Issues on the way to an Open (Climate) Modelling Ecosystem

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With considerable help from the ES-DOC team; especially, Gerry Devine, Mark Morgan, Sylvia Murphy, Charlotte Pascoe, and Allyn Treshansky.

A lot of this is from: Lawrence, B. N., Balaji, V., Bentley, P., Callaghan, S., DeLuca, C., Denvil, S., Devine, G., Elkington, M., Ford, R. W., Guilyardi, E., Lautenschlager, M., Morgan, M., Moine, M.-P., Murphy, S., Pascoe, C., Ramthun, H., Slavin, P., Steenman-Clark, L., Toussaint, F., Treshansky, A., and Valcke, S.: **Describing Earth system simulations with the Metafor CIM**, Geosci. Model Dev., 5, 1493-1500, doi:10.5194/gmd-5-1493-2012, 2012

Outline

Complex Models and Communities

- Context
    - Reprise: what is a model? (Software);
    - How do we construct models? (Methodology);
    - Who builds and uses models? (Communities);
    - How do they understand each other (Poorly)
    - How do we compare models (With Difficulty)

Documenting Simulation (as opposed to models)

- Metafor/Curator and CMIP5
- The Future: ES-DOC

Engagement

- Quality, Validation and Review

Context

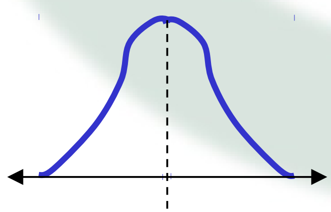
James Lovelock at the Geological Society, Burlington House,
5th May 2011

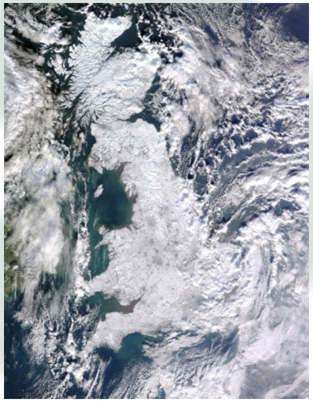
Science is still divided into co-existing disciplines each with its own language, journals and forceful defenders. We are tribal animals and such a trait is hard to resist.

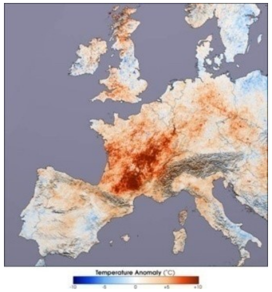
Societal needs for earth system science

1.	What is happening to climate? (globally, regionally and locally)	**Observation**	**Earth System Models (ESM)**
2.	Why is it happening?	**Attribution**	**Integrated Assessment Models (IAM)**
3.	What is going to happen?	**Prediction**	
4.	How can societies respond?	**Adaptation & Mitigation**	**Integrated Environmental Models (IEM)**

Information for decision making







Quite a few tribes there!

and so to

How we think about models

(Which is not how everyone does!)

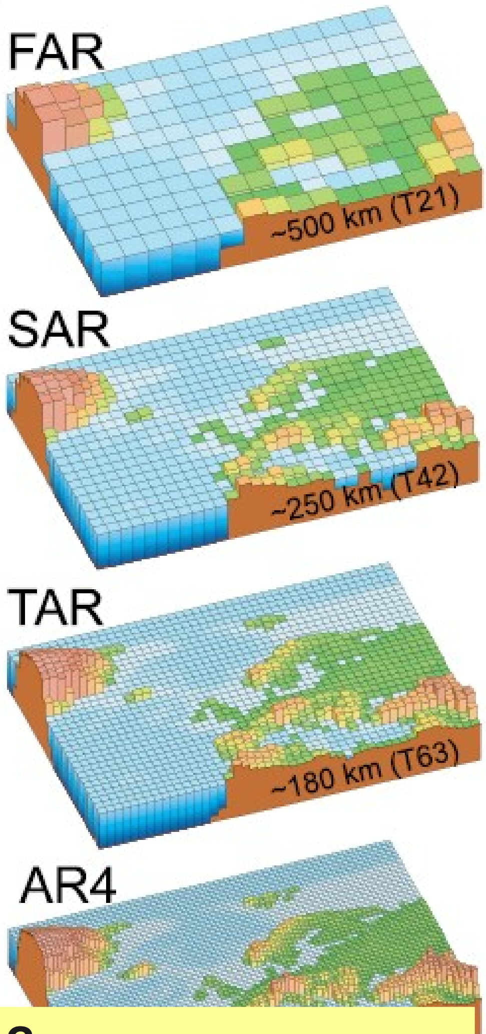
The world “model”
has somewhat wider usage!

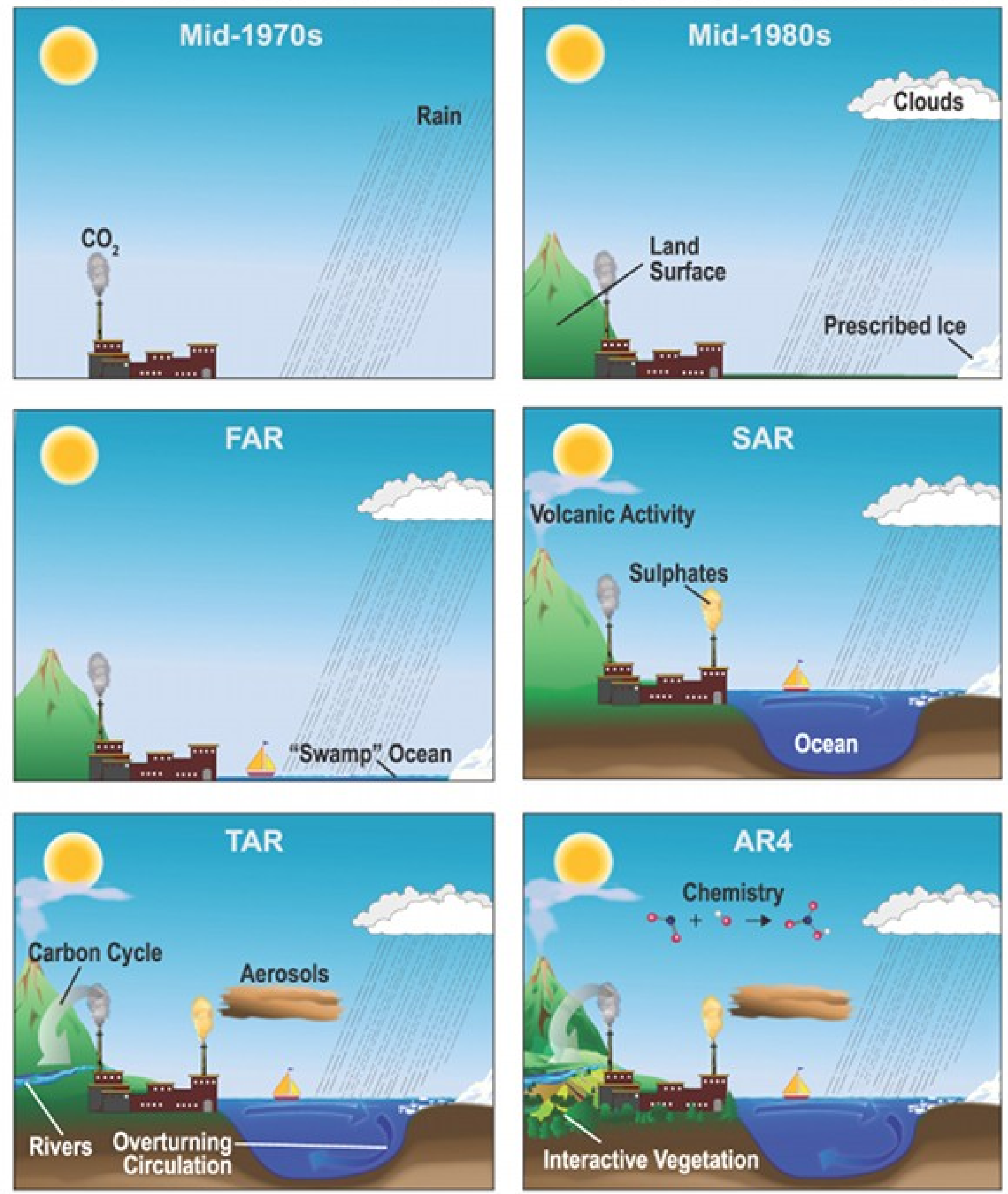
(It could be a person, a mouse, a hypothesis,
a statistical summary,
a 3D structure ...)

Sometimes it's easier to think of this sort of
model as a “simulator” …

The world in global climate models

FAR:1990
SAR:1995
TAR:2001
AR4:2007
AR5:2013





Earth System?

Add in a carbon cycle and ocean biogeochemistry

Simplified View of the Simulation Process

Identify and **understand processes**

Construct **mathematical** model of the **process**

(Sometimes) Create empirical/**statistical representation** of the process (aka "parameterisation")

Couple the process models together.

Test and improve the "integrated" systems

Prediction/Projection and Consequences

Simplified View of the Simulation Process

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Prediction/Projection and Consequences

Which processes?

What mathematical representation?

Which algorithm?

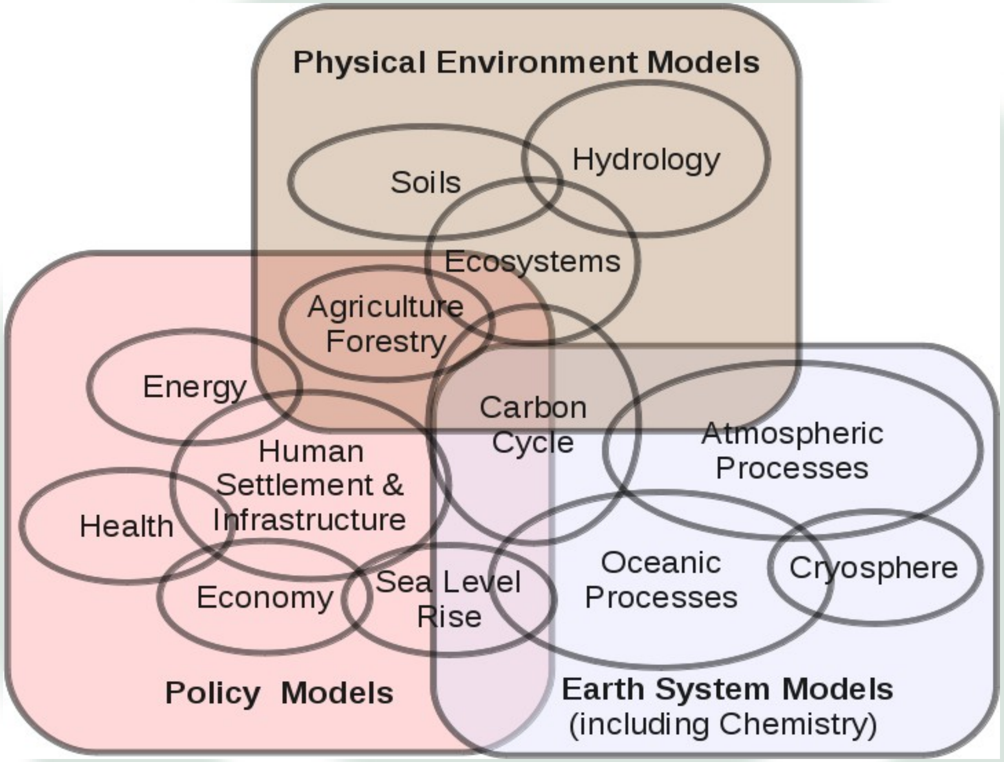
What parameters for the model/algorithm?

How coupled?

How tested? How well validated?

How used? To improve the model? To predict/project? In all cases, what and why?

Many, many processes, many, many communities!



Interconnected communities have problems which require coupling of models and sub-models between communities!

Not just a technical problem … language problems … scientific understanding problems … and …

(Figure adapted from Moss et al., 2010).

So what do they have in common?

They're all carrying out activities developing and using software to produce data which is used somehow to create knowledge which either informs policy or improves our scientific knowledge (or both).

In terms of a policy, a key requirement of this activity, is that it both depends on trust (between parties) and requires trust to be useful.

Trust depends on many things, but one of the key properties of trust is understanding ...

... and that's hard to come by when the linkage between one community and another is just data ...

Rowan Sutton: “There are no end-users of climate predictions”

Gavin Schmidt: “the public … will get used to dealing with climate model outputs … however, an increased amount of hand-holding will be necessary”

State of the Art: Model Comparison

Table 1 The models used in the present study, including, configurations (near the equator) and number of years of simulations

Model	Institution	Atmosphere resolution	Ocean resolution	Length picntrl	Length 1pctto2x	Length 1pctto4x
CCSM3	NCAR (USA)	T85L26	1.125°×0.27°L40	230	150	n/a
CGCM3.1(T47)	CCCMA (Canada)	T47L31	1.85°×1.85°L29	500	150	150
CNRM-CM3	Meteo-France/CNRM (France)	T63L45	2°×0.5°L31	390	100	110
CSIRO-Mk3.0	CSIRO (Australia)	T63L18	1.875°×0.84°L31	380	10	n/a
ECHAM5/MPI-OM	MPI-M (Germany)	T63L31	1.5°×0.5°L40	332	100	81
FGOALS-g1.0	LASG/IAP (China)	T42L26	1°×1°L33	150	80	n/a
GFDL-CM2.0	GFDL (USA)	2.5°×2°L24	1°×0.33°L50	500	100	160
GFDL-CM2.1	GFDL (USA)	2.5°×2°L24	1°×0.33°L50	500	150	160
GISS-AOM	NASA/GISS (USA)	4°×3°L12	4°×3°L16	251	n/a	n/a
GISS-EH	NASA/GISS (USA)	5°×4°L20	2°×2°L16	500	80	150
GISS-ER	NASA/GISS (USA)	5°×4°L20	5°×4°L13	400	100	n/a
INM-CM3	INM (Russia)	5°×4°L21	2.5°×2°L33	330	n/a	n/a
IPSL-CM4	IPSL (France)	2.5°×3.75°L19	2°×0.5°L31	230	80	n/a
MIROC3.2(hires)	CCSR/NIES/FRCGC (Japan)	T106L56	0.28°×0.1875°L47	100	10	n/a
MIROC3.2(medres)	CCSR/NIES/FRCGC (Japan)	T42L20	1.4°×0.5°L43	500	100	150
MRI-CGM2.3.2	MRI (Japan)	T42L30	2.5°×0.5°L23	350	150	150
PCM	NCAR (USA)	T42L18	0.66°×0.5°L32	350	96	90
UKMO-HadCM3	HadleyCentre (UK)	3.75°×2.5°L19	1.25°×1.25°L20	341	10	n/a
UKMO-HadGEM1	HadleyCentre (UK)	1.875°×1.25°L38	1°×0.33°L40	80	10	n/a
SINTEX T30	IPSL/INGV (France,Italy)	T30L19	2°×0.5°L31	200	n/a	n/a
SINTEX T106	INGV/IPSL (Italy,France)	T106L19	2°×0.5°L31	100	n/a	n/a
SINTEX T106mod	IPSL/INGV (France,Italy)	T106L19	2°×0.5°L31	100	n/a	n/a
HadOPA	CGAM/IPSL (UK,France)	3.75°×2.5°L19	2°×0.5°L31	100	n/a	n/a

The only flux corrected model is MRI-CGM2.3.2

1: Tabulate some interesting property (and author grafts hard to get the information)

Guilyardi E. (2006): El Niño- mean state - seasonal cycle interactions in a multi-model ensemble. Clim. Dyn., 26:329-348, DOI: 10.1007/s00382-005-0084-6

State of the Art: Model Comparison

TABLE 1. List of IPCC global coupled climate models analyzed in the present study and
Model resolution is characterized by the size of a horizontal grid on which model output wa
levels. Spectral models are also characterized by their spectral truncations. Equilibrium clima

Model label and climate sensitivity	Resolution	Institution a
CGCM3.1(T47) 3.6 K	96 × 48 L32 T47	Canadian Centre for Climate Modellin (http://www.cccma.ec.gc.ca/models/cg
CGCM3.1(T63) 3.4 K	128 × 64 L32 T63	Canadian Centre for Climate Modellin (http://www.cccma.ec.gc.ca/models/cg
CNRM-CM3 n/a	128 × 64 L45 T63	Centre National de Recherche Météor manuscript submitted to *Climate Dy*
ECHAM5/MPI-OM 3.4 K	192 × 96 L31 T63	Max-Planck-Institut für Meteorologie,
ECHO-G 3.2 K	96 × 48 L19 T30	Meteorological Institute of the Univers Research Institute, South Korea (Mi
GFDL-CM2.0 2.9 K	144 × 90 L24	Geophysical Fluid Dynamics Laborato et al. 2006)
GFDL-CM2.1 3.4 K	144 × 90 L24	Geophysical Fluid Dynamics Laborato et al. 2006)
GISS-AOM n/a	90 × 60 L12	Goddard Institute for Space Studies La http://aom.giss.nasa.gov)
GISS-ER 2.7 K	72 × 46 L20	Goddard Institute for Space Studies La Russell et al. 2000)
INM-CM3.0 2.1 K	72 × 45 L21	Institute of Numerical Mathematics, R
IPSL-CM4.0 4.4 K	96 × 72 L19	Institut Pierre-Simon Laplace, France (http://dods.ipsl.jussieu.fr/omamce/IP
MIROC3.2(hires) 4.3 K	320 × 160 L56 T106	Center for Climate System Research, J
MIROC3.2(medres) 4.0 K	128 × 64 L20 T42	Center for Climate System Research, J
MRI-CGCM2.3.2 3.2 K	128 × 64 L30 T42	Meteorological Research Institute, Jap
NCAR-CCSM3 2.7 K	256 × 128 L26 T85	National Center for Atmospheric Rese
NCAR-PCM 2.1 K	128 × 64 L26 T42	National Center for Atmospheric Rese et al. 2006)

TABLE 2. Description of model parameterizations for stratiform (i.e., large scale) and convective precipitation.

Model name	Stratiform precipitation	Convective precipitation
CCSM3, CCSM2	Prognostic condensate and precipitation parameterization (Zhang et al. 2003)	Simplified Arakawa and Schubert (1974) (cumulus ensemble) scheme developed by Zhang and McFarlane (1995)
CGCM3.1	Precipitation occurs whenever the local relative humidity is supersaturated	Zhang and McFarlane (1995) scheme
CNRM-CM3	Statistical cloud scheme of Ricard and Royer (1993)	Mass flux convection scheme with Kuo-type closure
CSIRO-Mk3.0	Stratiform cloud condensate scheme from Rotstayn (2000)	Bulk mass flux convection scheme with stability-dependent closure (Gregory and Rowntree 1990)
ECHAM5/MPI-OM	Prognostic equations for the water phases, bulk cloud microphysics (Lohmann and Roeckner 1996)	Bulk mass flux scheme (Tiedtke 1989) with modifications for deep convection according to Nordeng (1994)
FGOALS-g1.0	Same as PCM	Zhang and McFarlane (1995) scheme
GFDL-CM2.0, GFDL-CM2.1	Cloud microphysics from Rotstayn (2000) and macrophysics from Tiedtke (1993)	Relaxed Arakawa–Schubert scheme from Moorthi and Suarez (1992)
GISS-AOM	Subgrid-relative humidity-based scheme	Subgrid plume and buoyancy-based scheme (online at http://aom.giss.nasa.gov/DOC4X3/ATMOC4X3.TXT)
GISS-ER	Prognostic stratiform cloud based on moisture convergence (Del Genio et al. 1996)	Bulk mass flux scheme by Del Genio and Yao (1993)
HadCM3	Large-scale precipitation is calculated based on cloud water and ice contents (similar to Smith 1990)	Bulk mass flux scheme (Gregory and Rowntree 1990), with the improvement by Gregory et al. (1997)
HadGEM1	Mixed phase cloud scheme (Wilson and Ballard 1999)	Revised bulk mass flux scheme
INM-CM3.0	Stratiform cloud fraction is calculated as linear function of relative humidity	Lagged convective adjustment after Betts (1986), but with changed referenced profile for deep convection
IPSL-CM4	Cloud cover and in-cloud water are deduced from the large-scale total water and moisture at saturation (Bony and Emmanuel 2001)	Moist convection is treated using a modified version (Grandpeix et al. 2004) of the Emanuel (1991) scheme
MIROC3.2-medres MIROC3.2-hires	Prognostic cloud water scheme based on Le Treut and Li (1991)	Prognostic closure of Arakawa–Schubert based on Pan and Randall (1998) with relative humidity–based suppression (Emori et al. 2001)
MRI-CGCM2.3.2a	Precipitation occurs whenever the local relative humidity is supersaturated	Prognostic Arakawa–Schubert based on Pan and Randall (1998)
PCM	Precipitation occurs whenever the local relative humidity is supersaturated	Zhang and McFarlane (1995) scheme

Kharin et al, Journal of Climate 2007 doi: 10.1175/JCLI4066.1

Dai, A.,J. Climate 2006 doi: 10.1175/JCLI3884.1

2: Provide some (slightly) organised citation material (and author and readers graft hard to get the information)

State of the art: Model Comparison

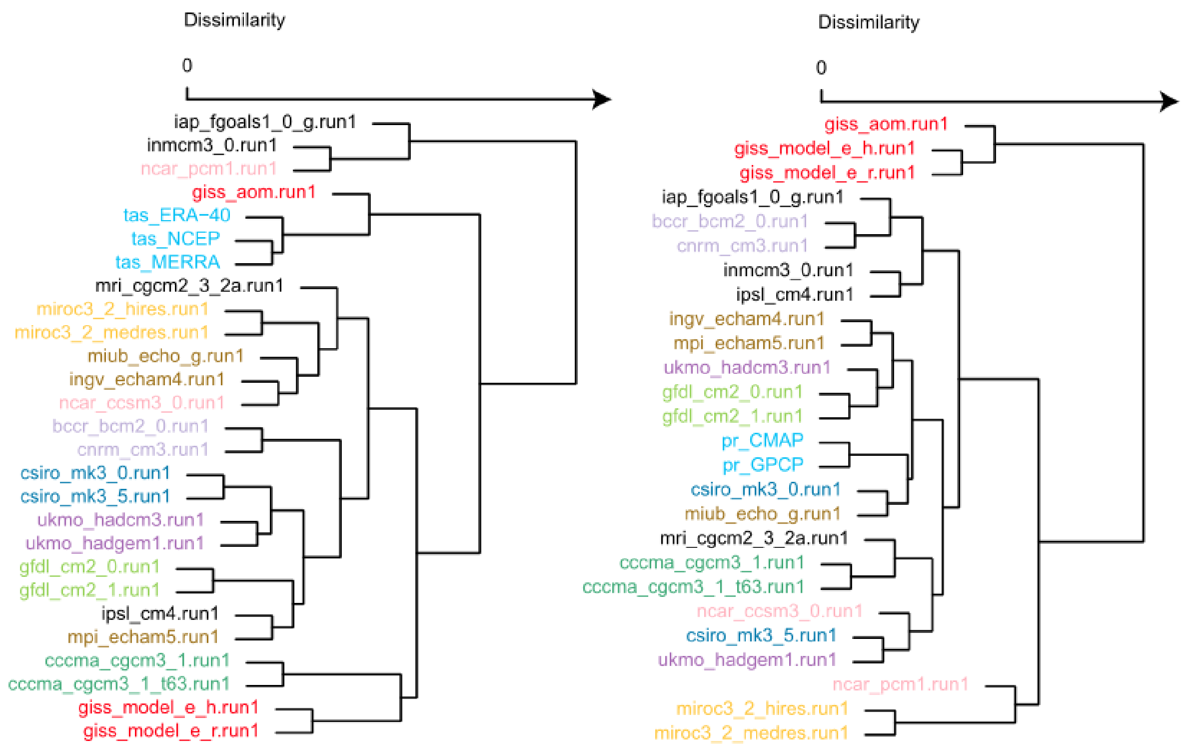


Figure 1. Hierarchical clustering of the CMIP3 models for (left) surface temperature and (right) precipitation in the model control state. Models from the same institution and models sharing versions of the same atmospheric model are shown in the same color. Observations also are marked by the same color. Models without obvious relationships are shown in black.

Masson, D., and R. Knutti (2011), Climate model genealogy, Geophys. Res. Lett., 38, L08703, doi:10.1029/2011GL046864.

3: Resort to statistics to discover something we should **know** (or at least suspect)

So, can we improve the information about the process?

All parties are carrying out **simulations** which **conform** to **experimental requirements** which exploit both **initial data** and **specific versions of software** which encapsulate **specific science** to produce **output data** which is **available somewhere** using some **service**.

And all these concepts can be described, and both the **quality of the descriptions** and the **quality of each of the steps** can be themselves be described.

Ideally,

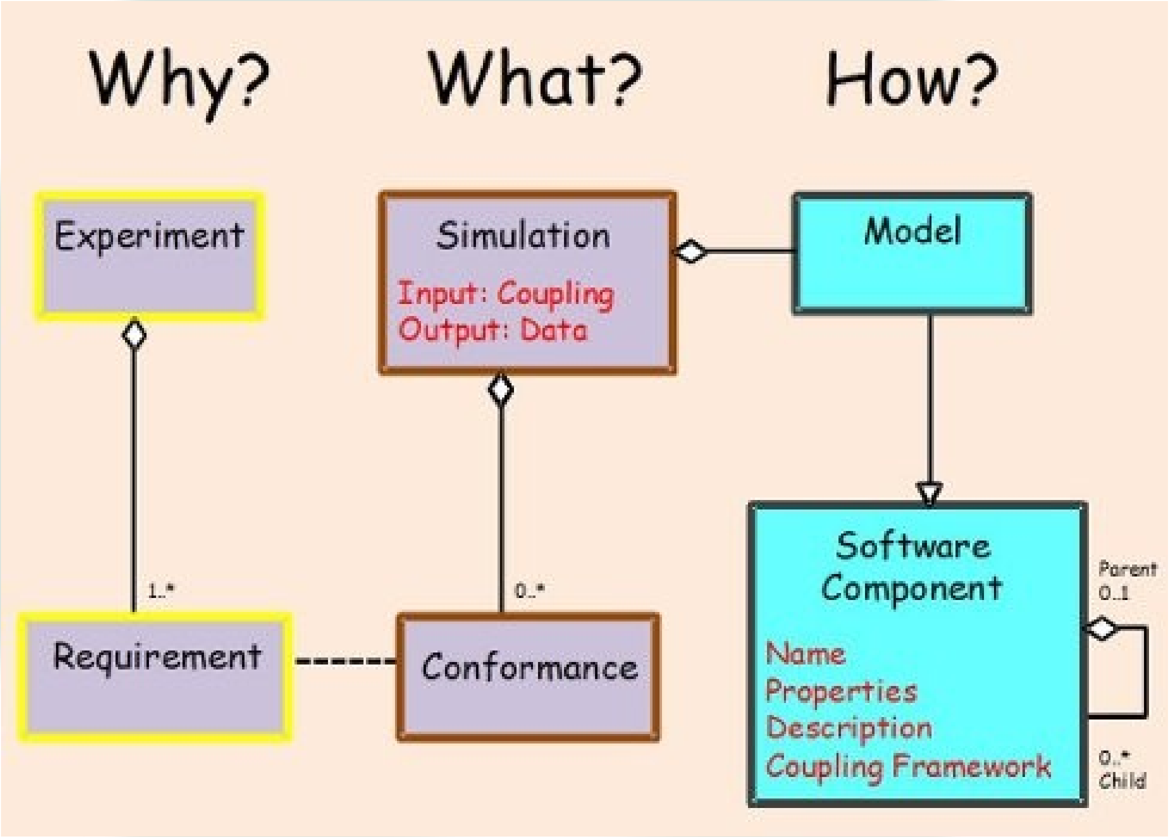
- these descriptions themselves are **indexed, comparable, and searchable**, and
- both the participants in the process, and the users of it, can exploit it all!

From those concepts, we can, and have, built infrastructure ...

A few quick words about what we have built before we talk about what it's for …

- A “Common Information “Model” (CIM) for describing the process.
- Some vocabularies to exploit it …
- Tools to create and consume content

A Common Information “Model”



… and more … platform … data etc.

Experiments and Requirements

Project CMIP5

ID 1.3 noVolc1960

Short Name noVolc1960

Long Name decadal 10 year hindcast without volcanoes

Description Hindcast without volcanoes. Additional 10 year runs for experiment 1.1 without including the Agung, El Chichon and Pinatubo eruptions. The atmospheric composition (and other conditions) should be prescribed as in the historical run (expt. 3.2) and the RCP4.5 scenario (expt. 4.1) of the long-term suite of experiments. Ocean initial conditions should be in some way representative of the observed anomalies or full fields for the start date. Land, sea-ice and atmosphere initial conditions are left to the discretion of each group. Simulations should be initialized towards the end of 1960, 1975, 1980, 1985, and 1990. Calendar start date can be 1st September, 1st November, 1st December or 1st January, according to the convenience of the modeling group. Dates should allow complete years/decades to be analyzed. A minimum ensemble size of 3 should be produced for each start date.

Rationale Volcano-free hindcasts. Assess the impact of volcanic eruptions on decadal predictions.

NUMERICAL REQUIREMENTS

Boundary Conditions

Name 1.3.bc.ant_aer **Description** Imposed changing concentrations or emissions of aerosols (anthropogenic)

Name 1.3.bc.ant_aer_prec **Description** Imposed changing concentrations of aerosol (anthropogenic) precursors

Name 1.3.bc.ant_wmg **Description** Imposed changing atmospheric composition (anthropogenic)

Name 1.3.bc.LU **Description** Imposed changing land use

… (skipping some) ...

Initial Conditions

Name 1.3.ic.oc ID ic.007 Description Ocean Initial Conditions must represent in some measure the observed anomalies for the start date used

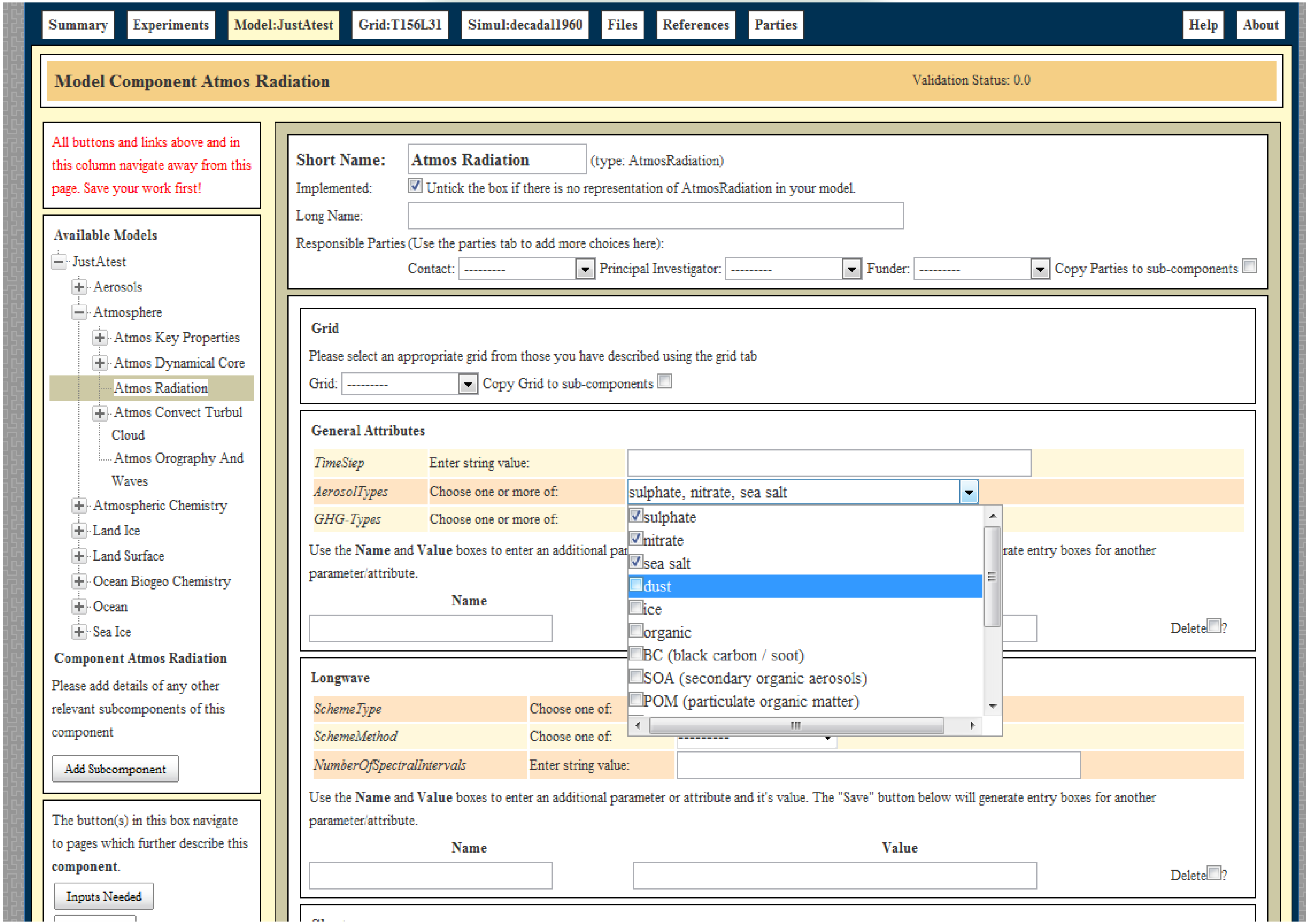
Spatio Temporal Constraints

Name 1.3.stc.decadal_10yr ID stc.001 **Description** Run for 10 years

Name 1.3.stc.decadal_30yr ID stc.003 **Description** Run for 30 years

Can ask the question (and compare answers) to "How was land use forcing done" (How did simulations conform to requirement 1.3.bc.LU)

Tooling to collect model scientific descriptions of models (e.g. CMIP5 questionnaire):



Toolng Exploits Vocabularies: Consensus Process

2 Recording the information on **mindMaps**

3 Structuring and use of **key rules** so that the mindMaps can be interpreted for different usages

4 Storing dynamical mindMaps under Metafor SVN repository

5 Capturing **feedbacks** from other scientits:

mindMaps submitted via e-mail or discussed on Webconf or face meetings…

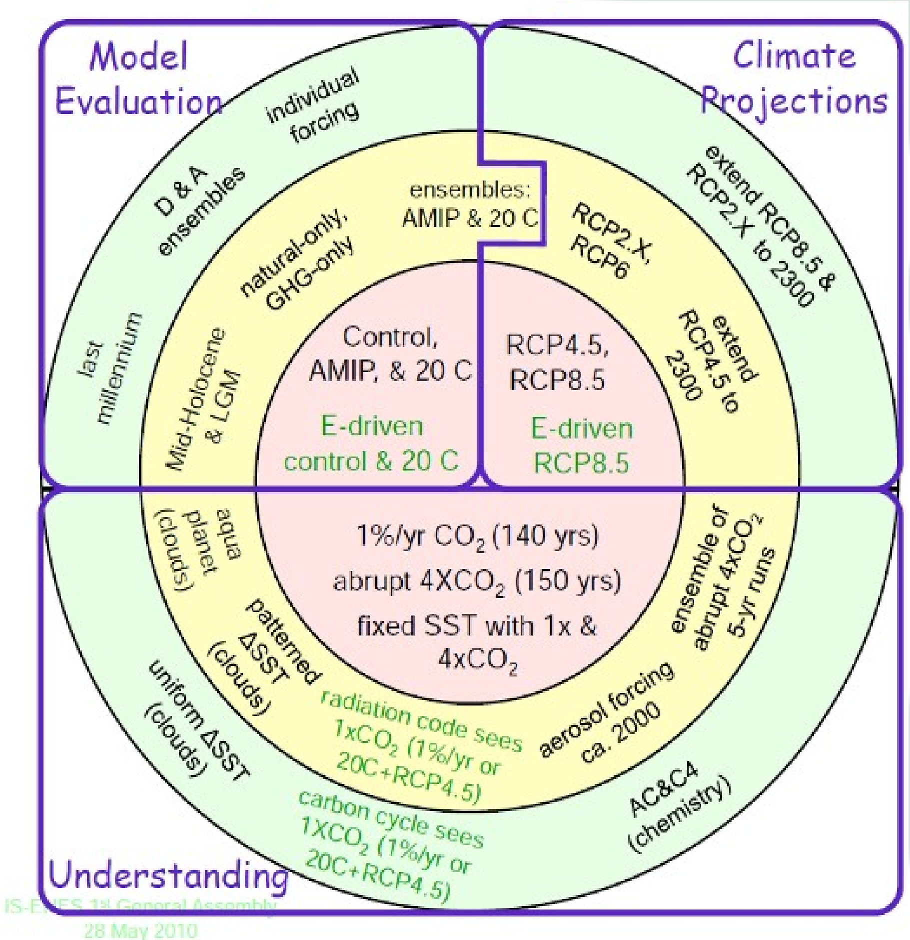
Ingestion of existing standards (eg. ESG's atmos Dynamical Core)

6 Workout conflicting views (if any) to find a **consensus**

1 **Scientific expertise** from an initial set of scientists ("Interviews")

Single "standard" description that fits all institution models.

Consider CMIP5



CMIP5 Federated Archive

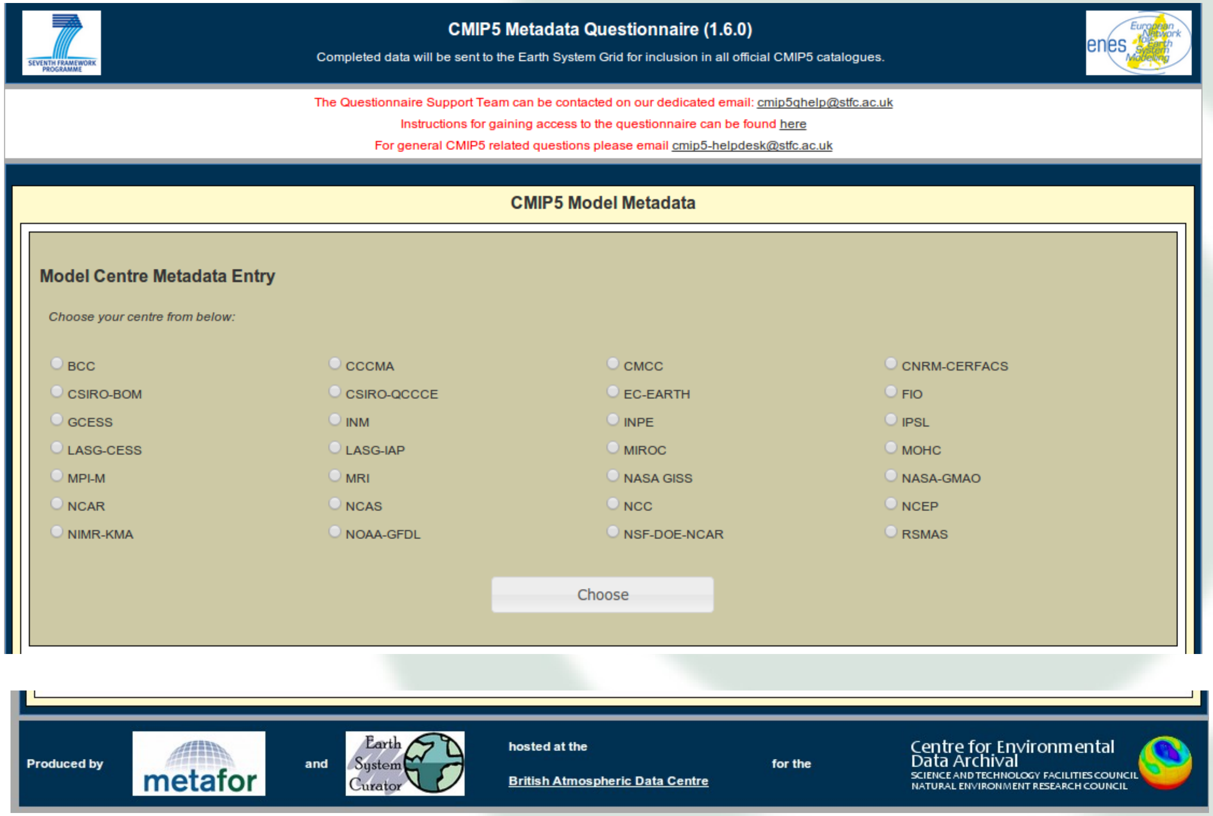
Summary	
Modeling centers	27
Models	59
Experiments	96
Data nodes	22
P2P Index	11
Datasets	57830
Size	1,795.11 TB
Files	3,900,145

(Nov 30, 2012)

Never mind the decadal projections etc

Intimidating!

… but some of it is quite well described …



http://q.cmip5.ceda.ac.uk

As of September, 2012, the “Metafor” Questionnaire had been used to document:

42 different model configurations,

used in over

600 simulations

from

17 institutions!

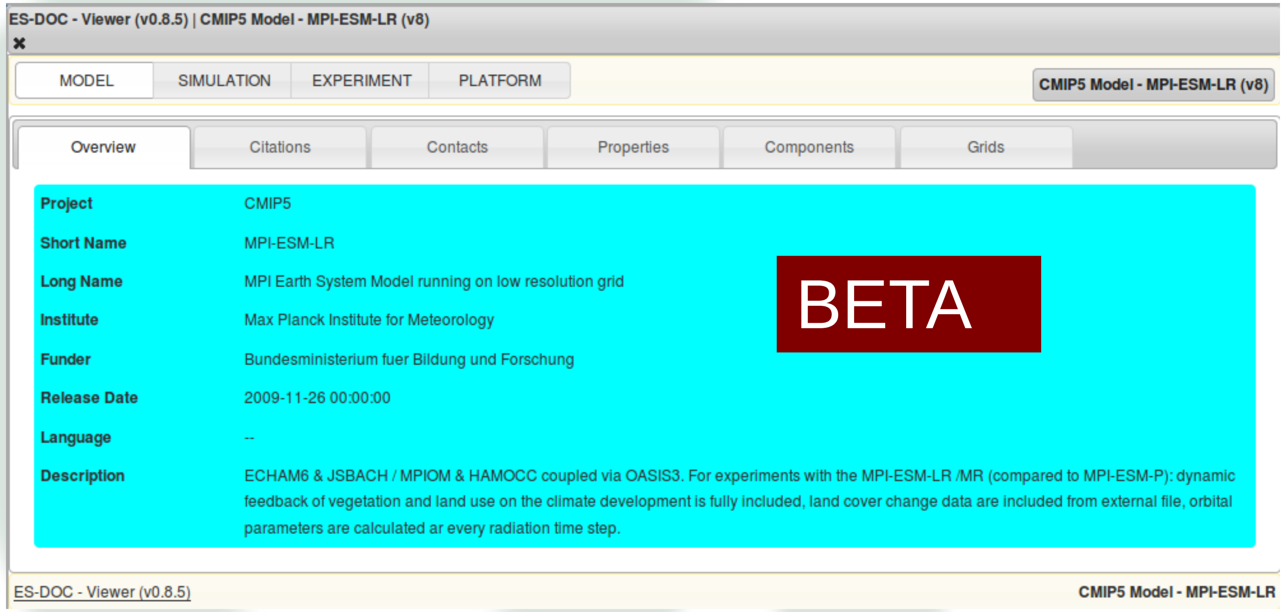
Where is that information?

Three different ways to get to the same content:

1) Alongside data information in the ESGF search interface.

2) From the questionnaire itself (publication table at the bottom)

3) A new es-doc site coming soon.



NB: ongoing problems with browsers … keeping this as a beta

On twitter, follow @esdocumentation for public announcements as to when we think this will be ready (otherwise, just keep looking).

Currently we have viewers, but **tools for user generated tables and comparisons will come with the next big release.**

ES-DOC - Viewer (v0.8.5) | CMIP5 Model - HadGEM2-ES (v2)

MODEL | SIMULATION | EXPERIMENT | PLATFORM — CMIP5 Model - HadGEM2-ES (v2)

Overview | Citations | Contacts | Components | Grids

- **Aerosols**
  - Emission & Concentration
  - Model
  - Transport
- **Atmosphere**
  - Convection Cloud Turbulence
    - Cloud Scheme
    - Cloud Simulator
  - Dynamical Core
    - Advection
  - Orography & Waves
  - Radiation
- **Atmospheric Chemistry**
  - Emission & Concentration
  - Gas Phase Chemistry
  - Heterogen Chemistry
    - Stratospheric
    - Tropospheric
  - Photo Chemistry
  - Transport
- **Land Ice**
  - Sheet
- **Land Surface**
  - Albedo
  - Carbon Cycle
    - Vegetation
  - Energy Balance

Atmosphere > Convection Cloud Turbulence > Cloud Scheme

Overview

The large-scale cloud scheme for liquid cloud is that of Smith (1990), in which cloud water and cloud amount are diagnosed from total moisture and liquid water potential temperature using a triangular probability distribution function. The width of this distribution is diagnosed from the variability of the moisture and temperature of the surrounding grid points. A representation of the difference between cloud area fraction and cloud volume fraction is made by subdividing a single model layer into three. HadGEM1 and later models introduced an updated version of the Wilson and Ballard (1999) microphysics scheme. Transfers between water categories (ice, liquid water, vapor, and rain) are calculated based on physical process equations using particle size information.

Properties

Cloud Scheme Attributes > Cloud Overlap : Other

Cloud Scheme Attributes > Cloud Overlap Scheme : Maximum-random Overlap

Cloud Scheme Attributes > Processes : Area Cloud Fraction, Diagnostic RH_crit

Cloud Scheme Attributes > Separated Cloud Treatment : Yes

Sub Grid Scale Water Distribution > Coupling With Convection : Coupled With Deep And Shallow

Sub Grid Scale Water Distribution > Function Name : Symmetric Triangular Distribution

Sub Grid Scale Water Distribution > Function Order : One Moment

Sub Grid Scale Water Distribution > Type : Diagnostic

Citations

Short Title	Smith 1990
Full Title	Smith R. N. B., (1990) A scheme for predicting layer clouds and their water content in a general circulation model. Quarterly Journal of Royal Meteorological Society, 116, 435-460.
Location	--

Short Title	Wilson 1999
Full Title	Wilson D. R., and S. P. Ballard (1999) A microphysically based precipitation scheme for the Met Office Unified Model.. Quarterly Journal of Royal Meteorological Society, 125, 1607-1636.
Location	--

ES-DOC - Viewer (v0.8.5) — CMIP5 Model - HadGEM2-ES

Credit: Mark Morgan, IPSL

Comparisons of specifics are possible

MODEL ID	INSTITUTION	LAND SURFACE CARBON CYCLE IMPLEMENTED?	OCEAN BIO CHEMISTRY (CARBON CYCLE) IMPLEMENTED?	AEROSOL SCHEME TYPE	PROGNOSTIC AEROSOL TREATMENT	LIST OF NUTRIENT SPECIES
GISS-E2CS-R	NASA Goddard Institute for Space Studies USA	False	False	bulk; modal	3D mass/volume mixing ratio for aerosols	Ocean BioGeoChem component not implemented
GISS-E2CS-H	NASA Goddard Institute for Space Studies USA	False	False	bulk; modal	3D mass/volume mixing ratio for aerosols	Ocean BioGeoChem component not implemented
NorESM1-ME	Norwegian Climate Centre	True	True	other		Iron (Fe); Nitrogen (N); Phosphorus (P); Silicium (Si)
NorESM1-M	Norwegian Climate Centre	True	True	other		Iron (Fe); Nitrogen (N); Phosphorus (P); Silicium (Si)
CFSv2-2011	National Centers for Environmental Prediction	False	False	Aerosol component not implemented	Aerosol component not implemented	Ocean BioGeoChem component not implemented
GFDL-ESM2M	NOAA Geophysical Fluid Dynamics Laboratory	True	True	Aerosol component not implemented	Aerosol component not implemented	Iron (Fe); Nitrogen (N); Phosphorus (P); Silicium (Si)

(from the Metafor questionnaire,
table by Gerry Devine,
user controlled tables coming soon)

… but …

Coverage is far from complete.

Most (but not all) models are quite well described.

Simulation descriptions are less well done, and the conformance to experiments even less well done.

We have very little quality control information, of the model output, **or of these descriptions themselves.**

Peer Review of the Simulation Descriptions

- It was hard to generate the CMIP5 metadata content … and some groups have put more effort in than others, and it shows in quality!
- Even a cursory look suggests a lot of missing material, and a lot of material that might have been erroneously copied.
- Questionnaire output has already been used in the AR5 drafts; process led to improvements in input material, but this has yet to be fed back round the loop … so that all users get the benefit.
- Significant scope for modelling centres to do bilateral “checking of each others' work” … but it'd be yet more work, and the rewards are as yet not visible ...
- The tooling has not yet been up to facilitating peer review, but the new comparison tools should expedite this (and show the worth of the effort in doing so).

Next Steps

We need to work on community expectations;

- how to use this information,
- how to validate it, and
- the role of peer review (who, when, how)?

We need to fix the problems we know we have in the underlying model

- in particular, the confusion between the scientific view of the code, and the software view of the code.

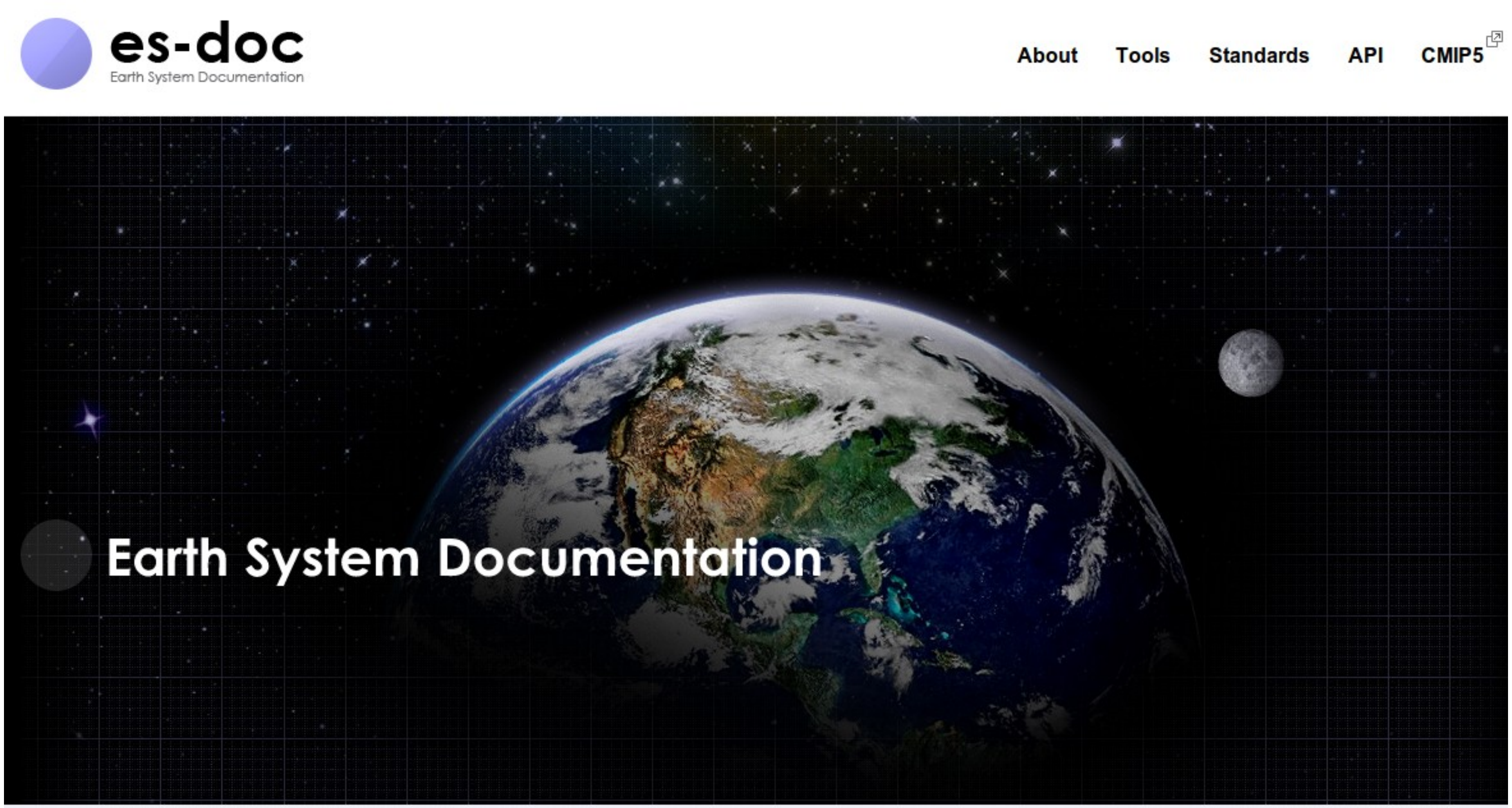
We need to put in place a governance structure to manage the future evolution.

- The hard work thinking about that is done, we expect to do this under the auspices of WGCM and the existing CF governance.

ES-DOC

New global activity, initially supported by both European and American projects; taking this further ...

New website and tool release imminent (days to weeks).



On twitter, follow @esdocumentation or @bnlawrence for public announcements

This talk should have been subtitled:

“Trust depends on understanding what has been done … in detail!”

as much as on

“Who has done it”

(our traditional approach for modelling, but not for science in general)

We have made some steps with infrastructure to help, but the infrastructure will be useless without active engagement by the community, both in terms of creating and criticising/reviewing the required documentation