Image-based Early Detection System for Wildfires

OMKAR RANADIVE, JISU KIM, SERIN LEE,
YOUNGSEO CHA, HEECHAN PARK, MINKOOK CHO,
YOUNG K. HWANG

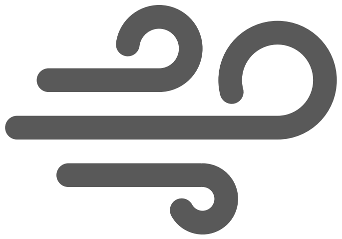
2021 Wildfire Statistics for USA

58,733 fires

7.13 million acres burned

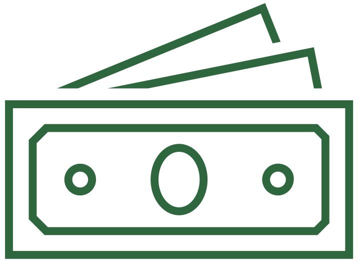
https://www.ncei.noaa.gov/access/monitoring/monthly-report/fire/202113

Damage caused by wildfires



Air Pollution

Structural damage

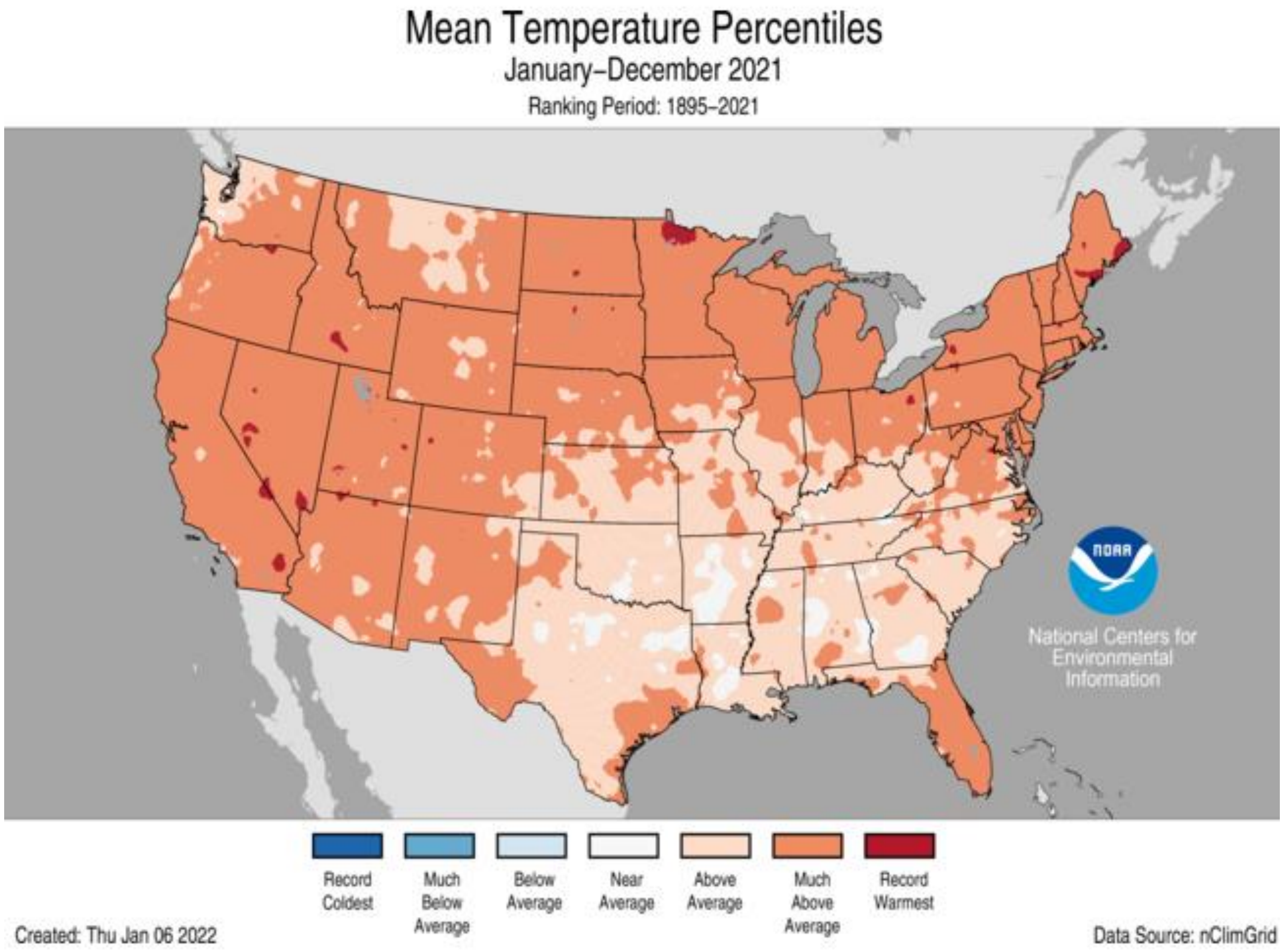


Billions in losses

Death

Effects of climate change

- Global warming is causing warmer and drier conditions
- Drier soils and vegetation are more susceptible to burning
- A global increase in large and severe wildfires is expected in the coming years

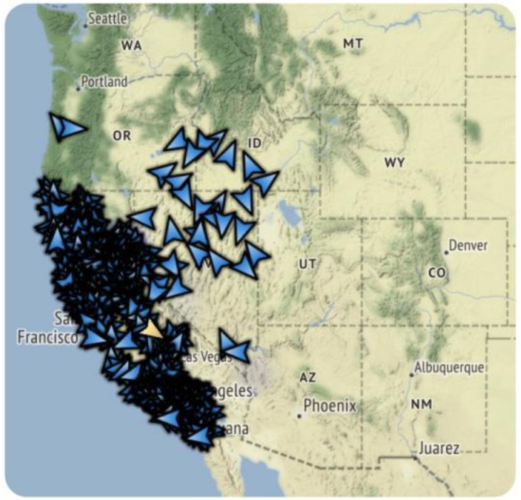

Mean Temperature Percentiles
January–December 2021
Ranking Period: 1895–2021
Record Coldest
Much Below Average
Below Average
Near Average
Above Average
Much Above Average
Record Warmest
Created: Thu Jan 06 2022
Data Source: nClimGrid
NOAA
National Centers for Environmental Information

Alert Wildfire Cameras

- Began as a collaboration between Nevada Seismological Lab and Forest Guard Team
- Currently, it is a big network with **700+** PTZ cameras

Network Partners

Coverage Area



Cameras

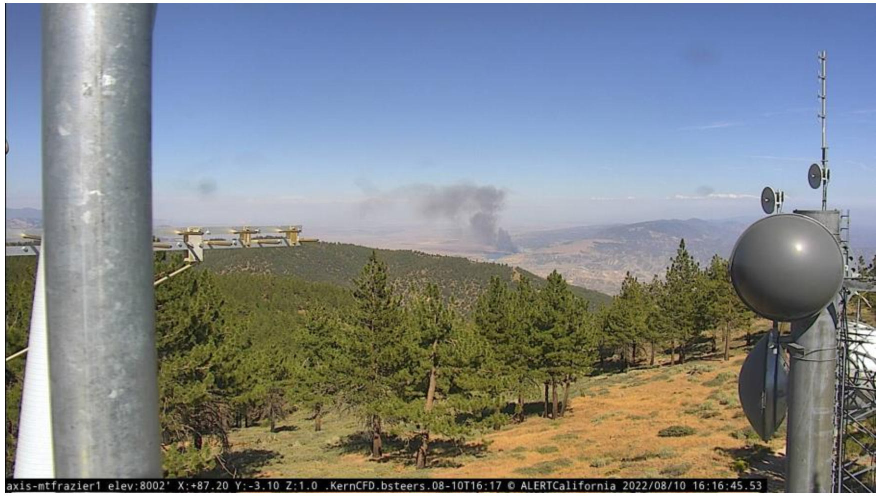
AXIS Q6055-E PTZ Network Camera

The Dataset


IMAGE
COURTESY OF
PG&E
axis-barnhamsouth elev:1552' X:-135.20 Y:-4.00 Z:20.7 .ACOPS.ethan.08-12T14:35 © ALERTCalifornia 2022/08/12 14:35:48.62


IMAGE
COURTESY OF
PG&E
axis-sanluisreservoir2 elev:1703' X:+76.55 Y:-2.95 Z:14.2 .CalFireMMU.mlawler.07-25T16:50 © ALERTCalifornia 2022/07/25 16:50:59.58


axis-breckenridgepeak2 elev:7530' X:-150.06 Y:-5.99 Z:2.0 © ALERTCalifornia 2022/08/14 17:44:47.98


axis-mtfrazier1 elev:8002' X:+87.20 Y:-3.10 Z:1.0 .KernCFD.bsteers.08-10T16:17 © ALERTCalifornia 2022/08/10 16:16:45.53

The Dataset

- We gathered data from over 400 different Alert Wildfire cameras
- We labeled the images with bounding boxes and categorized them as wildfire vs non-wildfire
- The final dataset consists of 90,000 images

Key idea: Perform early detection of wildfires; i.e., ideally, detect the smoke

Wildfire Alert System Overview

Firespotting Cameras → **AI in the Cloud** → **Human-in-the-Loop** → **Immediate Alert**

Firespotting Cameras

Send image data to the cloud
Provided by ALERT Wildfire

AI in the Cloud

Deep-learning algorithms **detects smoke**, sends wildfire alerts for confirmation

Human-in-the-Loop

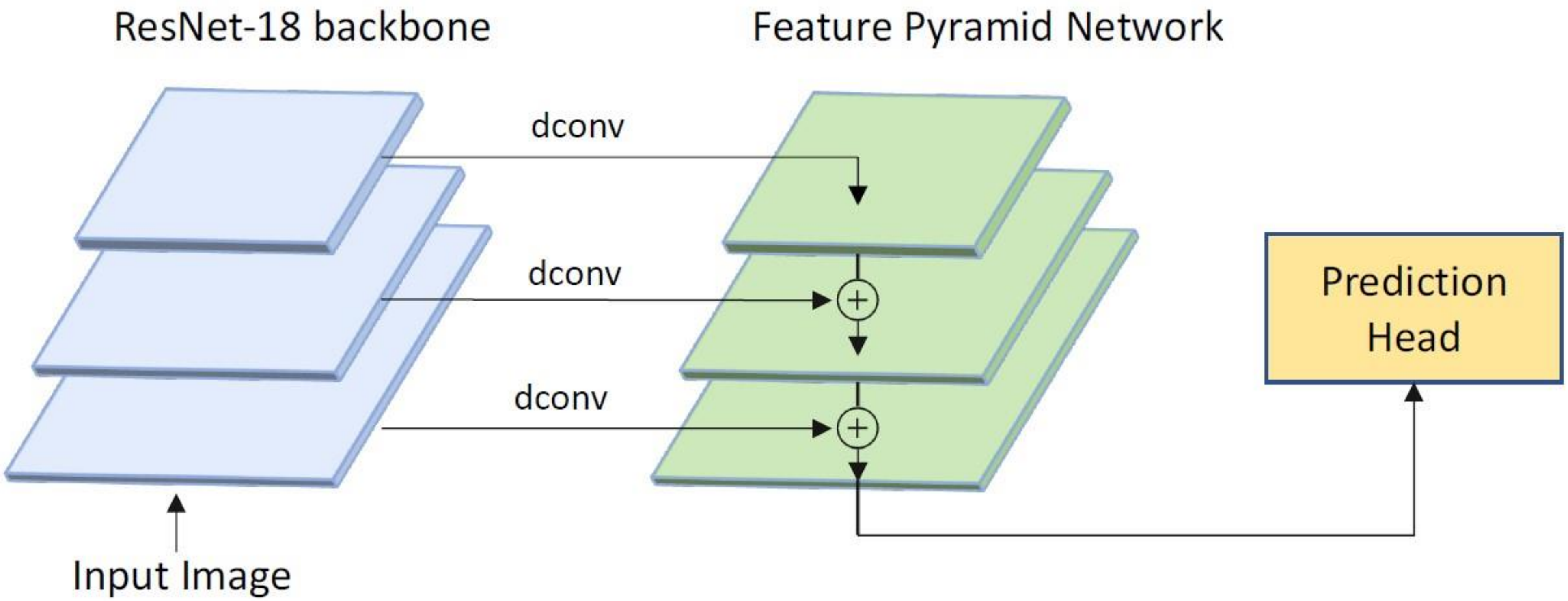
1 person per 250+ cameras filters AI results for false alarms, **confirms alerts**

Immediate Alert

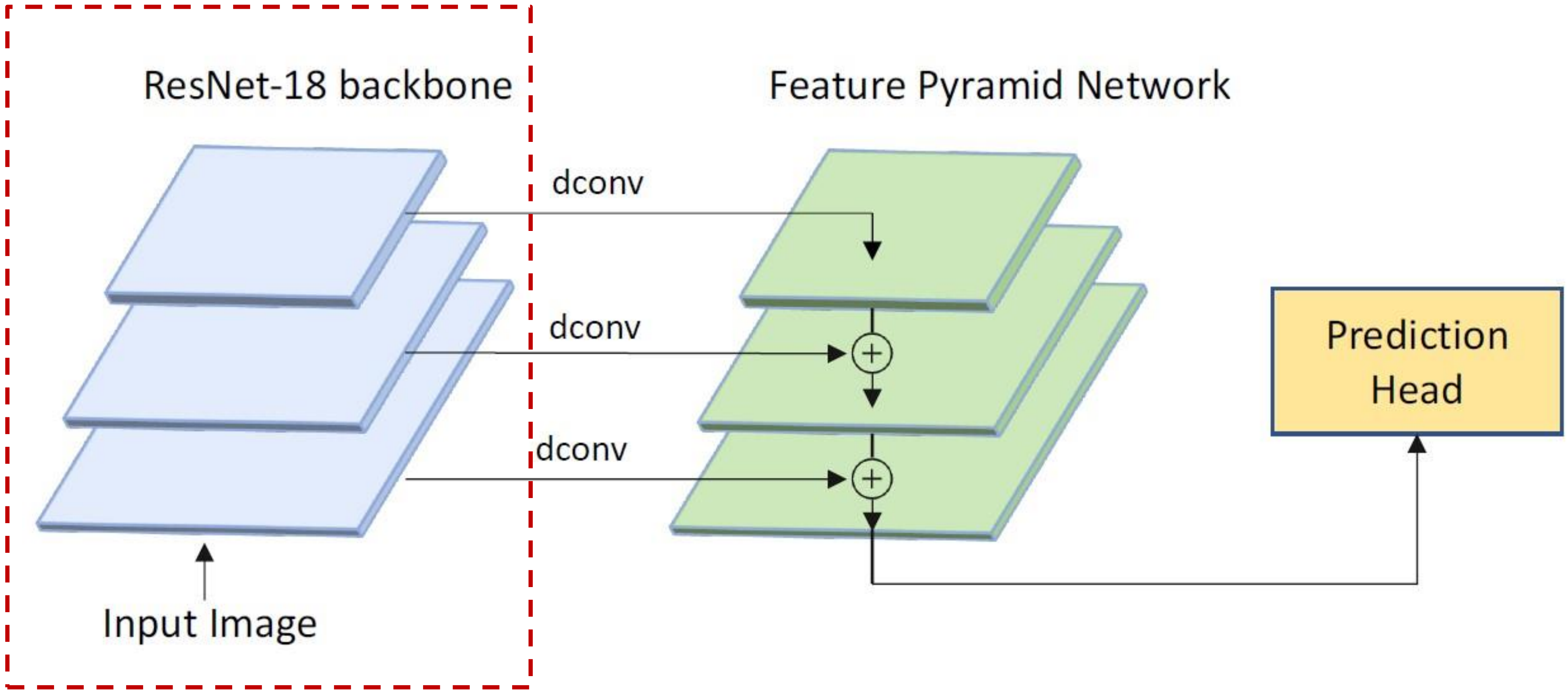
Human-confirmed fires populate on dashboard, triggers an **alert to users** by SMS, e-mail

Smoke is difficult to detect - it can be of varying scales

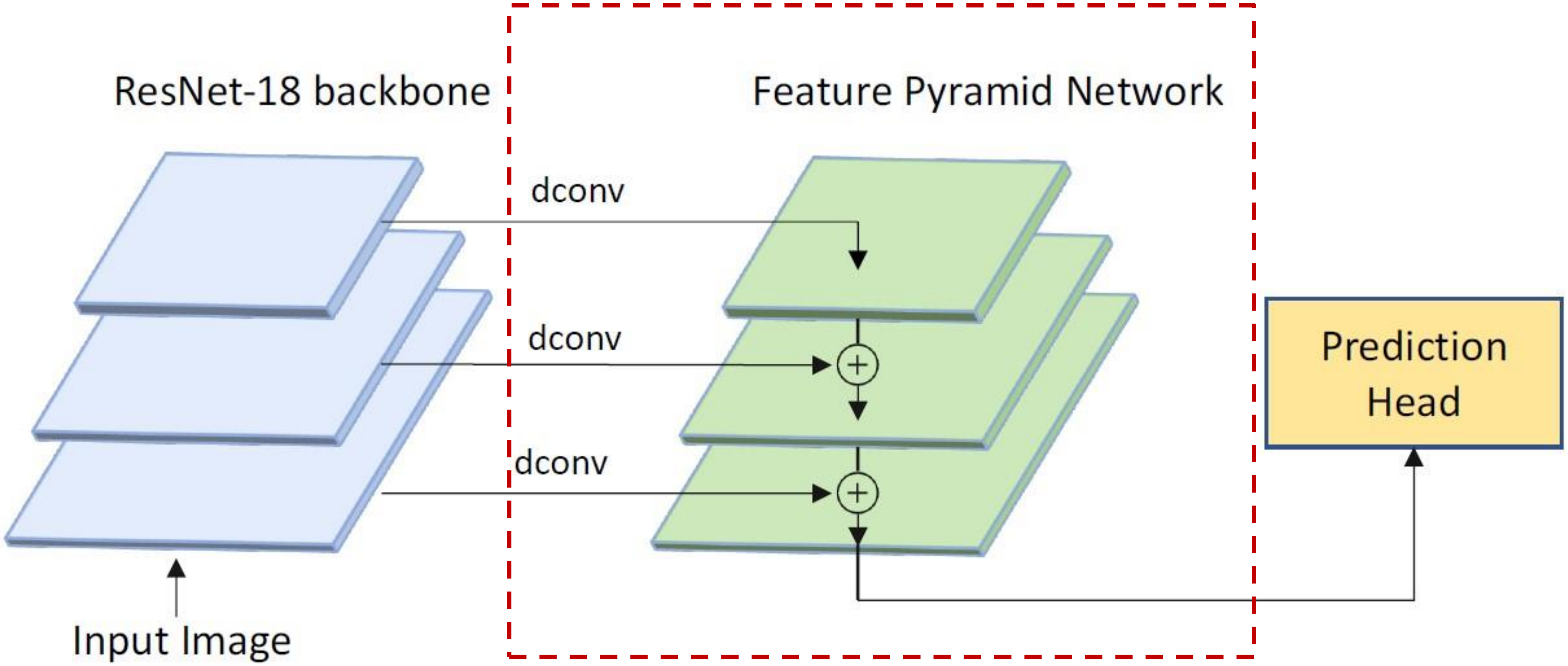
Model Architecture



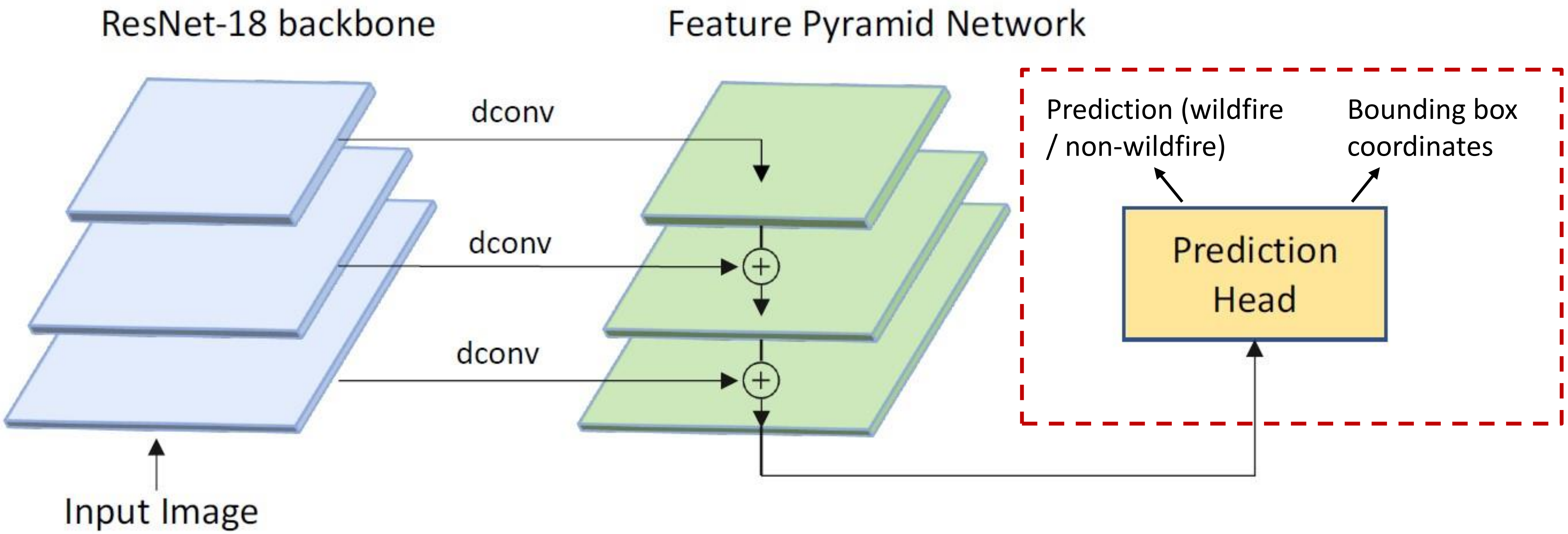
Model Architecture



Model Architecture



Model Architecture



Loss Function

$$loss = \frac{1}{N_{pos}}\left(\sum_{x,y} L_{cls}(p_{x,y}, c_{x,y}) + \sum_{x,y} \mathbb{1}_{\{c_{x,y}=1\}} L_{reg}(t_{x,y}, t^*_{x,y}) + \sum_{x,y} \mathbb{1}_{\{c_{x,y}=1\}} L_{cen}(t^*_{x,y})\right)$$

Loss Function

$$loss = \frac{1}{N_{pos}} (\underbrace{\sum_{x,y} L_{cls}(p_{x,y}, c_{x,y})}_{\text{Focal Loss}} + \sum_{x,y} \mathbb{1}_{\{c_{x,y}=1\}} L_{reg}(t_{x,y}, t^*_{x,y}) + \sum_{x,y} \mathbb{1}_{\{c_{x,y}=1\}} L_{cen}(t^*_{x,y}))$$

$p_{x,y}$: Predicted score

$c_{x,y}$: Ground truth label

Loss Function

$$loss = \frac{1}{N_{pos}}(\sum_{x,y} L_{cls}(p_{x,y}, c_{x,y}) + \underbrace{\sum_{x,y} \mathbb{1}_{\{c_{x,y}=1\}} L_{reg}(t_{x,y}, t^*_{x,y})}_{\text{IOU Loss}} + \sum_{x,y} \mathbb{1}_{\{c_{x,y}=1\}} L_{cen}(t^*_{x,y}))$$

$t_{x,y}$: Ground truth coordinates

$t^*_{x,y}$: Predicted coordinates

Loss Function

$$loss = \frac{1}{N_{pos}}(\sum_{x,y} L_{cls}(p_{x,y}, c_{x,y}) + \sum_{x,y} \mathbb{1}_{\{c_{x,y}=1\}} L_{reg}(t_{x,y}, t^*_{x,y}) + \sum_{x,y} \underbrace{\mathbb{1}_{\{c_{x,y}=1\}} L_{cen}(t^*_{x,y})}_{\text{Centerness Loss}})$$

$t^*_{x,y}$: Predicted coordinates

Loss Function

$$loss = \frac{1}{N_{pos}}\Big(\sum_{x,y} \underbrace{L_{cls}(p_{x,y}, c_{x,y})}_{\text{Focal Loss}} + \sum_{x,y} \overbrace{\underbrace{\mathbb{1}_{\{c_{x,y}=1\}} L_{reg}(t_{x,y}, t^*_{x,y})}_{\text{IOU Loss}} + \sum_{x,y} \underbrace{\mathbb{1}_{\{c_{x,y}=1\}} L_{cen}(t^*_{x,y})}_{\text{Centerness Loss}}}^{\text{Only calculated for positive samples}}\Big)$$

$p_{x,y}$: Predicted score

$c_{x,y}$: Ground truth label

$t_{x,y}$: Ground truth coordinates

$t^*_{x,y}$: Predicted coordinates

$t^*_{x,y}$: Predicted coordinates

Adaptive Training Sample Selection (ATSS)

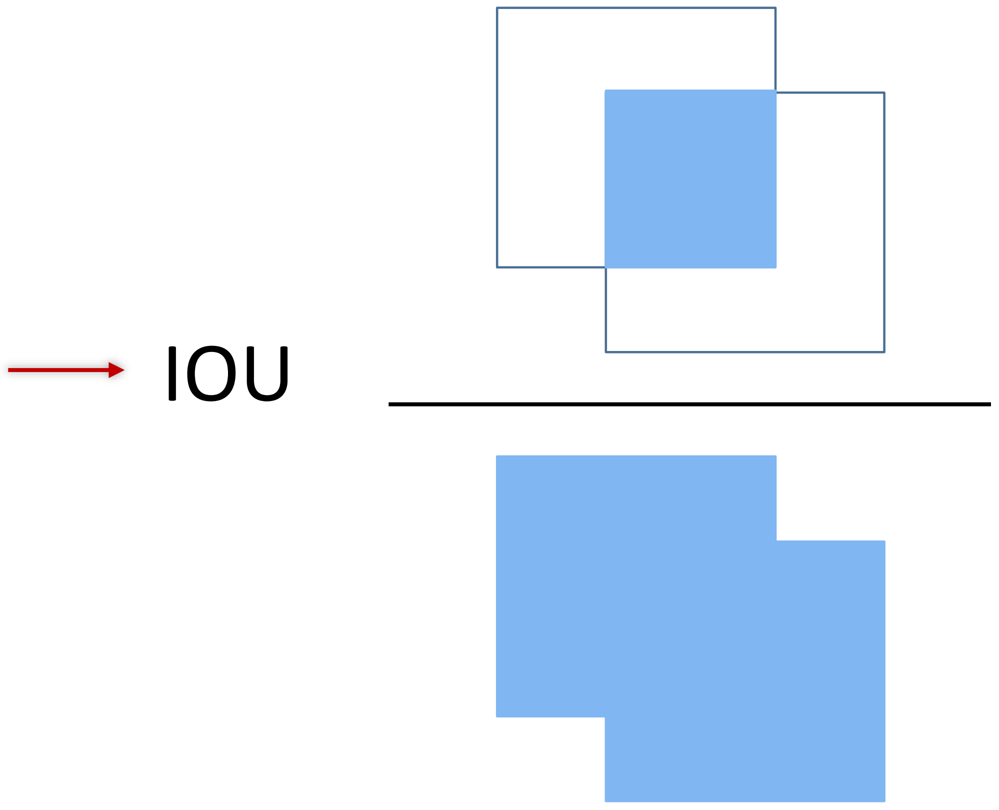
- Model performance is dependent on how pos/neg samples are selected
- ATSS selects samples based on statistical characteristics
- We use a modified version of ATSS

Modified Adaptive Training Sample Selection

Begin by considering all points inside the ground truth bounding box as candidate points

Modified Adaptive Training Sample Selection

Calculate IOU between ground truth bounding box and the bounding box predicted by each candidate point



Modified Adaptive Training Sample Selection

Calculate final score for each candidate point as follows:

$$Score_{x,y} = (IOU)_{x,y} * p_{x,y}$$

Then, calculate the threshold as follows:

$$T = \mu_{scores} + \sigma_{scores}$$

Samples with score > T are considered as positive samples

Modified Adaptive Training Sample Selection

Original ATSS

Modified ATSS

Results

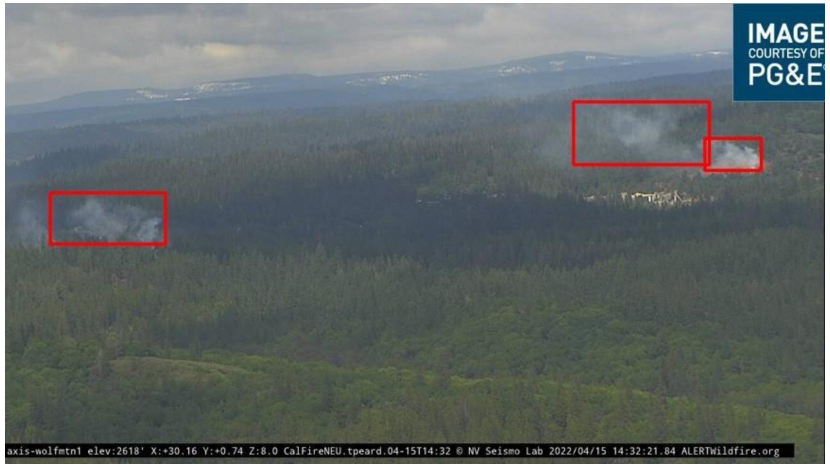


IMAGE
COURTESY OF
PG&E
axis-wolfmtn1 elev:2618' X:+30.16 Y:+0.74 Z:8.0 CalFireNEU.tpeard.04-15T14:32 © NV Seismo Lab 2022/04/15 14:32:21.84 ALERTWildfire.org


60 48 09/08/07 S 183° HPWREN:MW
ALERT
SDG&E CAMERAS
axis-mtwoodson elev:2881' X:+64.64 Y:-3.39 Z:1.0 CalFireMVU.nsoto.04-17T11:54 © UCSD/HPWREN 2022/04/19 09:55:25.46 ALERTWildfire.org

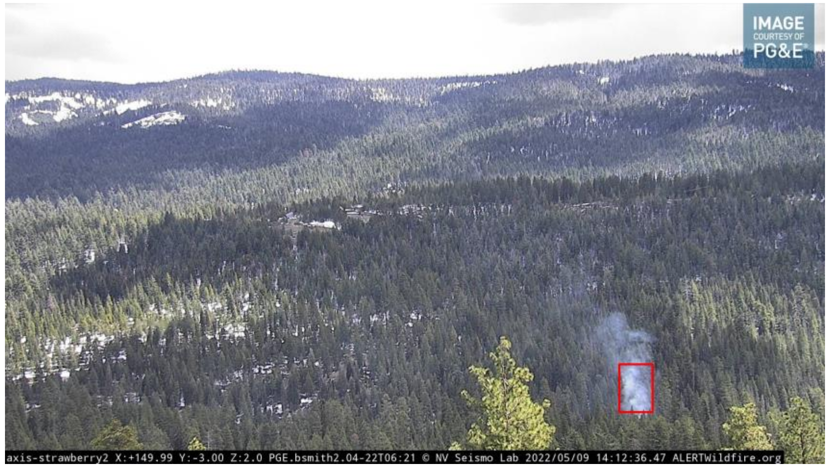


IMAGE
COURTESY OF
PG&E
axis-strawberry2 X:+149.99 Y:-3.00 Z:2.0 PGE.bsmith2.04-22T06:21 © NV Seismo Lab 2022/05/09 14:12:36.47 ALERTWildfire.org


axis-oatmtnnorth2 elev:3451' X:+168.02 Y:-4.83 Z:12.2 SCE.twhitman.05-15T16:00 © NV Seismo Lab 2022/05/15 16:34:34.25 ALERTWildfire.org

Results

- Highly accurate (91.6%)
- High true positive rate (81.6%) and low false positive rate (7.5%)
- Evaluation Study (Jun’22 – Jul’22): Total of 869 wildfire smoke events

Time taken to detect wildfire smoke	% of smoke events detected (cumulative)
Within 60 seconds from start of the smoke	60.5%
Within 3 minutes from start of the smoke	76.8%
Within 5 minutes from start of the smoke	86.9%
Over 5 minutes from start of the smoke	100%

Conclusion

- The system is currently being used in the USA to monitor and detect wildfire smoke from hundreds of cameras daily
- First responders can respond faster and protect people and property better
- Our system is also being used by utility companies to protect transmission lines and other infrastructure assets
- ML based monitoring systems are crucial in the fight against climate change