Dataset description

Turbulent Ekman flow with cubic small-scale surface roughness under stable stratification ($Re_D = 1000$, $Ri_\Lambda = [0, \ldots, 256]$)

Direct numerical simulation – Set-up and vertical profiles

Jonathan Kostelecky [1]⋆,▲, Cedrick Ansorge [2]⋆
⋆ *Freie Universität Berlin, Institut für Meteorologie*
▲ *Universität zu Köln, Institut für Geophysik und Meteorologie*

November 7, 2024

1 Metadata

Collection This dataset is part of the collection *Turbulent wall-bounded flow*[3].
The collection is freely available and hosted by Refubium, the institutional repository of Freie Universität Berlin.

DOI 10.17169/refubium-45292

HPC systems The data was generated under the project `TrainABL` on the supercomputer `HAWK` at Höchstleistungsrechenzentrum Stuttgart (HLRS, in Germany).

Code The data was generated by the tool-suite for turbulence simulation `tLab`[4].

Related Publication
10.1017/jfm.2024.542

2 The dataset

2.1 Physical setting

The physical case corresponds to stratified Ekman flow over a rough surface. The canonical flow configuration is characterized by four parameters: the geostrophic wind vector $\mathbf{G} = (G_1, G_2, 0)^T$ (with the magnitude $G = \sqrt{G_1^2 + G_2^2}$, rotated here by $\approx 18.1°$ w.r.t. the coordinate direction O_x), the constant kinematic fluid viscosity ν, the Coriolis parameter f, and the buoyancy difference B_0 between the wall and free stream. The Rossby radius $\Lambda = G/f$ is the length scale implied for this choice of parameters. The flow is then governed by two

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[1] j.kostelecky@posteo.de
[2] cedrick@posteo.de
[3] refubium.fu-berlin.de/handle/fub188/42710
[4] github.com/turbulencia/tlab

Case (`ID`)	Ri_Λ	Ri_B	Grid	$t^{-}_{\mathrm{start}}[1/f]$	$t^{-}_{\mathrm{end}}[1/f]$	$\Delta t^{-}_{\mathrm{sim}}[1/f]$	#iterations
`N`	0	0.000	A	64.96	66.02	1.06	29500
`S001`	1	0.073	A	66.02	66.61	0.58	16000
`S002`	2	0.147	A	66.61	67.06	0.44	11800
`S004`	4	0.293	A	67.06	67.78	0.71	17800
`S005`	5	0.367	A	67.78	68.26	0.48	11800
`S008`	8	0.587	A	68.26	69.02	0.74	17800
`S012`	12	0.880	A	69.02	69.53	0.51	11800
`S016`	16	1.174	A	69.53	69.98	0.44	10300
`S020`	20	1.467	A	69.98	70.38	0.39	8800
`S032`	32	2.348	A	70.38	70.84	0.45	9800
`S042`	42	3.081	A	70.84	71.40	0.55	11800
`S064`	64	4.695	A	71.40	71.84	0.43	8800
`S128`	128	9.390	A	71.84	72.32	0.48	8800
`S128P`	128	9.390	B	72.32	74.27	1.95	40600
`S192P`	192	14.086	B	73.49	74.46	0.97	19000
`S256P`	256	18.781	B	73.49	75.68	2.19	41400

Table 1: Simulations cases of this dataset. Time in eddy-turnover times f^{-1}; t^{-}_{start} start, t^{-}_{end} end and $\Delta t^{-}_{\mathrm{sim}}$ total simulation time of the cases. #iterations is the total number of Runge–Kutta time-integration steps used for integration of the problem over the respective time span.

dimensionless numbers, since the molecular Prandtl number $Pr = 1$, i.e. the kinematic diffusivity equals the viscosity, and the Rossby number $Ro = 1$. The Reynolds number Re and the Froude number Fr are given as (for comparison, the scaled bulk Richardson number Ri_B)

$$Re_\Lambda = \frac{G\Lambda}{\nu}, \quad Fr_\Lambda = \frac{G^2}{B_0\Lambda} = Ri_\Lambda^{-1} \quad \text{and} \quad Ri_B = \frac{B_0\delta_{\mathrm{neutral}}}{G^2}. \tag{1}$$

The small-scale surface roughness at the lower domain boundary is given in the file `geometry2d.nc` and is identical for all cases: 56×56 square blocks with a uniform height and width distribution. It also features identical statistical properties as case `r3` in the study 10.1017/jfm.2024.542, but corresponds to a realization on a grid with slightly higher resolution / smaller grid spacing.

2.2 Simulation cases

This dataset contains 16 simulation cases which are driven by the same large-scale forcing and exposed to a rough surface. Members of the parametric set of simulations differ by stable density stratification, which is imposed via a Dirichlet boundary condition (viz. constant temperature difference between upper and lower domain boundary). The cases are listed in Tab. 1 and labelled by their `ID` (`N, S001,..., S128, ..., S256P`) according to the stratification measured by the Richardson number Ri_Λ; `N` stands for neutral stratification, `S` for stable. The simulations were carried out sequentially in time starting from the neutral case `N`, a suffix `P` indicates three concurrent runs for very stable stratification (`S128P, S192P, S256P`).

Here the bulk Richardson number Ri_B is evaluated based on the boundary layer thickness of the neutrally stratified case `N` such that it does not evolve over the course of simulation. The choice of $Re_\Lambda = 5 \cdot 10^5$ corresponds to $Re_D = 1000$ ($Re_D = DG/\nu$, with the laminar Ekman-layer depth $D = \sqrt{2\nu/f}$) and a friction Reynolds number $Re_\tau \approx 2700$ for the neutrally stratified case. Two computational grids are used: (A) $N_{xz} \times N_y = 3840^2 \times 704$, (B) $3840^2 \times 576$ with similar spatial resolution of approximately $\Delta(xz)^+_N \times \Delta y^+_{N,\text{wall}} = 2.6^2 \times 1.0$ wall units and a domain size in terms of the Rossby radius of $(L_{xz} \times L_y)/\Lambda^3 = 0.27^2 \times 0.26$ for grid (A), and $0.27^2 \times 0.11$ for grid (B).

2.3 Contents of the dataset

This dataset holds the two metadata files

- `Data_Description_Re1000_rough_stable.pdf` (this file) containing the data set description in portable document format (PDF),
- `geometry2d.nc`, which holds the geometry of all cases in the form of a two-dimensional horizontal plane where the height of obstacles in grid cells from the ground level is given.

For the set of 16 simulations, the primary data are given in namelist files in ASCII format (denoted by suffix `.ini`) as required by the tool suite `tLab` (for details, the reader is referred to the documentation of the open-source code available under `github.com/turbulencia/tlab`). The actual statistical data are provided in the network common data format self-documenting file type (netCDF) and denoted by the suffix `.nc`. The naming convention for the set of 16 simulations is as follows:

`ri`⟨ri⟩`_re`⟨re⟩_⟨*nx*⟩`x`⟨*ny*⟩`x`⟨*nz*⟩_⟨date⟩_⟨case⟩_⟨type⟩`.`⟨suffix⟩

For example `ri00.00_re1000_3840x0704x3840_20231206_n_avg.nc`, where

⟨ri⟩	is the Richardson number $Ri_\Lambda = G\Lambda/B_0$,
⟨re⟩	the Reynolds number $Re_D = GD/\nu$ with $D = \sqrt{2\nu/f}$, the Ekman layer depth scale
⟨nx⟩	the number of grid points in direction of Ox (similar for ⟨ny⟩, ⟨nz⟩)
⟨date⟩	the start date of the simulation on the HPC cluster in the format YYYYMMDD.
⟨case⟩	the case identifier used in the corresponding paper, indicating the bulk stability.
⟨type⟩	the type of data, either `avg1s` for scalar statistics, `avg` for flow statistics, and
⟨suffix⟩	is the file suffix indicating the file type (`.ini` for primary data / `.nc` for statistics)

2.4 Variable information

The statistical data is available in self-documented netCDF format, and it contains a wide array of parameters, encompassing vertical profiles of velocity and scalar variables (temperature/buoyancy as active and for some cases also passive scalars), scalar and momentum budget terms, as well as statistical moments up to the fourth order of velocities, scalars, and derivatives. These parameters provide a comprehensive perspective on Ekman flow dynamics. They are organized into distinct groups. Within the subsequent table, you will find numerous variables grouped together, accompanied by their descriptions and associated equations.
In order to fully describe the geometry of the surface roughness, there is a horizontal domain slice in netCDF format, that describe the positions and heights of the roughness elements in grid points.

Vertical profiles flow

Mean

rR	density (RA)	$\overline{\rho}$
rU	u, x-component of the velocity (RA)	$\overline{u}$
rV	v, y-component of the velocity (RA)	$\overline{v}$
rW	w, z-component of the velocity (RA)	$\overline{w}$
rP	π dynamic, reduced pressure (RA)	$\overline{\pi}$
rT	T, caloric temperature (RA)	$\overline{T}$
re	e, internal energy (RA)	$\overline{e}$
rh	h, enthalpy (RA)	$\overline{e+(\Gamma_0-1)Ma^2\frac{p}{\rho}}$
rs	s, entropy (RA)	$\overline{s}$
rB	B, buoyancy (RA)	$\overline{B}$
fU	u, x-component of the velocity (FA)	$\langle u\rangle$
fV	v, y-component of the velocity (FA)	$\langle v\rangle$
fW	w, z-component of the velocity (FA)	$\langle w\rangle$
fT	T, caloric Temperature (FA)	$\langle T\rangle$
fe	e, internal energy (FA)	$\langle e\rangle$
fh	h, enthalpy (FA)	$\left\langle e+(\Gamma_0-1)Ma^2\frac{p}{\rho}\right\rangle$
fs	s, entropy (FA)	$\langle s\rangle$

Fluctuations

Tke	turbulence kinetic energy	$\overline{\frac{1}{2}u_i'u_i'}$
Rxx	Reynolds stress R_{11}	$\overline{u'u'}$
Ryy	Reynolds stress R_{22}	$\overline{v'v'}$
Rzz	Reynolds stress R_{33}	$\overline{w'w'}$
Rxy	Reynolds stress R_{12}	$\overline{u'v'}$
Rxz	Reynolds stress R_{13}	$\overline{u'w'}$
Ryz	Reynolds stress R_{23}	$\overline{v'w'}$
rP2	pressure fluctuation (RA)	$\overline{\pi'\pi'}$
rR2	density fluctuation (RA)	$\overline{\rho'\rho'}$
rT2	temperature fluctuation (RA)	$\overline{T'T'}$
fT2	temperature fluctuation (FA)	$\langle T'T'\rangle$
re2	internal energy fluctuation (RA)	$\overline{e'e'}$
fe2	internal energy fluctuation (FA)	$\langle e'e'\rangle$
rh2	enthalpy fluctuation (RA)	$\overline{h'h'}$
fh2	enthalpy fluctuation (FA)	$\langle h'h'\rangle$
rs2	entropy fluctuation (RA)	$\overline{s's'}$
fs2	entropy fluctuation (FA)	$\langle s's'\rangle$

DerivativeFluctuations

U_y1		$\overline{\partial_y u}$
V_y1		$\overline{\partial_y v}$
W_y1		$\overline{\partial_y w}$
U_ii2		
U_x2		$\overline{(\partial_x u')^2}$
U_y2		$\overline{(\partial_y u')^2}$
U_z2		$\overline{(\partial_z u')^2}$
V_x2		$\overline{(\partial_x v')^2}$
V_y2		$\overline{(\partial_y v')^2}$
V_z2		$\overline{(\partial_z v')^2}$
W_x2		$\overline{(\partial_x w')^2}$
W_y2		$\overline{(\partial_y w')^2}$
W_z2		$\overline{(\partial_z w')^2}$
U_x3		$\overline{(\partial_x u')^3}$
U_y3		$\overline{(\partial_y u')^3}$
U_z3		$\overline{(\partial_z u')^3}$
V_x3		$\overline{(\partial_x v')^3}$
V_y3		$\overline{(\partial_y v')^3}$
V_z3		$\overline{(\partial_z v')^3}$
W_x3		$\overline{(\partial_x w')^3}$
W_y3		$\overline{(\partial_y w')^3}$
W_z3		$\overline{(\partial_z w')^3}$
U_x4		$\overline{(\partial_x u')^4}$
U_y4		$\overline{(\partial_y u')^4}$
U_z4		$\overline{(\partial_z u')^4}$
V_x4		$\overline{(\partial_x v')^4}$
V_y4		$\overline{(\partial_y v')^4}$
V_z4		$\overline{(\partial_z v')^4}$
W_x4		$\overline{(\partial_x w')^4}$
W_y4		$\overline{(\partial_y w')^4}$
W_z4		$\overline{(\partial_z w')^4}$

Vorticity

Wx	vorticity (x-component)	$\overline{\partial_z v-\partial_y w}$
Wy	vorticity (y-component)	$\overline{\partial_x w-\partial_z u}$
Wz	vorticity (z-component)	$\overline{\partial_y u-\partial_x v}$
Wx2	fluctuation of x-Vorticity	$\overline{\partial_z v'-\partial_y w'}$
Wy2	fluctuation of y-Vorticity	$\overline{\partial_x w'-\partial_z u'}$
Wz2	fluctuation of z-Vorticity	$\overline{\partial_y u'-\partial_x v'}$

RxxBudget

Rxx_t	time-rate of change of R_{11}	$\overline{\partial_t R_{11}}$
Bxx	buoyancy production	$2b_x\overline{u'B'}$
Cxx	advection in y-direction	$-\overline{v}\ \partial_y\overline{u'u'}$
Pxx	shear-production	$-2\ \overline{u'v'}\ \partial_y\overline{u}$
Exx	viscous dissipation	
PIxx	pressure-velocity correlation Π_{11}	$2\ \overline{u'p'}$
Fxx	Coriolis production	$2f_y\overline{u'w'}$
Txxy_y	divergence of T_{112} turbulent transport	$\partial_y R_{112}$
Txxy	vertical transport T_{112}	$\overline{u'u'v'}-2\nu\overline{\partial_y(u-\langle u\rangle)}$
Gxx	pressure variable-density term	0
Dxx	viscous variable-density term	

RyyBudget

Ryy_t	time-rate of change of R_{22}	$\overline{\partial_t R_{22}}$
Byy	buoyancy production of Ryy	$2b_y\overline{v'B'}$
Cyy	advection in y-direction	$\overline{v}\ \partial_y\overline{v'v'}$
Pyy	shear production	$-2\overline{v'v'}\partial_y\overline{v}$
Eyy	viscous dissipation	
PIyy	pressure–velocity correlation Π_{22}	$2\overline{v'p'}$
Fyy	Coriolis production	0
Tyyy_y	divergence of T_{222} turbulent transport	$\partial_y R_{222}$
Tyyy	vertical transport T_{222}	$\overline{v'v'v'}\ +\ 2\overline{v'p'}-2\nu\overline{(\partial_y v)(v-\langle v\rangle)}$
Gyy	pressure variable-density term	$2(\overline{v}-\langle v\rangle)\partial_y\overline{p}$
Dyy	viscous variable-density term	

RzzBudget

Rzz_t	time-rate of change of R_{33}	$\overline{\partial_t R_{33}}$
Bzz	buoyancy production	$2b_z\overline{w'B'}$
Czz	advection in y-direction	$-\overline{v}\ \partial_y\ \overline{w'w'}$
Pzz	shear production	$-2\overline{v'w'}\partial_y\ \overline{w}$
Ezz	viscous dissipation	
PIzz	pressure–velocity correlation Π_{33}	$2\overline{w'p'}$
Fzz	Coriolis production of Rzz	$-2f_y\overline{u'w'}$
Tzzy_y	divergence of T_{332} turbulent transport	$\partial_y R_{332}$
Tzzy	vertical transport T_{332}	$\overline{w'w'v'}-2\nu\overline{(\partial_y w)(w-\langle w\rangle)}$
Gzz	pressure variable-density term	0
Dzz	viscous variable-density term	

RxyBudget

Rxy_t	time-rate of change of R_{12}	$\overline{\partial_t R_{12}}$
Bxy	buoyancy production	$b_x\overline{u'B'}+b_y\overline{v'B'}$
Cxy	advection in y-direction	$-\overline{v}\partial_y\overline{u'v'}$
Pxy	shear production	$-\overline{u'v'}\partial_y\overline{v}-\overline{v'v'}\ \partial_y\overline{u}$
Exy	viscous dissipation	
PIxy	pressure-velocity correlation Π_{12}	$\overline{p'\,(\partial_y u-\partial_x v)}$
Fxy	Coriolis production of Rxy	$f_y\overline{v'w'}$
Txyy_y	divergence of T_{122} turbulent transport	$\partial_y R_{122}$
Txyy	vertical transport T_{122}	$\overline{u'v'v'}\ +\overline{u'p'}$
Gxy	pressure variable-density term	$(\overline{u}-\langle u\rangle)\partial_y\overline{p}$
Dxy	viscous variable-density term	

RxzBudget

Rxz_t	time-rate of change of R_{13}	$\overline{\partial_t R_{13}}$
Bxz	buoyancy production	$b_x\overline{u'B'}+b_z\overline{u'B'}$
Cxz	advection in y-direction	$-\overline{v}\ \partial_y\overline{u'w'}$
Pxz	shear production	$-\overline{u'w'}\ \partial_y\ \overline{w}-\overline{v'w'}\ \partial_y\overline{u}$
Exz	viscous dissipation	
PIxz	pressure–velocity correlation Π_{13}	$\overline{p'\,(\partial_z u-\partial_x w)}$
Fxz	Coriolis production	$f_y(\overline{w'w'-u'u'})$
Txzy_y	divergence of T_{132} turbulent transport	$\partial_y R_{132}$
Txzy	vertical transport T_{132}	$\overline{u'w'v'}$
Gxz	pressure variable-density term	0
Dxz	viscous variable-density term	

RyzBudget

Ryz_t	time-rate of change of R_{23}	$\overline{\partial_t R_{23}}$
Byz	buoyancy production	$b_y\overline{v'B'}+b_z\overline{w'B'}$
Cyz	advection in y-direction	$-\overline{v}\partial_y\overline{v'w'}$
Pyz	shear production	$-\overline{v'v'}\ \partial_y\ \overline{w}-\overline{v'w'}\ \partial_y\overline{v}$
Eyz	viscous dissipation	
PIyz	pressure–velocity correlation Π_{23}	$\overline{p'\,(\partial_z v-\partial_y w)}$
Fyz	Coriolis production	$-f_y\overline{u'v'}$
Tyzy_y	turbulent transport divergence	$\partial_y R_{232}$
Tyzy	vertical transport T_{232}	$\overline{v'w'v'}\ +\ \overline{w'p'}$
Gyz	pressure variable-density term	$(\overline{w}-\langle w\rangle)\partial_y\overline{p}$
Dyz	viscous variable-density term	

TkeBudget

Tke_t	time-rate of change of Tke	$\overline{\partial_t\frac{1}{2}R_{ii}}$
Tke	turbulence kinetic energy	$\frac{1}{2}R_{ii}$
Buo	buoyancy production of Tke	$\frac{1}{2}B_{ii}$
Con	advection in y-direction	$\frac{1}{2}C_{ii}$
Prd	shear production	$\frac{1}{2}P_{ii}$
Eps	dissipation	$\frac{1}{2}E_{ii}$
Pi	pressure–velocity correlation	$\frac{1}{2}\Pi_{ii}$
Trp	sum of transport terms	$\frac{1}{2}T_{ii2}$
Trp1	transport due to triple correlation terms	$\overline{u_i'u_i'v'}$
Trp2	transport by pressure–velocity correlation	$2\overline{v'p'}$
Trp3	viscous transport	$-2\nu\overline{(\partial_y u_i)(u_i-\langle u_i\rangle)}$
Trp1_y	divergence of triple correlations	$\partial_y\overline{u_i'u_i'v'}$
Trp2_y	divergence of pressure–velocity correltion	$2\partial_y\overline{v'p'}$
Trp3_y	divergence of viscous transport	$-2\nu\partial_y\overline{(\partial_y u_i)(u_i-\langle u_i\rangle)}$
G	pressure variable-density term	$\frac{1}{2}G_{ii}$
D	viscous variable-density term	$\frac{1}{2}D_{ii}$
Phi	mean viscous dissipation rate	
UgradP		$\overline{u_i\partial_{x_i}p}$

HigherOrder

rU3		
rU4		
rV3		
rV4		
rW3		
rW4		

Acoustics

gamma		
C2		
Rho_ac		
Rho_en		
T_ac		
T_en		
M_t		
rRP		
rRT		

RhoBudget

RhoFluxX		
RhoFluxY		
RhoFluxZ		
RhoDil1		
RhoDil2		
RhoTrp		
RhoProd		
RhoConv		$-\overline{v}\partial_y\overline{\rho'\rho'}$

Stratification

Pot	potential energy	
rRref	background density profile	
rTref	background temperature profile	
BuoyFreq_fr	buoyancy frequency	
BuoyFreq_eq	buoyancy frequency	
LapseRate_fr	lapse rate	
LapseRate_eq	lapse rate	
PotTemp		
PotTemp_v		
SaturationPressure		
rPref	background pressure profile	
RelativeHumidity		
Dewpoint	dewpoint temperature	
LapseRate_dew		

Roughness

eps_0	fluid fraction (grid-based approach)	
eps_1	solid fraction (grid-based approach)	
eps_f	fluid fraction (volume-based approach)	
eps_s	solid fraction (volume-based approach)	

Vertical profiles scalar

Mean

rS	scalar (RA)	$\overline{s}$
rQ	scalar source (RA)	
rS_y	y-derivative of scalar (RA)	$\overline{\partial_y s}$
fS	scalar (FA)	$\langle s\rangle$
fS_y	y-derivative of scalar (FA)	$\langle\partial_y s\rangle$
fQ	scalar source (FA)	

Fluctuations

Rsu	covariance R_{su} (of scalar s and velocity u)	$\overline{s'u'}$
Rsv	covariance R_{sv} (of scalar s and velocity v)	$\overline{s'v'}$
Rsw	covariance R_{sw} (of scalar s and velocity w)	$\overline{s'w'}$
rS2	scalar variance R_{ss} (RA)	$\overline{s's'}$
rS3		$\overline{s's's'}$
rS4		$\overline{s's's's'}$
fS2	scalar variance (FA)	$\langle s's'\rangle$
fS3		$\langle s's's'\rangle$
fS4		$\langle s's's's'\rangle$

DerivativeFluctuations

S_x2		$\overline{(\partial_x s')^2}$
S_y2		$\overline{(\partial_y s')^2}$
S_z2		$\overline{(\partial_z s')^2}$
S_x3		$\overline{(\partial_x s')^3}$
S_y3		$\overline{(\partial_y s')^3}$
S_z3		$\overline{(\partial_z s')^3}$
S_x4		$\overline{(\partial_x s')^4}$
S_y4		$\overline{(\partial_y s')^4}$
S_z4		$\overline{(\partial_z s')^4}$

RssBudget

Rss_t	time-rate of change of R_{ss}	$\overline{\partial_t R_{ss}}$
Css	advection in y-direction	$-\langle v\rangle\ \partial_y\overline{s's'}$
Pss	gradient production	$-2\overline{s'v'}\partial_y\langle s\rangle$
Ess	molecular dissipation	
Tssy1	turbulent transport due to triple correlation	$\overline{s's'v'}$
Tssy2	transport	$-2\kappa_d\overline{s'\partial_y s'}$
Tssy_y	turbulent transport	$\partial_y(\mathrm{Tssy1}+\mathrm{Tssy2})$
Dss	diffusion variable-density term	
Qss	source	

RsuBudget

Rsu_t	time-rate of change of R_{su}	$\overline{\partial_t R_{su}}$
Csu	advection in y-direction	$-\langle v\rangle\ \partial_y\overline{s'u'}$
Psu	shear and gradient production	$-\overline{s'v'}\partial_y\langle u\rangle\ -\overline{u'v'}\partial_y\langle s\rangle$
Esu	molecular dissipation	
PIsu	pressure redistribution	$\overline{p'\partial_x s'}$
Tsuy1	turbulent transport due to triple correlation	$\overline{s'u'v'}$
Tsuy2	transport	
Tsuy_y	turbulent transport	$\partial_y(\mathrm{Tsuy1}+\mathrm{Tsuy2})$
Dsu	diffusion variable-density term	
Gsu	pressure-flux	0
Bsu	buoyant production	0
Fsu	Coriolis production	$f_y\overline{s'w'}$
Qsu	source	

RsvBudget

Rsv_t	time-rate of change of R_{sv}	$\overline{\partial_t R_{sv}}$
Csv	advection in y-direction	$-\langle v\rangle\ \partial_y\overline{s'v'}$
Psv	shear and gradient production	$-\overline{s'v'}\partial_y\langle v\rangle\ -\overline{v'v'}\partial_y\langle s\rangle$
Esv	molecular dissipation	
PIsv	pressure redistribution	$\overline{p'\partial_y s'}$
Tsvy1	turbulent transport due to triple correlation	$\overline{s'v'v'}$
Tsvy2	transport	
Tsvy3	transport	$\overline{p's'}$
Tsvy_y	turbulent transport	$\partial_y(\mathrm{Tsvy1}+\mathrm{Tsvy2}+\mathrm{Tsvy3})$
Dsv	diffusion variable-density term	
Gsv	pressure-flux	$\overline{s'\partial_y p'}$
Bsv	buoyant production	$\overline{\rho b's'}$
Fsv	Coriolis production	0
Qsv	source	

RswBudget

Rsw_t	time-rate of change of R_{sw}	$\overline{\partial_t R_{sw}}$
Csw	advection in y-direction	$-\langle v\rangle\ \partial_y\overline{s'w'}$
Psw	shear and gradient production	$-\overline{s'v'}\partial_y\langle w\rangle\ -\overline{v'w'}\partial_y\langle s\rangle$
Esw	molecular dissipation	
PIsw	pressure redistribution	$\overline{p'\partial_z s'}$
Tswy1	turbulent transport due to triple correlation	$\overline{s'v'w'}$
Tswy2	transport	
Tswy_y	turbulent transport	$\partial_y(\mathrm{Tswy1}+\mathrm{Tswy2})$
Dsw	diffusion variable-density term	
Gsw	pressure-flux	0
Bsw	buoyant production	0
Fsw	Coriolis production	$-f_y\overline{s'u'}$
Qsw	source	

CrossScalars

Cs1		
Css1		

Roughness

Sbcs	scalar boundary values applied on solids	
eps_0	fluid fraction (grid-based approach)	
eps_1	solid fraction (grid-based approach)	
eps_f	fluid fraction (volume-based approach)	
eps_s	solid fraction (volume-based approach)	

Horizontal distribution of roughness elements

HorizontalSlice	
eps2d	horizontal (x,z) distribution of roughness heights of the elements in grid points