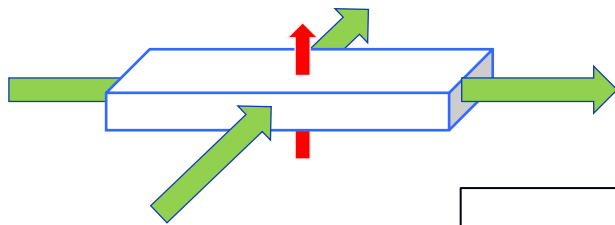
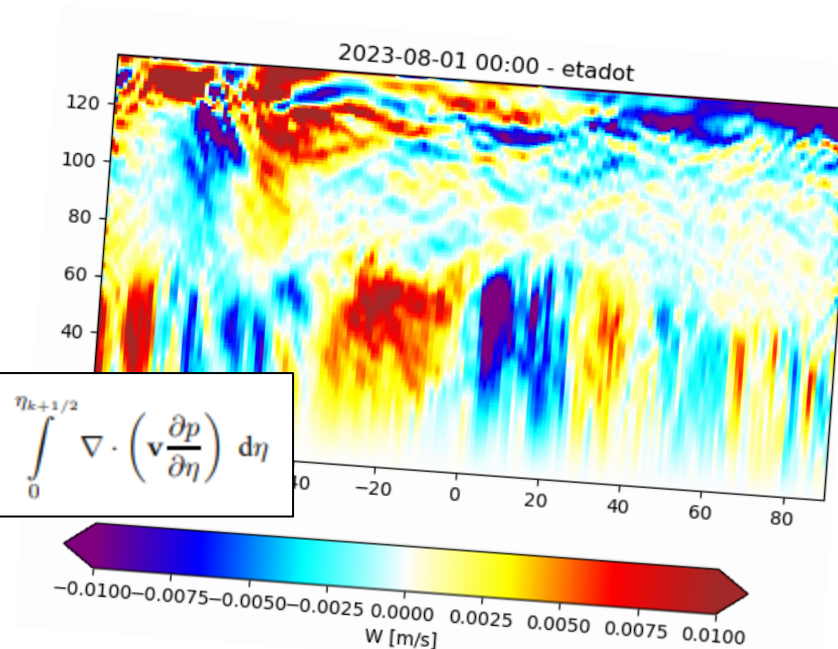


Vertical mass fluxes - revision?

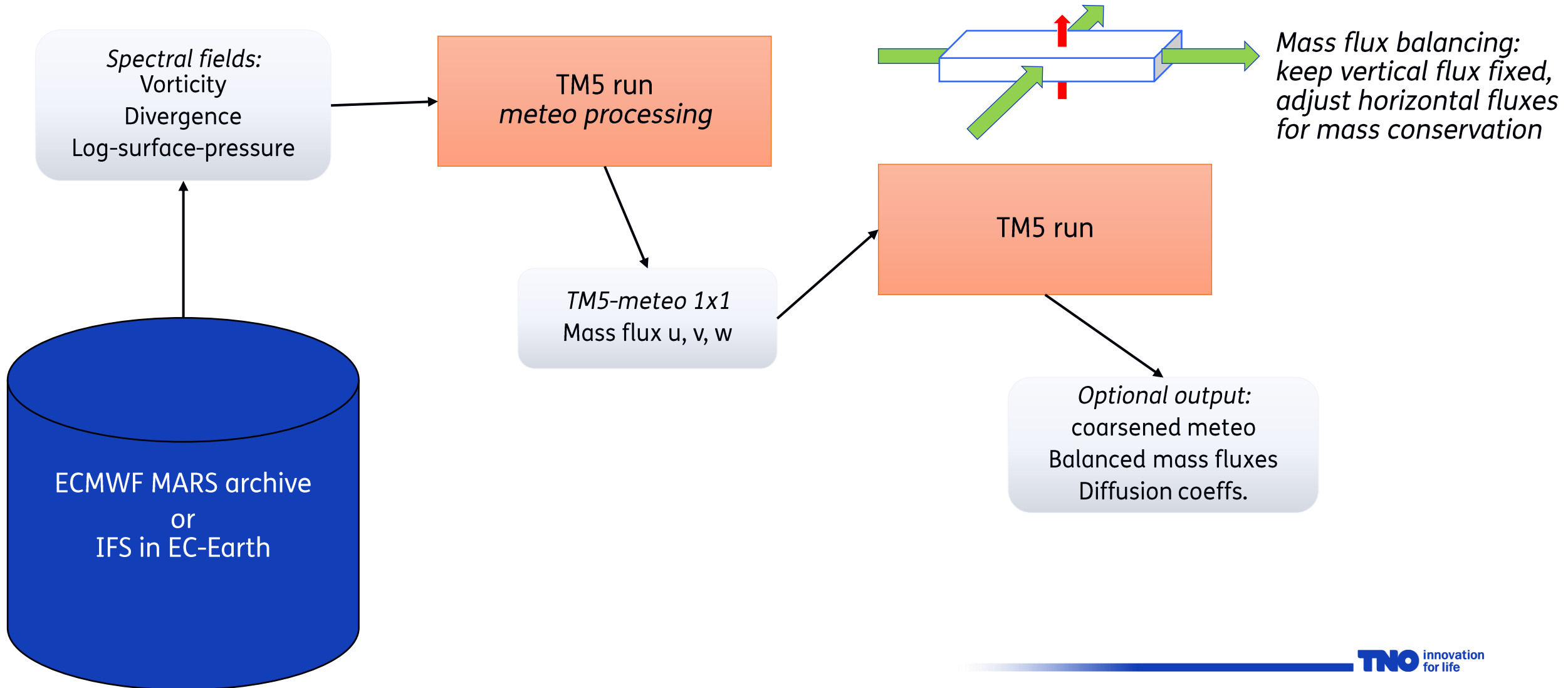
Arjo Segers (TNO), Twan van Noije (KNMI)



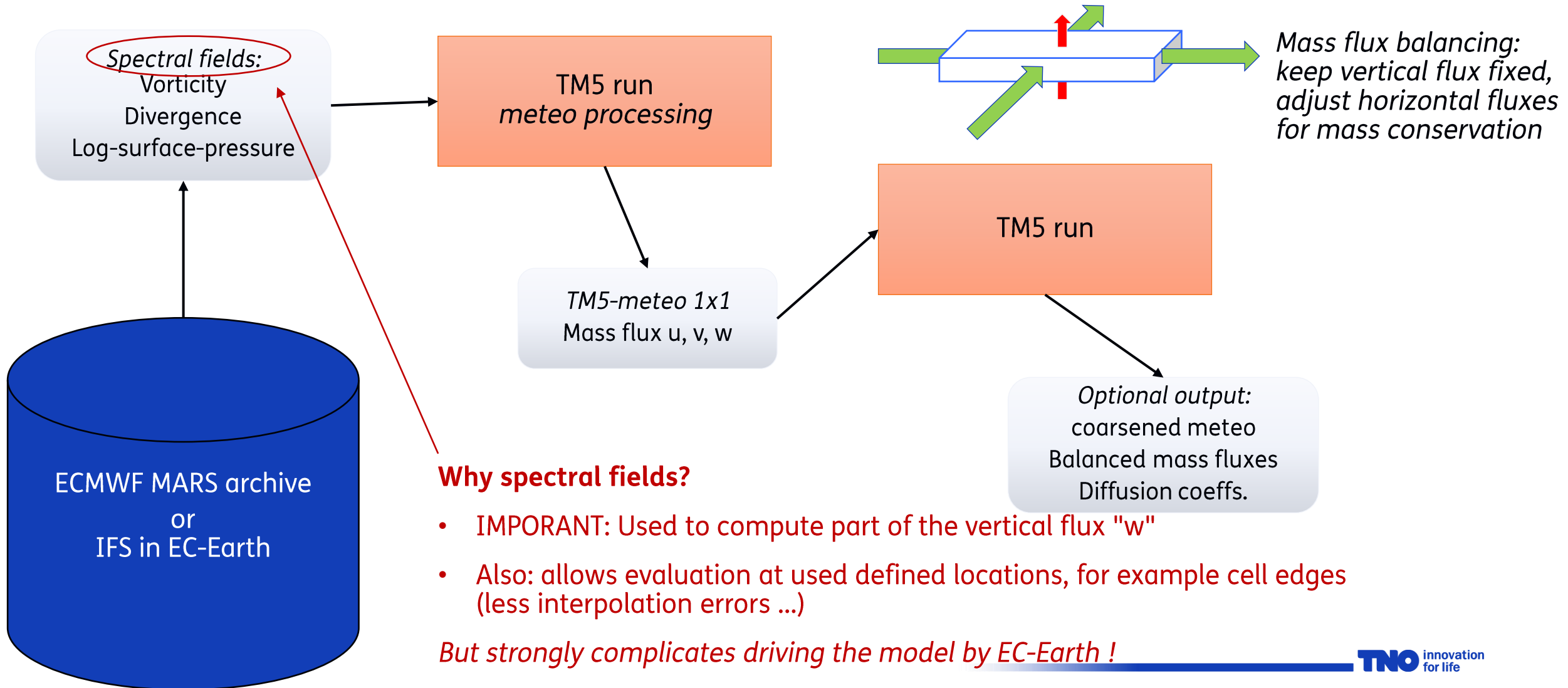
$$\left(\dot{\eta} \frac{\partial p}{\partial \eta}\right)_{k+1/2} = -\frac{\partial p}{\partial t} - \int_0^{\eta_{k+1/2}} \nabla \cdot \left(\mathbf{v} \frac{\partial p}{\partial \eta}\right) d\eta$$



Mass fluxes for advection



Mass fluxes for advection



Vertical mass flux

- Vertical mass flux following IFS Documentation:

$$\left(\dot{\eta} \frac{\partial p}{\partial \eta}\right)_{k+1/2} = - \frac{\partial p}{\partial t} - \int_0^{\eta_{k+1/2}} \nabla \cdot \left(\mathbf{v} \frac{\partial p}{\partial \eta} \right) d\eta \quad [\text{Pa s}^{-1}]$$

Computed in TM meteo processing

- From spectral (VO,D,lnsp):

$$\begin{aligned} \nabla \cdot (\mathbf{v}_k \Delta p_k) &= (\nabla \cdot \mathbf{v}_k) \Delta p_k + \mathbf{v}_k \cdot (\nabla(\Delta p_k)) \\ &= D_k (\Delta a_k + \Delta b_k p_s) + \frac{\mathbf{V}_k}{\cos \phi} \cdot (\nabla(\ln p_s)) p_s \Delta b_k \end{aligned}$$

- Evaluated at grid points:
 - D
 - V=(U,V)
 - $\nabla(\ln p_s)$
 - p_s

Vertical mass flux

- Vertical mass flux following IFS Documentation:

$$\left(\dot{\eta} \frac{\partial p}{\partial \eta}\right)_{k+1/2} = -\frac{\partial p}{\partial t} - \int_0^{\eta_{k+1/2}} \nabla \cdot \left(\mathbf{v} \frac{\partial p}{\partial \eta}\right) d\eta \quad [\text{Pa s}^{-1}]$$

Computed in TM meteo processing

- From spectral (NO D Insp):

MARS Catalogue Compute instead vertical flux from "ETADOT" ?

Time (2 values)	Step (19 values)	Level (137 values)	Parameter (30 values)
06:00:00 18:00:00	0 1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9 10	Divergence Eta-coordinate vertical velocity Fraction of cloud cover Geopotential Logarithm of surface pressure Mean downdraught detrainment rate Mean downdraught mass flux Mean eastward wind tendency due to parametrisations Mean northward wind tendency due to parametrisations Mean specific humidity tendency due to parametrisations

Vertical mass flux

- Vertical mass flux following IFS Documentation:

$$\left(\dot{\eta} \frac{\partial p}{\partial \eta}\right)_{k+1/2}$$

Eta: dimensionless vertical coordinate [0,1] in IFS

Requires:

- 3D ETADOT fields
- dp/deta from:
 - hybride coefficients a and b
 - surface pressure
 - "eta" definition

From IFS manual Part III

2.2.2 Finite-element vertical discretisation

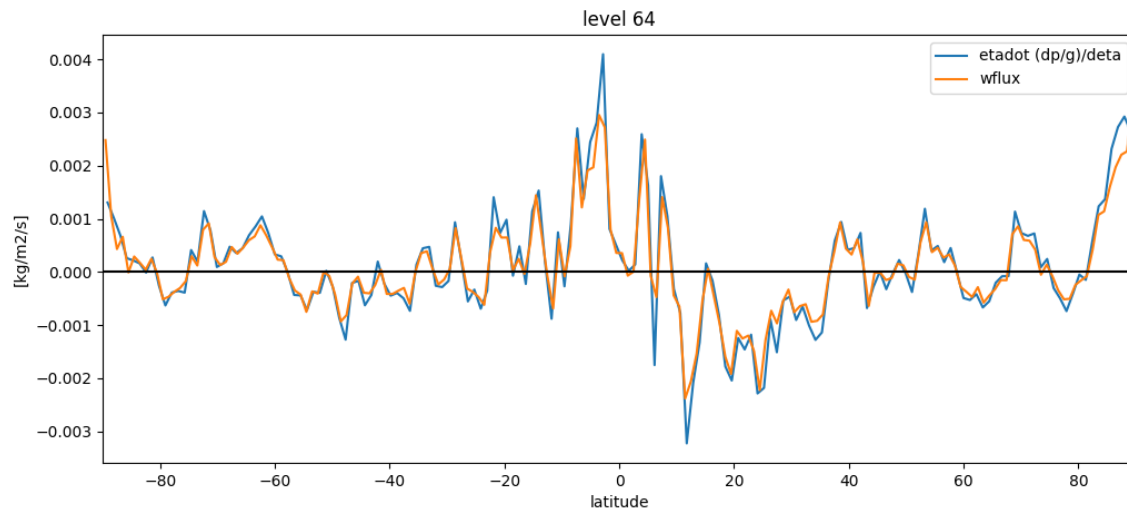
In Cy24r3 the vertical discretisation was changed in the operational model from the finite-difference discretisation in Lorenz staggering described in the previous subsection to a finite-element discretisation using cubic B-splines as basis functions.

For the finite-element (FE) discretisation, all variables (even pressure) are kept at the same levels (full levels), i.e. the values of pressure at full levels and not at half levels are required. Also, the values of the derivatives $dA/d\eta$ and $dB/d\eta$ at full levels are now needed, from which the vertical derivative of pressure can be computed according to $\partial p / \partial \eta = (dA/d\eta) + (dB/d\eta) p_s$. In the semi-Lagrangian version of the evolution equations these are the only vertical derivatives required. They are constant in time and linked to the definition of the vertical coordinate. It is therefore convenient to change the definition of the vertical coordinate and supply $(dA/d\eta)_k$ and $(dB/d\eta)_k$ at full levels (instead of $A_{k+1/2}$ and $B_{k+1/2}$ at half levels) such that

$$\left(\frac{\partial p}{\partial \eta}\right)_k = \left(\frac{dA}{d\eta}\right)_k + \left(\frac{dB}{d\eta}\right)_k p_s \quad (2.27)$$

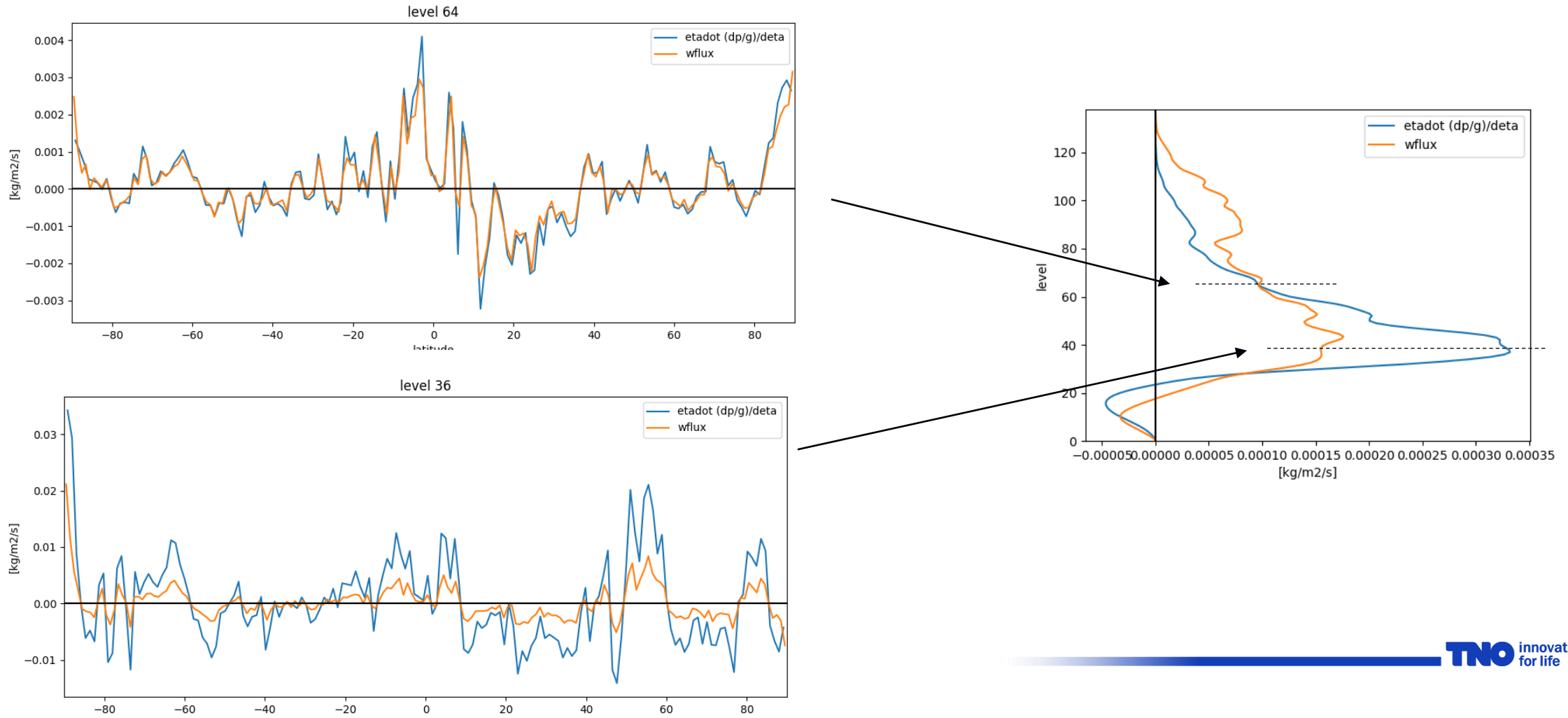
Vertical massflux from etadot and dp/deta

- Downloaded ETADOT, guessed dp/deta, computed vertical flux, compared to TM5 vertical mass flux



Vertical massflux from etadot and dp/deta

- Downloaded ETADOT, guessed dp/deta, computed vertical flux, compared to TM5 vertical mass flux



Vertical mass flux

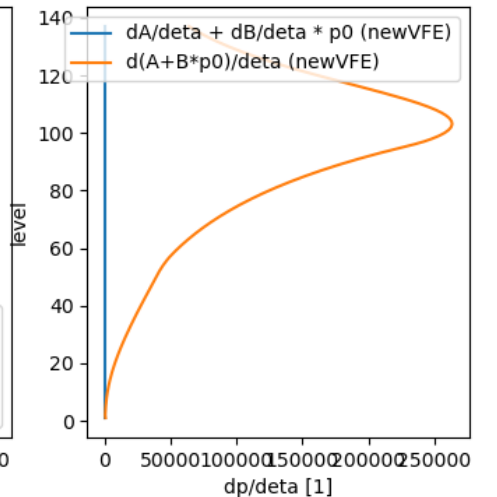
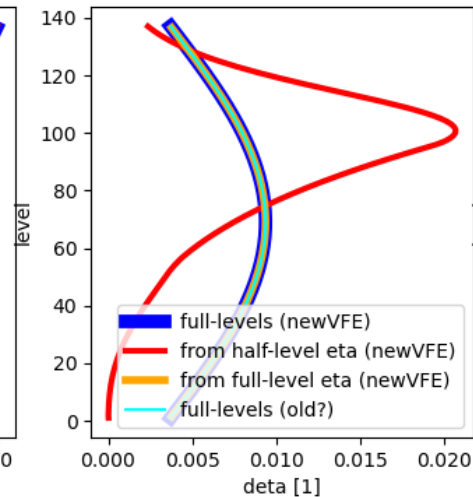
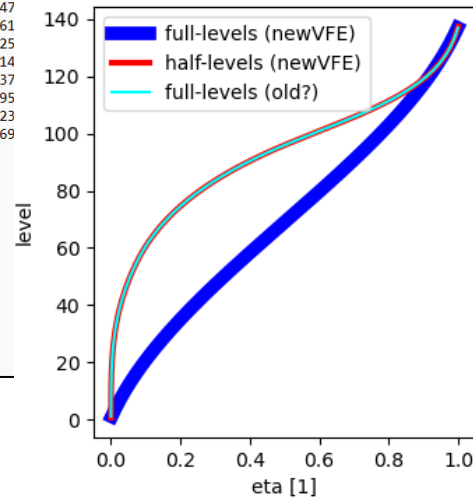
- Michail Diamantakis (ECMWF):
"Eta-coordinate is printed by IFS; not available in tables ..."

JLEV	A	B	eta	deta	dA/deta	dB/deta	m/p _{rc} =1/p _{rc} *dp/deta
1	0.9999238950	0.0000000000	0.0000098710	0.0000197421	0.9997414328	0.0000000000	0.9997414328
2	2.5506433458	-0.0000000000	0.0000251794	0.0000108747	0.9997414328	0.0000000000	0.9997414328
3	3.8831581091	0.0000000000	0.0000383337	0.0000154339	0.9997414328	0.0000000000	0.9997414328
4	5.7455445031	-0.0000000000	0.0000567188	0.0000213362	0.9997414328	0.0000000000	0.9997414328
5	8.2853289030	0.0000000000	0.0000817910	0.0000288082	0.9997414328	0.0000000000	0.9997414328
6	11.6731760638	-0.0000000000	0.0001152351	0.0000380800	0.9997414328	0.0000000000	0.9997414328
7	16.1030124701	0.0000000000	0.0001589655	0.0000493808	0.9997414328	0.0000000000	0.9997414328
8	21.7916881079	-0.0000000000	0.0002151229	0.0000629340	0.9997414328	0.0000000000	0.9997414328
9	28.974						0.9997414328
10	37.92						0.9997414328
11	48.90						0.9997414328
12	62.22						0.9997414328

* A, B and some more things at full levels:							
JLEV	A	B	eta	deta	dA/deta	dB/deta	m/p _{rc} = 1/p _{rc} * dp
1	1.0850077622	0.0000000000	0.0018576815	0.0037153629	0.0053136369	0.0000000000	0.0053136369
2	2.5928600424	0.0000000000	0.0056387550	0.0038467841	0.0028269542	0.0000000000	0.0028269542
3	3.8414522661	-0.0000000000	0.0095511978	0.0039781016	0.0038797262	0.0000000000	0.0038797262
4	5.7082578498	0.0000000000	0.0135948719	0.0041092464	0.0051922542	0.0000000000	0.0051922542
5	8.2321674316	-0.0000000000	0.0177695699	0.0042401496	0.0067941506	0.0000000000	0.0067941506
....							
124	1521.1197643094	0.9270505736	0.9388302115	0.0053961157	-0.4973447164	0.0000178968	1.3160457215
125	1263.1013344893	0.9364289976	0.9441634983	0.0052704579	-0.4574584584	0.0000168135	1.2461735293
126	1032.6887560699	0.9450172074	0.9493707012	0.0051439479	-0.4158425648	0.0000157422	1.1792362374
127	828.6956443787	0.9528583307	0.9544510012	0.0050166521	-0.3767664454	0.0000147256	1.1153054466
128	649.5386899201	0.9599988712	0.9594036459	0.0048886375	-0.3369982574	0.0000137326	1.0544538143
129	494.3999139050	0.9664769809	0.9642279504	0.0047599714	-0.2978368083	0.0000127757	0.9966633030
130	361.6306345917	0.9723378113	0.9689232968	0.0046307215	-0.25987847		
131	250.7899251143	0.9776135316	0.9734891353	0.0045009556	-0.21925161		
132	160.6132622152	0.9823430887	0.9779249843	0.0043707422	-0.18150525		
133	90.7941955829	0.9865548254	0.9822304301	0.0042401496	-0.13807114		
134	41.1297469214	0.9902743734	0.9864051281	0.0041092464	-0.09593637		
135	11.7034046186	0.9935231227	0.9904488022	0.0039781016	-0.04732995		
136	1.1381641019	0.9963371558	0.9943612450	0.0038467841	-0.00964023		
137	-0.00087125409	0.9988229334	0.9981423185	0.0037153629	0.00000069		

* A and B at half levels:						
JLEV	A	B	ETA	ALPHA	S	
0	0.000000	0.000000000000	0.000000000000	0.000000000000	0.000000000000	
1	2.000365	0.000000000000	0.000019742068	0.000019742068	0.000000000000	
2	3.102241	0.000000000000	0.000030616739	0.000030616739	0.000000000000	
3	4.666084	0.000000000000	0.000046050667	0.000046050667	0.000000000000	
4	6.827977	0.000000000000	0.000067386895	0.000067386895	0.000000000000	
5	9.746966	0.000000000000	0.000096195079	0.000096195079	0.000000000000	
6	13.605424	0.000000000000	0.000134275094	0.000134275094	0.000000000000	
7	18.608931	0.000000000000	0.000183655866	0.000183655866	0.000000000000	
8	24.985718	0.000000000000	0.000246589862	0.000246589862	0.000000000000	
9	32.985710	0.000000000000	0.000325543648	0.000325543648	0.000000000000	

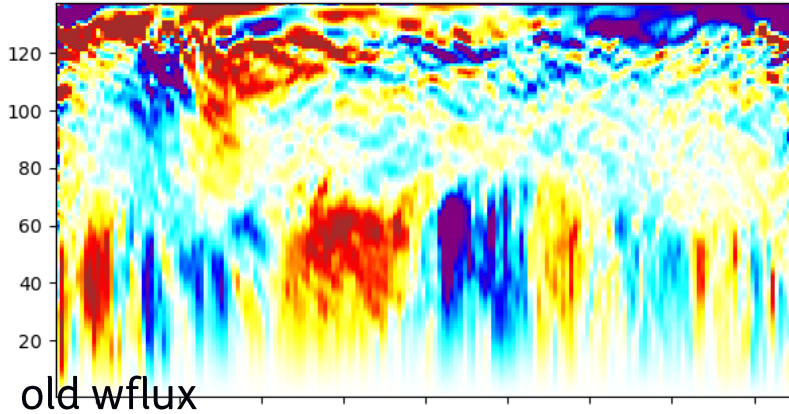
Obtained prints of eta, deta, dA and dB, ...



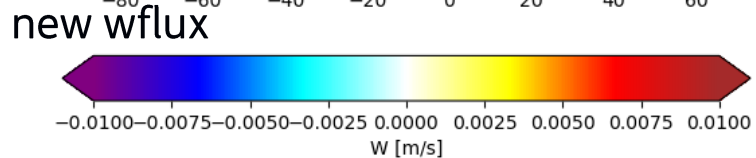
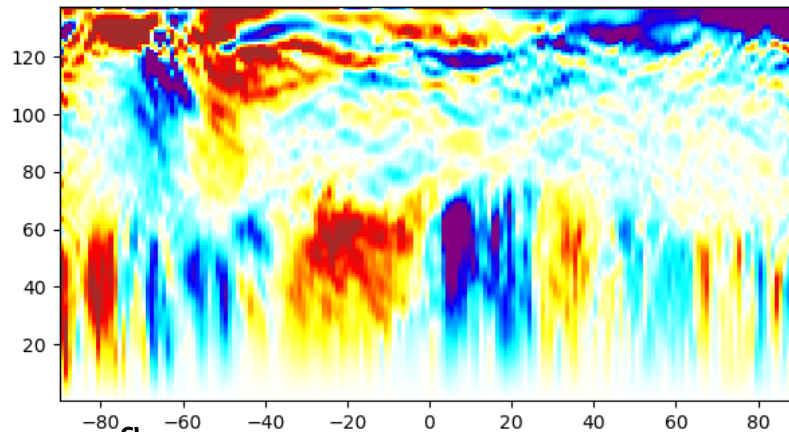
TM5 CH₄ simulations with new vertical flux

- Implemented version that uses "etadot" instead of "mfw"

2023-08-01 00:00 - mfw

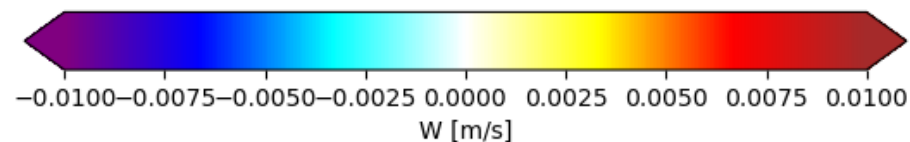
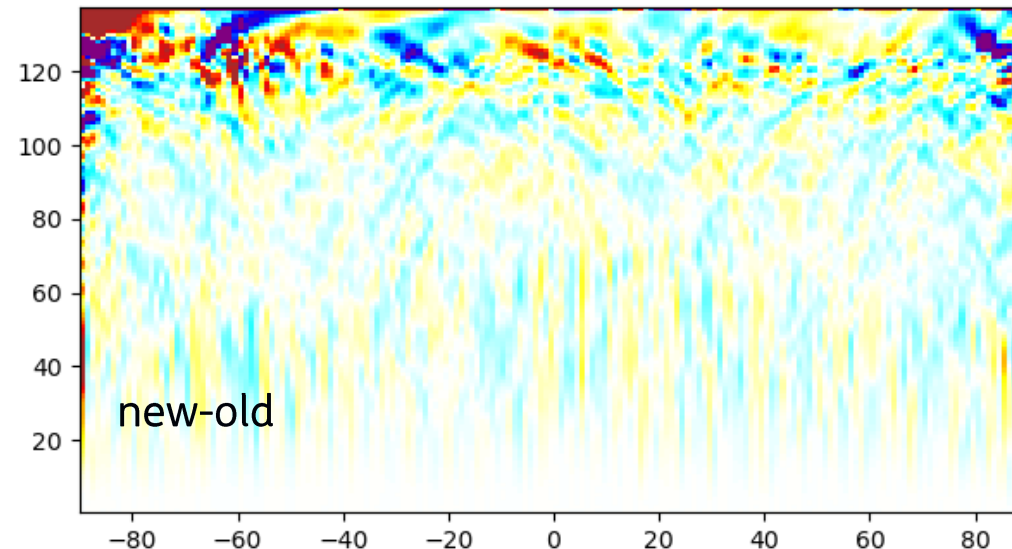


2023-08-01 00:00 - etadot



After 1 month of simulation,
zonal averages in "windspeed" calculated from vert. mass flux

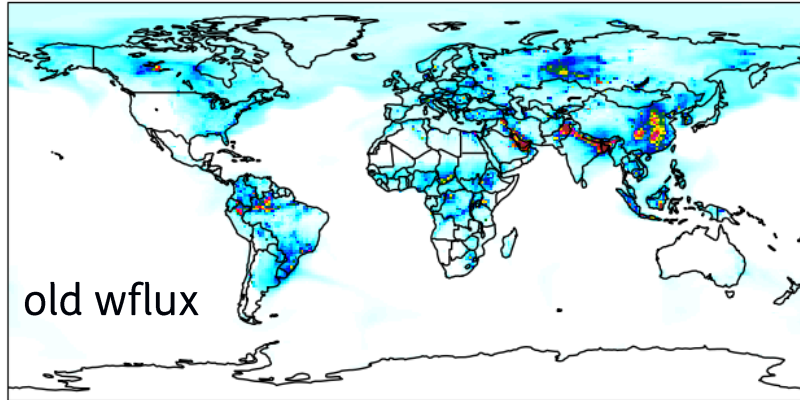
2023-08-01 00:00 - etadot-mfw



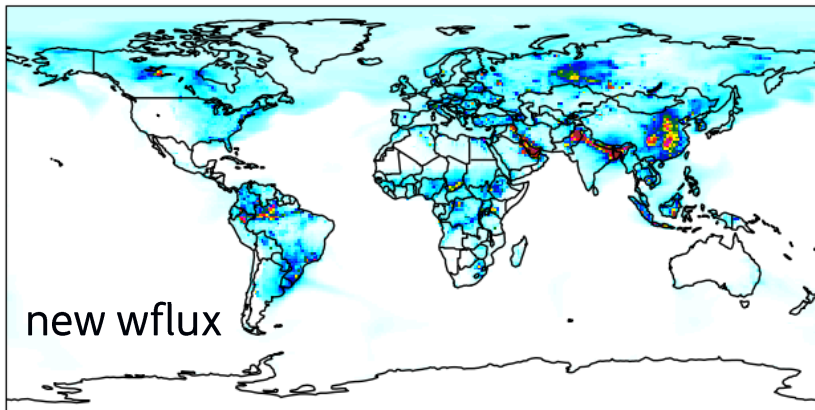
TM5 CH₄ simulations with new vertical flux

- Tested with CH₄ simulation, 137 layers, 1°x1°, initialized with 1600 ppb

2023-08-01 00:00 - mfw

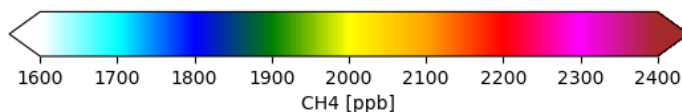
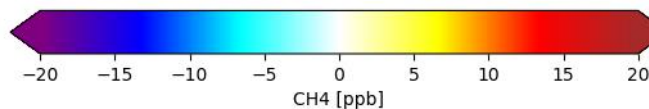
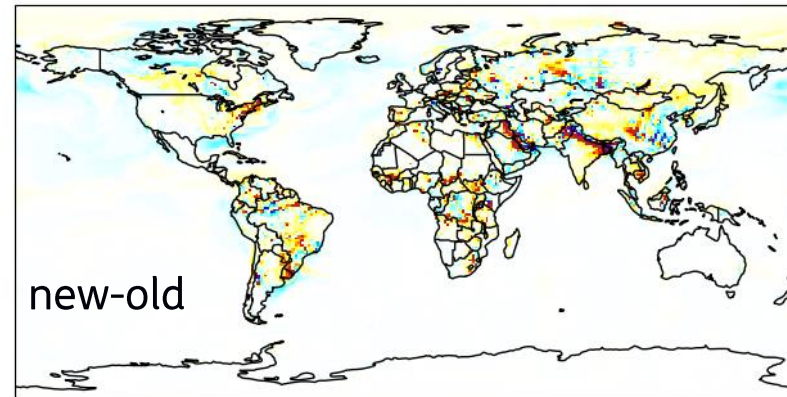


2023-08-01 00:00 - etadot



After 1 month of simulation,
no structural differences in surface concentrations

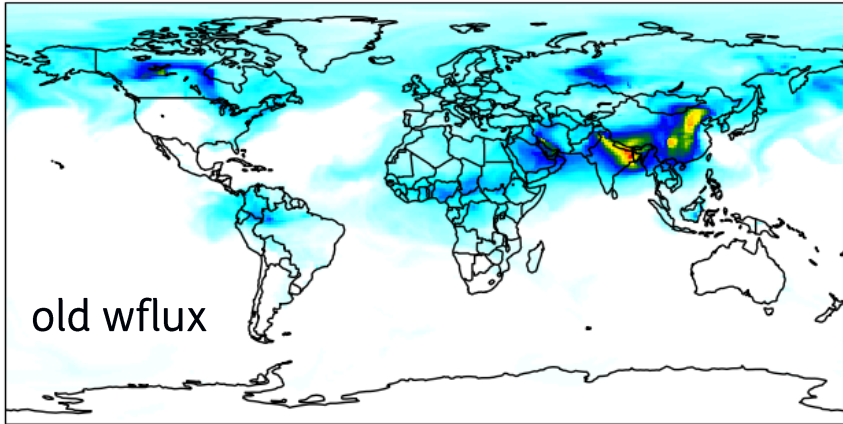
2023-08-01 00:00 - etadot-mfw



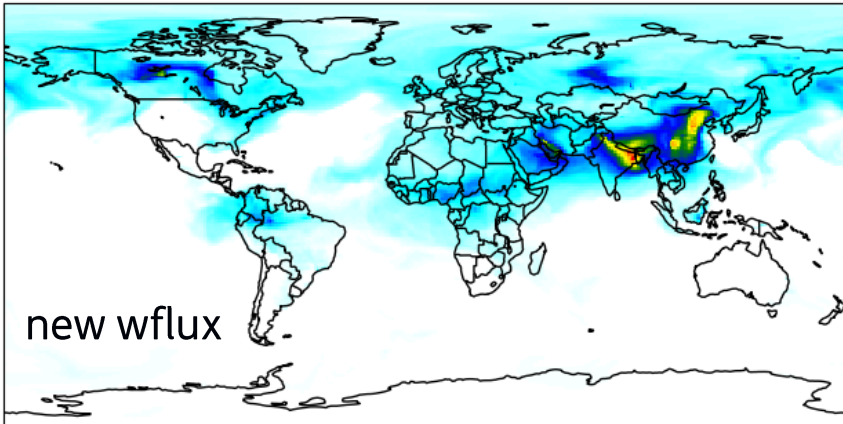
TM5 CH₄ simulations with new vertical flux

- Tested with CH₄ simulation, 137 layers, 1°x1°, initialized with 1600 ppb

2023-08-01 00:00 - mfw

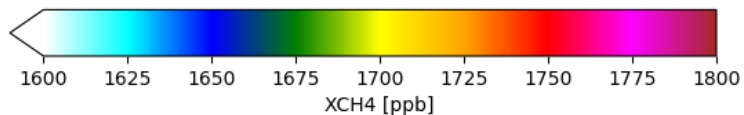
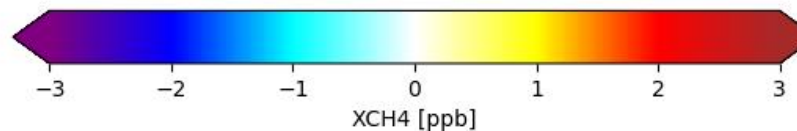
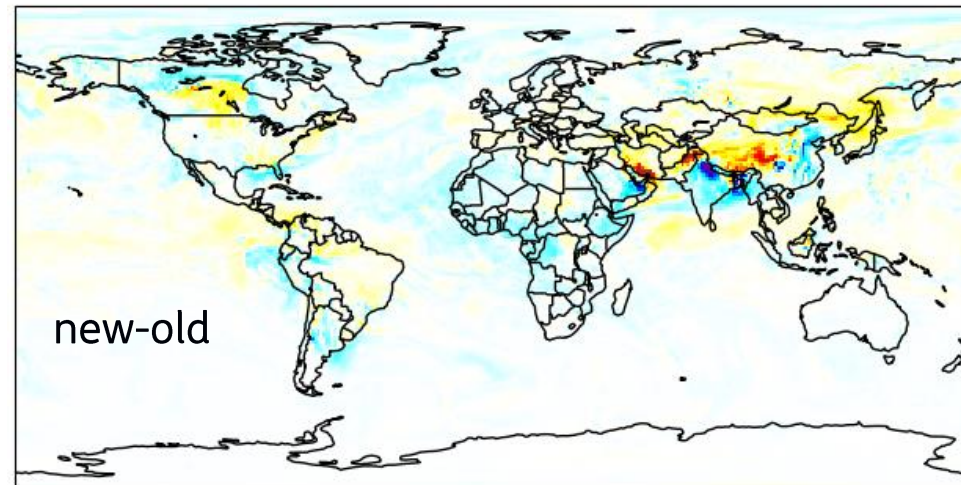


2023-08-01 00:00 - etadot



After 1 month of simulation,
no structural differences in column mixing ratios

2023-08-01 00:00 - etadot-mfw



Summary and outlook

Can we replace "MFW" by "ETADOT"?

- Yes, but use the correct "eta" definition ...

Should we replace "MFW" by "ETADOT"?

- Not necessary for standard TM5-runs
- ... but might be useful in EC-Earth coupling

TM5 on ECMWF reduced grid

Task list

- Vertical mass flux
- Mass balancing
- Advection code
- ...

