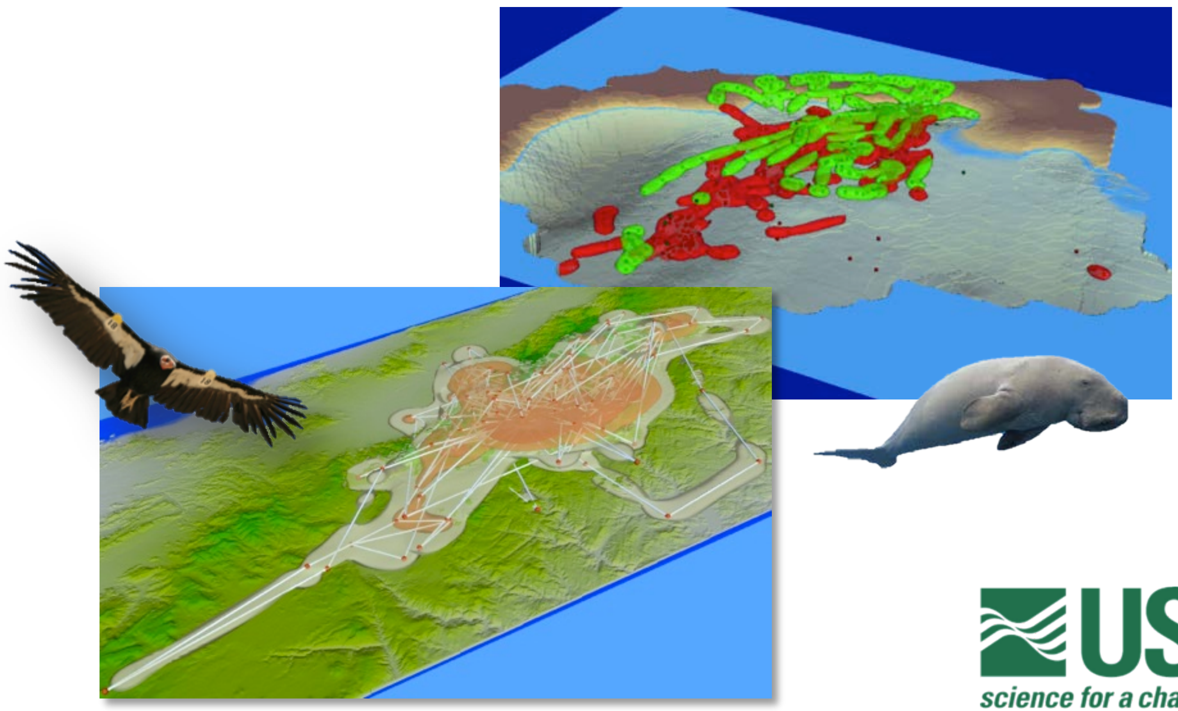
Biotelemetry revolution - estimating animal space use in 3D to avoid costly environmental impacts

Robert Sinkovits

SDSC IPP Webinar Series – August 20, 2014



Overview

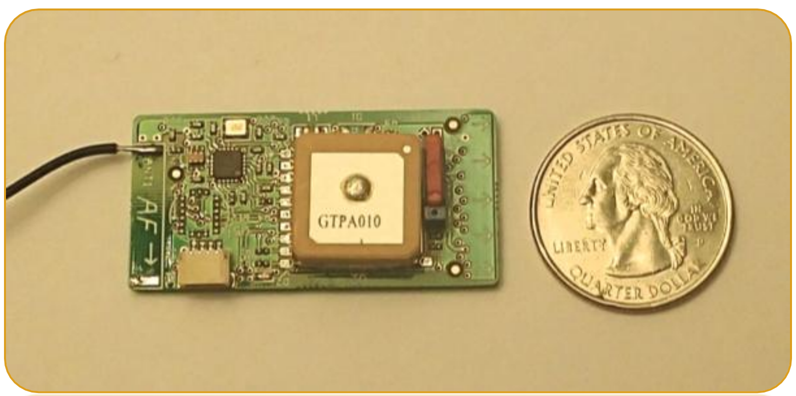
- Describe animal space use prediction in three dimensions, computational challenges and it's applicability to carrying out an accurate environmental impact study
- Present a case study involving industry, government and non-profit organizations to address the impact of a proposed wind farm on the California Condor
- Highlight the impact that SDSC expertise can have on your project

Understanding environmental impact

- All new infrastructure projects (buildings, roads, power plants, pipelines, dams, airports) need to undergo an environmental impact study
- Even though the project may pass the study, faulty predictions can have a devastating impact on both the environment and on a company's bottom line (e.g. imagine trying to move a wind farm)
- Accurate modeling of animal space use in three dimensions can reduce the likelihood of false positives and negatives

Biotelemetry revolution

- Increasing sophistication and miniaturization of digital biotelemetry devices, e.g. GPS
- Enabling detailed information to be collected on the spatial behaviors of wildlife difficult to observe directly



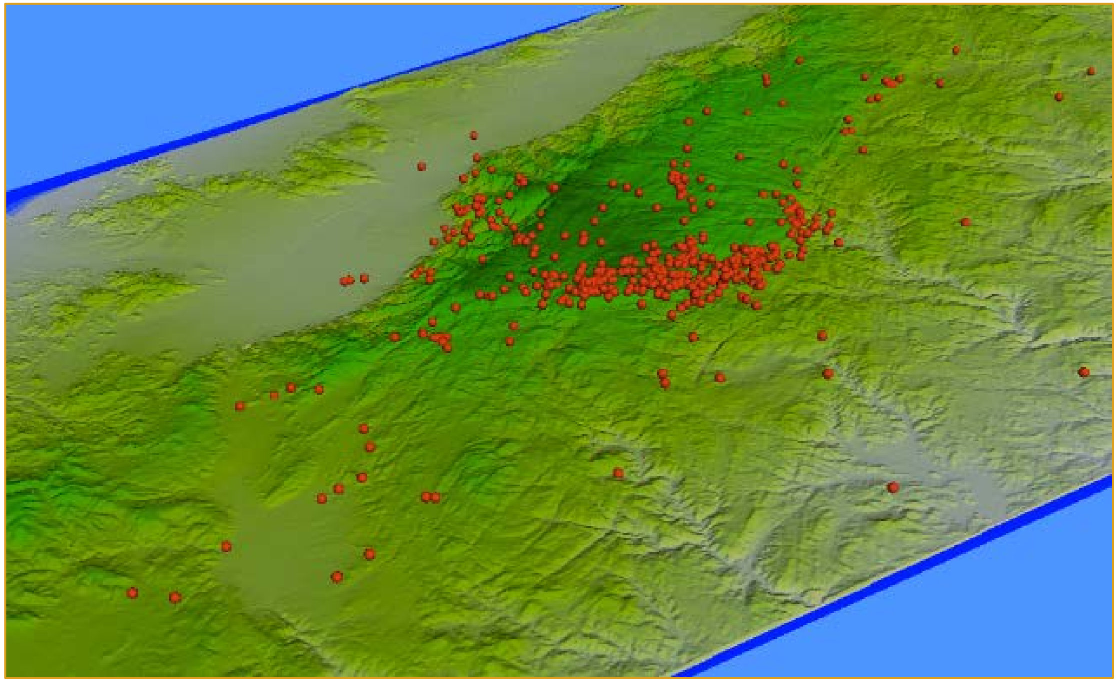
Biotelemetry revolution

Crowded marketplace of vendors offering higher resolution longer-term trackers for smaller species.

Microwave Telemetry, Inc.
NORTH STAR
TELONICS
Skorpa TELEMETRY
TELEMETRY Solutions
CELLULAR TRACKING TECHNOLOGIES
FOLLOWIT Keep track of everything.
biotrack
TechnoSmArt TRACKING SYSTEMS FOR ANIMALS
SIRTRACK®
VECTRONIC Aerospace innovative technology for science and research
Wildlife Computers Innovative Tags for Innovative Research
ATS ADVANCED TELEMETRY SYSTEMS
LOTEK WIRELESS FISH & WILDLIFE MONITORING
BlueSky TELEMETRY

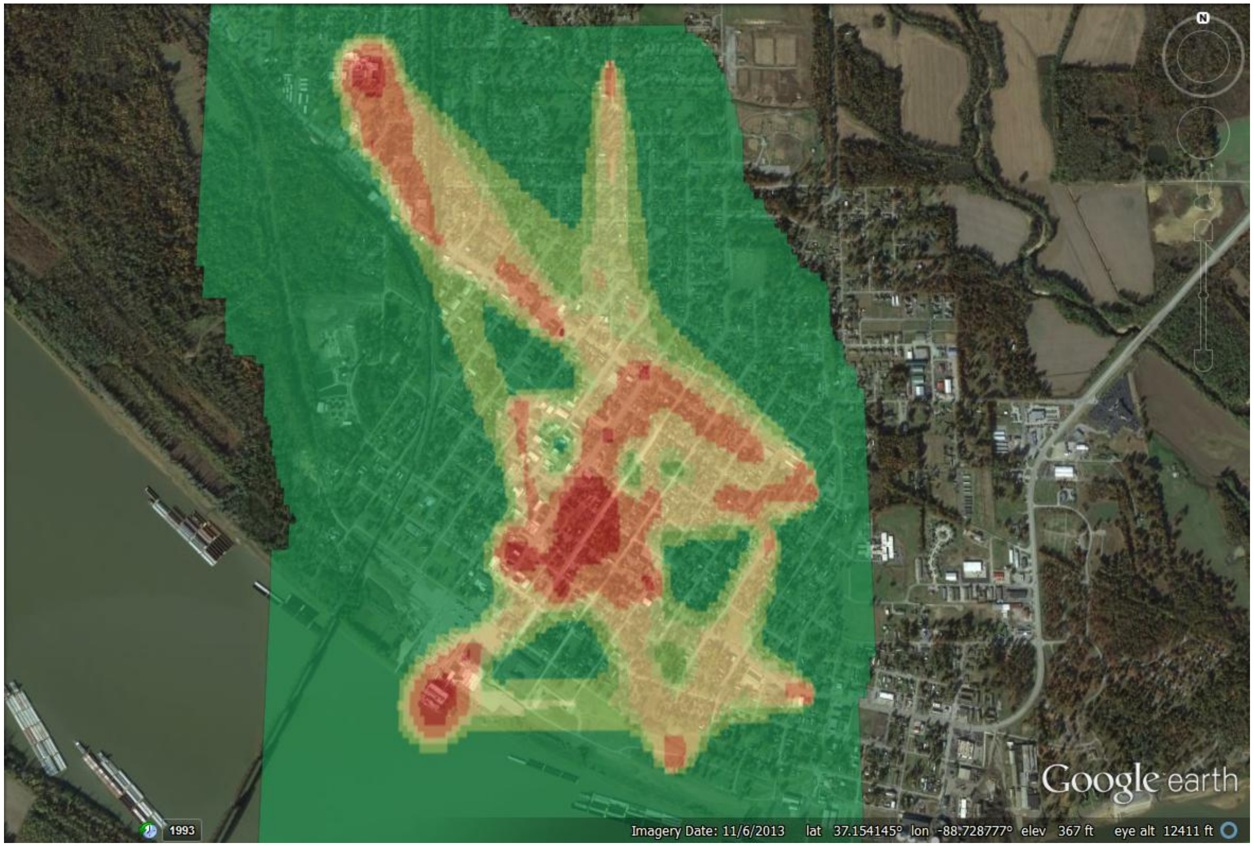
Turning discrete observations into home ranges

Biotelemetry devices give us discrete readings (x,y,z coordinates), typically spaced an hour apart. Need to turn this raw data into home ranges, fairly well defined areas where the animal spends its time.



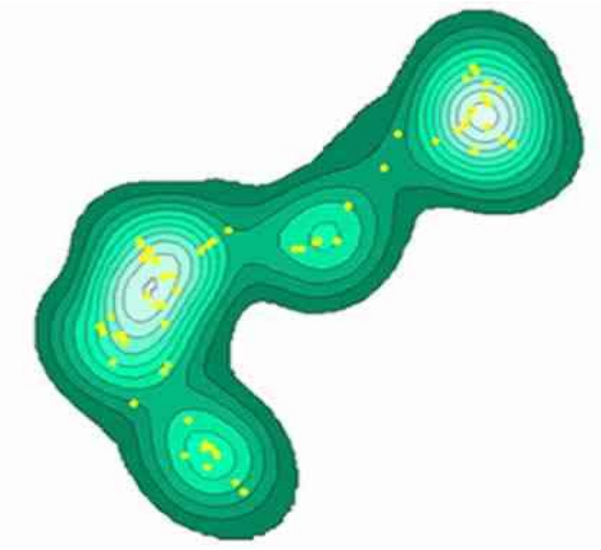
2D home range estimation

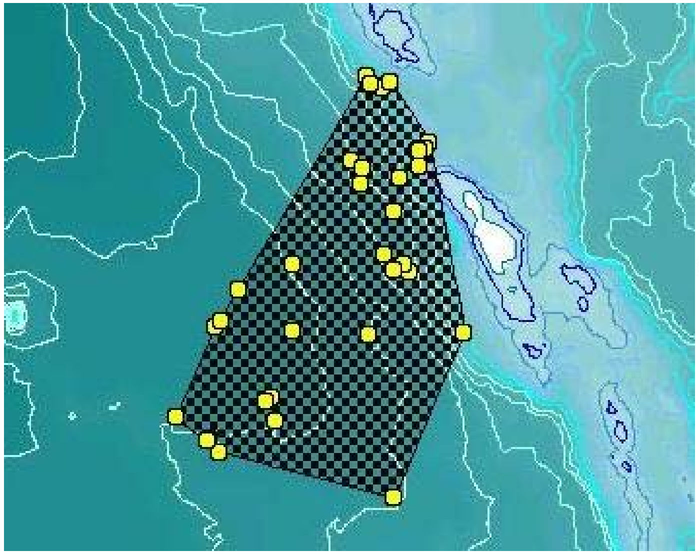
2D home range estimation

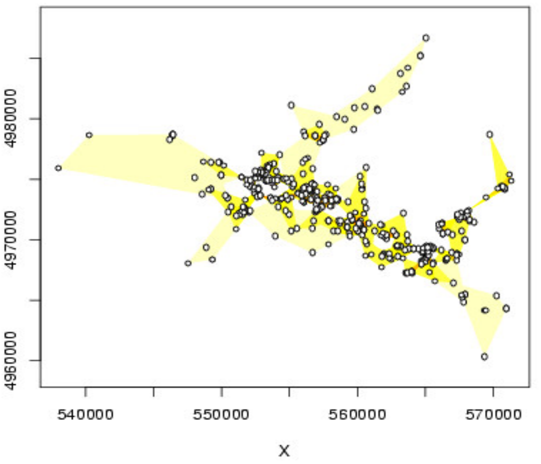


From 2D to 3D

Previous home range estimators constrain models of animal space use to a biologically unrealistic 2D flatland. The current work extends this into 3D using a Movement-Based Kernel Density Estimator (MKDE)

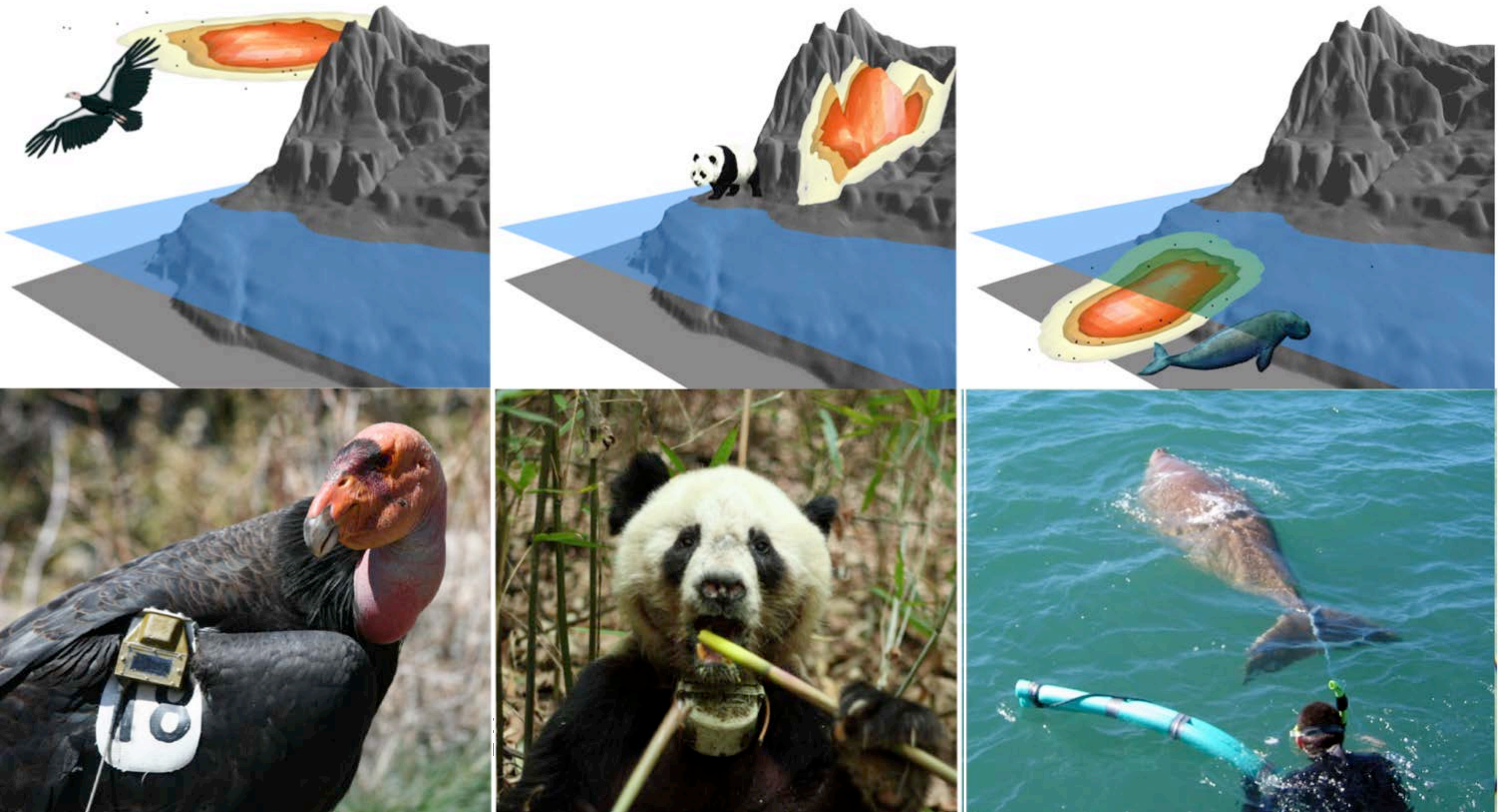






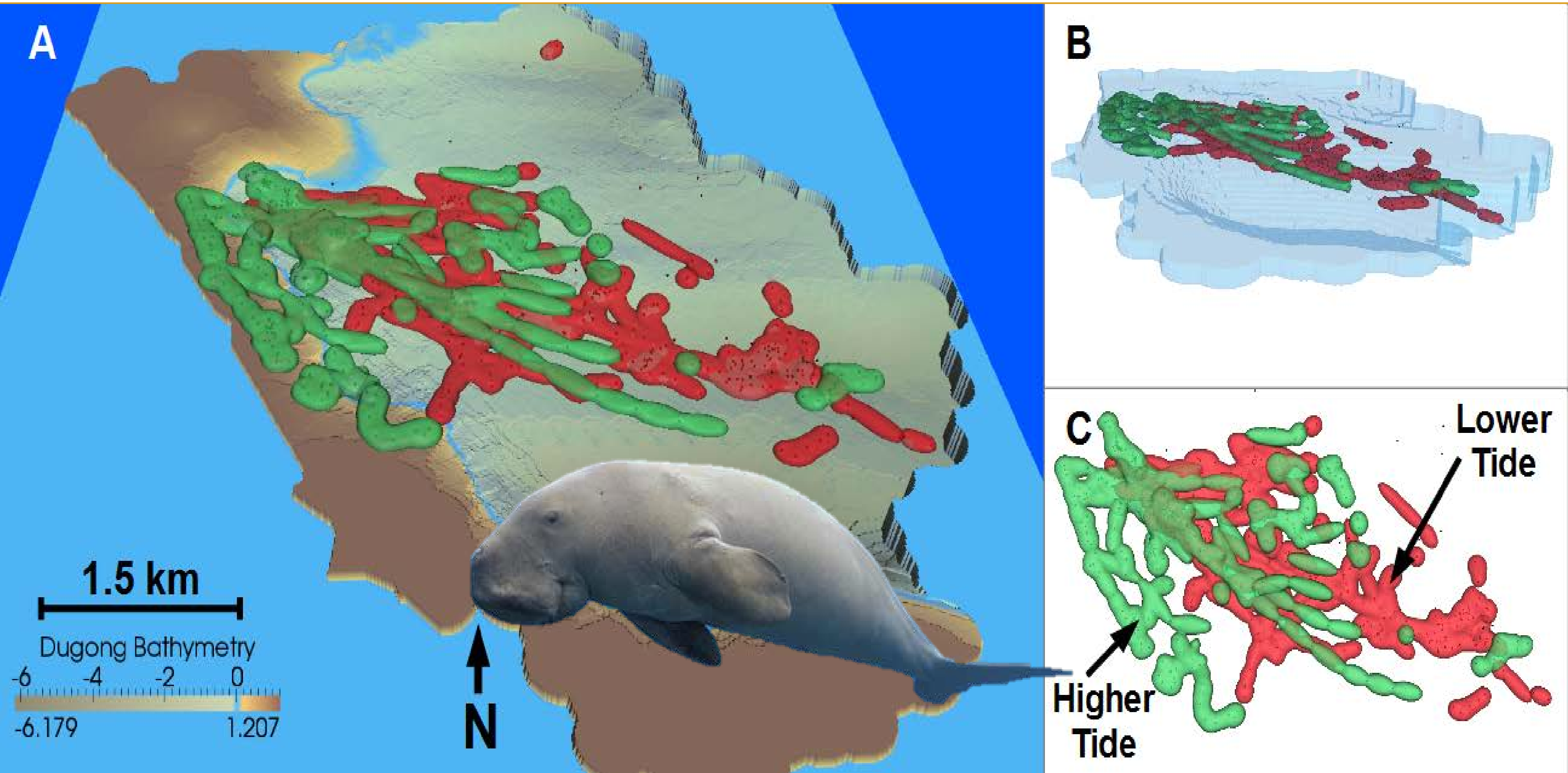
3D space use model important for animals with a large vertical component to their movement

AVIAN **TERRESTRIAL** **AQUATIC**



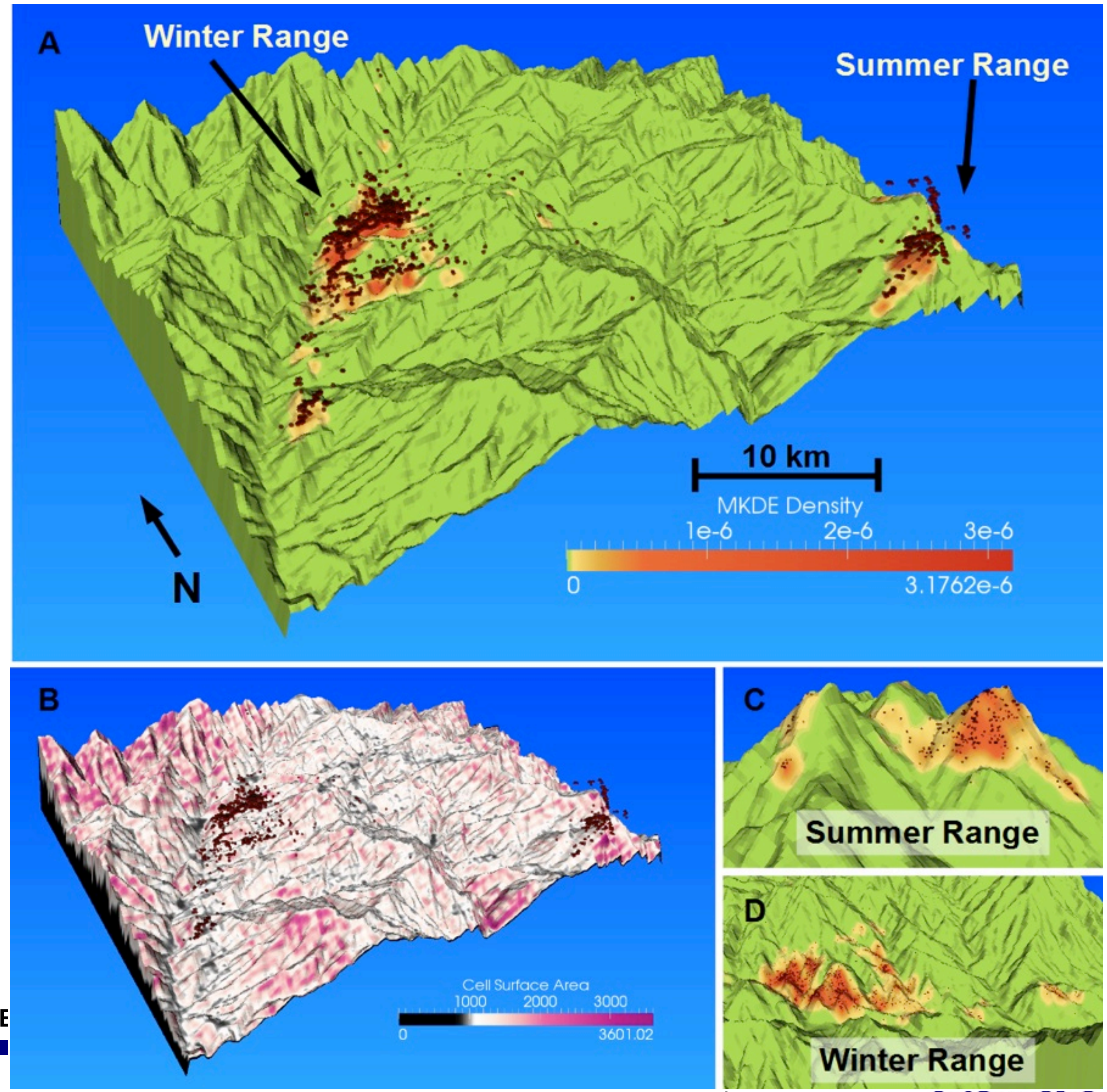
Aquatic 3D MKDE

Low to median tide = red volumes
Median to high tide = green volumes



Terrestrial 2.5D MKDE

Surface area based on 2.5D showed a 31-56% increase in home range over 2D MKDE estimates

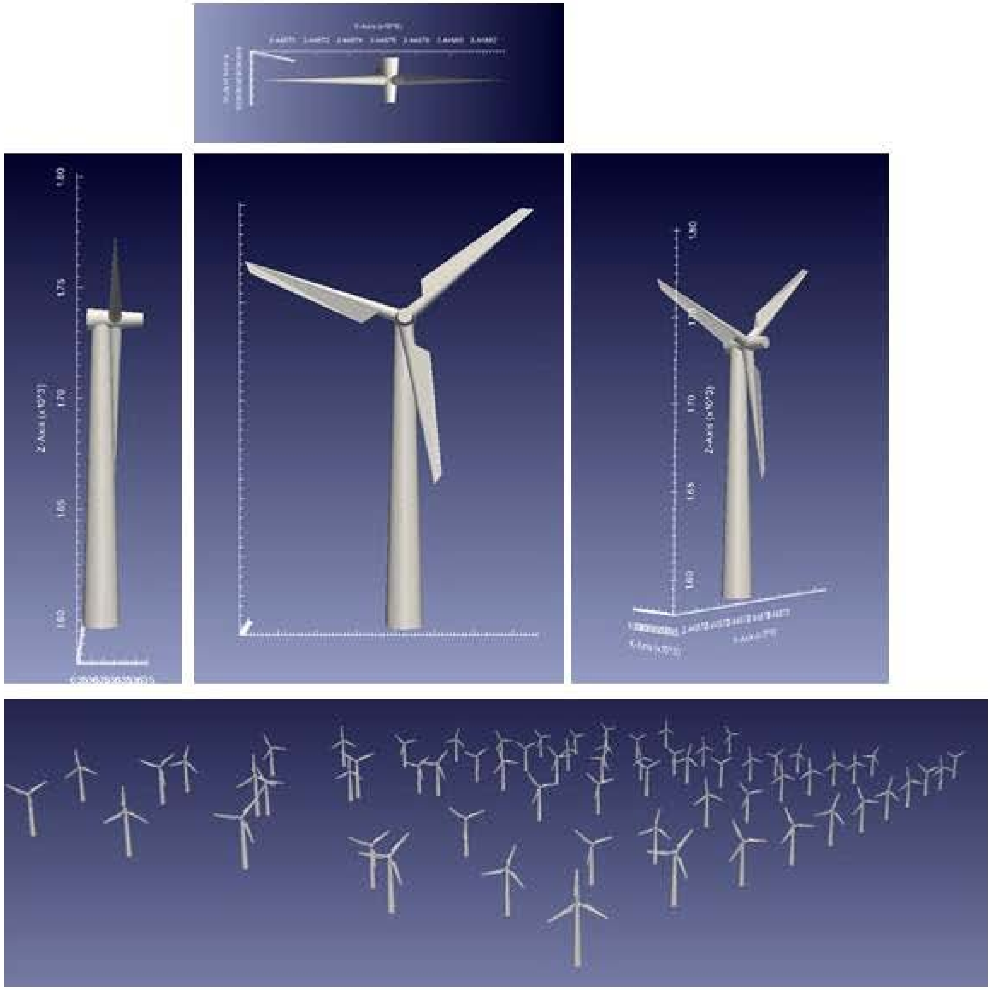


- Critically endangered species
- All 22 remaining wild condors captured in 1987
- Reintroduction into wild in 1991
- Total population now up to 435 (237 wild, 198 captive)

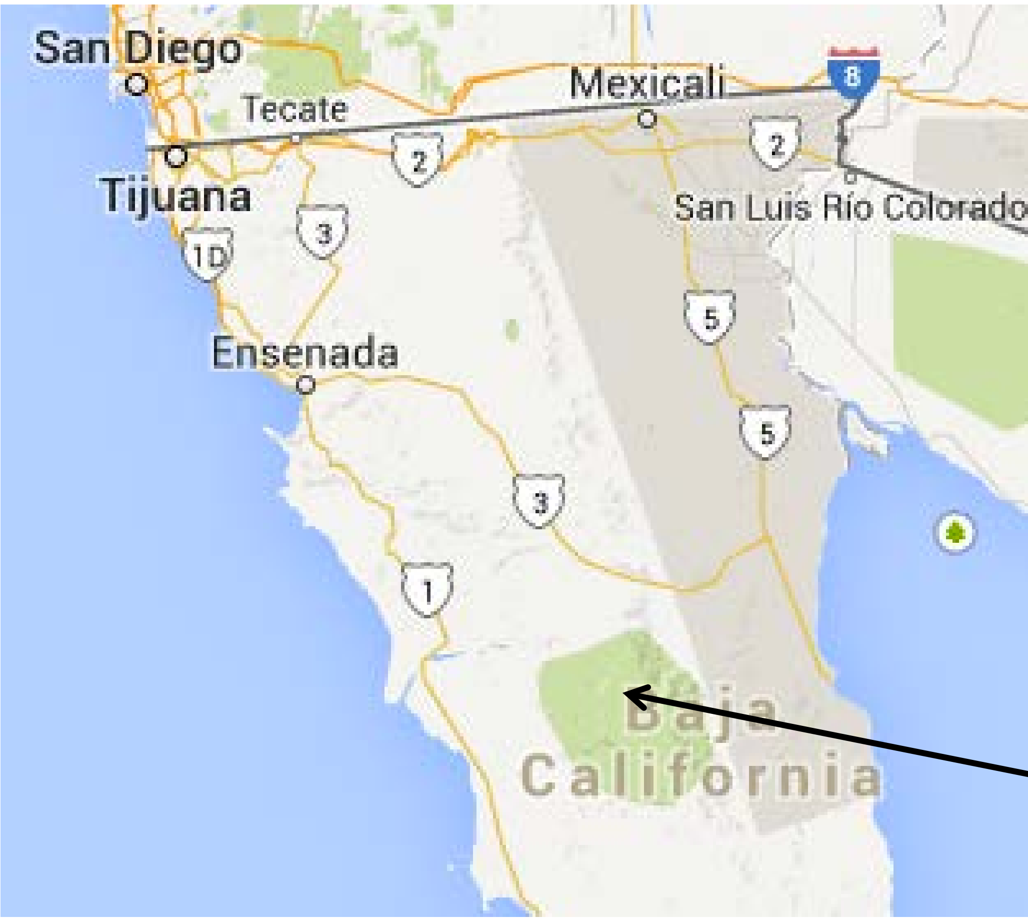
CA condor – major vertical component to movements

Example conservation application

3D vector models of wind turbines based on industry specs used to generate a hypothetical wind farm

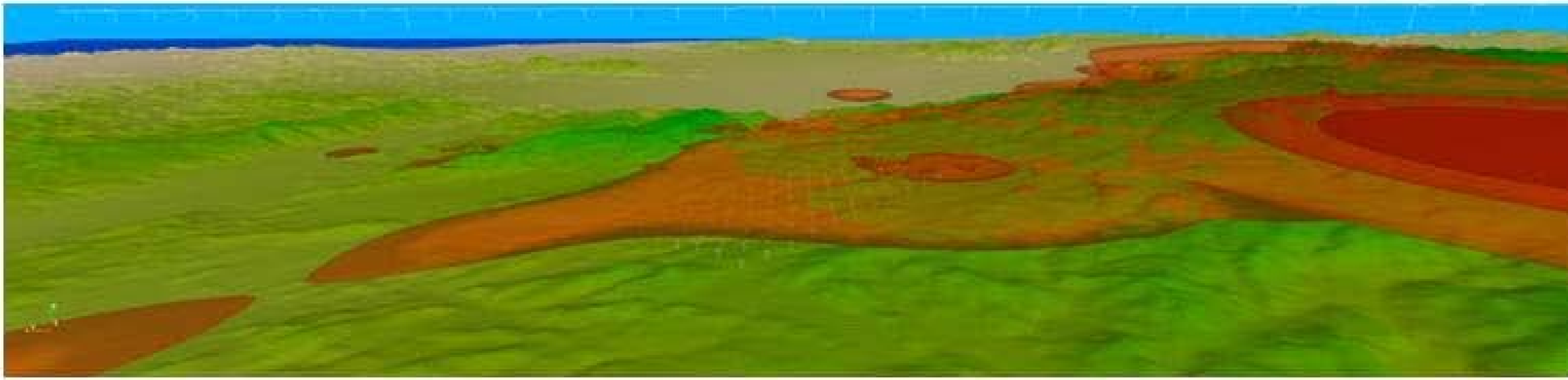


Example conservation application



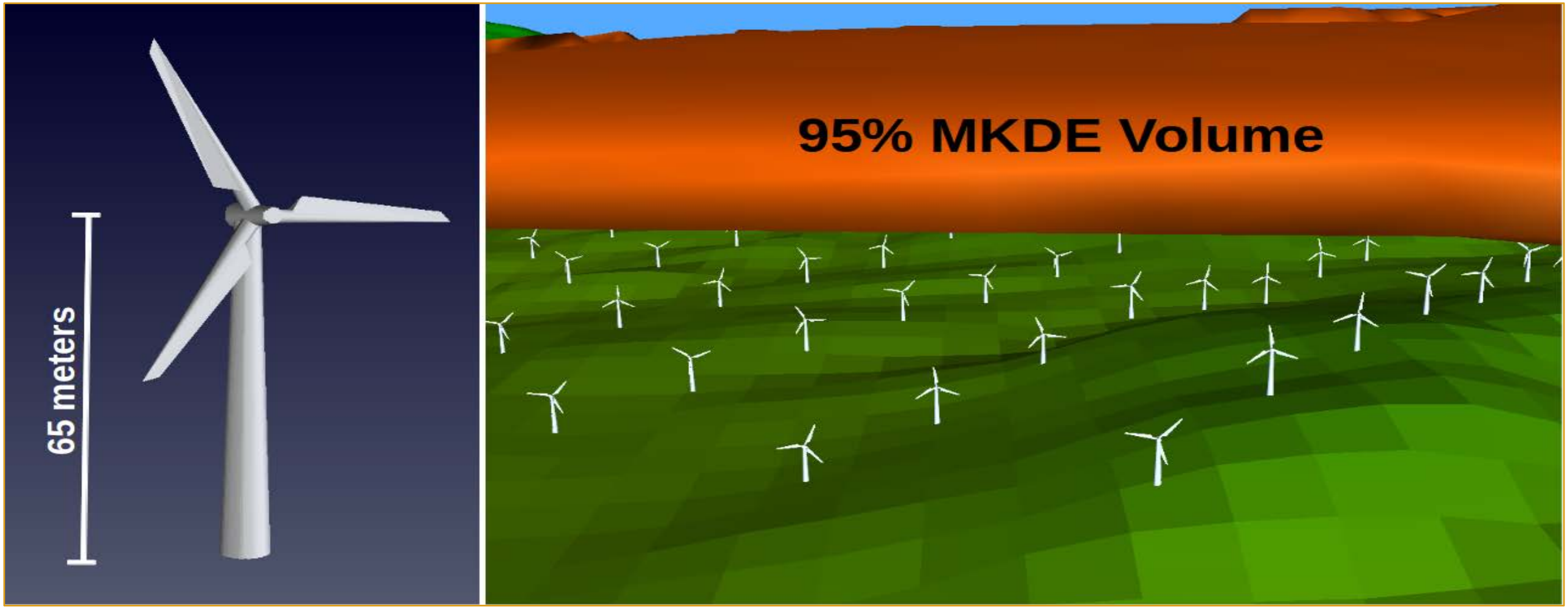
Sierra de San Pedro Mártir National Park, San Diego Zoo Global California condor reintroduction site

Wind farm visualized in relation to the condor 3D MKDE 95% volume.

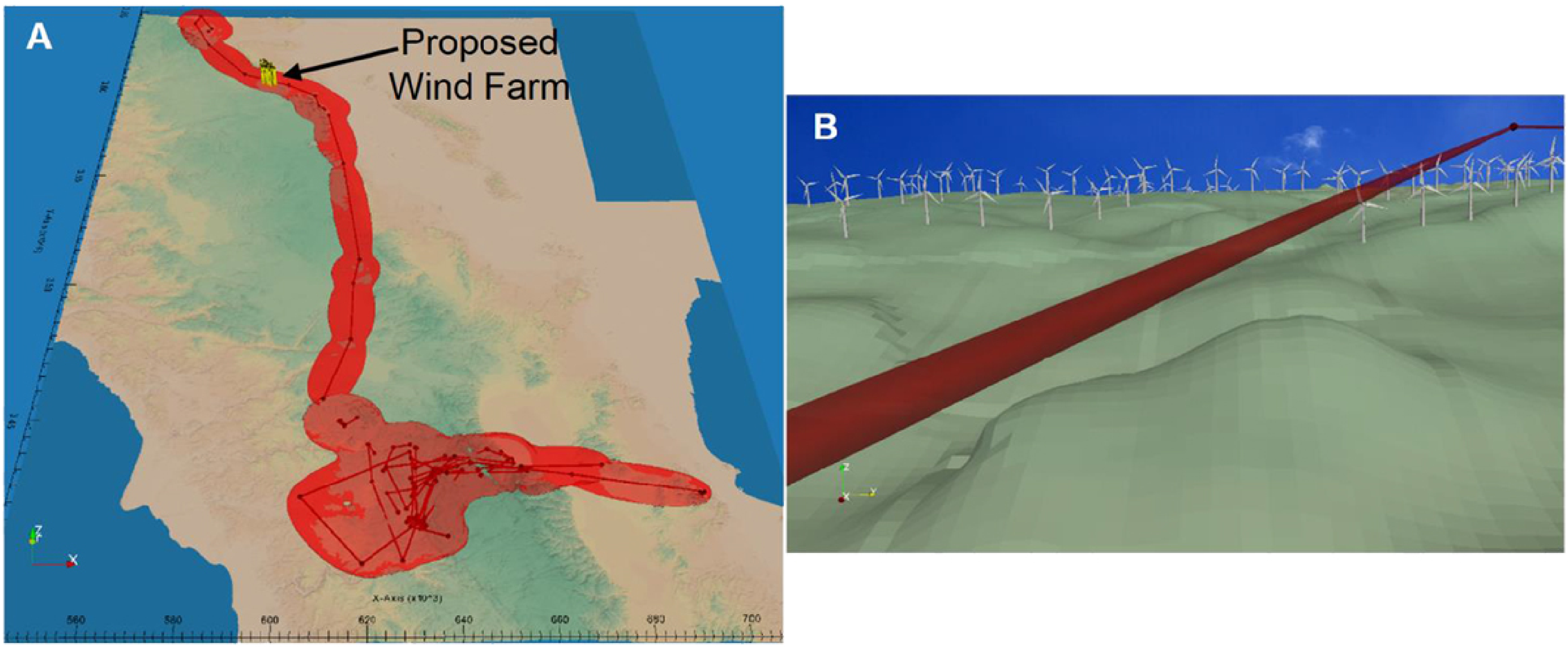


Example conservation application

- ***Many turbines fall beneath the volume & don't intersect it.***
- ***2D MKDE would suggest otherwise.***



Example conservation application



Challenges with 3D MKDE

3D space use models are obviously superior to 2D models, especially when animals make extensive use of the 3rd dimension via flying, climbing or swimming.

The drawback to the 3D model is the computational expense. Need to evaluate a more complex function over a larger number of voxels.

$$O(N^2) \rightarrow O(N^3)$$

SDSC Contribution – code optimization

337 observations of single Condor 10/2010, Timings from single Gordon node

version	t(s)	speedup
Original	1829	1.0
Optimized	42.5	43.0
Opt w/ d=100	3.87	472
Opt w/ d=60	1.67	1095
Opt w/ d=50	1.25	1463
Opt w/ d=40	0.87	2102
Opt w/ d=30	0.67	2729
Opt w/ d=20	0.46	3976

Original version of code took ~ 30 minutes to process data for single bird month. Processing complete data sets is a supercomputing problem

SDSC Contribution – code optimization

337 observations of single Condor 10/2010, Timings from single Gordon node

version	t(s)	speedup
Original	1829	1.0
Optimized	42.5	43.0
Opt w/ d=100	3.87	472
Opt w/ d=60	1.67	1095
Opt w/ d=50	1.25	1463
Opt w/ d=40	0.87	2102
Opt w/ d=30	0.67	2729
Opt w/ d=20	0.46	3976

Optimization of software, but no changes to algorithm or results. Run time reduced to under a minute

SDSC Contribution – code optimization

337 observations of single Condor 10/2010, Timings from single Gordon node

version	t(s)	speedup
Original	1829	1.0
Optimized	42.5	43.0
Opt w/ d=100	3.87	472
Opt w/ d=60	1.67	1095
Opt w/ d=50	1.25	1463
Opt w/ d=40	0.87	2102
Opt w/ d=30	0.67	2729
Opt w/ d=20	0.46	3976

Very generous cutoff applied for distance from kernel origin where contributions are made to the voxel density. Run time is a few seconds

SDSC Contribution – code optimization

337 observations of single Condor 10/2010, Timings from single Gordon node

version	t(s)	speedup
Original	1829	1.0
Optimized	42.5	43.0
Opt w/ d=100	3.87	472
Opt w/ d=60	1.67	1095
Opt w/ d=50	1.25	1463
Opt w/ d=40	0.87	2102
Opt w/ d=30	0.67	2729
Opt w/ d=20	0.46	3976

Tighter cutoff results in very small numerical differences, probably still more than good enough for quick answer. May be ideal for field work.

OK, so the code runs a lot faster …

The current problems (e.g. dozens of condors tracked for several years) no longer need supercomputers. Can probably run on your laptop in under an hour.

BUT …

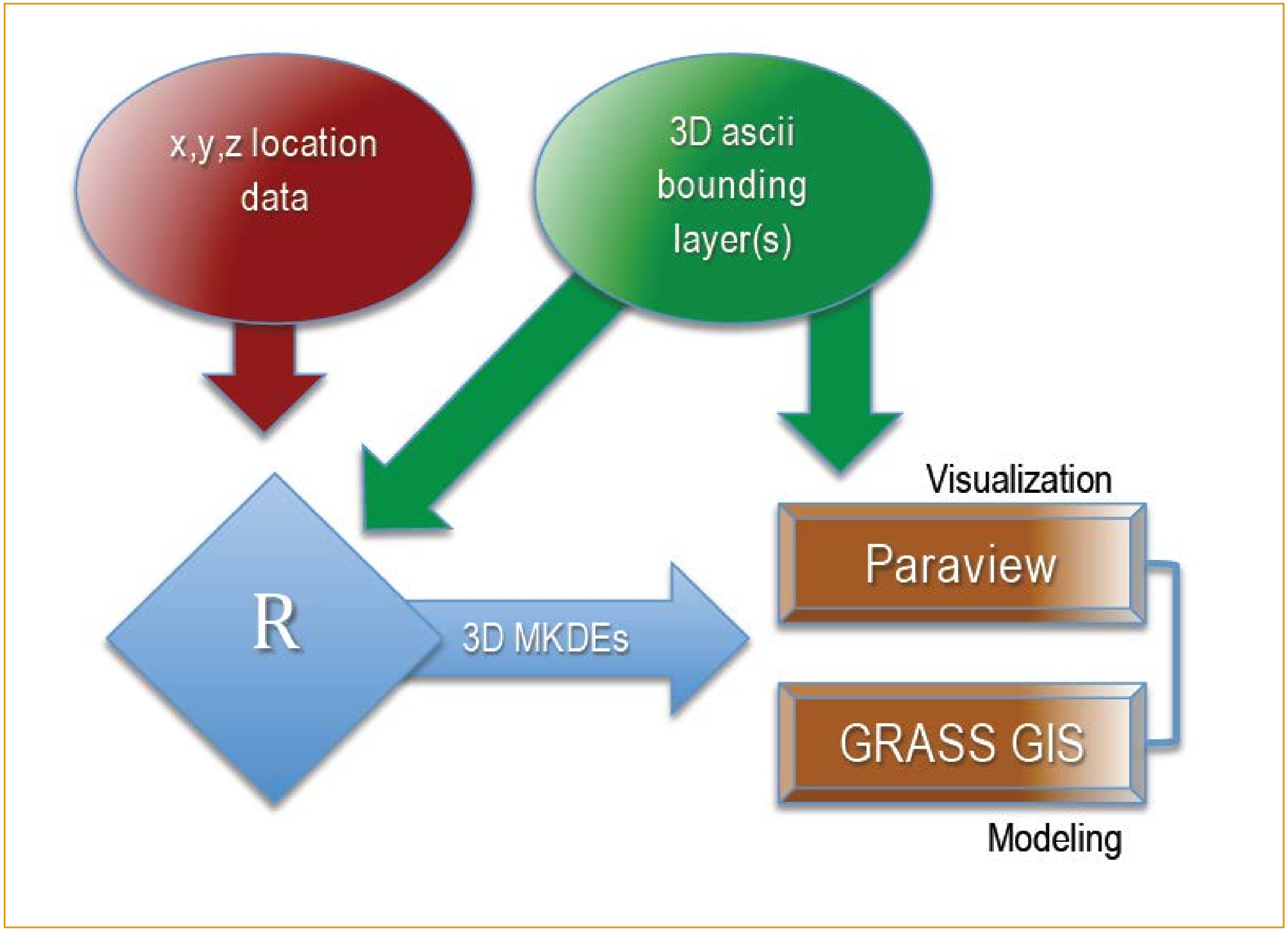
We can now shift our attention to much more difficult problems involving more animals and observations per animal. Tough problems become easy, insanely hard problems become doable.

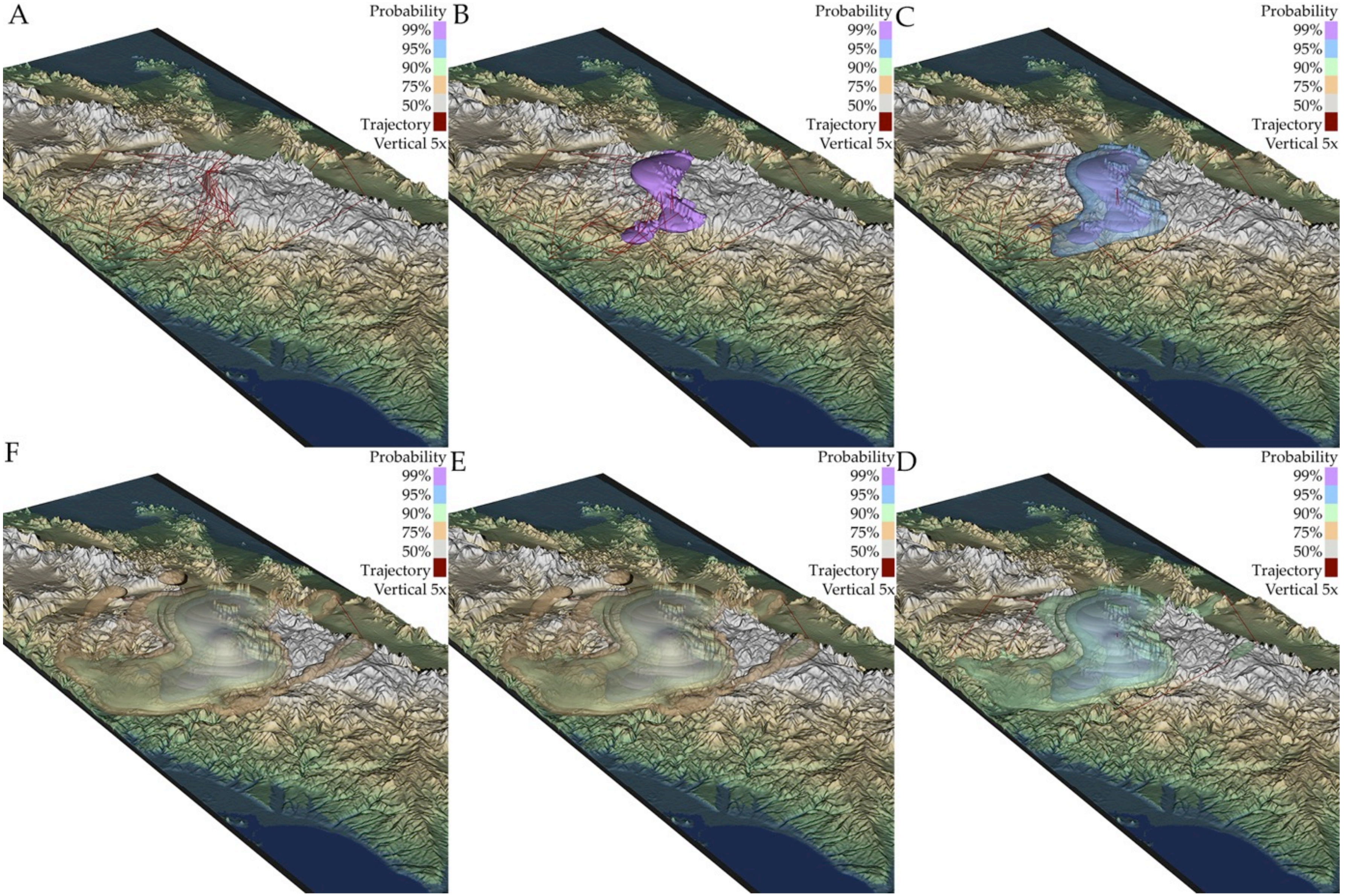
EASY	MEDIUM	HARD	INSANE

← fewer animals/observations ……..........…. more animals/observations →

EASY	MEDIUM	HARD

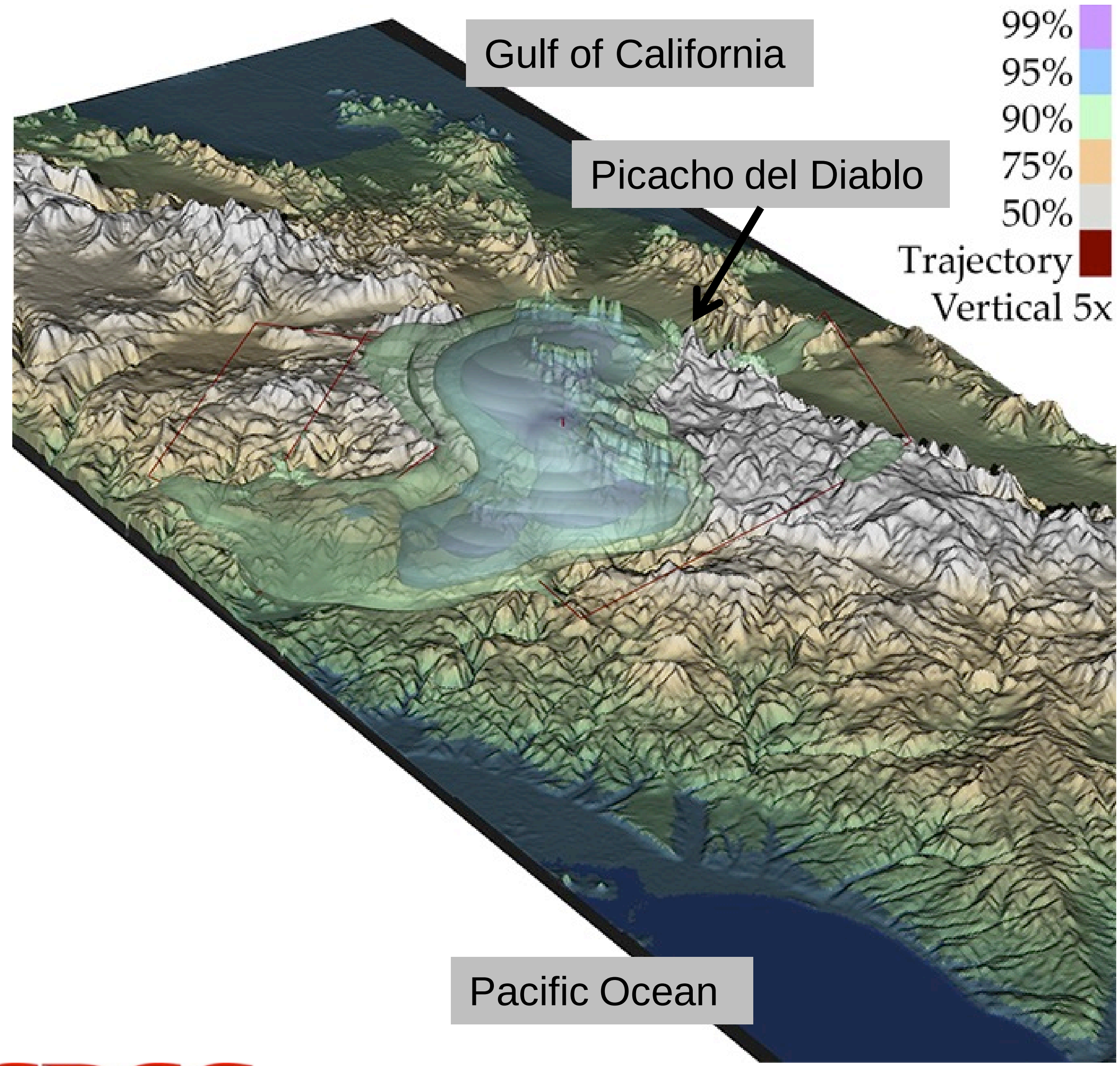
SDSC contribution - visualization





A
B
C
F
E
D
Probability
99%
95%
90%
75%
50%
Trajectory
Vertical 5x

Vis meets HPC



As an example of a challenging problem that is now much more easily doable, we constructed a movie from 949 MKDEs of a breeding pair using a sliding window two days in width and at 1-day increments

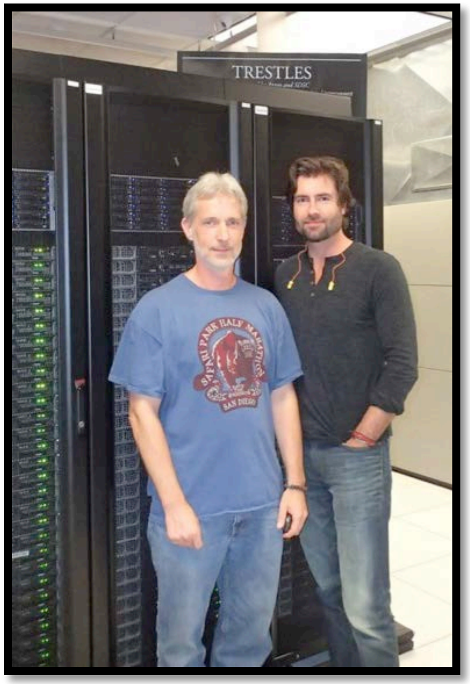
This would have taken more than 1000 Gordon core hours, not accounting for errors, false starts, parameter exploration, etc.

BREEDING PAIR: CONDORS 261 & 217

Summary

- Biotelemetry revolution makes it possible to track a wider range of species over longer periods of time
- Modeling animal space use in 3D can lead to more accurate environmental impact studies, saving infrastructure projects many potential headaches.
- SDSC can work with you in multiple ways
  - Access to storage and compute resources
  - Expertise in software optimization, visualization, parallel computing, predictive analytics, large scale data bases, workflows
  - Training in a wide range of topics

Acknowledgments



James Sheppard (SDZ)
Jeff Tracey (USGS)

SDSC

Amit Chourasia

Glenn Lockwood

Mahidhar Tatineni

United States Fish and Wildlife Service, Instituto Nacional de Ecologia, Comision Nacional Para El Conocimiento y Uso de la Biodiversidad, Secretaria de Medio Ambiente y Recursos Naturales, Wildcoast/Costasalvaje, Sempra Energy, Michael Wallace, Lisa Nordstrom and the SDZG condor field team. NSF grant: OCI #0910847 Gordon: A Data Intensive Supercomputer