CLIMATE SCALE

Beyond the Average Year:
Climate-Aware EYA for Brazilian Wind

Gil Lizcano and Ana López
Climate Scale

VORTEX

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What we'll cover

- Brief presentation of Climate Scale
- Motivation: From ‘an average year’ to ‘climate-aware’ EYA
- In practice: Factoring climate variability and climate change footprint into EYA

Climate Scale

WE SUPPORT

Asset Managers / Investors / Technical Teams

Deploy specialised risk analysis for multiple applications and build in climate resilience for climate proofing assets.

Sustainability Teams

Report the financial implications of climate change to investors and meet sustainability requirements #EUTaxonomy #TCFD #ESRS #IFRS #CSRD ...

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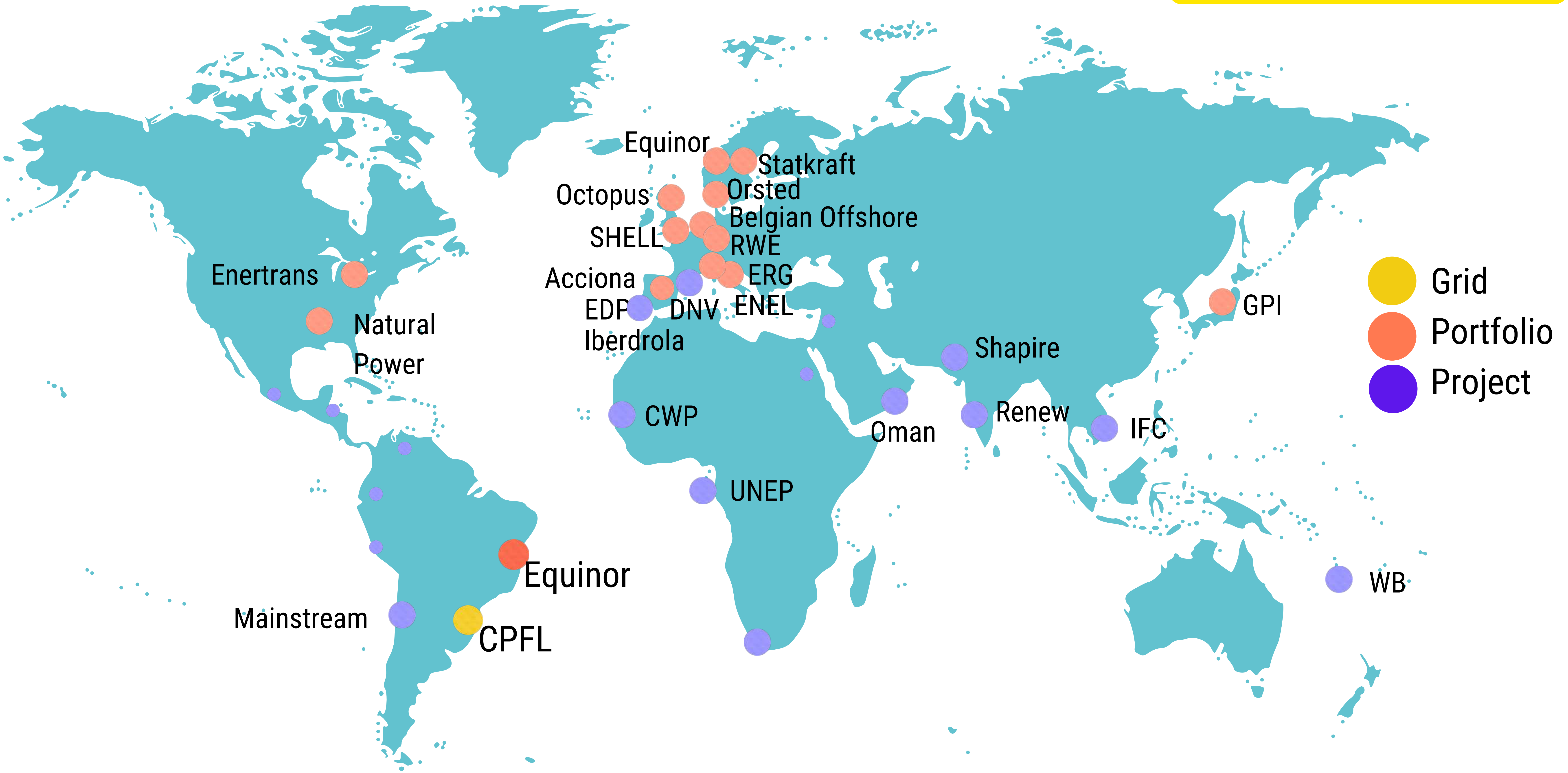

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Dados Climáticos Acionáveis
Riscos físicos abrangentes relacionados ao clima para relatórios de sustentabilidade

Riscos Climáticos
Dados climáticos baseados em ciência para uma análise precisa dos impactos climáticos em qualquer lugar do mundo.

Projeções Climáticas de Alta Resolução
Compreender, quantificar e relatar riscos físicos do clima em projetos e portfólios usando dados climáticos robustos e downscaled, para os climas presente e futuro.

Acompanhamento especializado ao longo de todo o processo, para interpretar os dados climáticos, as projeções futuras e avaliar as incertezas.

Three questions the industry can't yet answer with confidence

1. **Which assets face material climate risk in the next 20 years?**

   Design standards must reflect forward climate — not historical norms

2. **How do we meet climate-proofing regulations and stakeholder expectations?**

   Regulators demand evidence — shareholders demand strategy

3. **Where should adaptation investment go for maximum resilience and return?**

   Financial impact must drive prioritisation — not guesswork

Climate risks → decisions → strategy

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Where the industry stands today on climate risk

Most developers are here

P50 approach
Most likely outcome only

Uses historical averages
No uncertainty range
Optimistic by design

Verdict
Too aggressive

P90 approach
Conservative stress test

Generic % penalty added
Same value for all sites
Not tied to real projections

Verdict
Placeholder
most common

Risk-based approach
Asset-specific projection

Downscaled climate models
Ensemble uncertainty bands
Site + scenario specific

Verdict
Best practice
few do this

This talk: how to reach the right side — faster and with more confidence

Less rigorous → More rigorous

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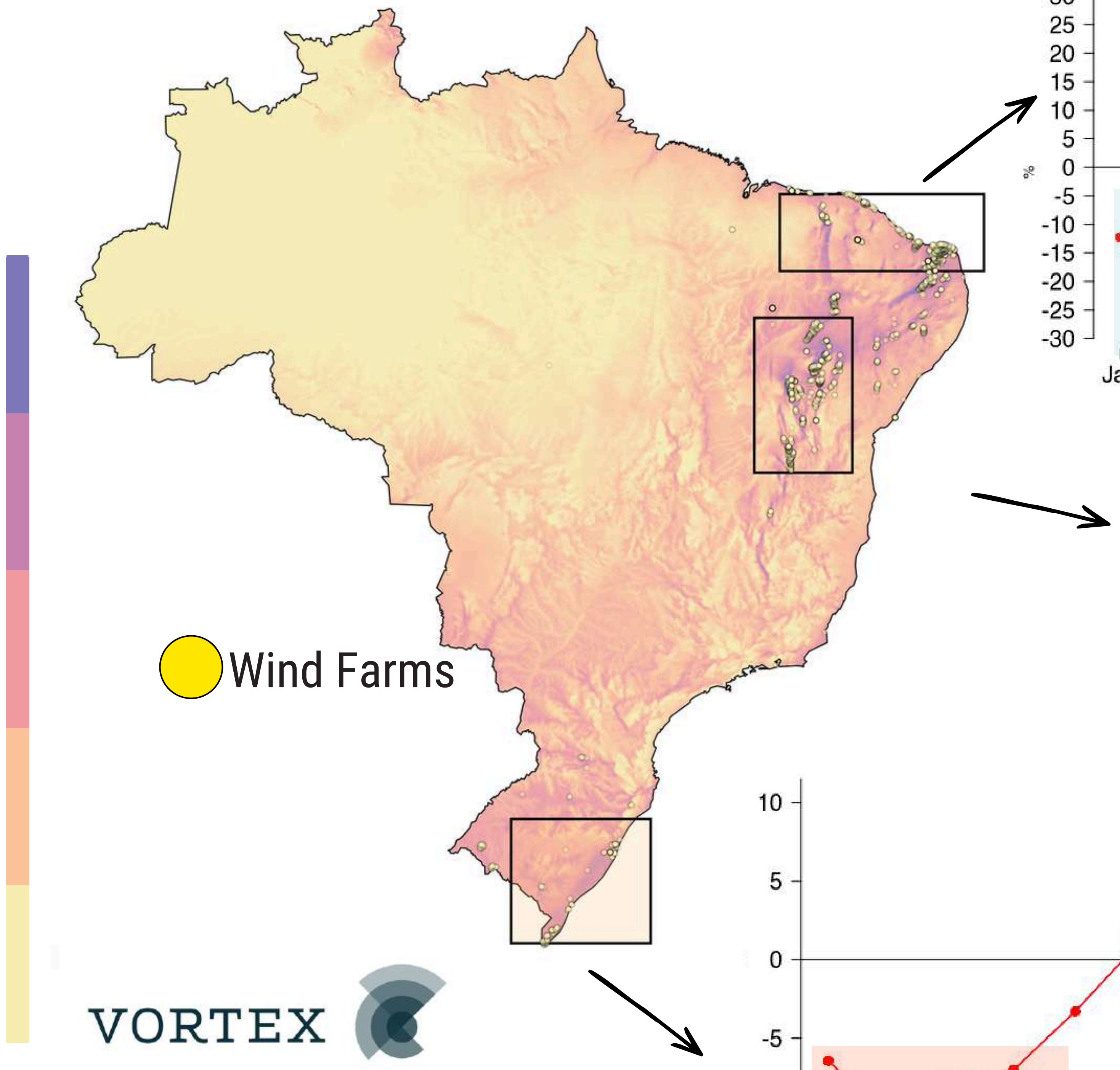
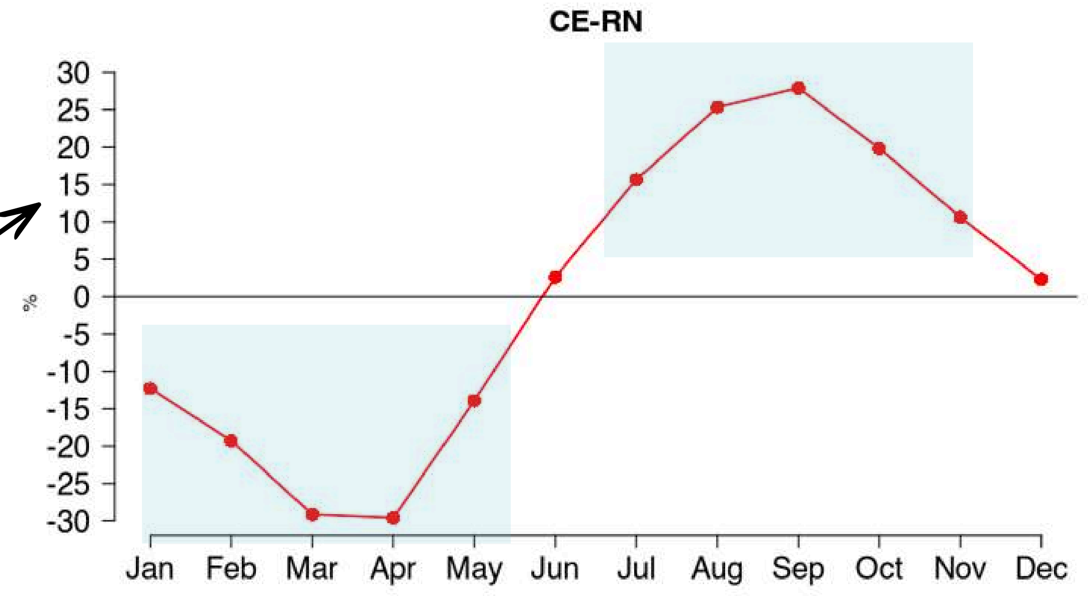
What 40 years of data already show

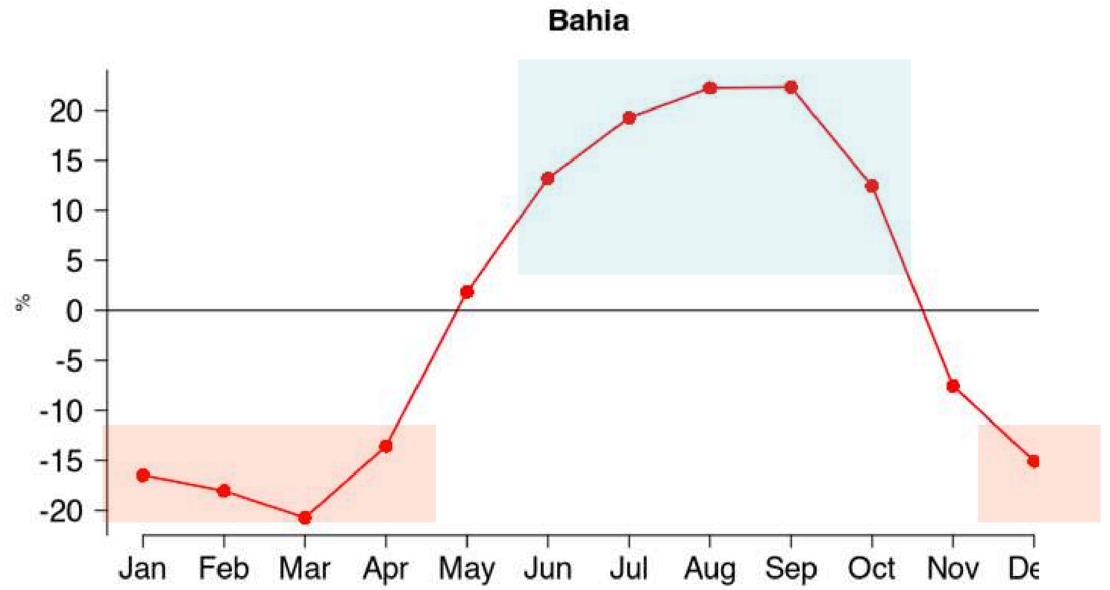
Long-Term Wind Speed at 100m
WRF-ERA5 (1km)

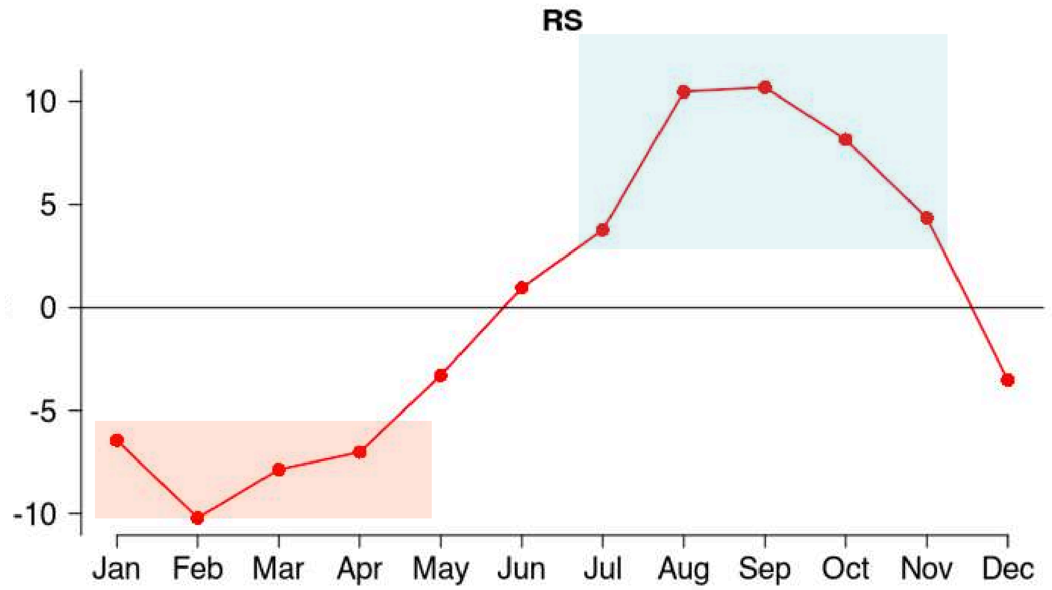




High Wind Season

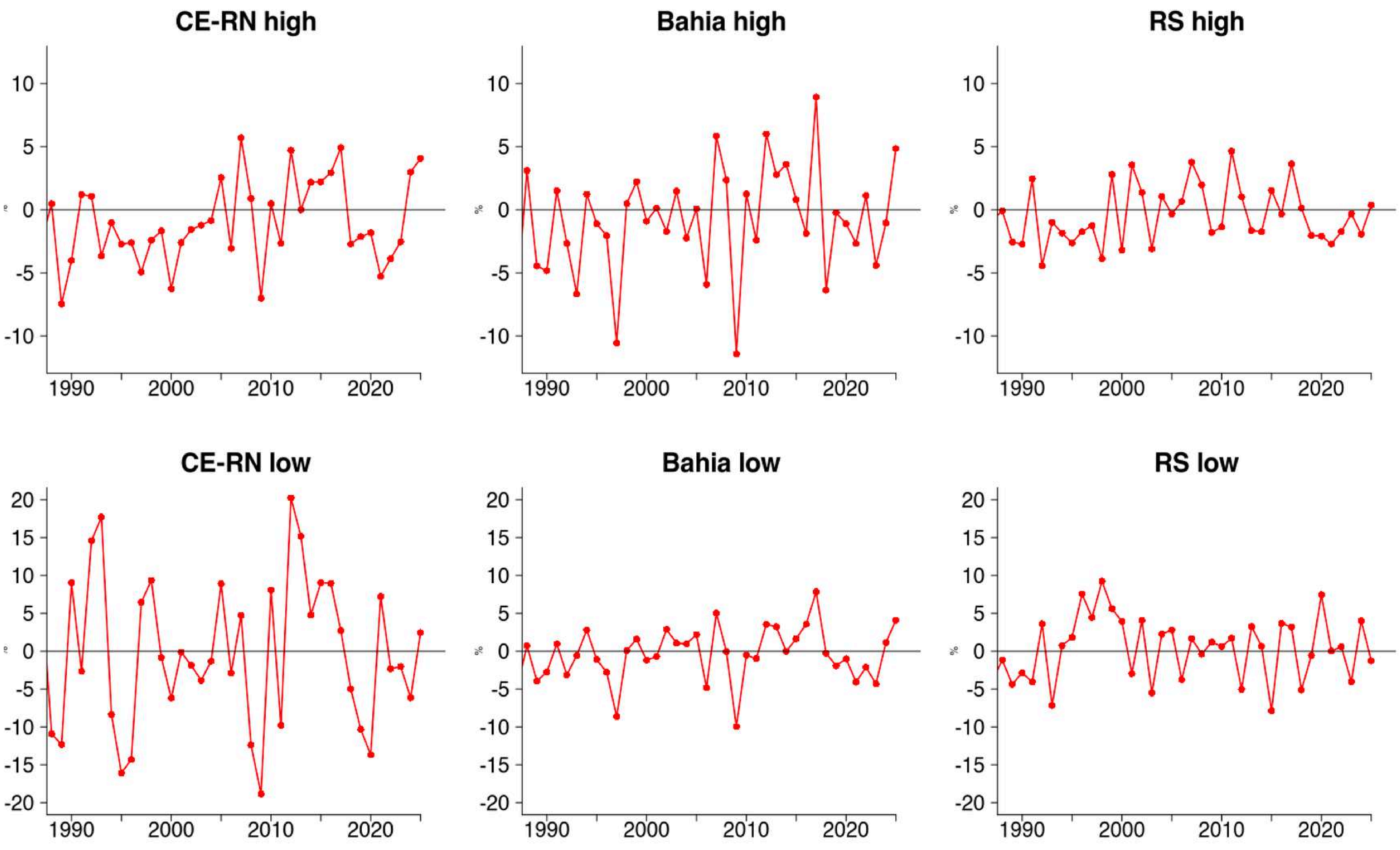
Low Wind Season





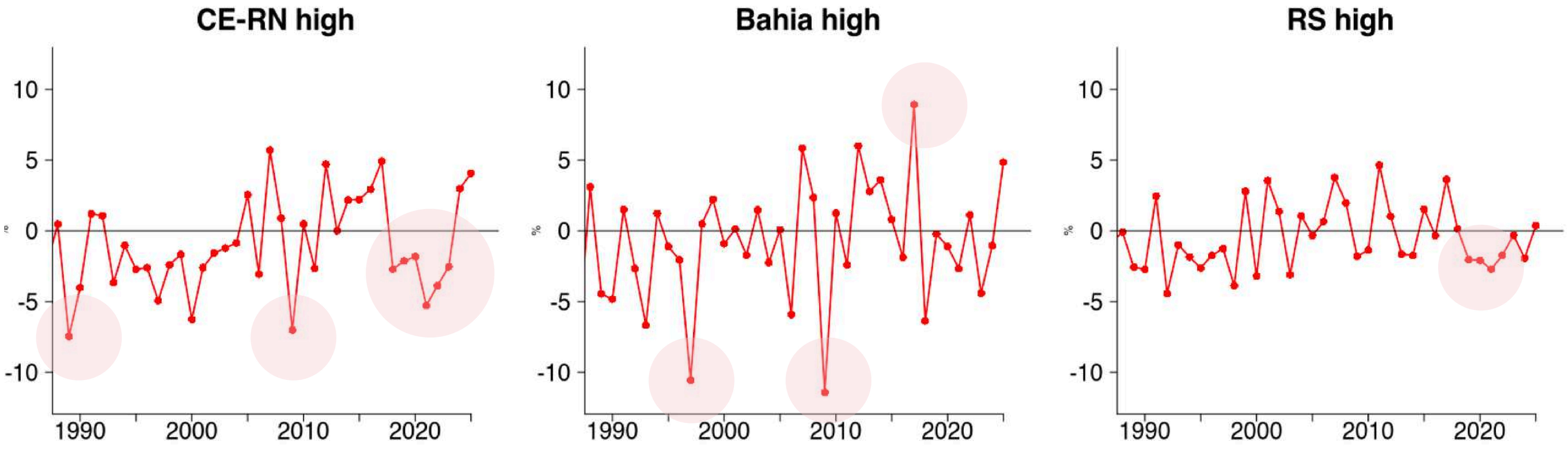
Annual Cycle for 100m Wind Speed / ERA5
aggregated average over each box

Wind variability across three Brazilian regionsy



100m Wind Speed
Seasonal Anomaly
Baseline: 2006-2025
ERA5

Signal or noise? Spotting a trend inside natural variability



100m Wind Speed
Seasonal Anomaly
Baseline: 2006-2025
ERA5

- Lower latitude → Increased variability → Single events with higher impacts → Climate Vulnerable
- Slight upward trend, interrupted by a 5-year low phase → Natural Variability?

→ Can we distinguish a climate warming signal from internal variability, and **where does this signal primarily reside?**

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What's driving that variability, region by region

The warming signal is widespread and can emerge across all scales: where, how, when?

NE Coast
Ceará, RN

- ENSO
- Meridional Mode
- Atlantic Niño
- MJO
- AMV-PDO

Outcome
Trade Stregth

Bahia
Transition Zone, Complex

- NE Trades
- SASH flank
- SACZ Influence

Outcome
Persistent coastal easterlies

Southeast
Subtropics

- SASH
- SAM
- ENSO
- SACZ Dipole
- PDO/AMV

Outcome
Northeasterly inflow

Intraseasonal

Interannual

Decadal

AMV — Atlantic Multidecadal Variability
ENSO — El Niño–Southern Oscillation
ITCZ — Intertropical Convergence Zone
MJO — Madden–Julian Oscillation
NE — Northeast
PDO — Pacific Decadal Oscillation
RN — Rio Grande do Norte
SACZ — South Atlantic Convergence Zone
SAM — Southern Annular Mode
SASH — South Atlantic Subtropical High
SST — Sea surface temperature

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The full driver-by-driver breakdown (available on request)

Region	Driver	Timescale	Mechanism	Net effect on wind
NE coast (Ceará, RN)	ENSO	Interannual	El Niño shifts the Walker circulation, putting anomalous subsidence over northern NE Brazil and suppressing convection	Stronger trades, generally a good wind-power year; La Niña reverses this (more convection, ITCZ further south in autumn, weaker trades)
NE coast	Atlantic Meridional Mode	Interannual	The interhemispheric SST gradient sets the mean ITCZ latitude; a warm-north/cool-south phase holds the ITCZ further north	Intensifies the SE trades reaching the coast and reduces rainfall; the opposite phase weakens them — arguably as important as ENSO here
NE coast	Atlantic Niño (equatorial zonal mode)	Interannual, mainly austral autumn	Warm anomalies in the eastern equatorial Atlantic weaken the equatorial easterlies and pull the ITCZ south	Seasonal modulation of coastal trade strength
NE coast	MJO	Intraseasonal (30–60 days)	Modulates convection over the tropical Atlantic and NE Brazil	Short-lived swings in trade-wind strength
NE coast	AMV / PDO	Decadal	Shift the mean ITCZ position and change how often/intensely ENSO and dipole events occur	Sets the decadal backdrop the interannual modes operate against
Bahia	NE trade-wind system	Background	Same dynamics as Ceará/RN, attenuating with latitude	Baseline easterly flow along the northern Bahia coast
Bahia	SASH (western flank)	Persistent, variable	The high's western edge drives onshore flow along the coast	Persistent easterlies/northeasterlies
Bahia	SACZ	Intraseasonal	Convergence zone reaching the southern and western parts of the state	Locally disrupts the trade-dominated regime
Southeast	SASH variability	Dominant, variable	When intensified or displaced toward the continent it blocks frontal passages; when it weakens or retreats, transient systems take over	Strong, steady northeasterlies when intensified; more frontal disturbance when weak
Southeast	SAM / AAO	Intraseasonal to interannual	Positive phase pushes the storm track poleward	Positive: fewer fronts, steadier northeasterlies. Negative: more frontal activity, variable strong southerlies
Southeast	ENSO	Interannual	El Niño strengthens the subtropical jet, boosts cyclogenesis and frontal activity, and intensifies the South American low-level jet	More frontal, disturbed conditions and a stronger jet feeding moisture/momentum into the SE; La Niña favors blocking and SACZ-dominated patterns
Southeast	SACZ / monsoon dipole	Intraseasonal, partly MJO-driven	Active SACZ episodes reorganize low-level circulation, paired with a dipole further south	Episodic shifts in the SE wind pattern
Southeast	PDO / AMV	Decadal	Strengthen or weaken the typical ENSO teleconnection	Decadal backdrop for how strongly the ENSO/SASH signals come through

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Two rows worth a closer look for 2027

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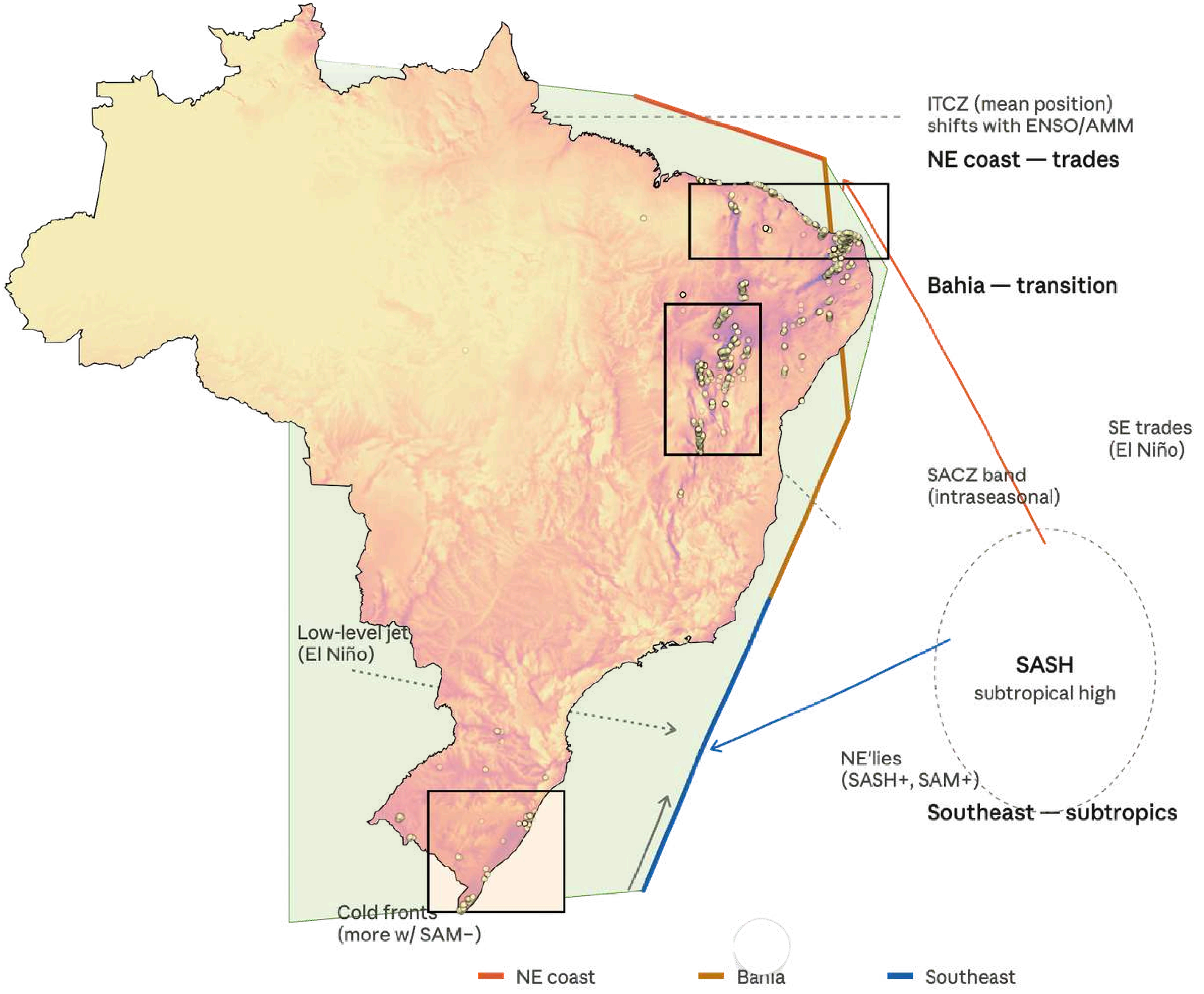
What historical data can – and can't – tell us



- Climate change can emerge through gradual shifts in mean circulation patterns.
- It can also appear as a higher probability of low and high anomaly conditions, including extreme blocking and favourable regimes.
- Wind is more variable than temperature, but that does not rule out underlying circulation shifts.
- We can help assess whether these signals are already emerging in your context.
- Ask Ana López

Three tiers of climate model, three different jobs

Standard CMIP6 GCM Coarse, multi-model ensemble	Downscaled CMIP6 High-res, driver-dependent	DestinE Climate DT Initialised, km-scale digital twin
Resolution ~100-250km	Resolution ~10-25km	Resolution ~5-10km
Period 1850-2100	Period Inherits driver period	Period 1990-2020 (observations) 2021-2050 (projections)
Scenarios Historical + SSPs / 30-40 models	Scenarios Inherits driver scenario	Scenarios SSP3-7.0 and 3 models only
Best for Large-scale circulation	Best for Site-level wind resource	Best for Near-term, observation-anchored km-scale projections,
Not for site-level wind resource	Not for new scenarios	Not for Probabilities and ensemble stats

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Where Climate Scale's downscaled data fits in

REPORTS SERIES

MAPS

Multiple hazards: daily CMIP6 statistics and time series, bias-adjusted with ERA5/Vortex data.

Downscaled CMIP6

High-res, driver-dependent

Resolution
~10-25km

Period
Inherits driver period

Scenarios
Inherits driver scenario

Best for
Site-level wind resource

Not for
new scenarios

ENERGY+

Climate Scale sub-daily CMIP6 wind speed and direction at 100 m, calibrated with 40 years of Vortex SERIES data

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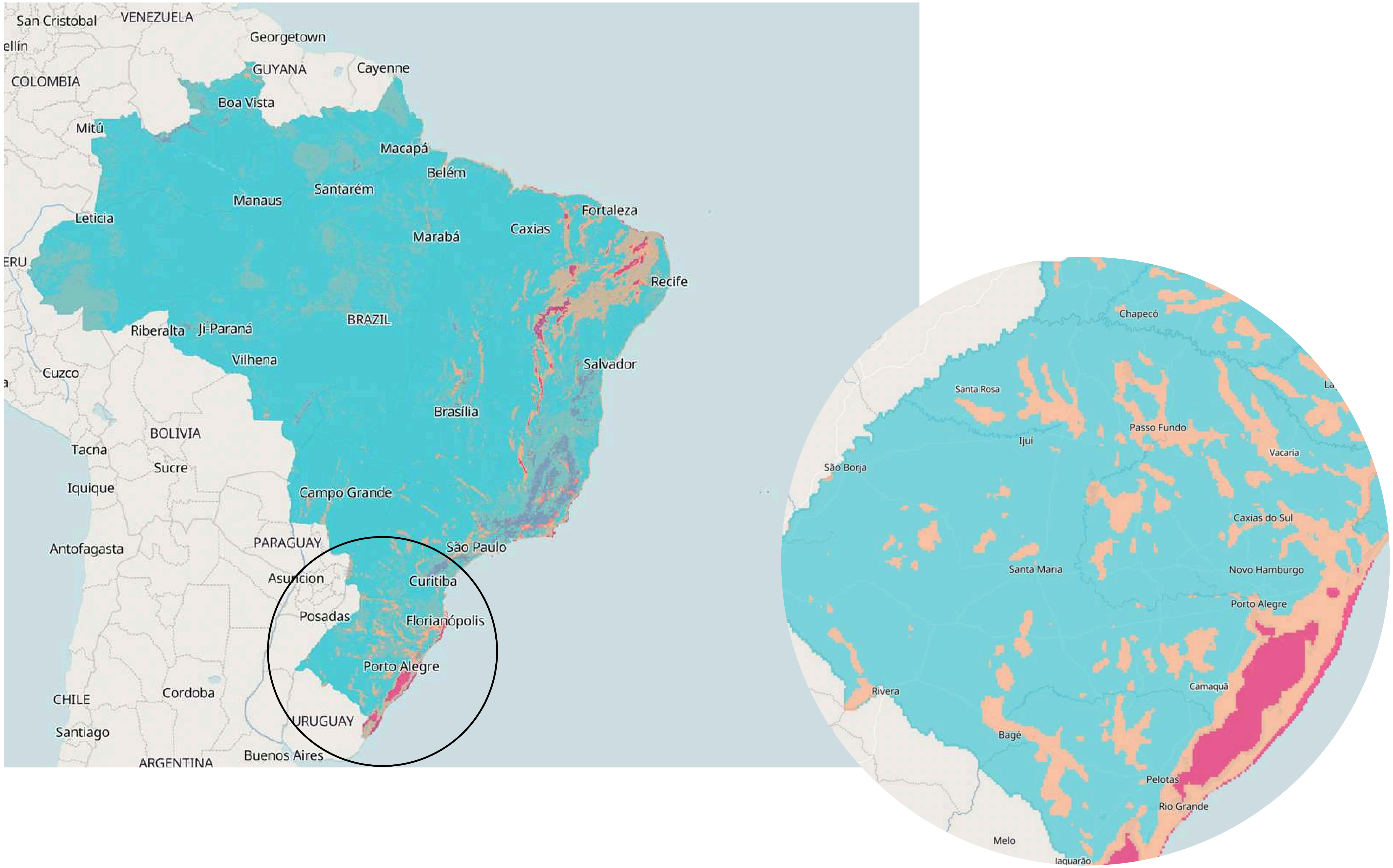
Data to drive decission

atlas.climatescale.com



Extreme Winds - Baseline

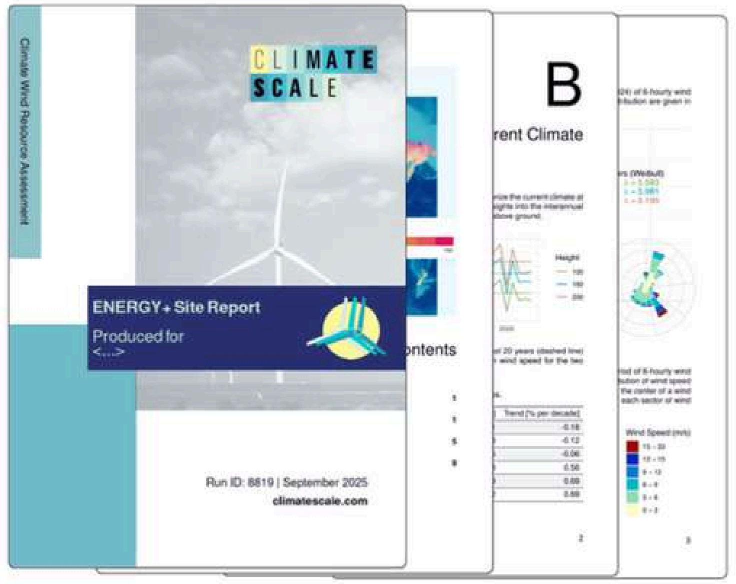
Sustained 10-min wind speed (50-yr return period) at 10 m height

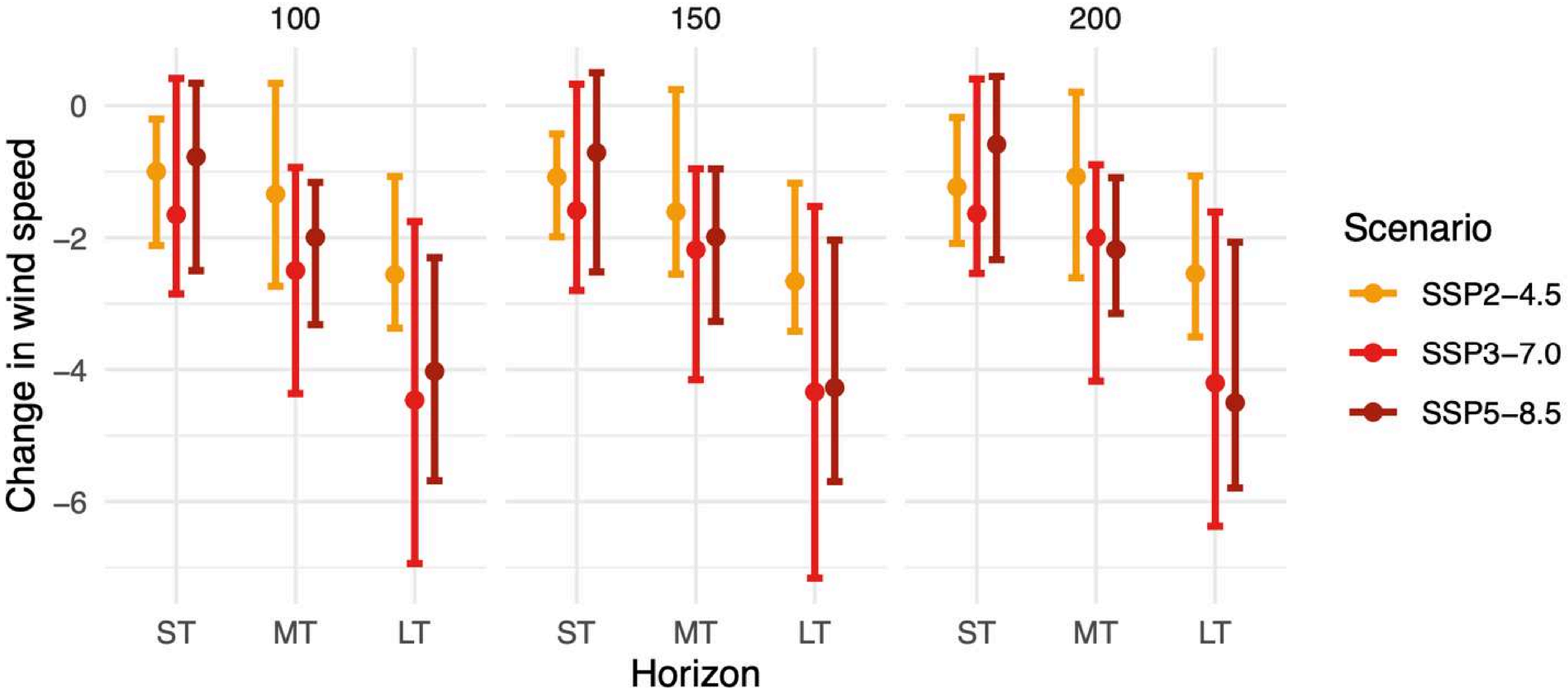
- VeryLow
- Low
- Medium
- High

DADOS HISTÓRICOS, DE ALTA RESOLUÇÃO

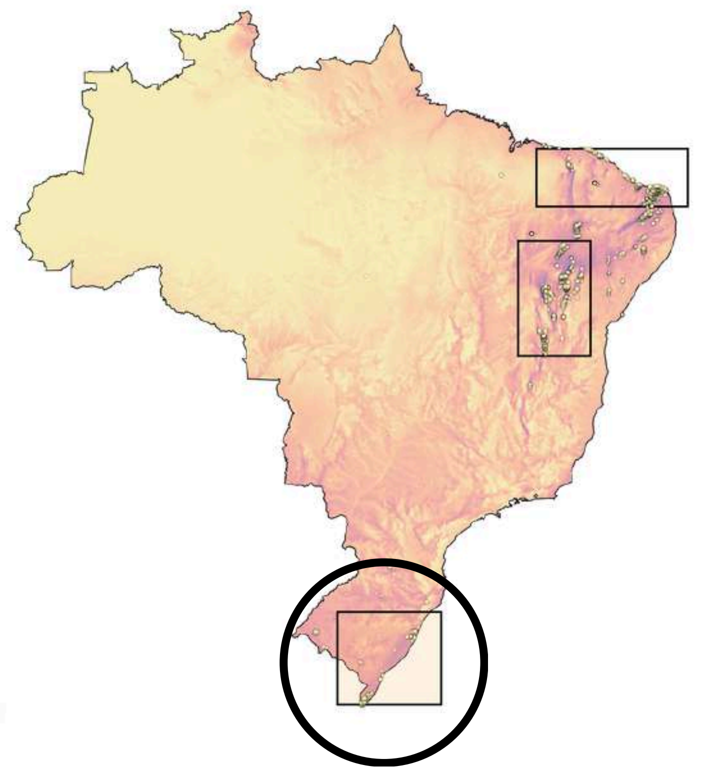
Data to drive decission

RELATÓRIOS E DADOS PRONTOS PARA DOWNLOAD





The numbers behind the headline: medians and uncertainty by scenario



	Period	temperature	wind speed		
long-term average	2006-2025	18.2 °C	7.65 m/s		
		change in °C	**change factor in %**		
		signal	**signal**	**uncertainty**	
Scenarios	Horizon	median	**median**	**- 1 STD**	**+ 1 STD**
SSP2-4.5	2026-2045	0.4	**0.5**	**-0.3**	**1**
	2046-2064	0.8	**0.4**	**-0.5**	**1.3**
	2080-2099	1.4	**0**	**-1.7**	**1**
SSP3-7.0	2026-2045	0.4	**0.1**	**-0.8**	**0.7**
	2046-2064	0.9	**0**	**-0.8**	**0.7**
	2080-2099	2.2	**-0.3**	**-1.5**	**0.8**
SSP5-8.5	2026-2045	0.4	**0.8**	**-0.1**	**1.3**
	2046-2064	1	**0.6**	**-1.1**	**1.6**
	2080-2099	2.7	**0**	**-1.2**	**1.3**

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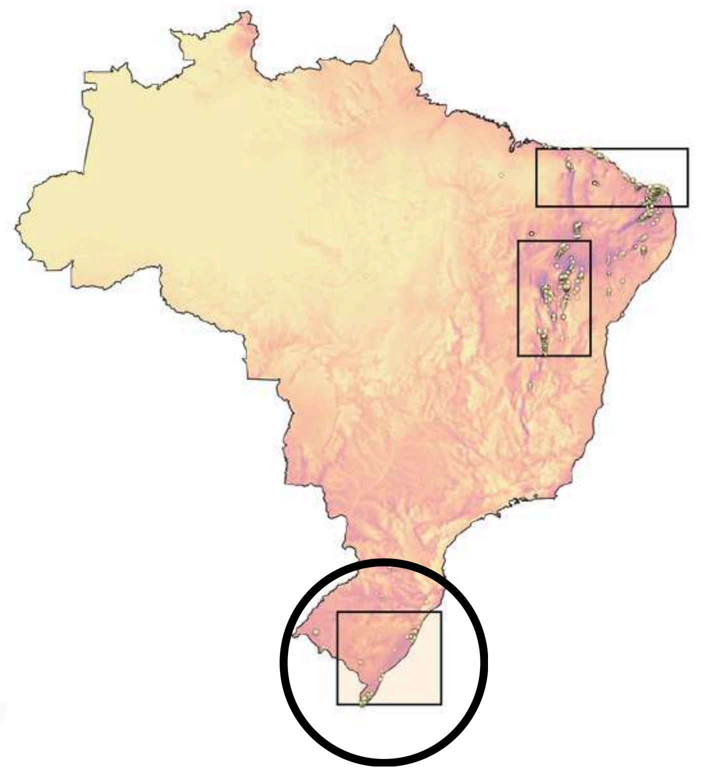
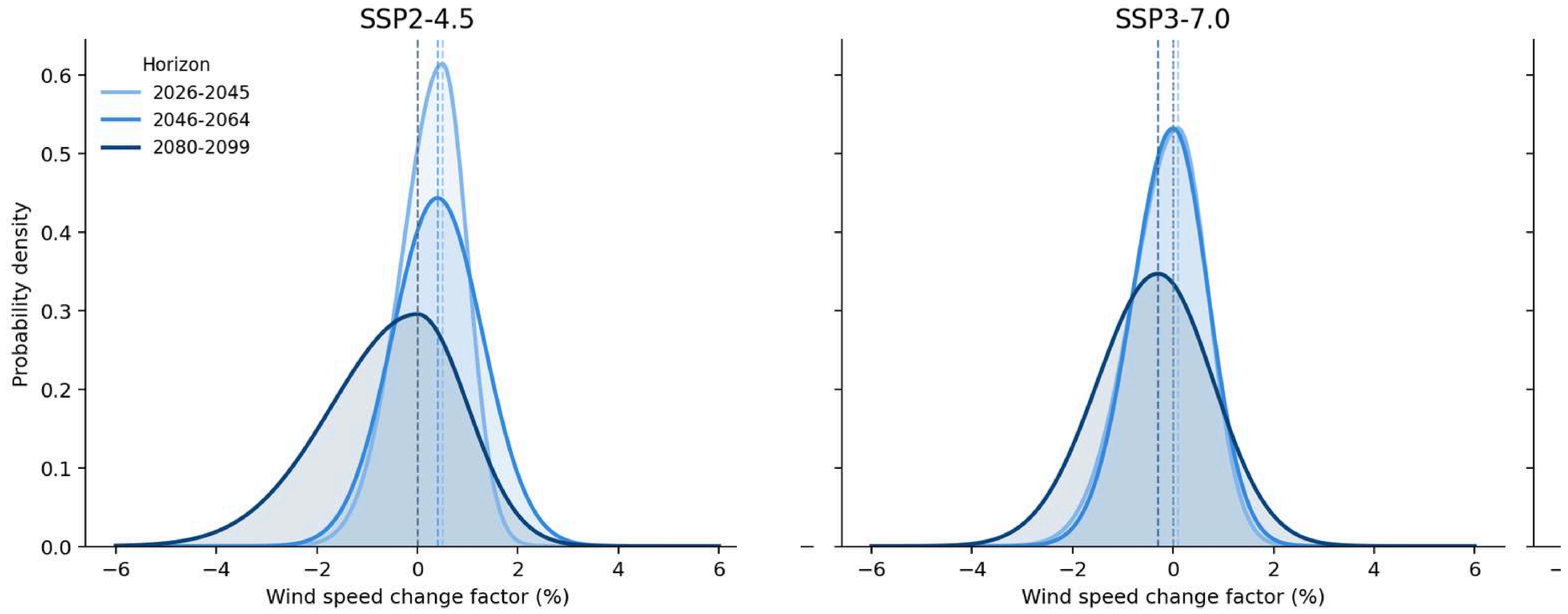
The headline result for your reportT





- Downscaled CMIP6 projections, calibrated to site Vortex data, point to a positive direction for long-term wind speed
- Near-term (2026–2045): ~70–75% probability of a positive change under SSP2-4.5 and SSP3-7.0
- Uncertainty widens over time as natural variability outweighs the forced climate signal
- **Bottom line: resource more likely to benefit than be harmed by climate change, strongest confidence near- to mid-term**

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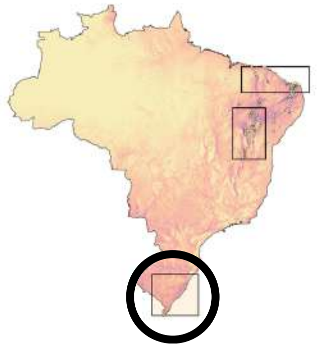
Ready-to-paste language for your EYA



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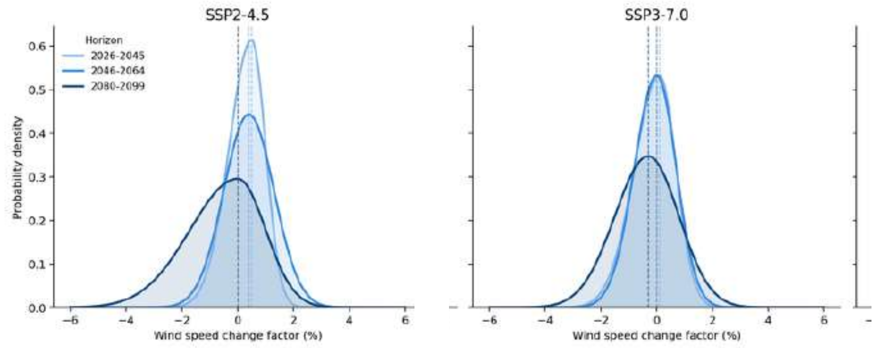


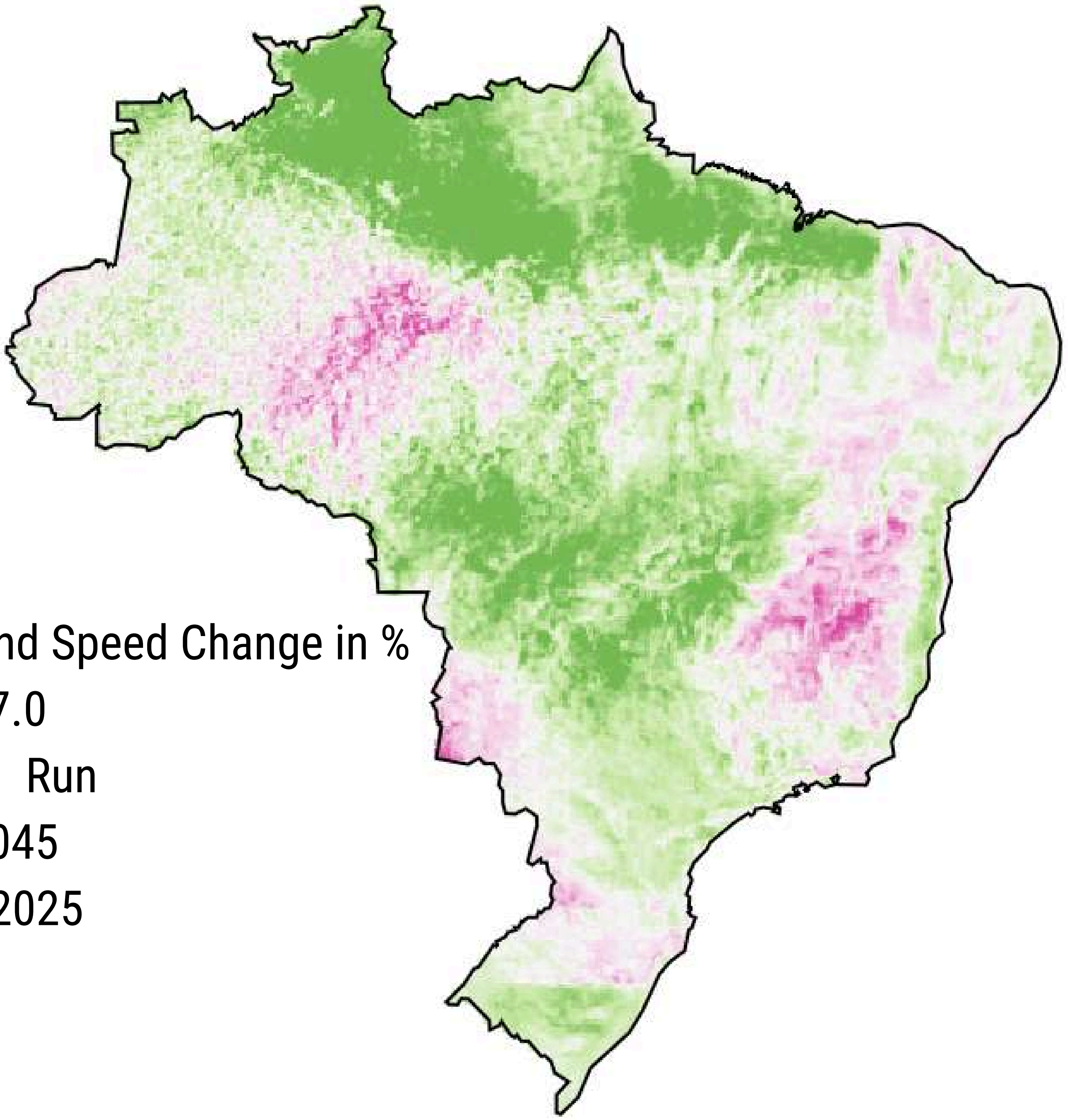
YOUR WINDFARM EYA REPORT

Climate change sensitivity of long-term wind resource

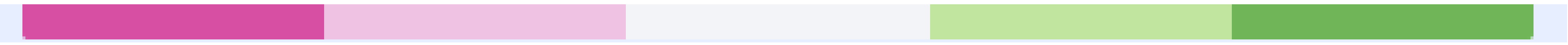
Downscaled CMIP6 climate projections, calibrated against the site's reference Vortex wind dataset, indicate that the most likely direction of change in long-term average wind speed at the site is positive. For the near-term horizon (2026–2045), which remains closely aligned with current emissions trends across the scenarios assessed, treating the reported median and 17th/83rd percentiles as an asymmetric (split-normal) distribution around the median implies an approximate 65–76% probability of a positive change under **SSP2-4.5** and 45-50% for SSP5-7.0.
This confidence narrows at longer horizons as natural climate variability becomes a progressively larger share of the total signal relative to the forced climate-change response. The effect is most pronounced under SSP2-4.5, where the percentile spread awidens to a markedly asymmetric -1.7% to +1.0% range, bringing the implied probability of a positive change down to roughly even odds by the end of the century. This widening reflects the growing relative weight of natural variability under a moderate-emissions trajectory rather than a shift toward a more negative central estimate.
Taken together, the best available data support the conclusion that the long-term average wind resource at the site is more likely to benefit from, than be adversely affected by, the climate-change-related signal captured in these projections, with that confidence strongest in the near- to medium-term.

Verified by CLIMATE SCALE

Beyond wind: more hazards, more resolution

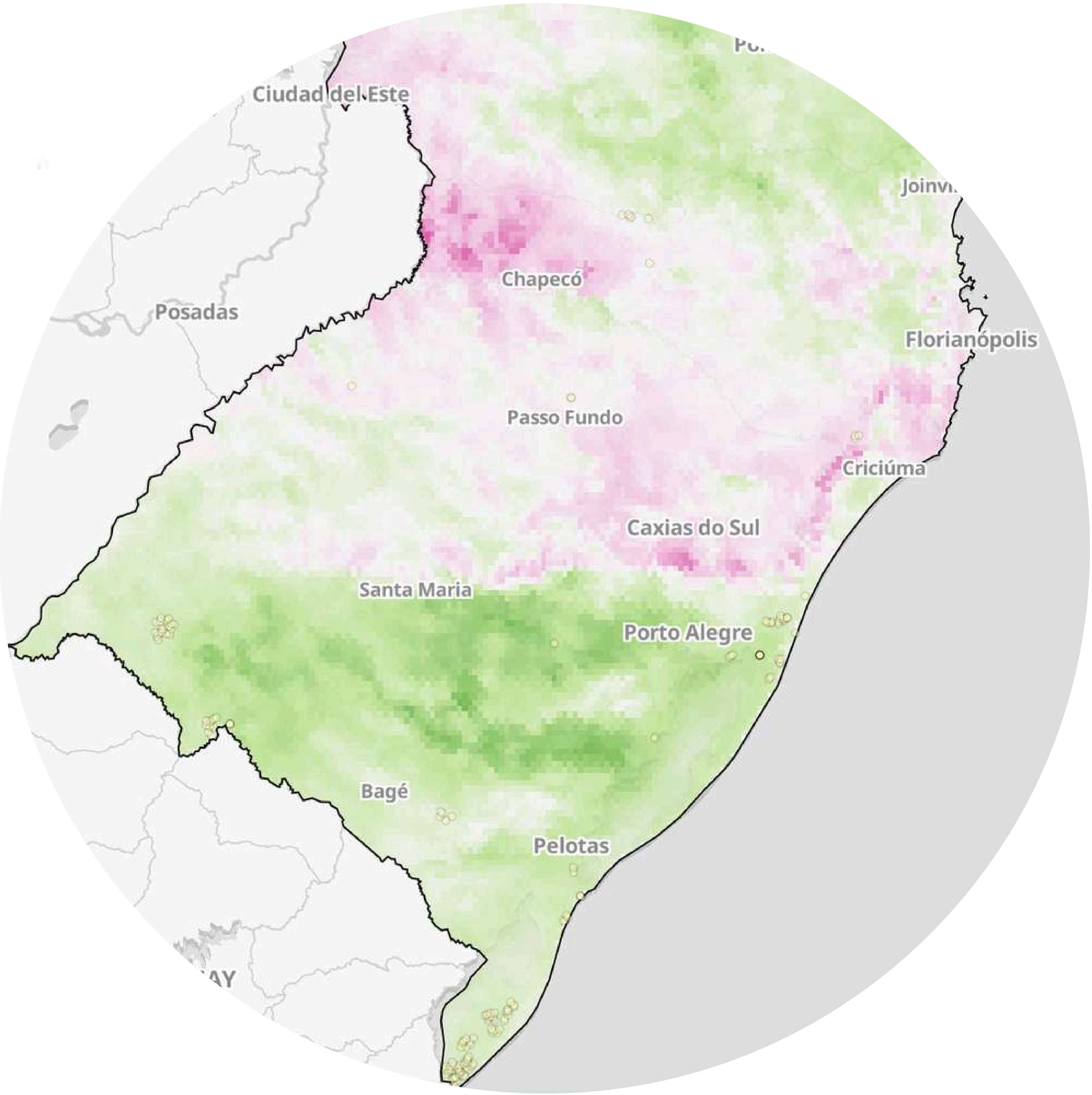


Near Surface Wind Speed Change in %
Scenario: SSP3-7.0
IFS Single Model Run
Horizon: 2026-2045
Baseline: 2006-2025



Negative Change

Positive Change



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Get in touch to:

- Learn more about our data and tools
- Get a custom analysis of your assets
- Train your team on climate risk
- Strengthen your reporting and sustainability strategy
- Or just because you're curious

Email us → melike.dugan@climatescale.com

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