Synthesis on Maintaining PCC Pavement Smoothness

Jerod Gross, Snyder & Associates, Inc. / CP Tech Center

IOWA STATE UNIVERSITY
Institute for Transportation

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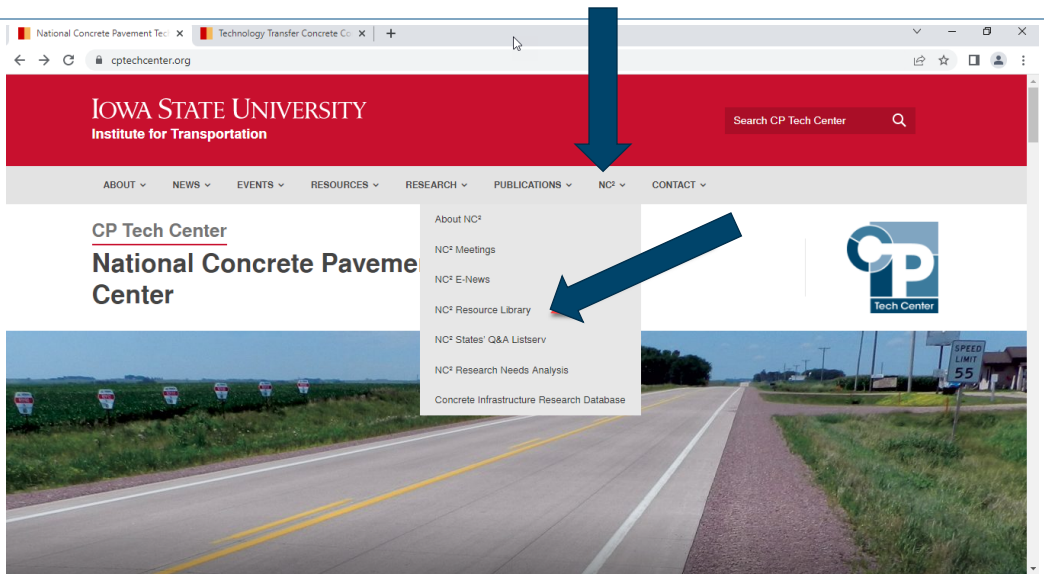

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NC² Resource Library

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MAP/Tech Briefs | Guides/Manuals | Final Reports | Spreadsheets | Videos

Search

2022	Mechanistic-Empirical Design Methods for Concrete Pavement Solutions	Tech Brief
2022	Synthesis on Maintaining PCC Pavement Smoothness	Final Report
2022	Synthesis on Maintaining PCC Pavement Smoothness State Specification Table	Spreadsheet
2022	In Situ Cyclic Loading of Concrete Pavement Overlays Supported on Geotextile and Asphalt Interlayers: Buchanan County Road D-16	Final Report
2022	Appendices: In Situ Cyclic Loading of Concrete Pavement Overlays Supported on Geotextile and Asphalt Interlayers: Buchanan County Road D-16 (ZIP file)	Final Report
2022	Synthesis of Rapid-Setting Repair Materials	Final Report
2022	Rapid-Setting Repair Materials Listing and Links	Spreadsheet
2021	Optimizing Concrete Pavement Opening to Traffic	Tech Brief

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FOR MORE INFORMATION

For NC² Resource Library questions, contact:

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ADDITIONAL TRAINING BY FORMAT

The CP Tech Center provides concrete pavement training promoting best practices (including with new tools/methodologies) as follows:

- Webinars/videos
- Guides/manuals
- NC² MAP tech briefs, etc. (current page)

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What is Smoothness?

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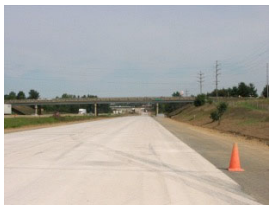
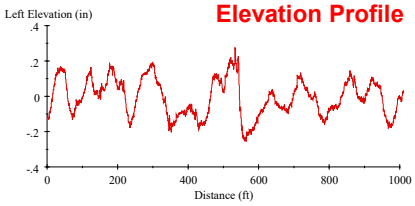
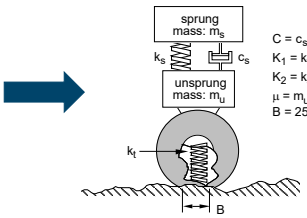
Profile Measurement

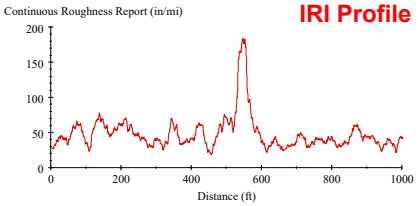






$C = c_s/m_s = 6.0\ sec^{-1}$
$K_1 = k_t/m_s = 653\ sec^{-2}$
$K_2 = k_s/m_s = 63.3\ sec^{-2}$
$\mu = m_u/m_s = 0.15$
$B = 250\ mm$

IRI



Smoothness QA/QC: "Measuring and Specifying Pavement Smoothness." *Tech Brief FHWA-HIF-16-032* (2016) 12 p.
Real-Time Smoothness: https://cptechcenter.org/real-time-smoothness/

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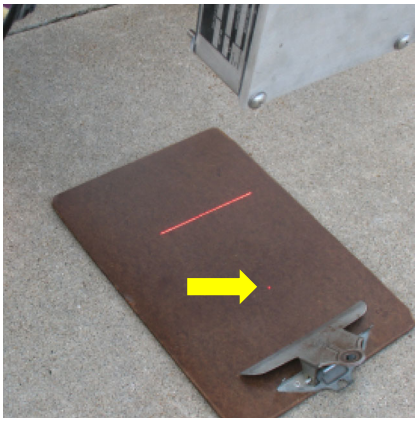
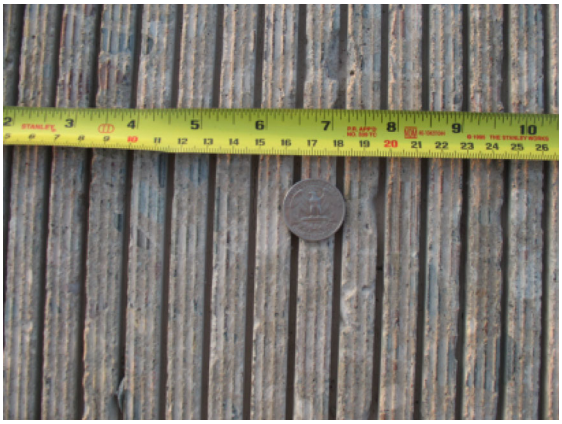
Measurement Issues: Sensor & Texture





Start Here, Follow the Reference Chain: Perera, R.W. and Karamihas, S.M., "Study for Establishing Regional Certification Centers for Inertial Profilers." Federal Highway Administration (2014).

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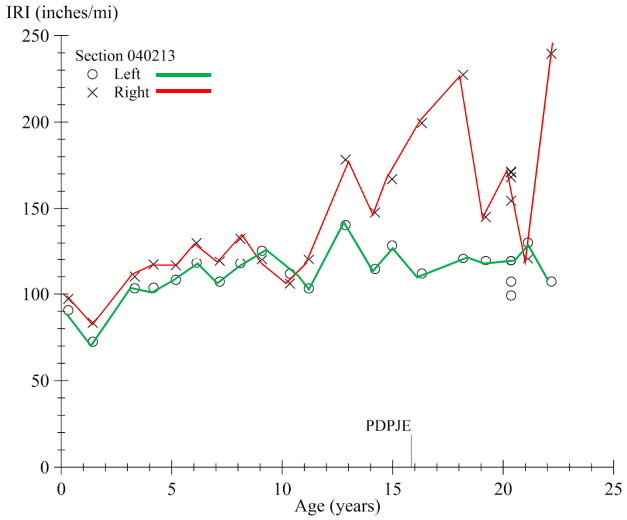
Measurement Issues: Curl and Warp



LTPP Section 040213
- Arizona SPS-2 section
- Jointed plain PCC
- 15-ft joint spacing
- lower flexural strength (550 ksi)
- lower slab thickness (8 inches)
- dense graded aggregate base

PDPJE – partial depth patching at joints and elsewhere

Source: Karamihas, S.M., Punnackal, T., Dufalla, N, and Senn, K., "Advancing Profile-Based Curl-and Warp Analysis Using LTPP Profile Data." *Federal Highway Administration Report FHWA-HRT-20-066* (2020) 485 p.

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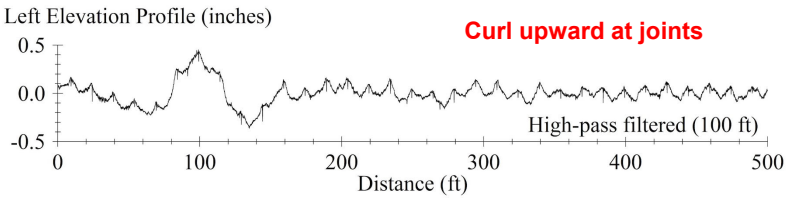
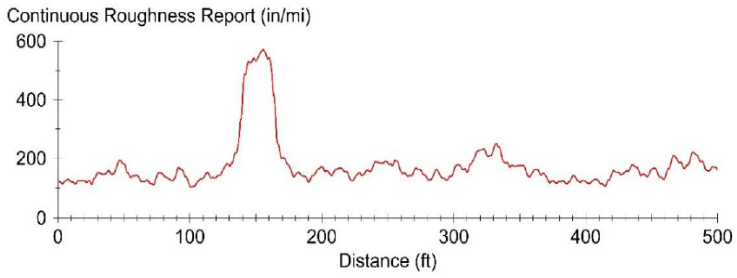
Measurement Issues: Curl / Warp & Cracking



Curl upward at joints

LTPP Section 040213
14.3 years after construction

Left IRI: 114 in/mi
Right IRI: 145 in/mi



Longitudinal cracking reflects IRI

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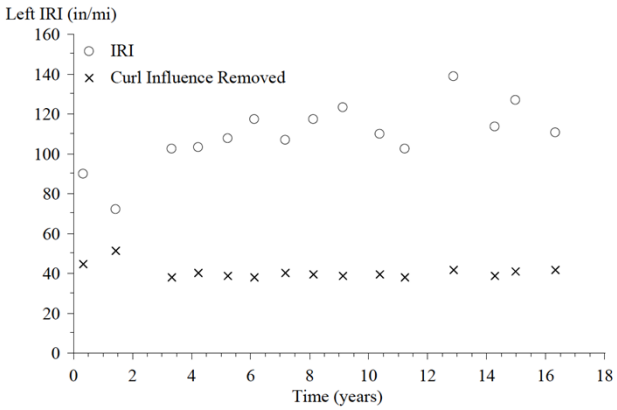
Measurement Issues: Curl and Warp



Cyclic Roughness Data Source: Chang, G.K., et al. *Impact of Temperature Curling and Moisture Warping on Jointed Concrete Pavement Performance. Volume I. Data Collection*. Contract DTFH61-02-C-00077, FHWA, Washington, DC. (2007).
Pertinent Reference List: See FHWA-HRT-20-066 Appendix A.

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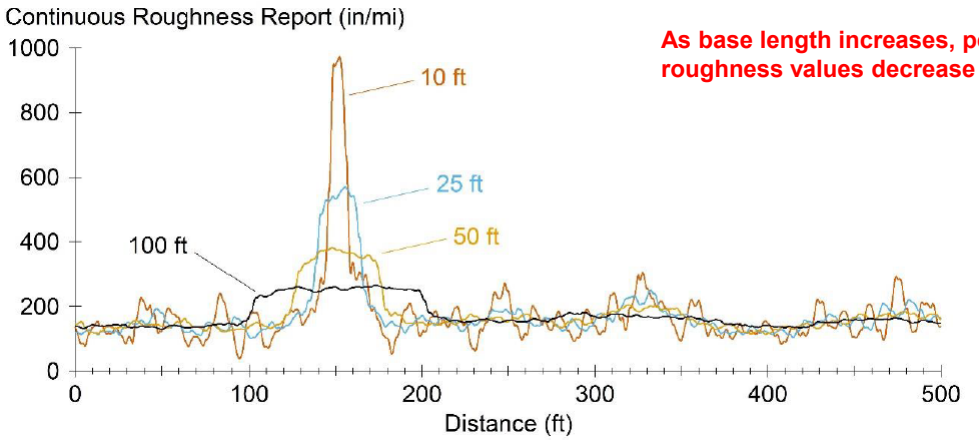
ALR: Roughness Profile



As base length increases, peak roughness values decrease

Karamihas et al. 2021, FHWA LTPP program

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State of Practice – NCC States Specifications

Category	Number of States
Incentives / Disincentives	32
Areas of Localized Roughness (ALR)	17
Specify line laser	11
Specify wheel base for grinder	9 (8 states min. 12', 1 state 25')

	< 150 Inches per mile	> 150 Inches per mile
Trigger to Grinding (Preservation)	6 states	4 states

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State of Practice – State Specifications

IRI Acceptance	Number of States Low Speed (<45 mph)	Number of States High Speed (≥45 mph)
<40 inches per mile		2
40 – 90 inches per mile	3	21
90 – 135 inches per mile	2	1
10' straight edge	3	
16' straight edge	2	
PI 0 - 10	3	1
PI 10 – 20	1	1
PI 20 - 30	1	

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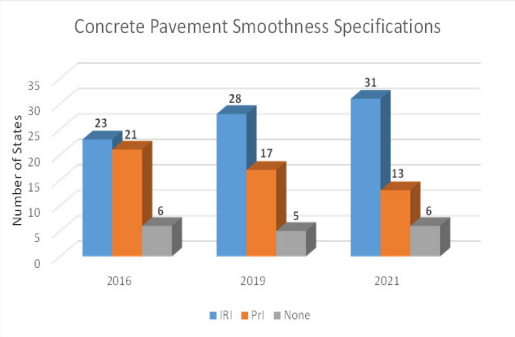
State of Practice - The Move to IRI

Conversion from Profile Index to IRI specification / development of Smoothness Specification

- Pavement Smoothness Index Relationships, Smith, et al., 2002
- Evaluation of INDOT Construction Smoothness Specifications, Pellinen & Chou, 2003
- Implementation of an International Roughness Index for MNDOT Pavement Construction and Rehabilitation, Wilde, 2007
- ACPA/IGGA Guide-Pavement Smoothness Requirements, 2013 Task Force



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Literature Search

Table 4. Literature search summary

Publication Year	Authors	Title	Summary	Link
2021	Karamihas, Punnackal, Dufalla, Senn	*Advancing Profile-Based Curl-and-Warp Analysis Using LTPP Profile Data*	The project expands the analysis to Long-Term Pavement Performance (LTPP) projects in different climates to build models to predict curl and warp based on environmental and structural factors and to examine the contribution of curl and warp to the structural response of the pavement system.	N/A
2020	Chatti, Haider, Muslim, Lee, Carvalho	*Feasibility of Using LTPP Data to Improve Use of FWD and Longitudinal Profile Measurements*	Feasibility evaluation for using LTPP SMP and diurnal measurements to develop guidelines for improved use of FWD and longitudinal profile data for PCC and HMA condition evaluation.	https://trid.trb.org/View/1530597
2019	Kontsaragiri, Algarni, Rung, Whitney, Fowler, Bhasin, Fetner, Tsimikisafe, Amirkhanian	*Friction and Texture Retention of Concrete Pavements*	ALDOT study of friction on diamond ground PCC pavements with carbonate aggregates.	https://www.igga.net/wp-content/uploads/2019/11/Friction_Texture_Retention_Concrete_Pavements.pdf
2019	Anderson, Uhlmeyer, Russell, Simonson, Littleton, McKennan, Weston	*Polyester Polymer Concrete Overlay*	Study of diamond ground PCC pavements and polyester polymer concrete (PPC) use as a repair strategy for pavements with extensive wear from studded tires.	https://www.wsdot.wa.gov/research/reports/fullreports/797-2.pdf
2019	Fick, Merritt, Taylor	*Implementation of Best Practices for Concrete Pavements: Guidelines for Specifying and Achieving Smooth Concrete Pavement*	Provides guidelines on how to specify and build smooth concrete pavements.	https://intrans.iastate.edu/app/uploads/2019/12/smooth_concrete_pvmt_guidelines_w_cvr.pdf
2018	Buttlar, Alavi, Brown, Stills, Mesa, Okenfuss	*Pavement Roughness Measurement Using Android Smartphones: Case Study of Missouri Roads and Airports*	Evaluation of an Android smartphone application to assess airport pavement condition. The study found the application to be an effective low cost tool for assessing airport pavement condition.	https://spexternal.modot.mo.gov/sites/cm/CORDT/cmr18-010.pdf
2018	IGGA and ACPA	*Review of Industry Developed Smoothness Specifications*	Evaluation of industry developed smoothness specifications for agencies.	https://docplayer.net/102940959-Review-of-industry-developed-smoothness-specifications.html

55 documents dating back to 1997

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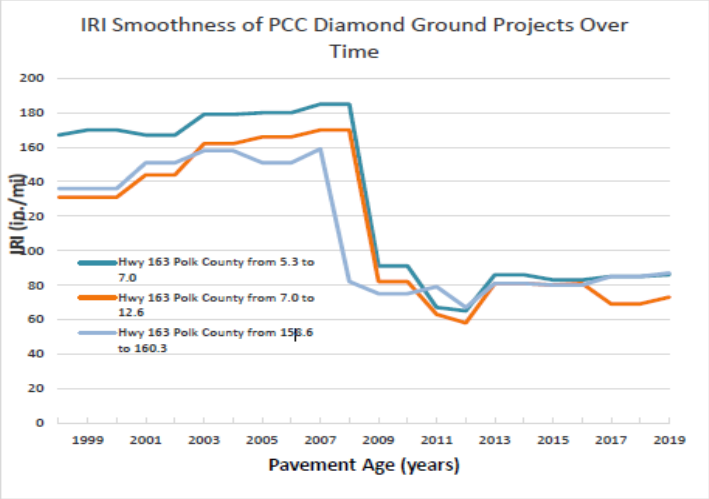
State IRI Data



Highway 163 East of Des Moines
1964 10" PCC
FA-216(8)

2007 DBR & Grinding
NHSN-163-1(76)--2R-77

2019 Traffic 7825 (28% trucks)

2019 IRI 82

2019 PCI 70

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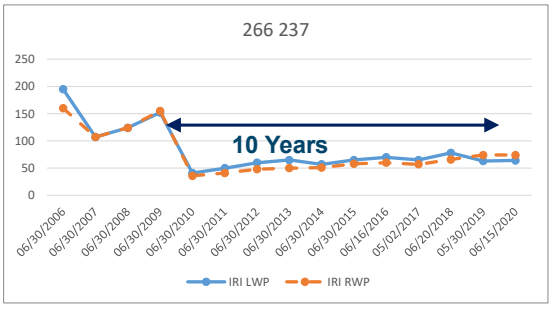
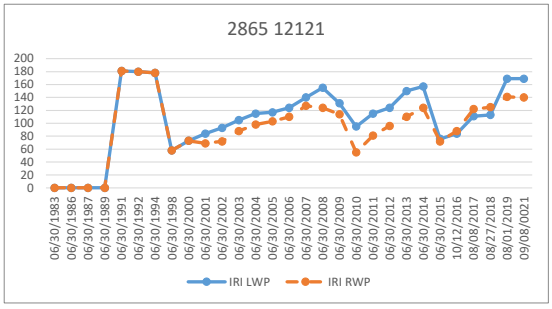
State IRI Data





Left graph: data indicates at least a 10-year performance

Right graph: data may indicate a structural deficiency or support issue

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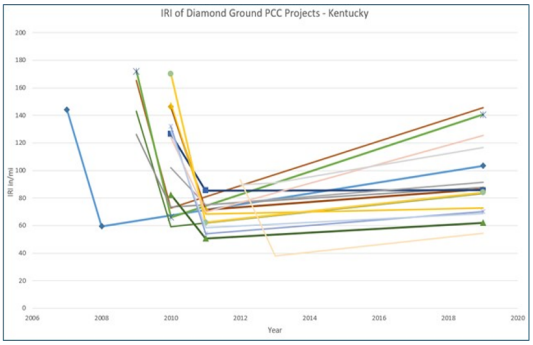
Case Studies

- Kentucky
  - 536 lane miles 2007 – 2012
- Utah (Darter & Biel, 2016)
  - 60 projects, 900 miles
  - up to 20-year additional life
- California (Rao et al., 1999)
  - 76 sections
  - 14-year additional life
- Arizona
  - Grinding specification 2021



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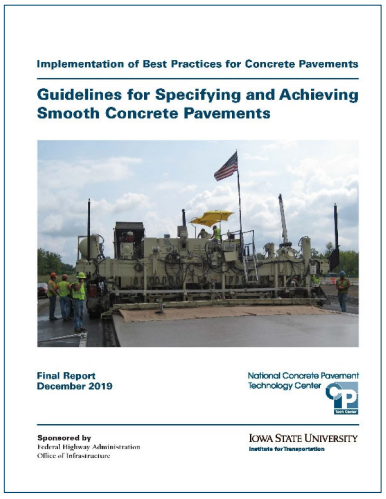
Achieving Smoothness

- Guidelines for Specifying and Achieving Smooth Concrete Pavements, Fick, Merritt, Taylor, 2019
  - Design
  - Construction
  - Measuring Smoothness
- Investigation of the Effect of Curling on as Constructed Smoothness and Ride Quality of KDOT Portland Cement Concrete (PCC) Pavements, Siddique, 2004
- Constructing Smooth Concrete Pavements, ACPA wikipave

  https://wikipave.org/index.php?title=Constructing_Smooth_Concrete_Pavements



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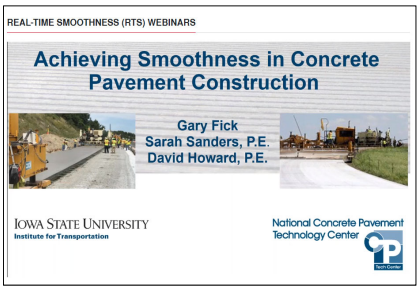
Other Resources

- Real-Time Smoothness (RTS) Webinars – CP Tech Center 2020
  - https://cptechcenter.org/webinars-and-videos/
- RTS Page
  - https://cptechcenter.org/real-time-smoothness/



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Synthesis Conclusions

- **Sensor type, curl / warp and ALR** can significantly affect IRI
- Mixtures with good **workability** are effective at producing smooth pavements with slipform paver
- Several **construction practices** are identified to improve smoothness
- Pavements with **initial low IRI** has best potential for increased service
- Timely and adequate **curing** has potential to improve smoothness

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Synthesis Conclusions

- Diamond grinding is effective for improving ride quality
  - **Maintaining smoothness depends on selecting the right candidate**
- Additional analysis
  - Evaluate the IRI profiles to investigate high IRI
    - Spot laser vs. line laser (texture)
    - Curl & warp

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Meet our COVID Dog

"Duke"

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Thank you

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Duke