Sea-level Rise Modeling Handbook: Resource Guide for Coastal Land Managers, Engineers, and Scientists

Ashley Fortune: Good afternoon from the U.S. Fish and Wildlife Services National Conservation Training Center in Shepherdstown, West Virginia.

My name is Ashley Fortune and I would like to welcome you to our webinar series held in partnership with the US Geological Survey's National Climate Change and Wildlife Science Center.

The NCCWSC Climate Change, Science, and Management webinar series highlights their sponsored science projects related to climate change impacts and adaptations, and aims to increase awareness, and inform participants, like you, about potential and predicted climate change impacts on fish and wildlife.

I would like to welcome Emily Fort, Data and Information Coordinator from the NCCWSC to introduce today's speaker. Emily?

Emily Fort: Thanks, Ashley. Welcome, everybody. We're happy to have you. Tom Doyle is an Ecosystem Modeler with the USGS National Wetlands Research Center in Lafayette, Louisiana.

His research focuses on ecosystem analysis and modeling with a special emphasis on climate reconstruction, forest growth and succession, floodplain inundation, and landscape habitat simulation.

He has developed dozens of simulation models to investigate the role of natural and anthropogenic disturbance and climate change on marsh/forested wetland structure and diversity of coastal and riverine ecosystems of the southeastern United States and the Caribbean region.

His model applications focus on forecasting effects of sea-level rise, hurricanes, altered freshwater flow, wastewater use, drought and related aspects of ecosystem management and restoration. With that, I'm going to turn it over to Tom. Thanks so much.

Tom Doyle: Thank you, Emily. I appreciate that introduction. Today's presentation is on "Sea-level Rise Modeling Handbook," that was commissioned through funding with the Southeast Climate Science Center for the benefit, largely for the LCCs, Landscape Conservation Cooperatives, and for DOI land managers and biologists department wide.

The goal of the project was to effectively produce a document that was an easy, magazine-type read of an understanding of the science and simulation models, related to sea-level rise impacts on coastal ecosystems.

With that, I was given some other commission of other assignments to help to do an effective job, at least of trying not to make these documents ultra-technical or designed for a research scientist only, but for non-experts.

That involved conducting a number of training sessions or feedback sessions with various agency offices across the northern Gulf Coast that included both state and federal, at that point.

I was trying to be more inclusive than just DOI and expanded the effort to include other agencies, Department of Defense, NOAA, NGOs and everything else, inviting them to the table and to tell me the kind of questions and needs they had for resource material.

And understanding the whole matter of sea-level rise from a climate change perspective, and the type of exercises or assignments they were engaged in, for which I could tailor the handbook for their best benefit.

The idea was that they would be able to sit down at a single read and read through it, especially complete. It started out with the goal of 20 pages, but it's more like 50, at this point.

Right now, for those who are asking about what the status of that product is, it's still in USGS Fundamental Science Practices review and is in final edits by our science publication publishing network.

They tell me that they think that it may be out in another month or two as they complete some last minute or final edits and formatting for the document.

We'll find a way to get it distributed to folks as it becomes available as an online link, an electronic document, as a USGS professional papers series.

There are two major divisions in the handbook outlined, the first of which is understanding sea level change. In that section, I cover some of the tools and methodologies for reconstructing and observing sea level rise related to, and I'll break that outline down further.

The second major component are the various tools, decision support tools and models and databases and the like that have been used for simulating sea level rise effects on coastal ecosystems. That'll be the latter half of this presentation by way of example used in the deal.

With understanding sea level change, to make sure the readership understands where we've been and where we're going and the respect of how these models have been used and what value they represent.

We go through a basic understanding of the Earth's hydrosphere. That is that the volume of water that's in Earth's hydrosphere is finite, but the form of that water, the different types that it can take, is dynamic.

Meaning, more in ocean or less on some land, as I'll show.

Secondly, different methodologies and the understanding that we have of the effects of plate tectonics, glaciation and ice melt on the rise and fall of sea level, affected mostly by the change in size of ocean basins, the impact of planetary cycles, and the more recent melt period of record.

Then, I'll take a section that's on the contemporary sea level record that highlights the value of tide gauge records, long term, and also, the more short term, but more recent satellite altimetry records.

Effectively show how those records, while often reported as being different or expressing different rates of sea level, are more compatible than people might realize.

I hope to cover some of that during this presentation, as well as how, used together, tell us a lot more about the land motion aspects and subsidence of different coastal sectors of the coast.

Then, lastly, in this section, talk about the national climate change assessment of 2012, where we now have new future projections for sea level, which are used in most models in some form or fashion to project the potential change of sea level.

We start with the Earth's hydrosphere, which is a finite water supply, but the question is, where is it in the hydrosphere? 97 percent or 3/4 of the Earth's surface is covered by water in our ocean basin. That's the largest percent.

The rest of it that you see on this sheet with regards to the glacial ice sheets, that portion that's stored in the terrestrial component on land surface and ground water, surface water is less than three percent.

It's that three percent that fluctuates between ice conditions that account for something on the order of 120 meters of rise and fall in the glaciation cycles, that I'll mention more about here shortly.

Yet, one of the things that I highlight in this paper is that, when we hear about climate change projections, not for sea level, but for say, temperature or precipitation, one of the questions people should ask, if they are hearing that a given region or sector of the coast is going to become drier as a function of precipitation record, that you might be asking, well, where is it getting wetter?

Because water is like energy, neither created nor destroyed, it changes form.

The major changes that account for sea level rise, of course, is the volumetric change of input from ice melt. Then the other effect is its actual temperature affect on water expansion.

Because we've found in the reference material that we use to prepare the report, different values for the degree of expansion that can be expected for, say, a 1 degree change in ocean temperatures over 1,000 meters of depth.

We include in the handbook an appendix on the functions of how water volume changes with mass and with temperature. Not so much that people will try to use it, but they'll know where this information comes from.

As you can see, water volume for the same mass of fresh water and salt water is different. Here you have salt water at 35 parts per thousand, compared to fresh water at 0 parts per thousand.

Given that they are at the same mass, they occupy a different volume. Then, if you add a component of added temperature, meaning that warmer water takes up more volume than colder water.

To answer the question I started with, which is, using these functions that are included in the appendix, 1 degree change in ocean temperature over 1,000 meters for an average ocean temperature of 17 degrees, going from 17 to 18 represents a 23.03 centimeter rise in sea level.

That explains that whole effect.

While it may not seem plausible to think in terms of multi-millions of years, in terms of effects of change in sea level, but the configurations of our ocean basins are affected by the plate tectonic movements of our land masses.

As they break up or consolidate over this type of period, they've been causing differences in ocean depths in such a way that over the longer period leading up to the late Cretaceous period, the ocean basin was decreasing.

Over that longer time period has now been increasing.

This represents two different methodologies using sediment stratigraphy, from two different studies by Haq and others, '87, Kominz et al. in 2008, utilizing different methods of interpreting the sediment stratigraphy.

But both showing the same pattern of history of decreasing and increasing ocean basin volume over time, even though they're different in magnitude and timing.

The other major effect that we see now in the world of glaciation and over the period of the last half million years of Pleistocene epoch -- we have good data on various aspects of our environment -- both in terms of oxygen isotopes that are taken for foraminifera, specimens in the ocean depths that can be used to interpret sea level heights.

This has been done multiple times. This is the first graph showing you the effect of the planetary cycle of a Milankovitch time period of approximating 90 to 100,000 years of cooling and warming of the Earth, related to the orbital cycle.

You're seeing four different cycles over this 400 plus year cycle.

Then more currently, here in the contemporary time, we're gone through ice melt that has us, again, at a high sea level rise condition, what we refer to as a high stand.

In contrast to a low stand when the Earth has cooled down and more of that water is back in an ice cap covering largely Northern hemisphere.

Additional data sources of ice volume layers and concentrations of CO_2 gasses, all correspond or are concomitant with this long history and pattern of the effect of glaciation on our sea levels.

It wasn't, but 12,000 years or less than 20,000 years ago, that sea levels were 120 meters below current.

They're up for a period of time before we can expect them to rise. Although, with the increase of CO_2, in 400 parts per million as they are currently at this time, that's part of the driving aspect of a greenhouse effect and the fact that there's still 1 to 60 meters of available fresh water in ice, that has the potential to melt without the advent of another icing effect.

Then we look more currently in the Holocene record and there are a number of these. We pull this example from Balsillie and Donoghue, 2004, largely because it's a reconstruction of a number of sources of data from the different ocean systems globally.

From the Pacific, to the Red Sea, to the Caribbean, looking at both foraminifera O18 sample material and corals.

The same could be taken from carbon dating from mangrove, peats, and other things, where this corresponding curve of the ice melt of the last 20,000 years since the last glacial maximum is replicated quite beautifully, with a number of different types of biological and geological data sets for the most part.

Here again, we're at current a high stand of sea level that's been fluctuating and has influenced marine terracing along our coastline.

This is part of the confidence that we have of some of the factors, both in terms of planetary cycles and orbital cycles that contribute to sea level rise.

Then we bring it up to more contemporary sea level records of the last 100 or 200 years, for which we have numerous long-term tide gauge records that have been identified in geologically stable environments.

That means that the land component is not necessarily moving, either by uplift or by sinking, such that a reliable estimate of long-term sea level rise is on the order of one to two millimeters per year.

Then you see an overlap of the shorter satellite record of about the last 22 decades, and in many cases it's reported at a global mean sea level of about 3.3 or 3.4 millimeters per year.

Many times this is reported as an evidence of acceleration of sea level rise in contrast, to long-term tide gauge records.

Part of this handbook and our exercise is to show that it matters how you compare different rates and different methods, and that there are some rules that are best applied.

First of all, that each coastline, aside from the eustasy factors that we've talked about in terms of ocean volume, ice-melt, and thermal expansion of sea level, which we're calling the eustasy aspect.

There are other factors that are different related to the astronomical and meteorological conditions that account for a change in sea level height, together with a change in surface elevation, which can be affected as a function of the land subsiding, or deposition on the land, or the tilt of the land form, or the larger land mass as a function of isostatic rebound or glacial rebound from release of ice weight on the system is another example.

It's the combination of both this change in sea height and land height that makes up for an effective sea level rise at a given at location, or what's called a local or relative mean sea level. That is different for every location for all those factors that are involved.

As a case example used in the handbook, we look at relative sea level rise for the Northern Gulf Coast, where they share the same coastline and are fairly proximal to each other and/or the same body of water.

Here we have the example of Pensacola in northwest Florida on a stable geology that approximates that same long-term trend that I showed in the earlier slide, on the order of two millimeters per year.

In contrast with the Louisiana Delta Plain of the Mississippi River, Grand Isle which is five times greater than Pensacola, at around 10 millimeters per year, or one centimeter per year rate.

In contracts to Galveston, Texas, on the Chenier Plain which also has a high rate of sea level rise, not as much.

I'm going to make a little bit of a point here to show that part of the discoveries of doing this handbook and putting together the illustrations is that, Galveston is less about a natural effect of alluvial deposits compacting as it is about removal of groundwater causing subsidence.

Records that are well known for the Houston, Galveston area's respect to roads and housing constructions.

If we look at the more contemporary or the more recent satellite record over the last two decades, the US Topex, the Poseidon, and Jason satellite missions were commissioned at different times over this period, and are combined into a comprehensive record over this period.

You're seeing a 10-week record for each one of these points, where the satellites are doing a measurement from space.

As opposed to tide gauge on the shoreline and reading the water level from the basin or from the bottom-up, this is from the top-down of electromagnetic pulses that are sent to the earth.

The fact that, rather than being stationary like a tide gauge in the same harbor or same location, the satellites are always on a track.

Not necessarily sampling from the same specific location of the ocean, but always gathering some level of information of the height of the ocean body.

Here you see that the trend over this 20-year record, which is approximate to a 19-year tidal epic, which in effect provides some of the variation that you can expect astronomically, due to all the arrangements of the gravitational forces of the moon and the planetary alignments.

This provides you this accounting that we see which is the 3.4 millimeters per year slope, in the record.

The European community also has a satellite called AVISO. We also downloaded and stripped the data for this, as well, to compare with the US Topex, Poseidon, Jason merged set that I showed you.

The two sets are very compatible. In some cases the AVISO fills in data gaps for their satellite with the U.S. record, but both are providing a lot of confidence that these records are genuinely providing a good measurement of the change in ocean or sea height altimetry over this period of time, of record.

Again, the same rate on the order of 3.42 or there about for this 10-week re-measurement record that's needed.

I'm going to make the point and show again in the record that tide gauge and satellite records are very compatible, but in doing so, we have to be talking about rectifying to the same datum so that they are compatible in the sense of the reference that you're referring to.

That you're comparing the same time periods involved and that your records are complete, that there are no data gaps. This is a problem when looking at tide gauge records over the continent, or for any given location.

NOAA has historically recalculated the sea level trends for many of these more permanent gauges that you see along the coastline of North America, and such.

In this case, I've trimmed the record to look at the same period of record as the satellites, so that you get a fair analysis or comparison between gauges and between satellites.

As you can see, there are evidence of records of sea level that is falling effectively, not so much because we're losing eustasy in the oceans, but because the land is lifting that much faster over this same time period.

In other cases the degree of sea level rise on a regional basis is less or more, depending on the location.

Again, the component the tide gauges include is not only the eustasy aspect, but what's happening in terms of the land motion aspect of whether it's subsiding or uplifting.

If we go back to the Gulf of Mexico example of sites, if we to attempt to de-trend, to isolate, the degree of how much these gauges are representing a land motion change, we have to convert the satellite record from a 10-week record to monthly record, which adjusts the rate again to 3.32 millimeters per year.

In effect, for the same period of record, the gauges around the Gulf of Mexico, Key West, Pensacola, Grand Isle, and Galveston are all rising at a faster rate than the sea level.

For many people this is a confusing element that we wanted to bring into the education in this handbook.

The long-term record for these gauges is a much slower rate of sea level rise, but for the same comparative period these gauges are showing a rise effect greater than the satellite.

The difference of which is some degree of land motion that can be attributed to either local subsidence, or the tilt of the land form, or some other things that we don't explain here.

Then if we look at the tidal epic period of prior to the 1994, 2012, going back in time, we see that there are rates greater or lesser and comparable to the current rate.

Effectively, this might imply that there's not that strong of evidence for an absolutely acceleration or deceleration. That it's more or less holding similarly for this period of record.

The contrast, again, going back to Galveston, is that you have some periods of record where there are even higher rates of sea level which are more about the land motion effect.

Which in this case, is a period of time post World War II and prior to some local recognition of subsidence rates related to groundwater withdrawal.

Here you're seeing that there's evidence of the influence of man of different subsidence rates, that I associate more with the groundwater withdrawal effect than anything that's the property of the compaction of the types of sediments in those locations.

Then, when you look at the Key West record without the satellite record or residual satellite record, you see the same thing I showed before.

We illustrate this with both linear and curvilinear fits so that there is a land motion effect that, even though it's a stable geology...Same with Pensacola, which is about the same rate.

Then, for Grand Isle, weave in the fact that while, again, we're expecting to see a more constant residual rate due to subsidence of deltaic components, the early part of this record is relatively flat with a curvilinear acceleration here toward the end.

I'm not offering any explanation, I'm showing that this is the value in use of both gauge records and satellite records that are more compatible with each other than what, in many cases, has been reported.

Then, Galveston, for the more recent tidal epic, for this period, 1994, having a reduced land motion effect. It's almost similar to Pensacola and Key West.

Meaning that there is some evidence that due to restricted groundwater withdrawal, that rate has slowed down.

For the benefit of modeling, there's a need to have the future sea level rise projections that are generated from climate models, general circulation models, and to look at the potential range of possibilities.

In this case, from the lowest, which is a two millimeter per year record, which is business as usual or the historic record extended in the future, which is the low case scenario.

Which, it's only likely to be at least that much or more. Then, some intermediate possibilities of 0.5 and up to 1.2 millimeters and in some cases, adjusted in the 2012 above previous IPC reports of 2001 and 2007, as high as two meters over the next century or by 2100.

These are the kind of projections that many land managers and municipal coastal planners and practitioners are concerned about, and trying to make adaptation plans and strategies in lieu of.

There's a range of different types of predictive models for sea level rise that are highlighted in the report for the way we categorized them or identified them by their properties, and characteristics.

We established about six different types of groups of models from sea level rise simulation, and inundation models that are largely about the change in hydrology, GIS sea level rise mapping tools, which are decision support tools that are built on GIS capacities of water over land predictions, wetland change models, which incorporate habitat considerations in terms of ability to keep pace or the relationships that can affect what type of habitat precedes another habitat under different submergence rules.

There are a class of tools and methodologies for observing surface elevation and shoreline change. We talk about those models as well as a group.

Then there's an evolving group of models called niche based or species distribution models that are based more on climate envelope considerations of change and temperature and precipitation at, also, sea level.

Then more sophisticated ecosystem models that deal with leaf to landscape predictive capability of species and organism level changes, in terms of effects at the leaf layer all the way to the landscape to the stand level, where changes in CO2 in the atmosphere and everything else can have some feedback effect in these models.

Along with the direct impacts of flooding from sea level rise.

The layout of the different model groups that I've identified are put out in attribute tables by each group. In this case, you're looking at the sea level rise simulation inundation models.

We did our best to be as exhaustive or comprehensive in search of the literature and Internet and whatnot to categorize and to describe some of these different models.

Here you see this collective group that's identified and what agency/organization has developed the model, what kind of scale does it operate at, what is its spatial resolution that's identified. On what temporal scale does it operate?

What are some of the input parameters that are required to run the model or to produce output? What are the output parameters of the model?

Then, what are the citations in terms of where can I learn more about that model. In the body of the handbook are some abbreviated descriptions of each of these models that are illustrated.

One thing that's not included that was asked for in both the pre handbook feedback sessions with partners across the Gulf Coast and thereafter, was, could you add a component of how well the models perform and things like that?

Which got into more of whether we could test, evaluate, or do a sensitivity analysis on the models, which was not possible and was not within the scope of the project.

One of the things that continues to come up because people want to read about these different models, but have someone's expert opinion or a process that gives them a review of goods that we might do when we buy a TV or some other appliance that you want to know, how do they stack up against each other.

That's not included. There's nothing like that included in this report.

Among the sea level rise simulation inundation models that are highlighted in the handbook, I can illustrate, easily, the SLRRP, Sea Level Rise Rectification Program, as one step through of how the models are described.

This is a model that I developed for a Department of Transportation Gulf Coast study, where they wanted to know how different transportation sector features and assets could be impacted by sea level rise.

That would be rail, roads, ports, harbors and what elevations are those assets at.

Then, if choosing a near approximate gauge of location, the model uses historic observed data from tide gauges allowing a user to specify or accept a historic condition or customize it with a new subsidence or eustatic rate that effectively creates a projected sea level rise with all the numerical attributes of monthly astronomical and meteorological record, which is real, into the future above what the trend line was for that gauge over that period of record.

In this case, the user could select a global change scenario or do a customized deal. If the feature that they're looking at, wetland or rail or road, was at a one meter elevation, NAVD88, this model rectifies both the water level record and the orthometric level of the land surface or the feature together, so that we're dealing with apples and apples.

It shows you at what point for that given climate scenario or sea level scenario that is selected, that it might take 36 years or the year 2036 before you'd get a monthly or multiple monthly inundation of that feature.

Then again, because of the variability, maybe without, for a period of months or years. Then, eventually, over a 30 year or longer time period, before you'd get to the point where that feature would be permanently or subsequently submerged over the time period, compromised.

Of the GIS sea level rise mapping tools, these are the ones that use data sources that are readily available. These are also known as the “bathtub models”.

These are visualization tools that effectively use some understanding of elevation of the landform and an aspect of generally arbitrary water level that's unrectified.

It doesn't matter what the rectification is or what the referenced datum is necessarily. They're arbitrarily pulled together and effectively says that, whenever this water level condition exceeds a land elevation basis, whatever source, national elevation data set, LiDAR. It can be whatever source.

These are three primary examples, the NOAA sea level viewer, University of Arizona map visualization tool, and the USGS sea level rise animations that I can show you visually and are described in the section on these models.

There are more of them than what I'm showing, but these are good ones that are used and have been developed with pretty refined capacities.

You're seeing a window here. As you execute the program on the NOAA sea level viewer, it allows the viewer to increase the sea level rise effect up from one to six feet depth.

There are some other features that allow you to effectively simulate a marsh accretion and a few other things.

Then it gives you a result in field of view of where that flood extent and that shoreline extent would take place in a future condition with that kind of, in this case, six feet sea level rise bow.

These are very handy tools that work very well and are of more value education wise to appreciate what could happen more than what might technically happen at those specific locations.

This may have a lot of assumptions about hydrologic connectivity, and things that I'm not going to go into.

The same for the University of Arizona web map visualization, a good tool that they keep making a few changes to make some of the water aspects a little more rectified to the land datum and the like.

It's a water over land approximation that doesn't have a lot of the understanding of the biology or the geology of the location. It does an overlay exercise of the data sets themselves.

Same for the USGS sea level rise animations, with a little more socioeconomic considerations of population levels that may be impacted and other aspects of highways and cities and such, and a much broader range of sea level potential in terms of rise potential that can traumatize the whole effect.

In this case, up to six meters, which is well above current IPCC sanctioned sea level rise projections. We're within the range of plausibility if we have some serious ice melt conditions that may result.

The next class of models described in the handbook are the wetland change models, that basically consider the specific habitat type.

Don't have any kind of species level or organizational level at the local plant or necessary level, but with generic habitat types that are described often in the various sources of information that are used, like National Wetland Inventory data or TM imagery.

These models incorporate a rule set of potential changes of habitat switching, as it's often called, from one type to another based on the degree or change in land surface submergence.

The Coastal Ecological Landscape Spatial Simulator has a long history, and has been used in a number of different watersheds. It's still in production mode for application.

It basically uses a mass balance approach to the exchange of hydrology from cell to cell and uses fairly generic saltwater, fresh, and swamp conditions.

Again, relatively rudimentary, but something more than just water over land process to affect change. It has other features about it in terms of potential for subsidence, or for accretion processes to occur in these select habitats that can be used in the output.

A fairly common model now being used and adopted by certain agencies and NGOs and a very utilitarian and very visible or model with display functions and everything else so that you can see a more comprehensive range of habitat types.

It has a little more complicated rule set that can be applied of how one habitat, under a given submergence condition can either accrete and keep pace or doesn't keep pace with sea level, but converts from one type to another and is widely used with the SLAMM model.

Another version, it's spatial but it's more based on functional attributes of why you have salt marshes in certain locations of a certain tidal range, it's a Sea-Level Over Proportional Elevation Model.

It considers how the different relative sea level conditions at a given coastal reach...

In this case at a county level, for salt marsh effectively shows the displacement that would take going up slope of that habitat type in a functional design that's quite elegant for regional and national level scale application to project how much of the land form and how much marsh migration would take place up slope under these circumstances.

Surface elevation and shoreline erosion models that we highlighted a number of different types, they're not necessarily used quite in the same way to predict a change in shoreline, I'm not sure shoreline, but habitat condition at a park or regional scale.

Our tools that are used in other aspects of research or making predictions for shore land change that are very important to land managers at the moment.

The two that I'm going to highlight, do not necessarily exclude others is the Coastal Vulnerability Index and the Surface Elevation Tables and briefly introduce you to that.

Other methodologies like marsh geochronology, which uses cesium-137 or lead-210 dating to get an idea of whether marshes are keeping pace and what kind of accretion rates are there.

Salt marsh stratigraphy in evolution models, which are keeping up with the aggression or transgression of a coastal interface at a marsh and trying to make predictions based on the amount of subsidies of sediment, and the properties of the species involved to accrete organically.

Then tidal channel network models, we introduce some of that. We're looking at how, as sea level rises, how it affects the hydrology component of erosion within these small tidal channels at the coastal interface.

The Coastal Vulnerability Index is a USGS product, but basically, it utilizes the empirical information that's already available in historic map sets dating back hundreds of years of shoreline change, and essentially projects probability indexes for degree of erosion at a meter per year rate.

You immediately get a larger view at the regional or coastal view of what shorelines are more stable, and others that are more erodible, and this is another model type that we describe.

A technique that's being widely distributed now, both by different agencies, state and federal, and NGOs for different land forms is the surface elevation table.

Which effectively is a benchmark driven down into the substrate of, on wetland soils, equivalent to a benchmark on land that can be monitored and releveled over time to determine how much it's subsiding over those periods of records at different depths.

Because it uses a reference from up top of distance down to the marsh surface, or whatever surface it is, pond or other, that over time you can capture the rate of accretion and sedimentation that's going on with the inclusion of marker horizons. Some of that information is also provided.

Niche based species distribution models say basically that each species has a unique climate condition for which it's most optimum in its range.

It's tied to a particular precipitation or temperature record. While that's a concept that is driving some models to look at continental scale changes, temperature or predictions of temperature are done over continental scale.

This is an example of a species that is attuned to sea level condition more than it is to a necessarily a climate precip or temperature range. This is bald cypress.

A lot of this was work done through research studies I was involved in. It gives a good illustration of how, at a given elevation contour, you can find the larger extent and how that ties into the history of the geologic era of the late Pleistocene when the coastal plain was largely shaped.

That sea level drives cypress up slope and they persisted over this time period, excepting for conditions, more arid conditions in the Texas side of the system perhaps due to glacial aridity in the northeast section.

These are alternative models that are going to be important.

Here's another example from work looking at geologic record of evidence of mangrove that we think of as tropical in Florida, but there's record of increasing evidence or expansion of mangroves both in the northern hemisphere, here in the US, and also in the southern hemisphere.

The geologic record says that the Earth was warm enough in the Eocene period that mangrove expansion was much further than what it is even today.

This level of information and these kinds of models will make our understanding of how our land units can be changed over time.

An example of a niche-based model for climate envelope is another mangrove model that is looking at how temperature limits growth or expansion, and that freezes that injure tropical plants, in this case, mangroves, has an impact.

In a future climate when it's going to be more warm, it can be expected that different scenarios of sea level can allow for greater or lesser expansion of mangroves replacing temperate salt marshes as we move north.

The last set of models are the Leaf to Landscape Models. I know I'm pushing time. I hope you'll stay with me.

The WETLANDS, SELVA, and MANGRO models, basically are operating at a plant level, predicting how one plant can shade another, how leaf function both synthetically and/or the effect of CO2 in the atmosphere.

Along with other factors at the site for landscape level like sea level rise, and flooding conditions, and temperature can all impact species distribution on the landscape.

In this case, a species-based occurrence nomogram for northwest Florida for these different types showing where the zone of interface between marsh and forest ecotone and where impact of storm tides and high salinity wash have led to impact of dieback in these systems.

Effectively, this information was used in a habitat matrix probability context to push sea level upslope over the period of record showing how marsh would migrate at a species level and replace and/or impact the interface with the fresh water forested systems, and what that might mean in terms of area.

A more sophisticated model at the stem level dealing with individual regeneration patterns and individual tree orientation in terms of shade impacts is the MANGRO model connected with the SELVA model.

The two working hierarchically across an up and down scale from the leaf to the landscape effectively, being able to predict how mangroves would move upslope in a higher sea level condition and replace fresh water marshes, salinity, and sea water moved upslope.

The handbook is laid out with this larger understanding and information about the history of sea level in a geologic context.

The more recent context of how we're observing sea level with tide gauges and satellite information, and how that information is more compatible than some people have made it sound.

The various types and different kinds and details, characteristics of the different kinds of models that are being applied to look at the impact of future sea-level on our coastal ecosystems at a part region or continental scale.

I'm hoping that this handbook that has been peer reviewed but is still in some format and editing changes, is going to be released sometime in August 2014.

I credit some things to the Southeast Climate Science Center -- I got that backwards, sorry about that -- for funding this work and for setting up the webinar presentation. That concludes my presentation, if, by chance, there's an opportunity to take questions.

Ashley: Excellent. Thank you, Tom.

We do have a few question that have come in already. One from Kimberly and it says, "Do high and low points on the satellite correspond with tides? Also, are the subsistence rates reflected on the statistics from page 17 titled "Gauge ranges"?"

OK. The first question is, "Do high and low points on satellite correspond with tides?"

Tom: I wouldn't use the word tides, but the correspondence between tide gauge records and the satellite record is it fits very well in terms of the seasonal and most points.

We attempted to try to isolate a record near shoreline, which would correspond with each of the gauges.

The Gulf of Mexico as a whole is a bathtub. You can use readily one gauge to effectively predict another one very good for this monthly record of both the tide gauge and satellite record as a whole. They line up and correlate very highly.

"Is land moving up when tide is going up?" I'm not real sure how to answer that. There's a degree of which the water is going up that the satellites are recording. The tide gauges are showing the same thing.

It's that at the same time or over the same period those tide gauges may be going through a more localized process of sinking or even uplifting.

Ashley: Then we have another question; I'm scrolling back up here, from John. It says, "What causes the large annual scale fluctuations in sea level in the satellite data?"

Tom: Those are all the seasonal trends of water, where, in the Gulf of Mexico, you have the warmer waters and, in some cases, you're looking at storm effects from hurricanes and other things that effectively are moving water. This is a seasonality effect of colder water/warmer water.

Ashley: Then we have a question from Sean. He says, "Does the manual discuss the relative reliability of different methods of modeling?"

Tom: No. You mean in terms of either a sensitivity analysis or a certainty analysis kind of thing? There's no in-depth evaluation of the models themselves.

The code or the properties of how they function are not treated in the handbook, only the functionality of the models and the characteristics of their makeup and their use.

In some cases, the models have gone through a validation or verification, and there's a note to that aspect or whether they were unverified things. No hindcasts or other type of exercise was done to show that the results can be reasonably trusted or accepted.

Do you want me to watch these? From Nicole Metzger, she says, "Many of the tools shown are specific to the Gulf and Atlantic Coast, where sea-level rise levels can be simply added and they result in an inundation map to the new elevation contour to produce reasonable results.

However, in the West Coast and Pacific Coast, run-up dominates the coastal flood hazards. Run-up is not linearly proportionate. In other words, you cannot simply add sea-level rise to the still-water levels to estimate the effect of future scenarios.

The engineering analyses must be recalculated using the new still-water level inputs and may result in very different responses at the shoreline.

What tools are available to address the sea-level rise effects on the Pacific Coast?" The same would apply to the run-up of surge bubbles from hurricanes in the Gulf Coast, which is beyond the scope of the handbook to deal with phenomenal sea-level change effects of days, or hours, or whatever, effectively. As opposed to the long-term impacts or effects of sea-level rise necessarily.

I would agree with you that, even on a regional level, if I showed you the satellite record for the Pacific Coast, the eustatic sea level record is actually closer to zero.

Although that's not what's commonly reported since more of the water conditions of the Pacific-Atlantic are tropical waters, where it's a more comparable rate to the Gulf of Mexico.

Ashley: Thank you. Is there any data for Hawaii and other coastal territories?

Tom: When you say data, there are tide gauge records for Hawaii. That's true worldwide.

There are locations of tide gauges that are maintained by different nationalities or organizations. They are largely reported in the Permanent Mean Sea Level Database and website.

They're available publicly to download, just as the NOAA gauge information, NOAA Tides Online or historic information. Their gauges can be downloaded from NOAA's site, as well.

There are records for Hawaii. Of course for the satellite, you'd have to strip the data that overlays the portion of the Pacific around Hawaii to contrast those sets of records.

Ashley: OK, thank you. A question from Walter It says, "In view of the increased attention to sea-level rise in climate change, is there any effort to standardize by convention a common datum?"

Tom: In a global sense I don't know that that there is. I can't say that.

Eventually people recognize the value, or need or whatever, and they also recognize some of the complications involved in terms of an accepted geoid, or whatever.

The satellites themselves represent some kind of orbit. That can be described mathematically, so if that's used as a reference...

That's kind of geodesy question that is more involved than I should try to tackle or answer on this call, or relative to the field. The important thing is, though, we're back to, "It's important to compare apples to apples."

Records that are of the same time period are necessary. Records that are complete, meaning there's no missing data because that'll change the slope readily.

Because there are such strong seasonal records, as you can see even on this satellite record, if you take off the high of one or the low of one or the other, it can have an effect.

Of course, more or less depending on whether you're in the middle or the record or at the ends of the record but, even then, missing records or gaps present problems to compare rates.

The other aspect is that, it's best to compare them referenced to the same datum.

Ashley: Excellent, and our last question is from Andrew. It says, "What are most important in the future investments for the decreasing uncertainty in sea-level rise response, wetland change models? And, Is it better evaluation data, more information on accretion, better high-marsh, low-marsh models, or models that account for more of geophysical or biological processes?"

Tom: That's a great question. There's a lot in there in terms of how to improve existing models that we do have, because in all cases they're oversimplified in terms of the actual biological and geological processes involved.

In many cases, my personal opinion is that a lot of what we're seeing in terms of wetland loss, particularly for me in Louisiana, where I am, and an example that was given for Texas, it's more about man than it is about nature.

We've changed the tidal constituents of our basins by digging deeper harbors, having deep drafts, navigation canals further inland, so there are a host of complicating factors beyond the more simplified, "Do I have good LiDAR?"

In the case of LiDAR, some of that is still not as good as people indicate. In certain cases, I'm not saying in all cases.

One of the bigger things that we need to understand is the feedback processes that are geophysical and biological, that are much more complicated than what we have looked at before.

On the accretion rate, people have tried to use SETs or geochronology dating methods as a sole constituent that stays fixed or static over time and, effectively, I don't think that's the case.

Plants are getting the message, when it's higher than normal sea level anomalies, to grow new roots. Factors that can complicate whether they do that effectively or not are still not well understood.

In most cases, it's interrupted by conditions where we've impounded the coast, which as has been done in a lot of cases.

That's a great question. It's pretty loaded with a lot of possibilities.

I would agree that we need a better understanding of our geophysical and biological feedbacks.

The better record shows that because we've got peats, marshes, and mangrove systems that have kept pace from sea-level for the last thousands of years, because we can date the carbon, proves or shows that there is a capacity to keep pace with sea-level.

It may be some more of the other things that we do in our coastal settings, by way of management or interrupted effects of surface runoff.

There's a host of possibilities where groundwater withdrawal, all those things combine to aggravate or amplify the possibility for plant species to keep pace or to hold ground under these sets of conditions.

Ashley: Excellent. Thank you, Tom.

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