



Figure 1: Overview of our method PEINR. (a) We first calculate the difference field between the high-fidelity flow field and low-fidelity counterpart. (b) In physical encoding, we leverage Gaussian coordinate encoding and localized encoding to handle temporal information and spatial coordinates. (c) The TransSTF block fuses temporal and spatial information and consists of ResuMLP, multi-head attention and spectral block. (d) The generated high-fidelity flow fields are obtained by combining difference fields and low-fidelity counterparts.

Table 1: PSNR, SSIM $\times 10^2$ , CORR $\times 10^2$  and DD $\times 10^5$  values with different upscaling factors  $\alpha$  and improvement factors  $\beta$ . The best values are highlighted in bold.

(a) RT $\alpha=16$ $\beta=1$												
Dataset	PSNR	SSIM	CORR	DD	PSNR	SSIM	CORR	DD	PSNR	SSIM	CORR	DD
NIF	17.53 $\pm$ 0.00577	87.70 $\pm$ 0.00980	94.04 $\pm$ 0.000921	22.46 $\pm$ 3.0739	24.83 $\pm$ 0.00603	92.85 $\pm$ 0.00026	98.33 $\pm$ 0.00011	26.45 $\pm$ 4.247	35.09 $\pm$ 0.047	86.44 $\pm$ 0.00021	95.78 $\pm$ 0.0009	2991.72 $\pm$ 79.30
CoordNet	23.33 $\pm$ 0.00692	93.17 $\pm$ 0.00735	98.40 $\pm$ 0.000219	10.25 $\pm$ 1.00231	<b>45.34</b> $\pm$ 0.00261	99.67 $\pm$ 0.00013	<b>99.98</b> $\pm$ 0.00009	21.80 $\pm$ 1.720	42.71 $\pm$ 0.0061	94.88 $\pm$ 0.00054	98.61 $\pm$ 0.0003	98.46 $\pm$ 10.75
PEINR <sup>1</sup>	24.82 $\pm$ 0.00723	94.51 $\pm$ 0.00122	98.86 $\pm$ 0.000363	9.31 $\pm$ 0.9279	34.16 $\pm$ 0.00207	98.70 $\pm$ 0.00131	99.80 $\pm$ 0.00009	4.93 $\pm$ 0.529	50 $\pm$ 0.00074	96.47 $\pm$ 0.00029	98.96 $\pm$ 0.0000	72.92 $\pm$ 16.22
PEINR <sup>2</sup>	24.92 $\pm$ 0.00703	94.63 $\pm$ 0.00273	99.28 $\pm$ 0.000261	8.17 $\pm$ 1.1831	37.10 $\pm$ 0.00291	98.96 $\pm$ 0.00617	99.90 $\pm$ 0.00008	3.28 $\pm$ 0.738	70.03 $\pm$ 0.00019	99.80 $\pm$ 0.0001	<b>99.98</b> $\pm$ 0.0000	15.93 $\pm$ 3.01
PEINR	<b>26.91</b> $\pm$ 0.00552	<b>95.91</b> $\pm$ 0.00231	<b>99.31</b> $\pm$ 0.000236	<b>7.76</b> $\pm$ 0.5502	44.22 $\pm$ 0.00475	<b>99.76</b> $\pm$ 0.00442	<b>99.98</b> $\pm$ 0.00009	<b>2.51</b> $\pm$ 0.149	<b>74.15</b> $\pm$ 0.00036	<b>99.84</b> $\pm$ 0.00002	<b>99.98</b> $\pm$ 0.0000	<b>4.61</b> $\pm$ 0.41
(b) RT $\alpha=16$ $\beta=1.4$												
NIF	15.15 $\pm$ 0.00460	83.81 $\pm$ 0.00447	89.98 $\pm$ 0.0005	85.02 $\pm$ 8.023	23.93 $\pm$ 0.0128	90.00 $\pm$ 0.062	97.95 $\pm$ 0.00023	17.46 $\pm$ 1.06	48.43 $\pm$ 0.00878	95.64 $\pm$ 0.0041	98.81 $\pm$ 0.0005	193.82 $\pm$ 29.381
CoordNet	20.73 $\pm$ 0.00825	89.20 $\pm$ 0.00918	97.16 $\pm$ 0.0002	71.38 $\pm$ 4.129	<b>37.98</b> $\pm$ 0.00236	98.46 $\pm$ 0.00285	<b>99.91</b> $\pm$ 0.00004	8.78 $\pm$ 1.59	41.16 $\pm$ 0.00058	93.92 $\pm$ 0.00286	98.41 $\pm$ 0.0006	246.5 $\pm$ 38.026
PEINR <sup>1</sup>	21.45 $\pm$ 0.00437	89.65 $\pm$ 0.0006	97.61 $\pm$ 0.0001	26.32 $\pm$ 0.149	33.27 $\pm$ 0.00663	97.57 $\pm$ 0.0166	99.75 $\pm$ 0.00005	7.20 $\pm$ 1.99	37.14 $\pm$ 0.00031	96.50 $\pm$ 0.00319	99.10 $\pm$ 0.0005	314.26 $\pm$ 59.933
PEINR <sup>2</sup>	<b>22.08</b> $\pm$ 0.00531	90.78 $\pm$ 0.0009	97.88 $\pm$ 0.0001	27.20 $\pm$ 0.150	37.55 $\pm$ 0.00951	<b>98.66</b> $\pm$ 0.0802	99.90 $\pm$ 0.00005	3.71 $\pm$ 0.92	51.10 $\pm$ 0.00042	99.40 $\pm$ 0.00075	99.92 $\pm$ 0.0000	58.97 $\pm$ 12.059
PEINR	21.96 $\pm$ 0.00481	<b>90.92</b> $\pm$ 0.0006	<b>97.93</b> $\pm$ 0.0001	<b>22.09</b> $\pm$ 0.116	37.81 $\pm$ 0.00833	98.62 $\pm$ 0.0713	<b>99.91</b> $\pm$ 0.00002	<b>3.18</b> $\pm$ 0.42	<b>70.91</b> $\pm$ 0.00020	<b>99.46</b> $\pm$ 0.00032	<b>99.96</b> $\pm$ 0.0000	<b>25.38</b> $\pm$ 3.8148
(c) Cylinder $\alpha=4$ $\beta=1$												
NIF	17.53 $\pm$ 0.0301	80.12 $\pm$ 0.0864	82.88 $\pm$ 0.0009	131.58 $\pm$ 24.71	19.08 $\pm$ 0.029	78.20 $\pm$ 0.0283	84.80 $\pm$ 0.0068	286.9 $\pm$ 29.8	27.47 $\pm$ 0.7493	89.67 $\pm$ 0.0383	99.21 $\pm$ 0.00011	20.75 $\pm$ 1.5310
CoordNet	21.80 $\pm$ 0.0092	84.32 $\pm$ 0.0092	92.20 $\pm$ 0.0008	12.76 $\pm$ 2.58	19.31 $\pm$ 0.0048	85.09 $\pm$ 0.00907	90.30 $\pm$ 0.0002	172.7 $\pm$ 13.88	27.34 $\pm$ 1.0958	89.57 $\pm$ 0.00831	99.19 $\pm$ 0.00005	21.96 $\pm$ 1.1083
PEINR <sup>1</sup>	39.15 $\pm$ 0.00058	98.52 $\pm$ 0.00004	99.85 $\pm$ 0.00003	11.53 $\pm$ 1.03	35.7 $\pm$ 0.0009	98.88 $\pm$ 0.0081	99.86 $\pm$ 0.0000	49.6 $\pm$ 3.37	42.21 $\pm$ 0.8331	99.12 $\pm$ 0.00094	99.97 $\pm$ 0.00003	9.91 $\pm$ 1.291
PEINR <sup>2</sup>	39.47 $\pm$ 0.00040	98.52 $\pm$ 0.00001	99.85 $\pm$ 0.00003	7.63 $\pm$ 0.0167	38.9 $\pm$ 0.0004	98.89 $\pm$ 0.0046	99.81 $\pm$ 0.0000	11.25 $\pm$ 1.09	43.55 $\pm$ 0.5033	99.29 $\pm$ 0.00041	99.98 $\pm$ 0.00002	11.22 $\pm$ 1.759
PEINR	<b>40.04</b> $\pm$ 0.00019	<b>99.10</b> $\pm$ 0.00004	<b>99.89</b> $\pm$ 0.00002	<b>2.35</b> $\pm$ 0.0009	<b>40.34</b> $\pm$ 0.0001	<b>99.28</b> $\pm$ 0.00007	<b>99.88</b> $\pm$ 0.0000	<b>1.27</b> $\pm$ 0.00992	<b>45.26</b> $\pm$ 0.0931	<b>99.50</b> $\pm$ 0.00040	<b>99.98</b> $\pm$ 0.00002	<b>4.21</b> $\pm$ 0.806
(d) RM $\alpha=16$ $\beta=1$												
NIF	17.53 $\pm$ 0.00577	87.70 $\pm$ 0.00980	94.04 $\pm$ 0.000921	22.46 $\pm$ 3.0739	24.83 $\pm$ 0.00603	92.85 $\pm$ 0.00026	98.33 $\pm$ 0.00011	26.45 $\pm$ 4.247	35.09 $\pm$ 0.047	86.44 $\pm$ 0.00021	95.78 $\pm$ 0.0009	2991.72 $\pm$ 79.30
CoordNet	23.33 $\pm$ 0.00692	93.17 $\pm$ 0.00735	98.40 $\pm$ 0.000219	10.25 $\pm$ 1.00231	<b>45.34</b> $\pm$ 0.00261	99.67 $\pm$ 0.00013	<b>99.98</b> $\pm$ 0.00009	21.80 $\pm$ 1.720	42.71 $\pm$ 0.0061	94.88 $\pm$ 0.00054	98.61 $\pm$ 0.0003	98.46 $\pm$ 10.75
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PEINR	<b>26.91</b> $\pm$ 0.00552	<b>95.91</b> $\pm$ 0.00231	<b>99.31</b> $\pm$ 0.000236	<b>7.76</b> $\pm$ 0.5502	44.22 $\pm$ 0.00475	<b>99.76</b> $\pm$ 0.00442	<b>99.98</b> $\pm$ 0.00009	<b>2.51</b> $\pm$ 0.149	<b>74.15</b> $\pm$ 0.00036	<b>99.84</b> $\pm$ 0.00002	<b>99.98</b> $\pm$ 0.0000	<b>4.61</b> $\pm$ 0.41
(e) FFS $\alpha=16$ $\beta=1$												
NIF	15.15 $\pm$ 0.00460	83.81 $\pm$ 0.00447	89.98 $\pm$ 0.0005	85.02 $\pm$ 8.023	23.93 $\pm$ 0.0128	90.00 $\pm$ 0.062	97.95 $\pm$ 0.00023	17.46 $\pm$ 1.06	48.43 $\pm$ 0.00878	95.64 $\pm$ 0.0041	98.81 $\pm$ 0.0005	193.82 $\pm$ 29.381
CoordNet	20.73 $\pm$ 0.00825	89.20 $\pm$ 0.00918	97.16 $\pm$ 0.0002	71.38 $\pm$ 4.129	<b>37.98</b> $\pm$ 0.00236	98.46 $\pm$ 0.00285	<b>99.91</b> $\pm$ 0.00004	8.78 $\pm$ 1.59	41.16 $\pm$ 0.00058	93.92 $\pm$ 0.00286	98.41 $\pm$ 0.0006	246.5 $\pm$ 38.026
PEINR <sup>1</sup>	21.45 $\pm$ 0.00437	89.65 $\pm$ 0.0006	97.61 $\pm$ 0.0001	26.32 $\pm$ 0.149	33.27 $\pm$ 0.00663	97.57 $\pm$ 0.0166	99.75 $\pm$ 0.00005	7.20 $\pm$ 1.99	37.14 $\pm$ 0.00031	96.50 $\pm$ 0.00319	99.10 $\pm$ 0.0005	314.26 $\pm$ 59.933
PEINR <sup>2</sup>	<b>22.08</b> $\pm$ 0.00531	90.78 $\pm$ 0.0009	97.88 $\pm$ 0.0001	27.20 $\pm$ 0.150	37.55 $\pm$ 0.00951	<b>98.66</b> $\pm$ 0.0802	99.90 $\pm$ 0.00005	3.71 $\pm$ 0.92	51.10 $\pm$ 0.00042	99.40 $\pm$ 0.00075	99.92 $\pm$ 0.0000	58.97 $\pm$ 12.059
PEINR	21.96 $\pm$ 0.00481	<b>90.92</b> $\pm$ 0.0006	<b>97.93</b> $\pm$ 0.0001	<b>22.09</b> $\pm$ 0.116	37.81 $\pm$ 0.00833	98.62 $\pm$ 0.0713	<b>99.91</b> $\pm$ 0.00002	<b>3.18</b> $\pm$ 0.42	<b>70.91</b> $\pm$ 0.00020	<b>99.46</b> $\pm$ 0.00032	<b>99.96</b> $\pm$ 0.0000	<b>25.38</b> $\pm$ 3.8148
(f) Cylinder $\alpha=4$ $\beta=1.4$												
NIF	17.53 $\pm$ 0.0301	80.12 $\pm$ 0.0864	82.88 $\pm$ 0.0009	131.58 $\pm$ 24.71	19.08 $\pm$ 0.029	78.20 $\pm$ 0.0283	84.80 $\pm$ 0.0068	286.9 $\pm$ 29.8	27.47 $\pm$ 0.7493	89.67 $\pm$ 0.0383	99.21 $\pm$ 0.00011	20.75 $\pm$ 1.5310
CoordNet	21.80 $\pm$ 0.0092	84.32 $\pm$ 0.0092	92.20 $\pm$ 0.0008	12.76 $\pm$ 2.58	19.31 $\pm$ 0.0048	85.09 $\pm$ 0.00907	90.30 $\pm$ 0.0002	172.7 $\pm$ 13.88	27.34 $\pm$ 1.0958	89.57 $\pm$ 0.00831	99.19 $\pm$ 0.00005	21.96 $\pm$ 1.1083
PEINR <sup>1</sup>	39.15 $\pm$ 0.00058	98.52 $\pm$ 0.00004	99.85 $\pm$ 0.00003	11.53 $\pm$ 1.03	35.7 $\pm$ 0.0009	98.88 $\pm$ 0.0081	99.86 $\pm$ 0.0000	49.6 $\pm$ 3.37	42.21 $\pm$ 0.8331	99.12 $\pm$ 0.00094	99.97 $\pm$ 0.00003	9.91 $\pm$ 1.291
PEINR <sup>2</sup>	39.47 $\pm$ 0.00040	98.52 $\pm$ 0.00001	99.85 $\pm$ 0.00003	7.63 $\pm$ 0.0167	38.9 $\pm$ 0.0004	98.89 $\pm$ 0.0046	99.81 $\pm$ 0.0000	11.25 $\pm$ 1.09	43.55 $\pm$ 0.5033	99.29 $\pm$ 0.00041	99.98 $\pm$ 0.00002	11.22 $\pm$ 1.759
PEINR	<b>40.04</b> $\pm$ 0.00019	<b>99.10</b> $\pm$ 0.00004	<b>99.89</b> $\pm$ 0.00002	<b>2.35</b> $\pm$ 0.0009	<b>40.34</b> $\pm$ 0.0001	<b>99.28</b> $\pm$ 0.00007	<b>99.88</b> $\pm$ 0.0000	<b>1.27</b> $\pm$ 0.00992	<b>45.26</b> $\pm$ 0.0931	<b>99.50</b> $\pm$ 0.00040	<b>99.98</b> $\pm$ 0.00002	<b>4.21</b> $\pm$ 0.806
(g) SV $\alpha=64$ $\beta=1.4$												
NIF	17.53 $\pm$ 0.0301	80.12 $\pm$ 0.0864	82.88 $\pm$ 0.0009	131.58 $\pm$ 24.71	19.08 $\pm$ 0.029	78.20 $\pm$ 0.0283	84.80 $\pm$ 0.0068	286.9 $\pm$ 29.8	27.47 $\pm$ 0.7493	89.67 $\pm$ 0.0383	99.21 $\pm$ 0.00011	20.75 $\pm$ 1.5310
CoordNet	21.80 $\pm$ 0.0092	84.32 $\pm$ 0.0092	92.20 $\pm$ 0.0008	12.76 $\pm$ 2.58	19.31 $\pm$ 0.0048	85.09 $\pm$ 0.00907	90.30 $\pm$ 0.0002	172.7 $\pm$ 13.88	27.34 $\pm$ 1.0958	89.57 $\pm$ 0.00831	99.19 $\pm$ 0.00005	21.96 $\pm$ 1.1083
PEINR <sup>1</sup>	39.15 $\pm$ 0.00058	98.52 $\pm$ 0.00004	99.85 $\pm$ 0.00003	11.53 $\pm$ 1.03	35.7 $\pm$ 0.0009	98.88 $\pm$ 0.0081	99.86 $\pm$ 0.0000	49.6 $\pm$ 3.37	42.21 $\pm$ 0.8331	99.12 $\pm$ 0.00094	99.97 $\pm$ 0.00003	9.91 $\pm$ 1.291
PEINR <sup>2</sup>	39.47 $\pm$ 0.00040	98.52 $\pm$ 0.00001	99.85 $\pm$ 0.00003	7.63 $\pm$ 0.0167	38.9 $\pm$ 0.0004	98.89 $\pm$ 0.0046	99.81 $\pm$ 0.0000	11.25 $\pm$ 1.09	43.55 $\pm$ 0.5033	99.29 $\pm$ 0.00041	99.98 $\pm$ 0.00002	11.22 $\pm$ 1.759
PEINR	<b>40.04</b> $\pm$ 0.00019	<b>99.10</b> $\pm$ 0.00004	<b>99.89</b> $\pm$ 0.00002	<b>2.35</b> $\pm$ 0.0009	<b>40.34</b> $\pm$ 0.0001	<b>99.28</b> $\pm$ 0.00007	<b>99.88</b> $\pm$ 0.0000	<b>1.27</b> $\pm$ 0.00992	<b>45.26</b> $\pm$ 0.0931	<b>99.50</b> $\pm$ 0.00040	<b>99.98</b> $\pm$ 0.00002	<b>4.21</b> $\pm$ 0.806