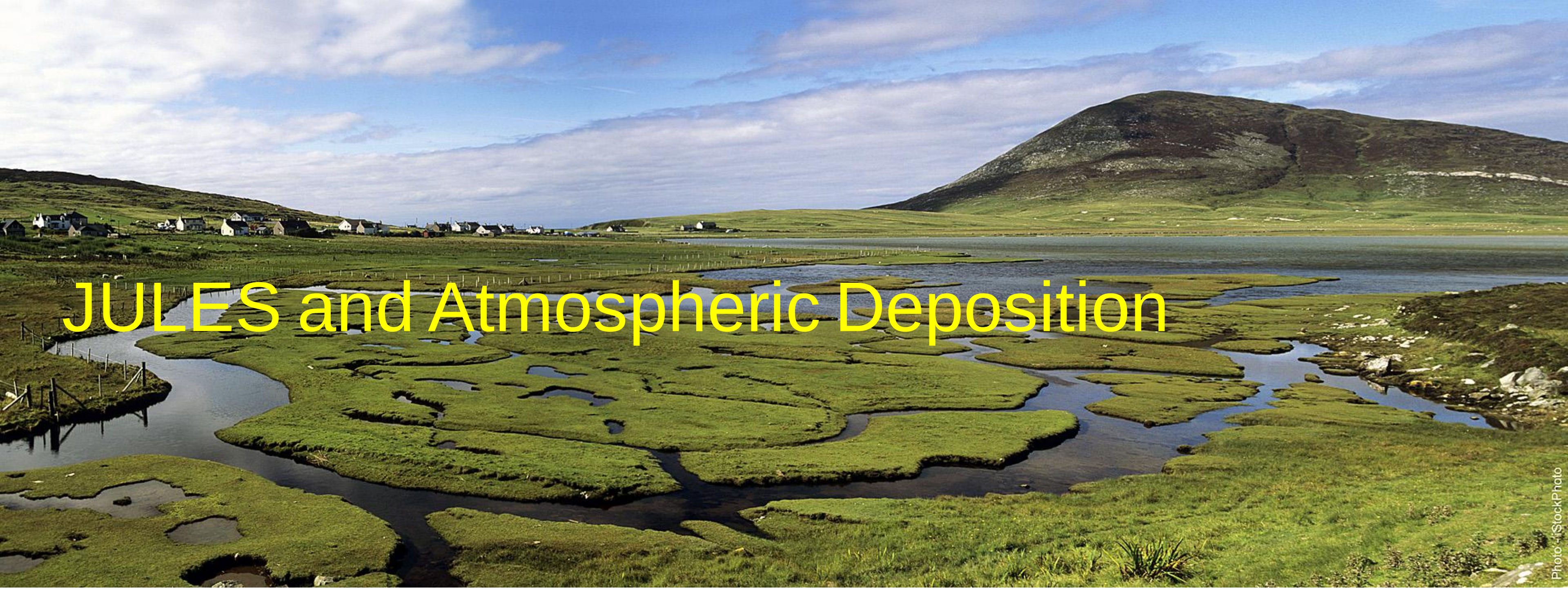

JULES and Atmospheric Deposition

Garry Hayman
Centre for Ecology and Hydrology

ACITES Dry Deposition Working Group

JULES Annual Science Meeting, Reading
1st July 2015

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Content and Acknowledgements

Content

1. Deposition: Background and current status
2. ACITES Dry Deposition Working Group
3. Future directions and open forum

Acknowledgements

- Federico Centoni
- David Stevenson
- Oliver Wild (and Catherine Hardacre)

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NERC National Centre for Earth Observation NATURAL ENVIRONMENT RESEARCH COUNCIL

Met Office

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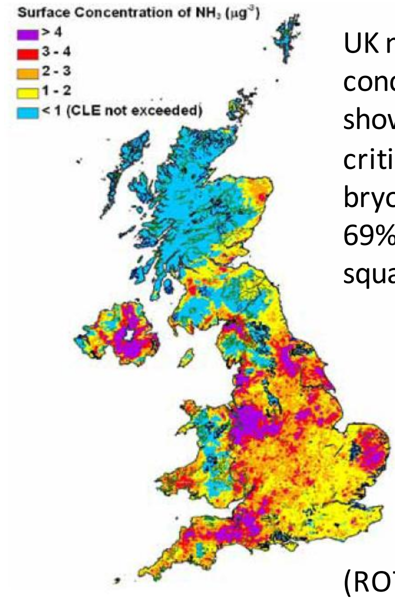
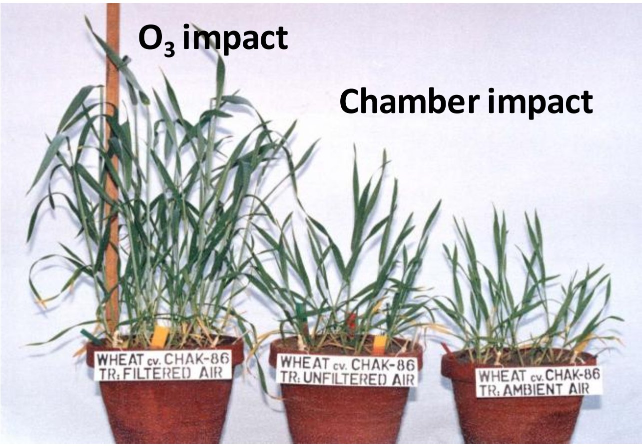
Relevance of Atmospheric Deposition

- Important atmospheric process
  - *Governs atmospheric abundance of many compounds (e.g., O_3, H_2O_2, HNO_3, SO_2, NH_3, aerosol, …)*
- Important process for the biosphere
  - *Governs input of key nutrients/oxidants to vegetation*
- Links atmosphere and biosphere
  - *Contributes to climate and Earth system feedbacks*



UK map of modelled NH_3 concentrations for 2003 showing exceedance of critical levels for sensitive bryophyte and lichen in 69% of the 1-km grid squares

(ROTAP, 2012)



O_3 injury to wheat, Pakistan (courtesy of A. Wahid)

- Policy-relevant implications for air quality, crop yields, etc.
  - *Critical loads for acid deposition and eutrophication*
  - *Ozone exposure and effects on human health and vegetation*
  - *Particulate matter (aerosol) and impact on human health*
  - *See talk and poster by Feung*

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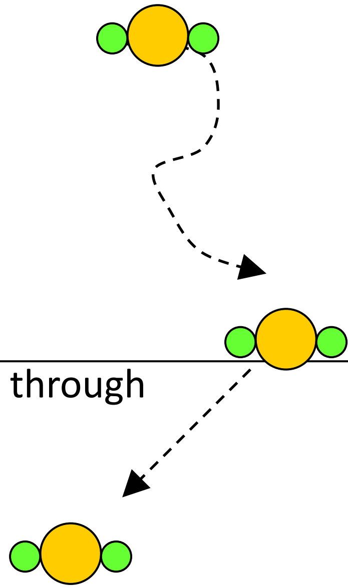
Modelling dry deposition processes

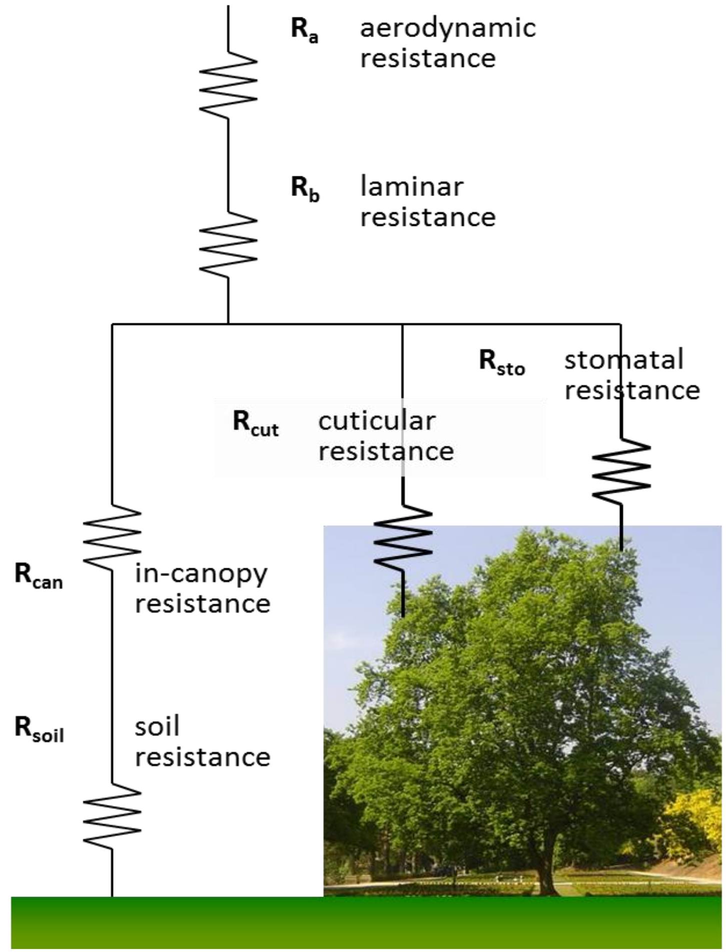


1. **Turbulent transport** through atmosphere

2. **Molecular diffusion** through laminar sub-layer

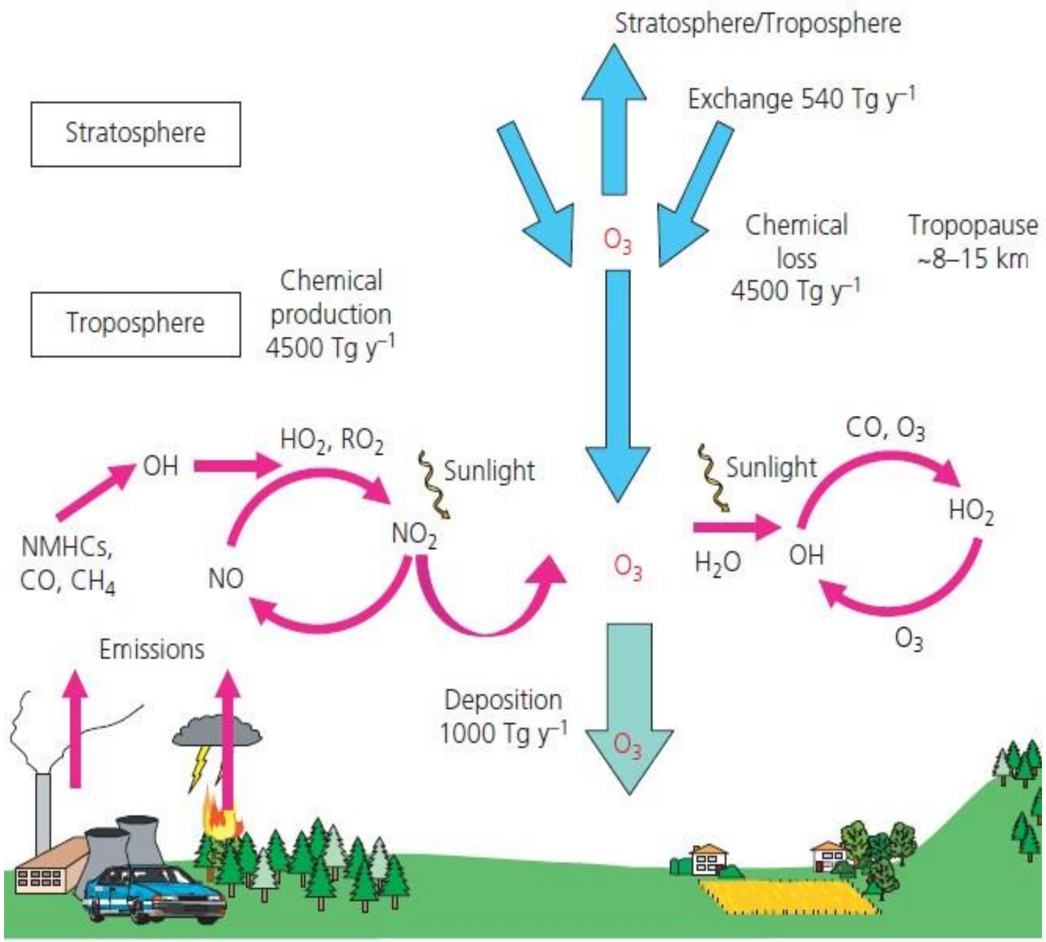
3. **Uptake** on surface by adsorption, followed by dissolution or reaction (depends on surface type: vegetation, soil, water, light, etc.)

Most atmospheric chemical transport models use a "Wesely-resistance" approach



Following slides focus on ozone but generally applicable ……….

Deposition: major contributor to uncertainty in global O_3 budget



Stevenson et al 2006; Royal Society, 2008

Dry deposition is one of the main source of intermodel variability in surface O_3 predictions

Model	Deposition Scheme[a]	Land Cover Classes[b]	Annual global O_3 deposition / Tg yr^{-1}
CAMCHEM-3311m13	Wesely	17	861
CAMCHEM-3514	Wesely	17	818
CHASER-v03	Wesely		939
FRSGC/UCI-v01	Wesely	9	943
GEMAQ-EC	Wesely	15	878
GEOSChem-v07	Wesely	11	913
GISS-PUCCINI-modelA	Wesely	8	975
GISS-PUCCINI-modelEaer	Wesely	8	1112
GISS-PUCCINI-modelE	Wesely	8	1179
GMI-v02f	Wesely		819
INCA-vSSz	Wesely	11	1256
LLNL-IMPACT-T5a	Wesely	13	1000
MOZARTGFDL-v2	Wesely	11	997
STOC-HadAM3-v01	Wesely	9	1095
STOCHEM-v02	Wesely	9	834
TM5-JRC-cy2-ipcc-v1	Wesely	4	844
ULAQ-v02	Prescribed[c]		1116
UM-CAM-v01	Prescribed[c]	5	1023
Average ($\pm 1\sigma$)			978 ± 127
Average seasonal amplitude[d]			38 ± 8
Average monthly range[e]			38 ± 6

Hardacre et al. 2015

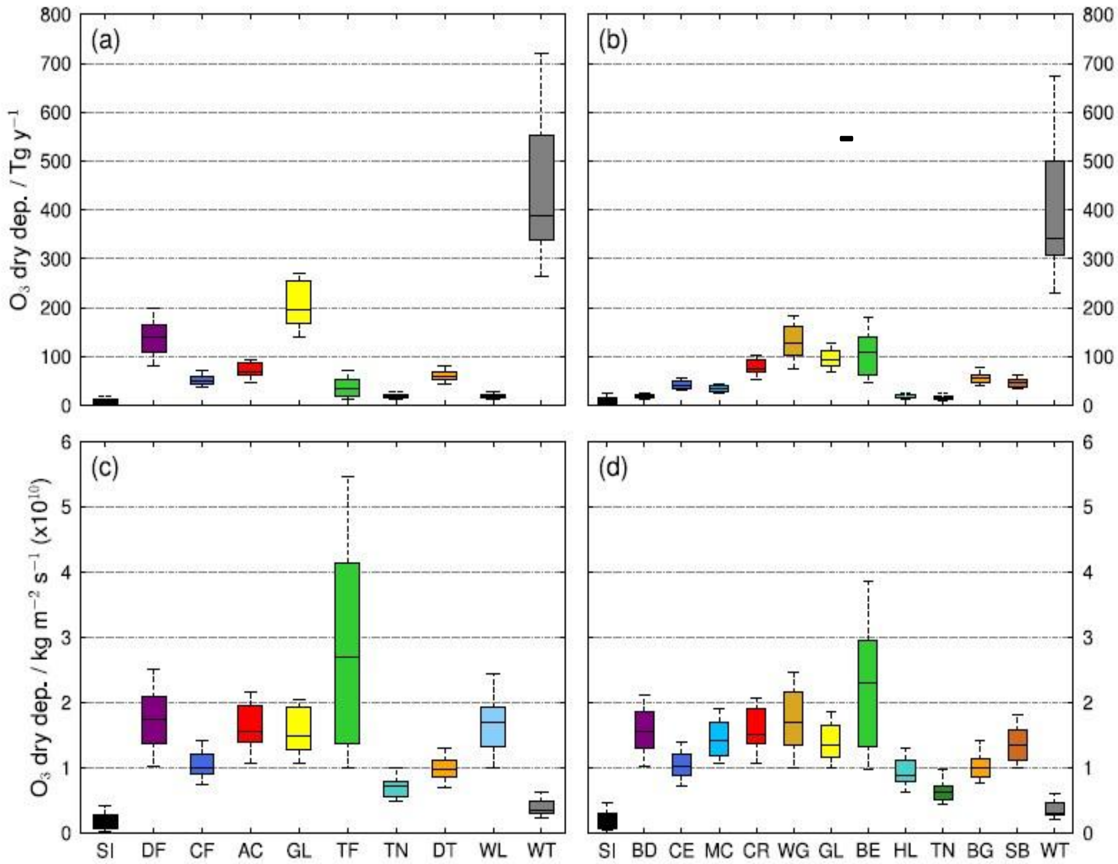
O_3 deposition to different land-cover types

Fluxes

Absolute

Normalised

by area



Olson Land Cover Classes:

SI: Snow/Ice

DF: Deciduous Forest

CF: Coniferous Forest

AC: Agricultural Land, Crops

GL: Grass Land

TF: Tropical Forest

TN: Tundra

DT: Desert

WL: Wetland

WT: Water

Figure 4. Normalised O_3 dry deposition partitioned to land cover classes using the OW11 **(a, c)** and GCLF **(b, d)** LCCs respectively. Upper panels show the contribution of each LCC to the annual global O_3 dry deposition flux, and lower panels show the average flux to each LCC. The box and whiskers for each land class represent the median, quartiles and 10th/90th percentiles.

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Analysis of HTAP model runs (Hardacre et al., 2015)

See also poster by Oliver Wild

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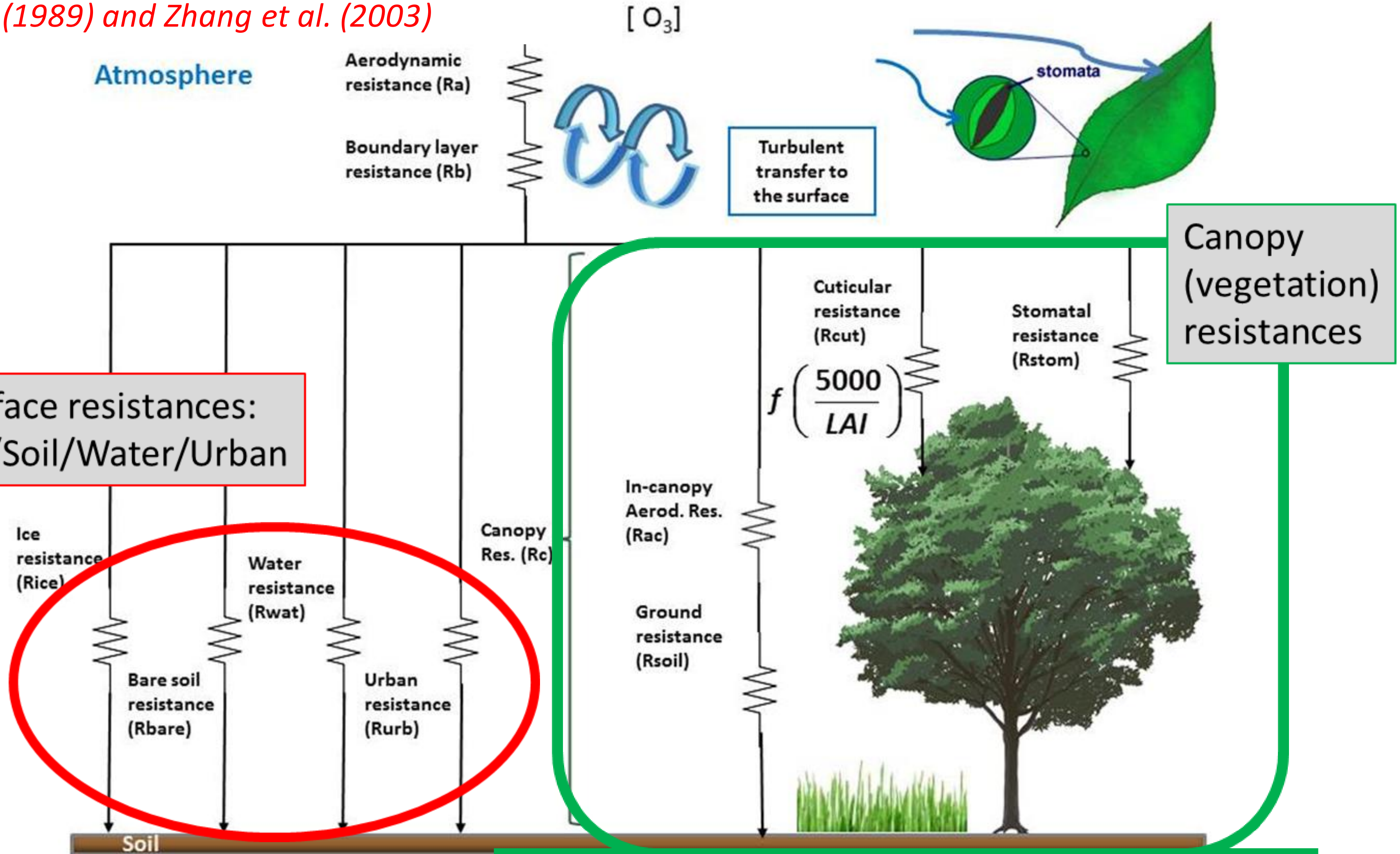
UKCA Dry Deposition Schemes

Wesely (1989) and Zhang et al. (2003)

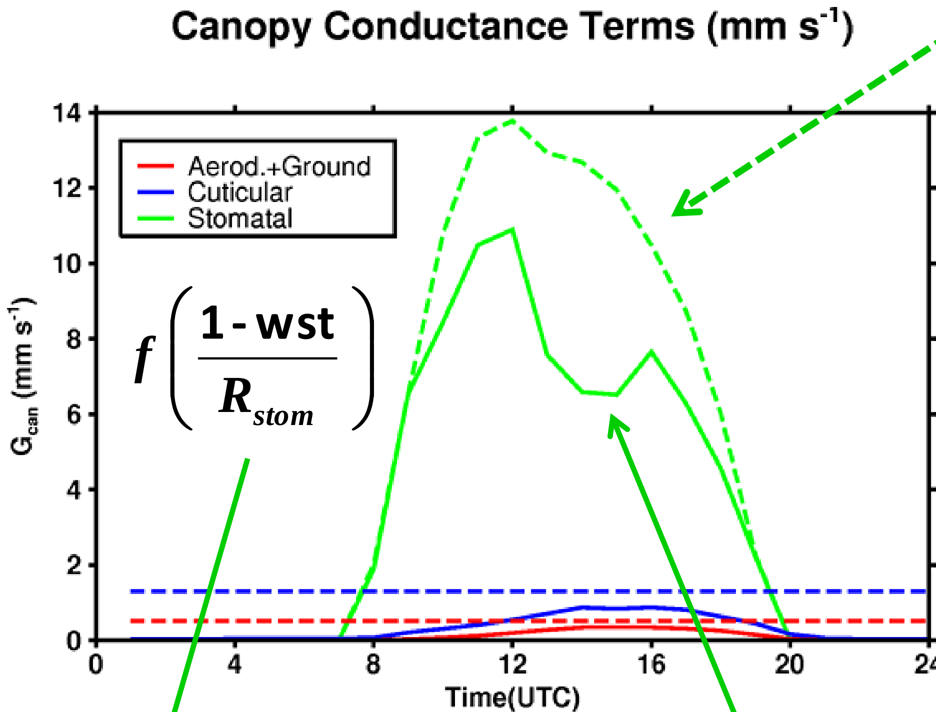


Broad/needle leaf trees, C3-C4 grass, shrubs

Canopy uptake differences

Amazon grid, Ozone – January (2000)

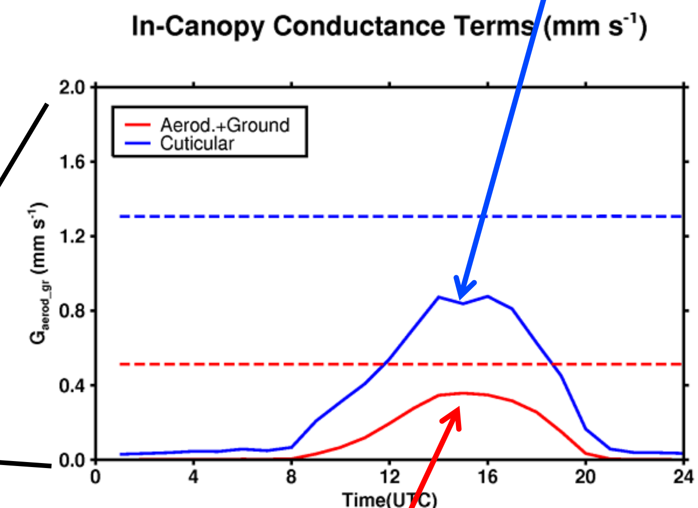
Wesely Scheme



$$f\left(\frac{1-\mathrm{wst}}{R_{stom}}\right)$$

wst = fraction of blocked stomata

$$f\left(RH, u_*, LAI\right)$$



$$f\left(LAI, u_*\right)$$

Zhang Scheme: Stomatal blocking effect when rain or dew in presence of strong SW radiation

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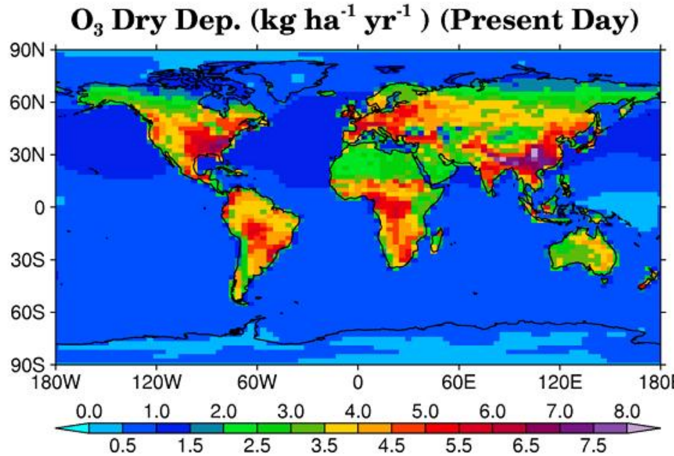
Courtesy of F Centoni(CEH/Edinburgh)

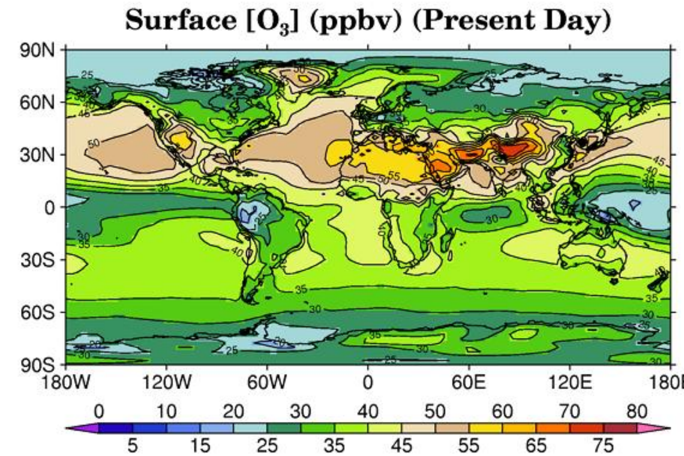
Scheme change effect on simulated O_3

Wesely Scheme



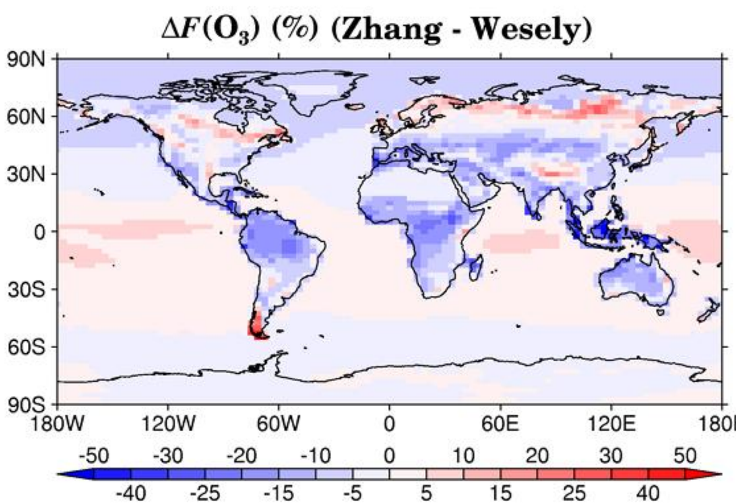
Total O_3 dry deposition = 1005 Tg yr^{-1}

Wesely Scheme



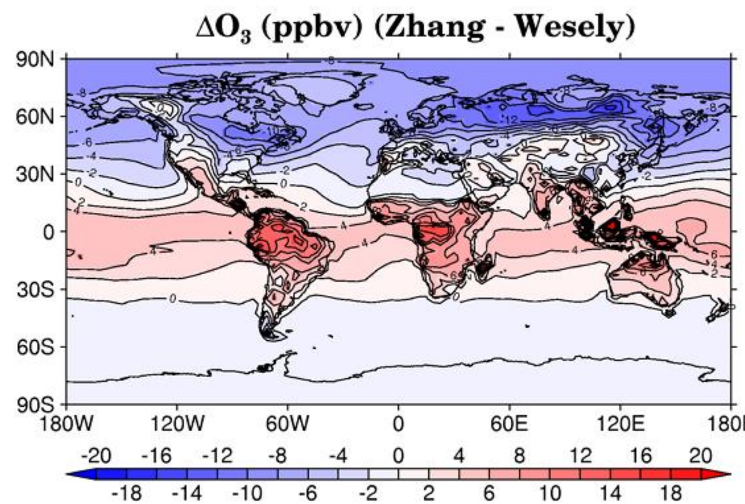
$[O_3]$ land = 36 ppb

Zhang - Wesely Scheme



Δ O_3 dry deposition = -5%

Zhang - Wesely Scheme



$\Delta[O_3]$ land = -1.3%

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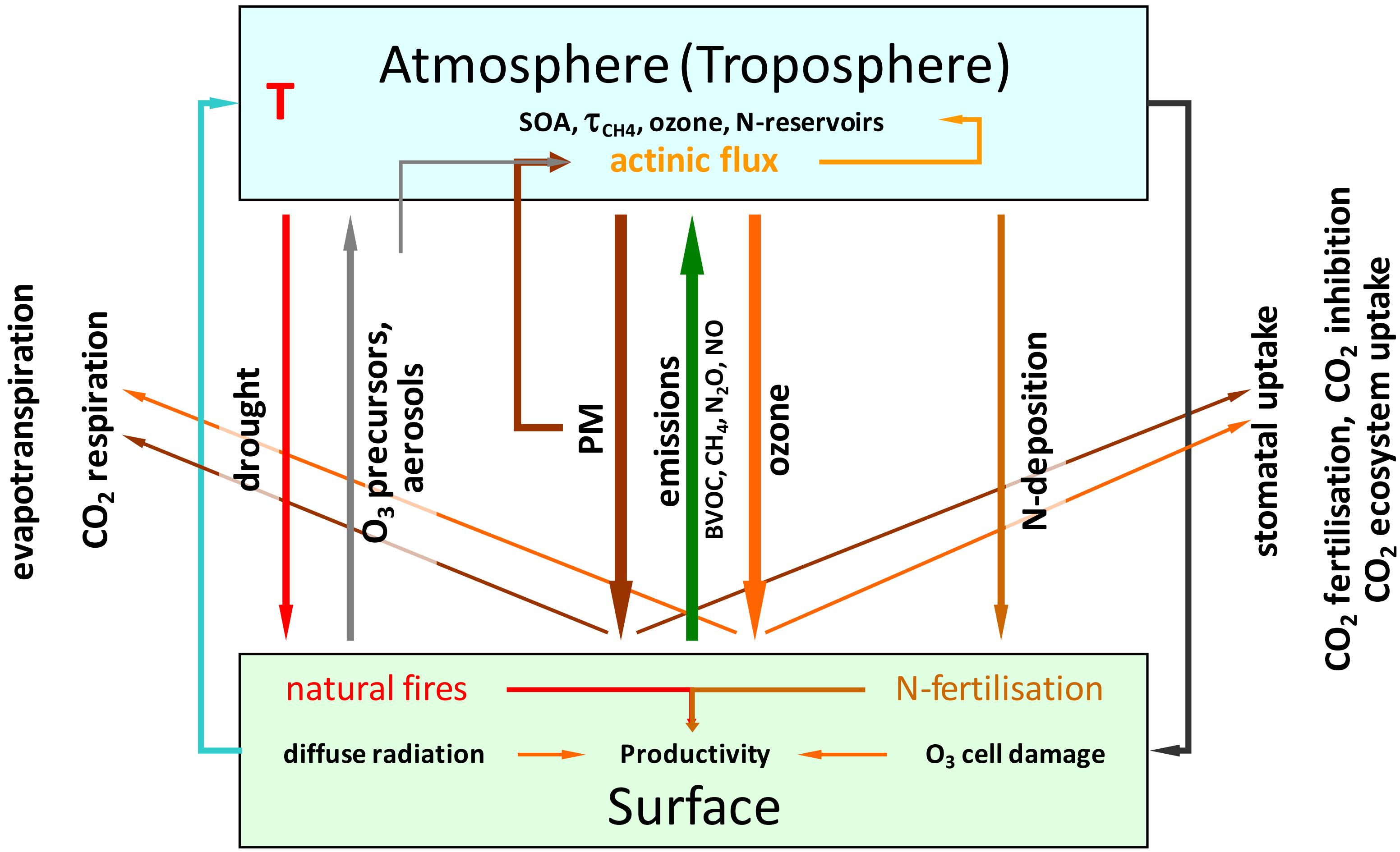
Courtesy of F Centoni(CEH/Edinburgh)

Looking to the future



There will be more coupling between land surface and atmospheric chemistry/composition, in both directions

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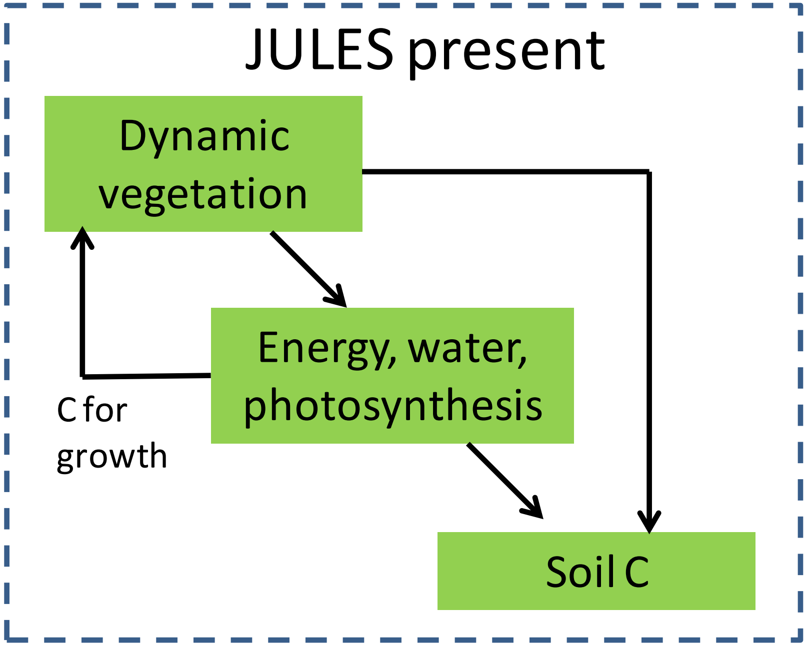
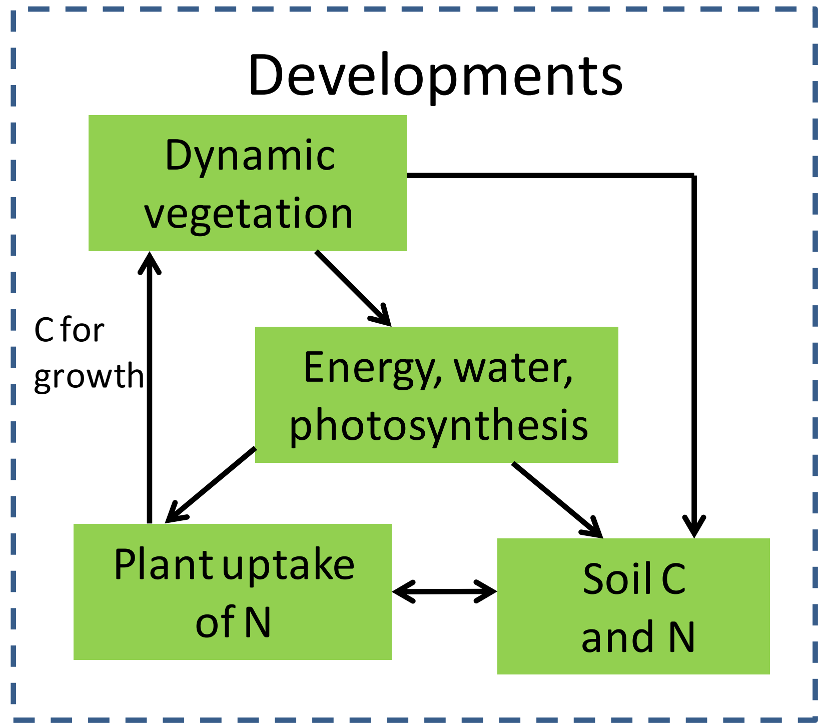
Courtesy of G Folberth (Met Office)

JULES: Adding terrestrial nitrogen-cycle



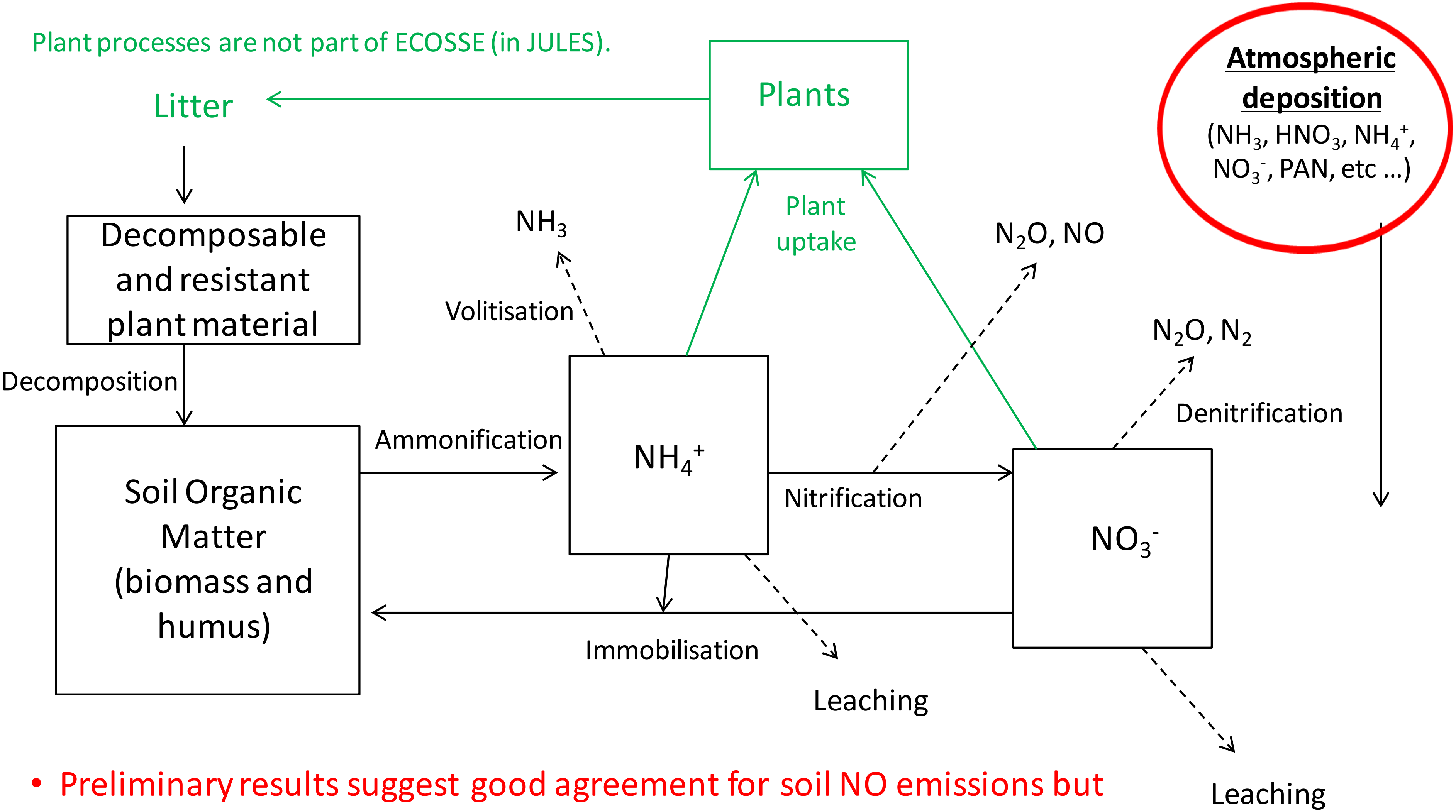
At present, JULES uses RothC.

- Until recently, no representation of soil nitrogen and effects on plants
- No layering of soil carbon



Courtesy of D Clark (CEH)

JULES: Schematic of Nitrogen cycle



- Preliminary results suggest good agreement for soil NO emissions but N_2O emissions currently too high

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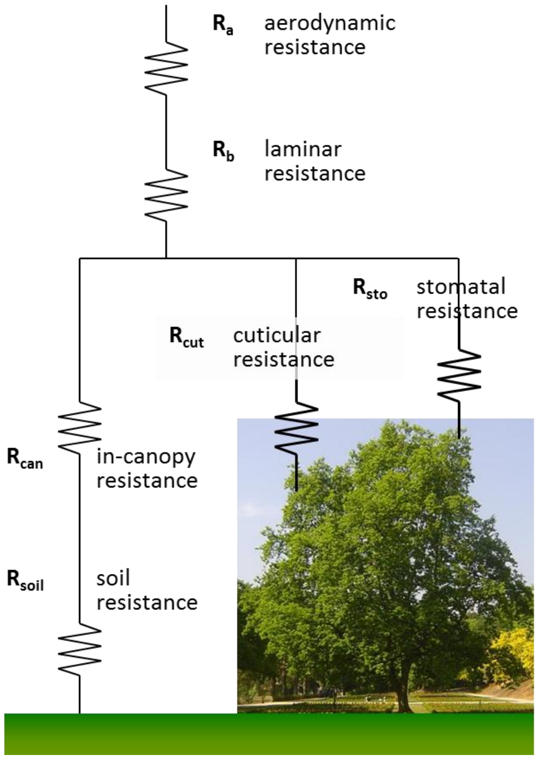
Courtesy of D Clark (CEH)

Dry Deposition working group

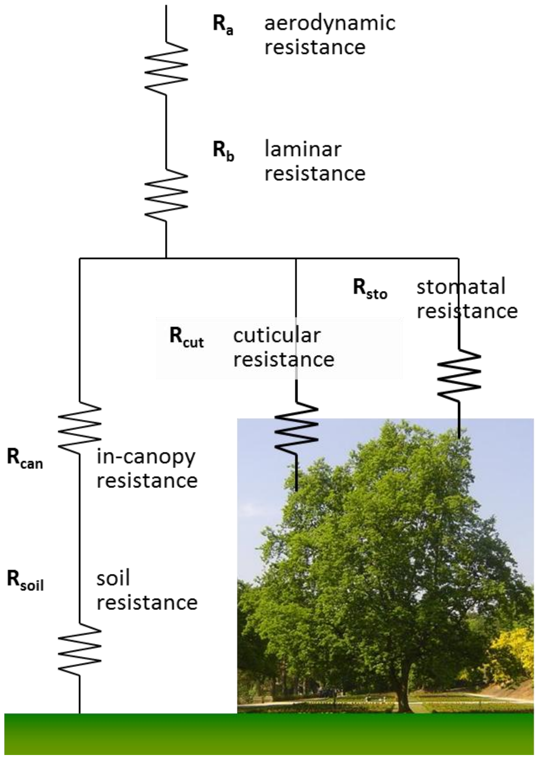
- Dry deposition working group formed as part of the NERC ACITES* project
- Currently involves:
  - O Wild (and C Hardacre, U. Lancaster)
  - G Folberth, F O'Connor, C Ordonez (Met Office)
  - G Hayman, E Nemitz, F Centoni (CEH)
  - L Emberson (SEI, York)
  - D Stevenson (U. Edinburgh)
  - M Val Martin (U. Sheffield)
- Informal meetings held at JULES (2013) and ACITES (2014, 2015) events
- Strategy (short) paper produced
- New members welcome



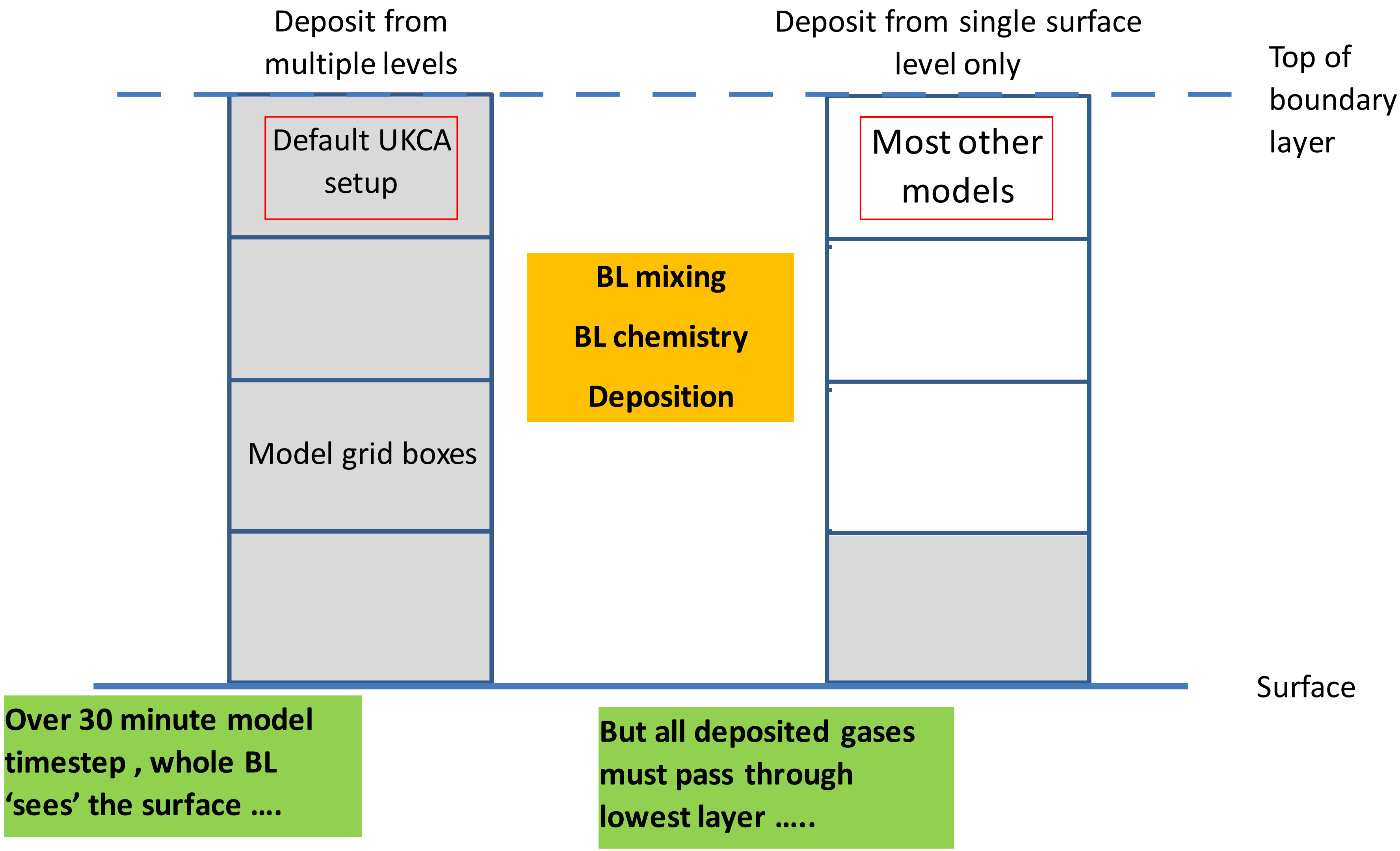
(*) ACITES = Atmospheric Chemistry in the Earth System
https://www.ncas.ac.uk/index.php/en/acites-news

ACITES Dry Deposition working group

- Co-ordinate efforts in linking the atmosphere with the land surface via dry deposition fluxes
- Aims/Actions
  - Outline the role and importance of dry deposition in the Earth system
  - Assess the current state of dry deposition in the major ESMs and identify any shortcomings
  - Adopt a similar approach to the Master Chemical Mechanism, including the creation of a "gold standard" (benchmark) model of dry deposition
  - Develop a plan with key milestones for the next 5-10 years
  - Develop links with international groups



Modelling dry deposition: How do we formulate models?



Both sorts of schemes implemented in UKCA model

Issues and open forum (1)

- Science
  - Sensitivity to stomatal vs non-stomatal partitioning (and effects on crops/radiative forcing)
  - Behaviour during extreme events (e.g. heatwaves)
  - Implications for past as well as future trends

- Considerations
  - Need/desire to update dry-deposition scheme in UKCA
  - Ensure consistency between UKCA and JULES
  - Development of 'offline' version of UKCA

  - JULES will increasingly require atmospheric 'deposition' inputs
  - Single or multi-layer schemes (for UKCA deposition, in-canopy chemistry)

Issues and open forum (2)

- Gather community opinion on how deposition should be handled in future

  - H_2O, energy, carbon exchange already in JULES. Addition of chemical species an extension?
  - Should JULES provide deposition parameters (e.g., r_c) as current or calculate deposition velocities (pft/species dependent) or mass fluxes (requires species concentrations)?
  - Single or multi-layer capability
  - 'MCM approach' to test/benchmark new science or more sophisticated process-based schemes being developed e.g., in EU ECLAIRE project, with traceable simplification for use in chemical transport and Earth System models
  - Resourcing
  - Any feedback/views/comments to Garry Hayman (CEH, garr@ceh.ac.uk)