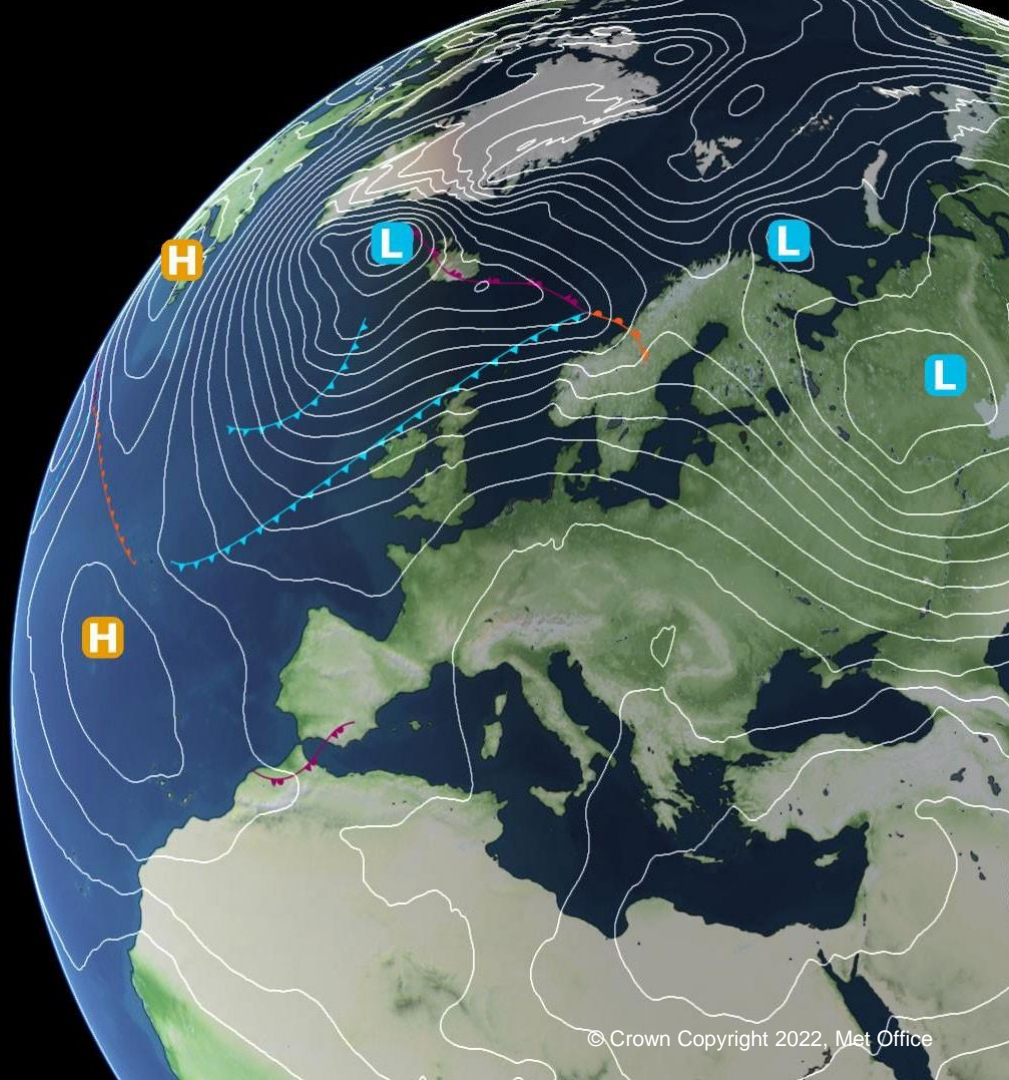


UK climate models

Alejandro Bodas-Salcedo

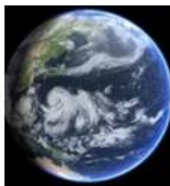
J. Mulcahy, M. Willet, C. Guiavarch, J. Rostron, D. Sexton, and many more.



Outline

- GC: physical climate configurations
 - UKESM: Earth system processes
 - CMIP7
 - COSP
 - Description
 - Examples for evaluation
 - Contribution
-

Global Seamless Physical Model

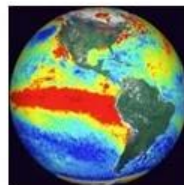


NWP

Deterministic Atmosphere & Marine



Atmos. Ensemble



GloSea (Seasonal)

CLIMATE

DePreSys (Decadal)



Climate Change UKESM1, UKCP18

Component Models
GAL, GO, GSI, GW

GC Model
GC.x



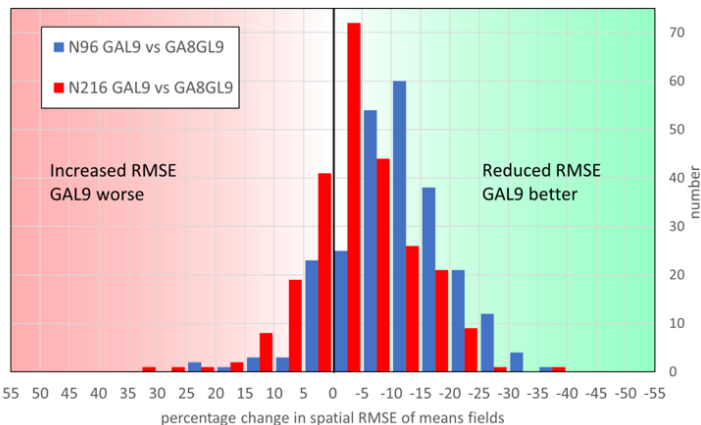
HadGEM3-GC5 physical climate



Met Office



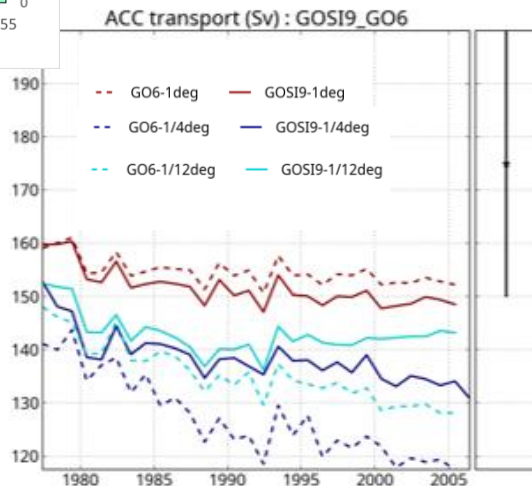
Histogram of change in spatial RMSE of mean fields in valnote



(Credit: Martin Willett)

General present-day performance improved relative to previous configurations

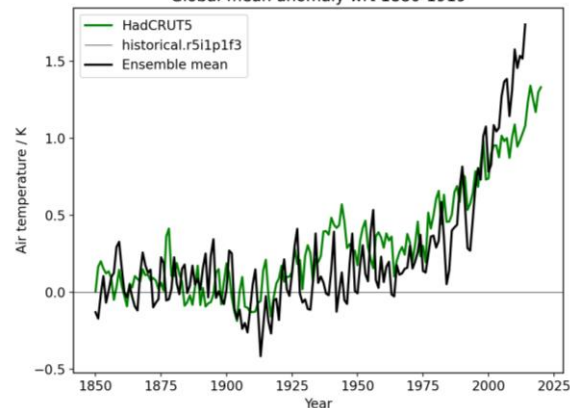
GC5 = **GAL9**
atmosphere + land
configuration + **GOSI9**
ocean & sea ice



(Credit: Catherine Guiavarch)

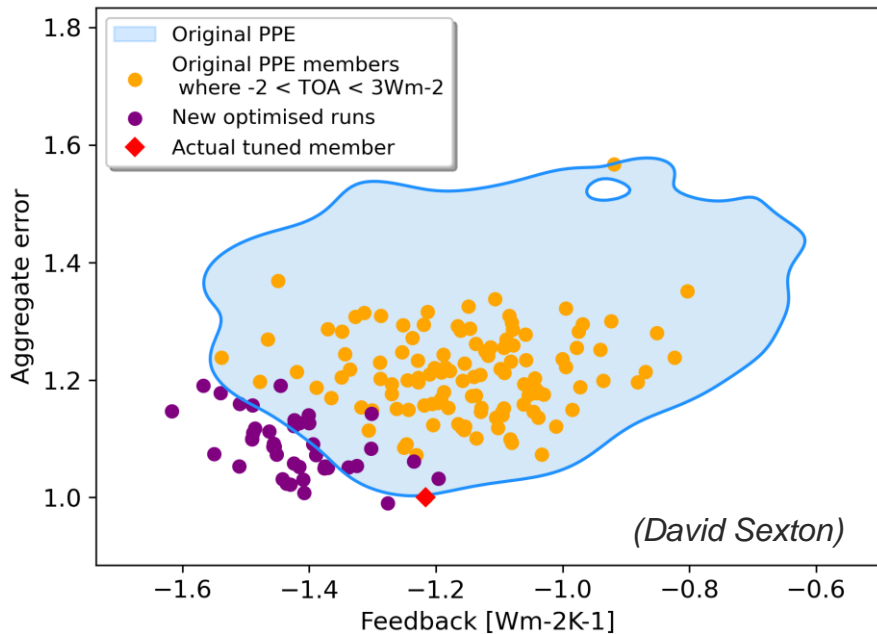
Transient historical performance

Global-mean anomaly wrt 1880-1919

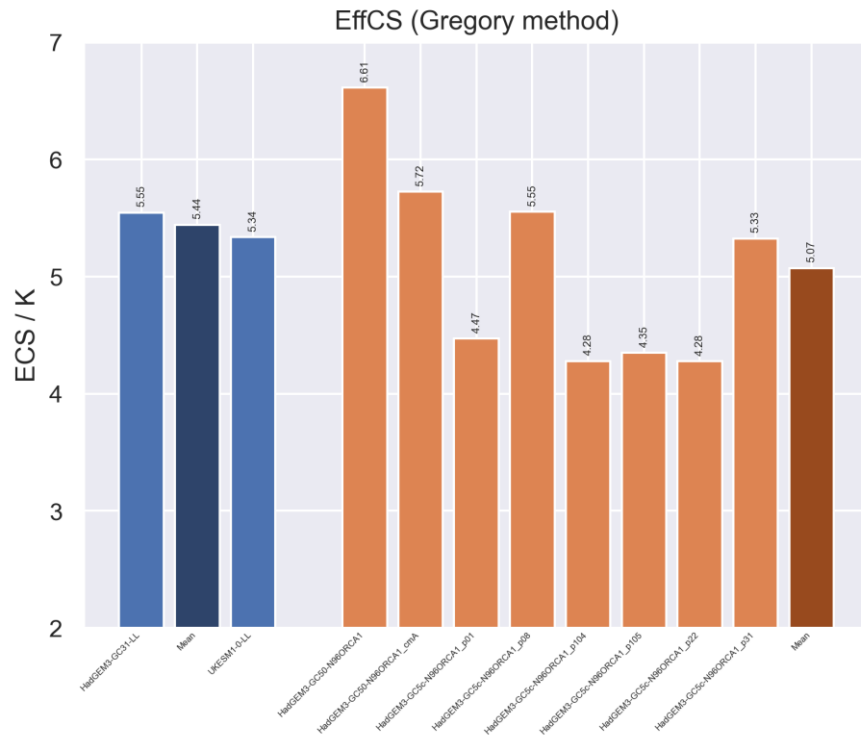


GC5 *historical* simulation warms too fast over recent decades. EffCS is very high (>6K), outside the range we pre-defined that we would accept for climate use.

GAL9.0 PPE (amip & amip-p4K)



Coupled simulations



Developments in future configurations

- GC6: new dynamical core on a cubed-sphere mesh; UM physics; completely new infrastructure (new code base).
- Unified physics: same physics configuration for global and regional that includes CoMorph (convection), CASIM (microphysics) and a single cloud scheme.
- ML-based physical parameterisations.

What is UKESM?



Met Office



- **UKESM** is the **UK's Earth System model** jointly developed by the Met Office and NERC (Natural Environment Research Council)
- UKESM consists of the HadGEM3 global coupled **physical climate model** plus additional components that model key **biogeochemical, chemistry, aerosol and vegetation and cryosphere** processes.
- UKESM1 officially released to the community in February 2019.
- UKESM1 used to provide a significant part of the UK's contribution to **CMIP6**.
- In 2023 an updated version **UKESM1.1** was released
- Also, a **Hybrid** (higher resolution atmosphere/ocean, lower resolution chemistry/ocean biogeochemistry) and **Fast** (low resolution version N48 ~250km) version have been developed
- Currently developing **UKESM2 → CMIP7 and beyond**

(Jane Mulcahy)

Brief History of UK ESMs



Met Office



HadCM3 **HadGEM2-ES** **UKESM1** **UKESM2**

1999 **2009** **2019** **??**



	1999	2009	2019	??
Carbon BGC	-C only	-C only	-CN coupled	-CN coupled
Vegetation dynamics	5 PFTs No LUC	5 PFTs Basic LUC	9 natural 4 crop/pasture LUC and harvest	13 PFTs
Ocean BGC	2 plankton types	HadDiat 4 plankton types	MEDUSA 4 plankton types	MEDUSA 4 plankton types
Aerosols		CLASSIC aerosols (mass-based)	UKCA-MODE aerosols (2-moment modal)	<i>UKCA-mode ++</i>
Chemistry		Tropospheric scheme	Stratospheric-tropospheric scheme	Stratospheric-tropospheric scheme
Ice sheets			Under development	Interactive Greenland & Antarctic IS
Wetlands/methane		Diagnostic wetlands	Diagnostic wetlands	Interactive CH4 emissions
Fire				INFERNO interactive emissions
Permafrost				Yes

(Jane Mulcahy)

UKESM1.3



Met Office



UKESM1.1

UKESM1.3

UKESM1.1 (Mulcahy et al, 2023)

plus

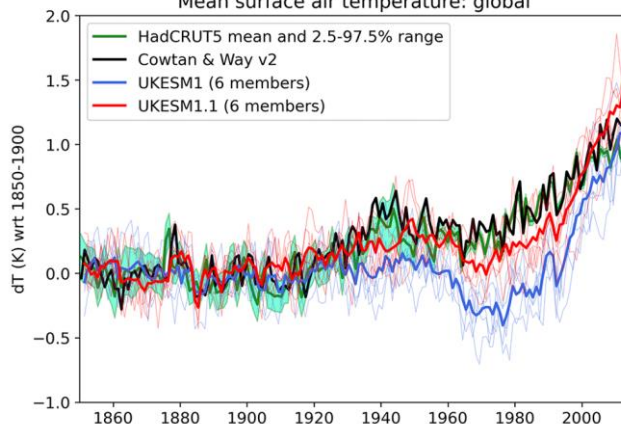
Emission-driven CO₂ and CH₄

Interactive ice-sheets

Currently running variant of this
(CH₄ emissions not included)

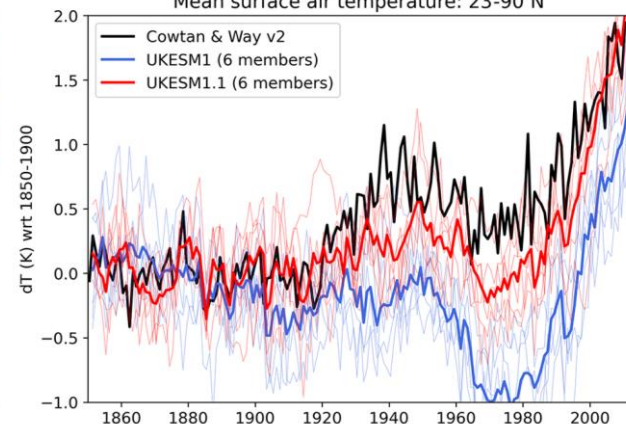
GLOBAL SAT

Mean surface air temperature: global



Northern Hemisphere

Mean surface air temperature: 23-90°N



UKESM1.1: Significant improvement in the historical GMST record is simulated, with the magnitude of the cold bias reduced by over 50 %. Small impact on ERFs & climate sensitivity

Mulcahy et al., (2023) GMD <https://doi.org/10.5194/gmd-16-1569-2023>

Forcing	UKESM1	UKESM1.1
Total anthropogenic	1.76	1.84
Well-mixed GHGs	2.91	2.84
Aerosol	-1.09	-1.01
Land use	-0.17	-0.22
EffCS	5.36K	5.27K

CMIP7 Fast Track

DECK

amip

piControl and esm-piControl

1pctCO2

abrupt-4xCO2

piClim-control

piClim-anthro

piClim-4xCO2

historical and/or esm-historical

Additions to the DECK since CMIP6

CMIP AR7 Fast Track

Climate services

DCPP

Initialised
prediction
(2025-2036)

ScenarioMIP

High scenario

Medium scenario

Low scenario 1

Low scenario 2

Low scenario 3

Process understanding

AerChemMIP

piClim-X

hist-piSLCF/hist-piAer

SSPX-SLCF

C4MIP

1pctCO2-bgc

1pctCO2-rad

esm-flat10-cdr

esm-flat10-zec

CFMIP

amip-p4k

amip-piForcing

abrupt-2xCO2

abrupt-0p5CO2

DAMIP

hist-nat

hist-aer

hist-GHG

GeoMIP

newGeoMIP

LMIP

land-hist

PMIP

LIGabrupt

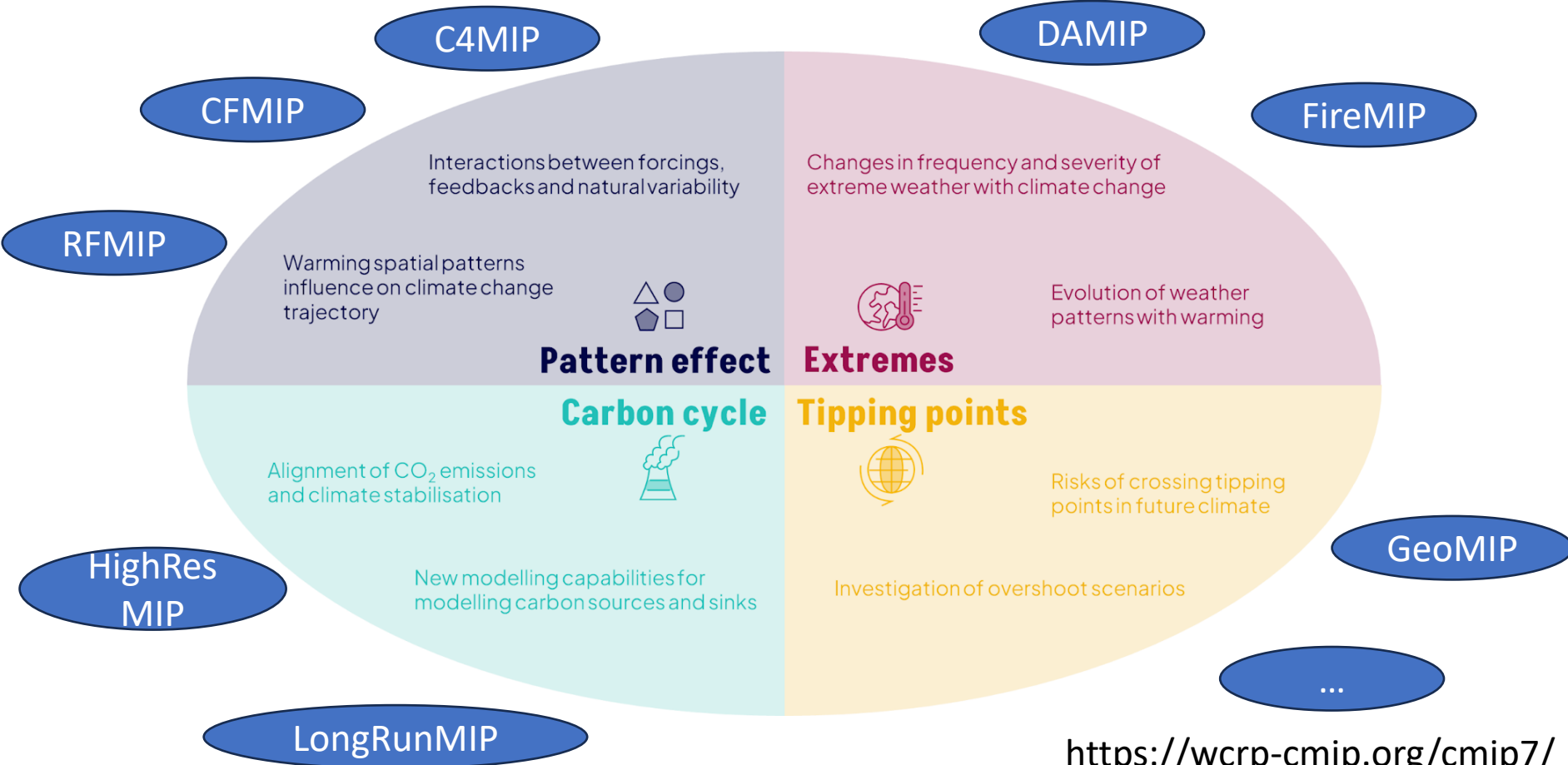
RFMIP

piClim-histaer

piClim-aer

piClim-histall

CMIP7 goals



COSP

Satellite simulation software for model assessment

BY A. BODAS-SALCEDO, M. J. WEBB, S. BONY, H. CHEPPER, J.-L. DUFRESNE, S. A. KLEIN, Y. ZHANG,
R. MARCHAND, J. M. HAYNES, R. PINCUS, AND V. O. JOHN
(*BAMS*, 2011)

Geosci. Model Dev., 11, 77–81, 2018

<https://doi.org/10.5194/gmd-11-77-2018>

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Geoscientific
Model Development  Open Access

The Cloud Feedback Model Intercomparison Project Observational Simulator Package: Version 2

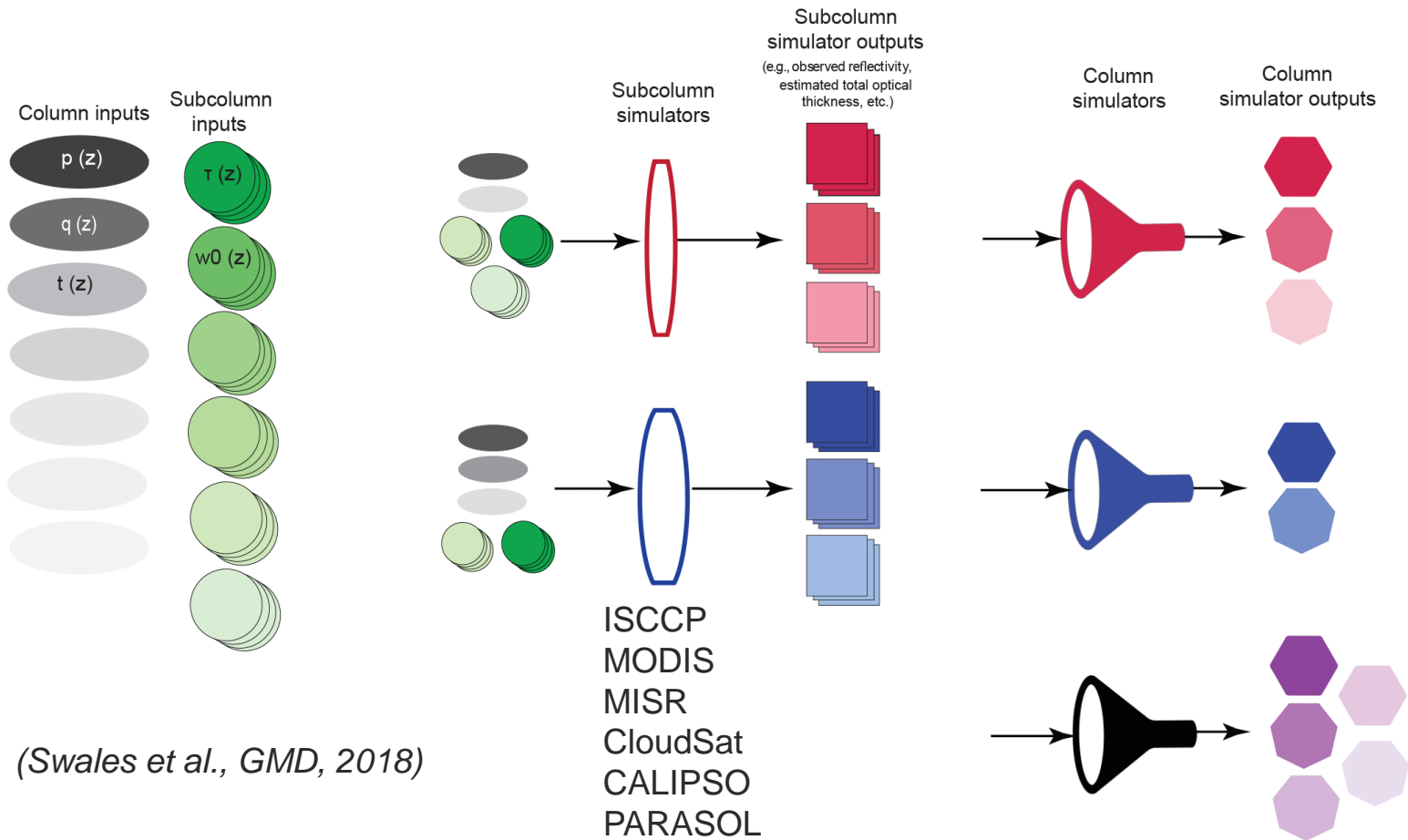
Dustin J. Swales^{1,2}, Robert Pincus^{1,2}, and Alejandro Bodas-Salcedo³

¹Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder, Colorado, USA

²NOAA/Earth System Research Laboratory, Boulder, Colorado, USA

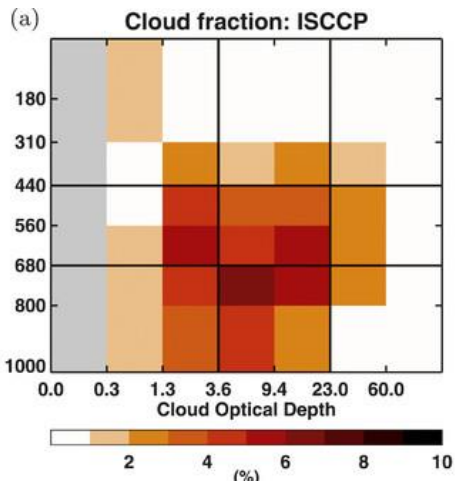
³Met Office Hadley Centre, Exeter, UK

(*GMD*, 2018)

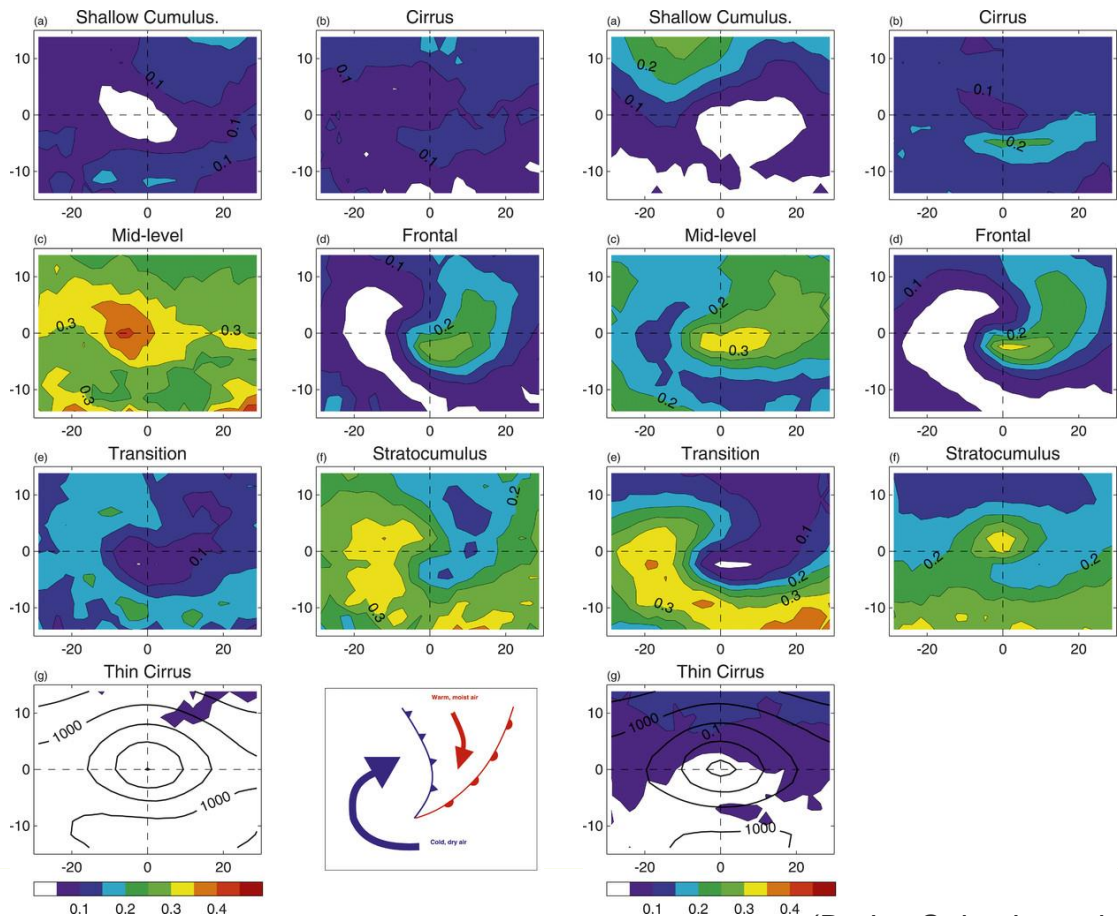


(Swales et al., GMD, 2018)

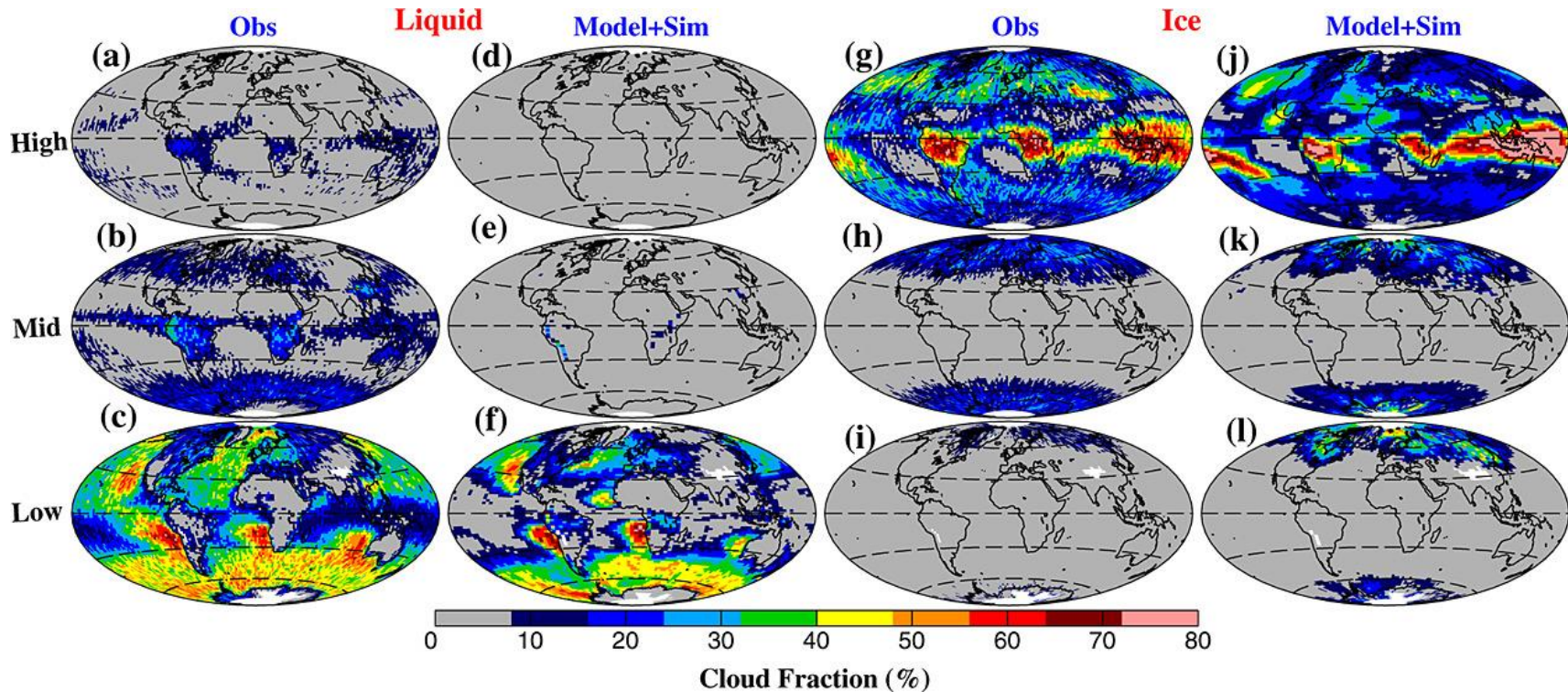
Evaluation with ISCCP



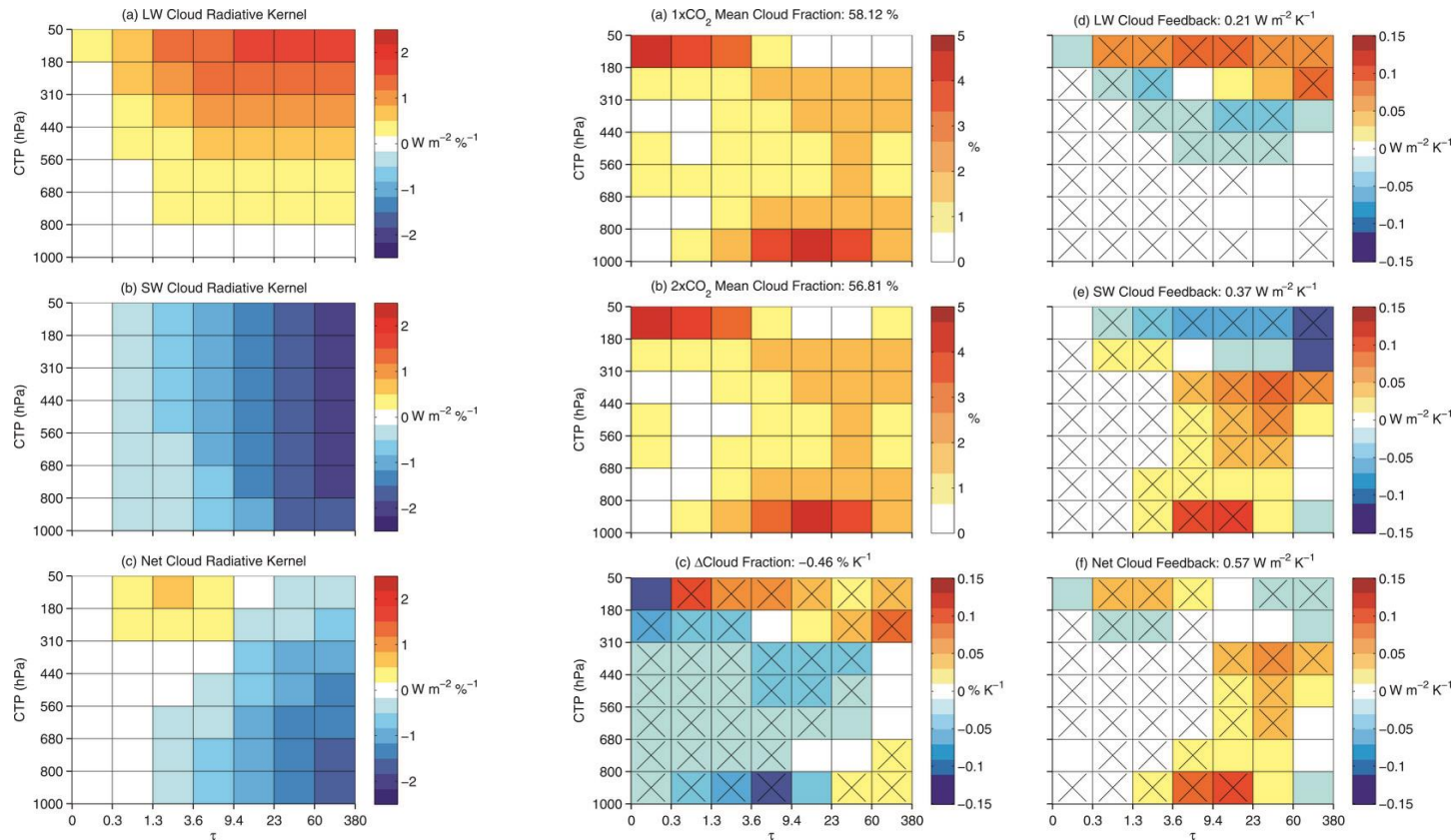
K-means clustering
Conditional sampling
around midlat. cyclones



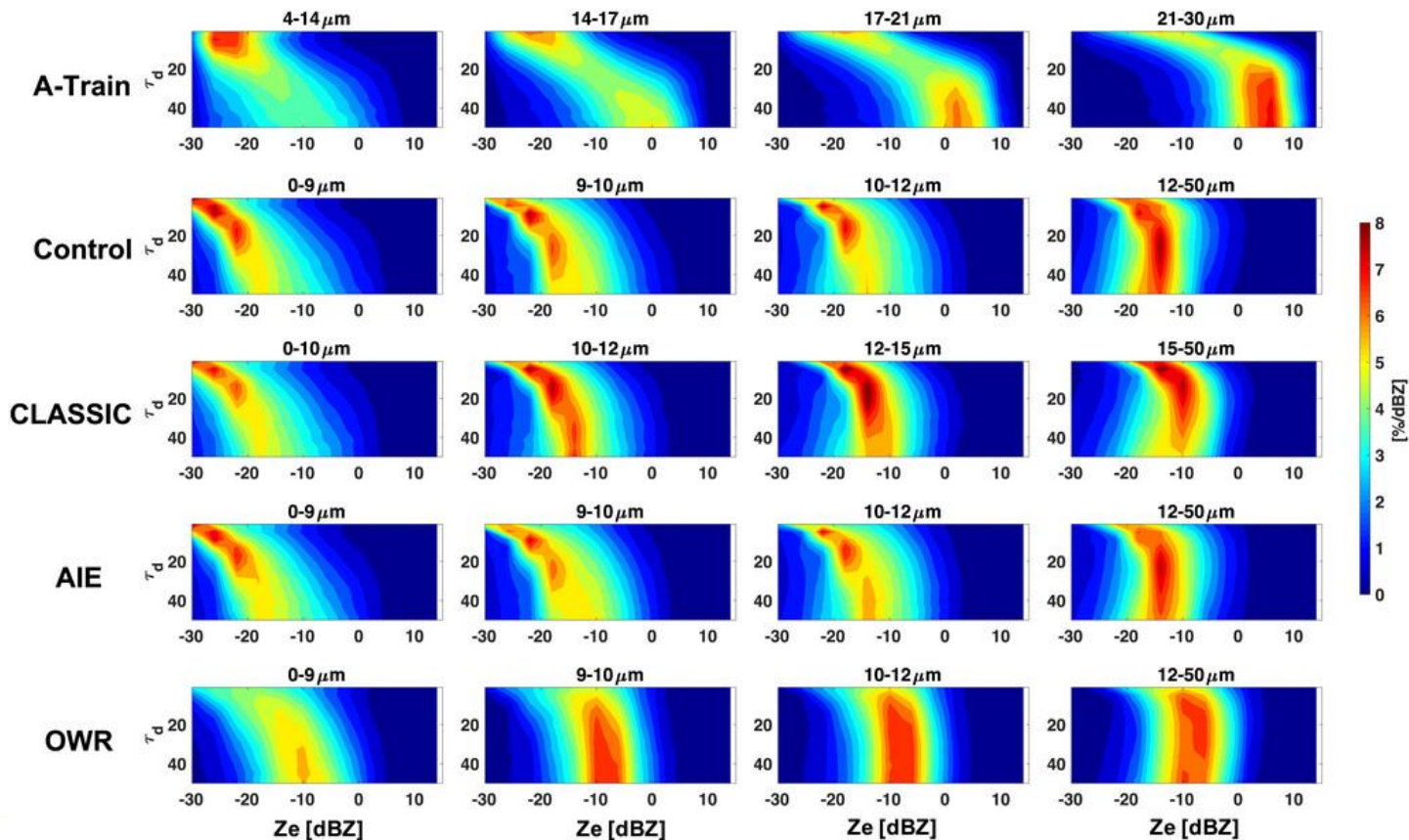
CALIPSO cloud fraction by phase



Feedback analysis



Evaluation with CloudSat & MODIS




COSP in CMIP6

	IS CA	IS CA	IS CA	MI MO PA CA CL	MO PA CA	MO PA CA CL
	cfMon-sim	cfDay-2d	cfDay-3d	CFMIP-cfMonExtra	CFMIP-cfDayExtra	Cf3hr-sim-new
amip	1979-	1979-	1979-	1979-	1979-	2008
piControl	140 years	140 years				
1pctCO2	140 years	140 years				
abrupt4xCO2	140 years	140 years				
historical	All years	All years				
cfMon-sim	cltisccp , albisccp , pctisccp , clisccp , cltcalipso , clcalipso , clmcalipso , clhcalipso , clcalipso					
cfDay-2d	cltisccp , albisccp , pctisccp , cltcalipso , clcalipso , clmcalipso , clhcalipso					
cfDay-3d	clisccp , clcalipso					
CFMIP-cfMonExtra	clcalipsoliq , clcalipsoice , cfadLidarsr532 , cfadDbze94 , clmisr , jpdftaureliqmodis , jpdftaureicemodis , clwmodis , climodis , cltmodis , parasolRefI					
CFMIP-cfDayExtra	jpdftaureliqmodis , jpdftaureicemodis , parasolRefI					
cf3hr-sim-new	clisccp , clcalipso , clcalipso2 , cltcalipso , clcalipso , clmcalipso , clhcalipso , cfadLidarsr532 , cfadDbze94 , clmisr , jpdftaureliqmodis , jpdftaureicemodis , parasolRefI					

IS	CA	CL
MI	MO	PA

new MODIS joint histograms #87

 Merged alejandrobodas merged 13 commits into CFMIP:master from caseywall17926:modis-diagnostics on Apr 2

 Conversation 13  Commits 13  Checks 5  Files changed 12



caseywall17926 commented on Mar 13


Contributor ...

We have written code to compute four new joint histogram diagnostics with the MODIS simulator:


- (1) CTP vs. COT histogram for ice-topped clouds
- (2) CTP vs. COT histogram for liquid-topped clouds
- (3) CWP vs. CER histogram for ice-topped clouds
- (4) CWP vs. CER histogram for liquid-topped clouds

(CTP: cloud-top pressure; COT: cloud optical thickness; CWP: cloud water path; CER: cloud particle size)



The joint histograms match the MODIS observational dataset described by Pincus et al. 2023 (<https://doi.org/10.5194/essd-15-2483-2023>).

 Upload multiple artifacts when CI fails



#90 by alejandrobodas was merged on Mar 21 • Approved

 Split CI workflows into gfortran and containerized


#88 by alejandrobodas was merged on Mar 16 • Approved

 Lfric warnings wp 


#82 by alejandrobodas was merged on Oct 27, 2023 • Approved

 Delete unused variables in quickbeam 

#81 by alejandrobodas was merged on Sep 13, 2023 • Approved

 Icarus: missing working precision and initialisation.

#78 by alejandrobodas was merged on Jul 21, 2023 • Approved

 Allocation of radar LUT. Delete unused variables. Update ifort KGO v002.

#77 by alejandrobodas was merged on Jun 7, 2023

- Open source distributed under 3-clause BSD license. Community-driven developments.
- COSP PMC look after the github repository: accept new changes, code reviews, regression tests.
- Major science changes need to demonstrate utility, e.g. intercomparison or evaluation paper.
- Changes should be discussed with the PMC from early stages to ensure that proposed work is in keeping with COSP objectives.

<https://github.com/CFMIP/COSPV2.0>

Hyperspectral capabilities in COSP?

- COSP is focused on clouds
 - How people imagine using hyperspectral observations for clouds?
 - Need fast RT to be run inline.
 - Calculations for all subcolumns may not be affordable.
 - Impact of TRUTHS sampling?
-

Summary

- Latest UK climate model configurations: GC5 and UKESM1.2
- Future climate model configurations
- Contribution to CMIP7
- COSP: overview, uses, contributions.