UFS stochastic physics

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CHAPTER 1

Getting Started

The stochastic physics currently only works with the UFS-atmosphere model

You should get the full system at https://github.com/ufs-community/ufs-weather-model, which will include the stochastic physics code.

In order to enable stochastic physics in a model run, you will need to turn it on via namelist options

CHAPTER 2

Users Guide

The stochastic physics currently only works with the UFS-atmosphere model

Currently, 3 stochastic schemes are used operationally at NCEP/EMC: Stochastic Kinetic Energy Backscatter (SKEB; Berner et al., 2009), Stochastically Perturbed Physics Tendencies (SPPT; Palmer et al., 2009), and Specific Humidity perturbations (SHUM), which is inspired by Tompkins and Berner, 2008. In addition there is the ability to perturb certain land model/surface parameters (Gehne et al., 2019 and Draper 2021), and a cellular automata scheme (Bengtsson et al. 2019) which interacts directly with the convective parameterization.

SKEB adds wind perturbations to model state. Perturbations are random in space/time, but amplitude is determined by a smoothed dissipation estimate provided by the dynamical core. Addresses errors in the dynamics - more active in the mid-latitudes

SPPT multiplies the physics tendencies by a random number O [0,2] before updating the model state. Addresses error in the physics parameterizations (either missing physics or unresolved subgrid processes). It is most active in boundary layer and convective regions

SHUM multiply the low-level specific humidity by a small random number each time-step. It attempts to address missing physics (cold pools, gust fronts), most active in convective regions

Land surface perturbations allow for land surface parameters such as Albedo, Soil Hydraulic Conductivity, LAI, and roughness lengths to vary in space. Addresses error in the land model and land-atmosphere interactions. The perturbation options are only available to NOAH and RUC-LSM land models.

Due to the model's numerics, any stochastic perturbation needs to be correlated in space and time in order to have the desired effect of upscale growth of the perturbations. This is achieved by creating a random pattern that has a specified decorrelation length-scale and is a first order auto-regressive process AR(1) in time with a specified decorrelation time-scale. (The CA random pattern generator also satisfies this condition)

Cellular automata is enabled through the physics namelist

Stochastic Paramter Perturbation (SPP) is avaiable for the FV3_HRRR physics suite

CHAPTER 3

Stochastic Physics Namelist

3.1 General options

Option	Description
NEW_LSCALE	Recommended, set to true if use the correct calculation for decorrelation length scale.
NTRUNC	Optional, Spectral resolution (e.g. T126) of random patterns, default is for model to determine proper truncation
LAT_S	Optional, number of latitude points for the gaussian grid (must be even), default is for model to determine gaussian grid
LON_S	Optional, number of longitude points for the gaussian grid (recommend 2xLAT_S, default is for model to determine gaussian grid
STOCHINI	Optional, set to true if wanting to read in a previous random pattern

3.2 SPPT options

Option	Description
SPPT	Amplitudes of random patterns.
SPPT_TAU	Decorrelation timescales in seconds.
SPPT_LSCALE	Decorrelation spatial scales in meters.
SPPT_LOGIT	Should be true to limit the SPPT perturbations between 0 and 2. Otherwise model will crash.
ISEED_SPPT	Seeds for setting the random number sequence (ignored if stochini is true)
SPPT_SIGTOP1	lower sigma level to taper perturbations to zero (default is 0.1)
SPPT_SIGTOP2	upper sigma level to taper perturbations to zero (default is 0.025)
SPPT_SFCLIMIT	.T.=tapers the SPPT perturbations to zero at model's lowest level (helps reduce model crashes)
SPPTINT	Optional, interval in seconds to update random pattern. Perturbations still get applied every time-step
USE_ZMTNBLCK	.T.=do not apply perturbations below the dividing streamline that is diagnosed by the gravity wave drag, mountain blocking scheme
PERT_MP	.T.=apply SPPT perturbations to all microphysics specis. If .F. the SPPT is only applied to u,v,t,qv
PERT_RADTEND	.T.=apply SPPT perturbations to cloudy sky radiation tendencies. If .F. then do not perturb any radiative tendencies
PERT_CLDS	.T.=apply SPPT perturbations to fraction (only works for RRTMG radiation), if using this option set PERT_RADTEND=.F.

3.3 SHUM options

Option	Description
SHUM	Amplitudes of random pattern.
SHUM_TAU	Decorrelation timescales in seconds.
SHUM_LSCALE	ecorrelation spatial scales in meters.
SHUM_SIGEFOLD	e-folding lengthscale (in units of sigma) of specific humidity perturbations, default is 0.2)
SHUMINT	Optional, interval in seconds to update random pattern. Perturbations still get applied every time-step
ISEED_SHUM	Seeds for setting the random number sequence (ignored if stochini is true).

3.4 SKEB options

Option	Description
SKEB	Amplitudes of random patterns.
SKEB_TAU	Decorrelation timescales in seconds
SKEB_LSCALE	Decorrelation spatial scales in meters (250)
ISEED_SKEB	Seeds for setting the random number sequence (ignored if stochini is true).
SKEBNORM	0-random pattern is stream function, 1-pattern is K.E. norm, 2-pattern is vorticity (default is 0)
SKEB_VARSPECT_OPT	0-gaussian (default), 1-power law (not tested)
SKEB_NPASS	number of passes of the del2 smoothing for the dissipation estimate (default is 11, minimum is 3)
SKEB_VDOF	the number of degrees of freedom in the vertical for the SKEB random pattern (default is 5)
SKEB_SIGTOP1	lower sigma level to taper perturbations to zero (default is 0.1)
SKEB_SIGTOP2	upper sigma level to taper perturbations to zero (0.025)
SKEBINT	Optional, interval in seconds to update random pattern. Perturbations still get applied every time-step

3.5 SPP options

Option	Description
SPP_VAR_LIST	List of parameterizations to be perturbed. Check compns_stochy.F90 for options.
SPP_PRT_LIST	SPP perturbation magnitudes used in each parameterization.
SPP_TAU	Decorrelation timescales in seconds.
SPP_LSCALE	Decorrelation spatial scales in meters.
ISEED_SPP	Seeds for setting the random number sequence (ignored if stochini is true).
SPP_SIGTOP1	Lower sigma level to taper perturbations to zero (default is 0.1)
SPP_SIGTOP2	Upper sigma level to taper perturbations to zero (0.025)
SPP_STDDEV_CUTOFF	Limit for possible perturbation values in standard deviations from the mean.

3.6 Land perturbation options

Option	Description
LNDP_TYPE	0, no perturbations. 1, old scheme (Gehne et al. 2019); 2, new scheme (Draper 2021)
LNDP_VAR_LIST	List of land perturbations parameters. Check compns_stochy.F90 for options
LNDP_PRT_LIST	Perturbation magnitudes used for each parameter perturbations.
LNDP_TAU	Decorrelation timescales in seconds.
LNDP_LSCALE	Decorrelation spatial scales in meters.
ISEED_LNDP	Seeds for setting the random number sequence (ignored if stochini is true).

CHAPTER 4

Developer's guide

Code is housed on github at https://github.com/noaa-psd/stochastic_physics. Please read more about the Development process at https://github.com/ufs-community/ufs/wiki/Developing-with-Gitflow.

Please make a fork and checkout the entire ufs-community weather model at https://github.com/ufs-community/ufs-weather-model and point to your fork of the stochastic_physics submodule.

4.1 Standalone testing

If you intend to make modifications to the stochastic physics source code, there is a simplified program that exercises the random pattern generator without needing to run the entire model. Please see README.standalone in the stochastic_physics directory.

4.2 Full model tests

The code updates are not expected to change existing results, so the full model regression tests need to be run. All of the tests must pass, although only a sub-set of tests are needed to consider adding changes to the stochastic_physics repository: fv3_control, fv3_stochy, fv3_ccpp_control, and fv3_ccpp_stochy. If the results are expected to change, then there needs to be scientific evidience that the change in results are what is expected.

CHAPTER 5

References

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CHAPTER 6

Source Code Documentation

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