Combining Adjoint Models and LUR: An Approach to Efficient Health Impact Assessment

Peter Rayner

September 29, 2017

THE UNIVERSITY OF MELBOURNE

What is an Adjoint Model?

- Find some scalar (y) which is a function of model output; e.g.
  - # of criteria exceedances, 99% quantile of NO_2
  - DALYs, # lung cancer cases, AQ-related health costs

What is an Adjoint Model?

- Find some scalar (y) which is a function of model output; e.g.
  - # of criteria exceedances, 99% quantile of NO_2
  - DALYs, # lung cancer cases, AQ-related health costs
- The adjoint calculates the derivative or gradient of that number with respect to model inputs;
  - Inputs may be emissions, initial conditions, model parameters, etc.

What is an Adjoint Model?

- Find some scalar (y) which is a function of model output; e.g.
  - # of criteria exceedances, 99% quantile of NO_2
  - DALYs, # lung cancer cases, AQ-related health costs
- The adjoint calculates the derivative or gradient of that number with respect to model inputs;
  - Inputs may be emissions, initial conditions, model parameters, etc.
- Very challenging to generate, *but*
- Adjoints can be almost automatically generated for some languages.

What's it good for?

- Used to minimise mismatch with observations (data assimilation or atmospheric inversion)
  - Estimate emissions (hard to do without an adjoint)
  - Estimate initial conditions (can do without the adjoint)

What's it good for?

- Used to minimise mismatch with observations (data assimilation or atmospheric inversion)
  - Estimate emissions (hard to do without an adjoint)
  - Estimate initial conditions (can do without the adjoint)
- If y, some health metric, and model inputs are emissions it shows the most efficient strategy for improvement;
- If we associate each emission reduction with a cost, we can also find the most cost-effective strategy

Extension to blended metrics

- Idea: weighted combination of the LUR and the model data
  - Construct high res model as combo of LUR & CTM
  - Construct high res *adjoint* as combo of LUR & CTM *adjoints*

Extension to blended metrics

- Idea: weighted combination of the LUR and the model data
  - Construct high res model as combo of LUR & CTM
  - Construct high res *adjoint* as combo of LUR & CTM *adjoints*
- "Blending" means combining model output with finer-scale information to produce high-resolution fields for health metrics;
- Metric still function of model output so technique holds *but* beware that emissions may affect fields being used in the blending process;
- Requires that the operator responsible for blending has an adjoint.

CMAQ

- Community Multi-Scale Air Quality Model
  - US EPA's meso-scale AQ model
  - Full photochemistry, aerosols
  - Scales: hemispheric down to $\approx 1\,\mathrm{km}$

CMAQ

- Community Multi-Scale Air Quality Model
  - US EPA's meso-scale AQ model
  - Full photochemistry, aerosols
  - Scales: hemispheric down to $\approx 1\,\text{km}$
- Offline CTM with strong links to WRF-CHEM
- Uses Kinetic Preprocessor (KPP) for chemistry which automatically generates adjoint of chemical solver
- Gas-phase adjoint working, aerosols not yet.

Conclusions & challenges

- LUR: high res, but no source-receptor relationship
- CTM: low res, source-receptor relationship characterised

Conclusions & challenges

- LUR: high res, but no source-receptor relationship
- CTM: low res, source-receptor relationship characterised
- We can generate a high-resolution adjoint by "blending"
- Allow us to look at scenarios, optimization, etc.

Conclusions & challenges

- LUR: high res, but no source-receptor relationship
- CTM: low res, source-receptor relationship characterised
- We can generate a high-resolution adjoint by "blending"
- Allow us to look at scenarios, optimization, etc.
- Challenges:
  - Aerosols not in CMAQ adjoint yet, only one domain
  - Emission inventories – still an issue
  - Adjoint construction for LUR, blended model
  - Intrepretation, communication, discipline boundaries