Introduction to Causality

AI4ER MRes Workshop

Schedule

1-2pm: Introduction to Causality lecture and discussion

2-2.15pm: break

2.15-3.15pm: Practical Causal inference lecture/discussion, followed by going through the notebook examples and questions

3.15-3.45pm: Tea/informal questions and discussion

3.45-4.15pm: Causal discovery lecture and discussion

4.15-4.45pm: Working through the code and trying on some synthetic data

4.45pm-5pm: Wrap up and hometime!

First - what is causality?

- Thoughts?
- What do we mean when we say ‘causal relationship’?

It is a big question…

Definitions of causality

Counterfactual theory of causality (David Hume, David Lewis)

- We define causation as a counterfactual relation.
  - Hume (18th century): “where, if the first object had not been, the second never had existed.”
  - Lewis (1973): “An event E causally depends on C if, and only if, (i) if C had occurred, then E would have occurred, and (ii) if C had not occurred, then E would not have occurred.”

- What do we think?

Probabilistic causality

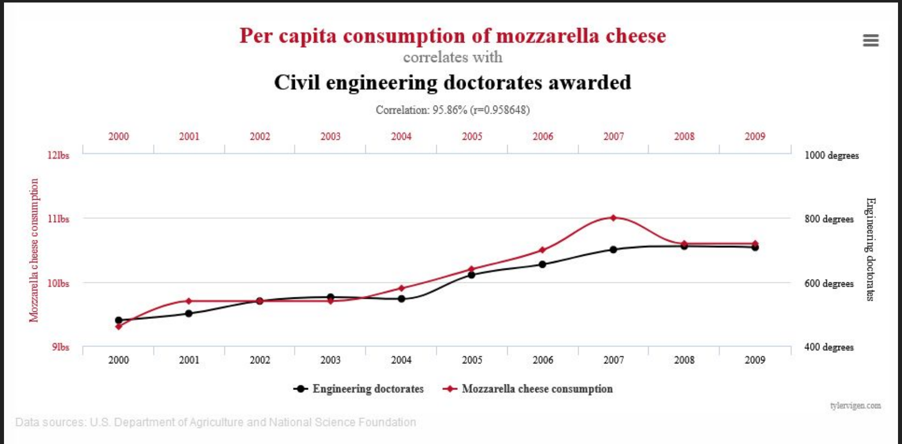
- Our previous definition is narrow.
- It does not allow for causation that increases the probability of something…it only allows for binary/deterministic cause and effect.

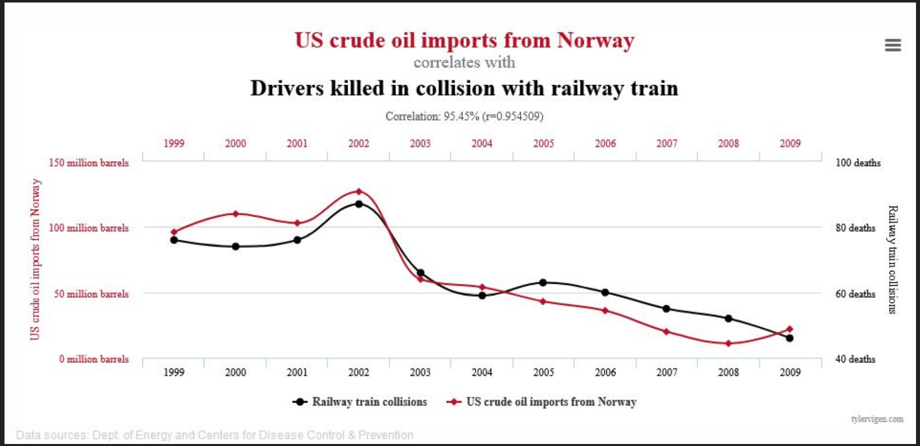
- We need probabilistic causality to cope with this.
- P(lung cancer | smoking) > P(lung cancer)
- We need extra conditions too…temporality, for example.

Now we have a feel for causality…

- Why do we care about it?
- Why is it particularly important for machine learners to know about it?

Correlation does not amount to causation!





Source: https://www.tylervigen.com/spurious-correlations

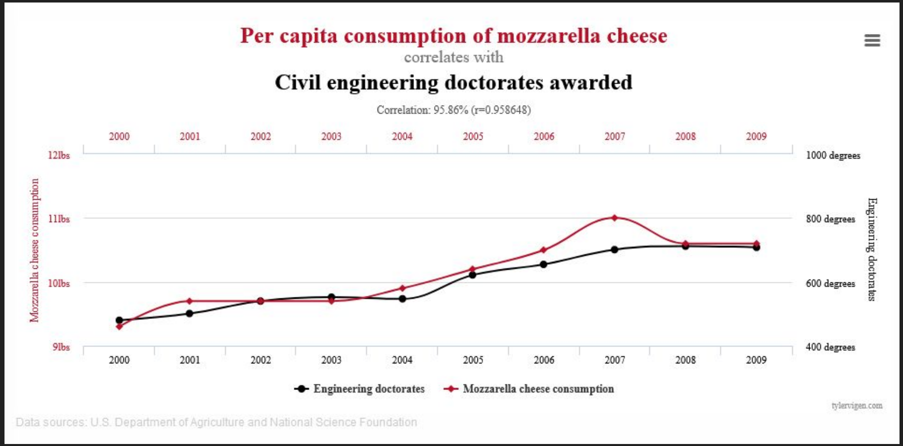



The key point is that ML is based on **correlations!**

- Linear regression, neural networks, transformers…all work based on correlations.
- And they work (sometimes) (amazingly) well!
- **This is often fine!!!**

For prediction, this is basically fine!

- If we are **only** interested in making predictions, this is usually ok.
- We do all the usual business of retrieving and cleaning a large dataset, making sure it is representative of our test data, optimisation, etc. etc.
- We can train our model, make predictions and they will probably be fine…

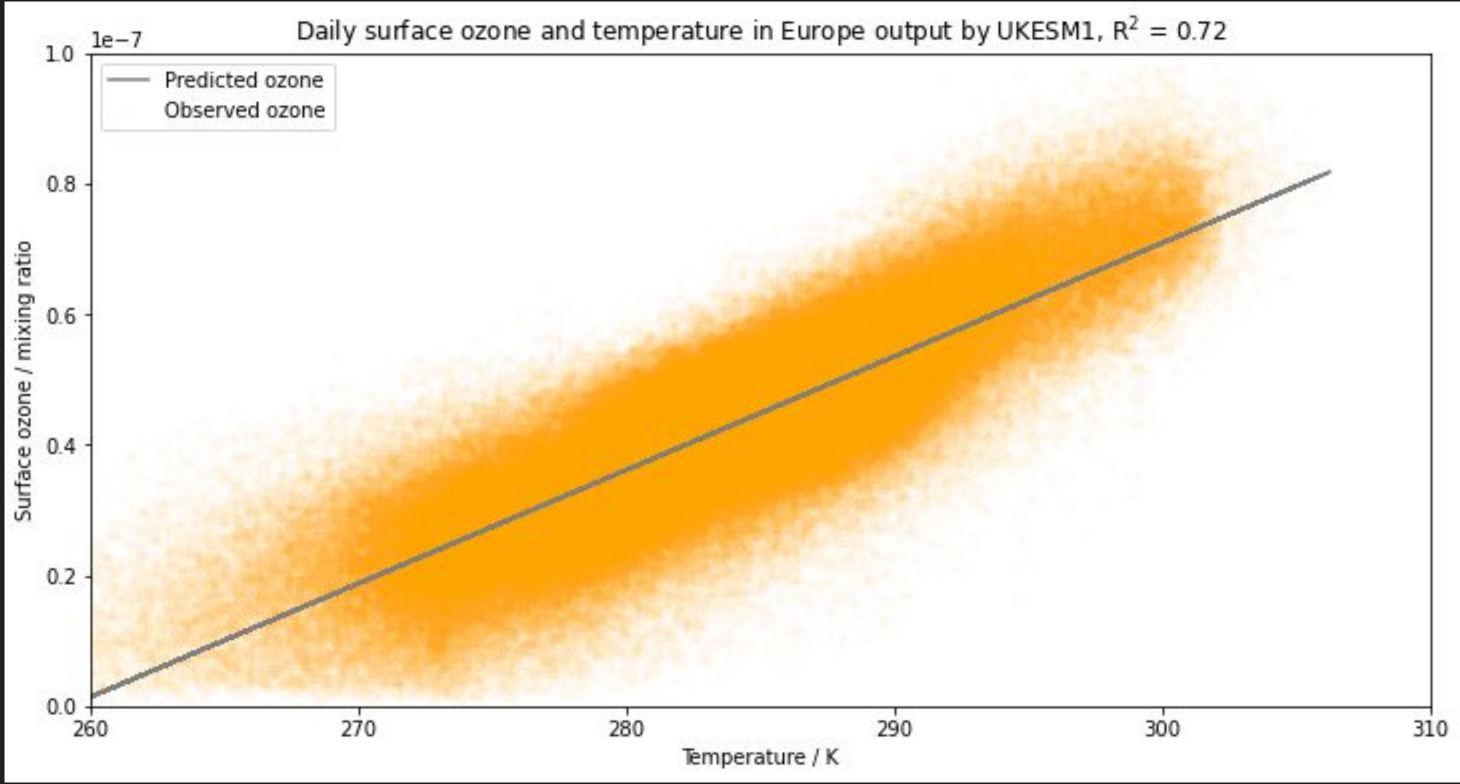


However!

- **If we want to do more than prediction on a very similar test set,** we are going to run into problems.

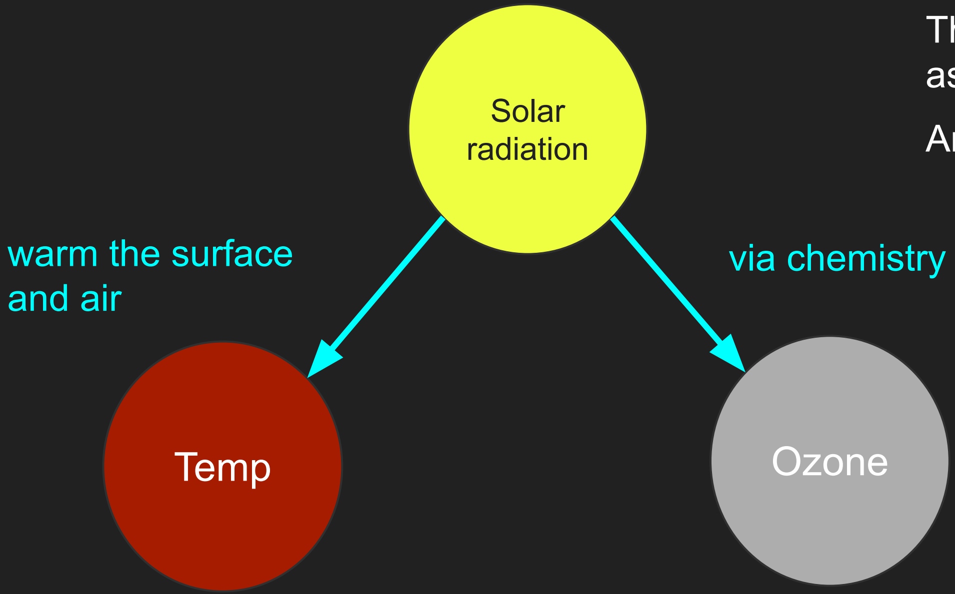
- In an ideal world, what else might we like to do with our models other than prediction? What are the most **useful** 'models' of the world that you know of? What do they give us?

Can we **predict** ozone pollution from temperature?



Mmmm, what a lovely ML model…

What if we actually want to **intervene**, to reduce ozone?



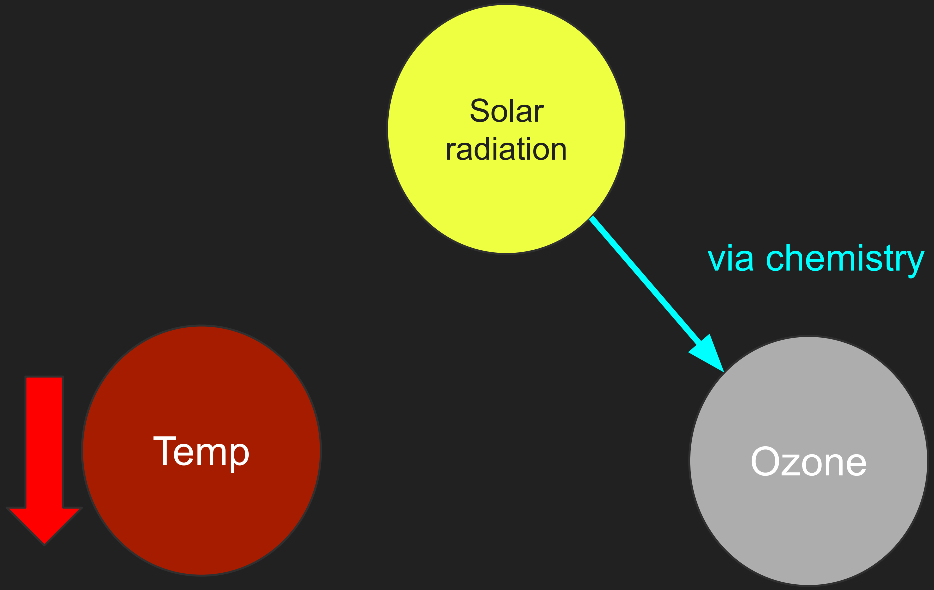
This sort of diagram is known as a **Directed Acyclic Graph**

Arrows denote a causal effect

This leads to temperature and ozone being **well correlated**; but there is no causal link!

Let’s follow the ‘advice’ of our ML model…

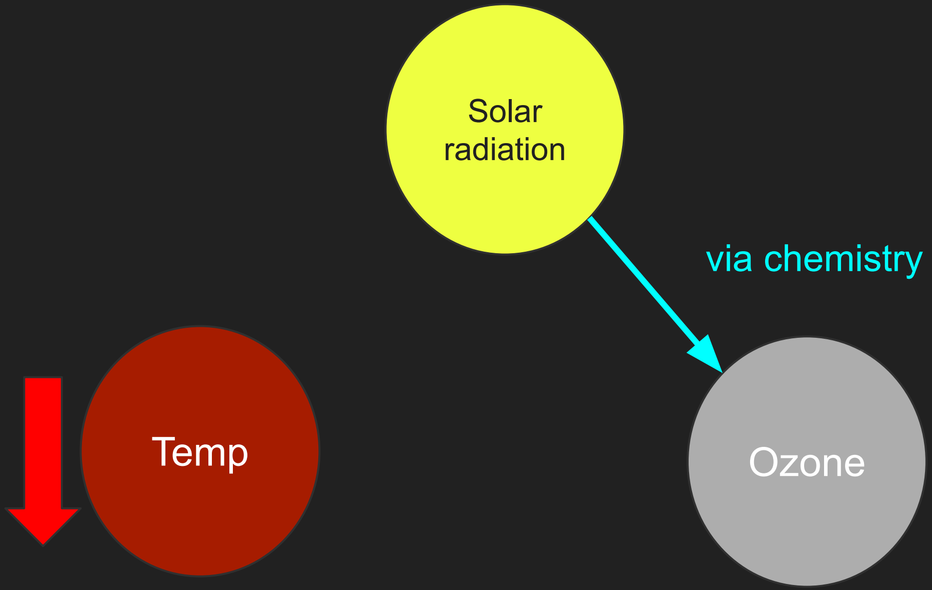
Let’s magically,
instantaneously,
reduce temperature!



What do we think will happen to ozone?

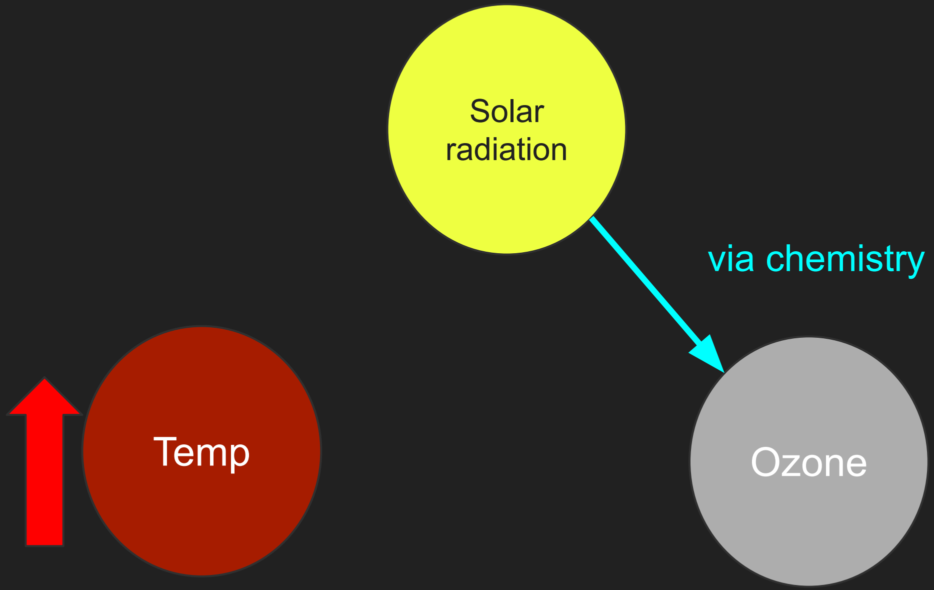
Let’s follow the ‘advice’ of our ML model…

Let’s magically,
instantaneously,
reduce temperature!



There will **be no effect** on ozone under our assumptions!

Or perhaps more pertinently, what might happen under climate change?



We expect temperature to increase

Again, no effect on ozone!

The four tiers of (data) science

1. **Description** *(data science)*
   a. What is happening? What does the data show?
2. **Prediction** *(data science/ML)*
   a. Can we predict what will happen next?
   b. Can we **predict Y given X**?
3. **Causation** *(science/maybe ML!)*
   a. **Why** did this happen?
   b. What would happen to **Y if we change X**? (**intervention)**
4. *Explanation (science)*
   a. *What is the mechanism for this phenomenon?*
   b. *How do we evaluate if this is the correct mechanism?*

Overall…

- Causation is important if we are interested in making interventions!
- Causation may help us make out of distribution predictions
- It helps us get closer to traditional science, particularly understanding mechanisms and why things happen! This is the basis for understanding the world.

Thoughts?