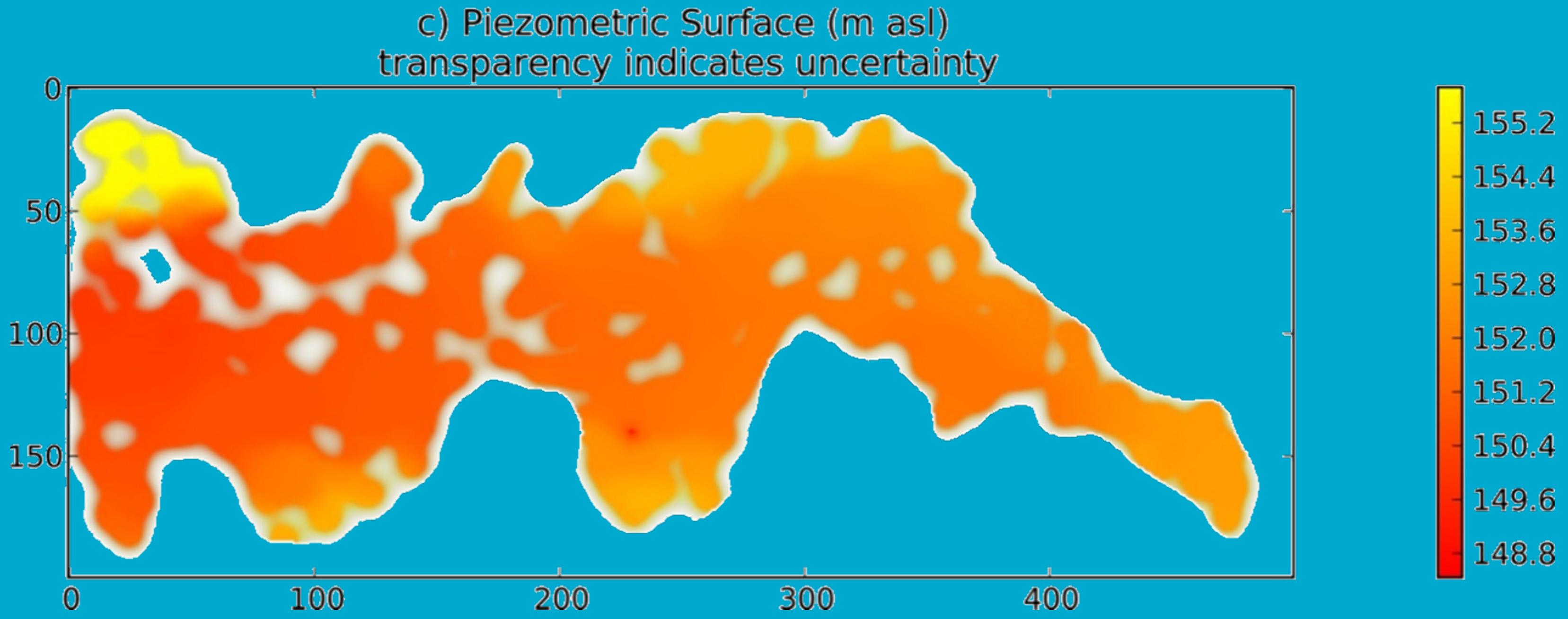


Managing uncertainty in water resource modelling: where to start?

Luk Peeters (luk.peeters@csiro.au)

Research theme leader Future Science Platform Deep Earth Imaging

ICEWaRM Webinar 30 March 2017

Why uncertainty analysis?

- The Economist 2016 most liveable cities

- Should I move?
- What is the scoring based on? / Who did the scoring?
- How different is the score between Adelaide and Melbourne?

http://www.eiu.com/public/topical_report.aspx?campaignid=liveability2016

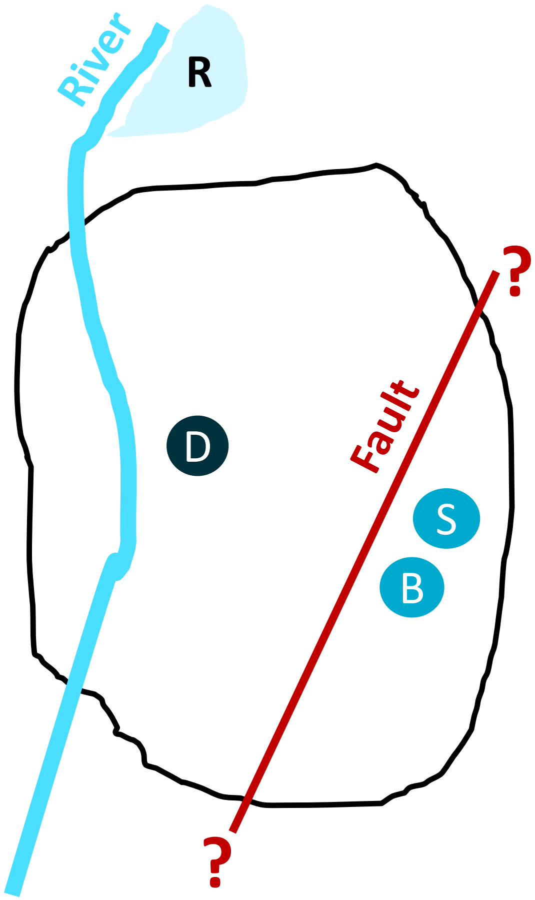
Uncertainty analysis

- Communication to stakeholders
- There is not a single answer from a model
- There is a range of predictions that are consistent with our current understanding of the system
- What if our current understanding of the system is wrong? How will that affect predictions?

- Honest and transparent on what we do and do not know
  - identify and remediate knowledge gaps
  - robust management strategies
- Build confidence in what we do know

Guillaume J H A, Hunt R J, Comunian A, Blakers R S and Fu B (2016) Methods for Exploring Uncertainty in Groundwater Management Predictions *Integrated Groundwater Management*, , 711-737 http://dx.doi.org/10.1007/978-3-319-23576-9_28

Example



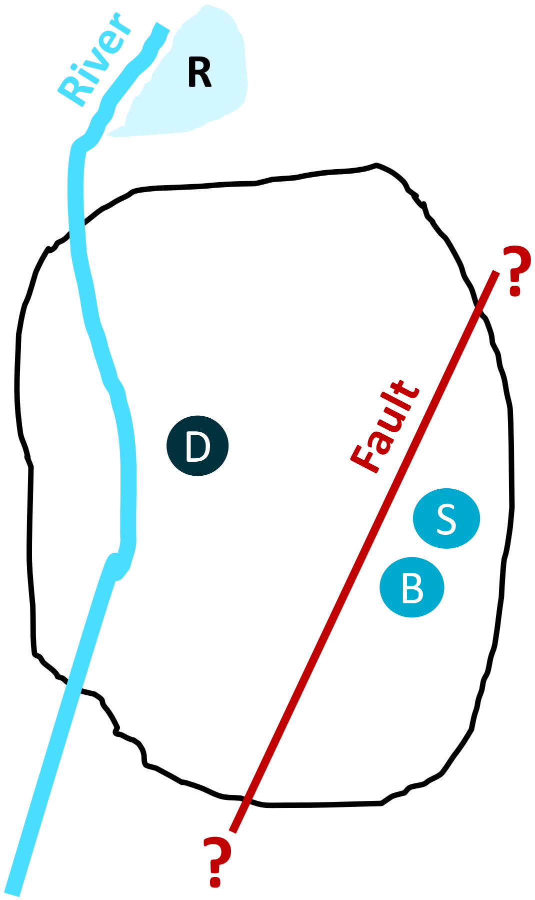
- Proposed irrigation development **D,** SW and GW

- Regulated river
- River maximally losing / disconnect from GW
- Alluvial aquifer
- Geological fault may be barrier to flow

- Spring **S**
  - drawdown threshold 20 cm
- Stock & Domestic bore **B**
  - drawdown threshold 200 cm
- River with RAMSAR wetland **R** downstream
  - needs flood every 3 years
  - cannot be dry for more than 14 days

- build model and do uncertainty analysis

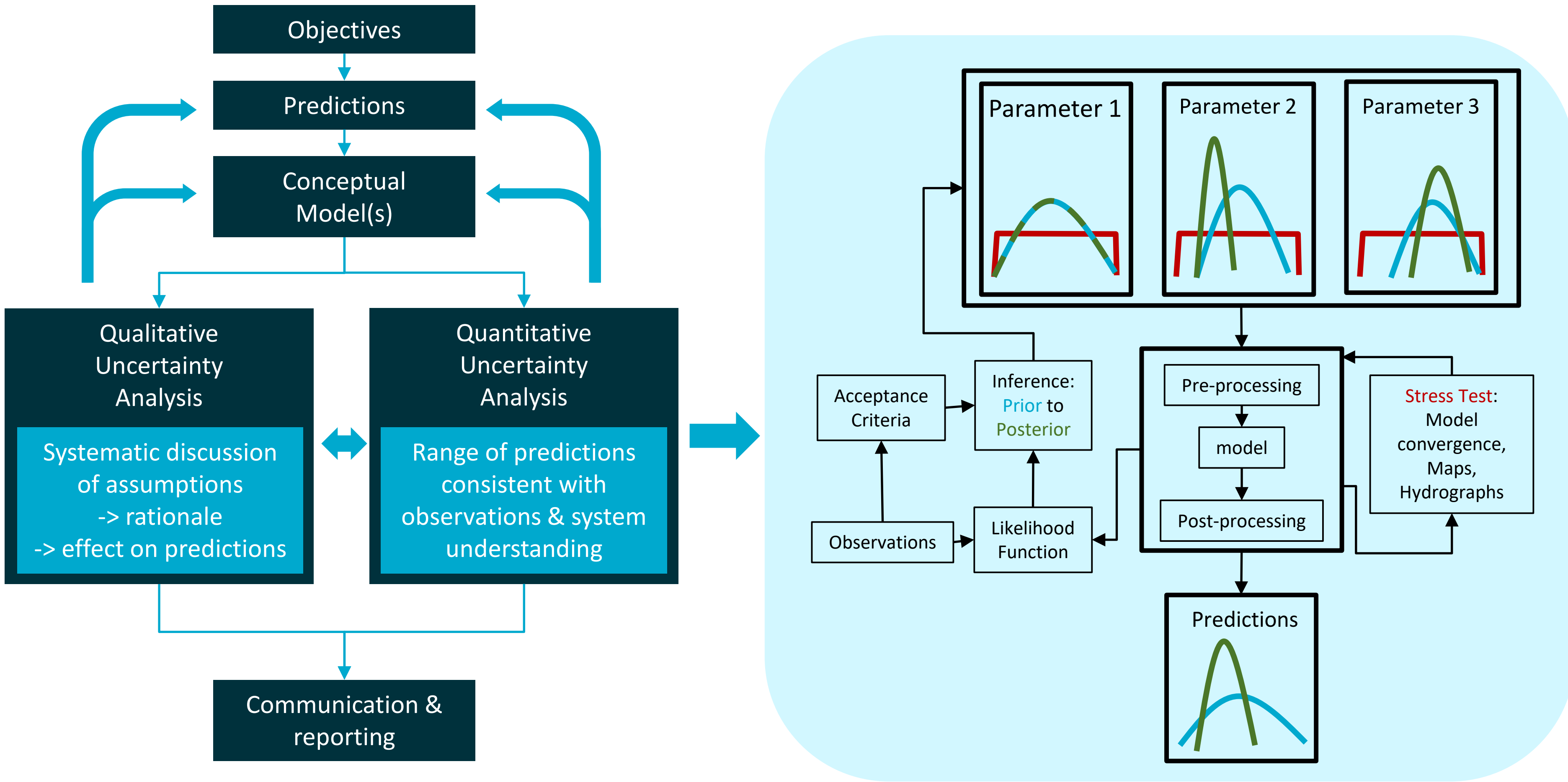
Where to start?



- Define objective
  - why model?
  - what is the research question?
  - Is the proposed development sustainable?
- Define predictions
  - what kind of model output do you need?
  - In the next 15 years, the development may not cause
    - > 20cm drawdown @ S
    - > 200cm drawdown @ B
    - increase no flow days @ R above 14 days
    - decrease flooding @ R to less than 1 in 3 years
- UA is only possible on **predictions**, not on a **model**

Liu Y, Gupta H, Springer E and Wagener T (2008) Linking science with environmental decision making: Experiences from an integrated modeling approach to supporting sustainable water resources management *Environmental Modelling & Software, 23*, 846-858

Uncertainty analysis workflow



Qualitative uncertainty analysis

- formal, structured discussion of all assumptions and model choices
- scoring (lo-med-hi) of 4 attributes:
  - data
    - Would this choice change if I had more data?
  - resources
    - Would this choice change if I had more time and money?
  - technical
    - Would this choice change if I had a better model?
  - effect on predictions
    - So what?

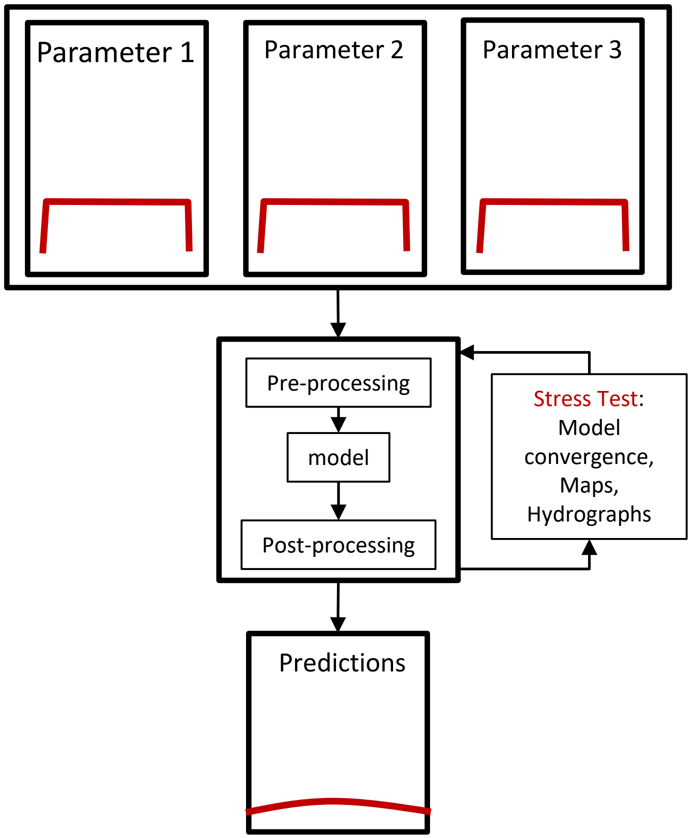
- Faults
  - D: High | R: High | T: High
  - GW: High | SW: Low
- no coupled SW-GW model
  - D: Medium | R: High| T: Medium
  - GW: Low | SW: Low
  - *provided river is disconnected*

Kloprogge P, van der Sluijs J P and Petersen A C (2011) A method for the analysis of assumptions in model-based environmental assessments Environmental Modelling & Software, Thematic issue on the assessment and evaluation of environmental models and software, 26, 289-301

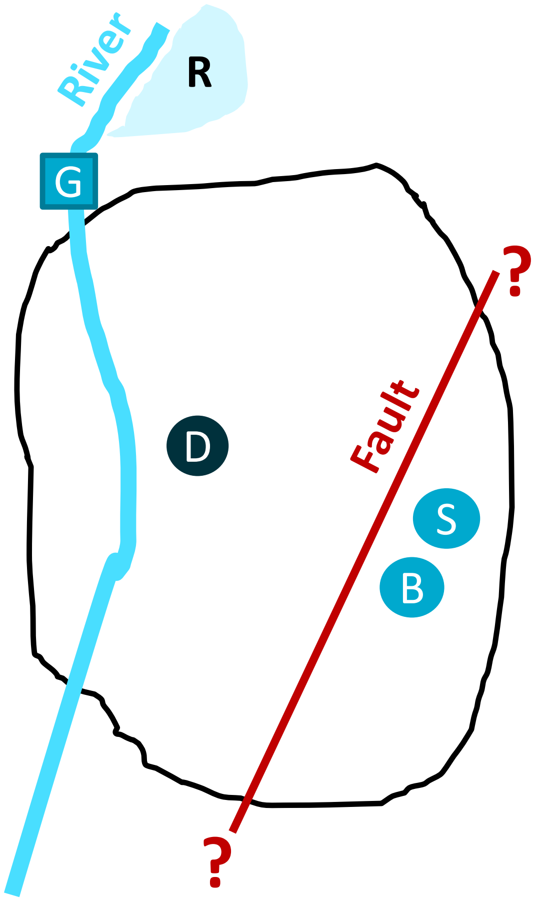
Peeters L J M, Pagendam D, Crosbie R S, Viney N R, Rachakonda P K, Dawes W R, Gao L, Marvanek. S, Zhang Y Q and McVicar T R (2017) Building confidence in environmental impact models through quantitative and qualitative uncertainty analysis *In preparation for Environmental Modelling and Software,*

What do I need to change to my model?

- parameter:
  - any model aspect you can change in an automated fashion
- automation / scripting
  - pre-processing:
    - multipliers / scaling / geostats
  - model
    - workflow of submodels
  - post-processing:
    - equivalents to observations
    - predictions – combine multiple scenario's (baseline minus development)
- stress test
  - break the model
  - do the scripts work?
  - does the model pass the laughing test?
  - parameter screening & ranges



How to bring in observations?

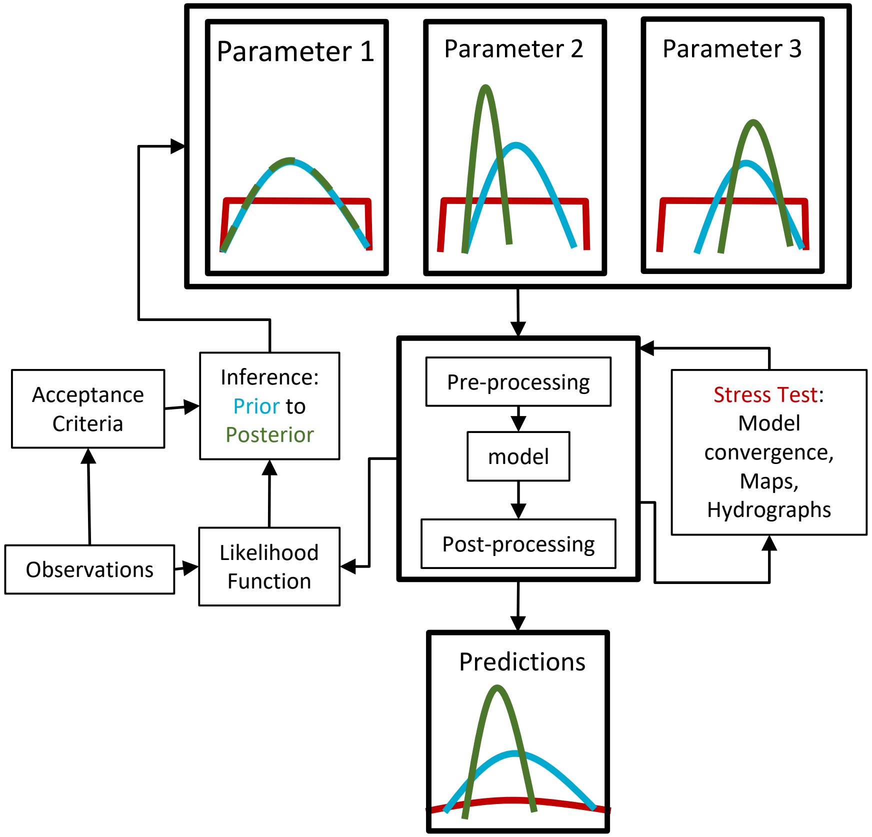


- observations
  - measurements of state variables
    - streamflow at gauge **G**
  - knowledge of the system
    - disconnected, ephemeral river
- objective / likelihood function
  - High vs low/no flow
  - River losses ~ GW / aquifer prop
- acceptance criteria
  - how much mismatch can be tolerated?
    - range
    - standard deviation of residuals
  - from observation uncertainty
    - rating curve uncertainty
    - minimum observable flow?

Guse B, Pfannerstill M, Gafurov A, Fohrer N and Gupta H (2016) Demasking the integrated information of discharge: Advancing sensitivity analysis to consider different hydrological components and their rates of change *Water Resources Research, 52*, 8724-8743

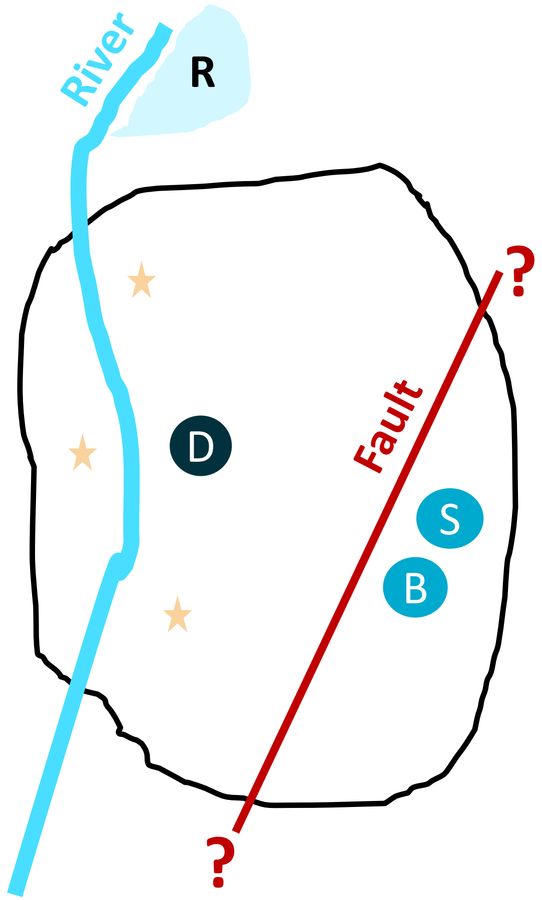
Constraining parameters and predictions

- specify prior for each parameter
  - informative
  - un-informative
- inference
  - constrain parameters and predictions with observations
  - PEST, DREAM, BATEA,…
- reducing **parameter** uncertainty does not necessarily mean reducing **predictive** uncertainty



White J T, Doherty J E and Hughes J D (2014) Quantifying the predictive consequences of model error with linear subspace analysis *Water Resources Research, 50*, 1152-1173 http://dx.doi.org/10.1002/2013WR014767

Parameter identifiability vs predictive uncertainty



- historical groundwater level observations ★
- Groundwater level:
  - diffuse recharge
  - river recharge
  - hydraulic properties
- Drawdown at **S** and **B**:
  - hydraulic properties
  - pumping rate at D
  - permeability fault

- Groundwater level obs
  - constrain river and diffuse recharge
  - do not constrain properties uniquely
  - do not reduce predictive uncertainty

Communication and reporting

- 8 steps in risk communication

1. All we have to do is get the numbers right
2. All we have to do is tell them the numbers
3. All we have to do is explain what we mean by the numbers
4. All we have to do is show them they've accepted similar risks in the past
5. All we have to do is show them it's a good deal for them
6. All we have to do is treat them nice
7. All we have to do is make them partners
8. All of the above

Spiegelhalter D (2017) Risk and uncertainty communication *Annual review of statistics and its application, 4*, 40

Communication and reporting

- report uncertainty as integral part of tables, charts and maps
- combine words, tables, charts and maps
- qualitative uncertainty analysis
- engage with stakeholders
- numeracy is important, trust is essential
- open and transparent

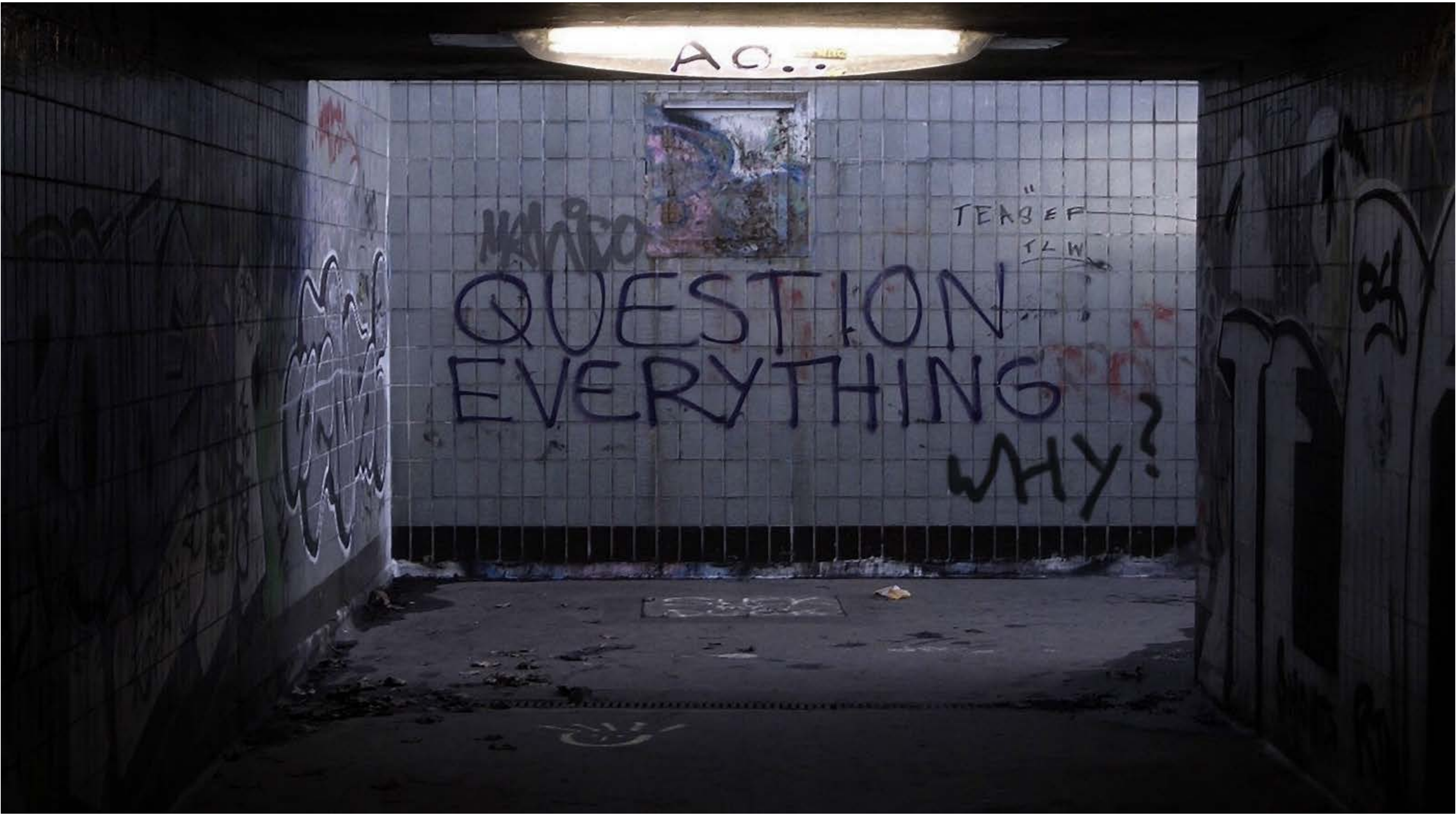
Spiegelhalter D, Pearson M and Short I (2011) Visualizing Uncertainty About the Future *Science, 333*, 1393-1400
http://www.sciencemag.org/content/333/6048/1393.abstract

Conclusions

- Figure out what the question is
- Entertain the possibility that you are wrong
- Observations are everything you know and measure
- Define what is a good model
- Past performance may not be an indication for future results
- Build trust by being trustworthy

Thank you

luk.peeters@csiro.au



https://www.flickr.com/photos/dullhunk/202872717/