Neural Networks for Fun and Prophet

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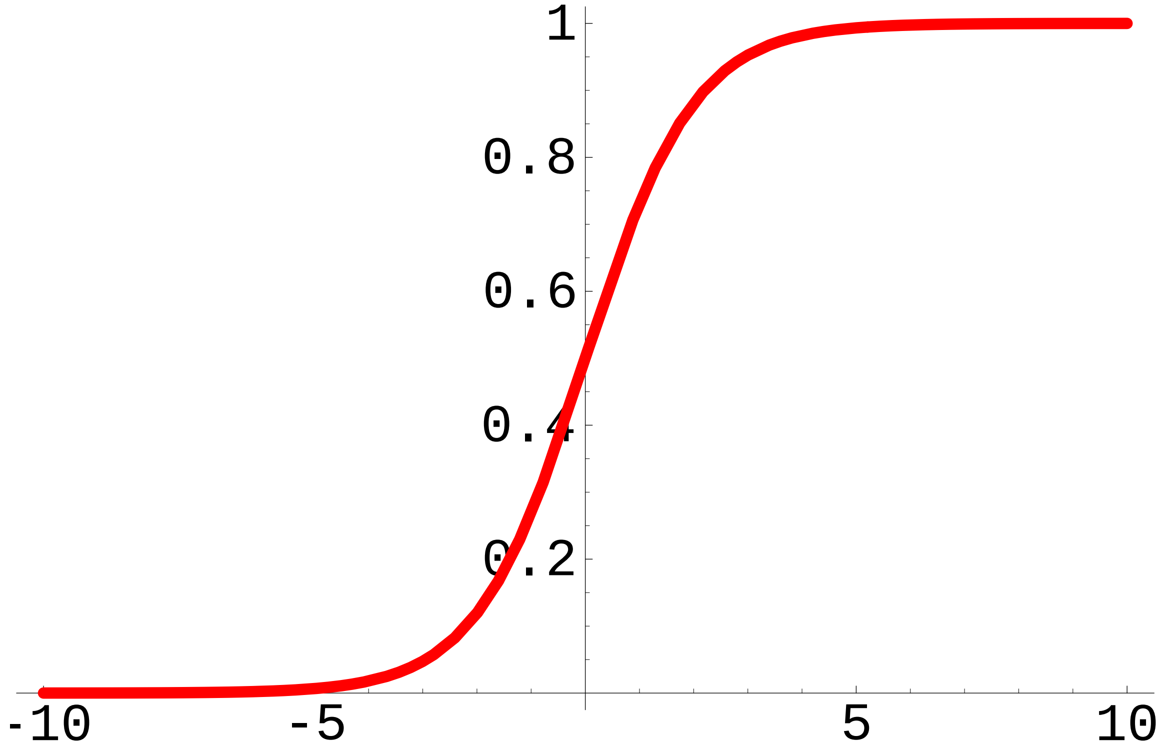
Summary:

- A gentle introduction to the workhorse of neural networks: *the backpropagation algorithm.*
- Applications to forecasting temperature and low clouds at SFO.

```
LogSig[x_] = 1. / (1 + Exp[-x])
```

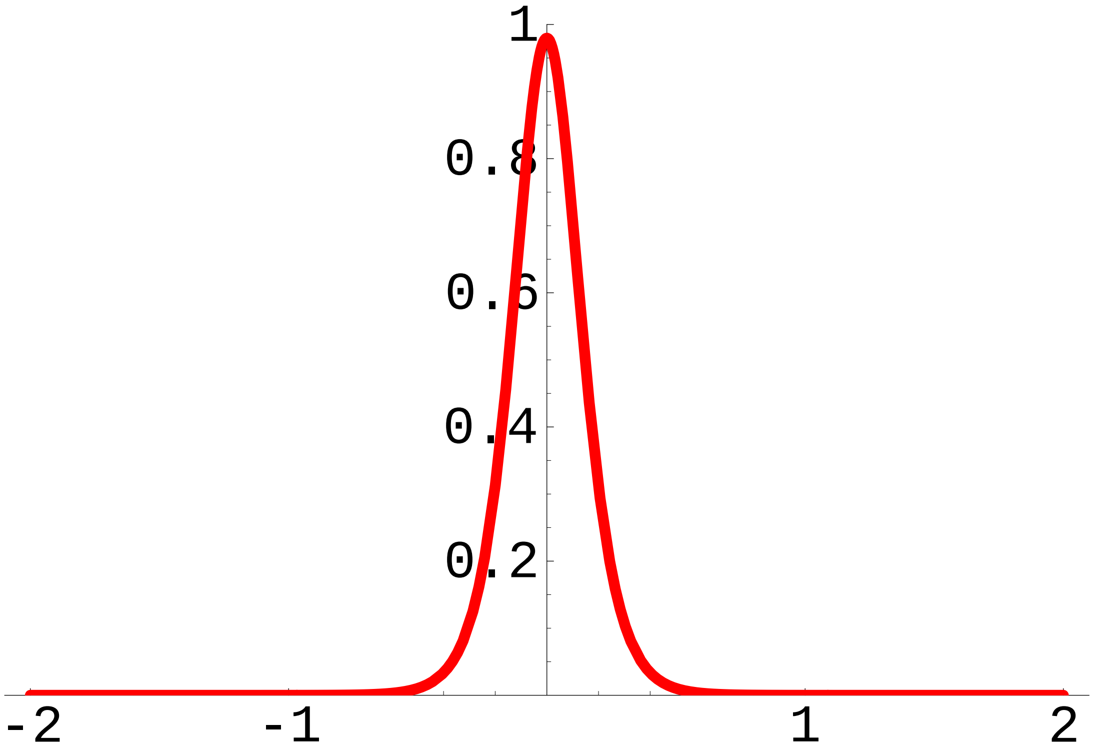
$$\frac{1.}{1 + e^{-x}}$$

```
Plot[LogSig[x], {x, -10, 10},
  PlotStyle → {{RGBColor[1, 0, 0], Thickness
```



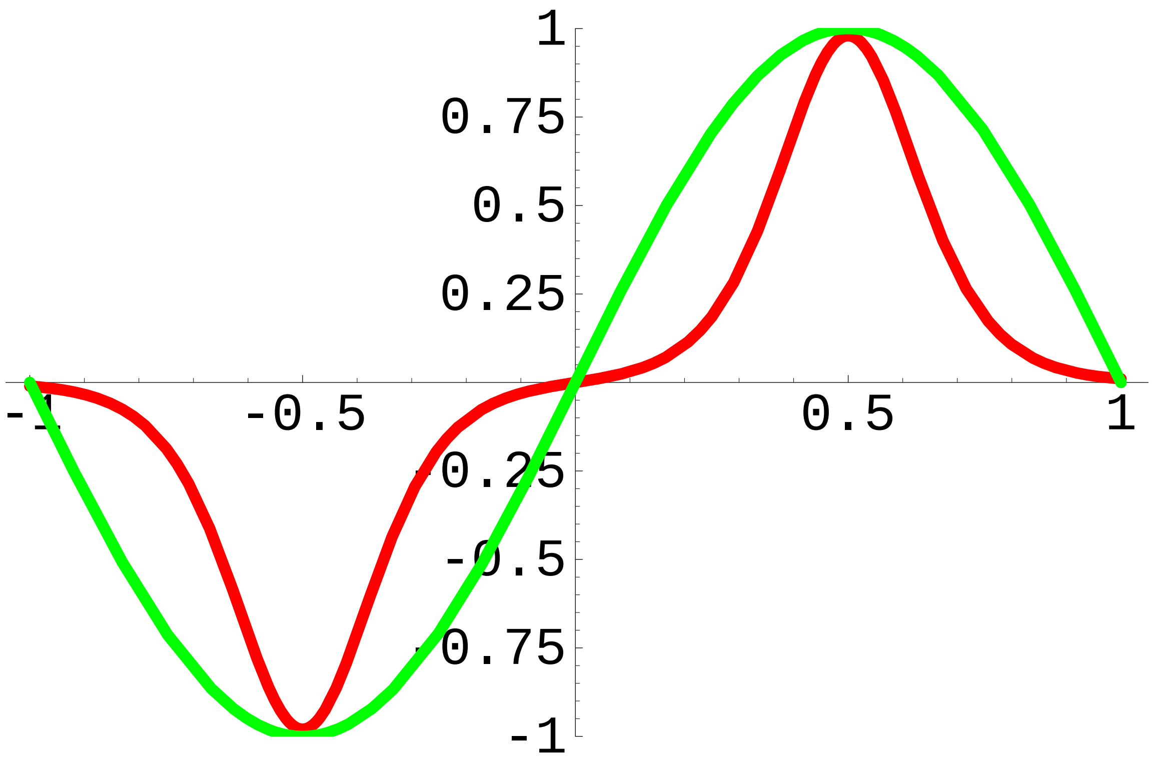
```
hump[x_] := -4 * LogSig[12 x - .5]
             + 4 * LogSig[12 x + .5]

Plot[hump[x], {x, -2, 2}, PlotRange → {0, 1},
  PlotStyle → {{RGBColor[1, 0, 0], Thickness
```



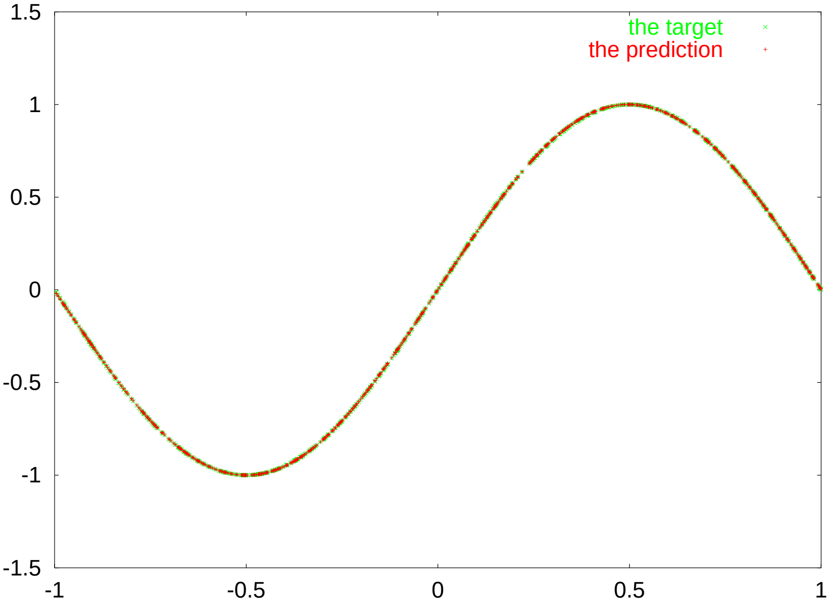
```
humps[x_] :=
 -4 * LogSig[12 x - 6.5]
  + 4 * LogSig[12 x - 5.5]
  - 4 * LogSig[12 x  + 6.5]
  + 4 * LogSig[12 x + 5.5]

Plot[{humps[x], Sin[Pi * x]}, {x, -1, 1},
  PlotRange → {-1, 1},
  PlotStyle → {{RGBColor[1, 0, 0], Thickness
    {RGBColor[0, 1, 0], Thickness[.01]}}];
```

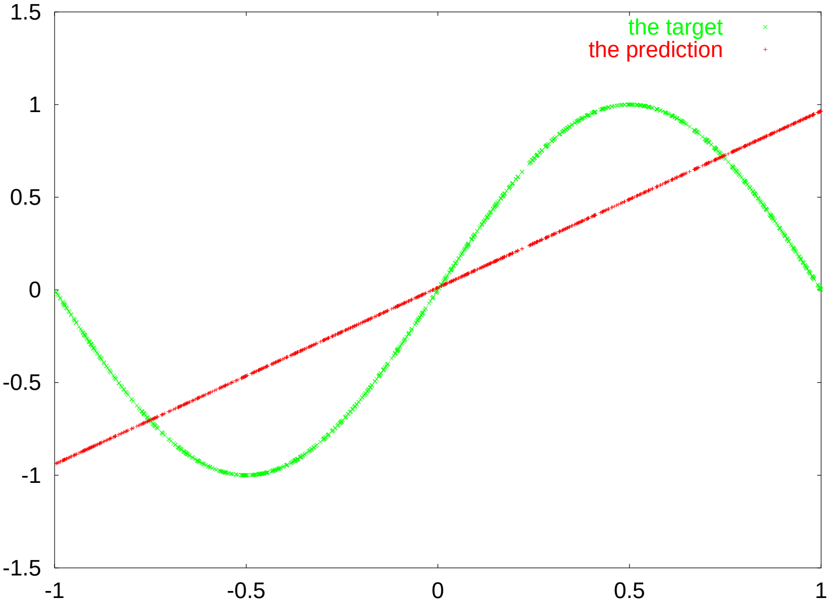


Neural network with one input, x, and one output, y, trained to hit $\sin(x)$.

fitting with four logsig functions:



fitting with linear function(s):



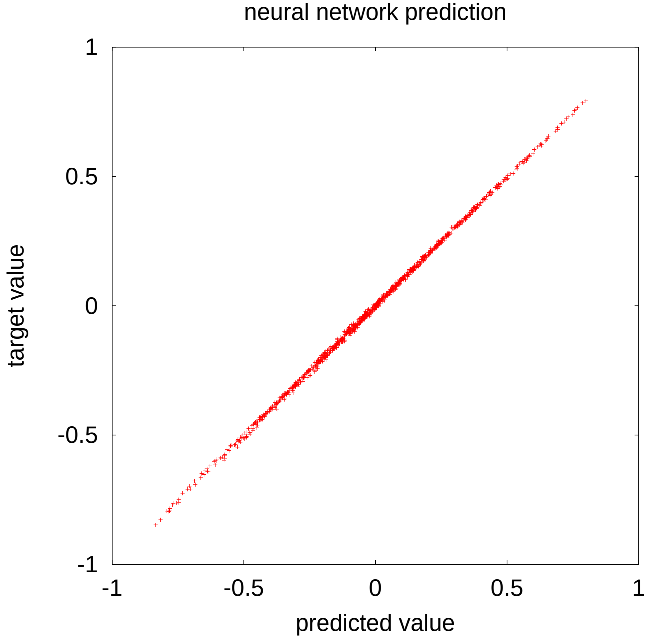
Imagine a big file with pairs of input-vectors and target-vectors:

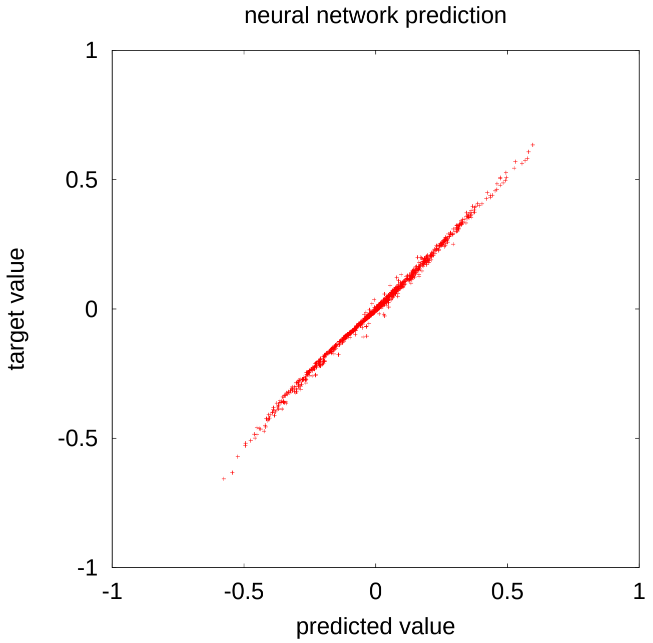
```
 0.558  -0.047  -0.194       0.095   0.073
-0.934   0.853   0.805       0.217  -0.051
-0.875   0.483   0.228      -0.048  -0.224
 0.780   0.021  -0.058       0.223   0.190
   .       .       .           .       .
   .       .       .           .       .
   .       .       .           .       .
```

Your job is to learn how to predict the target from the input.

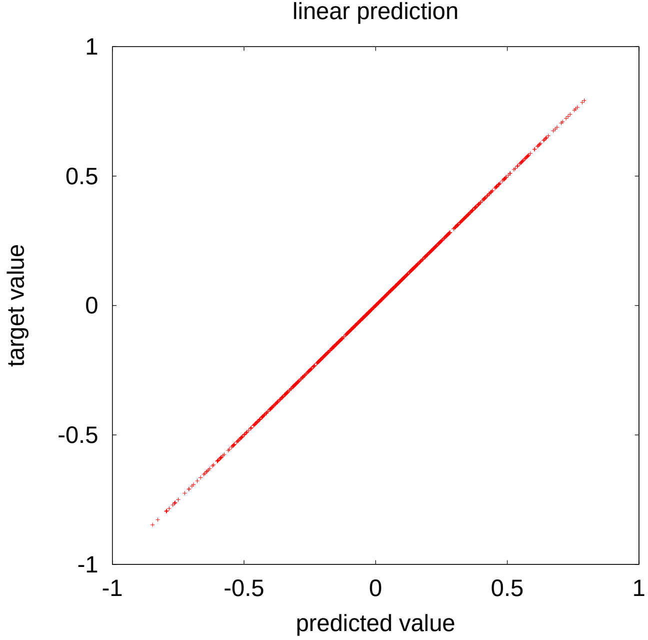
Three inputs (x, y, z), and two targets $(.3x + .3y + .3z,\ .4yz + .4x^3)$.

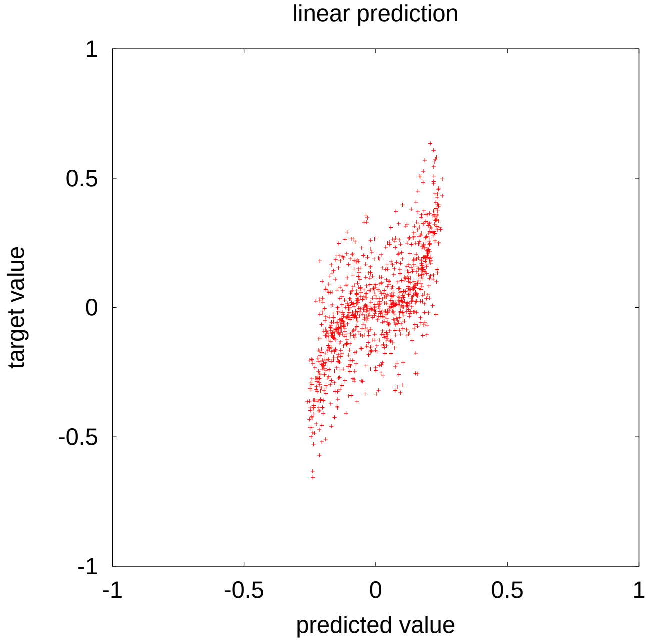
fitting with six logsig functions:





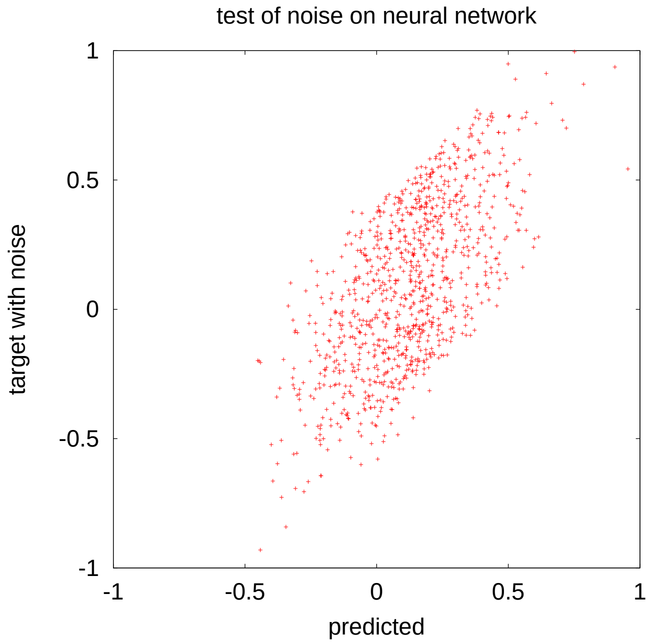
fitting with linear function:



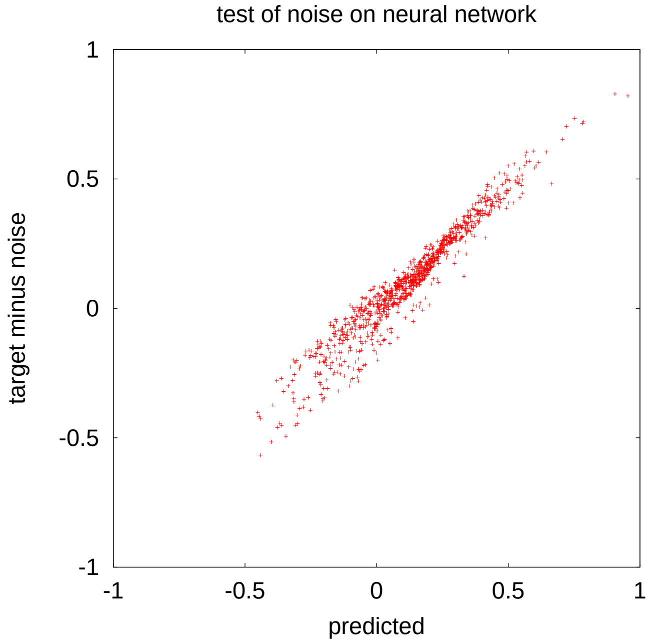


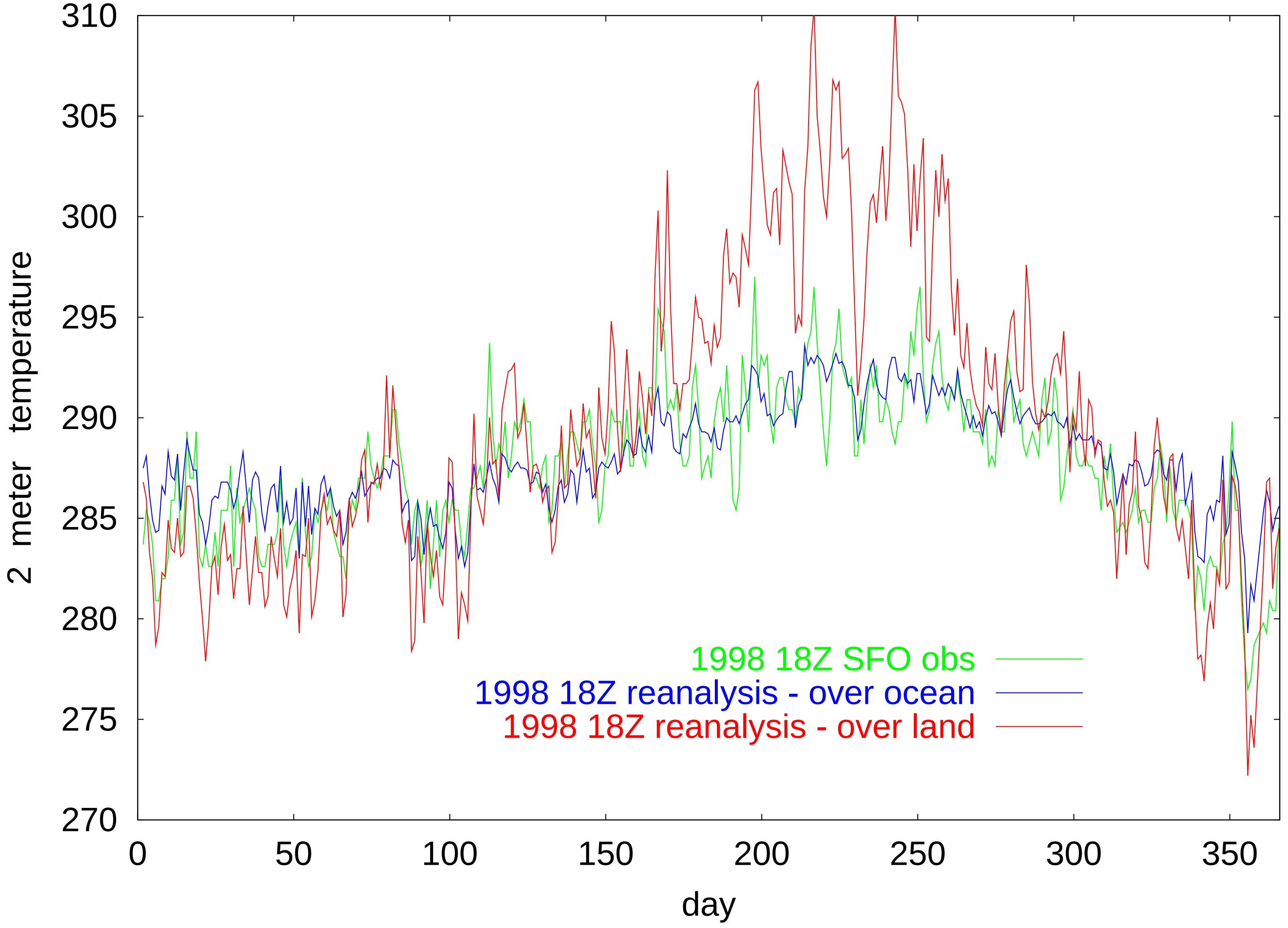
Three inputs (x, y, z), and one target $(.4yz + .4x^3 + .4 * \text{noise})$.

with noise:



plot with noise subtracted from target:

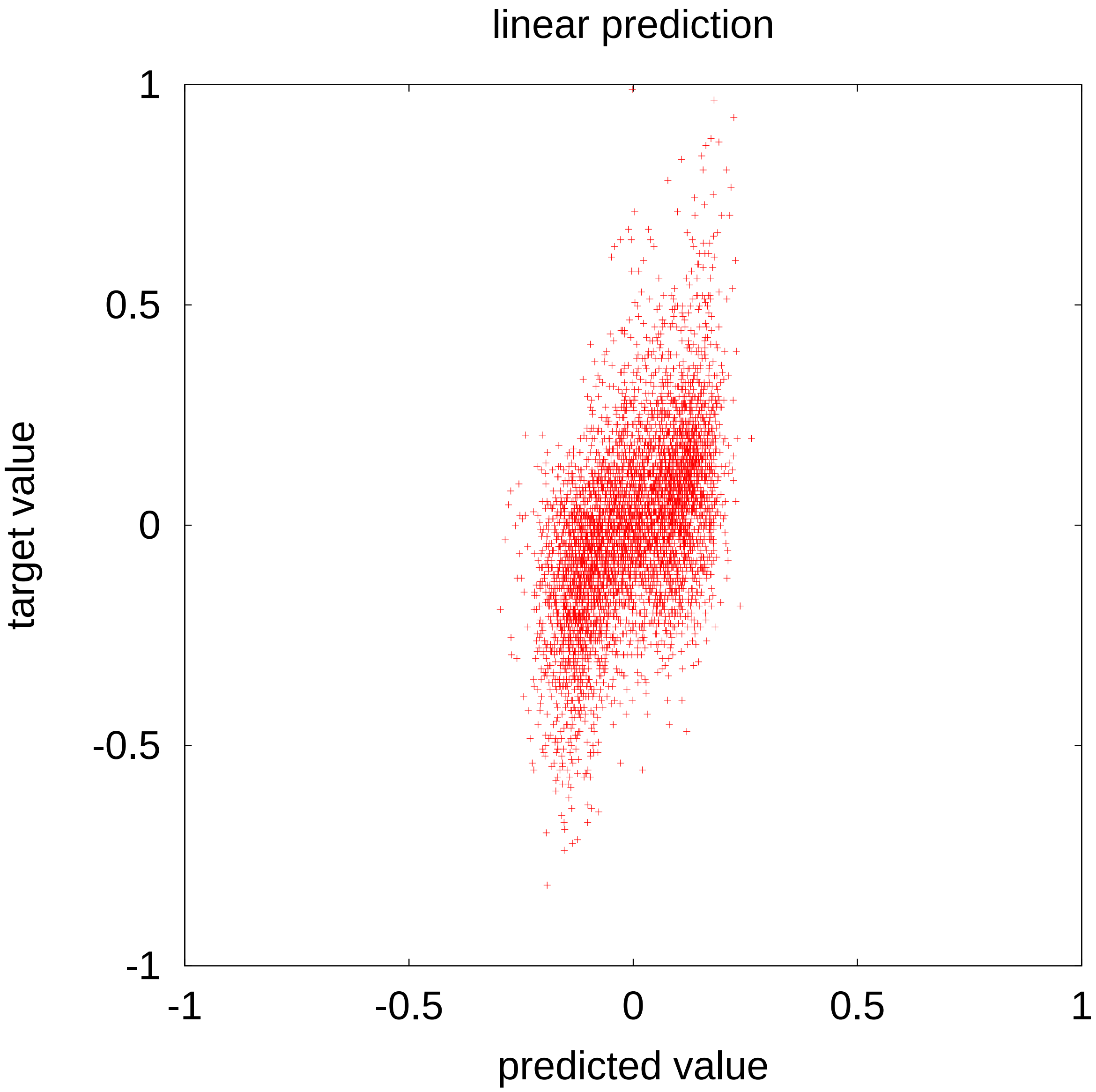



310
305
300
295
290
285
280
275
270
2 meter temperature
0
50
100
150
200
250
300
350
day
1998 18Z SFO obs
1998 18Z reanalysis - over ocean
1998 18Z reanalysis - over land

Train the neural network to predict the 18Z value of (SFO obs - T ocean) using the following from the reanalyis at 12 Z:

- 850mb u
- 850mb v
- 850mb T
- 850mb RH
- cosine of Julian day
- sine of Julian day
- prediction for T above ocean point
- prediction for T above land point

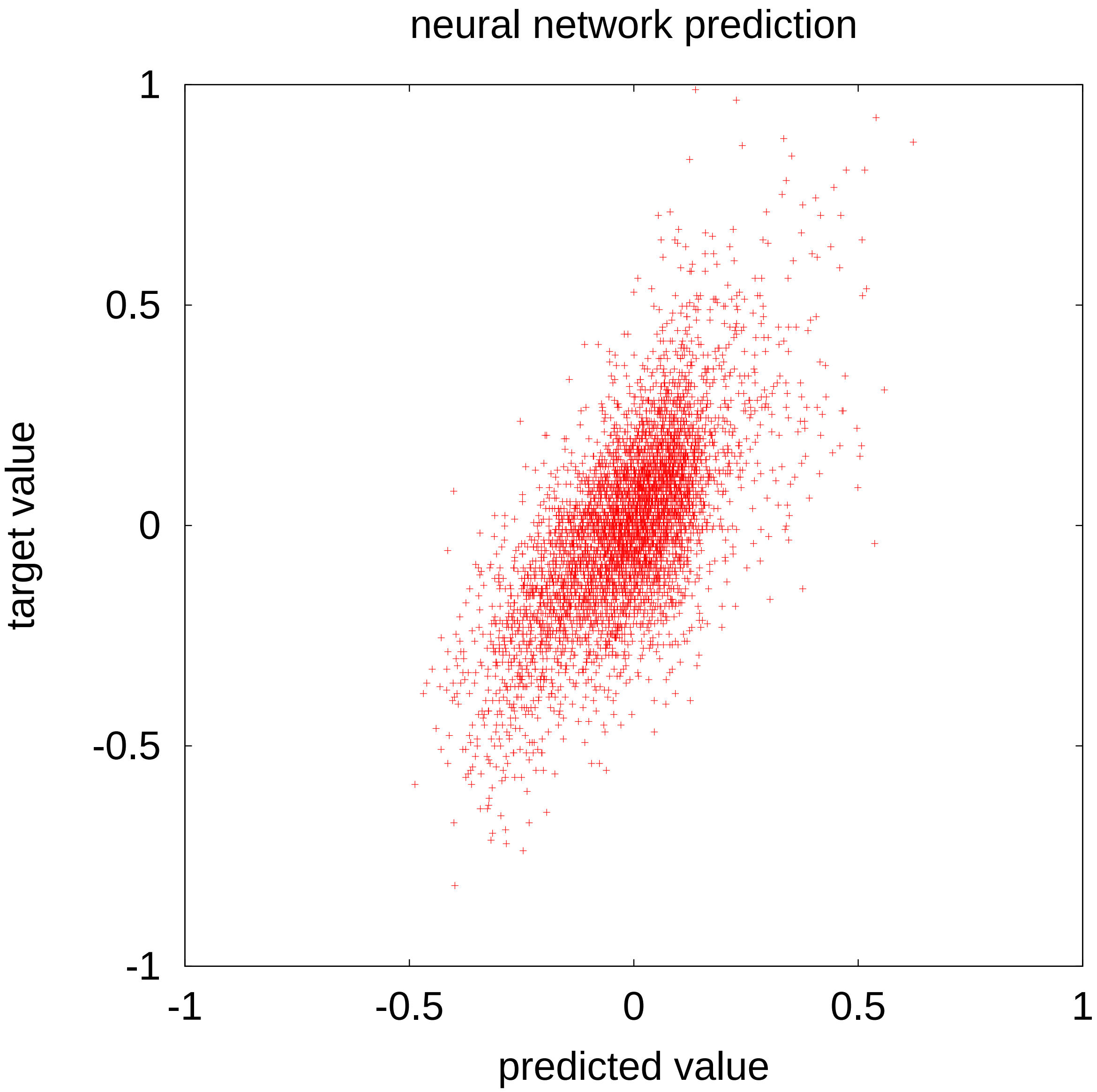
Predict (SFO obs T - rean. T ocean point):



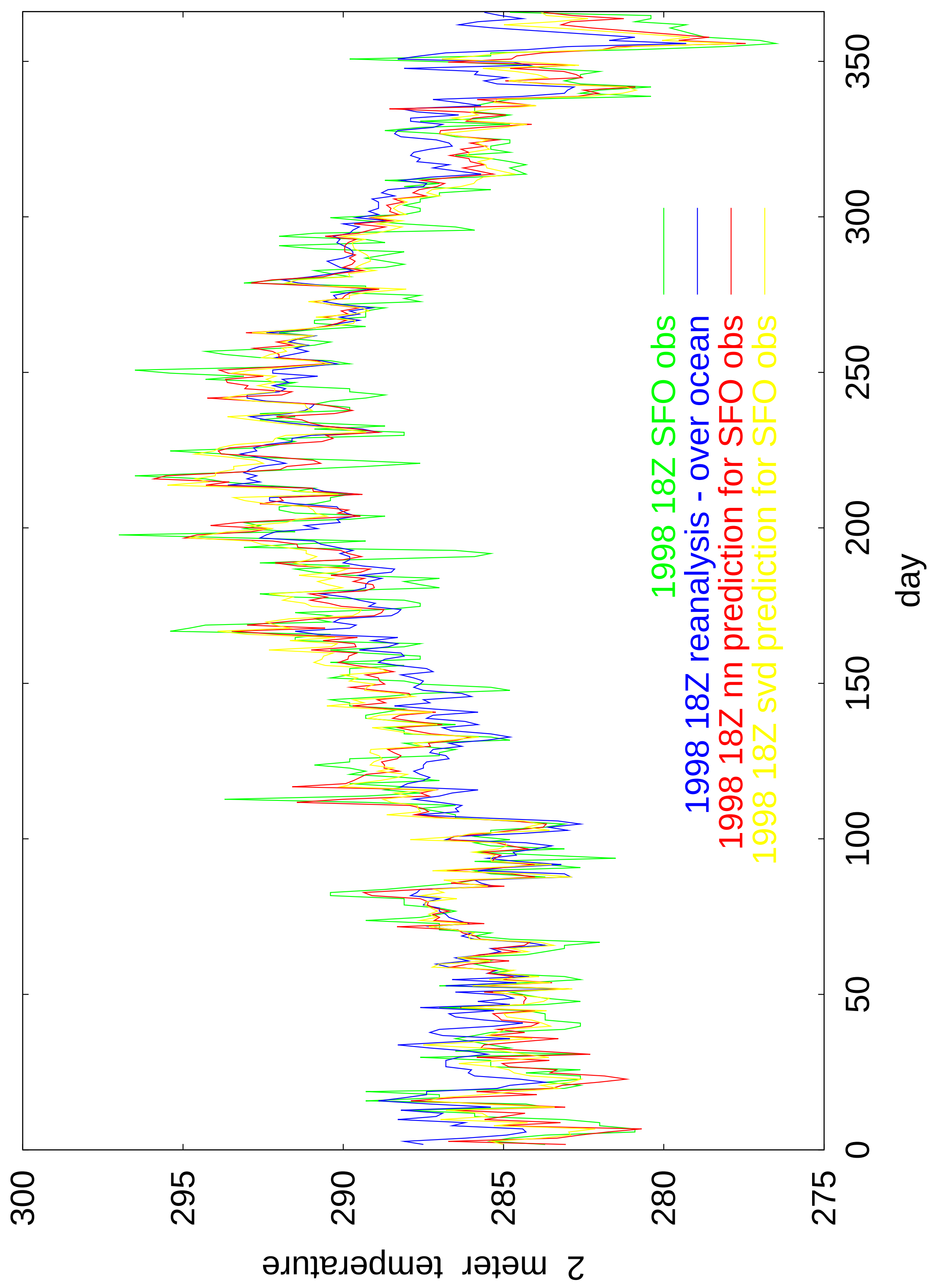
SVD average square error is 0.029

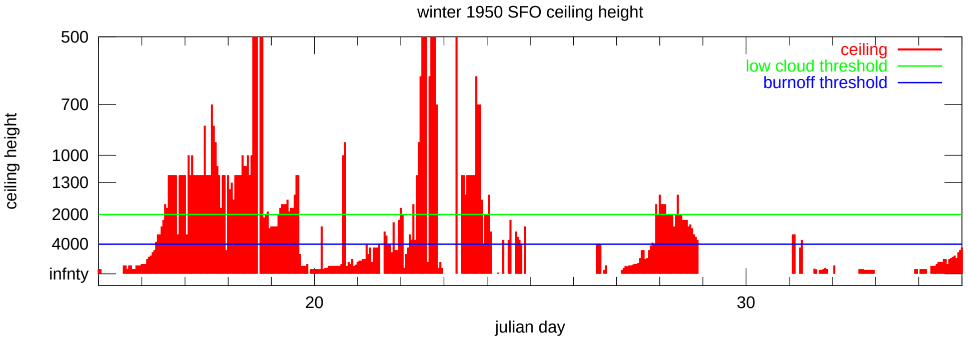
Predicting 0 would give square error of 0.040

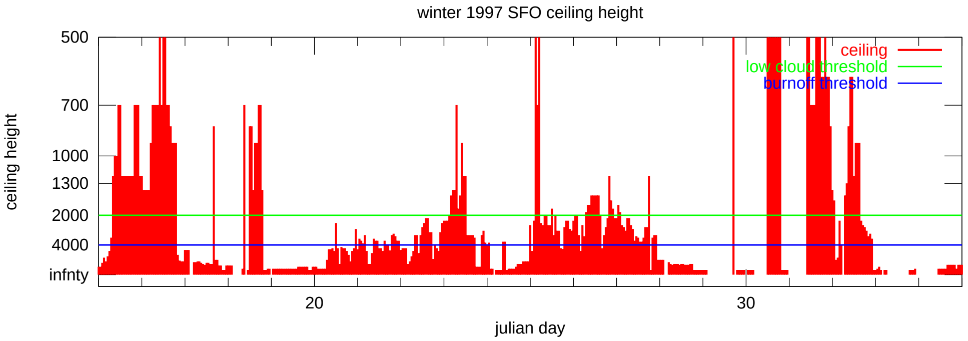
Predict (SFO obs T - rean. T ocean point):

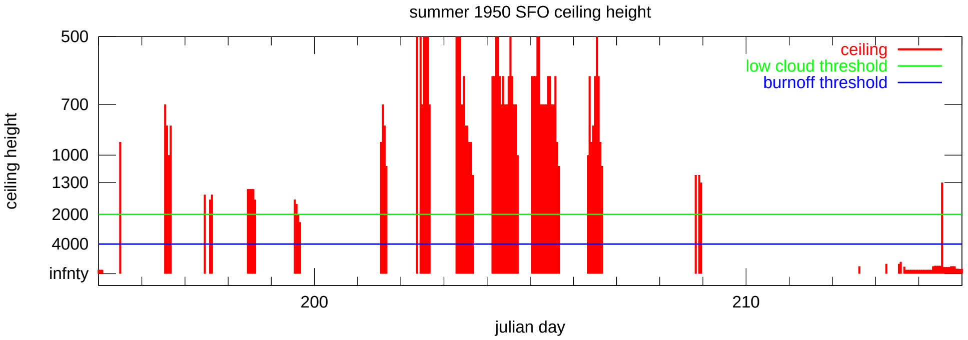


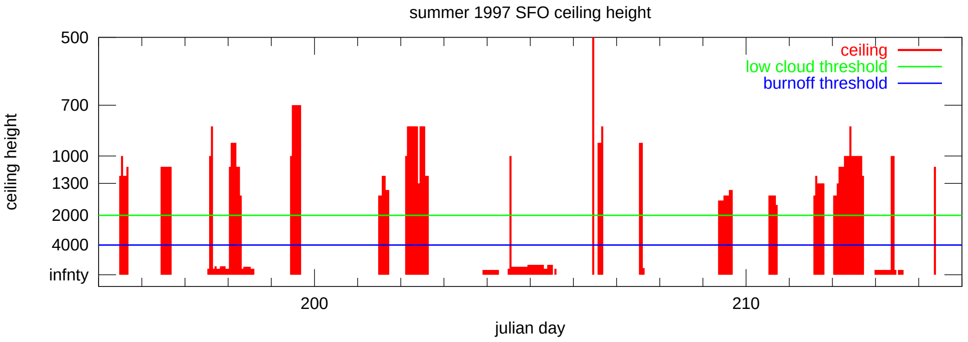
NN average square error is 0.022

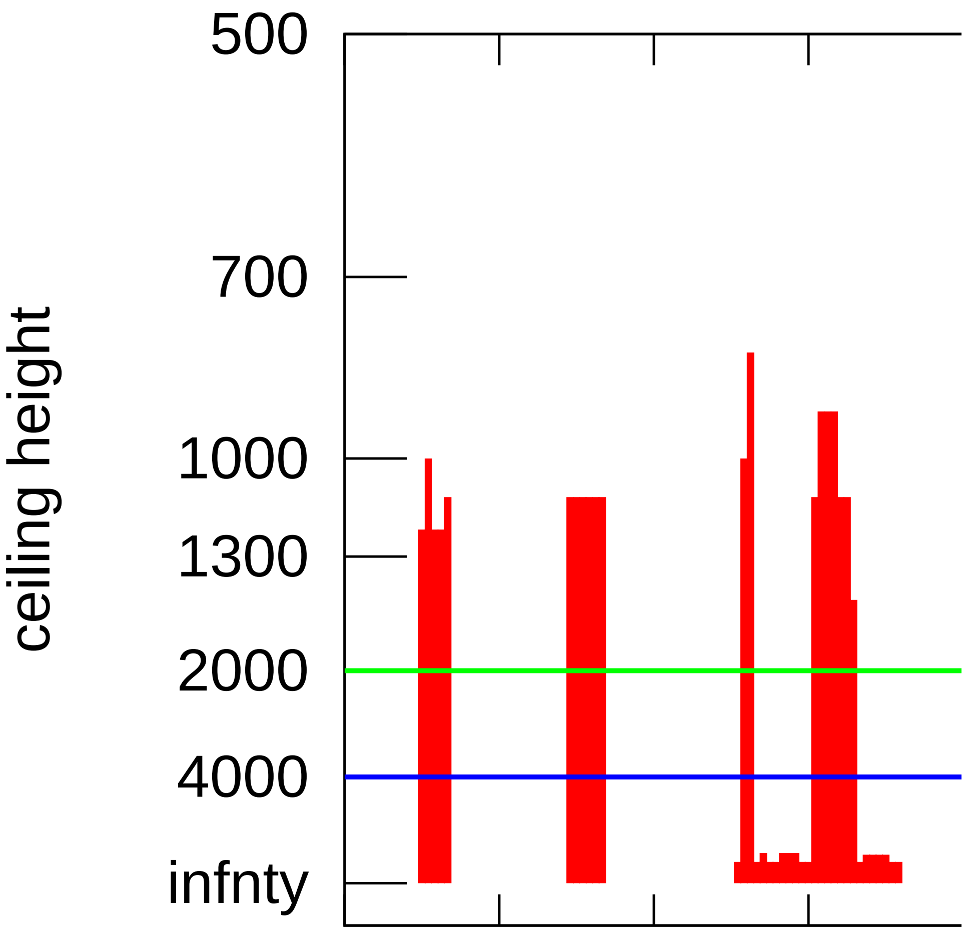

2 meter temperature
300
295
290
285
280
275
day
0
50
100
150
200
250
300
350
1998 18Z SFO obs
1998 18Z reanalysis - over ocean
1998 18Z nn prediction for SFO obs
1998 18Z svd prediction for SFO obs

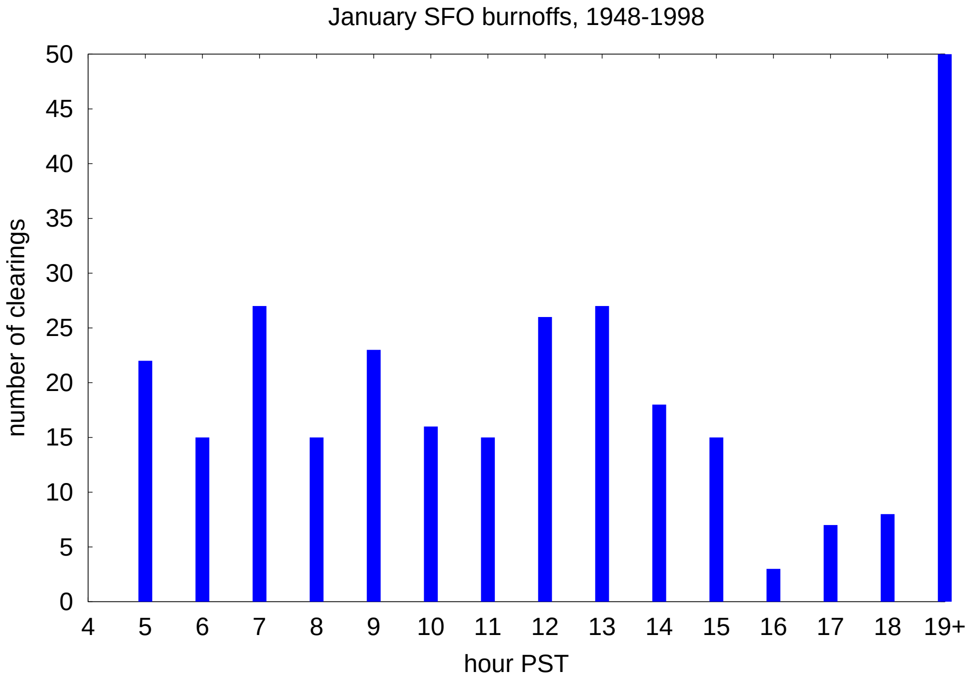

winter 1950 SFO ceiling height
ceiling height
500
700
1000
1300
2000
4000
infnty
20
30
julian day
ceiling
low cloud threshold
burnoff threshold


winter 1997 SFO ceiling height
ceiling height
500
700
1000
1300
2000
4000
infnty
20
30
julian day
ceiling
low cloud threshold
burnoff threshold

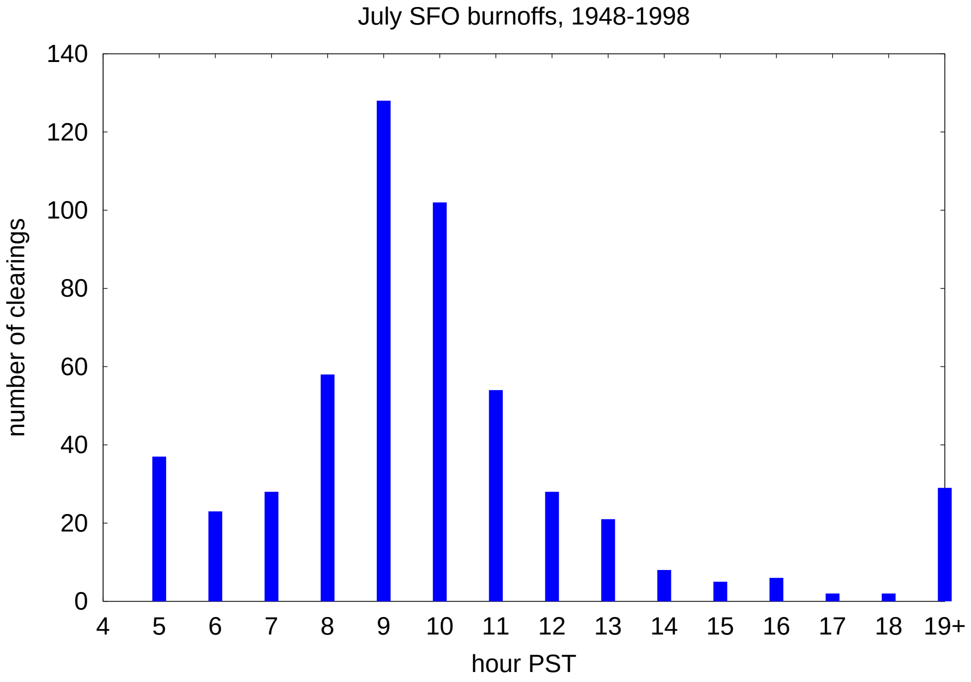

summer 1950 SFO ceiling height
ceiling height
500
700
1000
1300
2000
4000
infnty
200
210
julian day
ceiling
low cloud threshold
burnoff threshold


summer 1997 SFO ceiling height
ceiling height
500
700
1000
1300
2000
4000
infnty
200
210
julian day
ceiling
low cloud threshold
burnoff threshold


ceiling height
500
700
1000
1300
2000
4000
infnty

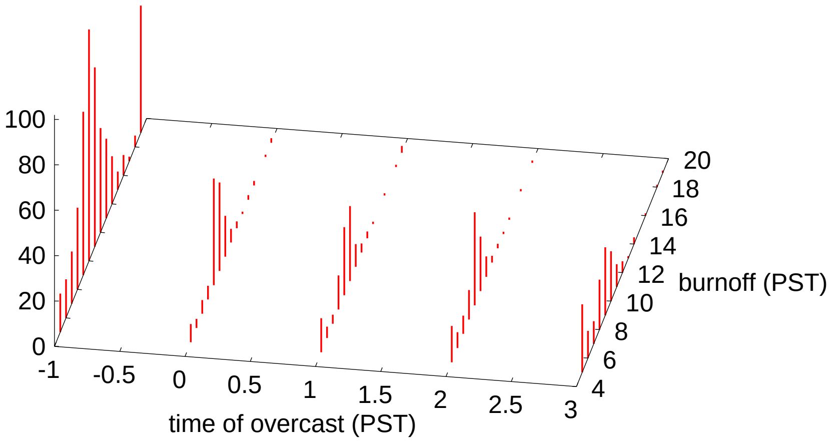


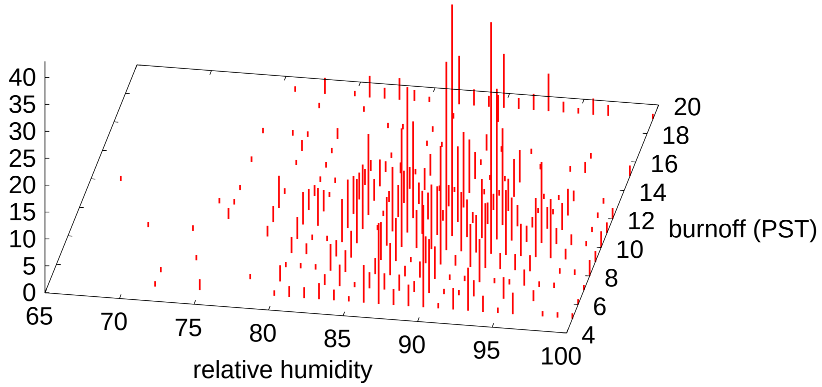
January SFO burnoffs, 1948-1998



July SFO burnoffs, 1948-1998

1948-1997 July-August SFO burnoff climatology


1948-1998 July-August SFO burnoff climatology


1948-1998 July-August SFO burnoff climatology

- Attempt to predict time of burnoff using time overcast begins and the 4 AM temperature, wind speed, wind direction, pressure, relative humidity, ceiling height, time overcast begins, and julian day.
- Data from 1948-1998. (Three hourly data from the 70's is excluded) 716 records are used for training, 357 for verification.

method	error with training data	error with verification data
predict mean to occur	.040	.040
SVD	.034	.034
neural network nread=1000	.026	.041

- Attempt to predict time of burnoff using the above surface obs, and the 12Z reanalysis fields at and above 850 mb. 20 variables.
- Data from 1955-1998. 572 records are used for training, 285 for verification.

method	error with training data	error with verification data
predict mean to occur	.040	.039
SVD	.030	.034
neural network nread=100	.031	.034
neural network nread=1000	.021	.064

- As before, but use only 4 variables identified by SVD to have the greatest weight: time of onset of overcast, reanalysis 12 Z 850mb u wind, 850 mb temperature, and 500 mb relative humidity.

method	error with training data	error with verification data
predict mean to occur	.040	.039
SVD	.033	.033
neural network nread=10,000	.031	0.037

```
subroutine forward_model(p)
real(mrl) p(:)
a0=p
do m=1,nl
call point_layer(m)
call f( dadn, a, matmul(w,am)+b, funco, ifun)
end do
end subroutine forward_model

subroutine backprop_sensitivities(t)
real(mrl) t(:)
call point_layer(nl)
s=-2*dadn*(t-a)
do m=nl-1,1,-1
        call point_layer(m)
        s=dadn*matmul(sp,wp)
end do
end subroutine backprop_sensitivities
```