

PROPOSED LIST FOR DATA OUTPUT AND DIAGNOSTICS

RAPID UK INTERCOMPARISON PROJECT

z-coordinate models with possibly curvilinear grids

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List of modifications:

1. It is now stated explicitly that the meridional overturning is to be computed globally and for each basin
2. I have now made the meridional heat transport a function of latitude only, since I am told the users of a curvilinear grid can make such a computation. I have also decided to ask for the meridional transport of freshwater instead of the transport of salt, also as a function of latitude. These transports are to be computed globally and for each basin.
3. In order to avoid the transport terms to depend on the reference value for temperature or salinity, it is proposed to compute the tendency terms for temperature and salinity instead. Since these terms can in principle be expressed as the divergence of some quantities, it is in principle possible to compute any kind of transport by summing the tendency terms from some wall where the normal component of the quantity vanishes...
4. New sea ice quantities: thermodynamic and dynamic growth
5. It was erroneously written in the previous version that information about curvilinear grid is not part of the CF-standard. This is not true. What is correct is that CMOR does not support it.
6. Correction of the tendency for sea ice thickness standard names

REMINDER OF EXPERIMENTS

1. Hosing experiments
2. CO2 increase experiments :
 - a. CONTROL
 - b. TRANSIENT
 - c. TRH20
 - d. CRH20

CURVILINEAR GRIDS

The project will allow the model results to be stored in their native grid, so that it is crucial that the proper information documenting the grid be stored as part of the output data. One problem with curvilinear grids is the computation of zonally-integrated quantities, which is straightforward to compute in

longitude/latitude grid models, but less so in curvilinear grids. Perhaps the simplest way to compute the zonally-integrated transport of whichever quantity we are interested in is by approximating it by the transport across a grid-based natural section that best approximate a zonal section as described below. Your comments and suggestions are of course welcome and appreciated. I assume that curvilinear grids can be looked at in the following way, and that u and v refer to the components of the velocity normal to the grid elements. The velocity components therefore refer to the normal components that pertain to the grid, and not necessarily to the classical meridional and zonal components.

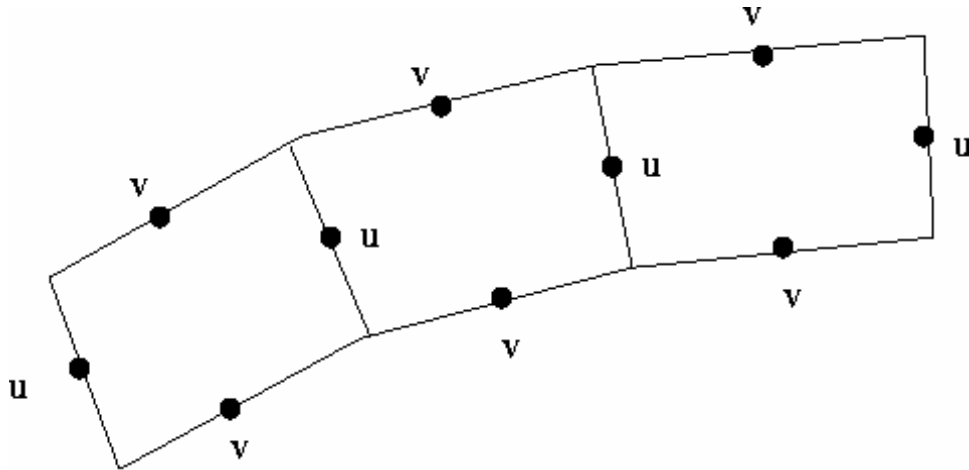


Fig.1: Schematic showing the expected arrangement for the variables for a curvilinear grid, where u and v refer to the normal components of the velocity to the grid boundary for which they are indicated

Computation of various transports quantities:

Transport can be computed through arbitrary sections,

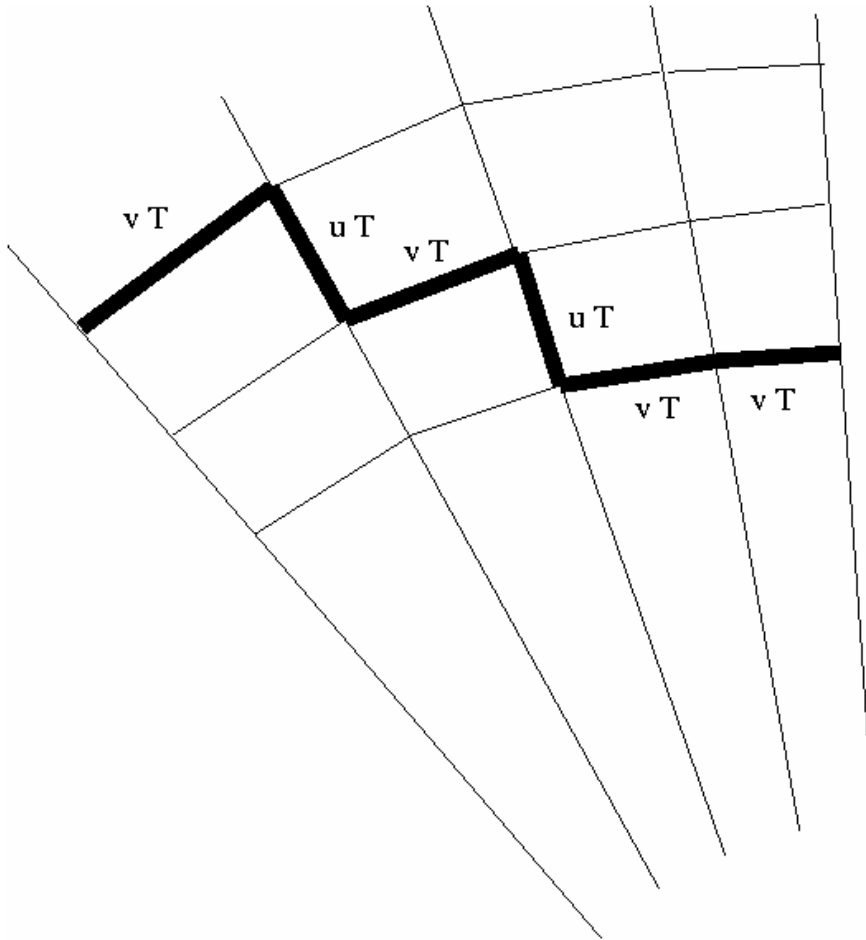


Fig.2: Example of a section through which the transport of any quantity (here temperature) could be computed for a curvilinear grid, indicated here as a thick line. If we know the terms $\text{Mean}(u T)$ and $\text{Mean}(v T)$ everywhere, we can in principle construct the heat transport through an arbitrary section. One way to approximate the transport through a zonal section would be by choosing a path that most closely follow a constant latitude. The same idea would apply to the computation of the mass transports and the definition of the MOC for a curvilinear grid.

OCEANIC VARIABLES

The output for oceanic variables fall into four time categories :

- 1) Time-independent description of the curvilinear grid
- 2) 1 day-mean over one full year
- 3) 5 day-mean over 10 years
- 4) monthly-means over the full duration of the experiments

This should allow us to address a range of issues for a wide range of time scales. To save disk space, only a selected set of variables will be selected. We also need to store informations about the curvilinear grid as comprehensively as possible.

1) Time-independent grid information

Sufficient information about the curvilinear grids needs to be provided. There are CF standard names for some of these, please refer to the CF standard for these. I'll try to find the relevant information when I find it. The type of information needed is the following:

- Longitude, Latitude, and depth of each variable u , v , w , T , and S
- Area sections A_u , A_v , A_w that are used in the computation of various transports
- Volume elements V_{ijk} that are used for the computation of budgets

I assume that each group will know best how to provide the required information so that budget and transports can be easily computed from the data provided.

2) 1 day mean for 1 year

Applicable to:

- a) *The first year when hosing is applied*
- b) *The first year of the CO₂ increase experiment*

We do not need it for the control run, nor for the partially coupled experiments

Potential temperature	3D field
Salinity	3D field
U-velocity	3D field
V-velocity	3D field
W-velocity	3D field
Sea Surface height (SSH)	2D field

1. Potential temperature
 - CF standard name: sea_water_potential_temperature
 - Units: K
 - Output variable name: theta0
 - Note: assumed reference height is sea level
2. Salinity
 - CF standard name: sea_water_salinity
 - Units: 1e-3 (i.e., ppt)
 - Output variable name: so

- Note: The unit of salinity is PSU (expressed here as parts per thousands)
3. U-velocity
 - CF standard name: eastward_sea_water_velocity
 - Units: m/s
 - Output variable name: uo
 - Note: use appropriate definition if using curvilinear grid
 4. V-velocity
 - CF standard name: northward_sea_water_velocity
 - Units: m/s
 - Output variable name: vo
 - Note: use appropriate definition if using curvilinear grid
 5. W-velocity
 - CF standard name: upward_sea_water_velocity
 - Units: m/s
 - Output variable name: wo
 - Note:
 6. Sea surface height (SSH):
 - CF standard name: sea_surface_height_above_geoid
 - Units: m
 - Output variable name: zos
 - Note: This height, when multiplied by the area fraction of the grid cell covered by ocean (or sea ice) yields the volume of water above the geoid. As defined here, the geoid is a surface of constant geopotential that, if the ocean were at rest, would coincide with mean sea level. Under this definition, the geoid changes as the mean volume of the ocean changes (e.g., due to glacial melt, or global warming of the ocean). Report zos as “missing” over grid cells that are entirely land. There are a couple of acceptable options for reporting this field: 1) if the geoid is defined to relate to the instantaneous volume of the ocean, the global mean of zos will always be zero, 2) if the geoid is defined relative to a time-mean sea level over some period, then the global mean of zos will be time-dependent. In either case a global mean time series of sea level should also be reported.
 - Note2: The above note is that of IPCC. Choose method as the simplest possible for the project, option 1 is satisfactory.

Diagnostics and scientific issues:

- Investigation of the adjustment mechanism of the MOC to deep water formation by means of coastally-trapped waves
- Connection of the coastally-trapped waves with equatorial dynamics. Test of the equatorial buffer idea. Excitation of planetary waves
- Investigation of time-sampling issues and associated uncertainties and errors

3) 5 day mean for 10 year (say which years, and for which experiments)

Applicable to:

- a) *The first 10 years of the hosing experiment*
- b) *The first 10 years of the CO2 increase experiment*

Do not apply to the control run, and the partially coupled experiments

Potential temperature	3D field
Salinity	3D field
U-velocity	3D field
V-velocity	3D field
W-velocity	3D field
Sea Surface height (SSH)	2D field

Note: See description for 1 day mean field for standard CF names.

Diagnostics and scientific issues

- Role of planetary wave dynamics on the variability of the MOC
- Role of spiciness anomalies on the variability of the MOC
- Seasonal variability of the MOC and meridional heat transports in z-coordinates and density-coordinates

4) Montly means (how to make generic outputs for sea ice?)

Applicable to all experiments

Sea Ice information

Given that all sea-ice models are probably different for each model, each group should make its best to store what they think is a necessary description of the behaviour of sea ice in their model. The fields below represent an example of what is used in HIGEM. To be adapted as appropriate for each mode, each group having the freedom of choosing what they think is best. In the list below, I propose to save at least sea ice thickness, and the sea ice fraction. Higem uses a lot more:

Sea Ice (aggregate) – based on HIGEM diagnostics – to be adapted for each model

- Sea Ice thickness
- Sea Ice U velocity
- Sea Ice V velocity
- Sea Ice concentration (classes 1-5)
- Sea Ice thickness (classes 1-5)
- Sea Ice thermodynamic growth
- Sea Ice dynamic growth
- Sea Ice strength

Other oceanic variables

3D means longitude, latitude, depth, time:month

2D means longitude, latitude, time:month or latitude,depth,time:month

CF standard names and units (only the variables not yet defined are described below)

- Potential temperature (3D, see above definition)
- Salinity (3D, see above definition)
- Eastward velocity component (3D, see above definition)
- Northward velocity component (3D, see above definition)
- Vertical velocity component (3D, see above definition)
- Sea surface height (2D, latitude, longitude, see above definition)
- Horizontal kinetic energy (3D)
 - Proposed CF standard name: `specific_kinetic_energy_of_sea_water`
 - Units: m^2/s^2
 - Notes: computed from the horizontal velocity component u^2+v^2
- Meridional overturning stream function (2D, latitude, depth)
 - CF standard name: `ocean_meridional_overturning_streamfunction`
 - Units: m^3/s
 - Output variable name: `stfmmc`
 - Notes: Note that the units do not include mass. This should include only the explicitly calculated, purely advective component and should exclude contributions of the ‘bolus velocity’ that arise, for instance, in the Gent-McWilliams parameterization
 - Notes 2: To be computed globally and for each basin separately (or at least for the Atlantic ocean)
- Speed of sound (3D)
 - CF standard name: `speed_of_sound_in_sea_water`
 - Units: m/s
 - Notes: Should be computed online, as one of the objective is to infer variances of temperature and salinity over the averaging period (added 19 June 2006)
- Density of sea water (3D)
 - CF standard name: `sea_water_density`
 - Units: kg/m^3
 - Notes: In-situ density of sea water, not potential density. If $1000 \text{ kg}/\text{m}^3$ is subtracted, the standard name `sea_water_sigma_t` should be used instead.
 - Notes 2: Should be computed online, as one the objective is to infer variances of temperature and salinity over the averaging period, by combining the information with that for the speed of sound (added 19 June 2006)
- Sea Ice thermodynamic growth (2D) (added 19 June 2006)
 - CF standard name: `tendency_of_sea_ice_thickness_due_to_thermodynamics`
 - Units: m/s
 - Note: Rate of change of sea ice gridbox mean thickness due to thermodynamic processes
- Sea Ice dynamic growth (2D) (added 19 June 2006)
 - CF standard name: `tendency_of_sea_ice_thickness_due_to_dynamics`
 - Units: m/s
 - Note: Rate of change of sea ice gridbox mean thickness due to dynamic processes

- Sea Ice thickness (2D)
 - CF standard name: sea_ice_thickness
 - Units: m
 - Output variable name: sit
 - Notes: This thickness, when multiplied by the average area of the grid cell covered by sea ice, yields the time-mean sea ice volume. Thus, for time means, compute as the weighted sum of thickness (averaged over the sea-ice covered portion of the grid cell) divided by the sum of the weights, with the weights equal to the area covered by sea-ice; Report as 0.0 in regions free of sea ice
- Sea Ice fraction (2D)
 - CF standard name: sea_ice_area_fraction
 - Units: %
 - Output variable name: sic
 - Notes: fraction of grid cell covered by sea ice

New diagnostics (added 19 june 2006): supersedes transports defined below

In principle, the sum of all tendencies should provide the total tendency for temperature and salinity. It follows that we should be able to reconstruct the heat transports by multiplying temperature by $\rho \times C_p \times \text{volume}$ of a cell, and salt transport by multiplying the tendency by $\rho \times \text{volume}$ of a cell.

- Tendency of temperature due to advection (3D) (added 19 june 2006)
 - Proposed CF standard name: tendency_of_sea_water_potential_temperature_due_to_advection
 - Units: K/s
 - Notes: Tendency of temperature due to advection only terms (without bolus advection if this term exists)
- Tendency of temperature due horizontal/isopycnal mixing (3D) (added 19 june 2006)
 - Proposed CF standard name: tendency_of_sea_water_potential_temperature_due_to_horizontal_diffusion
 - Units: K/s
 - Notes: Tendency term including horizontal/isopycnal mixing plus the effect of bolus advection if needed
- Tendency of temperature due to vertical diffusion (3D) (added 19 june 2006)
 - Proposed CF standard name: tendency_of_sea_water_potential_temperature_due_to_vertical_diffusion
 - Units: K/s
 - Notes: Tendency term including vertical diffusion/ mixed layer mixing, and convection mixing.
- Tendency of salinity due to advection
 - Proposed CF standard name: tendency_of_sea_water_salinity_due_to_advection
 - Units: psu/s
 - Notes: tendency term due to horizontal and vertical advection
- Tendency of salinity due to horizontal/isopycnal diffusion

- Proposed CF standard name:
tendency_of_sea_water_salinity_due_to_horizontal_diffusion
- Units: psu/s
- Notes: Include all the tendency terms that can be categorized as horizontal or isopycnal mixing, including bolus advection
- Tendency of salinity due to vertical mixing processes
 - Proposed CF standard name:
tendency_of_sea_water_salinity_due_to_vertical_diffusion
 - Units: psu/s
 - Notes: tendency terms due to vertical mixing processes, including vertical diffusion, mixed layer mixing, and convection mixing
- Northward heat transport (1D, latitude) (modified 19 june 2006)
 - CF standard name: northward_ocean_heat_transport
 - Units: W
 - Note; Northward means positive when directed northward. Transport is by seawater processes only (advection+mixing). To be computed globally and for each basin separately
- Northward freshwater transport (1D latitude) (modified 19 june 2006)
 - CF standard name: northward_ocean_freshwater_transport
 - Units: kg/s
 - Transport is by seawater and sea ice processes. To be computed globally and for each basin separately

Beginning of discarded fields (dated 19 june 2006), superseded by the computation of the tendency fields described above

- ~~Northward heat transport (3D)~~
 - ~~CF standard name: northward_ocean_heat_transport~~
 - ~~Units: W~~
 - ~~Notes: Northward means positive when directed northward, negative when directed southward, with the meaning of northward and eastward to conform to the natural directions of a curvilinear grid if the grid is not longitude/latitude. Transport is by all processes, both sea water and sea ice. To be computed for each v point as a function of position and depth.~~
- ~~Northward heat transport due to bolus advection (3D)~~
 - ~~CF standard name:
northward_ocean_heat_transport_due_to_bolus_advection~~
 - ~~Units: W~~
 - ~~Notes: Part of the transport associated with the eddy field~~
- ~~Northward heat transport due to diffusion (3D)~~
 - ~~CF standard name:
northward_ocean_heat_transport_due_to_diffusion~~
 - ~~Units: W~~
 - ~~Notes: Part of the transport associated with diffusive processes~~
- ~~Eastward heat transport (3D)~~
 - ~~Proposed CF standard name: eastward_ocean_heat_transport~~
 - ~~Units: W~~
 - ~~Notes: Same definition as for the northward heat transport, but computed with the coordinate defining the eastward direction in~~

the curvilinear grid system. Transport is by all processes, and is to be computed for each u point as a function of position and depth

- ~~Eastward heat transport due to bolus advection (3D)~~
 - ~~Proposed CF standard name:~~
~~eastward_ocean_heat_transport_due_to_bolus_advection~~
 - ~~Units: W~~
 - ~~Notes:~~
- ~~Eastward heat transport due to diffusion (3D)~~
 - ~~Proposed CF standard name:~~
~~eastward_ocean_heat_transport_due_to_diffusion~~
 - ~~Units: W~~
 - ~~Notes:~~
- ~~Northward salt transport (3D)~~
 - ~~CF standard name: northward_ocean_salt_transport~~
 - ~~Units: kg/s~~
 - ~~Notes:~~
- ~~Northward salt transport due to bolus advection (3D)~~
 - ~~CF standard name:~~
~~northward_ocean_salt_transport_due_to_bolus_advection~~
 - ~~Units: kg/s~~
 - ~~Notes:~~
- ~~Northward salt transport due to diffusion (3D)~~
 - ~~CF standard name:~~
~~northward_ocean_salt_transport_due_to_diffusion~~
 - ~~Units: kg/s~~
 - ~~Notes:~~
- ~~Eastward salt transport (3D)~~
 - ~~Proposed CF standard name: eastward_ocean_salt_transport~~
 - ~~Units: kg/s~~
 - ~~Notes:~~
- ~~Eastward salt transport due to bolus advection (3D)~~
 - ~~Proposed CF standard name:~~
~~eastward_ocean_salt_transport_due_to_bolus_advection~~
 - ~~Units: kg/s~~
 - ~~Notes:~~
- ~~Eastward salt transport due to diffusion (3D)~~
 - ~~Proposed CF standard name:~~
~~eastward_ocean_salt_transport_due_to_diffusion~~
 - ~~Units: kg/s~~
 - ~~Notes:~~

End of discarded field (dated 19 june 2006)

- Freshwater into the ocean (2D, longitude, latitude)
 - CF standard name: water_flux_into_ocean
 - Units: kg/m²/s
 - Output variable name: wfo
 - Notes: Water means water in all phases. The water flux into the ocean is the freshwater entering the sea water as the result of evaporation, precipitation, run-off, sea-ice effects, and freshwater flux correction considering only the ocean-portion of each grid cell

- Total heat flux into the ocean (2D, longitude, latitude)
 - CF standard name: surface_downward_heat_flux_in_sea_water
 - Units: W/m²
 - Notes: Downward means positive when directed downward. Compute as all heat fluxes entering the ocean (i.e., below the sea ice when applicable).

Diagnostics and scientific issues:

- Variability of the meridional overturning streamfunction
- Variability of the meridional heat transport
- Variability of the meridional freshwater transport
- Investigation of the meridional overturning streamfunction in density coordinates
- Quantification of the mixing
- Global density budget
- Global spiciness budget
- Global energetics
- Role of spiciness anomalies on decadal to centennial time scales

ATMOSPHERIC VARIABLES (monthly means only)

Monthly mean 2-d atmosphere data (longitude, latitude, time:month)

1. *Air pressure at sea level*
 - CF standard_name: air_pressure_at_sea_level
 - Units: Pa
 - Output variable name: psl
 - Note: this is not the pressure at the surface
2. *Precipitation flux*
 - CF standard name: precipitation_flux
 - Units: kg/m²/s
 - Output variable name: pr
 - Note: includes both liquid and solid phases
3. *Air Temperature*
 - CF standard name: air_temperature
 - Units: K
 - Output variable name: tas
 - Note: near-surface (usually, 2 meter) air temperature
4. *Surface eastward stress*
 - CF standard name: surface_downward_eastward_stress
 - Units: Pa
 - Output variable name: tauu

- Note:
5. Surface northward stress
 - CF standard name: surface_downward_northward_stress
 - Units: Pa
 - Output variable name: tauv
 - Note:
 6. Surface snow thickness
 - CF standard name: surface_snow_thickness
 - Units: m
 - Output variable name: snd
 - Note: this thickness when multiplied by the average area of the grid cell covered by snow yields the time-mean snow volume. Thus, for time means, compute as the weighted sum of thickness (averaged over the snow-covered portion of the grid cell) divided by the sum of the weights, with the weights equal to the area covered by snow. Report as 0.0 in snow-free regions.
 7. Surface upward latent heat flux
 - CF standard name: surface_upward_latent_heat_flux
 - Units: W/m²
 - Output variable name: hfls
 - Note:
 8. Surface upward sensible heat flux
 - CF standard name: surface_upward_sensible_heat_flux
 - Units: W/m²
 - Output variable name: hfss
 - Note:
 9. Surface downwelling long wave flux in air
 - CF standard name: surface_downwelling_longwave_flux_in_air
 - Units: W/m²
 - Output variable name: rlds
 10. Surface upwelling longwave flux in air
 - CF standard name: surface_upwelling_longwave_flux_in_air
 - Units: W/m²
 - Output variable name: rlus
 - Note:
 11. Surface downwelling shortwave flux in air
 - CF standard name: surface_downwelling_shortwave_flux_in_air
 - Units: W/m²
 - Output variable name: rsds
 - Note:

12. surface upwelling shortwave flux in air
 - CF standard name: surface_upwelling_shortwave_flux_in_air
 - Units: W/m^2
 - Output variable name: rsus
 - Note:
13. surface temperature
 - CF standard name : surface_temperature
 - Units: K
 - Output variable name: ts
 - Note: “skin” temperature (i.e., SST for the open ocean)
14. surface air pressure
 - CF standard name: surface_air_pressure
 - Units: Pa
 - Output variable name: ps
 - Note: NOT mean sea-level pressure
15. atmosphere water vapor content
 - CF standard name: atmosphere_water_vapour_content
 - Units: kg/m^2
 - Output variable name: prw
 - Note: vertically-integrated through the atmospheric column
16. runoff flux
 - CF standard name: runoff_flux
 - Units: $kg/m^2/s$
 - Output variable: mrro
 - Note: compute as the total run-off (including drainage through the base of the soil model) leaving the land portion of the grid cell divided by the land area in the grid cell; report as “missing” or 0.0 where the land fraction is 0.
17. Snow over land
 - CF standard name: surface_snow_amount_where_land
 - Units: kg/m^2
 - Output variable name: snw
 - Note: compute as the mass of surface snow on the land portion of the grid cell divided by the land area in the grid cell; report as “missing” or 0.0 where the land fraction is 0; exclude snow on vegetation canopy or on sea ice
18. Eastward wind
 - CF standard name: eastward_wind
 - Units: m/s
 - Output variable name: uas
 - Note: near-surface (usually 10 m) eastward component of wind
19. Northward wind

- CF standard name: northward_wind
 - Units: m/s
 - Output variable name: vas
 - Note: near-surface (usually 10 m) northward component of wind
20. Specific humidity
- CF standard name: specific_humidity
 - Units: 1 (i.e., dimensionless fraction)
 - Output variable name: huss
 - Note: near surface (usually 2 m) specific humidity
21. Incident shortwave flux at top of the atmosphere
- CF standard name: toa_incoming_shortwave_flux
 - Units: W/m²
 - Output variable name: rsdt
 - Note: incident shortwave at the top of the atmosphere
22. Outgoing shortwave flux at top of the atmosphere
- CF standard name: toa_outgoing_shortwave_flux
 - Units: W/m²
 - Output variable name: rsut
 - Note: at the top of the atmosphere
23. Outgoing long wave flux at top of the atmosphere
- CF standard name: toa_outgoing_longwave_flux
 - Units: W/m²
 - Output variable name: rtmt
 - Note: at the top of the atmosphere (to be compared with satellite measurements)

Monthly-mean 3-d atmosphere data (longitude,latitude,pressure,time:month)

Except for cloud area fraction, this data must be provided on pressure levels, taken at the pressure levels the closest to: 1000, 925, 850, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10hPa

1. Air temperature
 - CF standard name: air_temperature
 - Units: K
 - Output variable name: ta
 - Note:
2. Eastward wind
 - CF standard name: eastward_wind
 - Units: m/s
 - Output variable name: ua
 - Note:

3. Northward wind
 - CF standard name: northward_wind
 - Units: m/s
 - Output variable name: va
 - Note:
4. Specific humidity
 - CF standard name: specific_humidity
 - Units: 1 (i.e, dimensionless fraction)
 - Output variable name: hus
 - Note:
5. $\Omega = DP/Dt$
 - CF standard name: lagrangian_tendency_of_air_pressure
 - Units: Pa/s
 - Output variable name: wap
 - Note: commonly referred to as “omega”, this represents the vertical component of velocity in pressure coordinates (positive down)
6. geopotential height
 - CF standard name: geopotential_height
 - Units: m
 - Output variable name: zg
 - Note:
7. relative humidity
 - CF standard name: relative_humidity
 - Units: %
 - Output variable name: hur
 - Note:
8. Cloud cover in each layer
 - CF standard name: cloud_area_fraction_in_atmosphere_layer
 - Units: %
 - Output variable name: cl
 - Note: unlike all other fields in this table, the cloud fraction should be reported for each model layer (not interpolated to standard pressures). Includes both large-scale and convective cloud.