Transitions: Research to Applications (R2X)

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What is R2X at NOAA PSL?

- Rooted in **foundational and use-inspired innovative research** across all three themes

- **PSL science planning looks toward NOAA mission,** use by research or operations, or knowledge use by NOAA, National Climate Assessment & other agencies

- NOAA tracks categories of transition outputs: *system, process, service, tool, product, or assessment*

- NOAA tracks several stages in transitions, not just the final handoff
  - **E.g., proof of concept; tested as a demonstration, as a pilot, or tested in an operational setting, documented uptake of knowledge transfer**

- **Iteration** with core users & operational partners – not a one-way street
  - National Centers for Environmental Prediction (NCEP); NOAA Testbeds; Weather Forecast Offices & River Forecast Centers; Drought Monitor, FEWS NET
  - Fisheries Science Centers & Regional Offices, NOAA RISAs, DOI Climate Science Centers
  - O2R, and M2R (management needs to research)

- **Beyond consultancy role:** These relationships spur use-inspired R&D aimed at improving NOAA operations overall.

PSL contributions are often an early link in chain of transition to operations, service intermediaries, & end users

Model improvements to NCEP & National Water Model forecasts/products➜
- Improved forecasts by NWS NCEPs, Weather, & River Forecast Centers
- ➜ water management, emergency managers, recreation
- ➜ Weather Forecast Office flood statements ➜ safety of lives & property

Experimental predictions and guidance:
- **Drought research & product development**
  - ➜ NIDIS/US Drought Monitor/Outlook ➜ state drought preparedness & mitigation efforts
  - FEWS NET ➜ food security abroad ➜ national security
  - ➜ Situational awareness for extremes for emergency managers

Forecasts/projections of ocean conditions
- ➜ Fisheries policy decisions/management ➜ commercial fisheries' economic decisions ➜ benefits to coastal economies, food security

Types of transitions at PSL

- **Improve NOAA operational and experimental models**
  - Model diagnostics & evaluation, tools to do this, new parameterizations
  - Specific improvements transitioned into operational models including UFS, HRRR, GFS, National Water Model

- **Experimental Predictions and Guidance** – may be provided directly to users

- **Knowledge transfer, synthesis and assessments**
  - Significant activity at PSL, much is co-production with internal and external users
  - Support for NOAA Fisheries & Ocean Service, other Fed and State agencies: Reclamation, Army Corps, National Climate Assessment, State of Colorado, California Dept of Water Resources (CaDWR)

- **Analysis Tools** – used to diagnose, analyze, visualize, and datasets – often provided to the research & operations communities
  - Supported for ongoing use at PSL & community, contributes to model improvements
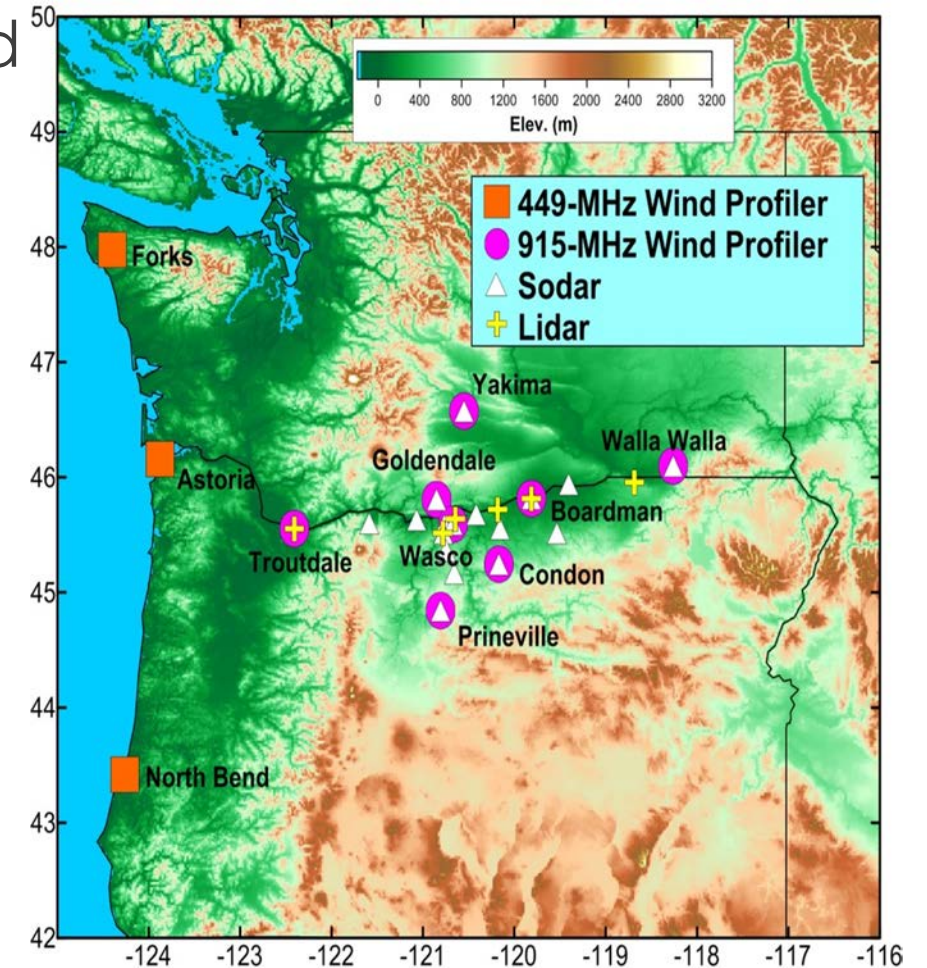
PSL improvements to NWS operations

"We don't make the models (usually), we make them better"

1) Wind Forecast Improvement Project (WFIP2)
2) 20th Century Reanalysis (20CRv3)
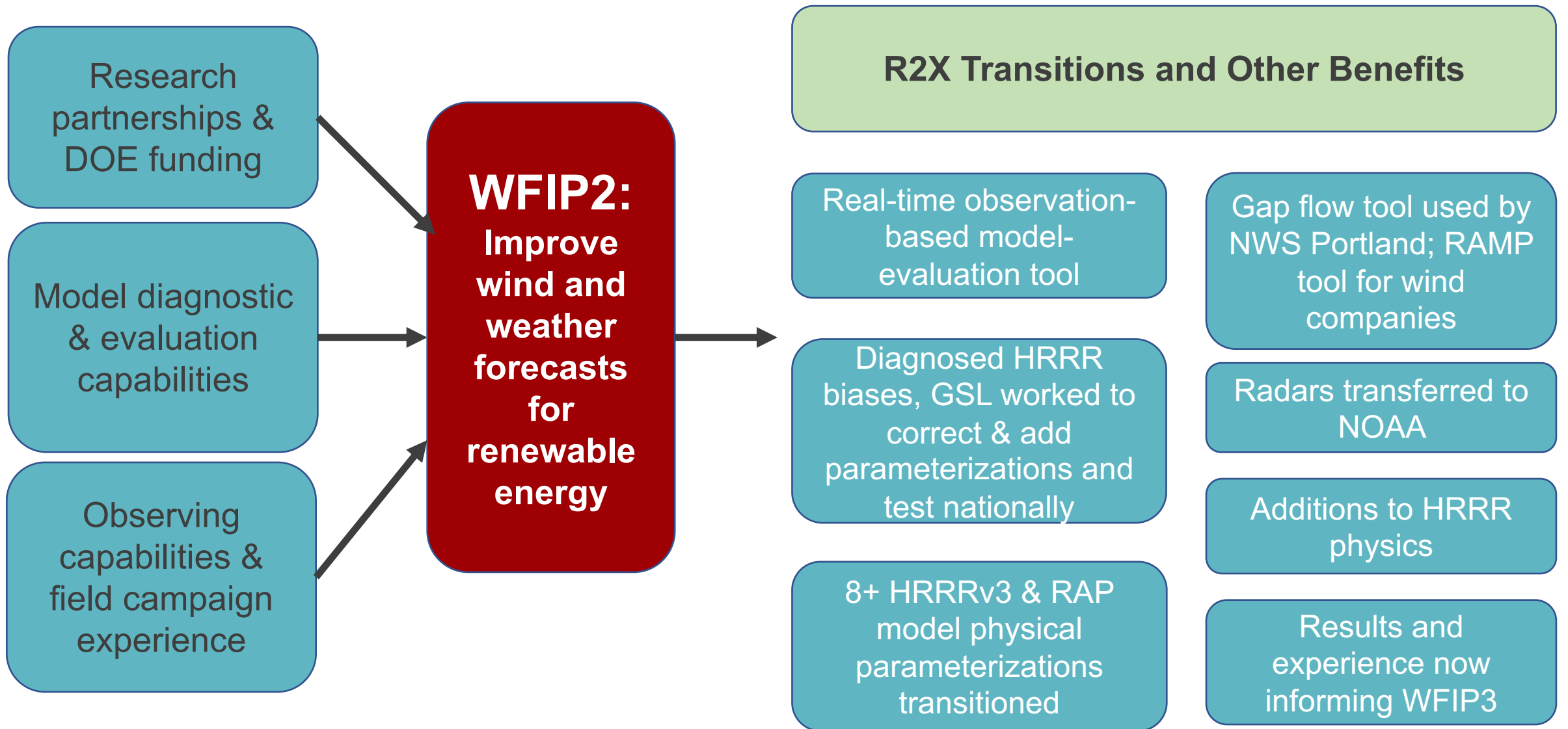3) Advanced Quantitative Precipitation Information (AQPI)

1) Wind Forecast Improvement Project (WFIP2)

- **Challenge:** improve short term weather & wind forecasts for renewable energy

- Improved parameterizations now operationalized in HRRRv3 & more will be operational in HRRRv4

- Long partnership with DOE, OAR Labs, universities & private sector wind companies

- **Indicator of satisfaction** is that DOE has returned to support WFIP3

- NOAA-CIRES **Technology Transfer Award** for improving forecasts of turbine-height winds and solar irradiance from the HRRR
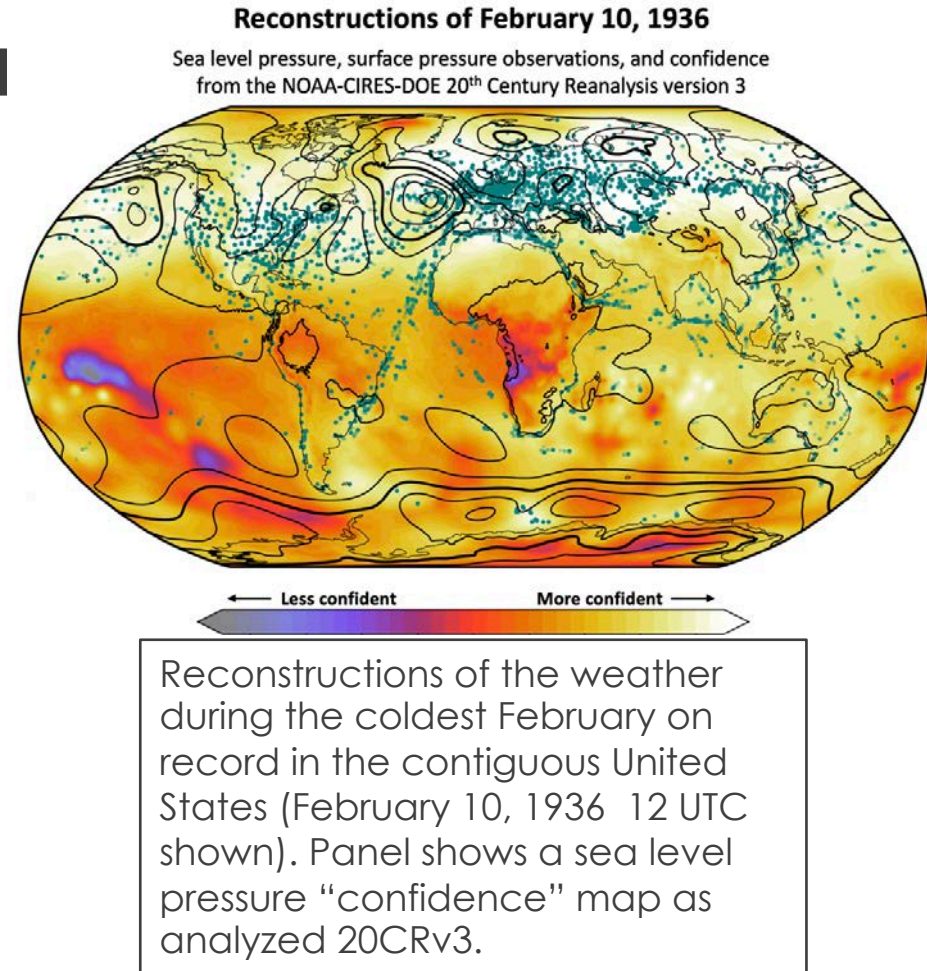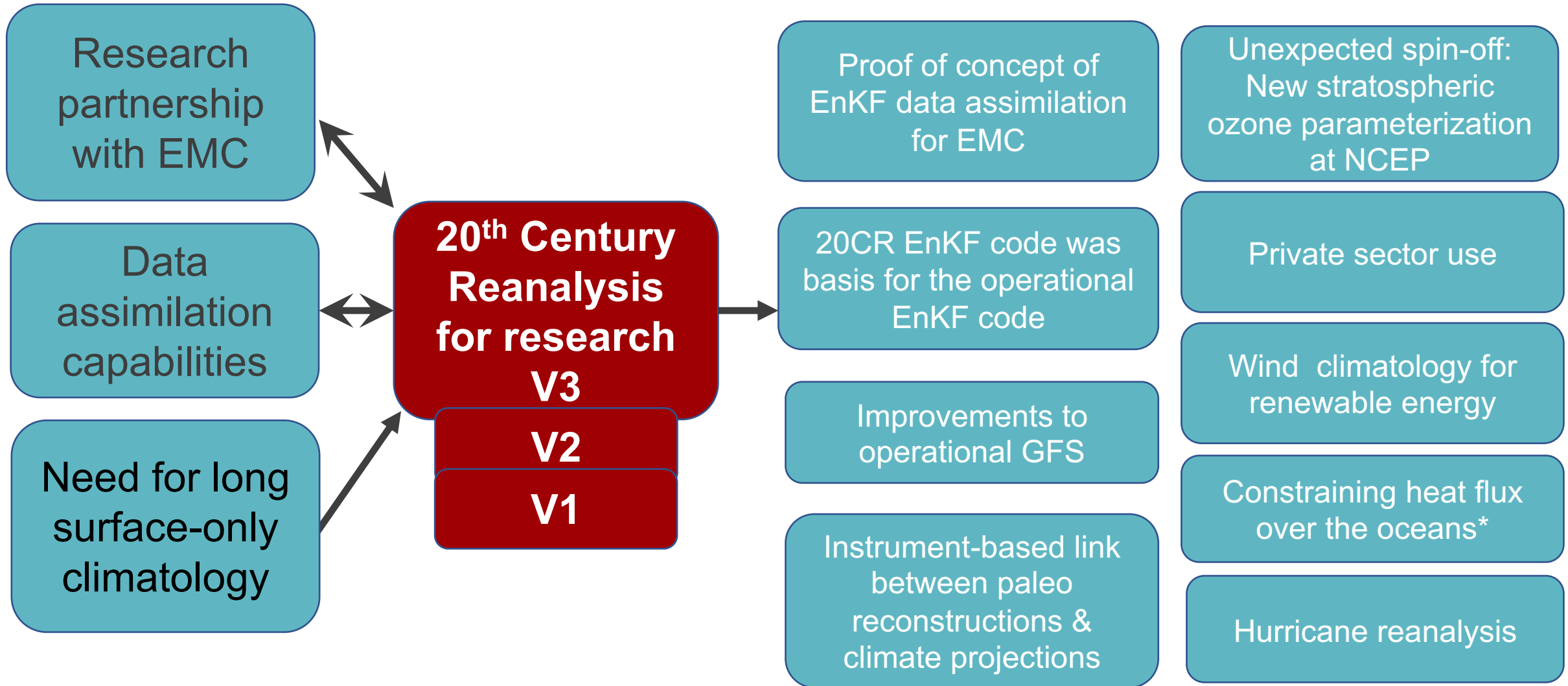
Multiple kinds of transitions

Research partnerships & DOE funding

Model diagnostic & evaluation capabilities

Observing capabilities & field campaign experience

WFIP2: Improve wind and weather forecasts for renewable energy

R2X Transitions and Other Benefits

Real-time observation-based model-evaluation tool

Diagnosed HRRR biases, GSL worked to correct & add parameterizations and test nationally

8+ HRRRv3 & RAP model physical parameterizations transitioned

Gap flow tool used by NWS Portland; RAMP tool for wind companies

Radars transferred to NOAA

Additions to HRRR physics

Results and experience now informing WFIP3

2) 20th Century Reanalysis V3

- **Challenge: Long time series of weather needed for scientific studies of weather & climate**
  - Reconstruction of 200 years of weather
  - Research dataset & data assimilation methodologies maintain & upgraded by PSL
  - Creativity to find and incorporate old weather data, e.g. citizen science effort to scan old ship logbooks
- **Indicators of success: ~1500 peer-reviewed articles cite use of dataset or its methodologies since 2015**
- **Version 3 released in 2019; Slivinski et al (2019)**
 - A top downloaded paper from QJRMS for 2018-2019; 40 Google Scholar citations

Reconstructions of February 10, 1936

Sea level pressure, surface pressure observations, and confidence from the NOAA-CIRES-DOE 20th Century Reanalysis version 3

Less confident ← → More confident

Reconstructions of the weather during the coldest February on record in the contiguous United States (February 10, 1936 12 UTC shown). Panel shows a sea level pressure "confidence" map as analyzed 20CRv3.

Multiple kinds of transitions

R2X Transitions and Other Benefits

Research partnership with EMC

Data assimilation capabilities

Need for long surface-only climatology

20th Century Reanalysis for research V3
V2
V1

Proof of concept of EnKF data assimilation for EMC

20CR EnKF code was basis for the operational EnKF code

Improvements to operational GFS

Instrument-based link between paleo reconstructions & climate projections

Unexpected spin-off: New stratospheric ozone parameterization at NCEP

Private sector use

Wind climatology for renewable energy

Constraining heat flux over the oceans*

Hurricane reanalysis

3) Advanced Quantitative Precipitation Information (AQPI) System

- **Challenge**: Forecasting extreme precipitation: Atmospheric rivers (ARs) provide water supply but often cause flooding.
  - **Orographic rainfall enhancement not detected by radars**, not well forecasted in MRMS or Mountain Mapper
- **AR Impacts:**
  - A few AR events provide 30-50% of CA's annual precipitation
  - Annual average of >$1B damages, >80% of flood damages in the western US
  - Sea level rise & urbanization exacerbate the problem
- **Regional effort, but national benefits for** improving extreme precipitation forecasting **and decision support** 1-12 hours
- Addresses **NOAA Precipitation Grand Challenge** goal; **Weather Ready Nation;** Supports **NWS Integrated Decision Support** & coastal preparedness
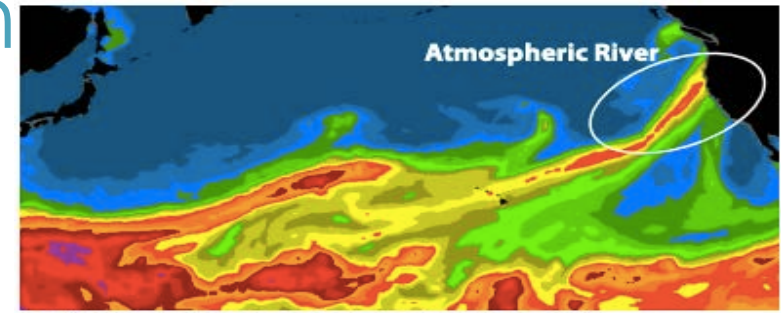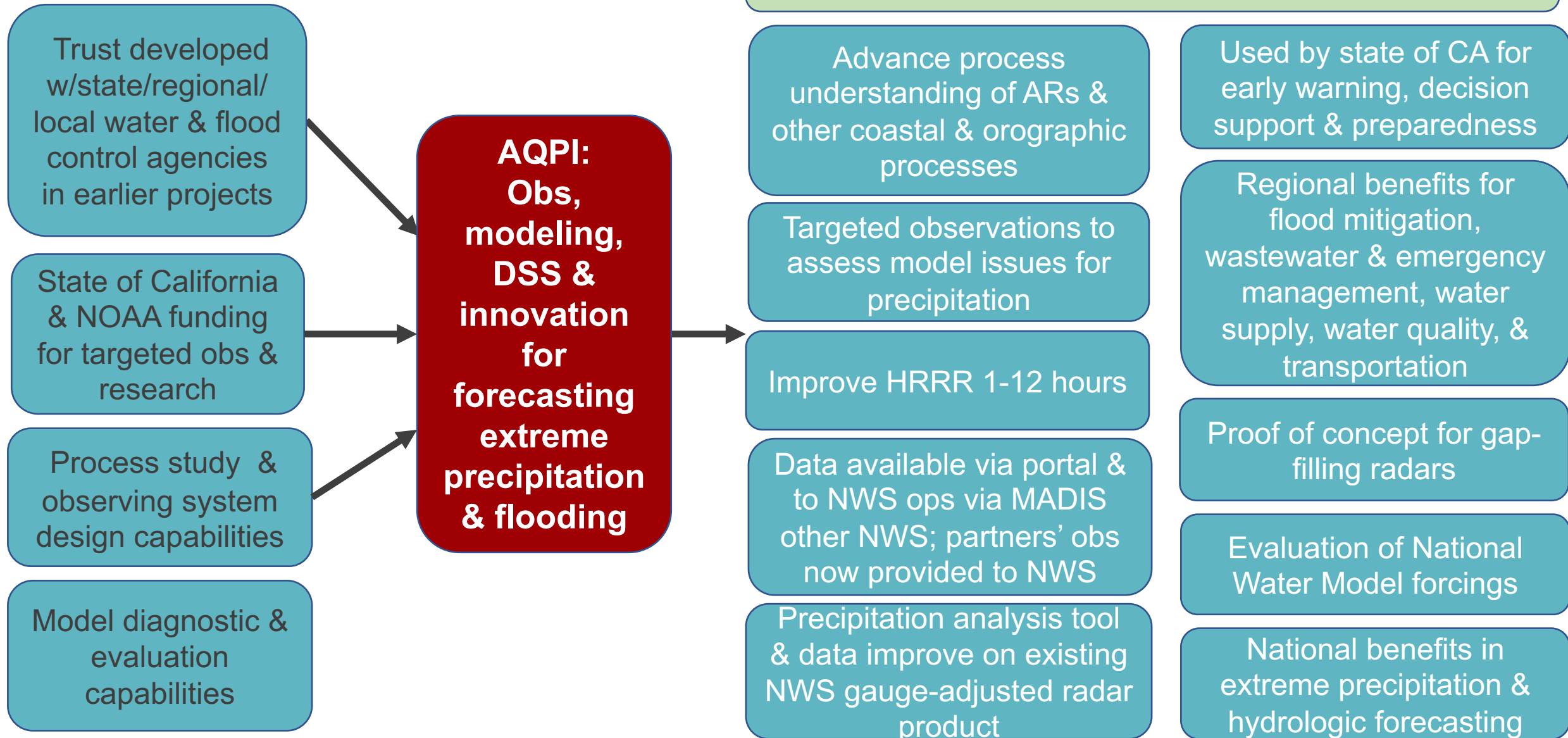

Satellite image of an atmospheric river in February 2017.
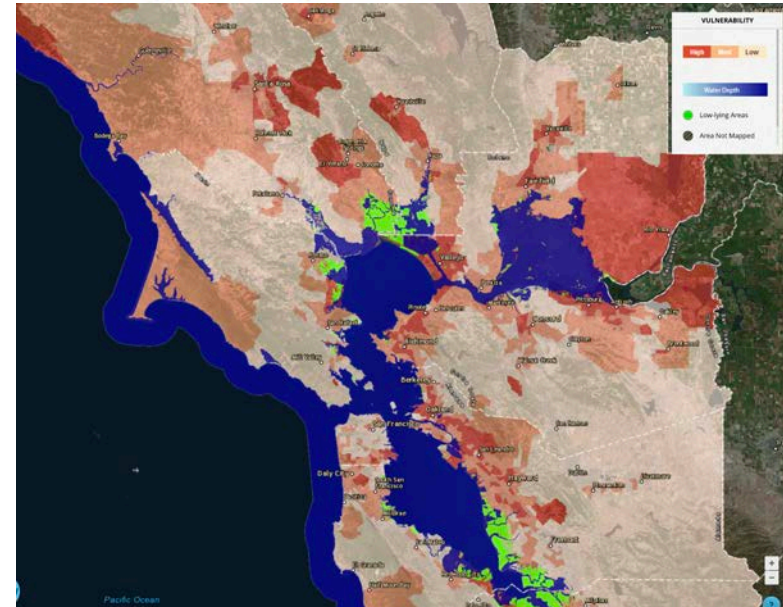
Top: PSL's expertise in satellite remote sensing allows us to make informative images of ARs like this
Bottom: Vulnerable SF Bay Area: 7+ million people, >350K people in 100 year flood plain; $46B in exposed structures

Multiple kinds of transitions

Transitions and other expected benefits

Trust developed w/state/regional/ local water & flood control agencies in earlier projects

State of California & NOAA funding for targeted obs & research

Process study & observing system design capabilities

Model diagnostic & evaluation capabilities

AQPI: Obs, modeling, DSS & innovation for forecasting extreme precipitation & flooding

Advance process understanding of ARs & other coastal & orographic processes

Targeted observations to assess model issues for precipitation

Improve HRRR 1-12 hours

Data available via portal & to NWS ops via MADIS other NWS; partners' obs now provided to NWS

Precipitation analysis tool & data improve on existing NWS gauge-adjusted radar product

Used by state of CA for early warning, decision support & preparedness

Regional benefits for flood mitigation, wastewater & emergency management, water supply, water quality, & transportation

Proof of concept for gap-filling radars

Evaluation of National Water Model forcings

National benefits in extreme precipitation & hydrologic forecasting

Experimental Products and Services

Pushing the envelope on NOAA's forecast capabilities.

1) Sub-seasonal to Seasonal (S2S) Forecasting
2) Evaporative Demand Drought Index
3) Air Quality Forecasting: PM2.5 & Ozone

1) Subseasonal-to-Seasonal Forecasting (S2S): two transitions to the Climate Prediction Center

- **Challenge:** S2S forecast skill is relatively low across much of the Western United States but is highly relevant for natural resource management, energy sector, and other uses, and important for longer range situational awareness for many sectors

- **Two examples discussed in other talks:**
  - Improving Winter Season Precipitation Forecasts (Nov-March). Focus on cold season; because of importance to water management
  - Suite of LIM forecast tools for Weeks 3/4 CONUS surface temperature forecasts
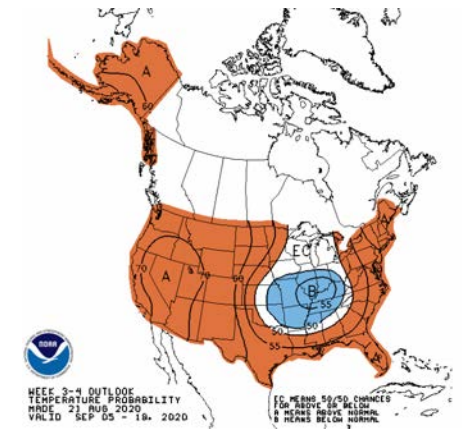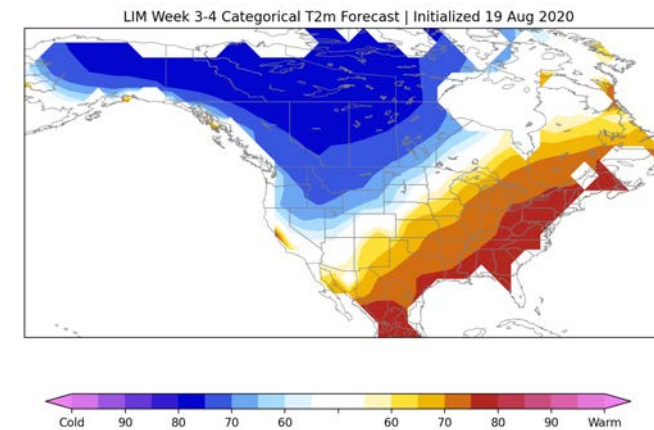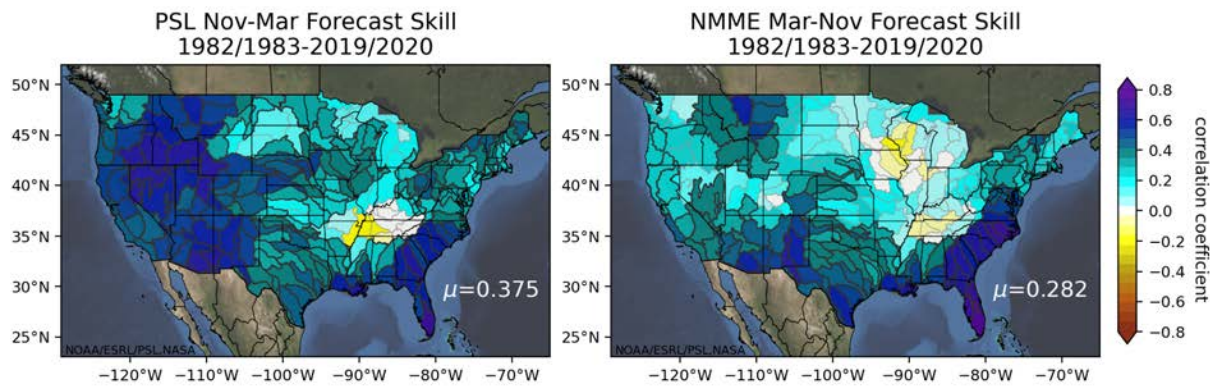
Winter Season Guidance

LIM T2m Probabilistic Forecast

CPC T2m Probabilistic

Collaboration to improve S2S forecasts

- Many years interaction with the Climate Prediction Center

- For LIM has included **participating in the weekly Week 3-4 Outlook Forecast Discussion** telecon (see next slide for an outcome). PSL staff have long participated in Drought & Seasonal forecast calls, resulting in research to understand processes, predictability & improve skill.

CPC home at the National Centers for Environmental Prediction in Maryland

- **Participation & hosting (2015) the annual Climate Diagnostics and Prediction Workshop**, annual visit by CPC Director Dr. David DeWitt to PSL; Newman and Hamill visits to CPC; DeWitt assigned staff person to work with Newman; staff detail to CPC

- Service activities benefit PSL understanding of needs: PSL staff serve on US CLIVAR panels with CPC personnel

- Winter season guidance funded by California Dept Water Resources. **Regional funding leveraged to develop a CONUS-wide product & improvement in skill**

- **Also builds on PSL's longstanding collaborations water resources managers**, including CaDWR, Reclamation, USACE & others (esp. Colorado River Basin) – e.g. analysis provided for the hydrologic units (HUCs) preferred by RFCs & water managers
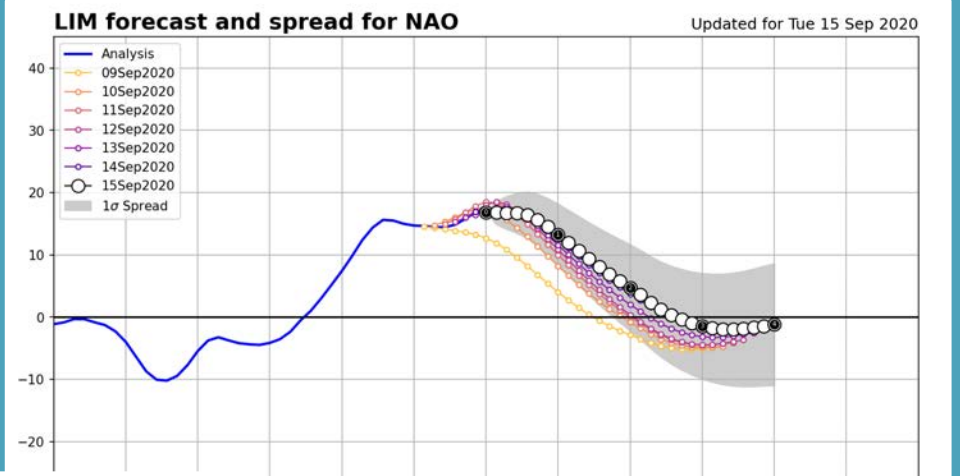
2m Temp Anomaly and Probabilistic Forecasts

LIM Week 3-4 T2m (C) | Initialized 06 Sep 2020

LIM Week 3-4 Categorical T2m Forecast | Initialized 06 Sep 2020

-3.0

Cold 90 80 70 60 60 70 80 90 Warm
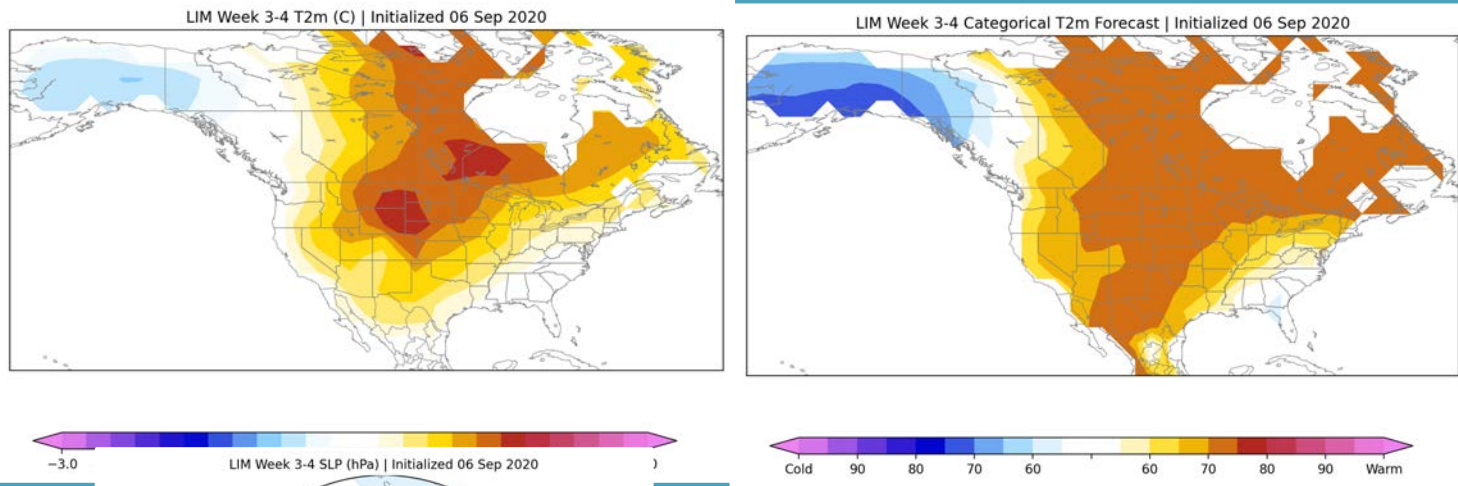
Teleconnection Forecast, Trend, and Spread

LIM forecast and spread for NAO

Updated for Tue 15 Sep 2020

- Analysis
- 09Sep2020
- 10Sep2020
- 11Sep2020
- 12Sep2020
- 13Sep2020
- 14Sep2020
- 15Sep2020
- 1σ Spread

40
30
20
10
0
-10
-20

500mb & SLP Forecasts

LIM Week 3-4 SLP (hPa) | Initialized 06 Sep 2020

-5 -4 -3 -2 -1 0 1 2 3 4 5

LIM Week 3-4 H500 (m) | Initialized 06 Sep 2020

-40 -32 -24 -16 -8 0 8 16 24 32 40
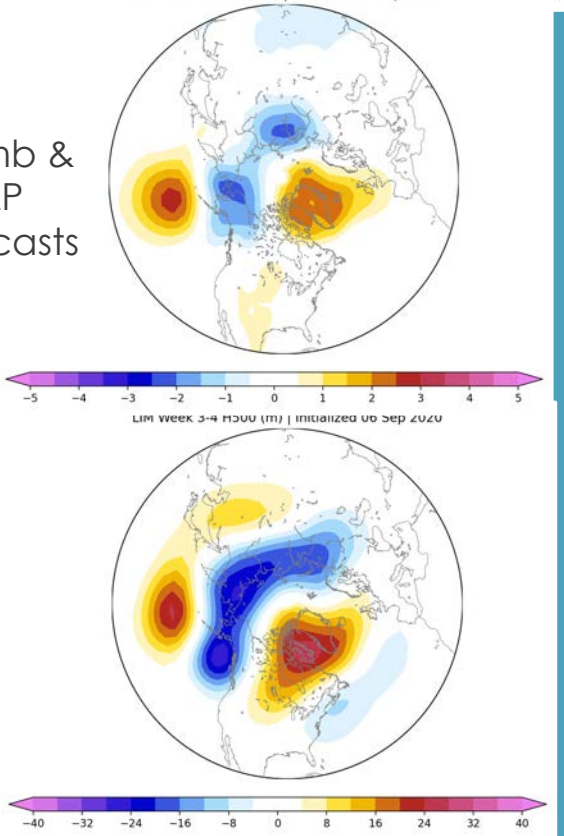
Hovmoller Analysis and Forecast

Tropical Heating | 7.5S – 7.5N

500hPa Height | 30N – 50N

12-May
19-May
26-May
2-Jun
9-Jun
16-Jun
23-Jun
30-Jun
7-Jul
14-Jul
21-Jul
28-Jul
4-Aug
11-Aug
18-Aug
25-Aug
1-Sep
8-Sep — Begin Forecast
15-Sep
22-Sep
29-Sep

0 60 120 180 240 300 0
Longitude

-150 -120 -90 -60 -30 0 30 60 90 120 150
W/m²

-60 -45 -30 -15 0 15 30 45 60
m

MJO Forecast and Spread

MJO phase space

Forecast for 18-Oct-2020 to 14-Nov-2020

68% Confidence
Forecast

7 Western Pacific 6

8 West. Hem. and Africa 5 Maritime Continent

1 Indian Ocean 4

2 3

RMM2 / RMM1

4 3 2 1 0 -1 -2 -3 -4

2) EDDI: Evaporative Demand Drought Index

- **Challenge:** Operational monitoring of the demand side of drought at user-relevant time & space scales.

- **Benefits are improved drought early warning and ongoing monitoring**, flash drought and fire-weather prediction.
- Funding from NIDIS, Weather Program Office, Climate Program Office

- **Transitioned to the National Water Center Dec 2019,** produced daily at NOAA. Value-added products generated at PSL. Available at PSL & disseminated to stakeholders by PSL

1-month EDDI categories for October 25, 2019

Drought categories | Wetness categories

| ED4 | ED3 | ED2 | ED1 | ED0 | | EW0 | EW1 | EW2 | EW3 | EW4 |
| 100% | 98% | 95% | 90% | 80% | 70% | 30% | 20% | 10% | 5% | 2% | 0% |

(EDDI-percentile category breaks: 100% = driest; 0% = wettest)

Generated by NOAA/ESRL/Physical Sciences Division

EDDI: The anomaly in evaporative demand at a specified timescale, for a given location, expressed as a percentile.

From idea to product: EDDI

Genesis of idea

2009-2012: working to improve dynamic ET estimates for CBRFC streamflow forecasting. Noticed that 2011 Texas drought was reflected in regional high evaporative demand

Early version of EDDI provided weekly to Colorado Climate Center, which provided to many of their stakeholders including the State Drought Task Force. Re-tooled based on feedback. 2012-15: NIDIS funding.

Tested & re-tooled based on feedback from regional & national stakeholders; tested in an operational environment, user engage-ment & agreement with National Water Center 2016-20 (WPO* funding)

Unexpected users: fire managers & FEWS NET. New CPO finding for wildfire component, 2017-19

2018-19:on USGS data portal; developed User Guide

Dec 2019: Operational daily product at NWS/NWC

2020: EDDI now dissem-inated & in use via NIDIS dashboard, NWC, WRCC, Drought Monitor, Drought Outlook, FEWSNET, & used by stakeholders in Agriculture, Ranching, Fire, Water

*Formerly OWAQ, Office of Weather and Air Quality

3) Air Quality Forecasting: PM2.5 & Ozone

- **Challenge:** Community Multiscale Air Quality Modeling System (CMAQ) used by NCEP & EPA had huge errors. NCEP had not been issuing PM2.5 forecasts, only ozone

- Increases in mortality associated with PM2.5 thresholds that can be forecasted

- Provided directly to **state & local air quality forecasters who use them for their air quality forecasts**
  - **Hourly product made possible by the skill of the hour-by-hour PSL post-processing system run at NCEP.**

- 2020 **NOAA Administrator's Award** for capability that *improves the lives of Americans & saves billions of dollars per year.*

AQ forecast from CA South Coast Air Quality Management District for one of 25 sub-areas
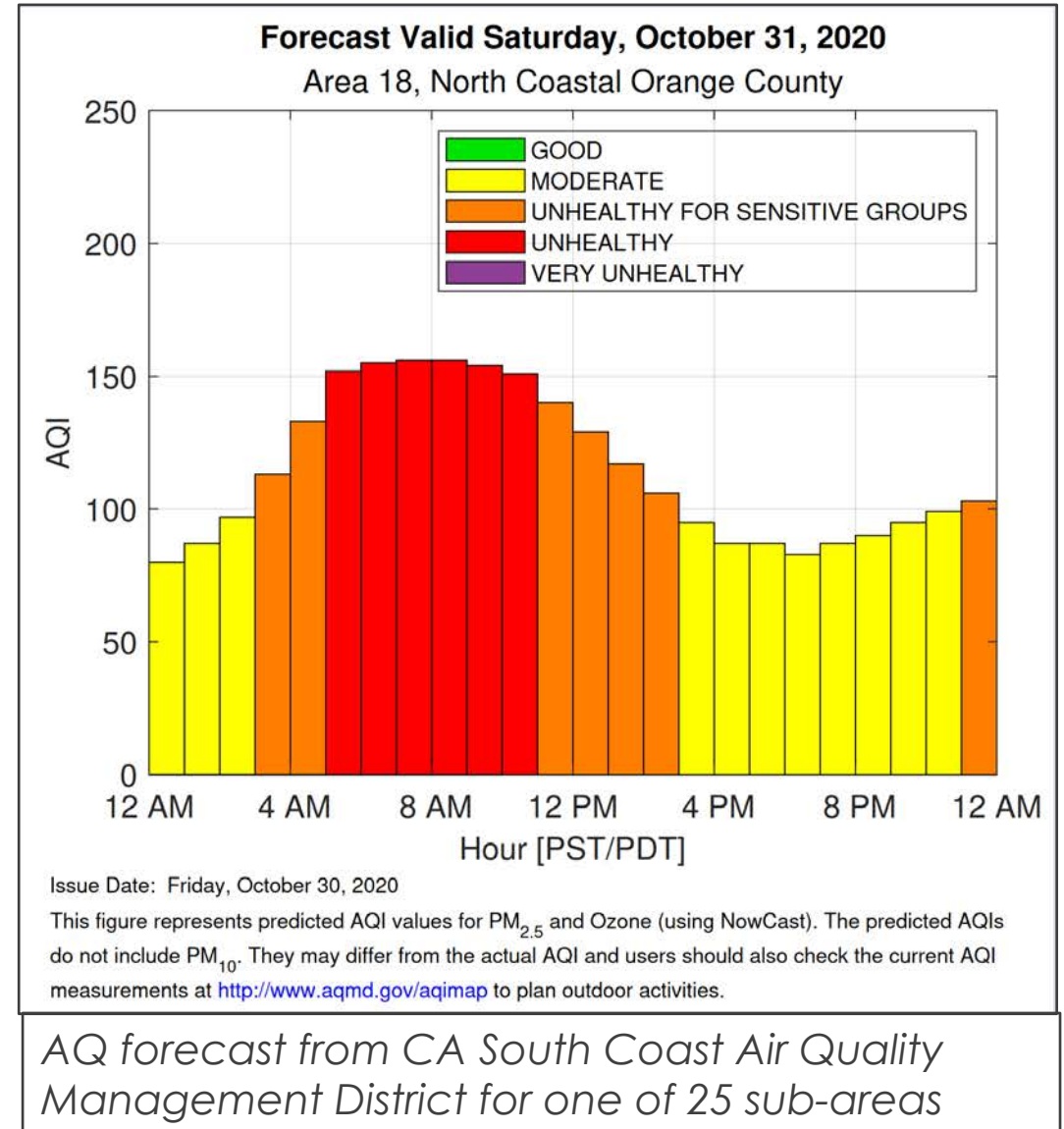
From idea to transition: forecasts of PM2.5 & Ozone

Genesis of idea

Early 2010s: large errors in CMAQ, NCEP only forecasting Ozone, not PM2.5. PSL realizes that post-processing skills might help reduce errors

Technique proven & used in operations at NCEP for PM 2.5 since January, 2016

Technique extended to ozone, used in operations at NCEP since Dec 2018

Weather Program Office* funding: to develop & test enhanced process for operations at NCEP/EMC. Successfully transitioned by end of grant (2016-19)

EMC asks PSL to apply for Disaster Supplemental Funds. Effort will enhance these predictions for wildfires & to make probabilistic forecasts. Began May 2020.

2020: First-in-US hour-by-hour PM2.5 & ozone forecasts being issued in CA.

Knowledge transfer: Synthesis & Assessments

Transforming science-based weather, water, & climate knowledge into actionable science for NOAA stewardship responsibilities.

1) Climate Change Web Portal

2) Inform NOAA Fisheries' responsibilities to reduce marine resources' future vulnerabilities and increase resiliency to varying and changing climate

3) Interface of anadromous fisheries & water management

1) Climate Change Web Portal

Challenge: Need a more efficient way to visualize & disseminate complex model output for core partners

- Iterative conversations with NOAA Fisheries informed development – led to pre-analyzed fields & graphics for targeted applications: water & fisheries

- Feedbacks to PSL research

- Early funding from Reclamation & Army Corps; now funded by NOAA Fisheries' Integrated Ecosystem Assessment (IEA)

Tool supports knowledge exchange & pilot effort for vulnerability assessments: https://www.esrl.noaa.gov/psd/ipcc/
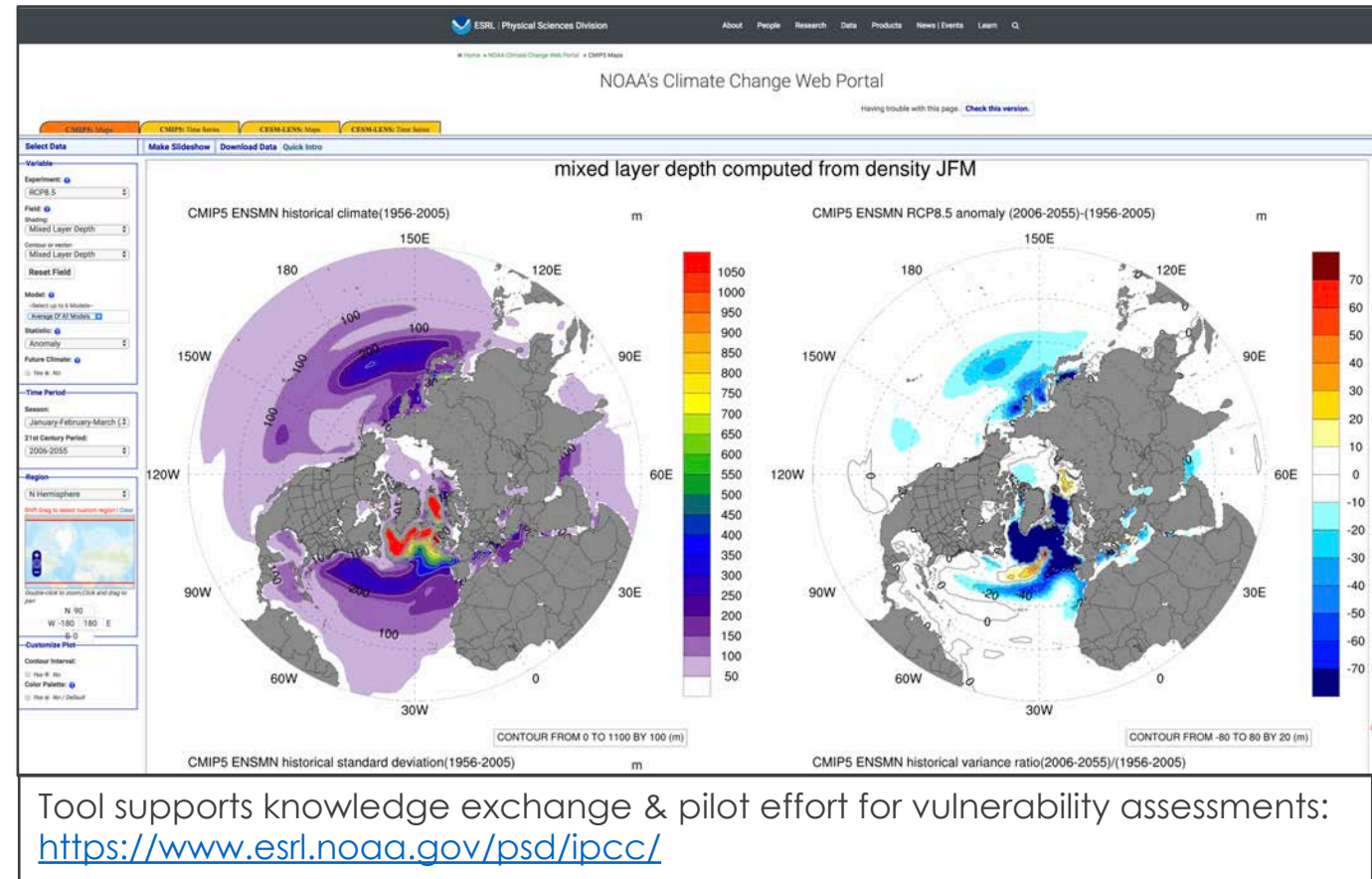
2) Inform NOAA Fisheries' responsibilities to reduce vulnerabilities & increase resiliency

- **Challenge:** What's wanted is on-going engagement to provide the expert assessment, synthesis & guidance, to be used in policy & decision making, not simply handoff of a product

- **Leadership and participation in** cross-line-office **Climate and Fisheries initiative**, to meet NMFS climate information needs across timescales

- **Collaborating with fisheries scientists to incorporate climate and ocean model output in ecological modeling & evaluation of management strategies** (e.g., effects of climate variability & change on lobsters, cod, sardines, albacore tuna, swordfish, and other species).

- **Participate in NMFS vulnerability assessments and scenario planning** for marine species and habitats, including Integrated Ecosystem Assessment programs and **Habitat blueprint**

Vulnerability Assessment for Northeastern US Continental Shelf

A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the Northeast U.S. Continental Shelf

Jonathan A. Hare [icon], Wendy E. Morrison, Mark W. Nelson, Megan M. Stachura, Eric J. Teeters, Roger B. Griffis, Michael A. Alexander, James D. Scott, Larry Alade, Richard J. Bell, Antonie S. Chute, Kiersten L. Curti, Tobey H. Curtis, [...], Carolyn A. Griswold [view all]

Published: February 3, 2016 • https://doi.org/10.1371/journal.pone.0146756

PSL contribution & ongoing guidance

- PSL contributed to first of its kind NMFS effort

- **Results inform adaptation of marine fisheries management & conservation to climate change and decadal variability**

- Indicator of satisfaction: PSL asked to participate in assessments underway for Bering Sea & California Current Ecosystems

3) Interface of fishery & water management: two examples

- **Challenge:** Balance needs for fish with flood control & reservoir water supply while minimizing conflict among competing water users.

- **Pilot project** on improved use of weather information in managing water in California's Russian River Basin: Forecast Informed Reservoir Operations (FIRO)

- **Applies PSL research on short-term weather forecasting** to marine resources

- FIRO demonstrated that **improved forecast information can aid decisions by USACE** & other water resource managers to balance flood and drought risks. A sign of satisfaction with the work is that they continue to fund it and now proposed for additional basins

- **Indicators of satisfaction** with the work:
  - USACE granted a "major deviation" in operations to test forecasting in their reservoir operations environment, if proved may re-write the water control manual for reservoir ops
  - Now proposed for additional basins
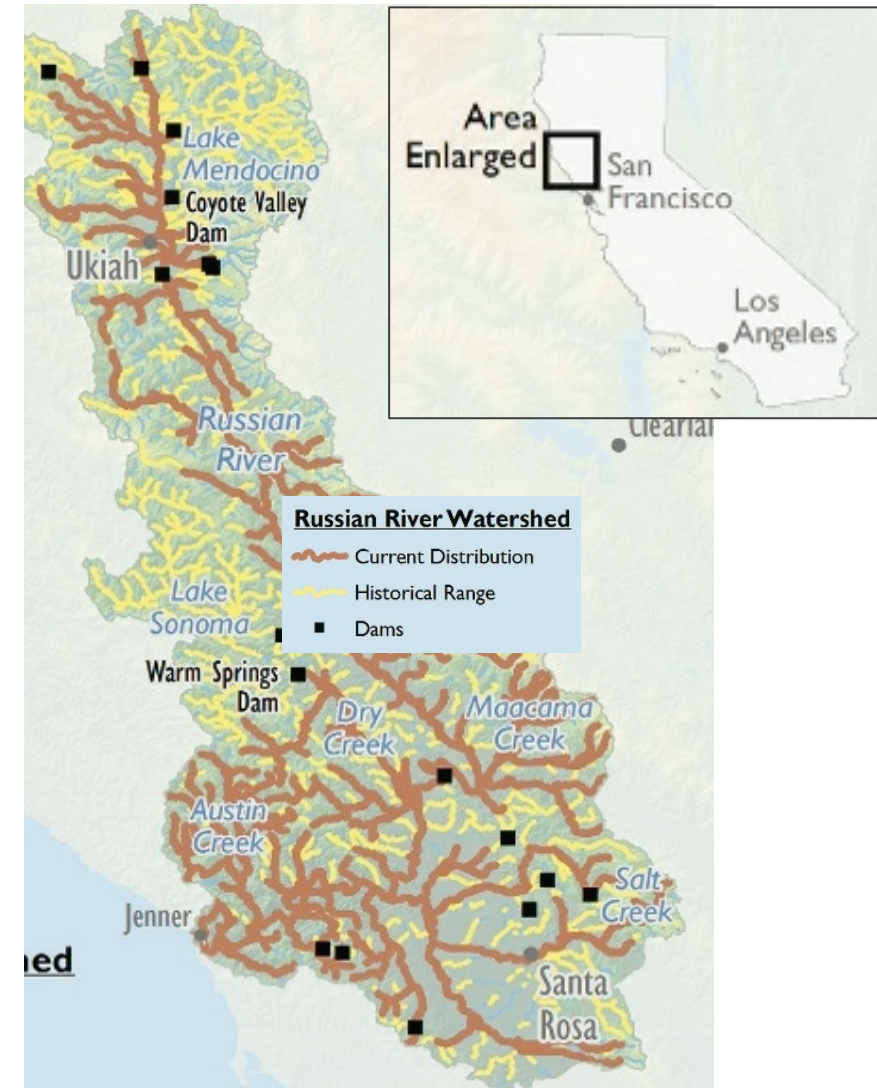
2nd example: Climate information to protect anadromous fish from hydropower impacts

- **Challenge: NOAA Fisheries asked PSL for guidance** on climate projections NMFS to assess future risks to fish needs, design fish passage, to protect habitat based on future conditions needed to inform their risk assessment in hydropower dam licensing
  - **NMFS has statutory authority to protect, mitigate, or enhance habitats** for fish and wildlife, including fish passage and impacts of reservoir operations
- Partnered with their efforts to **understand the combined effects of hydropower facilities and climate change** on anadromous fish & their habitats, and guidance on using climate futures in fish passage
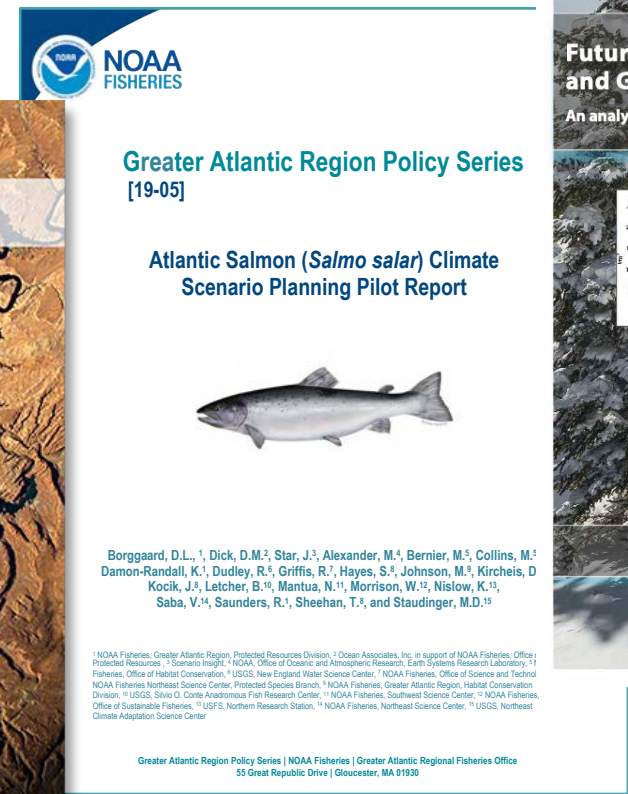

Susitna-Watana Project (AK)

Nuyakuk Project (AK)

La Grange Dam (CA)
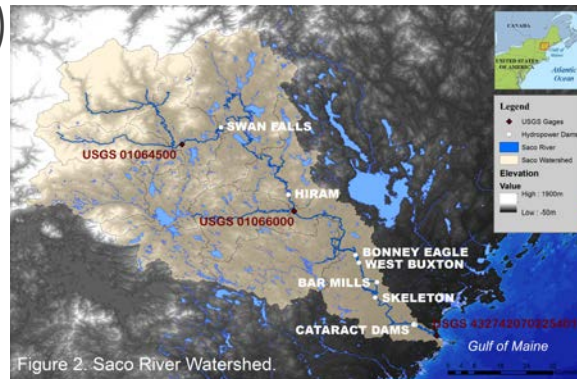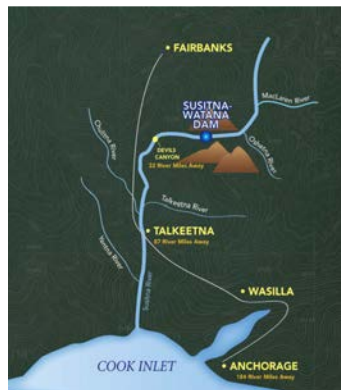
Hiram Dam (ME)
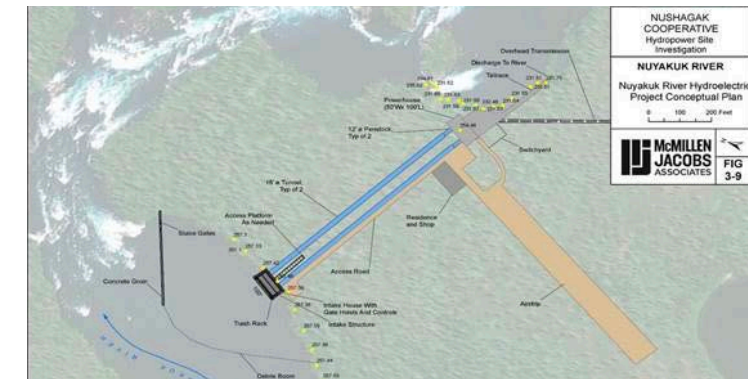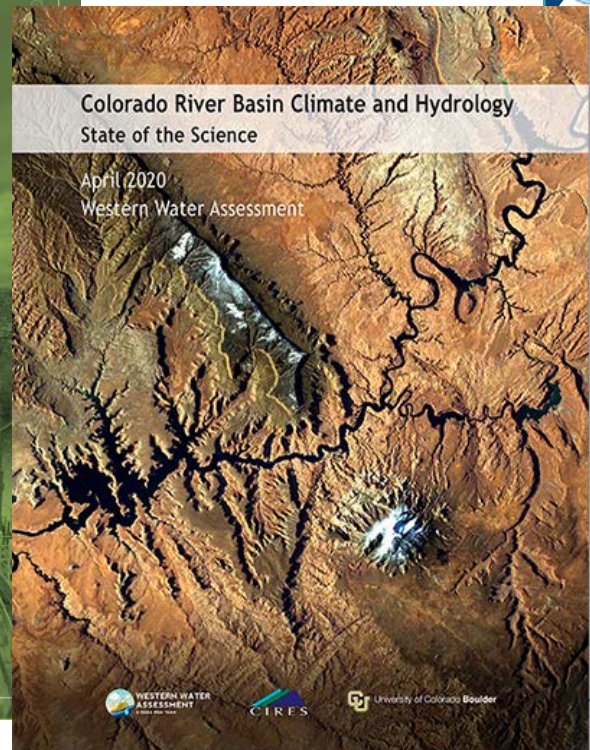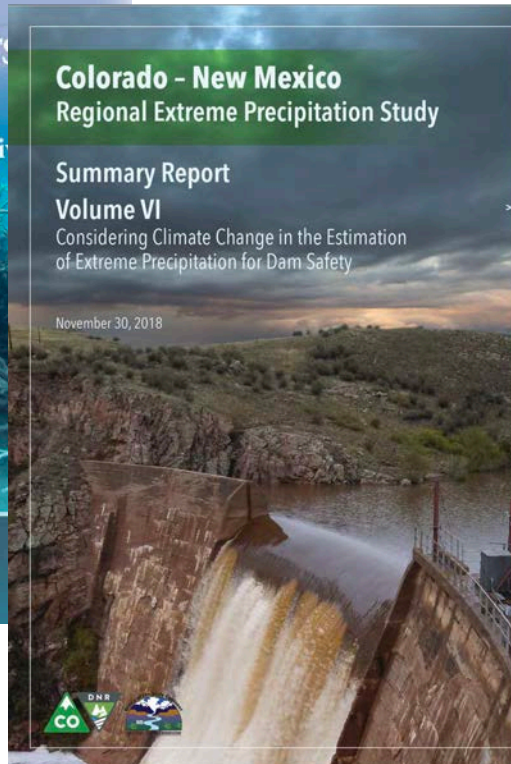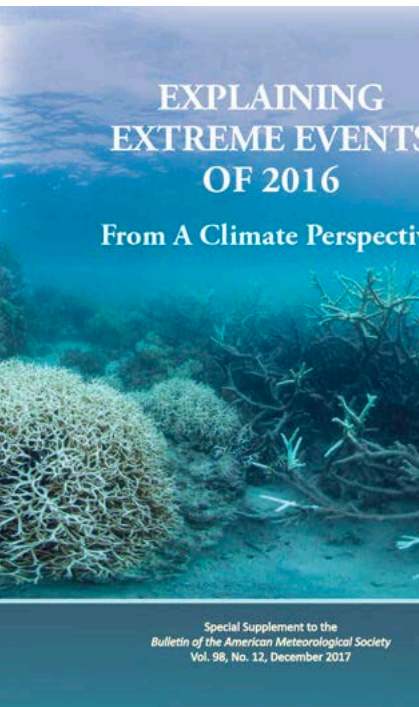
Assessment products cross the three PSL themes

Resulting from knowledge transfer and co-production
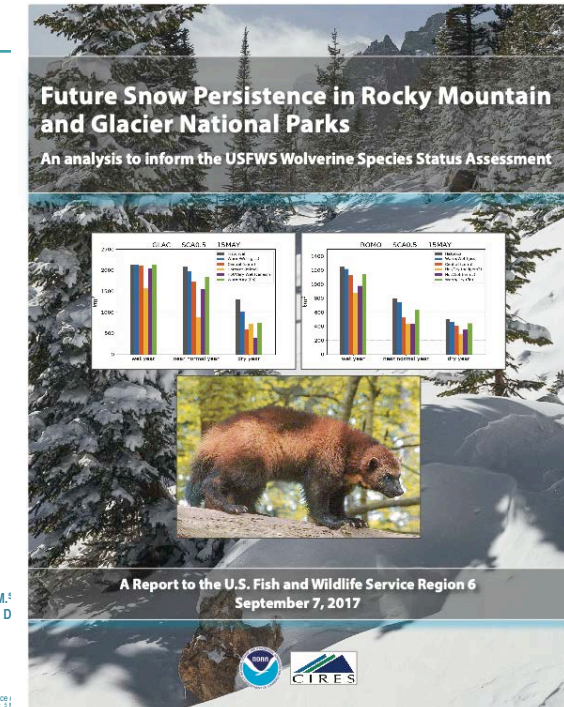
Transitions across themes - from this presentation

Water Resource Management

- EDDI – Evaporative Demand Drought Index
- AQPI – Advanced Quantitative Precipitation Information
- S2S forecasting
- Climate change & dam safety assessment
- Colorado River state of the science assessment

Marine Resource Management

- Climate Change Web Portal
- FIRO implications for onshore fisheries
- Fisheries vulnerability assessments, IEA, & Habitat Blueprint
- Impacts of hydropower on fisheries

Predicting Extremes

- WFIP2
- 20cRv3
- AQPI – Atmospheric river forecasting, extreme precipitation
- S2S forecasting
- Air Quality
- BAMS Explaining Extreme Events

PSL Transitions Summary – examples from other presentations

- **Modeling improvements**
  - Algorithm Development; Model Evaluation; Data Assimilation; Observations to verify/validate
- **Enhancing NOAA products and services**
  - NWM, GEFS, HRRR etc
- **Analysis Tools & datasets**
  - Arctic diagnostics toolkit for assessing UFS performance vs high quality observations
  - Web-based reanalysis intercomparison tools (WRIT)
  - Climate model visualization and analysis tool (FACTS)
- **Instruments:**
  - UAS routinely flown on the Hurricane Hunter, ocean surface wave radar, snow level radar
- **New products and services**
  - Coupled Arctic Forecast System (CAFS, Arctic sea ice forecasting and monitoring), S2S new forecasts and ID of forecast of opportunity
- **Knowledge exchange and use**
  - Ongoing work with NOAA Fisheries & NOS; Army Corps and Reclamation; Interpreting Climate Conditions

How we do transitions - emergent strategy

- **Some partnerships aimed at transitions**

- Take **calculated risks**

- Recognize that there's a **gestation period from initial idea to spin-offs and transitions**

- Sometimes **unexpected uses and users appear** – follow those too

- **Participation in testbeds**, formal or informal, has benefits for both sides

- Service activities often support our understanding of needs

- **Actively participate in workshops with operational & other users**
  - Co-hosted 2015 NWS Climate Diagnostics and Prediction Workshop; Host annual Fisheries IEA workshops in Boulder; Participate in NWS Climate Prediction Assessment Workshops and other use-oriented workshops

- **Recruit people interested in use-inspired work**
  - Hosted the first three PACE postdocs; others had existing user relationships

R2X Summary

- PSL uses a **variety of strategies to understand NOAA operational and other users' needs** and how we can contribute to them.

- Use-inspired **research strategies balance responsiveness to existing needs with innovation** in anticipation of future needs

- PSL cultivates a **culture of transition-oriented science and partnerships**

- Relationships with users have spurred **use-inspired R&D** aimed at improving NOAA operations overall, *and* enabled transitions

- **PSL is sought out for novel research advances** that have the potential of being transitioned

- PSL has a **pipeline** of efforts in various stages of proof of concept, testing, etc for transition in the next several years.