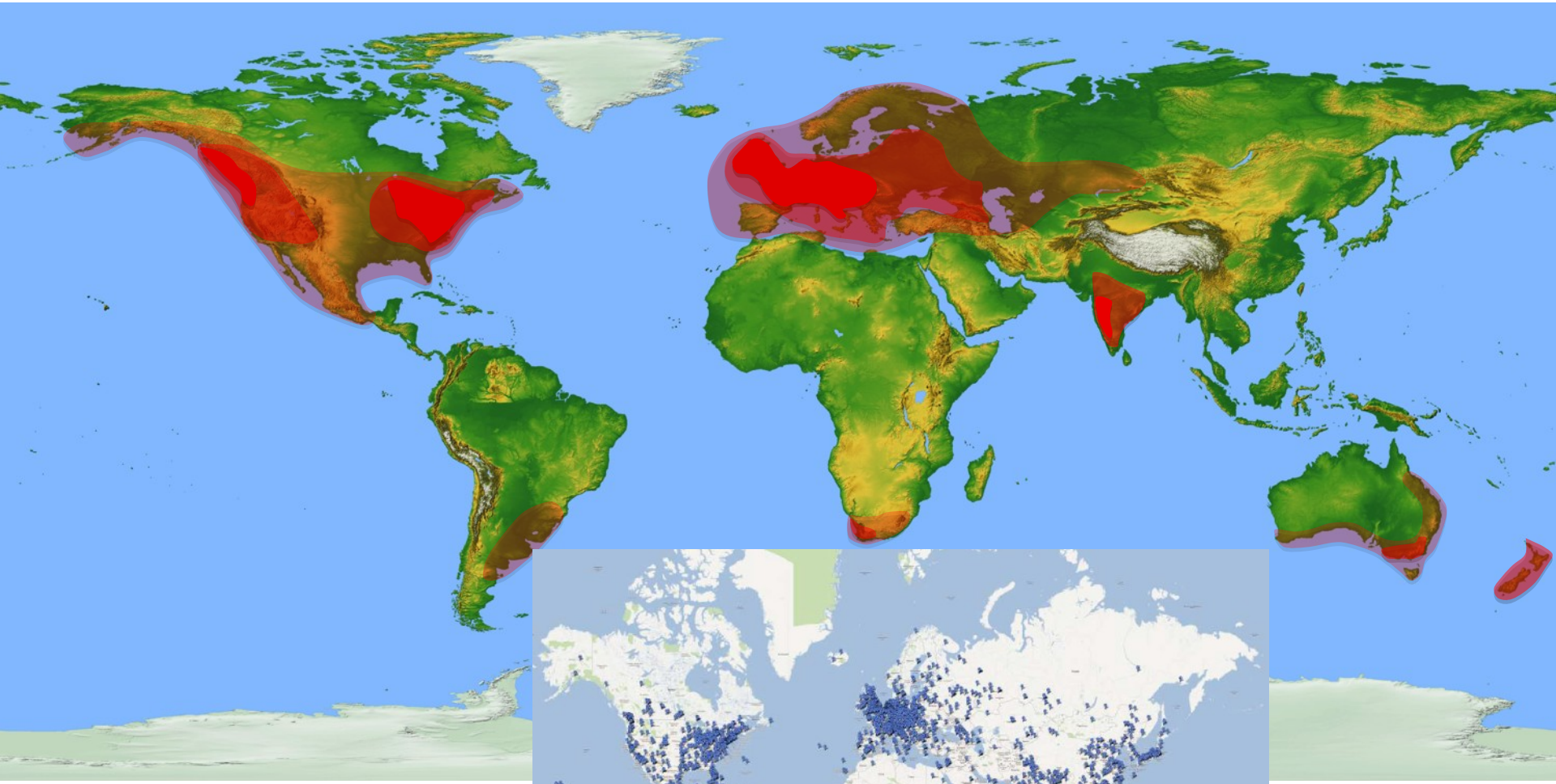
Растения Восточной Азии в ботанических садах мира:
предпосылки успеха интродукции

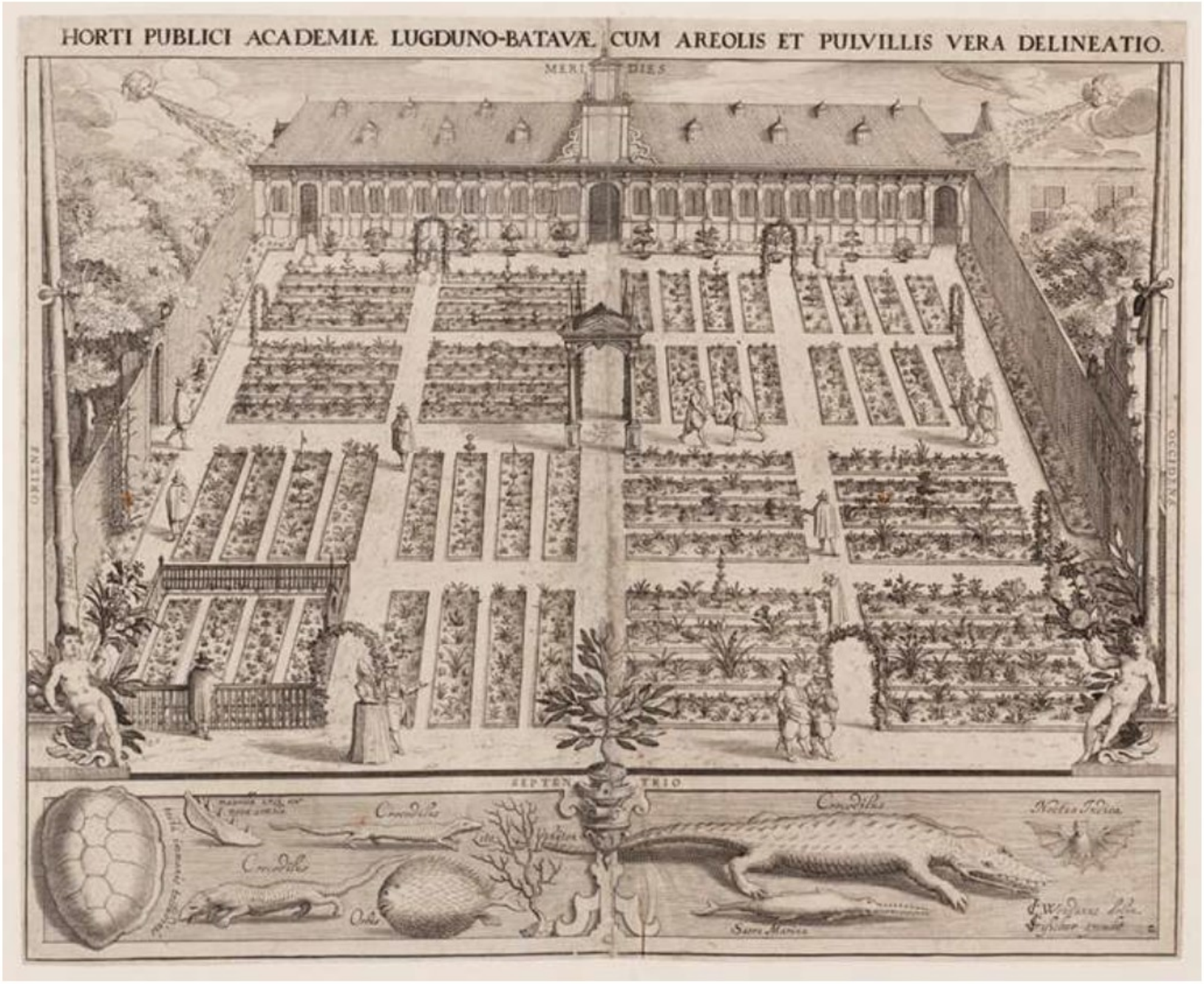
Павел Крестов
Ботанический сад-институт ДВО РАН
Биолого-почвенный институт ДВО РАН
Владивосток

восточноазиатские виды в ботанических садах

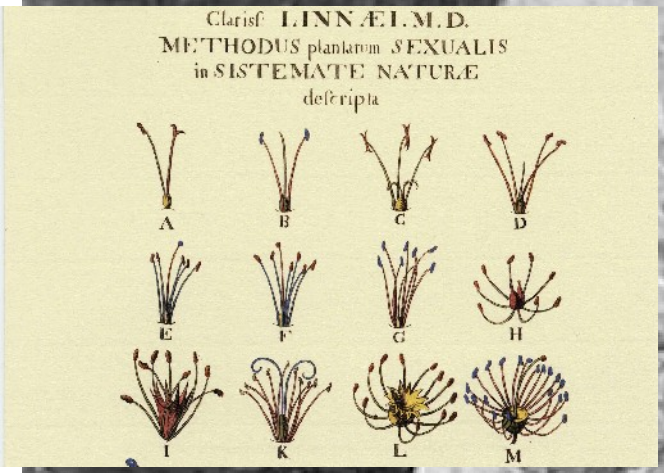
более 800 – 800-400 – 399-50



европейские ботанические сады – 1500-е годы: экзотика




Andromæda
ficta et vera.
Mystica et genuina.
Figurata et Depicta


Clarisſ. LINNÆI M.D.
METHODUS plantarum SEXUALIS
in SISTEMATE NATURÆ
deſcripta
A
B
C
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ETT HUNDRA KRONOR
RIKSBANK
100
1325995103

The Semper Augustus tulip is famous as the most expensive tulip bulb sold at the height of ***tulipmania*** in the Netherlands in 1637: 13,000 florins over 40x the annual salary of a skilled craftsman.

Tulipmania:
P. Brueghel
ca. 1640

Карл Иванович Максимович:
1859 to 1864 visited China, Korea and Japan…

…collecting Japanese barberry (*Berberis thunbergii*) sent to St. Petersburg botanical garden and subsequently to Arnold Arboretum in 1875

Notable European Botanical explorers of East Asia – "the golden age of European botany":

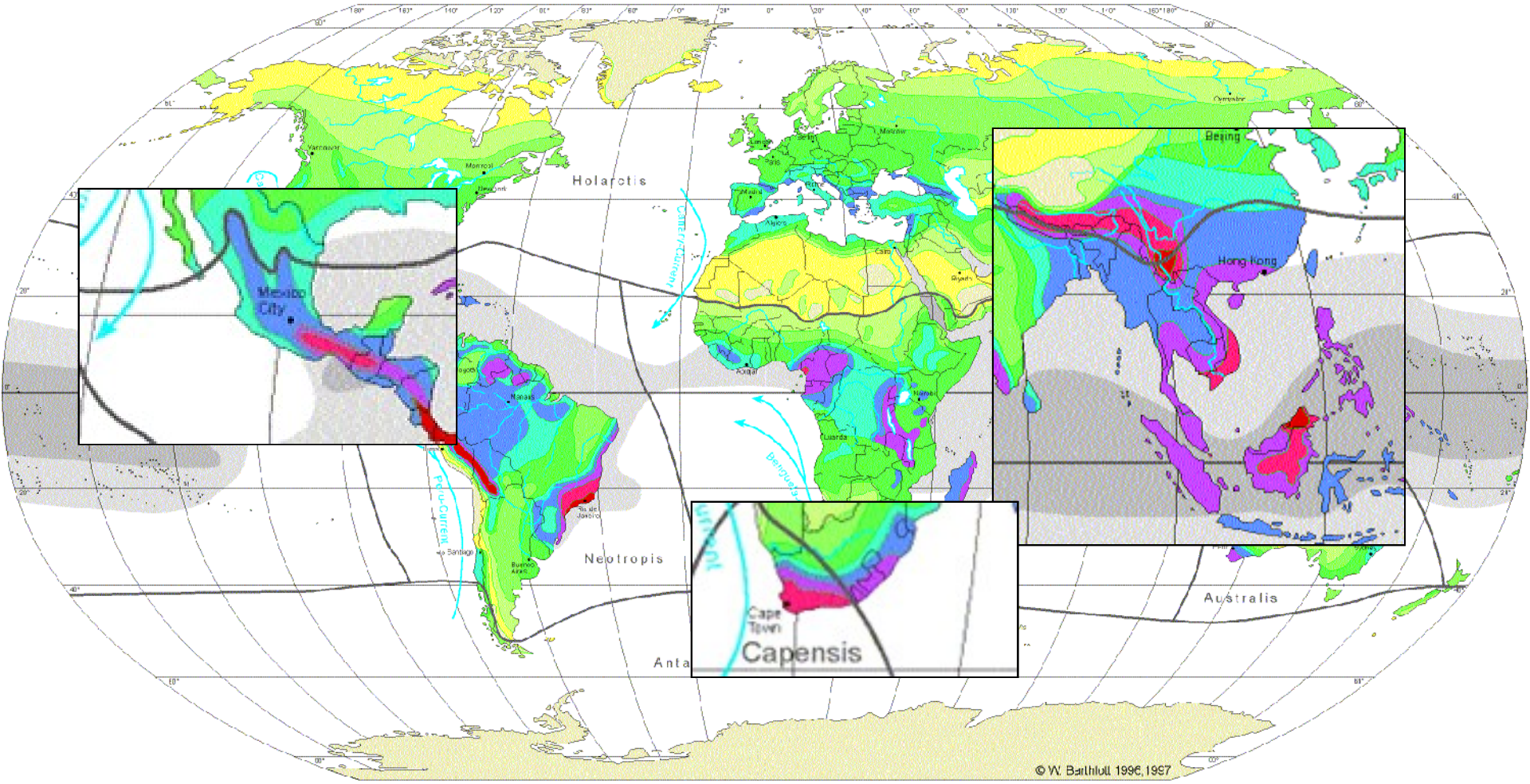
P. Osbeck 1750s
C. P. Thunberg 1770s – 80s
R. Fortune 1840s-60s
C. J. Maximovich 1850s – 60's
R. Oldham 1860s
A. David 1860s - 80s
P.J.M. Delavay 1860s- 90s
A. Henry 1880s
J. H. Veitch 1890s
E. H. Wilson 1890s- 1910s
C. S. Sargent 1900 (directed others 1870-1920s)
F. N. Meyer 1900s – 1910s
R Farrer 1900s-1920s
G. Forrest 1900s – 30s
F. Kingdon-Ward 1900s-50s,
J. Rock 1920-1940s

азиатские ботанические сады – 4000 лет назад: гармония, идеализированная природа


225 m
Pointer lat 35.659956° lon 139.763

почему Восточная Азия?

GLOBAL BIODIVERSITY: SPECIES NUMBERS OF VASCULAR PLANTS



Robinson Projection
Standard Parallels 38°N und 38°S
Scale 1: 130000000

Diversity Zones (DZ): Number of species per 10.000km²

- DZ 1 (<100)
- DZ 2 (100 - 200)
- DZ 3 (200 - 500)
- DZ 4 (500 - 1000)
- DZ 5 (1000 - 1500)
- DZ 6 (1500 - 2000)
- DZ 7 (2000 - 3000)
- DZ 8 (3000 - 4000)
- DZ 9 (4000 - 5000)
- DZ 10 (≥5000)

Capensis floristic regions

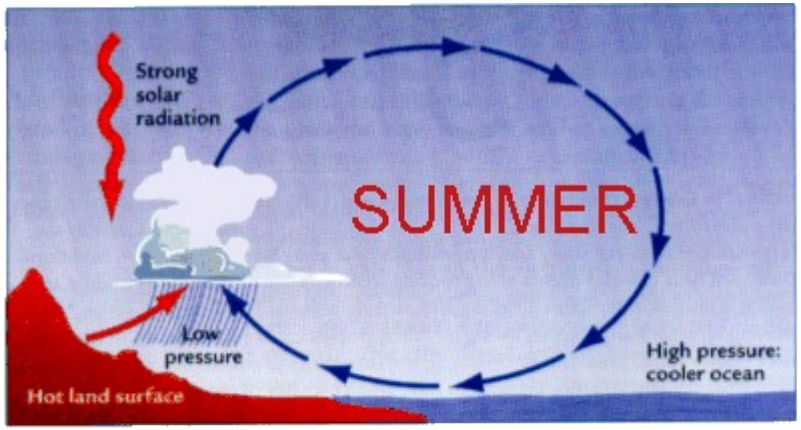
sea surface temperature
- >23°C
- >27°C

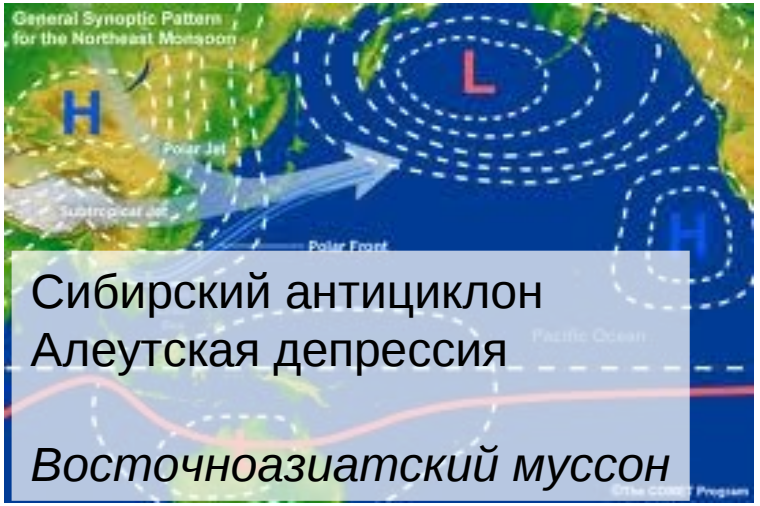
cold currents

W. Barthlott, N. Biedinger, G. Braun
F. Feig, G. Kier, W. Lauer & J. Mutke 1997
modified after
W. Barthlott, W. Lauer & A. Placke 1996
Department of Botany and Geography
University of Bonn
German Aerospace Research Establishment Cologne

Cartography: M. Gref
Department of Geography
University of Bonn

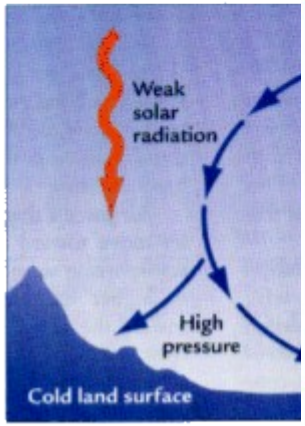
Муссон

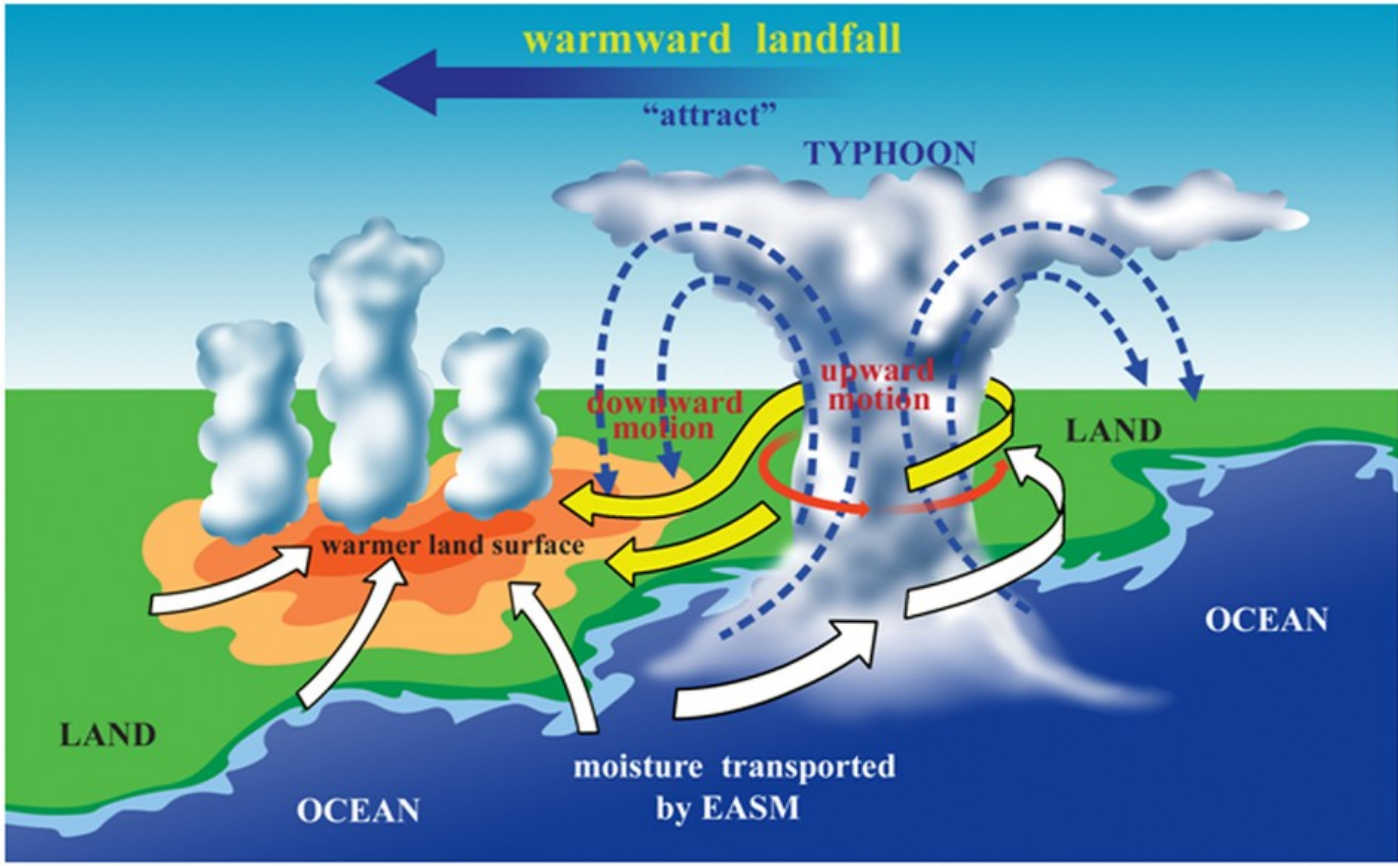




Сибирский антициклон
Алеутская депрессия

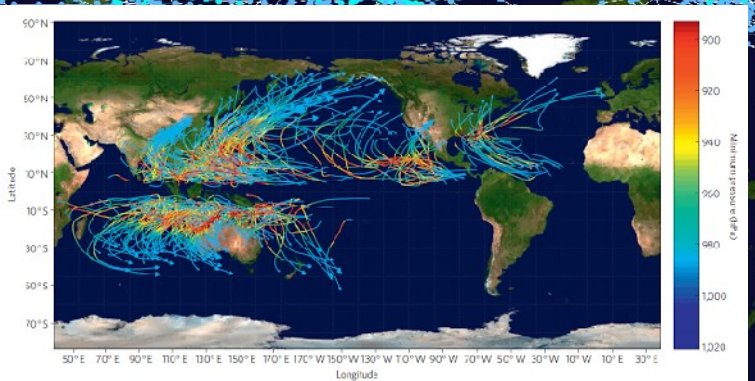
Восточноазиатский муссон



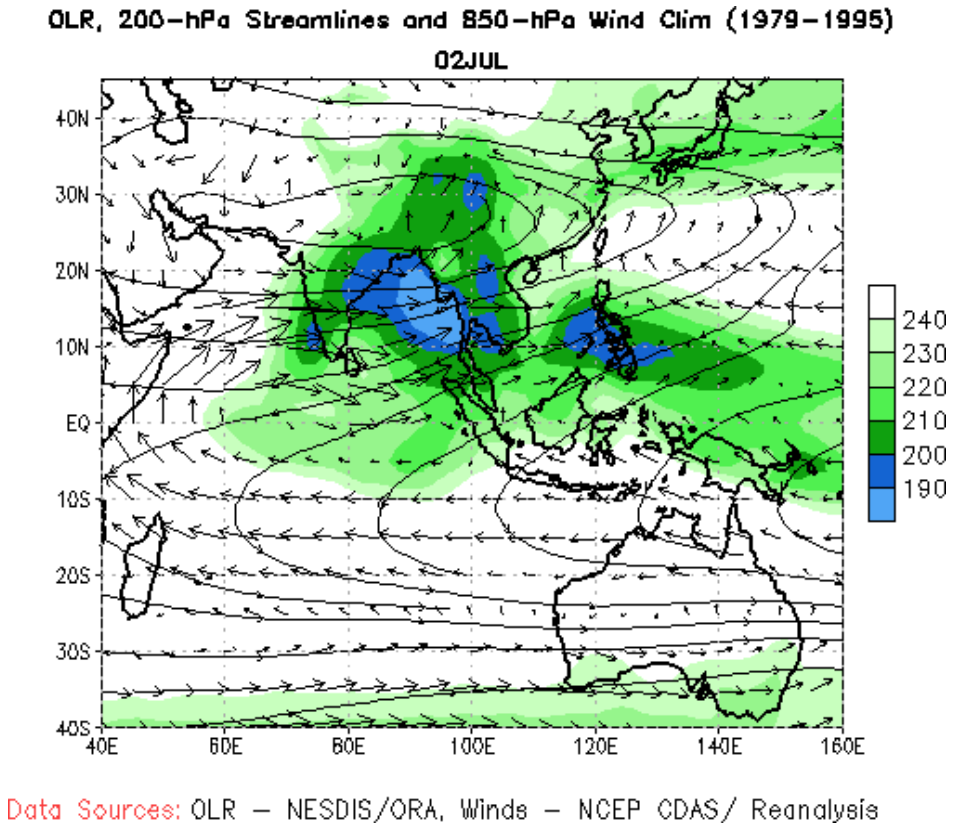


Основные очертания района активности муссона на востоке Азии

Следы тайфунов на Востоке Азии (Tokyo University of Information Sciences)



Дождевой индекс (Tokyo University of Information Sciences)

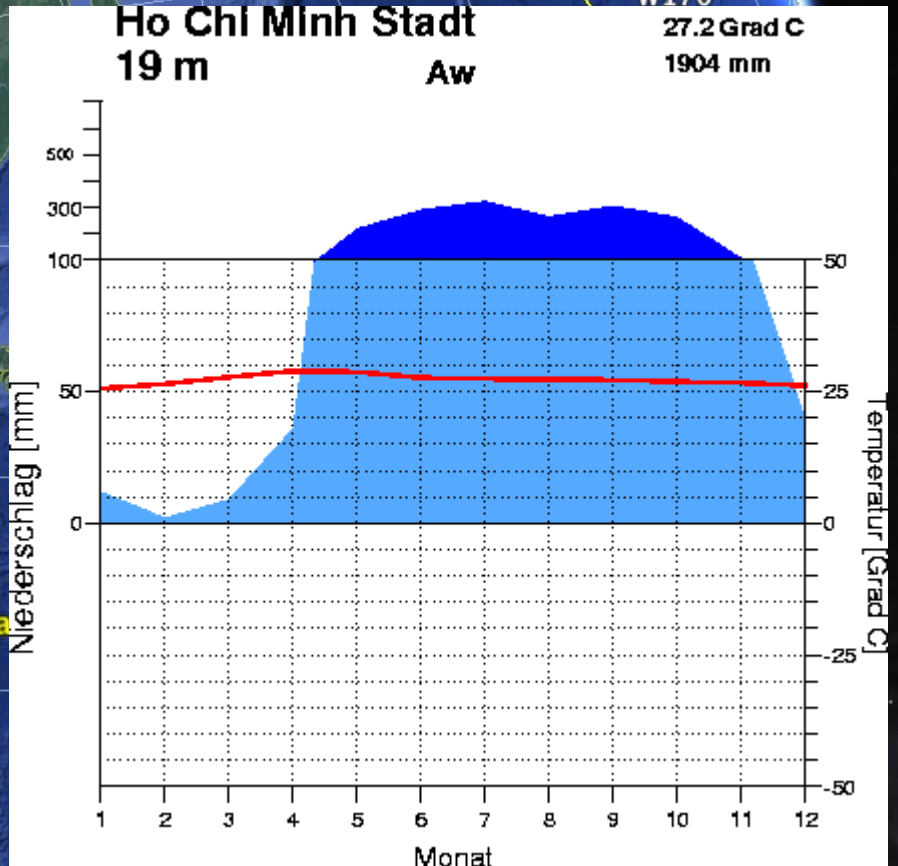


Динамика выпадения осадков:

на востоке Азии

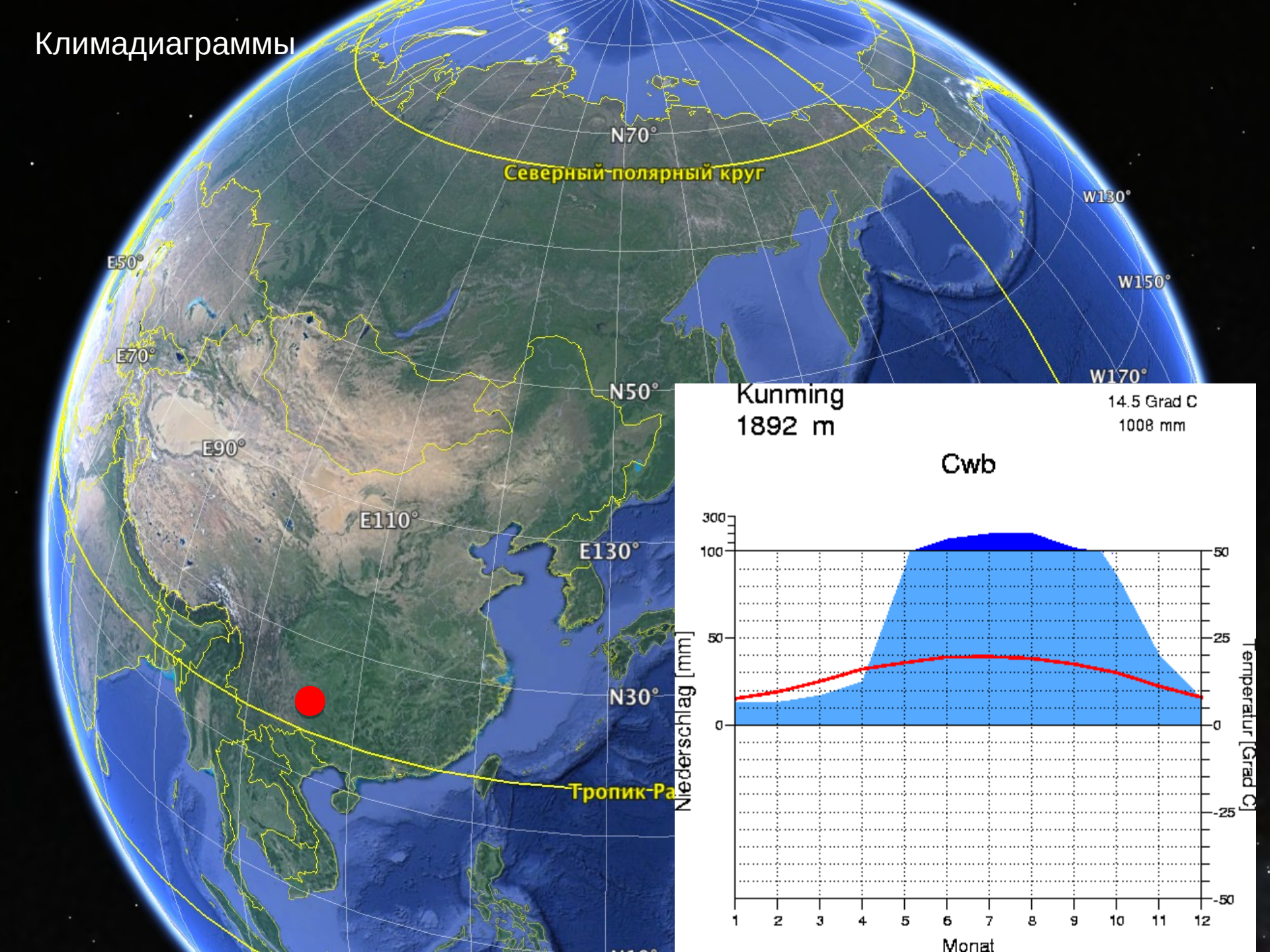
минимум зимой
и максимум летом

Климадиаграммы

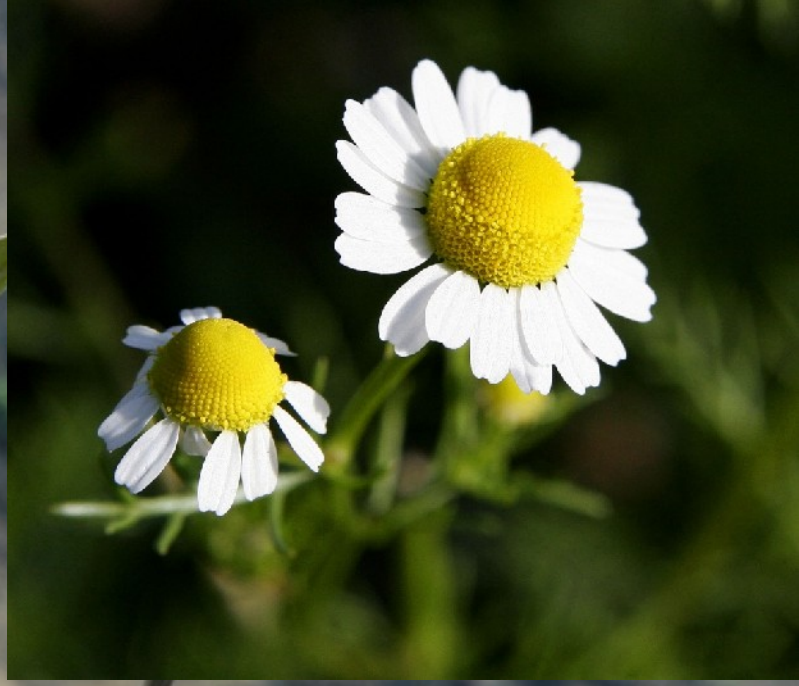


ЗОНА ПОЛУЛИСТОПАДНЫХ ШИРОКОЛИСТВЕННЫХ ЛЕСОВ

Климадиаграммы



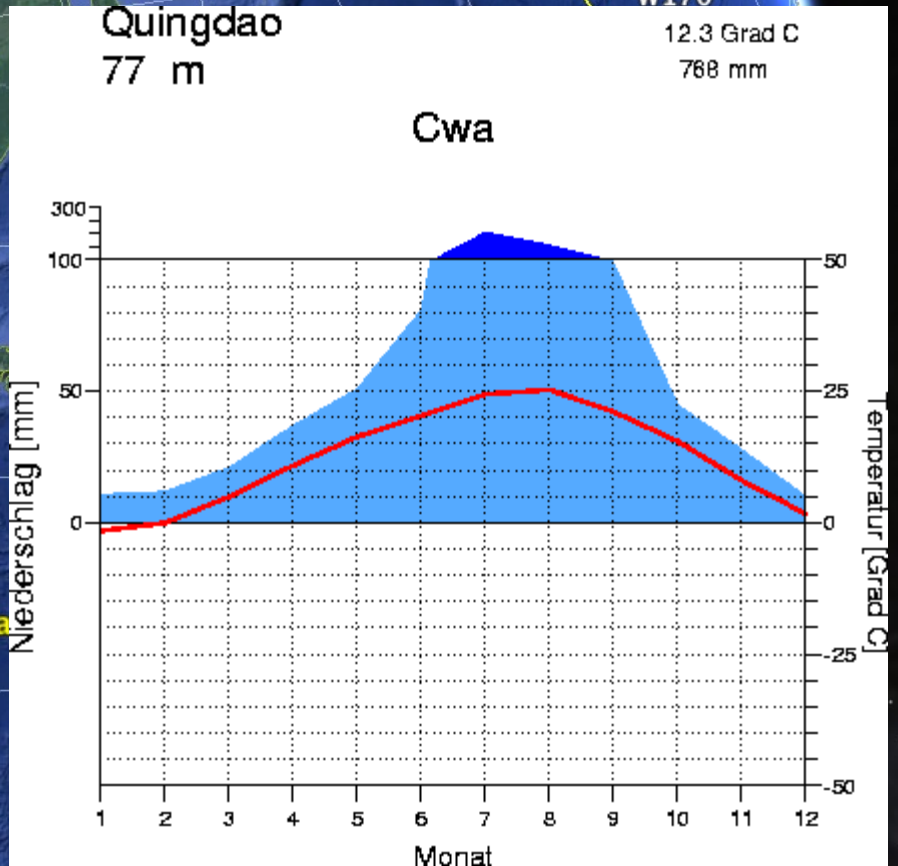

6000
5000
4000
3000
2000
1000
0
10
15
20.1
24.8
30



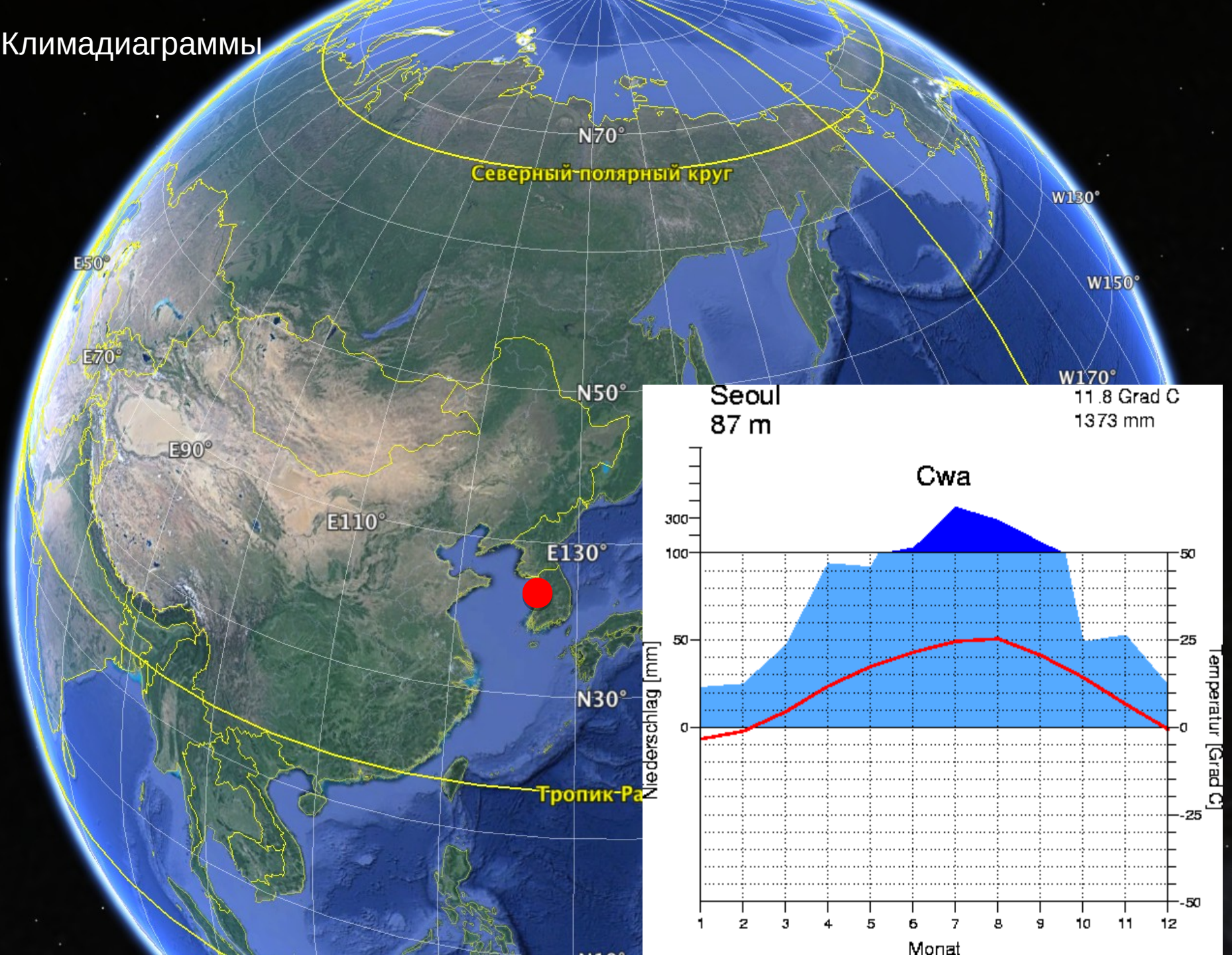
Nouelia insignis

Corallodiscus flabellatus

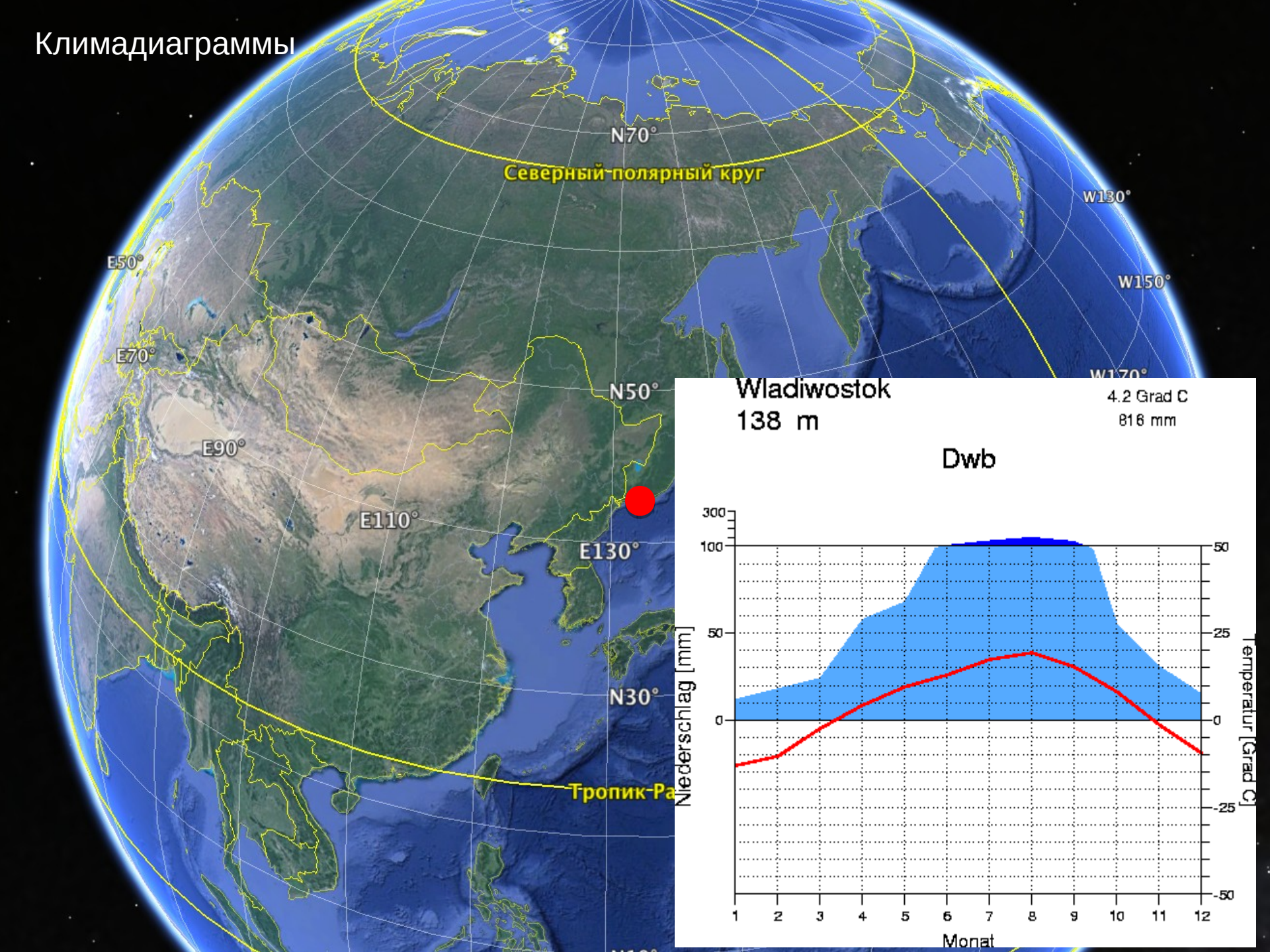
Климадиаграммы



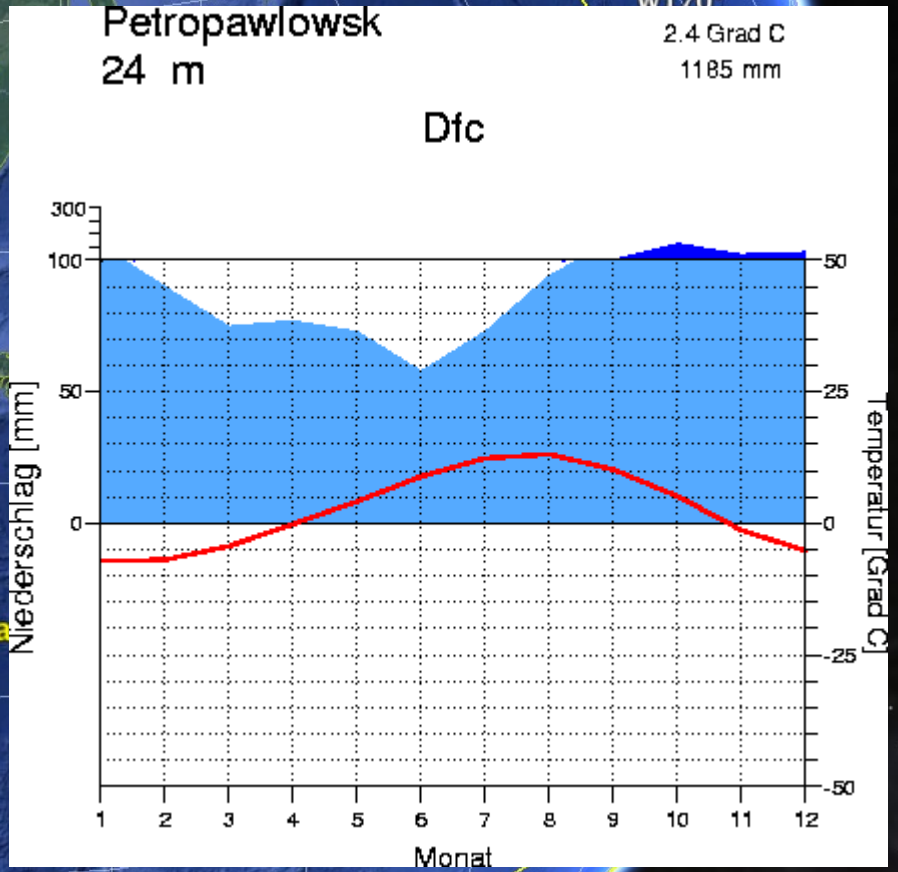
Климадиаграммы



Климадиаграммы

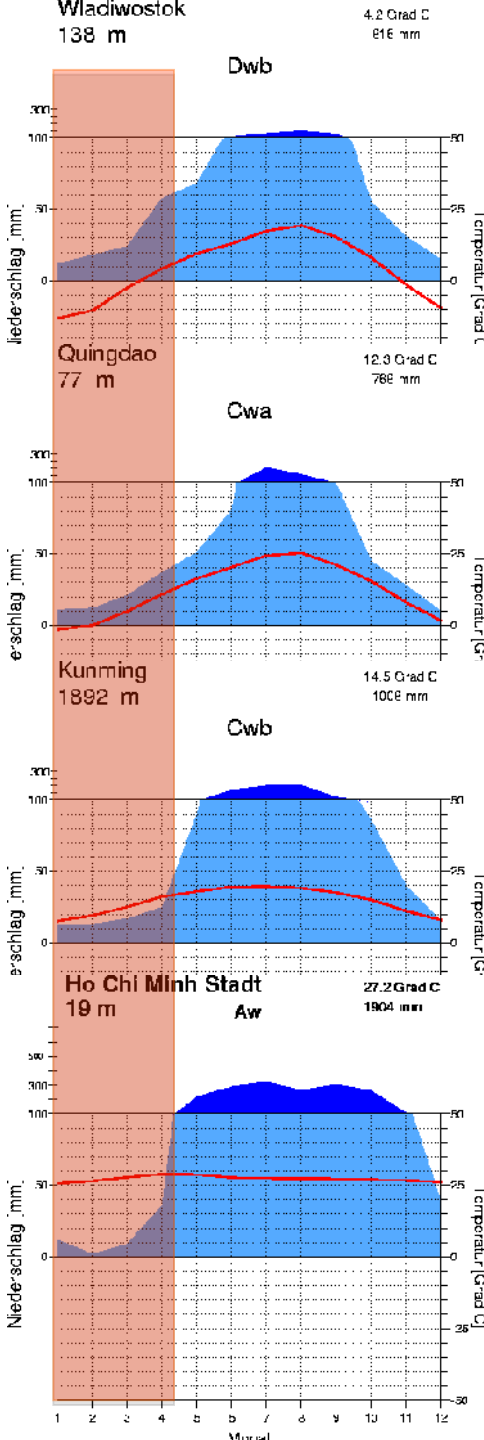


Климадиаграммы

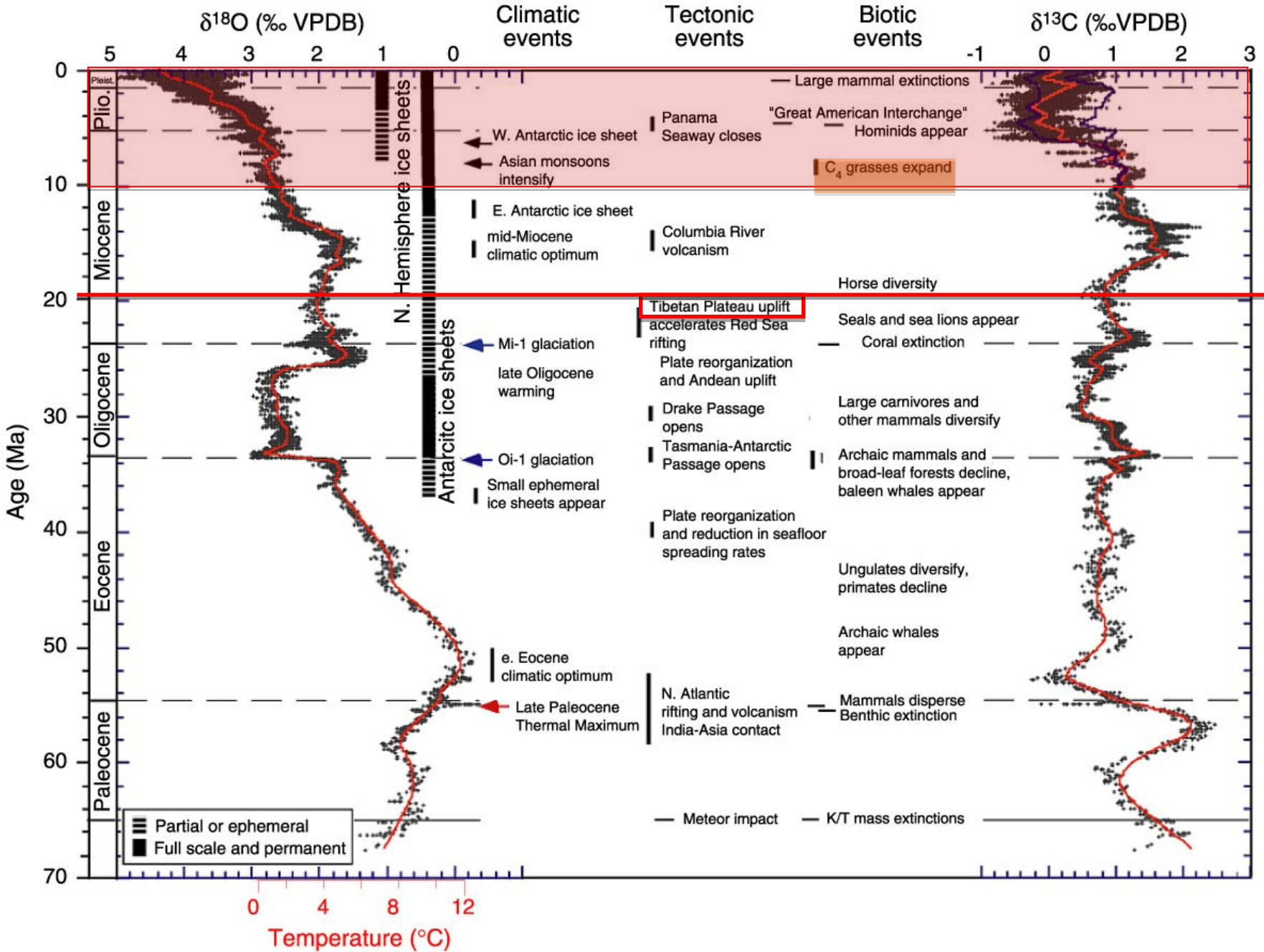


Распределение осадков в районах с муссонным климатом

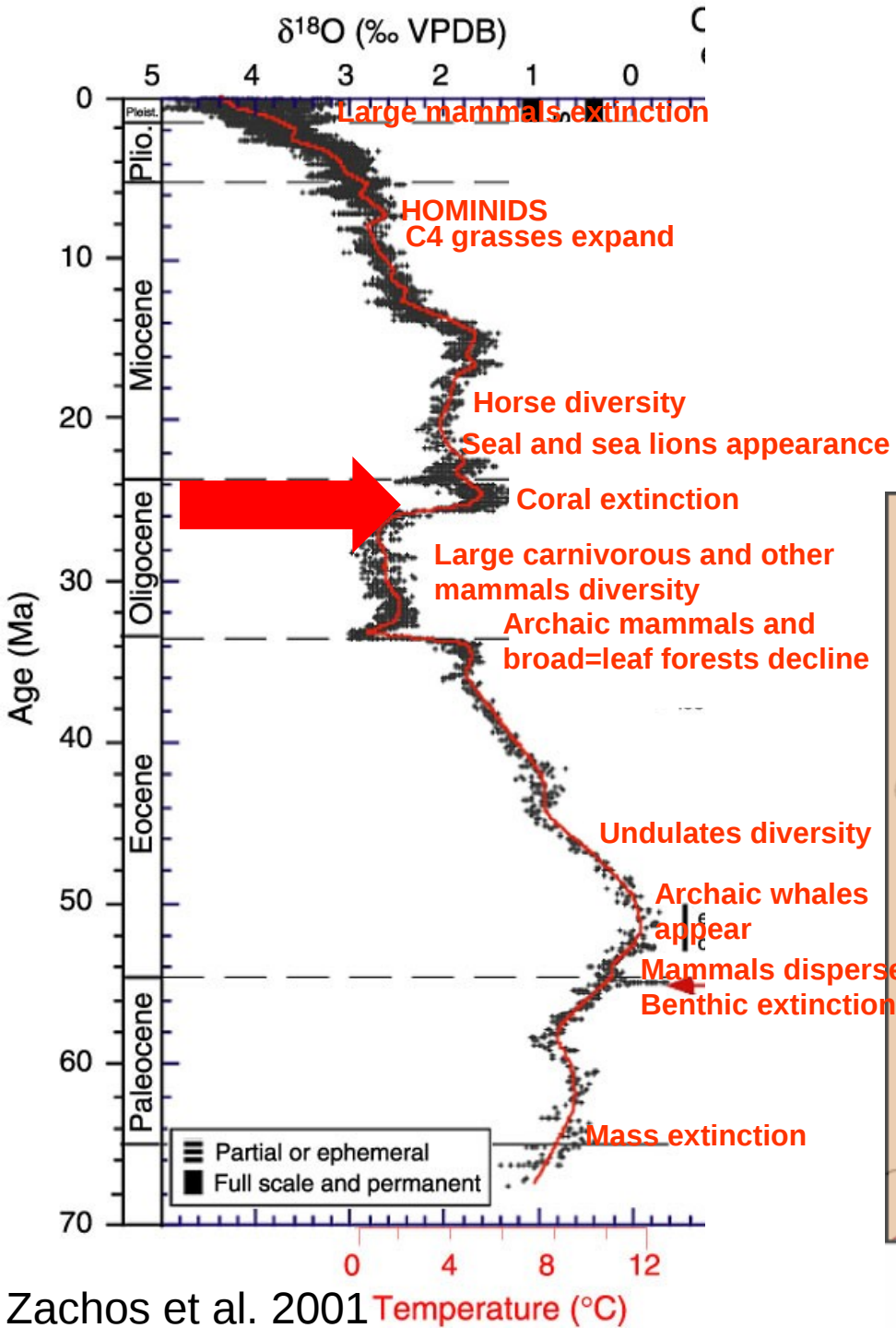
МАЛОЕ КОЛИЧЕСТВО ОСАДКОВ В ЗИМНИЕ МЕСЯЦЫ



Формирование азиатского муссона (Zachos et al., 2001)

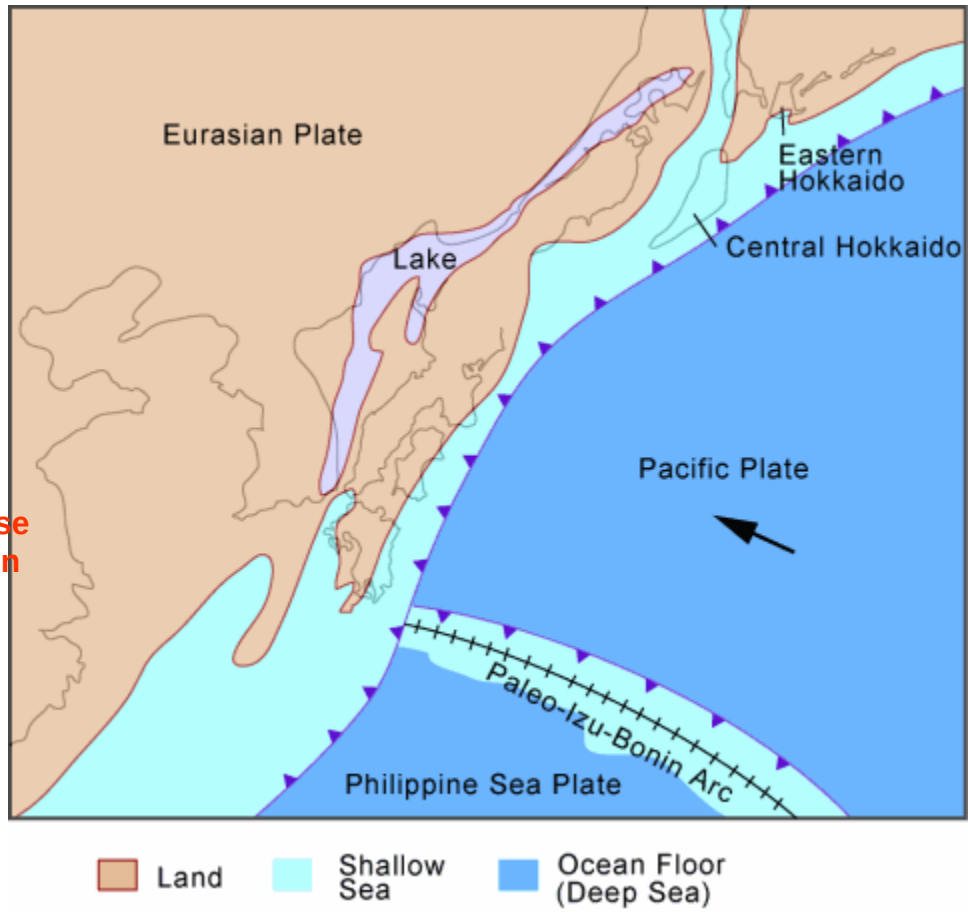


Sea of Japan formation

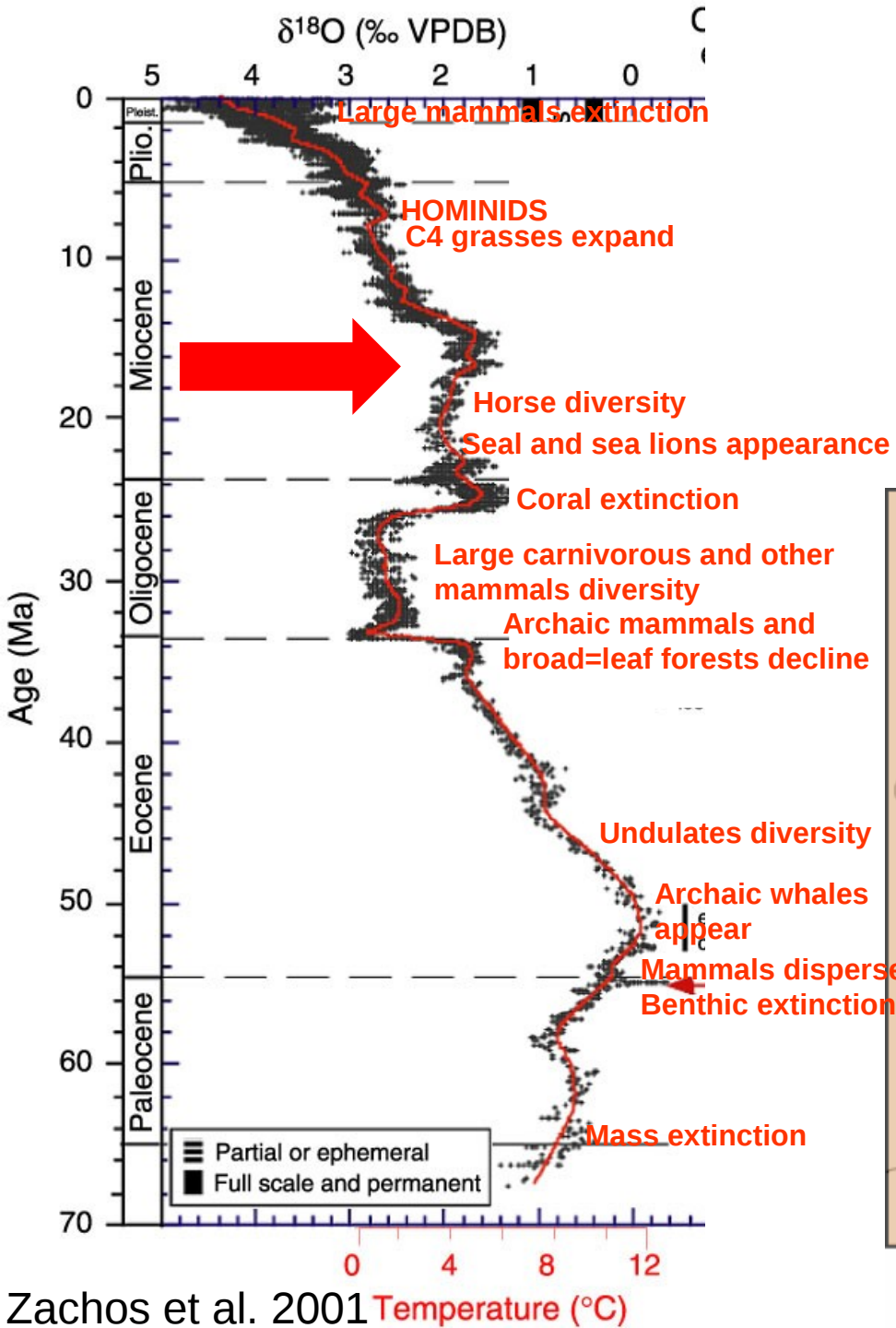


Zachos et al. 2001

ARCTOTERTIARY FLORA

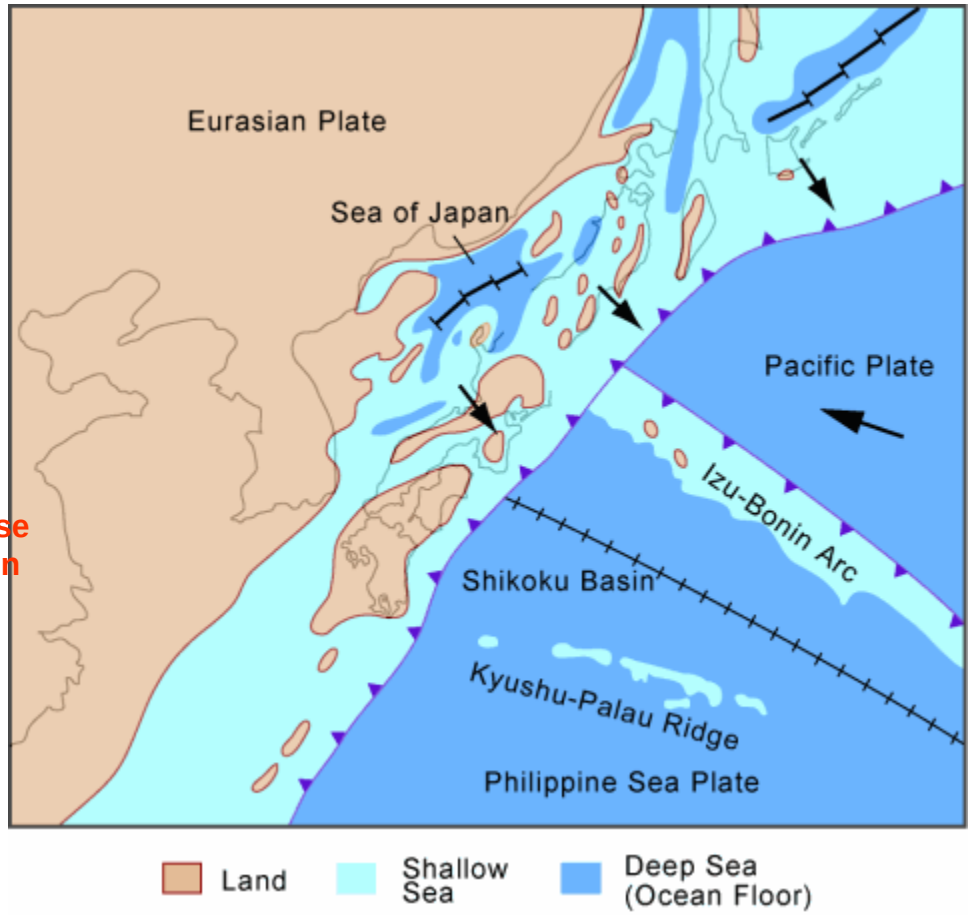


Sea of Japan formation

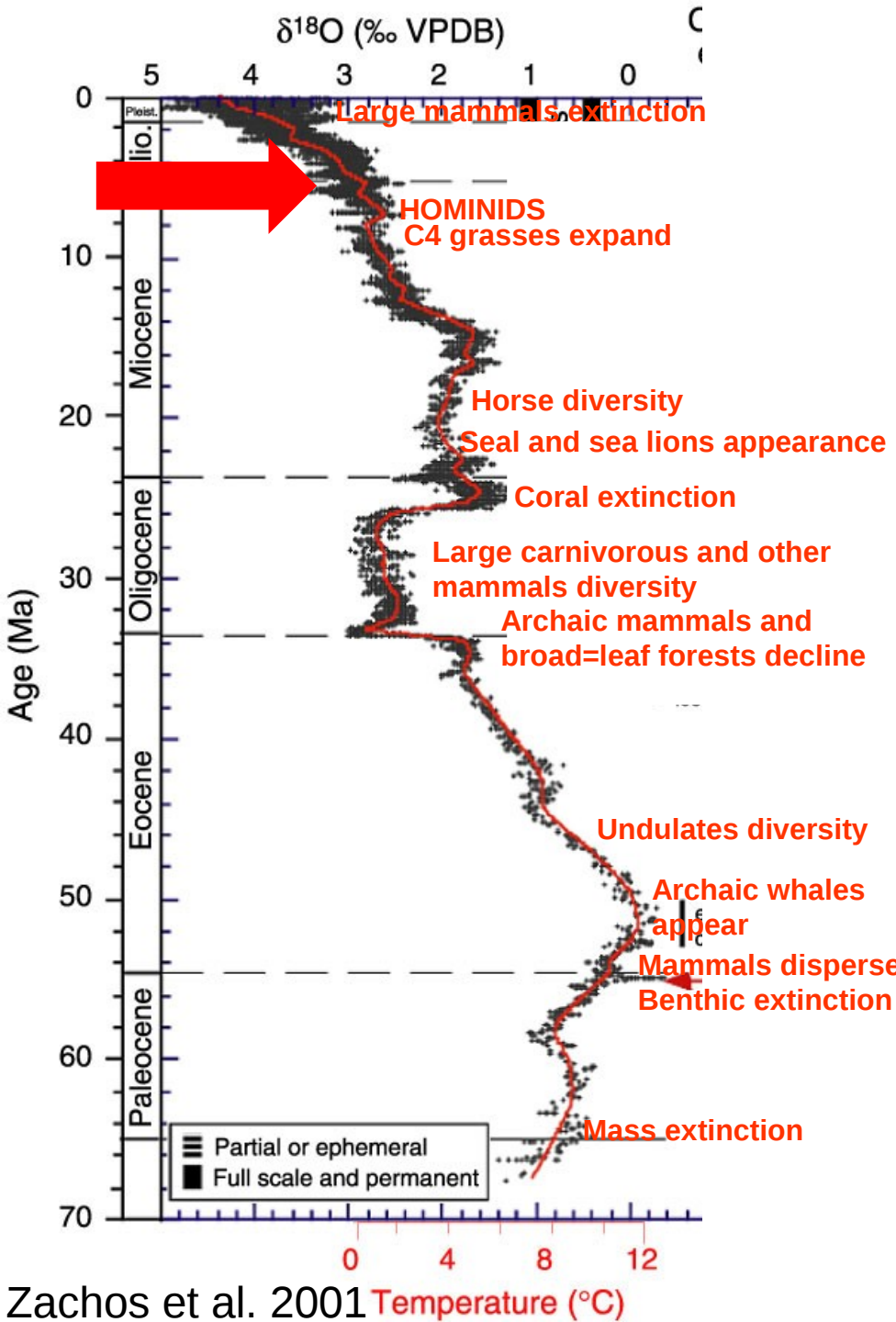


Zachos et al. 2001

ARCTOTERTIARY FLORA DECLINE
modern plant taxa formation



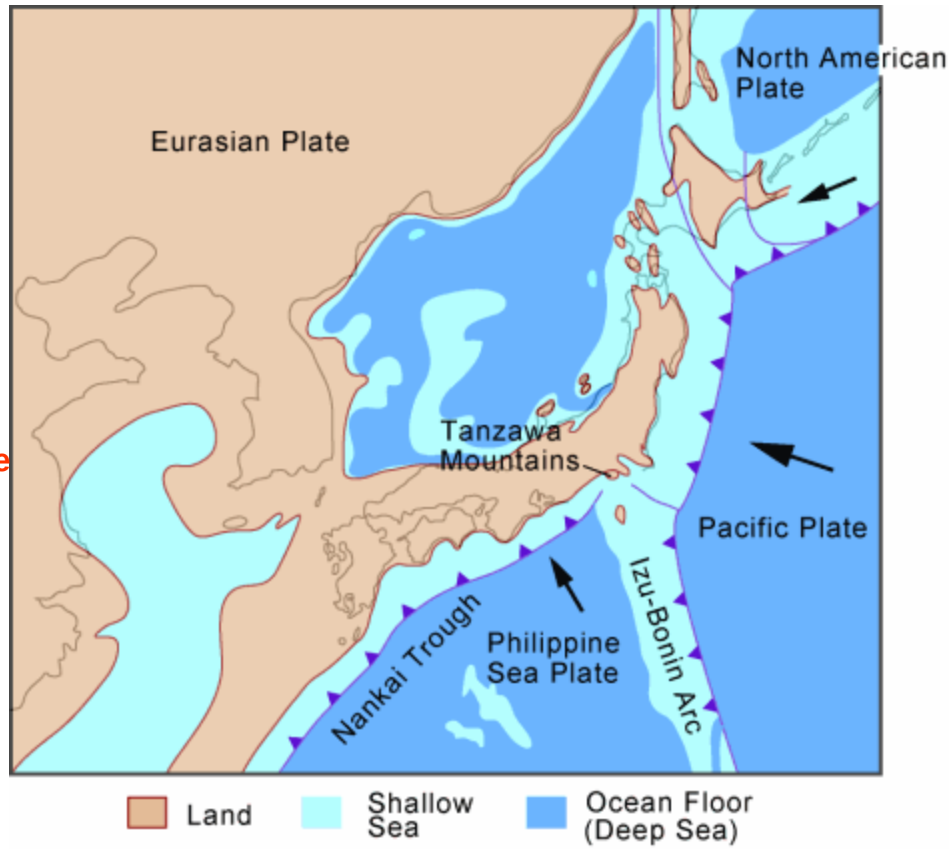
Sea of Japan formation



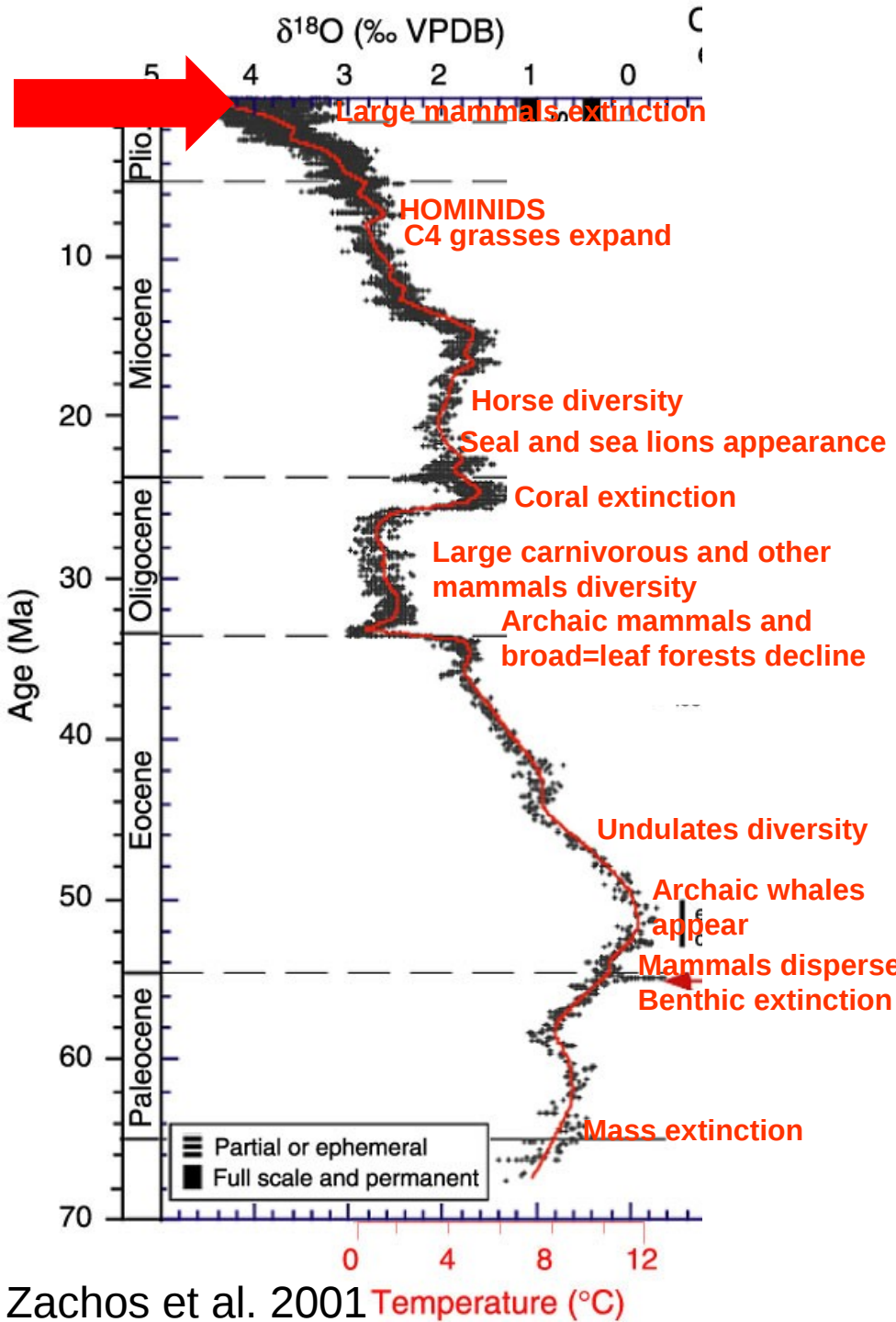
Zachos et al. 2001

Modern plant taxa formation

Species composition of island and mainland is the same



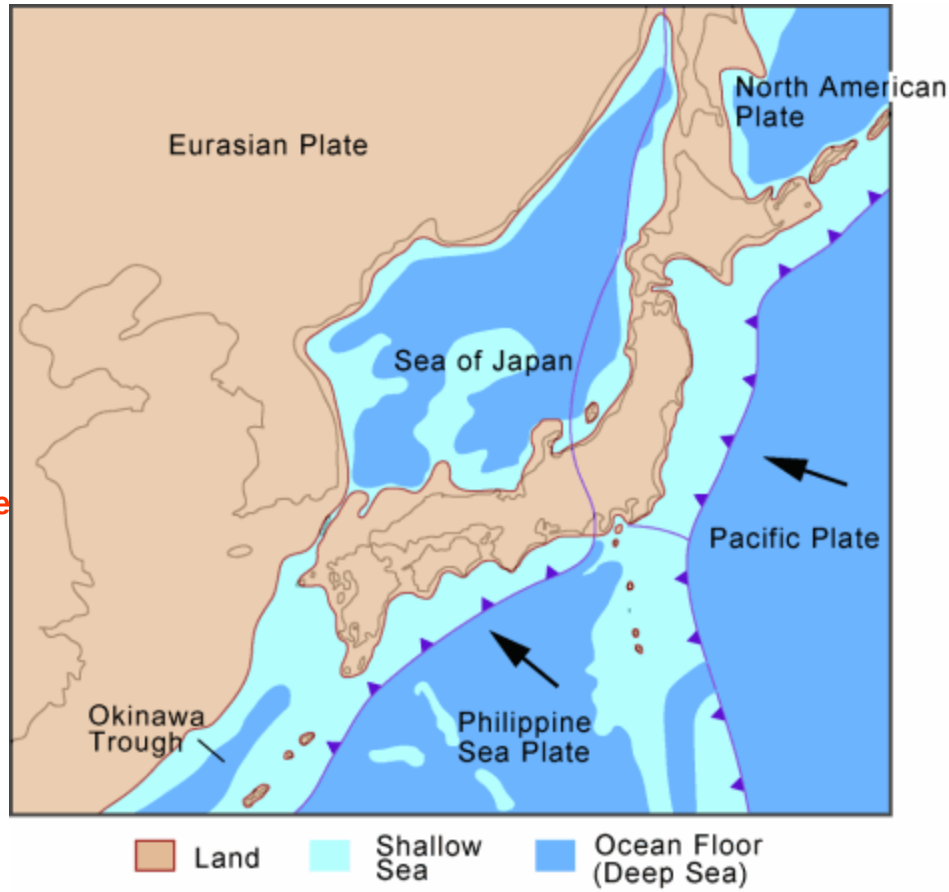
Sea of Japan formation



Zachos et al. 2001

Humidity dependent species on islands

Drought-tolerant species on mainland



материалы

База данных растительности

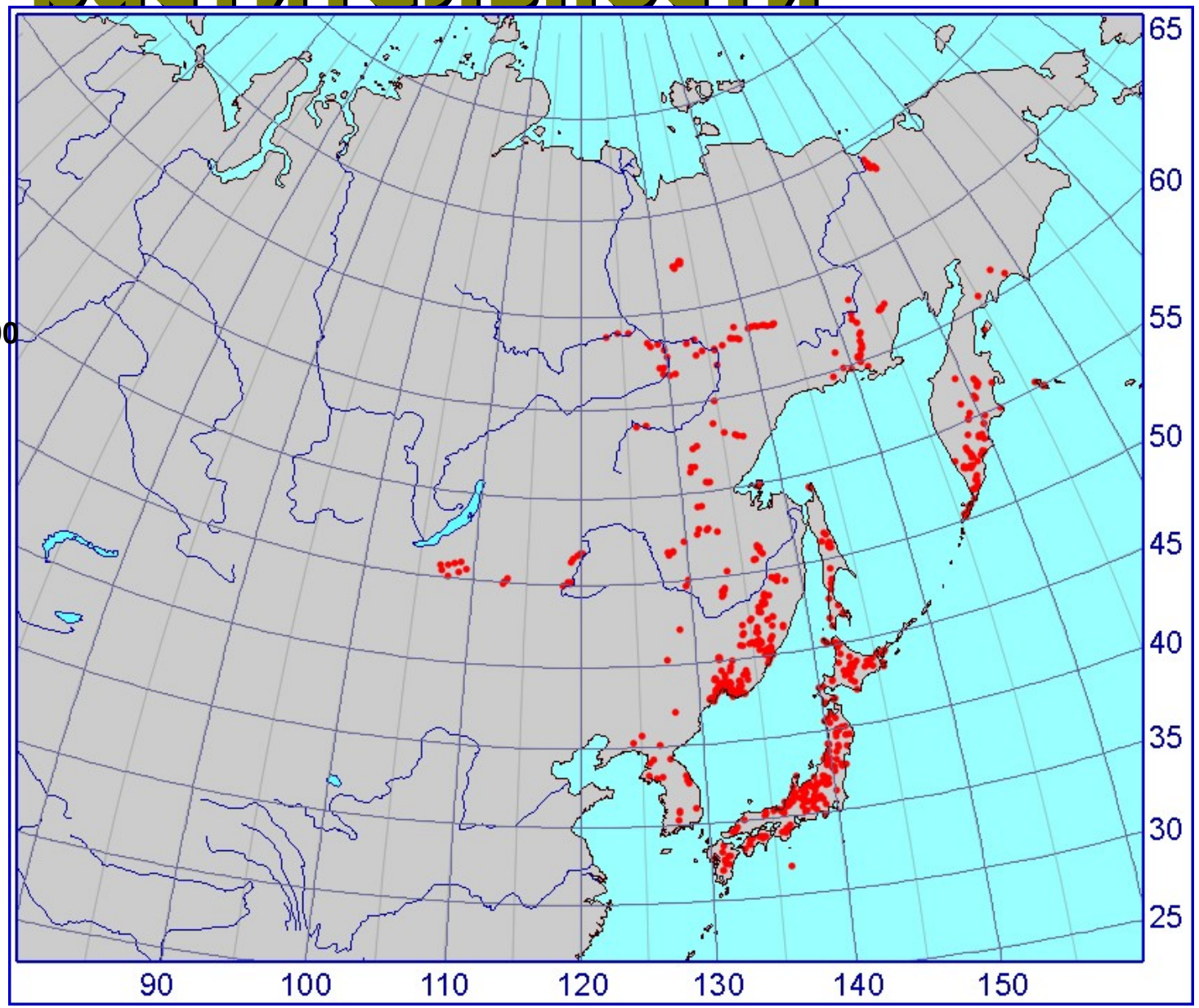
5500 описаний из различных регионов северо-восточной Азии

Источники:

полевые работы – 4000

публикации – 1500

(J.-W. Kim,
J.-S. Song
N.B. Ermakov
Y. Nakamura
В. Нешатаева
Л. Тюлина)



Климатическая база данных

comprises data on temperature and precipitation of 2200 climatic stations

observation period 1930-1960

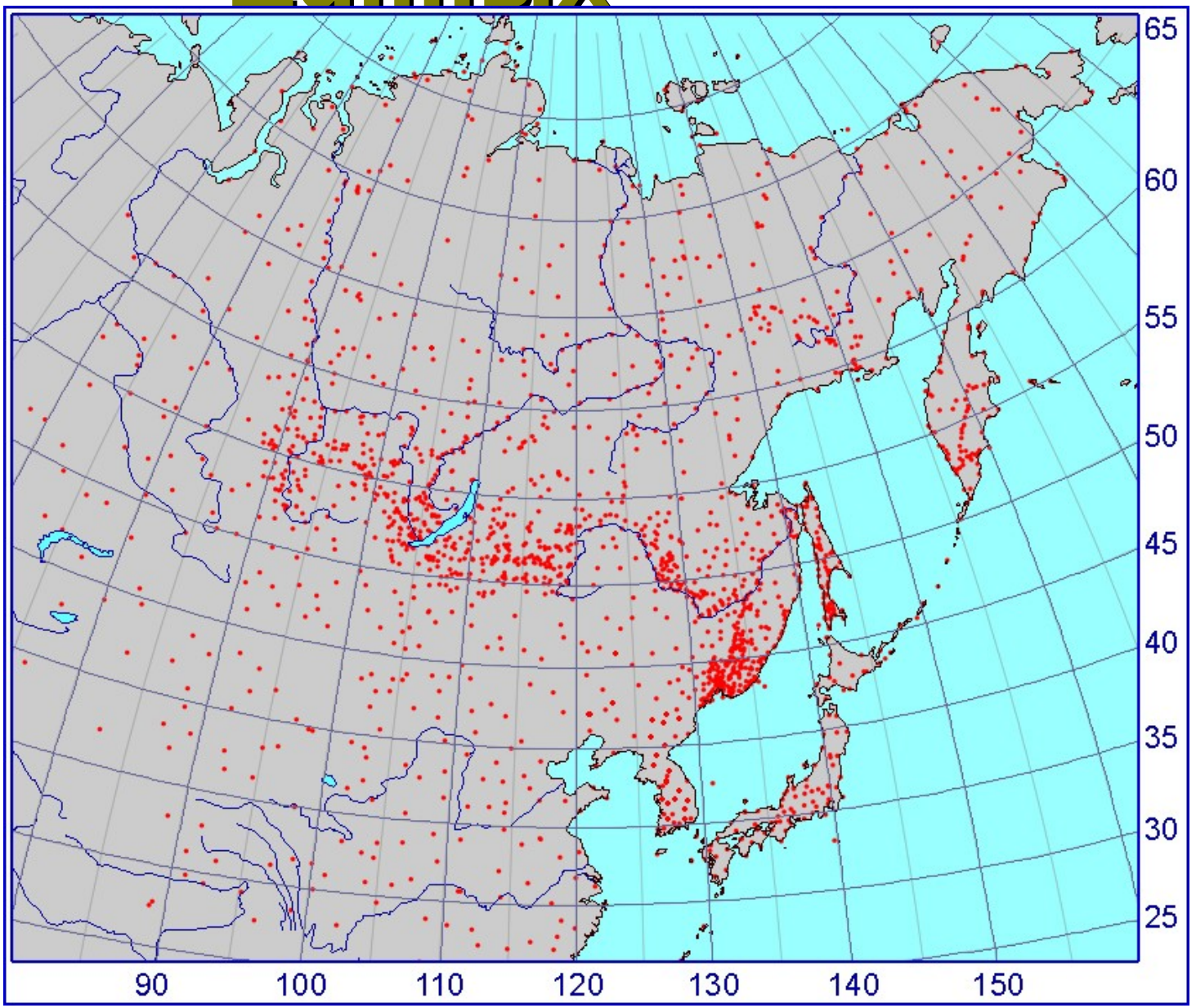
Sources

Reference book on climates of the USSR, 1962-1969

Zhang, Lin, 1983

Kim, 1982

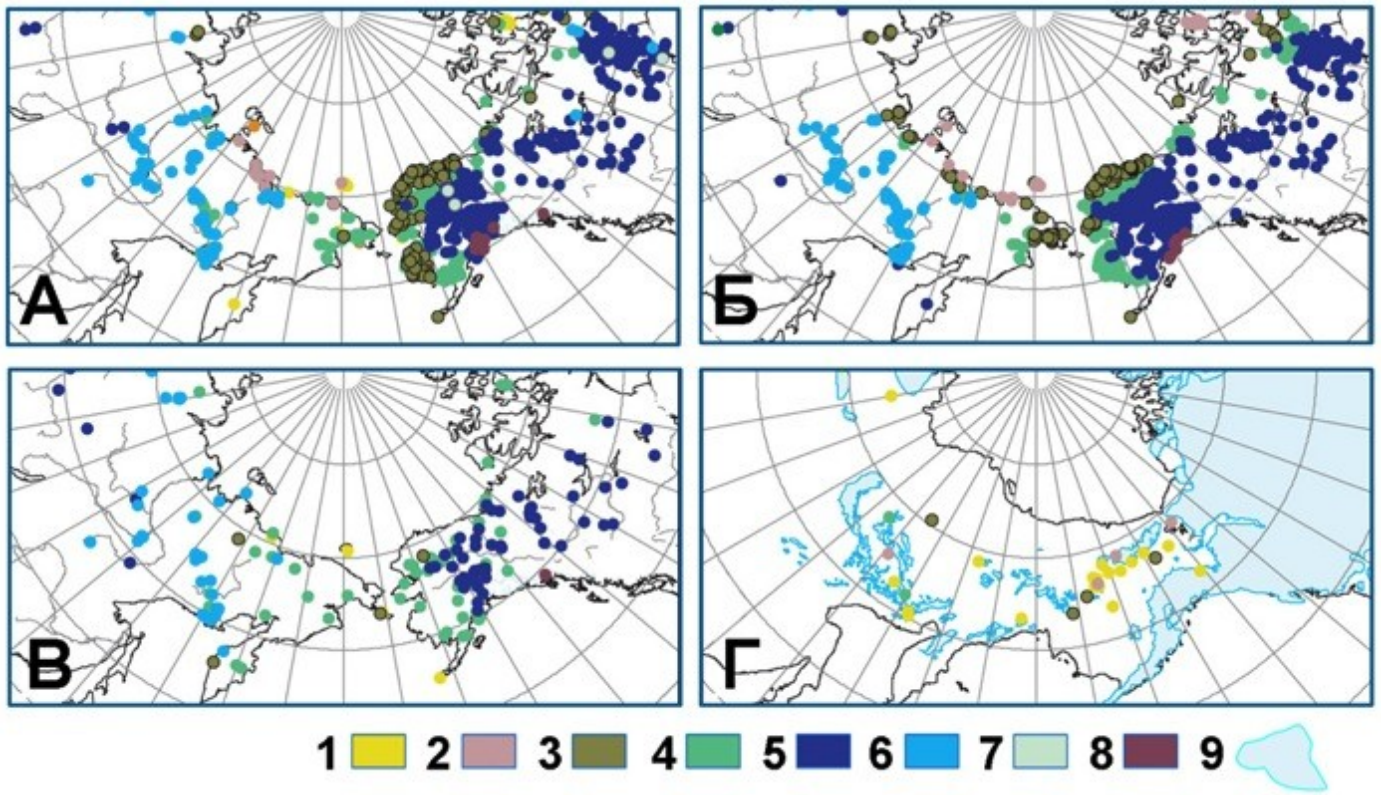
Japan Meteorological Agency, 1981-1983



Палеоданные

compiled from various literary sources for Northern Asia and western North America and palaeoreconstructions for Pleistocene and Holocene elaborated up to date

Bigelow, Brubaker, Edwards, Harrison, Prentice, Anderson, Andreev, Bartlein, Christensen, Cramer, Kaplan, Lozhkin, Matveyeva, Murray, McGuire, Razzhivin, Ritchie, Smith, Walker, Gajewski, Wolf, Holmqvist, Igarashi, Kremenetskii, Paus, Pisaric, Volkova (2003): Climate change and Arctic ecosystems: 1. Vegetation changes north of 55N between the last glacial maximum, mid-Holocene, and present. *J. GEOPHYSICAL RESEARCH* 108



анализ данных: климат

Важнейшие климатические факторы

солнечная радиация

тепло

влага

Биоклиматическая концепция Rivas-Martínez 1960-2008

SYSTEM OF INDICES (Rivas-Martínez 1960-2008, http://www.globalbioclimatics.org)

T: Mean annual temperature
M: Mean maximum temperature of the coldest month of the year
m: Mean minimum temperature of the coldest month of the year
Tmin: Mean temperature of the coldest month
Tmax: Mean temperature of the warmest month
P: Mean annual precipitation
Ps: Summer Precipitation (3 summer months)
Pw: Winter Precipitation (3 winter months)
Pp: Yearly Precipitation in warm months
Tp: Sum of the monthly average temperature of months with positive mean temperatures
Tps: Positive Summer Temperature
Ic: Continentality Index (yearly thermic interval). Ic = Tmax – Tmin
Io: Ombrothermic Index. Io = (Pp/Tp) *10.
It: Thermicity Index. It = (T + m + M) *10.
Pcm1: Precipitation of warmest four months of the year [Pcm1= Ps4]
Pcm2: Precipitation of the following four months.
Pcm3: Precipitation of the previous four months.
Ioe: Ombro-Evapotranspiration Index. The quotient resulting value between the yearly positive precipitation in mm and the value of Thornthwaite yearly evapotranspiration [Ioe=Pp/PE].

солнечная радиация

тепло

влага

какие индексы наиболее точно отражают распределение растительности?

широта, долгота и высота как основные переменные

climatic parameter = a + b*(Lat) + c*(Lon) + d*(Ele)

использование координат геоботанических описаний для определения климатических характеристик единиц растительности

$$
\begin{aligned}
IC = 109{,}497 + \; & A * [-24{,}600 - 1{,}168(Lat) + 0{,}428(Lon) - 0{,}014(Ele)] + \\
& B * [11{,}876 - 1{,}620(Lat) + 0{,}357(Lon) + 0{,}011(Ele)] + \\
& C * [118{,}506 - 2{,}583(Lat) + 0{,}033(Lon) - 0{,}016(Ele)] + \\
& D * [239{,}799 - 3{,}816(Lat) - 0{,}222(Lon) - 0{,}017(Ele)] + \\
& E * [182{,}521 - 2{,}433(Lat) - 0{,}511(Lon) + 0{,}003(Ele)] + \\
& F * [-95{,}013 + 0{,}217(Lat) + 0{,}038(Lon) + 0{,}009(Ele)] + \\
& G * [-110{,}699 + 0{,}499(Lat) + 0{,}138(Lon) - 0{,}009(Ele)] + \\
& H * [-173{,}362 + 1{,}323(Lat) + 0{,}308(Lon) - 0{,}006(Ele)] + \\
& I * [-117{,}564 + 0{,}459(Lat) + 0{,}280(Lon) - 0{,}005(Ele)] + \\
& J * [-132{,}027 + 3{,}060(Lat) - 0{,}795(Lon) - 0{,}003(Ele)] + \\
& K * [-252{,}014 + 4{,}102(Lat) - 0{,}489(Lon) + 0{,}007(Ele)] + \\
& L * [-55{,}489 - 0{,}446(Lat) + 0{,}101(Lon) - 0{,}005(Ele)] + \\
& M * [-48{,}522 - 0{,}456(Lat) + 0{,}054(Lon) - 0{,}003(Ele)] + \\
& N * [-119{,}560 + 1{,}010(Lat) + 0{,}059(Lon) - 0{,}006(Ele)] + \\
& O * [46{,}506 + 0{,}689(Lat) - 1{,}090(Lon) + 0{,}001(Ele)] + \\
& P * [26{,}362 + 1{,}404(Lat) - 1{,}216(Lon) + 0{,}011(Ele)] + \\
& Q * [1{,}669(Lat) - 1{,}114(Lon) + 0{,}024(Ele)] + \\
& R * [-81{,}987 + 0{,}027(Lat) + 0{,}140(Lon) - 0{,}006(Ele)] + \\
& S * [-106{,}834 + 1{,}410(Lat) - 0{,}212(Lon) - 0{,}002(Ele)] + \\
& T * [-48{,}503 + 1{,}876(Lat) - 0{,}807(Lon) + 0{,}003(Ele)] + \\
& U * [4{,}998 + 0{,}866(Lat) - 0{,}892(Lon) + 0{,}025(Ele)] + \\
& V * [-120{,}088 + 1{,}172(Lat) - 0{,}009(Lon) - 0{,}002(Ele)] +
\end{aligned}
$$

Биоклиматические индексы Rivas-Martinez 1995-2005

http://www.globalbioclimatics.org)

T: Mean annual temperature
M: Mean maximum temperature of the coldest month of the year
m: Mean minimum temperature of the coldest month of the year
Tmin: Mean temperature of the coldest month
Tmax: Mean temperature of the warmest month
P: Mean annual precipitation
Ps: Summer Precipitation (3 summer months)
Pw: Winter Precipitation (3 winter months)
Pp: Yearly Precipitation in warm months
Wk: Kira's warmth index (sum of monthly average temperatures over 5ºC)
Tp: Sum of the monthly average temperature of months with positive mean temperatures
Pn: Sum of precipitation in months with negative monthly temperatures
Tps: Positive Summer Temperature
Ic: Continentality Index (yearly thermic interval). Ic = Tmax – Tmin
Io: Ombrothermic Index. Io = (Pp/Tp) *10.
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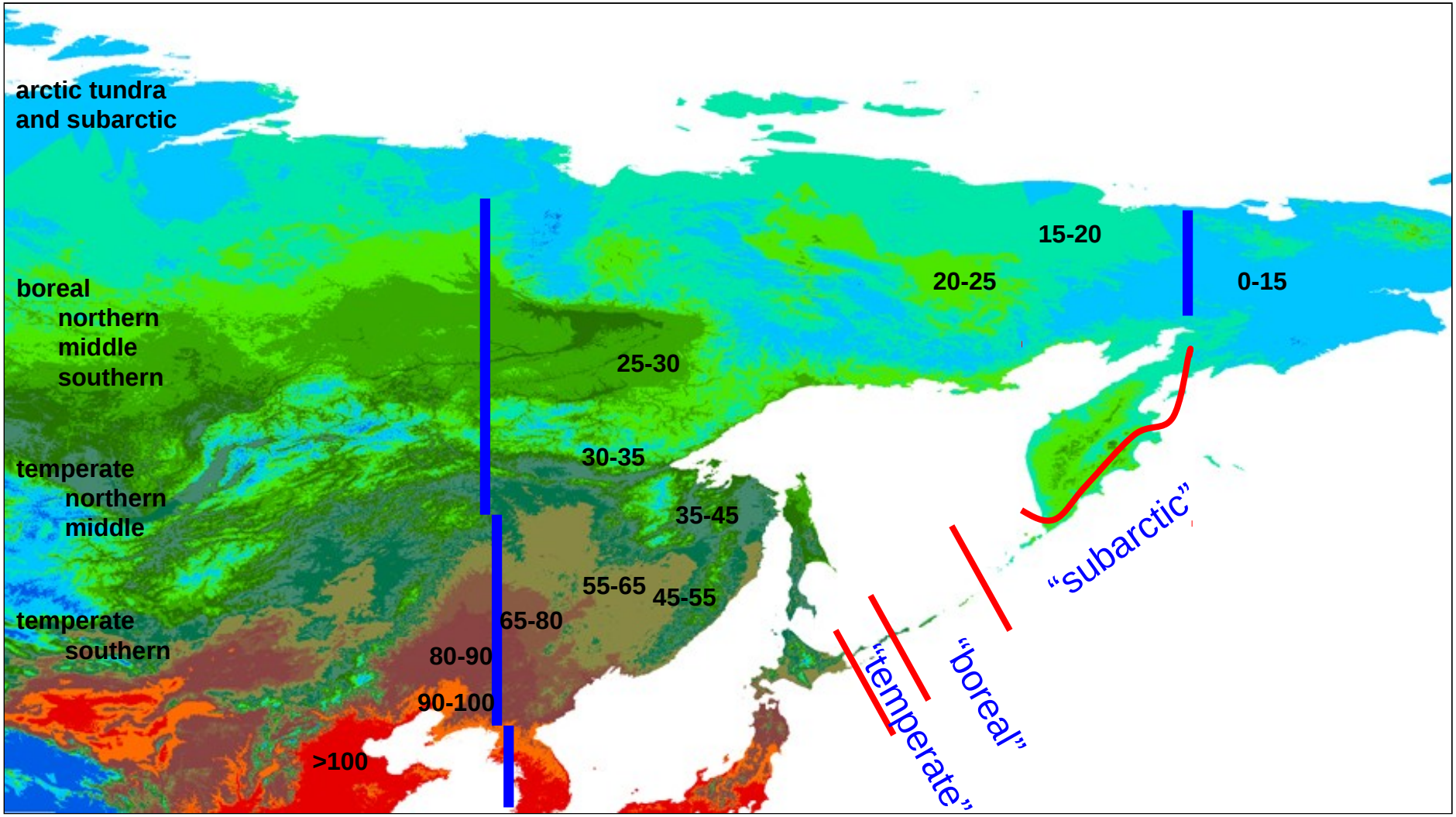
Pcm3: Precipitation of the previous four months.
Ioe: Ombro-Evapotranspiration Index. The quotient resulting value between the yearly positive precipitation in mm and the value of Thornthwaite yearly evapotranspiration [Ioe=Pp/PE].

	Adj. R^2	SS	df	MS	SS	df	MS	F	p
It	0.945984	74327444	87	854338.4	3690634	621	5942.711	143.5209	0.00
Ic	0.883374	125311.7	87	1440.364	15241.09	1152	13.23011	108.8702	0.00
Io	0.774693	22331.60	87	256.6851	5736.055	849	6.756248	37.99225	0.00
PN	0.775492	9380879	87	107826.2	2394134	835	2867.226	37.60645	0.00
Wk	0.969832	1039331	87	11946.34	29387.36	896	32.79840	364.2354	0.00
IOE	0.746998	127.4021	87	1.464392	31.94403	332	0.096217	15.21968	0.00

Warmth Kira's index (Wk, sum of monthly mean temperatures over 5ºC)



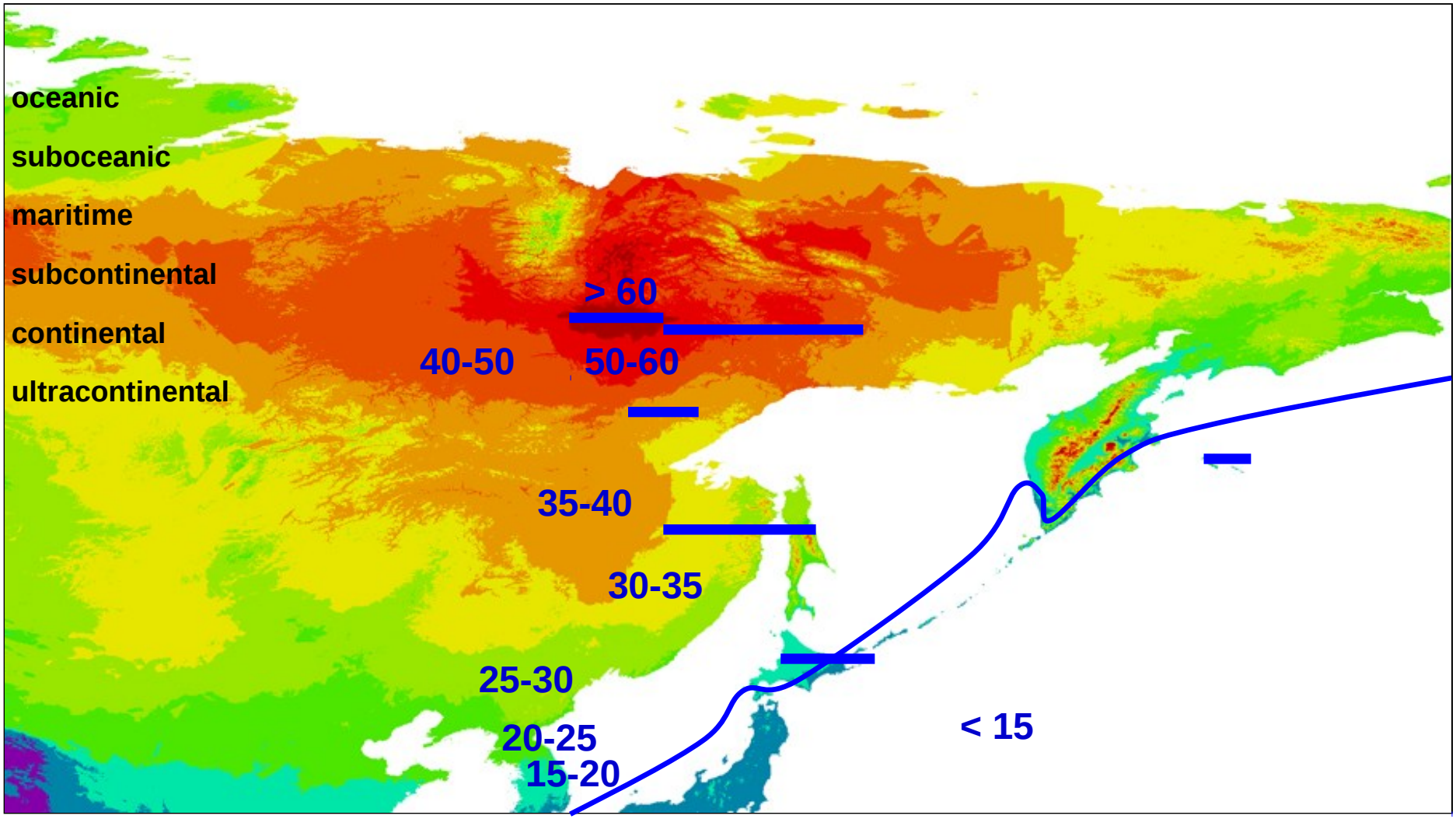
(Krestov et al. 2008)

Kira's coldness index (sum of monthly m

(Krestov et al. 2008)

sum of temperatures <5ºC is close to that of zone of nemoral deciduous forests in East Asia

Continentality index (IC = Tmax – Tmin)



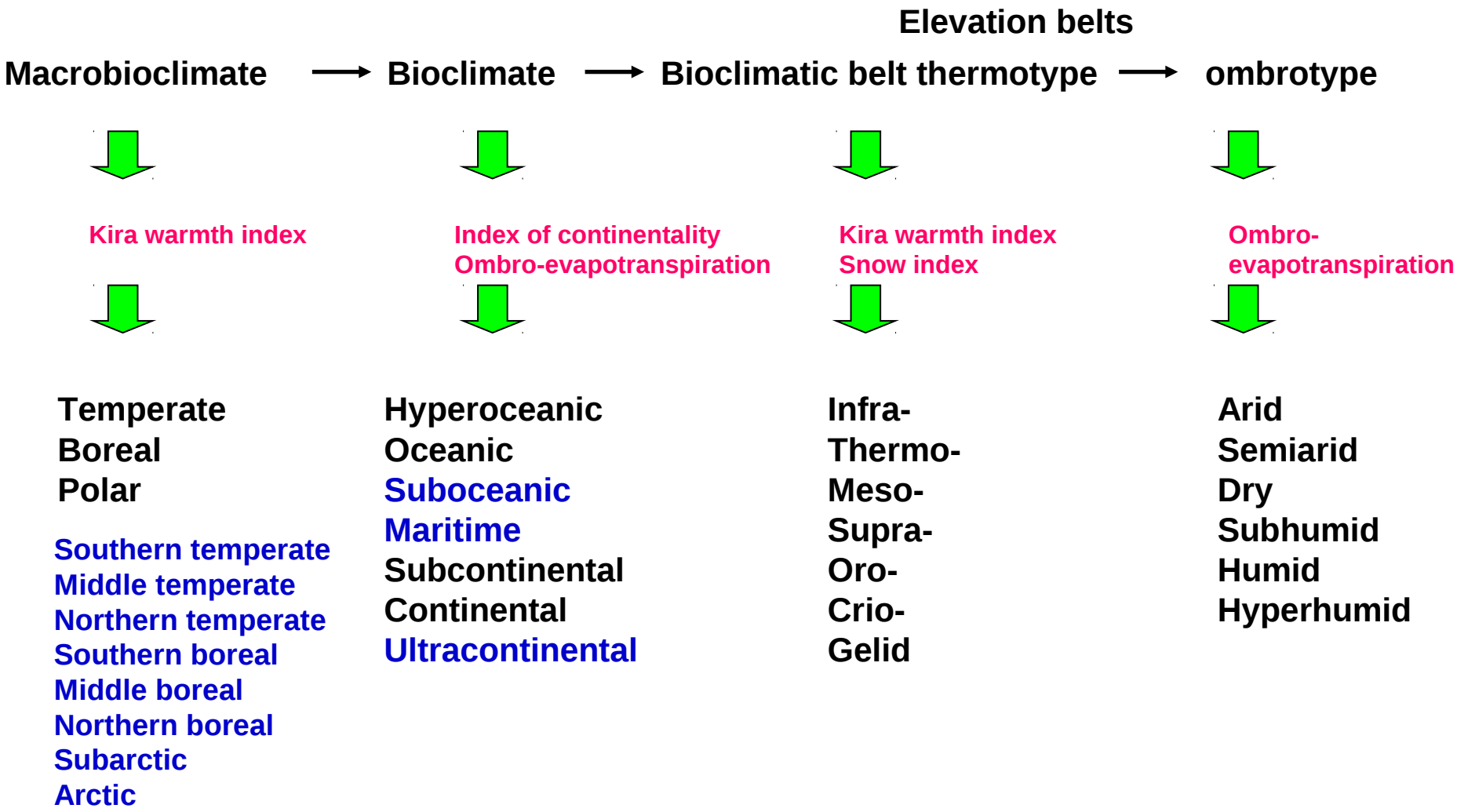
oceanic climate along the coast, sharp gradient towards the interior

Snow (Pn)

deepest for Asia snow cover
along the south coast

Rivas-Martinez' algorithm for bioclimatic diagnosis

(for polar, boreal and temperate macrobioclimates. Additions for Northeast Asia in blue)



анализ данных: растительность

Vegetation

Classification method – Braun-Blanquet

Zonal and azonal vegetation was classified into:

100 associations

see prodromus **29 alliances**

13 orders

10 classes

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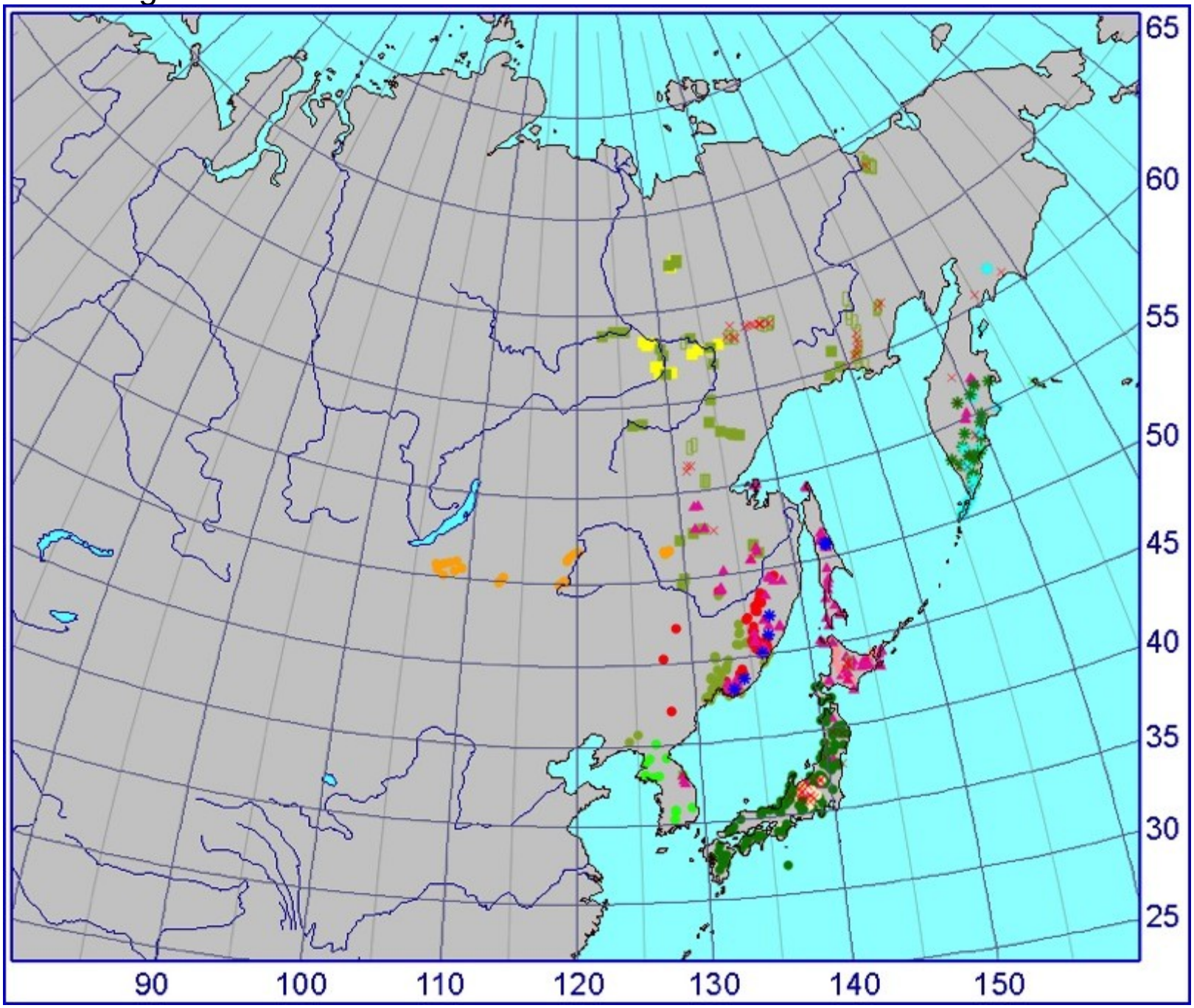
* X-D-I. Chamaecyparidion obtusae Hotta 1974

Distribution of oceanological data collection



Class
- Order
  - Alliance

Loiseleurio-Vaccinietea
- Arctericetalia

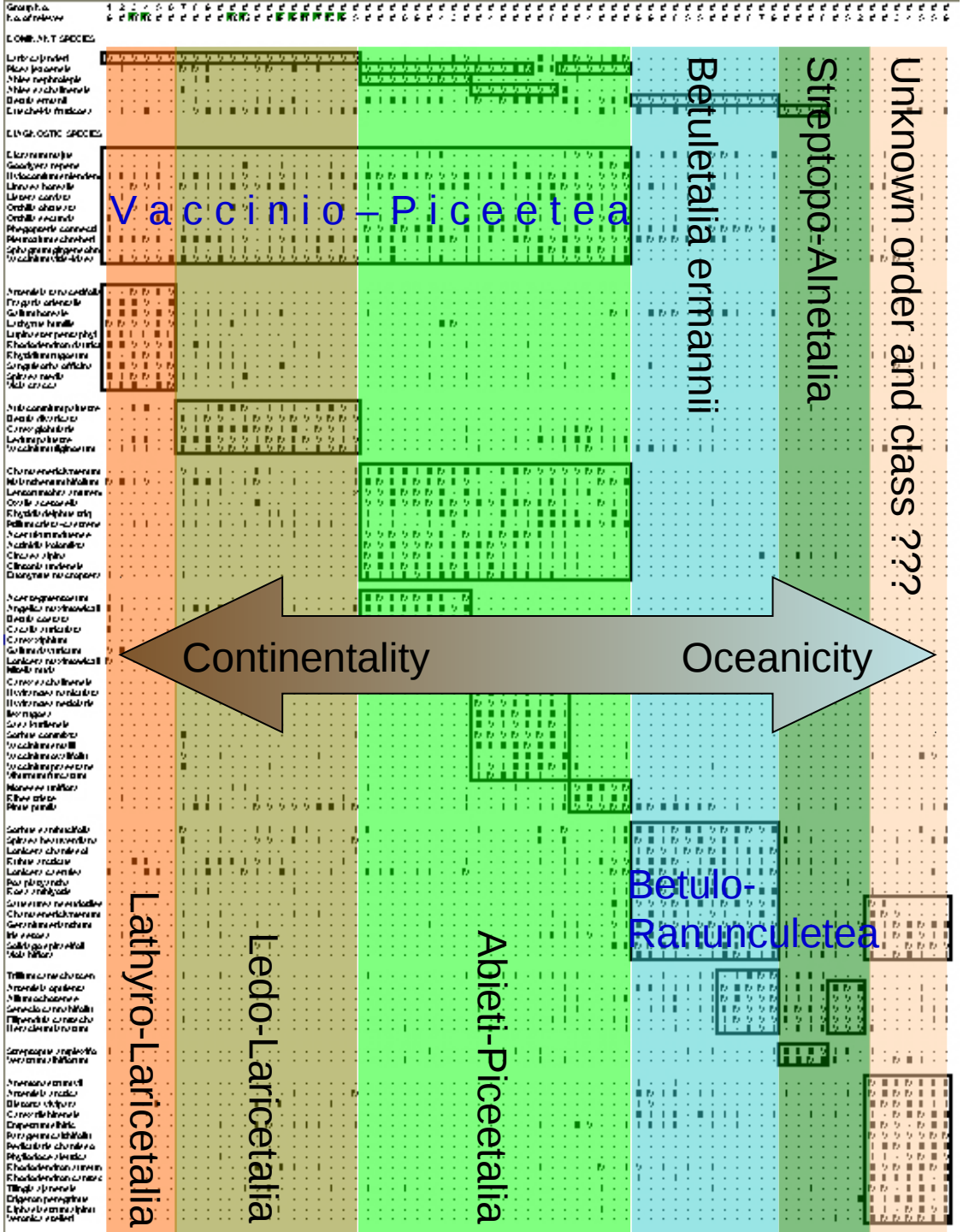
Phyllodoco-Harrimanelletea
- Harrimanelletalia
- Geetalia pentapetali

Dicentro-Stellarietea nipponicae
- Minuartietalia vernae-japonicae
- Saxifrago-Cardaminetalia nipponicae

Carici rupestris-Kobresietea bellardii
- Caricetalia tenuiformis
- Kobresio-Dryadetalia

Vaccinio-Piceetea
- Lathyro humilis-Laricetalia cajanderi
  - Aulacomnio acuminati-Laricion cajanderi
- Ledo palustris-Laricetalia cajanderi
  - Ledo palustris-Laricion cajanderi
  - Rhododendro aurei-Laricion cajanderi
  - Larici gmelinii-Betulion divaricatae
- Abieti-Piceetalia jesoensis
  - Pino pumilae-Piceion jezoensis
  - Abieti nephrolepidis-Piceion jezoensis
  - Piceion jezoensis
- Vaccinio-Pinetalia pumilae
  - Vaccinio-Pinion pumilae

Betulo ermanii-Ranunculetea acris
- Betuletalia ermanii
  - Pino pumilae-Betulion ermanii
  - Artemisio opulentae-Betulion ermanii
- Streptopo-Alnetalia maximowiczii
  - Athyrio brevifrontis-Weigelion middendorffianae
  - Alnion fruticosae
  - Filipendulion camtschaticae



анализ данных: взаимоотношения климат–растительность

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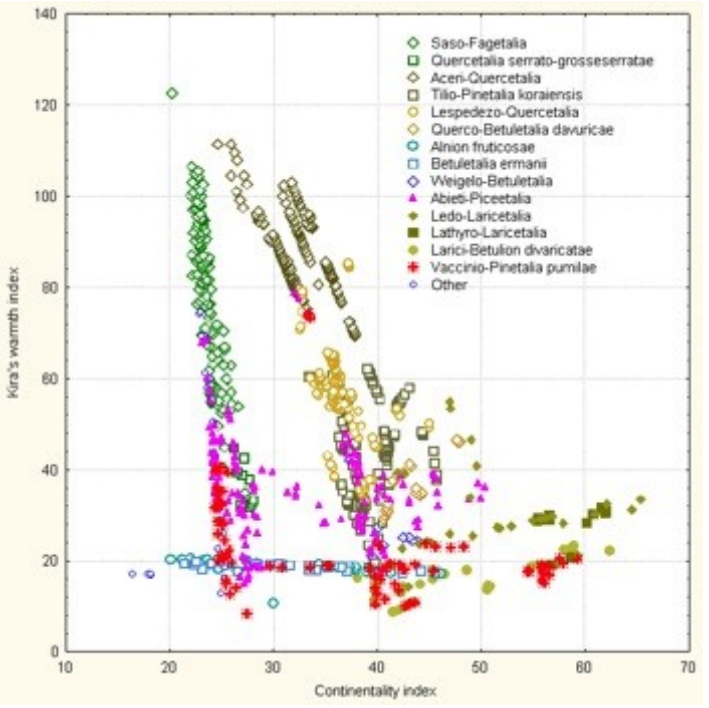

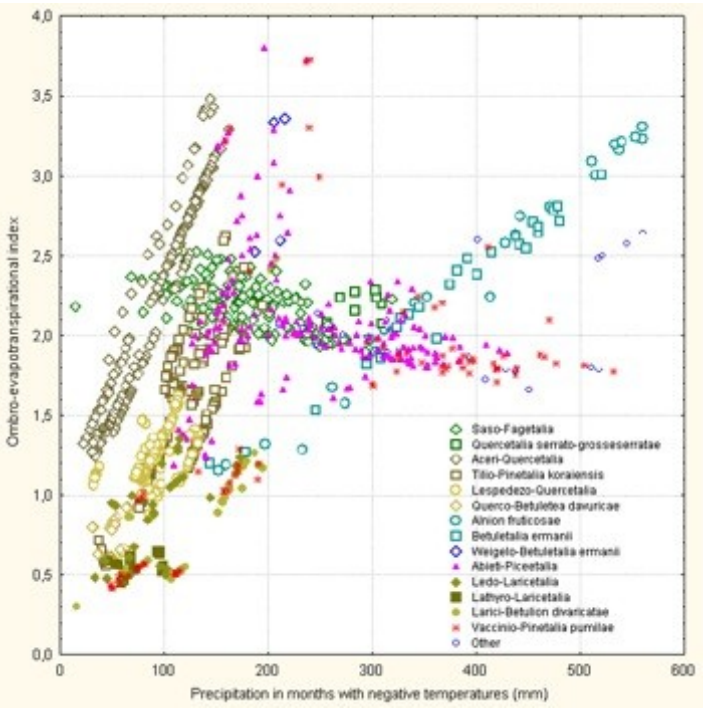

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500 releves

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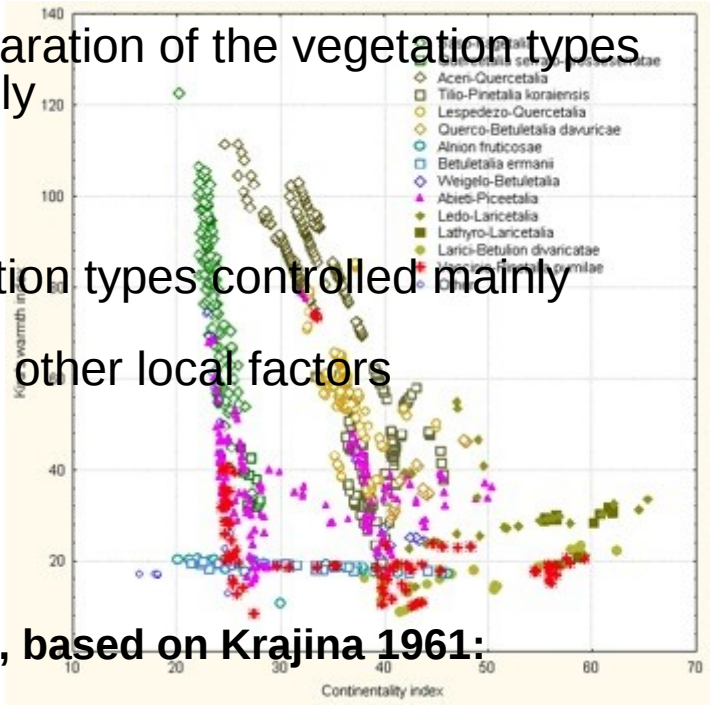
a “filter” for separation of the vegetation types controlled mainly

by climate

and the vegetation types controlled mainly

by edaphic and other local factors

is needed

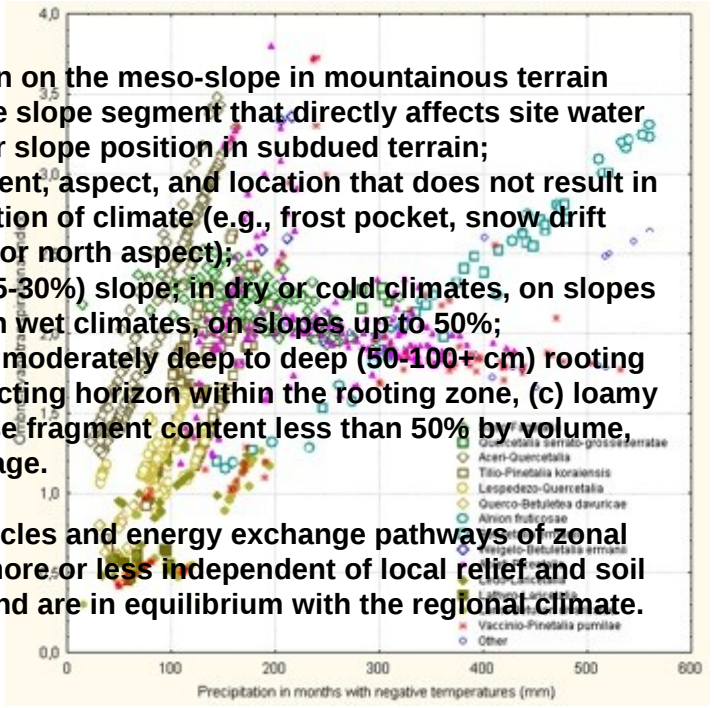


Pojar et al. 1991, based on Krajina 1961:

ZONAL SITE:

1. middle slope position on the meso-slope in mountainous terrain (meso-slope is the slope segment that directly affects site water movement); upper slope position in subdued terrain;
2. slope position, gradient, aspect, and location that does not result in a strong modification of climate (e.g., frost pocket, snow drift area, steep south or north aspect);
3. gentle to moderate (5-30%) slope; in dry or cold climates, on slopes to less than 5%; in wet climates, on slopes up to 50%;
4. soils that have: (a) a moderately deep to deep (50-100+ cm) rooting zone, (b) no restricting horizon within the rooting zone, (c) loamy texture with coarse fragment content less than 50% by volume, and (d) free drainage.

The biogeochemical cycles and energy exchange pathways of zonal ecosystems are more or less independent of local relief and soil parent material, and are in equilibrium with the regional climate.



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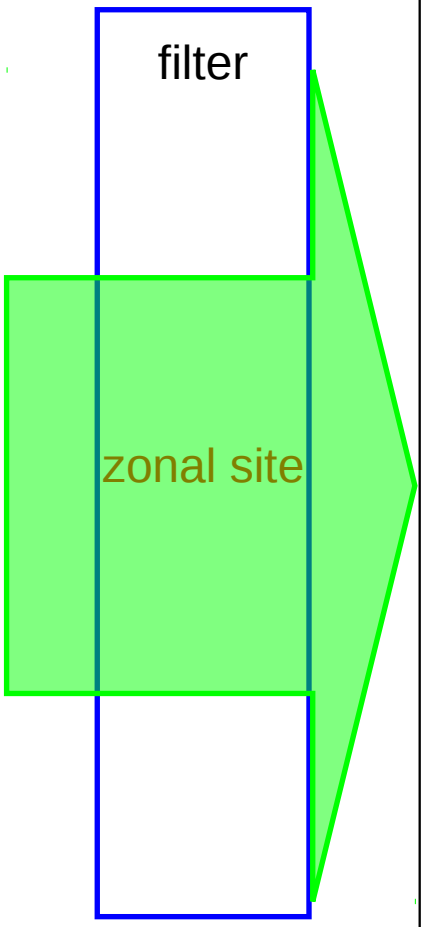

35 associations, 764 relevés

Kobresio-Oxytropidetum japonicae
Flavocetrario-Laricetum cajanderi
Salici krylovii-Laricetum cajanderi
Ledo-Pinetum pumilae
Vaccinio-Pinetum pumilae
Salici arcticae-Betuletum ermanii
Weigelo-Betuletum ermanii
Geranio erianthi-Betuletum ermanii
Artemisio opulentae-Betuletum ermanii
Dryopterido-Alnetum fruticosae
Glycerio-Alnetum fruticosae
Artemisio-Arnicetum unalascensis
Lathyro-Laricetum cajanderi
Ledo-Laricetum cajanderi
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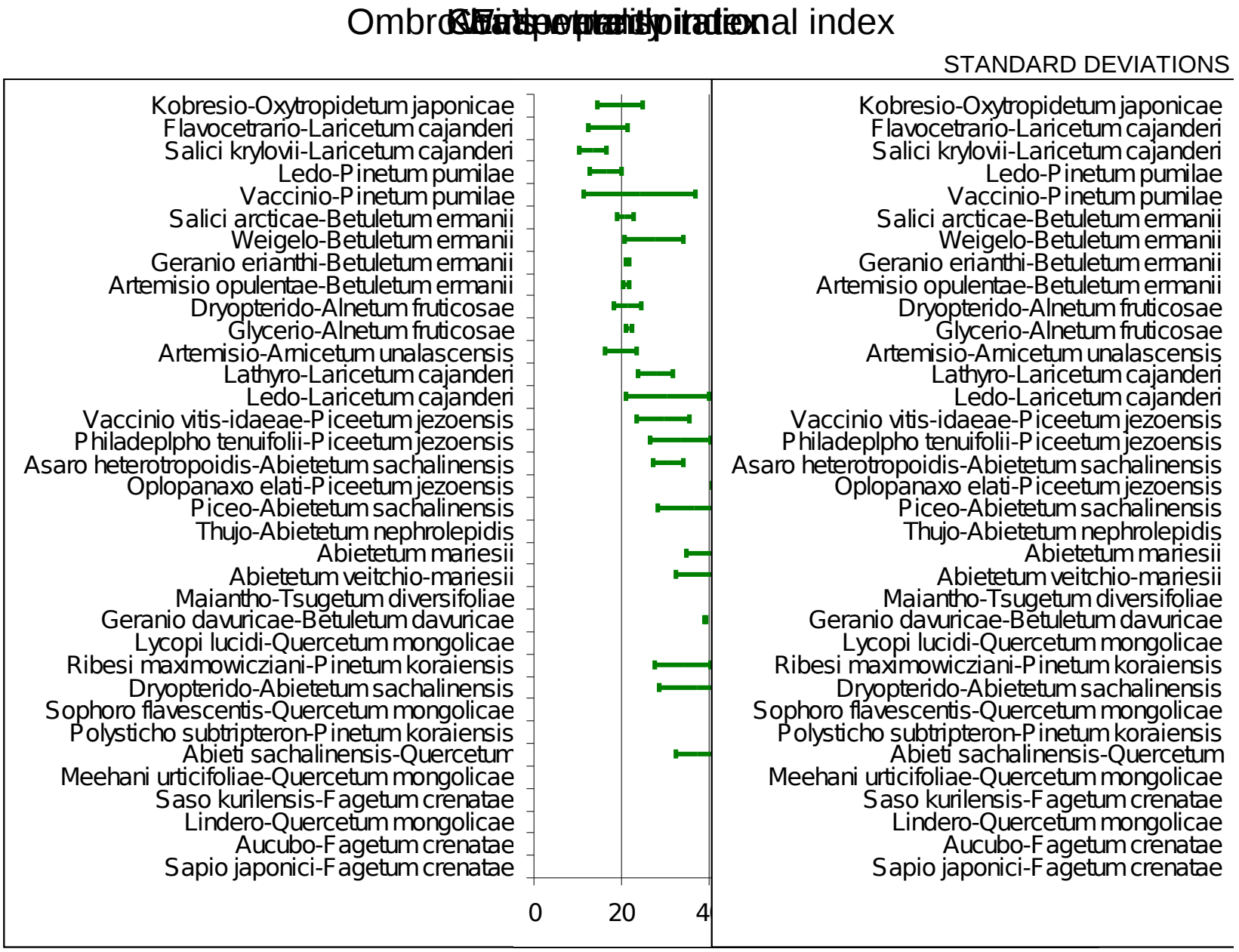
Philadeplpho tenuifolii-Piceetum jezoensis
Asaro heterotropoidis-Abietetum sachalinensis
Oplopanaxo elati-Piceetum jezoensis
Piceo-Abietetum sachalinensis
Thujo-Abietetum nephrolepidis
Abietetum mariesii
Abietetum veitchio-mariesii
Maiantho-Tsugetum diversifoliae
Geranio davuricae-Betuletum davuricae
Lycopi lucidi-Quercetum mongolicae
Ribesi maximowicziani-Pinetum koraiensis
Dryopterido-Abietetum sachalinensis
Sophoro flavescentis-Quercetum mongolicae
Polysticho subtripteron-Pinetum koraiensis
Abieti sachalinensis-Quercetum
Meehani urticifoliae-Quercetum mongolicae
Saso kurilensis-Fagetum crenatae
Lindero-Quercetum mongolicae
Aucubo-Fagetum crenatae
Sapio japonici-Fagetum crenatae


Ombrothermicity index
STANDARD DEVIATIONS
Kobresio-Oxytropidetum japonicae
Flavocetrario-Laricetum cajanderi
Salici krylovii-Laricetum cajanderi
Ledo-Pinetum pumilae
Vaccinio-Pinetum pumilae
Salici arcticae-Betuletum ermanii
Weigelo-Betuletum ermanii
Geranio erianthi-Betuletum ermanii
Artemisio opulentae-Betuletum ermanii
Dryopterido-Alnetum fruticosae
Glycerio-Alnetum fruticosae
Artemisio-Arnicetum unalascensis
Lathyro-Laricetum cajanderi
Ledo-Laricetum cajanderi
Vaccinio vitis-idaeae-Piceetum jezoensis
Philadeplpho tenuifolii-Piceetum jezoensis
Asaro heterotropoidis-Abietetum sachalinensis
Oplopanaxo elati-Piceetum jezoensis
Piceo-Abietetum sachalinensis
Thujo-Abietetum nephrolepidis
Abietetum mariesii
Abietetum veitchio-mariesii
Maiantho-Tsugetum diversifoliae
Geranio davuricae-Betuletum davuricae
Lycopi lucidi-Quercetum mongolicae
Ribesi maximowicziani-Pinetum koraiensis
Dryopterido-Abietetum sachalinensis
Sophoro flavescentis-Quercetum mongolicae
Polysticho subtripteron-Pinetum koraiensis
Abieti sachalinensis-Quercetum
Meehani urticifoliae-Quercetum mongolicae
Saso kurilensis-Fagetum crenatae
Lindero-Quercetum mongolicae
Aucubo-Fagetum crenatae
Sapio japonici-Fagetum crenatae
0
20
4

Krestov & Nakamura 2007

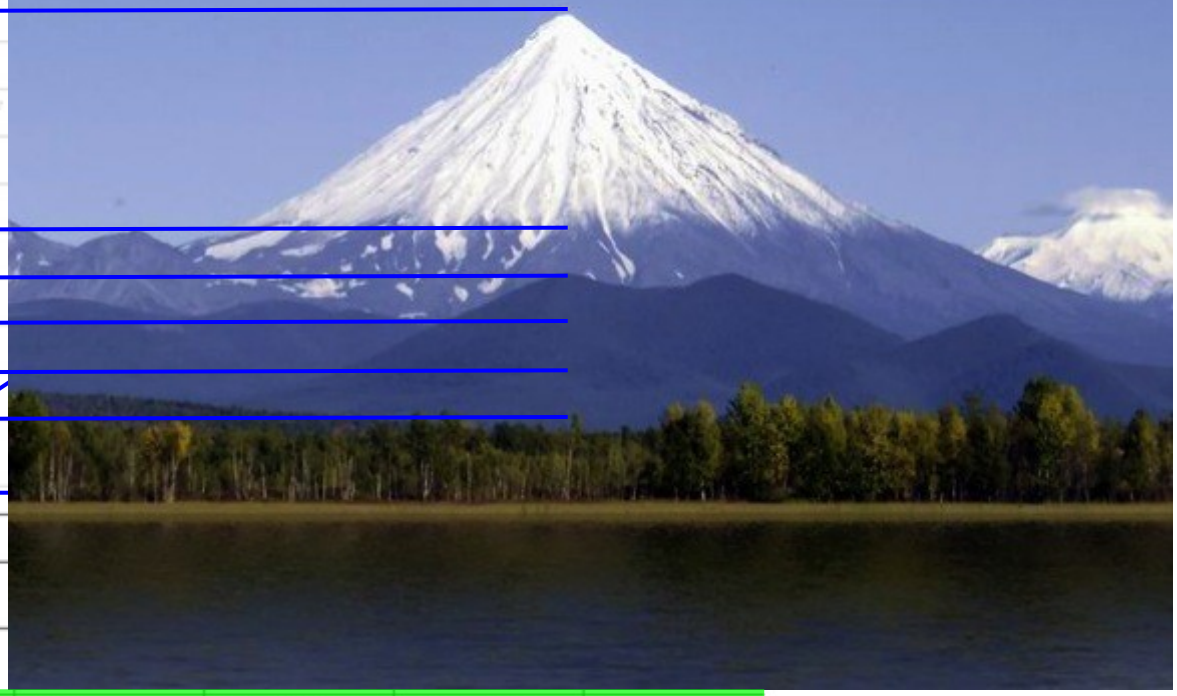
Table 4. Zonal associations/community types characteristic to bioclimatic regions and vertical belts of Northeast Asia.

Macrobioclimate / Latitudinal thermotype	ultracontinental	continental	maritime	suboceanic	oceanic
Suprapolar	–	–	Cryptogram comm.	Carex comm.	Cassiope comm.
Mesopolar	–	Poa arctilis comm.	Eriophorum vaginatum comm.	Vaccinio-Empetretum nigrae	Vaccinio-Empetretum nigrae
Thermopolar	Flavocetrario-Betuletum divaricatae	Laricetum gmelinii	Ledo-Pinetum pumilae	Hierochloo-Alnetum fruticosae	Artemisio-Arnicetum mollis
Crioroboreal	Kobresia comm.	Kobresia comm.	Dryas comm.	Carex comm.	Cassiope comm.
Oroboreal	Flavocetrario-Betuletum divaricatae				
Supraboreal	Flavocetrario-Betuletum divaricatae				
Mesoboreal	Ledo-Laricetum cajanderi				
Thermoboreal	Lathyro-Laricetum cajanderi				
Criorotemperate	Kobresia spp. comm.				
Orotemperate	No data				
Supratemperate	Caragano-Cleistogenetum squarrosae				
Mesotemperate	Caragano-Cleistogenetum squarrosae				
Thermotemperate	Stipo-Convolvuletum	No data	Lindero-Quercetum	Aucubo-Fagetum	–
Crioro-temperate	No data	No data	No data	Kobresio-Oxytropidetum	Kobresio-Oxytropidetum
Orotemperate	No data	No data	No data	Vaccinio-Pinetum	Vaccinio-Pinetum
Supratemperate	No data	No data	No data	Abietetum mariesii	Abietetum veitchio-mariesii
Mesotemperate	No data	No data	No data	Acero-Tilietum amurensis	Maiantho-Tsugetum diversifoliae
Thermotemperate	No data	No data	No data	Acero-Tilietum amurensis	Aucubo-Fagetum crenatae

Bioclimate and zonal vegeta

sectors

Volcano Klyuchevskoy, 4850 m a.s.l., Kamchatka



gelid

crioro-

oro-

supra-

meso-

thermo-

southern temperate

southern temperate

southern temperate

southern boreal

southern boreal

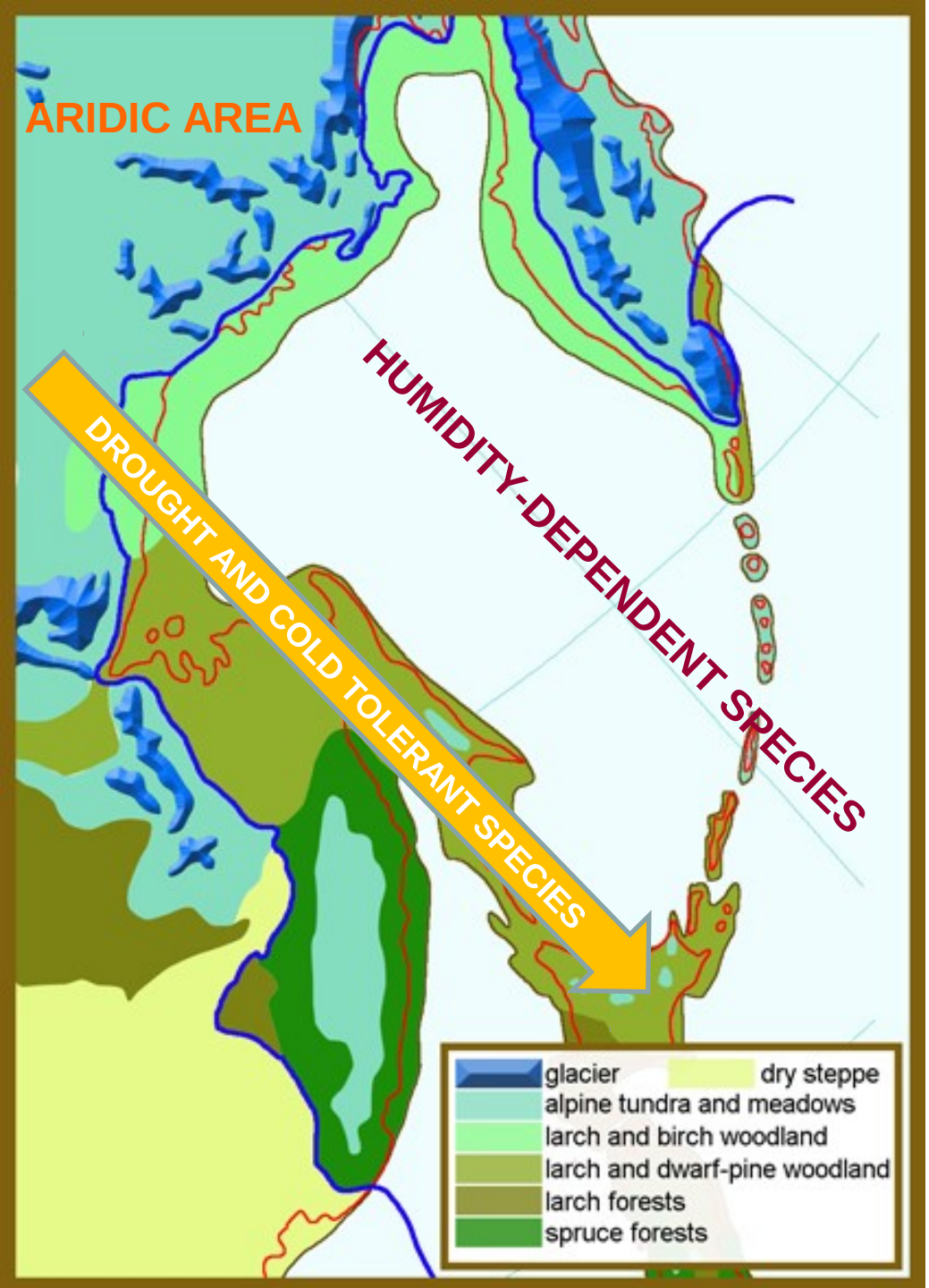
subpolar

zonobiomes

24 секторно-зональных подразделения растительного покрова, характеризующихся уникальным спектром высотной поясности, встроенных в 3-мерную общемировую фитогеографическую решетку Rivas-Martínez

основные события плейстоцена и голоцена

Pleistocene Maximum



No ice shield, glaciers on the mountain tops only

Sea level 120 m below that now, land bridges

Low temperatures and severe aridization in the whole area

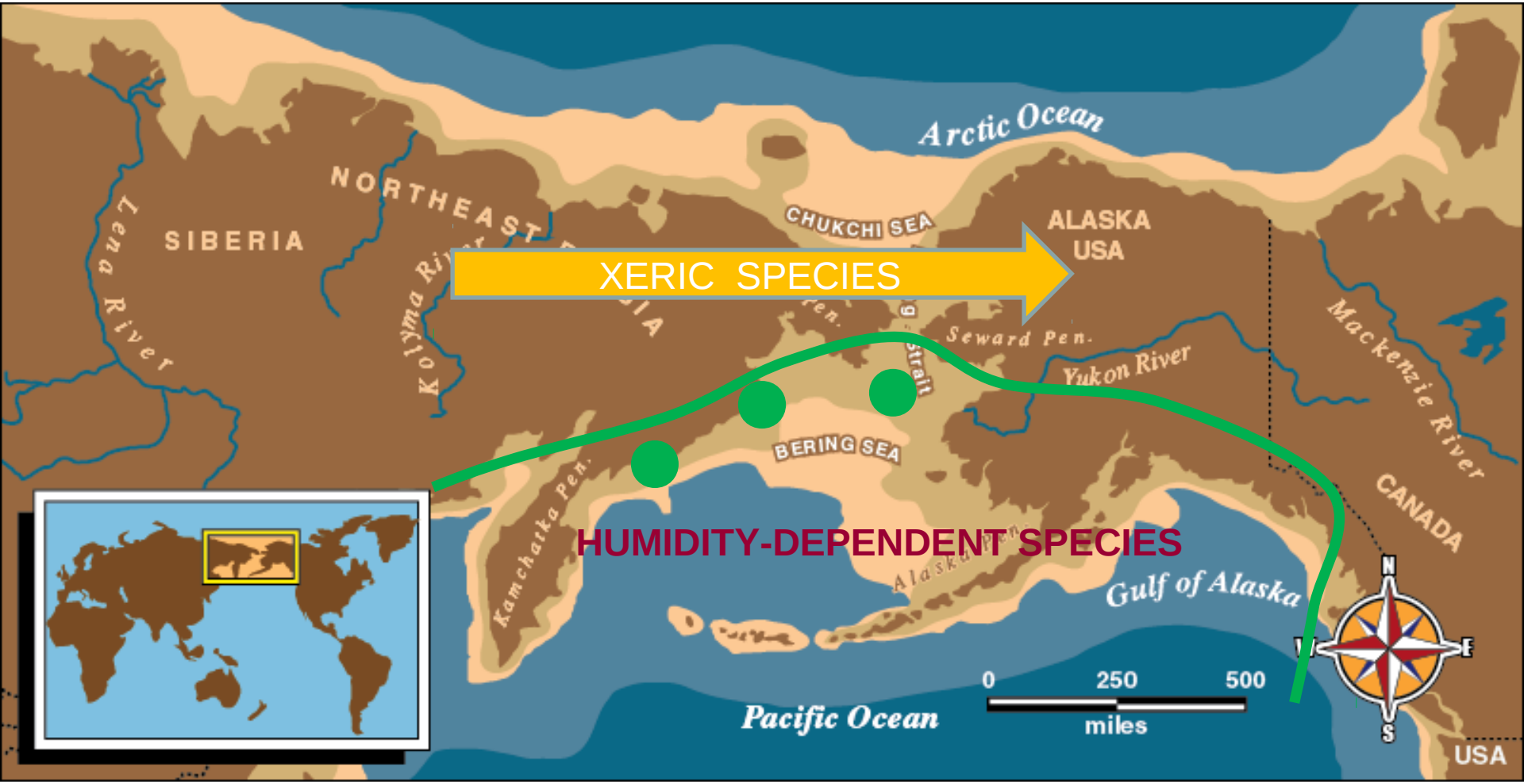
Tundra-steppe vegetation in most of northern Asia

Refugia for humidity-dependent species along the Pacific coast

Extensive migration of drought and

cold tolerant species in the insular and coastal areas

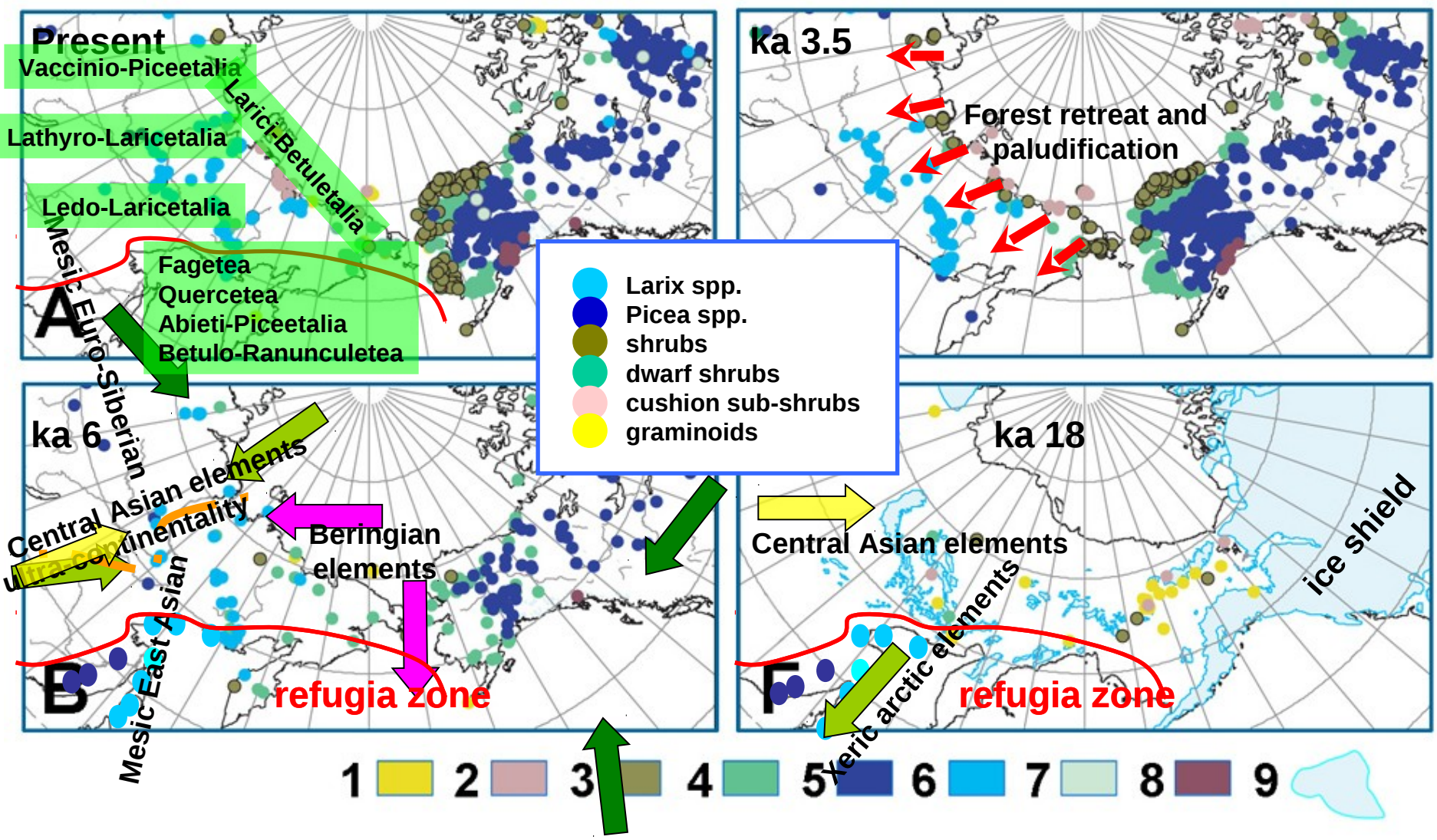
Pleistocene Maximum: Beringia and Hultenia perspective



Intensive migration processes of cold and drought tolerant species within the north faced macro-slope of the Beringian land bridge

More humid conditions within the Pacific faces macro-slope of the Beringian land bridge, high probability of refugia for humidity-dependent species

Bigelow, Brubaker, Edwards, Harrison, Prentice, Anderson, Andreev, Bartlein, Christensen, Cramer, Kaplan, Lozhkin, Matveyeva, Murray, McGuire, Razzhivin, Ritchie, Smith, Walker, Gajewski, Wolf, Holmqvist, Igarashi, Kremenetskii, Paus, Pisaric, Volkova (2003): Climate change and Arctic ecosystems: 1. Vegetation changes north of 55N between the last glacial maximum, mid-Holocene, and present. *J. GEOPHYSICAL RESEARCH* 108

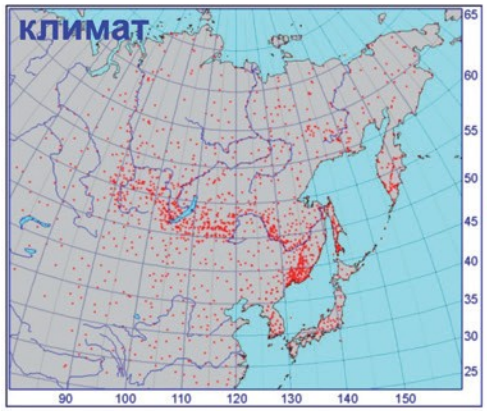


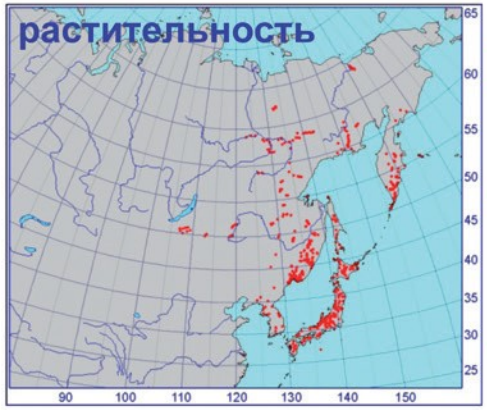
Моделирование распределения растительных единиц

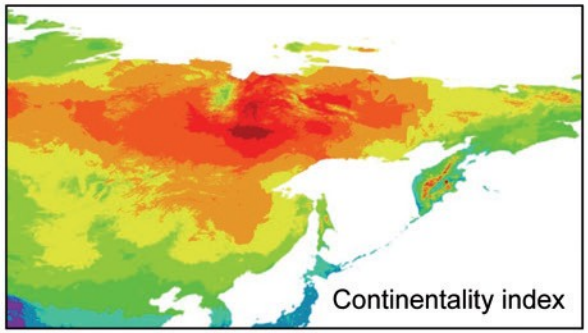
What we have:	bioclimatic models zonal ecosystems DEM
How we do:	Generalized additive models (GAMs) realized with an aid of GRASP algorithm
Results:	Probabilities of occurrence of a vegetation type calculated for each pixel (1 by 1 km) on the basis of 5 bioclimatic indices

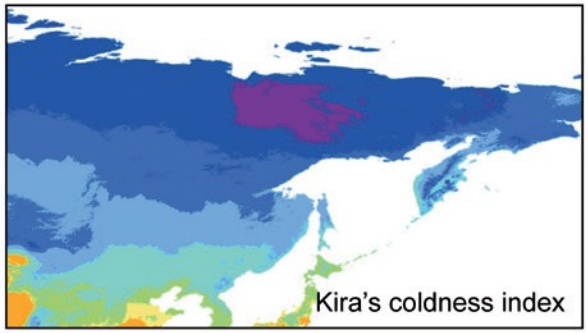
Прогнозное моделирование изменений экосистем при современных климатических флюктуациях совместно с Tokyo University of Agriculture

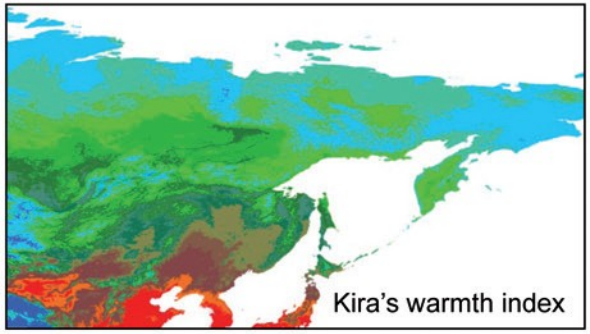
базы данных → биоклиматические модели



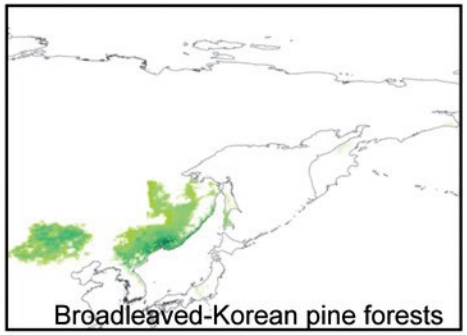


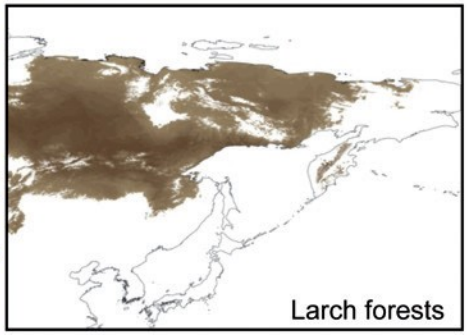


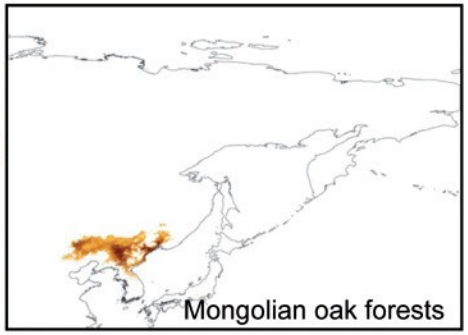


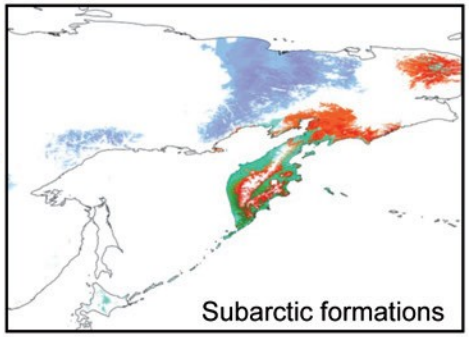


прогнозные модели распределения биоты





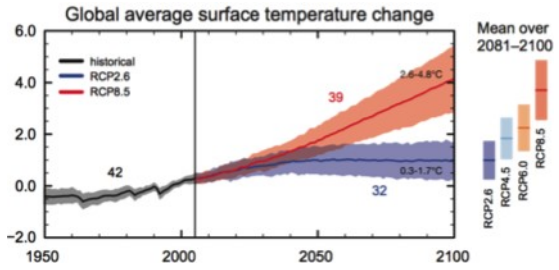




Krestov et al., 2010; Krestov & Omelko, 2012

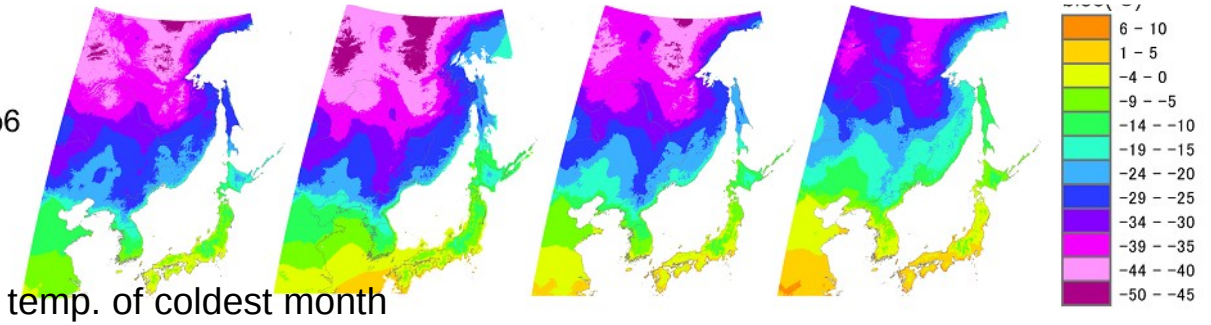
Climatic variables in four different periods

- **LIG (140,000 yrs BP)**
  Last interglacial period
- **LGM (21,000 yrs BP)**
  Last Glacial Maximum
- **Current**
- **Future (2081-2100)**



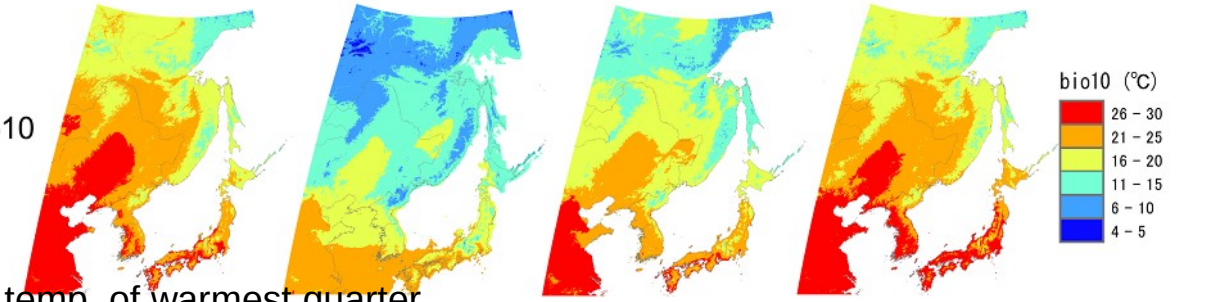
LIG (140,000 BP) LGM (21,000 BP) Current Future (2081-2100)

bio6



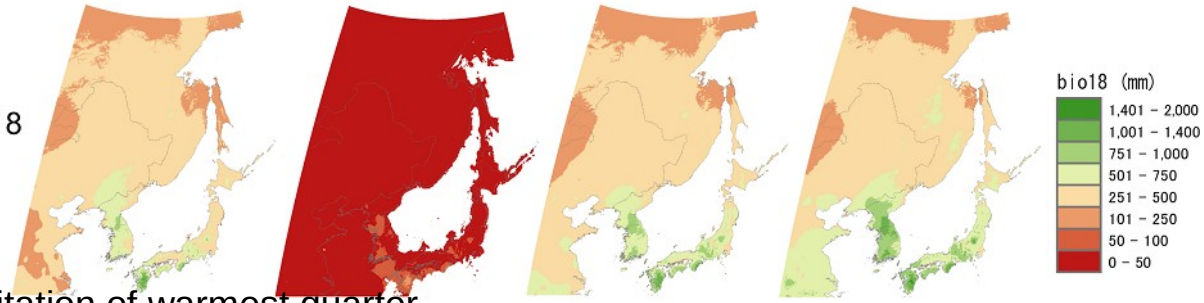
Mean temp. of coldest month

bio10



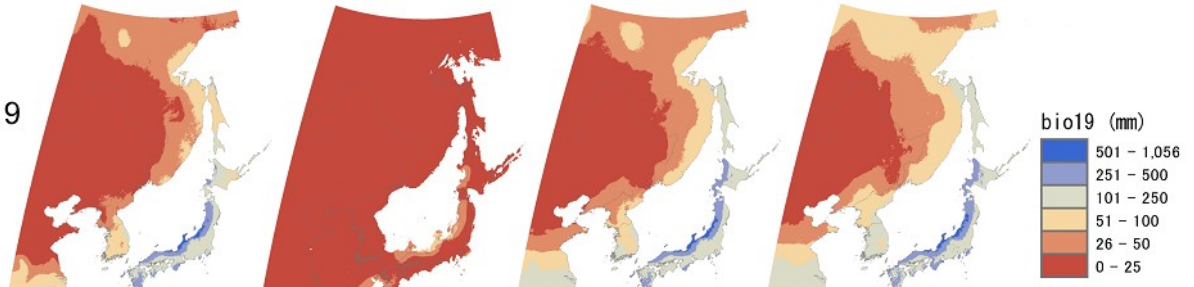
Mean temp. of warmest quarter

bio18



Precipitation of warmest quarter

bio19



Precipitation of coldest quarter

change of potential habitats of significant species in the past and forecast for 100 years

Совместно с Институтом лесоведения Японии

Pinus koraiensis

Occurrence probability

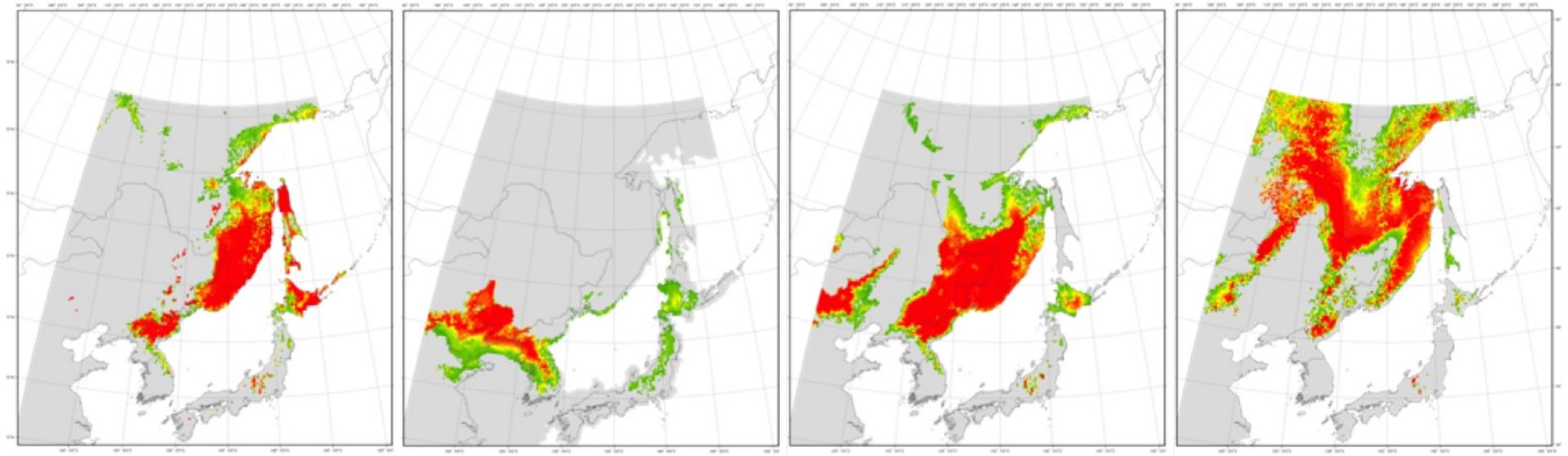
0.9 – 1
0.8 – 0.9
0.7 – 0.8
0.6 – 0.7
0.5 – 0.6
0.4 – 0.5
0.3 – 0.4
0.2 – 0.3
0.1 – 0.2
0.068 – 0.1
0 – 0.068

Last Interglacial period (140,000 yrs BP)

Last Glacial Maximum (21,000 yrs BP)

Current distribution 2000

2080-2100

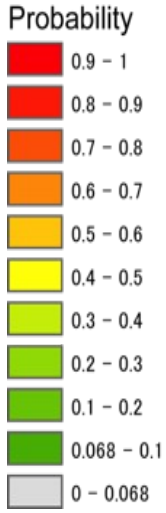


(!) ПРОГНОЗИРОВАНИЕ РЕСУРСОВ

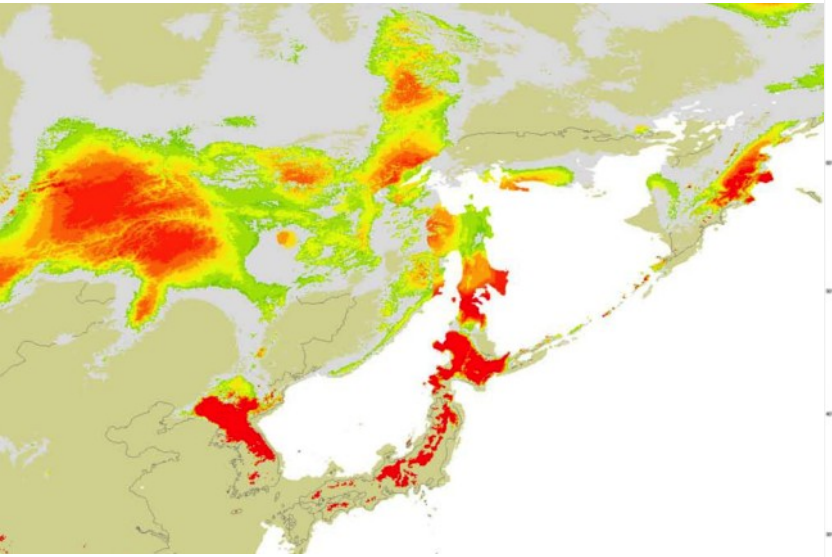
change of potential habitats of significant species in the past and forecast for 100 years

Совместно с Институтом лесоведения Японии

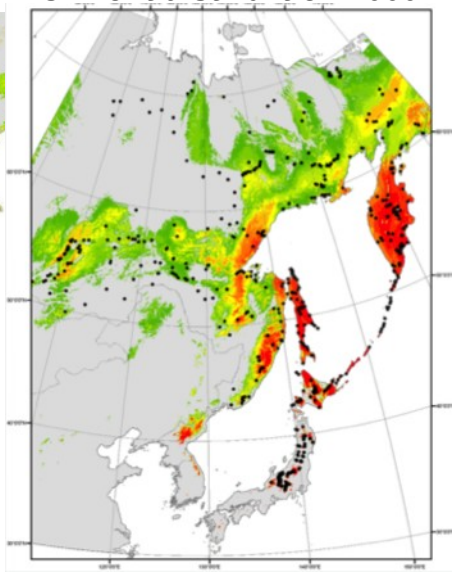
Pinus pumila



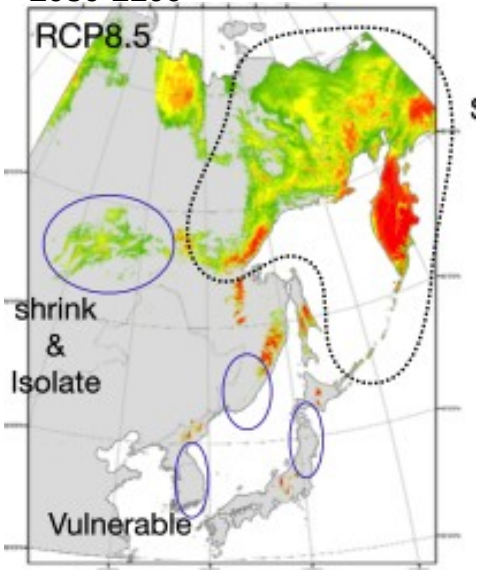
Last Glacial Maximum (21,000 yrs BP)



Current distribution 2000



2080-2100



(!) ПРОГНОЗИРОВАНИЕ РЕСУРСОВ

Эффект муссона и континентальность климата

Минимум осадков в зимнее время – небольшой, рано стаивающий снеговой покров – дефицит влаги и весенне-раннелетний период

Адаптации к широкому спектру «неблагоприятных условий» – огромный инвазионный потенциал восточноазиатской флоры

Обширная территория с ультраконтинентальным климатом во внутренних районах северо-востока Азии с минимумом осадков и большой амплитудой суточных и годовых температур

Отсутствие в течение длительного времени (с плиоцена) обмена мезофильными элементами между евросибирским и восточноазиатским флористическими комплексами

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