LSTM AND CNN APPLICATIONS TO FORECAST EARTHQUAKE MAGNITUDE PROBABILITY DISTRIBUTION

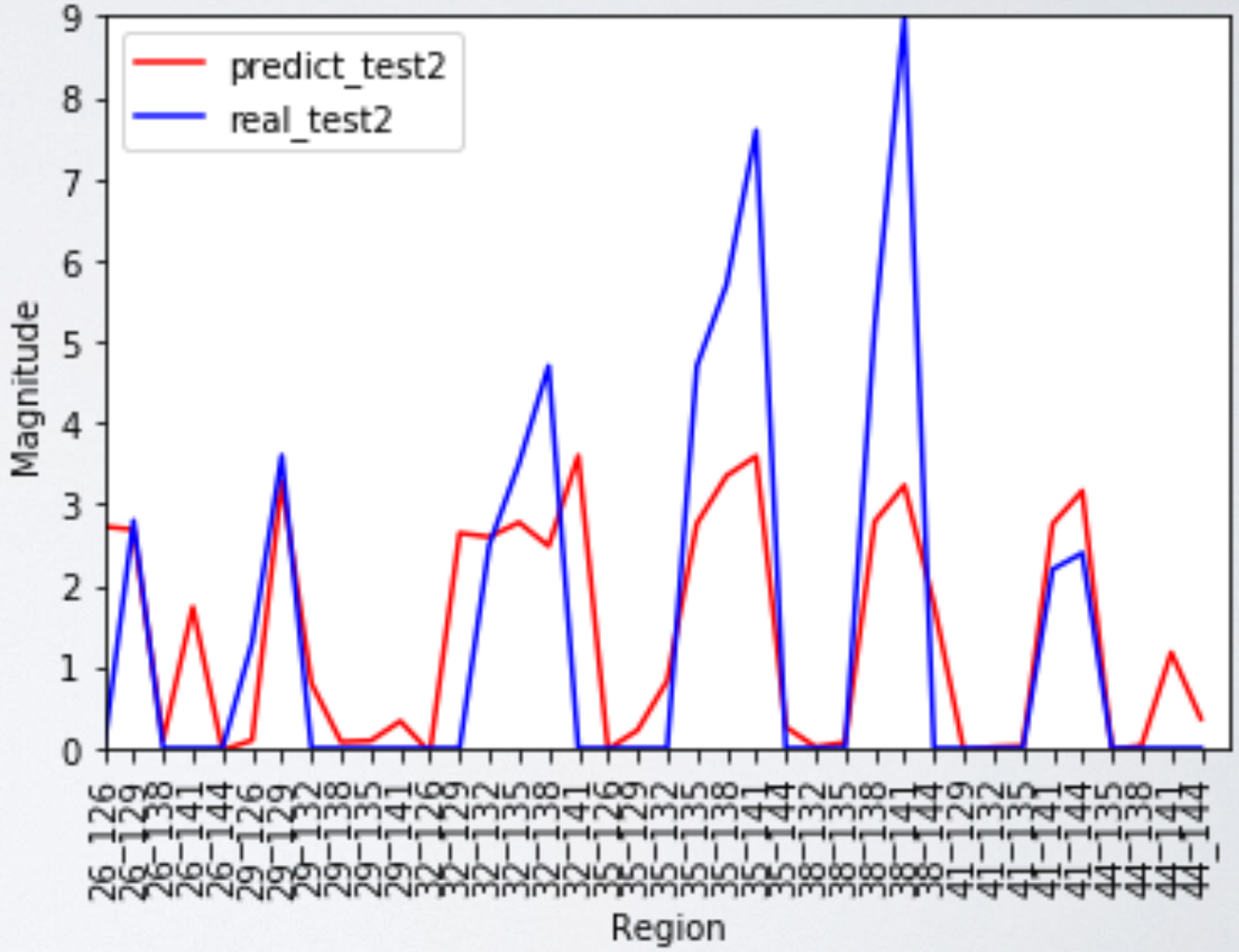
QI LIU
GSII :Applied Computer Science Course
ID:49186421

CONTENTS

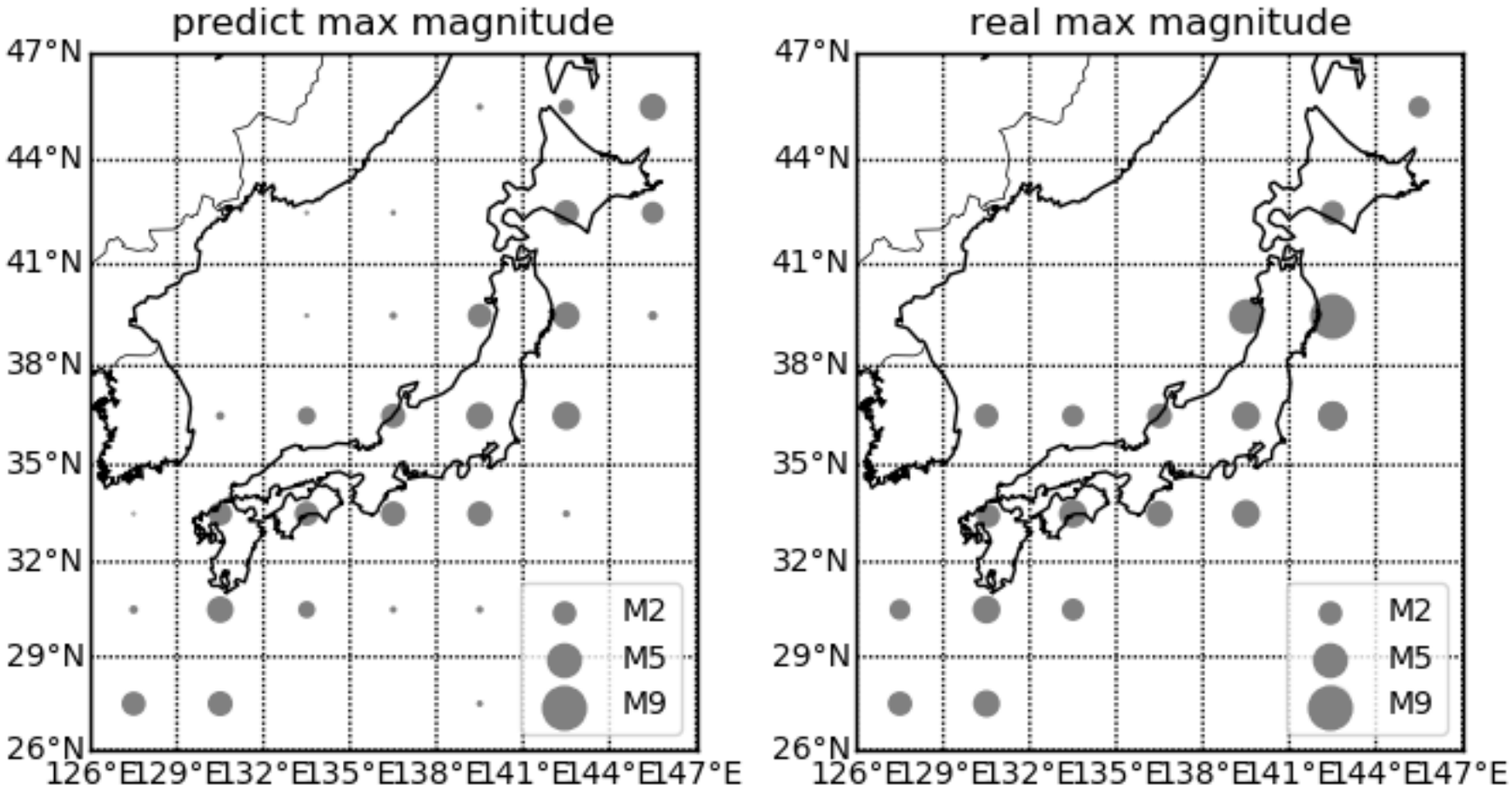
BRIEF INTRODUCTION

About earthquake prediction:

The Tohoku earthquake
There points:
1,WHEN
2,WHERE
3,WHAT(magnitude)



BRIEF INTRODUCTION

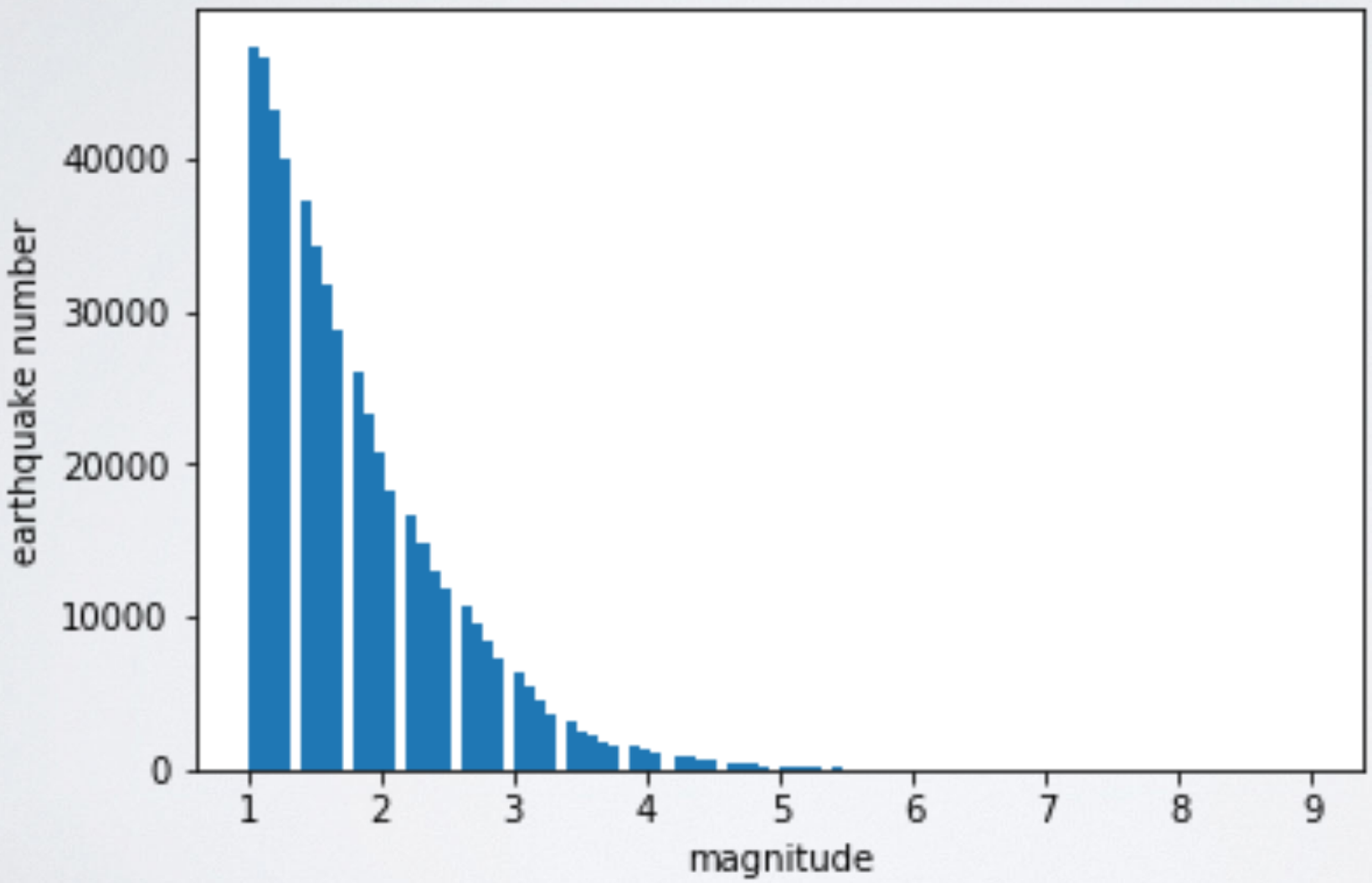


Accuracy:
when:one day
Where: approximate 300km*300km(longitude3 *latitude3)
What: Max (-4)

EARTHQUAKE EVENTS

EARTHQUAKE EVENTS

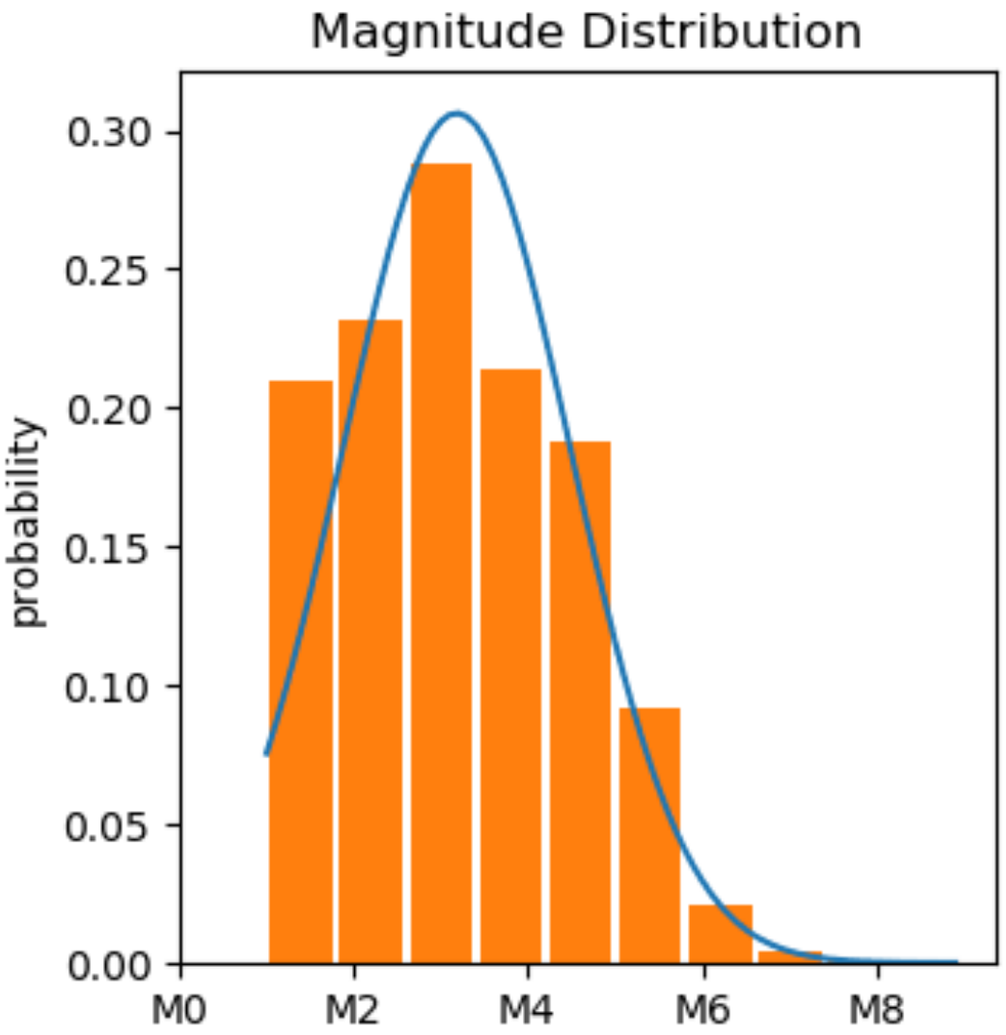
From 2000,1,1-2011,3,11

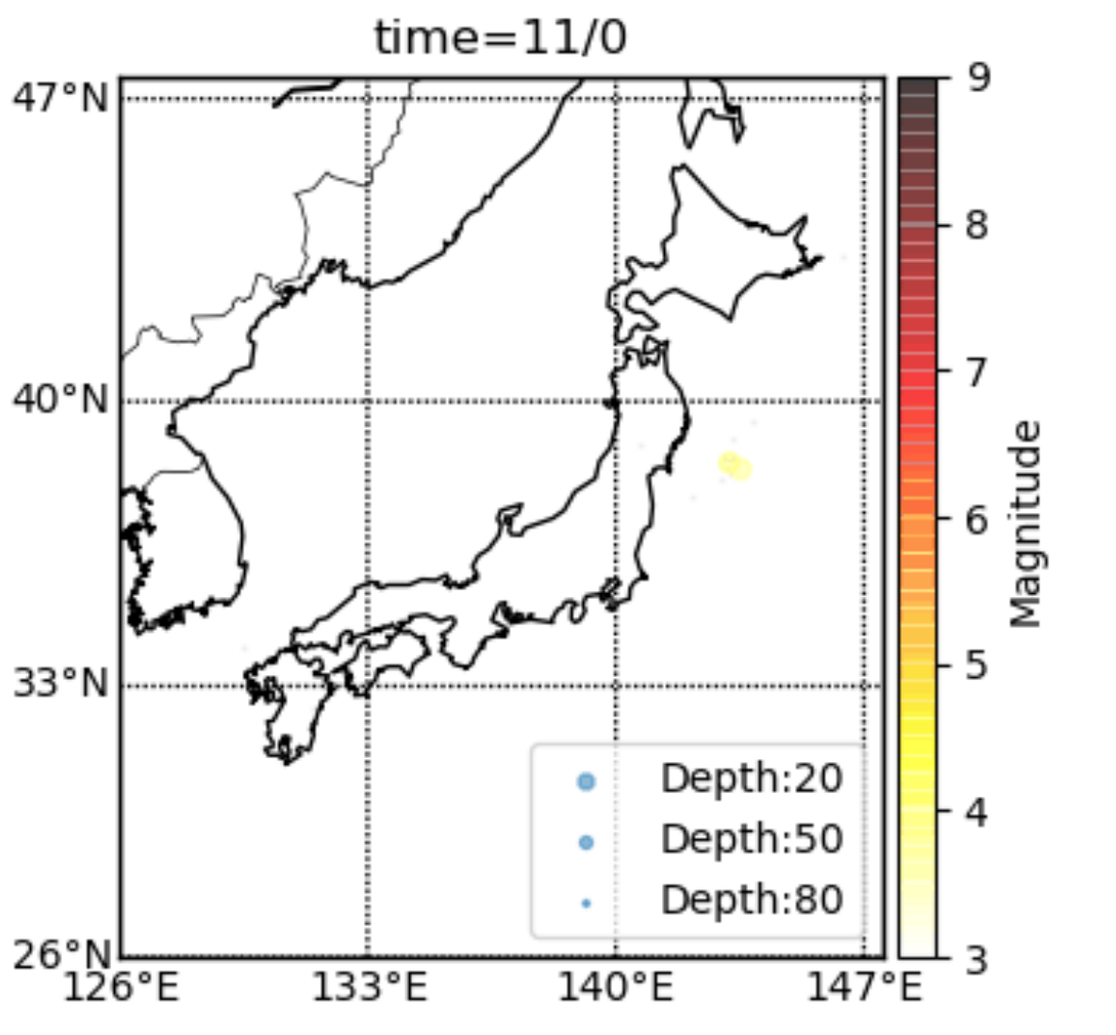


Poisson Distribution(discrete). Power law distribution(Continue)

EARTHQUAKE EVENTS

11 March 2011 ⟶ 12 March 2011

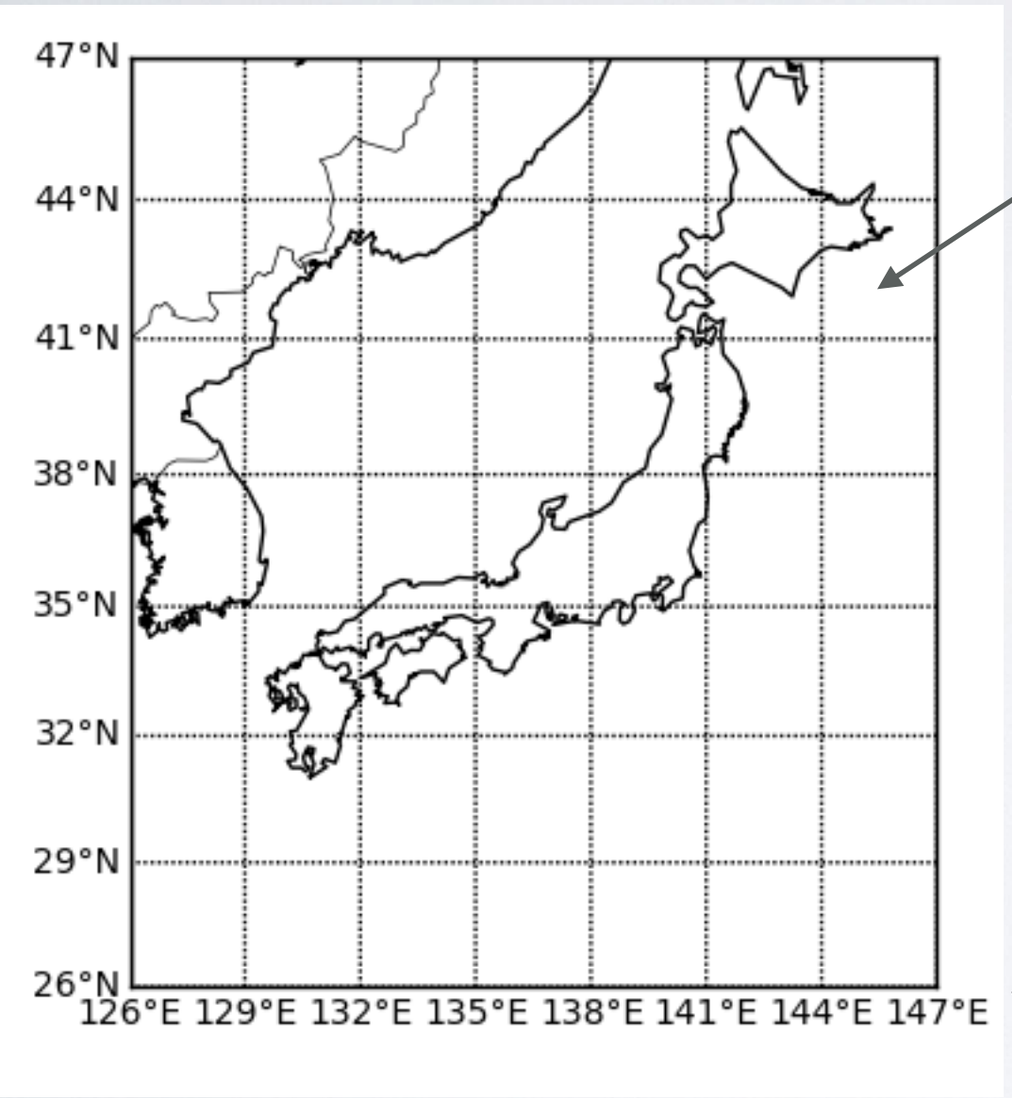




EXPERIMENT

DATA

Miller's cylindrical projection(3D-2D)



Longitude (3 degree),
Latitude(3 degree),
depth<100km

January 2000 ⟶ March 2011

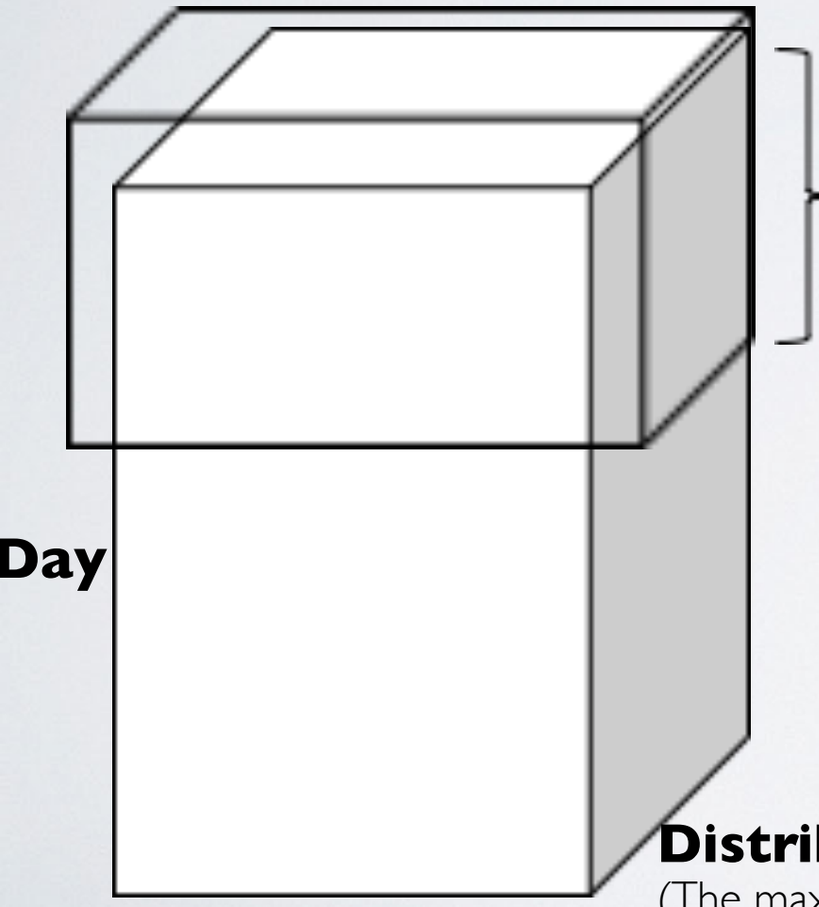
Every day(4087), for every box (49)has a table

One table(one dataset):
Magnitude distribution value(The maximum value, Median, Mean, Variance, Size(events number))

DATA

Training datasets: 95% of all datasets(3882*49)
Validation(Testing) datasets: 5% of all datasets(205)
Testing_2 datasets: M>6 in Validation datasets(71)

Training datasets X(Input 3D data):



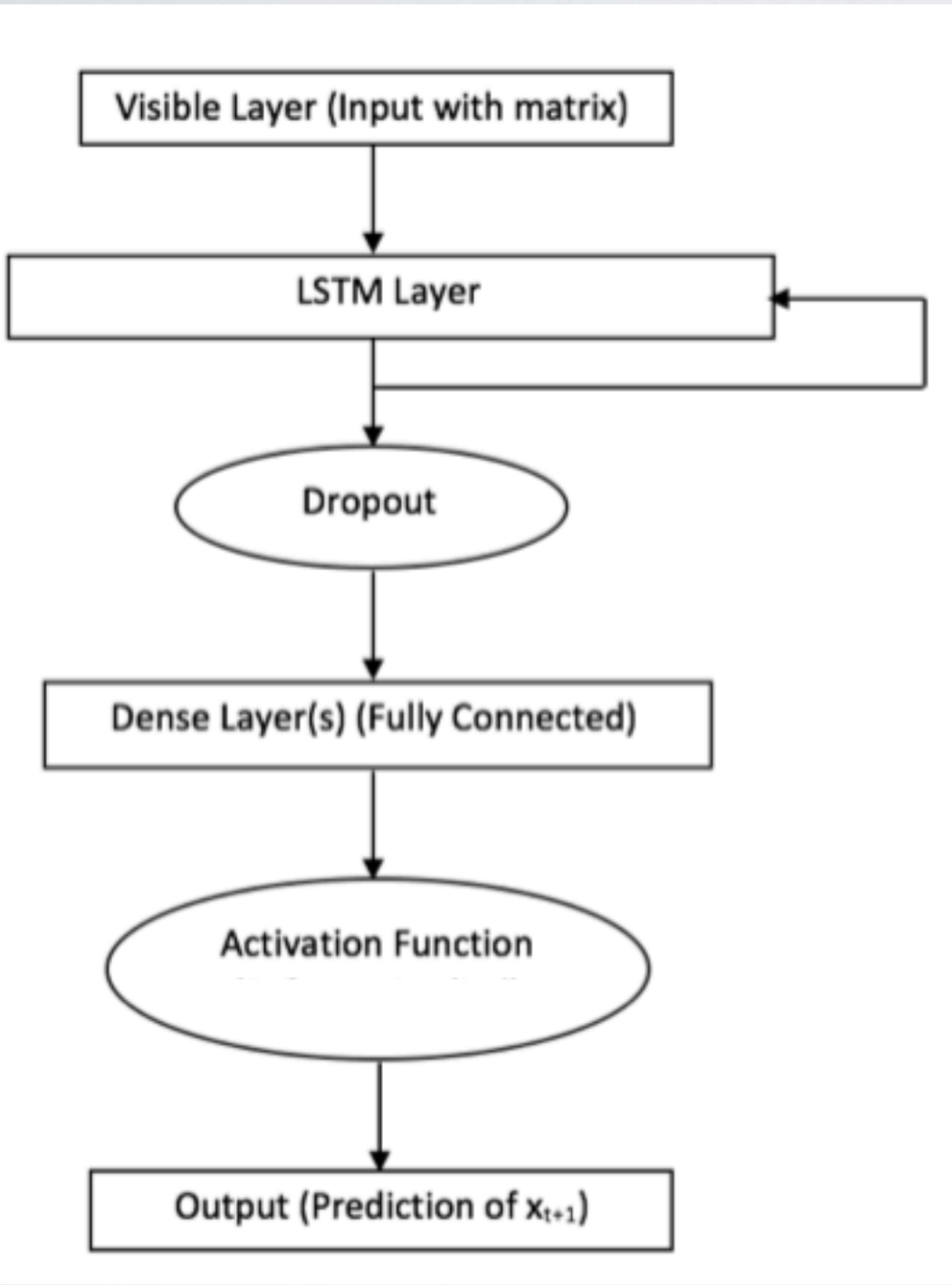
Training datasets Y(Label 2D data):

dayN+1

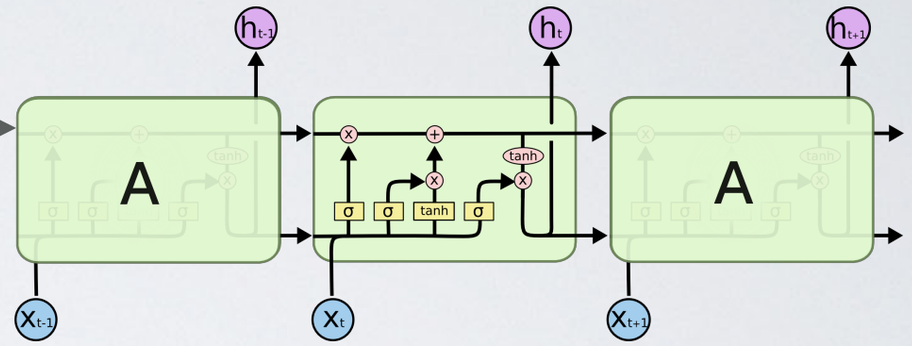
Max	Max	Max	Max	.....

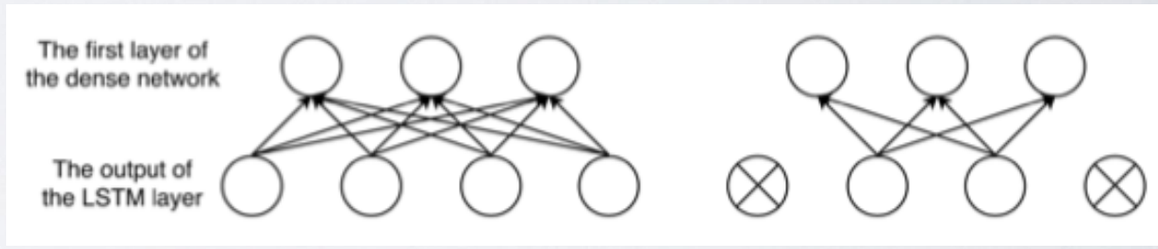
Regions

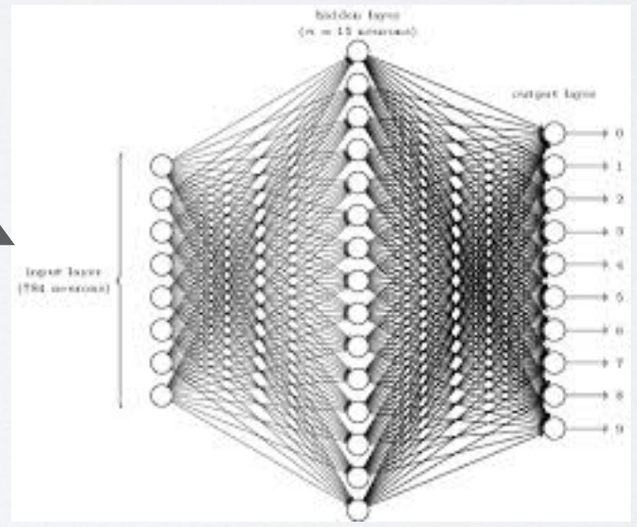
LSTM STRUCTURE



$$\begin{pmatrix} x_{z1}^{t1} \\ x_{z2}^{t1} \\ \vdots \\ x_{z9}^{t1} \end{pmatrix} \begin{pmatrix} x_{z1}^{t2} \\ x_{z2}^{t2} \\ \vdots \\ x_{z9}^{t2} \end{pmatrix} \cdots \begin{pmatrix} x_{z1}^{t11} \\ x_{z2}^{t11} \\ \vdots \\ x_{z9}^{t11} \end{pmatrix}$$







$$S_i = \frac{e^i}{\sum_j e^j}$$

j :Data number

Wang, Qianlong, et al. "Earthquake prediction based on spatio-temporal data mining: an LSTM network approach." IEEE Transactions on Emerging Topics in Computing (2017).

LSTM STRUCTURE OPTIMIZATION

MSE（Mean squared error）

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2$$

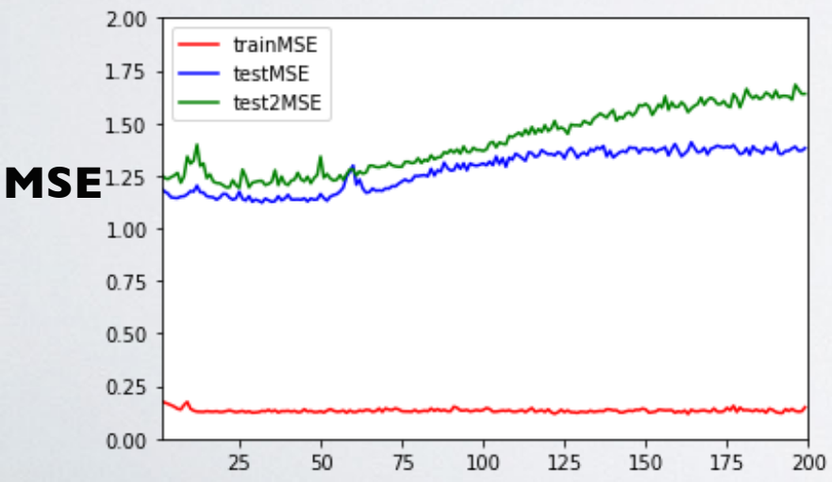
Hyperparameter:

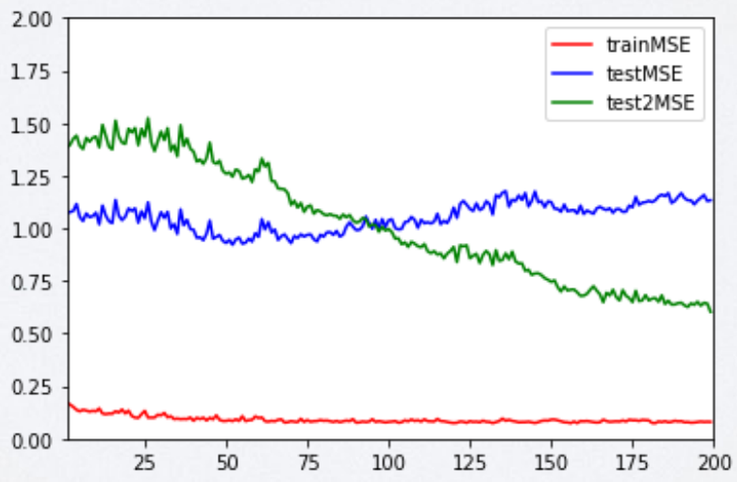
EPOCH=200
BATCH_SIZE=50
TIME_WINDOW=1
LR=0.001

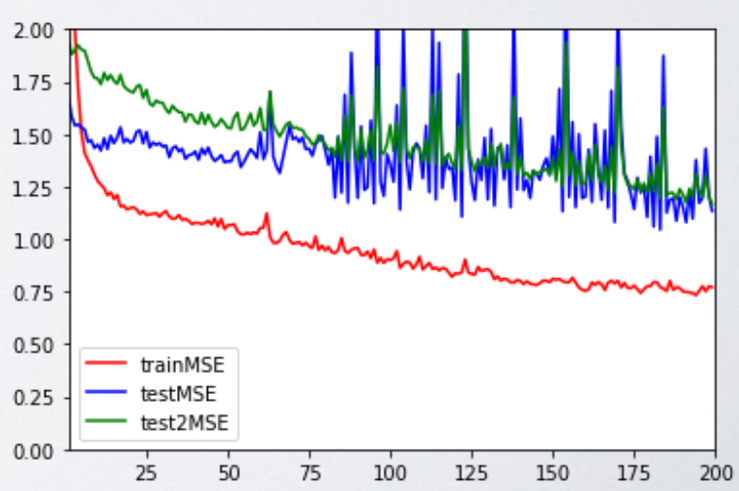
EPOCH=200
BATCH_SIZE=50
TIME_WINDOW=10
LR=0.001

EPOCH=200
BATCH_SIZE=50
TIME_WINDOW=100
LR=0.001

Graph:







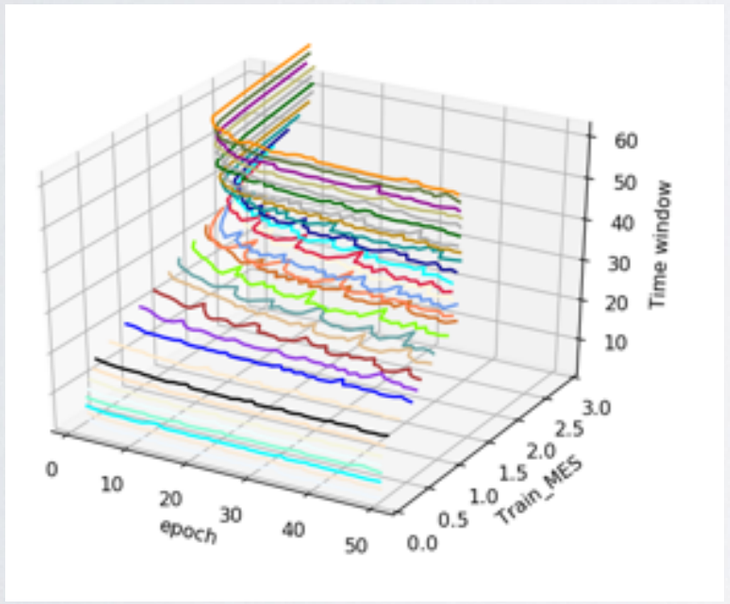
LSTM STRUCTURE OPTIMIZATION

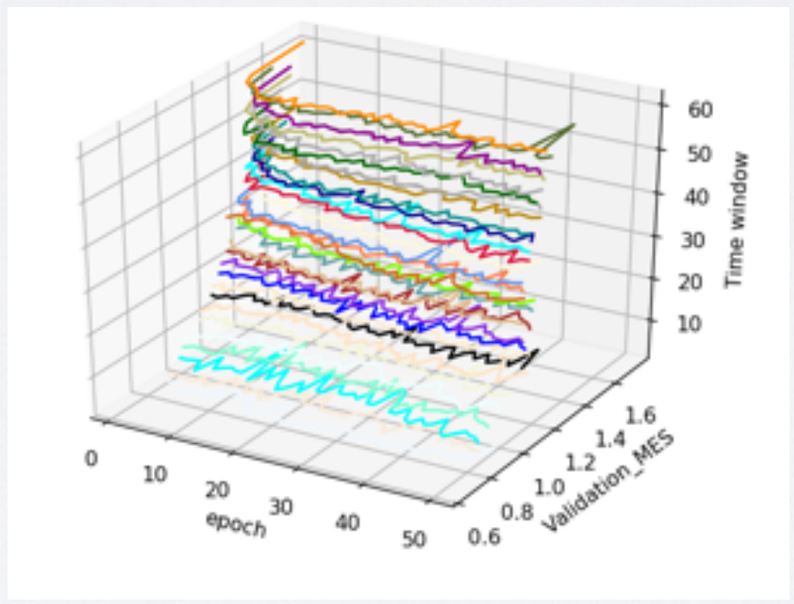
Hyperparameter space:

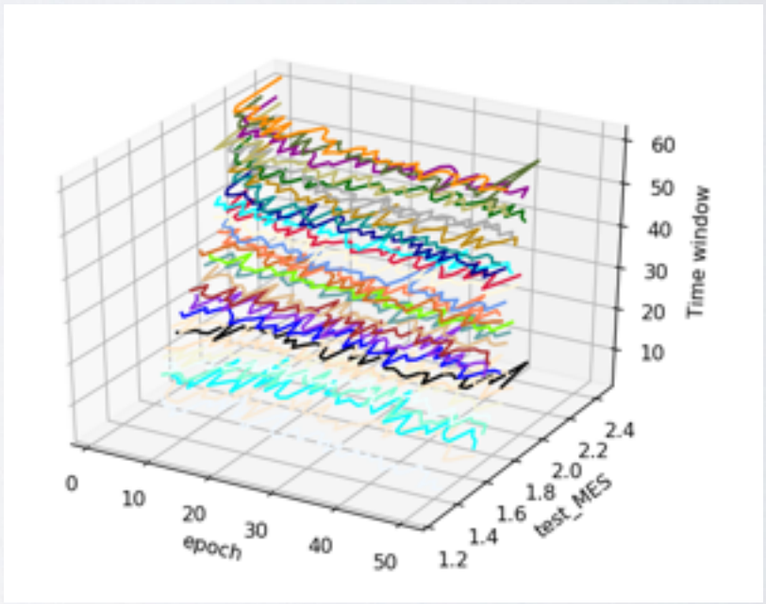
POCH=50
BATCH_SIZE=50
TIME_WINDOW=[0~100]
LR=0.001

POCH=50
BATCH_SIZE=50
TIME_WINDOW=[0~100]
LR=0.001

POCH=50
BATCH_SIZE=50
TIME_WINDOW=[0~100]
LR=0.001







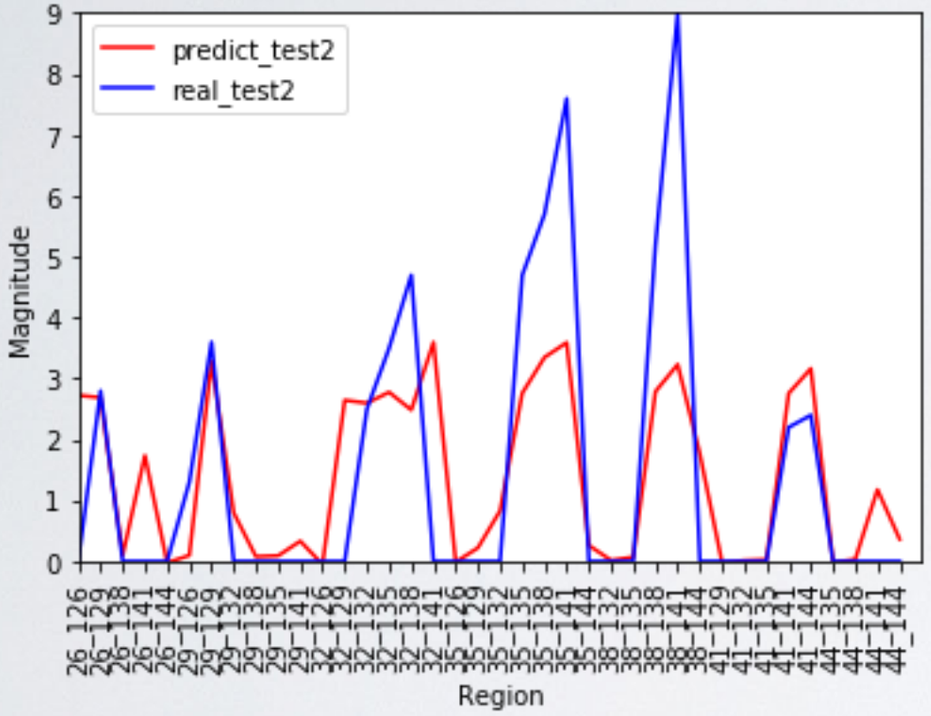
Training

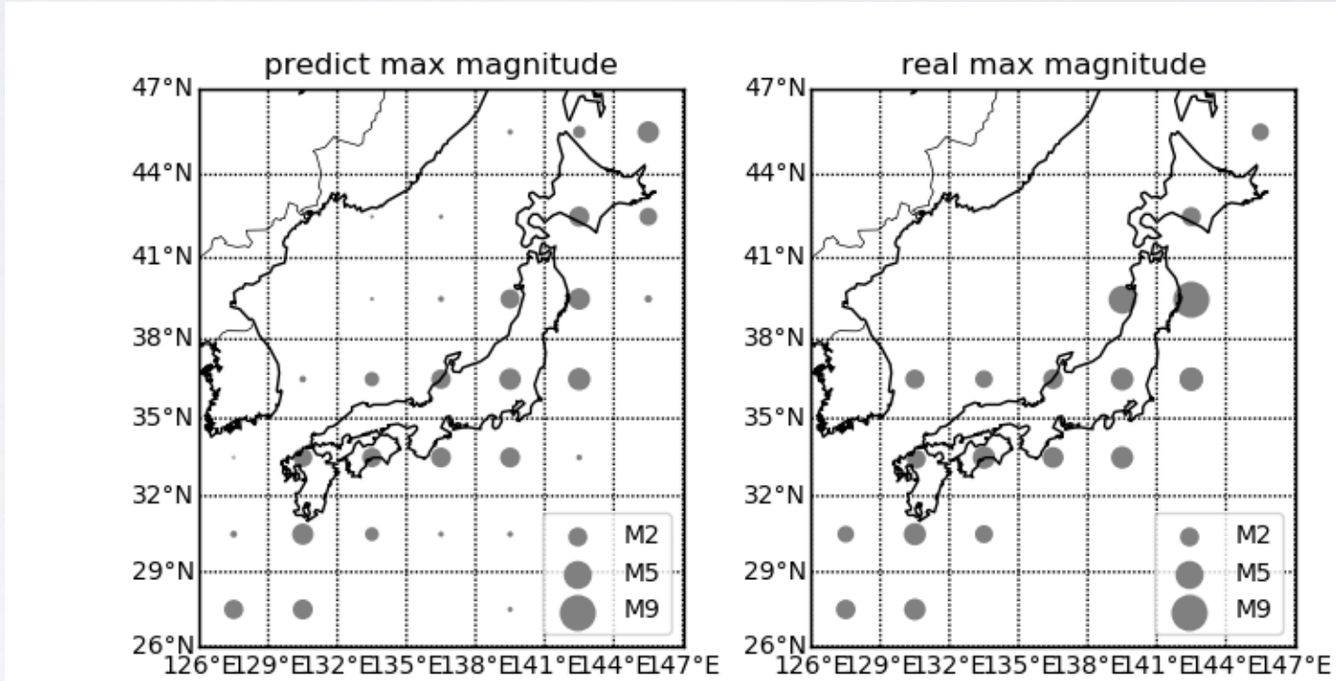
Validation

Testing

LSTM RESULT

2011/3/11





ANALYSIS

Problem:

- 1:Testing MSE diverge with training MSE converge(normal X)
- 2:Testing_2 MSE diverge with training MSE converge

Result:

- 1: Earthquake is randomly happened (Poisson Distribution)

- **2: Giant earthquake has a same law of distribution with all before earthquake as time series data in LSTM.**

EXPECT

- **Optimize the model in Hyper-parameter space**

X=(Batch size, Time window, LR,Epoch)

Y=Validation datasets MSE(30 epoch MSE average after model convergence)

a=(XY)^t(transpose)

New datasets of hyper parameter:A:{a|(XY)^t}

In A space find optimized point **a**.
And find hyper-parameter's law from MDS(Multidimensional scaling)

EXPECT

- **Classification of one region in one day (To different segment)**

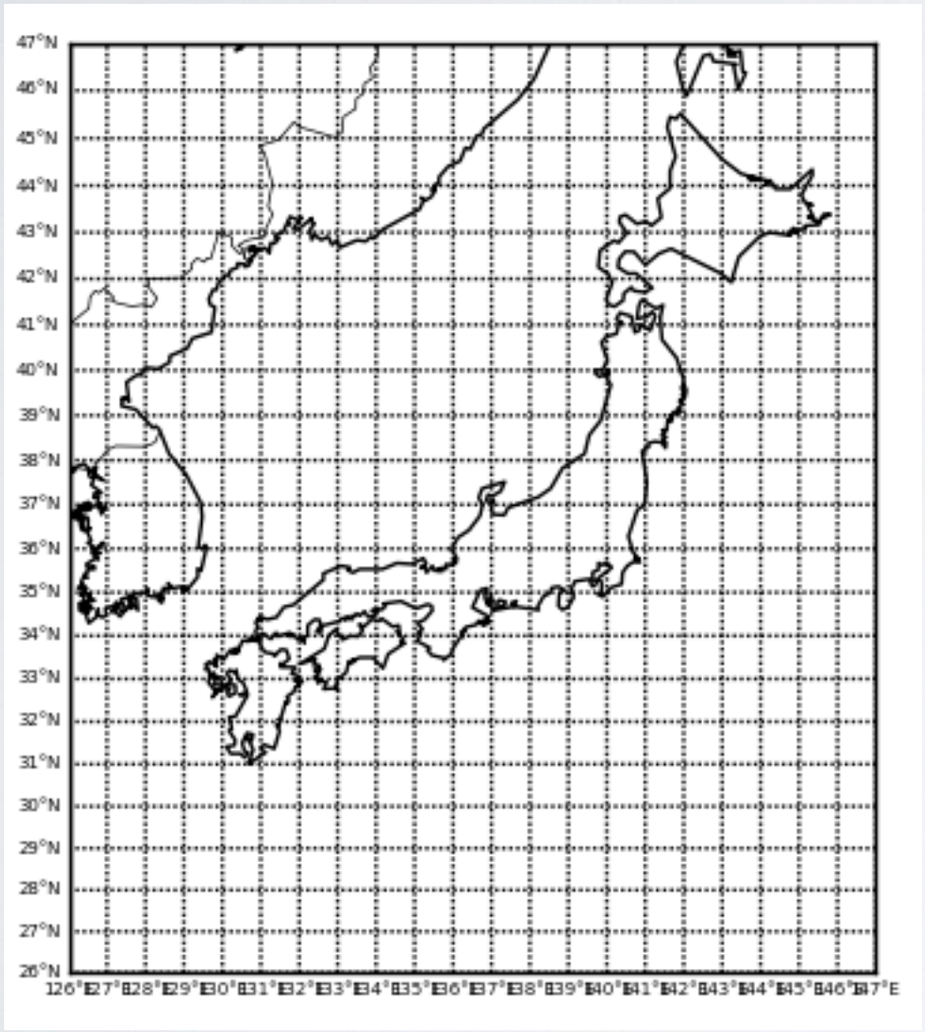
  CNN: n segments

- **Segment assessment(magnitude)**

  Datasets of M>n

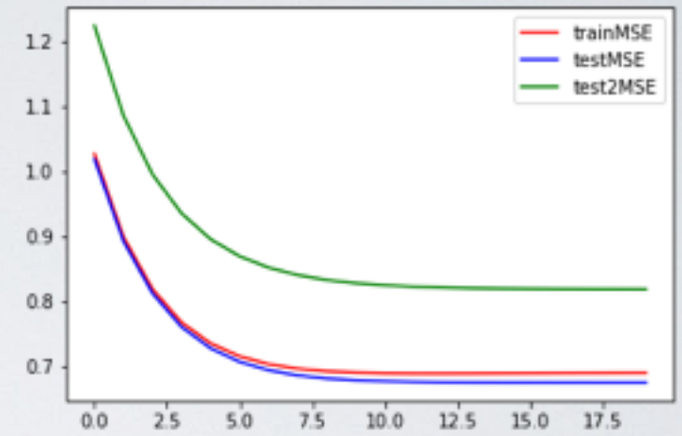
EXPECT

After we got optimize model:

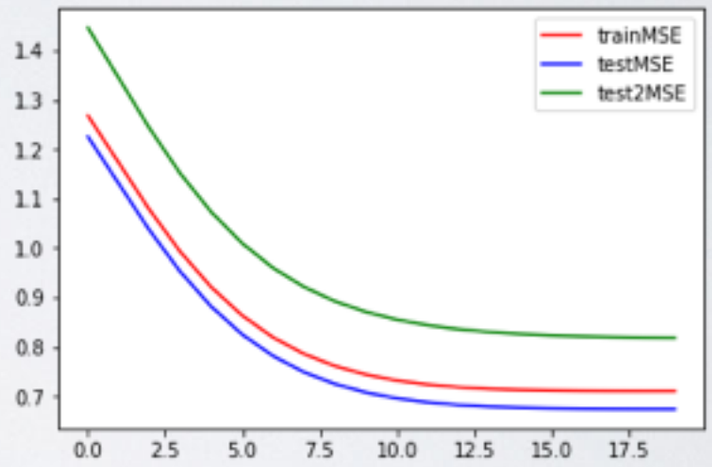


Space scale -> 1degree

Epoch=20
BATCH_SIZE=50
TIME_WINDOW=10
LR=0.005



Epoch=20
BATCH_SIZE=50
TIME_WINDOW=30
LR=0.005



Optimize

Epoch=100
BATCH_SIZE=50
TIME_WINDOW=?
LR=?

?

SUMMARY

REFERENCES

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