# Quantifying uncertainty in the potential distribution of an invasive species: climate and the Argentine ant

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## SUPPLEMENTARY MATERIAL

Table S1. Primary climate variables and their secondary transformations entered into the logistic regression analysis.

| Primary variable ($x$) | Secondary transformation | Definition |
|---|---|---|
| MINMIN | $x^2$ | Minimum of the 12 monthly means of daily minimum temperature (°C) |
| MINAVG | $x^2$ | Minimum of the 12 monthly means of daily mean temperature (°C) |
| MAT | $x^2$ | Mean annual temperature, i.e. mean of the 12 monthly means of daily mean temperature (°C) |
| MAXAVG | $x^2$ | Maximum of the 12 monthly means of daily mean temperature (°C) |
| MAXMAX | $x^2$ | Maximum of the 12 monthly means of daily maximum temperature (°C) |
| PPT | $\ln(x)$ | Annual precipitation + 1 ($cm.yr^{-1}$) |

Table S2**.** Source of records used to generate a global distribution map. Some records from Brazil were excluded because of doubts over the species identity of specimens from these areas (Orr *et al.* 2001; Tsutsui *et al.* 2001; Wild 2004)An excel spreadsheet of the geographical coordinates is available from the author.

| Country/ Island | References |
|---|---|
| Argentina | Orr *et al.* 2001, A. Wild (pers comm.) Suarez *et al.* 2001, Tsutsui *et al.* 2000 |
| Australia | Entomology Division 1977, Jenkins 1961, Majer 1993, Pasfield 1968, VanSchagen *et al.* 1993, S. Shattuck (pers comm.) |
| Azores | Suarez 2001 |
| Bermuda | Haskins 1988 |
| Brazil | A. Wild (pers comm.), Fowler & Bueno 1996, Majer & Delabie 1999, Orr *et al.* 2001 |
| Chile | Ripa *et al.* 1999, Snell 1975 |
| Costa Rica | Perfecto & Snelling 1995 |
| Easter Island | Morrison 1997 |
| France | Benois 1973, Blank 1949, Collingwood 1978, Giraud *et al.* 2002, Keller & Passera 1989 |
| Canary Isles | Suarez *et al.* 2001 |
| Hawaii | Cole *et al.* 1992, Wetterer 1998a,b |
| Italy | Giraud *et al.* 2002, Monaco & Abbicco 1987, Poldi 1995, Scirocchi & Mangia 1984, Suarez *et al.* 2001, Tsutsui *et al.* 2001b |
| Japan | Suarez *et al.* 2001, Sugiyama 2000 |
| Madeira | Fowler & Bueno 1984, Holway 1990 |
| Malta | Scheembri & Collingwood 1981 |
| Mexico | Suarez *et al.* 2001 |
| New Zealand | AMNZ, Charles *et al*. 2001, Harris & Ward 2003, P.J. Lester (pers. obs.), NZAC |
| Paraguay | A. Wild (pers comm..) |
| Peru | Suarez *et al.* 2001 |
| Portugal | Giraud *et al.* 2002, Way 1997 |
| South Africa | Addison & Samways 2000, Bond 1983, Bond & Slingsby 1984, Christian 2001, Gilimore 1986, Jackson 1980, Kock, 1989, 1990, Skaiffe 1955, DeKock 1990, Koen 1988, |
| Spain | Collingwood 1978, Cros *et al.* 1997, Giraud *et al.* 2002, Way 1997 |
| Uruguay | Suarez *et al.* 2001 |
| U.S.A. | Baker 1985, Barber 1916, Blachly & Forschler 1996, Chen & Nonacs 2000, Daar 1997, Dreistadt *et al.* 1986, Erickson 1971, Flanders 1956, Hee *et al.* 2000, Holway 1995, 1998, Human & Gordon 1996, Huxel 2000, Kennedy 1998, Klotz *et al.* 1995, 1996a, 2000, Knight & Rust 1990, Majer 1994, Markin 1970, Orr *et al.* 2001, Shorey *et al.* 1996, Stiles & Jones 2001, Suarez *et al.*1999, Suarez *et al.* 2001, Tsutsui *et al.* 2000, 2001, Vega & Rust 2001, Ward 1987, Wetterer 2001 |

**References for Table S2**

AMNZ. Auckland Museum of New Zealand, (insect collection).

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NZAC. National Arthropod Collection of New Zealand (Nelson).

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Table S3. Eleven different specifications representing the set of plausible candidate models. All models contained terms for annual precipitation (PPT) and ln(PPT). We constructed a full linear model (model specification *a*) which including all primary variables and their secondary transformations. However, interpretation of the predictions from this model could be complicated by the high correlations between some of the temperature variables, therefore we specified five parsimonious models (*b*-*e*) with low colinearity between their primary terms. These models were constructed to include one primary variable and its associated secondary term describing temperature maxima (MAXAVG or MAXMAX), one describing temperature minima (MINAVG or MINMIN) and a third described precipitation (PPT). Model *f* was the simplest, with just one primary variable describing temperature (MAT) and one for precipitation. Each of the simple models (*b*-*f*) were then respecified by including all two-way interactions between their primary variables (models *g*-*k*). This set of plausible models contrasts with the more traditional approach, in which a single model is chosen *a priori* as the actual or best representation of reality.

| Model | Description | Climate variables | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MINMIN | MINMIN$^2$ | MINAVG | MINAVG$^2$ | MAT | MAT$^2$ | MAXAVG | MAXAVG$^2$ | MAXMAX | MAXMAX$^2$ | PPT | LnPPT |
| *a* | Full linear model | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| *b* | Winter mean and summer mean | | | ✓ | ✓ | | | ✓ | ✓ | | | ✓ | ✓ |
| *c* | Winter mean and summer max | | | ✓ | ✓ | | | | | ✓ | ✓ | ✓ | ✓ |
| *d* | Winter min. and summer mean | ✓ | ✓ | | | | | ✓ | ✓ | | | ✓ | ✓ |
| *e* | Winter min. and summer max | | | ✓ | ✓ | | | | | ✓ | ✓ | ✓ | ✓ |
| *f* | Mean annual temperature | | | | | ✓ | ✓ | | | | | ✓ | ✓ |
| *g* | (*b*) + all 2-way interactions | | | ✓ | ✓ | | | ✓ | ✓ | | | ✓ | ✓ |
| *h* | (*c*) + all 2-way interactions | | | ✓ | ✓ | | | | | ✓ | ✓ | ✓ | ✓ |
| *i* | (*d*) + all 2-way interactions | ✓ | ✓ | | | | | ✓ | ✓ | | | ✓ | ✓ |
| *j* | (*e*) + all 2-way interactions | | | ✓ | ✓ | | | | | ✓ | ✓ | ✓ | ✓ |
| *k* | (*f*) + all 2-way interactions | | | | | ✓ | ✓ | | | | | ✓ | ✓ |

Table S4. Confusion matrix. $A$ = true positives, $B$ = false positives, $C$ = false negatives, $D$ = true negatives, sensitivity = $A/(A+C)$, specificity = $D/(B+D)$ and prevalence = $A+C$. Cell contents are proportions and sum to one.

| | | Observed | |
|---|---|---|---|
| | | present | absent |
| Predicted | present | *A* | *B* |
| | absent | *C* | *D* |

Table S5. Pearson correlation coefficients between the primary climate variables; in all cases $P < 0.001$, $n = 50186$.

| | MINMIN | MINAVG | MAT | MAXAVG | MAXMAX |
|---|---|---|---|---|---|
| MINAVG | 0.99 | | | | |
| MAT | 0.96 | 0.97 | | | |
| MAXAVG | 0.71 | 0.73 | 0.86 | | |
| MAXMAX | 0.64 | 0.68 | 0.82 | 0.98 | |
| LnPPT | 0.21 | 0.18 | 0.06 | -0.20 | -0.29 |

Table S6. a) Coefficients of the models fitted to the complete dataset. b) Climatic optima predicted by the non-interactive models. Variable names defined in Table S1.

a)

| Model terms | Model specification | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *j* | *k* |
| | - | - | - | - | - | - | - | - | - | - | - |
| Intercept ($\beta_0$) | 22.254 | 19.915 | 23.093 | 16.417 | 20.601 | 22.508 | 15.803 | 18.624 | 12.089 | 14.658 | 22.650 |
| MAT | -2.688 | | | | | 1.640 | | | | | 1.697 |
| MAXAVG | 1.357 | 0.854 | | 0.917 | | | 0.798 | | 0.734 | | |
| MINAVG | 2.148 | 0.793 | 0.786 | | | | 0.356 | 0.485 | | | |
| MAXMAX | 0.883 | | 1.020 | | 1.122 | | | 0.891 | | 0.744 | |
| MINMIN | -0.045 | | | 0.389 | 0.406 | | | | 0.264 | 0.601 | |
| PPT | -0.010 | -0.012 | -0.014 | -0.013 | -0.015 | -0.017 | -0.058 | -0.060 | -0.059 | -0.061 | -0.044 |
| $MAT^2$ | 0.039 | | | | | -0.052 | | | | | -0.058 |
| $MAXAVG^2$ | -0.017 | -0.022 | | -0.024 | | | -0.030 | | -0.025 | | |
| $MINAVG^2$ | -0.074 | -0.038 | -0.038 | | | | -0.052 | -0.048 | | | |
| $MAXMAX^2$ | -0.016 | | -0.021 | | -0.023 | | | -0.022 | | -0.018 | |
| $MINMIN^2$ | 0.022 | | | -0.031 | -0.032 | | | | -0.038 | -0.036 | |
| Ln(PPT) | 1.201 | 1.430 | 1.219 | 1.148 | 1.026 | 1.768 | 1.677 | 1.457 | 1.189 | 1.269 | 2.035 |
| lowtemp × hightemp | | | | | | | 0.027 | 0.013 | 0.008 | -0.009 | |
| lowtemp × PPT | | | | | | | 0.001 | 0.001 | 0.000 | 0.001 | |
| hightemp × PPT | | | | | | | 0.001 | 0.001 | 0.002 | 0.001 | |
| MAT x PPT | | | | | | | | | | | 0.001 |

b)

| Climate variable | Model specification | | | | | | Consensus of *b-f* |
|---|---|---|---|---|---|---|---|
| | *a* | *b* | *c* | *d* | *e* | *f* | |
| MAT (°C) | -34.3 | | | | | 15.7 | 15.7 |
| MAXAVG (°C) | 40.6 | 19.1 | | 18.9 | | | 19.0 |
| MINAVG (°C) | 14.5 | 10.4 | 10.5 | | | | 10.5 |
| MAXMAX (°C) | 27.2 | | 24.4 | | 24.3 | | 24.4 |
| MINMIN (°C) | 1.0 | | | 6.2 | 6.3 | | 6.3 |
| PPT (cm/yr) | 117 | 115 | 90 | 87 | 70 | 106 | 95 |

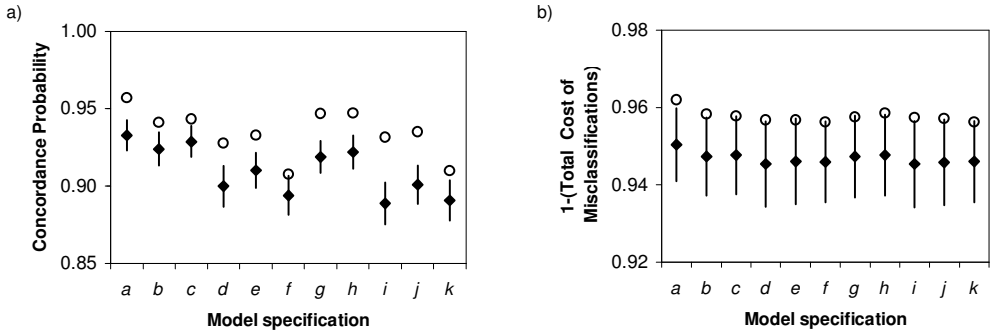


Figure S1. Two measures of model performance, (a) concordance probability (b) 1- (total relative cost of misclassifications). Open circles are the result of self-validation using the complete dataset; solid diamonds represent the mean (+/- s.e.) performance in a continental-scale cross-validation. In b) the cost of false positive relative to false negatives was set at 0.1, and the predicted probabilities were cross-classified at the optimal threshold for each model×partition combination.

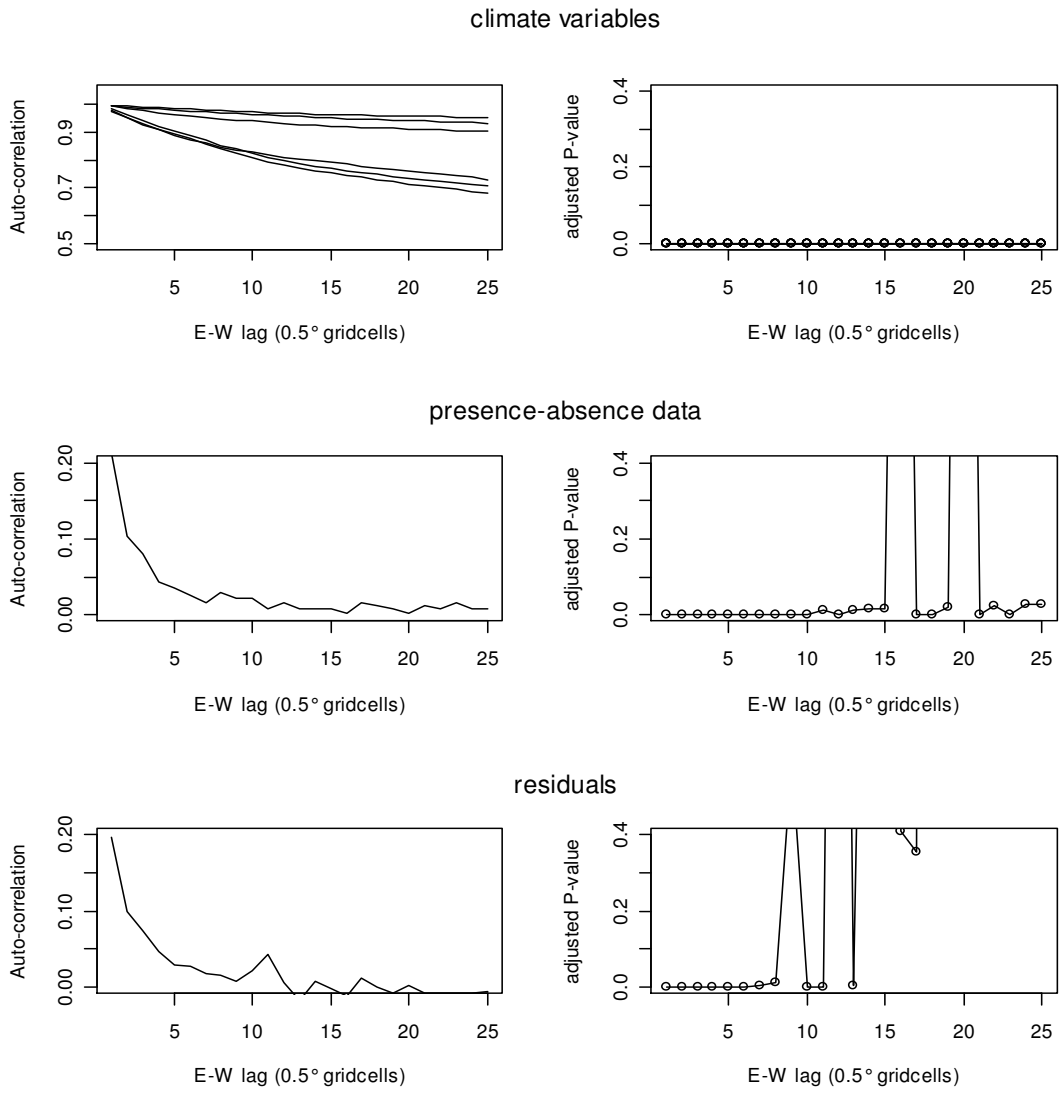


Figure S2. Correlograms (left) and sequentially adjusted P-values (right) at increasing lags in a east-west direction (the direction of maximum autocorrelation). a) Climate variables, (lines from top to bottom represent: MINAVG, MINMIN, MAT, PPT, MAXMAX and MAXAVG b) Presence-absence ant data c) Residuals from the multimodel average, measured on a probability scale. Although the model residuals display significant ($P < 0.05$) autocorrelation at lags of up to 8 half-degree gridcells, this is substantially less than the autocorrelation of the climate variables or the presence-absence distributional data.