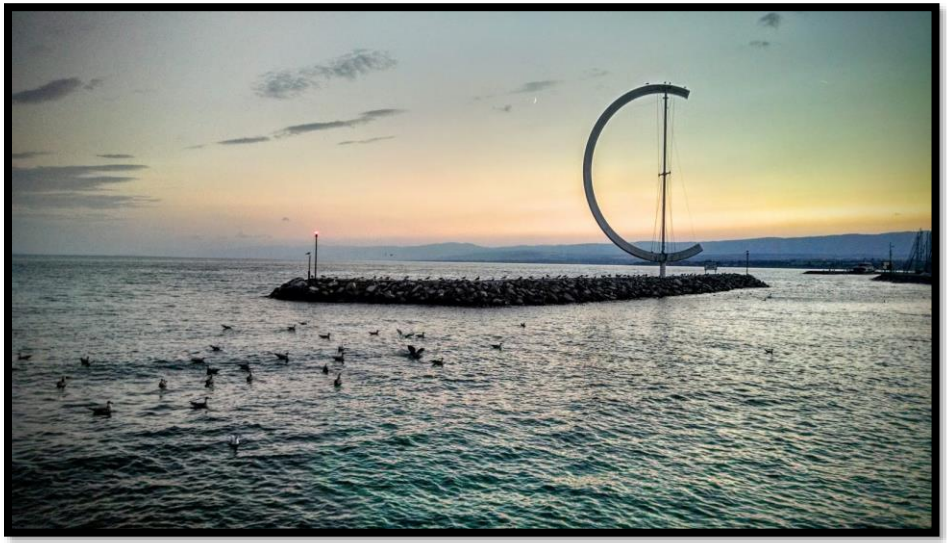
- Emailed Dr. Porté-Agel
  - Followed up on Skype
  - Offered to host me (easy part)
- Visa process (nightmare)
  - Work Visa
  - 3 month process
  - Traveled to Chicago and DC
  - Received visa 5 days before I left

Switzerland

Lausanne

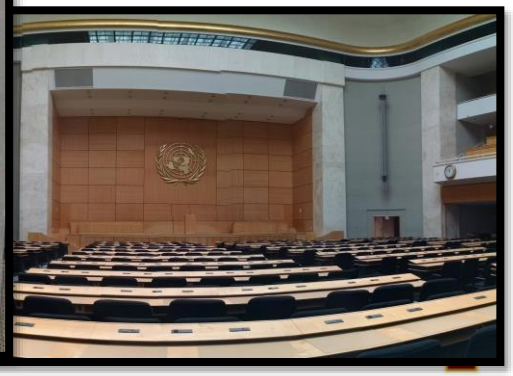
- Population: 146,372 (4th in Switzerland)
- Northernmost shore on Lake Geneva
- Smallest city in world w/ rapid transit system
- Olympic Capital

Lausanne



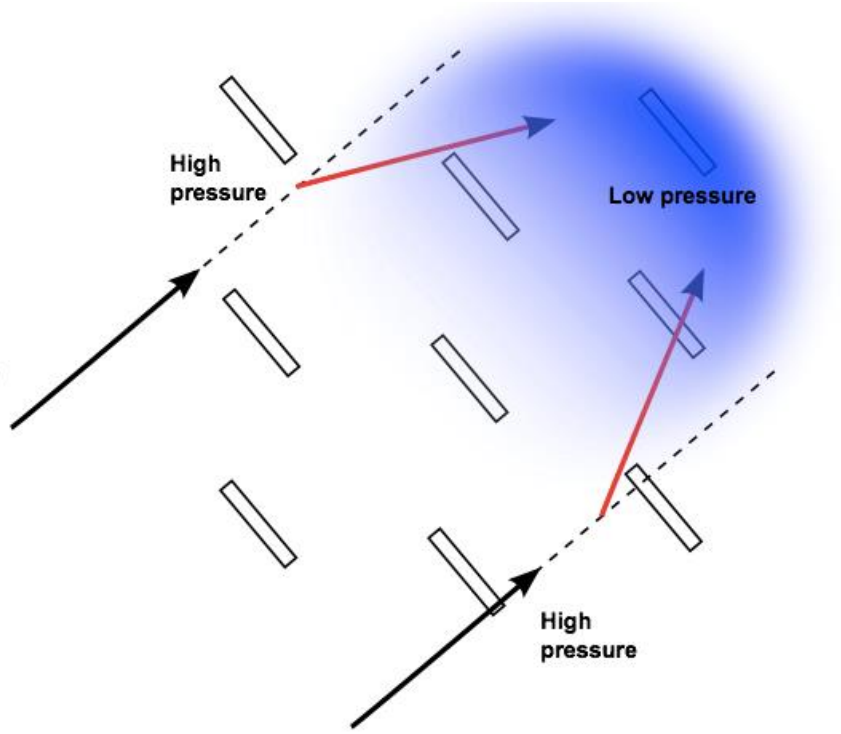
Travels


Direction
Depart
Epagny, village
Epagny, village
18.54
Trafic
Verkehr
TRAIN
SUSHI
Des couleurs d'ici,
www.tpf.ch



Surface Flow Convergence

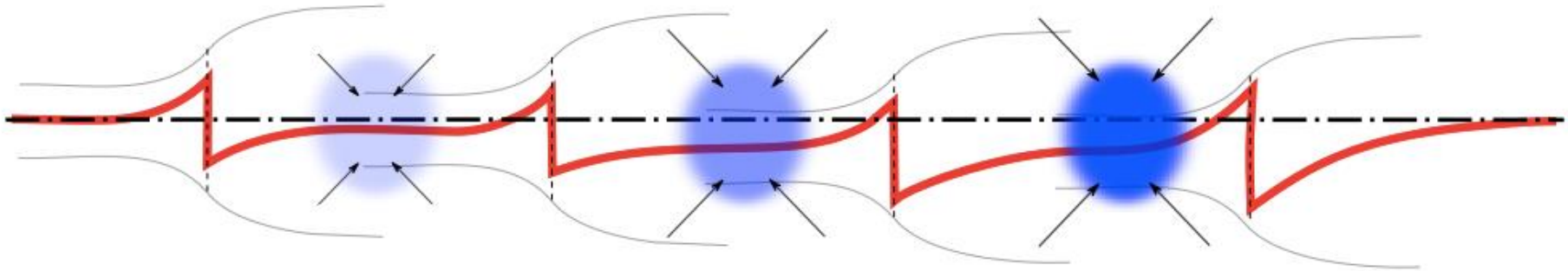
- **Observed**: Flow *veers* as it travels through a wind farm
- Near-ground measurements show **surface flow convergence**
- **Hypothesis:** pressure gradient imposed by turbines responsible



Surface Flow Convergence: How?

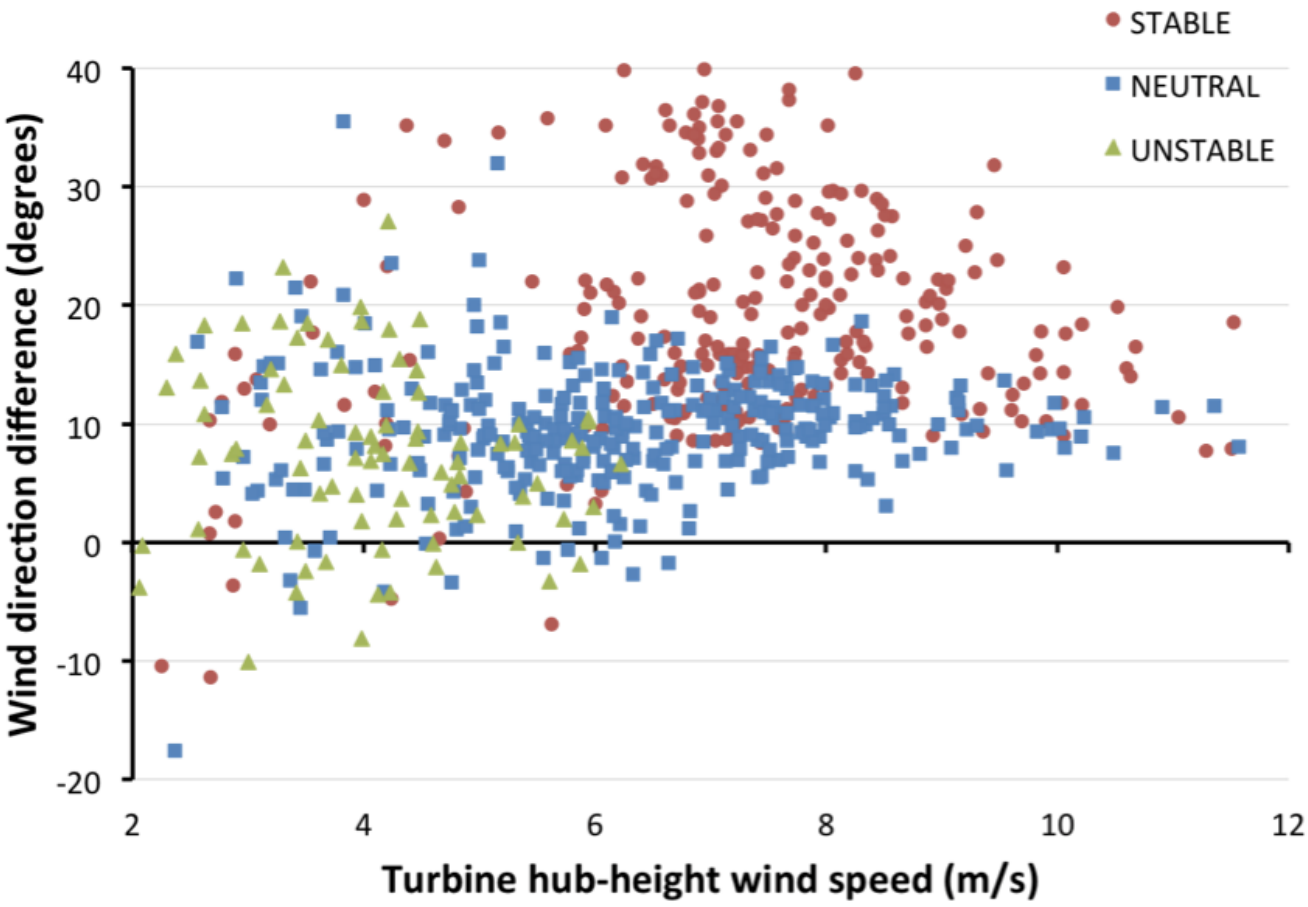
- Pressure drops across turbine
  - Recovers *far* downstream

- Complete pressure recovery may **not** be possible with closely spaced turbines



Increasing pressure deficit in deep arrays

Surface Flow Convergence: Data

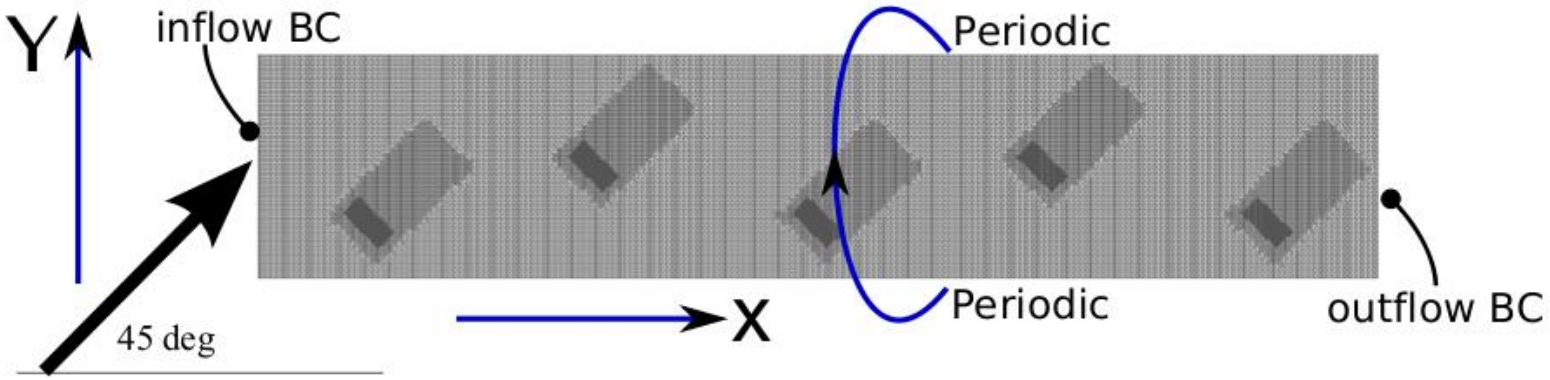


Surface flow veering observations (courtesy Prof. Eugene Takle; ISU)

Computational Analysis

- RANS + Actuator Disk
- OpenFOAM
- Validation:
  - 1-D Momentum Theory
  - Risø (Tellus) turbine

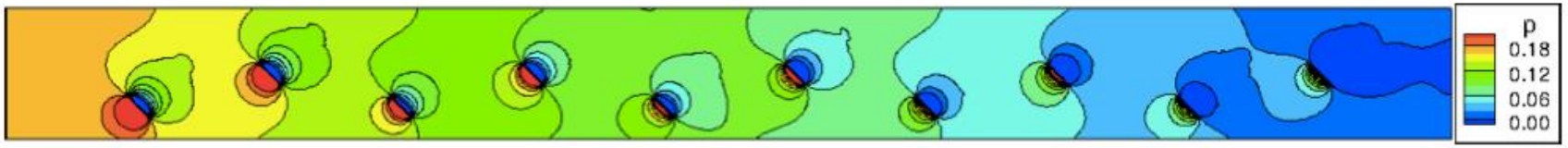
- **Infinite array**
  - Angled Inflow
  - Uniform & Neutral B.L.
- **Story County Wind Farm**
  - Crop/Wind-Energy Experiment (CWEX)



RANS Results

Semi-infinite wind farm at Hub Height (Uniform):

Compounding pressure drops



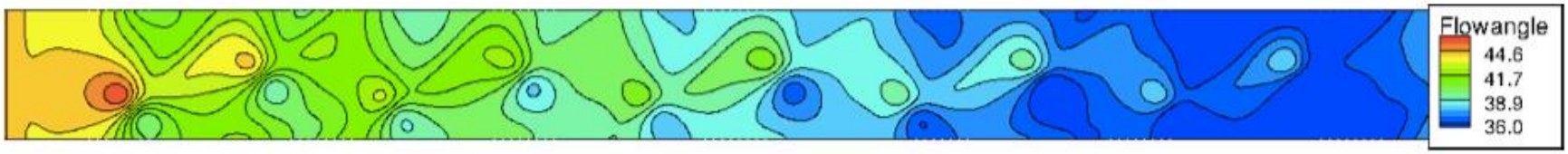
Flow Angle Change of ≈ 4°

RANS Results

Semi-infinite wind farm at surface (Neutral ABL):

Compounding pressure drops

Flow Angle Change of ≈ 8°… Much Higher!

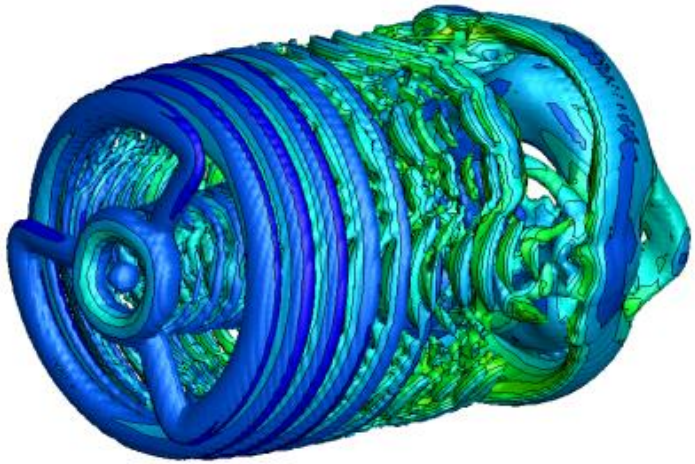


Balance between static and dynamic pressure

Large Eddy Simulation

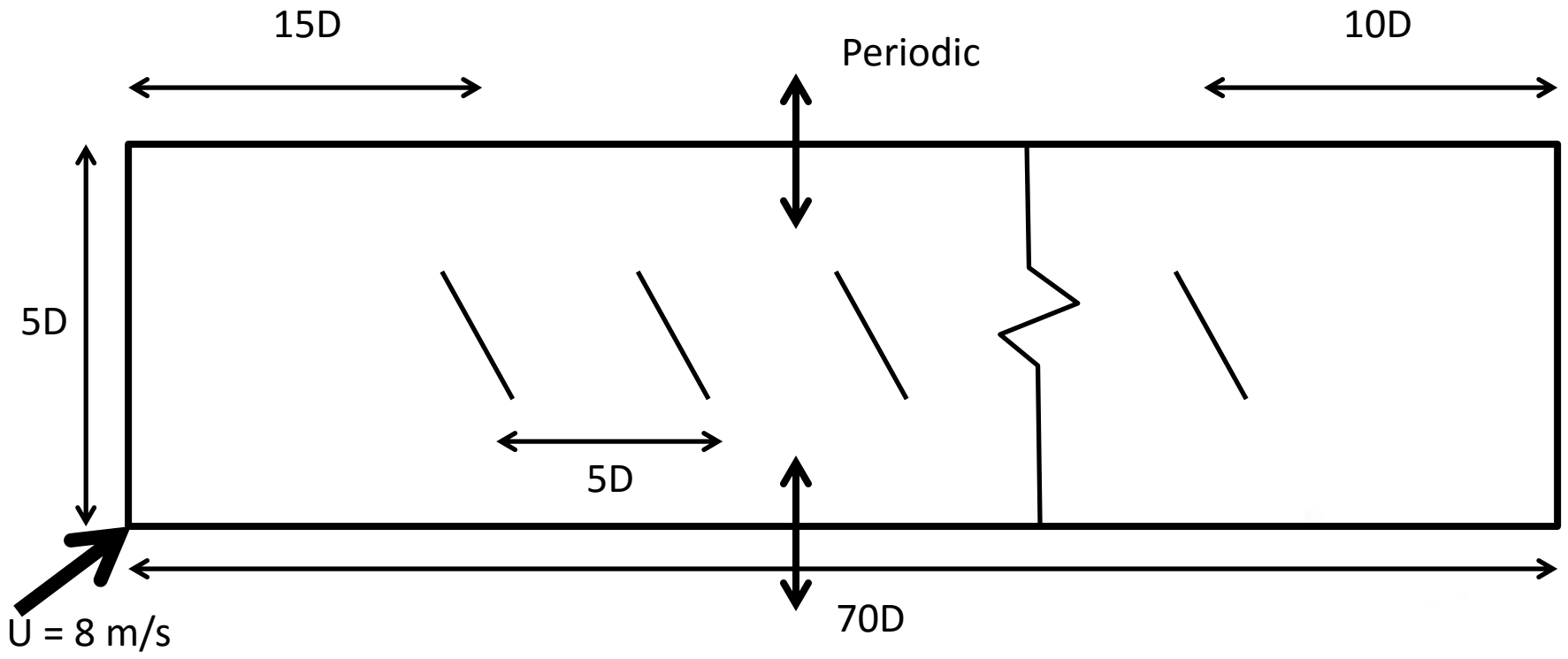
- How do unsteady phenomena affect SFC?
  - **Atmospheric Stability and Turbulence**
  - Wake Rotation
  - Coriolis Force?

- Implementation: **SOWFA**
  - OpenFOAM
  - **Actuator Line Model**

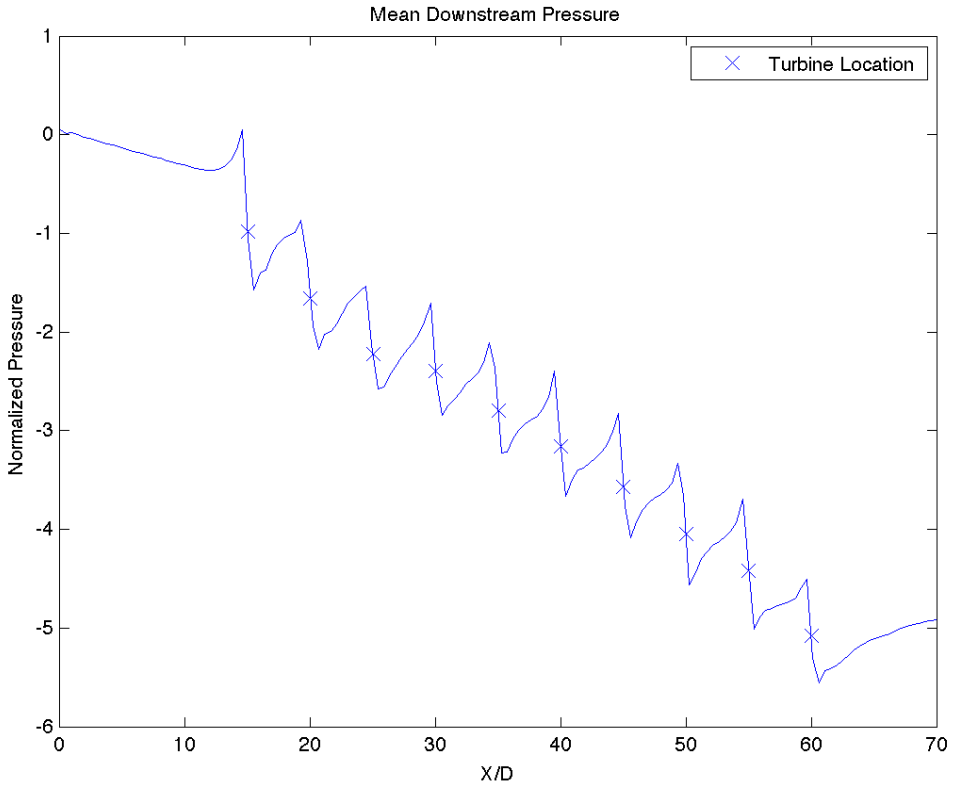


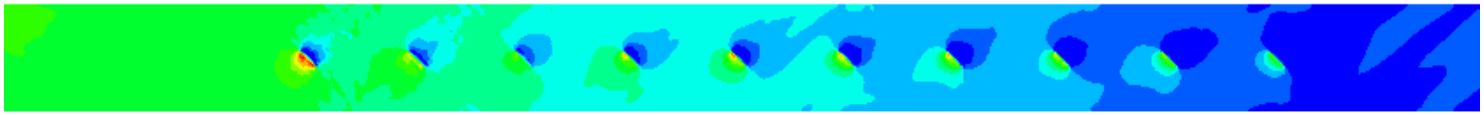
Domain

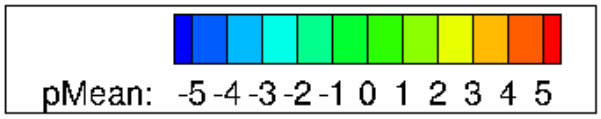
- Turbine: NREL 5MW Ref x10
  - D = 126 m
- Boundary Conditions (Uniform):
  - N-S: Periodic (Semi-infinite wind farm)
  - W-E: Inflow/Outflow
  - Top-Bottom: Slip



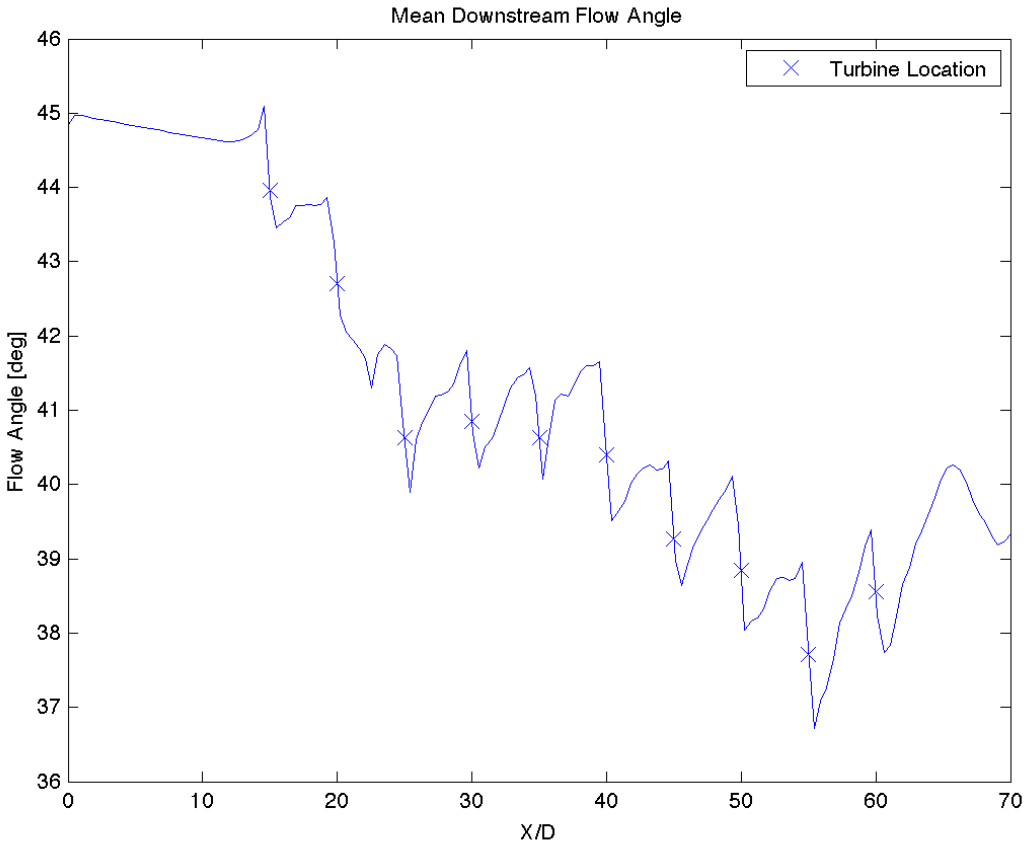
Uniform Results: Pressure

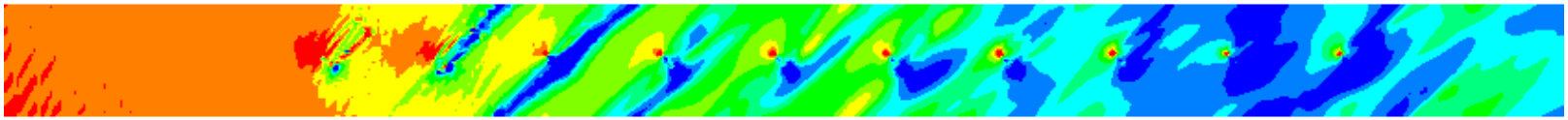


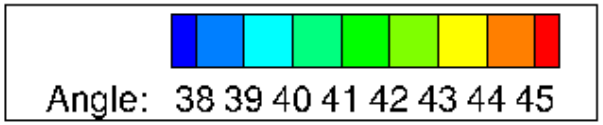




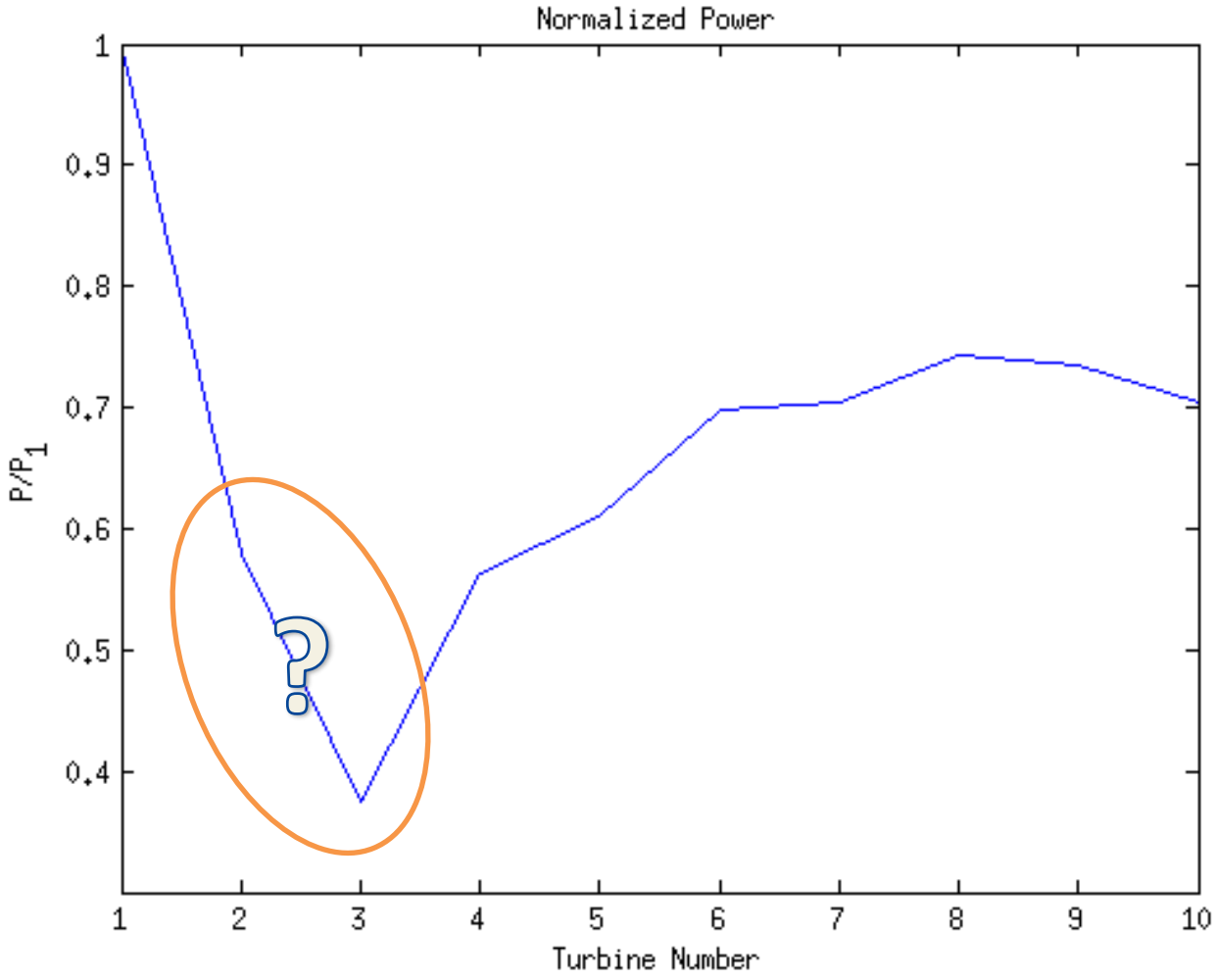
Uniform Results: Flow Angle







Uniform Results: Normalize Power



QUESTIONS?