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GOBIERNO DE ESPAÑA | MINISTERIO DE UNIVERSIDADES

ICME 2022

nextflow

European Research Council
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From wall measurements to three-dimensional turbulent-flow fields via GANs

A. Cuéllar[1], A. Güemes[1] A. Ianiro[1], O.Flores[1], R. Vinuesa[2], S. Discetti[1]

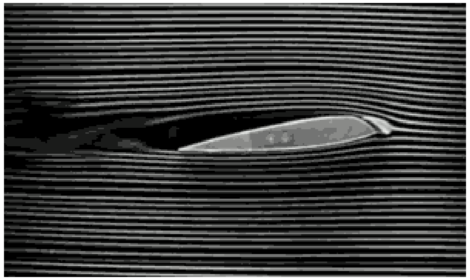
[1] Aerospace Engineering Research Group (UC3M)

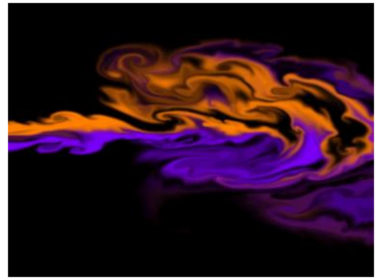
[2] FLOW, Engineering Mechanics (KTH)

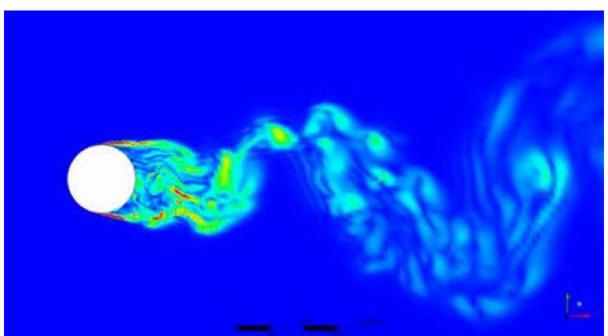
Aero space

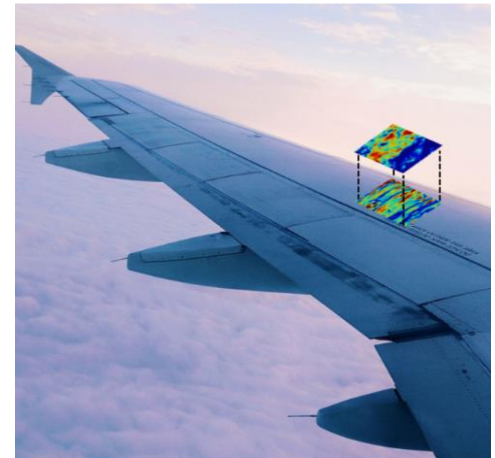
uc3m | Universidad Carlos III de Madrid

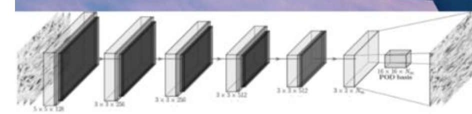
Flow sensing from wall measurements

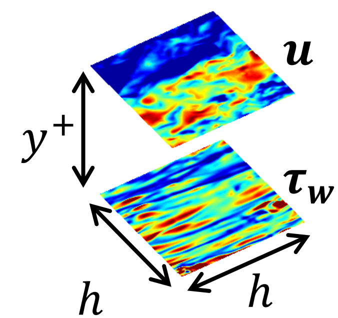












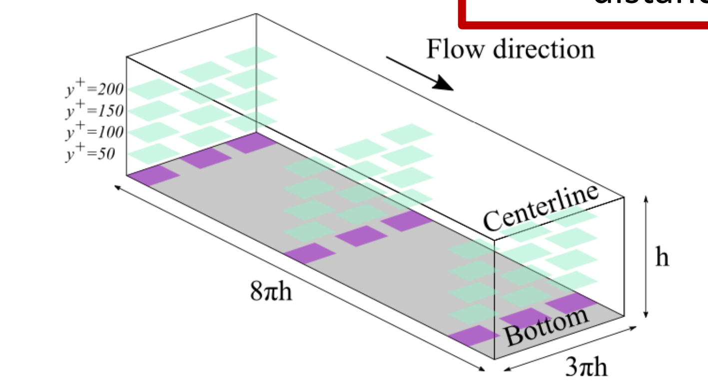
(Güemes, 2021)

Flow sensing from the wall (ML)

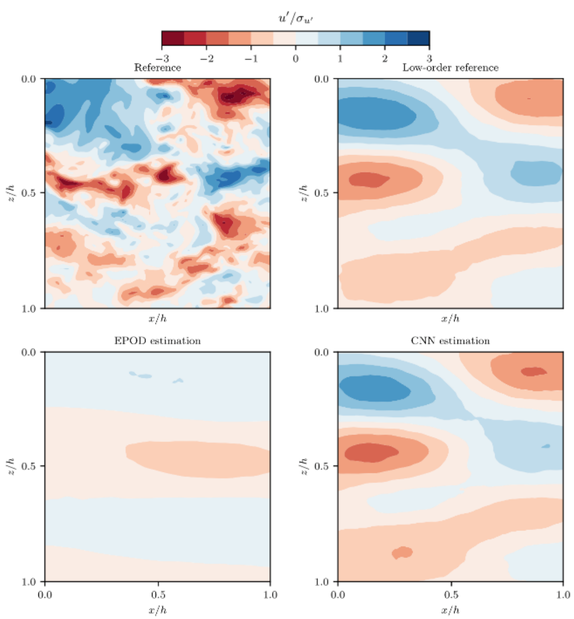
Estimation of fluid properties from wall quantities

- Linear methods
- Machine learning

One trained network for each wall-normal distance

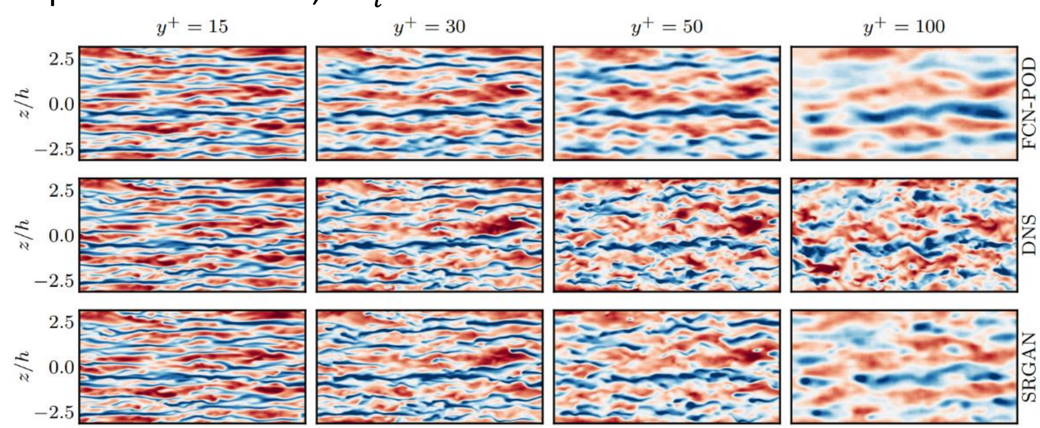


From Johns Hopkins Turbulent Data Base:
Channel Flow, $Re_\tau = 1000$



(Güemes, 2019)

From DNS (pseudo-spectral code):
Open channel Flow, $Re_\tau = 180$



(Güemes, 2021)

Flow sensing from the wall (ML)

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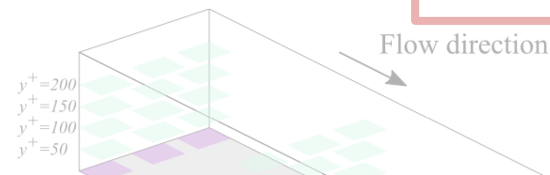

Fr
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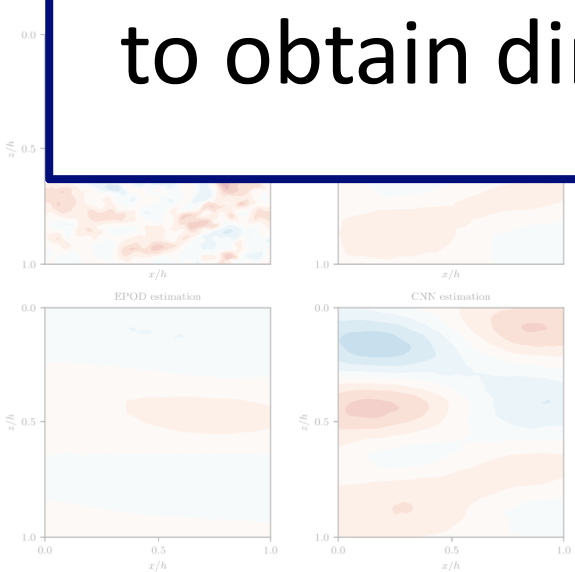
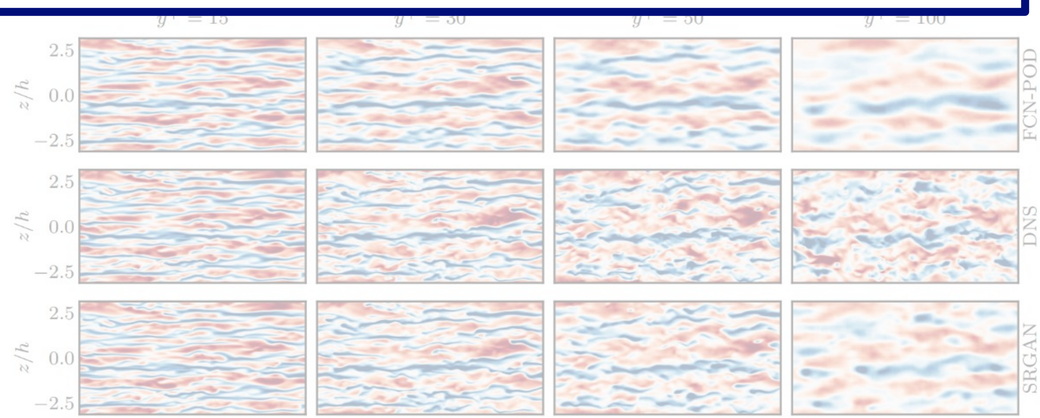
Is it possible to train a single architecture to obtain directly the full 3D estimation?



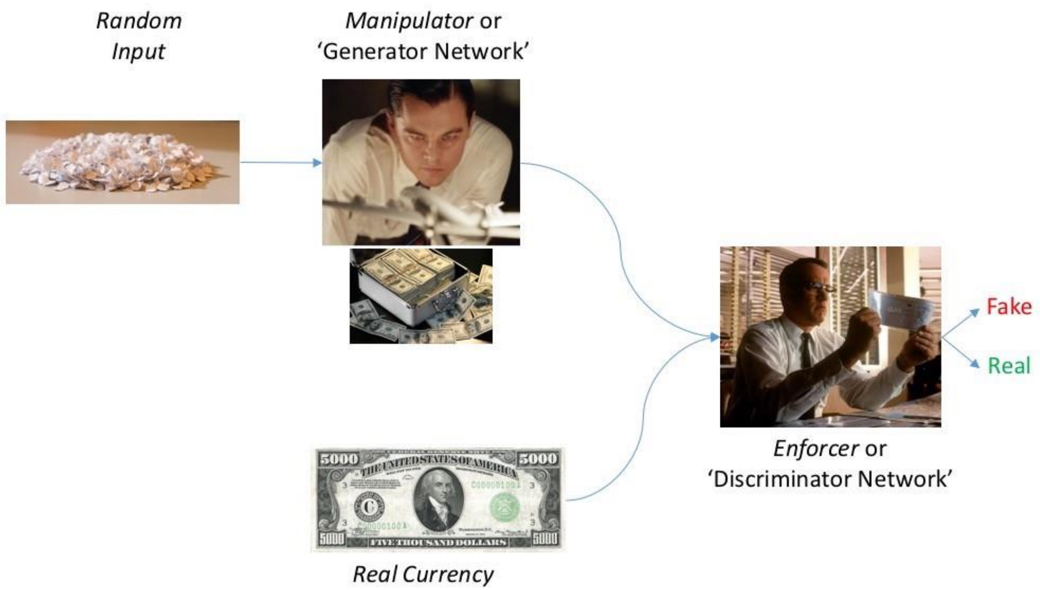
(Güemes, 2019)



(Güemes, 2021)

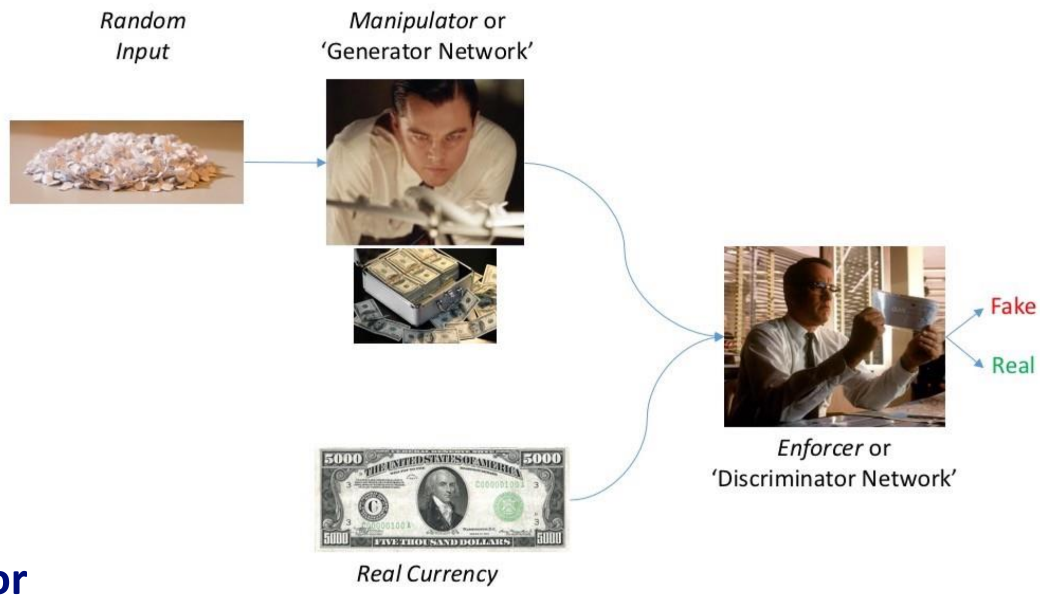
GANs: Generative Adversarial Networks

Example

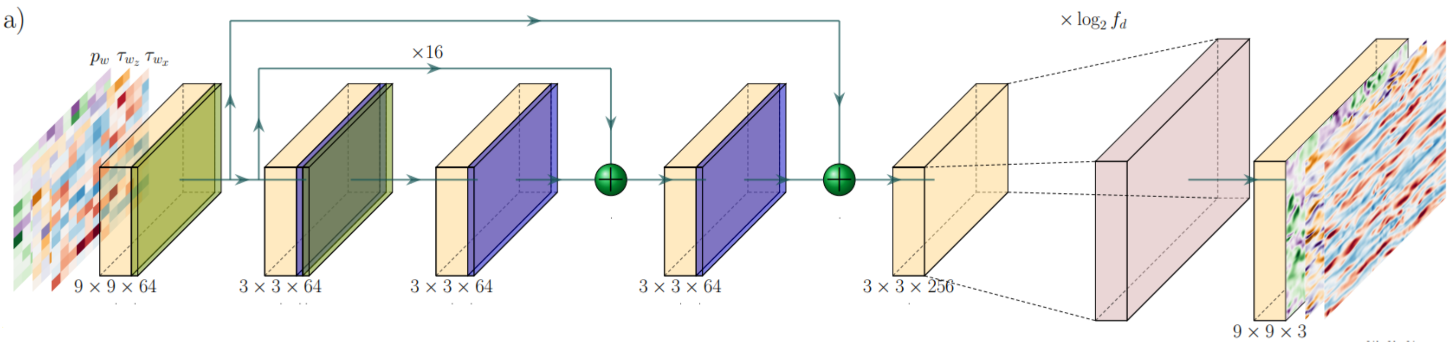


GANs: Generative Adversarial Networks

Example



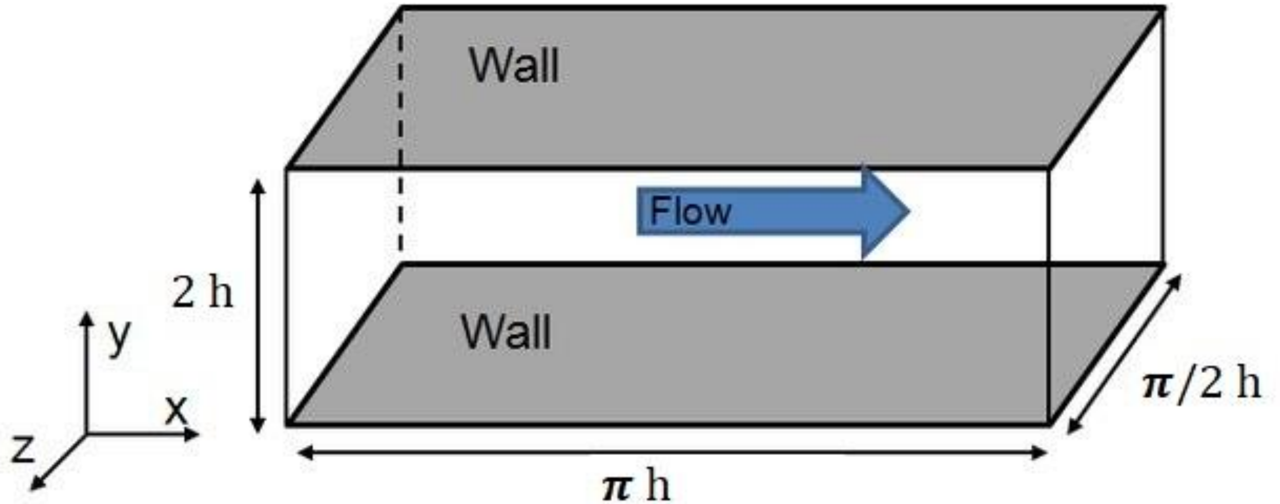
Generator



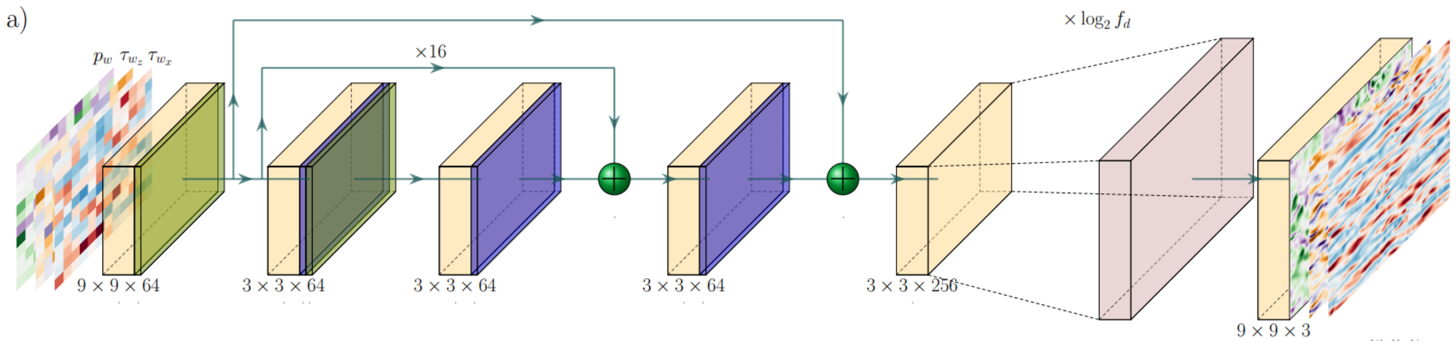
(Güemes, 2021)

The channel

- DNS database: Turbulent channel flow
- $Re_\tau = 200$
- x [0 - πh], y [0 – 2h], z [0 - $\frac{\pi}{2} h$]
- Points [64, 128, 64]

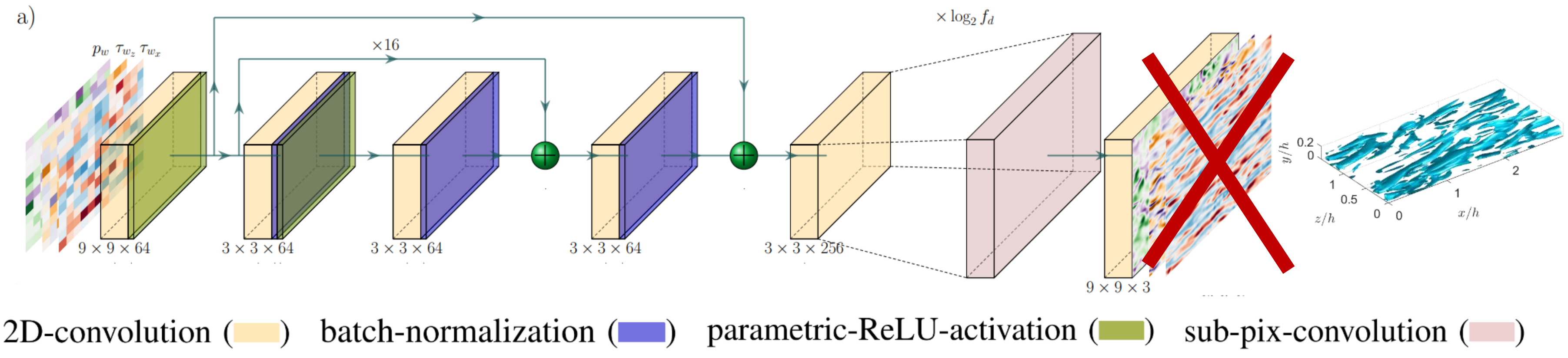


3D GAN



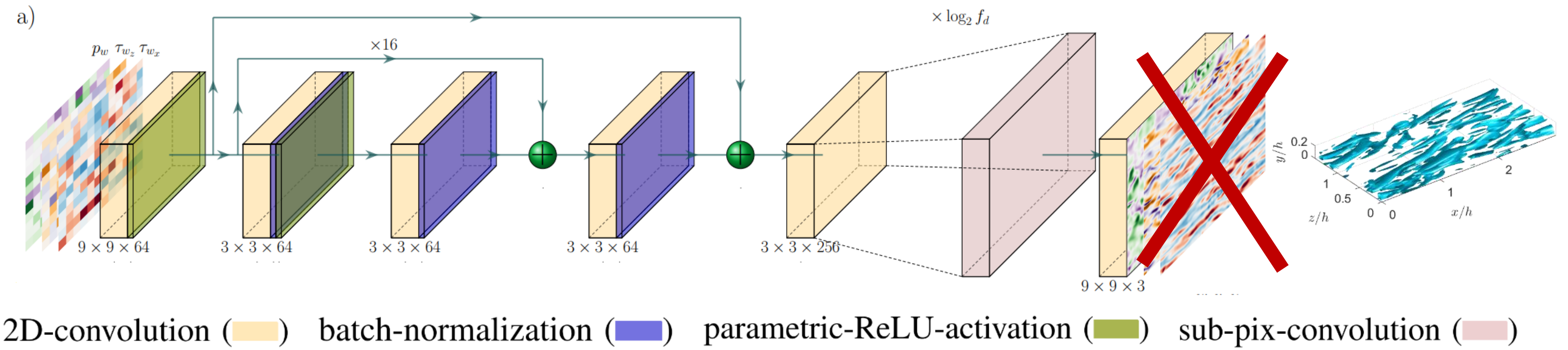
2D-convolution ( ) batch-normalization ( ) parametric-ReLU-activation ( ) sub-pix-convolution ( )

3D GAN



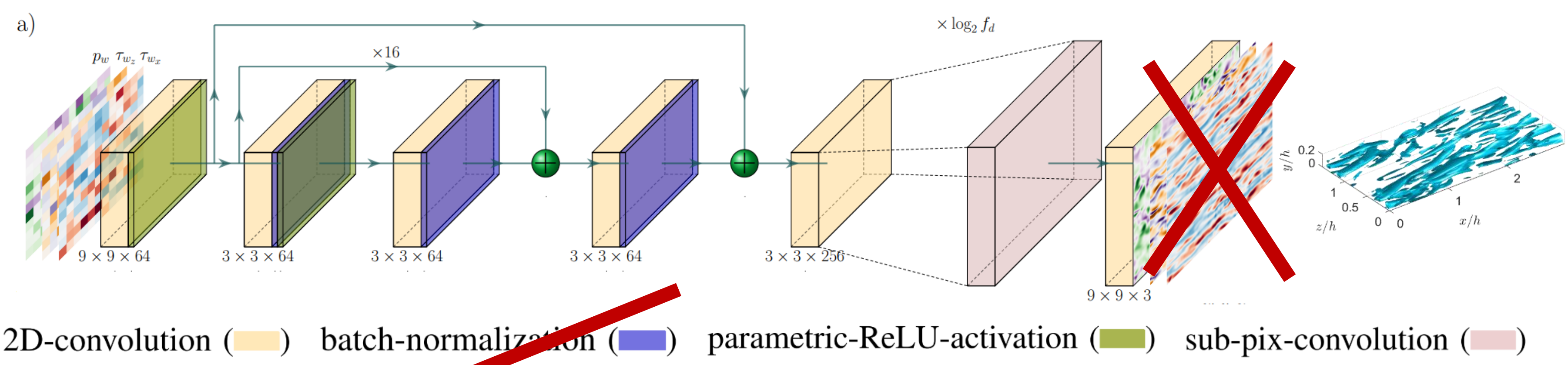
a)
p_w τ_{w_z} τ_{w_x}
×16
× log₂ f_d
9 × 9 × 64
3 × 3 × 64
3 × 3 × 64
3 × 3 × 64
3 × 3 × 256
9 × 9 × 3
y/h
0.2
0
z/h
1
0.5
0
0
1
2
x/h
2D-convolution ( ) batch-normalization ( ) parametric-ReLU-activation ( ) sub-pix-convolution ( )

3D GAN



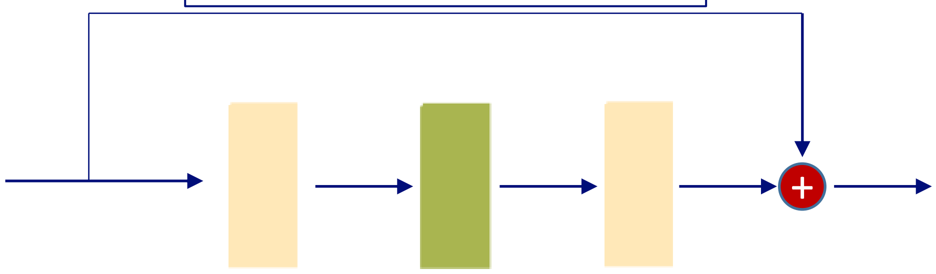
3D CONVOLUTION LAYERS

3D GAN

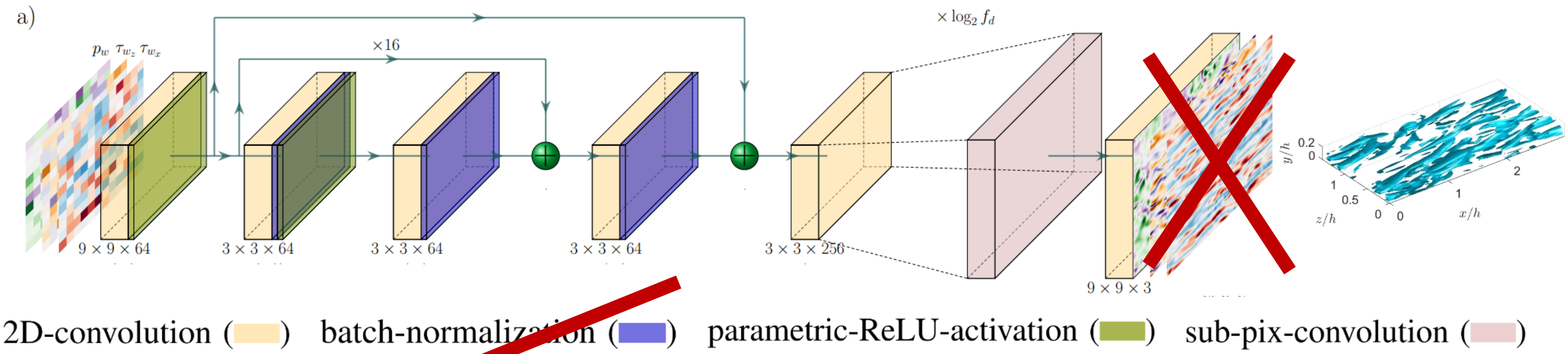


3D CONVOLUTION LAYERS

RESIDUAL BLOCK UNIT



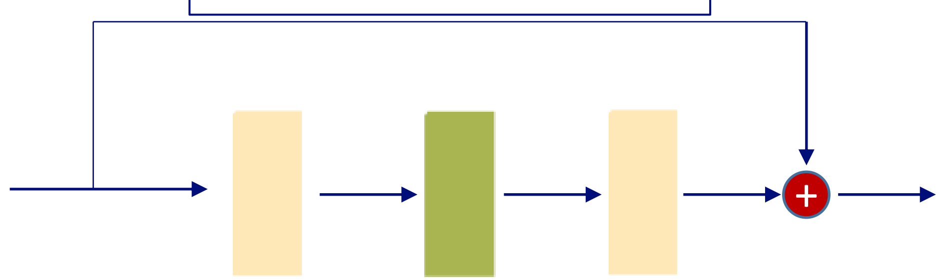
3D GAN



3D CONVOLUTION LAYERS

POSITION OF UP-SAMPLING LAYERS

RESIDUAL BLOCK UNIT



Flow sensing from wall-measurements

KEY ASPECTS

- Higher complexity, +1 dimension
- Computational power
- Number of trainable parameters

2D ➡ 3D

[SNAPSHOT , X , Y , Z , FILTER]

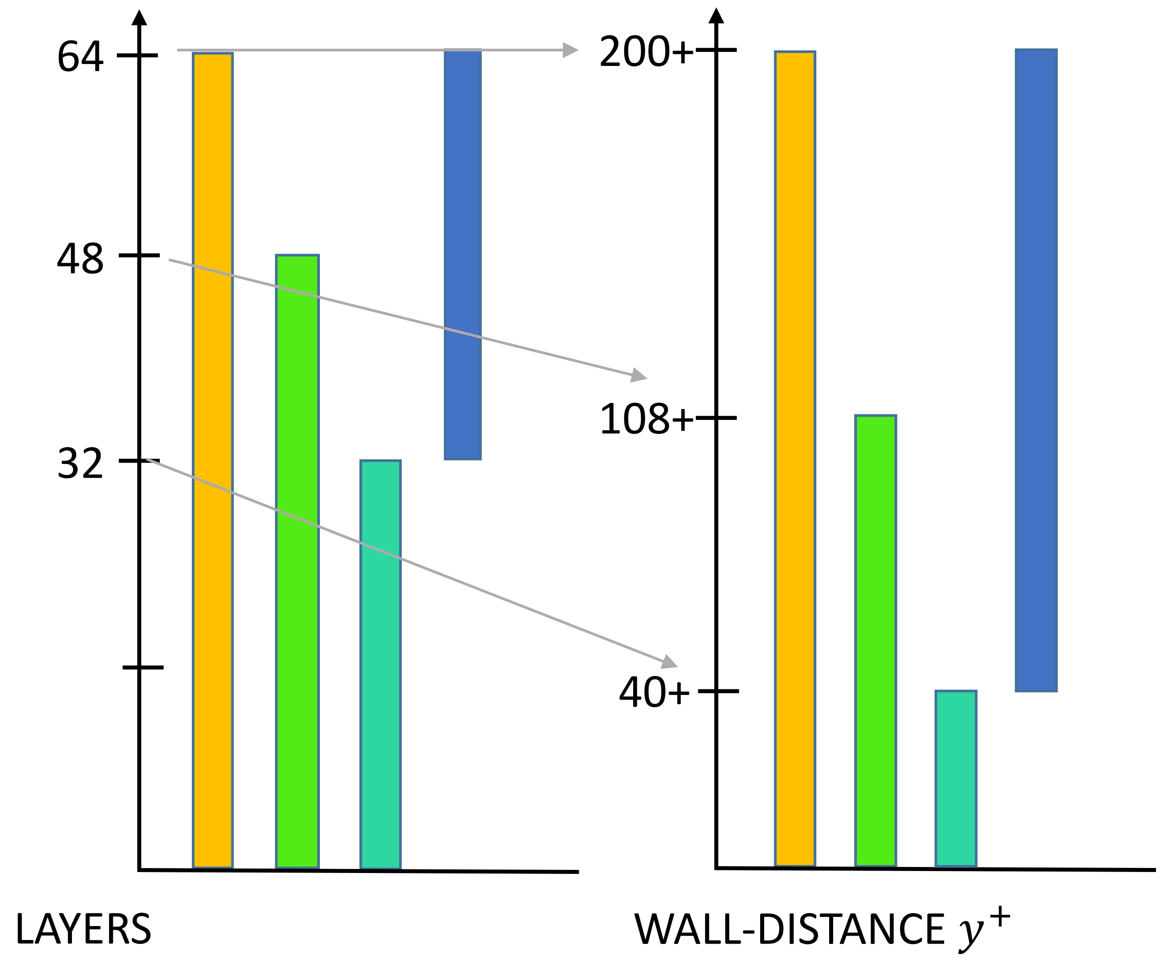
Results: CASES

A: 1 – 64

B: 1 – 48

C: 1 – 32

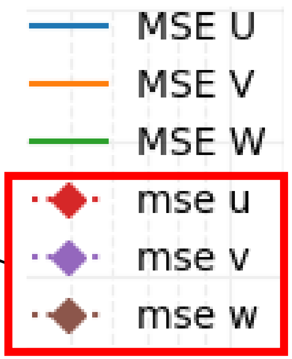
D: 33 - 64



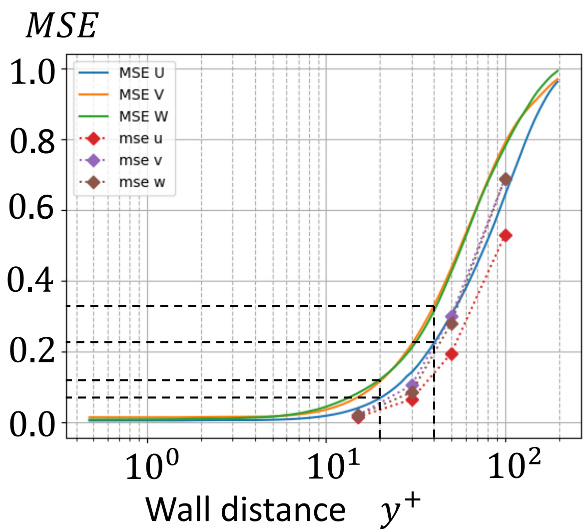
Results: CASES A, B, C

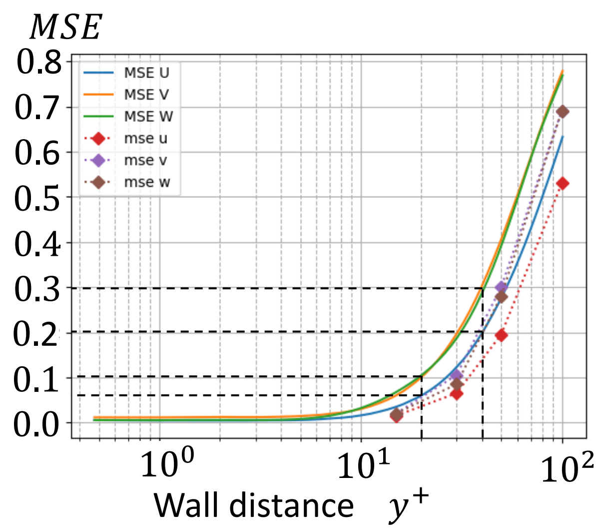
$$\boxed{MSE = \sqrt{(a - a^{*})^{2}}}$$

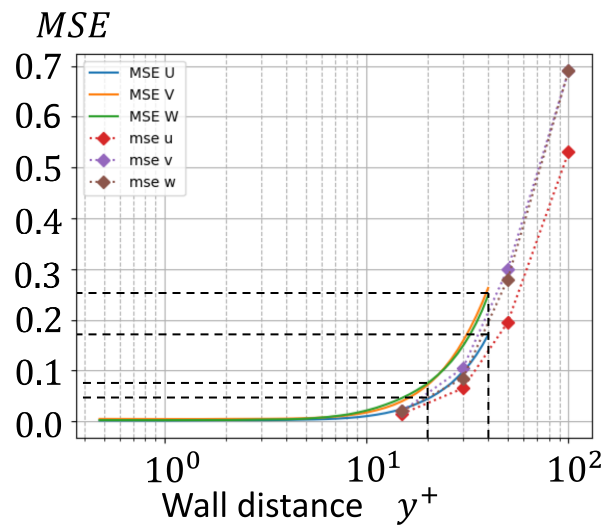
From Güemes *et al.* PoF 2021



ERROR: A > B > C







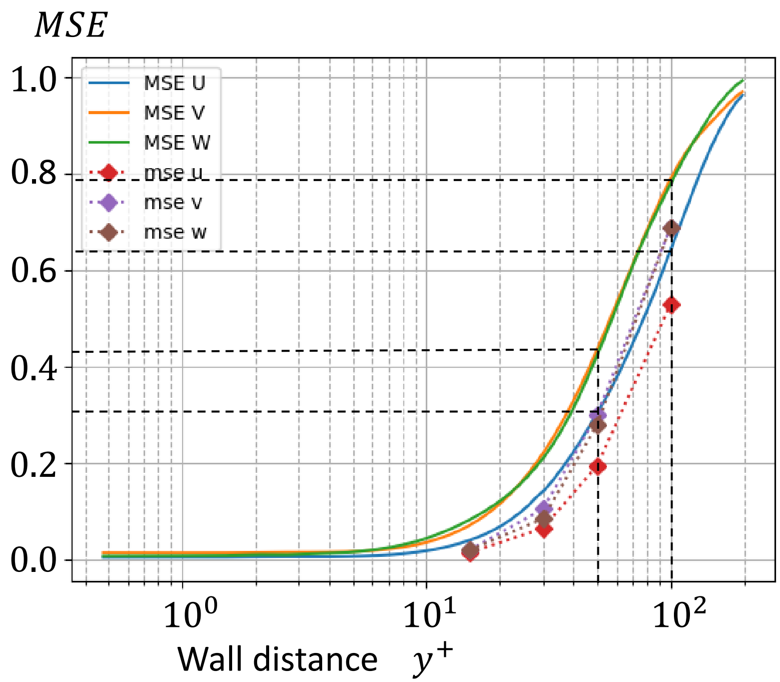
A: 1 – 64

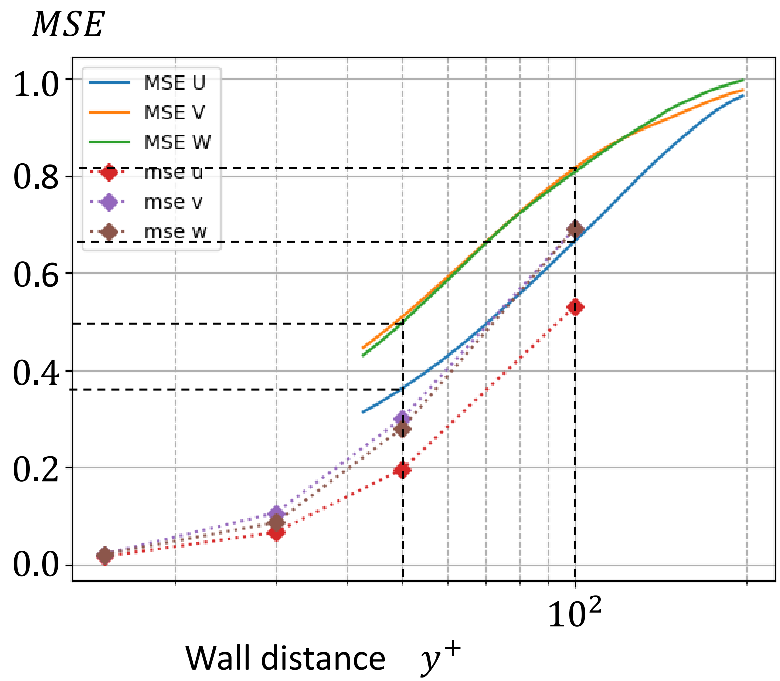
B: 1 – 48

C: 1 – 32

Results: CASE D

$$MSE = \sqrt{(a - a^*)^2}$$





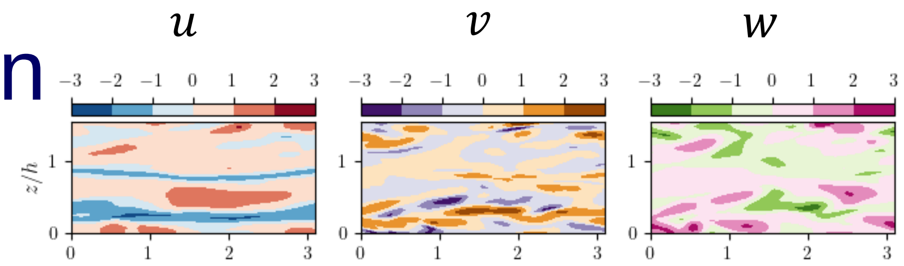
A: 1 – 64

D: 33 - 64

Results: Field prediction

$y^+ = 10$

DNS

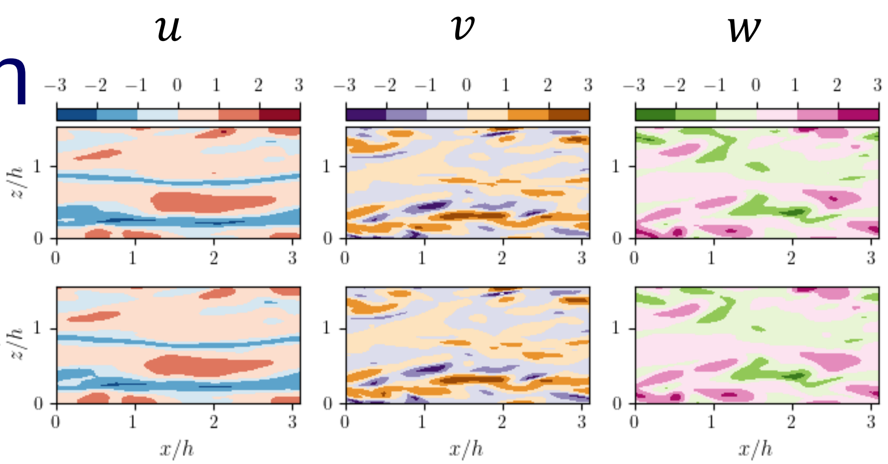


Results: Field prediction

$y^+ = 10$

DNS

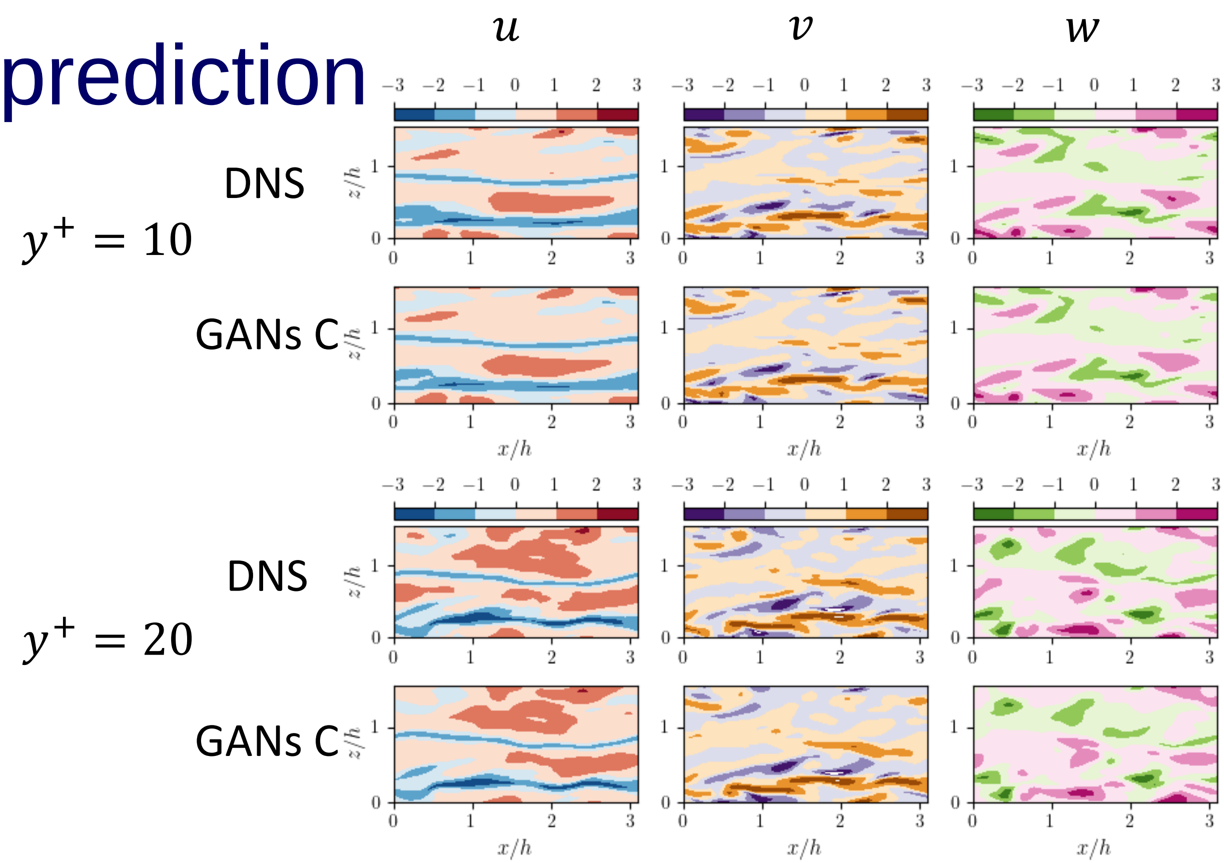
GANs C



MSE			
y^+	u	v	w
10	0.02	0.04	0.05

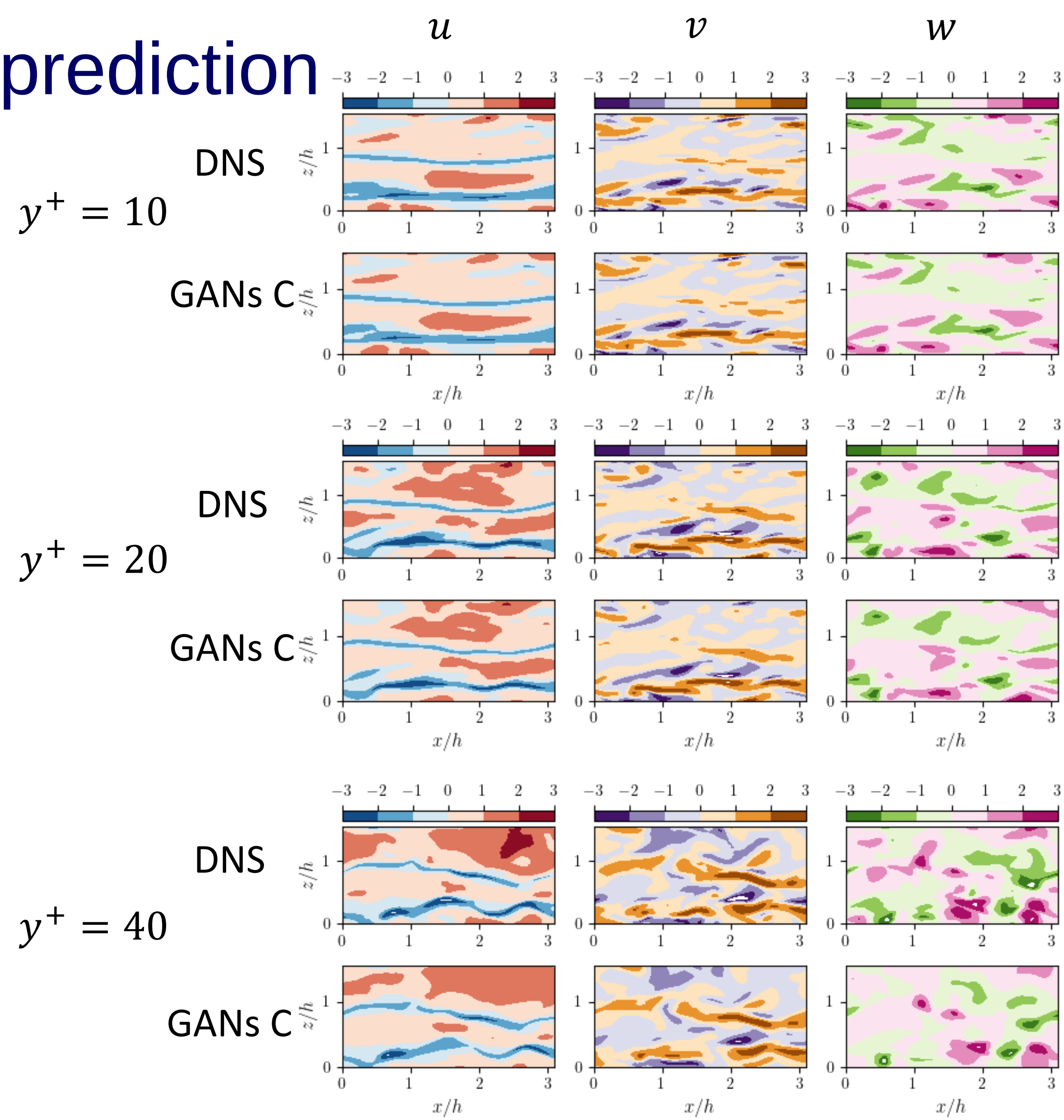
Results: Field prediction

MSE			
y^+	u	v	w
10	0.02	0.04	0.05
20	0.09	0.16	0.16



Results: Field prediction

MSE			
y^+	u	v	w
10	0.02	0.04	0.05
20	0.09	0.16	0.16
40	0.17	0.26	0.26



Conclusions

- "One-shot" 3D estimation is feasible with small loss of accuracy with respect to multi-plane GANs
- The number of trainable parameters can be significantly less than in multi-plane GANs
- The network estimates wall-attached structures

THANKS FOR YOUR ATTENTION

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MINISTERIO DE UNIVERSIDADES

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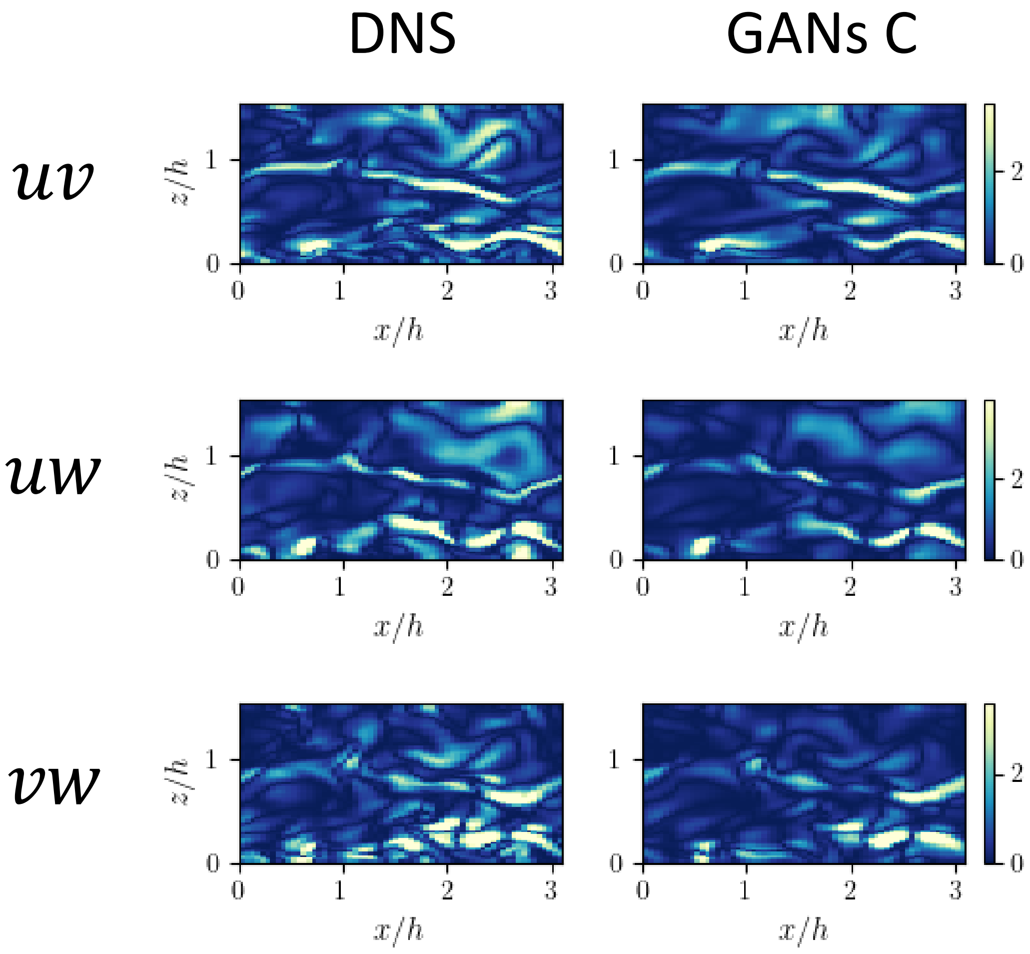
European Research Council

Established by the European Commission

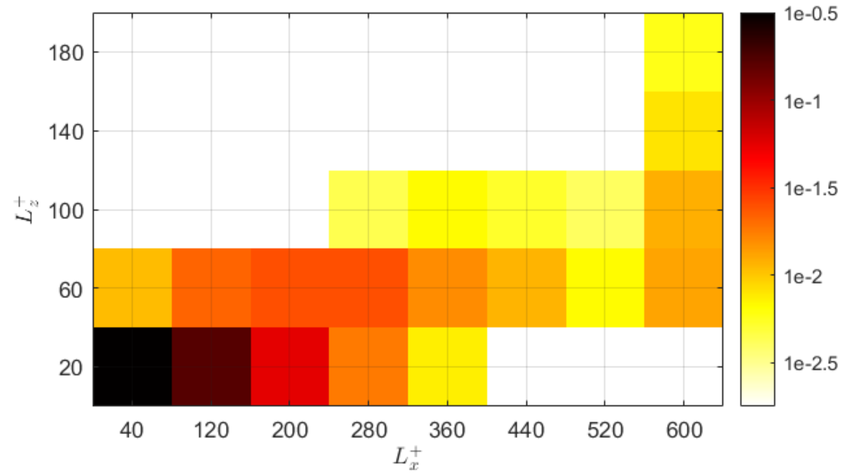
Results: Velocity component product

$y^+ = 40$



Results: Velocity component product

DNS



GANs C