Joint Weather & Climate Research Programme – a partnership in weather and climate research

Atmospheric Dry Deposition in JULES

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JULES Annual Meeting
Harper Adams University
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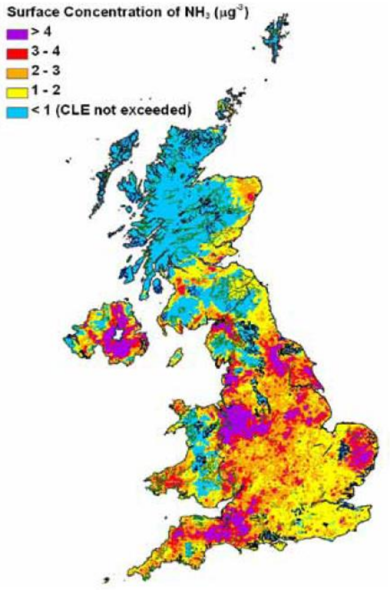
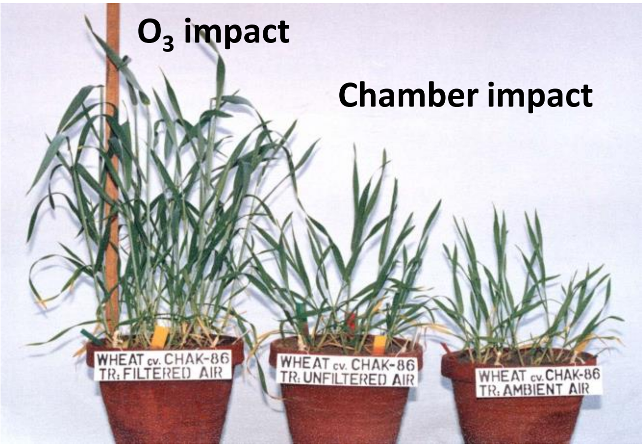
Outline

- Background
- Current progress
- Issues
- Next steps

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*

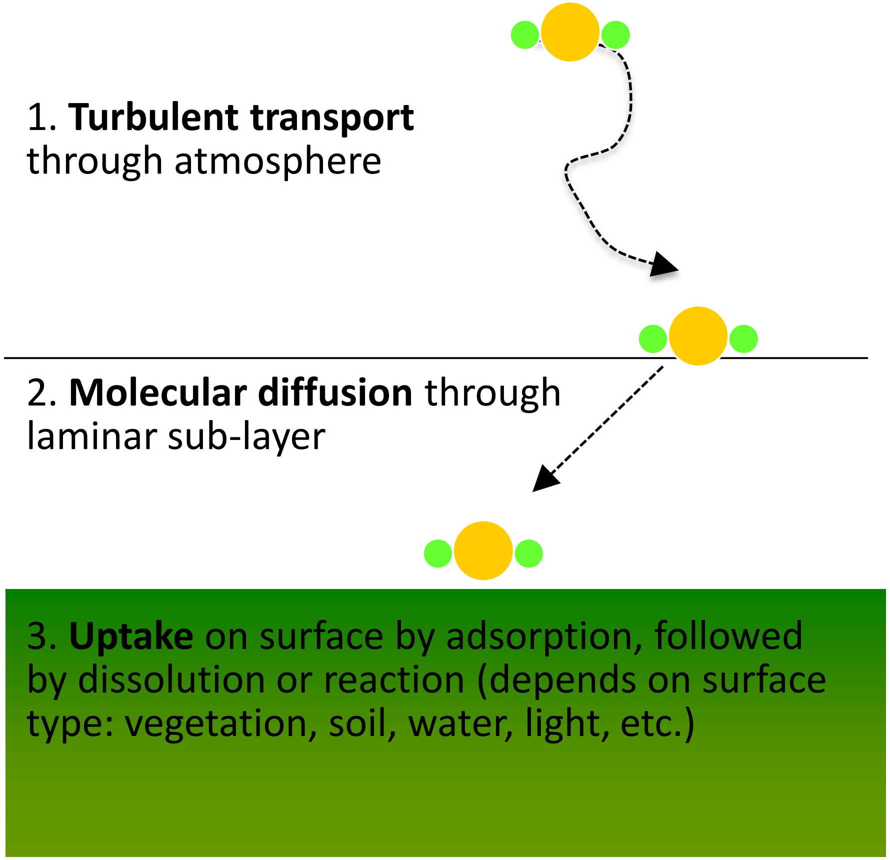




O_3 injury to wheat, Pakistan (courtesy of A. Wahid)

- 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*

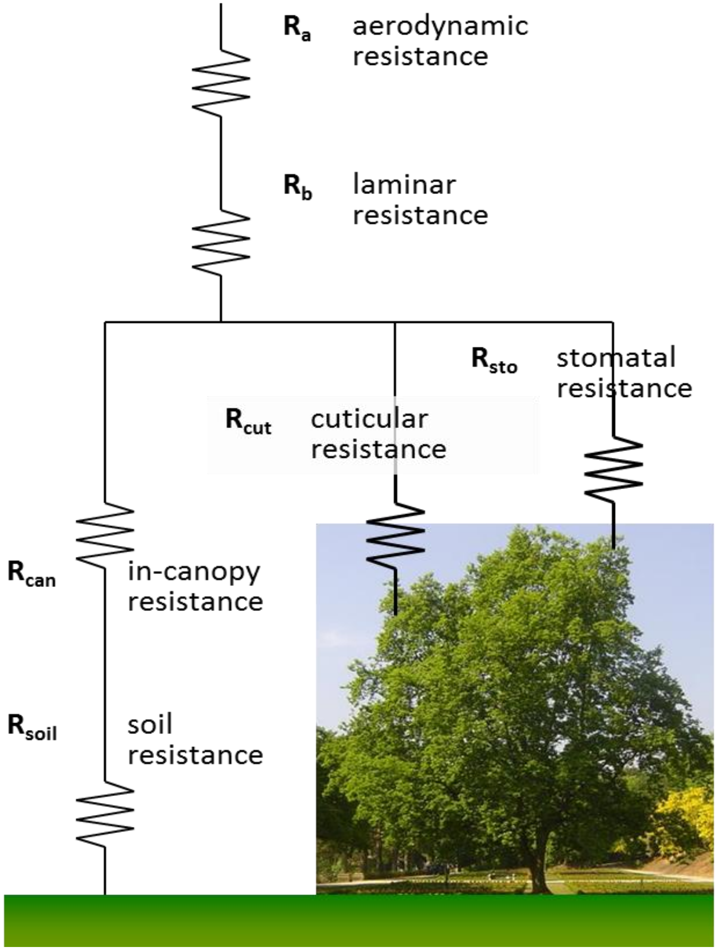
Modelling dry deposition processes



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.)



R_a aerodynamic resistance

R_b laminar resistance

R_{sto} stomatal resistance

R_{cut} cuticular resistance

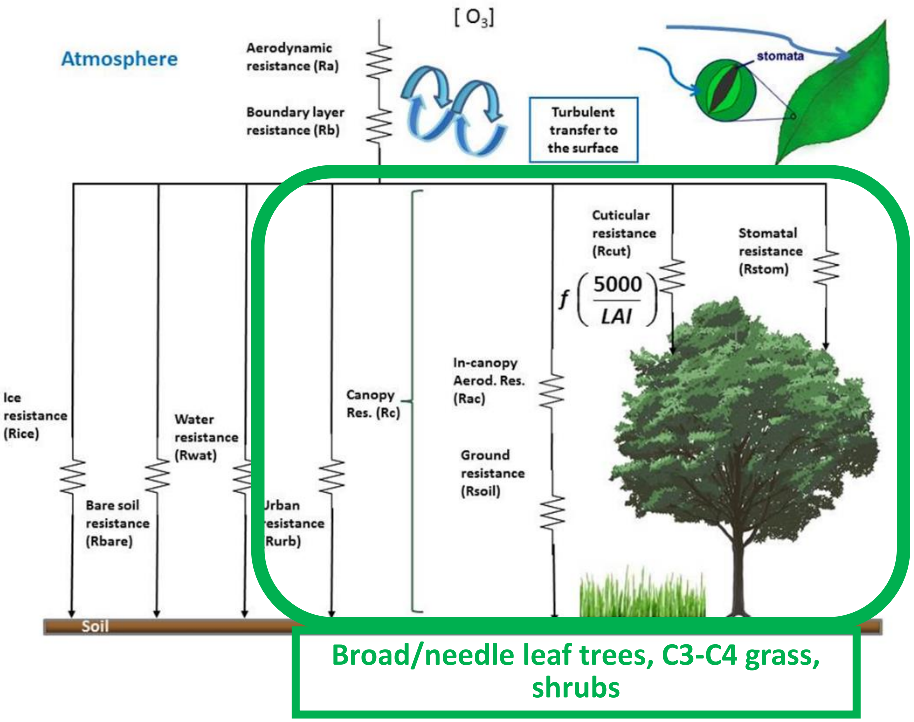
R_{can} in-canopy resistance

R_{soil} soil resistance

- Many atmospheric chemical transport models, including UK chemistry-climate and Earth System models, use a “Wesely-resistance” approach
- Atmospheric dry deposition currently in UKCA

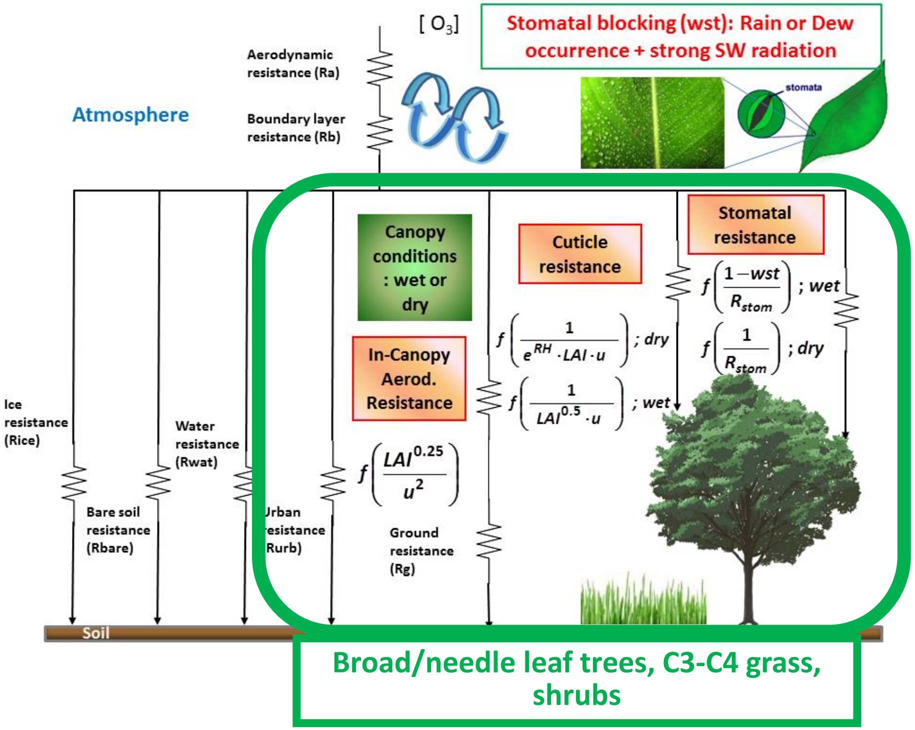
Dry deposition schemes in the UKCA model

Current scheme in UKCA (UKESM)



- ➢ Wesely (1989) scheme for gas-phase species
- ➢ Deposition of aerosol species based on roughness length and the use of prescribed deposition velocities. Also sedimentation.
- ➢ Need to mirror pft order/description used in JULES
- ➢ Default - O$_3$ vegetation damage (stomatal conductance) not activated in UKCA

HadGEM3 branch
F. Centoni (CEH & U. Edinburgh)



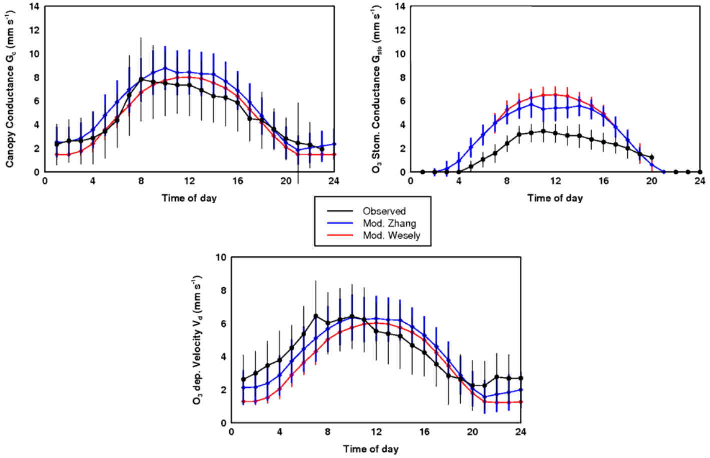
- ➢ Implementation of Zhang et al. scheme (Atmos. Chem. Phys. 2003) for O$_3$
- ➢ Allows for stomatal blocking when wet, which reduces stomatal uptake.

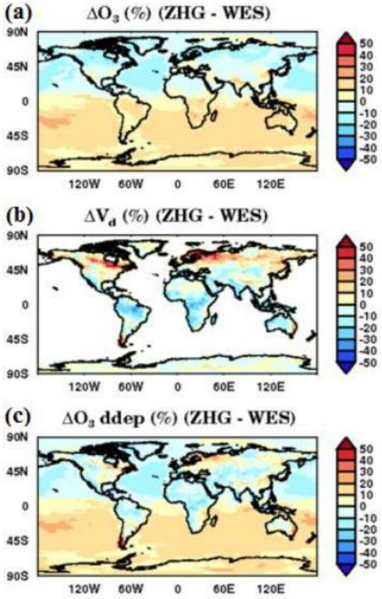
O_3 deposition velocity in the UKCA model:

(F Centoni CEH/U. Edinburgh)

- Also
    - Included missing terms: in-canopy aerodynamic (R_{ca}) and cuticular (R_{cut}) resistances, as part of non-stomatal in-canopy deposition fluxes
    - Disentangled stomatal from soil resistance term
- Site evaluation
    - Good ability to capture diurnal variation at selected sites
    - Less good where plants experience water stress (e.g., in the Mediterranean basin)
- Global runs
    - Comparison of ozone concentrations, deposition velocities and fluxes

Easter Bush, SE Scotland, (55N 3W)
Grassland, Spring 2002





Dry Deposition in UKESM: Future Requirements

- Tighter coupling to ecosystems
    - Increase consistency between UKCA (Gas and Aerosols) and JULES as more land surface types added
    - Oceans and the cryosphere
    - Consider 3D-canopy deposition model (link to CanEXMIP)
- Move towards more process-based dry deposition schemes
- Shift towards 'bidirectional surface exchange' schemes: deposition, (re-)emission and PBL mixing
    - Closure of the N-cycle (towards a fully coupled atmosphere-land surface scheme)

- Designing a new framework for modelling dry deposition
    - Community consultation and workshop held in 2016/2017
    - Where should dry deposition 'live'? – JULES~~, UKCA or new interface module~~

Current progress

- Implementation in JULES
  - Recoded UKCA gas-phase dry deposition routines (from UM vn10.9, October 2017) for use in JULES (version 5.0, October 2017)
  - JULES branch with JULES ticket 662: https://code.metoffice.gov.uk/trac/jules/browser/main/branches/dev/garryhayman/JULES_vn5.0_with_atmospheric_deposition
- Testing
  - Runs of standalone JULES at single sites using rose suites: u-at173 (Auchencorth Moss, 5 pfts), u-aw796 (Alice Holt, 5pfts) and u-ax313 (Alice Holt, 13 pfts) on CEH local linux system.
  - Created offline 'toy' model to compare outputs from JULES and UKCA deposition routines driven with the same values of the calling variables (taken from the standalone JULES runs)
  - Confirmed resistance and deposition velocity terms were the same (except where differences expected)
  - Ported to JASMIN: rose suites u-ax608 (Alice Holt, 13 pfts) and u-ax609 (Alice Holt, 5pfts)

Input & Output

	JULES standalone	UM-JULES (coupled)
Input	- Resistance parameters - Surface atmospheric concentrations (prescribed data)	- Resistance parameters - Surface atmospheric concentrations (UKCA)
Output	- R_a, R_b, R_c, deposition velocities - Deposition fluxes	- R_a, R_b, R_c, deposition velocities - Deposition fluxes

l_deposition_flux: true

Deposition namelists

```
&jules_deposition
dep_model=2,
l_deposition=.true.,
l_deposition_flux=.false.,
l_ukca_ddep_lev1=.true.,
/
&jules_depparm
bl_levels=20,
dep_species_names_io='O3','CH4','CO','H2','SO2','MeOOH',
ndep_species=6,
pft_codes_io=101,102,103,201,202,3,301,302,4,401,402,501,502, for current UKCA implementation
!pft_codes_io=102,103,101,202,201,3,301,302,4,401,402,502,501,
/
```

Notes

- l_deposition and l_deposition_fluxes are switches to use deposition and for calculating deposition fluxes (requires surface species concentrations)
- dep_model = 1 (current implementation in UM-UKCA); = 2 (implementation in JULES); = 3 (Zhang O_3 scheme)
- l_ukca_ddep_lev1 is UKCA switch to calculate BL separation used in calculation of deposition velocities (true – use separation of bottom level, dzl(:,:,1); false – effectively use height of BL)
- bl_levels is number of BL levels
- pft_codes_io – identifies and defines order of pfts (and hence surface types). Values shown for 13 pft implementation in UKCA (Commented out values are order in rose suite, u-ax313)

Code development

- jules/control/shared/
  - jules_deposition_mod.F90 – defines deposition namelists and namelist routines
- jules/initialisation/standalone/
  - init_jules_deposition_mod.F90 - reads deposition namelists
- jules/src/science/surface
  - jules_deposition_ctl_mod.F90 - control routine for deposition (gas-phase)
  - jules_deposition_ctl_mod.inc – temporary include file to print out variable values
  - jules_deposition_ra_rb_mod.F90 - calculates aerodynamic (R_a) and quasi-laminar (R_b) resistances
  - jules_deposition_rc_ukca_mod.F90 – calculates surface resistances (R_c)
  - jules_deposition_rc_zhang_o3_mod.F90 – F Centoni's implementation of the Zhang et al scheme for O_3 (transcribed from his HadGEM3 branch)
  - jules_deposition_rc_zhang_o3_mod.inc – temporary include file to print out variable values
  - jules_deposition_depvel_mod.F90 – calculates deposition velocity and first-order loss rates
  - jules_deposition_parm_mod.F90 – declaration of variables used in deposition
  - jules_deposition_pfts_mod.F90 – assigns surface types (and order) used in JULES run from input pft_codes_io
  - jules_deposition_ukca_constants.F90 – relative molecular masses

ukca_ddepctl.F90

ukca_raero.F90

ukca_surfddr.F90

ukca_ddcalc.F90

Code development

- Changes made to existing JULES code
  - jules/src/control/shared/max_dimensions_mod.F90 – add max number of deposition species
  - jules/src/control/shared/surf_couple_explicit_mod.F90 – friction velocity made available for standalone JULES
  - jules/src/control/standalone/control.F90 – calling routine for jules_deposition_ctl
  - jules/src/initialisation/standalone/allocate_jules_arrays.F90 – allocate deposition diagnostic and other arrays
  - jules/src/initialisation/standalone/init.F90 – calling routine for init_jules and input of deposition namelists (needs to be called before call to init_grid to set ndep_species)
  - jules/src/io/extract_var.inc – get values for output deposition diagnostics
  - jules/src/io/model_interface_mod.F90 – increased number of variables for output deposition diagnostics and added new output "types"
  - jules/src/io/variable_metadata.inc – increase total number of diagnostics for added output deposition diagnostics: dep_ra, dep_rb, dep_rc, dep_vd, dep_loss_rate, …. (output on land vector)
  - jules/src/science/surface/physiol_jls_mod.F90 – access stomatal conductance without bare soil evaporation

Toy Model: JULES vs UKCA

- Alice Holt, 1st-3rd July 2005, 13pfts (u-ax313)

JULES - values at time step 72 (12:00 2nd July 2005)

pft									
	1-BL D	2: BL EG trop	3-BL EG temp	4-NL D	5-NL EG	6-C3 grass	7-C3 crop	8-C3 past	9-C4 grass
	10-C4 crop	11-C4 past	12-shrub D	13-shrub EG	14-urban	15-water	16-soil	17-ice	
Timestep	72								

Surface resistance (R_c, s m^{-1})

O3	116.1936	118.2658	112.8428	119.8690	112.8699	97.6584	97.3913	97.3913	131.6371
	131.6833	131.6833	120.1543	127.9647	1.0000E+30	1.0000E+30	645.0000	1.0000E+30	
CH4	1.0632E+05	1.0631E+05	1.0630E+05	8.3994E+04	8.3996E+04	1.3980E+05	1.3981E+05	1.3981E+05	1.1320E+05
	1.1320E+05	1.1320E+05	1.5253E+05	1.5253E+05	1.0000E+30	1.0000E+30	1.0120E+04	1.0000E+30	
CO	3700.0000	3700.0000	3700.0000	7300.0000	7300.0000	4550.0000	4550.0000	4550.0000	1960.0000
	1960.0000	1960.0000	4550.0000	4550.0000	1.0000E+30	1.0000E+30	4550.0000	1.0000E+30	
H2	1275.4896	1275.4896	1275.4896	1275.4896	1275.4896	1670.9880	1670.9880	1670.9880	4423.1694
	4423.1694	4423.1694	1670.9880	1670.9880	1.0000E+30	1.0000E+30	1670.9880	1.0000E+30	
SO2	137.0000	111.1000	111.9000	131.3000	130.4000	209.8000	209.8000	209.8000	196.1000
	196.1000	196.1000	185.8000	196.1000	1.0000E+30	1.0000E+30	213.5000	1.0000E+30	
MeOOH	300.3000	270.3000	266.9000	238.0000	238.5000	366.3000	366.3000	366.3000	322.9000
	322.9000	322.9000	332.8000	392.2000	1.0000E+30	1.0000E+30	585.4000	1.0000E+30	

Setting Alice Holt latitude to 71.1833°N to test high-latitude option (only affects shrub pfts)

Surface resistance (R_c, s m^{-1})

O3	116.1936	118.2658	112.8428	119.8690	112.8699	97.6584	97.3913	97.3913	131.6371
	131.6833	131.6833	154.1053	153.4934	1.0000E+30	1.0000E+30	800.0000	1.0000E+30	
CH4	1.0632E+05	1.0631E+05	1.0630E+05	8.3994E+04	8.3996E+04	1.3980E+05	1.3981E+05	1.3981E+05	1.1320E+05
	1.1320E+05	1.1320E+05	4.9618E+04	4.9602E+04	1.0000E+30	1.0000E+30	3290.7332	1.0000E+30	
CO	3700.0000	3700.0000	3700.0000	7300.0000	7300.0000	4550.0000	4550.0000	4550.0000	1960.0000
	1960.0000	1960.0000	2.5000E+04	2.5000E+04	1.0000E+30	1.0000E+30	2.5000E+04	1.0000E+30	
H2	1275.4896	1275.4896	1275.4896	1275.4896	1275.4896	1670.9880	1670.9880	1670.9880	4423.1694
	4423.1694	4423.1694	10000.0000	10000.0000	1.0000E+30	1.0000E+30	10000.0000	1.0000E+30	
SO2	137.0000	111.1000	111.9000	131.3000	130.4000	209.8000	209.8000	209.8000	196.1000
	196.1000	196.1000	185.8000	196.1000	1.0000E+30	1.0000E+30	213.5000	1.0000E+30	
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	131.6833	131.6833	120.1543	127.9647	1.0000E+30	1.0000E+30	645.2000	1.0000E+30	
CH_4	1.0632E+05	1.0631E+05	1.0630E+05	8.3994E+04	4.1998E-24	4.1941E-24	4.1942E-24	4.1942E-24	4.1886E-24
	4.1886E-24	4.1886E-24	4.1947E-24	1.5253E+05	1.0000E+30	1.0000E+30	1.0120E+04	1.0000E+30	
CO	3700.0000	3700.0000	3700.0000	7300.0000	7300.0000	4550.0000	4550.0000	4550.0000	1960.0000
	1960.0000	1960.0000	4550.0000	4550.0000	1.0000E+30	1.0000E+30	4550.0000	1.0000E+30	
H_2	1275.4893	1275.4893	1275.4893	1275.4893	1275.4893	1671.7789	1671.7789	1671.7789	0.9083
	0.9083	0.9083	2.2865E+04	1275.4893	1.0000E+30	1.0000E+30	1275.4893	1.0000E+30	
SO_2	137.0000	111.1000	111.9000	131.3000	130.4000	209.8000	209.8000	209.8000	196.1000
	196.1000	196.1000	185.8000	196.1000	1.0000E+30	1.0000E+30	213.5000	1.0000E+30	
CH_3OOH	300.3000	270.3000	266.9000	238.0000	238.5000	366.3000	366.3000	366.3000	322.9000
	322.9000	322.9000	332.8000	392.2000	1.0000E+30	1.0000E+30	585.4000	1.0000E+30	

Setting Alice Holt latitude to 71.1833°N to test high-latitude option

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CH_4	1.0632E+05	1.0631E+05	1.0630E+05	8.3994E+04	4.1998E-24	4.1941E-24	4.1942E-24	4.1942E-24	4.1886E-24
	4.1886E-24	4.1886E-24	4.1947E-24	4.9602E+04	1.0000E+30	1.0000E+30	3290.7332	1.0000E+30	
CO	3700.0000	3700.0000	3700.0000	7300.0000	7300.0000	4550.0000	4550.0000	4550.0000	1960.0000
	1960.0000	1960.0000	4550.0000	2.5000E+04	1.0000E+30	1.0000E+30	2.5000E+04	1.0000E+30	
H_2	1275.4893	1275.4893	1275.4893	1275.4893	1275.4893	1671.7789	1671.7789	1671.7789	0.9083
	0.9083	0.9083	2.2865E+04	10000.0000	1.0000E+30	1.0000E+30	10000.0000	1.0000E+30	
SO_2	137.0000	111.1000	111.9000	131.3000	130.4000	209.8000	209.8000	209.8000	196.1000
	196.1000	196.1000	185.8000	196.1000	1.0000E+30	1.0000E+30	213.5000	1.0000E+30	
CH_3OOH	300.3000	270.3000	266.9000	238.0000	238.5000	366.3000	366.3000	366.3000	322.9000
	322.9000	322.9000	332.8000	392.2000	1.0000E+30	1.0000E+30	585.4000	1.0000E+30	

Comments and Issues

- JULES Deposition Code
  - Flexible on pft configuration and order
    - Currently using lookup tables in code to assign surface resistance parameters to pft and species
    - Following discussion, these parameter values will be passed via namelist to avoid code change if add/change pft
  - Boundary-layer height variable defined in JULES (zh) but fixed at 1 km in standalone version (needed to convert deposition velocities to deposition fluxes)
  - # of boundary layer levels (bl_levels, set in deposition namelist) and separation of boundary layer levels (dzl, fixed values for code development) not available
- UKCA (UM vn 10.9, October 2017)
  - Origin of surface resistance values unclear (UKCA 5-pft scheme from STOCHEM)
  - Inconsistency in surface resistance values between pft configurations
  - Latter parts of code in ukca_surfddr.F90 hardwired for standard 5 pft configuration
    - Various places: For tundra regions, n set to npft assumes that last pft is shrubs (ok for 5 pft configuration)
    - H_2 deposition to C4 grass uses a different formulation. n=npft-2 used for C4 grass
    - Values of CH_4 uptake only calculated for first 4 and last pft
    - Working with Alan Hewitt (Met Office) to correct this (UM ticket 4157)

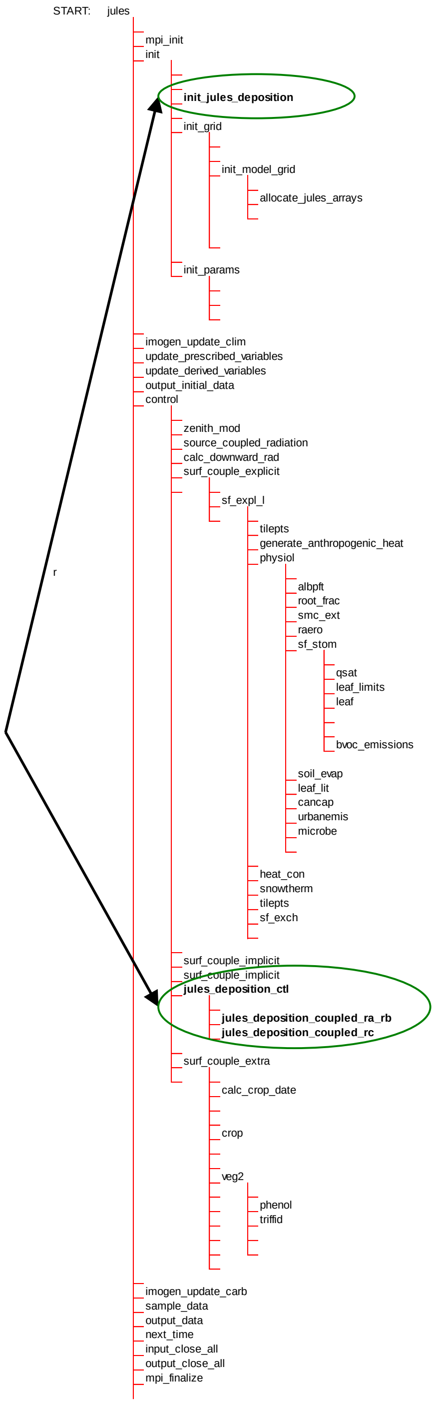
Relevant related activities

- JULES
  - Eleanor Blyth & Sebastian Garrigues: Review of aerodynamic resistance (R_a) schemes
  - Martin Best & Graham Weedon: Revise roughness lengths (which affect friction velocity), following evaluation of JULES friction velocity against FLUXNET observations of momentum flux. Relevant to aerodynamic resistance
- UKESM
  - Becky Oliver & Lina Mercado: Implementation and testing of new photosynthesis scheme, based on Medlyn et al.. Relevant to stomatal conductance
- US Ozone Deposition
  - Presentation at workshop (2017)
  - Paper on Ozone Deposition in preparation

Current and Future Work

- Comparison versus site observations
  - Code added to input and use surface species concentrations (Note: ozone available for ozone damage)
  - Get observational data – O_3 and other species
- Code development – JULES standalone
  - Add new CEH science from EMEP model (with CEH Edinburgh)
  - Standalone gridded runs at UK and global scale
  - Add Deposition code to JULES trunk (with Doug Clark, recommended to add small code changes)
  - *Add current UKCA aerosol code – discuss with dry deposition advisory group*
- Code development – coupled to UM
  - JULES driven with same inputs as standalone
  - Source variable values from UM
  - Fully couple
  - *Add Ashok Luhar's O_3 deposition scheme to oceans*

Calling tree



Atmospheric Deposition routines

Program/Subroutine	Directory	File
START: jules	src/control/standalone/	jules.F90
mpi_init	utils/mpi_dummy	mpi_routines.F90
init	src/initialisation/standalone	init.F90
init_jules_deposition	**src/initialisation/standalone**	**init_jules_deposition.F90**
init_grid	src/initialisation/standalone/grid	init_grid_mod.F90
init_model_grid	src/initialisation/standalone/grid	init_model_grid.inc
allocate_jules_arrays	src/initialisation/shared	allocate_jules_arrays.F90
init_params	src/initialisation/standalone	init_params_mod.F90
imogen_update_clim	src/control/imogen/	imogen_update_clim.F90
update_prescribed_variables	src/control/standalone/update	
update_derived_variables	src/control/standalone/update	update_derived_variables.inc
output_initial_data	src/io/output/	output_initial_data.inc
control	src/control/standalone/	control.F90
zenith_mod	src/control/standalone/	zenith_mod.F90
source_coupled_radiation	src/control/shared/	source_coupled_radiation_mod.F90
calc_downward_rad	src/control/standalone/	calc_downward_rad.inc
surf_couple_explicit	src/control/shared	surf_couple_explicit_mod.F90
sf_expl_l	src/science/surface	sf_expl_jls.F90
tilepts	src/control/shared	tilepts_jls.F90
generate_anthropogenic_heat	src/science/surface	generate_anthrop_heat_jls_mod.F90
physiol	src/science/surface	physiol_jls_mod.F90
albpft	src/science/radiation	albpft_jls_mod.F90
root_frac	src/science/surface	root_frac_jls_mod.F90
smc_ext	src/science/surface	smc_ext_jls_mod.F90
raero	src/science/surface	raero_jls.F90
sf_stom	src/science/surface	sf_stom_jls_mod.F90
qsat	src/science/surface	qsat_jls.F90
leaf_limits	src/science/surface	leaf_limits_mod.F90
leaf	src/science/surface	leaf_jls_mod.F90
bvoc_emissions	src/science/surface	bvoc_emissions_mod.F90
soil_evap	src/science/surface	soil_evap_jls.F90
leaf_lit	src/science/surface	leaf_lit_jls.F90
cancap	src/science/surface	cancap_jls.F90
urbanemis	src/science/radiation	urbanemis_mod.F90
microbe	src/science/surface	microbe_jls_mod.F90
heat_con	src/science/soil	heat_con_jls_mod.F90
snowtherm	src/science/snow	snowtherm_mod.F90
tilepts	src/science/surface	tilepts.F90
sf_exch	src/control/top_level/	sf_exch_jls_mod.F90
surf_couple_implicit	src/control/shared	surf_couple_implicit_mod.F90
surf_couple_implicit	src/control/shared	surf_couple_implicit_mod.F90
jules_deposition_ctl	**src/science/surface**	**jules_deposition_ctl_mod.F90**
jules_deposition_coupled_ra_rb	**src/science/surface**	**jules_deposition_coupled_ra_rb_mod.F90**
jules_deposition_coupled_rc	**src/science/surface**	**jules_deposition_coupled_rc_mod.F90**
surf_couple_extra	src/control/shared	surf_couple_extra_mod.F90
calc_crop_date	src/science/vegetation	calc_crop_date.F90
crop	src/science/vegetation	crop_mod.F90
veg2	src/science/vegetation	veg-veg2a_jls_mod.F90
phenol	src/science/vegetation	phenol_jls.F90
triffid	src/science/vegetation	triffid_jls.F90
imogen_update_carb	src/control/imogen	imogen_update_carb.F90
sample_data	src/io/output/	sample_data.inc
output_data	src/io/output/	output_data.inc
next_time	src/control/standalone	next_time.F90
input_close_all	src/io/output	close_all.inc
output_close_all	src/io/output	close_all.inc
mpi_finalize	utils/mpi_dummy	mpi_routines.F90
END of MODEL RUN		

Deposition variables - input

```
! Variable renamed to the equivalent used in JULES
! Variables with _ij are gridded (lon, lat), otherwise arrays on land points
!
! UKCA variable                     JULES equivalent
! -------------                     ----------------
! row_length                        row_length                ancil_info
! rows                              rows                      ancil_info
! bl_levels                         bl_levels                 ** jules_depparm namelist
! land_points                       land_points               ancil_info
! land_index                        land_index                ancil_info
! tile_pts                          surft_pts                 ancil_info
! tile_index                        surft_index               ancil_info
! timestep (sec_per_step)           timestep_len              model_time_mod
! sinlat (sinlat_pos)               as latitude               model_grid_mod
! tile_frac                         tile_frac                 passed via subroutine call
! t_surf                            tstar_ij                  passed via subroutine call
! p_surf                            pstar_ij                  passed via subroutine call
! dzl                               dzl_ij                    jules_deposition_parm
! zbl                               zbl_ij                    passed via subroutine call
! surf_hf                           surf_ht_flux_ij           passed via subroutine call
! u_s                               ustar_ij                  passed via subroutine call
! rh (rel_humid_frac)               rh_ij                     use qsat_wat
! seaice_frac                       ice_fract_ij              ancil_info
! stcon                             gc_surft                  prognostics
! soilmc_lp (soil_moisture_layer1)  smc_soilt                 prognostics
! fland                             fland                     coastal
! laift_lp                          lai_pft                   prognostics
! canhtft_lp                        canht_pft                 prognostics
! z0tile_lp                         z0h_surft                 passed via subroutine call
! t0tile_lp                         tstar_surft               prognostics
! canwctile_lp                      canopy_surft              prognostics
! For Zhang O3 scheme
! net_sw_down                       sw_down_ij                passed via subroutine call
```

Deposition variables - output

```
! Variables with _ij are gridded (lon, lat), otherwise arrays on land points
```

Existing

```
! UKCA variable                    JULES equivalent
! -------------                    ----------------
! nlev_with_ddep                   nlev_with_ddep(_ij)       jules_deposition_parm
! zdryrt                           dep_loss_rate(_ij)        jules_deposition_parm
!
```

New – all in `jules_deposition_parm` module

```
! JULES variable                                 definition
! --------------                                 ----------
! dep_ra(land_pts,ntype)                         aerodynamic resistance(s m^-1)
! dep_ra_ij(row_length,rows,ntype)

! dep_rb(land_pts,ndep_species)                  quasi-laminar resistance(s m^-1)
! dep_rb_ij(row_length,rows,ndep_species)

! dep_rc(land_pts,ntype,ndep_species)            surface resistance(s m^-1)
! dep_rc_ij(row_length,rows,ntype,ndep_species)

! dep_vd(land_pts,ntype,ndep_species)            deposition velocity(m s^-1)
! dep_vd_ij(row_length,rows,ntype,ndep_species)

! dep_loss_rate(land_pts,ndep_species)           first-order loss rate(s^-1)
! dep_loss_rate_ij(row_length,rows,ndep_species)

! dep_flux(land_pts,ntype,ndep_species)          species deposition flux(kg m^-3 s^-1)
! dep_flux_ij(row_length,rows,ntype,ndep_species)
```

Toy Model: JULES vs UKCA

- Alice Holt, 1st-3rd July 2005, 5pfts (u-aw796)

JULES - values at time step 72 (12:00 2nd July 2005)

pft	1-BL	2-NL	3-C3 grass	4-C4 grass	5-shrub	6-urban	7-water	8-soil	9-ice
Timestep	72								
Aerodynamic resistance (R_a, s m^{-1})									
	30.2690	29.7072	40.9614	41.1966	37.6612	53.9986	53.9986	53.9986	53.9986
Quasi-laminar resistance (R_b, s m^{-1})									
O_3	6.8386								
CH_4	2.6696								
CO	5.6586								
H_2	2.4081								
SO_2	7.5787								
CH_3OOH	7.2976								
Surface resistance (R_c, s m^{-1})									
O_3	149.8141	155.8510	97.0746	175.4059	125.2227	1.00E+30	1.00E+30	1.00E+30	1.00E+30
CH_4	1.9576E+05	1.5477E+05	2.5782E+05	2.0868E+05	2.8122E+05	1.00E+30	1.00E+30	1.00E+30	1.00E+30
CO	3700.0000	7300.0000	4550.0000	1960.0000	4550.0000	1.00E+30	1.00E+30	1.00E+30	1.00E+30
H_2	3026.7647	3026.7647	6651.4600	5220.4912	6651.4600	1.00E+30	1.00E+30	6.65E+03	1.00E+30
SO_2	100.0000	100.0000	150.0000	350.0000	400.0000	1.00E+30	1.00E+30	1.00E+30	1.00E+30
CH_3OOH	30.0000	10.0000	10.0000	10.0000	10.0000	1.00E+30	1.00E+30	1.00E+30	1.00E+30

Setting Alice Holt latitude to 71.1833°N to test high-latitude option

Surface resistance (R_c, s m^{-1})									
O_3	149.8141	155.8510	97.0746	175.4059	138.2023	1.00E+30	1.00E+30	1.00E+30	1.00E+30
CH_4	1.9576E+05	1.5477E+05	2.5782E+05	2.0868E+05	4.9647E+04	1.00E+30	1.00E+30	1.00E+30	1.00E+30
CO	3700.0000	7300.0000	4550.0000	1960.0000	25000.0000	1.00E+30	1.00E+30	1.00E+30	1.00E+30
H_2	3026.7647	3026.7647	6651.4600	5220.4912	10000.0000	1.00E+30	1.00E+30	1.00E+04	1.00E+30
SO_2	100.0000	100.0000	150.0000	350.0000	400.0000	1.00E+30	1.00E+30	1.00E+30	1.00E+30
CH_3OOH	30.0000	10.0000	10.0000	10.0000	10.0000	1.00E+30	1.00E+30	1.00E+30	1.00E+30

Toy Model: JULES vs UKCA

- Alice Holt, 1st-3rd July 2005, 5pfts (u-aw796)

UKCA - values at time step 72 (12:00 2nd July 2005)

pft	1-BL	2-NL	3-C3 grass	4-C4 grass	5-shrub	6-urban	7-water	8-soil	9-ice
Timestep	72								
Aerodynamic resistance (R_a, s m^{-1})									
	30.2690	29.7072	40.9614	41.1966	37.6612	53.9986	53.9986	53.9986	53.9986
Quasi-laminar resistance (R_b, s m^{-1})									
O_3	6.8386								
CH_4	2.6696								
CO	5.6586								
H_2	2.4081								
SO_2	7.5787								
CH_3OOH	7.2976								
Surface resistance (R_c, s m^{-1})									
O_3	149.8141	155.8510	97.0746	175.4059	125.2227	1.00E+30	1.00E+30	1.00E+30	1.00E+30
CH_4	1.9576E+05	1.5477E+05	2.5782E+05	2.0868E+05	2.8122E+05	1.00E+30	1.00E+30	1.00E+30	1.00E+30
CO	3700.0000	7300.0000	4550.0000	1960.0000	4550.0000	1.00E+30	1.00E+30	1.00E+30	1.00E+30
H_2	3026.7639	3026.7639	6668.8208	5221.5820	6668.8208	1.00E+30	1.00E+30	6.67E+03	1.00E+30
SO_2	100.0000	100.0000	150.0000	350.0000	400.0000	1.00E+30	1.00E+30	1.00E+30	1.00E+30
CH_3OOH	30.0000	10.0000	10.0000	10.0000	10.0000	1.00E+30	1.00E+30	1.00E+30	1.00E+30

Setting Alice Holt latitude to 71.1833°N to test high-latitude option

Precision difference of H_2 deposition parameters

Surface resistance (R_c, s m^{-1})	1-BL	2-NL	3-C3 grass	4-C4 grass	5-shrub	6-urban	7-water	8-soil	9-ice
O_3	149.8141	155.8510	97.0746	175.4059	138.2023	1.00E+30	1.00E+30	1.00E+30	1.00E+30
CH_4	1.9576E+05	1.5477E+05	2.5782E+05	2.0868E+05	4.9647E+04	1.00E+30	1.00E+30	1.00E+30	1.00E+30
CO	3700.0000	7300.0000	4550.0000	1960.0000	25000.0000	1.00E+30	1.00E+30	1.00E+30	1.00E+30
H_2	3026.7639	3026.7639	6668.8208	5221.5820	10000.0000	1.00E+30	1.00E+30	1.00E+04	1.00E+30
SO_2	100.0000	100.0000	150.0000	350.0000	400.0000	1.00E+30	1.00E+30	1.00E+30	1.00E+30
CH_3OOH	30.0000	10.0000	10.0000	10.0000	10.0000	1.00E+30	1.00E+30	1.00E+30	1.00E+30