



VERDALIS
Natural sound synthesis

SkyHowl

Synthesised wind

Version 0.4.0

CLAP instrument for Linux and Windows

Part of the Verdalis Plugin Suite

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Introduction

SkyHowl is a CLAP instrument that generates wind. Every gust, every aeolian tone and every rustling leaf is computed from noise, filters and resonators while the plugin plays – nothing is played back. No two winds are ever alike.

The model starts from an awkward fact. **Wind is silent.** Air in motion radiates essentially nothing on its own; everything a listener calls wind is the flow meeting something — a hillside, a wire, a twig, a leaf, the edge of a gap. So SkyHowl is built in two halves: a flow field, which makes no sound at all, and the sources that flow drives.

The flow field is a wind speed with three things happening to it at once: turbulence, discrete gusts, and a squall drift slower than a tenth of a hertz. What it drives is a broadband airflow bed, a low-frequency buffet, a bank of aeolian tones whose pitch is proportional to the wind speed — which is what howling actually is — and, as a bonus layer, foliage.

Every layer came out of measurement. The model and the factory presets were fitted against 63 field recordings by measuring the recording and the plugin's own output with the same analysis code and moving values until the two agreed. Where a number in this manual comes from a measurement or a paper, it says so.

SkyHowl 0.4.0 is an early version. The engine, the parameter set and the window are complete and the self-test passes, but the preset library is a first fit. *What is still being fitted* at the end of this manual lists what is known not to match yet, and it is worth reading before concluding that something is broken.

What is in this manual

Installing and *A first sound* are enough to get wind out of the plugin. *How it works* explains the model, and is worth reading before spending time in the parameter list — the layers are what the controls are named after. *Parameter reference* and *The preset library* are generated from the plugin itself, so they always describe the version on the cover. *Using it in a host* covers notes, automation, reproducible renders and CPU cost.

Installing

SkyHowl is one self-contained `.clap` file plus its `presets` folder. There is no installer, no shared library to place and nothing to register.

Linux

CLAP hosts scan `~/ .clap`. Copy the plugin folder from the release archive into it so that you end up with:

```
~/ .clap/SkyHowl/SkyHowl.clap
~/ .clap/SkyHowl/presets/
```

Then rescan plugins in your host. X11 and Cairo are the only external dependencies of the plugin window, and any Linux machine that can run a DAW has both.

Windows

CLAP hosts scan the common CLAP folder. Copy the plugin folder into:

```
C:\Program Files\Common Files\CLAP\SkyHowl\
```

so that `SkyHowl.clap` and `presets\` sit inside it, and rescan. There are no DLLs to install beside it — the window and its Cairo are linked in.

Keep the plugin and its presets together. The plugin finds its factory presets by looking for a `presets` directory next to its own binary. Moving the `.clap` file on its own leaves it with no factory presets at all.

Hosts

Tested with Bitwig Studio and Reaper. In Bitwig, `~/ .clap` is scanned by default; after installing, restart it or rescan under *Settings* → *Locations* → *Plug-in Locations*. SkyHowl then appears as an instrument under the vendor *Ravetracer*, and the factory presets are indexed through CLAP's preset discovery, so they show up in the host's own browser as well as in the plugin window.

Your own presets

`SAVE` in the plugin window writes to a user preset folder, which is created on first use:

PLATFORM	LOCATION
Linux	<code>\$XDG_CONFIG_HOME/SkyHowl/presets</code> , or <code>~/ .config/SkyHowl/presets</code>
Windows	<code>%APPDATA%\SkyHowl\presets</code>

User presets appear in the browser immediately, listed after the factory ones. They are plain text, so they can be copied between machines, kept in version control, or edited in any editor.

COLLECTIONS

A preset library is a shelf, and a long one is worth tidying. Your own presets are filed in **collections**: folders one level under the user preset directory. The browser lists the library down its left side — *All*, the factory presets, each of your collections, and *Unfiled* for presets saved into none — each with the number of presets in it. Clicking one lists just that one.

IN THE BROWSER	WHAT IT DOES
<code>NEW</code>	Makes a collection. It is listed at once, empty until something goes into it

RENAME	Renames the selected collection; its presets go with it
DELETE	Deletes the selected collection and every preset in it, after asking
Drag a preset onto a collection	Moves it there — or onto <i>Unfiled</i> to take it out of one
Right-click one of your presets	Renames it, changes its description, or deletes it

SAVE asks where a preset goes: pick a collection from the list — or *New collection...* to make one on the spot — then give the preset a name and, if you like, a **description**. The description is what the browser shows while the pointer is over the preset and what the help line shows while it is loaded: a sentence for whoever loads it next. Saving over one of your own presets offers its collection and its description again.

The factory presets are locked. They are part of the plugin, not files of yours, so they cannot be moved, renamed or deleted; to change one, load it, adjust it and save it as your own.

Collections are one level deep on purpose: a preset library is a shelf rather than a filesystem, and a tree deep enough to get lost in is one somebody will get lost in.

PRESET PACKS

A whole collection can be written out as a single file — a **preset pack**, extension `.skyhowlpack` — so a library can be handed to somebody else, or moved between machines, as one file rather than a directory.

With a collection selected in the browser:

BUTTON	WHAT IT DOES
EXPORT	Writes the selected collection — its presets and nothing else — as a pack into the <code>packs</code> directory beside <code>presets</code>
EXPORT AS...	The same, to a location you choose
IMPORT...	Lists the packs already in <code>packs</code> , plus <i>Other file...</i> for one from anywhere
REVEAL	Opens the folder the pack was just written to in the system's file browser

Importing adds the pack's presets to the library as a new collection named after the pack. Nothing is ever overwritten: importing the same pack twice gives two collections rather than a mixture of both versions in one.

A pack is the preset format again with a separator line between the presets, so it can be read, diffed and edited by hand like everything else here. It carries each preset's text verbatim rather than a re-serialised copy, which is what makes a round trip through a pack lossless.

EXPORT AS..., *Other file...* and **REVEAL** need the desktop's own file chooser — `zenity` or `kdiallog` on Linux, `xdg-open` to reveal, and the operating system's own on Windows. Where none is installed the buttons that need one are not drawn, and the plugin's own `packs` directory, which is where **EXPORT** writes, is enough on its own.

Building from source

The suite builds with a C++17 compiler and CMake 3.16 or newer. From the plugin folder:

```
./install.sh
```

That configures, builds, runs the self-test and installs to `~/.clap/SkyHowl/`. `SkyHowl_PREFIX=/some/where ./install.sh` overrides the destination, and `-DCLAP_INCLUDE_DIR=/path/to/clap/include` points the build at a CLAP checkout it cannot find by itself.

A first sound

1. Load SkyHowl on an instrument track.
2. Draw a long note — sixteen bars or more. The wind blows for as long as the note is held, and the release lets it drop.
3. Open the preset browser by clicking the preset name in the window header and try **Open Plain**, then **Howling Wind**, then **Rustling Leaves**.

Wind needs length, more than anything else in the suite. A gust takes seconds to arrive and pass, and a squall runs over minutes; a two-second note is a fragment of one gust and tells you almost nothing.

Three things to try first

Turn one knob: *Wind Speed*. It is the master control of the whole plugin. Level, brightness, the pitch of the howl and how fast the foliage rustles all follow it, because in the model they all follow the same U . Sweep it from 2 to 25 m/s and the sound goes from a breath to a gale without touching anything else.

Listen to the howl swoop. Load **Howling Wind** and hold a long note. Each time a gust arrives, the tone rises in pitch as well as in level. That is not an effect: vortices shed off an obstacle at $f = St \cdot U/d$, so a faster wind sheds faster. *Howl Track* is how much of that is applied, and the references confirm it — see *Howling is aeolian*.

Change the obstacle, then the terrain. *Obstacle* is what the wind is shedding off — grass, reeds, twigs, branches, wires, rock, a gap, a cave — and it sets the pitch, the sharpness and, crucially, whether the tone tracks the wind at all. *Terrain* is what the wind is crossing, and it multiplies the turbulence by real numbers: choosing *Forest* makes the wind two and a half times as gusty as *Plain*, which is the ratio the logarithmic wind profile gives for those two roughness lengths.

How it works

The flow, and what it drives

LAYER	WHAT IT IS
The flow	A wind speed $U(t)$, per channel, and completely silent. Its mean is <i>Wind Speed</i> ; on top of that sit turbulence (a von Kármán-shaped noise process whose intensity is σ/U , measured 4–27 % across the library), discrete gusts (0.6–33 a minute, gust factor 1.04–1.54) and a squall drift below 0.1 Hz, which carries a median 43 % of the whole envelope variance and is therefore not a detail.
Airflow	The broadband bed: turbulent noise through a four-pole tilt whose slope is a parameter. Its amplitude follows U^3 , because aerodynamic sound power from flow over a rigid surface goes as U^6 .
Buffet	The low end: the pressure fluctuation of the moving air rather than the noise it radiates. It follows the dynamic pressure, U^2 , so it grows more slowly than the bed.
Howl	The aeolian tones. A bank of resonant bands whose centre frequencies are $St \cdot U/d$ for obstacles of diameter d , so their pitch rises and falls with every gust.
Rustle	Foliage. A Poisson stream of leaf clicks, each a short band-limited ring at roughly $c/2L$ for a leaf of size L .

Turbulence is a spectrum, not a wobble

The wind speed's own fluctuations have a shape. In the inertial subrange Kolmogorov gives a velocity spectrum falling as $f^{-5/3}$, and that is what the engine generates: three one-pole-filtered noise sources an octave and a half apart, weighted 1 : 0.56 : 0.315. Those weights are $4^{-5/6}$ and $16^{-5/6}$, so summing them gives exactly that slope across the band they span. One filter would give –6 dB/octave, which is too steep to be turbulence, and white noise would give no shape at all.

The lowest of the three corners is tied to *Gust Rate*, because both are the same physical quantity seen from different ends: a turbulence length scale L crossing at speed U produces something every L/U seconds.

Turbulence is the intensity of that process, and it reads as the percentage meteorology reports — σ/U , measured 4 to 27 % across the library with a median of 10 %.

A gust is a fluctuation of the flow, not a sound

Gusts own no filter and no noise source in SkyHowl, because a gust makes no sound of its own. Each one is an envelope with a strength and a position, and what is heard is the bed and the howl responding to it. A gust arriving from the left raises the left channel's wind speed first, which is most of why real wind moves across a listener.

The strength distribution is heavy-tailed on purpose: most gusts are unremarkable and a few are much stronger, which is what a gust factor is a summary of. And the envelope is symmetric — the references' median rise/fall ratio is 1.01, so unlike a breaking wave a gust is not a transient. *Gust Shape* is there for when you want one anyway.

The level law: why a gust is such a large event

Aerodynamic sound from flow over a rigid surface radiates as a dipole, and Curle's 1955 result gives its power as U^6 . Amplitude therefore goes as U^3 , and a doubling of wind speed is **+18 dB**. That is *Speed Law* at 100 %, and it is worth knowing about before wondering why a gust is so much louder than the wind between gusts. Backing it off is not cheating — it is the one control that makes a physically correct wind fit inside a mix.

Howling is aeolian

A bluff body in a flow — a wire, a twig, a blade of grass, a branch — sheds vortices alternately from each side at the Strouhal frequency

$f = St \cdot U / d$ $St \approx 0.2 \text{ for a cylinder}$

so a 2.5 mm twig in an 8 m/s wind sheds at 640 Hz, which is the median tone frequency across the library’s tonal recordings. *Howl Size* is therefore a real diameter, not a pitch knob: the tonal references imply obstacles from 1.5 to 11.8 mm.

The interesting part is that **both the pitch and the level follow the same U**, so an aeolian tone has to rise in pitch as it gets louder. That is a prediction a recording can falsify, and the library confirms it: the tone’s pitch rises with the level in 12 of the 17 recordings that hold a steady tone at all, and in the four whose file names actually say *howling* the correlation runs from 0.52 to 0.87. It swoops a median 0.72 of an octave doing it. *Howl Track* is how much of that is applied.

Three details matter to how it sounds:

- **A howl is a band of noise, not a whistle.** The measured Q runs 1.1 to 16.5 with a median of 5.1, so each obstacle is a resonant band on its own noise rather than an oscillator. Taking *Howl Resonance* to the top of its range stops sounding like wind at all.
- **The tone comes up steeply.** Shedding needs the flow: below *Howl Onset* nothing happens, and above it the tone rises as the cube of the excess, following the same U^6 power law as the bed. That is why a howl arrives with the gust rather than fading in.
- **It wanders.** Vortex shedding is not a metronome — the local velocity drifts and the tone drifts with it. *Warble* is how much, and it is most of what makes a howl eerie rather than electronic.

A cavity does not track the wind

The *Gap* and *Cave* obstacles behave differently from the rest, and the reason is physics rather than voicing. A cavity resonates at a frequency its own geometry fixes; the flow only excites it, so its pitch barely moves however hard it blows. Those two obstacles therefore scale *Howl Track* down almost to nothing, which is what turns a howl into a drone.

The library cannot settle this on its own — its one cave recording tracks at -0.01 while everything else is positive, and across the tonal set there is no correlation between Q and tracking at all. The distinction is kept because it is sound physics, and it is flagged here because it was not measured.

An obstacle sees a smoother wind than a microphone

The shedding frequency follows a *smoothed* wind speed rather than the instantaneous one, because an obstacle does not see the free stream: it sees the flow averaged over the eddies that envelop it. Without that smoothing the tone chases every ripple of the turbulence and smears over two octaves, where the references measure a median swoop of 0.72 — a gust’s worth, not a turbulence spectrum’s worth.

Terrain roughness is arithmetic

The logarithmic wind profile gives a turbulence intensity of about $1/\ln(z/z_0)$ at height z over ground of roughness length z_0 , and z_0 is tabulated. At a listening height of 10 m, normalised to short grass:

TERRAIN	ROUGHNESS	GUSTINESS
Coast	open water	0.54×
Desert	sand	0.56×
Tundra	snow	0.77×
Plain	short grass	1.00×
Meadow	long grass	1.26×
Mountain	broken country	1.94×
Forest	forest	2.52×
Street	city	3.06×

Terrain also tilts the spectrum, scales the buffet and sets how enclosed the space is — 0.02 for open ground, where there is nothing close enough to reflect, against 0.85 for a street with walls on both sides.

The rustle: leaves, not hiss

Leaves do not hiss, they click. Each one is a separate collision, so the rustle is a Poisson stream of short band-limited rings at roughly $c/2L$ — a 40 mm leaf around 4.2 kHz, which is the median onset centroid across the library's foliage recordings.

The rate is what matters most, and there is a ceiling on it: the references have **15 to 40 resolvable onsets a second**, which is the rate at which they stop merging. Push *Rustle Density* past that and the clicks overlap into a wash rather than being separately audible, which is the difference between a rustle and a hiss. *Foliage* moves it deliberately: conifer needles and grass are set to merge, because that is what a sough is, while dry leaves are sparse and clatter.

Clatter is how impulsive each leaf is. It was measured as the variation of the onset flux, and the two ends of the library are unambiguous: 0.20 for a merged conifer-like hiss against 0.80 for dry leaves.

Leaves also have a threshold. *Rustle Onset* is the share of the mean wind speed at which they start moving at all, and at the default and an 8 m/s wind that is 2 m/s, which is about where real foliage begins.

Distance

Distance applies air absorption plus a downward tilt, with *Air* deciding how much of the top survives. The library's most distant recording is 117 dB down at 16 kHz and peaks at 63 Hz, which is the far end this has to be able to reach.

The plugin window

SkyHowl draws its own window with X11 and Cairo on Linux, and Cairo on the win32 backend on Windows. There is no toolkit dependency, which is what keeps the plugin one self-contained file. It is embedded in the host's own window through CLAP's GUI extension and repainted from the host's timer, and it resizes by zooming one layout, from half size to four times.

The window is the suite's, in SkyHowl's own dust-coral theme — the suite's other plugins are all cold, so wind, which everyone expects to be grey, is the one that gets to be warm. Streaklines run across the header behind the wordmark the way a wind tunnel shows a flow it cannot otherwise photograph: they flow faster the more gusts are in the air, and every new gust puts a shove into the whole field. Beside the preset name is a gust meter, showing how many are in flight and how many have passed.

Gestures

GESTURE	EFFECT
Drag a knob up or down	Change the value
Shift-drag	Fine control, a fifth of the travel
Double-click a knob, or right-click anything	Back to the default
Scroll wheel over a control	Step the value
Click a knob's value	Type a value in, with units
Click a selector's name	Open its list and pick a value
Click a selector's ◀ or ▶	Step one choice
Click the preset name	Open the preset browser
◀ or ▶ beside the preset name	Previous or next preset
SAVE	Save the current settings as a user preset
MIXER	Open the layer mixer

The line at the bottom of the window shows what the control under the pointer does — the same one-line explanation that appears in the *What it does* column of the parameter reference.

The mixer

Every layer's level lives on the panel that layer belongs to, which is right for editing one layer and wrong for balancing them against each other. MIXER opens the same controls arranged the other way round: one strip per layer, its level as a fader, its pan and its width as slim sliders under it. They are the plugin's own parameters, not a second set — moving a fader moves the knob on the panel, and the host sees the same automation it always would.

M mutes a layer and S solos one, which is how a preset gets built from nothing: solo one layer, get it right, bring the next one back. Several layers can be soloed at once.

Mute and solo are **not** parameters and are not saved with a preset. They work by holding a layer's level at the bottom of its range and remembering what it was, so while either is active the preset bar shows a SOLO ON or MUTE ON chip — click it to release every hold at once. SAVE releases them first, so a muted layer can never be written into a preset as a silent one, and so does loading a preset. Touching a held layer's fader also releases the holds rather than fighting the hand on it. Closing the mixer does not: soloing a layer and then going to its knobs on the panels is what the mixer is for.

Parameter reference

There are 53 parameters, grouped the way the plugin window groups them. Every one is automatable and modulatable from the host, and every one can be typed in directly by clicking its value in the window. The name in `code` is the key used in preset files.

WIND

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Wind Speed <code>wind_speed</code>	0.50 m/s ... 40.0 m/s	8.00 m/s	The mean wind speed, and the master control of the whole plugin: it sets the level, the brightness, the pitch of the howl and how fast the foliage rustles. 5 m/s is a breeze, 12 a strong wind, 25 a storm.
Turbulence <code>turbulence</code>	0.00 % ... 50.00 %	10.00 %	Turbulence intensity: the standard deviation of the wind speed over its mean, which is what a met station reports. Measured 4-27 % across the library, median 10 %.
Gust Rate <code>gust_rate</code>	0.20 /min ... 60.0 /min	3.50 /min	How often a coherent gust arrives. This is the turbulence length scale seen from the other end – a gust every L/U seconds. Measured 0.6-33 a minute, median 3.5.
Gust Depth <code>gust_depth</code>	0.0 % ... 100.0 %	50.0 %	How much faster a gust is than the mean. Sets the gust factor $U_{\text{max}}/U_{\text{mean}}$, measured 1.04-1.54 across the library.
Gust Length <code>gust_length</code>	300 ms ... 30.00 s	4.00 s	How long a gust takes to pass. Short ones slap, long ones swell.
Gust Shape <code>gust_shape</code>	0.0 % ... 100.0 %	50.0 %	Whether a gust arrives faster than it leaves. At 50 % it is symmetric, which is what the references measure: the median rise/fall ratio is 1.01, so unlike a wave a gust is not a transient.
Squall <code>squall</code>	0.0 % ... 100.0 %	30.0 %	A much slower drift on top of the gusting: sets of gusts rather than gusts. Not a detail – a median 43 % of the envelope variance in the library sits below 0.1 Hz.
Squall Rate <code>squall_rate</code>	0.20 /min ... 12.0 /min	1.20 /min	How often those sets come round. Minutes rather than seconds.

AIRFLOW

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Flow Level <code>flow_level</code>	-inf dB ... 6.00 dB	-18.00 dB	Level of the broadband bed: the sound of turbulent air going past whatever is there. Most of what wind is.
Flow Tone <code>flow_tone</code>	60.0 Hz ... 4.00 kHz	500 Hz	Where the bed's slope begins. Below this it is flat, above it falls at Flow Tilt.
Flow Tilt <code>flow_tilt</code>	-24.00 dB/oct ... 0.00 dB/oct	-8.70 dB/oct	The slope above Flow Tone. Kolmogorov's inertial subrange gives a velocity spectrum going as $f^{-5/3}$, which is -5 dB/octave; the library measures -22 to -2 with a median of -8.7, because radiation from a rigid surface steepens it further.
Buffet <code>buffet</code>	-inf dB ... 6.00 dB	-16.00 dB	The low-frequency pressure buffeting under everything: the thump of moving air rather than its hiss. Measured -58 to 0 dB relative to the whole, median -15.5.
Buffet Tone <code>buffet_tone</code>	20.0 Hz ... 300 Hz	70.0 Hz	Where the buffeting sits. Low enough to be felt more than heard.
Hiss <code>hiss</code>	0.0 % ... 100.0 %	30.0 %	The top end: fine-scale turbulence, above where the tilt has taken everything else away. Part of the bed rather than a layer of its own, so it follows Flow Level and disappears with it.
Speed Law <code>speed_law</code>	0.0 % ... 100.0 %	100.0 %	How hard the level follows the wind speed. At 100 % it is the physical law: aerodynamic sound power from flow over a rigid surface goes as U^6 (Curle), so amplitude goes as U^3 and doubling the wind is +18 dB. Lower it to keep a gusty wind inside a mix.

HOWL

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Howl Amount <code>howl_amount</code>	0.0 % ... 100.0 %	40.0 %	How much of the sound is aeolian tone rather than broadband flow. Zero is legitimate: only 17 of the library's 63 recordings hold a tone steadily enough to count as one.
Obstacle <code>obstacle</code>	Open, Grass, Reeds, Twigs, Branches, Wires, Rocks, Gap, Cave	Twigs	What the wind is shedding off. Bluff bodies – grass, twigs, wires – track the wind speed; a gap or a cave is a cavity whose pitch its own geometry fixes, so it barely moves.
Howl Size <code>howl_size</code>	0.30 mm ... 60.0 mm	2.50 mm	The obstacle's diameter, which is what its pitch actually is: Strouhal gives $f = 0.2 U / d$, so a 2.5 mm twig in an 8 m/s wind sheds at 640 Hz – which is the median tone frequency across the library's tonal recordings. They imply diameters of 1.5 to 11.8 mm.
Howl Spread <code>howl_spread</code>	0.00 oct ... 4.00 oct	0.40 oct	Spread of obstacle sizes either side of that. A single wire is one diameter; a hedge is every diameter at once.
Howl Voices <code>howl_voices</code>	1 ... 12	3	How many obstacles are shedding. One is a whistle, a dozen is a chorus.
Howl Resonance <code>howl_reso</code>	0.0 % ... 100.0 %	68.0 %	How narrow each tone is, as a Q from 0.8 to 12. Measured 1.1-16.5 with a median of 5.1: a howl is a narrow band of noise rather than a whistle, and taking this to the top of its range stops sounding like wind at all.
Howl Track <code>howl_track</code>	0.0 % ... 100.0 %	80.0 %	How much the pitch follows the wind speed. This is the one prediction of the model the references can falsify, and they confirm it: the tone's pitch rises with the level in 12 of the 17 tonal recordings, reaching 0.87 in the ones actually named howling. It swoops a median 0.72 of an octave as it does so.
Howl Onset <code>howl_threshold</code>	0.0 % ... 100.0 %	30.0 %	The share of the mean wind speed below which nothing sheds. Above it the tone comes up steeply, which is why a howl arrives with the gust rather than fading in.
Warble <code>warble</code>	0.0 % ... 100.0 %	25.0 %	How much each tone wanders around its own pitch. Vortex shedding is not a metronome: the local velocity drifts and the tone drifts with it. This is most of what makes a howl eerie rather than electronic.

RUSTLE

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Rustle Amount <code>rustle_amount</code>	0.0 % ... 100.0 %	30.0 %	How much foliage there is to hear. The bonus layer: wind in the open is one sound, wind in a tree is another.
Foliage <code>foliage</code>	None, Broadleaf, Dry Leaves, Conifer, Grass, Reeds, Bare Branches, Bushes	Broadleaf	What is rustling. Sets the pitch, the decay and how separately audible the individual leaves are.
Leaf Size <code>rustle_size</code>	5.00 mm ... 300 mm	41.0 mm	The size of one leaf, which sets what it radiates: roughly $c/2L$, so a 40 mm leaf clicks around 4.2 kHz. The library's rustle onsets measure a median centroid of 4.2 kHz over a 2.8-6.6 kHz range.
Rustle Density <code>rustle_density</code>	2.00 /s ... 800 /s	25.0 /s	Leaves heard per second at full wind. Keep it near the references'

			15-40: any faster and the clicks overlap into a wash instead of being separately audible, which is the difference between a rustle and a hiss.
Rustle Spread rustle_spread	0.00 oct ... 3.00 oct	1.00 oct	Spread of leaf sizes. No tree has one leaf size, and a mix of sizes is what stops a rustle sounding tuned.
Rustle Decay rustle_decay	2.00 ms ... 400 ms	18.0 ms	How long one leaf rings. Short and dead for a soft summer leaf, longer and harder for a dry one.
Rustle Onset rustle_threshold	0.0 % ... 100.0 %	25.0 %	The share of the mean wind speed at which leaves start moving at all. At the default and an 8 m/s wind that is 2 m/s, which is about where real foliage starts.
Clatter clatter	0.0 % ... 100.0 %	40.0 %	How impulsive each leaf is: a soft brush at zero, a dry clatter at one. Measured as the variation of the onset flux, 0.20 for a merged hiss against 0.80 for dry leaves.

PLACE

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Terrain terrain	Plain, Meadow, Forest, Mountain, Desert, Coast, Street, Tundra	Plain	What the wind is crossing. Roughness is what makes turbulence in the first place, so this biases the gusting as well as the spectrum and the space.
Distance distance	0.0 % ... 100.0 %	20.0 %	How far away the wind is. Distance takes the top off it: the library's most distant recording is 117 dB down at 16 kHz and peaks at 63 Hz.
Air air	0.0 % ... 100.0 %	50.0 %	How much of the high end survives that distance. Cold dry air keeps more of it.
Width width	0.0 % ... 100.0 %	75.0 %	Stereo spread. Measured L/R correlation across the library is 0.49 in the median, so wind is wide but not decorrelated.
Space Amount space_amount	0.0 % ... 100.0 %	20.0 %	How much of the surroundings you hear: a street, a valley, a cave mouth.
Space Size space_size	0.0 % ... 100.0 %	60.0 %	Size of that space, in metres of it.
Space Damping space_damping	0.0 % ... 100.0 %	50.0 %	How absorbent its surfaces are: bare rock rings, a forest does not.

FILTER

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Filter Type filter_type	Lowpass, Bandpass, Highpass, Notch	Lowpass	Shape of the output filter.
Highpass highpass	20.0 Hz ... 2.00 kHz	20.0 Hz	Permanent highpass, for keeping the buffeting out of a small speaker.
Filter Cutoff filter_cutoff	30.0 Hz ... 20.00 kHz	20.00 kHz	Corner of the output filter.
Filter Resonance filter_reso	0.0 % ... 100.0 %	10.0 %	Resonance of the output filter.
Filter Key Track	0.0 % ... 100.0 %	0.0 %	How far the filter follows the played note.

ENVELOPE

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Attack attack	1.00 ms ... 20.00 s	2.50 s	How long the wind takes to get up when a note starts.
Decay decay	5.00 ms ... 20.00 s	800 ms	Fall from the initial level to the sustain.
Sustain sustain	0.0 % ... 100.0 %	100.0 %	Level held while the note is down.
Release release	5.00 ms ... 30.00 s	4.00 s	How long it takes to drop after the note is let go. Wind does not stop at once.
Velocity To Level vel_to_level	0.0 % ... 100.0 %	50.0 %	How much velocity sets the level.
Velocity To Speed vel_to_speed	0.0 % ... 100.0 %	40.0 %	How much velocity sets the wind speed itself, which is not the same thing: a faster wind is brighter and higher as well as louder.

OUTPUT

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Output Gain gain	-inf dB ... 12.00 dB	0.00 dB	Output level.
Max Gusts max_gusts	4 ... 256	64	Ceiling on gusts and rustling leaves alive at once, so the cost is bounded.
Random Seed seed	0 ... 999	0	Non-zero gives the same wind every time. Zero is always different.

The preset library

23 factory presets ship with the plugin. They are installed beside the binary and exposed through CLAP preset discovery, so they appear in the host's own browser as well as in the plugin window's.

Arctic Cold

Dry cold air over snow. The reference falls at 18 dB an octave – almost nothing survives above 2 kHz – and its two channels are anti-correlated, which is why Width is at maximum. (*arctic, cold, dark, wide*)

Autumn Leaves

The same idea in a lighter wind, and mono: the reference's two channels are perfectly correlated, so Width is almost off. Flatter than Rustling Leaves and with the low buffet left in. (*leaves, autumn, light, mono*)

Bare Trees

Winter trees in a town, with nothing on them. The rustle is sparse and woody – twelve knocks a second rather than forty, each ringing three times as long as a leaf – and the gusts are very long: the reference gusts less than once a minute. (*trees, winter, bare, clatter*)

Beach Grass

Marram grass on a dune. The steadiest wind in the library – 4 % turbulence intensity – and the most merged rustle after the conifers, because a grass blade is small and there are five hundred of them a second. (*grass, coast, steady, merged*)

Between Houses

Wind funnelled down a gap between buildings. The reference gusts 33 times a minute – by far the fastest in the library – and has no slow drift whatsoever, which is what a street does to a wind. (*street, urban, fast, funnelled*)

Cave Mouth

Wind across the opening of a cave. A cavity resonance rather than a shed vortex, so its pitch is fixed by the geometry and hardly moves with the wind – the reference's tone is 15 dB prominent and its pitch/level correlation is zero. Howl Track is almost off, which the Cave obstacle enforces anyway. (*cave, cavity, drone, tonal*)

Conifer Sough

The sough of wind in pines: needles are small and there are millions of them, so instead of separate leaves there is a continuous merged hiss. The reference runs 260 onsets a second at the lowest flux variation in the library – 0.20, which is what merged means – over a very heavy low end. (*forest, conifer, sough, hiss*)

Desert Dune

Wind over sand. The reference has nothing below 125 Hz at all – 48 dB down at 31 Hz – so Buffet is off and a highpass keeps it that way. What is left is a broad bright band from a kilohertz upwards. (*desert, dry, bright, sand*)

Far Away

A gale heard from a long way off. The reference peaks at 63 Hz and is 117 dB down at 16 kHz – the most distant thing in the library – and its channels are almost perfectly correlated, which is what distance does to a stereo image. (*distant, low, dark, gale*)

Gentle Gusts

An unremarkable breezy afternoon: no tone worth the name, a broad flat bed and gusts that come and go. The reference's turbulence intensity is 18 %, which is high for open ground and is what makes it feel restless. (*gentle, gusty, broadband*)

Howling Storm

Named for what it sounds like rather than what it measures: the reference's peak frequency jumps almost an octave between frames, so there is no steady tone in it at all. It is a very fast, very broad storm bed – 13 gusts a minute and almost no slow drift. (*storm, strong, broadband, fast*)

Howling Wind

The archetype. The reference is the strongest confirmation in the library that howling is aeolian: its tone stands 15 dB above the bed, swoops two thirds of an octave, and its pitch tracks the level at a correlation of 0.87. Howl Track is therefore at maximum and the Q is deliberately low – 1.2 measured, so a broad band rather than a whistle. (*howling, tonal, storm, eerie*)

Meadow Breeze

A light wind over long grass. The reference has effectively nothing below 60 Hz, so Buffet is off and the whole sound sits in the mid band where the blades are. (*gentle, grass, summer*)

Mountain Ridge

Wind across a bare ridge. Slow, heavy and almost ungusty in the short term – a gust factor of 1.04, the lowest in the library – with two thirds of its variation slower than a tenth of a hertz. (*mountain, slow, heavy, open*)

Open Plain

Wind over flat open ground with a wire fence somewhere in it. The reference is unusually tonal for an open site – a narrow band near a kilohertz that holds its pitch to within a third of an octave – so this is one wire, not a hedge. (*open, plain, tonal, steady*)

River Reeds

Wind through reeds at a waterside. Hollow stems knock rather than brush, so the decay is long and the clatter high, and the whole thing sits on a very low bed – the reference peaks at 63 Hz and is 24 dB down by 500. (*reeds, water, hollow, low*)

Rustling Leaves

The rustle on its own: dry leaves close by, with barely any wind bed under them. The reference rises to a peak at 8 kHz and has nothing below 250 Hz, and its onsets sit at 6.4 kHz – the brightest in the library. (*leaves, rustle, dry, close*)

Snow Storm

A blizzard: long slow swells of wind with very little detail in them. The reference has no content at all above about 10 kHz, so the output filter is brought down to match rather than pretending otherwise. (*snow, storm, blizzard, slow*)

Soft Breath

Barely moving air, close by. The reference's spectrum rises towards the top rather than falling – the only one in the library that does – so Flow Tilt is nearly flat and most of the sound is Hiss. (*soft, quiet, close, hiss*)

Spooky Wind

A wind with something in it. The reference's tone is high-Q and only loosely tied to the level – a cavity being blown across rather than a twig shedding – and Warble is high, because a tone that wanders is the whole effect. (*spooky, eerie, tonal, warble*)

Underground

Air moving in a tunnel. Almost nothing above a kilohertz survives – the reference is 116 dB down at 16 kHz – and what is left is a low cavity drone in a hard, close space. (*tunnel, underground, drone, enclosed*)

Wind In Birches

Summer leaves on thin trunks. Rustle carries most of it: the reference detects 2.8 leaf onsets a second at a centroid of 3.5 kHz, which is a broadleaf of about fifty millimetres. (*trees, leaves, forest, summer*)

Winter Gale

A hard cold gale. The reference is the gustiest in the library – 22 % turbulence intensity and a gust factor of 1.41 – and it is almost all low end, with one very narrow band left near a kilohertz. Buffet is nearly at unity and Flow Level is well down under it. (*winter, gale, cold, buffet*)

Using it in a host

Notes

A note starts the wind and holding it keeps it blowing. The ADSR shapes the whole scene rather than individual gusts, and *Release* is what lets it drop. *Velocity To Speed* is worth knowing about: velocity can set the wind speed itself, which is not the same as setting the level — a faster wind is brighter and higher-pitched as well as louder.

SkyHowl needs long notes more than anything else in the suite. A gust takes seconds to arrive and pass and a squall runs over minutes, so almost all of the character is inaudible in a short note.

There are 16 voices, with 256 gusts and 768 leaves in shared pools, so the number of held notes cannot multiply the CPU cost without bound.

Automation and modulation

Every parameter is automatable, and host parameter modulation (`CLAP_EVENT_PARAM_MOD`) is supported globally. Per-note modulation and note expressions are ignored. Parameter changes are sample accurate, so an automation ramp over a bar — a storm getting up over *Wind Speed* and *Turbulence* — is a smooth move rather than a staircase at block boundaries.

Wind Speed is the one to automate. Because level, brightness, howl pitch and rustle rate all follow it, a single ramp does what would otherwise take five.

Reproducible renders

Random Seed at 0 never repeats. Any other value renders the same wind for the same notes every time. The initial squall phase, the first gust timer and each obstacle's size and position are derived from the voice's slot and key rather than from the shared generator, so a fixed seed promises the same wind even when note events arrive before the seed has been applied.

CPU cost

Cost is bounded by the pools, and the flow field itself is nearly free: it updates once every 64 samples, and its gains are ramped between updates so a gust does not step. The most expensive controls are *Howl Voices*, which decides how many resonators are running, *Rustle Density*, which decides how many leaves are alive at once, and *Space Amount*, which is the room model. Gusts are the cheapest thing in the plugin because they are silent: an envelope and a position, with no filter of their own.

Rendering and tails

Wind has a long tail — the release, the gust that was passing when the note went, and whatever the space is still doing with it. When bouncing, leave several seconds past the end of the note.

What is still being fitted

SkyHowl 0.4.0 is a first fit, and the measurements say where it is not there yet. All of this is in the plugin's `TODO.md` with what is known about it.

The presets swoop less than the references. Across the tonal presets the median swoop is 0.28 of an octave against the references' 0.72. The pitch follows a smoothed wind speed, and that smoothing — a fixed 0.65 s time constant — is probably too much of it.

The model does not reproduce one thing the library measures. Its broadband centroid does not reliably rise with level (median correlation -0.10), and the model says it should, because the bed follows U^3 and the buffet only U^2 . The recordings that darken as they get louder are the ones with the most energy below 50 Hz, which suggests that what is being measured there is microphone pseudo-sound and the drag of moving branches — neither of which is radiated wind. *Buffet* is what a preset has instead: raising it is what makes a gust rumble rather than hiss.

Twenty of the twenty-three presets have at least one band more than 6 dB from their reference, and all but two are within 10 dB. The two that are not are *Far Away*, whose reference has a 26 dB notch between two adjacent third-octaves that the model does not produce, and *Between Houses*, which is 14 dB short at 4 kHz.

Much of the reference library is band-limited by its codec, more severely than a listener would guess — one recording holds nothing above 3 kHz and several stop between 4 and 7. Bands above each reference's own bandwidth are not compared, because fitting the synthesis to a band the reference does not contain would be fitting it to an encoder. Before this was noticed, five presets appeared to be 20–50 dB too bright and three had had output filters put on them to compensate.

Reference and limits

Where the model comes from

- **Strouhal, V.**, *Über eine besondere Art der Tonerregung*, 1878 — vortex shedding at $f = St \cdot U/d$, which is what *Howl Size* and *Howl Track* are built on and the reason a howl swoops.
- **Curle, N.**, *The influence of solid boundaries upon aerodynamic sound*, 1955 — flow over a rigid surface radiates as a dipole with power going as U^6 . That is *Speed Law*, and the +18 dB per doubling of wind speed.
- **Kolmogorov, A. N.**, 1941 — the inertial subrange, $f^{-5/3}$, which is the shape of the turbulence process and the reference point for *Flow Tilt*.
- **von Kármán, T.**, on the spectrum of atmospheric turbulence.
- **Wieringa, J.**, *Updating the Davenport roughness classification*, 1992 — the roughness lengths behind the *Terrain* table, via $I \approx 1/\ln(z/z_0)$.
- **Sabine, W. C.** — the decay time of the space model, as elsewhere in the suite.

The papers themselves are not part of the release; they are not ours to redistribute. [tools/analysis/README.md](#) in the source tree records every measurement the library was fitted to, including the five bugs the measurements found.

Notes and limits

- Linux and Windows, x86-64. Plugin state is stored little-endian.
- 16 voices, with 256 gusts, 768 leaves and up to 12 aeolian resonators per voice in shared pools.
- The flow field runs at a control rate of one update per 64 samples, with its gains ramped between updates. Everything audible runs per sample.
- Host parameter modulation is supported globally. Per-note modulation and note expressions are ignored.
- Deliberately built without `-ffast-math` on x86 GCC that links `crtfastmath.o`, which would flip the FTZ and DAZ flags for the entire host process.
- Wind only. Several of the references also contain surf, rain, birds or crickets; those were used for their flow statistics and excluded from the spectral fit.

Versioning

Semantic versioning. **MAJOR** is an overhaul: a rewrite of the synthesis model, or a change that breaks existing presets or saved host state. **MINOR** adds something — a parameter, a layer, presets. **PATCH** is fixes that add nothing new.

License

MIT. The only external dependencies are the CLAP headers, which are MIT licensed, plus X11 and Cairo for the plugin window.

Everything the wind engine produces is computed at run time. SkyHowl also embeds a small amount of recorded audio by Jagadamba, obtained from freesound.org (sound ids 253799-253826) and used under the Creative Commons Attribution 4.0 International licence; it was decoded, loudness matched and embedded. See the LICENSE file in the plugin folder for the full notice.

Reference recordings used during development are not part of the release and are not redistributable.