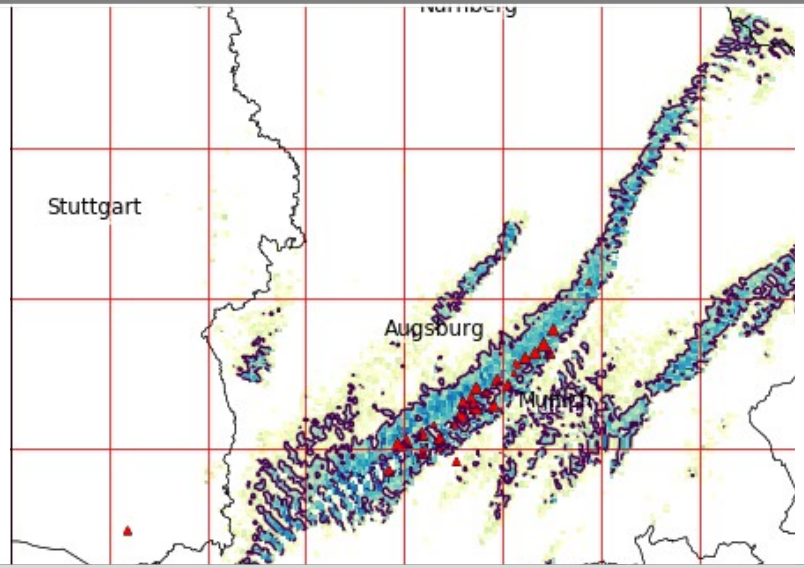
Karlsruhe Institute of Technology

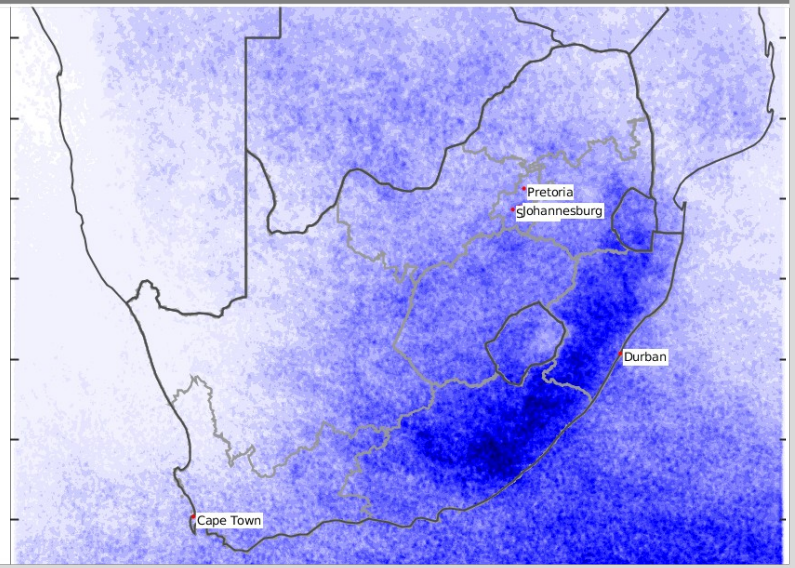
ECSS
European Conference on Severe Storms

Hail climatology and risk assessment combining satellite, radar and climate model data

Heinz Jürgen PUNGE

INSTITUTE OF METEOROLOGY AND CLIMATE RESEARCH – TROPSPHERE DEPARTMENT





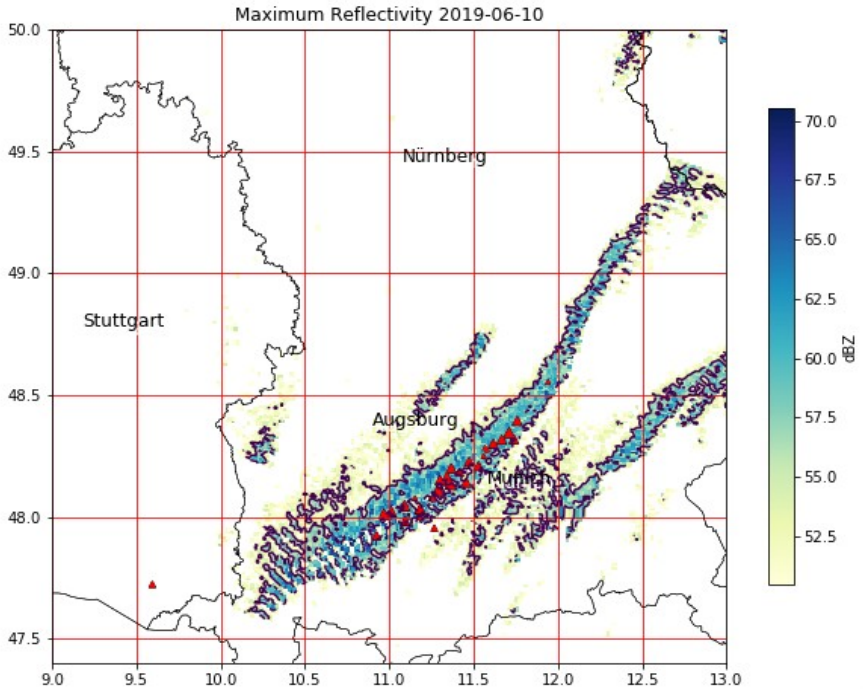
10-12 June 2019 thunderstorms

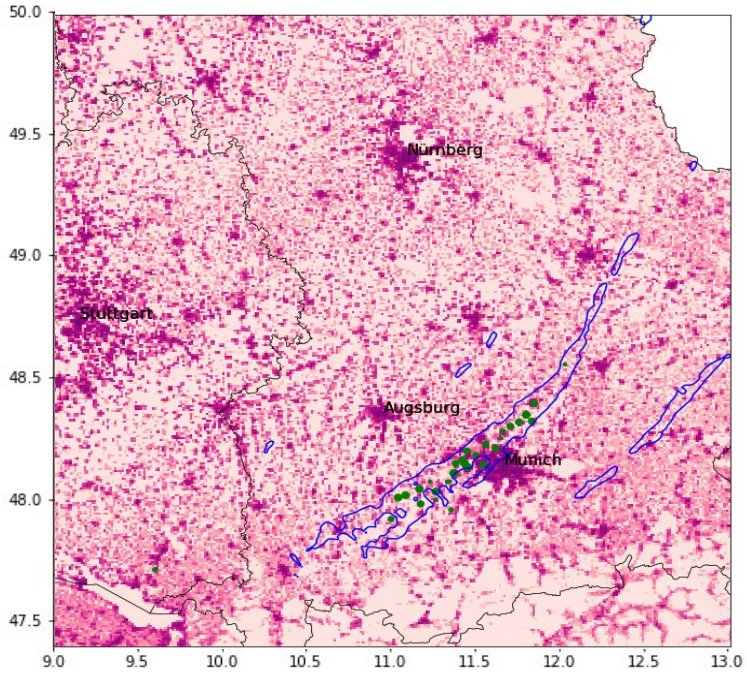
- Lubusz province: Hail stones up to 12cm on 11 June
- Berlin: flooding, wind damage on 11 and 12 June
- Near Munich: Significant hail damage on 10 June
- Cost estimate EUR 700-900 million

Munich hail storm on June 10, 2019

Storm track analysis using radar remote sensing

- Hail streak length over 100 km
- Exceptionally wide at early stages
- Diameter of largest stones: 6cm
- Total Damage ~ EUR 650 million (GDV)



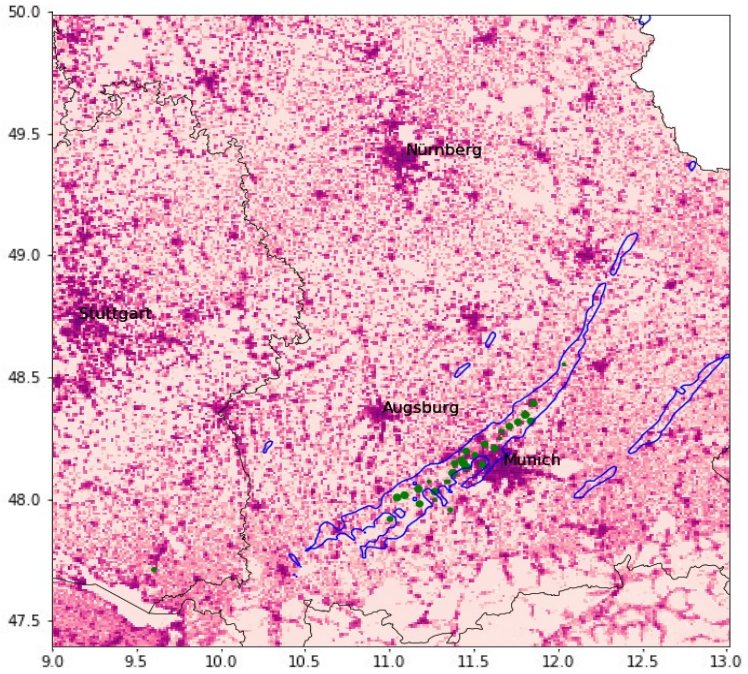


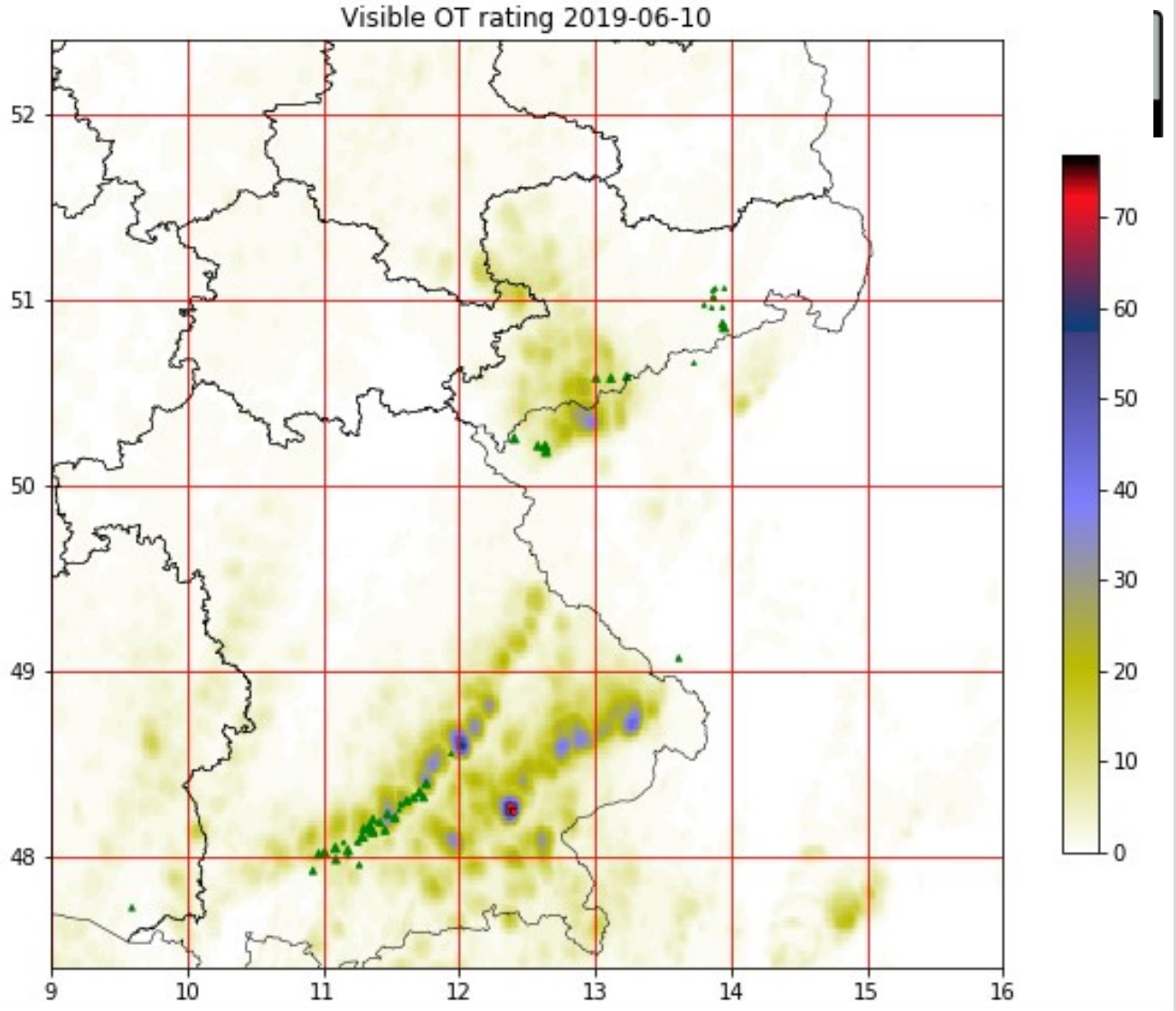
value of assets

Munich hail storm on June 10, 2019

Storm track analysis using
Radar (bottom) and Satellite (right) remote sensing

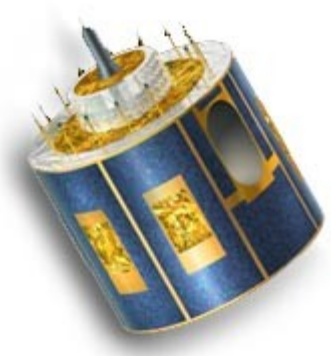
- Hail streak length over 100 km
- Exceptionally wide at early stages
- Diameter of largest stones: 6cm
- Damage several EUR 100 million



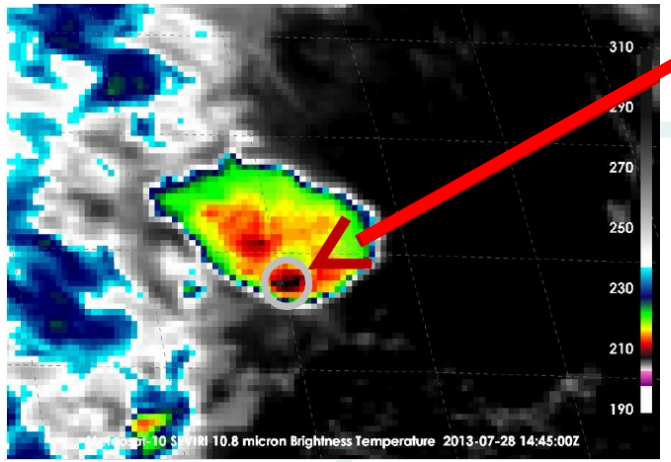


Hail observations: Satellite

- Overshooting tops (OTs): intrusions of convective cloud to lower stratosphere
- Indicator of very strong convective updrafts
- Detection of cold pixels in IR satellite imagery



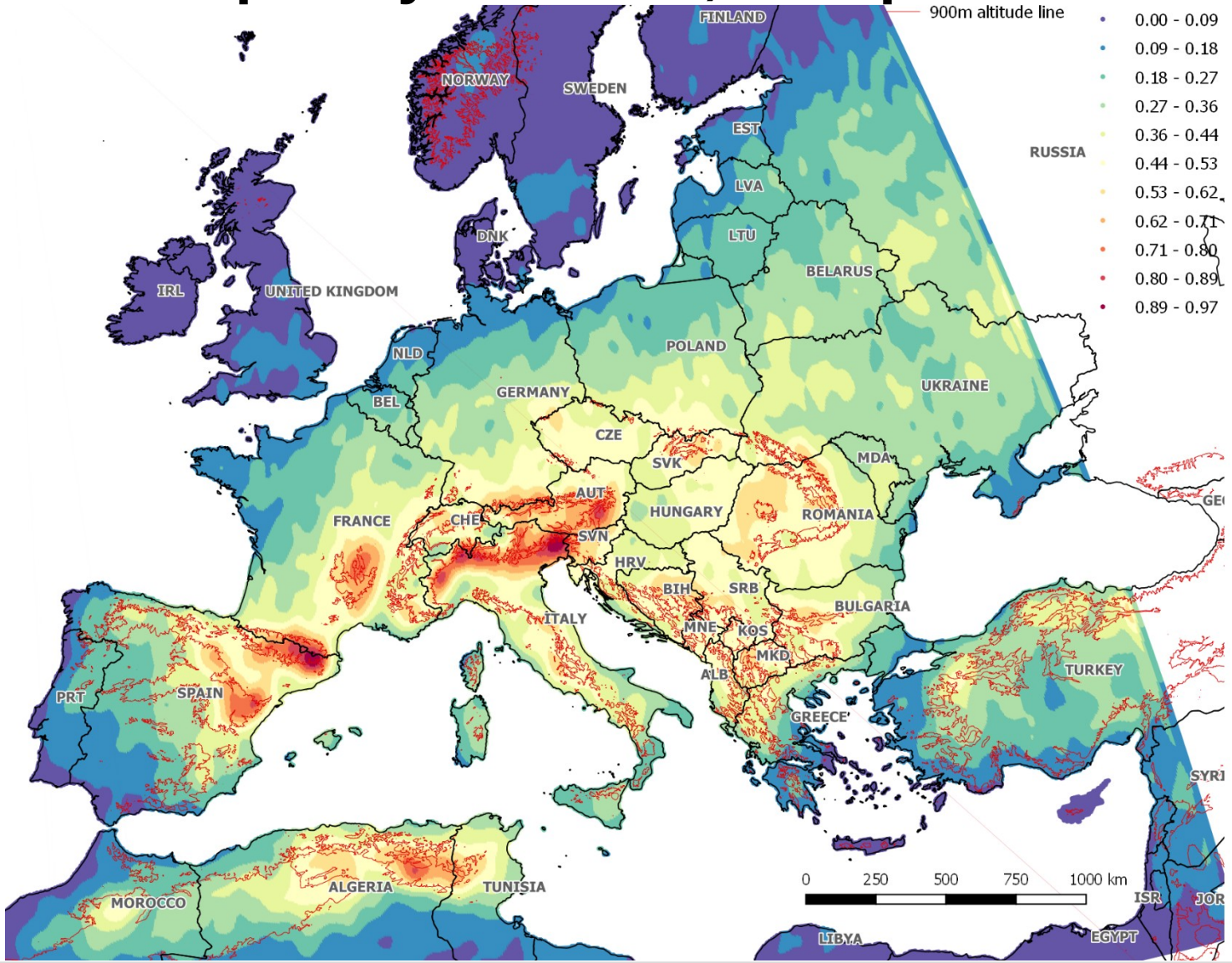
Meteosat



Meteosat (MSG):
SEVIRI instrument
cloud top temperatures

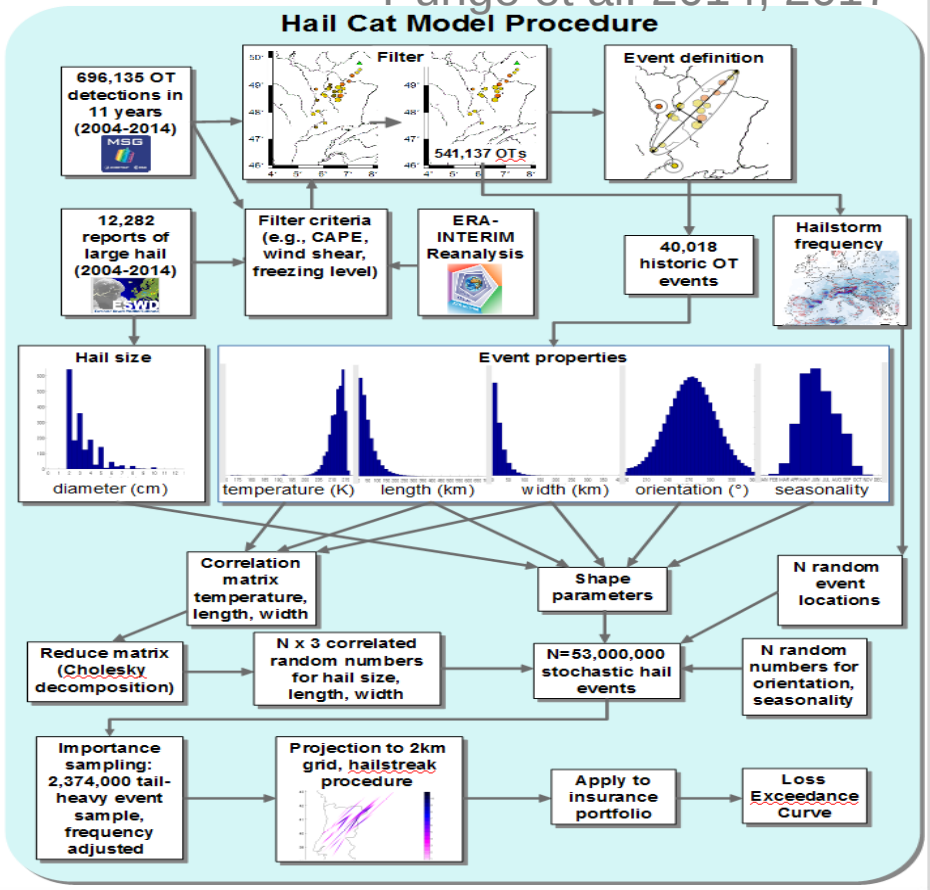
28 July 2013,
13-17 UTC

Hail frequency estimate, Europe



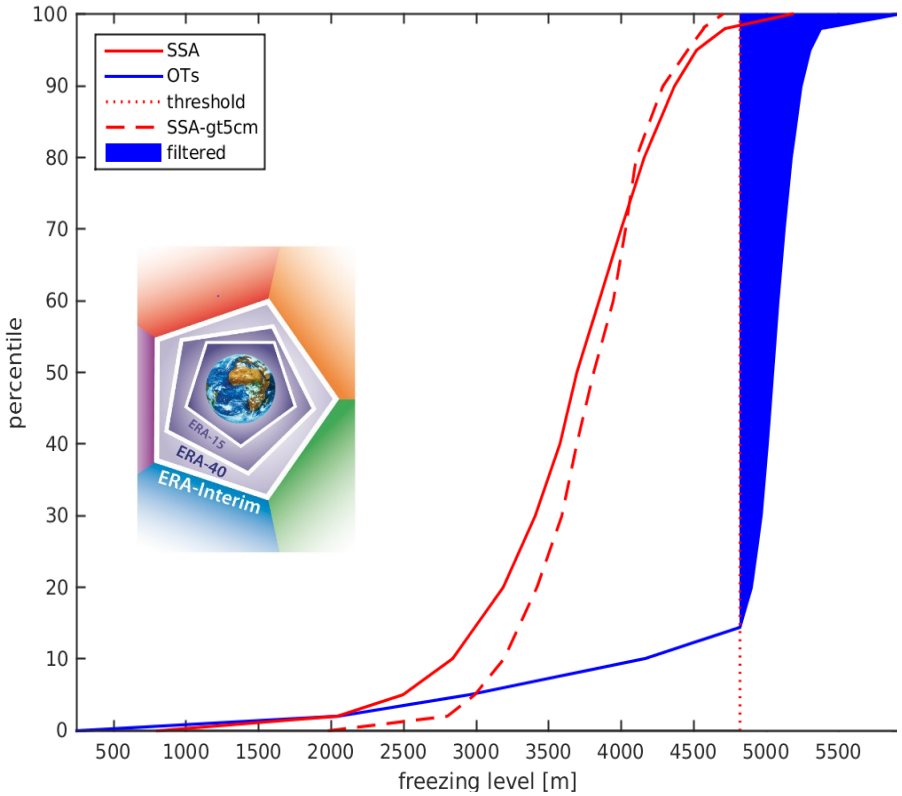
European Hail Model

Punge et al. 2014, 2017



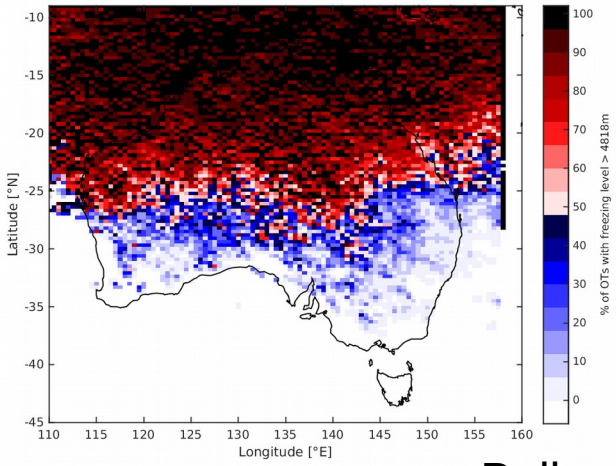
Overshooting top hail proxy for Australia

Filter OT data with reanalysis of hail report conditions

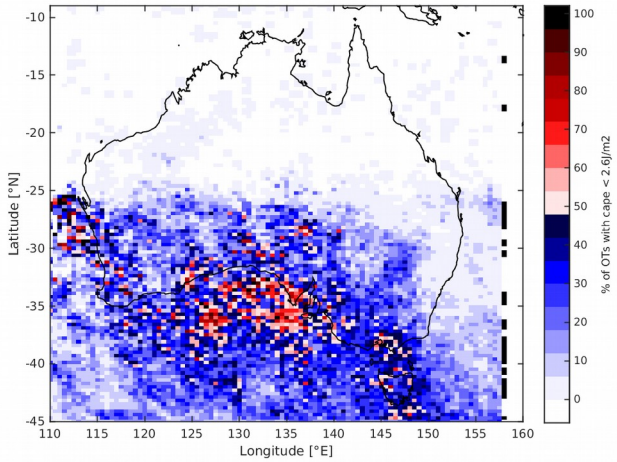


Bedka et al 2018

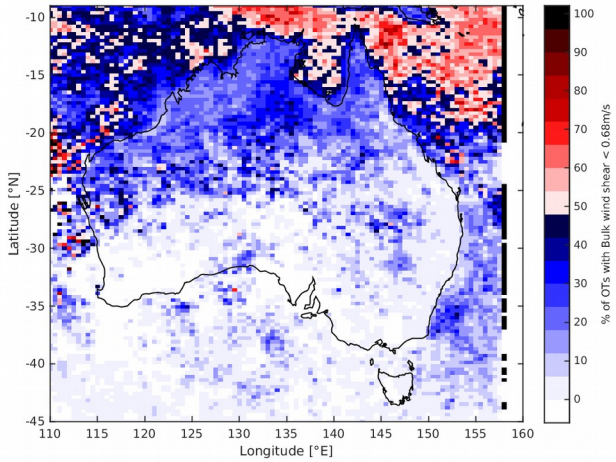
Freezing Level height



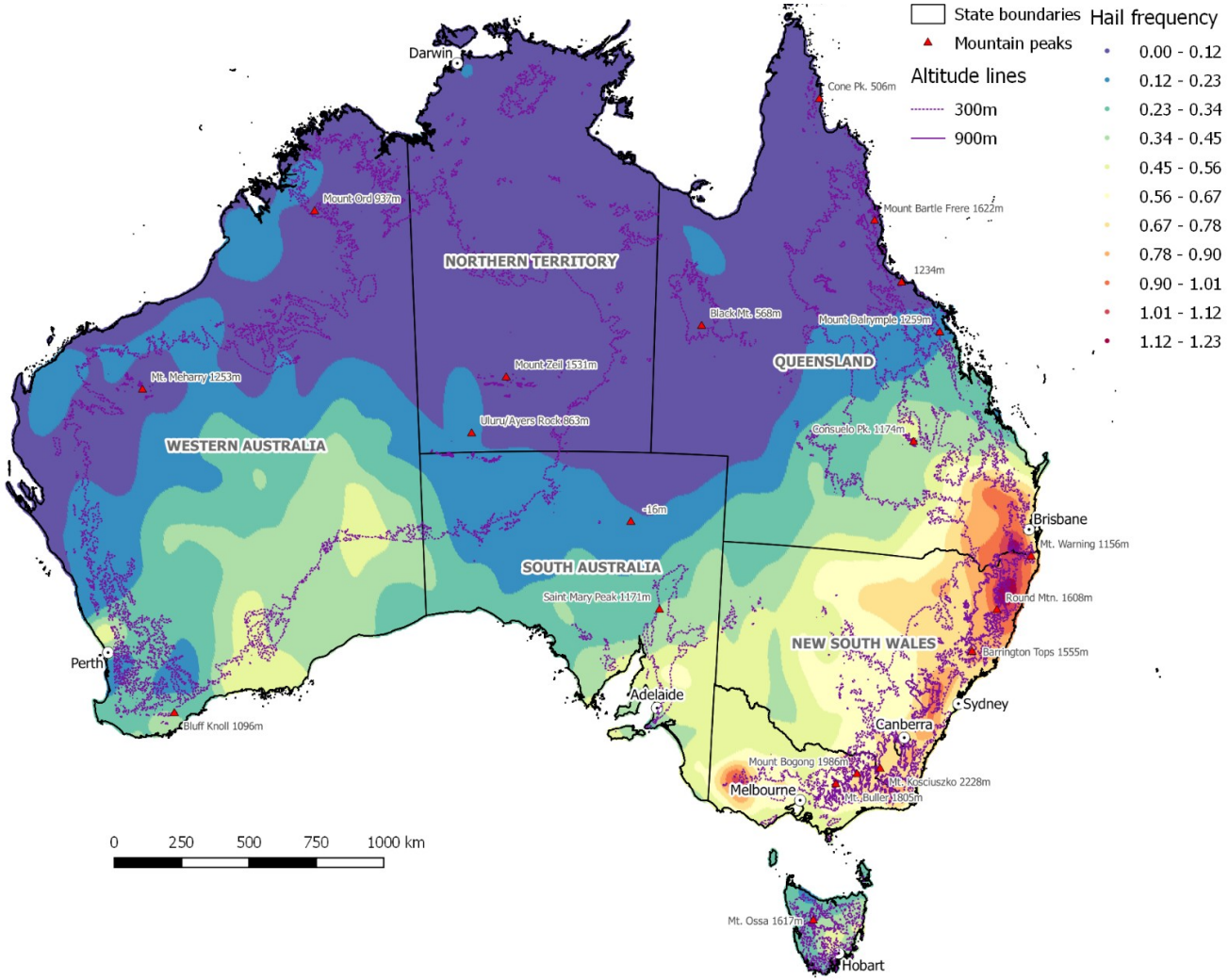
CAPE



Bulk wind shear



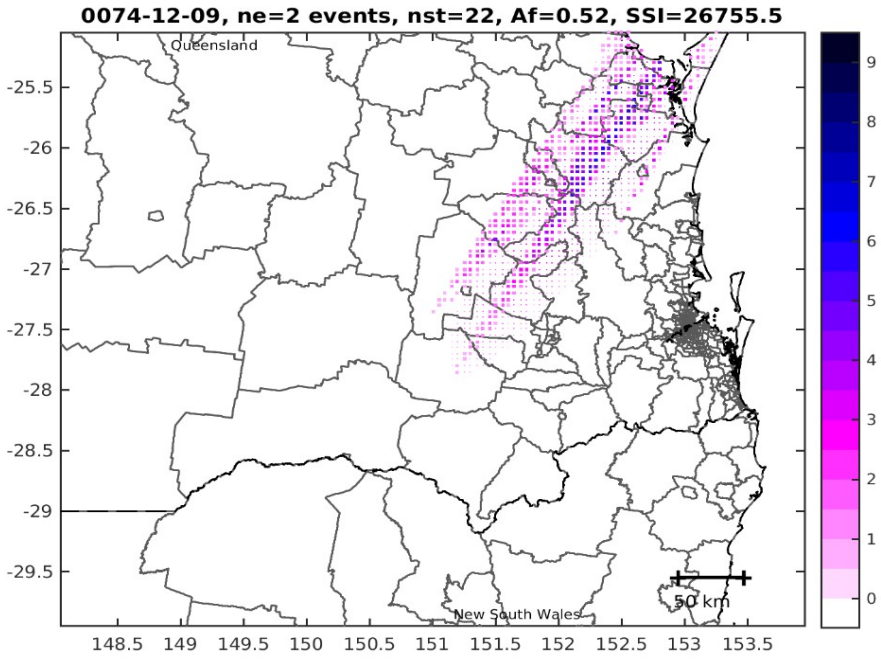
Hail frequency estimate for Australia



Karlsruhe Institute of Technology

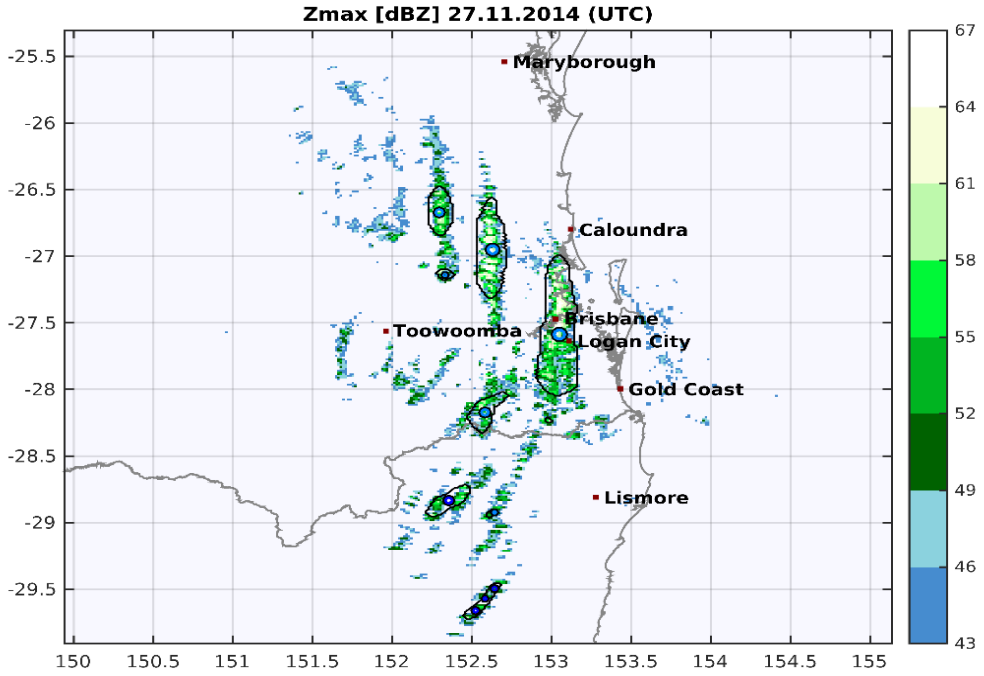
Willis Re

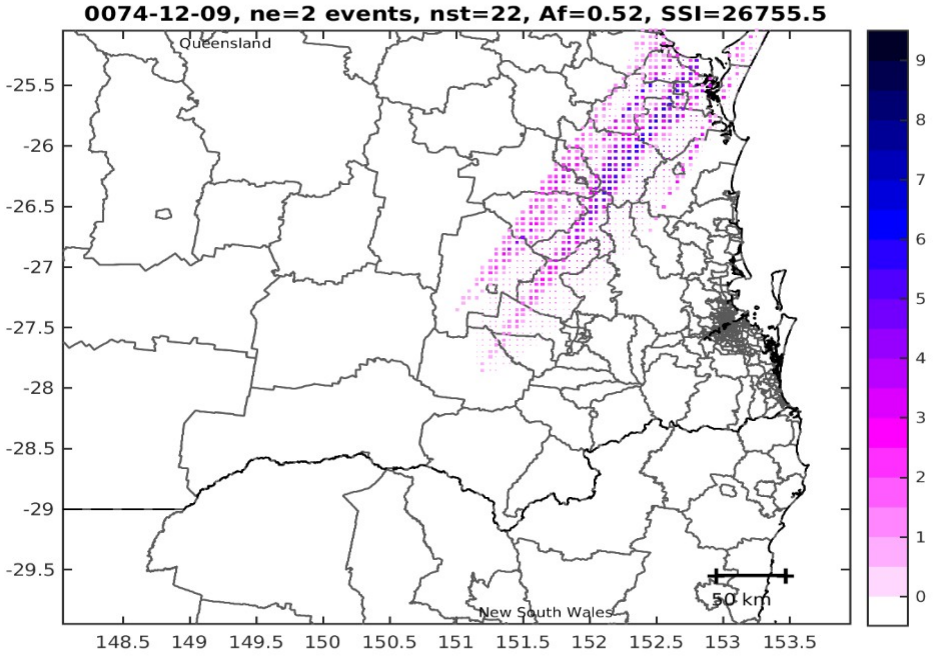
hail model under construction...



Stochastic modelling of hailstreaks in Australia

- Derive properties of hail streaks from radar (length, with, orientation, date...) as distribution function
- Estimate correlation among these
- Construct O(10^6) new streaks using these distributions





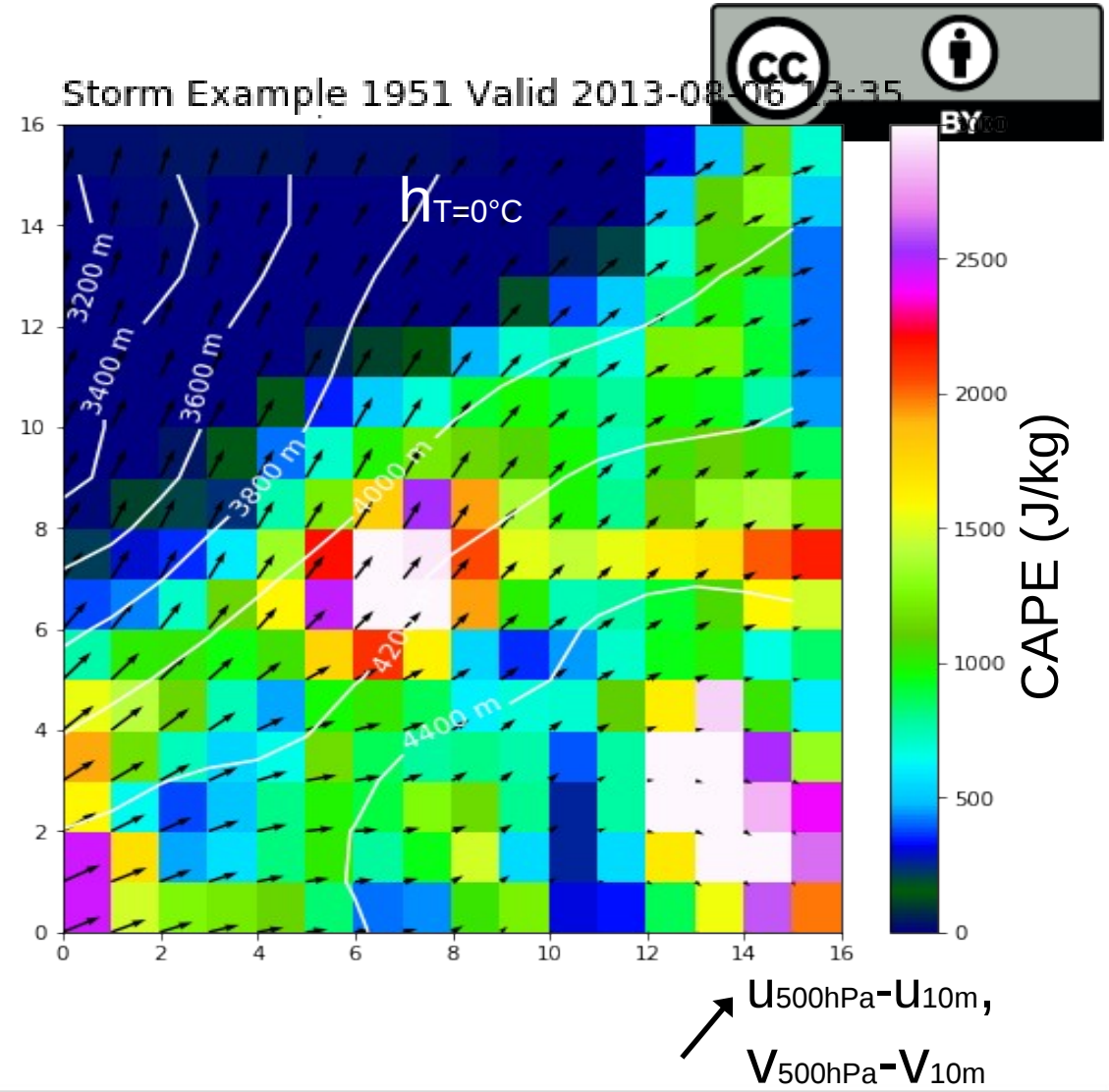
Machine learning hailstorm environment

Approach:

- Train algorithm to recognize typical patterns in the reanalysis conditions of past hail events

- Use reports of severe rain as null cases

- Classify remote sensing data as *hail* or *rain*



Machine learning hailstorm environment

Neural networks (NNs) in Tensorflow / Keras

256 grid points x 7 variables:

CAPE,

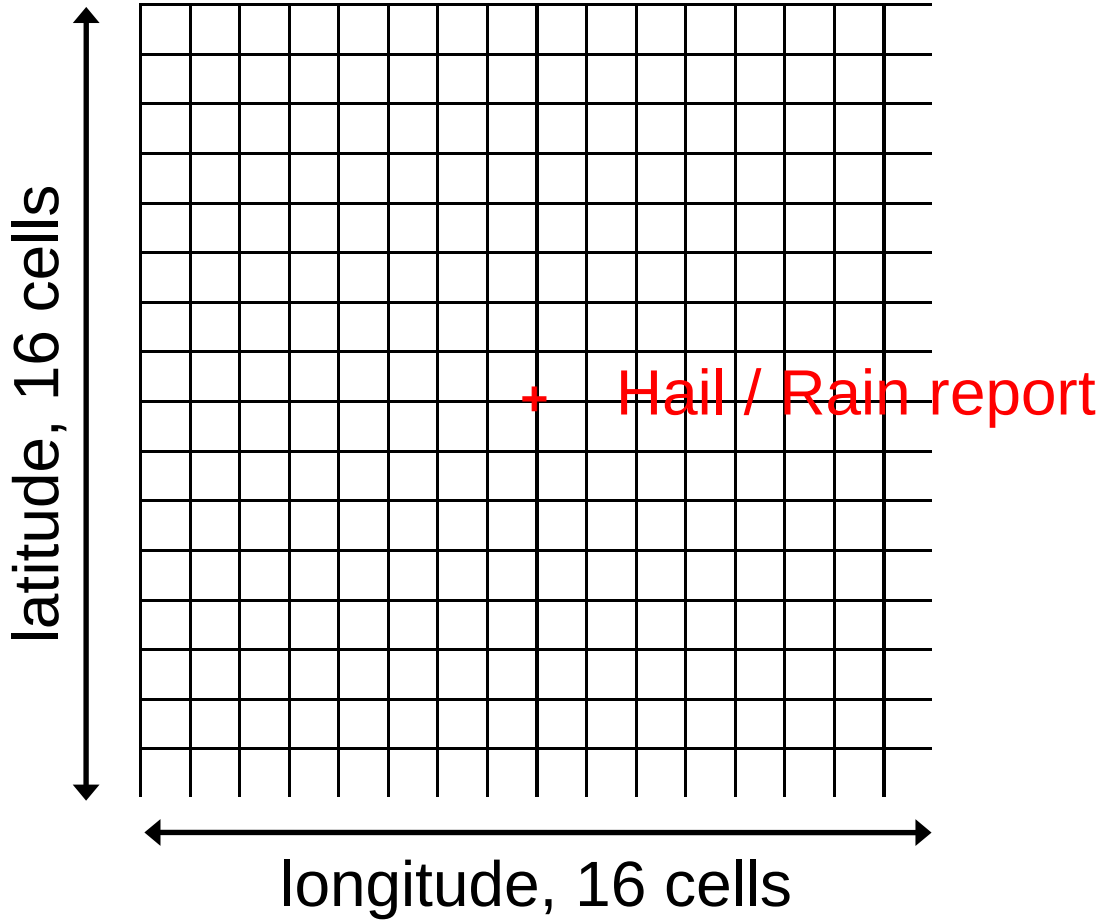
u_{500hPa}-u_{10m}, v_{500hPa}-v_{10m},

$h_{T=0°C}$,

$\theta_{e850hPa}$ - $\theta_{e500hPa}$,

T_{700hPa}-T_{500hpa},

T_{2m}-T_{d2m}



Dense / Convolutional NN Training

1. Dense neural network (DNN)

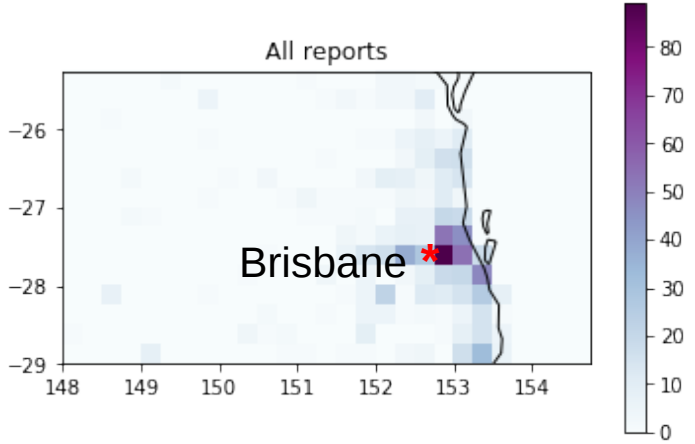
2. Convolutional neural network (CNN)

Layer (type)	Output Shape	Param #
input_1 (InputLayer)	(None, 16, 16, 7)	0
conv2d_1 (Conv2D)	(None, 16, 16, 8)	1408
activation_1 (Activation)	(None, 16, 16, 8)	0
dropout_1 (Dropout)	(None, 16, 16, 8)	0
average_pooling2d_1 (Average	(None, 8, 8, 8)	0
conv2d_2 (Conv2D)	(None, 8, 8, 16)	3216
activation_2 (Activation)	(None, 8, 8, 16)	0
dropout_2 (Dropout)	(None, 8, 8, 16)	0
average_pooling2d_2 (Average	(None, 4, 4, 16)	0
conv2d_3 (Conv2D)	(None, 4, 4, 32)	12832
activation_2 (Activation)	(None, 4, 4, 32)	0
dropout_2 (Dropout)	(None, 4, 4, 32)	0
average_pooling2d_3 (Average	(None, 2, 2, 32)	0
flatten_1 (Flatten)	(None, 128)	0
dense_1 (Dense)	(None, 1)	129
activation_4 (Activation)	(None, 1)	0

Total params: 17,585
Activation: Relu
Optimizer: Stochastic Gradient Descent

Calibration Region:

Southeast Queensland



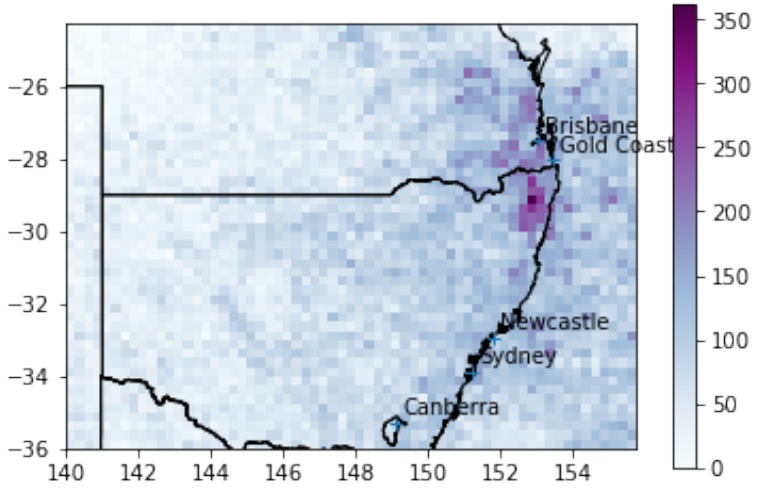
Brier Skill Score (BSS) on independent sample:

- Dense 0.43
- Convolutional 0.53
- Combined: 0.50

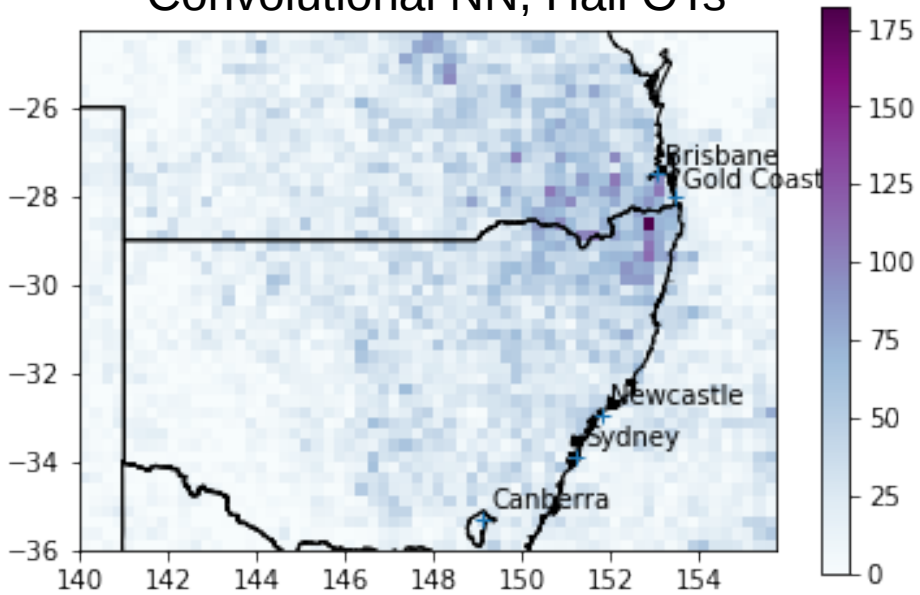
Application to discriminate hail / rain related OTs

Karlsruhe Institute of Technology

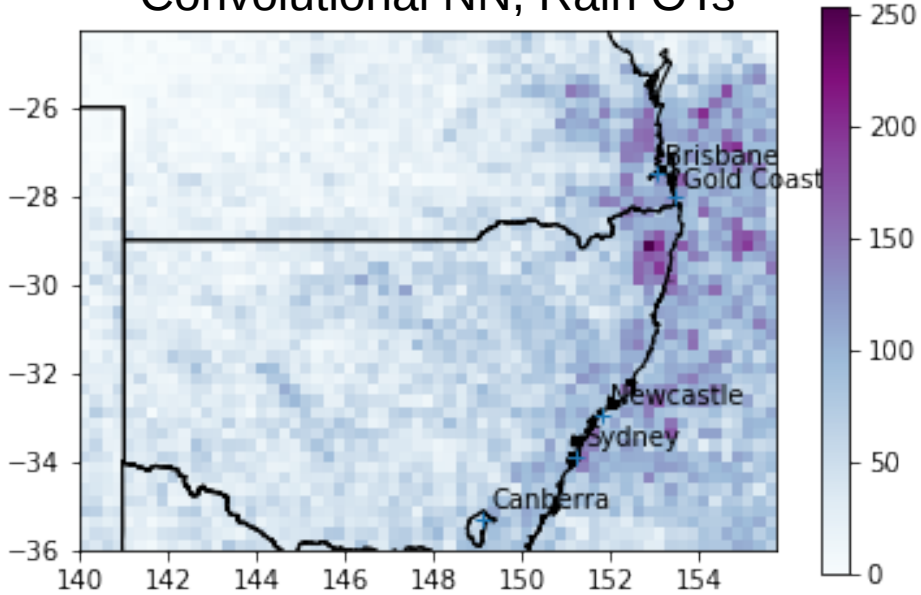
All OTs



Convolutional NN, Hail OTs



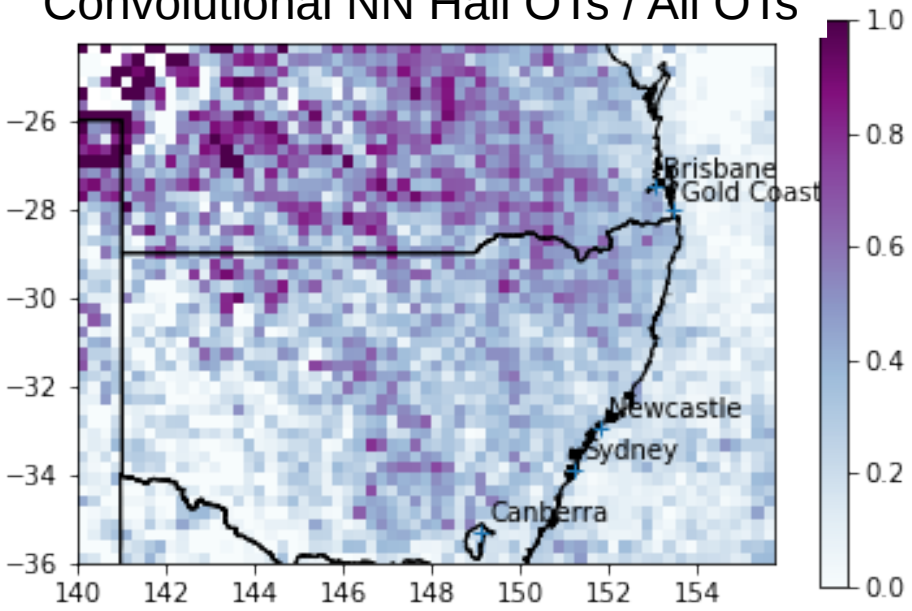
Convolutional NN, Rain OTs



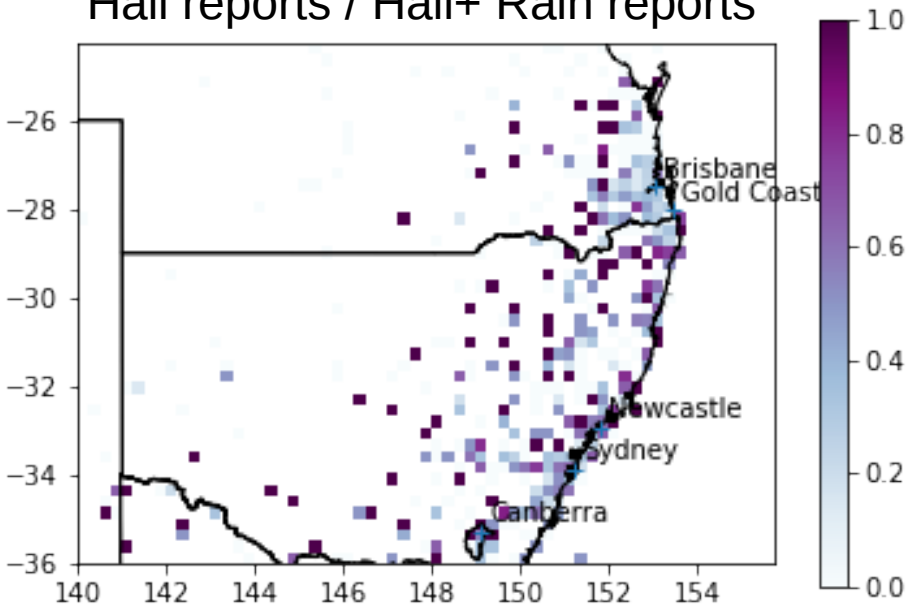
Application to discriminate hail / rain related OTs

Karlsruhe Institute of Technology

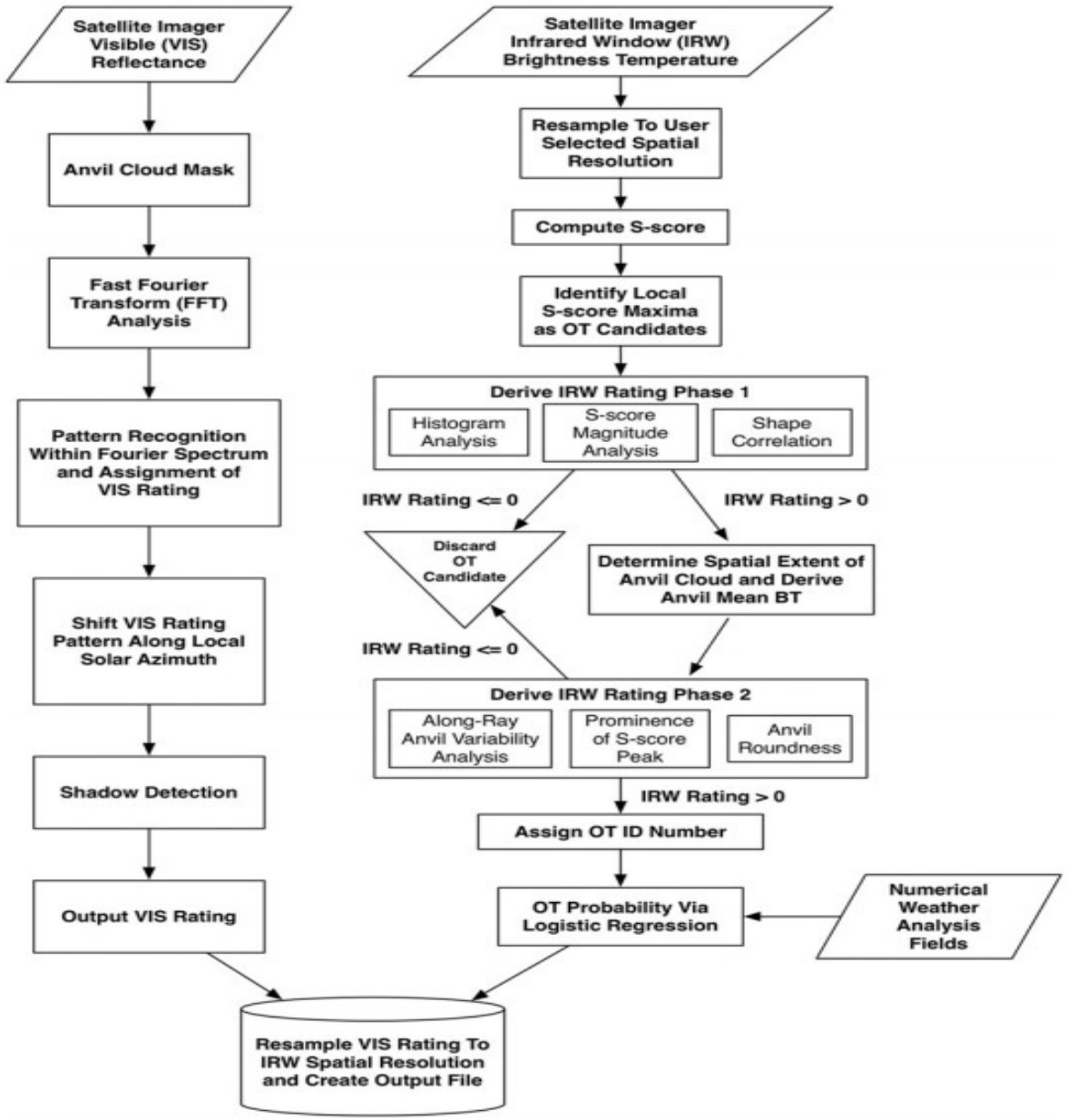
Convolutional NN Hail OTs / All OTs

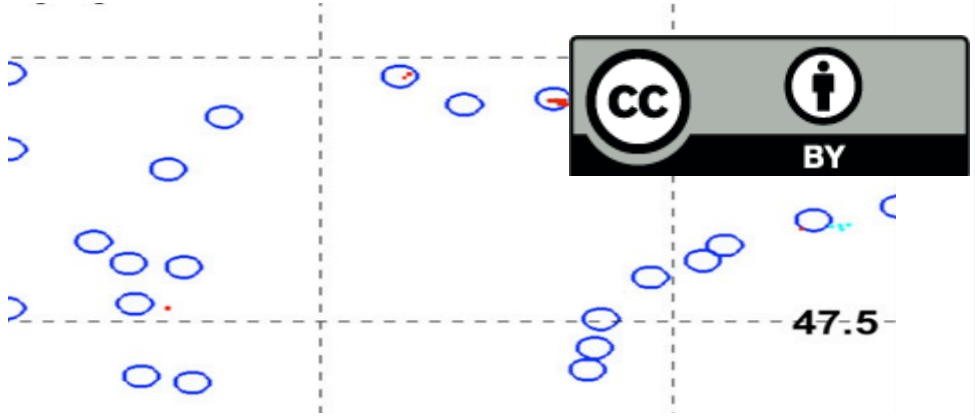


Hail reports / Hail+ Rain reports



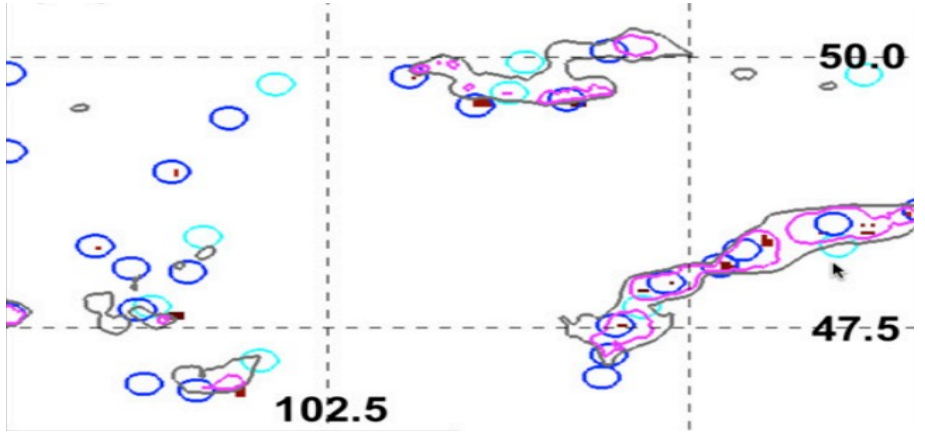
Overshooting cloud tops, new method (K. Bedka)





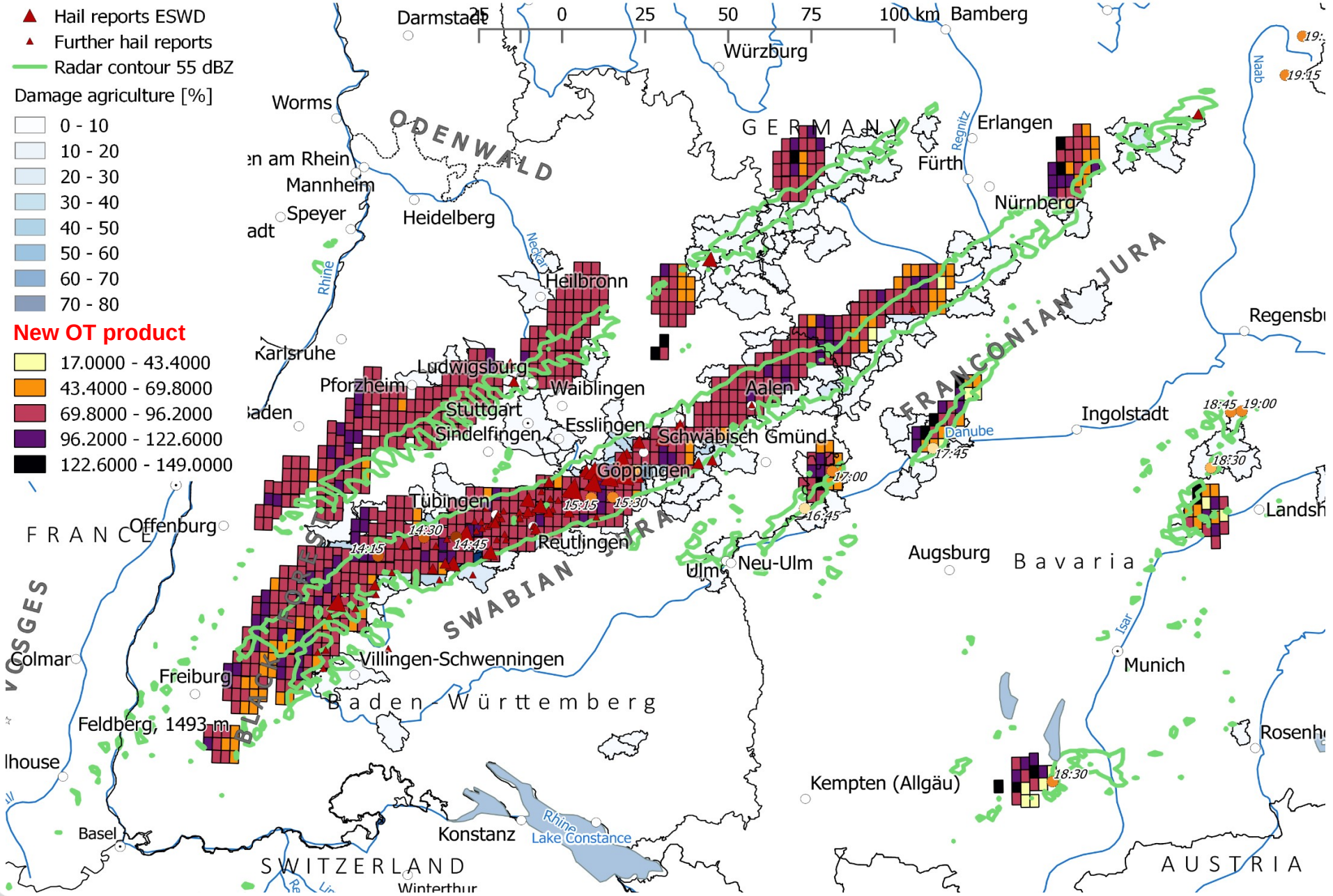
Bedka, 2010

OT, Manual identification



Bedka and Khlopenkov, 2016

No OT (Manual)



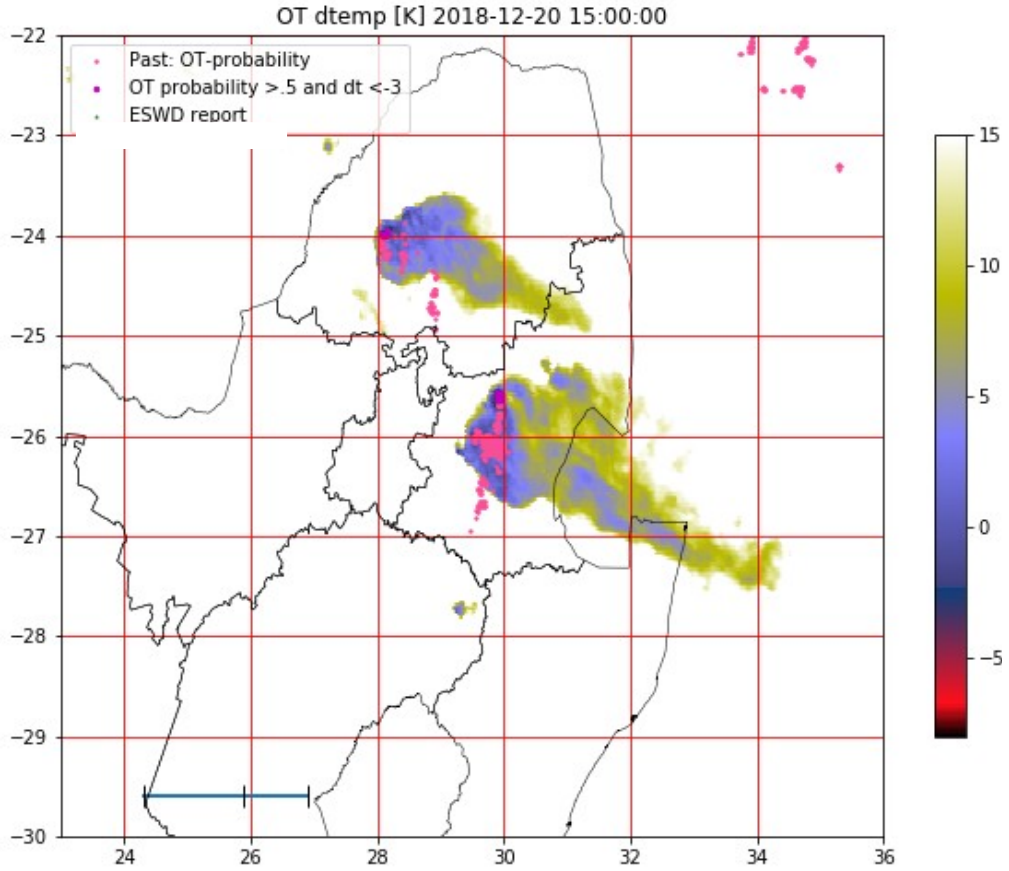
Karlsruhe Institute of Technology

Reutlingen, Germany, 28 July 2013

Total loss:
4.8 bn €
Insured loss,
27/28 July:
2.8 bn €

Munich Re, 2015

Hailstorms in South Africa



Conclusions

Hail risk model based on **satellite + reanalysis + reports** in the market for Europe

Australia: Combine **satellite + reanalysis + radar + reports** using convolutional neural network

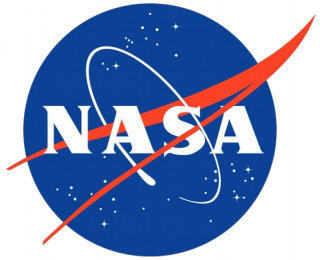
Next-generation satellite product + next-generation reanalysis + reports to understand hail hazard in South Africa

Conclusions

Hail risk model based on **satellite + reanalysis + reports** in the market for Europe

Australia: Combine **satellite + reanalysis + radar + reports** using convolutional neural network

Next-generation satellite product + next-generation reanalysis + reports to understand hail hazard in South Africa

… and: Assessment of Low Earth Orbit satellite hail products + Lightning detection under assessment in cooperation with  and Willis Towers Watson