SciANN_physics_informed_1d_transient_dirchlet

November 17, 2023

```python
[1]: import numpy as np
     import matplotlib.pyplot as plt
     import sciann as sn
```

```
-------------------- SCIANN 0.6.7.3 --------------------
For details, check out our review paper and the documentation at:
 +  "https://www.sciencedirect.com/science/article/pii/S0045782520307374",
 +  "https://arxiv.org/abs/2005.08803",
 +  "https://www.sciann.com".

 Need support or would like to contribute, please join sciann`s slack group:
 +  "https://join.slack.com/t/sciann/shared_invite/zt-ne1f5jlx-
k_dY8RGo3ZreDXwzOf~CeA"

TensorFlow Version: 2.8.0
Python Version: 3.8.8 (default, Apr 13 2021, 15:08:03) [MSC v.1916 64 bit
(AMD64)]

Outdated SciANN installation is found (V-0.6.7.3). Get the latest version
(V-0.6.7.4):
        > pip [--user] install --upgrade sciann
```

```python
[2]: Nx=5
     time=5
     x_data=np.linspace(0,1,Nx)
     time_data=np.linspace(0,time,time)
     [X_data,t_data]=np.meshgrid(x_data,time_data)
```

```python
[3]: ##Number of lattice nodes
     Nx=25
     ##time
     time=50
     ##meshing
     x_data=np.linspace(0,1,Nx)
     time_data=np.linspace(0,time,time)
     [X_data,t_data]=np.meshgrid(x_data,time_data)
     ##Macroscopic property
     T_data=np.zeros((time,Nx))
```

```python
f1eq=np.zeros((time,Nx))
f2eq=np.zeros((time,Nx))
##Temperatyre at left boundary
Tl=1
T_data[:,0]=Tl
##Temperature at right boundary
Tr=0
T_data[:,Nx-1]=Tr
##weights of digital particles
w1=1/2
w2=1/2
omega=1.5
tau=1/omega
##particle velocity distribution function
f1=np.zeros((Nx))
f2=np.zeros((Nx))
##post collision vdf
f1c=np.zeros((Nx))
f2c=np.zeros((Nx))
##Compute equilibrium vdf
f1eq=w1*T_data[0,:]
f2eq=w2*T_data[0,:]
##Initiliazation
f1=f1eq
f2=f2eq
##collision at lattice nodes
for i in np.arange(1,Nx-1):
    f1c[i]=f1[i]+omega*(f1eq[i]-f1[i])
    f2c[i]=f2[i]+omega*(f2eq[i]-f2[i])
##Boundary lattice nodes
f1c[0]=f1[0]
f2c[0]=f2[0]
f1c[Nx-1]=f1[Nx-1]
f2c[Nx-1]=f2[Nx-1]
##Streaming of digital particles
for i in np.arange(0,Nx-1):
    f1[i+1]=f1c[i]

for i in np.arange(0,Nx-1):
    f2[i]=f2c[i+1]

##Boundary conditions
##right boundary
f2[0]=Tr-f1[0]
##left boundary
f1[Nx-1]=Tl-f2[Nx-1]
##Macroscopic property
```

```python
for i in np.arange(1,Nx-1):
    T_data[0,i]=f1[i]+f2[i]

print(T_data[0,:])
# # ##iterating till required duration
iter=1
while(iter<time):
    ##Compute equilibrium vdf
    for i in np.arange(0,Nx-1):
        f1eq[i]=w1*T_data[iter-1,i]
        f2eq[i]=w2*T_data[iter-1,i]
    ##collision at lattice nodes
    for i in np.arange(1,Nx-1):
        f1c[i]=f1[i]+omega*(f1eq[i]-f1[i])
        f2c[i]=f2[i]+omega*(f2eq[i]-f2[i])
    ##Boundary lattice nodes
    f1c[0]=f1[0]
    f2c[0]=f2[0]
    f1c[Nx-1]=f1[Nx-1]
    f2c[Nx-1]=f2[Nx-1]
    ##Streaming of digital particles
    for i in np.arange(0,Nx-1):
        f1[i+1]=f1c[i]

    for i in np.arange(0,Nx-1):
        f2[i]=f2c[i+1]


    ##Boundary conditions
    ##right boundary
    f2[0]=Tr-f1[0]
    ##left boundary
    f1[Nx-1]=Tl-f2[Nx-1]

    ##Macroscopic property
    for i in np.arange(1,Nx-1):
        T_data[iter,i]=f1[i]+f2[i]

    iter=iter+1
```

```
[1.  0.5 0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
 0.  0.  0.  0.  0.  0.  0. ]
```
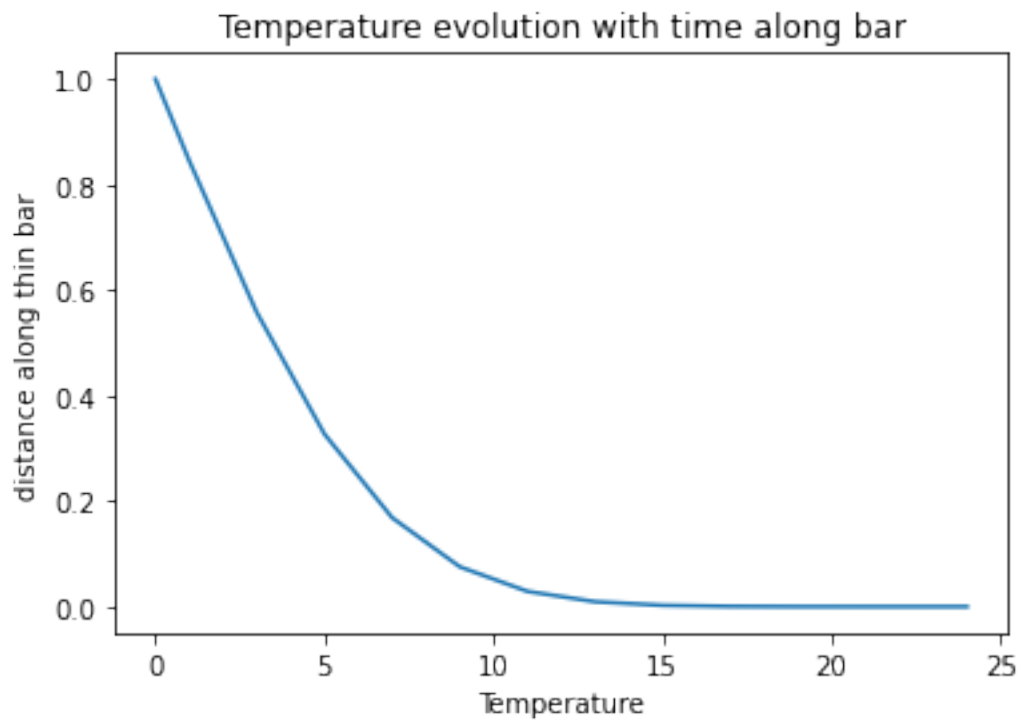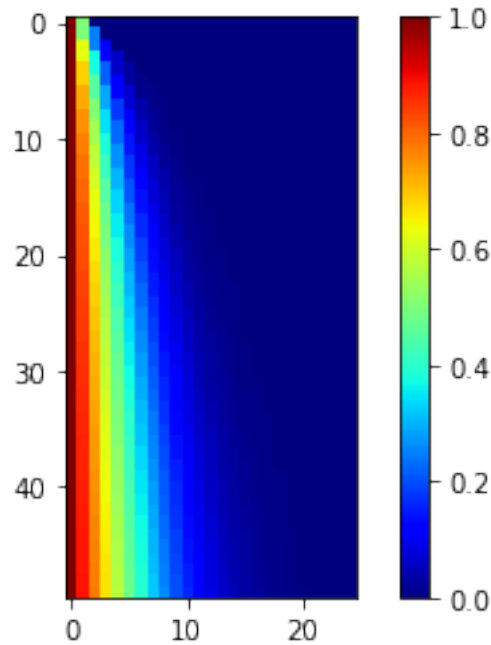
```python
[4]: plt.plot(T_data[25,:])
plt.xlabel('Temperature')
plt.ylabel('distance along thin bar')
plt.title('Temperature evolution with time along bar')
```

```
plt.show()
```

Temperature evolution with time along bar


```
[5]: plt.imshow(T_data,cmap='jet')
     plt.colorbar()
     plt.show()
```

```
[20]: ##Building neural network
      x=sn.Variable('x')
      t=sn.Variable('t')
      T_phy=sn.Functional('T_phy',[x,t],[30,50,50,30],activation='tanh')

      L1=sn.diff(T_phy,t,order=1)-0.020*sn.diff(T_phy,x,order=2)

      ##optimization
      m=sn.SciModel([x,t],[T_phy,L1])
```

```
[21]: m.train([X_data,t_data],[T_data,np.
       ↪zeros_like(T_data)],epochs=100,learning_rate=0.005)
```

```
Total samples: 1250
Batch size: 64
Total batches: 20

Epoch 1/100
20/20 [==============================] - 2s 6ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.2410 - T_phy_loss: 0.2352 - sub_5_loss: 0.0056 - lr: 0.0050 -
time: 1.6916
Epoch 2/100
20/20 [==============================] - 0s 3ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0853 - T_phy_loss: 0.0848 - sub_5_loss: 5.4757e-04 - lr:
0.0050 - time: 0.0968
```

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Epoch 3/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0798 - T_phy_loss: 0.0796 - sub_5_loss: 2.1901e-04 - lr:
0.0050 - time: 0.1605
Epoch 4/100
20/20 [==============================] - 0s 5ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0773 - T_phy_loss: 0.0771 - sub_5_loss: 1.4365e-04 - lr:
0.0050 - time: 0.1792
Epoch 5/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0746 - T_phy_loss: 0.0744 - sub_5_loss: 2.2108e-04 - lr:
0.0050 - time: 0.1767
Epoch 6/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0566 - T_phy_loss: 0.0564 - sub_5_loss: 1.0129e-04 - lr:
0.0050 - time: 0.1474
Epoch 7/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0340 - T_phy_loss: 0.0332 - sub_5_loss: 8.0880e-04 - lr:
0.0050 - time: 0.1479
Epoch 8/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0270 - T_phy_loss: 0.0265 - sub_5_loss: 4.7228e-04 - lr:
0.0050 - time: 0.1510
Epoch 9/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0145 - T_phy_loss: 0.0135 - sub_5_loss: 0.0010 - lr: 0.0050 -
time: 0.1472
Epoch 10/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0117 - T_phy_loss: 0.0090 - sub_5_loss: 0.0027 - lr: 0.0050 -
time: 0.1398
Epoch 11/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0112 - T_phy_loss: 0.0077 - sub_5_loss: 0.0035 - lr: 0.0050 -
time: 0.1490
Epoch 12/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0094 - T_phy_loss: 0.0061 - sub_5_loss: 0.0033 - lr: 0.0050 -
time: 0.1450
Epoch 13/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0105 - T_phy_loss: 0.0072 - sub_5_loss: 0.0033 - lr: 0.0050 -
time: 0.1414
Epoch 14/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0087 - T_phy_loss: 0.0050 - sub_5_loss: 0.0036 - lr: 0.0050 -
time: 0.1448
```

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Epoch 15/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0078 - T_phy_loss: 0.0041 - sub_5_loss: 0.0036 - lr: 0.0050 -
time: 0.1329
Epoch 16/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0084 - T_phy_loss: 0.0047 - sub_5_loss: 0.0038 - lr: 0.0050 -
time: 0.1331
Epoch 17/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0091 - T_phy_loss: 0.0055 - sub_5_loss: 0.0037 - lr: 0.0050 -
time: 0.1577
Epoch 18/100
20/20 [==============================] - 0s 5ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0077 - T_phy_loss: 0.0041 - sub_5_loss: 0.0036 - lr: 0.0050 -
time: 0.1702
Epoch 19/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0081 - T_phy_loss: 0.0046 - sub_5_loss: 0.0035 - lr: 0.0050 -
time: 0.1316
Epoch 20/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0074 - T_phy_loss: 0.0036 - sub_5_loss: 0.0038 - lr: 0.0050 -
time: 0.1442
Epoch 21/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0082 - T_phy_loss: 0.0048 - sub_5_loss: 0.0035 - lr: 0.0050 -
time: 0.1478
Epoch 22/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0093 - T_phy_loss: 0.0056 - sub_5_loss: 0.0036 - lr: 0.0050 -
time: 0.1503
Epoch 23/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0080 - T_phy_loss: 0.0044 - sub_5_loss: 0.0035 - lr: 0.0050 -
time: 0.1485
Epoch 24/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0074 - T_phy_loss: 0.0037 - sub_5_loss: 0.0037 - lr: 0.0050 -
time: 0.1489
Epoch 25/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0080 - T_phy_loss: 0.0042 - sub_5_loss: 0.0038 - lr: 0.0050 -
time: 0.1389
Epoch 26/100
20/20 [==============================] - 0s 5ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0076 - T_phy_loss: 0.0039 - sub_5_loss: 0.0037 - lr: 0.0050 -
time: 0.1696
```

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Epoch 27/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0078 - T_phy_loss: 0.0041 - sub_5_loss: 0.0037 - lr: 0.0050 -
time: 0.1523
Epoch 28/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0076 - T_phy_loss: 0.0041 - sub_5_loss: 0.0035 - lr: 0.0050 -
time: 0.1401
Epoch 29/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0085 - T_phy_loss: 0.0050 - sub_5_loss: 0.0034 - lr: 0.0050 -
time: 0.1340
Epoch 30/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0084 - T_phy_loss: 0.0051 - sub_5_loss: 0.0033 - lr: 0.0050 -
time: 0.1342
Epoch 31/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0084 - T_phy_loss: 0.0047 - sub_5_loss: 0.0037 - lr: 0.0050 -
time: 0.1451
Epoch 32/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0083 - T_phy_loss: 0.0046 - sub_5_loss: 0.0037 - lr: 0.0050 -
time: 0.1374
Epoch 33/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0077 - T_phy_loss: 0.0041 - sub_5_loss: 0.0036 - lr: 0.0050 -
time: 0.1437
Epoch 34/100
 9/20 [============>…] - ETA: 0s - batch: 4.0000 - size: 64.0000
- loss: 0.0087 - T_phy_loss: 0.0048 - sub_5_loss: 0.0039
Epoch 34: ReduceLROnPlateau reducing learning rate to 0.0024999999441206455.
20/20 [==============================] - 0s 5ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0081 - T_phy_loss: 0.0045 - sub_5_loss: 0.0036 - lr: 0.0050 -
time: 0.1760
Epoch 35/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0073 - T_phy_loss: 0.0036 - sub_5_loss: 0.0036 - lr: 0.0025 -
time: 0.1362
Epoch 36/100
20/20 [==============================] - 0s 5ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0073 - T_phy_loss: 0.0037 - sub_5_loss: 0.0036 - lr: 0.0025 -
time: 0.1560
Epoch 37/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0076 - T_phy_loss: 0.0041 - sub_5_loss: 0.0035 - lr: 0.0025 -
time: 0.1386
Epoch 38/100
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20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0078 - T_phy_loss: 0.0040 - sub_5_loss: 0.0038 - lr: 0.0025 -
time: 0.1564
Epoch 39/100
20/20 [==============================] - 0s 7ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0076 - T_phy_loss: 0.0042 - sub_5_loss: 0.0035 - lr: 0.0025 -
time: 0.1996
Epoch 40/100
20/20 [==============================] - 0s 5ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0073 - T_phy_loss: 0.0036 - sub_5_loss: 0.0037 - lr: 0.0025 -
time: 0.1183
Epoch 41/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0071 - T_phy_loss: 0.0036 - sub_5_loss: 0.0035 - lr: 0.0025 -
time: 0.1439
Epoch 42/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0076 - T_phy_loss: 0.0040 - sub_5_loss: 0.0036 - lr: 0.0025 -
time: 0.1485
Epoch 43/100
20/20 [==============================] - 0s 3ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0078 - T_phy_loss: 0.0042 - sub_5_loss: 0.0036 - lr: 0.0025 -
time: 0.1329
Epoch 44/100
20/20 [==============================] - 0s 3ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0077 - T_phy_loss: 0.0040 - sub_5_loss: 0.0037 - lr: 0.0025 -
time: 0.1319
Epoch 45/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0074 - T_phy_loss: 0.0037 - sub_5_loss: 0.0037 - lr: 0.0025 -
time: 0.1504
Epoch 46/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0075 - T_phy_loss: 0.0039 - sub_5_loss: 0.0036 - lr: 0.0025 -
time: 0.1417
Epoch 47/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0074 - T_phy_loss: 0.0038 - sub_5_loss: 0.0037 - lr: 0.0025 -
time: 0.1535
Epoch 48/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0076 - T_phy_loss: 0.0040 - sub_5_loss: 0.0036 - lr: 0.0025 -
time: 0.1479
Epoch 49/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0079 - T_phy_loss: 0.0043 - sub_5_loss: 0.0035 - lr: 0.0025 -
time: 0.1357
Epoch 50/100
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20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0072 - T_phy_loss: 0.0034 - sub_5_loss: 0.0038 - lr: 0.0025 -
time: 0.1368
Epoch 51/100
15/20 [=====================>…] - ETA: 0s - batch: 7.0000 - size: 64.0000
- loss: 0.0071 - T_phy_loss: 0.0037 - sub_5_loss: 0.0034
Epoch 51: ReduceLROnPlateau reducing learning rate to 0.0012499999720603228.
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0073 - T_phy_loss: 0.0036 - sub_5_loss: 0.0037 - lr: 0.0025 -
time: 0.1405
Epoch 52/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0072 - T_phy_loss: 0.0038 - sub_5_loss: 0.0034 - lr: 0.0012 -
time: 0.1480
Epoch 53/100
20/20 [==============================] - 0s 5ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0079 - T_phy_loss: 0.0043 - sub_5_loss: 0.0036 - lr: 0.0012 -
time: 0.1819
Epoch 54/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0071 - T_phy_loss: 0.0034 - sub_5_loss: 0.0037 - lr: 0.0012 -
time: 0.1471
Epoch 55/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0070 - T_phy_loss: 0.0034 - sub_5_loss: 0.0036 - lr: 0.0012 -
time: 0.1513
Epoch 56/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0071 - T_phy_loss: 0.0034 - sub_5_loss: 0.0037 - lr: 0.0012 -
time: 0.1379
Epoch 57/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0069 - T_phy_loss: 0.0033 - sub_5_loss: 0.0036 - lr: 0.0012 -
time: 0.1450
Epoch 58/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0071 - T_phy_loss: 0.0037 - sub_5_loss: 0.0035 - lr: 0.0012 -
time: 0.1568
Epoch 59/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0070 - T_phy_loss: 0.0034 - sub_5_loss: 0.0036 - lr: 0.0012 -
time: 0.1516
Epoch 60/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0069 - T_phy_loss: 0.0034 - sub_5_loss: 0.0035 - lr: 0.0012 -
time: 0.1465
Epoch 61/100
20/20 [==============================] - 0s 5ms/step - batch: 9.5000 - size:
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62.5000 - loss: 0.0069 - T_phy_loss: 0.0034 - sub_5_loss: 0.0036 - lr: 0.0012 - time: 0.1701
Epoch 62/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size: 62.5000 - loss: 0.0070 - T_phy_loss: 0.0034 - sub_5_loss: 0.0036 - lr: 0.0012 - time: 0.1387
Epoch 63/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size: 62.5000 - loss: 0.0070 - T_phy_loss: 0.0034 - sub_5_loss: 0.0036 - lr: 0.0012 - time: 0.1480
Epoch 64/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size: 62.5000 - loss: 0.0070 - T_phy_loss: 0.0033 - sub_5_loss: 0.0037 - lr: 0.0012 - time: 0.1360
Epoch 65/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size: 62.5000 - loss: 0.0071 - T_phy_loss: 0.0035 - sub_5_loss: 0.0037 - lr: 0.0012 - time: 0.1532
Epoch 66/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size: 62.5000 - loss: 0.0071 - T_phy_loss: 0.0037 - sub_5_loss: 0.0034 - lr: 0.0012 - time: 0.1461
Epoch 67/100
15/20 [=====================>…] - ETA: 0s - batch: 7.0000 - size: 62.0000 - loss: 0.0070 - T_phy_loss: 0.0035 - sub_5_loss: 0.0036
Epoch 67: ReduceLROnPlateau reducing learning rate to 0.0006249999860301614.
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size: 62.5000 - loss: 0.0071 - T_phy_loss: 0.0035 - sub_5_loss: 0.0036 - lr: 0.0012 - time: 0.1407
Epoch 68/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size: 62.5000 - loss: 0.0070 - T_phy_loss: 0.0032 - sub_5_loss: 0.0038 - lr: 6.2500e-04 - time: 0.1434
Epoch 69/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size: 62.5000 - loss: 0.0071 - T_phy_loss: 0.0037 - sub_5_loss: 0.0034 - lr: 6.2500e-04 - time: 0.1503
Epoch 70/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size: 62.5000 - loss: 0.0069 - T_phy_loss: 0.0032 - sub_5_loss: 0.0037 - lr: 6.2500e-04 - time: 0.1466
Epoch 71/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size: 62.5000 - loss: 0.0069 - T_phy_loss: 0.0033 - sub_5_loss: 0.0036 - lr: 6.2500e-04 - time: 0.1556
Epoch 72/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size: 62.5000 - loss: 0.0072 - T_phy_loss: 0.0036 - sub_5_loss: 0.0036 - lr:

6.2500e-04 - time: 0.1479
Epoch 73/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0070 - T_phy_loss: 0.0034 - sub_5_loss: 0.0036 - lr:
6.2500e-04 - time: 0.1597
Epoch 74/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0071 - T_phy_loss: 0.0035 - sub_5_loss: 0.0036 - lr:
6.2500e-04 - time: 0.1475
Epoch 75/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0070 - T_phy_loss: 0.0034 - sub_5_loss: 0.0036 - lr:
6.2500e-04 - time: 0.1458
Epoch 76/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0069 - T_phy_loss: 0.0033 - sub_5_loss: 0.0036 - lr:
6.2500e-04 - time: 0.1356
Epoch 77/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0068 - T_phy_loss: 0.0033 - sub_5_loss: 0.0035 - lr:
6.2500e-04 - time: 0.1584
Epoch 78/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0070 - T_phy_loss: 0.0034 - sub_5_loss: 0.0036 - lr:
6.2500e-04 - time: 0.1420
Epoch 79/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0070 - T_phy_loss: 0.0035 - sub_5_loss: 0.0035 - lr:
6.2500e-04 - time: 0.1468
Epoch 80/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0071 - T_phy_loss: 0.0034 - sub_5_loss: 0.0037 - lr:
6.2500e-04 - time: 0.1536
Epoch 81/100
20/20 [==============================] - 0s 5ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0070 - T_phy_loss: 0.0033 - sub_5_loss: 0.0037 - lr:
6.2500e-04 - time: 0.1663
Epoch 82/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0071 - T_phy_loss: 0.0035 - sub_5_loss: 0.0035 - lr:
6.2500e-04 - time: 0.1453
Epoch 83/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0071 - T_phy_loss: 0.0034 - sub_5_loss: 0.0037 - lr:
6.2500e-04 - time: 0.1502
Epoch 84/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0070 - T_phy_loss: 0.0034 - sub_5_loss: 0.0036 - lr:

```
6.2500e-04 - time: 0.1427
Epoch 85/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0069 - T_phy_loss: 0.0033 - sub_5_loss: 0.0036 - lr:
6.2500e-04 - time: 0.1468
Epoch 86/100
20/20 [==============================] - 0s 5ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0071 - T_phy_loss: 0.0036 - sub_5_loss: 0.0035 - lr:
6.2500e-04 - time: 0.1545
Epoch 87/100
15/20 [=====================>…] - ETA: 0s - batch: 7.0000 - size: 62.0000
- loss: 0.0074 - T_phy_loss: 0.0037 - sub_5_loss: 0.0036
Epoch 87: ReduceLROnPlateau reducing learning rate to 0.00031249999301508Ø7.
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0071 - T_phy_loss: 0.0035 - sub_5_loss: 0.0036 - lr:
6.2500e-04 - time: 0.1361
Epoch 88/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0070 - T_phy_loss: 0.0034 - sub_5_loss: 0.0036 - lr:
3.1250e-04 - time: 0.1362
Epoch 89/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0069 - T_phy_loss: 0.0033 - sub_5_loss: 0.0036 - lr:
3.1250e-04 - time: 0.1442
Epoch 90/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0069 - T_phy_loss: 0.0033 - sub_5_loss: 0.0036 - lr:
3.1250e-04 - time: 0.1435
Epoch 91/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0068 - T_phy_loss: 0.0033 - sub_5_loss: 0.0036 - lr:
3.1250e-04 - time: 0.1512
Epoch 92/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0070 - T_phy_loss: 0.0033 - sub_5_loss: 0.0036 - lr:
3.1250e-04 - time: 0.1510
Epoch 93/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0069 - T_phy_loss: 0.0033 - sub_5_loss: 0.0036 - lr:
3.1250e-04 - time: 0.1396
Epoch 94/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0068 - T_phy_loss: 0.0033 - sub_5_loss: 0.0035 - lr:
3.1250e-04 - time: 0.1423
Epoch 95/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0070 - T_phy_loss: 0.0034 - sub_5_loss: 0.0036 - lr:
3.1250e-04 - time: 0.1392
```

```
Epoch 96/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0069 - T_phy_loss: 0.0034 - sub_5_loss: 0.0035 - lr:
3.1250e-04 - time: 0.1457
Epoch 97/100
14/20 [====================>…] - ETA: 0s - batch: 6.5000 - size: 64.0000
- loss: 0.0071 - T_phy_loss: 0.0035 - sub_5_loss: 0.0036
Epoch 97: ReduceLROnPlateau reducing learning rate to 0.00015624999650754035.
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0069 - T_phy_loss: 0.0032 - sub_5_loss: 0.0037 - lr:
3.1250e-04 - time: 0.1580
Epoch 98/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0069 - T_phy_loss: 0.0032 - sub_5_loss: 0.0036 - lr:
1.5625e-04 - time: 0.1462
Epoch 99/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0068 - T_phy_loss: 0.0033 - sub_5_loss: 0.0036 - lr:
1.5625e-04 - time: 0.1535
Epoch 100/100
20/20 [==============================] - 0s 4ms/step - batch: 9.5000 - size:
62.5000 - loss: 0.0069 - T_phy_loss: 0.0033 - sub_5_loss: 0.0036 - lr:
1.5625e-04 - time: 0.1419
```

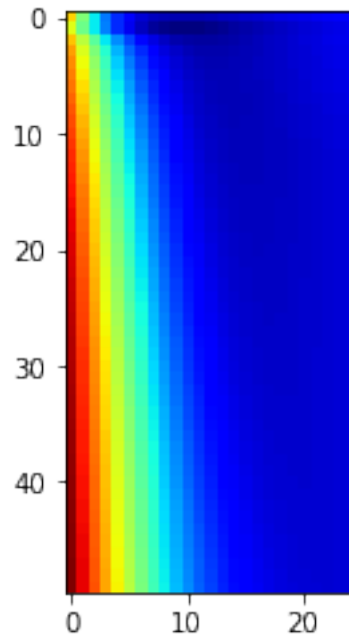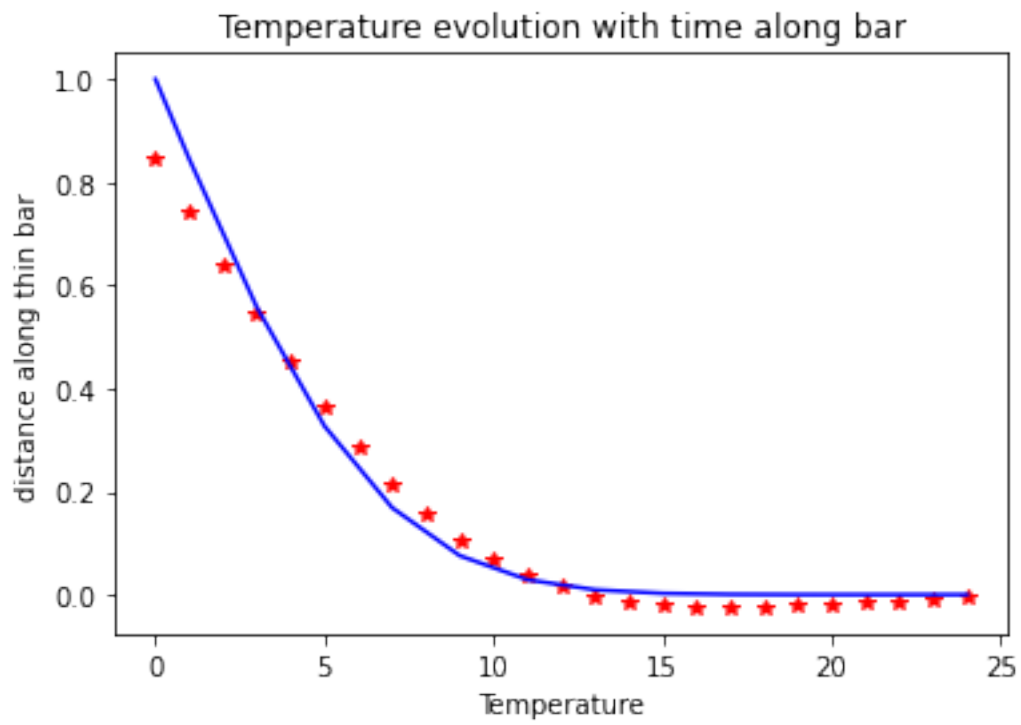[21]: <keras.callbacks.History at 0x2153e80bd90>

[22]:
```python
##Evaluate
T_pred=T_phy.eval([X_data,t_data])
# im=plt.pcolor(x_data,y_data,f_pred,cmap='seismic')
# plt.colorbar(im)
plt.imshow(T_pred,cmap='jet')
plt.show()
```

```
[23]: plt.plot(T_pred[25,:],'*r')
      plt.plot(T_data[25,:],'-b')
      plt.xlabel('Temperature')
      plt.ylabel('distance along thin bar')
      plt.title('Temperature evolution with time along bar')
      plt.show()
```

Temperature evolution with time along bar

[ ]: